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FORESTED WETLANDS

Functions, Benefits and the Use of Best Management Practices

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Front Cover: Heaths are a common bog vegetation, as suggested by "Big Heath," the local name for this black spruce bog in Maine.

Photo: Donald J. Leopold

Back Cover: Labrador Pond, a poor fen in New York

Photos: Donald J. Leopold

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and the Use of
Best Management Practices

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Best Management Practices

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INTRODUCTION

Wetlands are complex and fascinating ecosystems that perform a variety of functions of vital importance to the environment and to the society whose very existence depends on the quality of the environment. Wetlands regulate water flow by detaining storm flows for short periods thus reducing flood peaks. Wetlands protect lake shore and coastal areas by buffering the erosive action of waves and other storm effects. Wetlands improve water quality by retaining or transforming excess nutrients and by trapping sediment and heavy metals. Wetlands provide many wildlife habitat components such as breeding grounds, nesting sites and other critical habitat for a variety of fish and wildlife species as well as the unique habitat requirements of many threatened and endangered plants and animals. Wetlands also provide a bounty of plant and animal products such as blueberries, cranberries, timber, fiber, finfish, shellfish, waterfowl, furbearers and game animals. Although wetlands are generally beneficial, they can, at times, adversely affect water quality. Waters leaving wetlands have shown elevated coliform counts, reduced oxygen content and color values that exceed the standard for drinking water.


Donald J. Leopold

▲ Atlantic white cedar, *Chamaecyparis thyoides*, has formed a dense forest in this New Jersey bog.

While many wetland functions are unaffected by land management activities, some functions can be compromised or enhanced by land management activities. Deforestation, for instance, can reduce or eliminate the ability of a wetland to reduce flood peaks. On the other hand, retaining forest vegetation on a wetland can help retain the ability of the soil to absorb runoff water thus reducing peak flood flows. In addition, management of the forest can actually improve wildlife habitat and produce revenue to offset the cost of retaining the wetland for flood control. The key is to recognize environmental values and incorporate them into management decisions.

The purpose of this publication is to provide an understanding of some of the environmental functions and societal values of wetlands and to present an array of ***Best Management Practices,*** *or BMP's. Best management practices are devices and procedures to be considered and used as necessary to protect the environmental functions and societal values of wetlands during harvesting and other forest management operations.*

One of the earliest of the currently important definitions, often referred to as the Circular 39 definition, was developed by the U. S. Fish and Wildlife Service as part of a wetland classification system for categorizing waterfowl habitat. This classification is still used to differentiate between various wetland types for wildlife habitat purposes.

The term "wetlands"...refers to lowlands covered with shallow and sometimes temporary or intermittent waters. They are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs, fens and river overflow lands. Shallow lakes and ponds, usually with emergent vegetation as a conspicuous feature, are included in the definition, but the permanent waters of streams, reservoirs, and portions of lakes too deep for emergent vegetation are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist-soil vegetation.

Wetlands of the United States, Their Extent and Their Value for Waterfowl and Other Wildlife (Shaw and Fredine 1956)

DEFINITION

The term "wetlands" includes a variety of transitional areas where land based and water based ecosystems overlap. They have long been known to us by more traditional terms such as bog, marsh, fen and swamp. And while most people use these terms interchangeably, to many who study wetlands these terms have specific meanings which richly describe the various wetland environments they represent. However, before discussing the meaning of these traditional terms, we should look first at some general definitions of wetlands.

The Environmental Protection Agency (Federal Register 1980) and the Corps of Engineers (Federal Register 1982) agree on the following definition of wetlands which is used to legally define wetlands for the purposes of the Clean Water Act.

The term "wetlands" means those areas that are inundated or saturated by surface or ground water 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. Wetlands generally include swamps, marshes, bogs, and similar areas.

Corps of Engineers Wetlands Delineation Manual (U.S. Army Corps of Engineers 1987)

The Cowardin definition is one of the most comprehensive and ecologically oriented definitions of wetlands and was developed by the U. S. Fish and Wildlife Service as part of a wetlands inventory and classification effort…

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water...wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al., 1979).

These definitions are descriptions of the physical attributes of wetlands and are used chiefly to identify wetlands for regulatory purposes, but wetlands are more than physical places where water is present and certain plants grow. Wetlands perform a variety of unique physical, chemical and biological functions which are essential to the health of the environment and valuable to society, but which are also difficult to define or identify for regulatory purposes.

Wetlands exist between aquatic and terrestrial ecosystems and are, therefore, influenced by both. Wetlands are lands where water is present on the soil surface or within the root zone of plants, usually within about 18 inches of the soil surface. Because of the presence of water, wetlands have soil properties which differ from upland areas. Only hydrophytes, plants that are adapted to an environment where water is present in the root zone either permanently or for extended periods of time, can survive in such soils. The type of soil, the amount of organic matter, the depth to which the water table will rise, the climate, and the season and duration of high water will determine the kinds of plants that will grow in a wetland. Therefore, wetland types are identified, in part, by the kinds of plants that grow in them and the degree of surface flooding or the degree of soil saturation due to a high water table.

Any of these definitions may suffice for the purposes of protection and enhancement of wetland functions. However, for regulatory purposes, it is important to know that there are several similar definitions in common use, but the one that currently applies for the regulatory purposes of the Clean Water Act is the 1987 Corps of Engineers definition.

It is easier to avoid negative impacts on wetlands if the land in question is recognized as wetland at the beginning of the planning process. Identifying wetlands when the land is inundated or flooded with water is not difficult, but wetlands are not always inundated and many wetlands are never inundated.

Corps of Engineers

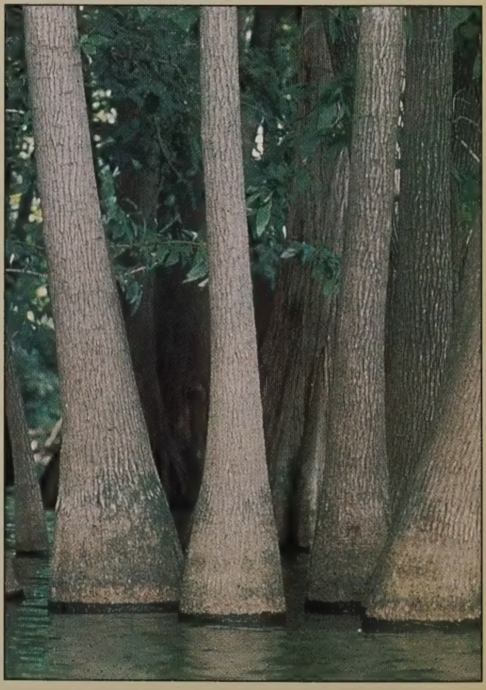
▲ Buttswell and knees of baldcypress, *Taxodium distichum*, are indicators of seasonal high water levels.

▲ Sediment deposits on leaves suggest a period of flooding.

Therefore, it is necessary to be able to identify wetlands by other means. While identification and delineation of wetlands under the Clean Water Act is a complex process involving soils, plant communities and hydrology, there are a number of easily recognized signs that can be used as indicators that the area may be a wetland and that it thus deserves further investigation.

David J. Welsch / U.S. Forest Service

▲ Buttressed roots and sediment stained trunks indicate seasonal flooding.

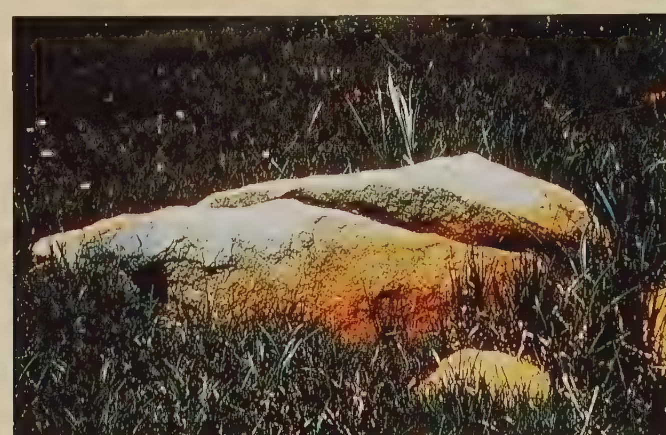


Donald J. Leopold

▲ Watermarks on trunks of these water tupelo, *Nyssa aquatica*, record past flood levels in an Illinois swamp.

David J. Welsch / U.S. Forest Service

▲ Drift lines, the linear deposits of debris at the base of these silver maple trees, *Acer saccharinum*, in this New York wetland record past flood events.



Corps of Engineers

▲ Water stained boulders mark past flood levels.

David J. Welsch / U.S. Forest Service

▲ Surficial root systems indicate saturated soils.

Wetland Characteristics

✔ **Water**
presence of water at or near the ground surface for a part of the year

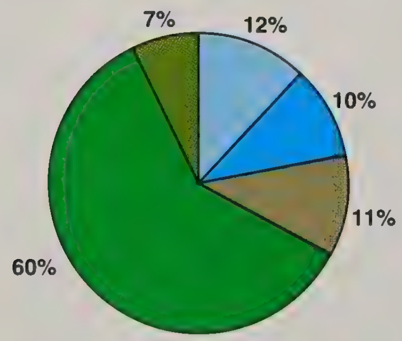
✔ **Hydrophytic Plants**
a preponderance of plants adapted to wet conditions

✔ **Hydric Soils**
soil developed under wet conditions

TRENDS

Unfortunately, the benefits wetlands provide to society and to individual landowners are neither widely understood nor appreciated. From the 1780's to the 1980's it is estimated that the 20 state Northeastern Area, an administrative unit of the U.S.D.A. Forest Service, lost 59 percent of its wetlands (Dahl 1990). To understand the forces of change, consider the Chesapeake Bay watershed, which comprises portions of the states of Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia. The Chesapeake Bay watershed has lost nine percent of its noncoastal marshes and six percent of its inland vegetated wetlands between the mid-1950's and the late 1970's (Tiner 1987). Forested wetland losses during this period were greatest for the state of Virginia which lost nine percent of its forested wetlands during a 21 year period (Tiner 1987). It should be noted for the purposes of data interpretation that Virginia is included in the Chesapeake Bay data, but is not included in the data for the Northeastern Area.

Distribution of Wetland Types in the Chesapeake Bay Watershed



After Tiner 1994

U.S.D.A. Forest Service Northeastern Area

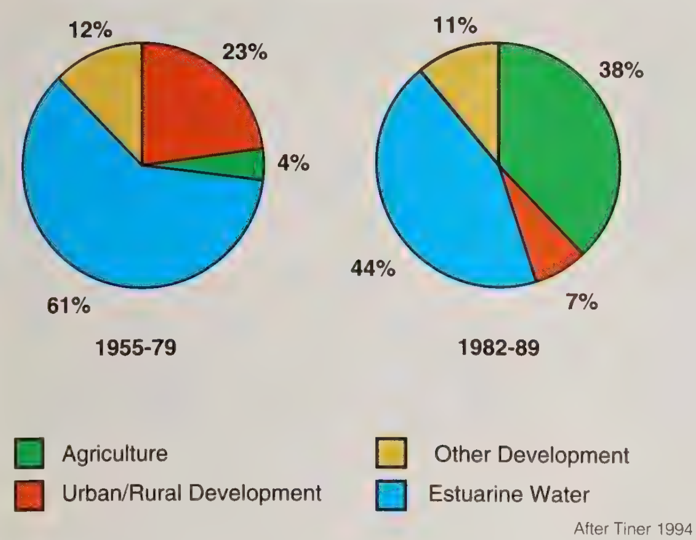
Wetland Losses in the Northeastern Area

thousands of acres

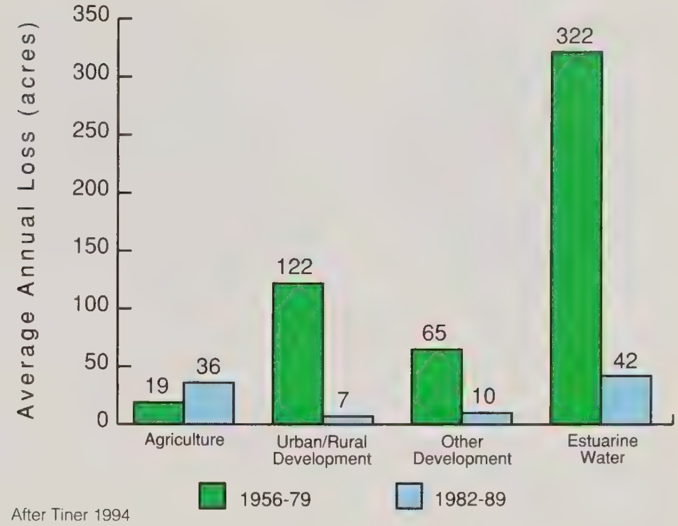
State	Estimated Wetland Circa 1780	National Wetlands Inventory 1980	Percent Change
Connecticut	670	173	-74
Delaware	480	223	-54
Illinois	8,212	1,255	-85
Indiana	5,600	751	-87
Iowa	4,000	422	-89
Maine	6,460	5,199	-19
Maryland	1,650	440	-73
Massachusetts	818	588	28
Michigan	11,200	5,583	-50
Minnesota	15,070	8,700	42
Missouri	4,844	643	-87
New Hampshire	220	200	-9
New Jersey	1,500	916	-39
New York	2,562	1,025	-60
Ohio	5,000	483	-90
Pennsylvania	1,127	499	-56
Rhode Island	103	65	-37
Vermont	341	220	-35
West Virginia	134	102	24
Wisconsin	9,800	5,331	-46
TOTAL	**79,791**	**32,818**	**-59**

Currently, about twelve percent of the wetlands in the Chesapeake Bay watershed are classified as estuarine or coastal wetlands (Tiner 1994). Coastal wetland losses continue to result from conversion to estuarine waters by rising sea levels, coastal erosion and dredging. Losses of coastal wetlands to agriculture have increased significantly since 1982.

Changes in Causes of Estuarine Emergent Wetland Destruction in the Chesapeake Bay Watershed

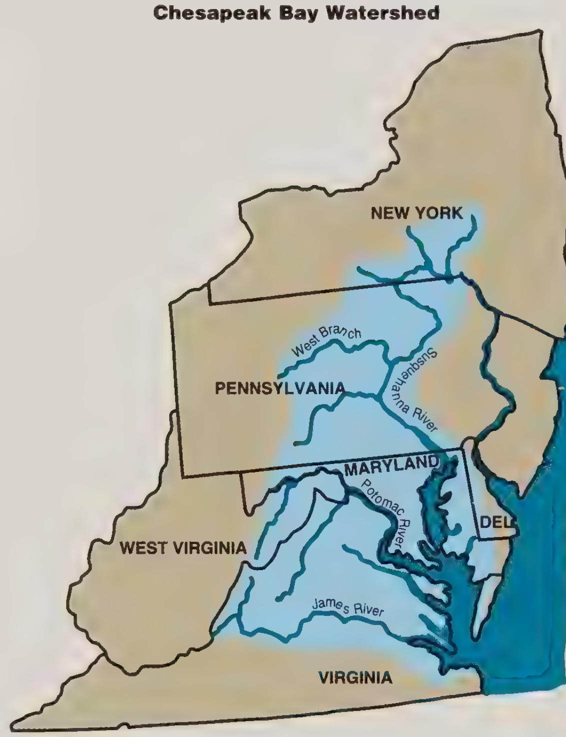


Changes in Causes of Estuarine Emergent Wetland Destruction in the Chesapeake Bay Watershed

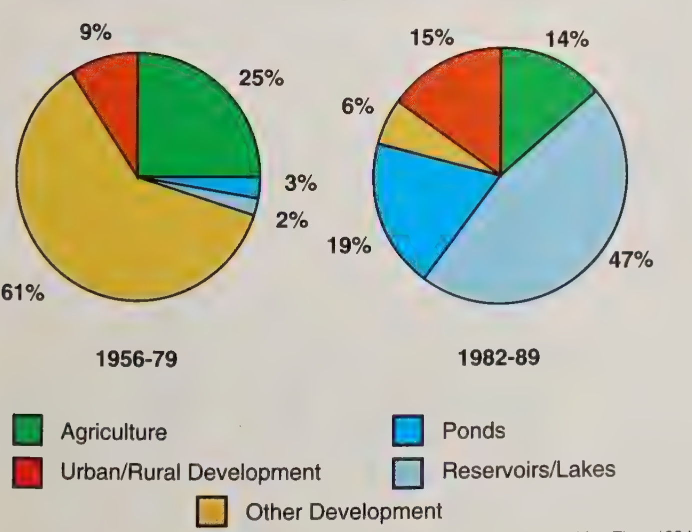


The remaining eighty-eight percent of wetlands in the Chesapeake Bay watershed are various types of inland wetlands. Sixty percent of the total wetlands in the Chesapeake Bay watershed are inland wetlands classified as palustrine forested wetlands. Actually, forested wetlands progress from forested wetlands to emergent wetlands to shrub-scrub wetlands and back to forested wetlands creating a sort of dynamic equilibrium as individual forests progress through the various plant successional stages in response to management activities or natural phenomena. Palustrine shrub-scrub wetlands and palustrine emergent wetlands make up ten and eleven percent of the total wetlands respectively. Consequently, appropriate forest management activities have the potential to favorably effect more than sixty percent of the total wetlands

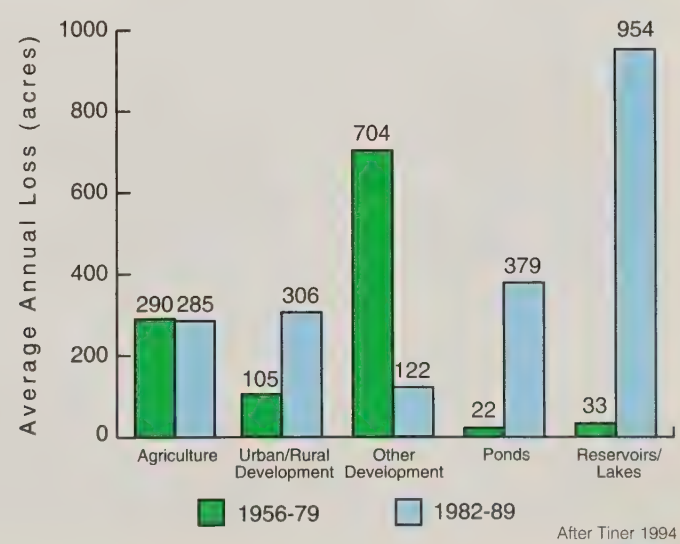
Chesapeak Bay Watershed



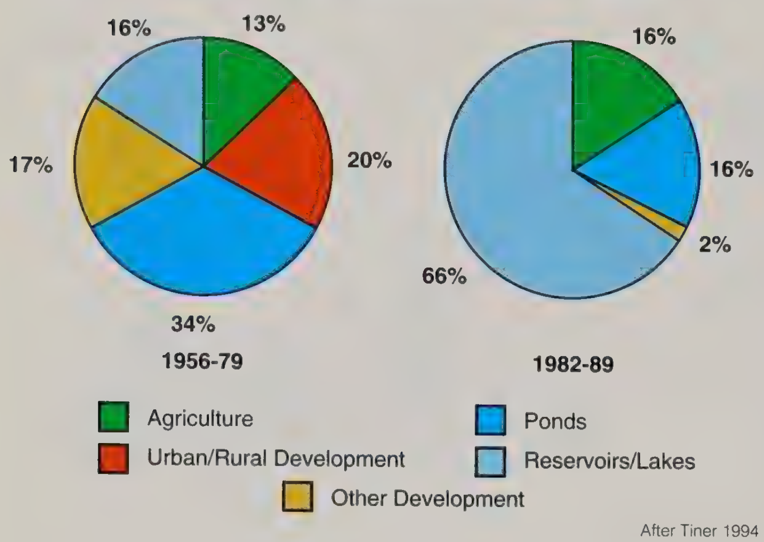
Changes in Causes of Palustrine Forested Wetland Destruction in the Chesapeake Bay Watershed



Changes in Causes of Palustrine Forested Wetland Destruction in the Chesapeake Bay Watershed



Changes in Causes of Palustrine Shrub-Scrub Wetland Destruction in the Chesapeake Bay Watershed



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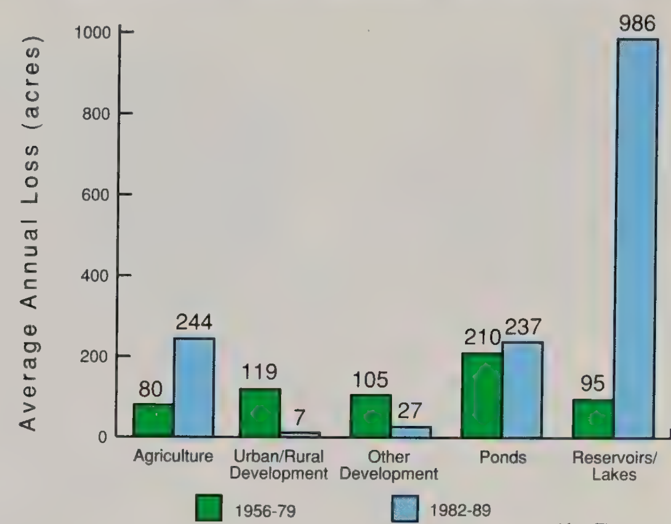
Changes in Causes of Palustrine Shrub-Scrub Wetland Destruction in the Chesapeake Bay Watershed



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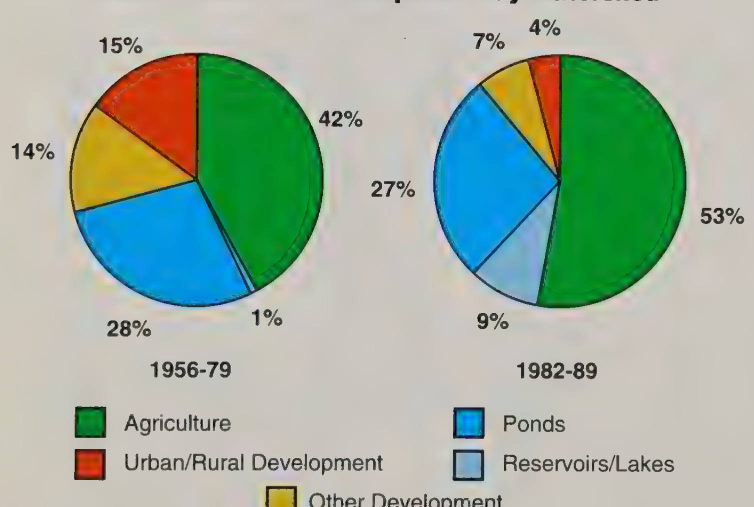
in the Chesapeake Bay watershed.

