National Wetlands Inventory
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Wetlands Inventory of the FAA Technical Center Atlantic City International Airport, New Jersey

U.S. Department of the Interior
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Wetlands Inventory
of the
FAA Technical Center
Atlantic City International Airport, New Jersey

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National Wetlands Inventory
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INTRODUCTION

In September of 1992, the United States Department of Transportation, Federal Aviation Administration (FAA) Technical Center, Atlantic City International Airport and the United States Department of the Interior, Fish and Wildlife Service (FWS), New Jersey Field Office developed an Interagency Agreement to bring FAA into compliance with a number of Federal Statutes and executive orders such as the National Environmental Policy Act for wildlife management and control as well as Section 4(f) of the Department of Transportation Act. One task under this Interagency Agreement is wetland cover typing within the limits of the FAA Technical Center. The Fish and Wildlife Service's National Wetlands Inventory (NWI) staff is responsible for completing this wetland cover typing. The following report contains the results of the wetlands cover typing or inventory of FAA Technical Center wetlands plus a discussion of wetland values.

METHODS

Wetlands inventory or wetlands cover type mapping for the FAA Technical Center was accomplished through utilization of a number of conventional remote sensing and cartographic techniques in combination with ground truthing and use of collateral data sources. The primary data source for this study was aerial photographs taken on March 10, 1991. The photography was 1:40,000 scale, color infrared imagery acquired from the National Aerial Photography Program. Prior to photointerpretation, collateral data sources were consulted. These sources included the Pleasantville U.S.G.S. topographic map, the updated and revised county soil survey maps prepared by Thornton Hole, U.S.D.A. Soil Conservation Service and wetland survey maps produced by FAA consultants. Stereoscopic photointerpretation was performed using a Cartographic Engineering stereoscope. Wetlands were delineated and classified according to the U.S. Fish and Wildlife Service's *Classification of Wetlands and Deepwater Habitats* (Cowardin et al. 1979), following standard NWI photointerpretation conventions. After initial photointerpretation was completed, NWI and New Jersey FWS staff conducted two days of ground truthing to correlate photographic signatures with actual hydrologic conditions, soil and vegetation types on the ground, resulting in revisions being made to wetland classifications and delineations on the photographs. A 1:24,000 scale draft map was produced by NWI and distributed to FAA and New Jersey FWS staff for review. To resolve mapping descrepencies identified by FAA on the draft NWI maps, NWI joined FAA and New Jersey FWS to conduct additional field work. Revisions resulting from this field work were used to produce the final NWI map for the FAA Technical Center. A 1:24,000 scale map showing wetlands and deepwater habitats on the FAA Center was prepared. Wetland acreage statistics were compiled using an electronic area measurement program.

RESULTS

The FAA Technical Center lands occupy approximately 5,001.2 acres, excluding both the Atlantic City Reservoir (125.4 acres) and the Laurel Memorial Cemetery (126.3 acres). Wetlands occupy 564.98 acres or 11.3% of the land surface within the FAA Technical Center Boundaries. Table 1 summarizes acreages of the different wetland types found in the study area.

Forested wetlands are the overwhelmingly dominant wetland type with approximately 519.4 acres representing nearly 92% of FAA's wetlands. Just over 88% (458.4 acres) of these forested wetlands are dominated by evergreen species including over 89.7 acres of Atlantic white cedar swamps, with the remaining 12% (61 acres) represented by broad-leaved deciduous species. Scrub-shrub wetlands represent only 2.3% (13.2 acres) of the total wetlands in the study area. Emergent wetlands are relatively scarce within FAA lands and make up only 0.9 percent (5.3 acres) of total wetlands. The remaining 27.1 acres (4.8% of FAA wetlands) is represented by nonvegetated ponds.

Because the FAA requested the highest possible detail in this mapping project, every attempt was made to exceed the standard NWI minimum mapping unit threshhold of 1-3 acres. The field work in addition to use of the FAA consultants wetland survey maps allowed detection of wetlands as small as 1/10th acre on the photography. Numerous small, narrow wetlands were mapped as linear features, far exceeding standard NWI conventions. These features, often only 1-3 feet wide, are too narrow to accurately area measure, however, their linear distance has been determined to be 1.4 miles in length. The majority of these wetlands are excavated drainage ditches filled with emergent vegetation and grasses. In addition to these vegeated wetlands, there were 2.3 miles of linear deepwater habitat mapped in the riverine system within FAA lands.

While time did not permit an exhaustive assessment of wetland plant communities at the FAA Center, plant communities encountered during photointerpretation verification exercises were recorded. These are listed in Table 2.

WETLAND VALUES[1]

New Jersey's wetlands have been traditionally used for hunting, trapping, fishing, cranberry and blueberry harvest, timber and salt hay production, and livestock grazing. These uses tend to preserve the wetland integrity, although the qualitative nature of wetlands may be modified, especially for salt hay, blueberry, and cranberry production and timber harvest. Human uses are not limited to these activities, but also include destructive and often irreversible actions such as drainage for agriculture and filling for industrial or residential development. In the past, many people considered wetlands as wastelands whose best use could only be attained through "reclamation projects." To the contrary, wetlands in their natural state provide a wealth of values to society. These benefits can be divided into three basic categories: (1) fish and wildlife values, (2) environmental quality values, and (3) socioeconomic values. The following discussion emphasizes the more important values of New Jersey's wetlands, with significant national values also mentioned. Roman and Good (1983) have summarized wetland values for the Pinelands. For an indepth examination of Wetland values, the reader is referred to Wetland Functions and Values: The State of Our Understanding (Greeson, et al. 1979). In addition, the Service has created and maintains a wetland values database which records abstracts of over 2000 articles (Stuber 1983).

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[1] The next section is modified from *Wetlands of New Jersey* (Tiner 1985). It explains in general, many of the diverse values of wetlands in New Jersey. Many of the functions and values of wetlands examined in this section directly apply to the wetlands of the FAA Technical Center.

Fish and Wildlife Values

Fish and wildlife utilize wetlands in a variety of ways. Some spend their entire lives in wetlands, while others use wetlands primarily for reproduction and nursery grounds. Many fish and wildlife frequent marshes and swamps for feeding or feed on organisms produced in wetlands. Wetlands are also essential for survival of numerous endangered animals and plants.

Fish Habitat

Inland as well as coastal wetlands in New Jersey are important fish and shellfish habitats, however for the purposes of this report, only inland wetland values will be discussed below.

