Chapter 2

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Existing Environment

- Introduction
- Physical Landscape Setting
- Regional Demographic and Socioeconomic Setting
- Refuge Administration
- Soils, Vegetation, and Habitat Types
- Wildlife Resources
- Refuge Visitor Services Program
- Cultural, Archaeological, and Historical Resources

2.0 Introduction

This chapter describes in detail the current physical, biological, and social environment of the Great Swamp NWR. It provides descriptions of the physical landscape, the regional setting and its history, and additionally, the refuge setting, including its history, current administration, programs, and specific refuge cultural and ecological resources. This chapter provides context for current refuge goals, issues, alternatives, and management direction, which are discussed in subsequent chapters.

2.0.1 Refuge Location and General Description

The 7,773-acre Great Swamp NWR is located 26 miles from New York City within the Townships of Chatham, Harding, and Long Hill of Morris County in north-central New Jersey (map 2-1). Great Swamp NWR is situated north of Interstate 78 and east of Interstate 287. The refuge has an approved acquisition boundary that would allow for the refuge to expand to 9,429 acres (map 2-2).

The refuge headquarters is located along Pleasant Plains Road in Harding Township. The refuge Visitor Center, also located along Pleasant Plains Road in Harding Township, is situated within the northwest portion of the refuge. The refuge is surrounded primarily by residential development, as well as natural areas. Natural areas adjacent to the refuge include Somerset County Environmental Education Center and Lord Stirling Park on the western refuge boundary, Morris County Great Swamp Outdoor Education Center on the eastern boundary, four Farmland Preservation properties, and one New Jersey Natural Lands Trust managed property. Figure 2-3 shows regional protected lands. An estimated 156,500 visitors came to the refuge in 2010.

Although established primarily for migratory waterfowl, the refuge's mosaic of vegetation communities, including forested wetlands, emergent wetlands, and various successional stages of uplands, provides habitats for a diversity of wildlife species (see attached wildlife list in appendix A). The refuge contains five major impoundments, encompassing approximately 500 acres. These impoundments are managed for marsh habitat that contains wetland plant communities similar to those that occur naturally in northern New Jersey.

2.1 Physical Landscape Setting

2.1.1 Physiographic and Landform Features

Physiography is the relationship between a particular location and the underlying geology. New Jersey includes four major physiographic provinces, known as Piedmont, Valley and Ridge, Highlands, and Atlantic Coastal Plain. Great Swamp NWR is located entirely within New Jersey's Piedmont Province.

The Piedmont Province is a 1,600 square mile area occupying approximately one-fifth of New Jersey. It is situated in northern and central New Jersey between the Highlands Province and inner portion of the Coastal Plain Province. The Piedmont Province is generally characterized by gently rolling plains with elevations typically ranging between 200 to 400 feet above Mean Sea Level (MSL). These elevated plains are separated by a series of erodible ridges. It is predominantly comprised of mildly folded and faulted sedimentary rocks of Late Triassic and Early Jurassic age (230 to 190 million years old) (NJDEP 2005a). Long Hill, also known as the third Watchung Mountain, is underlain by basalt layers, which formed by the cooling of magma that was released onto the surface as lava, while the valleys and lowlands are underlain by sandstone and shale (NJDEP 2005a).

Varying soil types have developed in the Piedmont Province as a result of glacial influences occurring at various periods over parts of the province. Vegetation communities within the region are more influenced by the specific hydrological regime than soil variation (Collins and Anderson 1994). Great Swamp NWR is underlain by two bedrock geology formations: Boonton Formation and Hook Mountain Basalt. Descriptions of these formations are as follows:

Boonton Formation (Lower Jurassic)

