A CONCEPTUAL FRAMEWORK FOR PINELANDS DECISION-MAKING

Prepared for the
NEW JERSEY PINELANDS COMMISSION

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INTRODUCTION

The major goal of both the federal and state legislation dealing with the Pinelands is the protection and preservation of the significant ecological and natural resources of the area.[1] Identifying what these resources are and under what conditions their continued existence may be assured is a prerequisite to the preparation of the Pinelands comprehensive management plan.

This report stems from a request of the Pinelands Commission staff to enlist a group of scientists to define the essential character of the Pinelands natural environment, to explain how it came to be, to forecast what might cause future change in it, and to identify planning policies and management actions to ensure the continued existence of the essential character of the present Pinelands environment.

The names of the scientists who participated in this project are listed on the page that follows; all were contributors to the recently-published book on the landscape of the Pinelands, entitled "Pine Barrens: Ecosystem and Landscape" and edited by Richard T. T. Forman.[2] The material in this book and that in previously published ecological inventories of the late Jack McCormick and other references cited in the Appendix were used as the foundation for Section 1 [SIGNIFICANT NATURAL RESOURCE FEATURES OF THE PINELANDS] and Section 2 [INFLUENCES ON THE HISTORICAL EVOLUTION OF THE PINELANDS].

The Science Participants offered helpful evaluations of draft material for Sections 1 and 2, and individually submitted comments for incorporation in Section 3 [INFLUENCES THAT COULD CAUSE CHANGE IN THE PINELANDS ECOSYSTEMS] and Section 4 [FUTURE CHANGE IN THE PINELANDS LANDSCAPE, ECOSYSTEMS, AND THEIR COMPONENTS]. The individual perspectives were woven together so as to develop an outline for the substance of Sections 3 and 4 of the report and identification of the issues that could form the basis for Section 5 [RECOMMENDATIONS FOR MANAGEMENT POLICIES AND ACTIONS].

The Science Participants, Leland Merrill and myself met at an all-day working conference to discuss the report material; members of the Pinelands Commission Staff were present as observers. From the meeting came a consensus which permitted the drafting of a preliminary

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[1] National Parks and Recreation Act of 1978, Section 502; State of New Jersey Pinelands Protection Act of 1979 (S3091).

[2] Forman, R.T.T., ed. 1979. "Pine Barrens: Ecosystem and Landscape." Academic Press. New York, New York.

report. This was circulated to all Science Participants for review; comments were incorporated in the final report.

Leland Merrill, Jr. coordinated contractual arrangements with the Pinelands Commission staff, recruited the Science Participants, and handled other administrative responsibilities involved in project execution; also, he has been responsible for preparation of the map of the Pinelands critical areas that accompanies the recommendations made in Section 5 of the report.

Beryl Robichaud

March 6, 1980

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SECTION 1

SIGNIFICANT NATURAL RESOURCE FEATURES OF THE PINELANDS

1.1. OBJECTIVE

The objective of this section is to provide a description of the essential character of the existing Pinelands environment and its unique and significant ecological and other natural resource features.

1.2. INTRODUCTION

That a contiguous forest of more than one million acres presently exists in the most densely populated state, and one of the smallest, in the country is in itself a unique feature of the Pinelands. Also of significance is the fact that many of the natural habitats of the Pinelands and the plants and animals that occupy these are very different from those in other areas of New Jersey.

Even more important is the fact that the Pinelands is truly a unique landscape. Although small patches of a few types of the Pinelands features can be found in the coastal areas of New York to New England, in the Appalachian Mountains and in other scattered small areas on this continent and others, there is no extensive area in the world that has the same patterns of natural habitats, distributions of plant and animal populations, and the particular variety of plant and animal species that are found in the Pinelands. The vast extensive plain of scrubby pine forest, the concentration of rare and unusual plant and animal species, and the dwarf forest of the Pine Plains combine to make the Pinelands a network of ecosystems recognized throughout the world as biologically distinctive.

Three sets of features contribute to the essential character of the Pinelands. First, there are the physical features of the landscape -- relief, soils, and hydrology primarily -- that distinguish the natural habitats of the Pinelands in which plants and animals live. Second, there are the living organisms themselves -- the plants and animals that characterize the Pinelands. And, third, there are ecosystem processes -- the dynamic interrelationships among and between the living organisms and their particular habitat elements. Such interrelationships have evolved through thousands of years, giving us the Pinelands as it exists today. Outside influences, natural and human-caused, may interrupt or modify these interrelationships and change the essential character of the landscape. This is the concern for the future. In this Section, the elements making up the essential character of the existing Pinelands environment are described, organized in four parts as follows:

1.3 Habitat Features of the Pinelands

1.4 Flora of the Pinelands

1.5 Fauna of the Pinelands

1.6 Ecosystem Interrelationships in the Pinelands

The particular factors that influenced the evolution of the present Pinelands landscape, to make the essential character what it is today, are described in Section 2.

1.3. HABITAT FEATURES OF THE PINELANDS

The Pinelands is located on the Atlantic Coastal Plain which extends northward to Cape Cod and southward to the tip of Florida and then continues westward into Mexico as the Gulf Coast Plain. It is a landscape of low relief with gentle undulations without steep cliffs, ridges, or valleys. It has a surface of unconsolidated sands and gravels with few boulders or hard rock strata present. Its area in New Jersey is delineated by the presence of sandy infertile soils as compared with those in bordering lands to the north, west and south. It is the distinctive characteristics of the Pinelands soils combined with particular surface and subsurface hydrological features that account for the differentiation of habitats in the Pinelands.

1.3.1. Soils of the Pinelands

The soils of the Pinelands, which have developed on sandy geologic deposits, are unusually porous and acid. The parent soil material has a larger proportion of coarse sandy particles than finer silt and clay particles. The greater the proportion of coarser particles in a soil, the less its capacity to retain both water and nutrients. Thus, even though the Pinelands receives at least the same amount of rainfall as its surrounding areas, the water drains so rapidly through the soil that little moisture or nutrients are left in the soil.

The Pinelands soils are not completely uniform in composition, and on the upland surfaces where the water table does not intrude, seven types (or series) of soils have been identified. These differ in capacities to hold water and nutrients though all have fairly small amounts of fine material and thus are droughty and low in fertility. One of the common soils of the Pinelands is called the Lakewood. This soil is droughty and very low in capacity to hold nutrients. It also is a very acid soil, with modal pH values in the upper soil horizons of about 4.6. In contrast to other soils that have formed in the same climatic region, the Lakewood resembles the infertile soils typical of colder regions. It, like Subarctic soils, is said to be a podzol, meaning that all of the finer particles and organic materials are leached out of the upper horizons of the soil, bleaching them in color as contrasted with the darker lower soil horizons. Such soils are always highly acid and impoverished in nutrients and moisture.

1.3.2. Hydrology of the Pinelands

Equally as distinctive as its soils are the hydrological features of the Pinelands. Most of the Pinelands is drained by rather closely spaced and somewhat parallel streams flowing to barrier bays along the Atlantic Ocean or south to the Delaware Bay. The Rancocas Creek is one of the major exceptions; it flows westward from its source in the Pinelands to drain into the Delaware River.

The first unique hydrological feature is the huge underground reservoir (or aquifer) of essentially unpolluted freshwater contained within the Pinelands boundaries. The source of water for both the aquifer and the Pinelands streams is the 45" of annual precipitation. Of this, about one-half percolates through the sandy soil to the ground-water reservoirs where it discharges directly to local streams or moves more slowly to discharge much later in lower portions of the drainage basin.

Except in extreme upland areas, the water table which is the upper surface of the aquifer is seldom more than 20 feet beneath the surface and in most places is even less. Where the water table intercepts the land surface, as it does frequently, a stream or wetland is formed. This results in a highly variable pattern of uplands and lowlands, one of the distinctive features of the Pinelands landscape.

The streams in the Pinelands are typically slow moving and shallow because of the very low topographic gradient. The unusual brown or so-called tea-colored stream waters result from the abundance of an organic iron complex derived from the oxidation of iron ions dissolved in ground-water and mixed with plant exudates at the surface. Bog iron accumulates on stream bottoms. The waters of both streams and lakes in the Pinelands are low in hardness, alkalinity and pH values, and most are generally high in humic complex especially during the growing season.

The characteristic stream water quality in the Pinelands can be expressed in terms of values that describe the least disturbed waters in the area. Selected parameter values are as follows:

pH - Value of less than 5.0

Nitrate-nitrogen concentration - Value of about .17 parts per million except higher in winter

Ammonia-nitrogen - Value of about .036 parts per million

Total phosphate - Value of about .019 parts per million

Percent saturation dissolved oxygen - 85%

The fact that the ground-water aquifer and most streams are still low in nutrients (or essentially unpolluted) in these days makes the Pinelands unusual. However, particular land-use activities in localized areas are beginning to change this. The streams are extremely sensitive to pollutants from agricultural and other run-offs and reflect the presence of these by changes in biological communities, such as the growth of algal blooms. The levels of nutrients and water in the streams of the Pinelands strongly affect the ecosystems and biological communities of the coastal estuaries.

1.3.3. Types of Pinelands Habitats

Varying patterns of surface water levels combined with gradient changes in soil texture and fertility create within the Pinelands different types of habitats for plants and animals. Differentiation of Pinelands habitats is made on the basis of the relative amount of soil moisture.

On the basis of a relative moisture gradient ranging from the wettest soil condition to the driest condition, four habitats are recognized in the Pinelands. These are as follows:

1. Streams and Lakes are Pinelands sites covered by water all year round. The waters are typically acid, low in nutrients, hardness and dissolved solids, but high in complexed organic-iron substances.

2. Marsh Habitats are sites on which there is standing water on the soil surface most of the year or which are subject to flooding regularly year round for some part of each day. Further distinction is made between saltwater and freshwater habitats based on water salinity.

3. Lowland Habitats (Swamps and Bogs) are sites on which there is standing water on the soil surface for only certain parts of the year, most often in winter and spring. Then, standing water may accumulate in depressions of land or above the soil surface where the water table is unusually high. By late summer the water on such sites normally will drop to below the soil surface.

   In some lowlands, because of poor drainage (where there is little or no movement of water) dead plant and other organic remains do not fully decompose to become part of the soil material but rather accumulate to form layers of material called peat. Accumulations of peat are accompanied by very acid conditions and low fertility to which some plants are intolerant. Because of this varying tolerance to the peat condition, lowland habitats are usually further differentiated. Lowlands with large accumulations of peat are called bogs and those without large amounts of peat are called swamps, though such differentiation cannot always be made with scientific exactness.

4. Upland Habitats are sandy sites in the Pinelands where the groundwater level is about 2 to 3 feet below the surface and may be as deep as 60 feet. Such sites, because of the poor water-holding capacity of the Pinelands soils, are excessively drained and low in soil moisture. Within the Pinelands upland category, there are variations in soil conditions based on soil texture and the capacity of particular soils to hold more moisture and nutrients than others.

1.3.4. Patterns of Habitat Diversity

The distinctive landscape of the Pinelands is shaped by patches of the four habitat types appearing throughout the area. In some cases lowland and upland habitats come together through transitional zones of varying moisture. In other cases upland and lowlands merge with abrupt boundaries. In still other cases small irregularities in the soil surface may produce an upland habitat as an enclave within a lowlands, or enclaves of lowland habitats in depressions within an uplands. Most of the time, but not always, different types of plants and animals tend to occupy different types of habitats. This produces in the Pinelands an unusually rich mosaic of habitat and landscape diversity.

1.4. FLORA OF THE PINELANDS

About 850 species of plants now grow in the Pinelands. Of these, 270 are identified as species introduced into the area by man and the remaining 580 are native. In the Pinelands, as in other areas, plant species with similar tolerance ranges and requirements for environmental resources such as light, water, nutrients, and heat may grow together naturally in more or less the same population proportions under particular habitat conditions. Such distinctive groupings are called vegetation types or plant communities (or associations). Gradations in soil moisture, acid and low-nutrient soil capacity and fire have been the primary controlling influences on the Pinelands flora.

References cited in the Appendix contain complete descriptions of the types of plants and plant communities found in the Pinelands. The purpose of this report is to identify the significant and unique characteristics of the flora as a component of the present Pinelands environment. This is done by looking at the flora from three aspects -- dominant species, geographic ranges of present flora, and vegetation types and their patterns of distribution.

1.4.1. Dominant Species of the Pinelands

The tree most characteristic of the Pinelands is the pitch pine.[1] Although this tree is the most abundant tree in the Pinelands, it grows only in sparse numbers in other areas of New Jersey. The domination of the pitch pine, along with the presence of shortleaf pine,[2] classifies the Pinelands as a region of extensive evergreen forest while the remaining upland forest land in New Jersey and that in neighboring states are identified as deciduous forests of dominant broad-leaved trees that shed their leaves in winter. The evergreen nature of the Pinelands is also reflected in the white cedar swamp forests although deciduous hardwood swamps have become more abundant in the lowlands.

The shrubs characteristic of the Pinelands are for the most part of the heath family and include species of cranberry, blueberry, leather-leaf, huckleberry, laurel, bearberry, sand myrtle, and many others.

1.4.2. Geographical Ranges of Rare and Unusual Species of the Pinelands Flora

Of the 850 identified plant species in the Pinelands, the majority of these have ranges that extend geographically north, west, and south of the Pinelands. But a distinctive feature of the Pinelands flora is the large number of species which reach either their northern or southern geographic limits in the Pinelands.

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[1] Known scientifically as Pinus rigida.

[2] Pinus echinata.

Of the total species, 109 plants of southern affinity reach the northern limit of their range in the Pinelands. The most commonly known of these include the turkey-beard, pixie moss, goat's-rue, American mistletoe, sand myrtle, bog asphodel, Pine Barrens gentian, goldencrest, and several species of asters, loosestrife, milkworts, goldenrod, violets, orchids, pipeworts, greenbrier, lobelia, grasses, rushes, and sedges.

Fourteen northern plants reach their extreme southern limit, or southernmost Coastal Plain limit, in the Pinelands. Included in these are the well-known curly grass fern and broom crowberry, and, also, cotton grass and certain species of sedges, asters, and goldenrod.

Botanists make other geographical distinctions in plant species distributions that make the flora of the Pinelands unusual. Both the broom crowberry and the curly grass fern are considered relict species which formerly had wide distributions, but now occur only as remnants in relatively small areas. In addition to the Pinelands, the broom crowberry is found only in the New York Shawangunk Mountains, in small areas of coastal Massachusetts and Maine, and on more northern coastal sites in Canada. Curly grass fern is even more limited, found also in Long Island bogs, but typically occurs much farther north in coastal areas of Canada.