Most freshwater fishes find wetlands essential for survival. In fact, nearly all freshwater fishes can be considered wetland-dependent because: (1) many species feed in wetlands or upon wetland-produced food, (2) many fishes use wetlands as nursery grounds and (3) almost all important recreational fishes spawn in the aquatic portions of wetlands (Peters, et al. 1979). Chain and grass pickerels are common throughout New Jersey (Hastings 1979) as are basses, crappies, bluegills, bullheads and carp. Hastings and Good (1977) found 17 species of fishes abundant in the freshwater tidal marshes of Woodbury Creek. Alewife and blueback herring use these types of wetlands as spawning and nursery grounds (Good, et al. 1975; Simpson, et al. 1983b). White perch commonly occur in freshwater tidal segments of Pine Barrens streams (Hastings 1979). The American shad spawns in freshwater streams. Historically, shad were abundant in the Delaware River system, but habitat losses and pollution have jeopardized their existence in New Jersey. A total of 19 shad spawning runs have been eliminated in the State. Today, the shad is a State-threatened species (N.J.D.E.P. and U.S.S.C.S. 1980). Thirty-six fishes have been reported in Pine Barrens streams, with 16 identified as characteristic species, including sunfishes, yellow bullhead, pirate perch, shiners and darters (Hastings 1979). Aquatic beds are recognized as important habitats for these latter species and the black-banded sunfish is especially abundant in dense beds.

Waterfowl and Other Bird Habitat

In addition to providing year-round habitats for resident birds, wetlands are particularly important as breeding grounds, overwintering areas and feeding grounds for migratory waterfowl and numerous other birds. Both coastal and inland wetlands are valuable bird habitats. Leck (1975) has described New Jersey's birds and their habitats.

New Jersey's inland wetlands serve as important nesting, feeding and resting areas for other resident and migrating birds. From 40-45 nesting species were observed in hardwood swamps of southern New Jersey, while fewer species were noted in mixed hardwood-cedar wetlands and pure Atlantic white cedar swamps (Wander 1980). Great crested flycatchers, pine warblers, towhees, chickadees, titmouses, prothonotary warblers, scarlet tanagers, vireos, acadian flycatchers, ovenbirds, black and white warblers, catbirds, common yellowthroats, brown creepers, hooded warblers and black throated green warblers were among the most important breeding birds. This study suggested that swamp size was somewhat less important than vegetative composition in determining avian diversity. Leck (1979) also identified eastern wood pewee, wood thrush, parula warbler, yellow warbler, redstart, and song sparrow as other breeding birds of cedar swamps. American bitterns, various waterfowl, long-billed marsh wrens, redwings, swamp sparrows and song sparrows nest in freshwater marshes, while veeries and yellowthroats utilize forested wetlands and wet thickets, respectively.

More than 30 species breed in northern cedar swamps near High Point State Park (Leck 1975). In the Great Swamp National Wildlife Refuge, wetland nesting birds include green heron, least bittern, American bittern, Canada goose, mallard, black duck, green-winged teal, blue-winged teal, wood duck, Virginia rail, sora, common gallinule, American woodcock, long-billed marsh wren, common yellowthroat and swamp sparrow. The wood duck is an important resident of forested wetlands where it nests in cavities of dead trees or in man-made nesting boxes. During migration, freshwater wetlands are important to many birds passing through New Jersey, especially for American woodcock (A. Petrongolo, pers. comm.).

Wetlands are, therefore, crucial for the existence of many birds, ranging from waterfowl and shorebirds to migratory songbirds. Some spend their entire lives in wetland environments, while others primarily use wetlands for breeding, feeding or resting.

Furbearer and Other Wildlife Habitat

Muskrat and beavers are the most important furbearers in New Jersey and they depend on wetlands. Muskrats are more abundant and wide ranging, inhabitating both coastal and inland marshes. By contrast, beavers tend to be restricted to inland wetlands, and are most abundant in Sussex County (Ferrigno 1984). In the Pine Barrens, beaver help perpetuate white cedar by feeding on hardwoods (Little 1950). Other wetland-utilizing furbearers include river otter, mink, raccoons, skunks, foxes, and weasels. Smaller mammals also frequent wetlands such as marsh and swamp rabbits, rice rats, numerous mice, meadow voles, bog lemmings and shrews, while large mammals may also be observed. White-tailed deer depend on white cedar swamps in the Pine Barrens and evergreen forested wetlands in northern New Jersey for winter shelter and food (Little 1950; Person 1983). They also use pitch pine lowlands for cover and breeding areas in winter (N.J.D.E.P. 1981).

Besides the animals previously mentioned, other forms of wildlife make their homes in wetlands. Reptiles (i.e., turtles and snakes) and amphibians (i.e., frogs and salamanders) are important residents. Turtles are most common in freshwater marshes and ponds. The more important ones nationally are the painted, spotted, Blanding's, map, pond, musk and snapping turtles (Clark 1979). In Pine Barrens wetlands, ten turtles may be found: bog, common snapping, eastern box, eastern mud, eastern painted, eastern spiny softshell, red-bellied, spotted, stinkpot and wood turtle (Conant 1979). The State-endangered bog turtle and State-threatened wood turtle depend on freshwater wetlands (N.J.D.E.P. and U.S.S.C.S. 1980). Along the coast, the diamond-backed terrapin is a common denizen of salt marshes.

Many snakes also inhabit wetlands, with water snakes being most abundant throughout the U.S. (Clark 1979). In Pine Barrens wetlands, several snakes can be found, including the black rat snake, eastern king snake, eastern worm snake, northern black racer, northern red-bellied snake, northern water snake, queen snake and rough green snake (Roman and Good 1983). The State-threatened northern pine snake and State-endangered timber rattlesnake also occur there. Garter snakes are probably common in New Jersey's inland wetlands.

Nearly all of the approximately 190 species of amphibians in North America are wetland-dependent at least for breeding (Clark 1979). Frogs occur in many freshwater wetlands and common frogs include the bull, green, leopard, mink, pickerel, wood and chorus frogs and spring peepers. For the Pine Barrens, Conant (1979) lists Fowler's toad, northern spring peeper, green frog, and southern leopard frog as abundant and eastern spadefoot and carpenter frog as common. He also reports that the State-endangered Pine Barrens treefrog is declining and is presently threatened by any drop in water table levels. Many salamanders use temporary ponds or wetlands for breeding, although they may spend most of the year in uplands. Common Pine Barrens salamanders include marbled salamander, red-backed salamander, and northern red salamander (Conant 1979). Numbers of amphibians, even in small wetlands, can be astonishing. For example, 1,600 salamanders and 3,800 frogs and toads were found in a small gum pond (less than 100 feet wide) in Georgia (Wharton 1978). In New Jersey, rare and State-endangered amphibians include the Pine Barrens treefrog, southern gray treefrog, blue-spotted salamander, eastern tiger salamander, eastern mud salamander and long-tailed salamander (N.J.D.E.P. and U.S.S.C.S. 1980).

