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Wetlands of the New Jersey Pinelands:
Values, Functions and Impacts

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PREFACE

This document is the reprinting of section one of a June 1983 report entitled, "Wetlands of the New Jersey Pinelands: Values, Functions, Impacts, and a Proposed Buffer Delination Model."[1] This literature review section on Pinelands wetlands values, functions and impacts provided much of the scientific foundation for development of a wetland-upland buffer delineation model. The 1983 proposed model underwent a one year field test, followed by revisions based on the test results.[2] The revised buffer delineation model is presented as a separate document.[3] This model is currently being used as a guideline for evaluating wetland-related applications by the New Jersey Pinelands Commission, the state agency responsible for management and planning in the Pinelands region. Because the proposed buffer model is now obsolete, it seems appropriate to reprint the literature review section as a separate document.

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[1] Roman, C.T., and R.E. Good. 1983. Wetlands of the New Jersey Pinelands: values, functions, impacts and a proposed buffer delineation model. Divison of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 123 p.

[2] Roman, C.T., and R.E. Good. 1984. Buffer delineation model for New Jersey Pinelands wetlands: Field Test. Division of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 68 p.

[3] Roman, C.T., and R.E. Good. 1985. Buffer delineation model for New Jersey Pinelands wetlands. Division of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 73 p.

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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

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[1]The 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).

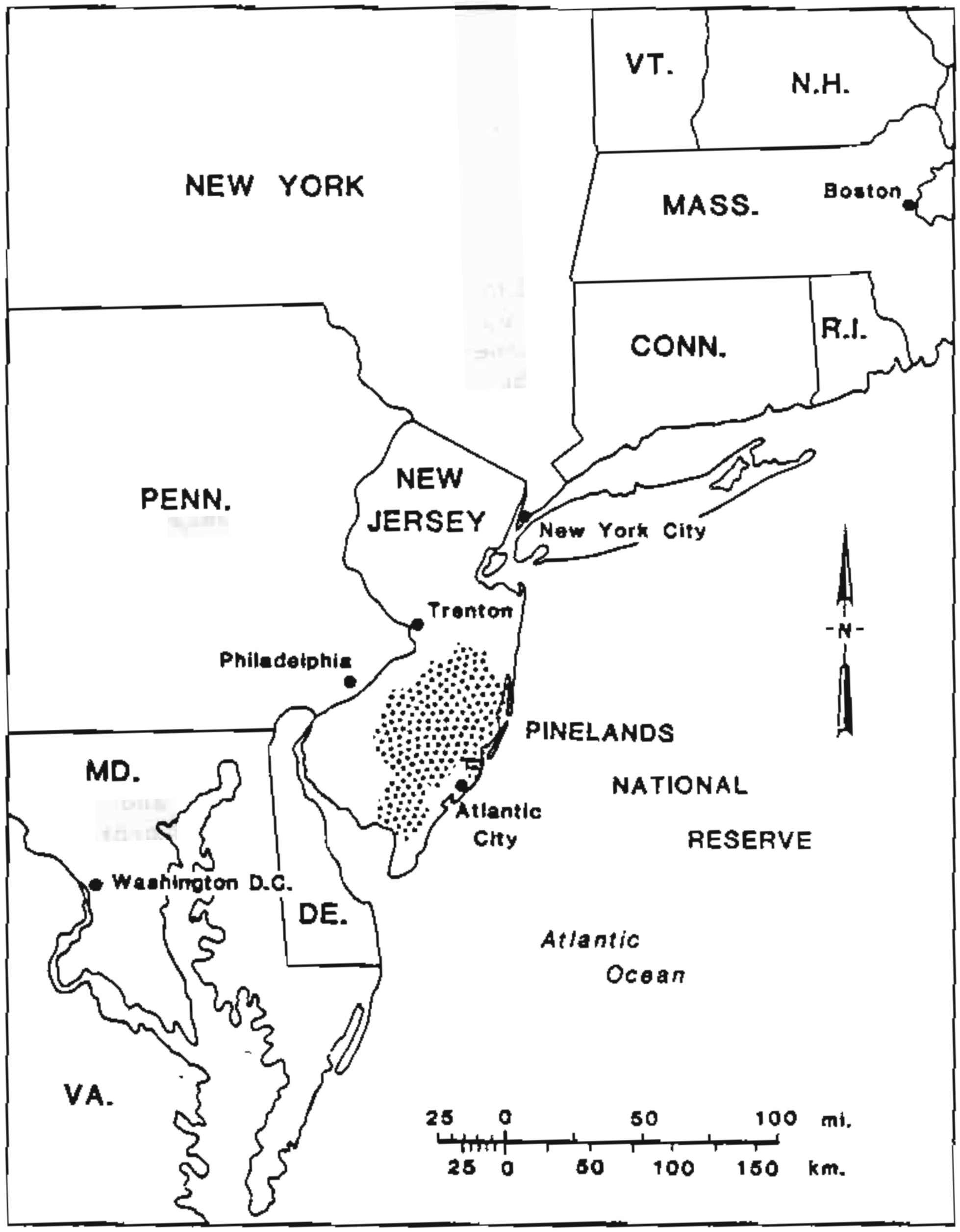

Fig. 1. Regional location of the Pinelands National Reserve.

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

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 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.

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)
TOTAL RESERVE WETLAND AREA	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)	
WETLAND TYPE CATEGORIES	
Pitch Pine Lowlands	46,270 (114,330)[2]
Coastal Marshes	32,320 (79,860)[3]
Cedar Swamps	8,680 (21,450)[4]

[1]From 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).