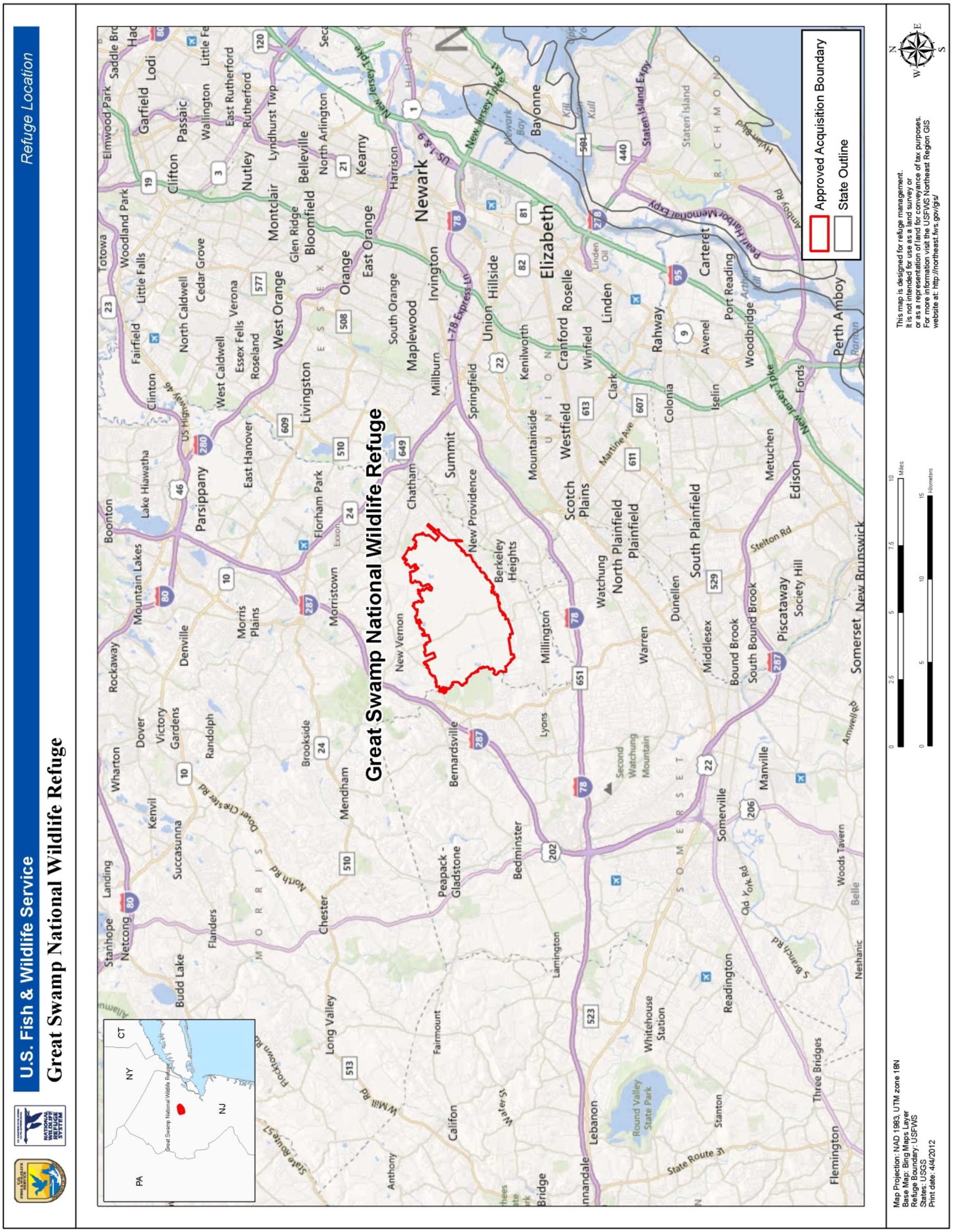
The Boonton formation consists of reddish-brown to brownish-purple, fine-grained, commonly micaceous sandstone, siltstone, and mudstone, in fining-upward sequences mostly 5 to 13 feet thick. Red, gray, and brownish-purple siltstone and black, blocky, partly dolomitic siltstone and shale are common in the lower part of Boonton unit. Irregular mud cracks, ripple marks, burrows, and evaporate minerals are abundant in Boonton's red siltstone and mudstone. The formation's gray, fine-grained sandstone may have carbonized plant remains and reptile footprints in middle and upper parts of the unit. Maximum thickness regionally is about 1,640 feet (Olsen 1980).

USFWS

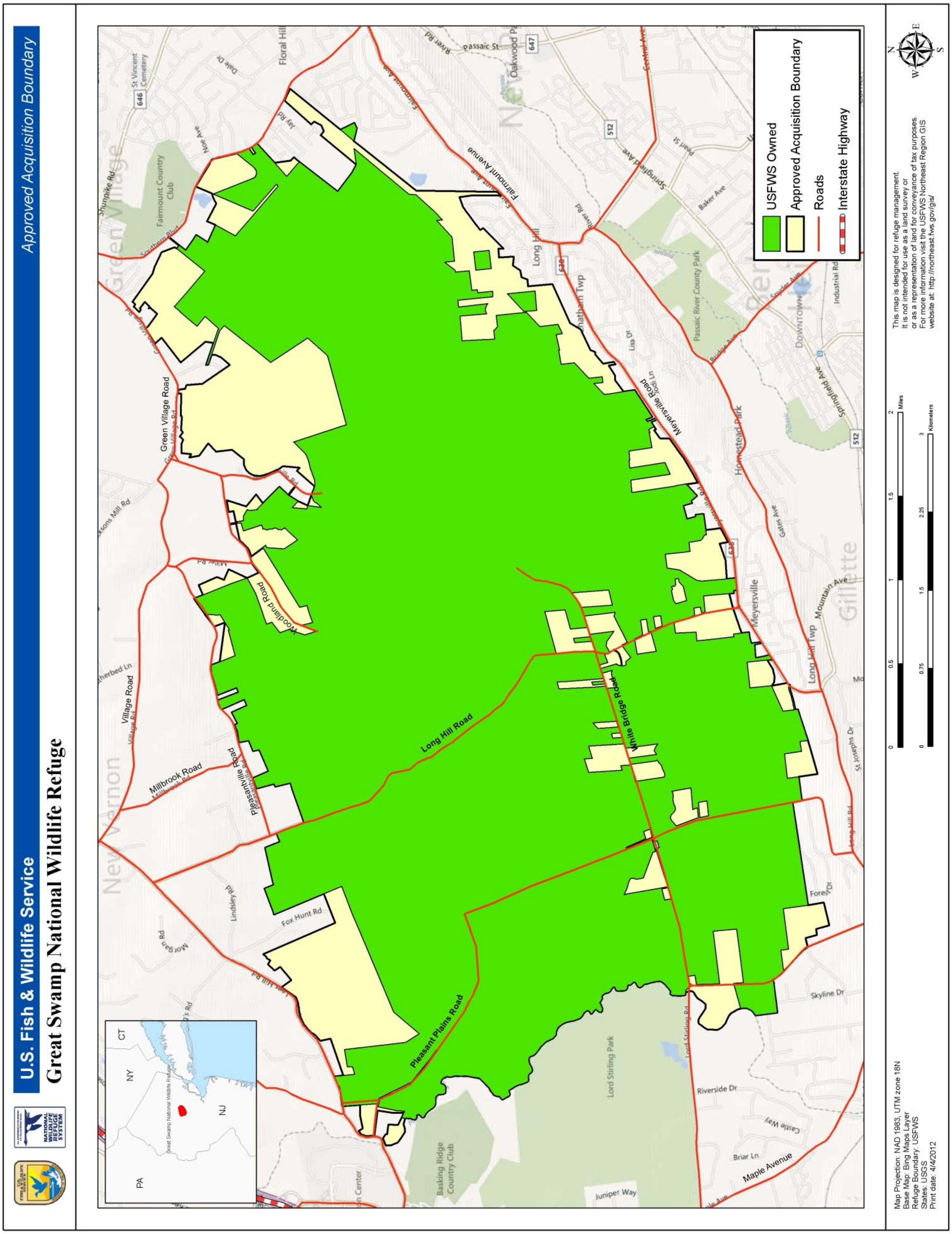
Hook Mountain Basalt (Lower Jurassic)