Environmental Quality Values

Besides providing habitat for fish and wildlife, wetlands play a less conspicuous but essential role in maintaining high environmental quality, especially for aquatic habitats. They do this in a number of ways, including purifying natural waters by removing nutrients, chemical and organic pollutants, and sediment, and producing food which supports aquatic life.

Water Quality Improvement

Wetlands help maintain good water quality or improve degraded waters in several ways: (1) nutrient removal and retention, (2) processing chemical and organic wastes, and (3) reducing sediment load of water. Wetlands are particularly good water filters because of their locations between land and open water. Thus, they can both intercept runoff from land before it reaches the water and help filter nutrients, wastes and sediment from flooding waters. Clean waters are important to humans as well as to aquatic life.

First, wetlands remove nutrients, especially nitrogen and phosphorus, from flooding waters for plant growth and help prevent eutrophication or over-enrichment of natural waters. New Jersey's freshwater tidal wetlands are important in reducing nutrient and heavy metal loading from urban runoff in the upper Delaware River estuary (Simpson, et al. 1983c). It is, however, possible to overload a wetland and thereby reduce its ability to perform this function. Every wetland has a limited capacity to absorb nutrients and individual wetlands differ in their ability to do so.

Wetlands have been shown to be excellent removers of waste products from water. Sloey and others (1978) summarize the value of freshwater wetlands at removing nitrogen and phosphorus from the water and address management issues. They note that certain wetland plants are so efficient at this task that some artificial waste treatment systems are using these plants. For example, the Max Planck Institute of Germany has a patent to create such systems, where a bulrush (Scirpus lacustris) is the primary waste removal agent. Numerous scientists have proposed that certain types of wetlands be used to process domestic wastes and some wetlands are already used for this purpose (Sloey, et al. 1978; Carter, et al. 1979; Kadlec 1979). New Jersey's freshwater tidal wetlands may be valuable as tertiary treatment systems (Whigham and Simpson 1976). It must, however, be recognized that individual wetlands have a finite capacity for natural assimilation of excess nutrients and research is needed to determine this threshold (Good 1982).

Perhaps the best known example of the importance of wetlands for water quality improvement is Tinicum Marsh (Grant and Patrick 1970). Tinicum Marsh is a 512 acre freshwater tidal marsh lying just south of Philadelphia, Pennsylvania. Three sewage treatment plants discharge treated sewage into marsh waters. On a daily basis, it was shown that this marsh removes from flooding waters: 7.7 tons of biological oxygen demand, 4.9 tons of phosphorus, 4.3 tons of ammonia, and 138 pounds of nitrate. In addition, Tinicum Marsh adds 20 tons of oxygen to the water each day.

Swamps also have the capacity for removing water pollutants. Bottomland forested wetlands along the Alcovy River in Georgia filter impurities from flooding waters. Human and chicken wastes grossly pollute the river upstream, but after passing through less than 3 miles of swamp, the river's water quality was significantly improved. The value of the 2,300 acre Alcovy River Swamp for water pollution control was estimated at $1 million per year (Wharton 1970). In New Jersey, Durand and Zimmer (1982) have demonstrated the capacity of Pine Barrens wetlands to assimilate excess nutrients from adjacent agricultural land and upland development.

Wetlands also play a valuable role in reducing turbidity of flooding waters. This is especially important for aquatic life and for reducing siltation of ports, harbors, rivers and reservoirs. Removal of sediment load is also valuable because sediments often transport absorbed nutrients, pesticides, heavy metals and other toxins which pollute our Nation's waters (Boto and Patrick 1979). Depressional wetlands should retain all of the sediment entering them (Novitski 1978). In Wisconsin, watersheds with 40% coverage by lakes and wetlands had 90% less sediment in water than watersheds with no lakes or wetlands (Hindall 1975). Creekbanks of salt marshes typically support more productive vegetation than the marsh interior. Deposition of silt is accentuated at the water-marsh interface, where vegetation slows the velocity of water causing sediment to drop out of solution. In addition to improving water quality, this process adds nutrients to the creekside marsh which leads to higher density and plant productivity (DeLaune, et al. 1978).

The U.S. Army Corps of Engineers has investigated the use of marsh vegetation to lower turbidity of dredged disposal runoff and to remove contaminants. In a 50 acre dredged material disposal impoundment near Georgetown, South Carolina, after passing through about 2,000 feet of marsh vegetation, the effluent turbidity was similar to that of the adjacent river (Lee, et al. 1976). Wetlands have also been proven to be good filters of nutrients and heavy metal loads in dredged disposal effluents (Windom 1977).

Recently, the ability of wetlands to retain heavy metals has been reported (Banus, et al. 1974; Mudroch and Capobianca 1978; Simpson, et al. 1983c). Wetland soils have been regarded as primary sinks for heavy metals, while wetland plants may play a more limited role. Waters flowing through urban areas often have heavy concentrations of heavy metals (e.g., cadmium, chromium, copper, nickel, lead, and zinc). The ability of freshwater tidal wetlands along the Delaware River in New Jersey to sequester and hold heavy metals has been documented (Good, et al. 1975; Whigham and Simpson 1976; Simpson; et al. 1983a, 1983b, 1983c). Additional study is needed to better understand retention mechanisms and capacities in these and other types of wetlands.

Aquatic Productivity

Wetlands are among the most productive ecosystems in the world and some types of wetlands may be the highest, rivaling our best cornfields. Wetlands plants are particularly efficient converters of solar energy. Through photosynthesis, plants convert sunlight into plant material or biomass and produce oxygen as a by-product. Other materials, such as organic matter, nutrients, heavy metals, and sediment, are also captured by wetlands and either stored in the sediment or converted to biomass (Simpson, et al. 1983a). This biomass serves as food for a multitude of animals, both aquatic and terrestrial. For example, many waterfowl depend heavily on seeds of marsh plants, especially in winter, while muskrat eat cattail tubers and young shoots.

Although direct grazing of wetland plants may be considerable in freshwater marshes, their major food value to most aquatic organisms is reached upon death when plants fragment to form "detritus." This detritus forms the base of an aquatic food web that supports higher consumers, e.g., commercial fishes. Thus, wetlands can be regarded as the farmlands of the aquatic environment where great volumes of food are produced annually. The majority of non-marine aquatic animals also depend, either directly or indirectly, on this food source.

Socio-economic Values

The more tangible benefits of wetlands to society may be considered socio-economic values and they include flood and storm damage protection, erosion control, water supply and groundwater recharge, harvest of natural products, livestock grazing and recreation. Since these values provide either dollar savings or financial profit, they are more easily understood by most people.

