

WETLANDS OF THE NEW JERSEY PINELANDS:
VALUES, FUNCTIONS, IMPACTS AND A
PROPOSED BUFFER DELINEATION MODEL

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EXECUTIVE SUMMARY

Wetlands represent an integral component of the Pinelands region, an area designated as the country's first National Reserve in 1978. Cedar and hardwood swamps, pitch pine lowlands, inland and coastal marshes, and shrub-dominated wetlands comprise about 35% of the 445,000 ha Reserve. As mandated by federal and state legislation, a Comprehensive Management Plan (CMP) was developed to preserve and protect the unique and essential character of the Pinelands. In the CMP, wetlands are recognized as a valuable resource deserving stringent protection.

The objectives of this study are first, to provide scientific background information supporting the purpose of the CMP's wetland management program. An extensive review of the values and functions of Pinelands wetlands is provided, along with a discussion of development activities which have the potential to cause significant adverse impacts on Pinelands wetlands. The second objective pertains to delineation of buffer protection areas between wetland boundaries and proposed upland development. Under the CMP's wetlands management program, development is not permitted within 300 ft of any wetland, unless the applicant can demonstrate that the proposed development will not have an irreversible effect on the wetlands ecological integrity. If so demonstrated, then reduction of the buffer can be considered. We propose a buffer delineation model designed to assist the applicant, the Pinelands Commission and local regulatory agencies in determining the minimum site-specific buffer width needed to protect the ecological integrity of wetlands.

PINELANDS WETLANDS VALUES AND FUNCTIONS

Wetlands provide several values and functions which are perceived as being beneficial to society and essential to the maintenance of ecosystem quality. Hydrologically, wetlands are particularly valuable in flood control. While flooding is not a regional problem in the Pinelands because of porous, well-drained soils, wetlands may play a significant role in flood control within developed Pinelands watersheds. In terms of regional water quality maintenance, the nutrient retention and removal function of wetlands is essential to the maintenance of exceptional quality water resources which characterize the Pinelands. The food web support values and closely related habitat values of Pinelands wetlands are recognized when considering the diversity of biota encountered, including a significant number of unique, threatened and endangered species. Pinelands wetlands also provide a rich regional heritage from recreational, educational, scientific and aesthetic perspectives. In terms of harvest value, cedar logging and blueberry/ cranberry agriculture provide economic incentives.

MAN'S IMPACTS ON THE VALUES AND FUNCTIONS OF PINELANDS WETLANDS

Development activities which modify the wetland-watershed hydrologic regime, alter surface and groundwater quality, or impose other detrimental impacts have degrading effects on the structure and function of Pinelands wetlands, and thereby contribute to the regional loss of society-based wetland values. Hydrologic factors, such as water table level, seasonal

flow patterns and surface water runoff are principle forces determining the ecological balance of wetlands. Long-term lowering or raising of the wetland water table level could contribute to shifts in vegetation structure and species composition. This would directly detract from wetland food web support and habitat functions. The water quality maintenance value of wetlands would be diminished by lowering the water table level or altering flow rates through wetlands. Also, lower water table levels decrease the role of wetlands as natural firebreaks.

With respect to water quality, the surface waters of Pinelands wetlands and aquatic habitats are characterized by low nutrients, high acidity and low suspended sediment levels. A unique biotic assemblage has evolved and adapted to these conditions. Water quality degradation, primarily related to non-point source inputs, would significantly detract from the ability of Pinelands wetland/aquatic resources to support such rich and unique biotic components.

PROPOSED BUFFER DELINEATION MODEL

An important strategy for the protection and preservation of wetland values and functions is to maintain buffer areas between wetland systems and adjacent upland development. A model is proposed for delineating the minimum site-specific width of buffer areas required between wetland boundaries and proposed upland development, while still maintaining the ecological integrity of the wetland and associated values and functions. The model is designed to deal systematically and consistently with the complexity of factors associated with development activities and related ecological impacts. An evaluation of overall wetland quality and an assessment of potential impacts provide a basis for this proposed buffer delineation model. In addition, the model is developed within the framework of the Pinelands regional planning strategy. *The model is not intended for immediate use by applicants, Pinelands Commission staff or local regulatory agency staff. Only following extensive field verification and incorporation of any appropriate revisions should the model be applied as a decision-making tool.*

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INTRODUCTION

PRESERVATION AND PROTECTION OF THE PINELANDS RESOURCES: AN OVERVIEW

The New Jersey Pinelands (also known as the Pine Barrens), an interrelated complex of uplands, wetlands and aquatic communities, represent a largely undeveloped region within the Northeast urban corridor (Fig. 1). Ecologically, the 445,000 ha Pinelands provide habitat for an unusual diversity of plants and animals, some well-adapted to a environment of frequent fires and acid, nutrient poor soils. Hydrologically, an outstanding feature of the Pinelands ecosystem is an extensive unconfined aquifer of exceptional quality. Streams of acid and nutrient poor waters transect the Pinelands landscape. Incentives for protection and preservation of the Pinelands were provided by recognizing the areas many unique natural and cultural attributes, coupled with development pressures from New York City, Philadelphia, Atlantic City and the resort-oriented New Jersey coast.

In 1978 the Pinelands were designated as the country's first National Reserve (National Parks and Recreation Act, section 502).¹ The overriding goals of this federal legislation, and of the New Jersey Pinelands Protection Act (1979) were to preserve, protect and enhance the significant values of Pinelands land, water and cultural resources. The state act further considers the need for environmentally compatible residential, commercial and industrial patterns of development. In response to the federal and state mandates, the NJ Pinelands Commission, the state agency responsible for planning and management of the Pinelands National Reserve, developed a Comprehensive Management Plan (Pinelands Commission 1980; hereafter referred to as the CMP). Based on an assessment of environmental and cultural resources and on an analysis of projected growth needs, the Pinelands Commission created several land use capability areas - the foundation of the CMP. This regional characterization of the Pinelands National Reserve provided a balance between preservation of the ecosystem's essential and unique character, and accommodation for growth.

The Pinelands Commission developed several management programs to insure that permitted development and land use activities in the Pinelands National Reserve proceed with minimal environmental impact. These programs establish minimum standards necessary to regulate the impact of development on Pinelands resources. The CMP's wetlands management program provides particularly stringent protection of wetlands - a resource which occupies about 35% of the Pinelands National Reserve. Through this

¹The Pinelands National Reserve has recently (April 1983) been designated as a Biosphere Reserve under the Man and the Biosphere Program (MAB) of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

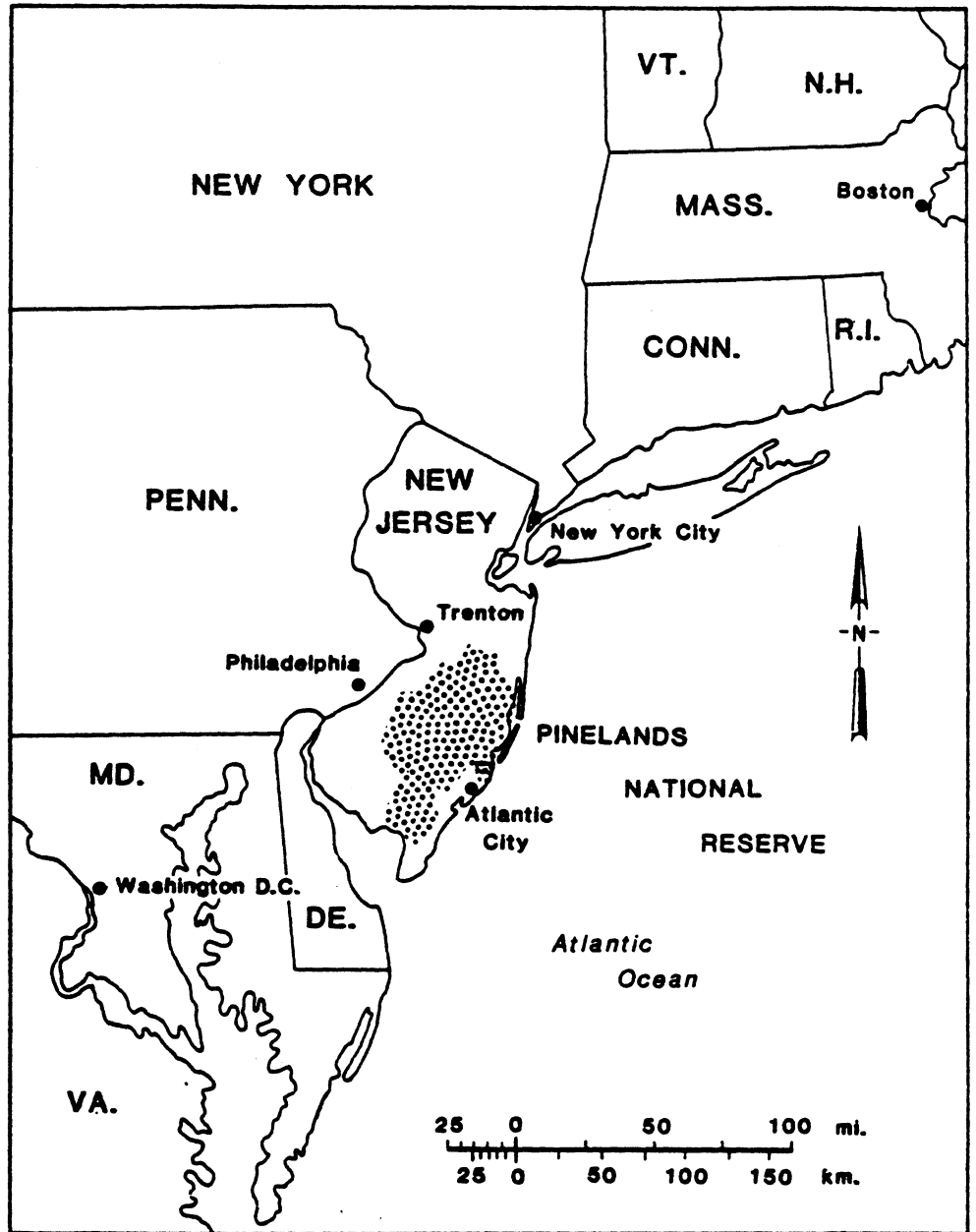


Fig. 1. Regional location of the Pinelands National Reserve.

program, Pinelands wetlands and their associated values and functions are recognized as an essential ecosystem component deserving priority protection. The entire wetlands management program is presented in Appendix 1 (CMP; Article 6, Part 1, Sections 6-101 through 6-114), while salient elements of the program are outlined below.

Pinelands wetlands are defined by hydrologic characteristics, soil type and vegetation. Coastal wetlands of the Pinelands National Reserve may include tidal marshes, swamps and mud flats, while inland wetland types include, but are not limited to Atlantic white cedar swamps, hardwood swamps, pitch pine lowlands, bogs, inland marshes, and lakes, ponds, rivers and streams. To protect the long-term integrity of these wetland resources several standards are set forth. Foremost is the provision that development in all Pinelands wetlands is prohibited except for some permitted exceptions. Permitted activities include berry culture, horticulture of native Pineland plants, and beekeeping. Forestry is permitted in wetlands provided that the activity conforms to regulations of the forestry management program (CMP, Article 6, Part 4, Sections 6-401 through 6-404). Low intensity recreational uses, like fishing, hunting, hiking and nature study are permitted on wetlands provided that the wetland is not altered. Activities such as wetland dependent recreational facilities (docks, piers, etc.), fish and wildlife management practices and public utility improvements (bridges, roads, utility lines, etc.) are conditionally permitted provided that the development or facility will not result in a significant adverse impact on the wetland. Determination of significant adverse impact is based on an evaluation of nine criteria related to hydrological, biological and chemical alteration of wetlands.

A most critical element of the Commission's policy toward protecting Pinelands wetlands is the provision that no development shall occur within 300 ft of any wetland, unless the applicant can demonstrate that the proposed development will not have a significant adverse impact on the wetland. Maintenance of a natural upland-wetland buffer provides a holistic ecosystem approach to wetland protection, thereby strengthening the intent and objective of the wetlands program.

PURPOSE OF STUDY

The objectives of this study are twofold. First, the intent and purpose of the CMP's wetlands management program will be supported and strengthened by providing scientific background information documenting, a) the values and functions of Pinelands wetlands, and b) assessing the potential for impacts to be imposed on wetlands by development practices.

The second main objective of this study focuses on implementation of the CMP's wetlands management program. More specifically, a model is proposed for delineating the minimum site-specific width of buffer protection areas required between wetland boundaries and proposed upland development, while still maintaining and preserving the ecological integrity of the wetland and associated values and functions. An evaluation of wetland quality and an assessment of potential impacts provide a basis for this proposed buffer delineation model.

The report is organized as follows;

- Pinelands wetlands are described from vegetation and soil perspectives.
- The values and functions of Pinelands wetlands are reviewed, including discussion of hydrologic and flood control functions, water quality maintenance values, food web support functions, habitat values and cultural values.
- Past and present development activities affecting Pinelands wetlands are described and impacts associated with these activities are assessed.
- A wetlands buffer delineation model is proposed.

VEGETATION AND SOILS OF PINELANDS WETLANDS

VEGETATION OF PINELANDS WETLANDS

The vegetation of the Pinelands is composed of a rich mosaic of upland and wetland communities. The wetlands comprise about 35% of the 445,000 ha (1.1 million acre) Pinelands National Reserve (Table 1). Over the past century several investigators have described and classified the diversity of wetland types encountered within this unique landscape. Among these studies are the earlier works of Stone (1911) and Harshberger (1916) with more recent descriptions of Pinelands vegetation by McCormick (1970; 1979), Robichaud and Buell (1973), Olsson (1979) and Sauer et al. (1980). Other relevant descriptions of Pinelands vegetation are cited herein.

The vegetation of the following dominant Pinelands wetland types is described: Atlantic White Cedar Swamps, Hardwood Swamps, Pitch Pine Lowlands, Shrub-dominated Wetlands, Herbaceous Inland Marshes and Coastal Tidal Marshes. Also included is a description of pitch pine - dominated communities which are often transitional between wetlands and uplands. Accompanying the vegetation descriptions is a list of the common flora associated with undisturbed forested and shrub-dominated wetlands of the Pinelands (Table 2). A description of Pinelands wetlands according to the U.S. Fish and Wildlife Service, National Wetlands Inventory, is found in Appendix 2.

ATLANTIC WHITE CEDAR SWAMPS

Atlantic white cedar swamps are typically found bordering streams from headwaters to areas under freshwater tidal influence. They may range in width from a few meters to broader expanses of 1600 m, or more, yet generally they do not exceed 300 m (McCormick 1979). Water flow through cedar swamps is generally sluggish. At present about 2% of the Pinelands National Reserve is occupied by cedar swamps (8,680 ha; see Table 1).

The vegetation of mature Atlantic white cedar swamps of the Pinelands has been described by Stone (1911), Harshberger (1916), Little (1951), McCormick (1970; 1979), Givnish (1971), Robichaud and Buell (1973), Olsson (1979) and Sauer et al (1980), among others. Mature Atlantic white cedar swamps are characterized by tall (15-20 m), dense, relatively even aged stands of *Chamaecyparis thyoides*. An occasional pitch pine (*Pinus rigida*) will reach the seemingly impenetrable canopy. Depending on the amount of light filtering through the canopy, red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*) and sweetbay (*Magnolia virginiana*) may form a continuous understory, or be relatively sparse. Some common wetland shrubs intermixed within the understory include highbush blueberry (*Vaccinium corymbosum*), swamp azalea (*Rhododendron viscosum*), sweet pepperbush (*Clethra alnifolia*) and dangleberry (*Gaylussacia frondosa*), to name a few.

Table 1. The areal extent of wetlands in the Pinelands National Reserve. Area of some specific wetland types are also included. Sources of these data are included as footnotes.

WETLAND TYPE(S)	AREA Hectares (Acres)
<u>TOTAL RESERVE WETLAND AREA</u>	153,950 (380,410) ¹
(i.e., cedar and hardwood swamps, pitch pine lowlands, inland and coastal marshes, shrub-dominated wetlands, lakes, ponds, rivers, streams)	
<u>WETLAND TYPE CATEGORIES</u>	
Pitch Pine Lowlands	46,270 (114,330) ²
Coastal Marshes	32,320 (79,860) ³
Cedar Swamps	8,680 (21,450) ⁴

¹From U.S. Fish and Wildlife Service National Wetlands Inventory summaries of wetland areas for the 50 U.S.G.S. 7.5 minute quadrangles covering the Reserve, it was determined that 121,630 ha (330,555 acres) of inland wetlands (i.e., palustrine, lacustrine and riverine types as defined by the U.S.F.W.S.) are within the boundaries of the Reserve. This area estimate added to the coastal marsh estimate (see above table) yields the total Reserve wetland area (153,950 ha).

²Area estimate from planimetry of Pinelands Commission vegetation map (1:300,000). Based on Fall 1978 and Spring 1979 aerial photographs.

³Area estimate from planimetry of Pinelands Commission vegetation maps (1:24,000). Based on Fall 1978 and Spring 1979 aerial photographs.

⁴Area estimate from planimetry of Pinelands Commission vegetation maps (1:24,000). Based on Fall 1978 and Spring 1979 aerial photographs. Further breakdown of the cedar swamp distribution within the Reserve reveals the following: Pinelands Preservation Area, 5160 ha (12,750 acres); Pinelands Protection Area, 2080 ha (5,130 acres); Outside state Pinelands boundaries but within Reserve boundaries 1440 ha (3,570 acres); Total Cedar Swamps in Reserve, 8680 ha (21,450 acres).

Table 2. Common flora of New Jersey Pinelands inland wetlands. For more complete species lists consult Harshberger (1916) and Little (1951), among others.

TREES

<i>Acer rubrum</i>	Red maple
<i>Betula populifolia</i>	Gray birch
<i>Chamaecyparis thyoides</i>	Atlantic White Cedar
<i>Liquidambar straciflua</i>	Sweet Gum
<i>Liriodendron tulipifera</i>	Tulip Poplar
<i>Magnolia virginiana</i>	Sweet Bay
<i>Nyssa sylvatica</i>	Black Gum
<i>Pinus rigida</i>	Pitch Pine
<i>Sassafras albidum</i>	Sassafras

SHRUBS

<i>Amelanchier</i> spp.	Serviceberry
<i>Chamaedaphne calyculata</i>	Leatherleaf
<i>Clethra alnifolia</i>	Sweet Pepperbush
<i>Gaylussacia baccata</i>	Black Huckleberry
<i>Gaylussacia dumosa</i>	Dwarf Huckleberry
<i>Gaylussacia frondosa</i>	Dangleberry
<i>Ilex glabra</i>	Inkberry
<i>Kalmia angustifolia</i>	Sheep Laurel
<i>Kalmia latifolia</i>	Mountain Laurel
<i>Leucothoe racemosa</i>	Fetterbush
<i>Lyonia ligustrina</i>	Maleberry
<i>Lyonia mariana</i>	Staggerbush
<i>Myrica pensylvanica</i>	Bayberry
<i>Rhododendron viscosum</i>	Swamp Azalea
<i>Smilax</i> spp.	Brier
<i>Vaccinium corymbosum</i>	Highbush Blueberry
<i>Vaccinium macrocarpon</i>	Cranberry

HERBS

<i>Carex</i> spp. and Cyperaceae	Sedges
<i>Drosera</i> spp.	Sundews
<i>Gaultheria procumbens</i>	Teaberry
Gramineae	Grasses
<i>Sarracenia purpurea</i>	Pitcher Plant
<i>Xerophyllum asphodeloides</i>	Turkey Beard

FERNS AND FERN ALLIES

<i>Lycopodium carolinianum</i>	Clubmoss
<i>Osmunda cinnamomea</i>	Cinnamon Fern
<i>Pteridium aquilinum</i>	Bracken Fern
<i>Schizaea pusilla</i>	Curly Grass Fern
<i>Woodwardia virginica</i>	Virginia Chain Fern

Table 2. Continued.

LIVERWORTS AND MOSSES

Polytrichum spp.

Sphagnum spp.

Haircap Moss

Sphagnum Moss

LICHENS

Cetraria spp.

Cladonia spp.

Harshberger (1916) and Little (1951) present extensive lists documenting the floral diversity of the cedar swamp herbaceous layer. Although the diversity of species is generally high, the herbaceous cover is often low because of the insufficient light penetrating the tree and shrub canopy. Most noticeable, however, is a mat of *Sphagnum* spp. carpeting the ground, with teaberry (*Gaultheria procumbens*) growing on the cedar hummocks. Open areas within mature cedar stands, created by windthrows or selective cutting, are often occupied by pitcher plants (*Sarracenia purpurea*), sundews (*Drosera* spp.), orchids, bladderworts (*Utricularia* spp.) and other herbaceous vegetation. In addition, curly grass fern (*Schizaea pusilla*) may be occasionally encountered.

The vegetation structure and species composition of Atlantic white cedar swamps can vary considerably from this typical mature community. Little (1950; 1951; 1979) discusses this variability as it relates to land use (i.e., logging or regrowth of abandoned cranberry bogs), hydrologic regime (i.e., flooding by beaver activity or man-induced flooding/drainage), fire history and biotic influences (i.e., deer browse). He makes particular reference to the presence of competing hardwoods, such as red maple, often intermixed with young reproductive stands of dense cedar growth following cutting or fire.

HARDWOOD SWAMPS

Hardwood swamps of the Pinelands are generally associated with streams, occupy poorly drained areas, or occasionally border Atlantic white cedar swamps or other wetland types. The vegetation of undisturbed Pinelands hardwood swamps has been described by Harshberger (1916), McCormick (1970; 1979), Olsson (1979), Ehrenfeld and Gulick (1981) and Ehrenfeld (1983). The 10-15 m canopy of mature swamps is typically dominated by red maple and black gum, however, in some swamps sweetbay can also be a principal associate. Other trees occasionally scattered throughout the canopy include gray birch (*Betula populifolia*), sassafras (*Sassafras albidum*), pitch pine and Atlantic white cedar. Robichaud and Buell (1973) indicate that hardwood swamps near the western Pinelands border (Inner Coastal Plain) or to the south are dominated by sweetgum (*Liquidambar styraciflua*) and tulip poplar (*Liriodendron tulipifera*). Near coastal regions of the Pinelands American holly (*Ilex opaca*) becomes a major component of hardwood swamps. Bernard (1963) describes the vegetation of these coastal lowland forests in southern New Jersey. The shrubs of Pinelands hardwood swamps form a dense and more or less continuous understory. The most conspicuous shrubs, often reaching 1-3 m, are highbush blueberry and sweet pepperbush, while swamp azalea, dangleberry, fetterbush (*Leucothoe racemosa*) and sheep laurel (*Kalmia angustifolia*) are intermingled. The herbaceous layer is generally more continuous than that described for the cedar swamp.

PITCH PINE LOWLANDS

The vegetation of the pitch pine lowland wetland type has been described by Harshberger (1916), Robichaud and Buell (1973), McCormick (1970; 1979) and Olsson (1979). Pitch pine lowlands occur in local depressions or more typically adjacent to other wetland types, particularly hardwood swamps and cedar swamps. With respect to areal extent, pitch pine lowlands constitute about 10% of the Pinelands National Reserve and are the dominant wetland type in the region (46,270 ha; see Table 1).

The canopy is composed almost exclusively of pitch pine. Where drainage is particularly poor, the low pitch pine canopy (5-6 m) may be somewhat open with a characteristic dense understory of leatherleaf (*Chamaedaphne calyculata*) and sheep laurel, either mixed or in monospecific stands. Among this low shrub understory are frequent patches of highbush blueberry.

Where drainage is slightly improved the pitch pine canopy is generally taller (up to 13 m) and more dense. An occasional understory tree (red maple, black gum, birch) may be mixed among the shrub stratum which includes the common sheep laurel, dangleberry, staggerbush (*Lyonia mariana*), fetterbush, and black huckleberry. *Sphagnum* spp. is often conspicuous in the wetter pitch pine lowland type. Where site conditions are drier and the shrub layer more open, the herbaceous layer can be well developed. Bracken fern (*Pteridium aquilinum*) and turkey beard (*Xerophyllum asphodeloides*) are especially noticeable following fire.

SHRUB-DOMINATED WETLANDS

This wetland type typically occurs in poorly drained and somewhat circular areas (locally know as spongs), or along stream and pond margins (McCormick 1970, 1979; Olsson 1979). Also included in the shrub-dominated wetland category are abandoned or inactive cranberry bogs. Leatherleaf and/or sheep laurel, with an associated lush mat of *Sphagnum* spp., generally dominate this complex. Highbush blueberry is often recognized as a co-dominant. Staggerbush, swamp azalea, sweet pepperbush, and other common wetland shrubs are often scattered throughout. Cranberry (*Vaccinium macrocarpon*) is especially conspicuous in recently abandoned bogs.

HERBACEOUS INLAND MARSHES

The freshwater herbaceous inland wetland community represents a fairly minor component of the Pinelands (McCormick 1979). Herbaceous vegetation dominated by grasses and sedges, especially *Carex bullata*, typically occupy the inland marsh (Harshberger 1916; McCormick 1979; Olsson 1979). This community occurs in isolated patches within slight depressions or more commonly along streams where they are referred to as savannas. Also, the inland marsh community occurs in abandoned cranberry bogs. When fringing ponds and lakes, bayonet rush (*Juncus militaris*) often dominates the herbaceous community. Also present along the lakeshore can be an assortment of aquatics including, white water lily (*Nymphaea odorata*), spatterdock (*Nuphar variegatum*), and bladderworts (*Utricularia* spp.).

COASTAL TIDAL MARSHES

A continuum of tidal marsh types, from saltwater to freshwater, are encountered along the river and estuarine systems of the Pinelands. Salt marshes generally fringe the coastal bays and downstream portions of the Pinelands rivers; areas of relatively high salinity. The vegetation of this estuarine salt marsh environment, as described by Good (1965), is dominated by saltwater cordgrass (*Spartina alterniflora*). Intertidal zones

of the salt marsh (areas flooded twice daily by the tides) are occupied by tall form saltwater cordgrass, while on the high marsh (flooded less frequently), a mosaic of vegetation is encountered, including short-form saltwater cordgrass, salt hay (*Spartina patens*), spikegrass (*Distichlis spicata*) and blackgrass (*Juncus gerardi*). Along the upland border, marsh elder (*Iva frutescens*), groundsel tree (*Baccharis halimifolia*) and switchgrass (*Panicum virgatum*) are often found blending into the coastal upland forest. Common reed (*Phragmites australis*) is especially prevalent along this border where disturbance has occurred.

Freshwater tidal wetlands occur at the other end of the salinity gradient where river input dominates the tidal system. Where fresh and saltwater mix, the brackish water tidal marsh is found. Recently, Ferren and Schyuler (1980) and Ferren et al. (1981) have described the vegetation of these intertidal habitats within the Pinelands. A diversity of species generally dominate the freshwater tidal marsh, including arrow-arum (*Peltandra virginica*), beggar-ticks (*Bidens* spp.), yellow water lily (*Nuphar luteum*) and wild rice (*Zizania aquatica*). Narrow-leaved cattail (*Typha angustifolia*), big cordgrass (*Spartina cynosuroides*), salt hay and common three square (*Scirpus americanus*) are frequently encountered in the brackish water marsh.

LOWLAND/UPLAND TRANSITION FOREST

In the Pinelands, with gentle topographic slopes (< 5%), there is often a corresponding gradual transition from wetland to upland community types. This transition area generally occurs along a gradient from the pitch pine lowlands and hardwood swamps to upland forests, although the transition community can also be recognized adjacent to the other wetland types described. Depending on several factors, most notably slope and water table depth, the transition area can range from only a few meters to a much broader expanse. Also, patches or "islands" of transition forest are often found intermixed within the broader pitch pine lowlands.

The vegetation of the transition community is similar to the pitch pine lowland type, although subtle changes in the flora and structure of the forest suggest drier site conditions (Harshberger 1916; McCormick 1979; Roman et al. 1983). The canopy dominant, pitch pine, is generally taller than in the lowland, while the shrub layer is usually composed of black huckleberry and dangleberry. Also present along this continuum from wetland to upland, especially toward the dry end of the gradient, is scrub oak (*Quercus ilicifolia*).

SOILS OF PINELANDS WETLANDS

Soil characteristics such as water holding capacity, drainage, nutrient content, chemical composition and acidity, influence the type of vegetation which can occupy or tolerate a site. The 45, or more, soil types of the Pinelands National Reserve, as mapped by the U.S. Soil Conservation Service (SCS), encompass a range of natural drainage classes from excessively drained (water is removed or drained from the soil very rapidly) to very poorly drained (water is removed from the soil so slowly that standing water remains at or near the surface during most of the

growing season). Pinelands soils which are classified as poorly drained or very poorly drained are often considered as wetland or hydric soils. The predominant hydric soils of the Pinelands are Atsion, Berryland, Pocomoke and Muck. Several additional soils are also included, but their distribution in the Pinelands is limited (poorly drained - Colemantown, Elkton, Fallsington, Pasquotank, and Shrewsbury; very poorly drained - Bayboro, inland and tidal marsh).

