

Appendix B



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Rough green snake

Habitat Management Plan

Prime Hook National Wildlife Refuge Habitat Management Plan

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Chapter 1. Introduction

1.1 Scope and Rationale

In 1963, Prime Hook National Wildlife Refuge (NWR) was established to protect migratory birds and preserve coastal wetlands along the Delaware Bay. Lands were later acquired in the early 1970s for the purpose of conserving endangered and threatened species, the protection of natural resources and incidental fish and wildlife-oriented development. In the past, the primary focus of the Refuge has been the restoration of wetland habitats and the management of waterfowl. Although waterfowl management will always be a priority, future habitat management efforts will also ensure the protection, management, and enhancement of native plant communities which will conserve shorebirds, secretive marsh birds, wading birds, landbirds, raptors, the endangered Delmarva fox squirrel, and benefit resident wildlife. Through several CCP scoping and other public meetings our conservation partners and members of the public helped Service and refuge staff develop a future management vision statement. This Refuge Vision Statement serves as a starting point and provides future direction for habitat management planning and implementation.

Prime Hook National Wildlife Refuge will comprise a variety of Delmarva coastal plain habitats, such as barrier island beach, freshwater and tidal wetlands, grassland, shrubland and forest. The refuge will manage, maintain, enhance, and where appropriate, restore habitats for native plants and animals, with an emphasis on migratory birds and rare species. A balanced approach will be used to ensure all wildlife-dependent recreational users experience quality opportunities. The refuge will be a leader in conservation, research and community partnerships, adapting to physical and community changes as necessary to maintain the ecological integrity of the refuge and build a stewardship ethic for current and future generations.

PHNWR is managed by the U. S. Fish and Wildlife Service as part of the National Wildlife Refuge System (NWRS). The mission of the NWRS is to *administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.*

The Refuge's Comprehensive Conservation Plan (CCP) and this Habitat Management Plan (HMP) are the primary tools used to guide refuge staff in achieving refuge objectives and the mission of the System. We have used the most recent refuge biological information and data, scientific literature, and ecological principles in developing this HMP to conserve and protect functional communities of native fish, wildlife, and plants. We view the highest measure of BIDEH as those natural habitats and associated wildlife populations that existed under historic conditions before humans altered the landscape. We have considered a range of habitat management strategies to meet our specific habitat goals and objectives and conducted survey of current refuge habitat conditions using the National Vegetation Classification System (NVCS) community mapping data, scientific reports, conservation partners' professional opinions and Service wildlife management expertise. We will provide for or maintain all appropriate native habitats and species.

This Habitat Management Plan is a dynamic working document with a long-term vision that provides guidance for the management of refuge habitats on an annual basis. The plan will provide direction for the next fifteen years (2010 – 2025), with subsequent reviews every five years, and use of adaptive management principles to assess and modify management activities as required. In the HMP we have considered and incorporated the role that refuge habitats play in international, national, regional, state, and local ecosystem plans. To the extent practicable, we craft our goals and objectives to be consistent with these plans, to assist in attaining the goals and objectives of conservation partners and the larger conservation community, in addition to achieving refuge objectives.

1.2 Legal Mandates

In the early 1960s the southeastern coastal marshes of Delaware were under threat of industrial development from oil refining and manufacturing industries. To help preserve these coastal wetland ecosystems from industrial developmental threats, PHNWR was established under the Migratory Bird Conservation Act (16 U.S.C. 715-715r, as amended on August 8, 1963, “...for use as an inviolate sanctuary, or for any other management purpose, for migratory birds.” Approximately 8,356 acres were acquired from sales of Migratory Bird Hunting and Conservation stamps for the purpose of migratory bird management.

Refuge boundaries were later expanded to include lands purchased under the Land and Water Conservation Fund (934 acres) under the authority of the Refuge Recreation Act (16 U.S.C. 460 k --- 460 k-4), as amended for the following purposes “...suitable for (1) incidental fish and wildlife-oriented recreation development, (2) the protection of natural resources, and (3) for the conservation of endangered species.”

The National Environmental Policy Act (NEPA) mandates our consideration of the impacts of our habitat management on environmental and cultural resources in planning federal actions. The Comprehensive Conservation Planning (CCP) process ensures compliance with NEPA, and serves as the basis for development of the HMP. In conjunction with the preparation of an Environmental Impact Statement (EIS) under the requirements of NEPA, the CCP process includes intra-Service consultation to fulfill the requirements of the Endangered Species Act (ESA). The Endangered Species Act (ESA) provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found.

The Refuge Improvement Act provides the United States Fish and Wildlife Service (Service) the authority to establish policies, regulations and guidelines governing habitat management planning within the System. The Act states that “... each refuge shall be managed to fulfill the mission of the System, as well as the specific purposes for which that refuge was established...” {Section 4(a)(3)} and that “In administering the System, the Secretary shall monitor the status and trends of fish, wildlife and plants in each refuge” {Section 4(a)(4)}. The Service has established Habitat Management Planning Policy derived from the statutory authority of the RIA and in June of 2002 published Chapter 620: Habitat Management Practices within the NWR System (620 FW 1) in the Service Manual.

The HMP policy delineates strategies and implementation schedules for meeting CCP goals and objectives related to wildlife and habitat management. If a habitat management strategy or activity is required to meet a specific habitat objective in the HMP, and it produces an economic output (like timber harvest or cooperative farming as examples), the requirements for administering refuge management economic activities in the Service’s Compatibility policy (603 FW 2) apply, i.e., written compatibility determinations and special use permits. However, compatibility determinations for habitat management activities that do not result in the generation of a commodity are not required. All habitat management activities described in this HMP have been addressed in the CCP.

1.3 Links to Other Plans

Refuge Plans

Habitat goals and objectives developed in the CCP/HMP will provide the groundwork for how the Refuge will conserve, protect, enhance and/or restore functional communities of native plants, fish and wildlife through specific management strategies and prescriptions. These habitat management strategies and prescriptions are linked with national and regional wildlife conservation plans including the Delaware Wildlife Action Plan. These links are explained in this section of the HMP.

Comprehensive Conservation Plan (CCP)

The 1997 RIA requires all Refuges to complete CCPs by 2012. A CCP is an all-encompassing document that guides all biological and public use actions on the Refuge for a 15 year period. Habitat goals and objectives developed in this HMP have been stepped-down from the Refuge's CCP.

Fire Management Plan (FMP)

A FMP is mandated by the Service policy for all Refuges that have "...vegetation capable of sustaining fire." The FMP addresses wildland and prescribed fire conditions and events with specific guidelines on the level of protection needed to ensure public safety, protect facilities, refuge resources and property, and restore and perpetuate natural biological processes. Prescribed fire is recognized as an important tool used to mimic ecological processes as an agent of disturbance that releases energy and renews habitats. Other fuels management strategies include mechanical thinning of vegetation and herbicide use. A FMP was completed for PHNWR on 2009. Habitat management goals and objectives developed in the FMP will also be incorporated into this HMP.

Habitat and Species Inventory and Monitoring Plan (HSIMP)

The HSIMP is another step-down plan from the CCP and will be completed 1-2 years after the CCP and HMP have been approved. At that time, habitat condition inventory and monitoring protocols essential to the HMP will be developed in accordance with the Service Manual: Habitat And Wildlife Inventory Monitoring Chapter (701 FW 2).

Monitoring wildlife populations as a sole indicator of wildlife habitat condition is usually not appropriate. However, habitat monitoring in association with wildlife response to habitat manipulations, provide the best measure of achieving HMP objectives (620 FW 1.14). Monitoring will be the primary basis for evaluating the effectiveness of management strategies, prescriptions, and actions to achieve habitat objectives set forth in the CCP/HMP.

Regional and State PlansUSFWS Migratory Bird Program (MBP) Strategic Plan

The MBP completed a 10-year strategic migratory management plan in 2004: A Blue- print for the Future of Migratory Birds - A Strategic Plan for 2004-2014 (USFWS 2004). National Wildlife Refuges provide high quality habitat for many migratory birds. The MBP is seeking to conserve and manage migratory bird populations and their habitats through strategic collaboration with partners committed to the same conservation goals.

Two key strategies of the MBP Plan are bird population monitoring and habitat management. Refuges are currently conducting biological surveys and managing habitat. Prime Hook's HMP will incorporate information from standardized monitoring protocols established while participating in several regional bird studies and from habitat assessments using the NVCS mapping inventories. There is an opportunity for the refuge to contribute to State- and region - wide assessments of bird population trends, and the effects of habitat management activities on migratory birds, by conducting strategies prescribed in this HMP.

North American Bird Conservation Initiative (NABCI)

The NABCI brings together the landbird (Partners in Flight), shorebird, water bird, and waterfowl national plans and consolidates them into a coordinated effort to protect and restore all native bird populations and their habitats of North America. These conservation partnerships reduce redundancy in the structure, planning and implementation of continental conservation goals and objectives. It also utilizes Bird Conservation Regions (BCRs) to guide landscape scale, science-based approaches to conserving birds and their habitats.

PHNWR lies within the New England/Mid-Atlantic Coastal Bird Conservation Region (BCR 30). This area has the densest human population in any region in the country. The highest priority birds of BCR 30 inhabit coastal wetland and beach habitats, especially Saltmarsh Sharp-tailed Sparrow, Nelson's Sharp-tailed Sparrow, Seaside Sparrow, Piping Plover, American Oystercatcher, American Black Duck, and Black Rail. The region also includes critical migration sites for Red Knot, Ruddy Turnstone, Sanderling, Semipalmated Sandpiper, and Dunlin. Other terns and gulls nest in large numbers along with mixed colonies of herons, egrets, and ibis on islands along the Delaware Bay and Chesapeake regions. These birds use Prime Hook NWR for a portion of their life cycle.

Estuarine complexes and salt marsh wetlands created behind barrier beaches in BCR 30 are extremely important to wintering and migratory waterfowl, including 65% of the total wintering American Black Duck population along with large numbers of Greater Scaup, Tundra Swan, Gadwall, Atlantic Brant, and Canvasback.

The Refuge plays an important role in the conservation of habitats for migrating and breeding birds identified in the BCR 30 plan. A comprehensive summary report prepared by Regional Biologist J. Casey (June 2007) collected the most current core information from BCR plans in Region 5 in relation to the bird species found on PHNWR, and this information was used to identify and prioritize specific resources of concern for refuge habitat management.

One hundred thirty-four species have been identified as priority species in the BCR 30 plan (Steinkamp 2008). The majority of these priority species use habitats associated with coastal ecosystems, including beach, sand, mud flats, estuaries, bays and estuarine emergent wetlands. Further review identified priority landbird species of other BCR plans that lie to the north and northwest of BCR 30, which included BCRs 12, 13, 14, and 28. Of the listed ninety-eight priority BCR species in these plans, 83% or 81 priority BCR species use PHNWR during the spring and/or fall migration period (Casey 2007).

The BCR 30 plan has linked bird species of greatest conservation need with their associated habitats that are necessary to sustain their populations. Eleven habitat suites have been identified as critical to conserve highest ranked migratory bird species with associated priority habitat management actions. This information has been incorporated in the Refuge's HMP for identifying Refuge top resources of concern and to establish habitat management priorities for the next 15 years.

North American Waterfowl Management Plan (NAWMP) & Atlantic Coast Joint Venture (ACJV)

The NAWMP outlines strategies in the U.S., Canada and Mexico to protect North America's remaining wetlands and to restore waterfowl populations through habitat protection, restoration, and enhancement actions. Implementation of this plan is accomplished at various regional levels within designated regional habitat "Joint Venture" areas.

The Refuge is part of the Atlantic Coast Joint Venture (ACJV) whose comprehensive conservation approach emphasizes all-bird habitat management. The goal of the ACJV is to *"protect and manage priority wetland habitats for migration, wintering and production of waterfowl, with special consideration to black ducks, and to benefit other wildlife in the joint venture area."*

In order to capture the conservation needs of a diversity of landscapes the ACJV has delineated planning areas into special focus and sub-focus areas. The state of Delaware contains four focus and three sub-focus areas together encompassing over 900,000 acres for waterfowl conservation. PHNWR lies within the Bayshore Focus Area.

The best waterfowl breeding and wintering habitats in the State are found in the Bayshore Focus Area. During the fall and winter hundreds of thousands of waterfowl utilize the areas for feeding and roosting with significant numbers of Canada goose, Snow Goose, Pintail, Black Duck, and Mallard. Over 60% of the Atlantic Flyway's Snow Goose population winters within this focus area. This area also contains concentrations of Northern Shoveler, American widgeon, and Gadwall in the State as well as being notable for the production of American Black Duck and Wood Duck.

The Bayshore Focus Area is also very important for other migratory birds. Located along the eastern coast of the Delaware Bay, it provides some of the most critical habitat (beach, dune, adjacent marshes and impoundments) for migratory shorebirds. This focus area is a major stopover site for over a million shorebirds including 80% of the Western Hemisphere's Red Knot population, along with substantial numbers of Dunlin, Ruddy Turnstone, Semipalmated Sandpiper, Least Sandpiper, Short-billed Dowitcher and others.

Major threats impacting waterfowl and other bird species in the Bayshore Area include sustained resort development, decreasing water quality in natural rivers, streams and bays, and invasive species. Forest and wetland habitats continue to be lost to facilitate agriculture and residential development. AJCV conservation management actions focus on protecting, restoring, and enhancing wetlands and associated upland habitats to form larger contiguous blocks of natural habitats along with connections to undisturbed beach habitats within the Bayshore coastal focus areas. Management recommendations and research priorities are incorporated into refuge habitat management planning and identification of monitoring elements. For example, this HMP places an emphasis on wetland restoration, which is the primary conservation recommendation put forward for the Bayshore Focus Area.

North American Waterbird Conservation Plan and Mid-Atlantic/New England/Maritimes Waterbird Conservation Plan (MANEM)

This plan is a partnership among individuals and institutions with interest and responsibility for conserving waterbirds and their habitats. The primary goal of the plan is to ensure that the distribution, diversity, and abundance of populations of breeding, migratory, and non-breeding waterbirds are sustained or restored.

The regional plan stepped down from the national plan pertinent to PHNWR is the Mid-Atlantic/New England/Maritimes Waterbird Conservation Plan (MANEM) which has compiled and interpreted scientific and technical information on the region's waterbird populations and habitats, assessed conservation status, developed strategies to ensure the persistence of sustainable waterbird populations in the region and identified waterbird priority species and habitat profiles for each state (MANEM Waterbird Plan 2006). This data will be incorporated in the Refuge's HMP.

U.S. Shorebird Conservation Plan and Northern Atlantic Regional Shorebird Plan

These plans are national and regional partnership efforts undertaken to make certain that stable and self-sustaining populations of all shorebird species are restored and protected. The North Atlantic Shorebird Plan listed priority shorebird species by habitat and scoring habitat use in the region with key "focal species" tabulated for each habitat type (Clark and Niles 2000). Shorebird conservation objectives are incorporated in this HMP, primarily through identification of priority resources of concern (ROCs).

Partners in Flight (PIF) Landbird Conservation Plan

The goal of each regional PIF plan is to ensure long-term maintenance of healthy populations of native birds, primarily passerines. Within each physiographic area, the plans rank bird species according to their greatest conservation needs, describe desired habitat conditions, develop biological objectives, and recommend habitat actions for priority birds. PHNWR lies with Physiographic Area 44, the Mid-

Atlantic Coastal Plain. Priority landbird habitats facing the highest threats include salt marshes, forested wetlands, mixed upland forests, and early successional upland plant communities.

Dealing with human population growth and urbanization while maintaining functional natural ecosystems is the greatest conservation challenge recognized in the Partners in Flight Plan for Area 44. The future of wildlife depends on protecting significant habitat patches for priority species. Identification and maintenance of those blocks large enough to support a full array of breeding birds are PIF's Area 44 highest conservation priority.

As coastal maritime, inland freshwater, and upland habitats are often adjacent, integrating the conservation objectives of priority land birds with those of waterfowl, shorebirds, and nesting waterbirds is the comprehensive conservation goal of the Area 44 plan. Specific habitat management recommendations pertinent to PHNWR, which are reflected in the objectives and strategies within this HMP, include:

- Continue strict protection of barrier beach and dune habitats to minimize productivity losses of priority species
- Protect salt marsh habitats for black rail, salt-marsh sharp-tailed sparrow, seaside sparrow, and American black duck
- Identify, prioritize, and protect all sites of high salt marsh
- Identify, manage and/or restore open lands > 50 ha with potential to support Henslow's sparrow
- Identify and protect forest blocks that support significant populations of prothonotary warbler, wood thrush, and Acadian flycatcher;

Recovery Plans

The Delmarva fox squirrel (DFS) was extirpated from Delaware by the early 1890s. In 1967 this squirrel was federally listed because it inhabited less than 10 % of its historic range. In accordance with the ESA, a recovery plan has been developed. The DFS recovery plan focused around two action objectives:

- Identify critical DFS habitat requirements
- Translocate DFS into suitable habitat outside areas within their historical range.

Range recovery expansion has occurred through eleven successful translocations conducted in the 1980s, of which one site was on PHNWR. To implement recovery actions in Delaware, Recovery Team Members in the late 1990s made the following Refuge management recommendations: 1) Reforest fallow open areas to add to the Refuge's base acres of forested upland habitats; 2) Augment current DFS Refuge population with additional translocations; and 3) Conduct a Population Viable Analysis (PVA) to estimate the Minimum Viable Population (MVP) needed to mitigate inbreeding and Founder's Effect, prevent problems of genetic drift and loss of heterozygosity, and then manage accordingly (Moncrief 1995). Forest management strategies identified in this HMP are guided by requirements identified in these DFS recovery and research efforts.

State Comprehensive Wildlife Conservation Strategy and Delaware Wildlife Action Plan

The Delaware Division of Fish and Wildlife, Delaware Department of Natural Resources and Environmental Control, has recently completed its Delaware Wildlife Action Plan with funding from the State Wildlife Grants program. The state plan acknowledges development pressure and loss of wildlife habitats as threatening the existence of most of Delaware's species of greatest conservation need (SGCN) such as the American oystercatcher, least tern, hooded warbler, carpenter frog, Delmarva fox squirrel, Coastal Plain swamp sparrow, Bethany firefly and many other species (DNREC 2005).

Fifty different vegetative community types have been delineated; several have been singled out as communities of conservation concern due to their rarity across Delaware's landscape, and featured as 'Key Wildlife Habitats' in Delaware's Wildlife Action Plan (DWAP; DNREC 2005). These communities are rare and underrepresented within the state landscape, have special significance in Delaware, are particularly vulnerable to disturbance, and/or have a high diversity of rare plants. As a result of any of these factors, DWAP's 'Key Wildlife Habitats' also harbor SGCN.

For example, large blocks of unfragmented forests and wetlands have been designated as Key Wildlife Habitats because of their importance to area sensitive faunal species. Due to habitat fragmentation in Delaware's wildland landscape, a minimum patch size of 250 acres has been used as the criteria defining a "large block." Key Wildlife Habitats have been assigned to wildland habitats with 1) any SGCN occurrences; 2) rare plants or plant communities on the landscape defined as Habitats of Conservation Concern, 3) forest blocks greater than 250 acres, and 4) wetland blocks greater than 250 acres. Refuge staff has consulted with the Division of Fish and Wildlife and Delaware's Natural Heritage and Endangered Species Program to consider opportunities for the Refuge to conserve, protect, and manage species and critical habitats identified in the state's comprehensive wildlife action plan. State wildlife and habitat goals and objectives have been incorporated into the Refuge's habitat management planning efforts and identification of priority resources of concern (ROCs), as appropriate.

1.4 Guiding Principles of Habitat Management

Within the next 15-year horizon, the management of Refuge habitats will be driven by four factors:

- Conserving biological integrity, diversity and environmental health;
- As climate change alters vegetative communities, species occurrence, and migration chronologies of wildlife, we will allow these changes to occur and avoid maintaining static refuge conditions.
- Basing habitat management goals, objectives, strategies, and prescriptions on focal species management;
- Fulfilling the Refuge's purposes and National Wildlife Refuge System mission and goals.