Current data indicates the primary threat to forested wetlands is conversion to ponds and reservoirs; a secondary threat is conversion to agriculture. The threat of conversion, both to agriculture and to lakes and ponds, has increased significantly for palustrine shrub-scrub and palu-strine emergent wetlands.

While figures impart a sense of the magnitude of what we have lost, they do not tell the entire story. Pollution, changes in the amount of water entering a wetland, drainage, urban development and other activities which may not necessarily occur in wetlands, often cause impacts to wetlands and result in severe degradation and impairment of function. Many of these impacts cause changes that are difficult to detect until related effects become apparent. At that point, only significant contributions of time and resources can repair the damage. Wetlands are extremely fragile and, in many cases, the damage may be irreversible.

Inland forested wetlands comprise the largest segment, almost 50 percent, of the remaining wetlands in the lower 48 states (Tiner 1987). Management strategies adopted for these wetlands could have a significant impact on the benefits these wetlands provide to society in the future.

Changes in Causes of Palustrine Emergent Wetland Destructionin the Chesapeake Bay Watershed



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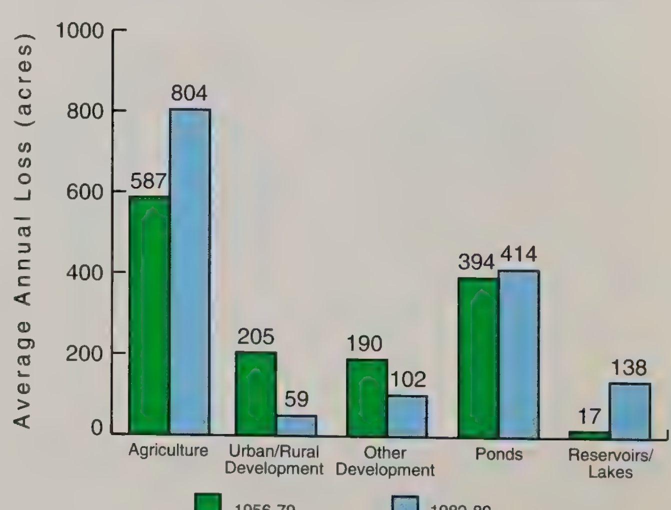
Changes in Causes of Palustrine Emergent Wetland Destruction in the Chesapeake Bay Watershed



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WETLAND CLASSIFICATION

Wetlands are classified by the U.S.D.I. Fish and Wildlife Service in a comprehensive hierarchical method that includes five systems and many subsystems and classes. The method is explained in the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin 1979). This classification method includes the marine system and the estuarine system which are ocean based systems and beyond the scope of this document. The other systems are the riverine, lacustrine and palustrine systems. The riverine system includes freshwater wetlands associated with stream channels, while the lacustrine system includes wetlands associated with lakes larger than 20 acres. The palustrine system includes freshwater wetlands not associated with stream channels, wetlands associated with lakes of less than 20 acres and other wetlands bounded by uplands. Most forested wetlands are in the palustrine system.

Classification of Wetlands and Deepwater Habitats of the United States

Cowardin 1979

Wetlands can be more simply classified into three broad categories of wetland types, based on the growth form of plants: (1) marshes, where mostly nonwoody plants such as grasses, sedges, rushes, and bullrushes grow; (2) shrub wetlands, where low-growing, multi-stemmed woody plants such as swamp azalea, highbush blueberry and sweet pepperbush occur; and (3) forested wetlands, often called swamps or wooded wetlands, where trees are the dominant plants.

However, these classification systems may be less than ideal for the purposes of this publication. Information more useful for protecting and enhancing the values of forested wetlands may be based on a knowledge of soils, hydrology and plant and animal communities present. General information of this type will be presented on the following pages for forested wetlands and other types of wetlands most often encountered in association with forest management operations in the Northeastern Area.

Joe Emerick

▲ Marshes often form along the shallow edges of lakes and streams and are characterized by grasses, sedges, rushes and other herbs, such as cattail, growing with their lower stems in the water.

David J. Welsch / U.S. Forest Service

▲ Shrub-scrub wetlands are characterized by low woody vegetation and may include forested wetlands that have been harvested and are in the process of regeneration to forest.

Joe Emerick

▲ Forested wetlands often resemble neighboring upland forest with their wetland status evident only from understory wetland plants such as skunk cabbage.

Organic Soil Wetlands

▲ Lost Pond, in the Adirondacks of New York, is only a small part of this bog which includes the black spruce, *Picea mariana*, and tamarack, *Larix laricina*, forest in the background.

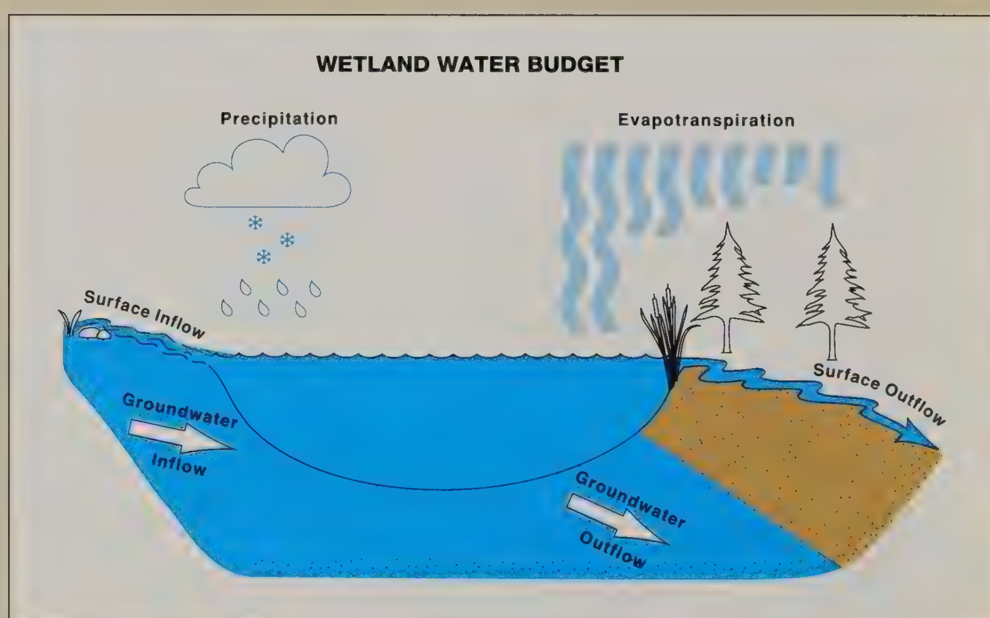
Bogs

The word bog often evokes a picture of a pond with a ring of sphagnum moss, but the term bog actually describes the larger area of wet organic soil in which these ponds occur. Bogs are generally formed in depressions where the combination of cool climates and abundant moisture retard the rate of decomposition resulting in an accumulation of organic matter. They are hydrologically open systems, but receive little or no discharge of water from groundwater aquifers and are, therefore, dependent on precipitation for moisture. Bogs produce near normal amounts of surface runoff and may recharge small

HYDROLOGY

Hydrology, the way in which a wetland is supplied with water, is one of the most important factors in determining the way in which a wetland will function, what plants and animals will occur within it, and how the wetland should be managed. Since wetlands occur in a transition zone where water based ecosystems gradually change to land based ecosystems, a small difference in the amount, timing or duration of the water supply can result in a profound change in the nature of the wetland and its unique plants, animals and processes.

Hydroperiod is the seasonal pattern of the water level that results from the combination of the water budget and the storage capacity of the wetland. The water budget is a term applied to the net of the inflows, all the water flowing into, and outflows, all the water flowing out of, a wetland. The storage capacity of the wetland is determined by the geology, the subsurface soil, the groundwater levels, the surface contours and the vegetation. The hydroperiod of coastal wetlands exhibits the daily and monthly fluctuations associated with tides,



▲ Water budget is the term applied to the net result of all water entering and leaving the wetland.

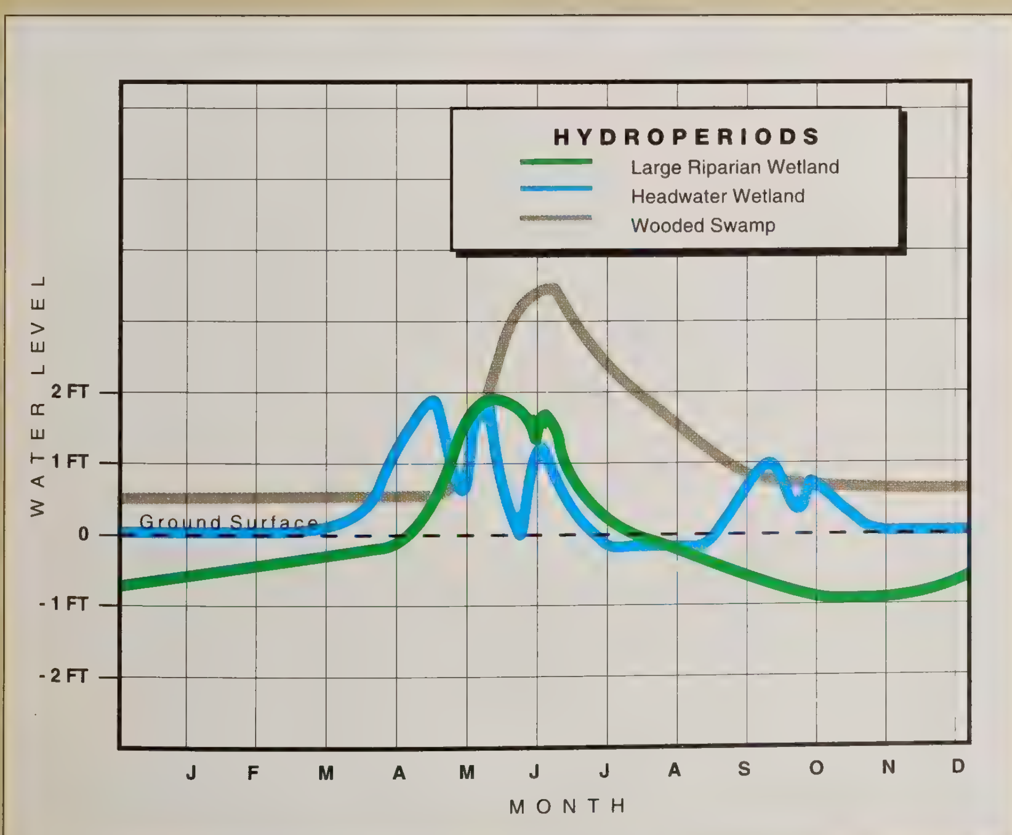
whereas inland wetlands tend to show, to a greater degree, the effects of storm and seasonal events such as spring thaw, fall rains and intermittent storm events.

In headwater areas where streams originate, watersheds tend to be small and have shallow soils with low water storage capacity. Hydroperiods of wetlands in headwater areas often show water levels that rise and fall rapidly in response to localized storm events which supply the streams and wetlands with runoff. An exception is areas where soils are dominated by sandy glacial deposits. These areas

Joe Emerick

▲ Alternating patterns of boreal forest, low vegetation and open water often indicate areas that are bogs interspersed with areas that are fens.

amounts of water to regional groundwater systems. The resulting chemistry produces nutrient poor acid conditions and less than average productivity. However, low tree productivity is largely offset by high moss productivity. This causes the accumulation of peat further restricting water movement and raising the



▲ Hydroperiod is the seasonal pattern of the water level that results from the combination of the water budget and the storage capacity for a specific wetland. It provides a clue as to logical operating season.

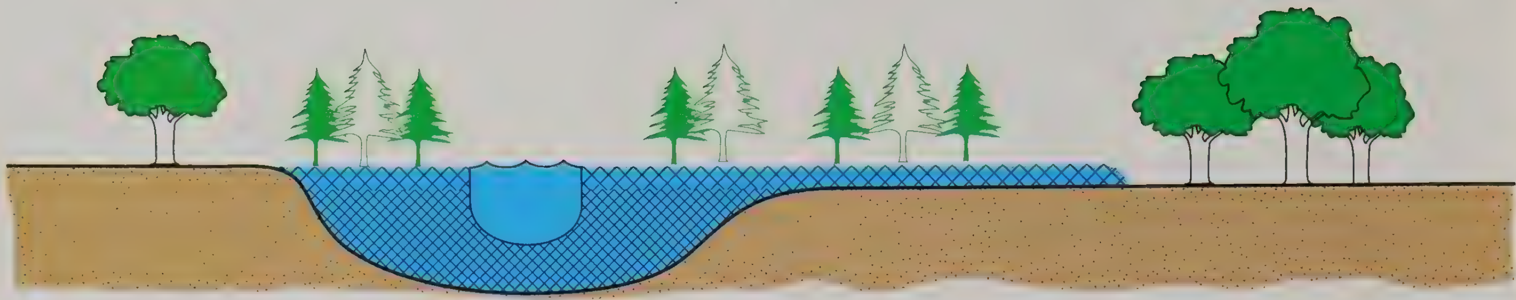
tend to have deeper soils, gentle slopes and more predictable hydroperiods. Sandy glacial deposits also tend to occur in colder climates and to be frozen for a period of the year often providing the opportunity to conduct management operations under frozen conditions.

Larger streams, which receive much of their water from the combined flows of many smaller streams, tend to respond more slowly to precipitation and exhibit the results of the average conditions over the larger combined watershed as opposed to local storm events.

Hydroperiods of wooded swamps associated with larger river systems tend to show water levels that reflect events general to the larger area such as fall rains and spring thaw and are, therefore, more predictable.

The number of times that a wetland is flooded within a specific time period, such as yearly, is known as the flood frequency. Flood duration is the amount of time that the wetland is actually covered with water. It should also be noted that many wetlands are never flooded, but the wetland definition does require the soil to be saturated for at least a part of the growing season. Only hydrophytes, a relatively

BOGS/BLANKET BOGS



▲ Bogs are formed where climates and ample moisture retard decomposition causing organic matter to accumulate. The spongelike organic matter holds water intensifying the process and can expand to overlay adjacent areas forming blanket bogs.

water table. This accumulation of water and peat is self intensifying and can eventually result in expansion and overlaying of adjacent areas with peat to create blanket bogs.

The dominant vegetation is adapted to the cold, wet, nutrient poor, acidic environment and includes black spruce, tamarack, Atlantic white cedar, Northern white cedar, alder, sphagnum moss, sedges and heaths ubiquitous to bogs such as highbush blueberry, cranberry and leatherleaf.

Joe Emerick

Joe Emerick

▲ Northern pitcher plant, *Sarracenia purpurea*, and round leaved sundew, *Drosera rotundifolia*, survive in nutrient poor bogs by trapping and digesting insects.

small group of vascular plants with special adaptations which includes many endangered species, are able to survive in soils that are saturated for more than a short period during the growing season. Therefore, the duration and timing of flooding and or saturation will limit the number of species that can survive in the wetland.

Residence time is a measure of the time it takes a given amount of water to move into, through and out of the wetland. Since chemical processes take time and follow one another sequentially, the degree to which wetlands can change water chemistry is determined to an extent by residence time. This is one reason why it is important not to create a channel across a wetland in the direction of flow, increasing outflow rate and decreasing residence time.

Wetlands receiving inflow from groundwater are known as discharging wetlands because water flows or discharges from the groundwater to the wetland. A recharge wetland refers to the reverse case where water flows from the wetland to the groundwater. Recharge and discharge are determined by the elevation of the water level in the wetland with respect to the water table in the surrounding area. Riparian wetlands often have both functions, they are discharge wetlands, receiving groundwater inflow from upslope areas and they are recharge wetlands in that they feed lower elevation groundwater through groundwater outflow. The same wetland may be a discharging wetland in a season of high flow and a recharging wetland in a dry season. Seeps at the base of mountains are often discharging wetlands formed by groundwater breaking through to the surface of the

Minnesota Department of Natural Resources

▲ Deeply rutted skid trails in wetlands can lower water tables and circumvent chemical processes by shortening the residence time of water.

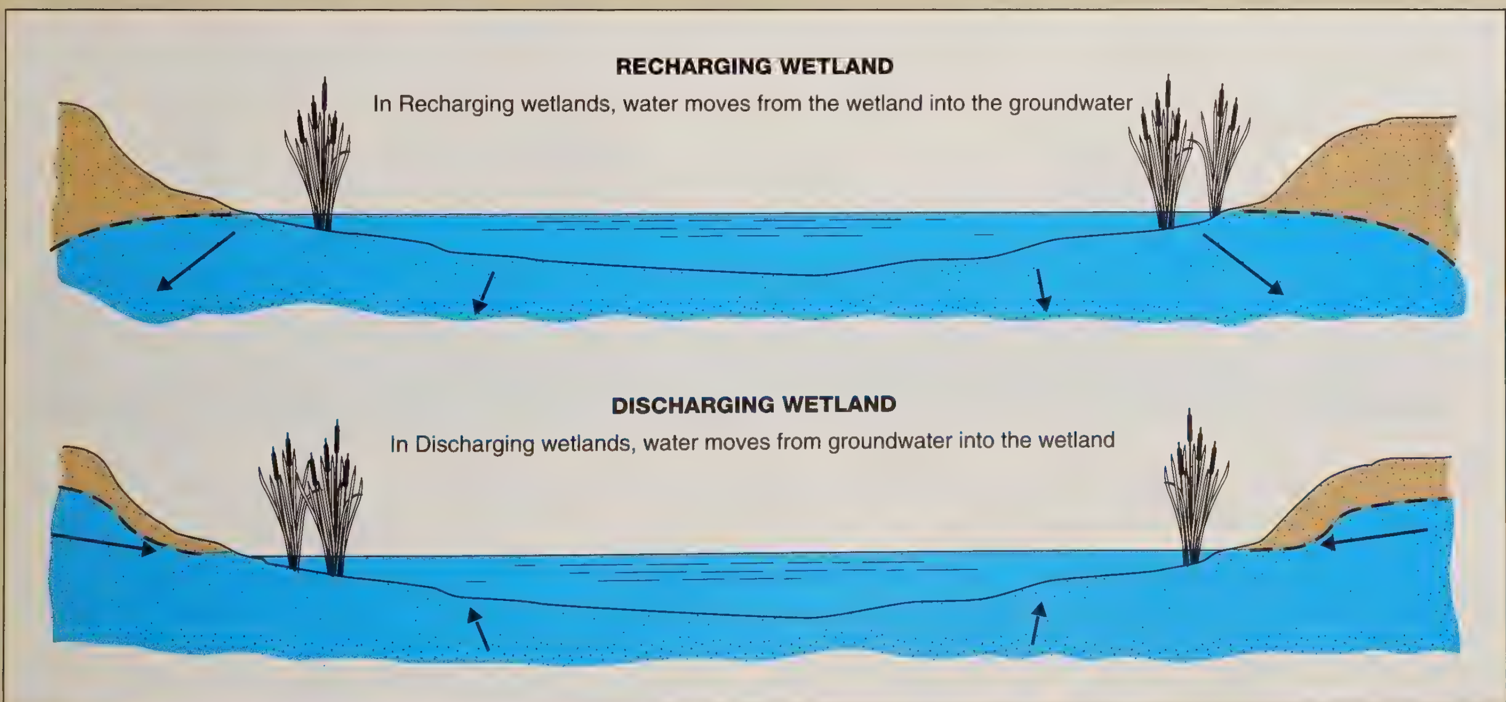
Other plants adapted to this environment include carnivorous plants such as pitcher plant and sundew and managers should address the possibility of threatened and endangered species in management plans for these areas.