Still another distinctive class of Pinelands plants are the endemic species which are restricted to a very small geographical area, such as to a locale within a state, to one state, or to several states. The Pinelands has four plant species classed as endemics, specific varieties of which are found only in the Pinelands and nearby Delaware. Included in this group are the sand myrtle, blazing star, Pickerings morning glory, and Knieskern's beakrush. Two more species, New Jersey rush and sticky boneset, are only found in a few additional southern locales.

A separate report has been made to the Pinelands Commission on 71 rare species of Pinelands plants including grasses, sedges, ferns, herbs, shrubs, and trees. Some of these, such as the curly grass fern and the broom crowberry, already have been cited as distinctive features of the Pinelands. The survival of each species is dependent on the existence of adequate numbers of suitable habitats.

1.4.3. Vegetation Types and Their Patterns of Distribution

Given the four kinds of Pinelands habitats identified earlier -- uplands, lowlands, marshland, and streams or lakes, we should expect an equal number of plant community types. But fire, acting independently or in concert with subtle variations in soil moisture and fertility, has been influential in the development of more diverse vegetation types. Other natural and man-made disturbances and subsequent successional processes also have added to the richness of community types. The result is a striking variety of Pinelands vegetation types that include the following:

1. Uplands

    Oak-dominated Forests
    Pine-dominated Forests
    Pine Plains
    Successional Stages of Vegetation -- herbs, woody invaders, woodland

2. Lowlands

    White Cedar Swamp Forests
    Hardwoods Swamp Forests
    Pitch Pine Lowlands Forests
    Bog and Other Successional Stages of Vegetation -- shrubby thickets

3. Marshlands

    Freshwater Marsh Communities (or savannas)
    Saltwater Marsh Communities

4. Streams and Lakes

    Aquatic Communities

Because other reports to the Commission as well as references cited in the Appendix describe fully the plant composition of these communities, such descriptive material is not included herein. Instead, comments are offered on significant and unusual features of the Pinelands types of vegetation.

The first unusual feature of the vegetation types of the Pinelands is that the forests are quite different in appearance and structure from their counterparts in other areas of New Jersey or in other regions within the same climatic regimen.

In the oak-dominated upland forests, the presence of the pines, small oaks, and heath shrubs creates a forest different in appearance and structure from the typical mixed oak forest on uplands found in central and northern New Jersey. In the upland pine-dominated forests the pitch pine, and to a lesser extent, the shortleaf pine, blackjack oak, post oak and the lower growing scrub oak and heath or heath-like shrubs create still a different forest structure. But the Pine Plains dwarf forest is the most unusual vegetation type of the uplands, and it is among the unique forest types in the whole world. The Pine Plains are characterized by the dwarf stature of the plant growth (plants not more than 10 feet high, and most much less than this), the abundance of scrub-form oaks and particular low shrub species, predominance of stump sprouts, and fire-adapted pitch pines, many with serotinous cones that open to disperse seeds only after heated by fire.

Equal variety in vegetation types occurs on the lowlands. The dominant tree and shrub composition differs not only among the types of lowland forests -- the white cedar swamps, the hardwoods swamp, and the pitch pine lowlands, but also none of the three replicates the typical type of lowland vegetation found on the nearby inner coastal plain or in the more northern lowlands of New Jersey. Of the lowland forests, the dense white cedar swamps represent a unique lowland forest. Although the white cedar grows elsewhere in southern New Jersey and in a few bogs in northern New Jersey, it does not reach the same abundance of growth as in the Pinelands.

Still another feature of the Pinelands vegetation types is their pattern of distribution. In some areas within both uplands and lowlands the vegetation types merge through a wide transition zone of mixed composition with no visible abrupt boundaries. In other locales there are sharp and visible demarcations of boundaries. Lowland vegetation may be seen as an enclave within an upland forest, or the reverse situation may occur.

A final characteristic of the patterns of Pinelands vegetation is its dynamic nature. As habitat components change in time, so do interactions among plant and animal populations and between them and other habitat components. In the Pinelands fire has been of paramount importance in influencing changes in vegetation types. More will be said about this in Section 1.6.

1.5. FAUNA OF THE PINELANDS

1.5.1. Factors Influencing Patterns of Animal Distribution in the Pinelands

The distinctive features of the Pinelands fauna are the unusual species that are present and the fact that some of the abundant species are rare or absent in neighboring regions. There are many reasons why this is so. Species of amphibians, reptiles, insects and particularly fish have varying tolerance ranges for habitat factors such as soil and water acidity. Species that can compete successfully in the low nutrient and dry soils and in the acid waters that characterize the Pinelands are not found on more fertile uplands or in waters of higher pH values. Also, some burrowing animals can compete more successfully on sites of the Pinelands sandy soils than on those of harder substrates.

The distinctive patterns of vegetation types that characterize the Pinelands provide varying types of horizontal and vertical structures for the breeding, feeding and sheltering of animals. The degree of uniformity of such structures may be a limiting factor on some species diversity as believed in the case of the Pinelands bird fauna. On the other hand, differences in pine-dominated and oak-dominated forests provide opportunity for greater diversity in certain groups of insects. Unique habitats and vegetation such as the cedar swamps permit equally unique fauna as well as flora species to establish themselves.

Fire also has affected the distribution patterns of animal populations in the Pinelands. In the short term, populations may be reduced by death caused by fire. In the longer range, and more important, fire causes changes in the composition and structure of vegetation, and animal communities respond to these changes. Changes in forest composition from oak to pine affects animals such as insects that feed on oak versus those which feed on pine. Changes in canopy coverage and in understory layers caused by fire influence patterns of animal distribution because of different feeding and nesting preferences. Also, frequency of fire has significant influence on food resources for animal populations; for example, acorn production in scrub oaks is stimulated by fire. Annual burning greatly reduces the litter and shrub coverage, but favors a cover of varied herbaceous plants, and will significantly decrease arthropod populations.

Humans have had an impact on all groups of fauna in the Pinelands. The destruction or modification of habitats, collection of species, and introduction of non-native species is reflected in present species populations of all fauna groups.

Finally, past climatic changes and animal migratory patterns are reflected in the composition of the Pinelands fauna. There are an unusually large number of southern-affiliated animals that reach their northern limits in the area, though there also are numerous examples of northern species reaching their southernmost limits in the area. Thus, as in the case of plant species, the Pinelands is a meeting ground for northern and southern range limits of certain indigenous fauna.

Five groups of animals comprise the major part of the Pinelands fauna. These are:

1.5.2 Mammals
1.5.3 Amphibians and Reptiles
1.5.4 Birds
1.5.5 Fish
1.5.6 Insects and Other Invertebrates

The significant features of each group as they contribute to the essential character of the Pinelands are described on the pages that follow.

1.5.2. Mammals of the Pinelands

Thirty-four species of mammals can be found in the Pinelands and an additional four more species of bats are found during migration periods. This is a good representation of the mammal population of New Jersey which is reported to total 49 species. None of the 34 species is restricted to the Pinelands. Within the area many of the mammals are common on both uplands and lowlands while others are habitat specific to one or the other. Fewer mammals are found on the Pine Plains than in other upland vegetation associations. Two of the mammal species, the house mouse and the Norway rat, were introduced by humans and are found in close association with settled areas.

One of the Pinelands species, the beaver, had vanished from the area because of excessive hunting. The species was reintroduced and it is reported that over 100 active beaver colonies now exist. Other species, such as the wolf and the black bear, once were found in the Pinelands, but now are extinct in the Pinelands. Although none of the mammal species is designated endangered by the State, the status of several species is undetermined, including the southern bog lemming, river otter, and rice rat.

Eighteen of the Pinelands mammal species are classified as game species. The most important of these, and the largest mammal in the Pinelands, other than humans, is the white-tailed deer. In size the deer is the only Pinelands mammal classed as large (a body length longer than 3.3 feet). Eleven of the mammals are considered intermediate in size with an adult body length excluding the tail of 10 to 40 inches. These include the opossum, eastern cottontail rabbit, woodchuck, beaver, muskrat, red fox, gray fox, raccoon, mink, striped skunk, and river otter. The remaining mammal species of the Pinelands are less than 10" in length, the smallest being the masked shrew which measures only 2" in length. The twenty-two small mammals include five insect eaters (the masked, least, and short-tailed shrews and the eastern and star-nosed moles), three species of breeding bats (little brown myotis, big brown bat, and eastern pipistrelle), thirteen species of rodents (eastern chipmunk, gray, red, and southern flying squirrels, rice rat, white-foot, house, and meadow jumping mice, red-backed, meadow, and pine voles, Norway rat, and the southern bog lemming), and one carnivore (the long-tailed weasel).

The white-tailed deer is the most conspicuous mammal in the Pinelands. Its summer range includes both uplands and lowlands and it winters mainly in the cedar swamp, hardwoods swamp and pitch pine lowlands. Excessive deer browsing has interfered with regeneration of cedar swamps that have been burned or cut over. Other of the mammals, even the squirrels, are not often seen in the Pinelands though tunnels and runs leave patterns on the sandy upland surfaces and trails of various small rodents can be seen in marshlands.

1.5.3. Amphibians and Reptiles (Herpetofauna) of the Pinelands

Amphibians and reptiles as a group contribute to the uniqueness of the Pinelands fauna. First, the total number of amphibian and reptile species in the Pinelands is considered large for an area with northern climate. In addition, the specific populations of amphibians (salamanders, toads, and frogs) and reptiles (turtles, lizards, and snakes) have unusual variety. Finally, some species are not found elsewhere in New Jersey, and of those many are now threatened species.

In its present composition Pinelands herpetofauna includes some species that are wide-ranging over areas of eastern and northeastern North America. Some species probably invaded from the northwest in the cooler period after the retreat of the glacier. However, southern coastal plains species contribute substantially to the diversity of the Pinelands herpetofauna. These species probably arrived in the warmer period of post-glacial time.

A report on amphibian and reptile species made for the Pinelands Commission identifies a total of 50 Pinelands species, comprised of 6 species of salamanders, 14 of toads and frogs, 11 of turtles, 3 of lizards, and 16 of snakes. Of the total, 1 species of frog, 2 of turtles, and 1 of snake are introduced species successfully reproducing in the area.

Of the total 46 native species, 29 are abundant in the Pinelands; these include 2 species of salamanders, 10 of toads and frogs, 7 turtles, 2 lizards, and 8 snakes. Another 9 species are limited to peripheral areas of the Pinelands with less acid soils and waters; these include 3 species of salamanders, 1 of frog, 2 of turtles, 1 of lizards, and 2 of snakes. Another 8 species are reported only as local populations in specific Pinelands locations; these include 1 species of salamander, 2 of frogs and 5 of snakes.

At present, 5 species of the Pinelands herpetofauna are classified by the State as endangered species. These include the eastern tiger salamander, the famous Pine Barrens treefrog, the southern (Cope's) gray treefrog, the bog turtle, and the timber rattlesnake. Four more species are classed as threatened -- eastern mud salamander, wood turtle, corn snake, and northern pine snake. An additional 6 species (4 salamanders, 1 toad, and 1 snake) are reported to have declining populations, and 14 species have been given an undetermined status. Some species populations have declined as a result of commercial and non-commercial collection of specimens. Other decreases in population have resulted from habitat disturbance. The sensitivity of the herpetofauna to polluted waters and their decline in the surrounding more urbanized regions gives critical importance to maintenance of the Pinelands populations.

Both upland and lowland sites are important in herpetofauna distribution patterns in the Pinelands. Salamanders, frogs, turtles, and certain snakes need proximity to the water of ponds or streams or of the lowlands of cedar, pitch pine, or hardwoods. Upland forests are important as sites for the breeding, food source, and shelter for major numbers of lizards and snakes and some salamanders which breed in woodland wet depressions. Disturbed sites such as gravel pits and abandoned fields and building structures serve as breeding areas for 14 of the herpetofauna species.

1.5.4. Birds of the Pinelands

Although the variety of bird species found in the Pinelands is not considered unusually rich, the bird inventory count made for the Pinelands Commission identifies a total of 299 species and three subspecies that occur regularly in the area; this count includes species of the barrier beach and coastal marshes.

The food supply in Pinelands habitats appears adequate to support a greater diversity of species, but characteristics of the vegetation structure appear to limit the number of species. Uniformity of upland forest heights and heath shrub composition play controlling roles in limiting variety in types of nests, nest material, and perches and, thus, bird distribution.

The birds that breed in the Pinelands favor certain habitats over others. Upland oak-pine and pine-oak forests and lowland hardwood swamp forests have higher numbers of breeding bird species than do the pitch pine lowlands and cedar swamps. Coastal marshes support a high diversity in migratory species and the inland marshes fewer species. Disturbed areas and their fringes such as cultivated agricultural land, abandoned fields, and residential developments support moderate diversities in bird populations.

At the species level, the rufous-sided towhee is the most abundant breeding bird in the Pinelands, though the catbird is more common in the lowlands. At the other extreme the wild turkey, once common in the Pinelands, is now extinct because of unrestricted hunting before the twentieth century. Attempts to reestablish it as a native population are not yet successful. Another lost species is the heath hen. Two endangered species of New Jersey are still found in the Pinelands though in decreasing numbers -- the bald eagle and the eastern bluebird. The Cooper's hawk, the northern parula, and the red-headed woodpecker, former residents, do not continue to breed in the Pinelands. In coastal marshes the rare osprey, black skimmer, and lesser tern still are found.

The Pinelands has sparse populations of some rare bird species with southern geographical affinities including the prothonotary warbler, hooded warbler, Swainson's warbler, and chuck-will's-widow. In addition, there are a few more northern species that breed irregularly in the area such as the white-winged crossbill and the saw-whet owl.

Complete lists of species by habitat types are available in a separate report made to the Pinelands Commission, and only the birds commonly found in each major type of Pinelands habitat are enumerated herein.

Common in all upland habitats are two birds of prey (the turkey vulture and the American kestrel), two game birds (the ruffed grouse and bobwhite), and several birds of southern affinity (the Carolina chickadee and in lesser numbers, the Carolina wren, and northern mockingbird). Other species have more limited distribution on the uplands. Typical breeding birds of mixed oak and pine forests include the rufous-sided towhee, screech owl, downy woodpecker, blue jay, tufted titmouse, red-eyed vireo, ovenbird, and black-and-white warbler. In contrast, species most likely to nest in forests abundant with pine are the towhee, pine and prairie warblers, and brown thrasher. Few bird species seem to prefer the dwarf Pine Plains.