The central theme guiding Refuge habitat management is the restoration and maintenance of natural habitats to meet refuge objectives, but also allow changes to occur in order to maintain, enhance, and restore biological integrity, diversity, and environmental health (BIDEH). Natural conditions and processes represent the highest measure of biological diversity, ecological integrity, and healthy ecosystems.

Guidance to accomplish this comes from specific Service BIDEH policy (See Section 3.2 of this plan for more details). This policy states that *"we use historical conditions as the frame of reference to identify composition, structure and functional processes that naturally shape ecosystems. We especially seek to identify keystone species, indicator species, and types of communities that occurred during a frame of reference."*[601 FW 3.12 (B)].

Maintaining or restoring existing elements of BIDEH on the Refuge depends on allowing natural processes and communities to develop in response to climate changes and other dynamic conditions. We identify umbrella species, indicator species, and types of natural communities that occurred during historic conditions to represent lost elements of biological integrity and environmental health. Where appropriate and feasible, we also manage for BIDEH by eliminating unnatural biotic and abiotic features and management strategies not necessary to accomplish Refuge purpose(s). We use historic conditions as an initial frame of reference to develop habitat goals and objectives (601 FW 3.15), but with consideration for likely future conditions in response to a changing climate.

Conservation Biology Principles

We have used the concepts of umbrella and indicator species as representatives of biological integrity and/or environmental health conditions (Table 1). These concepts also contributed to our identification of priority resources of concern, as outlined further in Chapter 3. Similar use of focal species has been made by other conservation biologists for site-specific biological planning projects (Chase and Geupel 2005). We have used the concept of umbrella species as appropriate targets for management and the concept of indicator species as representatives of historic biological integrity and/or environmental health conditions. In conservation biology, the protection of an umbrella species with concentrated management of its habitat requirements can extend protection for other priority resources of concern. For example, our decision to manage for larger Delmarva fox squirrel habitat patches makes the squirrel a good candidate umbrella species that benefits many breeding forest interior bird species, migratory landbirds, and a host of other forest-dependent resident wildlife. Similarly, American oystercatchers have been used as an umbrella species representative of overwash and sandy beach habitats.

An indicator species can be used to represent a measure of biological integrity and environmental health. A reliable indicator species can operate as a habitat assessment tool that can save time and money. We have chosen indicator species to be either an individual species or guild whose presence, absence, abundance, or relative well-being in a given habitat type is a sign of the overall health of its environmental condition and ecosystem functioning. For example, presence of the beach dune tiger beetle is indicative of quality, healthy beach and functional panic grass dune grassland habitats. In some cases, a species may serve as both an umbrella species and an indicator species simultaneously. We have chosen certain species or a particular guild as umbrella and/or indicator representatives of a habitat type and used them in developing habitat management objectives and strategies. As such, both groups of identified species are useful as monitoring targets.

Monitoring will be an integral component of biological planning using focal species, such as presence/absence as an inexpensive measure to gauge environmental health, relative abundance, and density of focal species as measures of biological integrity and diversity. Our habitat objectives incorporating specific focal species are based on numerous hypotheses and assumptions using the most recent and best available plant and wildlife survey information. These assumptions will be tested in on-going Refuge monitoring studies where focal species serve as key targets for monitoring endeavors to test the effectiveness of habitat management strategies and conservation actions or to adjust strategies and actions when outcomes do not meet expectations.

Table 1. Prime Hook NWR Indicator and Umbrella Species

Prime Hook NWR: Keystone and Umbrella species or guilds representative of biological integrity, diversity, and environmental health under historic conditions and rare or declining in today’s landscape.			
Species or Guild	Indicator	Umbrella	Habitat Type
American Oystercatcher	Yes	Yes	Overwash Dunes
Beach Dune Tiger Beetle	Yes		Sandy Beach & Dune Grassland
Little Wife Underwing	Yes		Red Cedar Woods, Maritime Shrubland
Delmarva Fox Squirrel		Yes	Mixed Hardwood Forest

Prime Hook NWR: Keystone and Umbrella species or guilds representative of biological integrity, diversity, and environmental health under historic conditions and rare or declining in today's landscape.

Long-Horned Beetle	Yes		Mature, diverse Southern Red Oak Heath Forest
Salt Marsh Passerines	Yes		Spartina High & Low Salt Marsh
Coastal Plain Swamp Sparrow	Yes		Spartina High Marsh, Maritime Shrub, Tidal Creek Shrubland
Henslow Sparrow		Yes	Early Successional (ES) Grasslands
River Herring	Yes		Aquatic Food Webs
Maritime Sunflower Borer Moth	Yes		Early Successional Grasslands
Wetland Lepidopterans	Yes		Peat Bog Communities
Obligate Rare Herptiles	Yes		Impoundments = ES Freshwater Marsh
Obligate ES Lepidoterans and other insect pollinators	Yes		ES Upland Communities

Metrics for indicator species remain to be determined. The best biological parameters to assess healthy habitat types and management actions of indicator species will incorporate biological measures at various levels to include a single metric and/or combination of:

- Presence/absence
- Index of Abundance
- Numbers per unit time
- Absolute density (Numbers per unit area)
- Nest densities, nest success, etc.
- Metrics to assess habitat diversity and heterogeneity
- Other population parameters

These habitat quality measures will be developed and refined over time and incorporated into a refuge Inventory & Monitoring plan. They will be used to monitor progress in achieving Refuge habitat restoration and management objectives.

Historic Range of Variability

Historic range of variability (HRV) is a method of restoration ecology describing natural ecosystems as having a range of historic conditions where they were self-sustaining and beyond which they move to a state of disequilibrium or unsustainability, due to degraded ecological integrity caused by anthropogenic stressors (Egan & Howell 2001).

Consideration of HRV can be used as a management tool to understand the dynamic nature of ecosystems, the processes that sustain and change them, the current state of the ecosystem in relationship to the past, and the possible range of conditions that are feasible to maintain and manage for in the future. It is a useful tool for determining a range of desired future habitat conditions (Landres et al 1999). This variability represents the variance of ecological and biological parameters over a specified temporal frame of reference. Our frame of reference has been set for approximately 400 years ago (European Settlement), when their disturbances started having significant influence on biological

condition of natural habitats. Using a HRV management approach considers a range of past habitat conditions when BIDEH elements were maximized and human stressors were minimal. Managing for HRV means restoring historic habitat conditions and maintaining an appropriate representation of those conditions that will ensure both short and long-term maintenance of BIDEH.

Historic conditions of Refuge habitats at this established frame of reference includes native Delmarva Coastal Plain plant communities dominated by mixed upland forests, swamps and emergent wetlands interspersed with transitional (grassland & shrubland) upland habitats. These transitional habitats were represented by small openings of grasslands and thickets influenced by a combination of fires set by aboriginal people, storms and beavers.

The current state of the Delmarva Coastal Plain ecosystem sustained a loss of 75% or more of mature forests, 50% or more loss of wetland habitats, and contains few to no acres of transitional or early successional upland habitats. Remaining fragments of natural areas on Refuge are considerably degraded (Sections 2.2, 2.3, and 2.4).

Managing for HRV for an ecosystem requires the selection of habitat and biological parameters necessary to sustain habitat goals and management objectives for target conservation species, called resources of concern (ROCS). See Chapter 3 for more information on ROCS. Through HRV, the refuge will select variables at all levels of biological organization and habitat classifications such as community type, patch size, tree size, tree density, canopy cover, population size, species composition, water depth and temperature, gene flow, etc., and use them in habitat objectives.

Chapter 2. Background

2.1 Refuge Location, Description and Geographic Setting

Prime Hook National Wildlife Refuge is located within the Atlantic Coastal Plain (BCR 30 and PIF Physiographic Region 44) along the southwestern shore of the Delaware Bay in Sussex County, Delaware. It is a Refuge within the Coastal Delaware NWR Complex (HMP Map 1). The Refuge, established in 1963, historically consisted of tidal marshes and agricultural lands with both habitats heavily grazed by cattle. The landscape surrounding the Refuge was dominated by small farms producing vegetables and small grains. From the 1990s to present day, resort and residential development and intensive agricultural operations (corn, soybean and chicken production) are the dominant land uses bordering the Refuge.

Natural habitats are dominated by emergent wetlands interspersed with swamp and upland forests representative of the Delmarva Coastal Plain ecosystem. Eighty percent of PHNWR's vegetation cover types are influenced by tidal and freshwater creek drainages that discharge into the Delaware Bay with associated coastal marsh habitats. The remaining twenty percent are composed of upland habitats. NVCS cover typing of the Refuge has resulted in the delineation of 37 land cover types including vegetation and anthropogenic communities and water surface coverages (HMP Maps 2-7).

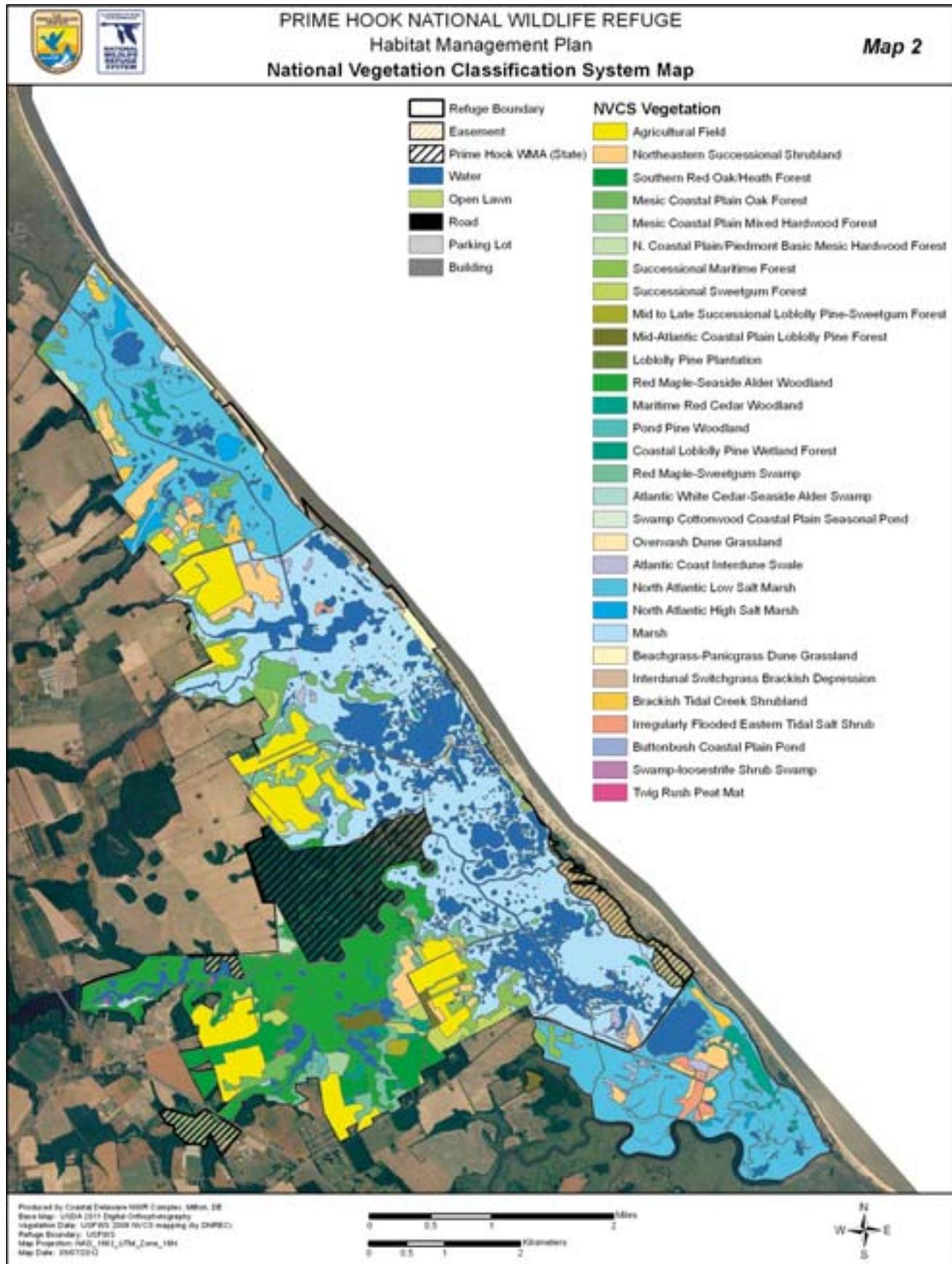
Other natural wildland habitats and managed wetlands immediately adjacent and/or near PRIME HOOK NWR include:

- 1) The Great Marsh (1,000 acres of salt marsh, owned by the town of Lewes) located just south of the Refuge,
- 2) Milford Neck WMA (5,459 acres), 3 miles north of the refuge above Mispillion Inlet;
- 3) Ted Harvey Conservation Area (2,661 acres), 9 miles north of the refuge above Bower's Beach;
- 4) Little Creek WMA (4,721 acres), 15 north of Prime Hook NWR above Port Mahon;
- 5) Prime Hook WMA (698.2 acres), adjacent to Prime Hook NWR
- 6) Bombay Hook NWR (16,000 acres), 25 miles north of the refuge.

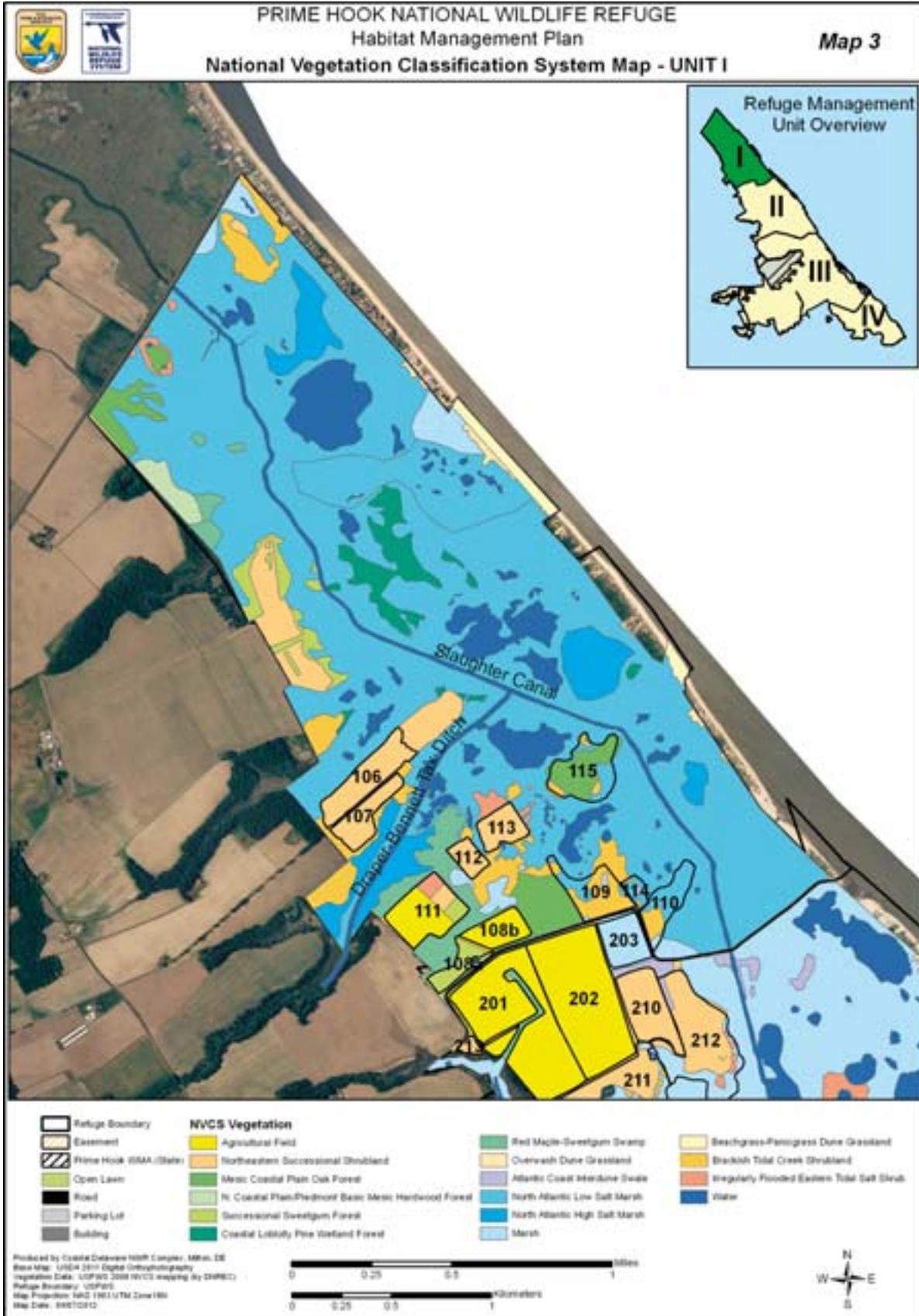
Map 1. Delmarva area National Wildlife Refuges



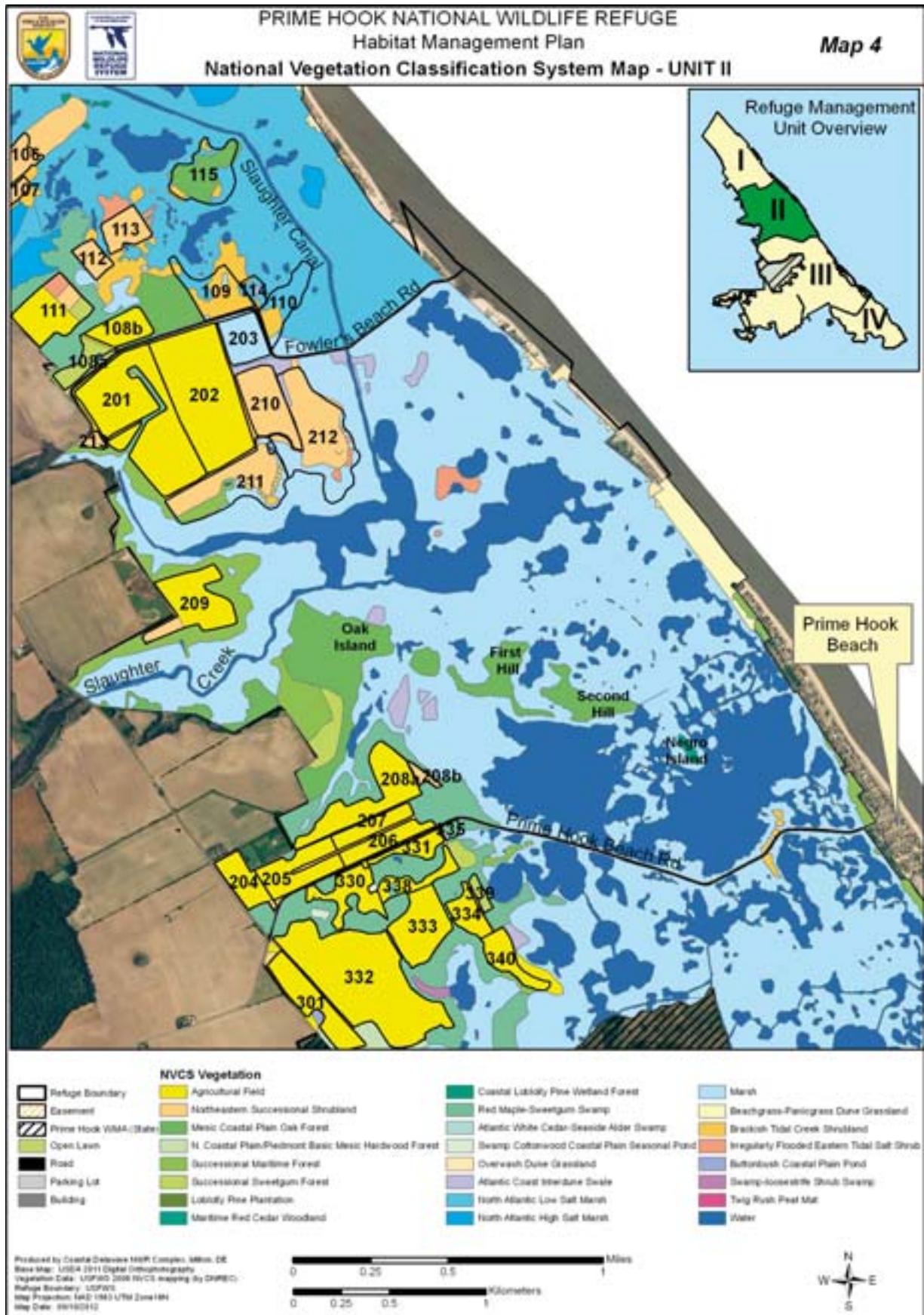
Map 2. National Vegetation Classification System Map - Overview (2006)