Wildlife using bogs include bog lemmings, four-toed salamander, spruce grouse, massasauga rattlesnake, wood frog, moose, spotted turtle, water shrew, ribbon snake and neotropical birds such as the olive-sided flycatcher, northern parula warbler, bay-breasted warbler and blackpole warbler.

There is seldom reason to enter the floating sphagnum mats surrounding open water portions of bogs and the best advice is to go around them. Forested bog peatlands tend to occur in areas such as Minnesota, Michigan and Maine where the ground freezes during the winter months. Management activities on the forested areas should be restricted to periods when the surface is sufficiently frozen to support harvesting and other equipment and should utilize the Best Management Practices listed for frozen conditions.

▲ Spotted turtle, *Clemmys guttata*, likes slow water and numerous insects common in bogs.

▲ Northern parula warbler, *Parula americana*, finds lichen, *Usnea*, nesting material, in bogs.



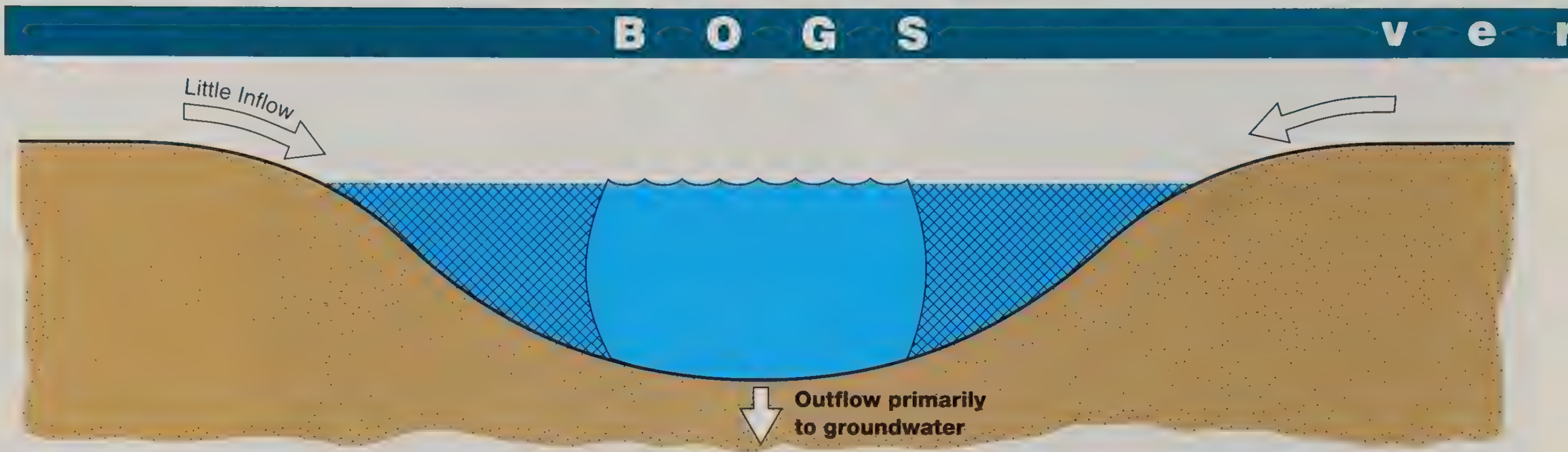
▲ Fluctuating water tables can cause wetlands to shift back and forth from Discharging to Recharging.

ground at the base of steep slopes. Vernal ponds often occur in these areas, but are an exception in that groundwater flow to and from vernal ponds is practically nil in the northeast. Mountain top swamps are often recharging wetlands with groundwater outflows to a water table much lower in elevation.

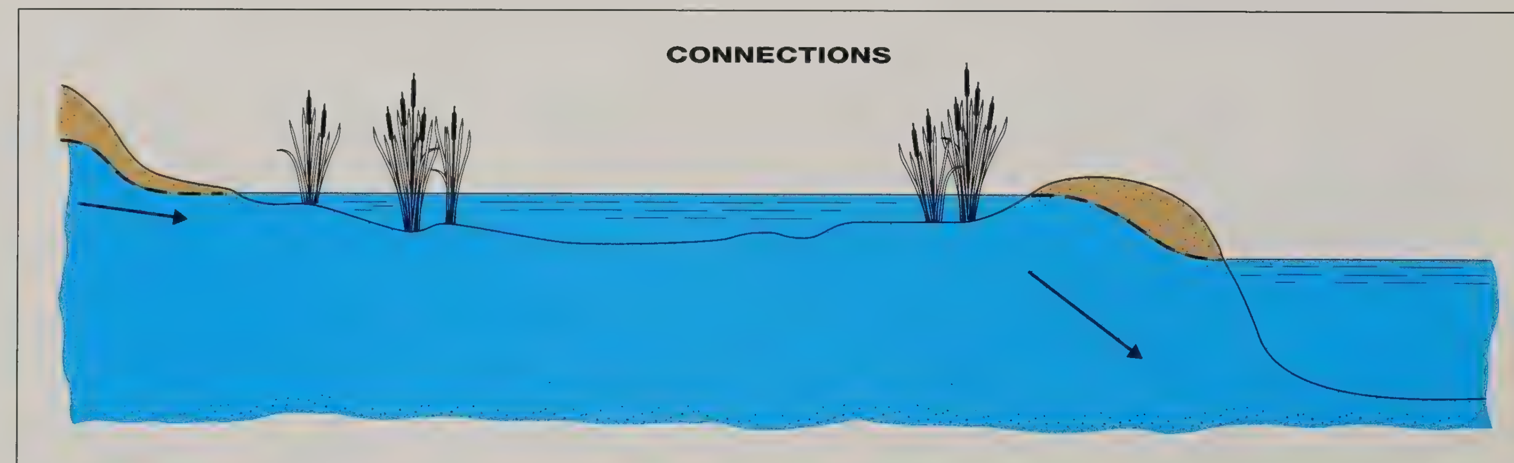
Inflow water reaches the wetland from precipitation, surface flow, subsurface flow and groundwater flow. Surface flow includes surface runoff, stream-flow and flood waters. Flood waters can carry nutrient laden sediments to forested floodplains where these sediments are

Fens

The feature that distinguishes fens from bogs is the fact that fens receive water from the surrounding watershed in inflowing streams and groundwater, while bogs receive water primarily from precipitation. Fens, therefore, reflect the chemistry of the geological formations through which these waters flow. In limestone areas the water is high in calcium carbonate resulting in fens that are typically buffered to a near neutral pH of 7. However, the level of calcium or magnesium bicarbonate varies widely in fens. At low levels of bicarbonate the pH may be closer to pH 4.6 resulting in an acid



▲ Bogs receive water primarily from precipitation with realtively little water from surface flows and discharge only to groundwater. Resulting organic accumulations contribute to their acidity.



▲ Wetlands are often connected with outflows of one becoming the inflows of the next. The water supply to the lower wetland is often delayed until the upper one fills.

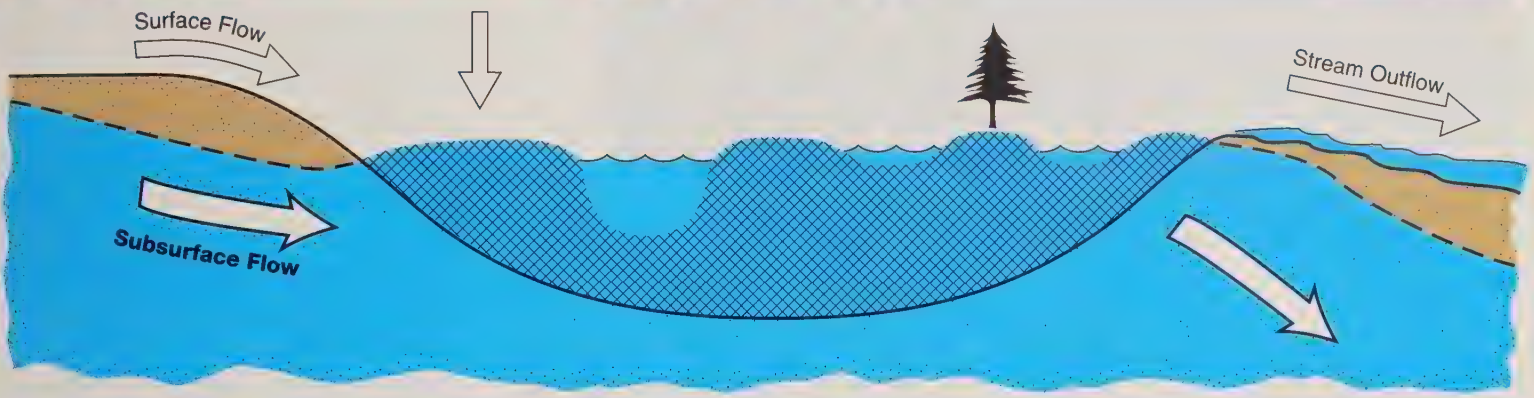
deposited making the soil very fertile. Forested floodplains can be very productive.

Outflow leaves the wetland by evaporation, transpiration, surface flow, subsurface flow or groundwater flow. Evaporation is water given off to the atmosphere as water vapor. Transpiration is the process whereby water taken up by plant roots is released as vapor to the atmosphere from the plant leaves. Surface flows out of wetlands can be small or large and are often the origin point of streams. Wetlands are often connected, to a degree, with surface and groundwater outflows of one wetland supplying the inflows to other wetlands lower in the watershed. The water supply to the lower wetland can be delayed until the upper wetland fills to a point where additional water runs off. As a result, some wetlands will not be as well supplied as others in dry periods.

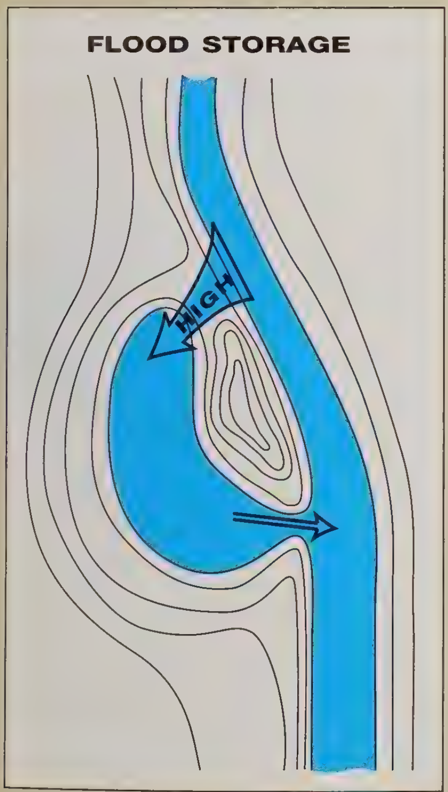
As stated previously, the water storage capacity of the wetland is affected by the soil, the groundwater level and the surface contour. Wetlands generally occur in natural depressions in the landscape where geologic or soil layers restrict drainage. The surface contours act to collect precipitation and runoff water and feed it to the depressed area. Groundwater recharge can take place if the soil is not already saturated and the surface contours of the basin hold the water in place long enough for it to percolate into the soil. In many cases the shape of the basin is such that it can be rapidly filled fen. At very high levels of bicarbonate, the water may reach a pH of 9. Thus, there is much variation among fens with respect to acidity and they often do not have the extreme acid conditions associated with bogs.

The common features of both bogs and fens are that they accumulate peat and occur in similar climatic and physiographic regions. Indeed, they often occur side by side, one grading into the other. Under the right conditions, peat can accumulate in low domes that effectively separate rain water in the dome from calcium rich groundwater in the underlying fen.

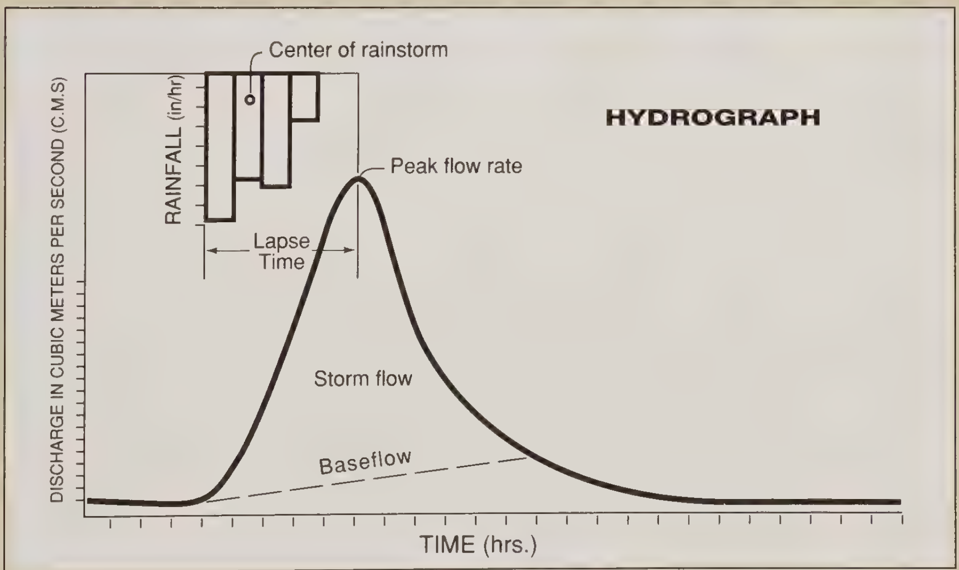
S U S F E N S



▲ Fens receive both surface and subsurface water and have both surface and subsurface outflows. As a result, fens tend to reflect the chemistry of the underlying geology and can be quite alkaline when fed from limestone sources.



▲ Flood protection is often the result of topographic features of the wetland which cause it to fill rapidly at high flows but release water slowly during lower flows.



▲ A hydrograph shows the volume and timing of flows at a given point in a watershed.

by precipitation or flood waters and the water slowly released by a restricted surface outlet, by slowly permeable soil or by geologic conditions.

The water storage capacity of the wetland determines the volume and timing of water reaching the stream from precipitation. The precipitation reaches the stream in the form of groundwater or surface runoff to contribute to streamflow discharge. A hydrograph is a graph of the volume and timing of streamflow discharge measured at a certain point in the watershed. The hydrograph shows the lapse time, the amount of time between the onset of precipitation and the peak stormflow dis-

David J. Welsch / U.S. Forest Service

▲ The open areas of Bear Meadows, a poor fen in Central Pennsylvania, support a lush growth of leatherleaf, *Chamaedaphne calyculata*, and highbush blueberry, *Vaccinium corymbosum*,

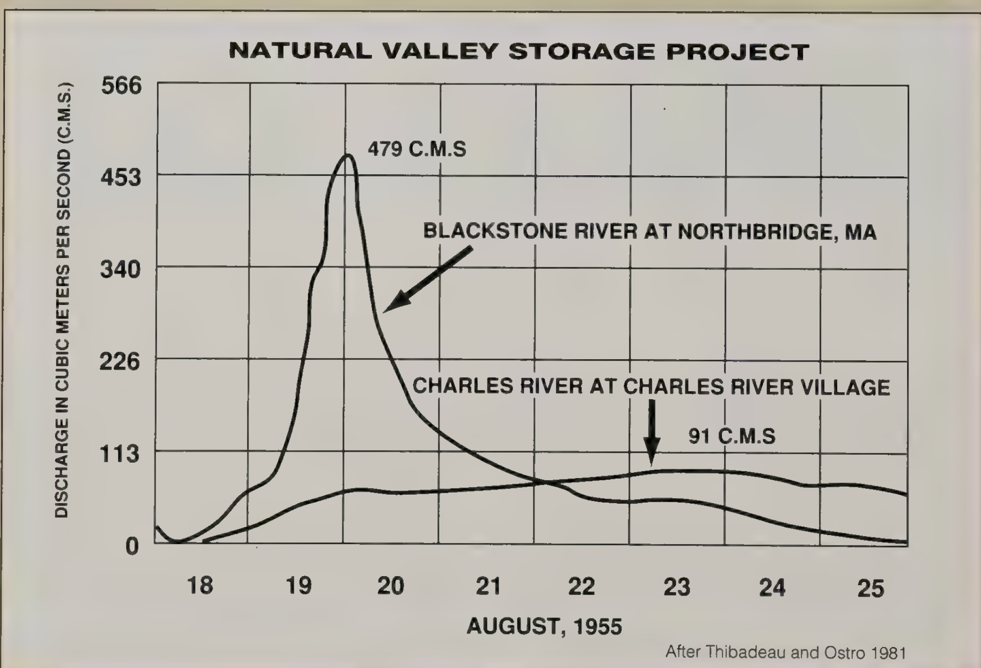
Ann Rhoads, Morris Arboretum of the University of Pennsylvania

▲ Leatherleaf, an acid loving plant, often forms floating rings around the edges of ponds.

The plant community of the fen is more varied than that of a bog and where heaths are more plentiful in bogs, sedges tend to be more plentiful in fens. Typical cool, wet climate vegetation is common with acid loving species occurring as scattered inclusions on hummocks. The species composition of acid fens is similar to bogs and includes black spruce, Virginia pine, tamarack, willow, birch, orchids, leatherleaf and random sphagnum mats.

As noted previously, many fens are acidic. However, fens receiving water from limestone or calcium carbonate

charge. It also depicts the volume and distribution of the stormflow discharge over time. Wetlands tend to have longer response times and lower peak stormflows distributed over longer time periods. Urban and developed lands tend to have short response times and high volume, short duration stormflow discharges. The overall effect is that watersheds with wetlands tend to store and distribute stormflows over longer time periods resulting in lower levels of streamflow and reduced probability of flooding.



▲ Peak flow for the Charles River watershed is much lower than peak flow for the Blackstone, a similar watershed with fewer remaining wetlands.

The Natural Valley Storage Project, a 1976 study by the U.S. Army Corps of Engineers (COE) concluded that retaining 8,500 acres of wetlands in the Charles River Basin near Boston, Massachusetts could prevent flood damages estimated at $6,000,000 for a single hurricane event. Projected into perpetuity the value of such protection is enormous. Based on this study, the COE opted to purchase the wetlands for $7,300,000 in lieu of building a $30,000,000 flood control structure (Thibodeau and Ostro 1981).

Loss of floodplain forested wetlands and confinement by levees have reduced the floodwater storage capacity of the Mississippi by 80 percent increasing dramatically the potential for flood damage (Gosselink et al., 1981) The 1993 flood proved this prediction to be true and resulted in immeasurable damage. Yet governments are allowing and even assisting the rebuilding of some of these same levees fostering potentially more damage in the future instead of promoting land use change to restore the wetlands and reduce the potential for future damage.