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

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

[4]Area 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	
Acer rubrum	Red maple
Betula populifolia	Gray birch
Chamaecyparis thyoides	Atlantic White Cedar
Liquidambar straciflua	Sweet Gum
Liriodendron tulipifera	Tulip Popular
Magnolia virginiana	Sweet Bay
Nyssa sylvatica	Black Gum
Pinus rigida	Pitch Pine
Sassafras albidum	Sassafras
SHRUBS	
Amelanchier spp.	Serviceberry
Chamaedaphne calyculata	Leatherleaf
Clethra alnifolia	Sweet Pepperbush
Gaylussacia baccata	Black Huckleberry
Gaylussacia dumosa	Dwarf Huckleberry
Gaylussacia frondosa	Dangleberry
Ilex glabra	Inkberry
Kalmia angustifolia	Sheep Laurel
Kalmia latifolia	Mountain Laurel
Leucothoe racemosa	Fetterbush
Lyonia ligustrina	Maleberry
Lyonia mariana	Staggerbush
Myrica pensylvanica	Bayberry
Rhododendron viscosum	Swamp Azalea
Smilax spp.	Brier
Vaccinium corymbosum	Highbush Blueberry
Vaccinium macrocarpon	Cranberry
HERBS	
Carex spp. and Cyperaceae	Sedges
Drosera spp.	Sundews
Gaultheria procumbens	Teaberry
Gramineae	Grasses
Sarracenia purpurea	Pitcher Plant
Xerophyllum asphodeloides	Turkey Beard
FERNS AND FERN ALLIES	
Lycopodium carolinianum	Clubmoss
Osmunda cinnamomea	Cinnamon Fern
Pteridium aquilinum	Bracken Fern
Schizaea pusilla	Curly Grass Fern
Woodwardia virginica	Virginia Chain Fern

Table 2. Continued.

LIVERWORTS AND MOSSES	
Polytrichum spp.	Haircap Moss
Sphagnum spp.	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/draining), 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 popular (*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]

[1]From 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.

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

[3]Depth 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.

[4]Transitional 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 disasterous 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).

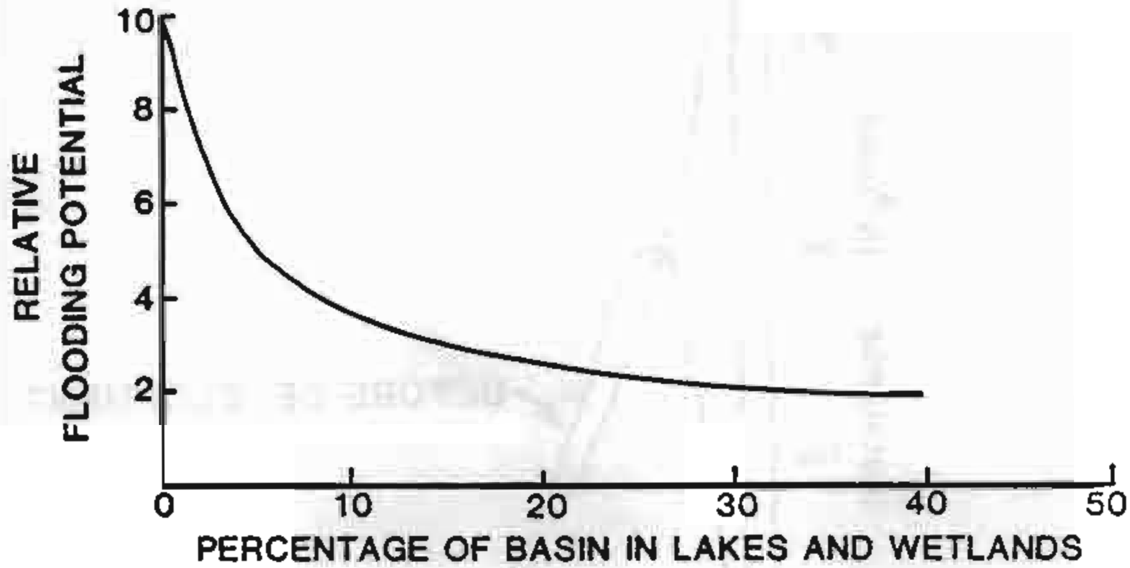

Fig. 2. Relative flooding potential in basins with different percentages of lakes and wetlands. Curve is based on data from Wisconsin watersheds. Note the significant increase in the potential for flooding in basins with a low percentage of lakes and wetlands (redrawn from, Novitzki 1979).