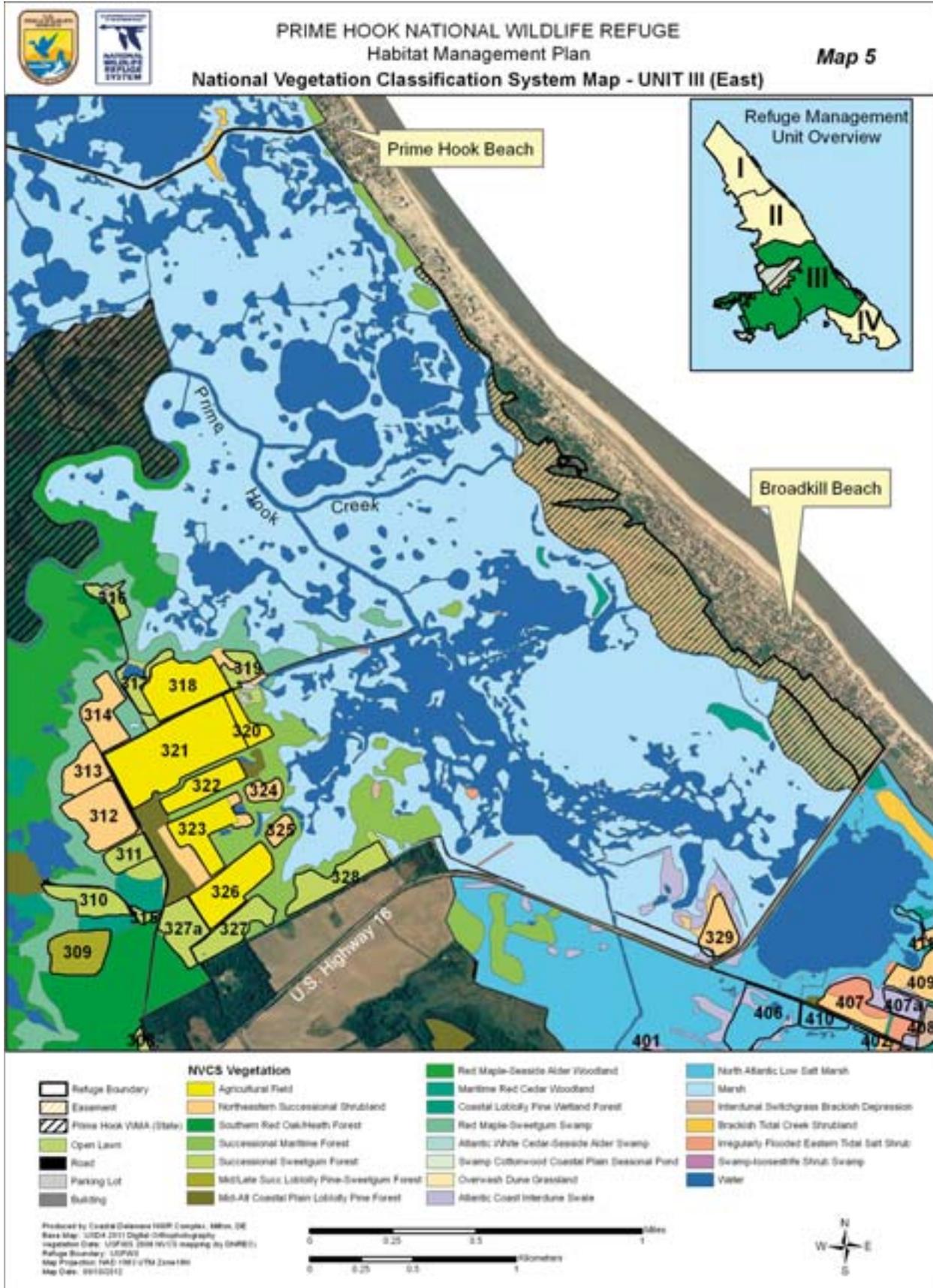
Map 3. National Vegetation Classification System Map - Unit I



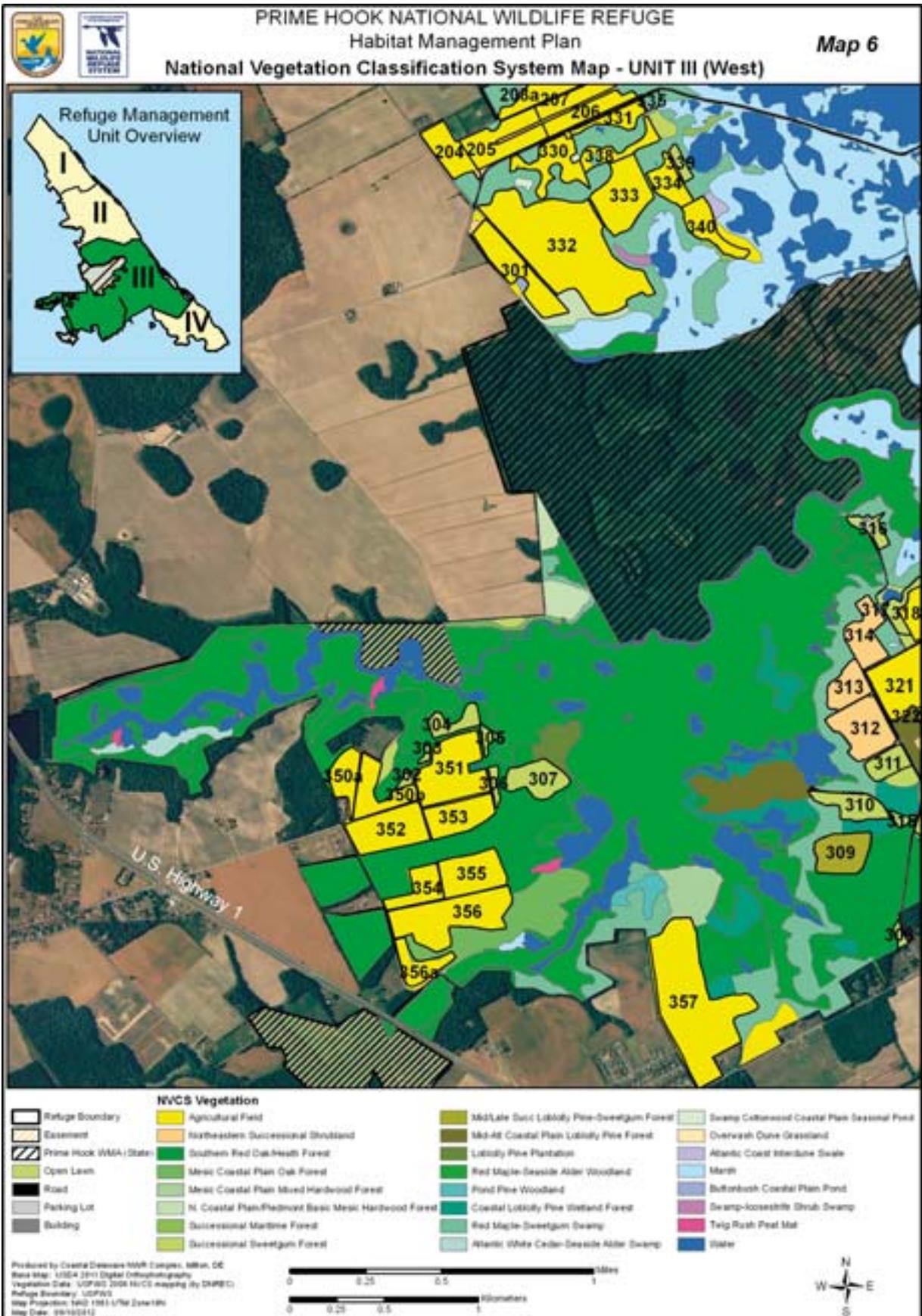
Map 4. National Vegetation Classification System Map - Unit II



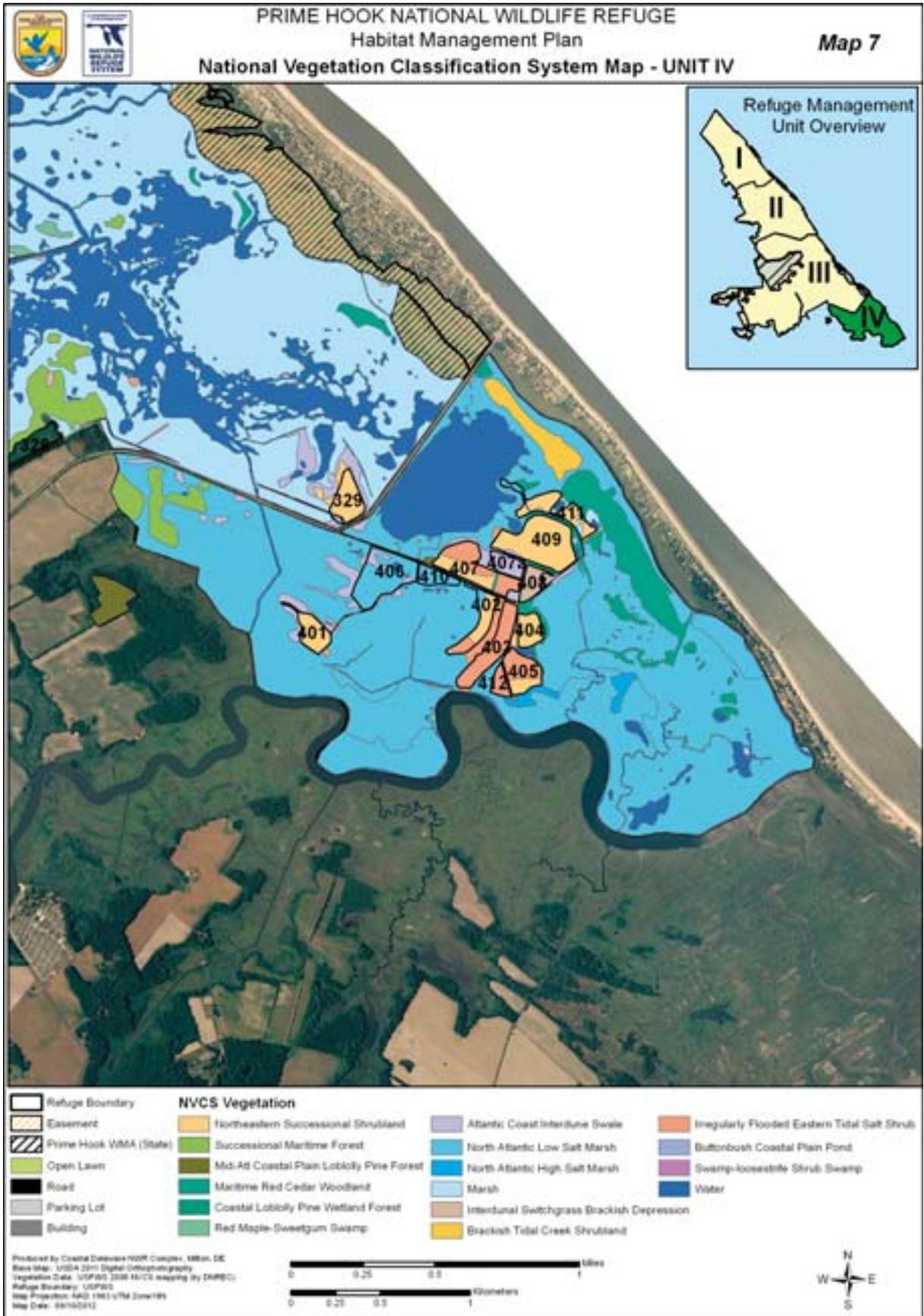
Map 5. National Vegetation Classification System Map - Unit III (East)



Map 6. National Vegetation Classification System Map - Unit III (West)



Map 7. National Vegetation Classification System Map - Unit IV



2.2 Management Units: Geographic Description, Topography, Soils and Historical Perspective

Prime Hook NWR can be described as an elongated coastal strand of ten thousand acres that lies parallel to the Delaware Bay. For management purposes, the Refuge has been divided into four management units transected by four state roads which run perpendicular to the Bay. All managed fields on the refuge and other place names referenced in the HMP are labeled in HMP Maps 3–7. Fields with numerical names in the one-hundreds are located in Unit I, two-hundreds in Unit II, etc.

UNIT 1 (HMP Map 3)

This area comprises the northern most end of the refuge and is delineated by Slaughter Beach Road as its northern boundary, overwashed barrier dunes and a portion of the Slaughter Beach community houses on the east, Fowler's Beach Road on the south, and an upland fringe of scrub-shrub areas on the western boundary.

Hydrology

There is currently no water level management capability in Unit I, which contains about 1,400 acres of salt marsh. Tidal salt water is the primary source of water for the unit, which flows approximately two miles from the DE Bay through the Misspillion Inlet and into Slaughter Canal entering through Slaughter Canal.

Attenuated tidal flow provided by Slaughter Canal bisects Unit I and receives its afflux from the ditches and creeks within the salt marshes in Unit I. The Draper-Bennett Tax Ditch drains the southwestern portion of this unit, which ultimately feeds into the Slaughter Canal. Daily tidal action has a 4.4 foot range and salinities range from 5 to 25 ppt in the Canal. During drought periods, the salinity can get as high as 30 ppt. Rainfall, new and full moon tides, and spring and neap tides maintain the salt marsh community within Unit I. Natural formations of inlets from overwash events along the Bay shoreline rejuvenate tidal marsh habitats in Unit I through maintenance of salinity levels and deposition of nutrients and sediments carried by tidal flow. During the past 30 years several of these mini-inlets have opened and closed along this shoreline. Currently, a breach in the southern portion of Unit I has restored tidal flow into the unit east of the Slaughter Canal.

Soils and Topography

Unit I is dominated by Transquaking and Misspillion soils (TP) which, along with a smaller proportion of Sunken mucky silt loam (SuA), constitute most of the salt marsh habitats. Other soil types found in upland areas include Hammonton sandy loam (HnA) and loam sand (HmA), Carmichael loam (CaA), Hurlock sandy loam (HvA) and loamy sand (HuA), Ingleside loamy sand (IeA and IeB), Marshyhope sandy loam (MdA), Pineyneck loam (PyA), and Unicorn loam (UIA).

Management History – Upland Fields 1978 – 2008 (HMP Map 3).

- **Fields 101-105:** not tilled during this period and have reverted to brush (*Morella*, *Iva*, & *Baccharis*). This area was hydro-axed in late 1980s to set back succession. No management has taken place since the late 1980's. These fields are not depicted on the map.
- **Field 106/107:** farmed in early 1970s but Refuge lacks access to this area.
- **Field 108a:** tilled in early 1970s, but farming was ceased in 1972 because field was too wet.
- **Field 108b:** planted until 2006 alternating between corn and soybeans.
- **Field 109** planted in wildlife mixture 5 times in past 30 years.
- **Field 110** reverted to Brush mostly bayberry (*Morella*); too wet to cultivate.
- **Field 111:** farmed until 2006; 10 acres removed in 1990s, too wet to cultivate.
- **Field 112:** managed as grasslands.

- **Field 113:** managed as grasslands.
- **Field 114:** reverted to brush.
- **Field 115:** reverted to brush and saplings.

Current Vegetation

We have listed the National Vegetation Classification System community associations and habitat descriptions that apply to each of the four management units. Acreages presented in habitat objectives reflect approximations from NVCS mapping.

Management Unit I is the northernmost unit at Prime Hook and totals 1,624.9 acres [657.5 ha (Table 2 and HMP Map 3). Of the total acres, 1,504.7 acres (608.9 ha) are natural communities and 120.2 acres (48.6 ha) are anthropogenic communities. This management unit receives tidal, brackish water inputs from Slaughter Creek which results in the development of *Spartina* Low Salt Marsh, the largest vegetation community in Unit I. A small Wax-Myrtle Shrub Swamp located at the south end of the Unit is the smallest vegetation community mapped. Part of this unit experienced an arson-set marsh fire under high wind conditions (45 + mph) on March 10, 2002 that burned approximately 1,300 acres.

Table 2. Acreage of Natural and Anthropogenic Communities in Management Unit I

Natural Community	UNIT I acreage (ha)
Atlantic Coast Interdune Swale	0.3 (0.1)
Beachgrass-Panicgrass Dune Grassland	12.5 (5.1)
Brackish Tidal Creek Shrubland	73.9 (29.9)
Coastal Loblolly Pine Wetland Forest	34.2 (13.8)
Coastal Plain Depression Swamp	39.9 (16.1)
Marsh	33.2 (13.4)
Mesic Coastal Plain Oak Forest	49.6 (20.1)
Mesic Rich Forest	10.6 (4.3)
Mid-Atlantic Maritime Salt Shrub	10.8 (4.4)
Overwash Dune	5.1 (2.0)
Successional Sweetgum Forest	31.2 (12.6)
<i>Spartina</i> High Salt Marsh	75.2 (30.4)
<i>Spartina</i> Low Salt Marsh	982.0 (397.4)
Open Water	146.2 (59.2)
Natural Community Total	1,504.7 (608.9)
Anthropogenic Community	
Agricultural Field	25.6 (10.4)
Northeastern Successional Shrubland	90.1 (36.4)
Road	4.5 (1.8)
Anthropogenic Community Total	120.2 (48.6)
UNIT 1 Total	1,624.9 (657.5)

UNIT II (HMP Map 4)

This management unit is just south of Unit I and is an impounded wetland system. It is bounded on the north by Fowler's Beach Road, barrier dunes and sand dike plus the Prime Hook beach community on the east, Prime Hook Road on the south, and an upland interface on the west. Prior to 2009, when large breaches formed along the eastern barrier dunes, this unit was managed solely as a freshwater impoundment through the manipulation of water levels at water control structures and the exclusion of tidal flow. Presently, the unit is subjected to daily tidal influence through the breaches and consists of a larger expanse of open water than is reflected in the 2005 vegetation mapping acreage.

Hydrology

During storm tides this sand dune system has been breached several times and washouts have deposited sand and salt water into the Unit II impoundment. Freshwater input is from Prime Hook Creek, which flows from the west. Delaware Bay's normal tidal ranges are from 3 to 3.5 feet except for storm surges and spring tides (± 6.5 ft). Tidal flow enters Slaughter Canal from the Delaware Bay through Unit I salt marshes into the northern portion of Unit II and fresh water flow enters Unit II on the west from Slaughter creek.

Soils and Topography

The area is relatively flat with the exception of four upland islands surrounded by wetland habitats. The dominant soil type of 1,500 acres in Unit II Transquaking and Mispillion soils (TP) which, along with Sunken mucky silt loam (SuA), which together constitute most of the wetland habitats. Negro Island consists of Hurlock loamy sand (HuA). Second Hill soils are Glassboro sandy loam (GoA). First Hill consists of Ingleside sandy loam (IgA) and Glassboro sandy loam (GoA). *Oak Island is made up of (SaB) Sassafras sandy loam with 2 to 5 percent slopes.* The remaining 600 acres of upland forest, croplands and grasslands consist of Pineyneck loam (PyA), and Unicorn loam (UIA), Carmichael loam (CaA), and Glassboro sandy loam (GoA).