The dominant hydric soils of the Pinelands, as well as soils which exhibit characteristics transitional between typical upland and wetland soils, are listed in Table 3. Also included is an indication of each soils drainage class, hydrologic soils group, depth to seasonal high water table and vegetation communities commonly associated with the soils.

The very poorly drained muck type soil generally supports Atlantic white cedar swamps and hardwood swamps. A typical soil profile would consist of less than 1 m of muck, or finely decomposed organic material, over sand (Soil Conservation Service 1971; Burlington County, N.J.). Generally the muck or peat depth in Pinelands swamps is shallow, although Buell (1970) reports a peat depth of near 2.5 m in one Pinelands cedar swamp, while Little (1951) suggests the maximum peat depth in the Pinelands is probably only 3 m, or so. In contrast, peat depths in northern New Jersey bogs are reported in excess of 4 m (Niering 1953).

The very poorly drained Pocomoke and Berryland soils, and the poorly drained Atsion, all with less organic content than muck, support a variety of wetland types as noted in Table 3. These soil types are well suited for blueberry and cranberry agriculture; however, carefully designed systems with drainage ditches and dikes are needed for controlling water levels.

The moderately well to somewhat poorly drained soils common to the Pinelands (Lakehurst, Klej and Hammonton) support a gradient of vegetation types from pitch pine lowlands, and hardwood swamps through transitional pitch pine communities to upland pine/oak or oak/pine types. This variation is principally related to the wide range in depth to seasonal high water table of these transitional soils. For example, a Lakehurst soil with a depth to seasonal high water table near 1.5 ft, may support a pitch pine lowland community, while the same soil type with a deeper water table (> 1.5 ft) could support an upland pine/oak forest.

Table 3. Dominant hydric and transitional soil types of the New Jersey Pinelands. Included are drainage class, hydrologic soil group and depth to seasonal high water table, as designated by the U.S. Soil Conservation Service, and frequently encountered vegetation communities (wetland and transitional types).

SOIL TYPE	DRAINAGE CLASS	HYDROLOGIC SOIL GROUP	DEPTH TO SEASONAL HIGH WATER (ft)	TYPICAL VEGETATION COMMUNITIES
Muck	Very Poorly Drained	D	+1.0 to 0 ¹	Cedar Swamp, Hardwood Swamp
Pocomoke	Very Poorly Drained	D	0 to 0.5 ¹	Pitch Pine Lowland, Hardwood Swamp, Shrub-dominated wetland, Berry Agriculture
Berryland	Very Poorly Drained	D	0 to 0.5 ¹	Pitch Pine Lowland, Hardwood Swamp, Shrub-dominated wetland, Berry Agriculture
Atsion	Poorly Drained	D	0 to 1.0 ¹	Pitch Pine Lowland, Hardwood Swamp, Shrub-dominated wetland, Berry Agriculture

Table 3. Continued.

SOIL TYPE	DRAINAGE CLASS	HYDROLOGIC SOIL GROUP	DEPTH TO SEASONAL HIGH WATER (ft)	TYPICAL VEGETATION COMMUNITIES
Klej	Moderately Well or Somewhat Poorly Drained	B	1.0 to 2.5 ²	Transitional ⁴
Lakehurst	Moderately Well or Somewhat Poorly Drained	A	1.0 to 5.0 ²	Transitional ⁴
Hammonton	Moderately Well or Somewhat Poorly Drained	B	1.5 to 4.0 ³	Transitional ⁴

¹From list of hydric soils of N.J. (U.S. Soil Conservation Service). According to Cooperative Soil Surveys (U.S. Soil Conservation Service) of various counties in the Pinelands, the estimated range of depth to seasonal high water table often varies between counties.

²Depth to seasonal high water range from Burlington County Cooperative Soil Survey (SCS, 1971). As noted above, range may vary in other Pinelands counties.

³Depth to seasonal high water range is from Ocean County Cooperative Soil Survey (SCS, 1976). As noted above, the range may vary in other Pinelands counties.

⁴Transitional denotes a variety of vegetation community types encountered along an upland to wetland continuum.

PINELANDS WETLANDS VALUES AND FUNCTIONS

INTRODUCTION

Wetlands provide several values and functions which are essential to the maintenance of environmental quality within the Pinelands, and on broader scales, within the mid-Atlantic region and nationwide. The five general wetland values and functions which are discussed below have provided incentives for wetland protection in the Pinelands. Hydrologically, Pinelands wetlands function as natural flood control areas within developed regions. With respect to water quality, the pollution filtration attributes of wetlands are essential to the maintenance of pristine surface waters in the Pinelands. The food web support functions of Pinelands wetlands and habitat values of these resources are recognized especially when considering the diversity of biota encountered, including a significant representation of unique, threatened and endangered species. Finally, the cultural attributes of Pinelands wetlands are considerable, including their harvest values (i.e., logging, blueberries, cranberries) and heritage values of recreation, aesthetics, research and education.

HYDROLOGIC VALUES AND FUNCTIONS OF WETLANDS

An in-depth understanding of general wetland values and functions is dependent upon our knowledge of wetland hydrologic functions. In a recent review of wetland hydrology, it was suggested that all natural wetland functions, including primary productivity, wildlife habitat, nutrient cycling, heritage, harvest and aesthetics are linked to the presence, movement, quality and quantity of water (Carter et al. 1979). The flood and stormwater control function of wetlands is addressed below, along with a discussion of wetland-groundwater interactions, a primary controlling force in the ecological functioning of Pinelands wetlands.

FLOOD AND STORMWATER CONTROL

Wetlands, with a sponge-like water holding capacity, coupled with their topographic location in low-lying areas function as detention basins effectively lowering downstream flood crests and slowing the velocity of destructive water flow. Several studies, mostly conducted in the northern U.S., have quantified the flood attenuation attributes of wetlands. Among these, a study by the Army Corps of Engineers is most notable (cited in Larson 1973). Following a five year engineering analysis of the Charles River basin (Massachusetts), the Corps recommended an innovative flood control management plan which called for the acquisition of 3,400 ha of wetlands to function as "natural" storage areas within the watershed.

Purchase of these wetlands would ensure the protection of a natural flood control system, while also resulting in a more cost-effective alternative to traditional man-made structures. Novitzki (1979) has focused on the hydrologic characteristics of Wisconsin's wetlands and lakes and documents their role in flood and storm flow abatement. Based on regression relationships Novitzki (1979) has shown that flood peaks are significantly lower in watersheds with a relatively high percentage of wetlands/lakes as compared to basins with few or no natural storage areas (Fig. 2). This relationship clearly illustrates that wetland/lake losses from drainage basins having a relatively low percentage of these resources (urban areas) could result in a significantly greater flood hazard than respective losses from less developed watersheds (more wetlands).

As outlined above, the flood control capability of wetlands is generally considered a major value, especially in northern areas where snow melt represents a considerable source of flood waters. However, in the Pinelands excessive flooding is rare primarily due to the gradual topographic gradients and the porous, sandy, well-drained character of the soils. For example, Markley (1979) estimates that over 60% of Pinelands soils are classified by the SCS as being within the A and B hydrologic soil groups (i.e., excessively to moderately well drained soils with high to moderate infiltration rates even when thoroughly wetted). Related to these factors Rhodehamel (1979) suggests that only 6% of the Pine Barrens annual precipitation reaches streams (and presumably wetlands) as direct runoff (i.e., direct input onto surfaces, overland flow, and rapid interflow), essentially negating the possibility for disastrous floods.

This scenario may be different on a local level in the Pinelands, especially when developed watersheds are considered. Increased impervious surfaces occurring with suburbanization often results in increased surface water runoff, with the potential for flooding. Wetlands and other natural water storage areas within developed Pinelands watersheds undoubtedly play a significant role in mitigating flood and stormwaters. For example, Fusillo (1981) studied the effects of large-scale residential development on stormwater runoff in a peripheral area of the Pinelands (Winslow Township, Camden Co., N.J.). As noted in Fig. 3, prior to development of the drainage basin, short duration rainstorms resulted in a slow rise and low peak stream flow. Following development of about 12% of the watershed, peak stream flow discharge from storms of similar rainfall and duration were considerably elevated. Presumably, this development included the clearing and covering (with impervious surfaces) of upland areas, along with the direct loss of wetlands.

In addition to storing or detaining water during flooding conditions, wetlands also function in erosion control. Wetland vegetation serves to modify erosional processes in both inland and coastal environments by; 1) stabilizing and binding the substrate with belowground plant parts, 2) dissipating wave and water velocity energy, and 3) trapping sediment (Allen 1979; Garbish et al. 1975).

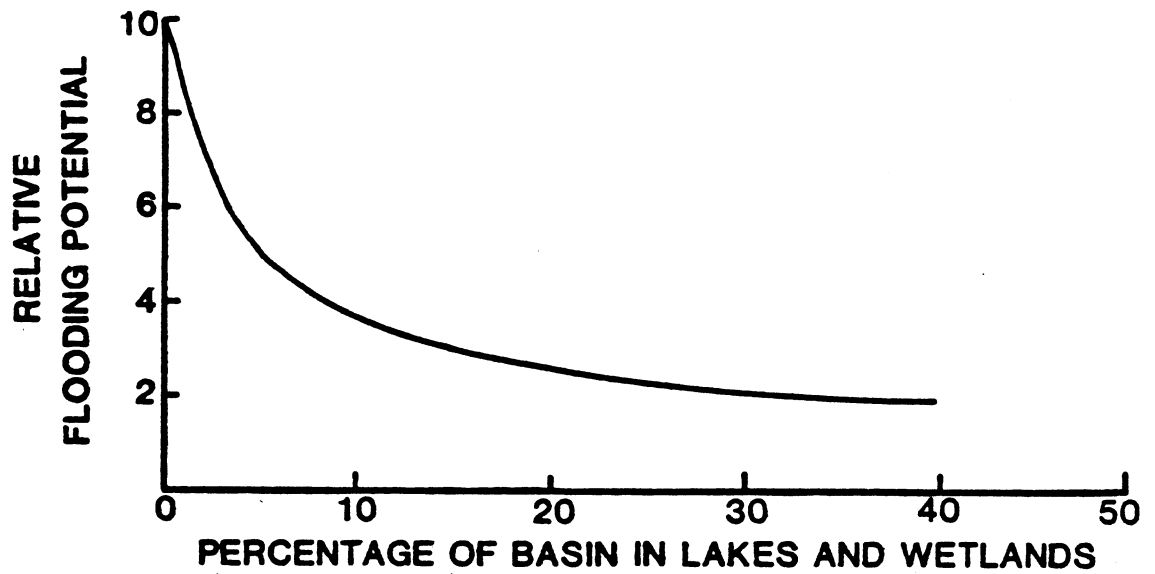


Fig. 2. Relative flooding potential in basins with different percentages of lakes and wetlands. Curve is based on data from Wisconsin watersheds. Note the significant increase in the potential for flooding in basins with a low percentage of lakes and wetlands (redrawn from, Novitzki 1979).

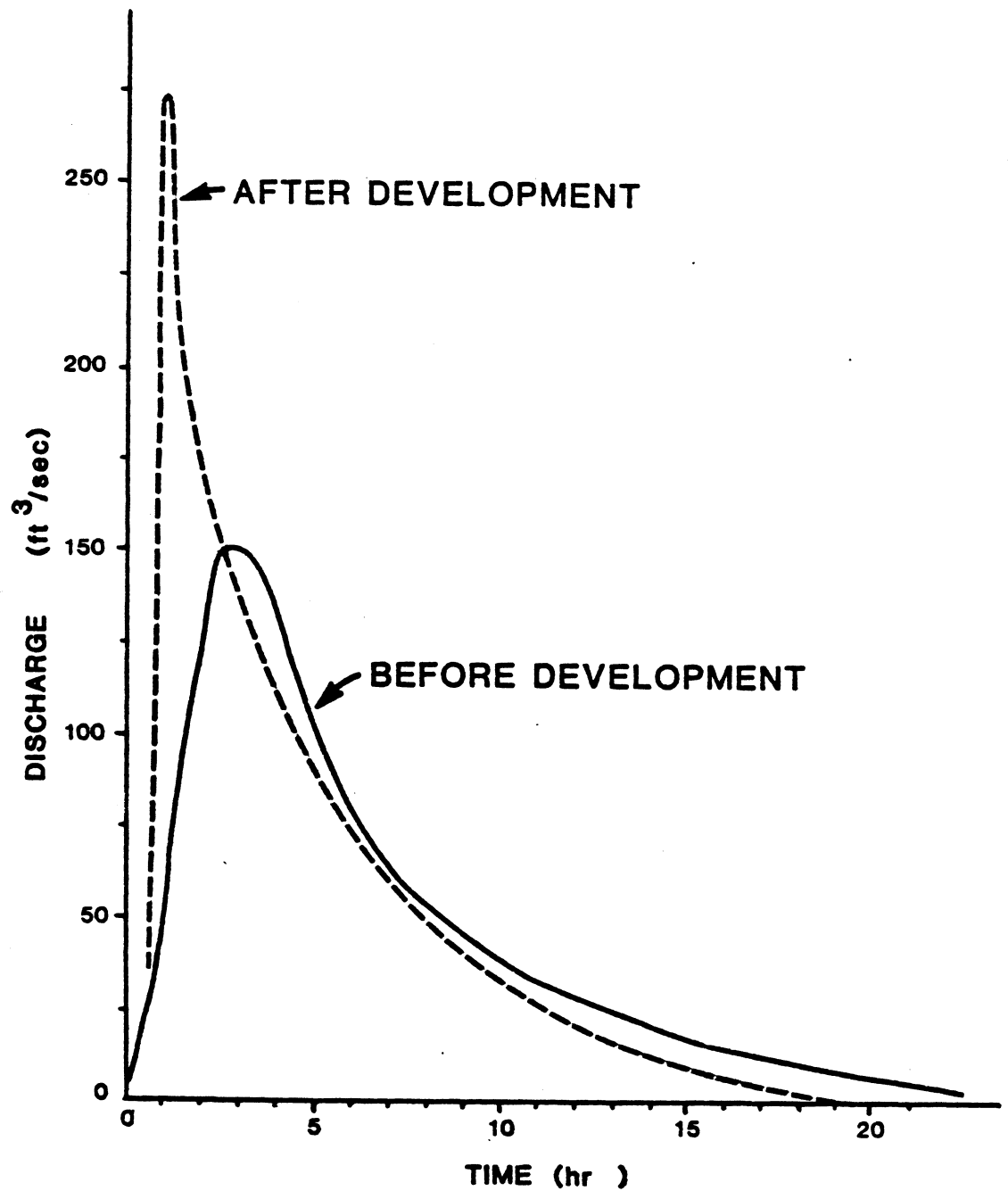


Fig. 3. Comparison of unit-hydrographs of a Pinelands subwatershed (portion of the Upper Great Egg Harbor River) before and after development. The hydrographs are for high intensity/short duration storms. Note that urbanization results in increased peak discharge (redrawn from, Fusillo 1981).

GROUNDWATER-WETLAND INTERACTIONS

The hydrologic relationship between inland wetlands and groundwater resources is poorly understood. After reviewing the literature, Carter et al. (1979) and more recently Adamus and Stockwell (1983), conclude that few studies indicate significant aquifer recharge from wetlands. Under most conditions inland wetlands function as discharge areas (water is released from the aquifer to the wetland). This is especially true in the Pinelands where the groundwater from upland recharge areas flows down hydraulic gradients to discharge into wetlands and stream courses (Ballard 1979). Rhodehamel's (1979) hydrologic budget of the Pinelands indicates that rivers, streams and presumably wetlands are almost exclusively fed by groundwater baseflow. The importance of the close hydrologic connection between Pinelands wetlands, surface waters and groundwater will be realized in our discussion of water quality maintenance values.

RELATIVE HYDROLOGIC VALUE OF PINELANDS WETLANDS

The role of wetlands in flood control is dependent upon several site specific characteristics such as, wetland size and shape, the percentage and relative distribution of wetlands within the watershed, and surrounding upland soil types and land use patterns (Clark and Clark 1979; Adamus and Stockwell 1983). These factors, and others, should be considered when assessing the relative flood control and stormwater storage capabilities of Pinelands wetlands.

Developed vs. Undeveloped Watersheds

Flooding is generally not a problem in undeveloped regions of the Pinelands because of the porous soils and rapid infiltration rates. However, in developed Pinelands regions where a significant percentage of these porous soils may be covered with impervious surfaces or otherwise cleared, wetlands and other depression features (i.e., lakes, ponds, streams) may be especially valuable in flood control. Also related, wetlands located immediately upstream of development store floodwaters and abate potentially damaging stream velocity before the developed area is impacted.

Stormwater Storage Capacity - Wetland Size and Soil Type

In general, the greater the surface area of a wetland the greater will be its stormwater storage capacity. A related parameter includes soil type; most noticeably the water table and drainage characteristics. Wetlands with a water table usually near, or at, the surface have little capacity to store floodwaters belowground; especially in spring when water table levels are greatest (i.e. very poorly drained soils). However, wetland types such as pitch pine lowlands which generally have an unsaturated soil layer of 12-18 inches (30-45 cm), or more, have the capacity to store or retain floodwaters belowground, as well as aboveground.

Wetland Shape and Vegetation Composition

Based on an extensive review, Adamus and Stockwell (1983) state that wetlands with irregular boundaries, meandering streams, and/or constricted outlets probably slow the velocity of floodwaters. Streams flowing through Pinelands cedar and hardwood swamps, with characteristic dense vegetation and diverse sheet flow, would be particularly efficient at slowing floodwater velocities.

WETLANDS AND WATER QUALITY MAINTENANCE

For over a decade researchers have been investigating the role of wetlands as natural water purification systems. This research effort was triggered, in part, by two widely cited studies. In one study, Grant and Patrick (1970) suggested that the tidal freshwater Tinicum Marshes (Delaware River) can assimilate excess nutrient inputs from sewage treatment plants. In another, Wharton (1970) investigated the water quality purification and nutrient assimilation attributes of a Georgia river-swamp and concluded that these systems have the capacity to function as natural purification systems. More recently, numerous studies, reviewed by Sloey et al. (1978) and Kadlec (1979), have been conducted nationwide on a variety of wetland types documenting the ability of these ecosystems, when properly managed, to assimilate nutrients applied as sewage effluent. Although additional research is needed, the controlled management of wetlands for wastewater assimilation appears to be an attractive alternative to traditional tertiary treatment.

Much research has focused on the mechanisms and pathways associated with wetlands and their ability to assimilate, recycle and store excess nutrient inputs, particularly nitrogen and phosphorus. A fundamental pathway for storage of nutrients by wetlands involves uptake first by primary producers, followed by incorporation of nutrients as litter/detritus into the sediments. Ehrenfeld (in press) reports that total annual nitrogen uptake by Pinelands hardwood swamps of varying hydrologic regimes ranges from 73-85 kg N/ha/yr. Of this annual uptake, between 21% and 28% is retained as structural tissue, while the remainder (72-79%) is returned to the system as litter. For pitch pine lowlands 84% of the annual nitrogen uptake (96 kg N/ha/yr) was retained, with 16% returned as litter. Due to the high percentage of evergreen tissue (within both the tree and shrub canopy) in the pitch pine lowland community, significantly more nitrogen is retained annually (Ehrenfeld, in press). However, it should be pointed out that these evergreen tissues are eventually returned as litter, similar to the deciduous situation, yet at a more variable rate. To summarize, an effective mechanism for long-term nutrient retention by forested Pinelands wetlands is storage within structural tissue. On a short-term basis, hardwood swamps effectively retain nutrients as photosynthetic tissue during the growing season, while for pitch pine lowlands this short-term retention mechanism appears more variable.

The ultimate fate of returned biomass, or litter, in quantitative terms is unknown. However, the relationship between this detritus pool, decomposition pathways and nutrient storage by wetlands has been studied.

Anaerobic wetland soils, particularly muck type soils in the Pinelands, promote slow rates of organic matter decomposition relative to soils with oxidized or partially oxidized soil profiles (Klopatek 1978). This organic matter accumulation (i.e., peat formation) represents an effective and relatively long-term nutrient storage mechanism. For example, Buell (1970) determined from radiocarbon dating that Pinelands cedar swamps with peat/muck deposits of up to 2 m have been accumulating organic matter, and presumably retaining nutrients as organics, for over 10,000 years. It can be concluded that Pinelands wetlands with muck type soils have a greater potential to store nutrients, over the long-term, than do wetlands with partially oxidized soil profiles (i.e., Atsion or Berryland soils).

Related to wetland decomposition processes, a significant nitrogen removal mechanism (not nitrogen retention/storage as previously discussed) is denitrification. Denitrification, a bacterially-mediated process, reduces nitrate-N to molecular nitrogen (primarily nitrogen gas) which is usually purged from the system. Durand and Zimmer (1982) report a loss of nitrogen from Pinelands swamp-streams at a rate of 383 - 5621 kg N/km²/yr. The importance of this removal to the overall nitrogen budget of Pinelands wetlands is unknown. In other wetland systems, a review by Adamus and Stockwell (1983) reveals considerable variation from less than 1% to an 80% loss of annual nitrogen inputs by denitrification.

In addition to, 1) nutrient retention by vegetation, 2) long-term retention/storage as accumulated organic material, and 3) removal by denitrification, nutrients can be removed from surface waters by incorporation into the sediments. Sediments of wetlands, stream courses and aquatic systems are generally considered as sinks for nutrients, especially phosphorous. However, several factors govern the sediments capacity for nutrient removal. These include pH, dissolved oxygen concentrations, differentials between sediment and water column nutrient concentrations, sediment type, and others (Klopatek 1978; Farnworth et al. 1979). These processes of nutrient retention and general nutrient dynamics in freshwater wetlands have been reviewed in detail (Klopatek 1978; Prentki et al. 1978; Richardson et al. 1978; Simpson et al. 1978; Kibby 1979; Whigham and Bayley 1979).

The nutrient retention and removal attributes of wetlands are particularly relevant in the Pinelands for regional, watershed-wide or diffuse source pollution control and water quality maintenance. Contaminants can be introduced to wetlands from a variety of sources. These include, groundwater flow containing contaminants from septic systems and landfills, excess nutrients and associated pollutants from agricultural and urban runoff, or the introduction of contaminants by precipitation. The extensive agricultural areas, numerous rural development sites (with septic systems) and several urbanized watersheds of the Pinelands represent significant non-point source threats to water quality.

Durand and Zimmer (1982) present evidence suggesting that certain Pinelands wetlands have the natural capability to assimilate excess nutrients. Their studies were conducted on tributaries of the Mullica

River watershed. One tributary, Wesickaman Creek, flows through a hardwood swamp, but the channel is poorly defined so water is generally dispersed throughout the swamp. This results in relatively high water retention times enabling the swamp to buffer the effects of nutrient input from upstream development (about 30% of the Wesickaman Creek watershed is disturbed). In contrast, they found that a hardwood swamp along the Great Swamp Branch, where upland development accounts for 90% of the drainage area, was not able to assimilate the excess nutrient loads. Apparently, the stream channel is well-defined and in most cases agricultural fields extend directly adjacent to the creek. Durand and Zimmer (1982) suggest that if nutrient laden waters have the opportunity to slowly pass through wetlands, as in Wesickaman Creek, then the system can assimilate a majority of these nutrients (up to 95% of available N), probably through plant uptake and incorporation into sediments.

It should be noted that degradation of the ecosystem will occur before the natural assimilatory capacity of wetlands is approached. Ehrenfeld (1983) has shown that the vegetation structure of wetlands in developed Pinelands watersheds is significantly altered as compared to undeveloped basins. Research is needed to predict the natural treatment threshold of wetlands without significant alteration of ecosystem function (Good 1982). Similarly, the long-term cumulative effects of excess nutrient loads, pathogens, heavy metals and other contaminants on wetland ecosystems must be addressed.

RELATIVE WATER QUALITY MAINTENANCE VALUE OF PINELANDS WETLANDS

When assessing the relative water quality maintenance value of Pinelands wetland types, several factors should be considered. These assessment characteristics refer exclusively to the wetland role in "natural" non-point source pollution filtration, as opposed to management for point source municipal wastewater treatment. The value of wetlands as "managed" tertiary treatment systems is discussed by others (Sloey et al. 1978; Kadlec 1979).

Wetland Soil Type

Wetlands with organic and anaerobic substrates generally have a high potential for nutrient retention/storage. This is based on several factors, as reviewed below;

- a) Organic matter is required as an energy source for denitrifying bacteria, the mediators of denitrification (Kadlec 1979; Durand and Zimmer 1982). Also, because nitrate, the required nitrogen species for denitrification, is formed via nitrification under aerobic conditions, rates of denitrification are often highest where an anaerobic-aerobic interface is common (Adamus and Stockwell 1983).
- b) Nutrients, particularly nitrogen and phosphorus, can form complexes with, or be adsorbed onto organic compounds, with subsequent incorporation into the sediments (Farnworth et al. 1979).
- c) Decomposition generally occurs at a slower rate in saturated, anaerobic sediments, than in aerobic sediments (Chamie and Richardson 1978; Klopatek 1978).

Based on these factors, it is concluded that Pinelands wetlands with muck soils, or other saturated/anaerobic very poorly drained soils, would be most efficient at nutrient retention. These wetland types include, cedar swamps, hardwood swamps, inland marsh, abandoned and active cranberry bogs, and saturated shrub-dominated wetlands.

Hydrologic Regime

In general, wetlands with sluggish stream flow, sheet flow, and saturated soils have a high potential for nutrient retention (Mulholland 1981; Durand and Zimmer 1982). These conditions promote longer contact time between the wetland and nutrient-laden surface waters, thereby increasing the opportunity for nutrient retention. In the Pinelands, broad cedar swamps, hardwood swamps and abandoned bogs often exhibit these characteristics.

Vegetation Factors

The density and structure of wetland vegetation affects the wetland's nutrient retention capabilities in several ways. Dense vegetation often slows water flow, thereby promoting sedimentation and nutrient retention (Boto and Patrick 1979). With respect to structure, wetlands with predominantly woody vegetation have a higher capacity for long-term nutrient storage within plant tissue, as opposed to herbaceous vegetation. As previously noted, Ehrenfeld (in press) found that of the annual nitrogen uptake by hardwood swamps 21-28% was retained within woody structural tissue following litterfall. Also related, Chamie and Richardson (1978) found that the decomposition rate of woody stems of leatherleaf, bog birch (*Betula pumila*), and willow (*Salix* spp.) was significantly slower than the corresponding rate for leaves. The high concentration of structural materials, such as cellulose, hemicellulose and lignin, probably accounts for the slower rate in woody tissue.

In terms of wetland substrate type and nutrient assimilation by vegetation, Whigham and Bayley (1979) compiled data from several freshwater wetland nutrient studies and found that aboveground vegetation in wetlands with organic substrates (> 50% organic material) seems to accumulate less nitrogen and phosphorus than vegetation in wetlands with inorganic substrates. However, aside from this apparent high nutrient accumulation in inorganic substrate wetlands, Whigham and Bayley (1979) further suggest that wetlands with organic substrates may have the greatest potential for assimilating excess nutrients by long-term storage in peat (i.e., organic substrate).

In summary, Pinelands wetlands with dense vegetation, organic substrates, and associated with stream courses, probably have a high capacity for nutrient retention. Also, Pinelands wetlands with predominant woody vegetation (trees and shrubs) have a greater ability to retain nutrients as structural tissue on a year-round basis, than do herbaceous-dominated wetlands. Wetlands dominated by herbaceous vegetation are generally efficient at retaining nutrients as photosynthetic tissues during the growing season (Kibby 1979).

Surrounding Land Use Patterns

Considering the demonstrated role of wetlands in water quality maintenance, it follows that wetlands within developed or agriculturally-dominated watersheds would be particularly valuable in retaining non-point source inputs. Several studies have documented increased nutrient inputs to watersheds following urbanization and suggest that wetlands may play a significant role in assimilating these excess inputs (Hopkinson and Day 1980 a,b; Watson et al. 1981).

In the Pinelands, Durand (1979) and Durand and Zimmer (1982) have shown increased inputs of nitrogen to surface waters draining agricultural watersheds, as opposed to undisturbed watersheds. They cite the importance of wetlands in nutrient assimilation and retention. In short, Pinelands wetlands located within or downstream of development and/or agricultural areas are potentially valuable as nutrient retention basins.