Donald J. Leopold

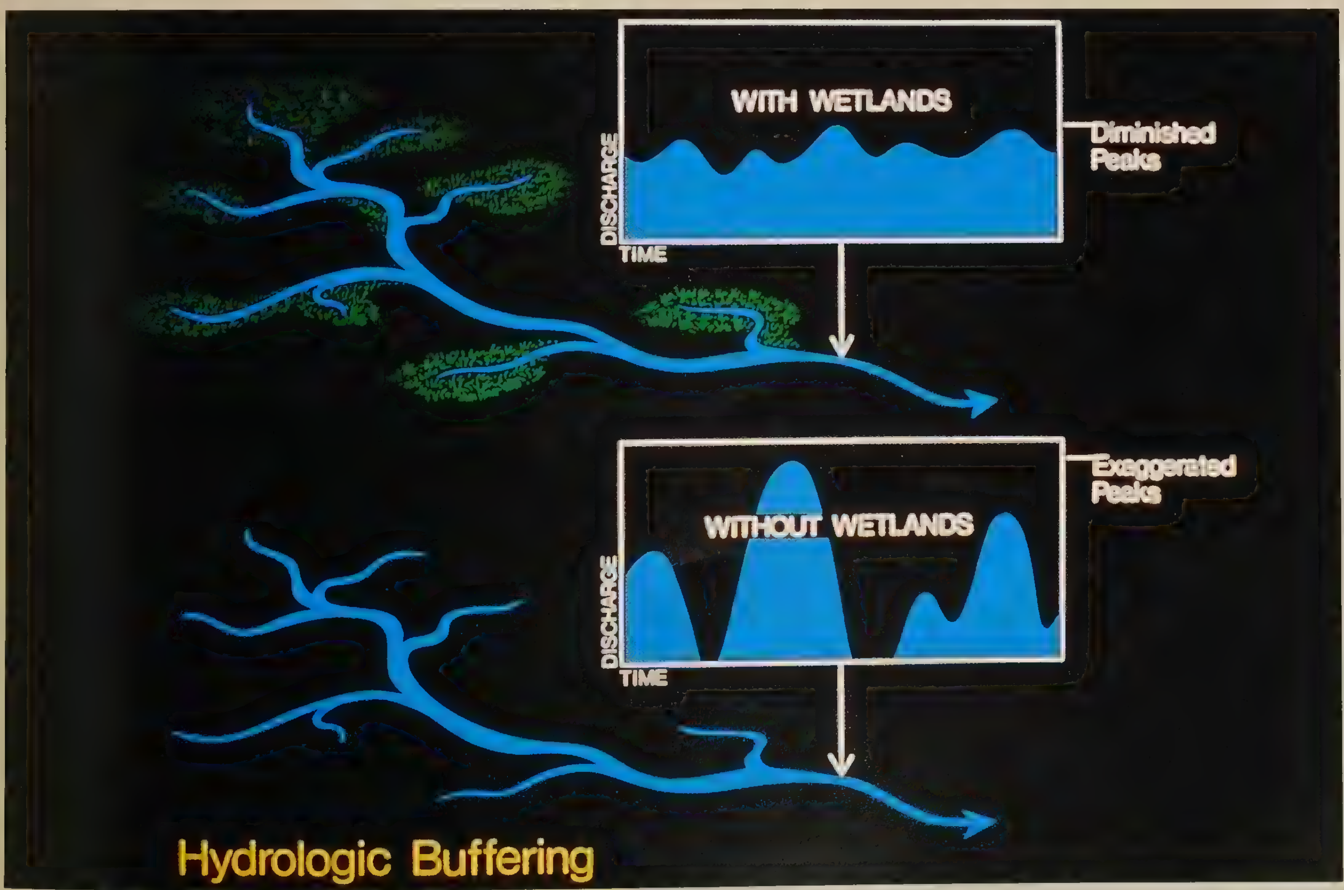
▲ Spreading globeflower, *Trollius laxus*, favors more alkaline wetlands.

Western Pennsylvania Conservancy

▲ The dam in the upper portion of this photo verifies beaver use of fens. Sparse vegetation marks the alkaline seepage around the perimiter.

geologic sources are much less acidic. These calcareous fens support a group of plants that differs somewhat from the group of plants found in acid fens. The calcareous fens tend to be dominated by grasses and sedges as well as calcium loving trees such as northern-white cedar and Atlantic white cedar instead of the sphagnum moss common to acid fens.

Some species of wildlife such as bog turtles are more common in calcareous fens where they use the shrub layer for aestivation, or summer hibernation, particularly in the northeast.



BSC Group, Boston, Massachusetts

▲ Wetlands within a watershed reduce flooding by desynchronizing peak flows.

▲ Bog turtles, *Clemmys muhlenbergii*, tend to favor the habitat conditions surrounding calcareous fens for summer aestivation.

▲ Palm warbler, *Dendroica palmarum*, breeds and feeds in the low bushes common in fens.

Wildlife species groups associated with acidic fens are similar to those associated with bogs. They include species such as the bog lemming, four-toed salamander, spruce grouse, wood frog, moose, spotted turtle, water shrew and ribbon snake and neotropical birds such as the northern waterthrush and palm warbler.

Because surface outflows trigger their damming instinct, beaver will occasionally occupy fens when more desirable habitat is unavailable.

The tea colored surface outflow from fens, while not trophy trout water, provides important habitat for small, newly hatched brook trout. The trout survive because the organic acids that impart color to the water also tend to congeal soluble forms of aluminum which could otherwise be toxic to trout, particularly young trout. Trout in these streams have been observed to survive spring "acid shock" loading when trout in nearby clear streams have not survived.

Europeans refer to peatlands, both

▲ Dull gray general soil background, or matrix color, and bright red-orange iron concentrations, or mottles, indicate a fluctuating water table.

SOILS

One of the identifying characteristics of wetlands, from both ecological and statutory points of view, is the presence of hydric, or wet, soils. Hydric soils are defined by the U.S.D.A. Natural Resources Conservation Service (NRCS) as "soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part".

The three critical factors that must exist for the soil to be classified as hydric soil are saturation, reduction and redoximorphic features. When a dominant portion of the soil exhibits these three elements the soil is classified a hydric soil.

Saturation, the first factor, occurs when enough water is present to limit the diffusion of air into the soil. When the soil is saturated for extended periods of time a layer of decomposing organic matter accumulates at the soil surface.

Reduction, the second factor, occurs when the soil is virtually free of elemental oxygen. Under these conditions soil microbes must substitute oxygen-containing iron compounds in their respiratory process or cease their decomposition of organic matter.

Donald J. Leopold

▲ Showy ladyslipper, *Cypripedium reginae*, favors more alkaline wetlands.

Western Pennsylvania Conservancy

▲ Grasses, *Gramineae*, dominate the alkaline portions of this fen.

bogs and fens, with the word "mire" which says a lot about operating in these areas. Machinery can be "mired down" unless operations are conducted under frozen conditions. These areas, by virtue of the conditions necessary for their existence, are rarely dry, so operating in a dry season is all but impossible.

Redoximorphic features, the third factor, include gray layers and gray mottles both of which occur when iron compounds are reduced by soil microbes in anaerobic soils. Iron, in its reduced form, is mobile and can be carried in the groundwater solution. When the iron and its brown color are thus removed, the soils show the gray color of their sand particles. The anaerobic, reduced zones can be recognized by their gray, blue, or blue-gray color. The mobilized iron tends to collect in aerobic zones within the soil where it oxidizes, or combines with additional oxygen, to form splotches of bright red-orange color called mottles. The mottles are most prevalent in the zones of fluctuating water and thus help mark the seasonal high water table.

The blue-gray layer with mottling generally describes wetland mineral soils. However, where saturation is prolonged, the slowed decomposition rate results in the formation of a dark organic layer over the top of the blue-gray mineral layer. Although classification criteria are somewhat complex, soils with less than 20 percent organic matter are generally classified as mineral soils and soils with more than 20 percent organic matter are classified as organic soils. For the purposes of this document, the organic layer becomes important when it reaches a thickness of approximately 16 inches. Under the right conditions, the layer can grow to many feet in thickness.

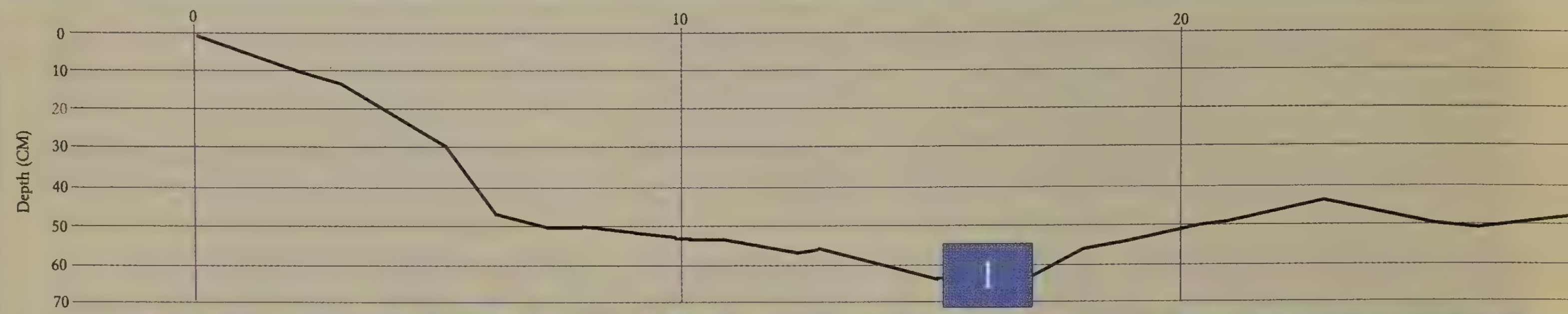
Howard C. Smith

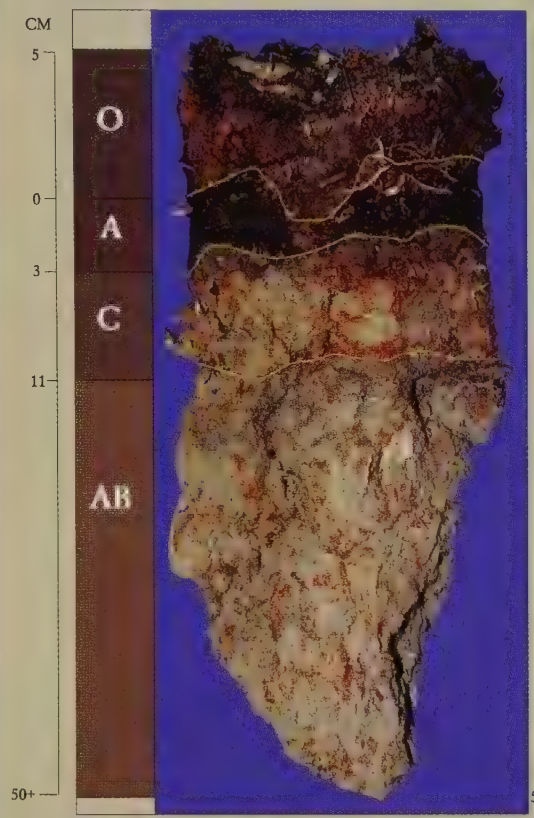
▲ Organic soils are characterized by very dark color and either fibrous or gelatinous structure.

The organic soils are separated in the soil survey into Fibrists, Saprists, and Hemists. The Fibrists, or peat soils, consist of soils in which the layer is brown to black color with most of the decomposing plant material still recognizable. In Saprists, or muck soils, the layer is black colored and the plant materials are decomposed beyond recognition. The mucks are black and greasy when moist and almost liquid when wet. Mucks have few discernible fibers when rubbed between the fingers and will stain the hands. The Hemists, mucky peats, are in between in both color and degree of decomposition.

Identification of larger areas of hydric soil has been simplified. They are identified on maps available at U.S.D.A. Natural Resources Conservation Service (NRCS) county offices.

The amount and decomposition of the organic component determines several important differences between mineral and organic wetland soils.

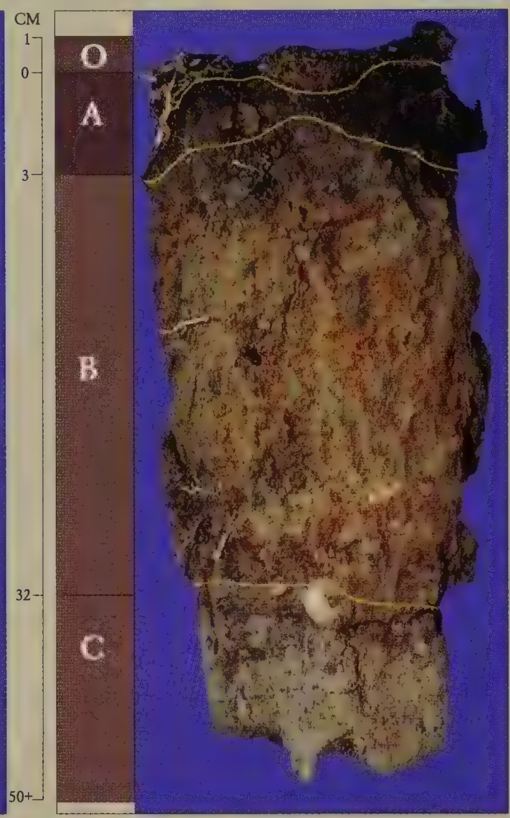




#1 Hydric Soil

O = incompletely decomposed organic debris
A = black muck in surface
C = recently trapped sediment
AB = buried surface or original soil

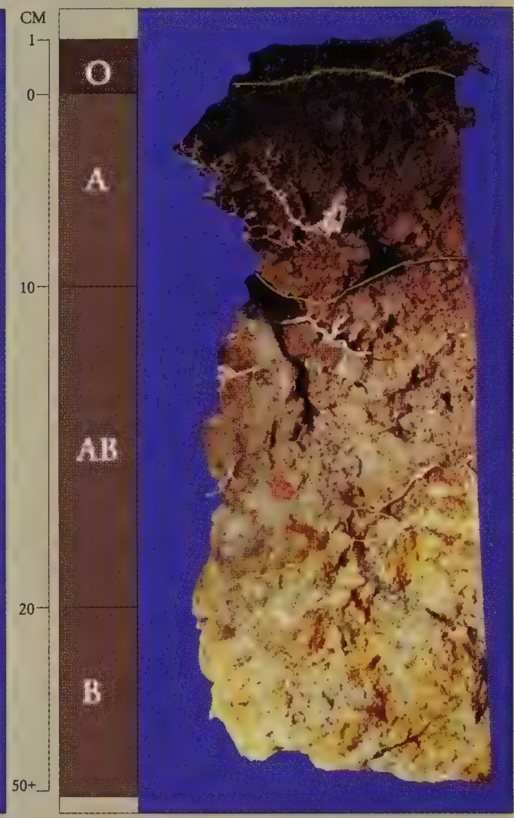
Profile #1 is a hydric soil and the wettest of the soils in this photo series. It shows two hydric soil characteristics, a thickened organic layer, explained below, and a gray matrix explained under the second profile. Profile #1 occurs at the lowest point in the wetland and is inundated for extended periods of time. The ponded water fills the soil pores preventing air from entering the soil. A few days of soil saturation is usually sufficient for soil microbes to exhaust the supply of dissolved oxygen in the soil water. The lack of oxygen slows the process of microbial decomposition causing partially decomposed organic matter to accumulate above the mineral layers of soil creating the thickened O and A layers apparent in this soil profile. The thick organic layer at the soil surface indicates a hydric soil.



#2 Hydric Soil

O = decaying organic debris
A = very dark gray organic matter incorporated into mineral surface
B = zone of fluctuating water table gray matrix with many strong brown iron concentrations.
C = zone of extended periods of saturation, gray matrix with few strong brown iron concentrations.

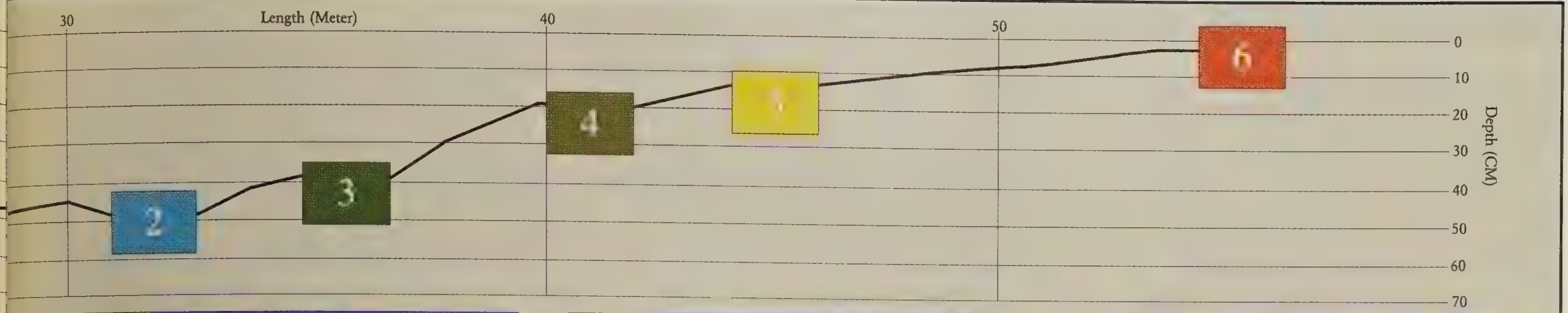
Profile #2, also a hydric soil, is somewhat higher in the landscape and although still subject to fluctuating water tables and lengthy periods of saturation, is not inundated for long periods. Therefore, the soil shows the gray matrix color in the B and C layers, but not the thickened organic surface. Without oxygen, microbes must utilize iron compounds to obtain energy from organic matter. In the process, iron compounds are converted from insoluble to soluble and flushed out leaving the gray background color. As iron precipitates in the aerated zones, additional soluble iron migrates from anaerobic sites unitl they become so depleted of iron that the gray color predominates. The term matrix is used to describe conditions in the dominant volume of soil within a layer. A soil layer is considered to be anaerobic when the soil matrix is dominated by gray depletion color. Layers B and C show the gray matrix indicating that these layers are saturated for long periods. The dull gray matrix extending to the soil surface indicates a hydric soil.

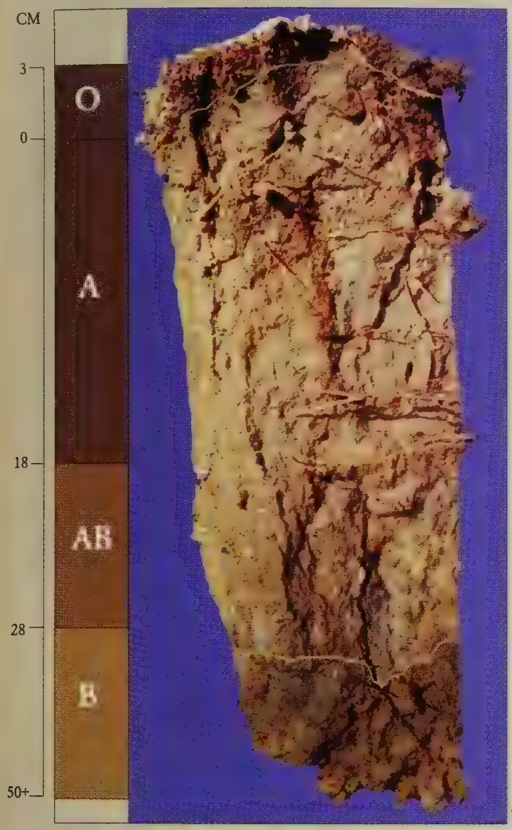


#3 Hydric Soil

O = organic debris
A = very dark grayish brown organic accumulations in surface.
AB = dark gray matrix and strong brown iron concentrations.
B = dark gray matrix with light gray depletions and strong brown iron concentrations.

Profile #3 is also a hydric soil and although saturated for shorter periods of time, still shows the strong gray matrix color all the way to the soil surface. Fluctuating water levels in the soil allow air to fill the larger pores as the water level lowers and then trap the air as the water level rises again. When the iron dissolved in the water encounters a zone of trapped air, it forms a strong red-brown colored precipitate. The precipitated colors are known as concentrations or mottles and are evident here in the AB and B layers. The gray matrix with bright mottles extending to very near the soil surface indicates a hydric soil.