Breeding species in the cedar swamps include the catbird, eastern wood pewee, yellow-throated vireo, yellowthroat, American redstart, and song sparrow. Shallow lakes and streams attract the green heron, great egret, wood duck, spotted sandpiper and other migratory birds. In the marshlands red-winged blackbirds are abundant.

Species commonly found around human developments include the introduced non-native species -- starling, house sparrow, and rock dove, as well as robins and the chipping sparrow.

Numerous other species are found in the Pinelands in nonbreeding seasons. In winter these commonly include the slate-colored junco, mourning dove, Carolina chickadee, blue jay, and various waterfowl depending on the amount of open water and freezing weather. The more common of the latter include the mallard, black duck, and Canada goose.

During the spring and fall migratory seasons, additional species pass through the Pinelands as transients. The most abundant of these overland are flights of hawks especially the sharp-shinned hawk and flocks of smaller thrushes, sparrows and warblers including in abundant numbers the myrtle or yellow-rumped warblers and the white-throated sparrow.

Fire appears to have some impact on bird abundance in the Pinelands. The eastern bluebirds which have declined in total population have shown increases on burned sites. This is also true of the common nighthawk and chipping sparrows. On the other hand, birds such as the towhee and brown thrasher are found to decrease after fire.

1.5.5. Fish of the Pinelands

Measured in numbers of species, the fish of the Pinelands are low in diversity. A total of 70 species of freshwater fish has been reported for the whole State of New Jersey, and of these only 16 species are truly characteristic of the Pinelands. Additional native fish species are present, however, in peripheral areas of the Pinelands where the water is less acid than that typical of the region. Also, a small number of introduced species are surviving and breeding in these peripheral waters. Finally, several marine fish move into the tidal portions of the larger Pinelands rivers to spawn.

Though low in species numbers, the fish fauna reflects the unique character of the Pinelands. The species characteristic of the Pinelands are not commonly found in other areas of New Jersey, but are mostly associated with those of the more southern Atlantic Coastal Plain. Some reach their northern limits in the Pinelands, and a few are disjuncts in distribution pattern as described earlier. The acidity and slow-moving character of the Pinelands waters combined with the low nutrients are important habitat conditions for these species.

Many of the characteristic species are strongly patterned and sought for aquariums. This is true of the blackbanded sunfish, the fish said to be the most characteristic of the Pinelands. This fish of striking black and straw-colored bands is found in most streams and lakes. There are other sunfish typical of the Pinelands and these include the banded, blue spotted, and the mud sunfish. The eastern mudminnow also is common throughout the area, and particularly identified with cedar swamp water are the yellow bullhead, pirate perch, ironcolor shiner, and swamp darter.

Pickerel is a distinctive fish in the Pinelands because of its attraction to fishermen. Other native but less abundant species include the redfin pickerel, creek chubsucker, tadpole madtom, tessellated darter, brown bullhead, and the American eel.

Another group of fish occurs in waters of the Pinelands where the acidity is lower than the typical pH because of influences such as agricultural run-offs. In this group are the golden shiner, white sucker, redbreast sunfish, pumpkinseed, and yellow perch. And very occasionally, the silvery minnow and American lamprey are found in non-acid waters.

Several marine fish (anadromous fish) spawn in the lower portions of the Pinelands larger rivers, but never appear to enter the more acid upland streamwaters. The blueback herring, alewife, American shad, and striped bass are among such fish.

A number of non-native species of fish have been introduced into the Pinelands streams and lakes, but few have been able to survive and become natural reproducing populations. Three, however, appear to be successful in the less acid or neutral waters; these are the large-mouth bass, the bluegill sunfish, and the black crappie.

I.5.6. Insects and Other Invertebrates of the Pinelands

Insects and other invertebrates are the most common fauna in the Pinelands both in species and population numbers. Included in this group of Pinelands fauna are insects such as grasshoppers, beetles, moths, butterflies, pine sawflies, gall wasps, leaf hoppers, wasps, bees, flies, ants, crickets, cicadas, termites, and aquatic dragonflies, damselflies, water bugs and striders, and mosquitos. Typical other invertebrates in the Pinelands include mites, spiders, sowbugs, pillbugs, millipedes, and centipedes.

There are no counts on the total number of insect and other invertebrate species found in the Pinelands, but it is estimated that a compilation of such a species list would take volumes.

Sample studies made of specific habitats and areas in the Pinelands indicate that flies probably occur in the greatest numbers, but beetles, bees, wasps, and ants have the greatest diversity in numbers of species. Since about half of the insect species depend on plants for their food, their diversity is dependent on variation in plant cover. High acidity and low nutrients of soils and waters is a limiting factor for certain species. For example, earthworms are not usually found in the Pinelands because of the low nutrient, acidic, coarse soils. Tree snails which normally could be expected are not present because of the lack of calcium for shell-building. On the other hand, Pinelands habitat factors have led to richness in certain insect groups including moths and gall wasps, that feed on pine and oaks, and tiger beetles and velvet ants which inhabit sandy areas.

Many species of insects and other invertebrates reach the northern or southern limits of their ranges in the Pinelands with more species reaching their northern limits. The leaf-cutting ant is a characteristic species of southern affinity common in the Pinelands, but rare or absent in other parts of New Jersey. Eight species of tabanid flies of southern affinity also reach their northern range in the Pinelands, but two more species of the same fly are of northern affinity and the Pinelands is the southern limit of their range.

Insects said to be characteristic of the Pinelands include several underwing moths which have hindwings brilliantly colored in reds, oranges, and yellow, a light orange noctuid moth, and several small beautiful butterflies and skippers. Two species of moths are known to be endemics, restricted to the Pinelands and found nowhere else.

Above surface and soil invertebrate populations are essential to the existence of all other living plant and animal organisms in the

Pinelands. A high number of the species are plant eaters, feeding on leaves, fruit, flowers and, then, in turn serving a critical role in the food chain by being fed upon by other insects, herpetofauna, fish, birds, and mammals. Other insect species are scavengers feeding upon dead plant and animal parts, and then serving as food for predators. Insect pollinators are vital for seed reproduction of plants. Finally, soil invertebrates perform essential ecosystem functions by aiding decomposition of soil particles, incorporation of organic material into soils, and the release and accumulation of nutrients in the soil. For these reasons, actions taken to change invertebrate species representation and abundance can be detrimental for all other organisms. Pesticides can alter the essential ecosystem dynamics. While periodic burning enhances the richness of herbaceous plants and some soil invertebrates, annual burning is detrimental to the diversity and population dynamics of this group of insects.

1.6. ECOSYSTEM INTERRELATIONSHIPS IN THE PINELANDS

As essential to the Pinelands character as individual species of plants and animals are the dynamic interrelationships that exist among and between the living organisms and elements of their physical environment.

The structure of the existing ecosystems in the Pinelands has evolved over thousands of years based on the interrelationships among living organisms and particular physical factors. Sandy soils of low nutrient and water-retention capacity, acid surface and ground waters with low amounts of nutrient, and frequent wild fire have been controlling influences in creating the particular environment that favors the growth and reproductive success of the species typically found in the Pinelands. Species not capable of competing successfully under these particular environmental conditions have been sifted out.

Ecologists sometimes call the Pinelands landscape an ecological mosaic, meaning an area with a variety of similar habitat and vegetation types and animal populations distributed in patches over the landscape. The patches may change in time, such as happens in the Pinelands when wild fire comes. But, overall the Pinelands biological communities are said to be in dynamic equilibrium with their habitat components. This means that maintenance of the natural communities as they exist today is dependent upon the maintenance of critical environmental conditions. A change in any one of the ecosystem components, living or physical, will cause change in the interrelationships among all other elements of the system, and may result in changes in ecosystem components themselves.

The interrelationships between living and non-living components of an ecosystem are extremely complex and not fully understood by ecologists. This is true of the Pinelands where there are processes of energy and nutrient exchange and gene flow among members of a single species population, among many species and their physical components on a given site, among habitat sites, such as between uplands and lowlands within the Pinelands, and between the total Pinelands ecosystem and those in neighboring regions.

Of overriding significance is the fact that disturbance of the complex network of ecosystem interrelationships endangers the existence of the living components of the system, the plants and animals that characterize the Pinelands. Also of importance is the fact that there are strong interrelationships between the ecosystem components of the Pinelands and those of the estuaries, and disturbance of processes within the Pinelands will have impact on the beneficial uses of estuaries. More will be said in Section 3 about the disturbance of ecosystem interrelationships and the resulting impact on the Pinelands.

SECTION 2

INFLUENCES ON THE HISTORICAL EVOLUTION OF THE PINELANDS

2.1. OBJECTIVE

The objective of this section is to identify the significant natural and man-related influences that are believed to have made the Pinelands landscape and ecosystems what they are today; and to present in an organized fashion scientific assumptions about the historical evolution of the Pinelands landscape and ecosystems.

2.2. INTRODUCTION

The present Pinelands landscape and ecosystems have their origin in natural processes that started millions of years ago. Only general knowledge of the particular geologic events and climatic changes that caused formation of the Pinelands area and the times at which these occurred is available. The history of the origin and development of the present plant and animal populations cannot be fully documented, nor is there complete agreement or understanding of man's influence on the Pinelands. Nevertheless, scientists have uncovered enough evidence to make it possible to draw reasonable assumptions about the evolutionary history of the Pinelands and the significant influences on this history.

In this section the significant natural and man-made influences that are believed to have made the Pinelands landscape and ecosystems what they are today are identified. These are presented in four groups sequenced chronologically to give a sense of the historical evolution of the Pinelands. The groups are:

2.3 Influences of Early Geologic Processes Prior to the Pleistocene Ice Age

2.4 Influences of the Pleistocene Ice Age (10,000 to 1.8 Million Years Ago)

2.5 Influences on the Pineland Resources from 10,000 Years Ago to the Time of European Colonization

2.6 Influences of Humans on the Pinelands from European Colonization to the Present

2.3. INFLUENCES OF EARLY GEOLOGIC PROCESSES PRIOR TO THE PLEISTOCENE ICE AGE

The geologic processes of deposition, eustatic sea level changes, erosion, and land uplift are responsible for the present topographical and hydrological features of the Pinelands; and the present mineral soils have developed from geologic parent material. Topography, hydrology and soils as well as climate have a controlling influence on plant and animal populations, and, thus, geologic processes in the past, as they will in the future, have had a significant influence on the Pinelands landscape.

Prior to the Pleistocene Ice Age which is assumed here to have started about 1.8 million years ago, two particular geologic processes were important in the evolution of the Pinelands landscape. The first is a period of marine deposition which started about 100 million years ago and ended about five million years ago. The second is a period starting about five million years ago when the present surface topography of the Pinelands began to form.

2.3.1. Coastal Plain Formation, 5 to 170 Million Years Ago

The Pinelands area is located on the Atlantic Coastal Plain which started to develop about 170 million years ago when the trailing eastern edge of North America was formed through the process of sea-floor spreading. About 100 million years ago the sea covered the land leaving sedimentary deposits composed mostly of clays, silts, sands, and gravels. When the sea withdrew, erosion proceeded and streams and wind carried away some or all of the sediments.

In southern New Jersey deposition and erosion processes occurred many times, and resulted in total deposits over the basement rock ranging from a veneer covering to layers 1300 to 6000 feet thick. It is these deposits that form the coastal plain in which the Pinelands is located.

Formation names have been given to distinctive and mappable units of these clays, silts, sands, and gravels. In the area of the Atlantic Coastal Plain now designated as the Pinelands, the last marine deposit in this time was named Cohansey Sand, which overlies a previous deposit, called the Kirkwood Formation. Both are important in the subsequent processes in which the surface of the Pinelands evolved.

2.3.2. Development of the Pinelands Surface

About five million years ago the sea withdrew from southern New Jersey and the land uplifted leaving exposed at the surface the most recent sedimentary deposits. In the Pinelands area this was primarily the Cohansey Sand, which now undergirds almost all of the present Pinelands. The older Kirkwood Formation is exposed at the surface only along the northern and western borders of the Pinelands.

The Cohansey Sand is comprised mostly of clean yellow quartz sand with variable amounts of fine to coarse, silty, and clayey sand in proportions uniform enough to distinguish three different characters of water permeability within the Pinelands. The Cohansey Sand is an uncemented sand, not lithified like sandstone. The Kirkwood Formation also is unconsolidated composed mostly of sand, silt, clay and a little gravel.

Subsequent to the exposure of the Cohansey Sand Formation, patches of gravels, sands, silts and clay were deposited in localized areas on the Coastal Plain. These formations are identified as the Beacon Hill, Bridgeton, Pensauken, and Cape May Formations. The first three depositions are assumed here to be pre-Pleistocene depositions although there is not complete agreement on the age of the four deposits. From a landscape viewpoint, the Beacon Hill Gravel Formation is important; today it caps many of the highest hills on the Pinelands because the original sands surrounding the Beacon Hill Gravel were eroded away leaving the gravel as a hill. This unusual geological feature is known as an "inversion of topography" because the younger gravelly streambed deposits form hilltops and the underlying deposit, principally the Cohansey Sand, forms the lower surface. It is the continuing geologic processes of aggradation (deposits) and gradation (erosion) that have been paramount in the development of the Pinelands landscape as it exists today.

The exposure of sand as the dominant surface material had a major influence in the ultimate development of the Pinelands for several reasons. First is that soils which develop from parent surficial geologic material will vary by the nature of the parent material as well as being influenced by other factors such as climate. Soils differ in their water-holding capacities, in their acidity, and in the type and amount of mineral elements most needed by plants -- such as, nitrogen, phosphorous, calcium, magnesium and potassium. Each plant species exhibits a specific range of need and tolerance for both water and particular nutrients as well as for other factors such as soil acidity. A plant species that grows and reproduces successfully on one type soil may not be able to exist under different conditions. The soils that developed over time from the Cohansey Sand and patches of subsequent deposits are low in moisture retention (droughty), low in nutrients, and high in acidity. These characteristics interacting with other factors have a great influence on the type of vegetation and in the type of animal populations developed in the Pinelands, as will be described later.

The low relief of the Pinelands developed because of the nature of the Cohansey and underlying formations and the relative gentle uplift and nearshore plain of deposition. Finally, the nature of the Cohansey Sand and the Kirkwood Formation are responsible for the character of both surface and ground-water systems.