WETLAND FOOD WEB VALUES AND FUNCTIONS

Primary productivity is the rate at which solar energy is captured by plants and converted to biomass; the energy source which all consumers are ultimately dependent. Wetland agricultural yields, timber harvests, fish and wildlife production and overall ecosystem quality are directly related to our understanding of this primary production function and its relationship to energy flow pathways within the complex wetland food webs.

PRIMARY PRODUCTION

Richardson (1979) has reviewed the literature on net primary productivity of several freshwater wetland types, including sedge-dominated marshes, cattail and reed marshes, freshwater tidal marshes, bogs and swamp forests. In addition several reviews dealing with the following specific wetland types have been conducted: freshwater/brackish water tidal marshes (Whigham et al. 1978), prairie glacial marshes (van der Valk and Davis 1978), northern bog marshes (Reader 1978) and salt marshes (Turner 1976). Discretion should be used when comparing production estimates from an array of different wetland types and geographical locations, but in general, the tidal marshes and inland cattail/reed marshes appear to exhibit the greatest primary production (up to 2000 gm/m²/yr). The mean productivity of all the wetland types reviewed by Richardson (1979) was 1500 gm/m²/yr about three times greater than that reported for upland grassland ecosystems of the U.S.

This phenomenon, that wetlands are often more productive than upland communities, has long been recognized, especially with respect to the salt marsh ecosystem (Odum 1961). Of the many factors influencing productivity, including nutrient availability, soil type, climate, and others, water flow or hydrologic regime seems to be a predominant forcing function which can be attributed to high wetland primary production (Gosselink and Turner 1978; Odum 1979). For example, Connor and Day (1976) report that Louisiana swamp-forest communities with moderate flow or seasonal flooding regimes generally exhibit higher primary production values than communities with slow flow or stagnant conditions. Similarly, in a review of forested wetland primary production, it was concluded that

production is generally higher in wetlands with flowing hydrologic regimes than in those with sluggish or non-existent flow (Brinson et al. 1981). Also, in the salt marsh ecosystem a strong positive correlation between tidal amplitude and primary production is reported (Steever et al. 1976). This hydrologic energy subsidy, circulating nutrients, dissolved oxygen and waste products, greatly benefits the functioning of wetland ecosystems often resulting in enhanced production.

Primary production estimates are available for several of the dominant Pinelands wetland community types. For example, Whigham et al. (1978) reviewed primary production of freshwater/brackishwater wetlands within the mid-Atlantic Coastal Plain and report production estimates as high as 2321 gm/m²/yr for wild rice stands in a Delaware River marsh (near the western periphery of the Pinelands). Squires and Good (1974) estimated the annual aerial primary production of tall and short saltwater cordgrass from a Great Bay (N.J.) salt marsh to be 1592 gm/m²/yr and 592 gm/m²/yr, respectively. At the Manahawkin (N.J.) salt marsh, Smith et al. (1979) estimated both above and belowground production and found the belowground component to be several times greater than the aboveground. As indicated in Table 4, there are a paucity of biomass and productivity estimates for inland wetland types of the Pinelands. It is clear that additional estimates of primary production, along with correlations of production and hydrologic regime, are needed for Pinelands inland wetland types. These data are necessary prerequisites toward the development of energy flow models and nutrient/carbon budgets.

SECONDARY PRODUCTION

Primary productivity supports consumer populations through trophic or food web pathways. Energy flow from primary production to consumers proceeds through two main pathways. First, the grazing food chain refers to direct consumption of live vegetation by a diversity of herbivores, including some invertebrates, fish, waterfowl and mammals. The majority of primary production, however, does not enter the grazing pathway but undergoes a complex of physical, chemical and biological changes during the decomposition process and forms a basis of detrital food webs. The essential component of detritus is the actual plant-derived particulate substrate with attendant microbial flora, while dissolved substances leached from decomposing plant material are also an integral part of the detrital make-up (Fenchel and Jorgensen 1977).

Several trophic studies have been conducted in wetland ecosystems, each emphasizing the significance of detrital subdized food web pathways. This wetland trophic research has focused primarily on estuarine ecosystems, such as, salt marshes (Teal 1962; Day et al. 1973; Nixon and Oviatt 1973; Heinle et al. 1977) and mangrove systems (Odum and Heald 1975). Aside from some initial, and now classic trophic research conducted by Lindeman (1942) in Cedar Bog Lake (Minnesota), and an earlier study by Odum (1957) investigating a Florida spring, few comprehensive trophic or energy flow studies have been conducted on inland freshwater wetland or aquatic systems.

Table 4. Biomass and net primary production estimates for inland forested wetlands of the New Jersey Pinelands.

WETLAND TYPE	NUMBER OF SITES STUDIED	BIOMASS (kg/ha)	PRODUCTIVITY (kg/ha/yr)	INVESTIGATOR(S)
HARDWOOD SWAMPS ¹				
a) Flood Plain	2	132,572	5,434	Ehrenfeld (in press)
b) Wet Swamp	4	146,227	6,643	Ehrenfeld (in press)
c) Dry Swamp	4	150,065	5,857	Ehrenfeld (in press)
HARDWOOD SWAMPS	5	91,637 - 193,903 ²	-	Ehrenfeld and Gulick (1981)
HARDWOOD SWAMP	1	316,104	-	Reynolds et al. (1979)
CEDAR SWAMP	1	268,423	-	Reynolds et al. (1979)
PITCH PINE LOWLANDS	2	55,820	8,027	Ehrenfeld (in press)

¹Ehrenfeld (in press) defined three types of hardwood swamps according to hydrologic regime, a) Floodplain - flowing water was observed in winter and spring, b) Wet - standing water was present during the summer, c) Dry - moist forest floor but no standing water in summer. Biomass and production values are means of the sites studied.

² Biomass values shown are a range from the 5 sites.

Estuarine trophic studies have stressed the linkage, via detrital transport, between the primary producing communities (i.e., salt marsh vegetation) and the adjacent estuarine and nearshore coastal waters (see review by de la Cruz 1979). Recent studies are now beginning to recognize this detrital coupling between non-tidal freshwater wetlands and associated aquatic ecosystems. Organic carbon (detritus) budget studies on North Carolina swamp-stream ecosystems reveal a significant streamflow export of dissolved organics from these wetlands (Mulholland and Kuenzler 1979; Mulholland 1981). In fact, these studies suggest a much larger export from swamp-draining watersheds than from upland-draining basins. Trophically, these dissolved organic materials may become available and incorporated in downstream aquatic food webs. Durand (1979) has documented the coupling of Pinelands streams with estuarine bays and suggests that nitrogen inputs from the streams have a controlling influence on estuarine productivity.

Livingston and Loucks (1979) reviewed the food web values of wetlands, and in conclusion they state: "...if management of wetlands is to continue on a reproducible scientific foundation, additional interdisciplinary, quantitative study will be needed of the productivity and food web relationships in wetland and adjacent systems." This is especially true for the Pinelands, an area continuously under the threat of development and overexploitation. As the natural functioning of wetland systems is documented through long-term, regional or watershed-wide studies, the effectiveness of Pinelands management efforts in response to human impacts will be increased.

RELATIVE FOOD WEB SUPPORT VALUES OF PINELANDS WETLANDS TYPES

When assessing the relative food web support value of various wetland types it is often suggested that hydrologic regime be considered as an important criteria (Reppert et al. 1977; Gosselink and Turner 1978; Odum 1979; Adamus and Stockwell 1983). It is generally considered that wetlands driven by substantial hydrologic energy (i.e., tidal, regularly flooded, seasonally flooded, high-to-moderate streamflow rates, etc.) have a high potential for export of nutrients (carbon, nitrogen, phosphorous), and are thus valuable in downstream food chain support. Also, research suggests a general pattern of increased primary production of forested wetlands with moderate flow rates as opposed to those with still waters (Connor and Day 1976; Brown et al. 1979; Brinson et al. 1981).

Considering these hydrologic criteria, it seems that Pinelands wetlands associated with stream courses are potentially more valuable with respect to downstream or external food web support functions than are isolated Pinelands wetlands or those with very sluggish/negligible streamflow. When assessing the relative food web support value of wetlands, nutrient cycling and exchange within particular wetland systems should be considered, in addition to the hydrologic criteria.

HABITAT VALUE OF WETLANDS

An intimate relationship exists between wetland food web pathways and the value of wetlands as vital habitat for a diversity of animals. Among those inhabiting wetlands, the microbes and invertebrates constitute the

initial building blocks of complex food webs. These organisms, the bulk of wetland consumer biomass, provide life-supporting energy for the conspicuous end products of trophic pathways - fish, wildlife, and waterfowl. This wetland role of supporting an economically productive and recreationally-oriented animal population provided an incentive for wetland protection, which began over two decades ago. This conservation effort, while directly benefiting the sportsman, birdwatcher, naturalist and commercial harvester, also protects a host of non-game species and aids in the maintenance of a well-balanced and productive trophic structure.

The wetland and aquatic habitats of the Pinelands support a unique and rich faunal component. Some of the salient factors controlling animal abundance and diversity in these wet environments include; spatial setting with respect to adjacent terrestrial, wetland/aquatic or developed communities; substrate; vegetation structure; hydrologic regime; water quality; and competition/predation (Clark 1979). Of these factors, water quality, particularly high acidity, is probably the most important parameter controlling the faunal composition of Pinelands wetland and aquatic communities. The Pinelands many rivers, streams, small tributaries and frequently encountered ponds and lakes, are characterized by acid waters (pH 3.6 - 5.2) which are generally low in nutrients, hardness and turbidity (Patrick et al. 1979).

FISH, REPTILES AND AMPHIBIANS

Hastings (1979) recognizes only 16 indigenous or characteristic Pinelands fish (Table 5). These species are tolerant of highly acid Pinelands waters, require sluggish flow with dense vegetation, and experience reduced competition from other species. Several of these fish are somewhat restricted to the typical Pinelands aquatic environment, while others, although equally common and tolerant of the conditions are also widely distributed throughout New Jersey and the Atlantic Coastal Plain. In addition to these characteristic fish, Hastings (1979) notes the occurrence of peripheral, anadromous and introduced fish within the Pinelands, resulting in a total of 36 fish species. The most common peripheral fish, only tolerant of moderately acid to non-acid conditions, is the white perch (*Morone americana*), frequently found in tidal portions of rivers which drain the Pinelands. Anadromous marine fish which spawn in Pinelands rivers include striped bass (*Morone saxatilis*), and American shad (*Alosa sapidissima*), once common along the Delaware River and smaller rivers draining westward from the Pinelands but now threatened in New Jersey.

The Pinelands support an unusually rich assortment of reptiles and amphibians. Although inventories differ (Vivian 1980; McCormick 1970), it is generally accepted that 60, or so, herptiles have been reported in, or adjacent to, the Pinelands. These include common, endemic, peripheral and introduced species. Of these herptiles, 30 were selected for intensive study by the Pinelands Commission (CMP) because of their characteristic or unique distribution patterns, or because their populations are known to be declining. Wetlands and aquatic habitats provide habitat for a majority, or 25 of these species (Table 6). The unique assemblage of reptiles and amphibians in the Pinelands may be in part due to the acid waters which

Table 5. Common fish of the New Jersey Pinelands, including species generally restricted to characteristic Pinelands waters and species tolerant of these waters, yet also widely distributed throughout New Jersey (adapted from CMP; Hastings 1979).

<u>RESTRICTED DISTRIBUTION</u>	<u>WIDESPREAD DISTRIBUTION</u>
Banded Sunfish <i>Enneacanthus obesus</i>	American Eel <i>Anguilla rostrata</i>
Blackbanded Sunfish <i>Enneacanthus chaetodon</i>	Bluespotted Sunfish <i>Enneacanthus gloriosus</i>
Ironcolor Shiner <i>Notropis chalybaeus</i>	Brown Bullhead <i>Ictalurus nebulosus</i>
Mud Sunfish <i>Acantharchus pomotis</i>	Chain Pickerel <i>Esox niger</i>
Pirate Perch <i>Aphredoderus sayanus</i>	Creek Chubsucker <i>Erimyzon oblongus</i>
Swamp Darter <i>Etheostoma fusiforme</i>	Eastern Mud Minnow <i>Umbra pygmaea</i>
Yellow Bullhead <i>Ictalurus natalis</i>	Redfin Pickerel <i>Esox americanus</i>
	Tadpole Madtom <i>Noturus gyrinus</i>
	Tessellated Darter <i>Etheostoma olmstedii</i>

Table 6. Selected reptiles and amphibians of New Jersey Pinelands wetland habitats (adapted from CMP). Threatened (T) or endangered (E) status (N.J. Dept. of Environmental Protection and Pinelands Commission) is indicated.

<u>SNAKES</u>	<u>TOADS AND FROGS</u>
Eastern King Snake <i>Lampropeltis g. getulus</i>	Carpenter Frog <i>Rana virgatipes</i>
Eastern Worm Snake <i>Carphophis a. amoenus</i>	Eastern Spakefoot Toad <i>Scaphiopus h. holbrooki</i>
Northern Black Racer <i>Coluber c. constrictor</i>	Northern Cricket Frog <i>Acris c. crepitans</i>
Northern Pine Snake, (T) <i>Pituophis m. melanoleucus</i>	Pine Barrens Treefrog, (E) <i>Hyla andersoni</i>
Northern Red-bellied Snake <i>Storeria o. occipitomaculata</i>	Southern Gray Treefrog, (E) <i>Hyla chrysoscelis</i>
Queen Snake <i>Natrix septemvittata</i>	
Rough Green Snake <i>Opheodrys aestivus</i>	<u>TURTLES</u>
Timber Rattlesnake, (E) <i>Crotalus horridus</i>	Bog Turtle, (E) <i>Clemmys mühlenbergi</i>
	Map Turtle <i>Graptemys geographica</i>
	Red-bellied Turtle <i>Chrysemys rubriventris</i>
<u>SALAMANDERS</u>	Spotted Turtle <i>Clemmys guttata</i>
Eastern Mud Salamander, (T) <i>Pseudotriton m. montanus</i>	Wood Turtle, (T) <i>Clemmys insculpta</i>
Eastern Tiger Salamander, (E) <i>Ambystoma t. tigrinum</i>	
Four-toed Salamander <i>Hemidactylium scutatum</i>	
Marbled Salamander <i>Ambystoma opacum</i>	

effectively reduces competition from acid intolerant species. For example, Gosner and Black (1957) found that acid waters may limit the breeding activities of many amphibians, however, species such as the Pine Barrens Tree Frog (*Hyla andersoni*) and Carpenter Frog (*Rana virgatipes*) were found to be tolerant of acid conditions.

WETLANDS AS BIRD AND MAMMAL HABITAT

Wetlands provide the basic habitat requirements of food, cover and water for a diversity of wildlife. For example, several groups of birds utilize inland and coastal wetlands for rest spots during migrations, for foraging, and for nesting and breeding. These include waterfowl (ducks and geese), loons, divers, grebes, shorebirds and songbirds (Weller 1979). Some noteworthy avifauna of the Pinelands are the migratory waterfowl of tidal freshwater and coastal marshes, which attract hunters, while the osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), and assorted egrets, provide inspiration for the birdwatcher. The inland wetland types support many common songbirds, while also providing necessary habitat for such rare species as the red-shouldered hawk (*Buteo lineatus*) and barred owl (*Strix varia*). Brady (1980) reports that 299 bird species regularly occur in the Pinelands National Reserve, a significant proportion utilizing inland and coastal wetland environments. Wander (1980-81) studied the distribution and breeding status of birds in Pinelands wetlands, focusing on cedar and hardwood swamps. In general, pure hardwood swamps supported nearly a four-fold increase in nesting species (40-45 species) over cedar swamps. Wander (1980-81) suggests that the greater vegetation stratification or foliage height diversity of the deciduous swamps, along with an increased abundance of insects, provide a more suitable habitat for breeding bird utilization (i.e., feeding, nesting, singing). Lists and discussion of breeding birds characteristic of Pinelands inland forested wetlands are provided in Leck (1979), Brady (1980) and Wander (1980-81).

Of the 35 species of mammals found in the Pinelands, 32 utilize wetlands (Table 7). Hardwood swamps and pitch pine lowlands represent the most preferable wetland types frequented by mammals. Mammals most characteristic of wetlands in the Pinelands include, muskrat (*Ondatra zibethica*), the most sought-after furbearer in New Jersey; beaver (*Castor canadensis*), a mammal noted for its physical interaction with watercourses and wetlands; and the meadow vole (*Microtus pennsylvanicus*), a small mammal often prey for higher carnivorous animals of the wetland trophic structure. White-tailed deer (*Odocoileus virginianus*) are common in the Pinelands, especially in cedar swamps where they browse on Atlantic white cedar. However, this deer activity may inhibit reproduction of cedar swamps following fire or cutting (Little 1950). Evergreen swamps also provide a moderating effect during severe winter weather and hot summer periods, and thus are especially utilized by deer during these times. Also, in a telemetry tracking study, it was found that deer in the Pinelands utilize pitch pine lowlands as cover and breeding areas in winter (N.J. Dept. of Environmental Protection, 1981). In watersheds or sub-watersheds where cedar swamps are limited, the pitch pine lowlands may provide significant overwintering areas for deer herds.

Table 7. Selected mammals of New Jersey Pinelands wetland habitats (adapted from CMP).

Beaver <i>Castor canadensis</i>	Mink <i>Mustela vison</i>
Big Brown Bat <i>Eptesicus fuscus</i>	Muskrat <i>Ondatra zibethica</i>
Eastern Chipmunk <i>Tamias striatus</i>	Opossum <i>Didelphis virginiana</i>
Eastern Cottontail <i>Sylvilagus floridanus</i>	Pine Vole <i>Pitymys pinetorum</i>
Eastern Coyote <i>Canis latrans</i>	Raccoon <i>Procyon lotor</i>
Eastern Mole <i>Scalopus aquaticus</i>	Red-backed Vole <i>Clethrionomys gapperi</i>
Eastern Pipistrelle <i>Pipistrellus subflavus</i>	Red Fox <i>Vulpes fulva</i>
Flying Squirrel <i>Glaucomys volans</i>	Rice Rat <i>Oryzomys palustris</i>
Gray Fox <i>Urocyon cinereoargenteus</i>	River Otter <i>Lutra canadensis</i>
Gray Squirrel <i>Sciurus carolinensis</i>	Short-tailed Shrew <i>Blarina brevicauda</i>
Least Shrew <i>Cryptotis parva</i>	Southern Bog Lemming <i>Synaptomys cooperi</i>
Little Brown Bat <i>Myotis lucifugus</i>	Starnosed Mole <i>Condylura cristata</i>
Long-tailed Weasel <i>Mustela frenata</i>	Striped Skunk <i>Mephitis mephitis</i>
Masked Shrew <i>Sorex cinerus</i>	White-footed Mouse <i>Peromyscus leucopus</i>
Meadow Jumping Mouse <i>Zapus hudsonius</i>	White-tailed Deer <i>Odocoileus virginianus</i>
Meadow Vole <i>Microtus pennsylvanicus</i>	Woodchuck <i>Marmota monax</i>

In summary, several investigators have provided extensive inventories of fish, reptiles, amphibians, birds and mammals of the Pinelands (reviewed by, McCormick 1970; CMP). Hopefully, these studies will provide the basis and incentive for the initiation of research to document the trophic role, habitat requirements and natural history of these unique faunal communities.

WETLAND HABITAT FOR THREATENED AND ENDANGERED SPECIES

The rich biotic diversity of wetlands is necessary for the maintenance of an ecologically stable environment. Unfortunately, the destruction and loss of wetland habitat has contributed to an associated loss of plant and animal diversity. Several investigators have inventoried the threatened and endangered vascular plants of New Jersey (Fairbrothers and Hough 1973; Vivian and Snyder 1981), and more specifically, of the Pinelands (Fairbrothers 1979; Caiazza and Fairbrothers 1980). In the Pinelands there are 580 native vascular plant species (Fairbrothers 1979) of which 54, or a significant 9%, are recognized as threatened or endangered by the Pinelands Commission. Wetlands provide habitat for over 80% of these rare plants (Table 8). For example, of the 54 species, 29 can be found in shrub-dominated or bog wetlands, 21 species in hardwood swamps, 17 species in inland and coastal marshes, while cedar swamps and pitch pine lowlands are reported to support 6 species and 4 species, respectively (CMP). Curly grass fern, is one of the more renowned plants of the Pinelands. Although somewhat common in Pinelands cedar swamps, this boreal species reaches it's southernmost limit in the Pinelands while the most extensive populations are located in Nova Scotia and Newfoundland (McCormick 1970; 1979).

With respect to the Pinelands fauna, there are currently no threatened or endangered mammals, although the black bear (*Ursus americanus*) and the bobcat (*Lynx rufus*) have been extirpated from the area. Twenty-four bird species and nine reptiles and amphibians are recognized as threatened or endangered in the Pinelands (N.J. Dept. of Environ. Prot. and Soil Conservation Service, USDA, 1980; CMP). Of the birds, 20 species utilize inland and coastal wetlands, including the federally endangered bald eagle and peregrine falcon (Table 9). It appears that the tidal wetlands, especially coastal marshes and inland herbaceous wetlands, and shrub-dominated/bog wetlands provide essential and valuable habitat for these rare avifauna. Threatened and endangered reptiles and amphibians found in wetland habitats include the colorful Pine Barrens tree frog, southern gray tree frog (*Hyla chrysoscelis*), eastern tiger salamander (*Ambystoma t. tigrinum*), eastern mud salamander (*Pseudotriton m. montanus*), bog turtle (*Clemmys muhlenbergi*), wood turtle (*Clemmys insculpta*) and timber rattlesnake (*Crotalus horridus*). The northern pine snake (*Pituophis m. melanoleucus*) favors uplands, but also occurs in pitch pine lowlands and other wetland types. The wetland habitats of these threatened and endangered reptiles and amphibians and their status on the New Jersey threatened and endangered species list are indicated in Table 6.

Table 8. Threatened and endangered vascular plants of New Jersey Pinelands wetland habitats (adapted from CMP; Caiazza and Fairbrothers 1980; Vivian and Snyder 1981).

<u>SPECIES</u>	<u>STATUS</u>
Sensitive-joint Vetch <i>Aeschynomene virginica</i>	F, T
Red Milkweed <i>Asclepias rubra</i>	T
Pine Barrens Reedgrass <i>Calamovilfa brevipilis</i>	F, T
Barratt's Sedge <i>Carex barrattii</i>	T
Spreading Pogonia <i>Cleistes divaricata</i>	E
Rose-colored Tickseed <i>Coreopsis rosea</i>	T
Knotted Spike Rush <i>Eleocharis equisetoides</i>	E
Resinous Boneset <i>Eupatorium resinosum</i>	F, T
Pine Barrens Gentian <i>Gentiana autumnalis</i>	F, E
Swamp Pink <i>Helonias bullata</i>	F, T
New Jersey Rush <i>Juncus caesariensis</i>	F, T
Loesel's Twayblade <i>Liparis loeselii</i>	E
Southern Twayblade <i>Listera australis</i>	T
Boykin's Lobelia <i>Lobelia boykinii</i>	F, E
Canby's Lobelia <i>Lobelia canbyi</i>	T
Hairy Ludwigia <i>Ludwigia hirtella</i>	T

Table 8. Continued.

<u>SPECIES</u>	<u>STATUS</u>
Linear-leaved Ludwigia <i>Ludwigia linearis</i>	E
Climbing Fern <i>Lygodium palmatum</i>	E
Torrey's Muhly <i>Muhlenbergia torreyana</i>	F, T
Yellow Asphodel <i>Narthecium americanum</i>	F, T
Floating Heart <i>Nymphoides cordata</i>	T
Narrow Panic Grass <i>Panicum hemitomon</i>	T
Hirst's Panic Grass <i>Panicum hirstii</i>	F, E
American Mistletoe <i>Phoradendron flavescens</i>	T
Yellow-fringed Orchid <i>Platanthera ciliaris</i>	E
Crested Yellow Orchid <i>Platanthera cristata</i>	E
Southern Yellow Orchid <i>Platanthera integra</i>	F, E
Maryland Milkwort <i>Polygala mariana</i>	T
Slender Rattlesnake Root <i>Prenanthes autumnalis</i>	E
Awned Meadow Beauty <i>Rhexia aristosa</i>	E
Capitate Beakrush <i>Rhynchospora cephalantha</i>	T

Table 8. Continued.

<u>SPECIES</u>	<u>STATUS</u>
Slender Beaked Rush <i>Rhynchospora inundata</i>	T
Knieskern's Beaked Rush <i>Rhynchospora knieskernii</i>	F, T
Curly Grass Fern <i>Schizaea pusilla</i>	F
Long's Bulrush <i>Scirpus longii</i>	F
Slender Nut Rush <i>Scleria minor</i>	T
Reticulated Nut Rush <i>Scleria reticularis</i>	T
Sclerolepis <i>Sclerolepis uniflora</i>	T
Wand-like Goldenrod <i>Solidago stricta</i>	E
Flase Asphodel <i>Tofieldia racemosa</i>	E
Humped Bladderwort <i>Utricularia gibba</i>	T
White-flowered Bladderwort <i>Utricularia olivacea</i>	E
Purple Bladderwort <i>Utricularia purpurea</i>	T
Reclined Bladderwort <i>Utricularia resupinata</i>	E
Yellow-eyed Grass <i>Xyris flexuosa</i>	T

¹Threatened (T) and endangered (E) status from Caiazza and Fairbrothers (1980). "F" indicates that the plant is currently under consideration for inclusion on the federal list (U.S. Dept. of Interior) of threatened and endangered species (Vivian and Snyder 1981).

Table 9. Threatened and endangered bird species of New Jersey Pinelands wetland habitats (adapted from CMP).

ENDANGERED

Bald Eagle¹
Haliaeetus leucocephalus

Great Blue Heron
Ardea herodias

Black Skimmer
Rhynchops niger

Henslow's Sparrow
Ammodramus henslowii

Cooper's Hawk
Accipiter cooperii

Merlin
Falco columbarius

Least Tern
Sterna albifrons

Northern Harrier
Circus cyaneus

Osprey
Pandion haliaetus

Pied-billed Grebe
Podilymus podiceps

Peregrine Falcon¹
Falco peregrinus

Red-shouldered Hawk
Buteo lineatus

THREATENED

Roseate Tern
Sterna dougallii

Barred Owl
Strix varia

Savannah Sparrow
Passerculus sandwichensis

Bobolink
Dolichonyx oryzivorus

Short-billed Marsh Wren
Cistothorus platensis

Cliff Swallow
Petrochelidon pyrrhonota

Short-eared Owl
Asio flammeus

Grasshopper Sparrow
Ammodramus savaannarum

¹Also listed as endangered by the U.S. Dept. of Interior.

In order that the list of threatened, endangered or extinct species in the Pinelands does not escalate, habitats essential to the survival and maintenance of these species must be preserved and protected. This is especially true of the wetlands which provide refuge for a significant percentage of these unique biota.

RELATIVE HABITAT VALUE OF PINELANDS WETLAND TYPES

Review of Tables 5, 6 and 7 shows the diversity of fauna supported by Pinelands wetlands. However, even upon careful examination of these tables, few inferences can be made concerning the relative value of one Pinelands wetland as opposed to another. Before this direct approach to the ranking of Pinelands wetlands according to their respective habitat values can be adopted, it seems evident that additional inventories and population/community level studies are needed. In particular, studies to document life history strategies of several key wetland species would be most useful.

At present, techniques are available for evaluating the relative habitat value of wetlands according to general biological, physical and chemical characteristics. For example, Golet (1976; 1979) has devised a scheme for the quantitative assessment of wildlife habitat value for glaciated northeast inland wetlands and lists several such evaluation characteristics. Similarly, the U.S. Army Corps of Engineers (1980) has developed a Habitat Evaluation System (HES) which utilizes general biotic and abiotic characteristics as indicators of habitat quality for fish and wildlife. In addition, the Habitat Evaluation Procedures (HEP), developed by the U.S. Fish and Wildlife Service (1980), evaluates the quality and quantity of available habitat for selected wildlife species.

The habitat evaluation criteria as presented in these models or methodologies, along with suggestions by Clark and Clark (1979), Adamus and Stockwell (1983) and Adamus (1983) were incorporated into the following discussion of Pinelands wetlands relative habitat values. When assessing the relative habitat value of Pinelands wetland types the following general wetland and watershed/regional characteristics should be considered: 1) vegetation interspersion within wetland basin, 2) diversity of wetland types within watershed/region, 3) wetland size and 4) surrounding upland habitat. These biotic and abiotic factors were selected because they will enable a rapid habitat assessment, while still maintaining adequate reliability from a community level viewpoint. Note that these habitat evaluation criteria refer to biota other than aquatic biota (i.e. fish, aquatic invertebrates, etc.). Aquatic habitat evaluation is discussed in the following section.