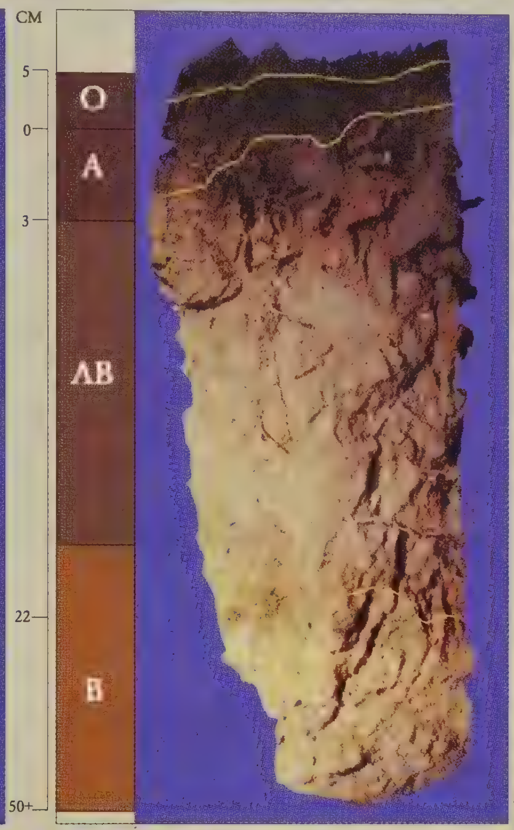




#4 NOT a Hydric Soil

- **O = leaf fragments over humus**
- **A = very dark grayish brown organic matter in surface.**
- **AB = light olive brown matrix with grayish brown depletions and strong brown iron concentrations**
- **B = light yellowish brown matrix with gray depletions and yellowish brown iron concentrations.**

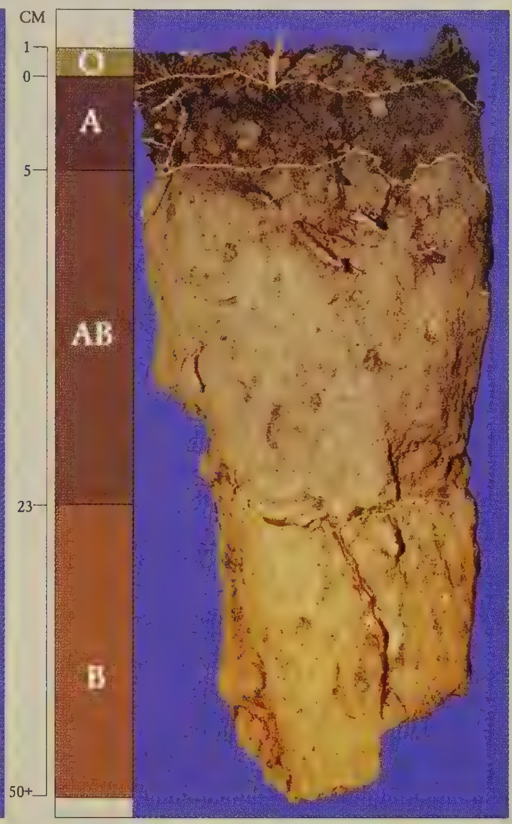
Profile #4 is significantly higher in the landscape and though it weakly displays wetness characteristics it is not a hydric soil. In both the A and B layers the matrix has medium colors associated with the original evenly distributed oxidized iron coatings on sand grains. Small areas of iron depletion and concentration exist, however the segregation process and attendant gray color is not dominant in any layer. This soil is probably saturated to the surface for only very short periods of time and is, therefore, not a hydric soil.



#5 NOT a Hydric Soil

- **O = leaf fragments**
- **A = very dark grayish brown organic matter in surface.**
- **AB = olive brown matrix with olive yellow iron concentrations.**
- **B = light olive brown matrix with pale brown depletions and yellowish brown iron concentrations.**

Profile #5 is not a hydric soil and shows evidence of saturation only in the deeper layers of the soil. As stated previously, iron depletions and concentrations are evidence of iron segregation due to saturation. The AB layer is saturated and anaerobic so infrequently that gray depletions are almost nonexistent. The deeper B layer shows faint depletions indicating that the soil is saturated only at depth and only for relatively short periods. Since the soil is seldom saturated to the surface and only saturated at depth for short periods of time, it is not a hydric soil.



Credit: Howard C. Smith

#6 NOT a Hydric Soil

- **O = leaf fragments**
- **A = very dark grayish brown organic matter in surface.**
- **AB = olive brown subsurface.**
- **B = yellowish brown subsoil.**

Profile #6 occupying the highest landscape position in this series, shows essentially no evidence of saturation and is not a hydric soil. In this soil the vertical redistribution of iron into horizons is associated with water percolating down through the soil profile. As a result, iron is evenly distributed within each of the soil layers. Saturation is either absent or restricted to such brief periods that the soil does not develop anaerobic conditions, thus preventing iron segregation and development of the gray matrix within the soil horizons. The absence of inundation also prevents the development of organic accumulations on the surface.

Mineral Soil Wetlands

Headwater Wetlands

Headwater wetlands are temporarily to seasonally flooded wetlands located at the origins of streams. Headwater wetlands have a hydroperiod that is characterized by predictable flooding associated with spring runoff and sporadic flooding associated with localized storm events. Headwater wetlands tend to be discharge wetlands where soil water and groundwater surface to become the origin of streams. Thus, these systems are hydrologically open and soluble inorganic material in groundwater plus soluble organic material in surface outflow are flushed causing headwater wetlands to be less acidic and more fertile than bogs and fens. The hydroperiod for headwater

David J. Welsch / U.S. Forest Service

▲ Black spruce, *Picea mariana*, and cinnamon fern, *Osmunda cinnamomea*, help identify this headwater wetland during a dry Pennsylvania summer.

Organic soils have lower bulk densities, that is lower weight per unit of volume, than mineral soils. Consequently, organic soils have more pore space and greater water holding capacity and while flooded can be more than 80 percent water by volume. By contrast, minerals soils are usually less than 55 percent water. However, water holding capacity has little effect on flood storage because the pores are usually filled and do not readily release moisture from the less porous lower layers.

The hydraulic conductivity, a measure of the speed at which water can move through the soil, varies considerably both within and between organic and mineral soils. While organic soils may have a larger water storage capacity, water movement may be considerably slower than in mineral soils. Much depends on the degree of decomposition of organic matter. However, the effect tends to extend the response time or period of time between the onset of a storm event and the resulting peak streamflow as discussed in the hydrology section.

Decomposition is also important in determining the location of the levels of greatest flow with respect to the surface in organic soils. The chart by Verry shows that more than 90 percent of the horizontal water flow in organic soil wetlands occurs at a depth of less than twelve inches below the surface. Relatively undecomposed organic matter near the surface creates larger pore spaces permitting greater flows. As depth increases and organic matter is more completely decomposed, pore spaces are blocked by ever finer particles of organic matter and flow is reduced.

HORIZONTAL WATER FLOW RATE AS A FUNCTION OF DEPTH BELOW THE SURFACE IN WETLANDS

Soil Horizon *(inches below the surface)*	Horizontal Water Flow Rate *(inches per hour)*	Reduction In Flow Rate *(percent)*	Degree of Decomposition *(1 to 10)*
0 – 3	250	0	1
3 – 6	140	44	2
6 – 9	63	75	3
9 – 12	21	92	4
12 – 18	7	97	5
18 – 24	3	99	6 & 7

Boelter and Verry 1977


Scott Jackson

▲ The northern dusky salamander, *Desmognathus fuscus, a good swimmer, climber and burrower, is well suited to headwater wetlands.*


© B. Schorre / Vireo

▲ The shy, elusive mourning warbler, *Oporornis philadelphia, favors moist thickets of headwater wetlands.*


Ann Rhoads, Morris Arboretum of the University of Pennsylvania

▲ Spotted touch-me-not, or jewelweed, *Impatiens capensis, is a common plant in headwater wetlands.*

wetlands shows spring time flooding as well as additional frequent flooding associated with even small local storms.

Common vegetation in headwater wetlands includes red maple, black gum, sweet gum, ash, swamp white oak, loblolly pine, nettles, and jewelweed.

Wildlife inhabiting the headwater wetlands include spring salamander, wood turtle, water shrew, common merganser, northern dusky salamander, two-lined salamander, beaver and moose and neotropical birds such as the Louisiana waterthrush and mourning warbler.

Landings and equipment storage areas should be kept out of headwater wetlands due to the frequent, unpredictable flooding common to these wetlands. Open hydrologic conditions mean extra care since pollutants introduced here can quickly affect downstream environments.

Organic soils tend to be richer than mineral soils in the nutrients important to plant productivity. But organic soils often have very low productivity because the nutrients present are bound in organic compounds and thus unavailable for plant growth. Therefore, unless the wetland receives an inflow of nutrients from other sources, the plant forms present are apt to be those with low nutrient requirements or special adaptations such as carnivorous plants.

When not flooded, organic soils generally have more hydrogen cations available, tending to make them more acid than mineral soils. Hence, acid loving plants are associated with organic soils. An example is the sphagnum mat or ring that forms around a bog lake. Exceptions are those fens which are influenced by limestone geology and thus receive calcium bicarbonate in groundwater. The bicarbonate easily removes the free hydrogen cations by forming water and carbon dioxide and results in fens that are neutral to basic.

Organic soils have a greater potential for removal of excess nutrients and other pollutants. Small soil particles with large surface to volume ratios have the ability to attract and hold positively charged ions, known as cations such as ammonium (NH4++) and calcium (CA++). The cations are adsorbed or loosely held by electrical attraction. Cations held in this way may be stored for extended periods in sediments or removed and incorporated into other natural compounds by chemical or microbial activity. When the adsorbed cations are incorporated into other compounds the soil particles become available to adsorb additional cations. In this way, wetland soils maintain their ability to remove and recycle excess nutrients and other pollutants. Cation exchange capacity is one measure of the potential for wetland soils to alter the chemistry of the waters moving through them and to transform nutrients into other forms.

Streamside Wetlands

Streamside wetlands may be narrow in upland areas and expand somewhat as the valleys widen along larger streams. Because these wetlands are associated with streams having larger watersheds, the hydroperiod has a more predictable pattern in which flooding is closely associated with spring thaw and larger, more regionalized storm events. Hydrographs for streamside wetlands also show some delay between storm events and peak flows due to the distance from the headwaters. Like headwater wetlands, streamside wetlands are hydrologically open.

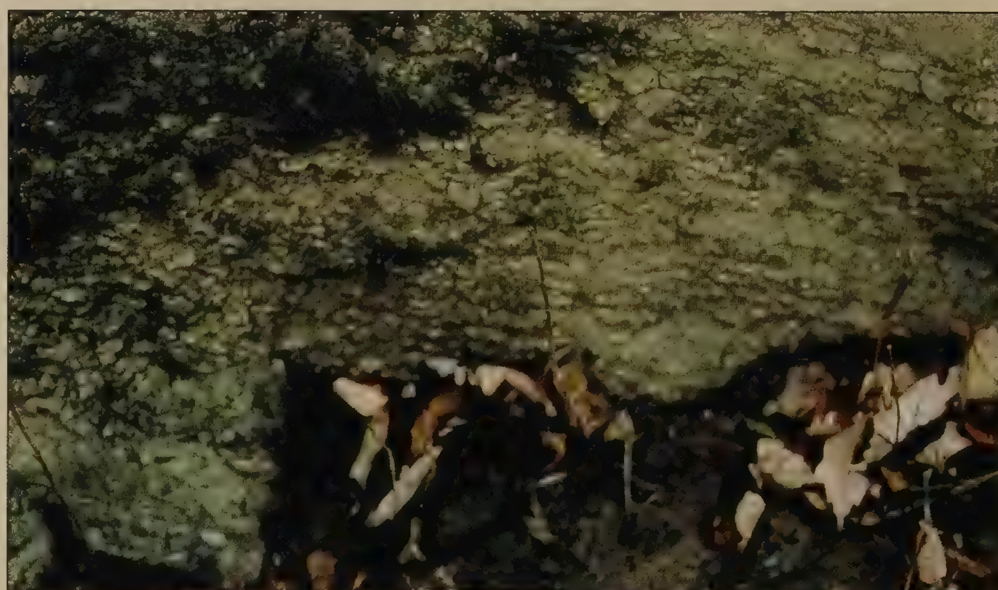
Scott Jackson

▲ In summer, the status of this Massachusetts streamside wetland is indicated only by subtle vegatative hints.

VEGETATION

Another of the physical characteristics used to identify wetlands is the presence of hydrophytic vegetation. The term hydrophyte comes from the Greek words *hydro*, meaning water, and *phyton*, meaning plant. The term hydrophyte includes all aquatic and wetland plants. However, the term is generally used to refer to vascular aquatic and wetland plants. Though hydrophytes represent only a small percentage of the total plant population, there are far too many to list here.

Upland plants normally have adequate soil oxygen available to the roots for use in the metabolic processes that convert food into energy. When soil saturation or flooding make oxygen unavailable, the metabolic process either stops altogether or shifts to anaerobic glycolysis, an enzymatic process that does not require oxygen to convert food into energy. Anaerobic glycosis produces much less energy than normal metabolic processes and causes an accumulation of toxic end products. Using anaerobic glycosis, most plants can produce only enough food to survive for short periods of time. Hydrophytic plants thrive in wetland soils in spite of the limitation or absence of oxygen because they are able to make special physiological adaptations.



David J. Welsch/U. S. Forest Service

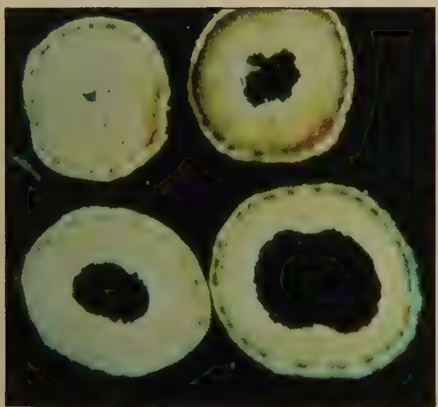
▲ Hypertrophied lenticels, horizontal swollen areas on the base of this silver maple tree, facilitate exchange of oyxgen between the tree tissue and the atmosphere.

Hydrophytic plants vary in the number of adaptations they exhibit, but generally those that exhibit a greater number of adaptations also exhibit greater tolerance to saturated soil conditions. Relatively few tree species, such as cypress and water tupelo, are able to make enough of these adaptations to tolerate flooding for more than a few weeks during the growing season. However, there are a number of species that exhibit one or more of these adaptations and thus tolerate varying degrees

Scott Jackson

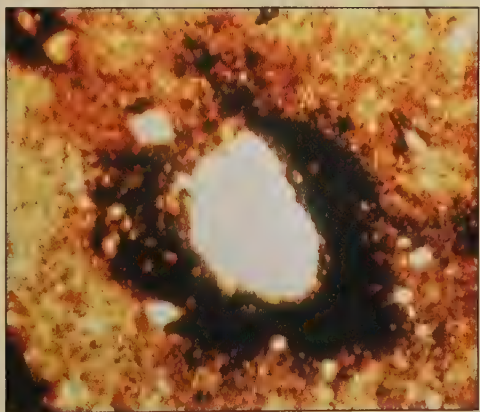
▲ Springtime floods remove all doubts as to the status of the streamside wetland seen in the picture at left.

The greatest variety of plant and animal species in the forest are associated with streamside wetlands. Vegetation associated with these wetlands include ostrich fern, sycamore, red maple, swamp white oak, green ash, river birch, black willow, privet, speckled alder and pin oak.



Corps of Engineers

▲ Alligator weed, *Alternanthera philoxeroides*: stem cross-sections show progressively larger aerenchyma formations from the drier site (upper left) to the wettest site sample (lower right).



Corps of Engineers

▲ A pore lining: the dark circle surrounding the opening is caused by oxidizing of iron by air reaching otherwise anaerobic soil through the pore opening.

Corps of Engineers

▲ An oxygenated rhizosphere or coloration of the exterior root surface caused by oxidizing of iron by air leaking out of the roots into otherwise anaerobic soil.

of soils wetness. Some plants such as green ash form hypertrophied lenticels, enlarged structures on the above ground portion of the plant that permit the exchange of gasses with the atmosphere facilitating the transfer of oxygen from the air to the plant tissue. Green ash and northern white-cedar grow large diameter, succulent roots at least partially composed of cells with air spaces between them, called aerenchyma, which facilitate movement of oxygen throughout the root tissue. Water hickory, black spruce and balsam fir develop fibrous, lateral root systems which tend to spread horizontally above the wetter soil levels. Larch, water hickory and water tupelo develop adventitious roots, extra roots on the tree stem, again, above the level of the wetter soil. Bald cypress and water tupelo develop a swelling at the base of the tree which helps resist windthrow and may facilitate the exchange of oxygen.

In some wetland adapted plants such as cordgrass, *Spartina*, the oxygen supply is large enough to cause oxygen to be diffused out through the roots oxygenating the rhizosphere, or outer surface of the root. Soil iron and manganese deposits in these areas are often oxydized by this method resulting in streaks of rust commonly seen in wetland soils.

Hydrophytic and other plants used to identify wetlands for regulatory purposes are listed in the National List of Plant Species that Occur in Wetlands, Biological Report 88(24), U.S. Department of the Interior, Fish and Wildlife Service. This publication lists five indicator categories for plants which can be found in wetlands: Obligate Wetland (OBL, > 99 percent occurrence), Facultative Wetland (FACW, 67-98 percent occurrence), Facultative (FAC, 37-67 percent occurrence), Facultative Upland (FACU, found in wetlands 1-33 percent of the time), and Obligate Upland (UPL, < 1 percent occurrence in wetlands in the area in question, but may be wetland plants in other regions). Abundant presence of species in the Obligate and Facultative Wetland indicator categories is a reliable indicator that a given tract of land is functionally a wetland. The absence of these species, however, is not a reliable indicator that an area is not a wetland, as these species may have been locally extirpated by severe disturbance or management.

Scott Jackson

▲ Royal fern, *Osmunda regalis*

Joe Emerick

▲ Common cattail, *Typha latifolia*

Corps of Engineers

▲ New York ironweed, *Vernonia noveboracensis*

The following is a list of some plants that commonly occur in wetlands in the Northeastern Area along with their indicator category for the northeastern region. This is not a comprehensive list, but merely a short list of readily identified plants the presence of which may indicate the need for further reconnaissance to determine if wetlands are present in the area. To be effective, a short list would have to be developed for a specific locale.

Common Name	Botanical Name	Category
swamp white oak	*Quercus bicolor*	FACW
northern white-cedar	*Thuja occidentalis*	FACW
green ash	*Fraxinus pennsylvanica*	FACW
black spruce	*Picea mariana*	FACW
tamarack	*Larix laricina*	FACW
water tupelo	*Nyssa aquatica*	OBL
highbush cranberry	*Vaccinium trilobum*	FACW
small cranberry	*Vaccinium oxycoccos*	OBL
leatherleaf	*Chamaedaphne calyculata*	OBL
buttonbush	*Cephalanthus occidentalis*	OBL
swamp azalea	*Rhododendron viscosum*	OBL
winterberry	*Ilex verticillata*	FACW
speckled alder	*Alnus rugosa*	FACW
swamp privet	*Forestiera acuminata*	OBL
swamp rosemallow	*Hibiscus moscheutos*	OBL
royal fern	*Osmunda regalis*	OBL
sensitive fern	*Onoclea sensibilis*	FACW
common cattail	*Typha latifolia*	OBL
soft-stem bulrush	*Scirpus validus*	OBL
wool-grass	*Scirpus cyperinus*	FACW
skunk-cabbage	*Symplocarpus foetidus*	OBL
round-leaved sundew	*Drosera rotundifolia*	OBL
pitcher plant	*Sarracenia purpurea*	OBL
American burreed	*Sparganium americanum*	OBL
common arrowhead	*Sagittaria latifolia*	OBL
common reed	*Phragmites australis*	FACW
purple loosestrife	*Lythrum salicaria*	FACW
cardinal flower	*Lobelia cardinalis*	FACW
New York ironweed	*Vernonia noveboracensis*	FACW
alligator weed	*Alternanthera philoxeroides*	OBL


Scott Jackson

▲ The spikes of sensitive or bead fern, *Onoclea sensibilis*, persist through the winter.


Joe Emerick

▲ American burreed, *Sparganium americanum*


Scott Jackson

▲ Sensitive fern, *Onoclea sensibilis*

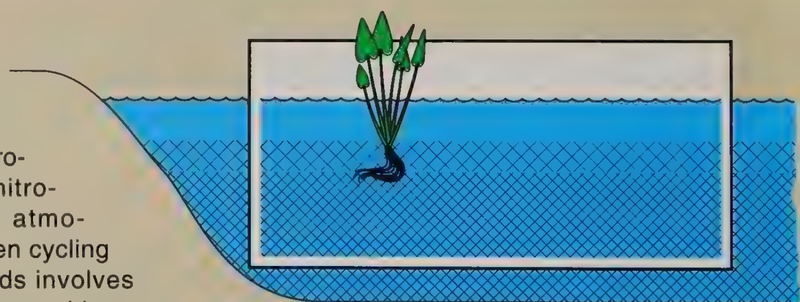
▲ Speckled alder, *Alnus rugosa*, a common shrub in streamside wetlands, is readily recognized by its catkins, or seed heads.