Management History – Wetlands

Until 1900, Unit II marshes remained unchanged, consisting of a freshwater system dominated with cattails and sedges. Landowners had the marsh drained and dug Slaughter Canal in the early 1900s to improve drainage of their upland areas by channelizing water north to Cedar Creek. In 1906 the Slaughter Canal dredging reached into Unit II and ended at Oak Island. Portions of Unit II were also heavily grid ditched during the 1930's for mosquito control. To maintain water on the marsh during the fall and winter for muskrat trapping and waterfowl hunting, private owners built water control structures at Fowler's Beach Road, Oak Island and near the bridge at Slaughter Creek to hold water.

The construction of Slaughter Canal in the 1930's vastly increased drainage in Unit II marshes and lowered water tables in upland areas. It significantly altered tidal exchange, leaving only a narrow band of tidal marsh along the edge of the canal and around Oak Island. The dredging of the canal also contributed to Phragmites colonization. By the 1980s, Unit II had completely reverted to a Phragmites jungle, with dense stands covering 1,000 acres (See Prime Hook's Environmental Assessment for Chemical Control of Phragmites and Proposed Marsh Rehabilitation-March 21, 1983).

In 1934, a dike was dug by dragline, along the eastern edge of the marsh from Slaughter Beach to Prime Hook Beach to prevent the bay from washing into the marshes. The deep borrow ditch is still evident today but several sections have been filled by washouts. Until the early 1950s, access to Prime Hook Beach was possible only by boat or during the dry summer by horse or vehicle. In 1953, a gravel roadway was constructed across the marsh and today this roadway is paved (Prime Hook Beach Road). It has effectively acted as a dike between Units II and III with small culverts under the roadway resulting

in some limited flow of water between the units. All of these activities have significantly altered the hydrology of Unit II wetlands (USFWS 1986).

In 1963, the Service proposed a water management plan to the public, which outlined marsh management needs for the entire refuge including Unit II. The plan was designed to impound refuge marshes without backing water against upland areas. Local residents expressed strong opposition to the proposal and the state Drainage Engineer felt that it had the potential to flood or waterlog contiguous agricultural lands as occurred at Bombay Hook NWR. A revised plan with inland canals to provide drainage of uplands was also strongly opposed. Subsequently, a “No Management” policy was adopted which resulted in a severe decline in the quality, quantity, and productivity of the Unit II marshes over the ensuing years (USFWS 1986).

From the establishment of the refuge in 1963 to 1986, Unit II had no water level management capabilities. In 1987 a large concrete water control structure was put into place and partially funded by the first DU Donor Project in the country (J. Howard Isaacs). The project cost about \$350,000 to install a concrete multi-bay water control structure with 11 separate bays, spanning 46 feet across the Slaughter Canal serving to impound 1,500 acres. Saltwater intrusion into Unit II is held in check by this structure located on the northern boundary at Fowler’s Beach Road. After water level management capability was restored, salinities within this impoundment range from 0 to 8 ppt year round.

The Environmental Assessment documentation (August 1986) for the reestablishment of water control in Unit II provide important information in linking the past with the present. The title of the EA itself is historically interesting “Reestablishment of Water Control in Unit II.” Prior to the refuge acquiring this area, both private land owners and the state mosquito control agency used timber sheeting to construct small water control structures throughout Unit II to manage water levels (USFWS 1986).

Historically, the majority of Unit II wetlands were formerly freshwater marsh. Slaughter Creek was the most significant watercourse in the unit, flowing southeasterly across the entire Unit II to Prime Hook Creek south to Prime Hook Road. The hydrology of Unit II was changed with the installment of water control infrastructure as water flows northward to Unit I from First and Second Hills to Fowler’s Beach Road but from Oak Island south, water flows in a southerly direction to Prime Hook Road.

Unit II restoration of water level management in 1987 significantly increased the water table of these marshes. Water sources which affect the hydrology of this unit today come from tidal action, runoff from Slaughter Creek, excess water from the Unit III, rainfall and local runoff. Tidal and freshwater exchange would also at the site of the water control structure when abnormal tides and storm surges cause water to flow over the top of stoplogs. Today, large breaches along the barrier dune permit daily tidal flow of brackish water from the Delaware Bay into Unit II, preventing water level management through the water control structures as was conducted for over two decades and resulting in an increased amount of open water relative to the acreage estimated during 2005 vegetation mapping.

Management History – Upland Fields 1978 – 2008 (HMP Map 4)

- **Field 201:** Tilled until early 1990s. Removed from farming, too wet to till. Returned to corn/soybean cultivation in 2006.
- **Field 202:** Tilled until 1991, then field was split into 2 section 202a managed as 64 acre areas in grassland; and 202b planted in corn and soybeans. 202b was put out of production and used in R5 Grassland Study 2001 – 2004. Put back to soybeans in 2006.
- **Field 203:** Switchgrass area currently reverting to brush.

- **Fields 204-208:** all fields cultivated in corn and soybeans until 2006.
- **Fields 210-212:** was grassland now reverting to brush/saplings with Phrag encroachment. Sprayed with herbicide and burned in 2007, partially mowed in 2008.
- **Field 213:** “Old corral” mowed in 1970s and 1980s and reverted to brush.

Current Vegetation

Total acreage of Unit II is 1,997.5 acres (808.3 ha) in size, of which 1,681.8 acres (680.6 ha) are natural communities and 315.7 acres (127.7 ha) are anthropogenic communities (Table 3 and HMP Map 4). The Generic Marsh cover type was identified as the largest vegetation community and the smallest is the Maritime Red Cedar Woodland. As of 2006, this Unit had been invaded (~100 acres) by the river seedbox (*Ludwigia leptocarpa*), a native plant of the south, but considered non-native in Delaware and apparently has invasive characteristics here at Prime Hook NWR. The presence of wetland vegetation identified in the 2005 vegetation mapping has been altered as a result of the introduction of tidal waters through breaches in the barrier dunes. Table 2-2 reflects the baseline vegetation community present prior to the formation of the breaches.

Table 3. Acreage of Natural and Anthropogenic Communities in Management Unit II

NVCS - Natural Community	UNIT II acreage (ha)
Atlantic Coast Interdune Swale	20.1 (8.1)
Beachgrass-Panicgrass Dune Grassland	22.6 (9.1)
Brackish Tidal Creek Shrubland	3.3 (1.3)
Coastal Plain Depression Swamp	47.2 (19.1)
Maritime Red Cedar Woodland	1.9 (0.8)
Generic Marsh	918.9 (371.8)
Mesic Coastal Plain Oak Forest	99.0 (40.0)
Mid-Atlantic Maritime Salt Shrub	7.2 (2.9)
Overwash Dune	4.2 (1.7)
Successional Maritime Forest	71.3 (28.8)
Successional Sweetgum Forest	9.4 (3.8)
Open Water	476.7 (192.9)
Natural Community Total	1,681.8 (680.6)
Anthropogenic Community	
Agricultural Field	221.8 (89.8)
Northeastern Successional Shrubland	82.2 (33.2)
Open Lawn	0.2 (0.1)
Road	11.5 (4.6)
Anthropogenic Community Total	315.7 (127.7)
UNIT II Total	1,997.5 (808.3)

UNIT III (HMP Maps 5 and 6)

Management Unit III is bounded by Prime Hook Beach Road on the north, Route 16 (Broadkill Beach Road) on the south, upland edge on the western boundary, and the Prime Hook and Broadkill Beach developments immediately adjacent to the refuge’s eastern boundary.

Hydrology

Unit III consists of roughly 4,400 acres which includes upland forest, impounded emergent marsh, Red Maple-Seaside Alder Swamp, low lying farmed areas, brush, barrier beach on the east, and 140 acres of flowage easement (Tract Nos. 84R, 99F & 99i) on the southeastern boundary of Unit III. This flowage easement drains directly into Prime Hook Creek and flows south to the water control structure of this watercourse. A large portion of Unit III is managed as a freshwater impoundment, however culverts under Prime Hook Rd. bring brackish and saline water in from Unit II, where breaches have restored full tidal flow.

Over the last 2,000 years, sedimentation filled a lagoonal area producing the refuge's marsh (Hoyte 1980). Hoyte extracted nine stratigraphic cores on PHNWR along the Slaughter and Prime Hook Creeks (Units II and III) and has suggested that lagoons behind barrier beaches changed from fresh water over the past 500 years to more saline influences. About 150 years ago, Unit III was a tidal marsh system with several small creeks and abundant potholes where Prime Hook Creek and Deep Hole Creek drained directly into the Delaware Bay (1.5 miles north of current Prime Hook Creek water control structure) (USFWS 1982).

Soils and Topography

Most of the wetlands in Unit III are relatively flat and lie below the 4 foot contour with a few islands rising above 4 foot (between 5 and 9 foot contour). These islands include Tea Cup Island, east of the headquarters ditch, Hay Hummock, south of Prime Hook Road and Bleacher's Island just west of the Prime Hook Creek water control structure. Prime Hook Creek and Petersfield Ditch are the principal water courses in Unit III. The majority of Unit III falls above 2.2 feet {mean sea level (msl)} which is the normal tidal range for the area and is flooded only when the tide is above normal (Spring tides plus storm surges).

The predominant soil types in Unit III are Transquaking and Mispillion soils (TP) and Broadkill mucky peat (Br), both characterized by having large quantities of organic matter on 2,500 acres of impounded wetlands. Soft sediments reach to about 30 feet below the marsh surface. Adjacent upland soils are non-plastic to slightly plastic sandy soil derived from fluvial deposits of the Pleistocene (Matthews and Ireland 1974). The other major soil types found in the Unit III Prime Hook Creek drainage basin include Rosedale loamy sand, Lenape mucky peat, Pineyneck loam (PyA), Carmichael loam (CaA), Hurlock loamy sand (HuA), and Henlopen-Rosedale complex. Minor soil types found in Unit III include Askecksy loamy sand, Broadkilk-Appoquinimink complex, Downer loamy sand, Evesboro loamy sand, and Klej loamy sand.

Management History – Wetlands

A major storm in 1911 plugged and sealed the Deep Hole Creek and Prime Hook Creek outlets to the Delaware Bay. The closing of these 2 outlets drastically changed the daily tidal influence and hydrology of Unit III. Prime Hook Creek now flows through the Petersfield Ditch to ultimately empty into the Broadkill River, which drains into the Delaware Bay about 2 miles south of the present-day refuge. In the 1920s several attempts were made by landowners to create or block drainage within the Unit III area to provide water control. In the 1930s Unit III marshes were heavily grid ditched for mosquito control (USFWS 1982).

Historically, during the 1940s and 1950s, marsh management (e.g., hydrologic manipulation to maintain and/or alter vegetation) on Prime Hook's wetland habitats had been a controversial issue between those who wanted marshes for hunting and trapping and farmers who wanted to drain the upland edges surrounding these wetlands. In 1951, landowners and the UD Cooperative Extension Service

unsuccessfully attempted to develop a plan for the management of Prime Hook marshes. Public Law 766 was enacted by Delaware in 1953 and prohibited the draining of Prime Hook Creek into the Delaware Bay between October 1 and March 10 of the succeeding year. This law was enacted for the benefit of the muskrat industry and permitted the blocking of any marsh draining. Several attempts were made afterwards to eliminate blockages including the use of dynamite by opposing landowners (USFWS 1982).

In the 1950s vegetation coverages in the area east of Petersfield Ditch at the lower end of Unit III consisted of salt hay (*Spartina patens*) and cordgrass (*S. alterniflora*). *Spartina* grasses were cut for hay and grazed by cattle through the late 1950s. The remainder of Unit III marsh, including much of the marsh west of the ditch was open water with cattail and pickerelweed as co-dominants. Brush was managed in drier areas by grazing and fire. Trees were mostly absent (USFWS 1982).

Phragmites was first observed along Prime Hook Road in Unit III also in the early 1950s and by 1965 it had spread south throughout the unit. Encouraged by drier conditions from mosquito ditching, draining, and excessive soil deposition, red maples began growing along Prime Hook creek, which was once a tidal emergent marsh. Just prior to Service acquisition, portions of the Unit III Prime Hook marshes were also managed by a system of water control structures and a pumping station in Unit III owned by Island Farm Corporation and King Cole, designed by the Soil Conservation Service to provide water for cattle (USFWS – 1982).

Between 1962 and 1968, all the outlets of Prime Hook Creek were permanently blocked either from severe storms or private landowner actions. These blockages severely hampered tidal flow, enhanced sediment deposition in Unit III marshes, and increased the elevation of these wetland habitats.

In 1963, the Service proposed a water management plan which outlined marsh management restoration needs for the entire refuge. It was designed to provide water for the Unit III marsh without backing up water against upland areas. As mentioned under Unit II, it was rejected, and a “No Management” policy was adopted by the Service. This management policy generated severe degradation of Unit III’s marshes, as environmental conditions proved detrimental to the quantity, quality, and productivity of Prime Hook’s wetland complex from the early 1960s to 1980 (USFWS 1982).

In 1968, a developer of Broadkill Beach had the Broadkill Sound excavated and ditched to drain 10.25 miles of marsh, one mile south of the current Prime Hook Creek water control structure. This action coupled with the retrogression of the blockages of Prime Hook Creek and Petersfield Ditch had continued to exacerbate cumulative negative impacts that contributed to a steady degradation of the Unit III marshes, hastening its drying out and causing considerable deterioration of wetland values. Severe droughts in 1977 and 1980 resulted in the complete desiccation of most potholes and water areas in the Unit III marsh. By 1984 much of Unit III became a *Phragmites* jungle. In addition to the loss of high quality marsh habitats, extreme fire hazards created by dense stands of *Phragmites*, threatened private property values adjacent to the refuge (USFWS 1982).

An Environmental Assessment for the Rehabilitation Management and maintenance of wetlands in Unit III was written in 1982 and by 1984 the water level management infrastructure to restore water level manipulation capability was in place. This infrastructure included a one mile dike east and west of the Petersfield water control structure, tying in the uplands areas to the structure and the construction of 2 large concrete structures, one spanning Petersfield Ditch (35 feet with 8 bays) and the second spanning Prime Hook Creek (20 feet long with 5 bays).

Although water level manipulation is still conducted, the vegetation, water levels, and salinity in Unit III have been influenced by the increased flow of brackish or saline water from Unit II through culverts under Prime Hook Rd., and over the road during storms and high tides.

Management History – Upland Fields 1978 – 2008 (HMP Maps 5 and 6):

- **Fields 301, 330, and 333:** tilled in corn/soybeans until 2006.
- **Field 334:** tilled until 1990; Maintained as early successional grassland w/some brush; mowed 2008.
- **Field 302: Pb-shot site:** cultivated for “goose browse” until 1987. Mowed until mid-1990s; Reverted to trees; Adjacent to private gun-club and current lead shot remediation area.
- **Fields 303-307:** cropped until 1986; Planted in 1987 to pasture mix and mowed annually until late 1990s, and currently reverting to shrubs/trees.
- **Fields 309-314:** cropped until 1987; crop yields poor, farmers gave up fields. Planted in crimson clover/barley mix and mowed annually until 2001, when planted to hardwoods.
- **Field 315:** Reverted to trees in 1970s; designated historic site.
- **Field 317:** Never tilled by USFWS; Used as grassland buffer but stopped mowing in 2000; currently reverting to dense sweetgums.
- **Field 318:** cropped in corn and soybeans until 2006.
- **Field 319:** pasture only never cropped; a portion is designated historic site.
- **Fields 321 & 332:** cropped until 2001-2004 part of R5 grassland study; Put back in corn and soybeans until 2006.
- **Fields 322 & 323:** cropped until 2006.
- **Fields 324 & 325:** cropped until 1982, dropped by farmer as too small in size; reverted to grasses and mowed annually until 2001 when it was planted to hardwoods.
- **Field 326:** cropped annually until 1998, too wet to till; planted in hardwoods in 2001.
- **Field 327:** “Cemetery field” tilled until 1983 then let revert to natural succession. Twice planted in trees with poor results.
- **Field 328:** tilled on and off until mid 1990s; planted in hardwoods in 2001.
- **Field 329:** never tilled, mowed as grassland until late 1990s; reverting to shrubs.
- **Fields 350-357:** newly acquired in 2001. Tilled in corn and soybeans until 2006.

Current Vegetation

Management Unit III is the largest of the Units and lies between Unit II and Unit IV. Like Unit II, it is a freshwater system and is non-tidal. It is 4,431.0 acres (1,793.1 ha) in size, of which 3,822.6 acres (1,546.9 ha) are natural communities and 608.4 (246.2 ha) are anthropogenic communities (Table 4 and HMP Maps 5 and 6). The Generic Marsh, which represents the refuge’s impounded wetlands, is the largest cover type and an Overwash Dune at the north end of the Unit is the smallest.

Unit III is the most biologically and ecologically diverse of all the Units (Note: Generic marsh and open water roughly correspond to impounded wetland areas). Unit III supports three vegetation communities that are currently known in Delaware only from Prime Hook NWR. These include the Twig Rush Peat Mat, Pond Pine Woodland and Red Maple-Seaside Alder Woodland. Prime Hook Creek flowing east to west roughly divides this unit into a northern half and southern half. This unit contains the largest amount of anthropogenic communities at 608.4 acres (246.2 ha), which is more than the other three units combined.

Table 4. Acreage of Natural and Anthropogenic Communities in Management Unit III

NVCS - Natural Community	UNIT III acreage (ha)
Atlantic Coast Interdune Swale	15.8 (6.4)
Atlantic White Cedar-Seaside Alder Woodland	9.8 (4.0)
Brackish Tidal Creek Shrubland	1.3 (0.5)
Buttonbush Coastal Plain Pond	0.8 (0.3)
Coastal Loblolly Pine Forest	41.5 (16.8)
Coastal Loblolly Pine Wetland Forest	56.3 (22.8)
Coastal Plain Depression Swamp	248.7 (100.6)
Interdunal Switchgrass Brackish Depression	0.7 (0.3)
Loblolly Pine Plantation	10.6 (4.3)
Loblolly Pine-Sweetgum Semi-Natural Forest	39.0 (15.8)
Maritime Red Cedar Woodland	7.8 (3.2)
Marsh	1314.7 (532.0)
Mesic Coastal Plain Mixed Hardwood Forest	19.2 (7.8)
Mesic Coastal Plain Oak Forest	43.8 (17.7)
Mesic Rich Forest	24.5 (9.9)
Mid-Atlantic Maritime Salt Shrub	1.5 (0.6)
Overwash Dune	0.2 (0.1)
Peat Mat	9.0 (3.6)
Pond Pine Woodland	7.2 (2.9)
Red Maple-Seaside Alder Woodland	699.3 (283.0)
Reed Canarygrass Eastern Marsh	1.9 (0.7)
Southern Red Oak/Heath Forest	289.1 (117.0)
Successional Maritime Forest	90.6 (36.6)
Successional Sweetgum Forest	88.0 (35.6)
Swamp Cottonwood Coastal Plain Pond	1.5 (0.6)
Open Water	797.9 (322.7)
Water-willow Shrub Swamp	2.2 (0.9)
Natural Community Total	3,822.6 (1,546.9)
Anthropogenic Community	
Agricultural Field	507.1 (205.2)
Building	0.3 (0.1)
Northeastern Successional Shrubland	73.4 (29.7)
Open Lawn	5.0 (2.0)
Parking Lot	1.6 (0.6)
Road	21.0 (8.5)
Anthropogenic Community Total	608.4 (246.2)
UNIT III Total	4,431.0 (1793.1)

UNIT IV (HMP Map 7)

Management Unit IV is surrounded by Rt. 16 on the north, the Broadkill Beach community on the east, the Broadkill River on the south and west, and the upland edge on the west.

Hydrology

Tidal action occurs along the Broadkill River, whose salinity ranges from 10 to 30 ppt. The majority of the water for Unit IV is provided through the Broadkill River. Some tidal action and leakage of salt water into the Unit IV impoundment also occurs during peak tides from a ditch connected to the Broadkill Sound. Rainfall and excessive runoff from Unit III are other sources that provide fresh water. However, normal runoff and tidal action are not sufficient to recharge the impoundment above its perimeter elevation.