Vegetation Interspersion within Wetland Basin

This factor is related to the ecotonal effect; a principle that species diversity increases with increased structural diversity of the habitat or amount of edge. For instance, Pinelands cedar swamps with several open windthrow areas and small pools interspersed throughout the system may provide better overall habitat than an even-aged, 100% cover cedar stand. Similarly, isolated shrub-dominated wetlands (sponges) within a larger forested pitch pine lowland could provide substantial edge. Also, Pinelands wetlands are often observed fringing stream courses in more or less well defined bands of cedar swamps and hardwood swamp, blending into pitch pine lowlands. This sequence of vegetation belting can potentially increase the edge effect.

Aside from interspersions of different wetland types within a contiguous wetland basin, diversity of structure or vegetation life forms increases habitat. A forested wetland with a well-developed structure of groundcover, low shrubs and understory, undoubtedly provides a diversity of habitat with respect to food availability, cover and nesting areas (U.S. Army Corps of Engineers 1980, HES).

Diversity of Wetland Types within Watershed/Region

In general, a high diversity or interspersions of wetland types within a given watershed or region indicates the potential for increased habitat, and thus, support for a greater diversity of biota. This diversity of wetland types increases the edge effect on a regional basis.

Wetland Size

As the wetland size increases it is often suggested that habitat value increases. Along a relative scale, Golet (1976) ranks wetlands greater than 500 acres to be of highest value, while systems less than 10 acres are assigned a low rank. In the Pinelands, inland wetlands have a fairly diffuse distribution with few large contiguous systems. More appropriately, Pinelands wetlands which are greater than 50 acres could be considered as especially valuable habitat, although additional research is needed (i.e., home range studies) before this area size can be substantiated.

When considering wetland size, the concept of wetland complexes should be realized as an important habitat value feature (Golet 1976; Clark and Clark 1979). One small isolated wetland (less than 10 acres) may not be important alone, yet its value becomes apparent when considered as part of a larger wetland complex. This concept may be especially applicable to developed Pinelands areas where once contiguous wetland systems have been fragmented by past development practices.

Surrounding Upland Habitat

Golet (1976) suggests that as habitat diversity in surrounding areas increases, the potential for enhanced wildlife diversity in the wetland increases. Wetlands bordered by undeveloped or agricultural lands are probably more valuable as wildlife habitat relative to wetlands within developed areas. However, wetlands within developed regions may be valuable as last-remaining refuges for wildlife.

RELATIVE VALUE OF PINELANDS AQUATIC HABITATS

The habitat value of Pinelands surface waters is limited when considered from a species diversity or recreational fishery context. The acid waters create an inhospitable environment only tolerated by a relatively low diversity of fish (Hastings 1979; Patrick et al. 1979). The habitat value of Pinelands surface waters is primarily based upon this inherent uniqueness. In addition, the Pinelands surface waters are relatively undisturbed when compared to other aquatic habitats along the highly developed northeastern Coastal Plain corridor; another quality contributing to value. Therefore, and with respect to relative value, Pinelands streams with typical acid pH (4.5 or less), low nutrients and sluggish flow rates should be considered as especially valuable aquatic habitat. In addition, the meandering, shallow, well-shaded streams, with a variety of aquatic vegetation for food and cover, and sandy/gravelly substrates constitute valuable and characteristic Pinelands aquatic habitat features.

WETLAND CULTURAL VALUES

WETLAND HARVEST

Today, inland and coastal wetlands support an economically valuable harvest. This is linked to an Indian and Colonial way of life when wetlands were viewed as providers of everyday sustenance. For example, food from wetlands, like blueberries, cranberries, wild rice, waterfowl, small mammals, fish and shellfish, provided primary staples in the early settler's diet. Furbearing mammals provided clothes while also supporting a lucrative fur trade. For shelter, wetland timber such as Atlantic white cedar was harvested for lumber, shingles and fence posts.

This early cedar harvest was especially prevalent in the Pinelands as nearly all the swamps were clearcut at least once and probably several times between 1700 and 1900 (McCormick 1970). Even today Atlantic white cedar is the most valued timber product of the Pinelands. However, lumbering activities are carefully managed to insure re-establishment and perpetuation of this resource.

Berry agriculture represents a significant aspect of wetlands heritage, culture and economic harvest in the Pinelands. Blueberry agriculture, as we know it today, began in the Pinelands, at Whitesbog. Here, the native highbush blueberry was hybridized and cultivated beginning in the 1920's. These early efforts revolutionized blueberry agriculture which is now an integral part of the Pinelands landscape, with nearly 3000 ha of the Pinelands acidic and poorly drained soils used in blueberry cultivation (Applegate et al. 1979).

The cranberry industry in the Pinelands, with an intricate system of dikes and sluiceways, ranks third in the Nation in production behind Wisconsin and Massachusetts. Cranberry bogs are especially dependent upon the high quality acidic waters of the Pinelands, as well as vast quantities of this water especially during the fall harvest when bogs are flooded and again in winter when flooded bogs are protected from freezing. In summary, berry culture in the Pinelands supports a rich culture and provides an economic stimulus.

The wildlife resources of Pinelands wetlands represent another significant harvest (see review, Applegate et al. 1979). Commercially, the muskrat is trapped from the many Pinelands wetland and aquatic habitats, especially tidal marshes. As a recreational resource many mammals, gamebirds, waterfowl and fish are harvested from the Pinelands. White-tailed deer, often found in dense cedar swamps, are frequently hunted in the Pinelands. This represents an extension of our earlier heritage when deer were also valued, although not for their recreational purposes, as they are today, but rather as sources of food, clothing and shelter. Waterfowl hunting in the Pinelands swamps, bogs and most notably, tidal marshes, represents another frequent recreational activity, especially during fall migrations along the Atlantic Flyway.

SOCIO-CULTURAL VALUES

The less tangible of wetland values are culturally perceived attributes related to aesthetics, recreation, education, research, history, and similar values. Niering (1979) refers to these values as socio-cultural or heritage values.

Wetlands are often viewed as distinct features offering diversity and scenic value to a natural landscape (Smardon 1979). For example, a flight over the Pinelands reveals striking bands of dark green cedar swamps dissecting the landscape. On the ground, these cedar swamps reward the naturalist, birdwatcher, and the like, with a cool, quiet solitude, while the hiker is usually inspired by the view of open shrubby wetlands, inland marshes, bogs, and small ponds scattered throughout the predominant forested mosaic. In a recent study conducted for the Heritage Conservation and Recreation Service of the U.S. Department of the Interior (Marsh 1981), it was concluded that the public prefers Pinelands landscapes of natural, undisturbed areas, as opposed to developed landscapes. Moreover, Pinelands wetlands, such as abandoned bogs and other water-related scenes, were generally preferred over upland and developed landscapes. This general appreciation for wetland aesthetics has been translated by many into art, verse and music, or captured by the nature photographer, thus providing a rich artistic heritage (Niering 1979; Reimold and Hardisky 1979).

Wetlands as a recreational resource provide an essential leisure outlet. Aside from hunting, trapping and fishing, wetlands are enjoyed by campers, birdwatchers, hikers, and picnickers, to name a few. In the Pinelands, canoeing along the slow moving streams with dense overhanging vegetation, represents a major recreational activity, especially for out-of-state enthusiasts.

For education and research wetlands provide outdoor classrooms and scientific laboratories. By studying a wetland, students of all ages and backgrounds can learn of ecological principles and of the delicate balance which wetland systems depend on for proper functioning. The socio-cultural values of wetlands are varied and often difficult to quantify, yet it is through these values - recreation, education, research - that an environmentally concerned public will learn to appreciate the importance of wetlands as a necessary component of the Pinelands ecosystem.

RELATIVE CULTURAL VALUES OF PINELANDS WETLAND TYPES

Assessing the relative cultural value of wetlands is often dependent upon qualitative and non-scientific perceptions; especially when dealing with the socio-cultural values. Similarly, the wetland harvest values may be perceived from divergent viewpoints. For instance, the mature cedar swamp is of considerable value to the forester, while others may consider the harvest of cedar to be an infringement upon the natural functioning ecosystem. Although there are difficulties in evaluating wetlands for their cultural attributes, these values nevertheless merit full inclusion in an evaluation scheme. The following relative cultural value assessment criteria are a fair representation, while also affording some degree of quantitatively-based perception.

- Wetlands with designated threatened or endangered species have a high cultural value. Clark and Clark (1979) state that rare species are an important part of a wetlands heritage value since they provide visible reminders of the importance of ecological and temporal change. They also suggest that the general public may find it easier to relate to a rare species, rather than with wetlands, thereby stimulating environmental

awareness. Of the 54 threatened and endangered plants found in the Pinelands, over 80% can be found in wetlands. This statistic alone seems to spotlight the sensitivity and overall value of wetlands.

- Wetlands unique or scarce to an area, or particularly threatened by development pressures or over-exploitation are especially valuable. As noted, cedar swamps have played an integral part in the development of a rich Pinelands heritage. This heritage value should be preserved. Today, as in the past, cedar swamps provide a harvest value and should be properly managed to insure the perpetuation of this unique cultural and economic resource.

- Wetlands within developed/populated areas are particularly valuable from aesthetic, recreational and educational perspectives. Wetlands located near schools and other learning centers are especially valuable as outdoor laboratories where students can learn of the many wetland values and functions, thereby promoting positive attitudes toward this natural resource.

MAN'S IMPACT ON THE VALUES AND FUNCTIONS OF PINELANDS WETLANDS

INTRODUCTION

The Pinelands wetlands provide a suite of values which directly benefit our society. It is unfortunate, however, that a significant proportion of this valuable natural resource has been destroyed by past man-induced actions. Even today, with seemingly stringent controls on development, both nationwide and in the Pinelands, wetlands are still threatened by the encroachment of man's development. Such degradation of wetlands should be eliminated; however, societal needs for growth can co-exist with resource conservation efforts through the implementation of ecologically-based management and planning programs. In order that wetland protection in the Pinelands proceeds in parallel with development, it is essential that we acquire an understanding of wetland impacts.

Therefore, the objectives of this section are first, to provide a overview of wetland development activities and associated environmental impacts from both historical and present-day perspectives, and second, to provide a framework and background of information necessary for the development of a procedure to assess the potential for impacts on Pinelands wetlands. Aside from addressing the actual development activities and associated detrimental impacts, it is suggested that comprehensive wetland impact assessment should include an analysis of wetland society-based values and their relationship to impacts, and, the ability to predict the magnitude of impact that particular activities have on wetlands.

IMPACTS ON PINELANDS WETLANDS - A HISTORICAL PERSPECTIVE

Historically, there have been numerous man-induced impacts on Pinelands wetlands. For example, extensive logging of Atlantic white cedar swamps has occurred in the Pinelands since European settlement. It is estimated, that with regeneration some Pinelands cedar swamps have been cut-over five, or more, times (see Applegate et al. 1979 for citations). Lacking proper management and reforestation techniques, these early logging activities undoubtedly resulted in a significant loss of cedar swamps with subsequent replacement by hardwood swamps (Little 1950).

The bog iron industry in the Pinelands (Pierce 1957), which flourished from the 1700's to the mid-1800's, had several impacts on wetlands. Excavation of bog-ore deposits, which are generally found as consolidated "beds" underlying watercourses and fringing wetland areas, resulted in the substantial disturbance of wetland and aquatic habitat.

Aside from the dredging of wetlands for recovery of the bog iron, and associated direct loss of habitat, sediment loads in the streams were undoubtedly elevated, especially during the actual excavation process. Very briefly, the steps to bog iron formation include (Crerar et al. 1979); first, the vertical and lateral migration of groundwater through iron-rich sediments, and then, the oxidation of this iron at aerated surfaces, such as streams and wetlands. This oxidation, a reaction presumably catalyzed by iron-fixing bacteria, results in iron precipitation, and formation of "beds" or iron coated surface sediment deposits.

In addition to the direct impact on the natural system, the bog iron industry and other industries, such as glass and paper, required enormous amounts of energy. While the furnaces and forges utilized charcoal for fuel, the machinery was generally operated by waterpower (Pierce 1957). To create waterpower, within the gentle topographic gradients of the Pinelands, dams were constructed. This, of course, resulted in the alteration of both upstream and downstream wetland habitats.

The production of charcoal in the Pinelands for iron and other industries also affected wetlands. Aside from the clearcutting of pitch pine lowlands, turf blocks, or mats of organic material and shrub roots, were excavated from wetlands and used to cover piles of cordwood, insuring a slow smoldering-type burn during the charcoal production process (Applegate et al. 1979). Similarly, turf was used in the cranberry industry to construct and stabilize dikes and dams. The dense shrub understory of pitch pine lowlands was probably a prime source of turf for these activities.

Other historical impacts on Pinelands wetlands included gathering of *Sphagnum* spp., which was used for surgical dressing and for packing nursery stock, among other uses. Moss gathering was a very common practice in the Pinelands until recent decades (McCormick 1955). Also, Pinelands wetlands provided ideal sites for the collection of landscaping shrubs, as well as wildflowers for florist's shops.

These historical impacts have, in part, provided a shaping influence on the character of the present-day Pinelands landscape (Olsson 1979). For example, many of the wetland and stream areas which were mined for bog ore are now open "savannah-type" areas exhibiting a rich floristic and habitat diversity. Likewise, many former turf areas and borrow pits now support herbaceous/shrubby vegetation, again providing wetland habitat diversity to a landscape of cedar, hardwood and lowland forests.

PRESENT DEVELOPMENT ACTIVITIES IN THE PINELANDS

In contrast to most historical impacts the present development trends and pressures on Pinelands wetlands are much more severe; often resulting in the near irreversible loss of the resource. The following is a discussion of these development activities occurring on, or adjacent to, Pinelands wetlands. Darnell (1976) and Clark (1977) provide extensive reviews of wetland development activities.

FILLING AND DREDGING

Filling and dredging operations represent a threat to wetlands which completely obliterates the resource. Nationwide, and in the Pinelands, considerable portions of wetlands were devastated by filling. Today, as our scientific data base begins to document the value of wetlands, public pressure to fill has diminished. In the past, Pinelands wetlands were sacrificed for a number of reasons, including solid waste disposal sites, commercial, residential and industrial development, utility line rights-of-way and road construction. For the most part, filling and dredging of Pinelands wetlands has been halted with adoption of the CMP. Only isolated filling and dredging operations are currently approved in the Pinelands, usually limited to small peripheral encroachment, such as road, bridge or right-of-way maintenance. It is also probable that minor unapproved wetland filling occurs. It may appear that these small scale filling and dredging projects cause only minor, site specific impacts. However, when considered cumulatively and from a watershed-wide or regional perspective, the impacts could be considerable, especially on a long-term basis.

DRAINING

Drainage of wetlands for reclamation as agricultural lands is another major cause of wetland loss. In fact, it is estimated that wetland drainage for agriculture was responsible for 87% of nationwide wetland losses from the mid-1950's to the mid-1970's (Frayer et al. 1982). Pinelands wetlands, particularly pitch pine lowlands, are often drained and reclaimed for blueberry cultivation. The poorly drained Atsion soils and very poorly drained Pocomoke and Berryland soils provide ideal substrate for blueberry cultivation when water levels are adequately controlled. Wetlands are also drained for mosquito control (most common in tidal wetlands), or have been reclaimed for residential, commercial and industrial development sites.

WATER LEVEL CONTROL STRUCTURES

Included in this category are structures which could cause changes in a wetlands hydrologic regime. For example, numerous inland streams are dammed for the cranberry industry, creating ponds with a resulting loss of wetland habitat. Many Pinelands streams were dammed in the 1800s for the bog iron industry, and today are still maintained for cranberry agriculture. Also, dams are constructed for the creation of open water habitat for recreational fish and wildlife management.

Water control structures which generally have more subtle impacts on wetlands (although loss of wetland habitat can result) include, construction of dikes, levees, roads, causeways, bridges, utility lines and other structures with the potential to alter, restrict, divert, or otherwise interfere with a wetlands normal hydrologic regime. For example, roads on a fill bed are frequently seen bisecting Pinelands wetlands. Oftentimes, culverts or bridges to allow for hydrologic exchange are lacking. Stream channalization (i.e., stream widening, deepening or straightening) for flood control or mosquito control represents another water control practice. In the Pinelands, stream channalization is often associated with cranberry and blueberry agriculture areas.

VEGETATION REMOVAL

Vegetation removal refers to the clearing of land adjacent to wetlands for agriculture, building sites, roadways, utility lines, and other such activities; or, refers to the cutting of timber from wetlands. In the Pinelands harvest of Atlantic white cedar has historically been, and is currently, a major natural resource industry. Recognizing the potential for significant degradation and loss of this unique Pinelands habitat, cedar logging is a closely regulated activity (CMP 1980; Article 6, Section 6, Part 4). Mandates are required to insure that environmentally sound harvest and reforestation techniques are employed.

Land clearing adjacent to wetlands has several possible impacts on wetlands. These include, increased surface water runoff, alteration of wetland flow patterns, alteration of wetland water table level, increased sedimentation, inputs of excess nutrients leached from the denuded landscape and alteration of wildlife habitat. To help mitigate these impacts certain guidelines are set forth in the CMP (Article 6, Part 2, Section 6-203), including a provision that only minimal cleared areas, enough to accommodate the development shall be allowed and that these cleared areas must be stabilized and landscaped (with native vegetation) within six months after construction.

IMPERVIOUS SURFACES

Impervious surfaces are those which significantly reduce and often eliminate infiltration of surface water. Activities which contribute to waterproofing of the landscape include roads, driveways, parking areas, buildings, etc.

Impacts to the wetland caused by impervious surfaces are similar to those described for vegetation removal, especially with respect to accelerated surface water runoff. In addition, impervious surfaces on uplands decrease groundwater recharge by the diversion of precipitation to surface runoff. Considering the close hydrologic connection between groundwater, surface water, and wetlands, extensive impervious surfaces in the Pinelands could cause significant reduction in wetland water table levels on both regional and local scales.

WATER POLLUTION INPUTS

The primary point source inputs to wetlands and watercourses include wastewater from sewage treatment facilities and industrial waste discharges. In the Pinelands, most municipal wastewater facilities provide secondary treatment.

Considering the overall rural character of the Pinelands, except within localized areas of the developed periphery, point source inputs are relatively few. However, non-point or diffuse sources of pollution inputs may be considerable. For example, the primary means of domestic wastewater treatment in the Pinelands is by the on-site septic system. Other non-point inputs include runoff of fertilizer and biocides from agricultural areas and residential/commercial landscapes, leachate from

landfills, and inputs from road, stormwater and urban runoff. The highly permeable and chemically inert character of the Pinelands soils and underlying sand are often inefficient at renovating these non-point source inputs (Brown et al. 1980).

GROUNDWATER WITHDRAWAL

Wetlands, streams and surface waters of the Pinelands represent areas where the groundwater level is at, or near, the surface for most of the year. Any significant reduction, or increase, in the groundwater level could alter the overall delineation, structure and function of wetlands. Considering this relationship, groundwater withdrawal could result in a lowering of wetland water tables and a significant reduction in the augmentation of stream baseflow by groundwater input. Withdrawal for municipal and industrial use could result in regional or watershed-wide water table lowering, while local withdrawal for agricultural irrigation or domestic use could result in site specific impacts.

Related to groundwater withdrawal is the problem of saltwater intrusion and associated aquifer contamination. At present this does not appear to be a problem in the Pinelands, however, as water demands increase, especially in response to the resort-oriented coastal Pinelands areas, the problem could become significant (Good 1982). In addition, groundwater withdrawal with the potential to decrease stream baseflow could cause a downstream shift in the estuarine freshwater/saltwater interface, thereby altering the structure and delineation of biotic communities (Durand et al. 1974).

SIGNIFICANT ADVERSE IMPACTS ON PINELANDS WETLANDS

Associated with Pinelands wetlands are several values and functions which are perceived as being beneficial to society. Included among these values and functions are, 1) the wetlands role in flood protection, 2) wetlands as natural water purification systems, 3) food web support functions, 4) habitat values, and 5) wetland cultural and heritage values. These values are well documented by the scientific community and provide a basis for the formulation of wetland protection policies. It follows that wetland impacts should be perceived in terms of loss or reduction of these human or societal values. Darnell (1979) suggests that environmental impact should be defined as any significant modification of human values which have been assigned to nature. This conceptual linkage between impacts and wetland values should be incorporated within the Pinelands wetlands protection program.

Presently, significant adverse impacts on Pinelands wetlands are defined as those modifications which will have an irreversible effect on the ecological integrity of the wetland and its biotic components (CMP; Article 6, Section 6-107; Appendix 1). Although most development activities occurring on, or adjacent to wetlands ultimately alter the wetlands biotic conditions, these same activities also have the potential to alter other wetland values and functions, such as, flood

control and aesthetic/cultural attributes. The nine significant adverse impacts listed in the CMP (Article 6 Section 6-107; Appendix 1) should be viewed from this overall wetland value perspective. By analyzing wetland impacts according to this broad approach, the decision-maker will be able to judge the benefit of a particular development project to society, against the loss of society-based wetland values which may result from the development. Throughout the following discussion, wetland development activities and associated environmental impacts will be considered from this wetland value perspective.

Presented in Table 10 are the significant adverse impacts on wetlands, as stated in the CMP. They are organized according to the general categories of hydrologic impacts, water quality impacts, food web support/habitat impacts, and cultural/heritage impacts. Cultural/heritage impacts on wetlands are not included within the CMP and have been added. Some of the more salient relationships between wetland development activities and potential significant adverse impacts are listed in Table 11.

WETLAND DEVELOPMENT, IMPACTS AND VALUES

The discussion below provides documentation of significant adverse impacts on Pinelands wetlands along with some reference to the relationship between these impacts and the loss or reduction of wetland values and functions. Darnell (1976) provides a comprehensive review with much supporting evidence to document the impact of development activities on wetlands. In addition, reviews by Clark (1977), Clark and Clark (1979), Shuldiner et al. (1979) and Adamus and Stockwell (1983) provide some general background. With respect to the Pinelands, Robichaud (1980) addresses human modification of the ecosystem, with specific reference to wetlands.

Hydrologic Impacts

Hydrologic factors, such as, wetland water table level and groundwater interactions, seasonal flow patterns, and surface water runoff represent the principle driving forces which determine the structure, function, maintenance and value of wetlands. First, and as noted in Table 11 impacts which alter the natural hydrologic regime of wetlands can result in detrimental ecologic or biotic consequences. For example, Givnish (1973) suggests that lowered water tables in Pinelands cedar swamps, imposed by groundwater withdrawal, could cause long-term vegetational changes in the drier pitch pine lowland or shrub dominated wetland types. Clark and Clark (1979) suggest that an increase in the water table level of an Atlantic white cedar swamp by 15-25 cm, over a growing season, would probably result in the ultimate death of the cedar. When considering the gradual topographic gradients in the Pinelands, coupled with the apparent correlation between vegetation communities and water table depth (see previous discussion of wetland soils), it seems that long-term increases or decreases in wetland water table levels, of only 10-20 cm could cause significant alteration in community structure and composition. This becomes especially apparent when considering that the typical range in water table depth between Pinelands cedar swamps and pitch pine lowlands (near the dry end of continuum from lowland to upland) is only 45 cm, or so.

Table 10. Significant adverse impacts on Pinelands wetlands with the potential to alter a wetlands ecological integrity and associated values and functions. Impacts are directly from the CMP (Article 6, Section 6-107; Appendix 1) except for the addition of cultural impacts.

HYDROLOGIC REGIME IMPACTS

1. An increase in surface water runoff discharging into a wetland
2. A change in the normal seasonal flow patterns in the wetland
3. An alteration of the water table in the wetland

WATER QUALITY IMPACTS

4. An increase in erosion resulting in increased sedimentation in the wetland
5. A change in the natural chemistry of the ground or surface water in the wetland

FOOD WEB SUPPORT/HABITAT IMPACTS

6. A loss of wetland habitat
7. A reduction in wetland habitat diversity
8. A change in wetlands species composition
9. A significant disturbance of areas used by indigenous and migratory wildlife for breeding, nesting, or feeding

CULTURAL IMPACTS

10. An alteration in wetland cultural, heritage, recreational, or aesthetic attributes
-

Table 11. Relationship between development activities and associated adverse impacts on Pinelands wetlands. The numbers correspond to the ten significant adverse impacts listed in Table 10, and are categorized according to hydrologic (1-3), water quality (4-5), food web support/habitat (6-9) and cultural (10) impacts. The impacts included for each development activity are those which can be predicted with some degree of certainty; however, in some cases the listed impacts may not occur, or additional impacts may be included. Primary impacts refers to those which occur immediately following, as well as during initiation of the development practice. Secondary impacts are those which generally exhibit a lag time before the actual impact is noticeable. Both primary and secondary impacts may persist over the long-term.

Table 11.

DEVELOPMENT OR MODIFYING ACTIVITIES	POTENTIAL SIGNIFICANT ADVERSE IMPACTS ON PINELANDS WETLANDS							
	PRIMARY IMPACTS				SECONDARY IMPACTS			
	Hydro	Water Qual.	Food/Habitat	Cultural	Hydro	Water Qual.	Food/Habitat	Cultural
<u>FILLING/DREDGING</u>								
Major Projects (filling/dredging >50% of a wetland basin)	2,3	4,5	6,9	10	1		7,8	
Minor Projects (causeways, rights-of-way, peripheral filling/dredging)		4,5	6,9	10	1,2,3		7,8	
<u>DRAINING</u>								
Blueberry culture, commercial, residential or industrial development, etc.	2,3	5	6,9				7,8	10
<u>WATER LEVEL CONTROL</u>								
Impounding Structures (dams and dikes, etc.)								
Downstream Effects	2,3	5					6,7,8,9	10
Upstream Effects	2,3		6,9	10				
Other Water Flow Restricting Structures (roads, rights-of-way, etc.)								
Downstream Effects	2,3	5					6,7,8,9	10
Upstream Effects	2,3						6,7,8,9,	10
Channalization(see draining)								
<u>VEGETATION REMOVAL</u>								
Removal of Upland Vegetation (agriculture, housing, etc.)	1	4,5			2,3		7,8	10
Removal of Wetland Vegetation (Logging)	2,3	5	7,8,9	10				
<u>IMPERVIOUS SURFACES</u>								
Roads, Parking lots, buildings, etc.	1	5			2,3		7,8	10
<u>WATER POLLUTION INPUTS</u>								
Non-Point Source								
urban/agriculture inputs (fertilizers, etc.)		4,5					7,8,9	10
septic system, landfill leachate, etc.		5					7,8,9	10
Point Source (municipal, industrial discharge)	1	5		10	3		7,8,9	
<u>GROUNDWATER WITHDRAWAL</u>	3	5					7,8,9	10

Modification of seasonal flow patterns in wetlands and streams could also cause significant impacts to the biota. Although few studies address this impact, Darnell (1978) cites the reduction in natural populations, altered species compositions, and frequent reduction in productivity as indications that aquatic species encounter difficulty in adapting to modified seasonal flow patterns. In the Pinelands, the characteristic fish populations, well-adapted to the sluggish streamflow (Hastings 1979) and the abundant assemblage of amphibians may be significantly altered by streamflow modifications.

In addition to biotic alterations, the wetlands role in water quality maintenance and nutrient retention is closely affected by hydrologic impacts. As previously noted, Durand and Zimmer (1982) suggest that wetlands with long water retention times (i.e., sluggish, diverse flow patterns) have a high potential for assimilating excess nutrients. Activities which increase flow through wetlands could, therefore, significantly diminish from this water quality maintenance function. Kuenzler (1976) found that nitrate-nitrogen levels in channelized streams of the North Carolina coastal plain were 10-20 times higher than in natural streams. It is apparent that channelization effectively reduces the retention time of the water in contact with the wetland "purification" system. Channelization of Pinelands streams with adjacent upland agriculture, urbanization or cranberry/blueberry areas, could result in a significant export of nutrients which would otherwise have been retained by wetlands.

Along with altered streamflow, lowered water table levels can also affect the wetlands role in nutrient retention. Organic matter decomposition generally occurs at a faster rate under aerobic rather than anaerobic conditions (Chamie and Richardson 1978; Klopatek 1978). A general lowering of the water table would effectively increase the volume of aerobic sediments, contributing to accelerated rates of organic matter decomposition. It has been suggested that Pinelands cedar swamps would be particularly affected (Givnish 1973). Accelerated organic matter decomposition could result in increased nutrient loading to Pinelands surface and groundwaters.

Lowered water table levels may also increase the susceptibility of wetlands to fire. Pinelands wetlands, especially broad cedar and hardwood swamps, often function as natural firebreaks (Little 1979). With lowered water table levels the dehydrated peat would contribute to the fuel layer. In fact, Little (1979) states that during unusually dry periods soil organic matter could be consumed by fire down to the water table or underlying mineral soil.