2.4. INFLUENCES OF THE PLEISTOCENE ICE AGE (10,000 TO 1.8 MILLION YEARS AGO)

An epoch of glaciation known as the Pleistocene started about 1.8 million years ago and ended only about 10,000 years ago. During that time at least three of the four major ice advances reached New Jersey. The last, known as the Wisconsin, came the furthest south, but it stopped 10 to 40 miles north of the Pinelands area. Between the successive advances extended intervals of warmer climate have occurred. During these intervals glacial ice melts and the glacier retreats. The climatic changes and advances and retreats of the glacier affect sea level because of the varying amount of water tied up in the ice. When glaciation was at its maximum, sea level was at its lowest, extending by many miles eastward the Atlantic coastline of the United States. When the climate is warmer and glacial ice melts, as at present, land areas previously covered by vegetation are inundated by sea water. These events of the Pleistocene epoch had major impacts on the Pinelands.

In the millions of years prior to the Pleistocene when the Coastal Plain was being formed, it is assumed that plant and animal populations were present in the long periods when the sea did not cover the land. Evidence of the types of species that were present then is meager, but some interpret it to indicate that a few species that existed in these ancient times may also exist in the present communities. Slightly more evidence is available on the plant and animal communities of the later Pleistocene time and on the influence that climatic and sea level changes had on these.

Although the glacial ice did not encroach on the Pinelands area, it is believed that in the late Pleistocene when the Wisconsin ice was present, the climate in the Pinelands was considerably cooler, and probably wetter, than at present. Many scientists believe that at this time the Pinelands area was covered by a forest similar to that now present in northern New England and Canada (a spruce-fir boreal forest). A few believe that the climate was so cold that the Arctic type of tundra vegetation existed here. In either case, the assumption is that the Pinelands plant and animal populations as we know them today developed only after the Wisconsin ice began to retreat about 10,000 years ago.

When the glacier started its final retreat from New Jersey, the sea level was still far to the east of the present eastern coastline. This increased the coastal migratory path for both southern and northern species. As will be discussed later, this had influence on the composition of the modern Pinelands flora and fauna.

2.5. INFLUENCES ON THE PINELANDS RESOURCES FROM 10,000 YEARS AGO TO THE TIME OF EUROPEAN COLONIZATION

Although the topography, soils, and hydrological features of the Pinelands stem from the geologic processes that took place over millions of years as just described, the plant and animal populations, as we know them today, developed in the last ten thousand years. The two most important influences on this slowly evolving development have been climatic changes through time and the interactions of natural biological succession and evolutionary adaptation processes with the particular physical components of the Pinelands environment and fire disturbance.

2.5.1. Influence of Climatic Changes on the Pinelands Flora and Fauna

Because every type of plant and animal has temperature and other environmental limits above and below which physiological processes cease and an optimum range for maximum growth and reproduction, climatic as well as other environmental factors have controlling influences on species distributions. While a species may flourish under the climatic and soil condition in one geographic region, or even on one site within a region, it may be unable to reproduce successfully or even to exist in another region or site having a single environmental condition outside its tolerance. Thus, as climatic conditions change so will the geographic ranges of living organisms. A warming trend has resulted in northward migration of southern species and cooling brings the more northern species southward.

It is believed that climatic changes in the last 10,000 years caused northward and southward dispersals of plant and animal populations and that these are reflected in present populations in the Pinelands. The cool moist period which existed when the glacier ice started to retreat about 10,000 years ago was followed by a warmer (hypsithermal) period about 5,000 years ago that lasted several thousand years before the climate again turned colder. Enhanced by the enlarged coastal migratory route when the sea levels were lower, during the warmer post-glacial period plants and animals of more southern regions migrated northward with some of them colonizing the Pinelands. It is believed that the white cedar, a relative newcomer to the Pinelands, colonized during this period. To a lesser degree migration also proceeded northward and then east to the Pinelands from the southern Appalachian area. During this same period the characteristic tree of the Pinelands, the pitch pine, may have migrated as far north as Quebec.

During the subsequent cooling period and southward migration of species, some of the southern species survived in the Pinelands. The alternating warm and cool climatic changes occurred when there were no artificial barriers to species migration and no significant human destruction of ecological habitats in the Pinelands. Although there is evidence of prehistoric man in New Jersey, his numbers were low and even the Indian population in the State is estimated to only have been as high as 7,000 to 10,000.

The climatic and migration factors are reflected in the present Pinelands resources in three ways:

1. The flora and fauna have an unusual composition of southern species that reach the northern limit of their range in the Pinelands; northern species that reach the southern limit of their range there; and, last, species common to surrounding areas in the State.

2. Many of the unusual Pinelands plant and animal species have geographical ranges that are discontinuous (disjunct); for example, the species is found in the Pinelands, the Carolinas, and Florida.

3. Hybridizations have occurred among northern and southern species. For example, there is hybridization of pitch pine with three southern tree species, all of which overlap its range in this area and hybridization between three pairs of northern and southern snakes.

2.5.2. Interactions of Biological Competition, Succession, Evolutionary Adaptation, and Fire Disturbance

Overlaid on the climatic factors just described are the interactions of the natural biological processes of competition, succession and evolutionary adaptation with the particular resource components of the Pinelands in the presence of fire disturbance.

Today's flora and fauna of the Pinelands reflect the success of specific species in invading and maintaining themselves competitively in the particular habitats that characterized the Pinelands and in the presence of frequent fire. Terrestrial species are fire-adapted with tolerance for sandy soils of low nutrient-content and water-retention capacity and aquatic species adapted to acid waters of low-level nutrients.

Fire has influenced greatly development of present patterns of plant and animal distribution in the Pinelands. This is because some species, by nature of their structure, are more insulated from heat than others and therefore less susceptible to fire damage. Also, some trees and shrubs are able to produce stem and/or root sprouts quickly after fire damage while others have little or no resprouting capability. Seeds of some plants are destroyed by fire; the seeds of others germinate more quickly when exposed to the heat of fire or when left exposed on relatively bare soil rather than in a thick litter of leaves. Fire damage which produces major changes in the surface litter also affects the community composition of soil arthropods, birds, bryophytes, and lichens. Soil-covering mosses and lichens are favored by fires that create bare spots.

Fire can be a common natural phenomenon caused by lightning and spread by high winds. Because the fire-prone nature of the Pinelands droughty soils, litter surface and vegetation itself has existed for thousands of years, it is believed that modern upland plant populations in the Pinelands have evolved in the context of a fire-adapted low nutrient droughty ecosystem. The native species in the Pinelands are highly inflammable yet highly resistant to killing by fire; most native upland species other than mosses and lichens sprout from underground stems or roots if their tops have been killed back. Pitch pine, the most abundant tree species, is also the most resistant to damage and killing by fire.

Recently, scientists have found that the pitch pine population occupying the Pine Plains appears to be genetically differentiated from other Pinelands populations with characteristics selected for better adaptation or survival under severely limiting factors, such as frequent fire and (or) unfavorable soil. Blackjack, bear (or scrub), and post oak, which are the more common oaks in the Pinelands, are able to survive under more frequent fire than the less common black, white, chestnut, and scarlet oaks that typically grow more abundantly in the mixed-oak forests on more fertile moist uplands.

In addition to fire ignited by lightning, prehistoric man and, then, Indians and subsequent settlers intentionally and accidentally caused fires. Their frequency, intensity, seasonality, and location all play roles in determining the influence of fire on species patterns. The moist lowland sites have been less affected than the uplands and often act as firebreaks. Cedars do not sprout after fire kill, but may regenerate their population on a burned site depending on interrelationships of several factors, such as availability of seed sources, litter surface and water level, and lack of hardwood competition. Also, given appropriate conditions, burned-over hardwood swamps may be replaced by cedar.

Whether fire alone or a complex of factors -- fire, soil texture, low soil moisture, and differences in soil ions account for the present types of upland forests in the Pinelands is controversial. Some believe that the present patterns of oak-pine, pine-oak, and pine plains vegetation represent various stages of succession leading ultimately to a mixed-oak forest if fire is currently eliminated as a disturbance. A contrary interpretation assumes that present plant patterns reflect a long history of evolutionary adaptation to a combined environment of frequent fire disturbance and sandy soils low in nutrients and moisture. Under the latter assumption given the particular habitat conditions, the pine plains may not revert for a long time to a pine-oak forest, nor will all other upland forest types now present proceed through successional stages to the mixed-oak climax found in nearby upland areas of New Jersey or even to an oak-pine composition. However, in research plots one type of fire regime has reproduced oak-pine stands, while on other plots in the same study area, a different type of fire regime has changed the composition to a predominantly pine-dominated forest type.

Natural factors other than fire disturbance have changed patterns of plant and animal distribution in the Pinelands. Habitat changes occur from disturbances such as wind throw which may create openings in forests to be filled by sequential stages of successional vegetation. Natural or animal-caused changes in drainage patterns can convert uplands to lowlands or the reverse. Beaver dams do this and in the process change tree composition in adjoining locales. Prehistoric man and then Indians may have altered the natural relative abundance of animal and plant populations by hunting and other fulfillment of life needs, but these actions left a small imprint as compared with those that followed the European colonization of the Pinelands.

2.6. INFLUENCES OF HUMANS ON THE PINELANDS FROM EUROPEAN COLONIZATION TO PRESENT

Though the patterns of species composition were established in the Pinelands through natural processes, the landscape of the Pinelands has been altered over the last 300 years by a wide variety of actions on the part of humans. Some of these actions have resulted in total obliteration of native plants and animals by the substitution of man-made structures for natural habitats. Others have caused such great modification in particular habitats that changes in relative species abundance and distribution have occurred. Many of the human influences have resulted in a reduction in the Pinelands habitat and species diversity, but a few have added to the existing variety of habitats and species. The more significant influences that humans have had on the Pinelands in the last 300 years and the actions that caused these are summarized below.

2.6.1. Modification of Species Patterns by Influence on Fire Frequency

Whether fire became more or less frequent after European settlement and more or less severe cannot be determined. Early settlers intentionally set fires to clear land, and others were accidentally ignited or spread out from their original source. As recreational use of the Pinelands increased through the years, so did the occurrence of accidental fire. On the other side, interest in protection of human life and man-made structures brought improvements in fire control efforts over the years including restrictions on burning.

On uplands frequent fire favors pine and specific oak species over the more mesic oaks and on lowlands fire may or may not favor white cedar over the swamp hardwoods depending upon the presence or absence of other factors identified in Section 2.5.2. The abundance of cedar swamps has decreased in this period as has savanna type vegetation, and fire may have played opposite roles in these cases. In the first, increased fire may have caused the decrease, and in the latter situation fire control may be the factor preventing natural maintenance of savannas, though other influences are also attributed to both changes.

2.6.2. Modification of Species Patterns by Timbering

Both upland and lowland forests of the Pinelands were subject to extensive timbering up through the mid-nineteenth century when the demand for fuelwood and charcoal decreased because coal replaced wood as a source of fuel. It is estimated that prior to this time, upland stands convenient to water transportation were clear cut every 25 years and less accessible forests probably every 40 years. From the time of early colonial settlement cedar wood has been in great demand for lumber and posts, and it has been estimated that by 1980, most cedar swamps had been clear cut five to seven times.

With reduction of the demand for fuelwood, there has been some recovery in the upland tree size, but there has been continued cutting of pine through the years for sawmills, piling, poles, and pulpwood. It appears that while thinning or partial cutting may favor the development of oaks, clear-cutting favors pine and this is important in continuing the pine-dominated composition in the Pinelands. On the other hand, as mentioned earlier, cedar swamps have decreased and those that remain do not contain the large-sized trees described in journals of early visitors to the Pinelands. Clear-cutting can favor regeneration of cedars if seed sources and other factors are favorable. But because cedars are shade-intolerant, thinning or partial harvesting of the overstory has favored the replacement of cedars by hardwoods.

2.6.3. Obliteration of Natural Landscape and Habitats by Man-Made Structures

The use of land for housing developments, industry, highways and other supporting infrastructures obliterates specific habitats and natural communities and the result has significant implications for the Pinelands. The reduction in natural ecosystems means that the relative abundance of habitats and species patterns is altered; for example, reduction of lowland habitats and cedar swamps in particular. On the species level the result has caused extinction of some species with others being classified as endangered or threatened.

Recently, attention has focused on perhaps the most important implication of landscape obliteration in the Pinelands -- that is, creation of discontinuities in the Pinelands natural vegetation that make dispersal barriers for flora and fauna. More will be said about this in Section 3.

2.6.4. Alteration of Species Patterns by Habitat Modification

In ways other than those already described, man's actions in the last 300 years have modified the Pinelands landscape and the natural habitats thereon, and in so doing have changed species patterns. As examples, draining of lowlands has decreased directly the amount of swamp vegetation types; pollutants, such as agricultural fertilizers, pesticides, herbicides, and organic and inorganic wastes, entering streams directly or seeping through the soils to ground-water levels and then to stream waters have caused nutrient and pH changes that natural species of the flora and fauna cannot tolerate. In some areas intensive recreation and use of off-road vehicles have compacted soils to the extent that native species cannot regenerate themselves.

On the other hand, modification of the landscape by humans also has led to increased ecological diversity in some instances. For example, abandoned farmland will pass through a series of successional stages of vegetation types before reverting to forest. Edges of highways controlled by mowing also exhibit successional vegetation. Abandoned cranberry bogs and former bog-iron and sand and gravel mining pits when excavated below ground-water level have produced ponds, bogs, or swamp habitats. In these, as in cut-over cedar swamps, unusual species of plants often are found.

2.6.5. Alteration of Native Flora and Fauna by Disturbance of Natural Predator-Prey Relationships

Man has disturbed the natural predator-prey and plant-herbivore relationships that evolved in the Pinelands without human interference. As a new predator in the environment, the human hunter has eliminated certain species of Pinelands fauna, such as the black bear, wolf, heath hen, native turkey, and beaver although efforts to repopulate the latter appear to be successful. In addition, zealous plant and animal collectors as well as commercial dealers have reduced native populations of particular native species.

Herbicides, insecticides and other forms of artificial pest control have changed natural ecosystem relationships. The kill-off of natural predators through such methods or through hunting has led to outbreaks of pest disturbances. It has been suggested by some (and disputed by others) that excessive deer browsing which has seriously curtailed regeneration of cedar swamps reflects an artificial disturbance of natural predator-prey relationships.