Soils and Topography

Unit IV topography is relatively flat with less than one percent slope. Much of the area lies below the three foot contour. Dominant soils found in this unit are Broadkill-Appoquinimink complex (Ba), Broadkill mucky peat (Br), Transquaking and Mispillion (TP), and Purnell mucky peat (Pu). The largest variation in Tidal marsh soil profiles is the depth to underlying material, which in most places is sandy. The depth ranges from 2 to 3 feet in some hummocks and near the boundaries with upland soils, to an undetermined depth in the interior of broad marsh areas. These areas where tidal fluctuations are great, the horizons are completely liquid. Other minor soil types found in upland habitats include Askecksy loamy sand (AsA), Fallsington sandy loam (FaA), Hammonton loamy sand (HmA) and sandy loam (HnA), Hurlock sandy loam (HvA), and Rosedale loamy sand (RoB).

Management History – Wetlands

Prior to Service ownership, this marsh had been excessively drained by man-made ditches. When the refuge was established, about 1,000 acres of tidal salt marsh surrounded about 150 acres of farm fields. Before 1963, private owners maintained pumping stations for ponds in Units III and IV for cattle and to manage waterfowl and muskrats. Much of the marsh was grid ditched for mosquito control.

The vegetation was predominantly salt marsh cordgrass (*Spartina alterniflora*) and salt hay (*S. patens*) with several patches of high-tide bush (*Iva frutescens*). Unit IV was continually grazed by cattle on the Island Farm which was operated as a large cattle feed-lot operation from the early 1950s up to refuge establishment. Cattle continued to graze in Unit IV until the early 1970s.

In 1980, an Environmental Assessment was written to rehabilitate 200 acres of Unit IV's brackish marsh with the construction of water control structures. Two concrete control structures with logs on the impoundment side and flap gates on the tidal side were installed in 1982 to impound this wetland (Vergie's Pond). By 2003 these structures were seriously deteriorated and were subsequently replaced in 2005 in order to maintain water level management capability in this unit.

Management History – Upland Fields 1978 – 2008 (HMP Map 7):

- **Field 401:** cropped until 1982; maintained as grassland (mowed annually) to 2008.
- **Fields 402-405 & 409:** cropped until 1999; ceased farming due to salt water encroachment; mowed every other year.
- **Field 406:** never cropped, only maintained as grassland.
- **Field 407:** maintained as grasslands until 1985; cropped in corn and soybeans until 1996; currently, has reverted to grassland with some brush encroachment.
- **Field 408:** never cropped only maintained in grassland/brush.

- **Field 410:** never cropped; last area used by Henslow's sparrow in 1970s; maintained as grassland in early 1960s and 1970s; brush encroachment treated with hydroaxe in 1990s to re-establish switchgrass community.
- **Field 411:** never cropped; maintained as grassland.

Current Vegetation

Management Unit IV is the southernmost management unit and is the smallest of all the units with a total area of 1,176.4 acres (476.0 ha), of which 1,111 acres (449.6 ha) are natural communities and 65.3 acres (26.4 ha) are anthropogenic communities (Table 5 and HMP Map 7). Unit IV receives tidal and brackish input from the Broadkill River and as a result, the largest natural community in Unit IV is the *Spartina* low salt marsh. The smallest natural community is an Interdunal Switchgrass Brackish Depression. A Coastal Bay Shore/Succulent Beach is located within the impounded portion of Unit IV and is covered under the general Marsh category. Unit IV is the only known location for this community in Delaware.

Table 5. Acreage of Natural and Anthropogenic Communities in Management Unit IV

NVCS - Natural Community	Unit IV acreage (ha)
Atlantic Coast Interdune Swale	30.5 (12.3)
Brackish Tidal Creek Shrubland	17.7 (7.1)
Coastal Loblolly Pine Forest	9.7 (3.9)
Interdunal Switchgrass Brackish Depression	5.7 (2.3)
Maritime Red Cedar Woodland	66.2 (26.8)
Marsh	4.1 (1.6)
Mid-Atlantic Maritime Salt Shrub	40.4 (16.3)
<i>Spartina</i> High Salt Marsh	7.8 (3.1)
<i>Spartina</i> Low Salt Marsh	774.8 (313.5)
Successional Maritime Forest	22.0 (8.9)
Water	132.2 (53.5)
Natural Community Total	1,111.1 (449.6)
Anthropogenic Community	
Building	0.2 (0.1)
Northeastern Successional Shrubland	58.7 (23.7)
Road	6.4 (2.6)
Anthropogenic Community Total	65.3 (26.4)
Unit IV Total	1,176.4 (476.0)

2.3 Physical and Geographic Setting

Climatic Influences

Delaware's climate is generally mild, continental weather moderated by the effects of the Atlantic Ocean in general, so periods of sustained hot or cold temperatures are typically brief. Extreme temperatures are moderated by the Delaware Bay, the Atlantic Ocean and the Chesapeake Bay. On refuge, weather

conditions are mild year round with temperatures ranging from 32° F for an average low and 80° F for an average high. Normally summer ocean breezes keep the Refuge cooler than inland areas and most winter days are mildly attenuated by the same breezes.

Yearly and seasonal precipitation is highly variable. Average annual refuge rainfall is 41.98 inches. Snowfall is usually light, averaging 10 to 15 inches per year. Prevailing winds from March through October are from the northwest except during summer months when they become more southerly. Prevailing winds from November through February are northeast. Average annual wind speed is about 9 mph, but winds can reach 50 to 60 miles per hour or higher during summer thunderstorms, hurricanes or intense winter northeasters. These climatic conditions correspond to USDA Plant Hardiness Zone (7a). Native plant and ecological restoration biologists refer to the USDA zones for guidance in selecting appropriate species and planting times.

The entire refuge lies within Delaware's Coastal Zone and is subject to periodic flooding by coastal storms. Most of the Refuge lies within the 100 year floodplain. The March storm of 1962 inundated 90% of the current refuge lands. When PHNWR is subjected to intense winter storms with strong sustained winds and high tides, this leads to extreme flooding of impoundments with saline Delaware Bay waters and severe erosion of dunes and impoundment dikes, resulting in heavy salt water intrusion of freshwater wetlands and adjacent upland habitats. This occurred on the winter of 1998 from a severe Nor'easter, and again in 2006 from Hurricane Ernesto, and 2008 from another Nor'easter on May 11th.

Delaware's Landscape Ecology

The state of Delaware occupies approximately 1.3 million acres along the mid-Atlantic coast. Despite its small size, the state possesses a diversity of flora and fauna since it spans 2 physiographic provinces. More than 1,000 species of wildlife are known to presently occur or have occurred in the past with approximately 125 different types of vegetative communities recently mapped in the Delaware Wildlife Action Plan (2005).

The Delaware Natural Heritage Program, tracks rare species distribution and abundance using the methodologies of the international network of Natural Heritage Programs. This methodology allows for comparison of species status across all taxa, and for this reason was chosen by the State of Delaware as the foundation for determining Species of Greatest Conservation Need (SGCN) in Delaware's Wildlife Action Plan. The state plan identifies 457 species of greatest conservation need associated with 50 different habitats required to support rare flora and fauna (DNREC 2005).

Floristically, Delaware lies within the transition zone, in which species of southern and northern affinities intermingle. This creates a unique biological interface of falling on the southern end of the most northern ranges of species and also at the most northern end of the southern ranges of flora and fauna, a situation that serves to heighten its biological diversity. Avian diversity also derives from the state's location on the Delaware Bay, adjacent to the Atlantic Ocean and its strategic placement along a major migration route on the Atlantic Flyway.

Wetlands Past and Present

Coastal wetlands found on the refuge are comprised of three wetland classifications as defined by NWI, these are; estuarine emergent, estuarine scrub-shrub, and intertidal flats. Estuarine wetlands represent about one-third of Delaware's marsh habitats with palustrine wetlands encompassing the remaining marsh habitats. About 75% of Delaware's vegetated wetlands are emergent or forested types. Ninety-eight percent of the state's wetlands occur in the coastal plain (Tiner 2001). More than 45,000 acres of the state's tidal wetlands were grid-ditched for mosquito control by the Civilian Conservation Corps in the 1930s (Whitman & Cole 1986).

During the past 300 years, Delaware has lost about 55% of its original wetland acreage. Channelization and drainage still pose serious problems for palustrine wetlands; large-scale drainage ditches are still constructed, lowering water tables. Restoration efforts are needed to improve water quality and function of these damaged wetlands and to re-establish the functions of lost wetland areas (Tiner 2001).

Open water environments account for approximately 4% of Delaware's cover-types. The state contains about 843 miles of perennial streams and creeks forming several drainage sub-basins that are distinctly different according to geographic location. Piedmont streams are exclusively freshwater with steeper gradients and swifter flow than Coastal Plain waterways. However, in estuarine creeks powerful currents can be generated by tidal flow and salinity varies seasonally with distance from the ocean or Delaware Bay. More than 1,000 acres have been classified as deepwater habitats (water depths > 6.6 feet) in Delaware (Tiner-1985).

Many small coastal plain streams in Sussex County have been channelized for drainage through a state "tax-ditch" system. Delaware Code Title 7, Chapter 41, provides the basis for a uniform system for establishing, financing, administering, maintaining, and dissolving tax ditch organizations in Delaware, under the supervision of DNREC. Currently more than 2,000 miles of channels in Delaware are managed by 228 tax ditches and political state subdivisions that have maintenance taxing authority. Tax ditch channels range in size from 6 to 80 feet wide and 2 to 4 feet deep. The dimensions depend upon the acreage being drained and the local topography (State of Delaware-1998). It has been estimated that 13% of the state's palustrine forested wetlands (mostly in Kent and Sussex Counties), continue to be drained by these tax ditches (Tiner-1985). Two tax ditches occur on the Refuge, Draper-Bennett Tax Ditch in Unit I and Naylor-Wells Tax Ditch in Unit III.

Prior to European settlement virtually all of Delaware's upland areas were forested. Transitional habitats representing small blocks of early successional grassland openings and thickets were more prevalent than today likely due to Native American set fires to maintain open areas for hunting (Tetra Tech 2004).

Agricultural and urban development have eliminated much of the forests of Delaware. By 1950 agricultural lands accounted for 904,000 acres of the state's 1,251,000 total acres. This had dropped to 600,000 acres by 2000, lost to commercial and residential development. Today, forested cover types have dropped significantly with the greatest losses occurring in Sussex County, leaving less than 150,000 acres remaining throughout the state. Continuing forest losses, forest fragmentation and clear cutting throughout Delaware have resulted in a loss of over 85% of forested habitats (ELI-1999 & DE Office of Planning 2005).

Delaware Natural Heritage Program (DNHP) data lists over 2,200 plant species, varieties, and hybrids of native (1,590) and non-native (610) vascular plants known to occur in Delaware. The overall flora is represented by 173 families and 770 genera. A full synopsis of the flora of Delaware is provided in "*The Flora of Delaware: An Annotated Checklist*" (McAvoy & Bennett -2001).

Species rarity on a local, regional, and global level as assessed by the DNHP is primarily a function of habitat loss. Habitat losses within the Delaware landscape have been due to the conversion of natural habitats to agriculture, commercial and residential development, and from draining and filling wetlands. Over 40% of the known native flora (620 taxa) are classified as species of Conservation Concern and are in need of some level of proactive protection (DNREC 2005).

Seventy-seven plant species are known from only a single population in Delaware; 171 species have not been reported in the state for 15 years or more (historical), and 57 species are considered to be extirpated from the state. Fifteen percent of the known native flora of the state is either historical or extirpated. Seven species in Delaware are listed by USFWS as either threatened or endangered, and 36 species are considered globally threatened by The Nature Conservancy.

Of the 620 plant species of Conservation Concern, 585 native species of plants are restricted to the Coastal Plain physiographic province. Forty-five percent of all rare plants in Delaware are found in freshwater non-tidal wetland habitats (or 266 species). Non-tidal freshwater wetlands in Delaware are not protected by the state. By comparison, 55 native species of Conservation Concern are found in tidal (fresh and saline) wetlands or 8% of all rare plants in the state. Tidal wetlands are state protected. There are 297 species of plants that occur in upland habitats (forests, forest canopy gaps, early successional habitats and coastal dunes) that are of Conservation Concern in Delaware. Natural upland habitats have been identified as rare key wildlife habitats in Delaware's 2005 Wildlife Action Plan. These habitats in Delaware have no regulatory protection (DNREC 2005).

2.4 Current Refuge Condition

In this section we have identified individual plant and community types, vegetative composition, invasive species, contaminant problems and other current conditions that affect habitat management. We have also identified existing rare floral and faunal species, declining, or unique natural communities, and species within the Refuge's boundaries. These species along with the focal species identified in Chapter 2 of the CCP are important to the management of biological integrity, diversity, and environmental health of the Refuge habitats.

Plant Communities at Prime Hook NWR

Thirty four natural vegetation communities were mapped on PHNWR by the Delaware Natural Heritage Program (DNHP) in 2005 and 2006. It should be noted that, as a result of the recent shoreline changes in Unit II (overwashes, inlets), these vegetation communities have been changing in composition and in size. With many of these areas in transition, the exact nature and extent of these changes are not known. Thus, we recognize that the vegetation map information is already outdated for portions of our managed wetland impoundments that have been affected by recent coastline changes. However, the vegetation map is still useful for much of the refuge uplands, and serves as a baseline summary of vegetation conditions. At the time of the mapping, the *Spartina* low marsh (1,685 acres) was the largest association and the Button Bush Coastal Plain Pond was the smallest (1 acres). Four associations (*) were identified on the Refuge that are unique in Delaware and found nowhere else in the state. These include the Red Maple/Seaside Alder (799 acres), Pond Pine Woodland (8 acres), Coastal Bay Shore/Succulent Beach (150 acres) and Twig Rush Peat Mat (10 acres) associations (See Table 6 and HMP Map 2). As of the preparation of this HMP, the vegetation map for the refuge is being updated by DNHP to reflect the changes in recent years, which will serve as a new baseline to track vegetation community changes as a result of future management and restoration.

Table 6. Habitat Types by Acres and NVCS Common Names on PHNWR in 2005-2006

HABITAT TYPE	ACRES	NVCS Association Common Names
Overwash Dune	17	Salt Meadow Cordgrass, Common Threesquare, Seaside Goldenrod (G2G3) (Habitat of State Conservation Concern)
Beachgrass/Panicgrass Dune Grassland	35	American Beachgrass, Bitter Panicgrass (G2) (Habitat of State Conservation Concern)
Atlantic Coast Interdunal Swale & Depression	74	Wax-Myrtle, Salt Meadow Cordgrass, Panicgrass Shrubland (G3) (Habitat of State Conservation Concern)
Mid-Atlantic Maritime Salt Shrub	60	Groundsel, Maritime Marsh Elder, Salt Meadow Cordgrass (Habitat of State Conservation Concern)
Maritime Red Cedar Woodland	76	Eastern Red Cedar, Northern Bayberry Woodland (G2) (Habitat of State Conservation Concern)
Southern Red Oak/Heath Forest	289	White Oak, Southern Red Oak, Dangleberry
Mesic Coastal Plain Oak Forest	193	Southern Red Oak, Willow Oak, American Holly

HABITAT TYPE	ACRES	NVCS Association Common Names
Successional Sweetgum Forest	180	Sweetgum, Loblolly Pine, Red Maple
Coastal Loblolly Pine Forest	51	Loblolly Pine, Wax-myrtle, Royal Fern
Mesic Coastal Plain Rich Forest	19	Tuliptree, Red Oak, Green Ash, Bellwort (Habitat of State Conservation Concern)
Mesic Coastal Plain Mixed Hardwood Forest	19	American Beech, Red & White Oak, Tuliptree, Christmas Fern
Pond Pine Woodland*	8	Pond Pine, Sweetbay, Highbush Blueberry, Atlantic Sedge (Habitat of State Conservation Concern)
Red Maple-Seaside Alder Swamp*	799	Red Maple, Seaside Alder Saturated Woodland (S1) (Habitat of State Conservation Concern)
Waterwillow Shrub Swamp	2	
Coastal Plain Depression Swamp	335	Sweetgum, Red Maple, Willow Oak, Fetterbush Flooded Forest (Habitat of State Conservation Concern)
Buttonbush Coastal Plain Pond	1	Buttonbush/Swamp Smartweed/Warty Panicgrass Shrubland (Habitat of State Conservation Concern)
Coastal Loblolly Pine Wetland Forest	91	Loblolly pine, Southern Bayberry, Royal Fern Saturated Forest
Atlantic White Cedar swamp	10	Atlantic White Cedar, Seaside Alder Seasonally Flooded Woodland
Cottonwood Coastal Plain Pond	2	Swamp Cottonwood, Red Maple, Pin Oak, Sweetgum (Habitat of State Conservation Concern)
Coastal Bay Shore/Succulent Beach*	150	
Impounded Freshwater/Brackish Wetlands → Generic Marsh = 2946 Water = 1554	4,500	(1/3 Perennial Vegetation) Wild Rice Marsh, Narrow-Leaf Cattail, Rosemallow Marsh, Fall Panicum, Olney Three-Square Marsh, Pond Lily Marsh, Cattail, Bulrush Marsh (2/3 Annual Moist Soil Veg) Sea Purslane, Spearscale Marsh (Habitat of State Conservation Concern)
Peat Bog Community*	10	Twig Rush, Ten-Angle Pipewort, Tawny Cotton Grass (S1) (Habitat of State Conservation Concern)
Salt Marsh	2,200	<i>Spartina</i> Low Salt Marsh, Salt Panne, <i>Spartina</i> High Salt Marsh, Bayberry-Salt Meadow Cordgrass (Habitat of State Conservation Concern)

Refuge plant surveys conducted in 2004 and 2005 by Delaware Natural Heritage Botanists provided data on habitat conditions and species composition at that time. The flora of PHNWR is represented by 100 families and 247 genera (See Appendix E of the CCP). The largest families are the sedge family (Cyperaceae) with 60 taxa and 11 genera, followed by the aster family (Asteraceae) with 57 taxa and 34 genera, and the grass family (Poaceae) with 45 taxa and 30 genera. The largest genera include: *Carex* (28 taxa), *Quercus* (9 taxa), *Eleocharis* (8 taxa), *Polygonum* (8 taxa), *Bidens* (7 taxa), *Eupatorium* (7 taxa), *Juncus* (7 taxa), *Asclepias* (6 taxa), *Cyperus* (6 taxa), and *Rhynchospora* (6 taxa).

The majority of Refuge plants are perennial broad-leaf herbs with 131 taxa, followed by annual broad-leaf herbs with 58 taxa. Graminoids (grasses, sedges, and rushes) are a large component of the Refuge's flora, equaling 112 taxa, (45 taxa of grasses, 60 taxa of sedges, and 7 taxa of rushes). Trees and shrubs are also very prominent in the flora, with 29 taxa of deciduous trees, 6 taxa of evergreen trees, 32 taxa of deciduous shrubs, and 5 taxa of evergreen shrubs.

True ferns [e.g., cinnamon fern (*Osmunda*)] and their relatives [e.g., tree club-moss (*Lycopodium*)] form a unique assemblage of the flora with 16 taxa. Most of the Refuge's flora is wetland plants (wetland indicator status of facultative-wet and obligate) represented by 236 taxa, compared to 189 that occur either occasionally in wetlands, or never occur in wetlands. The majority of the flora on the refuge has southern affinities with 104 taxa having a more southern natural geographic distribution. By comparison

47 taxa have a more northern natural geographic distribution. Documented rare plants included 42 species (7-S1, 20-S2, and 17-S3).

Rare Plants and Exemplary Communities

Exemplary natural communities are those that have been minimally impacted by humans and contain an exceptional diversity or unique rare plant species. The most significant community found on the Refuge was the Twig Rush Peat Mat. These sites (6 were mapped by McAvoy and Coxe 2007) support many state rare plant species and occur in open water within a shrub-dominated swamp matrix. This unique habitat develops on deep, mucky, peat that appears to float (true “quaking bog”). Of the six quaking bogs inventoried and mapped, the most exemplary was the “Prime Hook Bog,” described below.