Flood and Storm Damage Protection

In their natural condition, wetlands serve to temporarily store flood waters, thereby protecting downstream property owners from flood damage. After all, such flooding has been the driving force in creating these wetlands to begin with. This flood storage function also helps to slow the velocity of water and lower wave heights, reducing the water's erosive potential. Rather than having all flood waters flowing rapidly downstream and destroying private property and crops, wetlands slow the flow of water, store it for a period of time and slowly release stored waters downstream. This becomes increasingly important in urban areas, where development has increased the rate and volume of surface water runoff and the potential for flood damage. Although Fusillo (1981) has demonstrated this situation for the Pine Barrens, it is more applicable to northern New Jersey where flooding problems are prevalent.

In 1975, 107 people were killed by flood waters in the U.S. and potential property damage for the year was estimated to be $3.4 billion (U.S. Water Resources Council 1978). Almost half of all flood damage was suffered by farmers as crops and livestock were destroyed and productive land was covered by water or lost to erosion. Approximately 134 million acres of the conterminous U.S. have severe flooding problems. Of this, 2.8 million acres are urban land and 92.8 million acres are agricultural land (U.S. Water Resources Council 1977). Many of these flooded farmlands are wetlands. Although regulations and ordinances required by the Federal Insurance Administration reduce flood losses from urban land, agricultural losses are expected to remain at present levels or increase as more wetland is put into crop production. Protection of wetlands is, therefore, an important means to minimizing flood damages in the future.

The U.S. Army Corps of Engineers has recognized the value of wetlands for flood storage in Massachusetts. In the early 1970's, they considered various alternatives to providing flood protection in the lower Charles River watershed near Boston, including: (1) a 55,000 acre-foot reservoir, (2) extensive walls and dikes, and (3) perpetual protection of 8,500 acres of wetland (U. S. Army Corps of Engineers 1976). If 40% of the Charles River wetlands were destroyed, flood damages would increase by at least $3 million annually. Loss of all basin wetlands would cause an average annual flood damage cost of $17 million (Thibodeau and Ostro 1981). The Corps concluded that wetlands protection - "Natural Valley Storage" - was the least-cost solution to future flooding problems. In 1983, they completed acquisition of approximately 8,500 acres of Charles River wetlands for flood protection.

This protective value of wetlands has also been reported for other areas. Undeveloped floodplain wetlands in New Jersey protect against flood damages (Robichaud and Buell 1973). In the Passaic River watershed, annual property losses to flooding approached $50 million in 1978 and the Corps of Engineers is considering wetland acquisition as an option to prevent flood damages from escalating in the future (U.S. Army Corps of Engineers 1979). A Wisconsin study projected that floods may be lowered as much as 80% in watersheds with many wetlands compared with similar basins with little or no wetlands (Novitski 1978). Pothole wetlands in the Devils Lake basin of North Dakota store nearly 75% of the total runoff (Ludden, et al. 1983).

Recent studies at national wildlife refuges in North Dakota and Minnesota have demonstrated the role of wetlands in reducing streamflow. Inflow into the Agassiz National Wildlife Refuge and the Thief River Wildlife Management Area was 5,000 cubic feet per second (cfs), while outflow was only 1,400 cfs. Storage capacity of those areas reduced flood peaks at Crookston, Minnesota by 1.5 feet and at Grand Forks, North Dakota by 0.5 feet (Bernot 1979). Drainage of wetlands was the most important land-use practice causing flood problems in a North Dakota watershed (Malcolm 1978; Malcolm 1979). Even northern peat bogs reduce peak rates of streamflow from snow melt and heavy summer rains (Verry and Boelter 1979). Destruction of wetlands through floodplain development and wetland drainage have been partly responsible for recent major flood disasters throughout the country.

Besides reducing flood levels and potential damage, wetlands may buffer the land from storm wave damage. Salt marshes of smooth cordgrass are considered important shoreline stabilizers because of their wave dampening effect (Knudson, et al. 1982). Forested wetlands along lakes and large rivers may function similarly.

Erosion Control

Located between watercourses and uplands, wetlands help protect uplands from erosion. Wetland vegetation can reduce shoreline erosion in several ways, including: (1) increasing durability of the sediment through binding with its roots, (2) dampening waves through friction, and (3) reducing current velocity through friction (Dean 1979). This process also helps reduce turbidity and thereby improves water quality.

Obviously, trees are good stabilizers of river banks. Their roots bind the soil, making it more resistant to erosion, while their trunks and branches slow the flow of flooding waters and dampen wave heights. The banks of some rivers have not been eroded for 100 to 200 years due to the presence of trees (Leopold and Wolman 1957; Wolman and Leopold 1957; Sigafoos 1964).

Among the grass and grass-like plants, common reed and bulrushes have been regarded as the best at withstanding wave and current action (Kadlec and Wentz 1974; Seibert 1968). While most wetland plants need calm or sheltered water for establishment, they will effectively control erosion once established (Kadlec and Wentz 1974; Garbisch 1977). Wetland vegetation has been successfully planted to reduce erosion along U.S. waters. Willows, alders, ashes, cottonwoods, poplars, maples and elms are particularly good stabilizers (Allen 1979). Successful emergent plants include reed canary grass, common reed, cattail, and bulrushes in freshwater areas (Hoffman 1977) and smooth cordgrass along the coast (Woodhouse, et al. 1976).

Water Supply

Most wetlands are areas of ground-water discharge and some may provide sufficient quantities of water for public use. In Massachusetts, 40% to 50% of wetlands may be valuable potential sources of drinking water, since at least 60 municipalities have public wells in or very near wetlands (Motts and Heeley 1973). Prairie pothole wetlands store water which is important for wildlife and may be used for irrigation and livestock watering by farmers during droughts (Leitch 1981). These situations may hold true for New Jersey and other states and wetland protection could be instrumental in helping to solve current and future water supply problems.

Ground-water Recharge

There is considerable debate over the role of wetlands in ground-water recharge, i.e., their ability to add water to the underlying aquifer or water table. Recharge potential of wetlands varies according to numerous factors, including wetland type, geographic location, season, soil type, water table location and precipitation. In general, most researchers believe that wetlands do not serve as groundwater recharge sites (Carter, et al. 1979). A few studies, however, have shown that certain wetland types may help recharge ground-water supplies. Shrub wetlands in the Pine Barrens may contribute to ground-water recharge (Ballard 1979). Depressional wetlands like cypress domes in Florida and prairie potholes in the Dakotas may also contribute to ground-water recharge (Odum, et al. 1975; Stewart and Kantrud 1972). Floodplain wetlands also may do this through overbank water-storage (Mundorff 1950; Klopatek 1978). In urban areas where municipal wells pump water from streams and adjacent wetlands, "induced infiltration" may draw in surface water from wetlands into public wells. This type of human-induced recharge has been observed in Burlington, Massachusetts (Mulica 1977). These studies and others suggest that additional research is needed to better assess the role of wetlands in ground-water recharge.