Hook Mountain Basalt consists of dark-greenish-gray to black, generally fine-grained and very locally medium- to coarse-grained, amygdaloidal basalt. It is comprised of plagioclase, clinopyroxene, and iron-titanium oxides. This formation contains small to large vesicles lined with prehnite. This unit consists of at least two, and possibly as many as three major flows. The base of the lowest flow within this basalt is highly vesiculated. Hook Mountain Basalt's maximum thickness is about 360 feet (Olsen 1980).

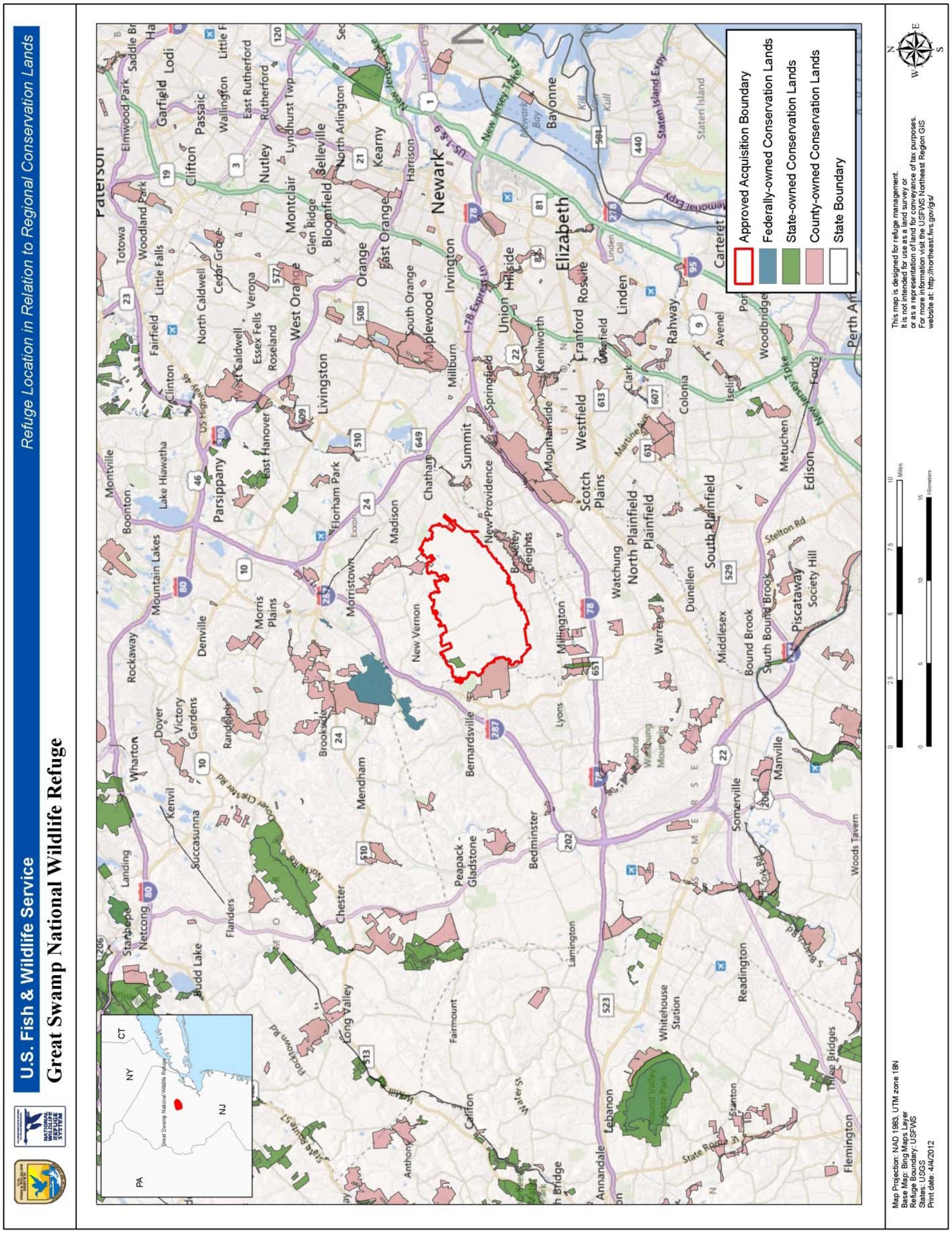
In addition to the two bedrock geologic formations, 14 surficial geology units are mapped as overlying the bedrock within the approved refuge acquisition boundary. Table 2-1 below identifies and describes the mapped surface geology units. These surface units are important in our understanding of the glacial and post glacial natural history of the refuge (Momsen, 2007).