The “Prime Hook Bog” is about 1.5 acres in size and is floristically diverse with 66 species and varieties documented. Twig rush sedge (*Cladium mariscoides*) is the dominant herb with many rare plants (See Table 7) including several insectivorous plants like purple pitcher-plants, round-leaf sundew, fibrous bladderwort, and southern bladderwort. In addition, a subspecies new to the flora of the State of Delaware and the Delmarva Peninsula was discovered here: the bushy bluestem (*Andropogon glomeratus* var. *hirsutior*).

Table 7. State-rare plants associated with the NVCS - Twig Rush Peat Mat Community on Prime Hook National Wildlife Refuge

SCIENTIFIC NAME	COMMON NAME	STATE RANK
<i>Alnus maritima</i>	Delmarva alder	S3
<i>Andropogon glomeratus</i> var. <i>hirsutior</i>	bushy bluestem	S1
<i>Bartonia paniculata</i>	twining bartonia	S2
<i>Bidens coronata</i>	tickseed sunflower	S3
<i>Bidens mitis</i>	small-fruit beggar-ticks	S2
<i>Cyperus diandrus</i>	Umbrella flatsedge	S1
<i>Drosera rotundifolia</i>	round-leaf sundew	S2
<i>Eleocharis robbinsii</i>	Robbins spike-rush	S3
<i>Eriocaulon decangulare</i>	ten-angle pipewort	S1
<i>Eriophorum virginicum</i>	tawny cotton-grass sedge	S1
<i>Eriocaulon parkeri</i>	Parker’s pipewort	S2
<i>Fuirena squarrosa</i>	hairy umbrella-sedge	S2
<i>Fuirena pumila</i>	Dwarf umbrella sedge	S3
<i>Juncus pelocarpus</i>	brown-fruited rush	S2
<i>Lycopus amplexans</i>	sessile-leaved bugleweed	S2
<i>Pogonia ophioglossoides</i>	rose pogonia	S2
<i>Rhynchospora alba</i>	white beakrush	S2
<i>Rhynchospora scirpoides</i>	Long-beaked beakrush	S2
<i>Sagittaria engelmanniana</i>	Engelmann’s arrowhead	S2
<i>Sagittaria graminea</i>	Grass-leaf arrowhead	S2
<i>Sarracenia purpurea</i>	purple pitcher-plant	S2
<i>Spiranthes cernua</i>	nodding ladies’-tresses	S3
<i>Utricularia fibrosa</i>	fibrous bladderwort	S2
<i>Utricularia juncea</i>	southern bladderwort	S2

In addition to rare vascular plant data, exceptionally large individual tree species (relative to PHNWR and the state of Delaware) were measured and recorded. One willow oak measured 53" diameter at breast height (dbh) with several other willow oaks in the 40" dbh range.

Nonvascular plants are the simplest of all land dwelling plants. Like their closest ancestors, the green algae, they lack an internal means of water transportation. They do not produce seeds or flowers. They generally only reach a height of one to two centimeters, because they lack the woody tissue (xylem and phloem) necessary for support on land. Because of their sensitivity to the environment around them, they can be useful indicators of environmental conditions as they are particularly susceptible to air and water pollution. They also serve as food for small animals and insects. Non-vascular plants grow from spores. Non-vascular plants include two distinctly related groups Bryophytes and Algae Bryophytes include the Bryophyta (mosses), the Marchantiophyta (liverworts), and the Anthocerotophyta (hornworts). A number of mosses and liverworts were documented in various habitats on the refuge by DNHP (Table 8).

Table 8. Nonvascular plants documented on Prime Hook National Wildlife Refuge

HABITAT (Refuge Unit)	SCIENTIFIC NAME (substrate)	TYPE
Southern Red Oak Heath Forest (Unit III)	<i>Amblystegium serpens</i> (bark)	moss
	<i>Capylium hispidulum</i> (base of tree)	moss
	<i>Coloejeunea biddlecomiae</i> (bark)	liverwort
	<i>Dicranum condensatum</i> (soil)	moss
	<i>Orthotrichum stellatum</i> (bark)	moss
	<i>Pylaisella selwynii</i> (bark)	moss
	<i>Tortella humilis</i> (base of tree)	moss
Coastal Loblolly Pine Wetland Forest (Units I and II)	<i>Aulacomnium palustre</i>	moss
	<i>Climacium americanum</i>	moss
	<i>Dicranum flagellare</i>	moss
	<i>Hypnum imponens</i>	moss
	<i>Isopterygium tenerum</i>	moss
	<i>Leucobryum albidum</i>	moss
	<i>Plagiothecium denticulatum</i>	moss
	<i>Thuidium delicatulum</i>	moss
	<i>Cephalozia connivens</i>	liverwort
	<i>C. lunilifolia</i>	liverwort
	<i>Cephaloziella rubella</i>	liverwort
	<i>Leucolejeunea clypeata</i>	liverwort
	<i>Lophocolea heterophylla</i>	liverwort
	<i>Nowellia curvifolia</i>	liverwort
	<i>Odontoschisma prostratum</i>	liverwort
	<i>Pallavacinia lyellii</i>	liverwort
<i>Sphagnum cuspidatum</i>	peat moss	
<i>S. palustre</i>	peat moss	

HABITAT (Refuge Unit)	SCIENTIFIC NAME (substrate)	TYPE
Twig Rush Peat Mat (Unit III)	<i>Sphagnum fimbriatum</i>	peat moss
	<i>S. recurvum</i>	peat moss
	<i>S. perichaetile</i>	peat moss
Early Successional / Open Field Habitats	<i>Riccia huebneriana</i> subsp. <i>Sullivanti</i>	liverwort
	<i>R. hirta</i>	liverwort
	<i>Notothylyus orbicularis</i>	hornwort

Rare Fauna

Zoological surveys were undertaken for reptiles, amphibians, and state-rare insects in 2004-2005 as part of the Refuge's CCP pre-planning baseline data inventory efforts. For insects, inventories focused on species of conservation concern (DNHP ranks: S1, S2, & SH) for which information regarding status (local, regional, global) were available. This included dragonflies and damselflies (Odonata), fireflies (Coleoptera: Lampyridae), tiger beetles (Coleoptera: Carabidae), moths and butterflies (Lepidoptera), and wasp species (Hymenoptera). Other species reported included undescribed species, new county and state records. Rare fauna documented on the refuge are summarized in Table 9.

Table 9. Rare fauna documented on Prime Hook National Wildlife Refuge

SPECIES GROUP	COMMON NAME	SCIENTIFIC NAME	STATE RANK	ASSOCIATED HABITAT(S)
Amphibians	Carpenter Frog	<i>Rana virgatipes</i>	S1	Coastal Plain Depression Swamp; Coastal Loblolly Pine Wetland Forest;
	Cope's Gray Treefrog	<i>Hyla chrysoscelis</i>	S1	
Reptiles	Ribbon Snake	<i>Thamnophis sauritus</i>	S2	Red Maple-Seaside Alder Woodland; Atlantic White Cedar-Seaside Alder Woodland
	Rough Green Snake	<i>Opheodrys aestivus</i>	S2	
Odonata	Elfin Skimmer	<i>Nannothemis bella</i>	S1	Twig rush peat mat; Impounded Freshwater Marsh
	Sphagnum Sprite	<i>Nehalennia gracilis</i>	S1	
	Lilypad Forktail	<i>Ischnura kellicotti</i>	S1	
Hemiptera: Delphacidae (Planthoppers)	Unnamed -Species is new to science	<i>Megamelus sp</i>		Twig rush peat mat
Coleoptera: Carabidae	Beach Dune Tiger Beetle	<i>Cicindela hirticollis</i>	S1	Beachgrass-panicgrass dune grassland; Overwash dune grassland
Lampyridae (Fireflies)		<i>Photuris pensylvanica</i>	S2	Twig rush peat mat; Red maple-seaside alder woodland; Impounded marsh
		<i>P. tremulans</i>	S2	
		<i>P. pyralomimus</i>		
		<i>P. frontalis</i>	S1	
Cerambycidae: (Long-horned Beetles)		<i>Prionus laticollis</i>	County Record	Southern red oak heath forest

SPECIES GROUP	COMMON NAME	SCIENTIFIC NAME	STATE RANK	ASSOCIATED HABITAT(S)
Lepidoptera (Butterflies and Skippers)	Great Purple Hairstreak	<i>Altides halesus</i>	S1	Red Maple Seaside Alder Swamp
	Southern Broken Dash	<i>Wallengrenai otho</i>	S1	Maritime Red Cedar Woodland
	Little Glassy Wing	<i>Pompeius verna</i>	SU	
	Delaware Skipper	<i>Anatrytone logan</i>	SU	Coastal Plain Depressions; Coastal Loblolly Pine Wetland Forest; Maritime Red Cedar Woodland
Moths	Hydrangia sphinx	<i>Darapsa versicolor</i>	S1	Red maple-seaside alder woodland
	Graphic Moth	<i>Drasteria graphica</i>	S1	Maritime Red Cedar Woodland (host plant = <i>Hudsonia tomentosa</i>)
	Blueberry Dart	<i>Xestia youngii</i>	S1	Twig rush peat mat
	Pitcher Plant Borer Moth	<i>Exyra fax</i>	S1	
	Maritime Sunflower Borer Moth	<i>Papaipema maritima</i>	S1	Early successional grassland; Successional maritime forest
	Little Wife Underwing	<i>Catocala muliercula</i>	State Record	All communities with significant component of southern bayberry (<i>Morella cerifera</i>)
	Marbled Underwing	<i>Catocala amrmorata</i>	S1	Southern red oak-heath forest
	Tearful Underwing	<i>Catocala lacrymosa</i>	S1	
	Praeclara underwing	<i>Catocala praeclara</i>	S1	Coastal Plain depression swamp; Coastal loblolly pine wetland forest; Red maple/seaside alder woodland
Noctuid Moths	<i>Zale metatoides</i> & <i>Z. metata</i>	S2	Coastal loblolly pine forest; Pond pine woodland	

Invasive Plants

Of the 429 plant taxa listed in Appendix E of the CCP, 46 are non-native of which eleven are considered to be invasive. Some of these invasive include spotted knapweed (*Centaurea bieberstei*), Canada thistle (*Cirsium arvense*), Japanese honeysuckle (*Lonicera japonica*), water-willow (*Ludwigia leptocarpa*), Japanese stilt-grass (*Microstegium vimineum*), reed canary grass (*Phalaris arundinacea*), alien common reed (*Phragmites australis* subsp. *Australis*), multi-flora rose (*Rosa multiflora*), porcelainberry (*Ampelopsis brevipedunculata*), autumn olive (*Elaeagnus umbellate*), and kudzu (*Pueraria Montana*).

Spotted knapweed and Canada thistle are restricted to roadside areas, fallow agricultural fields, edges of hedgerows, and early successional fields throughout the Refuge. Japanese honeysuckle is ubiquitous throughout the Refuge mostly in wooded habitats. Water-willow, which is adventive in Delaware (native further south), may dominate about 100 to 150 acres of impounded marsh in Unit III, depending upon annual water regimes that may promote germination of this annual species. Japanese stilt grass (about

50 acres) is mostly found on Oak Island, where it dominates the herbaceous layer. All invasive plants are scattered throughout the refuge.

Reed canary grass, another invasive species in Delaware dominates an old field habitat in Unit III (corners of Field # 328). This is the same location where the state-rare plant lance-leaf orange milkweed (*Asclepis lanceolata*) grows. The lance-leaf orange milkweed is abundant here and is the largest known population in the state (100+ individuals), where current annual mowing late in the growing season appears to be favoring this milkweed species by suppressing woody vegetation. Multi-flora rose is widespread throughout the Refuge, growing in scattered areas within hedgerows, thickets, early successional fields, and woodland edges.

Pollutants and Contaminants

The Clean Water Act (CWA-33USC 251) is the cornerstone of surface water quality protection of aquatic habitats and has established WQS (Water Quality Standards) for individual states in the US. If water bodies are designated as “impaired” by not meeting WQS, the most common state strategy is the development of a Total Maximum Daily Load (TMDLs) for a non-compliant watershed. TMDLs determine what level of pollutant load would be consistent with meeting WQS by allocating acceptable loads among sources of relevant pollutants.

State-wide water quality assessments performed by DNREC has shown that more than 90% of Delaware’s waterways are “impaired.” Impaired waters are deemed polluted waters suffering from excess nutrients, low dissolved oxygen, toxins, bacteria, or any combination of these problems. Delaware has 41 designated watershed boundaries and most of Prime Hook NWR is located within the Broadkill River Watershed which is approximately 69,000 acres in size.

The Broadkill River and its tributaries and ponds adjacent to the Refuge are impaired by high levels of bacteria and elevated levels of nitrogen and phosphorus as determined by state monitoring efforts (Broadkill Watershed Assessment-DNREC 2000). There has been a significant decrease in wetlands and forests over time as these natural filters have been converted to other uses and the area develops into a more urban/suburban watershed. A pollution control plan (Jan 2008) has established TMDLs for the Broadkill River Watershed requiring a 40% reduction in non-point source nitrogen load, 40% reduction in non-point source phosphorus load, and 75% reduction in non-point source enterococcus bacteria, relative to 2002-2003 DNREC baseline data. The Refuge partnered in developing strategies to abate Broadkill River Watershed pollution and on-going watershed water quality sampling includes sampling points both on and near the Refuge.

Sussex County’s extensive poultry industry produces over 600 million chickens and 1.6 billion pounds of manure annually (USDA 1997). In addition to nitrate and phosphate overloads that create hyper-eutrophication of adjacent waterways, poultry litter contains feed additives such as trace metals, antibiotics, and hormones. Excessive land application of poultry litter has resulted in severe water quality problems in surface and groundwater contamination in the Delmarva area (McGee et al 2003). Greater quantities of animal feed additives used in the poultry industry include metals such as arsenic, selenium, zinc copper and antibiotics. The majority of these additives are excreted and found at elevated concentrations in manure. Studies have indicated that these environmental contaminants are migrating to nearby surface waters (Miller et al 2000).

Due to the high density and intensity of agricultural operations and documented water quality problems throughout the peninsula, it seemed highly likely that contaminants associated with AFOs would represent a threat to Refuge ecological resources. This was the incentive to conduct a two-year investigation on Prime Hook NWR in Delaware and Blackwater NWR in Maryland, conducted by

contaminant biologists of the Chesapeake Bay Field Office (CBFO), "*Evaluating the Potential Water Quality Impacts of Animal Feeding Operations on National Wildlife Refuges on the Delmarva Peninsula.*" The purpose of the study was to assess water quality impacts on these two Refuges associated with AFOs by evaluating chemical and biological conditions impacted by animal feed additives and other "nontraditional" contaminants. Based on sampling results, PHNWR was the refuge with greater water quality problems associated with AFOs (McGee et al 2003).

Study results provided direct evidence of transport of tetracycline family of antibiotics and hormones from poultry litter applied to fields adjacent to refuge waterbodies on Prime Hook. Fish tissue data suggest that Refuge fish are being exposed to significant concentrations of estrogenic compounds from AFOs. Tissue data demonstrated that pesticides, hormones and high levels of antibiotics are significantly contaminating Refuge and Delmarva Peninsula waterbodies and that the negative impacts on fish and wildlife resources merits further investigation.

An unexpected result of the study was the finding that mercury contamination of piscivorous fish species from Refuge waterbodies of Slaughter Canal and Prime Hook Creek were at levels of human health concern. Refuge largemouth bass (LMB) exceeded EPA fish tissue residue criterion for mercury [Hg] in two waterways: Prime Hook Creek (0.54 ug/g) and Slaughter Creek (0.53-0.68 ug/g) {EPA Standard = 0.3ug/g}. Other contaminants of concern in Slaughter Creek included PCBs and Furan.

In 2006 the Refuge was included in the State of Delaware's "Toxics in Biota Monitoring Plan for FY 2006 and 2007. Further studies conducted by the state concluded that mercury is the primary risk driver for LMB in Prime Hook Creek and Waples Pond, and PCBs, Dioxin and Furans are the primary risk drivers in Slaughter Creek. In 2007 and 2008 these two waterbodies have been added to Delaware's Fish Consumption Advisories posted by DNREC annually in its State Fishing Guide.

For 37 years, The Broadkill Sportman's Club adjacent to the Refuge operated a trap-shooting range, located on the southwestern corner of the headwaters of Prime Hook Creek. Clay-target launchers were oriented so that expended lead shot dropped into a forested wetland and upland grassland area on Refuge lands. After many years of lead shot deposition, it was discovered that lead shot concentrations were as high as 57,868 pellets per square foot in some areas on Prime Hook National Wildlife Refuge.

The trap club was founded in 1962 on Pikes Neck, Sussex County. Service property boundaries surrounding the club were established in 1964. The club used five trap houses, each containing five shooting stations. Shotgun rounds were projected across a grassy field toward a wooded wetland intending to hit airborne clay targets above the field. Numerous lead shot pellets from misses and overshot trajectories often hit trees inside the Refuge boundary and falling to the ground, accumulating through the years.

The club was located in an upland area about 0.1 miles from the Refuge's Prime Hook Creek. The highest elevation of club lands is about 10 feet above sea level and most of the adjacent Refuge forested wetlands is 5 feet or less in elevation (Soeder & Miller 2003). The trap-shooting range was operated from 1962 to 1998, at which time a proposed land swap with the USFWS was initiated by the club.

Upon this request the Service initiated a Level One Contaminant Survey of Refuge lands. During August and October of 1998, CBFO Service personnel collected soil samples to determine the extent of lead concentrations in Refuge soils. Results showed significant lead contamination. The EPA and Service then ordered the club to discontinue depositing lead shot onto Refuge lands and in 2000 initiated a five-year clean-up project.

A preliminary assessment in 2000 determined that an affected area of 22 acres down-range of the club had accumulated most of the lead shotgun pellets with the highest densities concentrated in a designated “drop-zone” sized at 26,200 square feet. (Crowley & Richardson 2001). As part of an environmental risk assessment prepared by CBFO contaminant biologists, USGS investigated the potential for lead soaked soils to leach into the groundwater and minor tributaries feeding into Prime Hook Creek.

Study results verified that low pH ground water values probably from acid rain deposition helped to create exceedingly acidic environmental conditions responsible for dissolving lead carbonate off the pellets. Due to a lack of buffering capacity and adsorption sites in the silica-rich sediments of the area, the dissolved lead was then easily mobilized and moved into the groundwater on the Refuge.

The Service has physically excavated and removed part of the pellet-contaminated soils on Refuge property, which has since revegetated with native plants. The major source of groundwater contamination has been remediated on Refuge lands but not on club lands. The mitigation of high lead concentrations in Refuge ground water resources will require long-term monitoring to confirm the potential of natural attenuation of the system.

A Central Hazmat Fund Proposal submitted by CBFO contaminant biologists will provide long-term monitoring of the Refuge lead shot area, which included 5 wells sampled every three months for a two year period followed by every six months for an additional eight years. Using EPA and USGS methods for groundwater sampling, USFWS will obtain samples for analysis of total and dissolved arsenic, antimony and lead. Samples will be analyzed by Severn-Trent Laboratories (Edison, N.J.) and the results will be provided to Delaware Department of Natural Resources and Environmental Control (DNREC). This lab is certified by the State and data is provided with detection limits required by DNREC (8.68 ppb for SB, 4.70 ppb for As and 2.70 ppb for Pb).

The results will be reviewed by DNREC and statistical analyses will follow DNREC guidance for groundwater monitoring of the 5 wells each year. Depending on lead levels, groundwater monitoring could continue for up to 30 years. Groundwater monitoring is required under CERCLA (Comprehensive Environmental Response Compensation and Liability Act).

Additional threats to refuge communities, especially salt marshes and other wetlands, include oil spills and other petro-chemical contamination, as the Delaware Bay is the third largest shipping channel in the US, Refuge communities are also impacted by atmospheric mercury deposition.