Streamside wetlands provide habitat for the two-lined salamander, green frog, bullfrog, pickerel frog, leopard frog, musk turtle, wood turtle, box turtle, snapping turtle, muskrat, mink, otter, moose, great blue heron, green heron, black duck, wood duck, red-breasted merganser, kingfisher, woodcock, osprey and bald eagle. These also provide important

BIOGEOCHEMICAL CYCLES

The basic elements that occur in living organisms move through the environment in a series of naturally occurring physical, chemical and biological processes known as biogeochemical cycles. The cycle generally describes the physical state, chemical form, and biogeochemical processes affecting the substance at each point in the cycle in an undisturbed ecosystem. Many of these processes are influenced by microbial populations that are naturally adapted to life in either aerobic, oxygenated, or anaerobic, oxygen free, conditions. Because both of these conditions are readily created by varied and fluctuating water levels, wetlands support a greater variety of these processes than other ecosystems.

There is usually a physical state, chemical form, and location in the cycle in which nature stores the bulk of the various chemical elements. Pollution occurs when the cycle is sufficiently disturbed that an element is caused to accumulate at some point in the cycle in an inappropriate physical state, chemical form, location or amount disrupting environmental balance.



In the nitrogen cycle, for example, the bulk nitrogen is stored as nitrogen gas in the atmosphere.The nitrogen cycling process in wetlands involves both aerobic and anaerobic conditions. Nitrogen in the form of ammonium (NH_4) is released from decaying plant and animal matter under both aerobic and anaerobic conditions in a process known as ammonification. The ammonium then moves to the aerobic layer where it is converted to nitrate (NO_3). Nitrate not taken up by plants or immobilized by adsorption onto soil particles can leach downward with percolating water to reach the groundwater supply or move with surface and subsurface flow. Nitrate can also move back to the anaerobic layer where it may be converted to nitrogen gas by denitrification, a bacterial process, and subsequently returned to the atmosphere.

If both aerobic and anaerobic conditions were not available, some of the cycle processes would cease and pollutants could accumulate. In wetlands, anaerobic condition are amply provided by flooding and by saturated soils. However, the oxygen requiring processes take place in a thin oxydized zone usually existing at the soil surface. This layer may be only a fraction of an inch thick and is present even when the wetland is submerged. In many wetlands the water table fluctuates 12 to 18 inches each year with the summer level averaging between 4 and 18 inches below the surface of the soil. This zone of aeration is often called the active layer or in Russian soil terminology, where it was first used, the *acrotelm*.

Phosphorus, sulfur, iron, manganese and carbon also move through the wetland ecosystem in complex cycles. Sulfur and habitat for neotropical birds such as the yellow warbler, yellow-throated warbler and eastern phoebe.

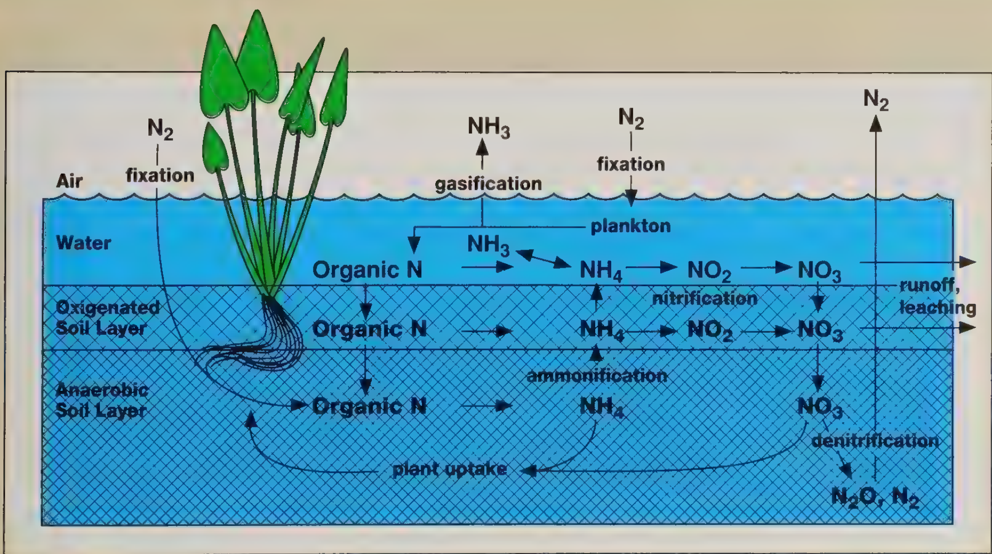
While flooding is somewhat more predictable in streamside wetlands than in headwater wetlands, they are still subject to occasional unexpected flooding. This, along with the relatively small area involved, makes it prudent to locate landings and equipment storage areas outside of these wetlands. When it is absolutely necessary for haul roads and skid trails to be located in the wetland, they must be designed so as not to impede the natural hydrology including the inflow and outflow of flood waters.


© W. Breene / Vireo

▲ Yellow warbler, *Dendroica petechia*, builds a nest of silver-gray fibers in low bushes of streamside wetlands, often adding new floors to avoid hatching eggs of invading cowbirds.


© Doug Wechsler

▲ Box turtle, *Terrapene carolina*, burrows in the mud of streamside wetlands to stay cool in summer.



After Mitsch and Gosselink 1993

▲ Nitrogen cycling in wetlands progresses more rapidly where there is a thin oxygenated soil layer present.

carbon, like nitrogen, have gaseous cycles. As a result of the biogeochemical cycle processes, sulfides and methane are released into the atmosphere attended by the smell of rotten eggs and swamp gas respectively. Phosphorus, however, has a sediment cycle with excess phosphorus being tied up in sediments, peat in organic wetlands and clay particles in mineral wetlands. However, although phosphorus retention is an important attribute of wetlands, sediment attached phosphorus is subject to resuspension and movement with water when sediments are disturbed.

The cycles are similar in that they provide storage for excess elements and require a certain amount of time to complete the chemical processes. The cycle processes also require the varying environments provided by aerobic and anaerobic conditions. In closed systems, the processes take place within the wetland. In open systems, like riparian wetlands, many elements can be imported from or exported to adjacent systems with surface and groundwater flows or flooding.

To avoid changing the natural biogeochemical function, it is important that the hydrology of the wetland, the inflow, outflow and residence time of the water, remain relatively undisturbed. It is also necessary to minimize disturbance to the aerobic zone of saturated soils. However, even with minimal disturbance, wetlands will continue to function as net receptors (sinks) or net exporters (sources) of various elements primarily due to seasonal and other natural fluctuations in the biogeochemical cycle processes.

Wooded Swamps

Wooded swamps include broad bottomland forests in the floodplains of large rivers with very large watersheds. As a result, the hydroperiod shows a very predictable pattern in which flooding is associated only with spring thaw and prolonged, regional storm events. Hydrographs for wooded swamps show greater delay between storm events and peak flows due to the remoteness of their headwaters. Wooded swamps are also hydrologically open and dependent, to a degree, on floodwaters for the delivery of nutrient laden silts affecting their fertility.

▲ Red maple, *Acer rubrum*, is a common species in wooded swamps such as Beckville Woods in Indiana.

WILDLIFE

Forested wetlands generally support a greater variety of wildlife than nearby upland forests. Wetlands are essential life support systems to a tremendous array of wildlife species. The variety of forested wetlands types and the associated variation in plant communities provide all of the essential habitat needs for species such as the wood turtle, massasauga, water shrew, muskrat, beaver and various ducks, geese and herons. Wetlands also provide one or more essential habitat needs for many other species such as the tree swallow, yellow warbler, alder flycatcher, star nose mole and woodcock.

Manipulation of wetland wildlife habitat or alteration of wildlife populations through management practices may be detrimental to wildlife. Alternatively, forest management practices can accomplish many wildlife objectives if conducted with consideration given to the principals of sound wildlife management. Objectives may be enhancing wildlife diversity or habitat, preventing destruction of habitat, providing for consumptive or non-consumptive use of wildlife or managing for a particular endangered or threatened species habitat.

© A. Walther / Vireo

▲ One third of all bird species, such as these snow geese, *Chen hyperborea*, depend on wetlands for one or more of their habitat requirements.

Wetlands are most often identified with waterfowl and, nationwide, all wild ducks, geese, swans, herons and bitterns require wetland, vernal ponds or spring seeps for reproduction activities. The central flyway,

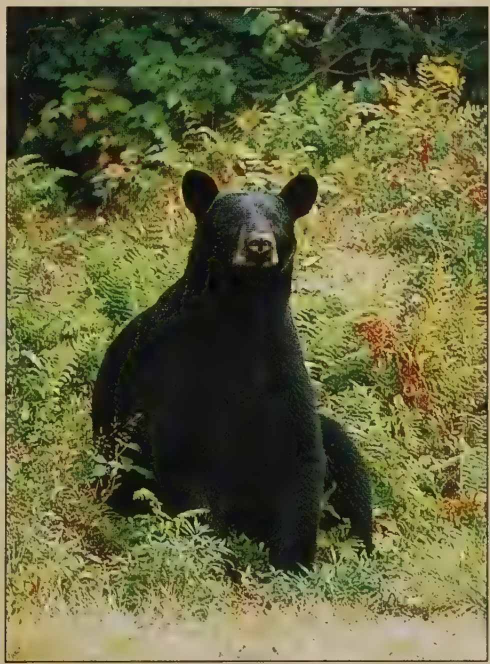
Donald J. Leopold

Joe Emerick

▲ Cinnamon fern, *Osmunda cinnamomea*, helps identify wooded swamps in summer, while the fertile spikes in the center of the fern remain as a clue throughout the winter.

© A. & E. Morris / Vireo

▲ Wooded swamps supply the snakes, frogs and small birds that constitute the diet of the red-shouldered hawk, *Buteo lineatus*.



Joe Emerick

▲ Black bear, *Ursus americanus*, spend more than 60 percent of their lives in wetlands.

a corridor composed of lakes, streams and wetlands scattered in a north-south direction through the central U.S., is used by millions of ducks and geese for their annual migrations because of the resting opportunities it provides. Waterfowl habitat needs change with the season, stage of life and type of waterfowl, yet the various kinds of wetlands provide for all of these habitat requirements. Wood ducks, for example, find their habitat needs in forested wetlands. In addition, one third of all U.S. bird species, about 230 out of 686 species, depend on wetlands for one or more of their life requirements. As an example, the tree swallow, while not totally dependent on wetlands, is dependent on wetlands for both nesting and feeding habitat. Red shouldered hawks prefer beaver ponds for feeding areas and woodcock make heavy use of alder thickets to search for summer earthworms.

Wetlands are important to mammals as a source of food and cover. Bears are omnivorous consumers and feed on fish, frogs and numerous berries found in wetlands. Bears are known to spend 60 percent of their time in spring and summer in forested wetlands and the remainder of their time moving between wetland areas (Newton 1988). Mink favor cover found in thickets in forested wetlands. White-tailed deer, beaver and weasel are examples of species that also utilize cover and food available in wetlands.

The rich food supply of microscopic algae and small invertebrates and the lack of predatory fish in vernal pools provides a

▲ Skunk cabbage, *Symplocarpus foetidus*, appears in early spring and grows so rapidly that heat of respiration helps it melt its way through the snow.

▲ False hellebore, *Veratrum viride*, is a conspicuous spring wetland plant.

Vegetation includes ostrich fern, royal fern, cinnamon fern, Canada mayflower, goldthread, starry false Solomon's seal, nodding trillium, American false-hellebore, lizard's tail, skunk cabbage, red maple, bald cypress, pin oak, swamp white oak, swamp chestnut oak, overcup oak, willow oak, cherrybark oak, black gum, water tupelo, swamp tupelo, cottonwood, sycamore, loblolly pine and Atlantic white cedar.

Wooded swamps provide habitat for wood duck, hooded merganser, spotted turtle, star-nosed mole, mink, raccoon, water snake, ribbon snake, wood frog, spring peeper, gray treefrog, spotted salamander, great blue heron, green heron, barred owl and neotropical birds such as the northern waterthrush,

habitat significant and sometimes critical to the continued survival of amphibians. Approximately one hundred ninety species of amphibians, including frogs, toads and salamanders, require wetlands such as vernal pools or spring seeps for reproduction activities. Some of these habitat requirements are unusual and very specific. The four-toed salamander makes its nest in the sides of sphagnum hummocks in such a way that the newly hatched salamanders fall directly into water, a condition critical to their survival. However, many other reptiles and amphibians have simply adapted to the fluctuating water levels commonly found in wetland environments.

Most freshwater fish feed in wetlands or on wetland produced foods. Wetlands in the flood plains of larger rivers provide spawning habitat for species such as bullhead, yellow perch, northern pike and muskellunge and are critical to the continued survival of these species. Yellow perch, walleye and bluegills leave open lake waters to spawn in shallow water wetlands.

Most commercial game fish use coastal wetlands as spawning and as nursery grounds. Striped bass, bluefish,

▲ This moose, *Alces alces*, a common wetland dweller, is just emerging with a lunch of aquatic plants.

salmon, menhaden and flounder are among the species of fish that depend on coastal wetlands. Shellfish such as oysters, clams, shrimp and blue crabs also depend on coastal wetlands for survival.

Although wetlands comprise only about five percent of the land area of the 48 contiguous states, almost 35 percent of the nation's threatened and endangered species either live in or depend on wetlands. Canby's dropwort is an example of an endangered plant species found in herba-

▲ American redstart, *Setophaga ruticilla,* is the only warbler with large orange to yellow tail patches.

◀ Large blueflag, *Iris versicolor,* occurs in swamps from Maine to Tennessee. The word "flag" is from the Middle English "flagge", meaning rush or reed.

common yellowthroat, blue-gray gnatcatcher and American redstart.

Because wooded swamps tend to be larger in land area, it may be necessary to locate some skid trails, landings or haul roads within them. These facilities should be held to the absolute minimum and constructed during the predictable dry periods. Skid trails, landings and haul roads must also be designed so as not to impede the natural hydrology including the inflow and outflow of flood waters.

▲ Coniferous wetland deer yarding areas provide relief from cold weather and deep snow.

ceous wetlands in Maryland.

Besides the direct habitat benefits provided to wetland dependent fish and wildlife species, wetlands also provide substantial indirect benefits to wildlife. Wetlands improve water quality for fish and wildlife by serving as nutrient sinks. Wetlands tend to reduce coliform levels as a result of prolonged exposure of the bacteria to sunlight, oxygen and cool water temperatures in the slow moving waters of colder wetlands. Wetlands improve aquatic habitat by slowing water movement and allowing sediment to settle out of the water column. Wetlands provide special protective cover for some species such as the special winter cover provided to pheasants by cattails.

Additional indirect benefits wetlands provide to wildlife include drinking water sites, special feeding sites and travelways. Special feeding sites are best characterized by spring seeps, the broad, very shallow water wetlands that provide the first snow free areas in early spring and are heavily used for feeding by wild turkeys. Wooded wetlands along large streams in otherwise open country are used as travelways by migrating neotropical birds and large mammals such as bear, deer and moose when traveling between larger tracts of forest.

In northern states where prolonged winters are combined with deep snows, the population of large ungulates such as deer and moose is directly dependent on the quality and quantity of the vegetation in the wooded wetlands of the region. Wetlands with overstory conifers for thermal cover and a dense understory for a food source are used by deer throughout the winter.

Bill Healy / U.S. Forest Service

▲ A spring seep on Twin Branch, Monongahela National Forest, West Virginia, shows the broad shallow character of the flow.

Spring Seeps

Spring seeps are broad shallow flows that occur where groundwater emerges on sloping terrain usually on the lower slopes of hillsides and mountains. They are discharging wetlands in these situations and can be the source of small streams. However, they may also percolate back into the groundwater becoming recharging wetlands.

Spring seeps are valuable to wildlife, particularly wild turkey, in severe winters because the emerging groundwater provides snow free feeding sites in winter and are among the first sites to provide green plants in spring.

Bill Healy/U. S. Forest Service

▲ Wild turkeys, *Meleagris gallopavo*, use spring seeps for snow-free foraging in early spring.

Bill Moriarity / U.S. Forest Service

▲ A spring seep on the Allegheny National Forest in Pennsylvania; ferns and mosses mark the broad shallow seep area.

Spring seeps are used by amphibians such as the northern dusky salamander, spring salamander and by neotropical birds such as the worm eating warbler, veery and wood thrush.

Plants to look for include moist site tree species, skunk cabbage, sedges, water cress, marsh marigold, goldthread, wintergreen and sensitive fern.

Where possible, haul roads and skid trails should be routed above the seep at a distance sufficient to avoid disturbing the flow. When roads or trails must pass below the seep they should pass at a point beyond where the seep has reentered the ground or where a defined channel permits an environmentally acceptable crossing such as a culvert.

© J. R. Woodward / Vireo

▲ Wood thrush, *Hylocichla mustelina, the only thrush with a bright reddish-brown head, has an unhurried, bell-like melody. It builds a nest of mud and grass in low shrubs.*

Beaver Ponds

Beaver respond to an instinct to impound flowing water. Consequently, beaver ponds usually expand and alter existing streamside wetlands. However, beaver also create ponds and wetlands where none would otherwise exist. Beaver pond ecosystems have their own life cycle. Trees and other vegetation are killed by the prolonged high water levels until little more than grasses and forbs remain. In time, the beaver's food supply will be depleted resulting in abandonment of the dam, lowering of the water table and a return to forest through plant succession. Once forested, the cycle starts over with beaver re-establishment. The hydrology of the wetland created by a beaver dam reflects the hydrology of the setting in which it is built. If the beaver dam is built in a headwater setting, the hydrology will be similar to that of a headwater wetland.

Many forest plants and animals depend on the site at different stages

David J. Welsch / U.S. Forest Service

▲ Beaver dam wetlands provide special habital needs of other species such as great blue heron. Note a tree top nest in the background.

in the cycle. Snags, large old dead trees, left in the pond from the forest cycle provide preferred nesting sites for herons and nesting cavity species. Hence both forest and pond cycles are necessary to sustain this habitat. Plants typical of beaver pond wetlands include pondweed, arrowhead, cattail, smartweed, alder, red maple, aspen, manna grass, rice cutgrass, bulrushes and sedges.

Joe Emerick

▲ Beaver, *Castor canadensis*, will often abandon their dams when preferred food species are depleted.

Joe Emerick

▲ Abandoned beaver dams provide a series of unique habitats as they progress through various successive stages on their return to forest conditions.

Wildlife species using beaver dam wetlands include beaver, great blue heron, green heron, red spotted newt, green frog, bullfrog, wood duck, black duck, hooded merganser, snapping turtle, water snake, ribbon snake, star nosed mole, mink, otter, moose, tree swallow, raccoon, spring peeper, gray treefrog, bullfrog. Neotropical birds such as the prothonatory warbler, Philadelphia vireo, tree swallow and ruby crowned kinglet also use beaver ponds.

Cornell Ornithology

▲ Great blue heron, *Ardea herodias*, the largest of the herons, approaches 48 inches tall and builds nests of twigs in swamps and on ridges overlooking broad rivers. It can often be seen in wetlands where it stands motionless for long periods, fishing.

© A. & E. Morris / Vireo

▲ The tree swallow, *Iridoprocne bicolor*, is the hardiest of the swallows and the only eastern/midwestern swallow with all white underparts. It nests in cavities or boxes near water.

Regulatory requirements vary from state to state. Check with your state fish and game department before disturbing a beaver pond. Bridging the narrow stream below the dam may be the best alternative for crossing drainages with beaver dams.

Joe Emerick

The great blue heron flies with slow, heavy wingbeats, appearing almost prehistoric.

Vernal Ponds

Vernal ponds are small ponds that are most obvious in the forest during the spring of the year. Although some vernal ponds may not meet the statutory definition of wetlands, they will be addressed here because the subject comes up whenever wetland forest management is discussed. The ponds derive their name from *vernalis*, the Latin word for spring, because they result from various combinations of snowmelt, precipitation and high water tables associated with the spring season. The ponds tend to occur in small depressions and while many dry up in late summer, a few have water year round. The ponds vary greatly in terms of recharge, discharge characteristics, source of water and geology. Those supplied by groundwater from limestone geology tend to be less acid and less variable in acidity. By definition, vernal ponds are free of fish and can, therefore, support a rich community of amphibians and invertebrates that would be difficult to sustain if fish were present.