2.7. SUMMARY OF PAST INFLUENCES OF HUMANS ON THE PINELANDS

Several observations can be made about the overall impact that humans have had on the Pinelands in the last 300 years. On the one hand, the degree of recovery from three century exploitation of cutting and burning of Pinelands forests is surprising and with few exceptions (cedar swamps, for one) the patterns of species distributions may be little different today than they were thousands of years ago. On the other hand, it is fortunate for the Pinelands landscape that more fertile land for agriculture existed around it in adequate supply, that the Pinelands was not located in the direct corridor of transit between New York and Philadelphia, and that mass transportation improvements still have not brought the area within easy commuting distance to either point.

The explosive population growth that occurred in New Jersey starting in 1850 and continuing to the present did not press on the Pinelands until the last two decades. In just that short time, viewed in the scale of a 10,000 year development life for the modern flora and fauna, a number of modifications have been made in the natural landscape. But despite past human actions, the Pinelands exists today as a unique and natural self-maintaining ecosystem. As such, it reflects the results of complex natural interlocking relationships between biological organisms and particular habitat conditions that have evolved over a period of thousands of years.

SECTION 3

INFLUENCES THAT COULD CAUSE CHANGE IN THE PINELANDS ECOSYSTEMS

3.1. OBJECTIVE

The objective of this Section is to identify specific natural and man-related influences that could alter significantly the Pinelands ecosystems and their components in the future and to project for each of the factors an estimated time interval by which a defined impact would be apparent in the Pinelands if the influence were not controlled.

3.2. INTRODUCTION

Just as natural forces molded the evolutionary history of the Pinelands in the past, so will they in the future. Long-term climatic changes may alter the composition of plant and animal populations and their patterns of distribution. The continuing process of geologic pedisedimentation occurs throughout the region, and slope retreat and stream erosion processes are lowering the level of the landscape relative to sea level. Ultimately, the entire Atlantic Coastal Plain in New Jersey may once again be covered with water. The time scale makes the event seem remote as the land is sinking into the sea only at the rate of a few inches per century.

Natural forces of tornados, ice storms, hurricanes, and drought are more immediate influences on the Pinelands. In the future, as in the past, these may be expected to cause destruction of some part of the natural landscape. In the past, recovery of the landscape from such destruction has been assured through the natural processes of succession. The Pinelands landscape, in fact, has been self-maintaining. The important question is whether it will remain so in the future. The answer to this question rests in an affirmative answer to a second question -- will human-related influences on the Pinelands be controlled so as to preserve the capacity of the natural landscape to maintain its essential character?

This Section focuses on the factors that, if left uncontrolled, could alter significantly the Pinelands ecosystems and their components; it identifies the human activities that are associated with each of the destructive influences. In Section 4 forecasts are made about the time scale in which changes would occur in the essential character of the Pinelands given no control over the factors that cause change. In Section 5 recommendations are made for policies and actions needed to ensure continuation of the capacity of Pinelands ecosystems to be self-regenerating.

3.3 FACTORS THAT COULD CAUSE SIGNIFICANT CHANGE IN THE PINELANDS ECOSYSTEMS

A variety of human-related actions, if left uncontrolled, could alter significantly the Pinelands ecosystems and their components in relatively short time. Among these are the activities listed on Table 3-1. Such actions may lead to the destruction of the Pinelands environment by contributing to one or more of nine factors that can cause fundamental change in the Pinelands ecosystem components and processes. These factors are as follows:

3.4 Changes in Water Quality

3.5 Changes in Water Level

3.6 Modification of Habitats

3.7 Fragmentation of the Contiguous Natural Landscape

3.8 Changes in Fire Frequency and Intensity

3.9 Disturbance of Soils

3.10 Selective Reduction in Populations of Native Species

3.11 Introduction of Non-Native Species

3.12 Changes in Air Quality

Different human-related activities may contribute to each of the nine factors, and any one activity may exert influence on more than one factor. For example, changes in water quality may be caused by a number of different actions, such as residential development sewage disposal, run-off of agricultural wastes, pollutants from landfill, etc. Likewise, a single activity, such as expansion of residential development, may exert influence over several, or even all, of the nine factors that cause environmental change.

The nature of the factors, if left uncontrolled, could alter significantly the Pinelands ecosystems; their causes and the results are described on the pages that follow.

Table 3.1

Human-Related Actions that Contribute to the Factors that Could Alter Significantly the Pinelands Ecosystems

Expansion of Residential, Industrial and Commercial Building and Activities

- Site clearing and drainage changes
- Continuing site maintenance
- Sewage and waste disposal
- Water effluents
- Air effluents
- Noise disturbance

Type and Geographical Distribution of Residential, Industrial and Commercial Expansion

- High density development
- Low density development
- Expansion of present developed areas
- Leapfrogging of development, scattered or high density

Transportation Systems, Highways, Right-of-Ways and other Supporting Infrastructure

- Site clearing and drainage changes
- Continuing site maintenance
- Noise disturbance
- Air effluents

Public Service Facility Expansions

- Water supply and need for ground-water pumping
- Sewer and waste disposal
- Fire control
- Public land management including forests and parks
- Specialized use of public land, e.g., military

Expansion of Extractive Industries

- Soil disturbance and drainage changes
- Waste disposal

Expansion of Landfill Areas

- Soil disturbance and drainage changes
- Pollutant discharges

Expansion of Agriculture

- Site disturbance and drainage changes for
  - Cranberry cultivation
  - Blueberry cultivation
  - Crops
- Liming, fertilizing and pest control maintenance

Recreation -- Types and Degree of Intensity

- Water
  - Boating
  - Swimming
  - Fishing
  - Collection of native species
  - Motorized activities -- noise and pollutants
- Land
  - Hunting
  - Camping, hiking, etc.
  - Use of off-road motorized vehicles
  - Collection of native species
  - Noise disturbance

Commercial Collection of Species

3.4. CHANGES IN WATER QUALITY

3.4.1. Nature of Water Quality Changes

Characteristically stream and ground-waters in the Pinelands have a low amount of nutrients and a high acidity (a low pH value). If typical plant and animal species are to remain in the area, the characteristic water quality values must be retained. These may be expressed quantitatively in terms of selected quality values now present in the least disturbed stream waters as follows:

pH - Value of less than 5.0

Nitrate-Nitrogen (NO_3) Concentration - Value of about .17 parts per million, except higher in winter

Ammonia-Nitrogen (NH_3) Concentration - Value of about .036 parts per million

Total Phosphate - Value of about .019 parts per million

Percent (%) saturation dissolved Oxygen - Value of about 85%, except considerably less in bogs

No characteristic values are given for total organic carbon and organic nitrogen, as the ranges for these vary widely seasonally.

3.4.2. Causes of Changes in Water Quality

The ecosystems of the Pinelands are said to be fragile and unusually susceptible to damage by changes in water quality because of the following interrelationships:

- The soils are poorly buffered, as are the stream waters.
- The soil has relatively little clay, is mainly sand, and has very short retention time. Therefore, anything put onto the soil will in a short interval of time reach the stream and the underground aquifers (see Section 1.3.1).
- The soils, because of their inability to retain organic and inorganic compounds, are dependent on the vegetation to maintain nutrient cycling. Therefore, altering the vegetation will greatly affect the soil nutrient levels and, in turn, the nutrient level in the streams.

- This interlocking system of soils and vegetation have produced ecosystems that demand low level nutrients. Therefore, any activity which significantly increases nutrient levels will bring about shifts in the vegetation and hence the animal life, and also shifts in the microflora.

Particular land-use activities that can significantly alter the values of water quality needed to maintain the Pinelands ecosystems are as follows:

1. Clearing of land

   Clearing of natural vegetation from land for building sites or road construction in the Pinelands results immediately in increased run-off, increased nutrient leaching, and increased sedimentation and siltation, all of which are reflected almost immediately in changes in water quality.

2. Disposal of sewage

   Water quality may be degraded by direct discharge of municipal or industrial sewage effluents into streams at a given point. In this case there will be an immediate impact on surface water quality, and it may not be localized because of downstream transport. The impact will be most severe on slow-moving waters or on pond waters where the prolonged nutrient enrichment will severely damage the natural ecosystems. Less immediate in time and intensity of impact are non-point sources of nutrient discharges such as from septic-tank discharges and storm water run-off. But the total effect of the increased use of septic systems in the Pinelands is dependent on their density and on particular soil characteristics. For these reasons, elevated nutrient loadings from these sources may have a significant impact on water quality changes in the future.

3. Run-off of agricultural wastes

   Excluding cranberry activities, agricultural development can have a significant impact on changing water nutrient levels, particularly nitrogenous nutrients. And, early in the growing season, phosphorous levels may get unusually high because of run-offs from fertilizers. The normally nutrient-poor soils of the Pinelands require heavy application of fertilizers for productive farming of crops other than cranberries. This causes disturbance of water quality because while ammonia-N is adsorbed in soils, excess ammonia-N is nitrified by soil microorganisms to nitrate-N, which in turn, is readily leached through the Pinelands soils to ground-water and then to surface waters. Also, run-off from agricultural as well as residential soils that have been limed lowers the acidity of ground and surface waters.

4. Landfill and solid waste disposal activities

Solid waste disposal in landfills may change the quality of ground-water in the Pinelands because of the sandy soils. Metal and mineral material dissolved from the wastes will leach through the soils to ground-water levels, though the effects of such disturbance may be delayed for several years. On the other hand, repeated applications of sewage sludge or effluent on existing natural communities may affect ground-water quality within a few months if the applications overload the capacity of plants and surface soil to retain the added nutrients. The practice of discharging agricultural processing wastes by power spraying has been particularly destructive to native vegetation.

5. Disposal of industrial chemical wastes

Because of the sandy soils, the Pinelands water quality is unusually susceptible to contamination by intentional or accidental disposal of chemical and petroleum industrial products in their transport or storage. The spoiling of the Raritan Bay area can serve as a model of the rapidity with which the quality of the water and ecosystems can be destroyed by chemical and petroleum pollution.

6. Recreational activities

Motorized boating and intensive canoeing or other water-recreational activities may cause deterioration of surface water quality through oil or other organic pollution. The results are reflected almost immediately in changes in quality.

3.4.3. Results of Changes in Water Quality

Changes which decrease the acidity of the ground and stream waters will cause dramatic changes in aquatic communities and in animal and plant communities that have evolved in iron-rich, acidic and low-nutrient waters. The characteristic fish of the Pinelands such as the chain pickerel, the eastern mudminnow, the ironcolor shiner, the pirate perch, the mud sunfish, the blackbanded sunfish, the blue spotted sunfish, and the swamp darter all would suffer with increased pH values of water. Likewise, amphibians which are dependent upon the waters of the Pinelands and which have adaptations to enable survival of their eggs and young larvae in the acid waters would be supplanted by other species. This includes organisms such as the unusual Pine Barrens treefrog, the Carpenter frog, and the four-toed salamander.

Increase of nutrients in the ground and surface waters can lead to the development of algal and associated bacteria growth in artificial lakes or slow-moving streams, causing algal and bacteria blooms that will result in dramatic changes in aquatic communities. Another result is to make the water unsafe for swimming.

Terrestrial plant communities are affected with increased loading of nutrients. Repeated applications of sewage or other sludge may modify plant composition, seemingly favoring plants found more on moist sites of the Inner Coastal Plain over native Pinelands species. A large number of endangered and threatened species are located in wetland habitats; overburdening amounts of nutrients, especially nitrogen compounds, herbicides and other pollutants in the waters of these habitats will destroy the few remaining species. Mineral-sediment deposits coming from erosion of cleared land are very detrimental to Atlantic white cedar and probably also to associated herbaceous plants, favoring in the long run hardwood swamp trees over the cedars. Large amounts of sediments released to surface waters with extensive development also are detrimental to aquatic biota.

Finally, because the entire freshwater supply of the coastal estuaries is derived from Pinelands drainage basins, degradation of the existing quality of stream water in the Pinelands will have serious impact on continued beneficial use of the estuaries.

3.5. CHANGES IN WATER LEVEL

3.5.1. Nature of Water Level Changes in the Pinelands

It is estimated that the ground-water reservoir within the Pinelands boundaries contains about 10.9 trillion gallons of freshwater. The only primary source for replenishment of the aquifer is precipitation, about one-half of which currently percolates through soils to ground-water level. Currently, about 90% of stream flow in the Pinelands is fed by ground-water discharge. Swamps and marshes for the most part represent sites on which ground-water level approaches the surface. Therefore, changes that reduce (or increase) the amount of ground-water in the Pinelands mean also changes in stream flow and in the delineation of upland and lowland habitat types. Also, changes in ground-water levels and Pinelands stream flow have a direct influence on salinity shifts in estuaries receiving outflows from Pinelands streams. Finally, these implications of water level changes must be examined in terms of the scale of such changes, such as in terms of

Regional-Inter-Regional Changes - Changes of such a magnitude that their impacts can be observed outside, as well as within a region such as the Pinelands.

Areawide Changes - Changes of such a magnitude that their impacts are observable at the basin-wide scale, or at a level where a substantial part of a basin or inter-basin effects are noticeable within the Pinelands.

Local Changes - Changes of such a magnitude that their impacts are observable in areas immediately adjacent to the source of the effect.

Site Specific Changes - Low order changes where effects are not observable away from the immediate vicinity of the source of the effect.

3.5.2. Causes of Water Level Changes

In the Pinelands pumping and transmission of large volumes of water represents the most significant cause of water level change potentially affecting ecosystems on a region-wide basis. A second cause of change in ground-water level stems from the decrease in ground-water recharge that occurs when precipitation cannot permeate soil surfaces to reach ground-water level. Such is the case when land is covered with structures and pavements. Precipitation lost in run-off to stream flow represents a decrease in ground-water supply. At a specific site level a variety of structural changes, such as drainage ditches, tile drains and other site modifications, may modify natural habitats around the site by altering the local water levels, but these have minor impact on the area ground-water levels. Filling, damming, shortening, and shifting the course of a stream will increase flooding, and alter significantly the character of habitats and their components, but have local impact on ground-water levels.

Changes in ground-water levels caused by pumping beyond safe yields can have a region-wide impact on stream flow in the Pinelands, particularly during low-flow periods. For example, it is estimated that the constant withdrawal of half the annual ground-water recharge (10 inches, 0.48 million gallons/day/sq. mi.) would in some years result in dry streams in the Pinelands for 30 days a year and produce exceedingly low flows in the proceeding and anteceding 30-day periods. The effects of this 3-month period upon salinity and nutrient relationships in bays and estuaries receiving flow from the Pine Barrens would be substantial. Overall, decreased stream flow would cause salinity gradients to move up estuaries resulting in a variety of ecological effects on related aquatic and wetland habitats.

On the areawide level the same basic recharge and flow figures would apply. At this scale, if significant reductions in stream flow were caused by excessive ground-water withdrawal, we would develop dry and low-flowing streams.