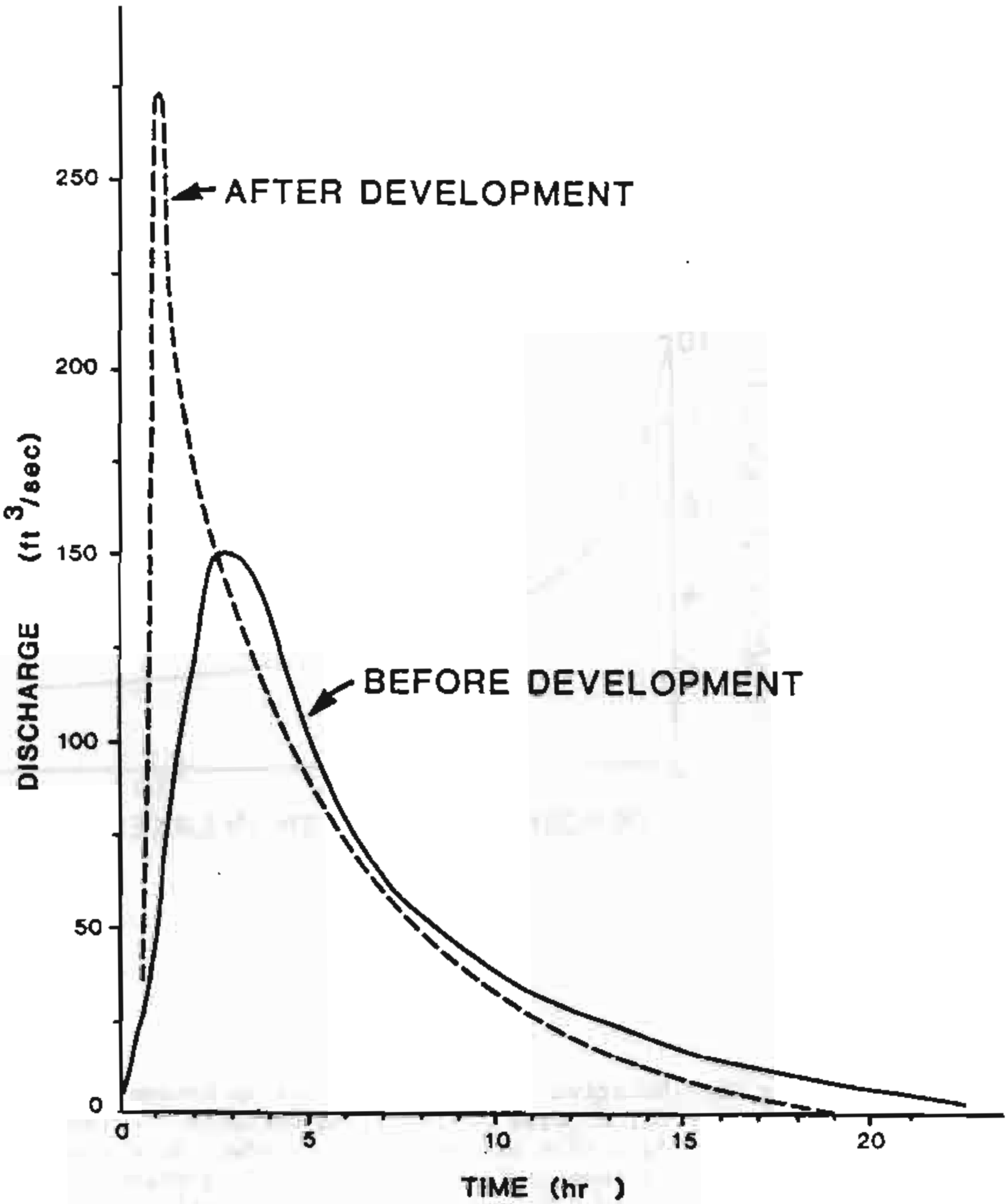

Fig. 3. Comparison of unit-hydrographs of a Pinelands subwatershed (portion of the Upper Great Egg Harbor River) before and after development. The hydrographs are for high intensity/ short duration storms. Note that urbanization results in increased peak discharge (redrawn from, Fusillo 1981).

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.

<u>Developed vs. Undeveloped Watersheds</u>

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.

<u>Stormwater Storage Capacity - Wetland Size and Soil Type</u>

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 $N/km^2/yr$. 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 dentrification, is formed via nitrification under aerobic conditions, rates of dentrification 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 dominanted 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 $gm/m^2/yr$). The mean productivity of all the wetland types reviewed by Richardson (1979) was 1500 $gm/m^2/yr$ 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/m^2/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/m^2/yr and 592 gm/m^2/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)

[1] Ehrenfeld (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 summ... 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 <u>within</u> 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).

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

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.

SNAKES

Eastern King Snake
Lampropeltis g. getulus

Eastern Worm Snake
Carphophis a. amoenus

Northern Black Racer
Coluber c. constrictor

Northern Pine Snake, (T)
Pituophis m. melanoleucus

Northern Red-bellied Snake
Storeria o. occipitomaculata

Queen Snake
Natrix septemvittata

Rough Green Snake
Opheodrys aestivus

Timber Rattlesnake, (E)
Crotalus horridus

SALAMANDERS

Eastern Mud Salamander, (T)
Pseudotriton m. montanus

Eastern Tiger Salamander, (E)
Ambystoma t. tigrinum

Four-toed Salamander
Hemidactylium scutatum

Marbled Salamander
Ambystoma opacum

TOADS AND FROGS

Carpenter Frog
Rana virgatipes

Eastern Spakefoot Toad
Scaphiopus h. holbrooki

Northern Cricket Frog
Acris c. crepitans

Pine Barrens Treefrog, (E)
Hyla andersoni

Southern Gray Treefrog, (E)
Hyla chrysoscelis

TURTLES

Bog Turtle, (E)
Clemmys muhlenbergi

Map Turtle
Graptemys geographica

Red-bellied Turtle
Chrysemys rubriventris

Spotted Turtle
Clemmys guttata

Wood Turtle, (T)
Clemmys insculpta

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

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 southermost 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).

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

Table 8. Continued.

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

Table 8. Continued.

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

[1]Threatened (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 Eagle[1]
Haliaeetus leucocephalus

Black Skimmer
Rhynchops niger

Cooper's Hawk
Accipiter cooperii

Least Tern
Sterna albifrons

Osprey
Pandion haliaetus

Peregrine Falcon[1]
Falco peregrinus

Great Blue Heron
Ardea herodias

Henslow's Sparrow
Ammodramus henslowii

Merlin
Falco columbarius

Northern Harrier
Circus cyaneus

Pied-billed Grebe
Podilymus podiceps

Red-shouldered Hawk
Buteo linelus

Roseate Tern
Sterna dougallii

THREATENED

Barred Owl
Strix varia

Bobolink
Dolichonyx oryzivorus

Cliff Swallow
Petrochelidon pyrrhonota

Grasshopper Sparrow
Ammodramus savannarum

Savannah Sparrow
Passerculus sandwichensis

Short-billed Marsh Wren
Cistothorus platensis

Short-eared Owl
Asio flammeus

[1]Also 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 .e 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 (spongs) 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 interspersion 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 interspersion 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 vegatation) 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 expecially 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

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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
FILLING/DREDGING								
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	
DRAINING								
Blueberry culture, commercial, residential or industrial development, etc.	2,3	5	6,9				7,8	10
WATER LEVEL CONTROL								
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)								
VEGETATION REMOVAL								
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				
IMPERVIOUS SURFACES								
Roads, Parking lots, buildings, etc.	1	5			2,3		7,8	10
WATER POLLUTION INPUTS								
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	
GROUNDWATER WITHDRAWAL	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 maintenence 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 ($\bar{x}$) 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 ($\bar{x}$)
Fusillo et al. (1980)	1966-1977	Oyster Creek	3.9-5.8 4.5(median) 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($\bar{x}$)
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)

[1] Denotes that values are for wetland waters and not stream waters.