Map 2-1. Refuge location



Map 2-2. Refuge Acquisition Boundary



Map 2-3. Regional Conservation Lands

TABLE 2-1: SURFICIAL GEOLOGY OF GREAT SWAMP NWR[1]		
Symbol	Geologic Name	Description[2]
Qaf	Alluvial Fan Deposits	Sand, pebble-to-cobble gravel, silt; brown, yellowish-brown, gray; moderately sorted, stratified. As much as 15 feet thick (estimated).
Qal	Alluvium	Sand, silt, clay, pebble gravel, locally pebble-cobble gravel; dark brown, brown, reddish-brown, gray; moderately to well sorted, stratified to massive. Contains variable amounts of organic matter. Locally, in and downstream from urban areas, contains demolition debris and trash. As much as 15 feet thick.
Qcal	Alluvium and Colluvium, Undivided	Interbedded colluviums as in units Qcg, Qcb, Qcbl, and Qcsl, and alluvium consisting of dark brown to yellowish-brown or reddish-brown silty sand, sandy silt, to clayey silt, with beds and lag veneers of subangular basalt pebbles and cobbles (adjacent to unit Qwb), shale chips and flagstones (adjacent to unit Qws), or subangular to subrounded cobbles and boulders of gneiss (adjacent to unit Qwg). As much as 15 feet thick. Lag deposits dominate in steeper reaches of valleys. Fine sediment, with variable organic matter, dominates in gently sloping reaches.
Qcbl	Basalt Colluvium, Silty Phase	Reddish-yellow, reddish-brown, light gray, very pale brown clayey silt to silty clay, minor fine sandy silt, with few subangular basalt pebbles. As much as 10 feet thick, but generally more than 3 feet thick. At foot of long, gentle slopes or at distal edge of aprons of block colluviums. Deposited in part by groundwater seepage. Occurs discontinuously along lower parts of most slopes on basalt bedrock.
Qe	Eolian Deposits	Very-fine to fine sand, silty fine sand; yellowish-brown to very pale brown; unstratified to weakly stratified. As much as 5 feet thick. Thin, patchy windblown silt and fine sand occur elsewhere in the quadrangle, particularly in the Great Swamp lowland and the Dead River valley. Laid down shortly after postglacial lakes drained, when wind entrained newly exposed silt and fine sand from the lake bed and terrace surfaces and deposited it on adjacent uplands.
Qe/Qwb	Eolian Deposits Weathered Basalt	Thin deposits of Eolian sediments (Qe) overlie the weathered basalt unit (see Qe description above). Qwb – Reddish-yellow, reddish-brown, light gray, to yellowish-brown clayey silt, silty clay to clayey coarse sand with some to many angular pebbles and cobbles of basalt and , in places on Second Watchung Mountain, gabbro. Most clasts have weathering rinds. Includes mixed clast-and-matrix sediment, fractured rock rubble, and saprolite that preserves original rock structure. Generally less than 10 feet thick over fractured, slightly weathered bedrock, which may be as much as 60 feet thick.
Qpl	Lake Bottom Deposits	Silt, clay, minor very-fine to fine sand; gray, light gray, light reddish-brown; laminated. As much as 70 feet thick. Deposited chiefly during the Moggy Hollow stage. Uppermost parts may have been laid down in the Great Notch, Stanley, and Millington stages, lowermost parts in the Chatham stage.
Qpmd	Deltaic Deposits	Fine-to-coarse sand and pebble-to-cobble gravel, minor silt and very fine sand. As much as 70 feet thick. Includes deltas at Summit and along the front of the terminal moraine in Chatham and Madison. Deposited in the Moggy Hollow stage of Lake Passaic.

TABLE 2-1: SURFICIAL GEOLOGY OF GREAT SWAMP NWR[1]		
Symbol	**Geologic Name**	**Description[2]**
Qpml	Lake Bottom Deposits	Silt, clay, minor very-fine to fine sand. As much as 120 feet thick. Deposited chiefly during the Moggy Hollow stage. Uppermost parts may have been laid down in the Great Notch, Stanley, and Millington stages.
Qps	Deltaic and Lacustrine-Fan Deposits	Fine-to-coarse sand, pebble-to-cobble gravel, very-fine to fine sand and silt; reddish-yellow, very pale brown, yellow. Generally massive due to deep weathering, weakly bedded in places. The gravel consists chiefly of gneiss and some quartzite, basalt, sandstone, and siltstone. Most gneiss, sandstone, and siltstone clasts are deeply weathered or decomposed; most feldspathic sand grains are partially or fully weathered to white clay. As much as 80 feet thick.
Qs	Swamp and Marsh Deposits	Peat and organic silt, clay, and minor fine sand; black, dark brown, and gray. As much as 20 feet thick, but generally less than 10 feet thick. Pine, spruce, and birch pollen in the basal 1.5 feet of a 5-foot core taken in these deposits near Meyersville, about 1 miles east of White Bridge, indicate that peat began to accumulate here before 9,000 years before present, based on radiocarbon dates elsewhere of the youngest occurrence of these trees in this region.
Qst	Stream Terrace Deposits	Silt, very fine-to-fine sand, minor fine-to-coarse sand and pebbly sand, rare pebble-to-cobble gravel; brown, very pale brown, yellowish-brown, light reddish-brown, light gray; moderately to well sorted, well stratified to unstratified, horizontally laminated in places. As much as 15 feet thick and forms terraces with surfaces 5-15 feet above modern floodplains and wetlands in the Passaic and Dead River valleys and the Great Swamp lowland. In the Great Swamp, the postglacial lake drained and the terrace deposits were incised between about 14,000 and 10,000 years before present, based on the age at which peat deposition began in the incised channels.
Qwb	Weathered Basalt	Reddish-yellow, reddish-brown, light gray, to yellowish-brown clayey silt, silty clay, to clayey coarse sand with some to many subangular pebbles and cobbles of basalt and, in places, gabbro. Most clasts have clayey-silty reddish-yellow weathering rinds. Includes mixed clast-and-matrix sediment, granular decomposed rock, fractured-rock rubble, and saprolite that preserves original rock structures. As much as 50 feet, but generally less than 20 feet thick.
Qws	Weathered Shale	Reddish-brown, brown, yellowish-brown clayey silt to silty clay with many shale chips or subangular pebbles and cobbles of siltstone. As much as 20 feet, but generally less than 5 feet thick.