Harvest of Natural Products

A variety of natural products are produced by wetlands, including timber, fish and shellfish, wildlife, peat moss, cranberries, blueberries. and wild rice. Wetland grasses are hayed in many places for winter livestock feed. During other seasons, livestock graze directly in many New Jersey wetlands. Along Delaware Bay, many New Jersey tidal marshes have been impounded for producing salt hay. These and other products are harvested for human use and provide a livelihood for many people.

In the 49 continental states, an estimated 82 million acres of commercial forested wetlands exist (Johnson 1979). These forests provide timber for such uses as homes, furniture, newspapers and firewood. Most of these forests lie east of the Rockies, where trees like oak, gum, cypress, elm, ash and cottonwood are most important. The standing value of southern wetland forests is $8 billion. These southern forests have been harvested for over 200 years without noticeable degradation, thus they can be expected to produce timber for many years to come, unless converted to other uses. Atlantic white cedar is the most profitable timber product from New Jersey's wetlands, but cedar stands are decreasing (Little 1950).

Many wetland-dependent fishes and wildlife are also utilized by society. Commercial fishermen and trappers make a living from these resources. From 1956 to 1975, about 60% of the U.S. commercial landings were fishes and shellfishes that depend on wetlands (Peters, et al. 1979). Nationally, major commercial species associated with wetlands are menhaden, salmon, shrimp, blue crab and alewife from coastal waters and catfish, carp and buffalo from inland areas. Recreational fishing, commercial fishing and shellfishing in New Jersey are valued at $217 million, $180 million, and $158 million, respectively (Bonsall 1977). Nationally, furs from beaver, muskrat, mink, nutria, and otter yielded roughly $35.5 million in 1976 (Demms and Pursley 1978). Louisiana is the largest fur-producing state and nearly all furs come from wetland animals. In New Jersey where muskrat dominates the harvest, furbearers produce an annual value of $3.5 million (Kantor 1977).

Many wetlands in southern New Jersey are cultivated to produce cranberries and highbush blueberries. Blueberry agriculture actually began in New Jersey at Whitesbog in 1916 and during the 1970's, the blueberry crop yielded a gross income of between $8-$14 million per year. Nationally, the State is second only to Michigan in blueberry production (P. Eck, pers. comm.). New Jersey also ranks third in the Nation in cranberry production which is valued at about $3.5 million annually (Applegate, et al. 1979). In addition, berries produced naturally in Pine Barrens and other wetlands in the State are harvested locally for personal consumption.

Although not as important in New Jersey as for some other states (e.g., New York and Michigan), some wetlands are mined for peat which is used mainly for enriching garden soils. For centuries peat has been used as a major fuel source in Europe. Recent shortages in other fuels, particularly oil and gas, have increased attention to wetlands as potential fuel sources. Unfortunately, peat mining destroys natural wetlands and most of their associated values.

Recreation and Aesthetics

Many recreational activities take place in and around wetlands. Hunting and fishing are popular sports. Waterfowl hunting is a major activity in wetlands, but big game hunting is also important locally. In 1980, 5.3 million people spent $638 million on hunting waterfowl and other migratory birds (U.S. Department of the Interior and Department of Commerce 1982). In 1982, an estimated 138,000 New Jersey residents purchased hunting licenses and they spent nearly 3 million person-days hunting wildlife (Snyder and Herrighty 1983). About 22% of these hunters participated in waterfowl hunting. Saltwater recreational fishing has increased dramatically over the past 20 years, with half of the catch represented by wetland-associated species. In 1979, nearly 1 million people, including 662,000 residents, fished in New Jersey's coastal waters. Estuarine-dependent fishes, i.e., fluke, bluefish, winter flounder and weakfish, were the most important species caught (N.J.D.E.P. 1982). Moreover, nearly all freshwater fishing, is dependent on wetlands. In 1975 alone, sportfishermen spent $13.1 billion to catch wetland-dependent fishes in the U. S. (Peters, et al. 1979).

Other recreation in wetlands is largely non-consumptive and involves activities like hiking, nature observation and photography, and canoeing and other boating. Many people simply enjoy the beauty and sounds of nature and spend their leisure time walking or boating in or near wetlands and observing plant and animal life. This aesthetic value is extremely difficult to evaluate or place a dollar value upon. Nonetheless, it is a very important one because in 1980, 28.8 million people (17% of the U.S. population) took special trips to observe, photograph or feed wildlife. Moreover, about 47% of all Americans showed an active interest in wildlife around their homes (U.S. Department of the Interior and Department of Commerce 1982).

Summary

Marshes, swamps and other wetlands are assets to society in their natural state. They provide numerous products for human use and consumption, protect private property, and provide recreational and aesthetic appreciation opportunities. Wetlands may also have other values yet unknown to society. For example, a microorganism from Pine Barrens swamps has been recently discovered to have great value to the drug industry. In searching for a new source of antibiotics, the Squibb Institute examined soils from around the world and found that only one contained microbes suitable for producing a new family of antibiotics. From a Pine Barrens swamp microorganism, scientists at the Squibb Institute have developed a new line of antibiotics which will be used to cure diseases not affected by present antibiotics (Moore 1981). This represents a significant medical discovery. If these wetlands were destroyed or grossly polluted, this discovery may not have been possible.

Destruction or alteration of wetlands eliminates or minimizes their values. Drainage of wetlands, for example, eliminates all the beneficial effects of the marsh on water quality and directly contributes to flooding problems (Lee, et al. 1975). While the wetland landowner can derive financial profit from some of the values mentioned, the general public receives the vast majority of wetland benefits through flood and storm damage control, erosion control, water quality improvement and fish and wildlife resources. It is, therefore, in the public's best interest to protect wetlands to preserve these values for themselves and future generations. This is particularly important to a densely populated state like New Jersey where extensive wetlands have already been lost, making the remaining wetlands even more valuable as public resources.

Table 1. Acreage of palustrine wetland types - FAA Technical Center. The predominant map code is listed in parentheses following the wetland type name.