In summary, examples have been cited to stress the importance of maintaining an unaltered wetland hydrologic regime. For example, changing the wetland water table level, by only 10-20 cm over a growing season, could contribute to shifts in community composition, structure and function, thereby affecting food web support and habitat values. The nutrient retention value of Pinelands wetlands can be diminished by lowering the water table level or altering flow rates through wetland streams. Also, lower water table levels increase the chance of wildfire either starting or breaking through these natural fire barriers.

Wetlands as firebreaks represent a valuable societal/cultural function. Finally, altering the natural wetland hydrologic regime, especially within urbanized areas, can alter or overstress the wetlands role in flood and stormwater control (see previous review of Fusillo 1981).

Water Quality Characteristics

Chemically, the surface waters of Pinelands wetlands and streams are characterized by low nutrient levels, high acidity and low suspended sediment loads. The unique fish, reptiles, amphibians and plant populations of Pinelands wetlands and aquatic habitats have evolved and adapted to these conditions. Alteration of these water quality conditions would significantly detract from the ability of Pinelands wetland/aquatic resources to support such rich and unique biotic components.

With respect to pH of Pinelands wetlands and streams, existing values in undeveloped watersheds are reportedly low (Table 12). Some investigators have found pH values as low as 3.8 within the sluggish flowing waters of Pinelands swamps. Based on these data, it seems appropriate to suggest that pH values in relatively undeveloped/undisturbed Pinelands watersheds are generally 4.5, or lower. Increased pH could alter the existing and unique Pinelands flora and fauna which are tolerant of these highly acidic conditions. Patrick et al. (1979), in a review of the literature on Pinelands aquatic flora, fauna and surface water chemical composition, found several species which are characteristic of the acid environment. They report that there are nine characteristic fish species (see also Hastings 1979; Table 5); abundant dragonflies, damselflies and whirligig beetles, with no mayflies and few caddisflies and other insect groups - an insect fauna reflecting acid conditions; and characteristic acid water diatoms (*Eunotia*, *Actinella*, *Anomoeoneis*, *Pinnularia*) and a characteristic red algae (*Batrachospermum*). Few blue-green algae were found in the acid and pristine Pinelands waters. Similarly, Moul and Buell (1979) describe a Pinelands algal flora typical of acid and nutrient impoverished conditions. In developed Pinelands watersheds, with noticeably elevated pH values (Table 12), there is probably a change in the biotic species composition to an assemblage which is uncharacteristic of the pristine acid tolerant Pinelands biota.

Elevated nutrient concentrations in Pinelands wetlands and streams are generally coupled with increased pH. Likewise, significant changes in the Pinelands characteristic or existing biotic communities are likely to occur. Within relatively undeveloped/undisturbed Pinelands watersheds, nitrate-nitrogen concentrations are generally very low (Table 13). In fact, nitrate-nitrogen concentrations obtained from particularly pristine Pinelands swamp-streams such as portions of the Mullica River or Oyster Creek, show mean annual levels near zero. With development and subsequent nutrient inputs from septic seepage, agricultural runoff and urbanization, nutrient enrichment of the surface waters is noted (Table 13).

In a recent study, Morgan et al. (1983) characterized the physical, chemical and biological features of undisturbed and disturbed Pinelands streams. The undisturbed streams studied exhibited pH values less than 4.5 and nitrate concentrations below 0.05 mg/l. Biologically, significant differences in plant and animal communities were noted between the two types of study sites. For instance, algal species richness and relative species diversity increased in disturbed streams. The macrophytes response

Table 12. Partial review of reported pH values from the New Jersey Pinelands. Values from relatively undeveloped and developed sites are compared. The "other" category denotes that the investigator(s) did not differentiate between undeveloped and developed. Ranges, medians, and/or means (x) are presented.

INVESTIGATOR(S)	STUDY DATE	WATERSHED(S) or REGION	pH		
			Undeveloped	Developed	Other
Morgan et al. (1983)	1982-1983	Mullica R. & Rancocas Basins	4.3 (\bar{x})	5.9 (\bar{x})	
Ehrenfeld (1983)	June 1979	Throughout Pinelands	3.82(\bar{x}) ¹	5.17(\bar{x}) ¹	
Durand and Zimmer (1982)	1977-1979	Mullica R. Basin	2.68-5.11 4.25(median)	4.05-6.42 5.05(median)	
Fusillo (1981)	1976-1978	Upper Great Egg Harbor R.		7.1(median)	
Means et al. (1981)	1970-1972	Cedar Creek & Mullica R.			3.9-5.9 4.51 (x)
Fusillo et al. (1980)	1966-1977	Oyster Creek	3.9-5.8 4.5(median) ₁ 3.8(median) ₁		
Robichaud (1980)	Lit. Review	Throughout Pinelands	less than 5.0		
Johnson (1979)	1963-1978	McDonalds Br. & Oyster Ck.	3.4-4.8		
Patrick et al. (1979)	1973 & 1975	Throughout Pinelands			3.6-5.2 4.4(x)
NJ Pinelands Commission (in house analysis)	STORET DATA	Pinelands National Reserve			2.8-8.7 4.7(median)
		Preservation Area	2.8-6.9 4.5(median)		
		Protection Area			3.5-8.3 4.6(median)

Table 13. Partial review of reported nitrate-nitrogen values for the New Jersey Pinelands. Values from relatively undeveloped and developed sites are compared. The "other" category denotes that the investigator(s) did not differentiate between undeveloped and developed. Ranges and/or mean values (\bar{x}) are presented.

INVESTIGATOR(S)	STUDY DATE	WATERSHED or REGION	NITRATE-N (mg/liter)		
			Undeveloped	Developed	Other
Morgan et al. (1983)	1982-1983	Mullica R. & Rancocas Basins	0.02 (\bar{x})	0.43 (\bar{x})	
Durand and Zimmer (1982)	1977-1979	Mullica R. Basin	0.01 - 0.22	0.50 - 2.56	
Fusillo (1981)	1976-1978	Upper Great Egg Harbor R.		0.51 - 1.70	
Fusillo et al. (1980)	1966-1977	Oyster Creek	0.0 - 0.25 0.03(\bar{x})		
Robichaud (1980)	Lit. Review	Throughout Pinelands	0.17 (higher in winter)		
Durand (1979)	1976-1977	Mullica River	<u>Summer</u> <u>Winter</u> .01-.04 .07-.13	<u>Summer</u> <u>Winter</u> .31-.38 .56-2.53 & .06-.25 .18-1.04	
Partick et al. (1979)	1973 & 1975	Throughout Pinelands			0.2 - 1.0
N.J. Pinelands Commission (in house analysis)	STORET DATA	Pinelands National Reserve			0 - 11.35 0.70(\bar{x})
		Preservation Area	0 - 2.99 0.24(\bar{x})		
		Protection Area			0 - 11.35 0.51(\bar{x})

to disturbance was indicated as a shift in dominant species from *Eleocharis* spp. and *Scirpus subterminalis* to *Sparganium americanum*, *Callitriche heterophylla*, and *Potamogeton epihydrus*. With respect to fish, disturbed stream sites were characterized by the presence of the tessellated darter and golden shiner (*Notemigonus crysoleucas*), along with a general decrease in abundance of eastern mudminnow, black banded sunfish, banded sunfish, mud sunfish and redfin pickerel.

In a recent study Ehrenfeld (1983) compared the vegetation of hardwood swamps from undisturbed Pinelands watersheds with those from developed watersheds. She attributes observed differences in species composition between the two sets of sites to be primarily related to divergent nutrient regimes, while also noting the possible role of altered hydrologic functions. Ehrenfeld's study indicates that developed swamps tend to lose herbaceous and shrub species characteristic of the Pinelands, such as, the carnivorous sundews and pitcher plants along with leatherleaf, sheep laurel and inkberry. Coupled with the loss of characteristic species, an invasion of Inner Coastal Plain vegetation was noted, particularly herbaceous flora and vines. These changes were recognized as a dramatic shift in the species composition and structure of the swamp understory from shrub-dominated to herb/vine- dominated. These findings clearly indicate that urbanization in the Pinelands, with the associated impacts of nutrient enrichment, hydrologic regime modification and others, has a degrading effect on the structure and presumably the habitat and food web support function of wetlands.

In addition to nutrient enrichment, increased sediment load to wetlands and streams could significantly alter the Pinelands unique biotic composition. Suspended sediment inputs are generally greatest during actual construction activities (Darnell 1976; Fusillo 1981; Adamus and Stockwell 1983), although more subtle or long-term inputs from agricultural, residential and urban areas can be equally detrimental to the system. Some of the salient effects of increased sediment loads on wetlands and aquatic environments, as reported by Darnell (1976), Farnworth et al. (1979) and Boto and Patrick (1979), include: decreased light penetration; decreased dissolved oxygen; increased BOD; adsorption and removal of nutrients, biocides, heavy metals and other toxics; interference with the physiological, feeding, and reproductive functions of aquatic animals; and general reduction in species diversity, standing crops, and productivity.

In terms of the society-based values and functions of wetlands, degradation of Pinelands wetlands pristine water quality characteristics would be most readily reflected in the loss of food web support and habitat value. In addition, wetlands are beneficial to society as natural purifiers of degraded water quality; however, ecosystem degradation will occur if thresholds or tolerance levels are approached.

Food Web Support/Habitat and Cultural Values

Throughout the discussion of hydrologic regime and water quality impacts, reference was made to the associated loss of food web support/habitat and cultural values. In general, development activities affect or alter the physical and/or chemical environment of the system, while changes in the ecological or biotic composition of wetlands and loss of cultural values are often secondary to these initial impacts (see Table 11).

BUFFER DELINEATION IN THE PINELANDS

INTRODUCTION

Appreciation for the values and functions of Pinelands wetlands and acknowledgment of potential environmental impacts imposed by man-induced development activities provided the incentives for strict protection of Pinelands wetlands (CMP; Article 6, Part 1, Sections 6-101 through 6-114; see Appendix 1). Some elements of the Pinelands wetlands management program include the prohibition of development on wetlands for residential, commercial, industrial and institutional purposes. Regulated uses on wetlands include berry agriculture, forestry, low intensity recreational activities and public utility improvements, to name a few. To further strengthen this protection mandate and to provide for preservation of wetland integrity, a buffer protection area of 300 ft is required between the wetland boundary and adjacent upland development, unless the applicant can demonstrate that the proposed upland development will not have a significant adverse impact on the wetland. Only then can reduction of the buffer be considered.

The buffer delineation model proposed herein will assist the applicant, the Pinelands Commission and local regulatory agencies in determining site-specific situations when it would be appropriate to, a) maintain a buffer area of at least 300 ft between wetland boundaries and proposed upland development, or b) reduce the buffer to some degree while insuring that no significant adverse impact to the wetland will occur. The model is designed to deal systematically and consistently with the complexity of ecological and impact-related factors associated with development activities in the Pinelands. In addition, the model is developed within the framework of the Pinelands land use planning strategy, and is therefore in keeping with the intent of federal and state Pinelands protection legislation; that is, to preserve, protect and enhance the essential ecological character of the Pinelands while still providing for environmentally compatible growth in, and adjacent to, existing developed areas.

Organization of this section of the report is as follows; 1) the rationale for maintaining wetland/upland buffer areas is briefly discussed, 2) the various land use planning areas as designated in the CMP are reviewed because they pertain to the buffer delineation model, and 3) a proposed buffer delineation model is presented which recognizes wetland values and functions, which assesses the potential for impacts on wetlands and which conforms to designated land use planning areas in the Pinelands. The proposed model is developed for application in the Pinelands Area; the boundaries of which were designated by the state Pinelands legislation.

This proposed buffer delineation model is not intended for immediate use within the Pinelands Commission's development and review process, nor is it intended for immediate use by applicants or local regulatory agencies. Extensive field verification is necessary to substantiate the model's effectiveness as a valid and workable field procedure. Only following the field testing and incorporation of any appropriate revisions should the buffer delineation model be applied as a decision-making tool.

WETLAND-UPLAND TRANSITION AREAS: An Introduction

Topographic gradients in the Pinelands are gradual with corresponding subtle changes in water table levels and soil characteristics. In response to these general factors dynamic ecological continua occur between wetlands and uplands. For resource management purposes exact wetland-upland boundary delineations are required. However, the ecological boundary can be several hundred meters broad, or at times, only a fringing area. Imperceptible changes in this dynamic transition zone may occur seasonally, while more noticeable changes occur over greater time frames, often in response to precipitation fluctuations or surrounding land use activities, such as streamflow alteration by cranberry farming. These transition zones represent necessary areas protecting wetland values and functions by buffering the impacts of upland development. Moreover, they are functional ecological extensions of wetlands.

The protective roles of buffer areas are many. In terms of the water quality maintenance role of wetlands, vegetated buffer areas act to filter surface water runoff and thus have an ameliorating effect on the input of water-borne contaminants to wetlands, especially during periods of excess stormwater runoff. These contaminants may include excess sediments, nutrients, oils, toxic substances (pesticides, heavy metals, etc.), and others. In the Pinelands, transition areas are particularly important in renovating septic tank seepage prior to introduction to the wetland/aquatic system. Hydrologically, buffer areas contribute to the maintenance of natural wetland water table levels, upland-wetland surface water drainage networks and groundwater recharge and baseflow characteristics. Aesthetically, vegetated buffers add visual diversity to the landscape.

In terms of wetland food web and habitat values, the wetland-upland transition area contributes to the protection or insulation of resident wetland flora and fauna from development impacts, while also playing an ecologically functional role. For instance, Porter (1981) stresses the critical importance of this edge-transition community to wetland associated wildlife in providing feeding, nesting and denning sites, breeding areas, cover, travel routes and vantage points. In addition to these roles, Pinelands wetland transition areas are notably valuable as habitat for amphibians and reptiles. For example, several reptiles and amphibians breed in wetland areas (such as cedar swamps and open bogs) then return to the terrestrial habitat after the breeding season.

In summary, an important strategy for the preservation of wetland values and functions is to maintain vegetated and relatively undisturbed buffer areas between wetland communities and adjacent upland development. This will insure protection of the critical and dynamic wetland community.

LAND USE PLANNING IN THE PINELANDS: A Review

The proposed buffer delineation model must be applicable within the framework of the CMP. Therefore, a brief review of the overall intent of the designated management/planning strategy for the Pinelands is appropriate. The overall goal set forth by state and federal Pinelands legislation is to preserve, protect and enhance the Pinelands essential character while providing for compatible economic growth and development. To satisfy this goal, the Pinelands Commission developed land use capability areas, each adhering to distinct management regulations. These land use types are distributed among a Preservation Area and a Protection Area; the boundaries of each designated by the state legislation (Fig. 4). An area near the coast is within the Pinelands National Reserve boundaries, yet outside the Pinelands Commission's jurisdiction. The NJ Coastal Management Program, administered by the NJ Department of Environmental Protection, regulates development within this coastal area. Permit programs of the Coastal Area Facility Review Act (N.J.S.A. 13: 19-10), the Wetlands Act (N.J.S.A. 13: 9A-1), and the Waterfront Development Act (N.J.S.A. 12: 5-3) are incorporated into the Coastal Management Program. It is intended that coastal development in this outside area be regulated in a manner consistent with the policies and objectives of the state and federal Pinelands legislation.

The goals of the Preservation Area, as stated in the CMP include the preservation of an extensive, contiguous land area in its natural state; the promotion of compatible agriculture, horticulture and recreation uses; the prohibition of any development incompatible with the area's preservation; the provision of a sufficient amount of undeveloped land for specific wilderness management practices; and the preservation of surface and ground water quality and quantity. The management goals of the Protection Area include the preservation and maintenance of the essential character of the existing Pinelands environment; the protection and maintenance of surface and ground water quality; the promotion of the continuation and expansion of agricultural and horticultural uses; the discouragement of piecemeal and scattered development; and the encouragement of appropriate patterns of development in or adjacent to areas already utilized for such purposes.

The Preservation Area includes the Preservation Area District, Special Agricultural Production Areas, portions of Agricultural Production Areas, Military and Federal Installation Areas, and some designated Pinelands Villages. The Protection Area includes the Forest Areas, Rural Development Areas, Regional Growth Areas, Pinelands Towns, portions of the Agricultural Production Areas, Military and Federal Installations and some Pinelands Villages. When delineating these various land use capability areas the Pinelands Commission took into account several criteria including, regional variations in existing environmental quality and, current and projected development patterns.

These land use capability areas are described below and in the CMP (Article 5, Part 2, section 5-203). See Appendix 3 (endpiece) for the regional distribution of these areas.

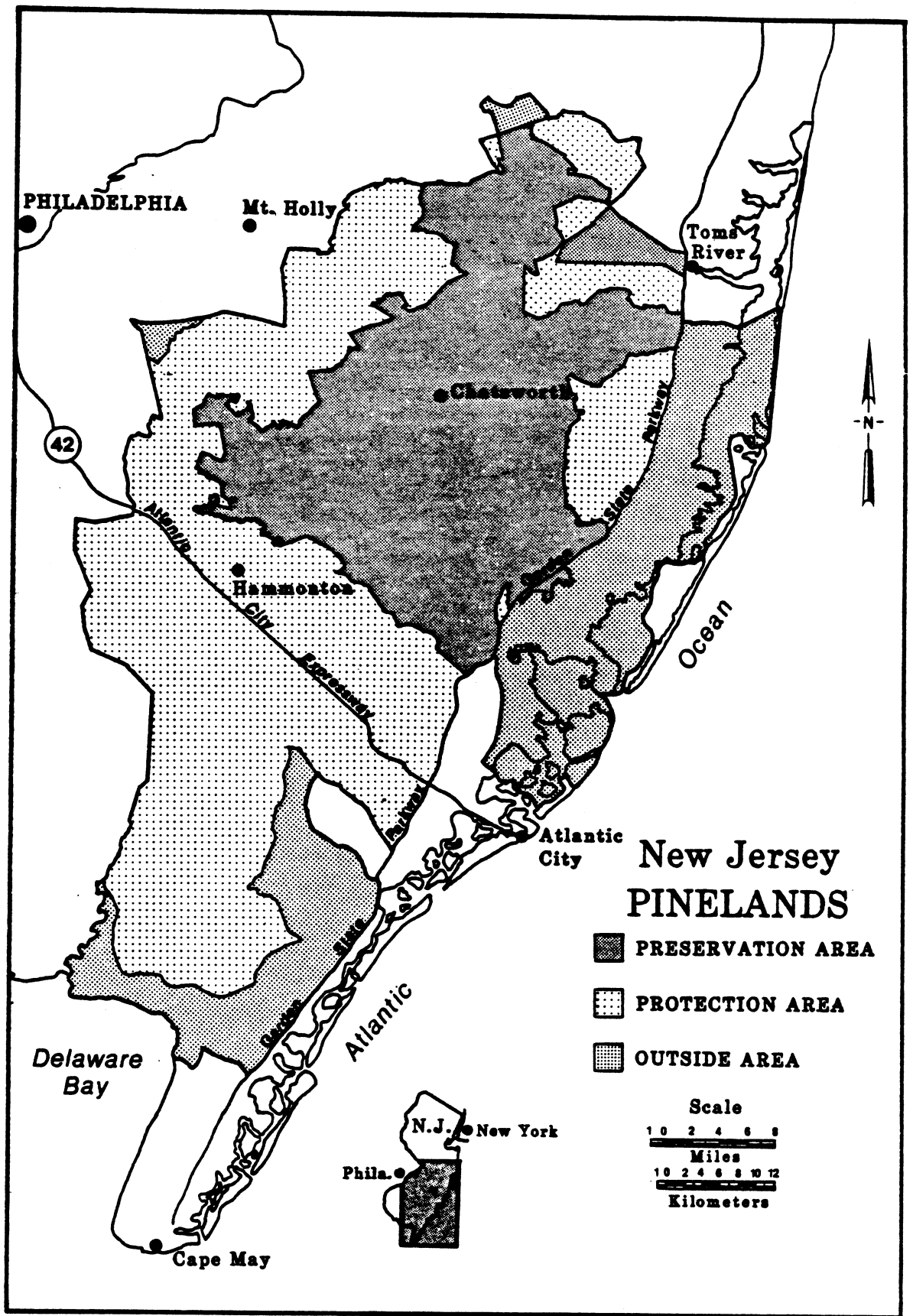


Fig. 4. The Pinelands National Reserve showing the Preservation Area and the Protection Area as designated by the N.J. Pinelands Protection Act, 1979. Collectively, these areas are known as the Pinelands Area. The Outside Area is in the Reserve, but not within the jurisdictional boundaries of the Pinelands Commission.

Preservation Area District

This heart or core area of the Pinelands environment contains many significant environmental and economic values that are especially vulnerable to degradation. It is a large, contiguous area of forest, transected by a network of pristine wetlands, streams and rivers, all of which support diverse plant and animal communities. The area must be protected from development and land uses that would adversely affect its long-term ecological integrity. Examples of acceptable activities include forestry, berry culture and low intensity recreational uses. To further insure the semi-wilderness features of the area, residential growth opportunities are limited to those persons who can demonstrate a cultural, social, or economic link to the essential character of the Pinelands.

Forest Areas

These are relatively undisturbed, forested areas which support characteristic Pinelands plant and animal species. They are an essential element of the Pinelands environment and are very sensitive to random and uncontrolled development. Residential development, is limited to one dwelling unit for each 15.8 acres of upland, privately held and undeveloped land. In addition to allowed uses in the Preservation Area District, some industrial/commercial activities are allowed provided they are related to Pinelands resources and adhere to strict environmental standards.

Rural Development Areas

Rural Development Areas are areas which are slightly modified and may be suitable for limited future development subject to strict adherence to environmental performance standards. They represent a balance of environmental and development-related values that are intermediate between the relatively undisturbed Forest Areas and existing growth areas. Residential dwelling units are permitted provided that the total number of new units does not exceed 200 units per sq. mile of private, non-wetland, undeveloped land. Cluster developments are allowed, as are commercial/industrial activities.

Regional Growth Areas

Regional Growth Areas are areas of existing growth or lands immediately adjacent thereto which are capable of accommodating regional growth influences while protecting the essential character and environment of the Pinelands. Within these growth areas, the Commission has set minimum standards governing the distribution and intensity of allowable residential development. For each Pinelands township or municipality the density of dwellings/acre varies from 1 unit to 3.5 units/acre of developable land. Industrial/commercial development is allowed provided environmental standards are maintained.

Pinelands Villages and Towns

Pinelands Villages and Towns are existing communities in the Pinelands which are appropriate for "infill" residential, commercial and industrial development that is compatible with their existing character.

Agricultural Production Areas

Agricultural Production Areas are areas of active agricultural use, together with adjacent areas of prime and unique agricultural soils or soils of statewide significance, which are suitable for expansion of agricultural operations.

Special Agricultural Production Areas

Special Agricultural Production Areas are discrete areas within the Preservation Area District which are primarily used for berry agriculture or horticulture of native Pinelands plants. They represent a unique and essential element of the Pinelands economy and are a part of the essential character of the Pinelands.

Military and Federal Installation Areas

Military and Federal Installation Areas are federal enclaves within the Pinelands. They represent a unique element of the Pinelands landscape and are a substantial resource to the region and the state, provided that their activities preserve and protect the unique natural, ecological, agricultural, archeological, historic, scenic, cultural and recreational resources of the Pinelands.

PROPOSED BUFFER DELINEATION MODEL

GENERAL ORGANIZATION

The proposed buffer delineation model is summarized in a decision-making flow diagram (Fig. 5). The evaluator (defined as the applicant, Pinelands Commission staff, or local regulatory agency staff) must ask sequentially the questions provided in the flow diagram. As noted, the initial aspect of the proposed buffer delineation model consists of six *special case buffer delineation guidelines*. These relate to specific situations or cases in the Pinelands that deserve particular attention. These *special case buffer delineation guidelines* refer to, 1) proposed development in the Preservation Area District, 2) resource extraction projects, 3) proposed development utilizing on-site domestic wastewater treatment systems, 4) infill-type development, defined as development of vacant property within areas of existing dense residential development, 5) proposed development adjacent to Atlantic white cedar swamps, and 6) proposed development within 300 ft of a surface water body or herbaceous inland marsh. Statements clarifying the intent of the *special case buffer delineation guidelines* and statements outlining the rationale for creating each of these guidelines are presented in the following section.

If none of the *special case buffer delineation guidelines* pertain to the proposed development activity or wetland site, then the evaluator will be directed to the *land capability areas buffer delineation procedure*. This procedure, presented in detail in a later section, is a three step process.

- 1) The evaluator must determine the relative values and functions of the site-specific wetland and surrounding wetlands-watershed which are associated with the proposed development. A relative wetland evaluation scheme is followed to derive a numerical index.

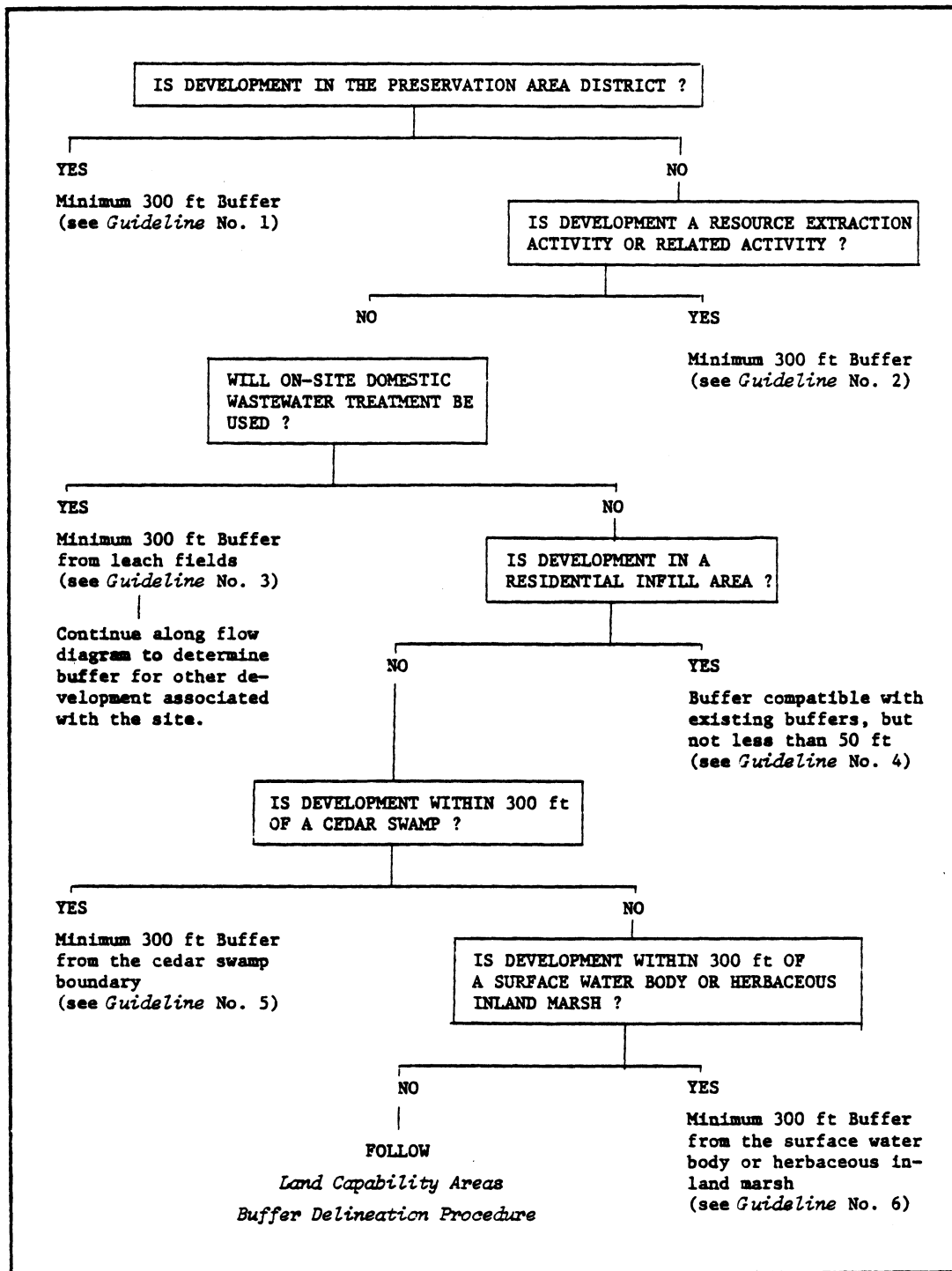


Fig. 5. Decision-making flow diagram for the proposed buffer delineation model. The evaluator must ask sequentially the questions provided. If answered "YES" the evaluator is directed to a *Special Case Buffer Delineation Guideline* for a detailed explanation of the buffer recommendation. If a buffer is not assigned according to the *Special Case Buffer Delineation Guidelines* then the evaluator is directed to the *Land Capability Areas Buffer Delineation Procedure*.