1 Surficial geology based upon the New Jersey Geological Survey, Scott D. Stanford, research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, 2007- 2008. Surficial geologic units identified include those within the approved refuge acquisition boundary.

2 Geologic descriptions (excerpts) obtained from New Jersey Department of Environmental Protection, Land Use Management, New Jersey Geologic Survey: Surficial Geology of the Bernardsville Quadrangle, Morris & Somerset Counties, New Jersey (Open-File Map OFM 74) and Surficial Geology of the Chatham Quadrangle, Morris, Union & Somerset Counties, New Jersey (Open-File Map OFM 69) (http://www.state.nj.us/dep/njgs/pricelst/geolmapquad.htm).

2.1.2 Major Natural Influences Shaping Landscape

Glacial Influence on Hydrology and Soils

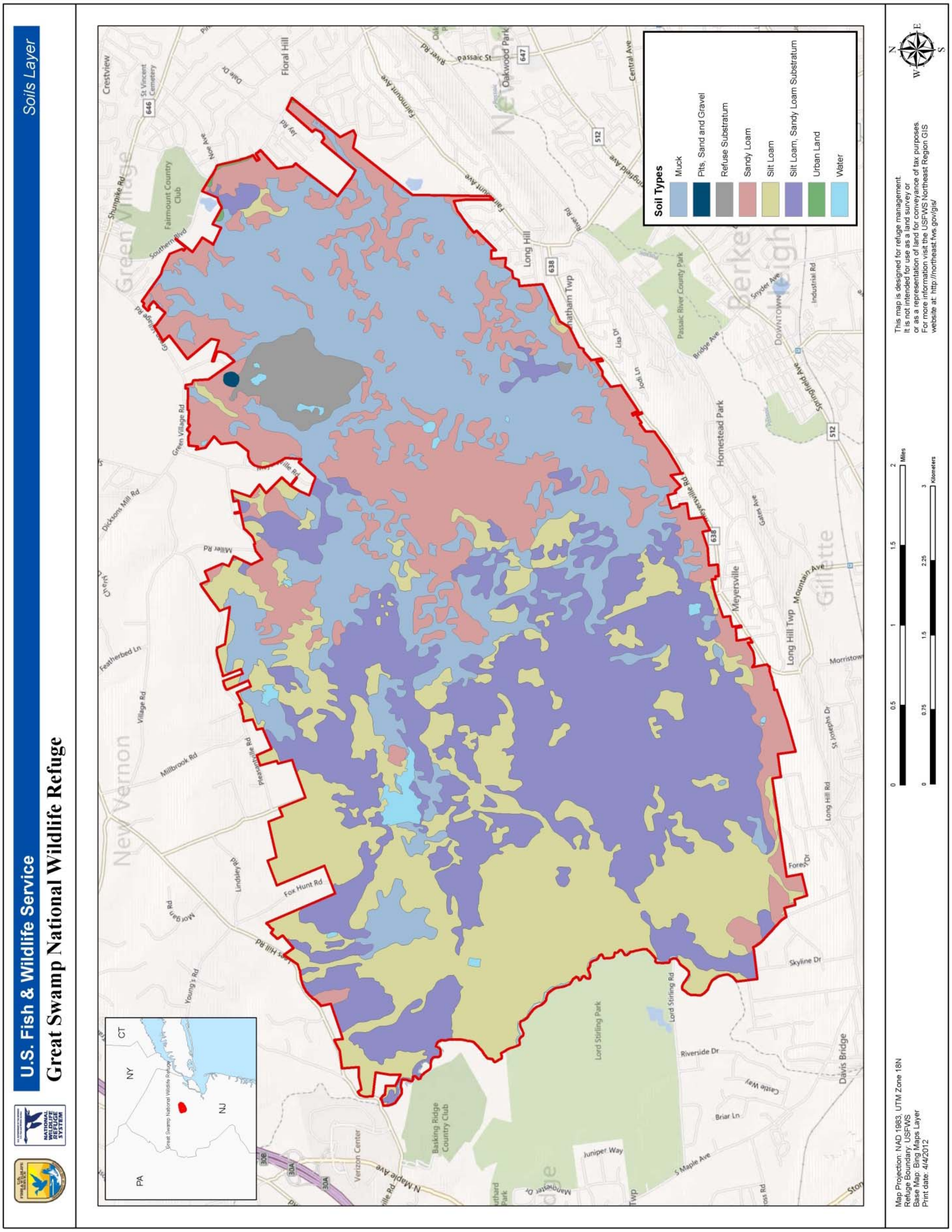
The Earth has experienced several glacial periods. Glaciers advanced and retreated over time as temperatures fluctuated. About one million years ago, the last ice age began, resulting in massive glaciers that transformed the shape of the earth. The fourth and last of these was known as the Wisconsin Glaciation. It is estimated that as this glacier approached the New York/New Jersey border, it was over one-half mile thick. As the Wisconsin Glacier advanced, it scraped and molded the valleys, slopes, and mountain tops of the region, leaving behind a landscape bare of vegetation. The ice sheet plowed through the earth carrying millions of tons of rock and soil, which was gradually deposited along its leading edge. This mass of glacial deposits stretched from Morristown to Madison to Chatham. Approximately 18,000 years ago, the leading edge of the glacier finally reached the Great Swamp watershed (GSW) area and stopped. The glacier remained relatively stationary for about 2,500 years until the global climate began to warm (Parrish and Walmsley 1997).