2.5 Changing Climate and Sea Level Rise

Climate Change

Climate change is an immense and serious challenge that will affect fish and wildlife profoundly. A growing body of evidence indicates that accelerating climate change, associated with increasing global temperatures, is affecting water, land, and wildlife resources (Titus et al. 2009). While climate change has occurred throughout the history of our planet, current changes are occurring at a greatly accelerated rate, largely as a result of the accumulation of greenhouse gases from human activities. Climate change can affect the migration phenology and body condition of migratory songbirds (Buskirk et al. 2009). Along our coasts, rising sea levels have begun to affect fish and wildlife habitats, including those used by waterfowl, wading birds and shorebirds on our National Wildlife Refuges.

Successful conservation strategies will require an understanding of climate change and the ability to predict how those changes will affect fish and wildlife at multiple scales. We need to develop, test, and implement conservation strategies to cope with to the physical changes in the coastal environment

resulting from climate change. Some of the current and predicted impacts of climate change in the coastal zone include:

- Shoreline erosion and shoreline displacement
- Displacement of wildlife (as critical habitats decline)
- Conversion of upland habitats to wetter habitats, freshwater habitats to saline
- Conversion of forested areas to emergent wetlands
- Conversion of tidal wetlands to mudflat or open water
- Decreased nearshore and/or freshwater recreational opportunities
- Damage to refuge facilities, roads, trails, towers, etc.
- Decreased water quality as a result of increased temperatures, and runoff associated with stronger, more frequent storm events
- Decreased groundwater availability due to changes in precipitation regimes

Refuge staff will need to increase cooperative efforts with science partners, such as DNREC, Ducks Unlimited, USGS, NOAA, and others to research and monitor the current and likely physical and biological impacts of climate change, and to assess species and habitat vulnerabilities. This information will be used to formulate guidelines or thresholds to mitigate habitat losses and/or assist ecosystem adaptation to the refuge's changing environment.

Sea Level Rise

Sea level rise (SLR), a manifestation of a warming climate, has been gradually occurring for thousands of years. Increasing ocean water volumes are caused by thermal expansion of water and the melting of polar ice caps. In addition to the volume of the ocean increasing, land in the Mid-Atlantic is actually sinking as a result of geologic changes near the surface and deep within the earth. This is known as shallow and deep zone subsidence. Thermal expansion, melting of the polar icecaps and subsidence all combine to contribute to relative sea level rise.

Sea level rise has been recognized as a key issue facing coastal communities for decades. The Federal Coastal Zone Management Act of 1972 directed local governments to anticipate and plan for the effects of sea level rise. At the International Level, a committee was formed to assess SLR on a global scale the Intergovernmental Panel for Climate Change (IPCC). In its Fourth Assessment Report (FAR), The IPCC estimated that global sea level could rise between 0.2 and 0.6 meters by the year 2100 based on projected greenhouse gas emissions scenarios. Some climatologists believe that far underestimates the potential rise in sea levels and suggest that SLR may exceed 1.0 meters (Rahmstorf 2007). At the national level, the U.S. Climate Change Science Program was formed to investigate climate change and sea level rise. This committee recently released a multi-year study entitled "Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region." This study discussed the potential impact from sea level rise using three scenarios for the year 2100: a rise of 1.3 feet (current rate), 1.6 feet; and 3.3 feet.

Potential impacts from SLR can vary significantly depending upon the scenario; therefore, different SLR scenarios should be evaluated to consider an entire range of potential effects. SLR has the potential to significantly impact the refuge, Delaware's coastal resources and communities, and Delaware's overall economy over the next several decades. As a result of higher sea levels, low lying coastal communities are becoming more frequently inundated during storm events. As storm events are predicted to become more frequent and more intense, coastal erosion and flooding events will likely be more severe than previously experienced. These impacts will have profound effects on the refuge. Structured decision making models are being developed to provide a framework that will allow the Service to proactively consider potential effects of SLR when making long-term infrastructure and habitat management decisions.

In 2008 and 2009 the Delaware Coastal Program (DCP) conducted a Sea Level Rise Affecting Marsh Model (SLAMM) exercise, using high resolution elevation data, at PHNWR. The model used estimated maximum and minimum sea-level predictions, assuming that the actual sea-level will probably fall somewhere within that range. However, certain conditions are predicted by both scenarios and we assume they are good predictors of the future environment at the refuge. By the year 2050, the model projects that at least half of the current upland area of the refuge will be lost (either converted to wetlands or open water), decreasing from 20% to, at most, 12% of the current land base. Open water and tidal mud flat areas may increase throughout the next 100 years.

If sea level rises at an accelerated rate to one meter in the next 100 years, the impact will be much greater on the refuge. By the year 2050 open water and mudflats comprise 26% of the refuge under high accretion rates, or possibly up to 58% of the refuge with low accretion rates. Under the worst case scenario, by the year 2100, up to 88% of the today's refuge could instead be open water or tidal mud flats and only 1% for the refuge would be uplands. The full report can be found in Appendix D of the Refuge CCP, or at <http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>. Additional information regarding climate change and sea level rise can be found at the Service's website, <http://www.fws.gov/home/climatechange>.

Overwash

Overwash is a natural manifestation of rising sea levels, but also critical to maintaining healthy emergent wetlands in barrier island systems of estuaries like the Delaware and Chesapeake Bays. Emergent marshes must, in part, receive periodic influxes of sediment, to help build marsh elevation sufficiently to keep pace with rising sea levels. When humans impede natural overwash and marsh building processes (e.g. by constructing dunes, filling overwash areas) they impede back-bay marsh development.

Notable storm induced overwashes occurred on the refuge in 1982, 1988, and 1999. The dunes were artificially rebuilt in 1999. In 2006, Hurricane Ernesto caused a beach overwash just north of Fowler's Beach Road on Prime Hook NWR. On May 12, 2008, a Nor'easter brought flooding that overtopped or completely removed beach dunes extending from the Slaughter Beach Community to the Prime Hook Beach community. This includes the 2006 overwash area.

The overwash north of Fowler's Beach Road joins the Delaware Bay to a lagunal tidal salt marsh. Overwashes provide nutrients and sedimentation that is vital for tidal salt marshes, and provides critical habitat for priority coastal migratory birds. The area immediately south of Fowler's Beach Road has formed inlets during the past few years, as well. The impacted area covers approximately 4,000 linear feet of beach, with 95% of the breaches on private lands. During high tides this area floods a freshwater impoundment, Unit II, with saline bay water. In response to inlet formation, thousands of shorebirds are using the Unit II overwashes, during migration. In addition to the shorebird response, State endangered least terns and American oystercatchers have been confirmed nesting in the overwash.

There were numerous changes in the refuge freshwater habitats caused by the Mother's Day Storm of 2008. The salt intrusion plus the lack of rains to flush the salt from the system slowed the healing process in the freshwater marsh. The winter and spring rains allowed the staff to slowly flush the system, and it is gradually return to a managed freshwater emergent community. The salt water intrusion resulting from the storm greatly reduced invasive plants such as *Phragmites* and hydrilla, at least temporarily. Unit II has been one of the refuge's historic, premier waterfowl areas, managed as a moist soil unit via water control structures installed by DU. Accordingly, following the 2008 overwash event, the refuge re-established the dunes in this area through a relatively minor dune repair, to prevent high tides from entering the freshwater impoundment from the Bay. At that time, the refuge reasoned that allowing the overwashes to continue could result in a species and habitat composition shift in Unit II, and change in the quality of the PHNWR's hunt program.

However, storms in 2009 created two large breaches in Unit II, elevating the situation from that of minor dune repair to major management activity. Thus an Environmental Assessment was prepared to conduct dune repair one more time. The repeated overwash events in recent years necessitated a reconsideration of traditional impoundment management objectives and strategies, to be evaluated during the CCP. At this point, reasoning for dune repair shifted from a goal of perpetual maintenance, to a goal of maintaining the status quo while the wetland's response to the hydrological changes and potential for restoration, could be studied, and management alternatives evaluated through the CCP. Legal challenges delayed the dune repair until 2011. By the time the repair was conducted, Hurricane Irene (August 2011) had reduced the amount of on-site material available significantly. The repair was conducted by the Shoreline section of DNREC to the best of their ability, but the breaches reopened merely weeks later. Daily tidal flow of salt water through the breaches and into Unit II continues.

Throughout the planning process, refuge staff carefully examined the numerous factors influencing management of the freshwater impoundments, Unit II in particular. These include not only the natural processes of overwash and beach migration, but also the elevation and accretion of the marsh surface, elevation and subsidence of the management infrastructure (roads and water control structures), and increasing storm frequency and intensity. A detailed account of these factors is provided within the CCP (Under Objective 3.1, in Alternative B of the Draft CCP). The resulting impoundment management objectives are outlined within this Habitat Management Plan. We continue to meet with DELDOT and DNREC to comprehensively assess the roads (which also serve as dikes), sea level rise, transportation safety planning and wildlife resources as we draft a water management and restoration plan for the site.

Chapter 3. Resources of Concern

3.1 Resources of Concern (ROCS)

Resources of Concern are defined in the Habitat Management Planning Policy as “*all plant and or animal species, species groups, or communities specifically identified in Refuge purpose(s), System mission, or international, national, regional, state, or ecosystem conservation plans or acts*” {620 FW 14 (G)}. Each refuge has one or more purposes for which it was established that guide its management objectives. For example, based on PHNWR’s purpose legislation, migratory birds and endangered species are priority resources of concern (ROCs) for the Refuge.

Other Service “trust resources” that are also considered as resources of concern include inter-jurisdictional fishes, wetlands, marine mammals. Further, refuges support other elements of biodiversity, including invertebrates, rare plants, unique natural communities, and ecological processes that contribute to biological integrity and environmental health at refuge, ecosystem, and broader scales (USFWS 1999, 2003).

The Refuge supports other elements of biological diversity that include rare plant, amphibian and invertebrate species, unique natural communities for Delaware, and natural ecological processes that contribute and/or sustain biological integrity and environmental health at the Refuge, state, ecosystem, and broader scales, and many of these elements are also considered resources of concern (See Appendix E of the PHNWR CCP).

Given the multitude of purposes, mandates, policies, regional, national, international, and state plans that apply to PHNWR, there is a need to identify and prioritize all the potential ROCS that the Refuge would be best suited to focus its habitat management objectives and associated strategies. We used the process described in the Service’s “*Handbook for identifying refuge resources of concern and establishing management priorities for the NWR System*” (USFWS – March, 2007). The first step in this process yielded a comprehensive list of resources of concern (CCP Appendix E – Table A).

From this process, we selected priority habitats (CCP Appendix E – Table 5), and priority resources of concern (CCP Appendix E - Table 6) for PHNWR were identified. These ROCs served as the foundation for developing management goals and objectives. This process is described in more detail in Section 3.3.

3.2 Biological Integrity, Diversity and Environmental Health (BIDEH)

The RIA in section 4(a)(4)(B) states that in administering the System the Service shall “...ensure that the biological integrity, diversity and environmental health of the System are maintained for the benefit of present and future generations of Americans...” The Service defines these terms in its policy (601 FW 3) for maintaining and restoring the biological integrity, diversity, and environmental health (BIDEH) of the National Wildlife Refuge System.

Wherever and whenever possible, Refuge habitat management will mimic and/or restore natural ecosystem processes and functions to maintain and enhance biological integrity, diversity, and environmental health. The policy states that “*We will, first and foremost, maintain existing levels of biological diversity, integrity, and environmental health at the refuge scale.* To help achieve this policy goal we have mapped the existing elements of BIDEH on the Refuge (CCP Appendix E - Tables 1-4) as our starting point in determining habitat goals and management objectives, strategies, and prescriptions, to first, maintain existing elements of ecological integrity and second, to restore lost elements of BIDEH when feasible.

Maintaining Biological Integrity and Scoring Biological Condition

Developing and using indicators that assess current habitat condition and measures the consequences of habitat management actions will improve Refuge management of BIDEH. James Karr's Index of Biological Integrity (1997) is useful in understanding biological integrity. Karr believes that biological condition is the primary indicator of ecosystem health.

Using the approach of Karr's multimetric index of biological integrity (IBI) for aquatic sites, the Service is currently developing a multimetric Salt Marsh Integrity Index to assess salt marsh condition and integrity on Refuges. Karr (2000) explains the idea of developing a multi-metric index as assessing the biological condition of a place along a continuum of human influence. He depicts this idea by plotting biological condition along the y-axis (representing a continuum from "pristine" to "nothing alive") versus along the x-axis (representing a continuum of human disturbance from "none" to "severe"). The slope of that graph defines a threshold range intercept on the y-axis where the site degrades from healthy to unhealthy.

Biological integrity is the condition of a place with its evolutionary legacy – parts (species) and processes (nutrient cycles, trophic structure, etc.) – still intact. Biological condition can degrade to a threshold beyond which the system is unsustainable. This threshold represents a biological tipping point beyond which neither the natural biota nor human activity can be sustained in a place (Karr 2000).

These are the principles the USFWS and scientists with the U.S. Geological Survey (USGS) are employing to develop a Salt Marsh Integrity Index, an ongoing project the refuge is participating in. It is envisioned that with the use of a structured decision making process we can apply multi-metric indices for other habitat types. Such indices will improve performance measures to monitor habitat management activities on other habitat types, like freshwater marshes, etc.

In planning habitat management activities we will focus on the establishment of native communities we believe can occur through natural succession and/or maintain native non-climax communities to best achieve Refuge purpose(s). We will favor techniques that set back succession such as water level management, prescribed fire, mowing and other techniques to maintain early successional communities for migratory birds and other priority resources of concern. But in the case of Delmarva fox squirrels, we wish to accelerate succession toward a more climax seral stage. When restoring habitats we attempt to re-establish native plant species and vegetative communities found under natural conditions and use native seed sources or rely on natural succession and native seed banks in ecological restoration projects.

Growing information that wildlife diversity can help buffer human populations from infectious disease point to the increasing evidence for the economically valuable ecological services provided by maintaining and increasing biodiversity. All refuge habitat management actions that increase biological integrity, diversity, and environmental health and avian diversity have the potential of providing a buffer against future disease outbreaks from refuge-produced mosquitoes.

Maintaining and increasing biodiversity has been recently shown to slow the spread of infectious disease to humans and wildlife. Recent infectious disease models illustrate a suite of mechanisms that can result in lower incidence of disease in areas of higher disease host-diversity (defined as the dilution effect). These models are particularly applicable to human zoonoses, i.e., infectious disease of wildlife or domestic animals that spill over into human populations (Keesing et al 2006; Krasnov et al 2007, Ostfeld and Keesing 2000). Examples of zoonoses include avian influenza, anthrax, Lyme's disease, and WNV, to name a few.

Research conducted in the eastern U.S., when the West Nile Virus (WNV) epidemic was in full swing in 2002, found fewer incidences of WNV in humans in areas with a diverse array of bird species (Swaddle and Calos 2008). This link between higher bird diversity and reduced human WNV infection is attributed to the fact that crows, jays, and other common West Nile viral hosts tend to increase in numbers when avian diversity is low. But when bird diversity is high, viral host populations remain in check, hindering their ability to spread disease. Similar studies showed how increased mammalian diversity decreased Lyme disease risk to humans (LoGiudice et al 2003).

3.3 Process for Determining Resources of Concern and Habitat Priorities

The refuge followed the process outlined in the Service's handbook (USFWS 2007) for prioritizing the key habitats and species upon which to focus habitat management actions in this HMP. First, a comprehensive list of potential resources of concern was developed from Refuge purpose and Service trust species that were found on the Refuge (CCP Appendix E – Table A), using the following list of regional and state wildlife and habitat data sources:

- BCR 30 Bird Species List
- PIF – Area 44 Bird Species List
- National and Regional Bird Conservation Plans for waterfowl, landbirds, shorebirds, and waterbirds
- USFWS Birds of Conservation Concern
- Federally Threatened and Endangered Species Listings
- State Threatened and Endangered Species Listings
- Anadromous Fish Resources Using Refuge Habitats
- Refuge Purpose/Service Trust Resources
- Delaware Natural Heritage Program Data
- Delaware Wildlife Action Plan (DWAP)
- Botanical and Zoological survey data plus NVCS habitat data to map existing elements of biological integrity, diversity and environmental health on PHNWR

Second, we cataloged existing elements of biological integrity, diversity and environmental health for each habitat type on PHNWR in tabular form (CCP-Appendix E, Tables 1 – 4). These tables also identified and listed specific habitat attributes and characteristics, described the natural processes responsible for these habitat conditions, and their respective limiting factors.

Consultation and coordination with state and other conservation professionals played an important role in the prioritization process. In collaboration with Bombay Hook NWR, Service Region 5 Biologists and Managers, cross-programmatic expertise from the Delaware Bay Estuary Program Office, State wildlife biologists, State of Delaware botanical and zoological experts, and a state community ecologist, were all participants in several collaborative meetings to narrow down the potential ROCS list and prioritize Refuge habitats, using all of the researched and compiled information described in ROCS handbook plus information from the DWAP.

To guide us in prioritizing this list, we considered the following concepts:

- Achieving Refuge purposes, and managing for trust resources as well as biological diversity, integrity, and environmental health can be addressed through the habitat requirements of “focal species” or species that may represent guilds that are highly associated with important attributes or conditions within habitat types. The use of focal species is particularly valuable when addressing USFWS trust resources such as migratory birds.

- The Bird Conservation Region (BCR) plans are increasing their effectiveness at ranking and prioritizing those migratory birds most in need of management or conservation focus. Although all species that make it to a ranked BCR priority list are in need of conservation attention, we selected focal species that were ranked High or Moderate in Continental concern with a High to Moderate BCR Responsibility. If there were too many or too few birds with these rankings for a given habitat type then species with the highest then high then medium final BCR ranking were chosen. (See www.abcbirds.org/nabci for BCR rules used to rank birds.)
- Habitat conditions on or surrounding the Refuge may limit the Refuge’s capability to support or manage for a potential species of concern. The following site-specific factors were evaluated:
 - Patch size requirements
 - Habitat connectivity
 - Compatibility of surrounding land uses
 - Environmental conditions: soils, hydrology, disturbance patterns, contaminants, predation, invasive species
 - Specific life history needs
- The likelihood that a potential species of concern would have a positive reaction to management strategies.

The next step required linking selected priority ROCS to habitats and then prioritizing mapped NVCS habitat types for habitat management. We did this by linking priority species to their habitat structural requirement needs. The refuge focused immediate management attention to the most important umbrella species that will also benefit a larger number of priority resources of concern species. Lower priority habitats were designated, which benefit fewer species or require less active management. Simplistically, this led to defining two habitat categories as either Priority I Habitats or Priority II Habitat (See CCP Appendix E – Table 5).

The Refuge’s Priority I habitats: 1) can be managed to provide the greatest conservation benefit to priority ROCS; 2) offer the greatest contribution to maintenance and restoration of BIDEH; 3) represents important ecological and ecosystem processes not well represented within state and regional landscapes; and, 4) in their current condition or as a result of other environmental factors suggests an urgent need for active management.

Priority II habitats are still important, providing value to a wide range of migratory birds and resident wildlife and contributing to the overall biodiversity at the Refuge scale. However they require less active management or are too limited in extent to make a meaningful difference on a larger landscape level. A summary of Refuge priority species and associated habitat types is in Table 10 below:

Table 10. Priority Habitats for Prime Hook NWR and Associated Priority Focal Species

Priority I Habitats	Associated Priority Focal Species
Barriers Beach Island Habitats <ul style="list-style-type: none"> • Overwash Areas • Beach/Panicgrass Dune Grassland • Atlantic Coast Interdune Swale • Maritime Red Cedar Woodland 	American Oystercatcher, Sanderling, Whimbrel, Migratory Shorebirds, Beach Dune Tiger Beetle, Little Wife Underwing;
Salt Marsh Habitats <ul style="list-style-type: none"> • Spartina High Salt Marsh • Spartina Low Salt Marsh • Salt Panne 	Black Rail, Clapper Rail, Least Tern, Gull-billed Tern, Black Skimmer, Willet, Saltmarsh Sharp-tailed Sparrow, Seaside Sparrow, Coastal Plain Swamp Sparrow, Henslow Sparrow, American Black Duck.