- 2) Next, the evaluator must determine the potential for the proposed development to cause on-site, cumulative and/or watershed-wide impacts. A potential for impacts scheme is followed to derive a relative numerical index.
- 3) Based on the relative wetland values numerical index and the potential for impacts numerical index, formulas are presented whereby appropriate buffer distances can be determined for each land use capability area in the Pinelands.

In summary, to delineate an appropriate buffer protection area according to the proposed buffer delineation model, the evaluator must conduct the following;

- 1) Preliminary Information Gathering - To begin the buffer delineation model the evaluator must have available the following:
 - The applicants site plan and associated materials for the proposed development (a detailed listing of application requirements is included in the CMP (Article 4, Part 1, Section 4-102).
 - Aerial photographs, USGS topographic maps, Pinelands Commission vegetation maps, National Wetlands Inventory maps, SCS soils maps, and other pertinent sources which detail the site location and surrounding areas.
- 2) Proposed Buffer Delineation Model - The evaluator must follow the decision-making flow diagram (Fig. 5). To determine an appropriate buffer for the site-specific situation the evaluator will be directed to an appropriate *special case buffer delineation guideline* and/or the *land capability areas buffer delineation procedure*.

SPECIAL CASE BUFFER DELINEATION GUIDELINES

The *special case buffer delineation guidelines* are presented below. Included with each guideline are, a) a buffer distance recommendation, b) a statement clarifying the intent of the recommendation, and c) a statement which briefly outlines the rationale for the buffer recommendation and the basis on which it was founded. Additional information supporting these rationale statements is found throughout the earlier sections of this report on wetland values, functions and impacts.

Special Case Buffer Delineation Guideline No. 1, PRESERVATION AREA DISTRICT

It is recommended that a minimum 300 ft buffer be maintained between wetland boundaries and any permanent development activities proposed for adjacent upland areas in the Pinelands Preservation Area District.

Clarifying Conditions: Permanent development refers to structures, private roads, driveways, parking lots, on-site wastewater treatment systems, clearing for right-of-ways, lawns and other development-related practices with the potential to cause long-term alteration of the landscape.

Rationale: The Preservation Area District represents an extensive, contiguous and mostly undeveloped portion of the Pinelands. This area is characterized by undisturbed watersheds, with wetland complexes providing critical habitat for a diversity of flora and fauna, including numerous threatened and endangered species. Headwaters of several Pinelands watersheds, including Cedar and Rancocas Creeks, and the Wading, Batsto and Mullica Rivers are within this inner core area. Extensive berry production areas are within the Preservation Area and are dependent upon adequate supplies of high quality water. In short, the Preservation Area District exemplifies the essential ecological, cultural, economic and aesthetic character of the Pinelands and is deserving of the highest priority for protection. All efforts possible should be adopted to protect this Pinelands core area from man-induced development impacts, thereby insuring the maintenance of a relatively undisturbed ecosystem -- a unique entity within the intensively developed Northeast.

It is recommended that a minimum 300 ft buffer area be maintained between wetland boundaries and proposed upland development activities in the Preservation Area District. This will aid in the maintenance and protection of wetlands within this Pinelands inner core ecosystem. As set forth by the state legislation and supported with adoption of the CMP, the Preservation Area District is recognized as an exceptionally valuable entity of the Pinelands and must be given utmost protection from environmentally degrading impacts. In keeping with this legislative intent, wetlands of the Preservation Area District should be afforded maximum protection, and thus a minimum 300 ft buffer is recommended.

Special Case Buffer Delineation Guideline No. 2, RESOURCE EXTRACTION

It is recommended that minimum 300 ft buffer areas be maintained between all Pinelands wetlands and any resource extraction activity.

Clarifying Conditions: Resource extraction is defined as those activities covered under the CMP's resource extraction management program (Article 6, Part 6, Sections 6-601 through 6-607); and other similar activities. In brief, resource extraction is defined as dredging, digging, extraction, mining and quarrying of sand, gravel or minerals. Included with this recommendation are activities associated with resource extraction such as wash plant areas, sedimentation ponds, topsoil storage areas, equipment storage areas, heavy equipment operation, structures, roads and parking areas.

Rationale: Associated with resource extraction is the potential for severe environmental impacts to be imposed on Pinelands wetlands. The areal extent of resource extraction operations in the Pinelands National Reserve is extensive. From an analysis of 1979 aerial photographs it was estimated that active and recently abandoned sand/gravel excavation sites occupied nearly 10,000 acres of the Reserve (CMP). Individual operations

probably average 200 - 300 acres, while the larger excavation sites can encompass over 1000 acres. Considering the regional extent of resource extraction in the Pinelands (i.e., about 1% of the Reserve's total area) and the large-scale of individual operations, environmental impacts on wetlands are undoubtedly significant.

The most immediate and noticeable impact associated with resource extraction is the removal of vegetation and soil, thereby resulting in the direct loss of habitat. Hydrologically, the potential for impacts is significant. For instance, commercial excavation activities can extend to a depth of "...65 ft. below the natural surface of the ground existing prior to excavation unless it can be demonstrated that a depth greater than 65 ft. will result in no significant adverse impact relative to the proposed final use or on off-site areas" (CMP; Article 6, Part 6, Section 6-606). The natural upland to wetland flow of both surface and groundwater would be altered, with the potential for changing seasonal flow patterns, accelerating surface water runoff and changing water table levels in wetlands (Darnell 1976). Coupled with increased runoff, there is the potential for increased siltation of wetlands and streams. In addition, resource extraction operations would have a significant impact on the microclimate of surrounding areas. Havens (1979) suggests that with removal of Pinelands natural vegetation, air and soil temperatures would increase with the transfer of this heat to surrounding areas (such as wetlands). Also, with the loss of evapotranspiration, combined with the high air temperatures, Havens (1979) states that relative humidity would decrease locally.

To maintain the integrity of wetlands within the vicinity of resource extraction operations, it is recommended that minimum 300 ft buffer areas be maintained between wetland boundaries and resource extraction activities. The buffer should aid in the maintenance of wetland wildlife habitat and food web functions, natural hydrologic links, function to filter excess suspended sediments associated with resource extraction operations and ameliorate microclimate alterations.

Special Case Buffer Delineation Guideline No. 3, ON-SITE DOMESTIC WASTEWATER TREATMENT

It is recommended that a minimum 300 ft buffer be maintained between the wetland boundary and the septic leach field of on-site wastewater treatment systems.

Clarifying Conditions:

1) Included with this recommendation are activities such as wastewater spray irrigation and land application of sewage and septage.

2) This recommendation refers only to location of the septic leach field, spray field or sewage/septage application area relative to the wetland boundary. To determine an appropriate buffer for other development activities at the proposed site (i.e., structures, roads, etc.), the evaluator should refer to other sections of the proposed buffer delineation model (i.e., proceed sequentially along the decision-making flow diagram (Fig. 5). For septic leach fields, it is suggested that the dwelling unit be located adjacent to, or upgradient from, the leach field. If the dwelling unit is downgradient of the leach field, then there will be a necessity to pump wastewater upgradient to the leach field.

Rationale: Pinelands surface and groundwaters are characterized by low nutrients and low pH. Pinelands wetland and aquatic ecosystems have adapted to this regime. In order to maintain the typical and unique biota of the Pinelands, the existing undisturbed water quality must be preserved. In terms of contamination of this water resource, the Pinelands soils are generally chemically inert, poorly buffered, and highly permeable, and thus, are often considered ineffective at renovating pollution inputs.

An effective way to minimize surface and groundwater contamination by septic leachate, wastewater spray irrigation or sewage/septage leachate is to insure adequate dilution by infiltrating precipitation, and nutrient uptake by vegetation. Based on an areal dilution model (Brown et al. 1980) which takes into account soil drainage characteristics, nitrogen loading, precipitation input, and surface area of a conventional-type septic leach field, it is predicted that a lot of 3.2 acres is needed to insure that the average concentration of nitrate exiting a given parcel of land or entering Pinelands surface waters will not exceed 2 mg NO₃-N/l. A similar areal dilution model for the Pinelands was developed independently by Trela and Douglas (1979).

These areal dilution models assume that the contaminated water and diluted water will be completely mixed, yielding an average concentration of the contaminant throughout the property limits (i.e., 2 mg NO₃-N/l throughout a 3.2 acre parcel). However, upon contact with the groundwater, contaminants from a diffuse point source, such as a septic leach field, generally do not mix completely, but rather, the contaminants flow as a plume in the direction of the hydraulic gradient (Brown et al. 1980).

Accounting for this hydraulic coupling of septic discharges with groundwater hydrodynamics and dilution by groundwater recharge, Harlukowicz and Ahlert (1978) have developed a model, intended for application in the Pinelands, to predict the travel distance necessary for contaminated groundwater to reach acceptable levels. Depending on the model input variables, the predicted distances to acquire a minimum 2 mg NO₃-N/l concentration, range from 325 ft to 600 ft (Table 14).¹ As noted, it is predicted that a deforested site would require a shorter distance for nitrate dilution (other factors remaining equal), than for a forested site. It is assumed that in deforested sites more precipitation is available as recharge-dilution water. In forested sites, a percentage of the input precipitation is intercepted or transpired by vegetation, with less water available for recharge-dilution; and thus, greater attenuation distances are needed. However, Harlukowicz and Ahlert (1978) state that this conclusion is premature since plant uptake of nitrogen is not included in the model. The previously discussed areal dilution model (Brown et al. 1980) assumes that from 4.5 - 9% (depending on soil type) of the nitrogen input from the septic leach field is taken-up by vegetation.

¹The Harlukowicz and Ahlert (1978) model assumes that the typical septic system serves a household of 5 people. According to Brown et al. (1980) and Trela and Douglas (1979) a more appropriate figure is 3.5 people. Assuming a household of 3.5 people, would decrease the wastewater output by 30%, thereby decreasing the predicted attenuation distances as calculated by Harlukowicz and Ahlert (1978; see Table 14).

Table 14. Selected results from the Harlukowicz and Ahlert (1978) model for predicting attenuation of groundwater nitrate contamination by dilution processes (adapted from Tables 6.6 and 6.7 in Harlukowicz and Ahlert 1978). Distances hydrologically downgradient from septic leach fields which are necessary for attenuation of groundwater nitrate contamination to an acceptable 2 mg/l level are listed. Major input variables include, varying background nitrate levels and forested vs. completely deforested landscapes downgradient of the leach field. Other model assumptions are included as footnotes¹.

Minimum Distances (ft) Predicted to Attenuate Groundwater NO ₃ -N levels to 2 mg/l	Input Variables	
	Background NO ₃ -N in Groundwater (mg/l)	Vegetation Cover
600	0.0	Forested
325	0.0	Deforested
425	0.5	Deforested

¹Assumptions: Average precipitation; household with five people; Wastewater output (75 gal/capita/day); Leach field area (1200 ft²); Nitrate loading concentration at leach field (27 mg/l); Soil permeability (0.2 in/hr); Groundwater flow velocity (0.38 ft/day).

Finally, the Harlukowicz and Ahlert (1978) model is sensitive to the presence of background nitrate in the recharge groundwater, which results in an increased distance for dilution of contaminated groundwater. However, the 0.5 mg NO₃/l background level used by Harlukowicz and Ahlert (1978) is uncharacteristically high. While the Harlukowicz and Ahlert (1978) model represents an excellent approach to predicting nitrate dilution of contaminated groundwater plumes, the model's assumptions must be carefully assessed for their appropriateness in the Pinelands and extensive field studies must be conducted in order to verify the model predictions.

Along with models, field studies can be conducted to determine distances from septic leach fields at which nitrate levels will reach specified or acceptable concentrations. Walker et al. (1973) examined groundwater flow characteristics and monitored nitrate concentrations at several locations relative to septic leach fields (i.e. downgradient, upgradient, lateral). This study was conducted in Wisconsin, yet the results are somewhat comparable to the Pinelands, considering location of the study sites in areas of unconsolidated "sandy" glacial lake deposits and relatively flat topography. Based on downgradient nitrate concentrations from one of the Wisconsin field sites, a best-fit curve was derived to predict nitrate concentrations vs. distance from the septic leach field (Division of Water Resources, NJ Department of Environmental Protection, personal communication).² From this curve, it is predicted that a distance of 505 ft downgradient of the septic leach field is needed to reach a nitrate concentration of 2 mg/l in the contaminated groundwater plume. Considering that only three points from just one site were used to derive this curve, it is probable that there is a substantial error associated with the predicted 505 ft value. Therefore, this value should not be interpreted as an absolute buffer distance for application in the Pinelands, but rather, as evidence supporting the contention that in sandy soils there is a significant potential for nitrate contamination of surface waters/wetlands by conventional on-site wastewater treatment systems.

²The Division of Water Resources used data from the System 4 field site (Walker et al. 1973) to derive the curve. The concentration immediately adjacent to the System 4 septic leach field was 40 mg NO₃-N/l (identical to the value used in the Brown et al. model) and decreased to approximately 10 mg NO₃-N/l at 230 ft. downgradient. From these end points, and one intermediate point, the following curve was derived:

$$-0.0194x$$

$$y = ae$$

where y is the concentration at distance x (meters) from the septic leach field, and a is the initial nitrate concentration at point of entry (40 mg NO₃-N/l).

In summary, a comprehensive study is needed to first, develop a detailed linear dilution model (i.e., possibly an expansion of the Harlukowicz and Ahlert model) and then, calibrate the model with extensive field monitoring of hydrologic parameters and nitrate concentration. Until such a study is undertaken, assigning appropriate buffer distances between septic leach fields and wetland boundaries must be based on the available data. Therefore, it seems that a buffer of at least 300 ft between septic system leach fields and wetland boundaries is warranted in order that nitrate concentrations entering Pinelands surface waters do not exceed the 2mg/l standard. As additional studies are conducted in the Pinelands, it may be appropriate to require a minimum buffer of greater, or possibly less, than 300 ft, between septic system leach fields and wetland boundaries.

Special Case Buffer Delineation Guideline No. 4, INFILL-TYPE RESIDENTIAL DEVELOPMENT

If a proposed residential development site is considered an infill-type development then it is recommended that the assigned buffer be compatible with adjacent and nearby existing buffers, but not be less than 50 ft.

Clarifying Conditions: Before this guideline can be implemented discrete infill-type areas, or areas committed to development and already highly developed, must be identified. When delineating infill type areas, it is suggested that land use planners adhere to the following:

- a) Only residential areas should be considered for infill.
- b) The maximum infill lot size should be 1.0 acre.
- c) All infill lots must have direct access to a public road.
- d) Infill areas should be limited to areas within Pinelands Villages/Towns and Regional Growth Areas.

Rationale: From a regional planning perspective, allowing similar types of development within existing developed areas represents an efficient land use strategy. The Pinelands Commission supports this strategy. So that the opportunity for implementing this infill planning strategy is not restrained, it is recommended that wetland-upland buffer requirements be somewhat relaxed. Since this recommendation refers only to infill within existing intensively developed areas, the adjacent wetland may already be impacted and a limited amount of additional development will not add appreciably to the cumulative impacts on the site-specific wetland or regionally within the watershed or subwatershed. Therefore, it is recommended that in designated infill areas, assigned buffers be compatible with adjacent and nearby existing buffers, but not be less than 50 ft.

Special Case Buffer Delineation Guideline No. 5, ATLANTIC WHITE CEDAR SWAMPS

It is recommended that minimum 300 ft buffer areas be maintained between all Pinelands Atlantic White Cedar Swamp boundaries and any permanent development which is proposed for adjacent uplands.

Clarifying Conditions:

1) Cedar swamps are defined as; a) those wetlands of 1 acre or more which are mapped as cedar swamp on the Pinelands Commission vegetation maps (1: 24,000); or b) wetlands of 1 acre or more which are not mapped as cedar swamp, but which exhibit greater than 50% *Chamaecyparis thyoides* canopy cover; or c) wetlands of 1 acre or more, which are in an early stage of vegetation development (i.e., following fire, logging, or other natural or man-induced disturbance) and appear to be developing into mature cedar swamps.

2) Permanent development refers to structures, private roads, driveways, parking lots, clearing for lawns and other development-related practices with the potential to cause long-term alteration of the landscape.

3) This recommendation calls for a 300 ft buffer from the cedar swamp boundary. In situations when there is another wetland type present between the cedar swamp and wetland-upland boundary, the evaluator must do the following to delineate an appropriate buffer from the wetland-upland boundary.

- a) If the wetland between the cedar swamp boundary and actual wetland-upland boundary is > 250 ft, then this cedar swamp buffer delineation guideline does not pertain and the evaluator should proceed sequentially along the decision-making flow diagram (Fig. 5). This > 250 ft limit insures that a minimum 300 ft buffer will be maintained from the cedar swamp boundary, even if a 50 ft buffer is delineated between the proposed development and the actual wetland-upland boundary. According to the proposed buffer delineation model, 50 ft is the minimum buffer distance which can be assigned.
- b) If the wetland between the cedar swamp boundary and actual wetland-upland boundary is ≤ 250 ft, then the evaluator must first delineate a 300 ft buffer from the cedar swamp boundary. Second, the evaluator must proceed sequentially along the decision-making flow diagram (Fig. 5) to delineate a buffer distance from the wetland-upland boundary. Finally, the largest distance from the wetland-upland boundary to the proposed development is selected as the most appropriate buffer.

Rationale: Atlantic white cedar swamps are currently a valuable and limited component of the Pinelands landscape. Due to extensive logging activities and man's encroachment for development, the extent of cedar swamps in the Pinelands has been on the decline since European settlement. Even within the last few decades this decline has been noted. For example, Sauer et al. (1980) compared Pinelands vegetation maps prepared from 1956 to 1963 aerial photographs, with those from 1978 and 1979 photographs and noted an overall reduction in the extent and distribution of cedar swamps. Although no quantitative estimates were provided, they suggest a general trend toward conversion to hardwood swamps, especially in recently logged areas. However, they also observed some cedar reproduction in cut-over swamps, abandoned cranberry bogs, burned swamps

and other areas. Once considered an extensive forest resource and valuable habitat in the Pinelands, today only 2% of the 445,000 ha Pinelands National Reserve is occupied by cedar swamps (8,680 ha; see Table 1).

In terms of values and functions it has been noted in previous sections that cedar swamps are considered especially efficient at nutrient retention and maintenance of high surface water quality in the Pinelands. They provide essential habitat for a diversity of plants and animals, including the recreationally important white tailed deer, as well as numerous threatened and endangered biota which reside and/or breed in cedar swamps. Historically, cedar swamps supported a rich economic-commercial heritage, while today, cedar is still an economically important resource in the Pinelands.

To insure the perpetuation of cedar swamps in the Pinelands as a valuable ecosystem component, they must be protected from man-induced impacts. It is recommended that a minimum 300 ft buffer protection area be maintained between cedar swamp boundaries and any type of proposed permanent development. Among other roles this buffer area will protect cedar swamps from extensive windthrow damage. Cedar swamps are particularly susceptible to windthrow, considering the very shallow root systems of cedar and the spongy character of the muck/peat substrate (Little 1950). Cedar swamps are also sensitive to long-term water table fluctuations. Givnish (1973) suggests that lowered water table levels in cedar swamps could cause vegetational changes, while Clark and Clark (1979) state that water table increases of 15-25 cm over a growing season could result in death of cedar stands. Schneider and Ehrenfeld (1983) cite water table level decreases, along with water quality changes as factors contributing to complex vegetation changes in Pinelands cedar swamps following watershed suburbanization. Buffer areas are needed to maintain the natural upland to wetland hydrologic link, and to protect cedar swamps from man-induced water quality inputs. Finally, cedar swamps provide an especially valuable habitat for deer, breeding birds, threatened and endangered species, and a diversity of other flora and fauna. Buffer areas will protect the natural cedar to upland ecotone, an area heavily utilized as wildlife habitat, while also insulating the diverse cedar swamp wildlife populations from man-induced impacts.

Special Case Buffer Delineation Guideline No. 6, SURFACE WATER BODIES/ HERBACEOUS INLAND MARSHES

It is recommended that minimum 300 ft buffer areas be maintained between the edge/shoreline of all Pinelands surface water bodies or herbaceous inland marshes and any permanent development which is proposed for adjacent uplands.

Clarifying Conditions:

- 1) Surface water bodies are defined as a) lakes/ponds of > 1 acre, and b) permanent streams/rivers as indicated on USGS 7.5 minute topographic maps.

- 2) Herbaceous inland marshes are defined and described in the section of this report entitled, "VEGETATION AND SOILS OF PINELANDS WETLANDS." Herbaceous inland marshes, with their typical very poorly drained soils and corresponding water table levels near or at the surface year-round, have a direct hydrologic link with Pinelands surface waters. Also, they are commonly associated with stream, river, lake and pond margins. Therefore, for purposes of this guideline, herbaceous inland marshes are included in conjunction with surface waters of the Pinelands.
- 3) Permanent development refers to structures, private roads, driveways, parking lots, clearing for lawns and other development-related practices with the potential to cause long-term alteration of the landscape.
- 4) This recommendation calls for a 300 ft buffer from the edge or shoreline of any Pinelands surface water body/herbaceous inland marsh. In situations when there is a wetland present between the surface water body/herbaceous inland marsh and the actual wetland-upland boundary, the evaluator must do the following to delineate an appropriate buffer from the wetland-upland boundary.
 - a) If the wetland between the surface water body/herbaceous inland marsh and actual wetland-upland boundary is > 250 ft, then this surface water body/herbaceous inland marsh buffer delineation guideline does not pertain and the evaluator should proceed sequentially along the decision-making flow diagram (Fig. 5). This > 250 ft limit insures that a minimum 300 ft buffer will be maintained from the surface water boundary/herbaceous inland marsh even if a 50 ft buffer is delineated between the proposed development and the actual wetland-upland boundary. By following the proposed buffer delineation model, 50 ft is the minimum buffer distance which can be assigned.
 - b) If the wetland between the surface water body/herbaceous inland marsh and actual wetland-upland boundary is < 250 ft, then the evaluator must first delineate a 300 ft buffer from the surface water body/herbaceous inland marsh. Second, the evaluator must proceed sequentially along the decision-making flow diagram (Fig. 5) to delineate a buffer distance from the wetland-upland boundary. Finally, the largest distance from the wetland-upland boundary to the proposed development is selected as the most appropriate buffer.

Rationale: Surface waters of exceptional quality represent an ecologically fundamental value of the Pinelands ecosystem. The aquatic and wetland biotic communities which have evolved and adapted to this regime of low nutrients and low pH contribute to the unique and essential character of the Pinelands (CMP; McCormick 1970; Hastings 1979; Moul and Buell 1979). Degradation of this water quality affects these typical Pinelands assemblages. Morgan et al. (1983) report significant differences between algal macrophyte and fish communities when comparing

undisturbed and disturbed (i.e., elevated nutrient and pH levels) Pinelands streams. In another study, Ehrenfeld (1983) found that alteration of Pinelands water quality will affect the distinct flora which typifies Pinelands wetlands.

This buffer recommendation is founded on two basic premises. First, surface waters are a major factor contributing to the maintenance of a typical and unique Pinelands aquatic biota. Second, Pinelands waters are particularly susceptible to various forms of pollution. Chemically, soils and surface waters of the Pinelands are inert and poorly buffered and therefore ineffective at filtration/assimilation of pollutants; while hydrologically, contaminants introduced to the groundwater system can travel virtually unimpeded to surface waters and wetlands (Means et al. 1981). To insure that development practices will not degrade existing high quality surface waters, or further degrade the water quality within developed regions, it is recommended that a 300 ft buffer be maintained between all Pinelands surface water bodies and any proposed development. This recommendation supports an essential goal of the state legislation and of the CMP (Article 6, Part 8, Sections 6-801 through 6-806), each calling for the protection and maintenance of surface water quality in the Pinelands.

Herbaceous inland marshes are included with this buffer delineation guideline because of the close hydrologic coupling between these wetland communities and Pinelands surface water bodies. The surface water body - aquatic bed - emergent marsh community should be considered as a single ecologic unit. Also, recognition that the inland herbaceous wetland is a limited and scarce community type in the Pinelands (McCormick 1979), warrants their utmost protection from man-induced impacts.

LAND CAPABILITY AREAS BUFFER DELINEATION PROCEDURE

If the need remains to assign a buffer area after carefully examining the appropriateness of the *special case buffer delineation guidelines* to the proposed development activity then the evaluator should proceed to the *land capability areas buffer delineation procedure*. This aspect of the model is completed by following a three step process. First, the evaluator must assess the relative values and functions of the wetland, followed by a determination of the potential for impacts as imposed by the proposed development activity. Schemes are presented whereby these two aspects can be determined in a consistent manner. Finally, based on the relative value of the wetland, the potential for impacts and the land capability area in which the proposed development is located, appropriate buffer areas can be assigned.

Defining Boundaries for Evaluation

To maintain consistency in the relative values and functions evaluation process, appropriate dimensions of the wetland to be evaluated must be defined. When detailed site-specific field observations are required in order to satisfy a particular aspect of the procedure the evaluator will be directed to study the *wetland site review area*. To delineate this area the approximate dimensions should, a) be as wide as

the property limits of the proposed development site along the wetland-upland boundary and, b) extend at least 500 ft into the wetland along this boundary. If these dimensions result in an area of greater than 1 acre or less than 10,000 ft² (approximately 0.25 acre), or if the wetland is not 500 ft across, then the evaluator must alter these dimensions to derive an appropriate and representative *wetland site review area*. This range (0.25 - 1 acre) encompasses both the minimum area which can be studied to adequately represent a larger wetland unit and the most feasible maximum area to be studied by field reconnaissance. Ideally, the *wetland site review area* should (in most cases) cover a larger and more representative area; however, when considering the time, man-power and financial restraints often faced by the Pinelands Commission and local regulatory agencies, these dimensions seem to be the most feasible.

If the appropriate information needed for a particular aspect of the evaluation scheme can be obtained from maps and aerial photographs, then the evaluator will be directed to study the *wetland area*. It is defined as the total area of the wetland which is not fragmented, and thus, represents an individually discrete wetland unit. The *wetland site review area* is part of the *wetland area*. Fragmenting barriers can include, roads, railroads, filled/developed wetlands and other man-induced activities, or naturally caused barriers. Although streamflow is often maintained (i.e., bridges, culverts, etc.), the actual barrier should be considered as a boundary of the total wetland area. As a consistent criterion, the most feasible maximum *wetland area* to be evaluated should be 200 acres. If possible, the *wetland area* should include approximately equal areas both upstream and downstream of the proposed development site; however, location of the proposed development site relative to the total wetland area may necessitate disproportionate upstream and downstream areas. If the total wetland area is less than 200 acres, then the entire wetland unit would be defined as the *wetland area*.

The Wetland Evaluation Scheme

An essential aspect to assigning buffer areas between proposed upland development and wetland boundaries, is the evaluation of relative wetland values and functions. This evaluation will be based on, a) existing quality of the wetland, in terms of vegetation composition and water quality, b) relative water quality maintenance attributes, c) wildlife habitat, and d) socio-cultural values. The presence of threatened and endangered species as an important wetland value parameter is also incorporated into the scheme.

In developing this evaluation scheme, reference was often made to the numerous wetland evaluation methods currently in existence. Lonard et al. (1981) recently reviewed the objectives, merits and shortcomings of twenty wetland and wetland-related evaluation methods. Considerable variation in the methods was noted. For example, the Habitat Evaluation Procedures (HEP; U.S. Fish and Wildlife Service 1980), the Habitat Evaluation System (HES; U.S. Army Corps of Engineers 1980) and the Golet (1976) model were developed to specifically address wildlife and/or fish habitat values, while other procedures take a more comprehensive approach and attempt to evaluate wetlands based on several key values and functions (Larson 1976; Reppert et al. 1979; among others). A recent evaluation scheme developed for the Federal Highway Administration (Adamus 1983) attempts to alleviate

some of the problems associated with many of these methodologies by addressing all of the presently recognized wetland values and functions, and by having widespread or nationwide utility. These previously developed wetland evaluation methods, although not directly applicable for incorporation into the Pinelands wetlands evaluation scheme, provided extensive guidance when evaluating and organizing the data-base of Pinelands wetlands values and functions in a consistent and objective manner.

Vegetation Composition

The existing quality of a wetland can be judged, in part, by assessing the character of vegetation. Recently, Ehrenfeld (1983) suggested that urbanizing land use changes can substantially alter the vegetation structure and species composition of Pinelands forested wetlands. In conjunction with these vegetation changes, wetland values and functions are altered. When assessing the relative quality of a wetland one factor to consider should be vegetation composition. On a relative scale, undisturbed wetlands with characteristic vegetation composition and structure would be of a higher overall quality than wetlands exhibiting altered vegetation characteristics.