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	Summer .01-.04; Winter .07-.13	Summer .31-.38 & .06-.25; Winter .56-2.53 & .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 americanium, Callitriche heterophylla,* and *Potomogeton epihydrus.* With respect to fish, disturbed stream sites were characterized by the presence of the tesselated 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).

SUMMARY AND CONCLUSIONS

Pinelands wetlands, comprising approximately 35 percent of the Pinelands National Reserve, provide a variety of values and functions regarded as beneficial to society and essential to ecosystem maintenance and quality. Major types include Atlantic white cedar (*Chamaecyparis thyoides*) swamp, hardwood swamp usually dominated by red maple (*Acer rubrum*) and black gum (*Nyssa sylvatica*), pitch pine (*Pinus rigida*) lowlands, shrub-dominated wetlands and marshes. Hydrologically, wetlands are valuable in flood control. Because of the porous, sandy soils, flooding is not a regional problem, but wetlands may be locally helpful in preventing flooding in developed watersheds. Wetlands may play a more important role in maintaining the high water quality characteristic of the Pinelands by nutrient retention and removal. Nutrient retention appears to be favored by slow-moving water and dense woody vegetation which has a higher capacity for long-term storage. Only a few studies on productivity of the inland wetland swamps have been done so far but it appears that swamp productivity is in the range of low production coastal types and perhaps less than half that of the most productive marsh types.

The food web support values and closely related habitat values are recognized when considering the diversity of the biota encountered, including a significant number of unique, threatened or endangered species. Wetlands provide essential habitat for amphibians and are much utilized by snakes, mammals and birds. Many of the rare and endangered Pine Barrens plant species including orchids, sedges, rushes and ferns are also dependent on wetlands habitats. Pinelands wetlands also provide a rich regional heritage from recreational (canoeing, hunting, fishing), educational, scientific and aesthetic perspectives. In terms of harvest value, cedar logging, blueberry/cranberry culture and muskrat trapping provide economic opportunities.

Development activities which modify 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, thereby contributing to the regional loss or diminution of society based wetland values. Hydrologic factors, such as water table, seasonal flow patterns and surface water runoff are principle forces determining the ecological balance of wetlands. Long-term alterations in wetlands water table level could contribute to shifts in vegetation structure and species composition which would have adverse effects on 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. Lower water table levels also decrease the role of wetlands as natural firebreaks.

With respect to water quality, the surface water of Pinelands wetlands and aquatic habitats are characterized by low nutrients, high acidity and low suspended sediment levels. Water quality degradation, primarily related to nonpoint source inputs, would significantly detract from the ability of Pinelands wetland/aquatic resources to support their rich and unique biotic components. It is clear that much of the characteristic biota is relatively easily displaced by more aggressive plant and animal species from adjacent regions. Studies have indicated that disturbed Pinelands wetlands and waterways are subject of invasion by weedy and/or uncharacteristic plant species. Non-adapted fish and amphibian species are clearly excluded by the naturally acid waters. Long-term maintenance of these wetlands will depend on the exclusion of excess nutrient inputs and maintenance of the natural hydrologic regime.

REFERENCES CITED

Adamus, P.R. 1983. A method for wetland functional assessment, Vol. II; FHWA assessment model. U.S. Dept. of Transportation, Federal Highway Administration, Office of Research, Environmental Division, Washington, DC. FHWA-IP-82-24. 134 p.

Adamus, P.R., and L.T. Stockwell. 1983. A method for wetland functional assessment, Vol. I; Critical review and evaluation concepts. U.S. Dept. of Transportation, Federal Highway Administration, Office of Research, Environmental Division, Washington, DC. FHWA-IP-82-23. 176 p.

Allen, H.H. 1979. Role of wetland plants in erosion control of riparian shorelines. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 403-414.

Applegate, J.E., S. Little, and P.E. Marucci. 1979. Plant and animal products of the Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 133-146.

Ballard, J.T. 1979. Fluxes of water and energy through the Pine Barrens ecosystems. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 133-146.

Bernard, J.M. 1963. Lowland forests of the Cape May formation in southern New Jersey. Bull. N.J. acad. Sci. 8:1-12.

Boto, K.G., and W.H. Patrick, Jr. 1979. Role of wetlands in the removal of suspended sediments. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 479-489.

Brady, S.A. 1980. An assessment of the birdlife of the Pinelands National Reserve/Pinelands Area. Final report to the N.J. Pinelands Commission. 92 p.

Brinson, M.M., A.E. Lugo, and S. Brown. 1981. Primary productivity, decomposition and consumer activity in freshwater wetlands. Ann. Rev. Ecol. Syst. 12:123-161.

Brown, K.W., and Associates. 1980. An assessment of the impact of septic leach fields, home lawn fertilization and agricultural activities on groundwater quality. Final report to the N.J. Pinelands Commission. 104 p.

Brown, S., M.M. Brinson, and A.E. Lugo. 1979. Structure and function of riparian wetlands. In, Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Proceedings of a symposium, Dec. 11-13, 1978. U.S. Dept. of Agriculture, Forest Service, Washington, D.C. GTR-WO-12. p. 17-31.

Buell, M.F. 1970. Time of origin of New Jersey Pine Barrens bogs. Bull. Torrey Bot. Club 97:105-108.