Approximately 15,000 years ago, the global climate warmed considerably, causing the Wisconsin Glacier to retreat northward at a rate of about 100 feet per year. As the glacier retreated it left behind piles or layers of sediments, rocks, and other debris, known as glacial drift. The meltwaters of the glacier formed Glacial Lake Passaic, a 30-mile long, 10-mile wide, 200 to 300 feet deep freshwater lake that encompassed a majority of the present day Passaic River watershed. Eventually, the retreating glacier uncovered an outlet near Little Falls Gap causing the glacial waters to drain and ultimately creating Millington Gorge and the Passaic River. Although most of the water in the lake drained, extensive marshes and swamps still remain in this ancient lake bed, including the Great Swamp. Approximately 10,000 to 11,000 years ago, the Great Swamp lowland would have been seasonally wet and possibly in permafrost during certain cold intervals (Harris and Ziesing 2010). Radiocarbon dates derived from sediment core samples and pollen profile studies suggest that an open shallow lake environment encompassed the Great Swamp until approximately 6,678 years ago (Harris and Ziesing 2010).

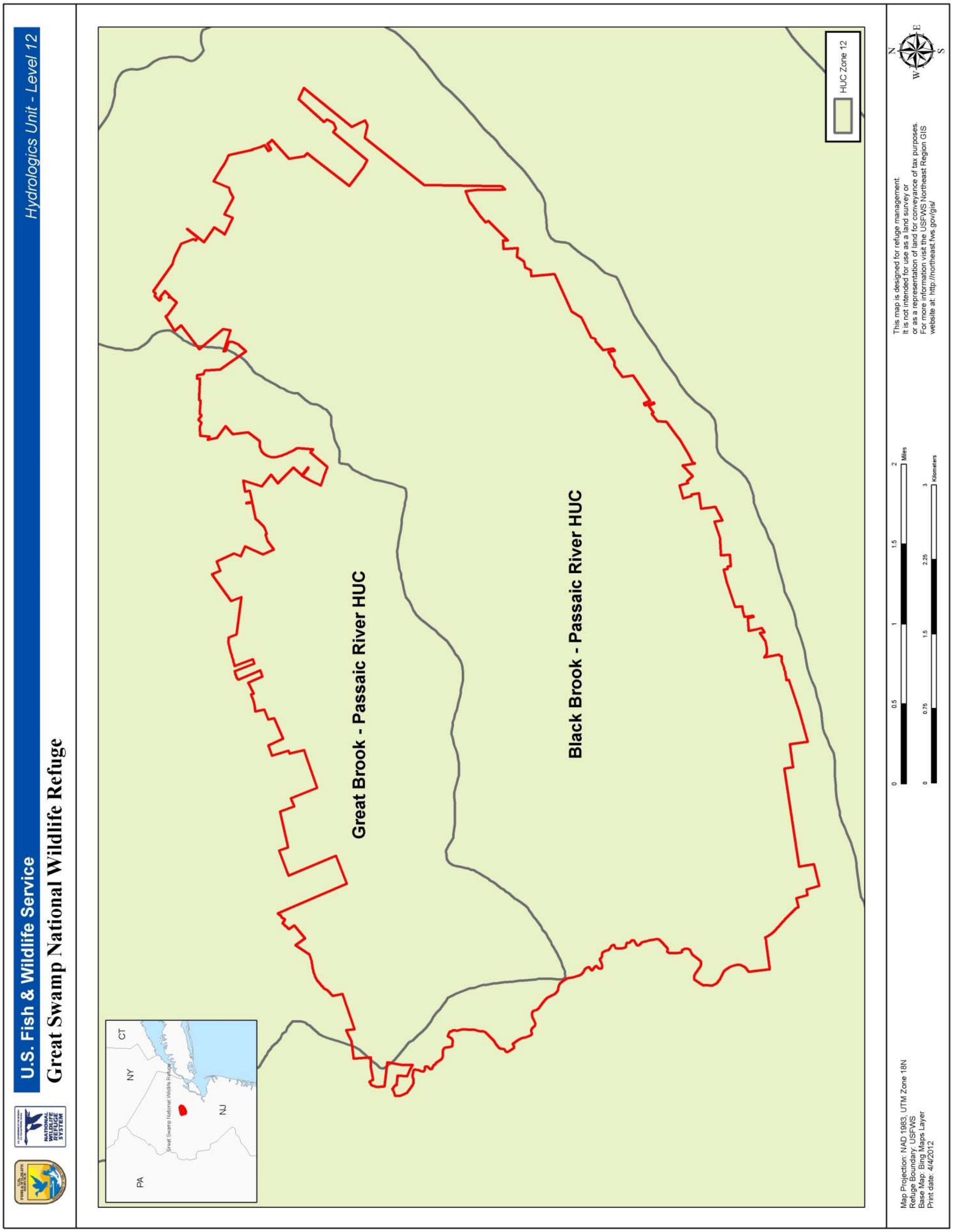
During the recession of the glacier, meltwaters carried large quantities of clay, silt, sand, and gravel into the glacial lake. More than 9,000 years ago, peat deposition began to accumulate as vegetation encroached upon the receding glacial lakeshore (Harris and Ziesing 2010). The western portion of the Great Swamp contains surficial clay deposits, which is covered by extensive thin deposits of peat. Thick deposits of clay, with interbedded glacial till and peat, underlie nearly the entire swamp (Waksman *et al*. 1943). Most of the peat deposits, generally ranging from 1 to 12 feet in depth, occur within the eastern portion of the refuge. Marked differences in landforms have been documented between the northeast and southwest halves of the refuge. The refuge contains a mosaic pattern of peat and swamp deposits and sand/gravel stream terraces (map 2-4), which were most likely a result of a complex interaction between wind, water, and post-glacier recession (Harris and Ziesing 2010).