Relative Analysis: To determine the vegetation character of a wetland along a relative scale from undisturbed to disturbed, the evaluator must qualitatively assess the species composition of the *wetland site review area*. Shrub and herbaceous species seem to be the most definitive indicators of the relative undisturbed-to-disturbed quality of wetland vegetation. To maintain consistency in this relative vegetation analysis, only shrubs will be considered since they can be identified year-round. Herbaceous species, especially those which are persistent year-round, should be used in support of the shrub analysis as will be noted later. Table 15, adapted from Ehrenfeld's (1983) study, provides a list of shrub and herbaceous species which characterize relatively undisturbed forested and shrub-dominated Pinelands wetlands.

If shrub species from Table 15 dominate the *wetland site review area*, then a high quality score should be assigned. For example, a pitch pine lowland dominated by a *Chamaedaphne calyculata* and *Kalmia angustifolia* shrub cover would be considered as high quality, while similarly, a hardwood swamp dominated by a diversity of characteristic shrubs from Table 15 would also be considered to be of high quality. The relative vegetation quality score is determined as follows:

High Vegetation Quality

> 90% of the total shrub cover within the *wetland site review area* is occupied by one, or more, of the shrub species listed in Table 15 3

Moderate Vegetation Quality

From 75 - 90% of the total shrub cover within the *wetland site review area* is occupied by one, or more, of the shrub species listed in Table 15 2

Table 15. Shrub and herbaceous species which are characteristic of Pinelands forested and shrub-dominated wetlands located within relatively undeveloped watersheds (adapted from Ehrenfeld, 1983).

SHRUBS

- Amelanchier intermedia* (Serviceberry)¹
Alnus serrulata (Alder)¹
Chamaedaphne calyculata (Leather-leaf)¹
Clethra alnifolia (Sweet Pepperbush)¹
Gaylussacia dumosa (Dwarf Huckleberry)²
Gaylussacia frondosa (Dangleberry)¹
Gaultheria procumbens (Teaberry)¹
Ilex glabra (Inkberry)¹
Kalmia angustifolia (Sheep Laurel)¹
Kalmia latifolia (Mountain Laurel)¹
Leucothoe racemosa (Fetterbush)¹
Lyonia mariana (Staggerbush)²
Myrica pensylvanica (Bayberry)²
Rhododendron viscosum (Swamp Azalea)¹
Viburnum cassinoides (Withe-rod)¹
Viburnum nudum (Possum Haw)²
Vaccinium atrococcum (Black Highbush Blueberry)¹
Vaccinium corymbosum (Highbush Blueberry)¹
Vaccinium macrocarpon (Cranberry)²

HERBS

- Aster nemoralis*²
Bartonia virginica (Gentianaceae)²
Carex collinsii (Sedge)²
Carex walteriana (Sedge)²
Drosera filiformis (Thread-leaved Sundew)²
Drosera intermedia (Sundew)²
Drosera rotundifolia (Round-leaved Sundew)¹
Dryopteris thelypteris (Marsh Fern)¹
Eleocharis tuberculosa (Spike Rush)²

Table 15. Continued.

HERBS (continued)

<i>Eriocaulon decangulare</i> (Pipewort) ²
<i>Orontium aquaticum</i> (Golden Club) ²
<i>Panicum ensifolium</i> (Panic Grass) ²
<i>Peltandra virginica</i> (Arrow-arum) ¹
<i>Pogonia ophioglossoides</i> (Rose Pogonia) ²
<i>Pontederia cordata</i> (Pickerel-weed) ²
<i>Pteridium aquilinum</i> (Bracken Fern) ¹
<i>Rhexia mariana</i> (Meadow Beauty) ²
<i>Rhynchospora gracilentata</i> (Beak-rush) ²
<i>Sagittaria</i> spp. (Arrow-head) ¹
<i>Sarracenia purpurea</i> (Pitcher Plant) ²
<i>Trientalis borealis</i> (Starflower) ¹
<i>Utricularia vulgaris</i> (Bladderwort) ¹
<i>Viola lanceolata</i> (Violet) ²

¹Species present at both undisturbed and disturbed study sites, but decreased in frequency of occurrence from undisturbed to disturbed conditions (adapted from Appendix 2 in Ehrenfeld 1983).

²Species found only at undisturbed study sites (adapted from Appendix 1 in Ehrenfeld 1983).

Low Vegetation Quality

< 75% of the total shrub cover within the *wetland site review area* is occupied by one, or more, of the shrub species listed in Table 15. 1

Additional factors are available to support and further document the relative vegetation analysis. For example, herbaceous species which characterize undisturbed forested and shrub-dominated Pinelands wetlands can be useful. If a particular wetland site is assigned a relative vegetation score of 3, then many of the herbaceous species, as listed in Table 15, may be present. At sites assigned a score of 1, the evaluator may expect to encounter several vine species (i.e., *Ipomoea lacunosa*, *Rhus radicans*, *Smilax* spp., among others), as Ehrenfeld (1983) reports that vines occur more frequently and in greater abundances in disturbed sites, as compared to undisturbed sites. Also, Ehrenfeld (1983) found a shift in disturbed site community structure towards an increased abundance and diversity of herbaceous species, with a corresponding decrease in shrubs. Generally, herbaceous species which are non-native to the Pinelands or cosmopolitan accounted for this observed community shift (i.e., *Allium vineale*, *Daucus carota*, *Phragmites australis*, *Taraxacum officinale*). See Ehrenfeld (1983) for a more complete listing of characteristic disturbed site species.

Existing Surface Water Quality

Surface waters of the Pinelands are characterized by low pH and low nutrient levels. The typical Pinelands flora and fauna within wetland and aquatic ecosystems are well-adapted to these conditions. With man-induced disturbance and subsequent increased pH and nutrient levels there is a documented change in the species composition of wetland vegetation (Ehrenfeld 1983) and aquatic habitats (Morgan et al. 1983). Therefore, when assessing the relative value of a wetland, one factor to consider is the existing surface water quality. Wetlands with high surface water quality, as assessed by pH and nitrate levels, have the potential to support typical Pinelands biota, and thus, are considered as particularly valuable.

Relative Analysis: Based on water quality data from the STORET computer data retrieval system (NJDEP, Div. of Water Resources), the Pinelands Commission conducted an analysis of 74 surface water quality sampling stations within the Pinelands (unpub. report, on file at Pinelands Commission office). As shown in Table 16, data from this Pinelands Commission analysis were organized to compare surface water pH and nitrate levels from relatively undisturbed basins and disturbed basins. Although additional water quality data are available for incorporation into this comparison (See Tables 12 and 13), this Pinelands Commission data set provided a means to define undisturbed and disturbed basins according to consistent criteria (i.e., percent of basin developed vs. undeveloped).

Based on the data presented in Table 16, the following scale was developed for assigning a relative surface water quality rating for wetland-stream courses.

pH

High Water Quality (pH \leq 4.5)	3
Moderate Water Quality (pH $>$ 4.6 - $<$ 5.9)	2
Low Water Quality (pH \geq 6.0).	1

NO₃-N (mg/l)

High Water Quality (\leq 0.05).	3
Moderate Water Quality ($>$ 0.06 - $<$ 0.69).	2
Low Water Quality (\geq 0.70)	1

To incorporate the existing surface water quality parameter into the relative wetland evaluation scheme, the evaluator must determine if pH and/or nitrate data are available for the stream or stream segment associated with the proposed development site. The primary source of these data is the STORET system (NJ DEP, Div. of Water Resources) and the U.S. Geological Survey, while other less extensive sources are also available (County monitoring programs; see also Tables 12 and 13). Water quality measurements that do not include seasonal monitoring for at least one year should be avoided.

To determine if a particular surface water monitoring station is applicable and representative of the wetland-stream segment under investigation, the evaluator should refer to aerial photographs to study the relationship between the proposed development site, surface water sampling station, and land uses surrounding each (i.e., particularly upstream). After determining that available data are appropriate, the evaluator will assign a relative pH and relative nitrate score, according to the above scales. The overall relative existing water quality score is determined by averaging the pH and nitrate scores. If only one water quality parameter is available, then it should be used alone to represent relative existing surface water quality. Since there is a relatively consistent relationship between pH and water quality in the Pinelands (CMP), using only one parameter would provide a valid representation of existing surface water quality. If data are not available then the evaluator must assume that the water quality is high (i.e., overall relative score of 3), unless the applicant can demonstrate otherwise. If the wetland is isolated with no apparent hydrologic connection to surface water, then the existing surface water quality rating must be omitted from the determination of relative wetland value.

Table 16. Median pH and mean nitrate values from representative undisturbed and disturbed Pinelands streams. The data presented are from an analysis conducted by the Pinelands Commission (unpub. report, on file at Commission office) which was based on the STORET system (NJ DEP, Div. of Water Resources). Undisturbed streams are within drainage basins of > 90% open space (i.e., not residential, commercial or industrial development) and < 7% agriculture (mostly limited to cranberry farming). Disturbed streams are within drainage basins of < 66% open space (i.e., 1/3 developed). For both the undisturbed and disturbed categories, the drainage basins listed contained no landfills, sewage treatment plants or non-domestic point source discharges.

DRAINAGE BASIN ¹	PINELANDS I.D. NUMBER	pH	NO ₃ -N (mg/l)
<u>UNDISTURBED</u>			
Toms River Basin: Jakes Branch	11-N	4.2	0.02
Cedar Creek Basin:	10-F	4.6	0.02
	11-O	4.5	0.03
Oyster Creek Basin:	18-B	4.4	0.04
	18-C	4.4	0.05
Westecunk Creek Basin:	27-J	4.6	0.10
Tuckerton Creek Basin:	35-I	4.7	0.07
Mullica River Basin: Wading River	16-2	6.0 ²	0.01 ²
Bass River	34-D	4.4	0.36 ²
Tuckahoe River Basin:	43-C	4.9	0.08
Maurice River Basin:	42-D	4.5	0.04
Rancocas Creek Basin: North Branch	8-H	4.1	0.07
UNDISTURBED STREAMS SUMMARY		$\bar{x} = 4.5$	$\bar{x} = 0.05$

Table 16. Continued.

DRAINAGE BASIN	PINELANDS I.D. NUMBER	pH	NO ₃ -N (mg/l)
<u>DISTURBED</u>			
Mullica River Basin:			
Atsion Sleeper	14-F	6.4	0.82
	23-8	6.3	0.30
Nescochague	23-7	5.1	0.85
Upper Great Egg Harbor R. Basin:			
GEHR	13-E	6.3	0.88
GEHR	22-F	6.7	0.59
Squankum Branch	22-K	6.4	1.71
Hospitality Branch	30-D	5.7	0.25
Rancocas Creek:			
South Branch	8-4	5.8	0.25
	15-5	5.6	1.97
Southwest Branch	14-4	5.9	0.25
DISTURBED STREAMS SUMMARY		$\bar{x} = 6.0$	$\bar{x} = 0.71$

¹If applicable minor basins within the larger basin are often noted.

²These values seem uncharacteristically high, and thus, were omitted from the \bar{x} calculations.

Water Quality Maintenance Value

Preserving the ecological value and essential character of the Pinelands is, in part, dependent upon maintaining surface and groundwater resources of exceptional quality. From a watershed or regional perspective, Pinelands wetlands have the natural capability to retain, store and remove nutrients, thus contributing to the maintenance of high water quality which characterizes the ecosystem.

Relative Analysis: To evaluate the relative water quality maintenance value of a Pinelands wetland or the relative capability of a wetland to retain or remove nutrients, several factors must be considered. These include, a) the potential for nutrient inputs to the wetland, b) nutrient removal/storage/retention capacity of the wetland soils, and c) nutrient retention by vegetation.

It must be emphasized that if a wetland is ranked as having a high water quality maintenance value, this should not imply that the wetland can tolerate excess nutrient inputs. The water quality maintenance value of a site-specific wetland must be viewed within a regional context. Wetlands with a high value are contributing to the maintenance of exceptional water quality which characterizes the Pinelands, while also providing for enhancement of degraded water quality. If site-specific wetlands are stressed with excess nutrients, then the regional, watershed-wide water quality maintenance role of these systems will be reduced.

a) Potential for nutrient inputs to the wetland - This criterion differentiates between wetlands which are associated with a stream course and wetlands which are not directly associated with a stream, and thus, are isolated. These isolated systems are primarily dependent on groundwater, surface runoff and precipitation for their water supply. Obviously, streamflow is an additional water supply source for wetlands associated with a water course. For this analysis wetlands that were once adjacent to a stream, but are currently fragmented by development and streamflow is diverted, are to be considered as isolated. Wetlands which are divided or crossed by a road, railroad, right-of-way, etc. but with stream flow maintained by bridges, culverts or other such means must still be considered as being associated with the stream.

Since wetlands associated with streams have more potential sources for nutrient inputs (i.e., streamflow, groundwater flow, runoff, and precipitation) than isolated systems, it follows that their water quality maintenance value would be enhanced; especially when considered from a regional or watershed-wide perspective. To evaluate the potential for nutrient inputs to wetlands, the following relative scheme is presented.

High Input Potential

Wetland is associated with a stream, river, lake
or other such water courses 3

Moderate Input Potential

Wetland is isolated from streams, rivers, lakes, or
other such water courses, and wetland is >100 acres. . . . 2

Low Input Potential

Wetland is isolated from streams, rivers, lakes, or other such water courses, and wetland is <100 acres. . . . 1

To determine whether a wetland is adjacent to a water course, and thus has a direct surface water hydrologic connection, the evaluator should consult aerial photographs and appropriate maps, in conjunction with field inspection.

b) Nutrient retention/removal capacity of wetland soils - Wetlands with organic and anaerobic substrates generally have a high potential for nutrient retention and removal. This is related to 1) slow decomposition rates under anaerobic conditions, thereby promoting nutrient retention by long-term incorporation of organic matter into the sediments/substrate, 2) adsorption of nutrients, particularly nitrogen and phosphorus, onto organic compounds with subsequent incorporation into the sediments, and 3) denitrification, a nitrogen removal mechanism, occurring under anaerobic conditions with organic matter providing an energy source for the mediating bacteria.

In the Pinelands saturated soils (i.e., promoting anaerobic conditions), with relatively high organic contents include Muck, Pocomoke, Berryland, and other soils classified as very poorly drained by the SCS. These soils are particularly efficient at promoting nutrient retention by incorporation of organic matter, by adsorption of nutrients onto organic compounds, and by nitrogen removal by denitrification. In addition, standing water, sluggish streamflow or sheetflow is often associated with wetlands of very poorly drained soils. This hydrologic regime enhances the opportunity for wetlands to retain nutrients, whether within the soils or by vegetation uptake, because the contact time between nutrient-laden waters and the wetland is increased. The nutrient retention/removal capacity of poorly drained wetland soils (i.e., Atsion) would be less, considering the lower organic matter content and lower water table levels (i.e., soil profile partially oxidized and limited standing water). To assess the relative capacity of Pinelands wetland soils to retain/remove nutrients, the evaluator should employ the following scheme within the *wetland area*.

High Retention/Removal Capacity

Very poorly drained soils, as classified by the SCS, occupy >75% of the *wetland area*. 3

Moderate Retention/Removal Capacity

Very poorly drained soils, as classified by the SCS, occupy from 50 - 75% of the *wetland area* 2

Low Retention/Removal Capacity

Very poorly drained soils, as classified by the SCS, occupy <50% of the *wetland area*. 1

The evaluator should use SCS soils maps, in conjunction with field inspection, to determine soil types and percent cover estimates in the *wetland area*.

c) Nutrient retention by vegetation uptake - A significant mechanism for nutrient retention in wetlands involves uptake by vegetation. Ehrenfeld (in press) notes that Pinelands hardwood swamps retain within woody structural tissue from 21-28% of the annual nitrogen uptake. It is apparent that in wetlands with relatively dense tree and shrub cover, retention by this mechanism could be substantial. To assess the relative capacity for Pinelands wetlands to retain nutrients by vegetation uptake and subsequent storage, the evaluator should employ the following scheme within the *wetland site review area*.

- Dense tree cover ($\geq 75\%$) and dense shrub cover ($\geq 75\%$) occupy the *wetland site review area* 3.0
- Dense tree cover ($\geq 75\%$) and moderate shrub cover (50 - 75%) or, moderate tree cover (50 - 75%) and dense shrub cover ($\geq 75\%$) occupy the *wetland site review area* 2.5
- Dense tree cover ($\geq 75\%$) and sparse shrub cover ($<50\%$) or, moderate tree cover (50 - 75%) and moderate shrub cover (50 - 75%) occupy the *wetland site review area*. 2.0
- Moderate tree cover (50 - 75%) and sparse shrub cover ($<50\%$) or, sparse tree cover ($<50\%$) and moderate shrub cover (50 - 75%) occupy the *wetland site review area*. 1.5
- Sparse tree cover ($<50\%$) and sparse shrub cover ($<50\%$) occupy the *wetland site review area* or, the *wetland site review area* is a herbaceous wetland type. 1.0
- The *wetland site review area* is predominantly unvegetated 0

To summarize, the relative water quality maintenance value of the *wetland site review area* and adjacent wetland-stream areas associated with the proposed development site should be determined by averaging the three criteria evaluated above (i.e., Potential Inputs + Soil Retention or Removal + Vegetation Uptake/3 = Relative Water Quality Maintenance Score).

Wildlife Habitat Value (Game and non-game species)

Pinelands wetlands provide necessary habitat for a diversity of animal species. Birds, including migratory waterfowl, songbirds, predatory birds and other avifaunal groups utilize Pinelands wetlands for feeding, nesting and breeding. Many mammals also frequent wetlands. Most notable are the white-tailed deer who browse on the young and palatable cedar seedlings, while also taking refuge in these evergreen swamps during winter and hot summer periods. Finally, Pinelands wetlands provide habitat which is essential to the survival and maintenance of many threatened and endangered animals; including a unique array of reptiles and amphibians which are well-adapted to the acid environment of Pinelands wetlands.

Relative Analysis: In this analysis, qualitative habitat features will be considered in order to predict the relative wildlife habitat value of Pinelands wetlands. Included will be an evaluation of vegetation interspersion, wetland size and surrounding land use types.

a) Vegetation Interspersion - Wildlife generally require more than one form or structural type of vegetation to satisfy their needs for food, cover and breeding (Golet 1976). This is related to the ecotonal effect which suggests that wildlife diversity and species abundances increase as the structural diversity of habitat, or edge, increases. Homogeneous stands of vegetation are commonly of least value to wildlife, while sites with several vegetation forms intermingled and scattered throughout are often considered as especially valuable wildlife habitat.

This vegetation interspersion factor is a relative measure of the abundance of edge and the degree to which different vegetation forms are intermingled throughout the wetlands. The evaluator should use aerial photographs and vegetation maps, in conjunction with field inspection, to evaluate vegetation interspersion within the *wetland area*.

High Vegetation Interspersion

Three or more vegetation forms or habitat types (i.e., deciduous tree stand, evergreen tree stand, deciduous shrub area, evergreen shrub area, windthrow areas, pools, streams, clearings, etc.) occupy the *wetland area*. . . . 3

Moderate Vegetation Interspersion

Two vegetation forms or habitat types occupy the *wetland area*. 2

Low Vegetation Interspersion

One vegetation form or habitat type dominates the *wetland area*. 1

Note - To be considered as a separate type, each vegetation form or habitat type must occupy in a continuous or patchy pattern, at least 10% of the *wetland area*.

b) Wetland Size - As wetland size increases, the potential to support wildlife may similarly increase. Also, in larger wetlands animal populations may be protected and somewhat isolated from man-induced peripheral disturbance, or natural events such as fire. The relative wetland size scale is as follows and pertains to the *wetland area*.

- The *wetland area* is \geq 50 acres. 3.0
- The *wetland area* is \geq 25 acres to <50 acres 2.5
- The *wetland area* is \geq 10 acres to <25 acres 2.0
- The *wetland area* is \geq 5 acres to >10 acres. 1.5
- The *wetland area* is <5 acres in size. 1.0

c) Surrounding Habitat - When determining the relative habitat value of a wetland, one factor to consider is the habitat value of surrounding areas. For instance, wetlands bordered by undeveloped or agricultural lands are often considered more valuable to wildlife than wetlands surrounded by development (Golet 1976). In addition, Golet (1976) suggests that as habitat diversity in the surrounding areas increases, the potential for enhanced wildlife diversity in the wetlands increases.

To evaluate the surrounding habitat factor the evaluator must assess the land use types present around the perimeter of the *wetland area*. This upland perimeter should be a band of at least 300 ft from the wetland-upland boundary. With reference to aerial photographs, coupled with field inspection, the following relative scale should be used.

Undeveloped Surrounding Areas

The upland perimeter of the *wetland area* is $\geq 75\%$ undeveloped or agricultural land 3

Moderately Developed Surrounding Areas

The upland perimeter of the *wetland area* is $\geq 50\% - < 75\%$ undeveloped or agricultural land 2

Developed Surrounding Areas

The upland perimeter of the *wetland area* is $< 50\%$ undeveloped or agricultural land 1

The relative wildlife habitat value of the *wetland site review area* and associated *wetland area* is determined by averaging the three criteria evaluated above (i.e., Vegetation Interspersion + Wetland Size + Surrounding Upland Habitat/3 = Relative Wildlife Habitat Score).

Socio-Cultural Values

The dominant socio-cultural values of Pinelands wetlands are related to recreation, education, visual/aesthetic qualities and uniqueness. While the evaluation of wetland socio-cultural values is often based on personal perceptions, guidelines are presented so the evaluator can assess and organize these qualitative perceptions in an objective manner.

As noted, for this aspect of the evaluation scheme the format has changed slightly. The evaluator must answer a series of questions related to the socio-cultural attributes of the *wetland area* and associated wetlands. Then, a scale is presented in order to translate the answers to these questions into a relative socio-cultural score.

Recreation

Is the wetland associated with a stream that is frequently canoed or a stream with the potential to be frequently canoed (see Cawley and Cawley 1971, Parnes 1978, and CMP for listings of Pinelands streams-rivers which are popular canoeing areas)? YES NO

Is the wetland area or surrounding wetland areas-streams known to be used by hunters, fishermen, or trappers; or is the wetland frequented by birdwatchers, painters, wildlife photographers, hikers or other passive recreation enthusiasts; or, does the wetland have a high potential to be frequented by the above mentioned? YES NO

Research and Education

Is the wetland currently used as a scientific study area for existing, on-going or long-term research?. . . . YES NO

Is the wetland in close proximity to schools, nature centers, camps, or other such educational facilities, thus offering the potential for formal nature study?. YES NO

Visual/Aesthetic

Does the wetland have a high visual/aesthetic quality in terms of landscape vistas, trails through the wetland, showy fall foliage, or other attributes which characterize the scenic resources of the Pinelands?. YES NO

Uniqueness

Is the wetland historically, archeologically, or scientifically significant, or associated with a Pinelands site having historical, archeological, or scientific significance?. YES NO

Is the wetland type unique to the watershed or subwatershed (i.e., a hardwood swamp in an area dominated by pitch pine lowlands) YES NO

Is the wetland located in an intensively developed area thereby providing open space within an urbanized landscape; or, is the wetland within a developed area, thereby having the potential to store floodwaters and abate floodwater velocities YES NO

Relative Socio-cultural Value Score: To determine the relative socio-cultural value score of the wetland, the following scale is provided.

High Socio-cultural Value

Of the socio-cultural questions, ≥ 5 were answered "YES" 3

Moderate Socio-cultural Value

Of the socio-cultural questions, 2 - 4 were answered "YES" 2

Low Socio-cultural Value

Of the socio-cultural questions, ≤ 1 were answered "YES" 1

Determining an Overall Relative Wetland Value Index

The overall wetland value of a particular wetland area located adjacent to a proposed development site is determined by assessing five general factors (existing vegetation composition, existing surface water quality, water quality maintenance value, wildlife habitat value, and socio-cultural value) and assigning a relative score for each. These scores are averaged to derive an overall relative wetland value index. Each individual factor is assigned equal priority in calculation of the index. The following scale enables the evaluator to translate this relative numerical index into a more comprehensible perspective.

	<u>Numerical Index</u>
<u>High value</u>	3.0 - 2.6
<u>High to moderate value</u>	2.5 - 2.1
<u>Moderate to low value</u>	2.0 - 1.6
<u>Low value.</u>	1.5 - 1.0

The five general factors considered in this scheme provide a broad and comprehensive representation of wetland value. Furthermore, they are readily applicable to almost all Pinelands wetlands, and thus, enable for a consistent evaluation process. Obviously, there are additional factors which could be included in the evaluation process; yet, when developing a scheme which can be feasibly incorporated into the Pinelands Commission's development and review process or feasibly used by applicants and local regulatory agencies, it is difficult to include all of the factors which collectively contribute to the overall value of a wetland. However, the presence of threatened or endangered species in the *wetland area* is considered as a particularly important wetland value and must be included in any wetland evaluation methodology.

Threatened and Endangered Species: If the *wetland area* is known to support resident and/or breeding populations of threatened or endangered species (as designated at state and federal levels), then it is recommended that the overall relative wetland value index be increased by one numerical unit (i.e., 1.0). It should be noted that the numerical value index cannot be increased above the maximum value of 3.0.

Rationale: National and international recognition of the Pinelands as an ecosystem deserving of priority preservation is partly related to a diversity of threatened and endangered biota. Related to geographic location, there are many species which reach their northern or southern limits within the Pinelands boundaries. For example, the eastern tiger salamander, a peripheral species which reaches its northernmost extent in Pinelands wetlands, is more common to the south. The cedar swamp inhabitant, curly grass fern is both a peripheral species with a northern affinity as well as a disjunct species since the Pinelands population is an outlier from the species main distribution in Nova Scotia and northward. Aside from natural phenonemon resulting in a biota of peripheral, disjunct, endemic, relic, and habitat restricted species (see Fairbrothers 1979), some species in the Pinelands are on the verge of local extinction because of man-induced activities. This is primarily related to loss of suitable habitat.

Threatened and endangered species of the Pinelands not only contribute to the unique character of the Pinelands - a feature which in itself must be maintained - but also, these rare species contribute to the regions genetic diversity and serve as gene pools for future evolutionary changes; they often play critical trophic roles in the ecosystem; and often, they are valuable as indicators of environmental quality. Scientifically, the presence of these rare species provides opportunities for the study of habitat requirements, genetic variability among disjunct populations, species migration pathways, biogeography, and the principals of ecosystem fragmentation and management. Finally, from a wetland cultural vantage, Clark and Clark (1979) suggest that the presence of threatened and endangered species may serve as a tool in bringing the overall value of wetlands to public attention and thus stimulate an interest in wetland preservation.

The key to maintaining these species at their present levels, or in enhancing their occurrence and distribution, is the preservation and protection of critical habitat. In the Pinelands, wetlands provide this critical habitat for a significant percentage of the ecosystems rare flora and fauna. This recommendation is made to increase the protection afforded to wetlands with rare species.

Potential for Impacts Scheme

Determining the significant adverse impacts to be imposed on wetlands by upland development practices represents the second major component of the *land capability areas buffer delineation procedure*. As summarized earlier (see Table 11), numerous development practices common to the Pinelands will alter wetland hydrologic regimes, water quality characteristics, biotic compositions, wildlife habitat values, food web support functions and cultural attributes. While individual development activities are associated with specific wetland impacts, such as the relationship between septic leach fields and contamination of wetland water quality (*Special Case Buffer Delineation Guideline* No. 3), it seems most feasible to collectively evaluate the development activities and associated impacts. Therefore, for purposes of this scheme the various activities and impacts are not considered individually, but rather, they are viewed as an integrated or collective unit for the evaluation of, a) wetland site-specific impacts, b) cumulative impacts on a regional level, and c) watershed-wide impacts.

Potential for Site-Specific Wetland Impacts

The potential for significant adverse impacts to be imposed on the site-specific wetland area relates to the intensity of development on the adjacent upland. For instance, as the percentage of upland that is permanently altered increases, there is a corresponding increase in the suite of potential impacts which are imposed on the adjacent wetland.

Relative Analysis: To determine the relative potential for wetland site-specific impacts, the intensity of permanent development proposed for the upland site must be considered. Permanent development refers to structures, roads, driveways, parking lots, clearing for lawns and other development-related practices which cause long-term alteration of the

landscape. Additional factors considered are, the use of pervious vs. impervious surfaces and the amount of lawn proposed. The following relative scale should be used by the evaluator. Access to detailed plans of the proposed development site is required.