Caiazza, N., and D.E. Fairbrothers. 1980. Threatened and endangered vascular plant species of the New Jersey Pinelands and their habitats. Final report to the N.J. Pinelands Commission. 38 p.

Carter, V., M.S. Bedinger, R.O. Novitzki, and W.O. Wilen. 1979. Water resources and wetlands. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 344-376.

Chamie, J.P.M., and C.J. Richardson. 1978. Decomposition in northern wetlands. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 115-130.

Clark, J. 1977. Coastal Ecosystem Management: A Technical Manual for the Conservation of coastal zone resources. J. Wiley and Sons, N.Y. 928 p.

Clark, J. 1979. Fresh water wetlands: habitats for aquatic invertebrates, amphibians, reptiles, and fish. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 330-343.

Clark, J., and J. Clark, eds. 1979. Scientists' report: National Symposium on Wetlands, Lake Buena Vista, Fla., Nov. 6-9, 1978. National Wetlands Technical Council, Washington, D.C. 12 p.

Conner, W.H., and J.W. Day. 1976. Productivity and composition of a bald cypress-water tupelo site and a bottomland hardwood site in a Louisiana swamp. Amer. J. Bot. 63:1354-1364.

Crerar, D.A., G.W. Knox, and J.L. Means. 1979. Biogeochemistry of bog iron in the New Jersey Pine Barrens. Chem. Geol. 24:111-135.

Darnell, R.M. 1976. Impacts of construction activities in wetlands of the United States. U.S. Dept. of Environmental Protection, Office of Research and Development, Corvallis, OR. Ecological Research Series, EPA-600/3-76-045. 392 p.

Darnell, R.M. 1978. Overview of major development impacts on wetlands. In, Proc. of the National Wetland Protection Symposium, Reston, VA, June 6-8, 1977. U.S. Dept. of Interior, Fish and Wildlife Service, Biological Services Program. FWS/OBS-78/97. p. 19-27.

Darnell, R.M. 1979. Impact of human modification on the dynamics of wetland systems. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 200-209.

Day, J.W., Jr., W.G. Smith, P.R. Wagner, and W.C. Stowe. 1973. Community structure and carbon budget of a salt marsh and shallow bay estuarine system in Louisiana. Center for Wetland Resources, Louisiana State University. LSU-SG-72-04. 80 p.

de la Cruz, A.A. 1979. Production and transport of detritus in wetlands. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 146-174.

Durand, J.B. 1979. Nutrient and hydrological effects of the Pine Barrens on neighboring estuaries. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 195-211.

Durand, J.B., M.L. Granstrom, and N.S. Rudolph. 1974. Water resources development in the Mullica River basin. Water Resources Bull. 10(2): 272-282.

Durand, J.B., and B. Zimmer. 1982. Pinelands surface water quality - Part I. Center for Coastal and Environmental Studies, Rutgers - the State University of N.J., New Brunswick, N.J. 196 p.

Ehrenfeld, J.G. in press. Wetlands of the New Jersey Pine Barrens: The role of species composition in community function. Am. Midl. Natr.

Ehrenfeld, J.G. 1983. The effects of changes in land-use on swamps of the New Jersey Pine Barrens. Biol. Conser. 25:353-375.

Ehrenfeld, J.G., and M. Gulick. 1981. Structure and dynamics of hardwood swamps in the New Jersey Pine Barrens: Contrasting patterns in trees and shrubs. Amer. J. Bot. 68:471-481.

Fairbrothers, D.E. 1979. Endangered, threatened, and rare vascular plants of the Pine Barrens and their biogeography. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 395-405.

Fairbrothers, D.E., and M.Y. Hough. 1973. Rare or endangered vascular plants of New Jersey. N.J. State Museum, Trenton, Science Notes No. 14. 53 p.

Farnworth, E.G., M.C. Nichols, C.N. Jann, L.G. Wolfson, R.W. Bosserman, P.R. Hendrix, F.B. Golley, and J.L. Cooley. 1979. Impacts of sediment and nutrients on biota in surface waters of the United States. Environmental Research Lab, Office of Research and Development, U.S. Environmental Protection Agency, Athens, Georgia. EPA-600/3-79-105. 314 p.

Fenchel, T.M., and B.B. Jorgensen. 1977. Detritus food chains of aquatic ecosystems. In, Advances in Microbial Ecology, Vol. I (M. Alexander, ed.). Plenum Press, N.Y. p. 1-58.

Ferren, W.R., Jr., R.E. Good, R. Walker, and J. Arsenault. 1981. Vegetation and flora of Hog Island, a brackish wetland in the Mullica River, New Jersey. Bartonia 48:1-10.

Ferren, W.R., Jr., and A.E. Schuyler. 1980. Intertidal vascular plants of river systems near Philadelphia. Proc. Acad. Natl. Sci. of Phila. 132:86-120.

Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. 1982. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. U.S. Fish and Wildlife Service. 18 p.

Fusillo, T.V. 1981. Impact of suburban residential development on water resources in the area of Winslow Township, Camden County, New Jersey. U.S. Geological Survey, Water Resources Division, Trenton, N.J. Water Resources Investigations, 81-27. 28 p.

Fusillo, T.V., J.C. Schornick, Jr., H.E. Koester, and D.A. Harriman. 1980. Investigation of acidity and other water-quality characteristics of Upper Oyster Creek, Ocean County, New Jersey. U.S. Geological Survey, Water Resources Division, Trenton, N.J. Water Resources Investigations 80-10. 29 p.

Garbish, E.W., Jr., P.B. Woller, and R.J. McCallum. 1975. Salt marsh establishment and development. Coastal Engineering Research Center, U.S. Army Corps of Engineers, Fort Belvoir, VA. Tech. Mem. No. 52. 110 p.

Givnish, T.J., ed. 1971. A study of New Jersey Pine Barrens cedar swamps. Report of the Princeton-NSF Cedar Swamp Study Group. 83 p.