Randy Cassell

▲ Vernal ponds should be located in late winter or early spring when the ponds are most readily recognized. Salamander activity is at its peak at this time.

Randy Cassell

▲ The marbled salamander, *Ambystoma opacum*, mates and males deposit sperm sacks (at right of head) on warm, rainy summer nights.

Randy Cassell

▲ The female marbled salamanders fertilize and deposit their eggs a few days after mating.

Typical pond users include salamanders such as the marbled salamander which migrates from burrows in the forest floor to the pond basin with the onset of fall rains. The males leave sperm sacks to be used by the females to fertilize the eggs which are deposited under rocks and leaves on the pond bottom. The adults then return to the forest and as the fall rains fill the pond the eggs hatch and the larvae feed on the invertebrate life of the pond. The Jefferson salamander migrates over the snow on rainy nights in late winter to slip into the pond through cracks in the ice. After mating, the females attach their egg masses to small twigs under water. The spotted salamander arrives after the Jefferson and similarly deposits egg masses on twigs under the water.

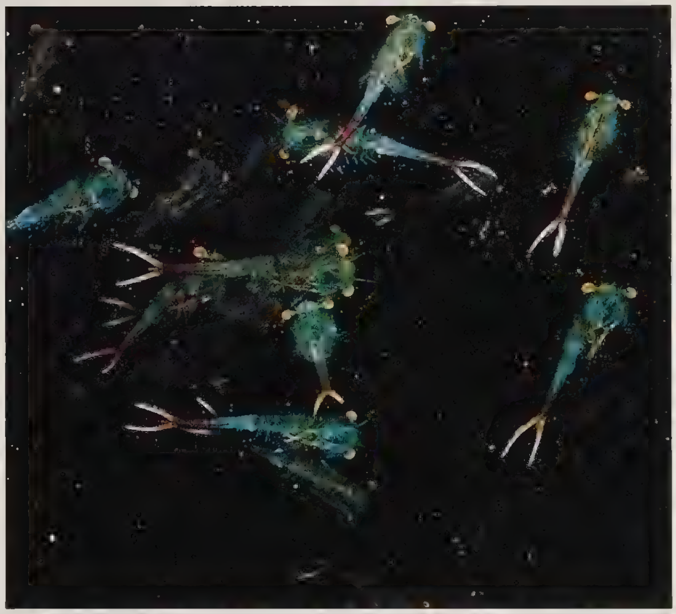
Randy Cassell

Jefferson salamanders, *Ambystoma jeffersonianum*, migrate throught the icy pond surface on late winter nights when temperatures are a degree or two above freezing and light rain is falling to mate in pairs and deposit eggs on twigs in the pond. ▶

Randy Cassell

◀ Spotted salamanders, *Ambystoma maculatum*, mate in groups shortly after the Jefferson salamanders and also attach their eggs to twigs where they will swell to large gelatinous masses.

These species are followed in turn by wood frogs, spring peepers, spadefoot toads, gray tree frogs, American toads and other amphibians who depend on the pond habitat for reproduction. The developing amphibians prey on fairy shrimp, copepods, daphnia, phantom midge larvae, and mosquito larvae and, in turn, are preyed upon by insect predators such as diving beetles, backswimmers and fishflies (Cassell 1993). Neotropical birds such as the worm eating warbler, veery and wood thrush also use the vernal pond area.



Randy Cassell

▲ These fairy shrimp and other pond life provide food for the voracious young salamanders.

Randy Cassell

▲ In the months that follow, wood frogs, *Rana sylvatica*, and other amphibians visit the ponds to lay eggs.

The ponds typically occur under the forest canopy with the pond basin relatively free of vegetation. Thinning of the canopy can result in accelerated evaporation rates shortening the duration of pond flooding and dehydrating the larvae before development is complete. Increased exposure to sunlight can also result in invasion of the pond by rice cutgrass, manna grass, sedges and buttonbush which appear to be more favorable to species such as green frogs, pickerel frogs and cricket frogs which are not typical of canopied ponds.

David J. Welsch / U.S. Forest Service

Buttonbush, *Cephalanthus occidentalis*

Larry Klotz

▲ Crown closure must be maintained over the pond to prevent destruction of the habitat by the invasion of buttonbush and other undesirable plants.

Deep tire ruts in the vicinity of the pond are also a problem. They can be a physical trap for young salamanders and turtles not developed enough to climb out of them. The ruts can also be mistaken for the pond destination by adults who deposit egg masses in the ruts. In both cases, the young will probably be eaten by predators or die of dehydration because the ruts usually dry out before the vernal ponds.

The ponds are easily recognized in early spring when they are filled with water and this is the best time to establish their location. In summer they are more difficult to recognize, but some indicators are blackened and compressed leaf litter, buttressed tree trunks, water marked tree trunks, and the presence of vegetation such as red maple, highbush blueberry and buttonbush.

Management plans should call for marking the location of vernal ponds and any necessary protective zones in the spring when the ponds are filled with water.

Randy Cassells

▲ Vernal ponds are difficult to recognize in summer, but buttressed trees, blackened leaves and water-stained trunks are clues.

Wetlands Best Management Practices

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WETLANDS
BEST MANAGEMENT PRACTICES

The following is a list of wetland best management practices intended to supplement existing upland forestry best management practices and to reduce potential adverse impacts of forest management activities on wetlands. Note that some upland BMP's have been included as appropriate to facilitate understanding. While some of the practices may be required by law, they are listed here simply as a means of protecting the wetlands functions and values.

This list is intended as an example and to be effective should be supplemented or refined by individual State Foresters in consultation with representatives of other natural resource management agencies such as the U.S. Army Corps of Engineers, Environmental Protection Agency, Natural Resources Conservation Service, Fish and Wildlife Service, State Water Quality Agency, consultant foresters, forest industry representatives and others for use in their respective states. The list should not be considered a checklist of mandatory practices as there will seldom be a situation in which all of the practices will be needed on the same area at the same time.

THREE PRIMARY CONSIDERATIONS

1. Consider the relative importance of the wetland in relation to the total property to be managed. Perhaps the wetland should simply be left undisturbed.
2. Protect the environment. Do not alter the hydrology of the wetland by:
   - restricting the inflow or outflow of surface, sub-surface or groundwater,
   - reducing residence time of waters,
   - introducing toxic substances,
   - changing the temperature regime.
3. Protect wildlife habitat to the extent that knowledge permits and to a level consistent with its value to society.

- **All of the BMP's in this document can be traced back to these three primary considerations.**

PLANNING

Identify and comply with federal, state, and local laws and regulations as discussed in the legal requirements section of this document.

Identify control points: those places within the area to be managed that should be accessed, those that should be avoided or those that need special consideration.

Some examples of control points are:

- Location of surface water, spring seeps and other wetlands. *Note that these are best located in the spring as many wetlands are difficult to identify during dry periods.*
- Location of environmentally preferable stream crossing points.
- Location of streamside management zones as described below.
- Location of areas requiring special equipment or timing of operations.

The timber sale contract or harvest agreement should contain language to require the use of the BMP's identified as necessary in the planning process.

Establish streamside management zones, strips of land bordering surface waters and in which management activities are adjusted to protect or enhance riparian and aquatic values. An example would be a strip managed for shade or larger trees to help maintain cooler water temperatures or provide large woody debris to streams respectively.

Establish filter strips, strips of land bordering surface waters, that are sufficient in width based on slope and roughness factors and on which machine access is controlled to prevent sedimentation of surface water.

Locate access system components such as roads, landings, skid trails, and maintenance areas outside of filter strips and streamside management zones.

To eliminate unnecessary soil disturbance, plan the most efficient access system to serve the entire property, then build only what is currently necessary.

Limit equipment entry into wetlands to the minimum necessary. Avoid equipment entry into wetlands whenever possible.

ACCESS SYSTEMS

Examples of BMP's presented in the Haul Roads section are based on BMP's being prepared by the Minnesota Department of Natural Resources, Division of Forestry and the Minnesota Wetland BMP Committee.

PERMANENT HAUL ROADS

Haul roads are travelways over which logs are moved while fully supported on the bed of a wheeled truck.

Timber haul costs include construction, hauling and maintenance of both roads and equipment. Use of poor practices to reduce construction costs only results in related increases in hauling and maintenance costs. A properly located and constructed road will be most cost efficient and will have limited adverse impact on water resources including wetlands and aquatic and riparian habitats.

Consider threatened and endangered species habitat, trout spawning seasons, and public water supplies when locating and building roads.

Avoid constructing roads through wetlands unless there are no reasonable alternatives.

Where roads must be constructed through wetlands, use the following and other BMP's to design and construct the road system so as neither to create permanent changes in wetland water levels nor alter the wetland drainage patterns.

Road drainage designs in wetlands must provide cross drainage of the wetland during both flooded and low water conditions.

Avoid road construction and use during spring thaw and other wet periods.

Use drainage techniques such as crowning, insloping, outsloping and 2 percent minimum grades as well as surface gravel and maintenance to ensure adequate drainage and discourage rutting and associated erosion and sedimentation.

Divert outflow from road drainage ditches prior to entering wetlands and riparian areas to minimize the introduction of sediment and other pollutants into these sensitive areas.

Minimize the width of the road running surface to the minimum necessary to safely meet owners objectives, typically 12 feet wide for straight sections and 16 feet wide for curves. Additional width may need to be cleared of large vegetation to accommodate plowed snow.

Cease road use if ruts exceed 6 inches in depth for more than 300 feet.

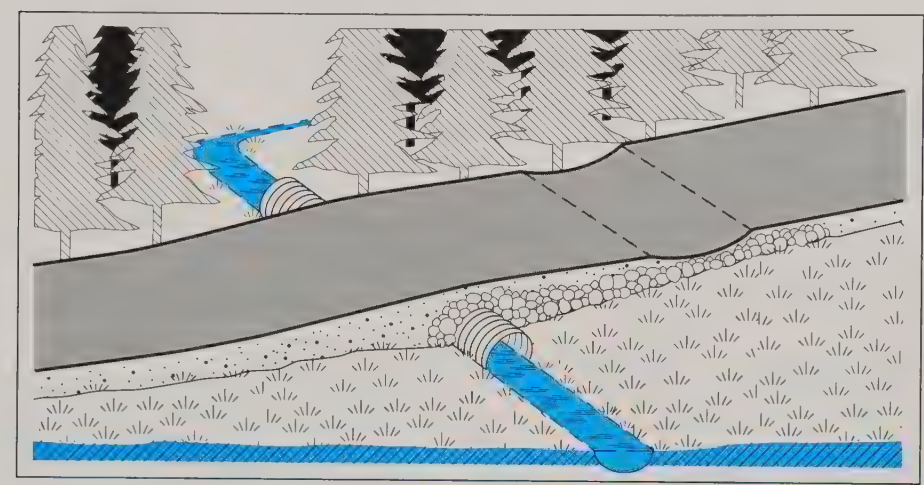
Consider use of geotextile fabric during construction to minimize disturbance, fill requirements, and maintenance costs.

All fills in wetlands should be constructed of free draining granular material.

Road Construction on Soils with Organic Layers in Excess of 16 Inches in Thickness

Organic soils vary greatly in strength and consultation with a registered engineer is advised when designing roads on these soils.

Permanent haul roads built on organic wetlands must provide for cross drainage of water on the surface and in the top 12 inches of soil. This can be accomplished through the incorporation of culverts or porous layers at appropriate levels in the road fill to pass water at its normal level through the road corridor.

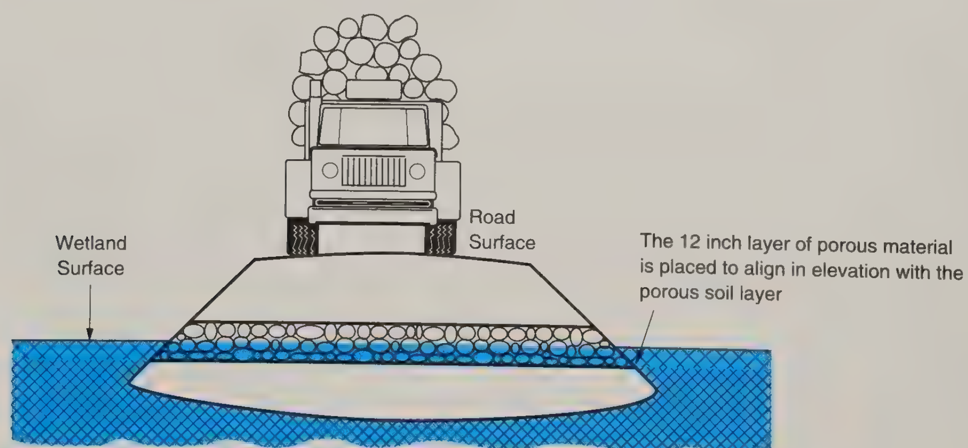


All culverts in organic soils should be 24 inch diameter and placed with their bottom half in the upper twelve inches of the soil to handle the subsurface flow and their top half above the surface to handle above ground flow. Failure to provide drainage in the top 12 inches of the soil can result in changes in the hydrology of the wetland and subsequent changes in water chemistry and plant and animal habitat.

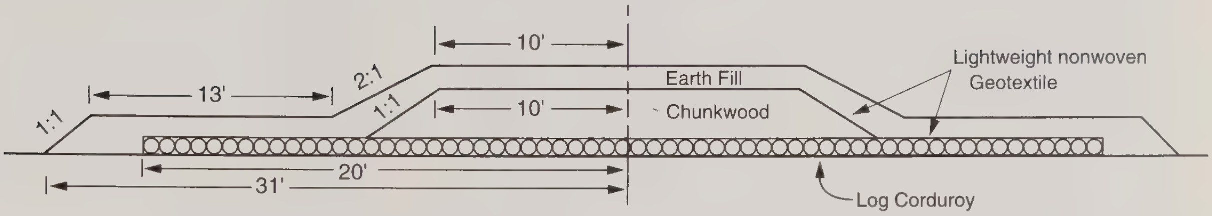
Road construction on soils with organic layers in excess of 4 feet in thickness

Where organic soils are greater than 4 feet deep, the road should be constructed across the top of the soil surface by placing fill material on top of geotextile fabric and/or log corduroy. The road will sink into the peat somewhat due to its weight and the low bearing strength of the soil and will require cross drainage to prevent interruption of the wetland flow.

POROUS ROAD DESIGN



ALTERNATIVE POROUS ROAD DESIGN
(shown in photo sequence below)



One method of drainage is to incorporate a 12 inch thick layer of porous material such as large stone or chunkwood into the roadbed. This material should be separated from the adjacent fill layers by geotextile fabric, and be incorporated into the road fill design so as to lie in the top twelve inches of the soil thus providing a continuous cross drainage.

Climate permitting, construction on soils with deep organic layers is best undertaken when the organic soil is frozen in order to preserve the strength of the root mat.

Where continuous porous layers are not used, culverts should be placed at points where they will receive the greatest support from the soil below. These areas generally occur near the edge of the wetlands or as inclusions where the organic soil is shallow.

Ditches parallel to the roadbed on both sides should be used to collect surface and subsurface water, carry it through the culvert and redistribute it on the other side. These ditches should be located three times the depth of the organic layer from the edge of the road fill unless otherwise determined by an engineer.

▲ A permeable section road being constructed by first laying geotextile fabric.

Construction on soils with organic layers between 1.3 and 4 feet in thickness

Where organic soils are less than 4 feet deep, fill can be placed directly on the peat surface and allowed to sink compressing or displacing the peat until equilibrium is reached. With this method, culverts are used instead of porous layers to move surface and subsurface flows through the road fill material.

Culverts should be placed at the lowest elevation on the road centerline with additional culverts as needed to provide adequate cross drainage.

Ditches parallel to the road centerline should be constructed along the toe of the fill to collect surface and subsurface water, carry it through the culvert and redistribute it on the other side.

▲ A corduroy of parallel laying logs is placed on top of the geotextile.

▲ Geotextile is then placed on top of the corduroy along with a layer of wood chunks to form the porous layer. Coarse gravel could be substituted.

▲ Another layer of geotextile is placed on top of the chunkwood to prevent contamination and sealing of the porous layer. The gravel running surface is placed on top of the geotextile fabric.

Road Construction on Mineral Soils or Those with Surface Organic Layers Less than 1.3 Feet in Thickness

Roads through mineral soil wetlands can be constructed using normal road construction techniques. Use geotextiles to increase bearing strength of the road and to preserve the bearing strength of fill material by preventing contamination with fine soil particles.

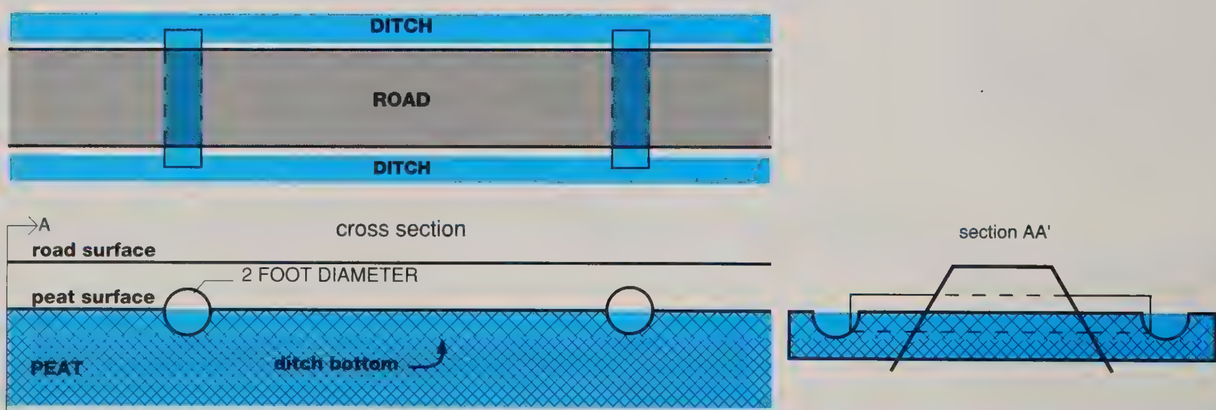
In mineral soil wetlands, a culvert should be placed at the lowest elevation on the road centerline with additional culverts as needed to provide adequate cross drainage.

Ditches parallel to the road centerline should be constructed along the toe of the fill to collect surface and subsurface water, carry it through the culvert and redistribute it on the other side.

Fills should be constructed of free draining granular material.

CULVERT LOCATION FOR ROADS ON MINERAL SOIL AND SHALLOW ORGANIC SOIL WETLANDS

plan view



24" diameter culverts should be installed with the lower half in the porous upper 12" layer of organic soil to accommodate drainage during normal and inundated conditions.

Maryland Department of Natural Resources

▲ Wooden mats are an efficient solution to temporary road access and can be carried and placed by a log truck.

Maryland Department of Natural Resources

▲ A mat road to a log landing in Maryland

▲ Geotextile and expanded metal sheets are used to strengthen an existing roaad.

▲ Removal of the geotextile and expanded metal leave the road surface relatively undisturbed.

TEMPORARY ROAD CONSTRUCTION ON ALL SOILS

Examples of BMP's used in the Temporary Roads section are based on methods in use in Maryland and Delaware.

For temporary roads, consider the use of support systems such as geotextiles and various wood and metal platform devices

Consider subsoiling or chiseling to break up compacted road surface to reestablish soil porosity when hauling is completed.

▲ Wooden mats vary considerably in construction and handling characteristics.

▲ Wooden mats can be used to provide mud-free highway approaches.

▲ Typical size of chunkwood fill material

▲ Gravel surface may be used directly over chunkwood fill for a lightweight road where a porous section is less important.

SKID TRAILS

Skid trails are rough travelways for logging machinery. Logs are often dragged over the skid trail surface only partially supported by the machine pulling them and partially supported on the trail surface.

Avoid equipment entry into wetlands especially those that can be logged by cable from adjoining uplands.

Where equipment entry into wetlands is unavoidable, minimize the area disturbed as well as the number of repeated passes over the same trail.

Ruts over 6 inches in depth can block normal subsurface drainage and create surface channels resulting in either a raised water table or shorter residence time and excessive drainage. Do not create a pattern of trails with 6 inch ruts that either blocks or facilitates drainage.

Use low ground pressure equipment when possible or tracked vehicles on both organic soil wetlands and mineral soil wetlands where soils have greater than 18 percent fines as defined by the Natural Resources Conservation Service. Use conventional tires on skidders only when the ground is dry or frozen.