Palustrine Wetland Type	Acreage
Emergent (PEM)	
Temporarily Flooded (PEMA)	0.79
Seasonally Flooded (PEMC)	2.19
Seasonally Flooded/Saturated (PEME)	1.36
Semipermantly Flooded (PEMF)	0.93
Total Emergent Wetlands	*5.27*
Forested (PFO)	
Evergreen (PFO4)	
Temporarily Flooded (PFO4A)	106.33
Saturated (PFO4B)	134.34
Seasonally Flooded (PFO4C)	7.72
Seasonally Flooded/Saturated (PFO4E)	209.98
Deciduous (PFO1)	
Temporarily Flooded (PFO1A)	0.62
Saturated (PFO1B)	1.35
Seasonally Flooded (PFO1C)	38.92
Seasonally Flooded/Saturated (PFO1E)	20.13
Total Forested Wetlands	519.39
Scrub-shrub (PSS)	
Evergreen (PSS4)	
Saturated (PSS4B)	1.15
Deciduous (PSS1)	
Temporarily Flooded (PSS1A)	4.67
Seasonally Flooded (PSS1C)	0.92
Seasonally Flooded/Saturated (PSS1E)	6.50
Total Scrub-Shrub Wetlands	13.24
Unconsolidated Bottoms (PUB)	
Semipermantly Flooded (PUBF)	0.65
Permanently Flooded (PUBH)	8.98
Artificially Flooded (PUBK)	17.05
Unconsolidated Shores (PUS)	
Seasonally Flooded (PUSC)	0.4
Total Nonvegetated Wetlands	27.08
GRAND TOTAL WETLANDS	**564.98**

Table 2. Examples of palustrine forested wetland plant communities at the FAA Center and vicinity. This listing is not intended to be comprehensive, but simply presents some communities observed during ground truthing exercises associated with NWI photointerpretation. Wetland type refers to the NWI map code following Cowardin, et al. (1979).

Dominance Type (Wetland Type)	Common Associates	Less Common Species
Red Maple (PFO1C)	Sweet Bay, Cinnamon Fern, Sweet Pepperbush, Swamp Azalea, Fetterbush	Common Greenbrier, Royal Fern, Highbush Blueberry, Inkberry (edge)
Pitch Pine-Red Maple (PFO4/SS1E)	Sweet Pepperbush, Inkberry	Atlantic White Cedar, Switchgrass, Post Oak, Common Reed, Lowland Broomsedge, Woolgrass, Soft Rush, Black Gum, Bayberry (edge)
Pitch Pine (PFO4E)	Red Maple	Soft Rush, Fetterbush, Chokeberry, Switchgrass, Common Greenbrier, Multiflora Rose (edge)
Black Gum (PFO1B)	Highbush Blueberry, Common Greenbrier	American Holly, Hawthorn, Sweet Bay, Ground-pine, Hair-cap Moss
Pitch Pine-Black Gum-Red Maple (PFO4/1B)	Peat Moss, Cinnamon Fern, Dangleberry, Common Greenbrier	Ground-pine, Hair-cap Moss, American Holly, Sweet Bay, Inkberry
Pitch Pine (PFO4E)	Pin Oak, Red Maple, Fetterbush	American Holly, Wintergreen, Highbush Blueberry, Sweet Pepperbush, Dangleberry, Bracken Fern (edge)
Pitch Pine (PFO4B)	Sweet Pepperbush, Red Maple, Black Gum, Highbush Blueberry	Winterberry, Swamp Azalea, Bracken Fern, Cinnamon Fern, Chokeberry, Sweet Bay, American Holly, Common Greenbrier, Mountain Laurel, Staggerbush, Wintergreen
Pitch Pine-Black Gum (PFO4/1A)	Highbush Blueberry, Common Greenbrier, Wintergreen, Dangleberry	Bracken Fern, Scrub Oak

(Table 2. continued)

Pitch Pine-Black Gum (PFO4/1A)	Red Maple, Common Greenbrier, Highbush Blueberry	Inkberry, Switchgrass, Staggerbush, Black Jack Oak, Fetterbush, Post Oak, Sedge, Bracken Fern, Sheep Laurel, Sweet Pepperbush, Hair-cap Moss, Bog Moss, Dangleberry
Atlantic White Cedar (PFO4Eg)	Sweet Pepperbush, Highbush Blueberry, Swamp Azalea, Marsh Fern, Cinnamon Fern, Peat Moss	Mountain Laurel, Swamp Dewberry, American Holly, Red Maple, Sweet Bay, Bayberry
Pitch Pine (PFO4B)	Black Gum, Red Maple, Sweet Bay, Mountain Laurel, Highbush Blueberry, Fetterbush	Inkberry, Common Greenbrier, Cinnamon Fern, Dangleberry, Winterberry, Swamp Azalea
Pitch Pine-Red Maple-Black Gum (PFO4/1E)	Mountain Laurel, Sweet Bay, Highbush Blueberry, Peat Moss, Swamp Azalea, Swamp Dewberry, Cinnamon Fern, Sweet Pepperbush	Common Greenbrier, American Holly, Atlantic White Cedar

Table 3. List of major wetland values.

FISH AND WILDLIFE VALUES

- Fish and Shellfish Habitat
- Waterfowl and Other Bird Habitat
- Furbearer and Other Wildlife Habitat

ENVIRONMENTAL QUALITY VALUES

- Water Quality Maintenance
  - Pollution Filter
  - Sediment Removal
  - Oxygen Production
  - Nutrient Recycling
  - Chemical and Nutrient Absorption
- Aquatic Productivity
- Microclimate Regulator
- World Climate (Ozone layer)

SOCIO-ECONOMIC VALUES

- Flood Control
- Wave Damage Protection
- Erosion Control
- Ground-water Recharge
- Water Supply
- Timber and Other Natural Products Energy Source (Peat)
- Livestock Grazing
- Fishing and Shellfishing
- Hunting and Trapping
- Recreation
- Aesthetics
- Education and Scientific Research

References

Allen, H.H. 1979. Role of wetland plants in erosion control of riparian shorelines. In: P.E. Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 403-414.

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

Ballard, J.T. 1979. Fluxes of water and energy through the Pine Barrens ecosystems. In: R.T.T. Forman (editor). Pine Barrens: Ecosystem and Landscape. Academic Press, Inc., New York. pp. 133-146.

Banus, M., I. Valiela, and J.M. Teal. 1974. Export of lead from saltmarshes. Mar. Poll. Bull. 5: 6-9.

Bernot, C. 1979. Water Bank: Keeping Wetlands Wet. The Minnesota Volunteer 42(246):4.

Bonsall, S. 1977. The Fishing Industry of New Jersey. Rutgers Univ., Center for Coastal and Environmental Studies, New Brunswick, NJ 9 pp.