On a local scale, specific factors can influence the hydrological interrelationships. Soil types, ground-water gradients, confining beds, surface water gradients and stream distributions are all material to the quantification of effects of pumping. At larger scales (basins, regions) these variations "average out" to produce overall properties which may have low utility at the local level. In addition, a given amount of water withdrawal or recharge at one location may have little or no effect on water level, while at another location the same amount of water withdrawal or recharge would have substantial adverse impact on ground-water levels and, thus, on aquatic and lowland habitats. Prediction of impacts is dependent upon the placement and volume of water withdrawal or recharge relative to local hydrologic conditions which may accentuate or retard expression of impacts on adjacent areas.

Any expansion of development in the Pinelands will have an impact on the water levels, and consumptive use of water is generally correlative with development density. Projects of large magnitude such as a major water supply system withdrawing millions of gallons per day would have adverse effects upon areawide and regional hydrology. Almost every type of development project, except the smallest isolated activities, would result in adverse effects on the local level of groundwater. Furthermore, there is a finite number of projects that can be located within one area without causing adverse areawide impacts. A similar relationship exists between areawide water levels and those in the total Pinelands region; in this sense, all ground-water levels of scale in the Pinelands are interrelated through progressive cumulative stresses upon the total system.

There is also a fundamental relationship between water quantity and quality. When water is withdrawn from an aquifer and is eventually discharged to a treatment plant and into the sea, the water is lost from the system (consumptive use). When waste water is discharged into onsite waste disposal systems and then back into the aquifer, very little water is lost (non-consumptive use). However, by definition, the waste water recharged into the aquifer by non-consumptive uses is chemically and/or biologically degraded. This is the paradox of having development in a region such as the Pinelands where the soils offer little waste water treatment. If water is used consumptively water levels and quantity will be degraded; if water is used non-consumptively water quality will be degraded. If we add to this paradox the effects of non-point source pollution with consumptive use of water, we can degrade both quantity and quality of water. Long Island is a textbook example of such a case.

Non-consumptive use of water requires recharge to the aquifer through the soil. If the rate of recharge is substantial, relative to local hydrologic factors at the site, local ground-water levels may be locally elevated resulting in habitat changes. Additional impacts may result from the addition of biological active pollutants in the waste water.

3.5.3. Results of Changes in Water Levels

Existing ground-water levels are responsible for the diversity of Pinelands habitat types (see Section 1.3), and, thus, for much of the diversity in vegetation types. Changes in the stream flow or ground-water level or the timing of availability would have dramatic effects on the character of the Pinelands.

Drops in ground-water level would have the greatest impact on aquatic and wetland habitats. Animals and plants of aquatic systems and those that occupy marshlands and swamps would be stressed beyond the limits of their physiological tolerance with the lowering of the water table. As a result there would be wholesale destruction of communities. Depending on the intensity and duration of the induced water level changes, this would occur in relatively short time after the habitat conditions changed. Cedar and hardwood swamps, pine lowlands, and freshwater marshlands would be most affected. But detrimental changes also would develop on many upland sites where the water table is normally only a few feet below the land surface.

The change in stream flow caused by excessive withdrawal of water would destroy certain aquatic communities and reduce the concentrations of characteristic Pinelands fish and the abundance of reptiles and amphibians that depend upon stream waters. Reduced flow also would cause upstream shifting of the upper limits of salinity gradients in the estuaries which receive stream outflow from the

Pinelands. Upstream changes in salinity levels would result in movement of more predators into the bays causing destruction of important shellfish seed beds. Also, there would be displacement of freshwater vegetation as the salinity gradients moved upward.

Significant downward changes in water level will drastically affect the endangered and threatened species because such a large number are located in wetland associations. Water level modified by roadside ditches, mosquito ditches, partial or complete removal of vegetation, damming, and destruction of organic matter will result in species extinction in the immediate area. Such activity does not have to be restricted to the location of the detected problem, as downstream sites some distance from the cause can also be affected. Changes in water level produce two physiological phenomena harmful to plants -- drought and flooding. Both the extent of the drought and flooding, and the correlation of the timing with specific stages of the yearly life cycle are significant in terms of abundance and survival of endangered and threatened species.

3.6. MODIFICATIONS OF HABITATS

3.6.1. Nature of Modification in Habitats

Two major influences of habitat modification have already been discussed under separate headings -- changes in water quality and water levels. In this section other significant influences on the natural habitats of the Pinelands are discussed. These include influences that cause complete destruction of the specific habitats and those that simply modify the habitat conditions for plants and animals.

3.6.2. Cause of Habitat Modification

The activities that cause significant change in the natural habitats of the Pinelands are as follows:

1. Obliteration of Natural Landscape and Habitats by Man-Made Structures

   The use of land for housing developments, industry, highways and other supporting infrastructures obliterates specific habitats and natural communities. This has significant implications for the Pinelands. The reduction in natural ecosystems means that the relative abundance of habitats and species patterns of distribution and abundance are unnaturally altered.

2. Modification of Habitats by Timbering Activities

   Timbering activities in the Pinelands in the future, as they have in the past, may modify the natural forest and its plant and animal communities in many ways. Selective cuttings of specific species may change the composition of a forest type so completely that it loses its identity, such as the change on a site from a cedar forest to a hardwoods swamp forest. On the other hand, ecologically-sound forest practices can ensure persistence of desirable species and the regeneration of selected forest types.

   Timbering activities under any conditions, however, cause change in natural plant and animal communities by altering the vertical and horizontal structures of vegetation that occur naturally without disturbance. This results from changes in the canopy cover and thereby light conditions within the forest. Structure changes also affect the feeding, nesting, and habitation opportunities for birds and other animals. Removal of fallen logs means loss of log habitats and associated animal communities; on the other hand, left-over slash may add to habitat diversity.

3. Modification of Habitats by Other Land-Use Practices

Excluding here consideration for soil and water disturbance, the only other significant modification of the natural habitats of the Pinelands results from maintenance activities on public lands such as the degree to which these may be partially cleared of natural vegetation or mowed. Where rare or threatened species are growing, mowing or partial clearing to be useful must be coordinated with the life cycle of the species. Mowing during flowering destroys the next year's seed supply, while mowing after the fruit matures may have no effect. In some areas mowing is beneficial because it limits woody growth and allows survival of endangered and threatened herbs -- but the time of mowing must be coordinated with the proper stage of the life cycle to be of value.

3.6.3. Results of Habitat Modifications

The impact of past timbering activities on the forests of the Pinelands is discussed in Section 2.6.2. The evidence of the impact of past uncontrolled cutting is in hand. In a well-controlled situation, the recycling time of cutting would allow the regrowth to maximum stature of the forests. If older forest communities are not allowed to persist, the species characteristic of these areas will not survive. The logging of white cedar in the Pinelands may have already violated this recycling time to the point of species loss, for very few old-stand cedar forests persist in the Pinelands.

With sound forest management practices, a multiplicity of species rotation stages can exist at different locations within a forested area. In such a case, the regeneration of forests operates much like that in a natural landscape with extinctions and recolonizations taking place within and among patches of vegetation (Section 3.7.3). The persistence of species under such a system will depend upon the mobility or recolonizing ability of the organism in question.

In contrast to the ability to control timbering activities for beneficial use, the modification or destruction of habitats that comes with the replacement of natural landscape by man-made structures will lead to an enlarging list of rare and threatened species in the Pinelands and ultimate extinction of some species that exist today. The diversity of habitats and community types will diminish and with it the characteristics that make the Pinelands distinctive today. More will be said about this in the next section.

3.7. FRAGMENTATION OF THE PINELANDS NATURAL LANDSCAPE

3.7.1. The Meaning of Fragmentation of the Pinelands Landscape

The Pinelands evolved as one large natural landscape unit with the boundaries delineated by the patterns of soil and hydrological qualities described in Section 1.3. There were no man-created barriers to the dispersal and migration of animals and plant species within the Pinelands area itself or with neighboring regions. That the Pinelands encompassed large areal size, unbroken in continuity of natural vegetation, led to the development of its essential character; these two elements are crucial to its continued maintenance.

Fragmentation of a natural landscape means that the continuity of the landscape is artificially interrupted; at the extreme a fragmented landscape is one that is dissected into small isolated patches of natural growth without continuous corridors interconnecting individual patches.

3.7.2. Causes of Landscape Fragmentation in the Pinelands

The greatest contributing influence to the fragmentation of the Pinelands landscape has been, and will be, the leapfrogging of development and scattered single-home construction. The development and supporting infrastructure creates barriers for dispersal of plants and animals and reduces the scale of natural landscape units (or operating space) for animals and plants. Highways and cleared rights-of-way also create barriers which result in the death of many creatures and reduce migration potential even when distances are small. Land cleared of natural vegetation for agriculture, extractive industries, or even for intensive recreation such as creation of artificial lakes, add to landscape dissection.

3.7.3. Results of Landscape Fragmentation in the Pinelands

If development is allowed to spread in an uncontrolled fashion through the Pinelands and further dissect the natural landscape into smaller and isolated patches, the essential character of the region will be lost. There is substantial evidence illustrating the effects of size of patches of habitat on the species numbers and abundances within the patches. Larger contiguous patches of habitat can support more species with a much lower probability of extinction. Population sizes vary from year to year. The climatic variability in the temperate zone yields fluctuations in population sizes of species which, if population size is initially low, may result in extinction. Extinctions may be local in nature, e.g., occurring in only some patches, or they can be of greater magnitude. The extinction probability is reduced, however, by larger patches of habitat.

If local extinction does occur within a single habitat, recolonization of the patch is possible if the same species is present in nearby habitats. The movement from these colonizing sources to habitats in which an organism has been exterminated is a function of distance from the source and the conditions of the intervening landscape. Movement between habitat patches is greatly facilitated by patches which are close together or which are joined by corridors of similar habitat.

Today the Pinelands landscape is a series of habitat patches and corridors. For example, undisturbed landscape along streams serves as a natural dispersal corridor for movement of animals and seed dissemination of plants unable to survive in upland conditions. Each habitat type has its own array of plant and animal species. If the size of any one of these patches is reduced the numbers of individuals of the species within the patch are reduced. This increases the probability that extinction of a species in that patch may occur. Local extinctions are not unusual, but when they occur, recolonization of that species from an adjacent patch can usually be rapid unless patches of similar habitat are too far away or are small enough so extinction has occurred there as well.

The maintenance of a very large patch or core of natural vegetation, and preferably two such large patches of habitat, with minimal human disturbance will be essential for the maintenance of the essential character of the natural resources of the Pinelands. The presence of outlying patches will also aid the probability for permanence in species representation, for not only will the large patches supply the smaller patches with a greater diversity of natural species than might be expected in the absence of such patches, but also the smaller patches may serve as recolonization sites from which the large patches could be repopulated were a species to go extinct there.

Fragmentation of the Pinelands landscape into small isolated patches will result in decreased diversity of species and community types, and in so doing, endanger the capacity of the ecosystems to be self-maintaining. In addition, the lack of dispersal corridors will retard the natural development of genetic variability in the flora and fauna of the Pinelands. Such genetic variability occurs at different levels -- among individuals within a population on a contiguous site, among sites within the Pinelands area and between the Pinelands and ecosystems outside the Pinelands. The development of genetic variability has been very important in the past in ensuring adaptability, continued evolution and thus survival of the unique patterns and species of Pinelands plants and animals.

Large contiguous areas of natural landscape interconnected with adequate dispersal corridors are necessary also to ensure continuation of natural hybridization through genetic exchange. In the past hybridization has played an important role in enlarging the essential genetic diversity in the Pinelands (Sections 2.5.1 and 2.5.2); it is known to occur within groups of important Pinelands plant species -- for example, within groups of pines, oaks, blueberries, grasses, and sedges. It is believed important that natural hybridization take place to provide genetic combinations which will do well in areas modified by man. Because hybrids often do better on disturbed sites than their parents, they play an important short-term role (2 - 20 years) in the reestablishment of vegetation on sites modified by man. The longer term role of natural hybridization is to maintain and enlarge the genetic diversity essential for the continued existence of the natural communities.

The time interval over which the results of landscape fragmentation could be observed in the Pinelands is dependent upon the rapidity with which uncontrolled development would take place. Many impacts are local or of a defined geographic nature. The effects may be easily apparent by the extinction of a rare species or the disappearance of a particular vegetation type. But the impact on the Pinelands ecosystem as a whole may not be apparent for some time. Because of the complexity of ecosystem processes and the spatial and temporal heterogeneity in patterns of biological distribution, small changes are often obscured. The critical concept to incorporate into landscape planning is that small changes can have dramatic effects on the continued viability of natural communities, particularly those that exist in the Pinelands.

3.8. CHANGES IN FIRE FREQUENCY AND INTENSITY

3.8.1. Nature of Change in Fire Frequency and Intensity in the Pinelands

The natural plant and animal communities of the Pinelands evolved over thousands of years in the presence of and as a result of frequent wildfire (see Section 2.5.2). The species now present compete successfully under the impact of periodic fires; if the occurrence of fire is reduced in its frequency or in its intensity, the patterns of species abundance and distribution now found in the Pinelands would change.

Scientists talk about fire frequency in two ways. First is regional fire frequency, which describes the interval for the occurrence of fire in a given geographic region, usually in terms of number of fires per year. The term point fire frequency is used to describe the frequency or average recurrence interval at any given point, selected randomly, in a specific area; for example, it has been suggested that in northeastern Maine the point fire frequency (or the average time interval between fires) at any random point exceeds 800 years.

A recent unpublished research report suggests that while the total number of annual wildfires occurring in the Pinelands has remained about the same during this century, the total number of acres burned annually has dropped sharply in the past four decades. Earlier this century, any point randomly selected in the Pinelands was burned at 22-year intervals and since 1940 the interval between burning has increased to 72 years, a dramatic change. If this trend were to continue, the existing patterns of vegetation types and associated animal populations in the Pinelands would be significantly changed.

3.8.2. Cause of Change in Fire Frequency and Intensity

Before human settlement wildfires were natural occurrences in the Pinelands, probably occurring more frequently in periods of long drought and in greater scope in times of high winds. Since the first human settlement of the Pinelands fires have been accidentally and intentionally ignited. In the last century, at least, the combination of greater interest in protection of lives and property in inhabited areas and improved fire control equipment and practices accounts for the reduction in the total number of acres that have been burned.