Historic Natural Influences Shaping Vegetation and Wildlife Patterns

Great Swamp NWR and the surrounding region have undergone various vegetation community changes over the past 20,000 years. These changes, both natural and anthropogenic in nature, have been driven by soils development, hydrology, keystone species impacts, and agriculture. Although fires did occur within Great Swamp NWR, they were not thought to be a major factor driving the regional ecology (Momsen 2007).


U.S. Fish & Wildlife Service
Great Swamp National Wildlife Refuge
Soils Layer
Soil Types
Muck
Pits, Sand and Gravel
Refuse Substratum
Sandy Loam
Silt Loam
Silt Loam, Sandy Loam Substratum
Urban Land
Water
This map is designed for refuge management.
It is not intended for use as a land survey or
or as a representation of land for conveyance of tax purposes.
For more information visit the USFWS Northeast Region GIS
website at: http://northeast.fws.gov/gis/
Map Projection: NAD 1983, UTM Zone 18N
Refuge Boundary: USFWS
Base Map: Bing Maps Layer
Print date: 4/4/2012
Miles
Kilometers

Map 2-4. Soils



Map 2-5. Hydrologic Units

The retreat of the Wisconsin Glacier was characterized by a long period of tundra that was present until about 12,000 years ago. Continual weathering and erosion of rock over time released nutrients and created new soils for plants to grow. Pollen evidence supports the post-glacial existence of treeless, or tundra-like, vegetation along much of the southern margin of the receding glacier (Spurr and Barnes 1980), including Great Swamp. Tundra-like conditions were followed by a shorter interval of transitional, open, spruce-hardwood woodland, which was succeeded by open spruce woodland. Subsequently, a mixed deciduous-coniferous forest replaced the spruce woodland approximately 9,500 years ago. This mixed forest occurred before a boreal forest could establish (Spurr and Barnes 1980). Additional pollen profile studies conclude that pine, spruce, and birch species inhabited the Great Swamp approximately 9,000 years ago (Harris and Ziesing 2010). During the post-glacial warming trend, hardwood forests from the south advanced to the north and a migration of new animals and plant species arrived in the northeast, while herds of large mammals (such as mastodons and wooly mammoth) traveled north, eventually dying out. The new surroundings attracted much smaller animals, such as rabbit, turkey, waterfowl, and white-tailed deer.

The post-glacial hydrologic changes of Great Swamp initially drove vegetation succession and the development of diverse wetland habitats (Momsen 2007). Evidence of the post glacial influence on community characteristics, including peat and soil development and vegetation patterns, is currently evident primarily in the Wilderness Area. The western managed portions of the refuge had undergone intense post-colonial agricultural disturbances that impacted vegetation patterns to the present day (Momsen 2007).

2.1.3 Great Swamp Watershed and Subwatersheds

The refuge lies within the GSW, which is situated within the southern portion of the Upper Passaic River watershed [Hydrologic Unit Code (HUC) 11] (map 2-5). The GSW refers to a collection of adjoining subwatersheds (HUC 14) that feed the hydrology of Great Swamp. The GSW spans approximately 55 square miles (35,200 acres) and is bound by a ridge of the Appalachian Mountains to the northwest, the third Watchung Mountain to the south, and the Loantaka Moraine to the northeast (Parrish and Walmsley 1997). The GSW includes the subwatersheds listed in table 2-2.

TABLE 2-2: SUBWATERSHEDS OF THE GREAT SWAMP WATERSHED (GSW)

Subwatershed	HUC-14 Subwatershed #	% of GSW	Square Miles (Acres)
Black Brook	02030103010060	27	14.85 (9,504)
Great Brook (above and below Green Village Rd)	02030103010030; 02030103010050	25	13.75 (8,800)
Loantaka Brook	02030103010040	10	5.5 (3,520)
Primrose Brook	02030103010020	10	5.5 (3,520)
Upper Passaic River (above Osborn Mills; Dead River to Osborn Mills)	02030103010010; 02030103010070	28	15.4 (9,856)

Black Brook, Great Brook, Loantaka Brook, and Primrose Brook flow through the refuge, generally in an east to west direction, before draining to the Passaic River, located along the western refuge boundary. The Passaic River forms the western refuge boundary.

Subwatershed Descriptions

The *Passaic River* meanders through seven counties and 45 municipalities before draining to Newark Bay. The Passaic River originates in Mendham Borough, Mendham Township, and Bernardsville. A relatively undeveloped portion of the river's watershed is adjacent to Great Swamp NWR. As the river continues to flow south, it traverses more refuge communities than any of the other local streams (GSWA 2009). The Passaic is joined by the Black Brook, Great Brook, Loantaka Brook, and Primrose Brook within the refuge and then flows through the Millington Gorge downstream of the refuge.

The *Great Brook* originates in multiple areas, with four tributaries forming its headwaters. The headwaters of Great Brook are bordered by ecologically rich wetlands, mature forests, meadows and floodplains, as well as heavily developed regions of Morris Township. The Great Brook enters the refuge just beyond Village Road in Harding Township (GSWA 2009).

The *Primrose Brook* originates in the Jockey Hollow section of Morristown National Historical Park and flows through the least developed subwatershed of Great Swamp NWR. Eventually, the brook enters the refuge near Lee's Hill Road in Harding Township (GSWA 2009).