Priority I Habitats	Associated Priority Focal Species
Impounded Wetland Habitats <ul style="list-style-type: none"> • Emergent Freshwater & Brackish Marsh • Coastal Plain Depressional Ponds • Twig-Rush Peat Mat Bog • Button-Bush Coastal Plain Pond 	American Black Duck, Northern Pintail, migrating Dabbling ducks, Snow goose, Canada goose, Virginia Rail, Forster’s Tern, Least Bittern, American Bittern, Short-billed Dowitcher, American Avocet, Greater/Lesser Yellowlegs, Alewife, Blue-backed Herring, American Eel, Hickory and American Shad, Striped Bass, American Eel, Rare Peat Bog Plants, Rare Obligate Amphibians;
Upland Forested Habitats <ul style="list-style-type: none"> • Southern Red Oak/Heath Forest • Mesic Coastal Plain Oak Forest • Coastal Plain Loblolly Pine Forest • Mesic Coastal Plain Mixed Hardwood Forest • Pond Pine Woodland • Mesic Coastal Plain Rich Forest 	Delmarva Fox Squirrel, Bald Eagle, Black and White Warbler, Wood Thrush, Scarlet Tanager, Yellow-Throated Vireo, Kentucky Warbler, Great-crested Flycatcher, Northern Flicker, Whip-poor-will, Bay-breasted Warbler, and other breeding and migrating landbirds;
Forested Wetland Habitats <ul style="list-style-type: none"> • Red Maple/Seaside Alder Swamp • Atlantic White Cedar/Seaside Alder Saturated Forest • Swamp Cottonwood Coastal Plain Pond 	Acadian Flycatcher, Prothonotary Warbler, Yellow-throated Vireo, Delmarva Fox Squirrel, Migratory landbirds.
Early Successional Upland Habitats <ul style="list-style-type: none"> • Early Successional Forested areas • Scrub/Shrub Habitats • Herbaceous, Farmed Areas 	Prairie Warbler, Brown Thrasher, Whip-poor-will, Willow Flycatcher, Western Towhee, Field Sparrow, Northern Bobwhite, Henslow’s Sparrow, Coastal Plain Swamp Sparrow, Maritime Sunflower Borer Moth, Migratory landbirds and waterfowl.

3.4 Habitat Requirements for Priority Resources of Concern

Species-habitat relationships of priority resources of concern were researched, listed, and described in Table 6 of CCP Appendix E. These relationships are central to understanding the precise habitat structure and habitat management strategies that are required to conserve target ROCS. Species-specific structural habitat requirements provided the framework to develop habitat objectives to conserve and support all of the focal priority wildlife species on the refuge for the next 15 years. Improved wildlife population monitoring conducted to implement the refuge’s new Inventory and Monitoring Plan (IMP) will provide subsequent evaluation of various planned habitat management strategies and prescriptions to meet focal species life history requirements.

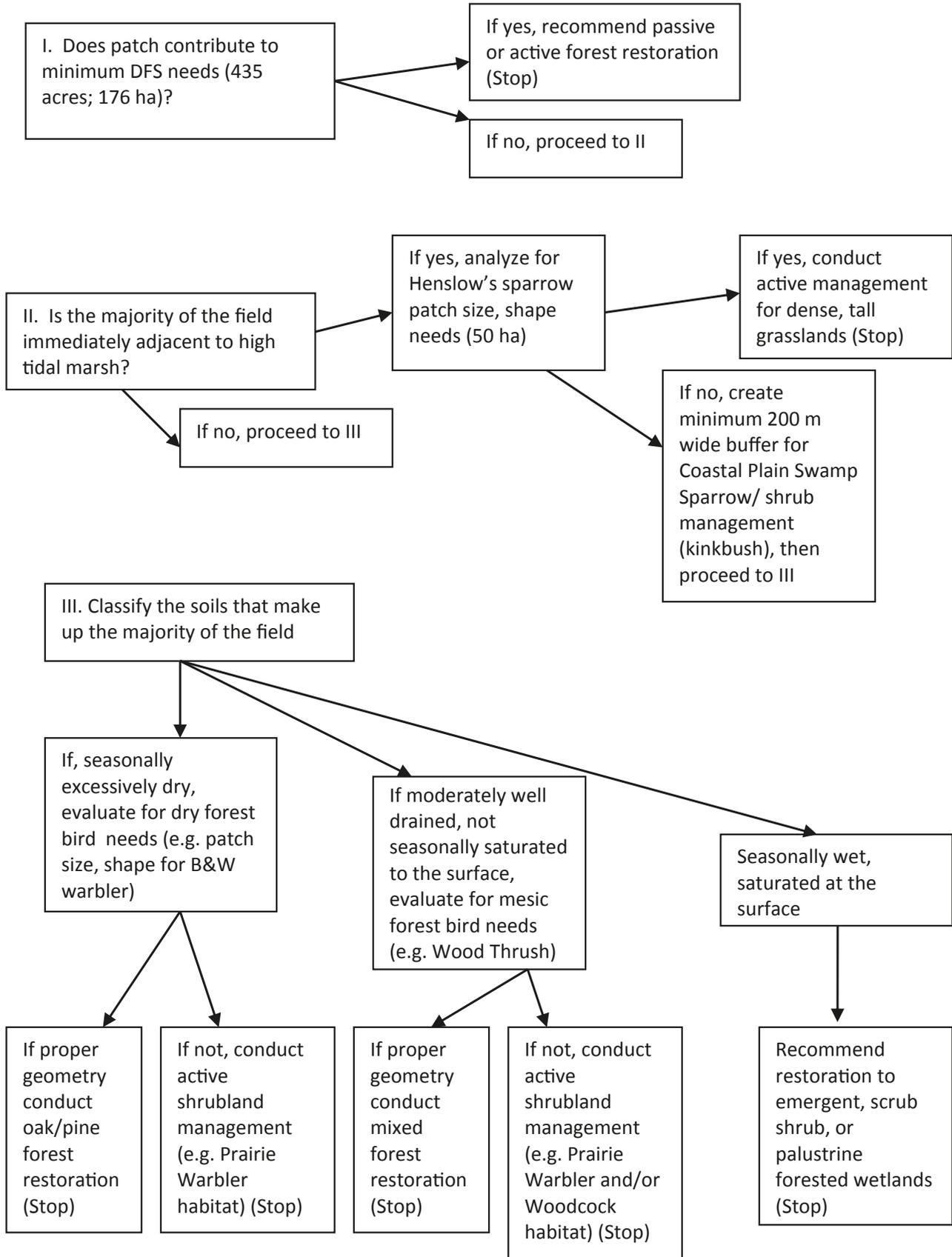
3.5 Conflicting Habitat Needs

Given the diversity of goals, purposes, and mandates for the NWRS, it is not uncommon to have conflicts over management priorities on a Refuge. Balancing the types and proportions of habitat conditions on the Refuge requires a thoughtful and documented process for determining the best course of action. Prime Hook NWR is taking a deliberate, transparent approach to resolving at habitat management conflicts associated with the HMP:

Open Fields versus Upland Forest Restoration

We utilized a habitat management decision process to guide where on the refuge we could best meet certain upland (primarily) objectives outlined in the HMP (Figure 1). This process incorporated the best available landscape and vegetation map data, soil type data, and literature on habitat requirements of identified priority species. Open fields were evaluated on the basis of the site capability (e.g., soil drainage) and potential contribution to the existing landscape context. This process is documented in greater detail in Appendix B [Not Yet Developed] of this HMP. The following flowchart summarizes how habitat management decisions were generally made. Deviations from the flowchart recommendations could occur at the discretion of refuge management.

Figure 1. Open Field Habitat Management Decision Flowchart



Mosquito Management in Salt Marshes

The Delaware Mosquito Control Section, under Service permits, has controlled mosquitoes on the refuge since its establishment in 1963. We have been working with our State partners to reduce the quantity of insecticides used on Refuge lands and ensure activities are consistent with the Service's policies. Mosquito management is a complicated issue for the Refuge. PHNWR is adjacent to residential beach communities where nuisance issues are amplified. A conflict of interests arises between nuisance complaints, managing refuge habitats for migratory birds, and maintaining and enhancing biological integrity, diversity, and environmental health within the refuge.

Although the refuge does not regard mosquito control, in and of itself, to be a salt marsh habitat management objective, the control of mosquitoes is a State priority and a reality of management of salt marshes in the State of Delaware. There have been three techniques employed to control mosquito populations on the Refuge within salt marsh habitats: use of the chemical adulticide, naled, source reduction using the chemical larvicides, Bti and Methoprene, and a biological control facilitated by open marsh water management (OMWM). These control methods are described in more detail in both the CCP, under Objective 1.3, and in HMP Appendix A.

Impoundment Management and Salt Marsh Restoration

As described briefly in Section 2.5 on Climate Change and Sea Level Rise, and in more detail in the Draft CCP (Under Objective 3.1 in Alternative B), the refuge faces considerable challenges and uncertainties regarding impoundment management. A Structured Decision Making (SDM) process is in development, cooperatively with other coastal refuges facing similar challenges. However, in the case of Unit II at Prime Hook NWR, changes are occurring presently and without an easy remedy. In the short-term, the refuge will likely have little choice but to restore Unit II to salt marsh, and this is outlined in Objective 3.1 below. Indeed, such restoration will have many biological benefits. However, there will also be trade-offs, as the freshwater impoundments do serve as valuable concentrated food sources for migrating and wintering waterfowl. The management fate for Unit III, in the long term, will be evaluated through the SDM process. Although both managed freshwater impoundments and salt marsh wetlands are valuable to wildlife, and even many species can and will utilize both habitat types, they cannot exist in the same place. Thus, this presents a conflicting habitat needs challenge that is actively being explored, even as the planning process proceeds.

3.6 Adaptive Management

The priority resources of concern and their respective habitat attributes were used to develop specific achievable habitat objectives. Many factors, such as the lack of resources, existing habitat conditions, species response to habitat manipulations, climatic changes, contaminants or invasive species, may reduce or eliminate the ability of the Refuge to achieve objectives. Although these limiting factors were considered during the development of management objectives, conditions are likely to change over the next 15 years and beyond. The Refuge will use adaptive management to respond to changing conditions that impair our ability to measure and achieve the habitat objectives. That will require the Refuge to establish and maintain a monitoring program to ensure that changing conditions can be detected and responded to adequately and efficiently. The monitoring program will be developed in accordance with 701 FW 2 as a step down plan.

Chapter 4. Habitat Management Vision, Goals, Objectives and Habitat Management Strategies and Prescriptions

This chapter outlines the Habitat Management Vision, as well as Goals and Objectives which are also associated with the refuge CCP. Strategies for each objective are provided as well. A detailed summary of all potential management strategies is provided in Appendix A of this Habitat Management Plan. Management prescriptions for open upland fields are summarized at the end of this chapter, because they span multiple management units and fulfill multiple management objectives.

Habitat Management Vision Statement: *We will conserve, restore, and enhance the biological diversity and ecological integrity of the Refuge's native plants and wildlife in wetland and upland habitats found within the Delmarva Coastal Plain Ecosystem.*

4.1 GOAL 1. (Barrier Beach Island and Coastal Salt Marsh Communities)

Manage, enhance and protect the dynamic barrier beach island ecosystem for migratory birds, breeding shorebirds and other marine fauna and flora. Perpetuate the biological integrity, diversity and environmental health of North Atlantic high and low salt marsh communities.

Objective 1.1 (Barrier Beach Communities: Overwash, Sandy Beach and Mudflat)

Maintain and monitor the dynamic nature and natural functioning of 1.5 miles of sandy beach, overwash dune-grassland and mudflat in Unit I parallel to the salt marsh management unit. Over time, permit the development of an additional approximately 1.5 miles of these features and communities along the shore of Unit II, as salt marsh restoration is pursued. These areas provide spawning habitat for horseshoe crabs, and nesting, foraging, and staging habitats for breeding (e.g., American oystercatcher, piping plover, least and common tern) and migrating shorebirds (e.g., red knot, sanderling, whimbrel) and other species of greatest conservation concern during critical periods (mid-March through mid-November). Barrier beach communities are characterized by the following attributes:

- Plant species typical of overwash grasslands include a mixture of *Cakile eduntula*, *Spartina patens*, *Schoenoplectus pungens*, *Cenchrus tribuloides*, *Triplasis purpurea*, and scattered *Baccharis halimifolia* seedlings.
- Diagnostic dune grassland species consist of a mixture of *Ammophila breviligulata*, *Solidago sempervirens*, *Panicum amarum*, and *Opuntia humifusa*.

In years when piping plovers, American oystercatchers, and/or least and common terns do nest, maintain suitable nesting habitat through beach closures, predator management, and public education to achieve minimum productivity rates, as defined within current recovery or management plans. Proposed productivity targets are as follows:

- 1.5 piping plover chicks per nesting pair on average over a five year period
- 0.35 American oystercatcher chicks per nesting pair
- 1 least/common tern chick per nesting pair

Rationale

Barrier beach island and coastal salt marsh habitats are priority conservation habitat-types within the Delaware Bay and the mid-Atlantic coastal region. Remaining undeveloped coastal saltwater wetlands in Delaware support the greatest diversity of species of conservation concern, while beach overwash

and dunes provide habitats for some of the state's and region's most critically rare and threatened species. Saltwater marsh and sandy overwash beach habitats also support a shorebird migration that has worldwide ecological significance.

Despite the heavy loss of habitat, Delaware Bay remains one of the country's most important migratory "stopovers" for hundreds of bird species (USFWS-Shore Technical Committee 2003). All remaining beach dune and overwash habitat patches are considered critical habitats regardless of size. These habitats are the most representative of the region, and should receive priority conservation protection on the Refuge, especially during the critical breeding and migration periods for highest priority shorebird species identified in BCR 30, BCC 2008, and bird and insect species identified in the DWAP (DNREC 2005).

On the Refuge, Barrier Beach Island habitats are comprised of five natural community types:

- Overwash Dunes
- Beachgrass/Panicgrass Dune Grassland
- Atlantic Coastal Interdune Swale
- Maritime Red Cedar Woodland
- Successional Maritime Forest

These highly dynamic habitats are closely related to the natural ecological processes of estuarine tidal creek shrubland, *Spartina* low and high salt marsh communities. Processes creating all of these habitat-types include tidal salt water flows and eolian actions that contribute to active sand deposition and/or erosion. Natural ecological processes responsible for shifting mosaics of sandy beach, mudflats and inland salt marsh habitat migrations have been impeded and/or altered by human activities within the state landscape.

Overwash dune communities of the mid-Atlantic are globally ranked as rare, and restricted to bayshore areas of Delaware, Maryland, Virginia, and some coastal areas of North Carolina. Dune-grassland communities are also rare, extending from Long Island to North Carolina. Less than 3,000 acres are currently undeveloped, and little of this acreage is protected (PHNWR NatureServe Report 2006). Comparing extent of Habitat Gap Class of Sparsely Vegetated and Unconsolidated shoreline on Refuge to State Habitat Gap Analysis Maps, it can be seen that although this coverage accounted for less than 0.4% of Refuge habitat-types, it accounts for 40% of the total coverage that is still left remaining in today's Delaware landscape.

Natural dynamic forces (e.g., tides, wind, and storms) are responsible for structuring overwash communities and creating shifting dune mosaics and contribute to these increasingly rare and threatened communities on the state landscape. These beach, dune grassland, and overwash communities are considered to be ephemeral components of a highly dynamic ecosystem, being buried over time by sand deposition and formed anew as other areas are subjected to overwash.

Importance to Priority Species and Species of Greatest Conservation Concern

Storm-maintained ecosystems are critical for the highest priority shorebird species identified in BCR 30 during breeding and migration periods, USFWS-Birds of Conservation Concern (2008) plus pollinator species, birds and rare insect species of greatest conservation need identified in Delaware's Wildlife Action Plan (2005). Maintaining natural coastal formation processes provides high quality breeding habitats critical for American oystercatchers, least terns, common terns, piping plovers, black skimmers, beach dune tiger beetles, and seabeach amaranth, which are all dependent on habitats maintained by coastal storms.

A dune system with overwash and ephemeral inlets, identified as a Key Wildlife Habitat of special conservation concern in the DEWAP and BCR 30 plan, is found from the northernmost private residence on Prime Hook Beach, north to Slaughter Beach. Beach heather (*Hudsonia tomentosa*), beach plum (*Prunus maritima*) and dune panicgrass (*Panicum amarum*) are interspersed with several overwash habitats along Unit I and Unit II. In 2006, Hurricane Ernesto plus several other Nor'easter storms of 2007 and 2008 expanded the overwash habitats, flattened most dune areas, and increased tidal flows in the salt marsh. This has increased habitat availability for shorebirds by providing greater amounts of invertebrate and fish food resources flowing in daily from the Delaware Bay for easier exploitation by nesting and migrating birds. Refuge sandy beach and overwash dune grassland habitats have recorded greater use by spring and fall migrating shorebirds since 2006. There has been an increase in nesting attempts by American oystercatcher, least terns, and common terns. Furthermore, observations of piping plovers staging on the Refuge, and spilling over from State -protected breeding piping plover beaches, suggest that refuge barrier beach island habitats could potentially host State and Federally endangered nesting shorebird species in the near future.

Immediately parallel to the Delaware Bay, Unit I habitats have increasingly become more important for both migrating and breeding shorebirds in the face of beach development along bay shore areas. The highest quality dunes remaining along the Delaware Bay shore occur from Big Stone Beach south to Beach Plum Island (Clancy et al. 1997) and have been identified as a Key Wildlife Habitat of special conservation concern in the DEWAP and the BCR 30 plan. Strand beach habitats along Unit I are migrating landward as a result of storm surges and sea level rise. Storms and high tides deposit wrack composed of algae, vascular plant fragments, and assorted mollusk shells, abundant casings of whelks and remnants of clams, crab, and fish. This rich, organic debris provides important feeding and breeding sites for a variety of invertebrates. Coupled with spawning sites for horseshoe crabs, wrack lines provide nutritious and plentiful natural food resources for migrating birds all year long and for nesting birds in the spring and summer.

Natural barrier beach island habitats and associated species are also threatened by a number of human activities such as the development of homes and cottages, artificial dune stabilization and replenishment, pedestrian activity, dogs running at large, and other public uses (Harrington and Drilling 1996; Pfister et al. 1992, 2008). According to Harrington (2003), human disturbance at non-breeding areas affect shorebirds by leading to reduced forage time, increased daily energy expenditure from increased numbers of flush flights (take-offs), loss of time for preening and resting, and decreased habitat availability due to chronic human disturbance. In addition, disturbance has been found to significantly lower body weights of shorebirds returning to Arctic breeding grounds (Harrington 2003, Pfister et al. 2008). This reduces the likelihood that birds will successfully complete their long-distance migrations and increases the possibility that they will arrive in poor condition on their breeding grounds. Pfister et al (2008) found reduced survivorship of sandpipers that do not achieve threshold weights at migration stopover sites. Shorebird research data strongly support the assertion that proactive management of public use and control of human-related trespass on critical habitats for both migrating and breeding shorebirds are the most effective management actions to benefit shorebirds, especially along coastal migration routes. .

The Importance of Detecting Changes in Shorelines

A major issue for the conservation, management, and vulnerability assessment of all refuge coastal wetland habitats in the face of climate change and sea level rise is the magnitude and rate of shoreline change in coming years. Coastal geomorphological changes and shoreline condition will be a direct consequence of sea-level rise inundation (CCSP-2009). Elements of monitoring coastal shoreline position provide coastal managers more detailed knowledge of the hydrodynamic forcing of sediment mobilization, transport, deposition, and measurements of morphologic change and ecosystem response. Compared to other geomorphological processes and responses, shoreline position is a highly valued