Simple annual burning of litter surfaces by controlled fire management does not accomplish the same function as wildfires that burn over forest crowns. For this reason the prescribed management programs for fire in the Pinelands must permit in the future frequent burning of larger areas of natural landscape and at varying intensities as required to maintain the existing patterns of vegetation types. As it cannot be expected that the public would accept the needed fire regime if it endangered lives or property, appropriate siting of expanded single family and residential development projects becomes a crucial factor in potential future change for the Pinelands.

3.8.3. Result of Change in Fire Frequency and Intensity

The impact of fire on the development of both upland and lowland types of vegetation has been described in Section 2.5.2. Because the timing of vegetation succession varies with the stage of succession, only generalized estimates can be made about the intervals by which the Pinelands would change without the regime of fire. Through time there would be a progressive loss of fire-adapted genotypes in numerous species, competition from non-native species which are not fire-adapted, and loss in the variety of species and community types now found on uplands and lowlands. Perhaps, within 100 years without influence, other than lack of a natural fire regime, the face of the Pinelands landscape would be very different from that today.

3.9. DISTURBANCE OF SOIL

3.9.1. Disturbance of Soil as a Factor of Environmental Change

The characteristic soils of the Pinelands have been described as sandy, acid, and low in nutrient- and water-retention capacity. Disturbance of these qualities may cause dramatic changes in the type of vegetation and animal populations that follow.

Other than those soil disturbances already discussed in relation to water quality and quantity changes, habitat modification and landscape fragmentation, the significant factors are disturbances in soil surface such as compaction, soil pollution (such as by salt), and change in soil structure by removal of top surface material.

3.9.2. Causes of Soil Disturbance

The thin organic soils of the Pinelands uplands are easily compacted by trampling that comes with the intensive use of a natural area for picnicking, camping, hiking, horseback riding, and similar recreational activities. The use of off-road vehicles and motorcycles is even more destructive to the soil structure, increasing plant regeneration time.

Clearing of land for agricultural use not only eliminates natural vegetation, but building of reservoirs, dikes, sand roads, and other changes associated with the cultivation of cranberries will modify soil conditions so as to alter community composition. On the other hand, if agricultural land is abandoned, depending upon the type of previous use and maintenance of the soil, regeneration of natural plant communities will occur through time.

Mining of sands, gravels, and other minerals results in severe changes in soil textures and structures as well as exposing ground-water on some sites. Extensive mining also causes serious erosion that provides a source of mineral-sediment deposits in nearby swamps.

The use of salt and herbicides for highway maintenance provides still another disturbance that causes change in native Pinelands communities.

3.9.3. Results of Soil Disturbance

While the type of soil disturbances just described may be local in nature, once disturbed, the structure of soil is slow to return to its natural state. The slow invasion of native plants on sandy roadsides where disturbance is low but persistent is indicative of this problem.

Land changes associated with the cultivation of cranberries provide suitable conditions for successional plant communities and, thus, are said to add to the diversity of vegetation types in the Pinelands. Also, abandoned farmland passes through a number of successional stages of vegetation creating more community diversity. Some of the present-day forest stands, such as pine stands of seedling origin on upland sites and white cedar stands in abandoned bogs, occur on formerly tilled sites. Though extractive mining pits favor particular pioneer species of plants, the damage to the soils is so severe that it may have an almost permanent effect on capacity for regeneration of natural plant communities.

In addition to the type of soil disturbances just described, there are the ecosystem disturbances originating from the clearing of land and the obliteration of natural landscape that is associated with human habitation and its supporting infrastructure and services. These have been discussed in previous sections of the report; Section 3.4.3 describes the impacts of land clearing on water quality; Sections 3.6.3 and 3.7.3 deal with the impacts that land scarification has on habitat modification and fragmentation of the natural landscape. In total, soil disturbance is a major force of influence on change in the Pinelands environment.

3.10. SELECTIVE REDUCTION IN POPULATIONS OF NATIVE SPECIES

3.10.1 Nature of Change

A variety of factors, many of which have already been discussed, may cause selective reductions in populations of native plants and animals in the Pinelands. In addition, uncontrolled collecting or killing of particular species of flora and fauna currently is causing, as it has in the past, extinction or near-extinction of rare species. Certain species of Pinelands fauna have already been eliminated by uncontrolled hunting, such as the black bear, wolf, native turkey, and beaver, although efforts to repopulate the latter appear to be successful, and plans are made for restocking of the native turkey.

3.10.2. Causes of Selective Reduction in Populations of Native Species

Excluding influences of habitat modification, reductions in selective populations of native species of flora and fauna in the Pinelands are greatly influenced by uncontrolled collecting, hunting and fishing activities. The collection of rare plants and animal species for commercial sale as well as by well-intentioned students of Pinelands natural history has an impact on the populations of these species. The fact that the region is within a day's access to large population centers increases the danger of loss through collection. Also, the nearer residential development is to critical habitat areas for rare and threatened species, the greater the potential loss to collectors.

3.10.3. Results of Selective Reductions in Populations of Native Species

Obviously, increasing levels of species collection in the Pinelands and uncontrolled fishing or hunting activities threaten the continued existence of the rare plants and animals that contribute to the uniqueness of the Pinelands. Colorful and rare organisms usually are the first fauna species to suffer. In the Pinelands snakes are one of the more vulnerable groups. They are collected as pets or destroyed as dangerous by most people who see them. This group of animals is particularly important in the Pinelands as the loose sandy soil provides an excellent substrate for fossorial animals and many species of snakes are found in the Pinelands. Burrowing snakes such as the scarlet snake, the corn snake, and the pine snake as well as others such as the eastern kingsnake, the rough green snake, and the eastern hognose snake are affected not only by persecution from collectors and transient individuals not educated in the value of snakes; also, their numbers have been depleted by disturbance of the soil and by increased highway traffic.

Removal of more common trees, shrubs, or herbs for landscape purposes, terrariums, Christmas or other decorations and reduction in populations of more common animals, while less important in immediate impact on the environment, over a larger time period may upset basic ecosystem interrelationships, such as those involved in food chains.

3.11. INTRODUCTION OF NON-NATIVE SPECIES

3.11.1. Nature of Potential Damage to Environment

It is reported that 270 vascular plant species, or about one-third of the Pine Barrens flora, are non-native species that have been introduced since the time of European colonization. In addition, introduced species of mammals, birds, fish, reptiles and insects are present, often associated with human habitats within the Pinelands.

Introduced species may have adverse effects on the integrity of the native Pinelands flora and fauna, particularly if the species comes from the same climatic zone. For one reason, an introduced species may be able to compete better than a native species for a particular resource and thereby eliminate the native species. Second, through interbreeding, the introduced species may adversely affect the gene pools of the species. This can lead to the extinction of the native species in its original genetic form though the species may continue with a modified genetic structure.

3.11.2. Cause of Change

The introduction of non-native species is associated primarily with residential settlement in the Pinelands. Non-native plantings are used to landscape the grounds, and these may escape and naturalize in adjoining forests. Exotic animal species may be released intentionally or accidentally from household captivity. In addition, free-roaming pets, such as carnivorous cats and dogs, influence animal life in the area and may significantly reduce isolated populations of small mammals, birds, or amphibians.

3.11.3 Result of Introduction of Non-Native Species

Thus far, introduced species do not appear to have damaged the natural communities of the Pinelands. There is always, however, a potential chance that a new introduced species coming from a similar climatic regime may compete so successfully against the native species that it inhibits the native species and may even become a new dominant in the community. As an example, introduction of non-native species to promote hunting or fishing activities may inhibit populations of native species.

There is also the danger that an introduced non-native insect may become a destructive pest to vegetation, such as the gypsy moth which already has caused extensive defoliation of oaks in some areas of the Pinelands.

3.12. CHANGES IN AIR QUALITY

3.12.1. Nature of Changes

Man-produced changes in air quality as yet have not had a significant impact on Pinelands vegetation or associated animal populations. However, this may not be so in the future. The types of air quality changes that appear to be of significance are increased levels of air pollutants such as SO_2, NOX, CO_2, and particulates, increased acid rains, and increase in ozone levels.

3.12.2. Cause of Changes

The changes in air quality identified in the previous section are caused primarily by industrial activities, particularly those located to the south, west, and northwest of the Pinelands. Residential development and transportation exhausts are secondary causes of air pollution in the area.

Point sources along the western boundary of the Pinelands have produced periodic episodes of damaging levels of fluoride and sulfur dioxide. If, in the future, there is relaxation of the standards on the use of higher sulfur fuels, there also may be periodic damage from local point sources of sulfur dioxide.

It is suggested that a major potential air quality problem for the Pinelands will come from overloads of ozone that originate in the Delaware Valley and lower Delaware Bay area. Already, the air quality standards for ozone have been exceeded many times per year across the Pinelands area.

3.12.3. Results of Changes in Air Quality

Different species have varying levels of tolerance to air pollutants. Herbaceous plants appear particularly sensitive to damage from the ozone; pines and oaks in the region have shown damage from fluorides and sulfur dioxide, which also are especially limiting on the lichen flora.

The results of acid rains have been observed in other forests in the East; tree productivity is reduced, less-tolerant plant species are eliminated, and fish populations particularly are damaged. Deterioration of air quality is quickly reflected in plant damage and extinctinction, and thus can cause rapid change in existing patterns of vegetation.

SECTION 4

FUTURE CHANGE IN THE PINELANDS LANDSCAPE, ECOSYSTEMS, AND THEIR COMPONENTS

4.1. OBJECTIVE

The objective of this section is to make a set of forecasts about the impacts that reasonable combinations of the influences identified in Section 3 would have on the existing Pinelands environment -- its landscape, ecosystems, and their components -- given no control over the influence. The forecasts are to be framed as assumptions about changes that would be apparent within each of three rough time scales: (1) changes apparent within the next 25-year period, (2) changes apparent within the next 100 years, and (3) changes that might occur over a longer span of time.

4.2. THE SIGNIFICANT THREATS TO THE PINELANDS ECOSYSTEMS

Natural landscape processes that have occurred in the past, are occurring today, and will continue to occur in the future, cause change in the landscape at a very slow rate.

Although some natural forces acting alone -- a hurricane or ice storm, for instance -- may have an immediate, apparent, and destructive effect on areas of the landscape, they do not directly attack the Pinelands capacity to regenerate itself through the natural processes of succession. Without the aggravation of man-induced influences it is probable that they would cause no discernible deterioration of the Pinelands environment in the time frames of 25 and 100 years, nor would the slower, more persistent geological and climatic forces of change. This is not true of man-induced influences which, if not controlled, will quickly accelerate the trend of deterioration of the Pinelands environment which they have already started.

In Section 3 nine factors, all man-related, are identified as the principal forces that could alter significantly the Pinelands ecosystems and their components in the future. Six of these factors, if not controlled by the Pinelands management plan, will have continuing and growing impact on the ecosystems and their characteristic components, and in relatively short time will destroy the essential nature of the Pinelands. These are:

Degradation of water quality (Section 3.4)
Lowering of water levels (Section 3.5)
Modification of habitats (Section 3.6)
Fragmentation of the natural landscape (Section 3.7)
Reduction in fire frequency (Section 3.8)
Disturbance of soils (Section 3.9)

A seventh factor, deterioration of air quality (Section 3.12), also has the potential to damage quickly and permanently the characteristic flora and fauna of the Pinelands. But as the sources for this influence lie primarily outside the boundaries of the Pinelands, it has been segregated to call attention to the need for separate controlling action.

The two remaining categories of influences while significant in causing local habitat disturbance and population changes, and even extinctions of native species, are relatively less destructive to the basic processes that ensure self-maintenance of the Pinelands ecosystems. These include the factors that relate to:

Selective reduction in populations of native species (Section 3.10)
Introduction of non-native species (Section 3.11)

Section 3 identifies the many different human activities that contribute to each of the nine forces of change enumerated above. It is suggested that six of these activities, in particular, will have a significant impact on the future of the essential character of the Pinelands environment, given no restricting controls. These are:

4.2.1. Uncontrolled Expansion of Residential Development in the Pinelands

Unrestricted residential development and associated infrastructures of private and public services will result in:

- land scarification and fragmentation that destroys or modifies critical natural habitats causing elimination or reductions in populations of native Pineland species and in diversity of community types

- degradation of water quality by adding sources of pollution
- endangerment to maintenance of ground-water levels by increasing consumptive use of water
- reduction in fire frequency in remaining areas of natural landscape by increasing demand for fire control
- introduction of non-native species and reductions in populations of certain native species by increased proximity of settlements to natural habitats
- degradation of air quality by increased pollution of fuel and automobile effluents

4.2.2. Uncontrolled Disposal of Waste and Sewage

If left uncontrolled, the disposal of sewage and polluting wastes of all types and from all sources will significantly change the essential character of the Pinelands by degrading surface and ground-water quality so that native species no longer can successfully compete and maintain their populations under the changed environemntal conditions. In need of control are point and non-point sources of waste and sewage disposal from residential, industrial, and commercial activities, public services, and landfills and pollutions associated with the use of agricultural fertilizers, pesticides, and herbicides.

4.2.3. Excessive Pumping of Pinelands Water

Excessive pumping of ground and surface water for consumptive use within the Pinelands area or for export outside the region would alter dramatically habitat environmental conditions and, therewith, the plant and animal species and vegetation types now present in the Pinelands. Many of the specific results that would develop from reduced ground-water levels and stream flow in the Pinelands are described in Section 3.5.5. But as well stated by one of the Science Participants, because of the complexity in surface and ground-water interrelationships, excessive pumping of water could result in opening a Pandora's box of ecosystem problems in the Pinelands and in related estuaries.

4.2.4. Uncontrolled Expansion of Industrial Development

Uncontrolled expansion of industrial development within the boundaries of the Pinelands will subject the ecosystems to stresses similar to those caused by residential developments. In addition, uncontrolled industrial development within (and outside the boundaries) of the Pinelands will cause to an even greater extent deterioration of air quality beyond levels that can be tolerated by the native flora and fauna.

4.2.5. Uncontrolled Timbering Activities

Uncontrolled timbering activities, whether for fuelwood or other wood products, will cause almost instant observable deforestation of a particular site. Although the impact of unrestricted timbering initially may be local in scale, within a relatively short time span enlarging areas of deforestation could be so extensive as to make the present Pinelands unrecognizable.

4.2.6. Continued Uncontrolled Collection of Rare and Threatened Species

If left uncontrolled, continued collection of rare and threatened species will result in extinction of many of the unusual fauna and flora species that have made the Pinelands biologically distinctive.