Blanchard Machinery Co., Columbia, SC

▲ High floatation equipment such as these extra wide tires helps to prevent rutting.

San Dimas Equipment Development Center / U. S. Forest Service

▲ Track vehicles with elevated pans also limit rutting.

Northern Logger and Timber Processor

▲ This track vehicle fells and bunches trees, reducing the density of the skid trail pattern.

Northern Logger and Timber Processor

▲ Note the difference in rutting between wide tire (left) and conventional tires (right) in the same skidding situation.

Use of high flotation tires on areas that are marginally operable with conventional equipment results in minimal impact. Use of high flotation tires to extend operations into areas that could not be operated with conventional equipment can result in adverse impacts.

Schedule the harvest during the drier seasons of the year or during time when the ground is frozen. Consider ceasing operations in areas where rutting exceeds 6 inches in depth.

Prepare skid trails for anticipated traffic and weather conditions including spring thaws to facilitate drainage and avoid unnecessary rutting, relocation and washouts.

Minimize the crossing of perennial or intermittent streams and waterways. Use portable bridges, poled fords and corduroy approaches or other mitigating measures to prevent channel and bank disturbance and sedimentation.

Cross streams at right angles and use bumper trees to keep logs on the trail or bridge and off the stream banks.

Do not skid through vernal ponds, spring seeps, or stream channels.

Use brush or corduroy to minimize soil compaction and rutting when skidding in wet areas.

Reduce skid volumes when skidding through wetland areas.

Northern Logger and Timber Processor

▲ This smaller feller/buncher uses a track system over rubber tires for versatility.

David J. Welsch/U. S. Forest Service

▲ The staggered-end design of this low-cost portable skidder bridge, built by John Conkey Logging Co., helps to keep it in position in use.

Carmine Angeloni / Massachusetts Division of Forests & Parks

▲ The skidder bridge consists of two sections, permitting it to be carried and placed by the skidder that will use it.

David Kittredge / University of Massachusetts

The skidder bridge is strong enough to carry the skidder without intermediate support. ▶

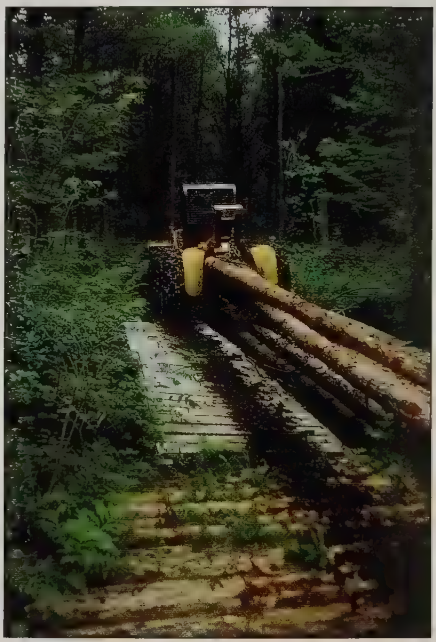
▲ Corduroy approaches help to control erosion and keep mud off the logs and out of the stream.

▲ These skidder ramps are lighter weight and will sometimes require logs for support.

LANDINGS

Keep the number and size of landings to the minimum necessary to accommodate the area, the products harvested and the equipment necessary to the activity prescribed.

Where possible, locate landings outside of wetlands and far from streams on well drained areas with gentle grades where drainage into and away from the landing can be controlled. These practices will minimize soil compaction as well as soil erosion and sedimentation of surface waters that can result from concentrated heavy equipment use.



▲ Several ramps can be used together to extend the length of the crossing.

▲ This is an excellent landing located on a well-drained area immediately adjoining the wetland.

If no other locations are practical, place landings on the highest ground possible within the wetland and use them under dry or frozen conditions only.

Geotextile fabric use at landing sites is recommended in wetlands and on soils with low bearing strength to minimize soil erosion and compaction.

Geotextile fabric is difficult to impractical to remove when covered with gravel or fill. Where removal is required consider the use of wood or metal platforms or mats with or without geotextiles as necessary.

Consult with Federal, State and local authorities regarding permit requirements before using fill or pads for landings located in wetlands.

MAINTENANCE AREAS

Locate maintenance areas to avoid the spillage of oil, fuel and other hazardous materials into wetlands. Store operating supplies of such materials away from wetlands.

Designate a specific location for draining lubricants and other fluids during routine maintenance. Provide for collection, storage and proper disposal.

Provide containers to collect fluids when the inevitable breakdown occurs in the wetland and repairs must be made on the site.

LOGGING UNDER FROZEN CONDITIONS

Avoid crossing springs, seeps and areas of water which do not freeze well.

Where water crossings cannot be avoided or frozen conditions cannot be relied upon, use portable bridges or poled fords. Temporary structures are preferable to permanent ones unless the crossing is on a permanent road.

Design the crossing to save the structure and accommodate high flows in the event of an untimely thaw.

Plow or pack snow in the operating area to minimize the insulation value and facilitate ground freezing. Clear enough area to accommodate future snow plowing.

Monitor the operating conditions closely after three consecutive nights of above freezing temperatures or the occurrence of warm rain. Cease operations when ruts exceed six inches in depth.When daytime temperatures are above freezing, but nighttime temperatures remain below freezing, plan to operate only in the morning and cease operations when rutting begins.

Plan to move equipment and materials to upland areas prior to the occurrence of thawing conditions.

STREAMSIDES AND STREAM CROSSINGS

Streamside Management Zones (SMZ's) are strips of land which border surface waters and in which management activities are adjusted to protect or enhance riparian and aquatic values. The width of SMZ's varies with the intended purpose. An example would be a strip managed for shade or larger trees to help maintain cooler water temperatures or provide large woody debris to streams.

Filter Strips are strips of land bordering surface waters and sufficient in width, based on slope and roughness factors, to prevent soil erosion and sedimentation of surface water.

Establish a streamside management zone with a minimum width equivalent to one and one half tree heights between heavy harvest cuts such as clearcuts or seed tree cuts and permanent and intermittent streams to prevent nutrient leaching into streams.

Establish a streamside management zone on perennial and intermittent streams. Maintain 50 percent crown cover to limit water and ground surface temperature increases. Manage for older trees at the water's edge to provide a natural supply of large woody debris and to shade the water surface. The necessary width of the zone will vary with climate and stream direction. SMZ's should normally be one and one half tree heights in width, however, due to sun position, a fifteen foot width may be all that is necessary on the north side of east-west running stream sections in northern latitudes.

Within the streamside management zone, maximize cable lengths and minimize the number and length of skid trails to reduce canopy and ground disturbance.

Establish filter strips on lands adjacent to lakes and streams using the following guide to control erosion and sedimentation of surface waters.

Percent slope	Recommended width of filter strip *(slope distance in feet)*
0 – 1	25
2 – 10	30 – 50
11 – 20	50 – 70
21 – 40	70 – 110
41 – 70	110 – 170

Roads and trails should be minimized in streamside management zones, but should be located outside of the filter strips except where stream crossing is necessary.

Naturally occurring woody debris should be allowed to remain in streams. However, avoid felling trees into streams and remove from the streams any tree tops and other slash resulting from the logging operation. In some cases, potential damage to the channel and bank will outweigh the need for removal.

FELLING PRACTICES

Precautions should be taken when logging near a wetland or stream. Felling trees into water bodies can cause habitat damage and disturb breeding and spawning areas of amphibious and aquatic species. However, naturally occurring woody debris is necessary to many stream functions and should be left undisturbed.

Avoid felling trees into nonforested wetlands. When such felling is unavoidable, remove the tree to high ground before limbing. Slash from trees felled on upland sites is considered fill material under the clean water act and may not be deposited on wetland sites.

Keep slash resulting from the logging operation out of streams and wetlands with standing water unless specifically prescribed for fish or wildlife habitat purposes. Normally, slash left in these areas uses oxygen needed by fish and other aquatic animals. Slash can also limit access of certain species to wetlands.

Review the section on vernal pools and temporary ponds for exceptions to these guidelines.

SILVICULTURE

Distribute the size, timing and spacing of regeneration cuts, including clearcuts, to minimize changes in ground surface and water temperature over the wetland as a whole. Maintain a crown cover of fifty percent or more during selection and thinning cuts. Exceptions may occur in very cold climates where low water temperatures are a habitat limitation.

On organic soils, conduct site preparation operations such as shearing and raking only when the ground is sufficiently frozen to avoid machinery breaking through the root mat.

Do not deposit slash and other residues from upland operations in wetlands.

WILDLIFE AND FISH

GENERAL CONSIDERATIONS

Timber activities in forested wetlands should be avoided during the breeding period of threatened and endangered fish and wildlife species known to inhabit the wetland.

Preserve areas where hummocks of thick sphagnum moss abut small or large pools of water as a unique habitat combination required by the four-toed salamander.

▲ An area of sphagnum humps; a critical nesting habitat for the four-toed salamander.

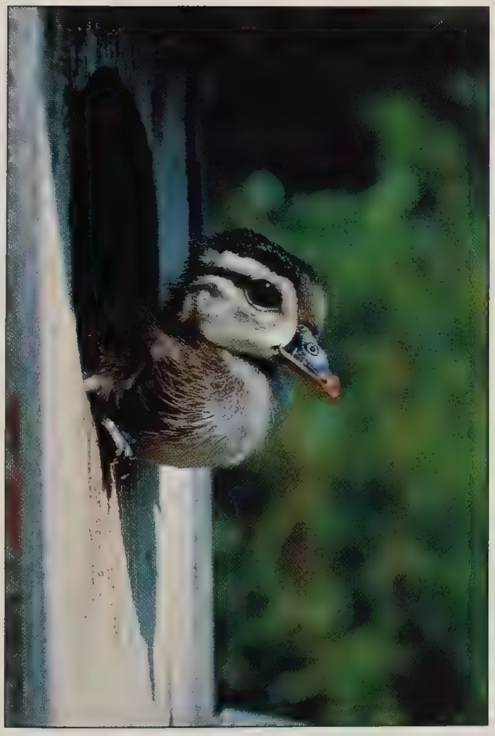
Scott Jackson

▲ Four-toed salamander, *Hemidactylium scutatum*

Scott Jackson

▲ In order to survive, four-toed salamander eggs must be nested so that the newly hatched salamanders will drop into the water.

Scott Jackson



▲ A wood duck chick about to jump from a nest box.

Cornell Ornithology

Avoid harvesting trees in wetlands April through June to protect breeding birds including neotropicals.

Leave as many as 15 dead and live nesting cavity trees per acre within 200 feet of water as nesting sites for wood ducks.

Avoid sedimentation of areas known to support spawning populations of brook trout, particularly during the October–December spawning season.

Adult male wood duck, *Aix sponsa*, inhabits freshwater marshes, wooded swamps and creeks. ▶

Cornell Ornithology

WITHIN A 50 FOOT WIDE WILDLIFE MANAGEMENT ZONE AROUND WETLANDS

Maintain 50 percent crown cover to avoid wide water and soil temperature fluctuations that can adversely affect fish and aquatic and amphibian habitat.

Leave 5-15 dead standing trees and snags per acre for insect feeding and for nesting and escape cavities for birds.

Manage for tall trees along the edge of lakes and rivers associated with wetlands to provide nesting sites for ospreys, eagles, and red-shouldered hawks.

Avoid disturbing rotting stumps where possible as they provide nesting substrate for musk turtles.

Joe Emerick

▲ An osprey, *Pandion haliaetus*, with young in a typical wetland nest site.

Ralph Tiner

▲ The orange ear patch clearly identifies this bog turtle.

Within calcareous fens where chalky, crumbly deposits are evident in surface pools, preserve and encourage scrub and/or shrub habitat as important over-wintering habitat for rare bog turtles.

Encourage and preserve herbaceous vegetative cover along wetland edges to provide shelter for frogs, ribbon snakes, hatching turtles, and small mammals.

Minimize skid trails and/or use cabling to reduce the area of soil compaction thus preserving habitat for small mammals and turtles.

WITHIN A 150 FOOT WIDE WILDLIFE MANAGEMENT ZONE AROUND WETLANDS

Avoid routing skid trails through areas with concentrations of physical structure such as dead logs, hollow logs, upturned roots, rock piles, rock outcrops and other debris.

Scott Jackson

▲ Structure created by logs and boulders is critical to small amphibian habitat and disturbance should be avoided.

Minimize skid trail density and heavy equipment use to avoid crushing the many turtles such as the spotted turtle, wood turtle and Blanding's turtle that either forage or aestivate (become dormant during the summer) in these areas.

Minimize ruts deeper than 6 inches below general ground level and regrade trails promptly to prevent trapping of juvenile salamanders and hatchling turtles.

Close logging roads and skid trails to vehicle use after cutting because exposed areas and pools that form where roads and trails cross wet areas are attractive hazards for turtles.

Avoid clearcutting in favor of harvesting methods that maintain a greater canopy cover like patch cuts, shelterwood cuts and selection cuts. Where clearcuts are unavoidable, cuts should be less than 10 acres in size and narrow and irregular in shape.

SPRING SEEPS

Do not skid through seeps.

Fell trees away from seeps.

Maintain at least 50 percent crown cover in the group of trees shading the seep to limit increases in water and ground surface temperature.

Avoid disturbing the soil around these areas to minimize sedimentation and disturbance of leaf litter.

Where haul roads must cross seeps, locate the haul road at least 150 ft. downslope from the origin of the seep. Also avoid road building within 150 ft. upslope from seeps. Both limitations are intended to protect the origin and continued flow of the seep.

Examples of BMP's presented in the section on Vernal Ponds are based on BMP's developed by researchers, foresters and wildlife biologists in Massachusetts, Pennsylvania and New York. Research is continuing in this area and changes are expected as more is learned about the importance of vernal ponds.

Vernal ponds provide critical habitat for a number of amphibians and invertebrates, some of which breed only in these unique ecosystems, and/or may be rare, threatened or endangered species. Although vernal ponds may only hold water for a period in the spring, the most important protective measure is learning to recognize these pond locations, even in the dry season. Foresters can then incorporate the guidelines below into their plans to ensure that these habitats thrive.

Maintain the physical integrity of the pond depression and its ability to hold seasonal water by keeping heavy equipment out of the pond depression and away from the perimeter walls at all times of the year. Rutting here could cause the water to drain too early, stranding amphibian eggs before they hatch. Compaction could alter water flow and harm eggs and/or larvae buried in leaf litter at the bottom of the depression.

Prevent sedimentation from nearby areas of disturbed soil to prevent disrupting the pond's breeding environment.

Keep tree tops and slash out of the pond depression. Although amphibians often use twigs up to an inch in diameter to attach their eggs, none should be added, nor existing branches removed. If an occasional top does land in the pond depression, leave it. Removal could disturb newly laid eggs or hatched salamanders.

Establish a buffer zone around the pond two chains (132 feet) in width. Maintain a minimum of 50 percent crown cover and minimize disturbance of the leaf litter and mineral soil which insulate the ground and create proper moisture and temperature conditions for amphibian migrations.

Schedule operations in the buffer area when the ground is frozen and covered with snow to minimize ground disturbance within the buffer area.

Avoid operating in the buffer area during muddy conditions which would create ruts deeper than 6 inches. Such ruts can result in trapping and predation of migrating juveniles and dehydration of mistakenly deposited eggs. Ruts should be filled and operations suspended until the ground is dry or frozen.

Locate landings and heavily used skid trails outside of the buffer area. Be sure any water diversion structures associated with skid trails and roads keep sediment from entering the shaded zone and the vernal pond.

Silt fences are formidable barriers to salamander migration. Do not use them in the buffer area and remove them from nearby areas as soon as practicable.

Close roads in the area to prevent off road vehicle disturbance to the pond and sensitive buffer zone.

LEGAL REQUIREMENTS

Mechanized land clearing and earth moving activities in wetlands, streams or other water bodies are regulated at the Federal level under Section 404 of the Clean Water Act. Many states also have regulatory programs which may require permits for activities in streams and wetlands. An approved forest management plan may be required by your state regardless of whether wetlands are involved or not.

Normal silvicultural activities which may involve earthmoving are exempt from regulation under section 404 of the Clean Water Act. However, to qualify for the exemption, the activity must be part of an established, ongoing operation. Furthermore, the exemption is interpreted by some to apply only to silvicultural activities resulting in the production of food, fiber and forest products. General permits may exist in some Corps of Engineer districts which authorize silvicultural activities for other purposes.

Any activity which converts a wetland into a non-wetland or affects the flow, circulation or reach of waters is not exempt. Conversion into a new use, such as clearing forested wetlands for pasture, crop land or development, requires a permit as well.

Normal silvicultural practices covered by the silvicultural exemption include planting, seeding, cultivating, minor drainage and harvesting. However, the silvicultural exemption does not include land recontouring activities such as grading, land leveling, filling in low spots or converting to upland. Minor drainage is the connection of upland drainage facilities to a stream or water body. This does not include any new drainage of wetlands or the construction of any ditches or dikes which drain or significantly modify a stream or wetland.

Maintenance of existing drainage ditches, structures and fill is exempt from federal regulation provided there is no modification of the original design. Construction and maintenance of forest roads are exempt if the work is done in accordance with the state approved Best Management Practices (BMP's).

A Federal permit is not needed to cut trees at or above the stump. However, mechanized land clearing, excavation, grading, land leveling, windrowing and road construction in wetlands will require a permit if the activity does not qualify for the silvicultural exemption.

It is recommended that a determination of any specific permit requirements be obtained from the district office of the U.S. Army Corps of Engineers as well as the state environmental or natural resources agency prior to initiating any activities in water or wetlands. This is particularly important in light of the ongoing changes in wetland regulations at both the state and federal level.

The Food Security Act of 1985 and the Food, Agriculture, Conservation and Trade Act of 1990 contain provisions which could cause loss of U.S.D.A. program benefits to persons conducting activities which may alter wetlands. Consult with your local U.S.D.A. Consolidated Farm Services Agency (formerly Agricultural Stabilization and Conservation Service) or U.S.D.A. Natural Resources Conservation Service (formerly Soil Conservation Service) if wetland is present to determine if proposed forest management activities would jeopardize U.S.D.A. benefits.

WHERE TO GO FOR ASSISTANCE

Contact the office of the State Forester for assistance in forest management on both uplands and wetlands. However, forest management activities on wetlands are subject to special regulations.

The District Office of the U.S. Army Corps of Engineers has the authority to determine which lands are subject to wetland regulations. The telephone number is listed in the "Government Offices" section of the telephone directory, normally under "Army," "Department of the Army" or "Department of Defense." Ask for the "Regulatory" or "Permits" Branch.

The following are the telephone numbers for the Corps of Engineers district offices serving Virginia and the twenty states of the Northeastern Area.

Baltimore, MD	(410) 962-3670
Buffalo, NY	(716) 879-4330
Chicago, IL	(312) 353-8213
Detroit, MI	(313) 226-2432
Huntington, WV	(304) 529-5487
Kansas City, MO	(816) 426-3645
Little Rock, AR	(501) 324-5295
Louisville, KY	(502) 582-6461
Memphis, TN	(901) 544-3471
Waltham, MA (New England Division)	(617) 647-8338
New York, NY	(212) 264-3996
Norfolk, VA	(804) 441-7652
Philadelphia, PA	(215) 656-6728
Pittsburgh, PA	(412) 644-6872
Rock Island, IL	(309) 788-6361 ext 6379
St. Louis, MO	(314) 331-8575
St. Paul, MN	(612) 220-0375
Tulsa, OK	(918) 581-7261

The County Soil Survey Report will provide an indication of whether your property may contain any hydric or wetland soils. These surveys are available from the county office of the U.S.D.A. Natural Resources Conservation Service.

The National Wetland Inventory is another source of information. These maps are produced by the U.S.D.I. Fish and Wildlife Service and correspond to the U.S.D.I. Geological Survey quadrangle maps (7.5 x 7.5 minutes). They can be obtained by calling 1-800-USA-MAPS. These maps are very general and should not be used for any regulatory purpose, but can provide useful information about areas where wetlands can be expected to occur. The only way to accurately determine the extent of wetlands on a property is to have a qualified individual inspect the property.

Information and photography of indicator and threatened and endangered plants can often be obtained from local botanical gardens or arboreta, such as the Morris Arboretum of the University of Pennsylvania as well as environmental centers and natural resource interest groups such as the Western Pennsylvania Conservancy.

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