Golet, F.C. 1976. Wildlife wetland evaluation model. In, Models for Assessment of Freshwater Wetlands (J.S. Larson, ed.). Water Resources Research Center, Univ. of Massachusetts, Amherst, MA. Publ. No. 32. p. 13-34.

Golet, F.C. 1979. Rating the wildlife value of Northeastern fresh water wetlands. In, Wetlands Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 63-73.

Good, R.E. 1965. Salt marsh vegetation, Cape May, New Jersey. Bull. N.J. Acad. Sci. 10:1-11.

Good, R.E., ed. 1982. Ecological solutions to environmental management concerns in the Pinelands National Reserve. Proceedings of a conference, April 18-22, 1982. Division of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University of N.J., New Brunswick, N.J. 47 p.

Gosner, K.L., and I.H. Black. 1957. The effects of acidity on the development and hatching of New Jersey frogs. Ecol. 38:256-262.

Gosselink, J.G., and R.E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whitham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 63-78.

Grant, R.R., Jr., and R. Patrick. 1970. Tinicum Marsh as a water purifier. In, Two Studies of Tinicum Marsh. The Conservation Foundation, Washington, D.C. p. 105-123.

Harshberger, J.W. 1916. The vegetation of the New Jersey Pine-Barrens. Christopher Sower Co., Phila.,, PA. Reprinted by, Dover Publ., Inc., N.Y. (1970). 329 p.

Hastings, R.W. 1979. Fish of the Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 489-504.

Heinle, D.R., D.A. Flemer, and J.F. Ustach. 1976. Contribution of tidal marshlands to mid-Atlantic estuarine food chains. In, Estuarine Processes, Vol. II (M. Wiley, ed.). Academic Press, Inc., N.Y. p. 309-320.

Hopkinson, C.S., Jr., and J.W. Day, Jr. 1980a. Modeling the relationship between development and storm water and nutrient runoff. Environ. Managmt. 4:315-324.

Hopkinson, C.S., Jr., and J.W. Day, Jr. 1980b. Modeling hydrology and eutrophication in a Louisiana swamp forest ecosystem. Environ. Managmt. 4:325-335.

Johnson, A.H. 1979. Acidification of headwater streams in the New Jersey Pine Barrens. J. Environ. Qual. 8:383-386.

Kadlec, R.H. 1979. Wetlands for tertiary treatment. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 490-504.

Kibby, H.V. 1979. Effects of wetlands on water quality. In, Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. Proceedings of a Symposium, Dec. 11-13, 1978. U.S. Dept. of Agriculture, Forest Service, Washington, D.C. GTR-WO-12. p. 289-298.

Klopatek, J.M. 1978. Nutrient dynamics of freshwater riverine marshes and the role of emergent macrophytes. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. 195-216.

Kuenzler, E.J. 1976. Observation of productivity of swamp streams in eastern North Carolina. In, Conference Report: The Environmental Impact of Freshwater Wetland Alterations on Coastal Estuaries. Sponsored by, Resource Planning Section, Office of Planning and Research, Georgia Dept. of Natural Resources. June 23, 1976. p. 33-45.

Larson, J.S. 1973. Wetlands and floods. In, A Guide to Important Characteristics and Values of Freshwater Wetlands in the Northeast (J.S. Larson, ed.). Water Resources Research Center, Univ. of Massachusetts, Amherst. Publ. No. 31. p. 15-16.

Larson, J.S., ed. 1976. Models for evaluation of freshwater wetlands. Water Resources Research Center, University of Mass. Publ. No. 32. 91 p.

Leck, C.F. 1979. Birds of the Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 457-466.

Lindeman, R.L. 1942. The trophic-dynamic aspect of ecology. Ecol. 23:399-418.

Little, S. 1950. Ecology and silviculture of white cedar and associated hardwoods in southern New Jersey. Yale Univ. School of Forestry Bull. 56:1-103.

Little, S. 1951. Observations on the minor vegetation of the Pine Barren swamps in southern New Jersey. Bull. Torrey Bot. Club 78:153-160.

Little, S. 1979. Fire and plant succession in the New Jersey Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 297-314.

Livingston, R.J., and O.L. Loucks. 1979. Productivity, trophic interactions, and food-web relationships in wetlands and associated systems. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 101-119.

Markley, M.L. 1979. Soil series of the Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Pres, Inc., N.Y. p. 81-93.

Marsh, E. 1981. Scenic preferences: The New Jersey Pine Barrens and coast. Prepared for the Heritage, Conservation and Recreation Service, U.S. Dept. of Interior.

McCormick, J.S. 1955. A vegetation inventory of two watersheds in the New Jersey Pine Barrens. Ph.D. Dissertation, Rutgers University, New Brunswick, N.J. 125 p.

McCormick, J. 1970. The Pine Barrens: A preliminary ecological inventory. N.J. State Museum, Trenton. Research Report No. 2. 100 p.

McCormick, J. 1979. The vegetation of the New Jersey Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 229-243.

Means, J.L., R.F. Yuretich, D.A. Crerar, D.J.J. Kinsman, and M.P. Borcsik. 1981. Hydrogeochemistry of the New Jersey Pine Barrens. N.J. Dept. of Environmental Protection and N.J. Geological Survey, Trenton, N.J. 107 p.

Morgan, M.D., R.W. Hastings, G.W. Wolfe, and K.R. Philipp. 1983. A comparison of aquatic species composition and diversity in disturbed and undisturbed Pinelands waters. Center for Coastal and Environmental Studies, Rutgers - the State University of N.J., New Brunswick, N.J. 116 p.

Moul, E.T., and H. Buell. 1979. Algae of the Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 425-442.

Mulholland, P.J. 1981. Organic carbon flow in a swamp-stream ecosystem. Ecol. Monogr. 51:307-322.