4.3. FORECASTS OF CHANGE IN THE PINELANDS

Forecasts of future potential ecological events in the Pinelands are difficult for several reasons. First, because of the complexity of ecosystem processes, ecological theory has dealt primarily with predictions about the persistence or extinction of individual species rather than whole ecosystems. Second, there is a lack of adequate data that identifies the full impact of varied land-use activities, operating individually and collectively, on habitat elements in the Pinelands. Although the effects of severe disturbances may be immediately discernible, less acute chronic disturbances may cause imperceptible, but very destructive, changes in ecosystem processes. Nevertheless, there is enough evidence, gathered after the fact, on the impacts of ecosystem disturbance to warrant the following predictions:

4.3.1. Changes Apparent Within a 25-Year Period

Given no control over residential, commercial, and industrial development in the Pinelands and disposal of the associated wastes and sewage, and given the extrapolation of the population growth trends of the last two decades into the future, it is reasonable to expect the Pinelands to change in a piecemeal fashion from a natural area which, when disturbed, had the capacity to regenerate its natural communities to an area in which regeneration of natural communities will be very difficult and finally impossible.

Degrading changes in water quality caused by the expanding development will be almost immediately apparent in changes of species composition in aquatic and terrestrial populations of plants and animals. Non-native species will be favored over native species; this, when combined with destruction of extensive areas of natural habitats, means that species characteristic of the Pinelands will become more difficult to find, if at all.

Expanding development in a leap frogged pattern of distribution will gradually dissect the contiguous natural landscape so that ecosystems become smaller in areal size and then exist only as patches of isolated units surrounded by man-made developments. In the process of expanding development, concern for the preservation of life and property will lead to more effective fire control and, thus, lengthen intervals of fire frequency in the natural ecosystems. The combined result of these conditions will be to reduce greatly the biological diversity now present in the Pinelands. Vegetation types dependent on a frequent fire disturbance regime will disappear; the species composition of other community types will decrease, and the natural ecosystems will become impoverished in numbers of native species.

The time span by which the changes just described take place will be accelerated if there is export of Pinelands water to outside regions or if consumptive use of water within the Pinelands region itself, leads to excessive pumping and lowering of the ground-water levels. But the ultimate results remain the same -- loss of self-regenerating ecosystems and, thus, loss of the essential character of the Pinelands environment. A prototype of this scenario occurred with similar ecosystems on Long Island.

4.3.2. Changes Apparent Within the Next 100 Years

Continuing with the same assumptions underlying the 25-year forecast, the trends of environmental deterioration already started in the Pinelands will be accelerated through time. Without controlling actions over land-use, within 100 years from now the word Pinelands will be meaningless from an ecological standpoint; only remnants of native species, depauperate park-like areas, will remain.

4.4.3. Change That Might Occur Over a Longer Span of Time

Under the given assumptions, the only further changes that would occur in the area once delineated as the Pinelands will result from natural landscape evolution. If long-term natural processes, such as those involved in climatic and sea level changes, continue in the future on approximately the same time scale as in the past, it will be many centuries from now before these will be reflected in the landscape.

SECTION 5

RECOMMENDATIONS FOR MANAGEMENT POLICIES AND ACTIONS

5.1. OBJECTIVE

The objective of this section is to offer recommendations for significant management policies and actions that are deemed important to achieve the goals set forth for the preservation of the essential character of the existing Pinelands environment.

5.2. INTRODUCTION

As stated in the New Jersey Pinelands Protection Act of 1979 (S3091), the first goal of the comprehensive management plan with respect to the Pinelands area shall be to "preserve and maintain the essential character of the existing Pinelands environment, including the plant and animal species indigenous thereto;" (Section 8.a.(1)).

In a discrete sense full achievement of this goal calls for total prohibition of further development in the Pinelands area and preservation of the landscape as it presently exists. This may be said to be true because any modification of the existing natural landscape, however small and however local geographically, will affect the abundance and distribution of both animal and plant species and, thus, have some impact on the essential character of the Pinelands.

In the Pinelands, as elsewhere, man-induced changes may certainly occur as a continuum with gradients in the severity that particular landscape modifications have on environmental conditions. But even small changes in habitat conditions will cause alterations in existing fluctuations of plant and animal populations that alter the probabilities of species extinction. Changes in population numbers and extinctions, in turn, lead to major changes in community structure and functions. Unfortunately, the impact of many man-related modifications of environmental conditions may not be apparent on a community or at total ecosystem level until long after the impact is seen on a local spatial level (for example , the disappearance of a particular swamp) or on a species level (the declining numbers of a particular plant or animal).

Although total restriction on modification of any part of the existing natural landscape in the Pinelands area represents an ideal policy for achieving the goal of maintaining the essential character of the Pinelands ecosystems, it does not appear to be compatible with other goals specified in the legislation. For this reason the fundamental criterion suggested herein for planning and management policies in the Pinelands is to limit landscape modifications to the extent necessary to ensure self-regeneration of the patterns of species abundance and distribution that make up the essential character of the Pinelands.

5.3. PLANNING POLICIES FOR THE PINELANDS

It is suggested that achievement of the goal to ensure preservation of essential and self-maintaining ecosystems that characterize the Pinelands while still accommodating compatible expansion in residential, commercial, and industrial development and indigenous agricultural activities calls for three fundamental management policies. These are:

5.3.1. Establishment of a Total Integrated System of Pinelands Critical Areas, Each Component of Which is Identified by Specified Geographic Boundaries

Functionally, this system would serve as a wilderness. Recreational, timbering, and indigenous agricultural activities should be permitted within the critical areas to the extent that each activity is compatible with the maintenance of the natural habitats, their biological components and ecosystem interrelationships. Within the boundaries of critical areas, there should be no further expansion of residential, commercial, and industrial development or other associated activities that may cause change in natural ecosystem processes and components. In fact, the long-range direction should be to try to decrease, when it becomes possible, existing human impacts on ecosystems within the designated critical areas.

5.3.2. Establishment of a Greenbelt Zone Around the Designated Critical Areas Which Will be Devoted to Recreational, Agricultural and Timbering Activities

This zone not only accommodates the designated activities but also provides a buffer zone that separates concentrations of people and property from the dangers of fire which must continue if the essential character of the Pinelands is to be retained.

5.3.3. Designation of the Remaining Area as the Zone for Expansion of Residential, Commercial and Industrial Activities

In this zone there should be restrictions only as needed to protect and maintain the significant values of natural resources in the entire Pinelands area as mandated by the legislation.

Recommendations for implementing actions in each of the policy areas are offered below.

5.4. DESIGNATION OF A TOTAL INTEGRATED SYSTEM OF PINELANDS CRITICAL AREAS

The proposed system of Pinelands critical areas has three components:

- Preservation of a large central core area;
- Preservation of specified areas of varying size outside the central core, which hereafter are referred to as critical area outliers;
- Preservation of corridor areas that interconnect core and outlier areas, and to the extent possible, connect the core area to forest patches or existing public lands that lie outside the boundaries of the Pinelands to the north, south, and west.

The integrated system of Pinelands critical areas proposed herein is detailed on the map enclosed with this report. The factors that were considered in the designation of critical areas are described below.

5.4.1. Designation of the Critical Core Area

Three criteria are used in establishing the boundaries for the core of the Pinelands critical areas system:

1. The core should be as large as possible in areal size so as to minimize the loss of species that will occur as intrusions are made into the total Pinelands area (see Section 3.7.3) and to permit varying patterns of fire disturbance.
2. The core area should encompass the least disturbed land and waters in the Pinelands area, and include good representatives of characteristic habitats, community types, and species populations.
3. The core area should include as its minimum ecological units several complete and contiguous stream drainage units and the upper undisturbed basins of other streams. In the unusual situation where the ground-water hydrology pattern does not conform exactly to that of surface water, the stream basin must be expanded to include the extremes of boundary.

5.4.2. Designation of Outlier Critical Areas

The following types of areas are considered for designation as outlier critical areas:

1. Complete, or upper parts of, stream basin units which lie outside of the critical core area but which still have waters

characteristic of the least disturbed streams in the Pinelands (see Section 3.4.1).

2. Adequately-sized land tracts of natural vegetation that lie along the north-south and east-west axes of the Pinelands area and can provide continuity for dispersal and genetic exchange among biological populations.

3. Upstream land tracts on which land-use activities must be restricted so as to preserve specific downstream critical areas.

4. Adequately-buffered habitats of particular threatened or endangered species or populations poorly represented in the core area.

5. Adequately-buffered habitats with unusual microduplicates of biological communities or ecosystems already represented in the core.

5.4.3. Designation of Critical Corridor Areas

The purpose of the critical corridor areas is to provide protected natural corridors for dispersal and migration of native animals and plants so as to ensure optimum living and migratory space for animals and genetic exchange potential among plants in the Pinelands area and between the Pinelands and neighboring forests (see Section 3.7.3). It is recognized that existing developments and infrastructures, highways particularly, prevent the establishment of an ideal corridor network for the Pinelands critical areas. As far as possible, however, four factors should be considered:

1. Corridors should be continuous strips of natural habitats and vegetation connecting each critical area with the core or with at least one other critical area.

2. Corridors should be aligned, where possible, along stream banks ideally stretching from headwaters to estuary.

3. To serve its function, each corridor should be of a size wide enough to include self-maintaining ecosystems that are able to withstand deterioration by the causes of change enumerated in Section 3.

4. Existing public lands not included in the critical core area or in any outlier critical areas should be considered as potential corridor connections in the critical area system. Also, lands bordering existing railroad tracks may serve as corridor areas.

5.5. MANAGEMENT POLICIES FOR THE PINELANDS CRITICAL AREAS

To achieve the legislated objectives, the following management policies are suggested for the Pinelands critical areas:

1. No further expansion of residential, commercial or industrial development should take place within the boundaries designated as critical areas.

2. Corollary with the objective of maintaining the critical areas so as to preserve the essential character of the Pinelands, recreational activities should be limited to those compatible with the maintenance of characteristic environmental conditions in each type of habitat. Certain types of activities, such as the use of off-road vehicles, should be prohibited in designated critical areas, but permitted in the area designated as the greenbelt zone. The intensity of recreational use in any designated critical area, or part thereof, must be kept within the limits necessary to ensure that the natural habitats, biological communities, individual species populations, and ecosystem interrelationships are not disturbed or altered by the recreational use or by the establishment and maintenance of facilities associated with that use.

3. Critical areas should be subject to varied patterns of a prescribed fire regime including simulation of wildfires so as to maintain the mosaic of landscape diversity as it existed before the influence of significant human impact.

4. Critical areas should be managed to assure continuation of the natural ecosystem processes and the types and patterns of vegetation and animal populations characteristic of the Pinelands. Timbering for wood products should be permitted only as it is compatible with the primary objective set forth for the critical areas. Forest management and cutting rotation techniques that may be used in the Pinelands greenbelt zone to ensure an optimum supply for wood products should not be the guide for forest management in the forests of Pinelands critical areas. Use of herbicides and pesticides for vegetation management and agricultural fertilizers and liming to change the natural habitat conditions should be discouraged. While recognizing that sound forest management practices may add to habitat and community type diversity in the critical areas, it also must be recognized that there is not complete understanding of the complex ecosystem interrelationships that make the Pinelands environment what it is today; thus, any man-induced disturbance of these interrelationships may destroy essential ecosystem processes and, thereby, endanger the biological components of the ecosystem.

5. Indigenous agricultural activities already located in critical areas should remain as they now exist; expansion of small cranberry or blueberry cultivation units into larger units within

the critical areas should not be permitted as it would create large islands of monoculture units as well as impact water levels by water diversion and damming.

6. All extractive and landfill solid waste disposal activities now carried on within critical areas should be relocated outside the boundaries of these areas. Many sites previously used for mining could be reclaimed for recreational use if such use is compatible with maintenance of the surrounding natural habitats.

7. Water should not be pumped for export outside of the Pinelands critical areas.

8. Collection of native plants in critical areas should be prohibited except for scientific research use. Legislation covering collection of native animal species should be enforced.

9. Non-native plants should not be introduced as plantings on public lands within the critical areas.

5.6. MANAGEMENT POLICIES FOR NON-CRITICAL AREAS IN THE PINELANDS

To maintain the essential character of the Pinelands while still achieving the multiple goals set forth in the legislation, a particular pattern of land-use outside the critical areas has been recommended.

Surrounding the critical areas where possible, should be a greenbelt zone devoted to a mixture of land-use activities, primarily recreational, timbering, and agricultural activities.

New residential, commercial, and industrial development should be planned in concentrated rather than in isolated units or as enclaves in the natural landscape. These should be located either adjacent to existing centers of concentration or several new centers might be established at the margins of the Pinelands. Concentration of development has many advantages. It results in the least amount of fragmentation of the natural landscape and permits the continuation of fire, which is necessary to maintain the essential character of the Pinelands while minimizing its danger to residents and property.

Given the pattern of a greenbelt recreational zone and concentrated areas of residential, commercial, and industrial development, the following management policies are recommended for land-use in the non-critical areas of the Pinelands.

1. A corridor of natural vegetation of approximately 300 feet should be maintained on each side of all streams in the non-critical areas to mitigate the impact of solids and nutrients entering the streams from bordering land-use activities.

2. A planned unit of residential, commercial, industrial development or supporting infrastructure, should be prohibited if it can not be demonstrated that the planned development will have no adverse effect on existing ground and surface water quality as defined in Section 3.4.1.

3. A planned unit of residential, commercial, industrial development or supporting infrastructure, should be prohibited if it will produce a lowering of water table heights through increased withdrawal by wells or through a reduction in aquifer recharge by loss through overland runoff.

4. Planned expansion of industrial development should be limited if it can not be demonstrated that the planned activity will have no adverse impact on existing air quality.

5. Use of land for agriculture and for various types and intensities of recreational activities should be encouraged throughout the non-critical areas to the extent that each activity can take place without altering existing water quality and water level conditions as described in Sections 3.4 and 3.5.

6. Timbering on private and public lands should be encouraged with forest management practices that ensure the optimum supply for wood products.

7. Location of landfill and solid waste disposal activities should be permitted in non-critical areas only if it can be demonstrated that surface or ground-water quality will not be contaminated. Likewise, application of sewage or other effluents should be limited and monitored to ensure that they do not overload the capacities of soils and native vegetation to retain the added nutrients.

8. Water should not be pumped from non-critical areas for export out of the region designated as the Pinelands area or reserve.

9. Collection of native plant species should be discouraged except for scientific research. Introduction of non-native species, particularly animals, should be discouraged through educational programs. Legislation covering collection of native animal species should be enforced.

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