<u>High Potential for Site-specific Impacts</u>	
High intensity development with $\geq 40\%$ of the total upland site area occupied by permanent development; and, if roads, driveways, parking lots, etc. are proposed, they will be impervious; and if proposed, lawns will occupy $\geq 1000 \text{ ft}^2$	3
<u>High Potential for Site-specific Impacts</u>	
High intensity development with $\geq 40\%$ of the total upland site area occupied by permanent development; and, if roads, driveways, parking lots, etc. are proposed, they will be pervious; and, lawns will occupy $< 1000 \text{ ft}^2$	2.75
<u>Moderate Potential for Site-specific Impacts</u>	
Moderate intensity development with >5 to $<40\%$ of the total upland site area occupied by permanent development; and, if roads, driveways, parking lots, etc. are proposed, they will be impervious; and, lawns will occupy $\geq 1000 \text{ ft}^2$	2.25
<u>Moderate Potential for Site-specific Impacts</u>	
Moderate intensity development with >5 to $<40\%$ of the total upland site area occupied by permanent development; and, if roads, driveways, parking lots, etc. are proposed, they will be impervious; and, lawns will occupy $< 1000 \text{ ft}^2$	2.0
<u>Low Potential for Site-Specific Impacts</u>	
Low intensity development with $\leq 5\%$ of the total upland site are occupied by permanent development; and, if roads, driveways, parking lots, etc. are proposed, they will be impervious; and, lawns will occupy $\geq 1000 \text{ ft}^2$	1.25
<u>Low Potential for Site-specific Impacts</u>	
Low intensity development with $\leq 5\%$ of the total upland site area occupied by permanent development; and, if roads, driveways, parking lots, etc. are proposed, they will be pervious; and, lawns will occupy $< 1000 \text{ ft}^2$	1.0

Note: If the proposed development is not specifically included within one of the above categories, then the evaluator must determine the category that is most appropriate.

These intensity categories ($\geq 40\%$, >5 to $<40\%$, and $\leq 5\%$ of the total upland site permanently developed) can be realistically applied within the Pinelands land capability areas. Industrial, high-use commercial, and some cluster residential development will generally be included under the high intensity range. At the other extreme, low intensity development will usually be limited to single family dwelling units on relatively large area lots in the Forest Area and parts of Rural Development Areas. As noted, within each general intensity of development category, proposed development sites with impervious surfaces and considerable lawn areas are assigned a higher relative score than sites using pervious surfaces and limited lawn area. These higher scores reflect the potential for impervious surfaces to alter the natural upland-wetland hydrologic link.

With respect to lawns, Brown et al. (1980) suggest that 52% of the inorganic nitrogen annually added to lawns as fertilizer can be lost as nitrate and leached to the groundwater. Considering this source of wetland water quality contamination, lawns should be kept to a minimum. According to the CMP, areas planted with non-native grasses, and presumably maintained as lawns, should not exceed 2000 ft² (Article 6, Part 2, Section 6-203). Assuming that lawns will be maintained (i.e., fertilizer applied periodically), the relative potential for site-specific impacts scale implies that as lawn area is decreased, the potential for water quality contamination will be less. In addition, this provision will encourage landowners to employ naturalistic landscaping techniques.

Potential for Cumulative Impacts on a Regional Basis

For the effective long-term protection of Pinelands wetlands values and functions, it is imperative that the potential for cumulative impacts be assessed on a regional basis. A development activity when considered individually may result in only minor and often acceptable wetland site-specific impacts; however, when considered in conjunction with existing or future activities within surrounding areas, the potential for cumulative impacts is recognized.

Relative Analysis: Evaluating the potential for cumulative impacts will be based on municipal density allocations. It is assumed that areas zoned for low density development will have less potential for cumulative impacts, relative to high density areas. Further, it is assumed that these zoned areas will eventually be developed to their maximum density allocation. This approach provides a consistent and objective means for predicting the long-term potential for cumulative impacts.

The range of density allocations varies within the different Pinelands land capability areas. Therefore, separate relative scales are presented (Forest Areas and Agricultural Production Areas; Rural Development Areas; and Regional Growth Areas). If the proposed development site is located in a Pinelands Town or Village, then the evaluator should follow the Rural Development Areas scale or the Regional Growth Areas scale, whichever is appropriate. To accomplish this aspect of the scheme and to assign a potential for cumulative impacts relative score, the evaluator must refer to local zoning maps. The relative scales are as follows;

FOREST AREAS AND AGRICULTURAL PRODUCTION AREAS

High Potential for Cumulative Impacts
 High density area (≤ 5 acres/unit) 3

Moderate Potential for Cumulative Impacts
 Moderate density area (>5 to <20 acres/unit) 2

Low Potential for Cumulative Impacts
 Low density area (≥ 20 acres/unit) 1

RURAL DEVELOPMENT AREAS

High Potential for Cumulative Impacts
 High density area (≤ 3.2 acres/unit) 3

Moderate Potential for Cumulative Impacts
 Moderate density area (>3.2 to <5 acres/unit) 2

Low Potential for Cumulative Impacts
 Low density area (≥ 5 acres/unit) 1

REGIONAL GROWTH AREAS

High Potential for Cumulative Impacts
 High density area (≥ 4 units/acre) 3

Moderate Potential for Cumulative Impacts
 Moderate density area (>1.25 to <4 units/acre) 2

Low Potential for Cumulative Impacts
 Low density area (≤ 1.25 units/acre) 1

Significance of Watershed-wide Impacts

In addition to site-specific wetland impacts, development activities adjacent to wetlands have the potential to impose significant adverse impacts on surrounding wetland and aquatic habitats. This becomes especially relevant when considering the potential for waterborne contaminants introduced at the development site to be transported downstream. Evaluating the relative significance of watershed-wide impacts, or impacts within wetland basins will be based on the surrounding land use types and the apparent sensitivity of these surrounding areas to impacts.

It is well-documented that with watershed development there is a degradation of Pinelands surface water quality (see Tables 12, 13 and 16). Similarly, Ehrenfeld (1983) reports a substantial change in the vegetation structure and species composition of Pinelands wetlands located within developed watershed. Several land use types in the Pinelands are particularly dependent upon impact-free conditions. The functioning and

essential character of these environmentally sensitive areas would be significantly affected if water quality, vegetation composition, habitat, hydrologic regime, or other environmental parameters were altered. Land use types which require high environmental quality to function effectively include, but are not limited to, open space/natural areas such as wildlife management areas, state forests, parks and recreation areas. Also, blueberry and cranberry operations are particularly dependent on unpolluted, acid waters. Finally, the essential ecological character of the Preservation Area District will be maintained only under a limited impact regime.

On the other hand, other land use types in the Pinelands are not as environmentally sensitive. For example, development activities and associated watershed-wide impacts would be less significant if the watershed immediately downstream of the development site was highly developed (i.e., dense residential, commercial or industrial).

Relative Analysis: To evaluate the significance of watershed-wide impacts a relative scale has been developed which incorporates several factors. For wetlands associated with a stream/water course the evaluator must determine the land use types associated with the wetland-stream and adjacent uplands within 2 miles downstream of the proposed development site.

Incorporated into this relative scale is an evaluation of the potential for significant wetland basin impacts; particularly pertaining to isolated wetlands (i.e., wetlands not directly associated with a stream/water course). Development activities adjacent to isolated wetlands have the potential to significantly alter the essential character and functioning of wetlands, aquatic habitats and water resources of environmentally sensitive areas which are part of the isolated wetland basin. Aside from environmentally sensitive areas and portions of the Forest Area with sparse development, the potential for significant isolated wetland basin impacts is assumed to be low (at least when considered relative to downstream watershed-wide impacts).

The evaluator should consult aerial photographs and land use maps, coupled with field verification, to evaluate the factors presented in the following relative scale.

High Potential for Significant Watershed-wide Impacts

The wetland adjacent to the proposed development site is associated with a stream/water course, and within 2 miles downstream of the development site there is any part of an environmentally sensitive open space/natural area, active cranberry agriculture area, or any portion of the Preservation Area District. 3.0

High to Moderate Potential for Significant Watershed-wide Impacts

The wetland adjacent to the proposed development site is associated with a stream/water course, and within 2 miles downstream of the development site there is any part of the Forest Area with low potential for development (> 20 acres/unit); or, the wetland is isolated from a stream/water course, and a portion of the wetland or upland area immediately adjacent to the isolated wetland is an environmentally sensitive open space/natural area, or portion of the Preservation Area District 2.5

Moderate Potential for Significant Watershed-wide Impacts

The wetland adjacent to the proposed development site is associated with a stream/water course, and within 2 miles downstream of the development site there is an area with moderate potential for development (> 5.0 acres - < 20 acres/unit); or, the wetland is isolated from a stream/water course, and a significant portion ($> 50\%$) of the upland immediately adjacent to the isolated wetland is a part of the Forest Area with a low potential for development (> 20 acres/unit). 2.0

Moderate to Low Potential for Significant Watershed-wide Impacts

The wetland adjacent to the proposed development site is associated with a stream/water course, and within 2 miles downstream of the development site there is an area with moderate to high potential for development ($> 1 - < 5.0$ acres/unit). 1.5

Low Potential for Significant Watershed-wide Impacts

The wetland adjacent to the proposed development site is associated with a stream/watercourse, and within 2 miles downstream of the development site there is an area with a high potential for development (≤ 1 acre/unit); or, the wetland is isolated from a stream/water course. 1.0

Note: Refer to the section on water quality maintenance (The Wetland Evaluation Scheme) for a detailed definition of wetlands associated with streams/water courses and isolated wetlands.

Environmentally sensitive open space/natural areas are defined as wildlife management areas, parks, forests or recreation areas of > 500 acres which are managed by federal, state or county agencies.

Two miles downstream should be measured as the distance along the actual stream/water course.

Determining a Relative Potential for Impacts Index

The potential for significant adverse impacts to be imposed on wetlands by upland development practices is determined by assessing three general factors (wetland site-specific impacts, cumulative impacts and

watershed-wide impacts, and assigning a relative score for each. These scores are averaged to derive a relative potential for impacts index. Each individual factor is assigned equal priority in calculation of the index. The following scale enables the evaluator to translate this relative numerical index into a more comprehensive perspective.

	<u>Numerical Index</u>
<u>High Potential for Impacts</u>	3.0 - 2.6
<u>High to Moderate Potential for Impacts</u> .	2.5 - 2.1
<u>Moderate to Low Potential for Impacts</u> . .	2.0 - 1.6
<u>Low Potential for Impacts</u>	1.5 - 1.0

Assigning Buffer Areas

The final step of the *Land Capability Areas Buffer Delineation Procedure* is the assignment of appropriate buffer areas. By averaging the relative wetland value index and potential for impacts index, a buffer delineation index is derived. Referring to Table 17, the evaluator can relate the buffer delineation index to an actual buffer distance.

As noted in Table 17, the minimum buffer distance which can be assigned is variable depending on location of the proposed development site with respect to Pinelands land capability areas. The rationale for creating these variable buffer scales is as follows. On a regional basis the Preservation Area District represents a baseline exemplifying the highest environmental quality of the Pinelands. There is a regional loss or degradation of this quality and a corresponding increase in development with a progression from Forest Areas/Agricultural Production Areas, to Rural Development Areas, to Villages and Towns, and finally to Regional Growth Areas. These regional variations in existing environmental quality and development patterns represent two of the many criteria used by the Pinelands Commission when developing the regions land use planning strategy. Coupled to this environmental gradient effect, it is assumed that there is a corresponding loss of characteristic wetland values and functions on a regional basis. It seems that this apparent degradation of regional wetland quality (not necessarily site-specific wetland quality) would justify the potential for some buffers to be less than 300 ft. This variable buffer provision will facilitate needs for growth in, and adjacent to, existing developed areas, as mandated by the Pinelands legislation.

It must be emphasized that the primary intent of this *land capability areas buffer delineation procedure* is to maintain or enhance the existing quality of wetlands. Providing for environmentally compatible growth is an important and necessary component, and thus has been incorporated into the procedure; however, priority consideration is placed on the preservation, protection and enhancement of Pinelands wetlands.

Table 17. Relationship between the buffer delineation index and actual buffer distances for Pinelands land capability areas. The buffer delineation index is determined by averaging the relative wetland value index and potential for impacts index. The buffer delineation index should be rounded-off and then a buffer distance assigned according to the appropriate land capability area.

Land Capability Areas	Buffer Index	Buffer Distance (ft)
Forest Areas and Agricultural Production Areas	3.0	300
	2.5	275
	2.0	250
	1.5	225
	1.0	200
Rural Development Areas and some Villages/Towns ¹	3.0	300
	2.5	250
	2.0	200
	1.5	150
	1.0	100
Regional Growth Areas and some Villages/Towns ¹	3.0	300
	2.5	240
	2.0	175
	1.5	110
	1.0	50

¹ See potential for impacts scheme (cumulative impacts section) to determine appropriate scale (i.e., Rural Development or Regional Growth) to use for Villages/Towns.

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APPENDIX 1

Pinelands Wetlands Management Program
(CMP; Article 6, Part 1, Sections 6-101 - 6-114)

PINELANDS WETLANDS MANAGEMENT PROGRAM

(Excerpted from CMP, Article 6, Part 1, Sections 6-101 - 6-114)

ARTICLE 6

PART 1—WETLANDS

Section 6-101.

Purpose

Coastal and inland wetlands constitute a vital element of the ecological character of the Pinelands. They are critical habitats for many threatened and endangered plant and animal species and play many other important roles including the maintenance of surface and ground water quality. This program is deemed to be the minimum standards necessary to protect the long-term integrity of wetlands.

Section 6-102.

Wetlands Management Program

In order to be certified under the provisions of Article 3 [CERTIFICATION OF COUNTY, MUNICIPAL AND FEDERAL INSTALLATION PLANS] of this Plan, a municipal master plan or land use ordinance must provide for the protection of the integrity of

wetlands. It is not necessary that the municipal program incorporate the literal terms of the program set out in this Part; rather, a municipality may adopt alternative and additional techniques which will achieve equivalent protection of the wetlands defined in this Part, as would be achieved under the provisions of this Part.

Section 6-103.

Wetlands

Wetlands are those lands which are inundated or saturated by water at a magnitude, duration and frequency sufficient to support the growth of hydrophytes. Wetlands include lands with poorly drained or very poorly drained soils as designated by the National Cooperative Soils Survey of the Soil Conservation Service of the United States Department of Agriculture. Wetlands include coastal wetlands and inland wetlands, including submerged lands.

Section 6-104.

Coastal Wetlands

Coastal wetlands are banks, low-lying marshes, swamps, meadows, flats, and other lowlands subject to tidal inundation which support or are capable of supporting one or more of the following plants:

salt meadow grass (*Spartina patens*),
spike grass (*Distichlis spicata*),
black grass (*Juncus gerardi*),
saltmarsh grass (*Spartina alterniflora*),
saltworts (*Salicornia europaea* and *Salicornia bigelovii*),
sea lavender (*Limonium carolinianum*),
saltmarsh bulrushes (*Scirpus robustus* and *Scirpus paludosus* var. *atlanticus*),
sand spurrey (*Spergularia marina*),
switch grass (*Panicum virgatum*),
tall cordgrass (*Spartina pectinata*),
hightide bush (*Iva frutescens* var. *oraria*),
cattails (*Typha angustifolia* and *Typha latifolia*),
spike rush (*Eleocharis rostellata*),
chairmaker's rush (*Scirpus americanus*),
bent grass (*Argostis palustris*),
sweet grass (*Hierochloa odorata*),
wild rice (*Zizania aquatica*),
Olney's threesquare (*Scirpus olneyi*),
marsh mallow (*Hibiscus palustris*),
salt reed grass (*Spartina cynosuroides*),
common reed grass (*Phragmites communis*),
pickerel grass (*Pontederia cordata*),
arrowheads (*Sagittaria* spp.),
spatterdock (*Nuphar variegatum*),
red maple (*Acer rubrum*), and
Atlantic white cedar (*Chamaecyparis thyoides*).

Coastal wetlands include those lands which are delineated by the New Jersey Department of Environmental Protection on official maps at a scale of 1:2,400 listed in N.J.A.C. 7:7A-1.13.

Section 6-105.

Inland Wetlands

Inland wetlands include, but are not limited to:

A. Atlantic White Cedar Swamps.

Atlantic white cedar swamps are areas dominated by Atlantic white cedars (*Chamaecyparis thyoides*) and supporting one or more of the following hydrophytic plants:

red maple (*Acer rubrum*),
sweetbay (*Magnolia virginiana*),
blackgum (*Nyssa sylvatica*),
dangleberry (*Gaylussacia frondosa*),
highbush blueberry (*Vaccinium corymbosum*),
swamp azalea (*Rhododendron viscosum*),
fetterbush (*Leucothoe racemosa*),
sweet pepperbush (*Clethra alnifolia*),
inkberry (*Ilex glabra*),
pitcher plant (*Sarracenia purpurea*),
sundew (*Drosera* spp.),
cinnamon fern (*Osmunda cinnamomea*),
royal fern (*Osmunda regalis*),
and sphagnum moss (*Sphagnum* spp.).

B. Hardwood Swamps.

Hardwood swamps are areas dominated by red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*) and/or sweetbay (*Magnolia virginiana*) and supporting one or more of the following hydrophytic plants:

gray birch (*Betula populifolia*),
pitch pine (*Pinus rigida*),
Atlantic white cedar (*Chamaecyparis thyoides*),
sweet gum (*Liquidambar styraciflua*),
sweet pepperbush (*Clethra alnifolia*),
highbush blueberry (*Vaccinium corymbosum*),
swamp azalea (*Rhododendron viscosum*),
fetterbush (*Leucothoe racemosa*),
leatherleaf (*Chamaedaphne calyculata*),
dangleberry (*Gaylussacia frondosa*),
cinnamon fern (*Osmunda cinnamomea*),
chain fern (*Woodwardia* spp.),
and rushes (*Juncus* spp.);

or other lowland forests dominated by one or more of the following plants:

sweetgum (*Liquidambar styraciflua*),
pin oak (*Quercus palustris*),
and willow oak (*Quercus phellos*).

C. Pitch Pine Lowlands.

Pitch pine lowlands are areas dominated by pitch pine (*Pinus rigida*) and supporting one or more of the following hydrophytic plants:

red maple (*Acer rubrum*),
blackgum (*Nyssa sylvatica*),
gray birch (*Betula populifolia*),
leatherleaf (*Chamaedaphne calyculata*),
dangleberry (*Gaylussacia frondosa*),
sheep laurel (*Kalmia angustifolia*),

highbush blueberry (*Vaccinium corymbosum*), sweet pepperbush (*Clethra alnifolia*), and wintergreen (*Gaultheria procumbens*).

D. Bogs.

Bogs are areas dominated by hydrophytic, shrubby vegetation including:

cranberry (*Vaccinium macrocarpon*), leatherleaf (*Chamaedaphne calyculata*), sheep laurel (*Kalmia angustifolia*), highbush blueberry (*Vaccinium corymbosum*), swamp azalea (*Rhododendron viscosum*), sweet pepperbush (*Clethra alnifolia*), dangleberry (*Gaylussacia frondosa*), or staggerbush (*Lyonia mariana*).

Sphagnum moss (*Sphagnum* spp.), pitcher plant (*Sarracenia purpurea*), sundew (*Drosera* spp.), and sedges (*Carex* spp.) are among the herbaceous plants which are found in bogs. Active cranberry bogs and shrub thickets dominated by leatherleaf (*Chamaedaphne calyculata*) are included in this category.

E. Inland Marshes.

Inland marshes are areas which are dominated by hydrophytic grasses (*Gramineae*) and sedges (*Carex* spp.) and which include one or more of the following plants: pickerelweed (*Pontederia cordata*), arrow arum (*Peltandra virginica*), cattail (*Typhus* spp.), and rushes (*Juncus* spp.).

F. Lakes and Ponds.

Lakes and ponds are seasonal or permanent standing bodies of water.

G. Rivers and Streams.

Rivers and streams are bodies of water which periodically or continuously contain moving water or which form a link between two bodies of standing water.

Section 6-106.

Development Prohibited

Development shall be prohibited in all wetlands in the Pinelands except as specifically authorized in this Part.

Section 6-107.

Significant Adverse Impact

A significant adverse impact shall be de-

emed to exist where it is determined that one or more of the following modifications of a wetland will have an irreversible effect on the ecological integrity of the wetland and its biotic components:

1. An increase in surface water runoff discharging into a wetland;
2. A change in the normal seasonal flow patterns in the wetland;
3. An alteration of the water table in the wetland;
4. An increase in erosion resulting in increased sedimentation in the wetland;
5. A change in the natural chemistry of the ground or surface water in the wetland;
6. A loss of wetland habitat;
7. A reduction in wetland habitat diversity;
8. A change in wetlands species composition; or
9. A significant disturbance of areas used by indigenous and migratory wildlife for breeding, nesting, or feeding.

Section 6-108

Agriculture and Horticulture

Horticulture of native Pinelands species and berry agriculture shall be permitted in all wetlands subject to the requirements of Part 5 [AGRICULTURE] of this Article. Beekeeping shall be permitted in all wetlands.

Section 6-109.

Forestry

Forestry shall be permitted in all wetlands subject to the requirements of Part 4 [FORESTRY] of this Article.

Section 6-110.

Fish and Wildlife Management

Fish and wildlife management activities shall be permitted in all wetlands subject to the minimum standards of all other parts of this Article; provided that the management activity does not have a significant adverse impact, as set forth in Section 6-107, on the wetland in which the activity is carried out; and provided that the activity conforms to all

state and federal regulations. On a case by case basis, fish and wildlife management proposals shall be evaluated relative to the scientific research value of the proposal.

Section 6-111.

Low Intensity Uses

Hunting, fishing, trapping, hiking, boating, swimming and other similar low intensity recreational uses shall be permitted in all wetlands provided that such uses do not involve any structure other than those authorized in Section 6-112.

Section 6-112.

Water-Dependent Recreational Facilities

A. Docks, piers, moorings, and boat launches for the use of a landowner shall be permitted in all wetlands, provided that the use will not result in a significant adverse impact, as set forth in Section 6-107, and conforms to all state and federal regulations.

B. Commercial or public docks, piers, moorings, and boat launches shall be permitted provided that:

1. There is a demonstrated need for the facility that cannot be met by existing facilities;

2. The development conforms with all state and federal regulations; and

3. The development will not result in a significant adverse impact, as set forth in Section 6-107.

Section 6-113.

Public Improvements

Bridges, roads, trails and utility transmission and distribution facilities shall be permitted in wetlands provided that:

A. There is no feasible alternative route or site for the facility that does not involve development in a wetland;

B. The public need cannot be met by existing facilities or modification thereof; and

C. The facility will not result in a significant adverse impact, as set forth in Section 6-107.

Section 6-114.

Wetland Transition Areas

No development, except for those uses which are specifically authorized in this Part, shall be carried out within 300 feet of any wetland, unless the applicant has demonstrated that the proposed development will not result in a significant adverse impact on the wetland, as set forth in Section 6-107.

APPENDIX 2

THE NATIONAL WETLANDS INVENTORY AND THE PINELANDS

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THE NATIONAL WETLANDS INVENTORY AND THE PINELANDS

The U.S. Fish and Wildlife Service (FWS) is currently conducting an inventory of all wetlands in the U.S. This National Wetlands Inventory (NWI) will create an extensive data base, both map and computer oriented, for decision-making concerning the management and protection of wetland resources. For this nationwide inventory, the FWS has developed a hierarchical-type wetland classification system based on a combination of ecological, biological, hydrological and substrate characteristics (Cowardin et al. 1979). It consists of five general systems (marine, estuarine, riverine, lacustrine and palustrine) and progresses to more specific wetland descriptors (i.e., subsystems, classes, subclasses, dominance types and modifiers). The result is a detailed classification of wetland habitats.

Mapping of New Jersey's wetlands is completed and NWI maps for the Pinelands are on file in the Pinelands Commission office. These are 1:24,000 scale, however other scale maps are also available (U.S. Fish and Wildlife Service 1982). To aid in the use of these maps for decision-making in the Pinelands, and to effectively use these NWI maps in conjunction with the Pinelands Commission vegetation maps, we have compared the wetland types as described in this report and by the Pinelands Commission, with the FWS NWI classification scheme (Table 1).

Several projects are planned by the NWI to supplement the maps. These include, 1) regional map reports to provide a descriptive correlation between wetland types denoted on the maps and their floristic composition (Tiner, in preparation), 2) lists of hydric soils and hydrophytic plants, 3) wetland community information to describe vegetation associations of particular regions growing under similar hydrological, climatic and geological/soil conditions, 4) statistical trend analysis to aid in the determination of wetland gains and losses, and 5) a digitally-oriented mapping system to be used in information updating and retrieval (Wilén and Pywell 1981). In summary, utilization of the NWI maps and extensive data base should aid in the inventory, protection, management and evaluation of Pinelands wetlands.

Referenced cited: Appendix 2

- Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979.
Classification of wetland and deepwater habitats of the United States. Office of Biological Services, Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C. FWS/OBS - 79/31.
103 p.
- Tiner, R.W., Jr. In preparation. Wetlands and deepwater habitats of New Jersey. U.S. Fish and Wildlife Service, Region Five, One Gateway Center, Suite 700, Newton Corner, MA.

U.S. Fish and Wildlife Service. 1982. Catalogue of National Wetlands Inventory Maps for the state of New Jersey. Region Five, One Gateway Center, Suite 700, Newton Corner, MA. February 1982.

Wilén, B.O., and H.R. Pywell. 1981. The National Wetlands Inventory. Paper presented at the In-place Resource Inventories: Principles and Practices - a National Workshop. Orono, Maine. August 9-14, 1981.

APPENDIX 2, Table 1. Pinelands wetland types classified according to the USFWS National Wetlands Inventory scheme.

WETLAND TYPE	SYSTEM	SUBSYSTEM	CLASS	SUBCLASS	DOMINANCE TYPE	Special Modifiers		
						WATER REGIME	WATER CHEMISTRY	SOIL
Atlantic White Cedar Swamp	Palustrine	None	Forested Wetland	Needle-leaved Evergreen	<i>Chamaecyparis thyoides</i>	Seasonally Flooded	Fresh/Acid	Organic
Hardwood Swamp	Palustrine	None	Forested Wetland	Broad-leaved Deciduous	<i>Acer rubrum, Nyssa sylvatica, Magnolia virginiana</i>	Seasonally Flooded	Fresh/Acid	Organic/Mineral
Pitch Pine Lowland	Palustrine	None	Forested Wetland	Needle-leaved Evergreen	<i>Pinus rigida</i>	Seasonally Flooded	Fresh/Acid	Mineral
Shrub-dominated Wetland (spong)	Palustrine	None	Scrub-Shrub Wetland	Broad-leaved Evergreen	<i>Chamaedaphne calyculata, Kalmia angustifolia</i>	Seasonally Flooded	Fresh/Acid	Mineral
Shrub-dominated Wetland (Cranberry Bog)	Palustrine	None	Scrub-Shrub Wetland	Broad-leaved Evergreen	<i>Vaccinium macrocarpon</i>	Seasonally Flooded	Fresh/Acid	Mineral
Herbaceous Inland Wetland (Inland Marsh)	Palustrine	None	Emergent Wetland	Persistent	Grasses and Sedges	Seasonally Flooded	Fresh/Acid	Organic
Herbaceous Inland Wetland (Pond Margins)	Lacustrine	Littoral	Emergent Wetland	Non-persistent	<i>Juncus militaris</i> and others	Semi-permanently Flooded	Fresh/Acid	Mineral
Herbaceous Inland Wetland (Pond Margins)	Lacustrine	Limnetic	Aquatic Bed	Vascular	<i>Nymphaea odorata</i>	Permanently Flooded	Fresh/Acid	Mineral

APPENDIX 2, Table 1. Continued.

WETLAND TYPE	SYSTEM	SUBSYSTEM	CLASS	SUBCLASS	DOMINANCE TYPE	Special Modifiers		
						WATER REGIME	WATER CHEMISTRY	SOIL
Tidal Marsh (Salt Marsh)	Estuarine	Intertidal	Emergent Wetland	Persistent	<i>Spartina alterniflora</i>	Regularly Flooded (low marsh)	Mixohaline	Organic/ Mineral
						Irregularly Flooded (high marsh)		
Tidal Marsh (Brackish Marsh)	Estuarine	Intertidal	Emergent Wetland	Persistent	<i>Spartina cynosuroides</i> , <i>Typha angustifolia</i>	Regularly Flooded (low marsh)	Mixohaline	Organic/ Mineral
						Irregularly Flooded (high marsh)		
Tidal Marsh (Freshwater Marsh)	Riverine	Tidal	Emergent Wetland	Non-persistent	<i>Peltandra virginica</i> , and others	Regularly Flooded (low marsh)	Fresh	Organic/ Mineral
	or Palustrine	None	Emergent Wetland	Persistent	Grasses/Sedges	Seasonally Flooded- Tidal	Fresh	Organic/ Mineral

APPENDIX 3
PINELANDS LAND USE CAPABILITY AREAS
(see endpiece)