Mulholland, P.J., and E.J. Kuenzler. 1979. Organic carbon export from upland and forested wetland watersheds. Limnol. Oceanogr. 24:960-966.

New Jersey Department of Environmental Protection. 1981. New Jersey's white-tailed deer: A report on New Jersey's deer management program for fiscal year 1981. Department of Environmental Protection, Division of Fish, Game, and Wildlife, Bureau of Wildlife Management, Trenton, N.J. Deer Report No. 8. 9 p.

New Jersey Department of Environmental Protection and Soil Conservation Service, USDA. 1980. Endangered and threatened species of New Jersey. 44 p.

Niering, W.A. 1953. The past and present vegetation of High Point State Park, New Jersey. Ecol. Monogr. 23:127-148.

Niering, W.A. 1979. Our wetland heritage: historic, artistic, and future perspectives. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. P. 505-522.

Nixon, S.W. 1980. Between coastal marshes and coastal waters - a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry. In, Estuarine and Wetland Processes: With emphasis on modelling (P. Hamilton, and K.B. Macdonald, eds.), Marine Science Vol. II. Plenum Press, N.Y. p. 437-525.

Nixon, S.W. C.A. Oviatt. 1973. Ecology of a New England salt marsh. Ecol. Monogr. 43:463-498.

Novitzki, R.P. 1979. Hydrologic characteristics of Wisoncsin's wetlands and their influence on floods, stream flow, and sediment. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 377-388.

Odum, E.P. 1961. The role of tidal marshes in estuarine production. New York State Conservationist 16:12-15, 35.

Adum, E.P. 1979. The value of wetlands: a hierachical approach. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 16-25.

Odum, H.T. 1957. Trophic structure and productivity of Silver Springs, Florida. Ecol. Monogr. 27:55-112.

Odum, W.E., and E.J. Heald. 1975. The detritus-based food web of an estuarine mangrove community. In, Estuarine Research, Vol. I (L.E. Cronin, eds.). Academic Press, Inc., N.Y. p. 265-286.

Olsson, H. 1979. Vegetation of the New Jersey Pine Barrens: A phytosociological classification. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, N.Y. p. 245-263.

Patrick, R., B. Matson, and L. Anderson. 1979. Streams and lakes in the Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 169-193.

Pierce, A.D. 1957. Iron in the Pines. Rutgers University Press, New Brunswick, N.J. 244 p.

Pinelands Commission. 1980. Comprehensive Management Plan for the Pinelands National Reserve (National Parks and Recreation Act, 1978) and Pinelands Area (New Jersey Pinelands Protection Act, 1979). Pinelands Commission, New Lisbon, N.J. 446 p.

Prentki, R.T., T.D. Gustafson, and M.S. Adams. 1978. Nutrient movements in lakeshore marshes. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 169-194.

Reader, R.J. 1978. Primary production in northern bog marshes. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 53-62.

Reimold, R.J., and M.A. Hardisky. 1979. Nonconsumptive use values of wetlands. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.D. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Servc., No. TPS79-2. p. 558-564.

Reppert, R.T., W. Sigleo, E. Stakhiv, L. Messman, and C. Meyers. 1979. Wetland values: Concepts and methods for wetlands evaluation.' U.S. Army Corps of Engineers, Institute for Water Resources, Research Report 79R1. 109 p.

Reynolds, P.E., K.G. Carlson, T.W. Fromm, K.A. Gigliello, R.J. Kaminski, 1979. Comparative biomass characteristics for three southern New Jersey lowland forests. In, Forest Resource Inventories: Workshop Proceedings (IUFRO), Vol. II (W.E. Frayer, eds.). Colorado State University, Fort Collins, Colorado. p. 677-694.

Rhodehamel, E.C. 1979. Hydrology of the New Jersey Pine Barrens. In, Pine Barrens: Ecosystem and Landscape (R.T.T. Forman, ed.). Academic Press, Inc., N.Y. p. 147-167.

Richardson, C.J. 1979. Primary productivity values in fresh water wetlands. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. P. 131-145.

Richardson, C.J., D.L. Tilton, J.A. Kadlec, J.P.M. Chamie, and W.A. Wentz. 1978. Nutrient dynamics of northern wetland ecosystems. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 217-241.

Robichaud, B. 1980. A conceptual framework for Pinelands decision-making. Final report to the N.J. Pinelands Commission. Center for Coastal and Environmental Studies, Rutgers - the State University of N.J., New Brunswick, N.J. 78 p.

Robichaud, B. and M.F. Buell. 1973. Vegetation of New Jersey: A Study of Landscape Diversity. Rutgers University Press, New Brunswick, N.J. 340 p.

Roman, C.T., R.A. Zampella, A.Z. Jaworski. 1983. Vegetation, soils and water table relationships in wetland to upland transition zones of the New Jersey Pine Barrens. Bull. Ecol. Soc. Am. (Abstract, in press).

Sauer, L., C. Franklin, C. Franklin, and R. Sauer. 1980. Forest vegetation in the Pinelands. Final report for the N.J. Pinelands Commission. 42 p.

Shuldiner, P.W., D.F. Cope, and R.B. Newton. 1979. Ecological effects of highway fills on wetlands. National Cooperative Highway Research Program, Reports 218A and 218B. Transportation Research Board, National Research Council, Washington, D.C.

Simpson, R.L., D.F. Whigham, and R. Walker. 1978. Seasonal patterns of nutrient movement in a freshwater tidal marsh. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 243-257.

Sloey, W.E., R.L. Spangler, and C.W. Fetter, Jr. 1978. Management of freshwater wetlands for nutrient assimilation. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 321-340.

Smardon, R.C. 1979. Visual-cultural values of wetlands. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.D. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 535-544.

Smith, K.K., R.E. Good, and N.F. Good. 1979. Production dynamics for above and below ground components of a New Jersey *Spartina alterniflora* salt marsh. Est. Coastal Mar. Sci. 9:189-201.