Boto, K.G. and W.H. Patrick, Jr. 1979. Role of wetlands in the removal of suspended sediments. In: P.E. Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 479-489.

Carter, V., M.S. Bedinger, R.P. Novitski and W.O. Wilen. 1979. Water resources and wetlands. In: P.E. Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 344-376.

Clark, J.E. 1979. Fresh water wetlands: habitats for aquatic invertebrates,amphibians, reptiles, and fish. In: P.E. Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 330-343.

Conant, R. 1979. A zoolological review of the amphibians and reptiles of southern New Jersey, with emphasis on the Pine Barrens. In: R.T.T. Forman (editor). Pine Barrens: Ecosystem and Landscape. Academic Press, Inc., New York. pp. 467-488

Cowardin, L.M., V. Carter, F.C. Golet, and T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Washington, DC. FWS/OBS-79/31. 103 pp.

Dean, R.G. 1979. Effects of vegetation on shoreline erosional processes.In: P.E. Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 415-426.

DeLaune, R.D., W.H. Patrick, Jr. and R.J. Buresk. 1978. Sedimentation rates determined by 137Cs dating in a rapidly accreting salt marsh. Nature 275: 532-533.

Demms, E.F., Jr. and D. Pursley (editors). 1978. North American Furbearers:Their Management, Research and Harvest Status in 1976. International Assoc. of Fish and Wildlife Agencies. 157 pp.

Durand, J.B. and B. Zimmer. 1982. Pinelands Surface Water Quality. Part I.Rutgers Univ., Center for Coastal and Environmental Studies, New Brunswick, NJ. 196 pp.

Ferrigno, D.M. 1984. Distribution and Population Trends of New Jersey Beaver Population. N.J. Dept. of Environmental Prot., Division of Fish, Game and Wildlife. Project No. W-59-R-6; Job IV-A. 21 pp.

Fusillo, T.V. 1981. Impact of Suburban Residential Development on WaterResources in the Area of Winslow Township, Camden County, New Jersey. U.S. Geol. Survey, Water Resources Div., Trenton. N.J. Water Resources Investigations 8-27. 28 pp.

Garbisch, E.W., Jr. 1977. Marsh development for soil erosion. In: Proc. ofthe Workshop on the Role of Vegetation in Stabilization of the Great Lakes Shoreline. Great Lakes Basin Commission, Ann Arbor, MI. pp. 77-94.

Good, R.E. (editor). 1982. Ecological Solutions to Environmental ManagementConcerns in the Pinelands National Reserve. Proceedings of a conference, April 18-22, 1982. Rutgers Univ., Div. of Pinelands Research, New Brunswick, NJ. 47 pp.

Good, R.E., R.W. Hastings, and R.E. Denmark. 1975. An Environmental Assessment of Wetlands: A Case Study of Woodbury Creek and Associated Marshes. Rutgers Univ., Mar. Sci. Ctr., New Brunswick, NJ. Tech. Rept. 75-2. 49 pp.

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. pp. 105-123.

Greeson, P.B., J.R. Clark and J.E. Clark (editors). 1979. Wetland Functions and Values: The State of Our Understanding. Proc. of the National Symposium on Wetlands. November 7-10, 1978. Amer. Water Resources Assoc., Minneapolis, Minnesota. 674 pp.

Hastings, R.W. 1979. Fish of the Pine Barrens. In: R.T.T. Forman (editor). Pine Barrens: Ecosystem and Landscape. Academic Press, Inc., New York. pp. 489-504.

Hindall, S.M. 1975. Measurements and Prediction of Sediment Yields inWisconsin Streams. U.S. Geological Survey Water Resources Investigations 54-75. 27 pp.

Hoffman, G.R. 1977. Artificial establishment of vegetation and effects of fertilizer along shorelines of Lake Oahe and Sakakawea mainstream Missouri River reservoirs. In: Proc. Workshop on the Role of Vegetation in Stabilization of the Great Lakes Shoreline. Great Lakes Basin Commission, Ann Arbor, MI. pp. 95-109.

Johnson, R.L. 1979. Timber harvests from wetlands. In: P.E. Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 598-605.

Kadlec, J.A. and W.A. Wentz. 1974. State-of-the-art Survey and Evaluation of Marsh Plant Establishment Techniques: Induced and Natural. Vol. I: Report of Research. Tech. Rept. D-74-9. U.S. Army Engineers Waterways Expt. Stat., Vicksburg, MS.

Kadlec, R.H. 1979. Wetlands for tertiary treatment. In: P.E. Greeson, etal. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 490-504.

Kantor, R.A. 1877. Estuarine and Wetland Resources: A Staff Working Paper. N.J. Dept. Environ. Prot., Trenton. 125 pp.

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

Knudson, P.L., R.A. Brocchu, W.N. Seelig and M. Inskeep. 1982. Wave dampening in Spartina alterniflora marshes. Wetlands (Journal of the Society of Wetland Scientists) 2: 87-104.

Leck, D. 1975. Birds of New Jersey. Their Habits and Habitats. Rutgers Univ. Press, New Brunswick, NJ. 190 pp.

Leck, C.F. 1979. Birds of the Pine Barrens. In: R.T.T. Forman (editor). Pine Barrens: Ecosystem and Landscape. Academic Press, Inc., New York. pp. 457-466.

Lee, C.R., R.E. Hoeppel, P.G. Hunt and C.A. Carlson. 1976. Feasibility of the Functional Use of Vegetation to Filter, Dewater, and Remove Contaminants from Dredged Material. Tech. Rept. D-76-4. U.S. Army Engineers, Waterways Expt. Sta., Vicksburg, MS.

Lee, G.F., E. Bentley, and R. Amundson. 1975. Effects of marshes on water quality. In: A.D. Hasler (editor). Coupling of Land and Water Systems. Springer-Verlag, New York. pp. 105-127.

Leitch, J.A. 1981. Wetland Hydrology: State-of-the-art and Annotated Bibliography. Agric. Expt. Stat., North Dakota State Univ., Fargo, ND. Res. Rept. 82. 16 pp.

Leopold, L.B. and M.G. Wolman. 1957. River Channel Patterns -Braided,Meandering, and Straight. U.S. Geol. Survey Prof. Paper 282-B.

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.

Ludden, A.P., D.L. Frink, and D.H. Johnson. 1983. Water storage capacity of natural wetland depressions in the Devils Lake Basin of North Dakota. J. Soil and Water Cons. 38(1): 45-48.

Moore, M. 1981. Pineland germ yields new antibiotic. Sunday Press(September 6, 1981), Atlantic City, NJ.