Soil Conservation Service. 1971. Soils of Burlington County, New Jersey. U.S. Department of Agriculture.

Soil Conservation Service. 1976. Soils of Ocean County, New Jersey. U.S. Department of Agriculture.

Squires, E.R., and R.E. Good. 1974. Seasonal changes in the productivity, caloric content, and chemical composition of a population of salt-marsh cord-grass (*Spartina alterniflora*). Ches. Sci. 15:63-71.

Steever, E.Z., R.S. Warren, and W.A. Niering. 1976. Tidal energy subsidy and standing crop production of *Spartina alterniflora*. Est. Coastal Mar. Sci. 4:473-478.

Stone, W. 1911. The plants of southern New Jersey and especial reference to the flora of the Pine Barrens and the geographic distribution of the species. N.J. State Museum, Annual Report, Trenton, N.J.

Teal, J.M. 1962. Energy flow in the salt marsh ecosystem of Georgia. Ecol. 43:614-624.

Turner, R.E. 1976. Geographic variations in salt marsh macrophyte production: a review. Contri. Mar. Sci. 20:47-68.

U.S. Army Corps of Engineers. 1980. A habitat evaluation system (HES) for water resources planning. Lower Mississippi Valley Division, Vicksburg, MS. 89 p.

U.S. Fish and Wildlife Service. 1980. Habitat evaluation procedures. Division of Ecological Services, USFWS, Dept. of Interior, Washington, D.C. ESM 102.

van der Valk, A.G., and C.B. Davis. 1978. Primary production of prairie glacial marshes. In, Freshwater Wetlands: Ecologic Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 21-37.

Vivian, V.E. 1980. Reptiles and amphibians of the New Jersey Pine Barrens. Final report to the N.J. Pinelands Commission. 76 p.

Vivian, V.E., and D. Snyder. 1981. Rare and endangered vascular plant species in New Jersey. U.S. Fish and Wildlife Service. 98 p.

Wander, W. 1980-1981. Breeding birds of southern New Jersey cedar swamps, Occasional Paper No. 138. N.J. Audubon (Records of N.J. Birds) 6:51-65.

Watson, V.J., O.L. Loucks, and W. Wojner. 1981. The impact of urbanization on seasonal hydrologic and nutrient budgets of a small Northern American watershed. Hydrobiol. 77:87-96.

Weller, M.W. 1979. Wetland habitats. In, Wetland Functions and Values: The State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 210-234.

Wharton, C.H. 1970. The southern river swamp - a multiple use environment. School of Business Admin., Georgia State Univ. Atlanta. 48 p.

Whigham, D.F., and S.E. Bayley. 1979. Nutrient dynamics in fresh water wetlands. In, Wetland Functions and Values: the State of our Understanding (P.E. Greeson, J.R. Clark, and J.E. Clark, eds.). Am. Water Resources Assoc., Tech. Publ. Ser., No. TPS79-2. p. 468-478.

Whigham, D.F., J. McCormick, R.E. Good, and R.L. Simpson. 1978. Biomass and primary production in freshwater tidal wetlands of the middle Atlantic coast. In, Freshwater Wetlands: Ecological Processes and Management Potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds.). Academic Press, Inc., N.Y. p. 3-20.

APPENDIX 1

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

APPENDIX 1

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 (*Hierochloe 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 deemed 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 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 modifers). 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 (Wilen 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.

<u>Referenced cited: Appendix 2</u>

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.

Wilen, 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.

						Special Modifiers		
WETLAND TYPE	SYSTEM	SUBSYSTEM	CLASS	SUBCLASS	DOMINANCE TYPE	WATER REGIME	WATER CHEMISTRY	SOIL
Atlantic White Cedar Swamp	Palustrine	None	Forested Wetland	Needle-leaved Evergreen	*Chamaecyparis thyoides*	Seasonally Flooded	Fresh/Acid	Organic
Hardwood Swamp	Palustrine	None	Forested Wetland	Broad-leaved Deciduous	*Acer rubrum, Nyssa sylvatica, Magnolia virginiana*	Seasonally Flooded	Fresh/Acid	Organic/ Mineral
Pitch Pine Lowland	Palustrine	None	Forested Wetland	Needle-leaved Evergreen	*Pinus rigida*	Seasonally Flooded	Fresh/Acid	Mineral
Shrub-dominated Wetland (spong)	Palustrine	None	Scrub-Shrub Wetland	Broad-leaved Evergreen	*Chamaedaphne calyculata, Kalmia angustifolia*	Seasonally Flooded	Fresh/Acid	Mineral
Shrub-dominated Wetland (Cranberry Bog)	Palustrine	None	Scrub-Shrub Wetland	Broad-leaved Evergreen	*Vaccinium macrocarpon*	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	*Juncus militaris* and others	Semi-permanently Flooded	Fresh/Acid	Mineral
Herbaceous Inland Wetland (Pond Margins)	Lacustrine	Limnetic	Aquatic Bed	Vascular	*Nymphaea odorata*	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	*Spartina alterniflora*	Regularly Flooded (low marsh)	Mixohaline	Organic/ Mineral
						Irregularly Flooded (high marsh)		
Tidal Marsh (Brackish Marsh)	Estuarine	Intertidal	Emergent Wetland	Persistent	*Spartina cynosuroides*, *Typha angustifolia*	Regularly Flooded (low marsh)	Mixohaline	Organic/ Mineral
						Irregularly Flooded (high marsh)		
Tidal Marsh (Freshwater Marsh)	Riverine	Tidal	Emergent Wetland	Non-persistent	*Peltandra virginica*, and others	Regularly Flooded (low marsh)	Fresh	Organic/ Mineral
	or							
	Palustrine	None	Emergent Wetland	Persistent	Grasses/Sedges	Seasonally Flooded-Tidal	Fresh	Organic/ Mineral