Motts, W.S. and R.W. Heeley. 1973. Wetlands and groundwater. In: J.S.Larson (editor). A Guide to Important Characteristics and Values of Freshwater Wetlands in the Northeast. University of Massachusetts, Water Resources Research Center. Pub. No. 31. pp. 5-8.

Mudroch, A. and J. Capobianco. 1978. Study of selected metals in marshes on Lake St. Clair, Ontario. Archives Hydrobiologic. 84: 87-108.

Mulica, W.S. 1977. Wetlands and Municipal Ground Water Resource Protection.In: R.B. Pojasek (editor). Drinking Water Quality Enhancement Through Source Protection Ann Arbor Science Publishers, Michigan. pp 297-316.

Mundorff, M.J. 1950. Floodplain Deposits of North Carolina Piedmont and Mountain Streams as a Possible Source of Groundwater Supply. N.C. Div. Mineral Res. Bull. 59.

National Wetlands Inventory. 1990. Photointerpretation Conventions for the National Wetlands Inventory. U.S. Fish and Wildlife Service, St. Petersburg, FL. 45 pp. plus appendices.

New Jersey Department of Environmental Protection and U.S. Soil Conservation Service. 1980. Endangered and Threatened Species of New Jersey. Cooperative publication. 44 pp.

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. Div. of Fish, Game and Wildlife, Trenton. Deer Report No. 8. 9 pp.

New Jersey Department of Environmental Protection. 1982. New Jersey Marine Fisheries Administration1982. 20 pp.

Novitzki, R.P. 1978. Hydrology of the Nevin Wetland Near Madison, Wisconsin.U.S. Geological Survey, Water Resources Investigations 78-48. 25 pp.

Odum, J.T., K.C. Egel, W.J. Mitsch, and J.W. Ordway. 1975. Recycling Treated Sewage Through Cypress Wetlands in Florida. Univ. of Florida, Center for Wetlands, Gainesville. Occassional Pub. No. 1.

Person, D. 1983. Deer Range Survey. N.J. Department of Environmental Protection, Division of Fish, Game and Wildlife. Project No. W-45-R-18; Study III. 5 pp.

Peters, D.S., D.W. Ahrenholz, and T.R. Rice. 1979. Harvest and value of wetlands associated fish and shellfish. In: Greeson, et al. Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assoc. pp. 606-617.

Robichaud, B. and M.F. Buell. 1973. Vegetation of New Jersey: A Study of Landscape Diversity. Rutgers Univ. Press, New Brunswick, NJ. 340 pp.

Roman, C.T. and R.E. Good. 1983. Wetlands of the New Jersey Pinelands: Values, Functions, Impacts and a Proposed Buffer Delineation Model. Rutgers Univ., Div. of Pinelands Research, New Brunswick, NJ. 123 pp.

Seibert, P. 1968. Importance of natural vegetation for the protection of the banks of streams, rivers, and canals. In: Nature and Environment Series (Vol. Freshwater), Council of Europe. pp. 35-67.

Sigafoos, R.S. 1964. Botanical Evidence of Floods and Floodplain Deposition,Vegetation, and Hydrologic Phenomena. U.S. Geol. Survey Prof. Paper 485-A.

Simpson, R.L., R.E. Good, B.J. Dubinski, J.J. Pasquale and K.R. Philipp.1983a. Fluxes of Heavy Metals in Delaware River Freshwater Tidal Wetlands. Rutgers University, Center for Coastal and Environmental Studies, New Brunswick, NJ. 79 pp.

Simpson, R.L., R.E. Good, M.A. Leck, and D.F. Whigham. 1983b. The ecology of freshwater tidal wetlands. BioScience 33(4): 255-259.

Simpson, R.L., R.E. Good, R. Walker, and B.R. Frasco. 1983c. The role of Delaware River freshwater tidal wetlands in the retention of nutrients and heavy metals. J. Environ. Qual. 12(1): 41-48.

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

Snyder, F. and L. Herrighty. 1983. Harvest, Recreational and Economic Surveys. N.J. Department of Environmental Protection, Division of Fish , Game and Wildlife. Project No. W-52-R-11: Study XVI. 26 pp.

Stuber, P.J.R. 1983. User's Handbook for the Wetland Values Database. U.S. Fish and Wildlife Service. W/RMMG-83/ w12. 47 pp.

Tiner, R.W., Jr. 1985. Wetlands of New Jersey. U.S. Fish and Wildlife Service, National Weltands Inventory, Newton Corner, MA. 117 pp.

Thibodeau, F.R. and B.D. Ostro. 1981. An economic analysis of wetland protection. J. Environ. Manage. 12: 19-30.

U.S. Army Corps of Engineers. 1976. Natural Valley Storage: A Partnershipwith Nature. New England Division, Waltham, MA.

U.S. Army Corps of Engineers. 1979. Passaic River Basin Study. Plan of Study. New York District. 240 pp.

U.S. Department of the Interior and Department of Commerce. 1982. 1980 National Survey of Fishing, Hunting and Wildlife Associated Recreation. Fish and Wildlife Service and Bureau of Census. 156 pp.

U.S. Water Resources Council. 1977. Estimated Flood Damages. Appendix B.Nationwide Analysis Report. Washing ton, DC.

U.S. Water Resources Council. 1978. The Nation's Water Resources 1975-2000.Vol. 1: Summary. Washington, DC. 86 pp.

Wander, W. 1980. Breeding birds of southern New Jersey cedar swamps. N.J.Audubon VI(4): 51-65.

Wharton, C.H. 1970. The Southern River Swamp - A Multiple Use Environment.School of Business Administration, Georgia State University. 48 pp.

Warton, C.H. 1978. The Natural Environments of Georgia. Georgia Dept. of Nat. Res., Atlanta. 227 pp.

Whigham, D.F. and R.L. Simpson. 1976. The potential use of freshwater tidalmarshes in the management of water quality in the Delaware River. In: J. Tourbier and R.W. Peirson, Jr. (editors). Biological Control of Water Pollution. Univ. of Pennsylvania Press. pp. 173-186.

Windom, H.L. 1977. Ability of Salt Marshes to Remove Nutrients and HeavyMetals from Dredged Material Disposal Area Effluents. Technical Rept. D-77-37. U.S. Army Engineers, Waterways Expt. Sta., Vicksburg, MS.

Woodhouse, W.W., E.D. Seneca, and S.W. Broome. 1976. Propagation and Use ofSpartina alterniflora for Shoreline Erosion Abatement. U.S. Army Coastal Engineering Research Center. Tech. Rept. 76-2.

Wolman, W.G. and L.B. Leopold. 1957. River Floodplains. Some Observationson Their Formation. U.S. Geol. Survey Prof. Paper 282-C.