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The *Black Brook* originates east of the refuge boundary and receives waters from five tributaries, which are bordered by heavily developed shopping plazas, recreational ball fields, golf courses, an apartment complex, the Rolling Knolls Landfill, forested wetlands, and the Tanglewood Lane Wastewater Treatment Plant. The brook flows through Great Swamp NWR and eventually into the Passaic River north of the intersection of White Bridge Road and Carlton Road.

The *Loantaka Brook* headwaters originate in the Township of Morris, where it is bordered by various land uses, including residential and commercial developments, recreational fields and the Woodland Wastewater Treatment Plant. The brook enters Great Swamp NWR just downstream of the 574-acre Loantaka Brook Reservation.

2.1.4 Water Quality and Quantity

Impoundments

Through the mid-1900s, the hydrology of Great Swamp NWR was historically disturbed by repeated attempts of draining and ditching for farming activities and stream alterations for flood and mosquito control purposes. In the 1960s, refuge staff began plugging the previously constructed drainage ditches and creating short dikes with small water control structures in attempt to restore more than 1,000 acres of previously drained wetlands. Five major impoundments, encompassing a total of approximately 500 acres, were constructed in the 1970s and early 1980s in order to provide wildlife habitat and influence plant composition and abundance (see table 2-3 below). This resulted in an increase in use by many wetland-dependent wildlife species (USFWS 1987a).

TABLE 2-3: IMPOUNDMENTS AT GREAT SWAMP NWR	
Impoundment Name	Acreage
Pool 1	114
Pool 2	295
Pools 3A & 3B	55 & 88, respectively
Middle Brook Pool	17

Between 1994 and 2001, moist soil units were maintained through periodic drawdown, which increased the presence of certain invasive species (see Modern Hydrological Influences in section 2.1.4). The current hydrologic processes on the refuge are a combination of natural fluvial, groundwater influence, and impoundment management. The refuge currently manages for marsh habitat that contains a diversity of wetland vegetation similar to natural marsh habitat in northern New Jersey. Draw-downs are conducted periodically to mimic a more natural drought cycle, which results in significant germination of annual plants and high seed production (USFWS 2003b).

Bimonthly water levels were recorded until 2005 at most water control structures to verify prescribed water levels in managed impoundments and at certain brooks and tributaries to document water level fluctuations in major waterways. Significant water level fluctuations between bimonthly readings were sometimes encountered due to storm events or drought conditions.

Surrounding Streams Influencing Great Swamp NWR

Upstream development within the GSW continues to increase, resulting in hydrologic changes and water quality degradation through elevated silt loads, higher floods, greater non-point pollution loads, faster peak flows, and reduced areas and periods of low-flow (minimal flow depth) characteristics. According to a *Water Quality Monitoring Report for Great Swamp Watershed,* prepared by Princeton Hydro and dated March 2007, the most “impacted” streams in the watershed are the Loantaka Brook, Great Brook, and Black Brook. These streams, located in the most developed areas of the watershed, generally failed to meet the State’s water quality standards under both baseflow and storm flow conditions (N.J.A.C. 7:9B). Conversely, the Upper Passaic River and Primrose Brook were consistently the most “healthy” streams. These streams typically met or exceeded the State’s water quality standards under both baseflow and storm flow conditions. The following is a summary of each of the five major rivers and streams impacting Great Swamp NWR:

Passaic River

Water quality monitoring indicates the upper portion of the Passaic River meets or exceeds every NJDEP Surface Water Standard (GSWA 2009). Although the nutrient concentrations during baseflow conditions are slightly higher than Primrose Brook, the Passaic River has much lower nutrient concentrations during stormflow events than any other stream in the watershed. However, based upon macroinvertebrate sampling conducted downstream of Route 287 between 1999 and 2001, the Passaic River is considered impaired even though the water chemistry data indicates the river is a reference stream. The poor results of the macroinvertebrate study may be a result of survey site location (i.e., downstream of Osborne Pond Impoundment), where water temperatures are elevated above normal and pH can fluctuate over the course of the day (i.e., photosynthetically driven pH; Lieb and Browne 2002).

Primrose Brook

Although some stream monitoring results indicate elevated concentrations of phosphorus, total Kjeldahl nitrogen and total suspended solids during some storm events, Primrose Brook is relatively pristine in nature and based upon macroinvertebrate surveys, the brook is highly ranked in overall stream health (Lieb and Browne 2002).

Great Brook

The overall water quality of Great Brook is "slightly impaired" based on the NJDEP Surface Water Quality Standards, U.S. Environmental Protection Agency (EPA) reference criteria, and in comparison to the watershed's reference streams (Lieb and Browne 2002). Biotic and water sampling results indicate that Great Brook is third in overall stream health when compared to the other streams of the watershed. Because Great Brook originates in areas that are suburbanized, where it is intensively subject to non-point pollutants and continuous development pressures, the preservation, protection and restoration of the upper reaches of this brook are critical for the ecological integrity of the refuge. Ongoing stream monitoring of Great Brook indicates that the water quality is variable from year to year (GSWA 2009).

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Black Brook

The overall baseflow water quality in Black Brook is "somewhat impaired" based on NJDEP Surface Water Quality Standards, EPA reference criteria, and in comparison to the watershed's reference streams. Of the five major streams in the watershed, Black Brook is fourth in terms of overall water quality due to elevated levels of phosphorus and total Kjeldahl nitrogen (Lieb and Browne 2002). The headwaters of the brook are impacted by the use of chemical fertilizers on adjacent lawns and from the nearby Fairmont Country Club (GSWA 2009).

Loantaka Brook

The headwaters of the Loantaka Brook originate in the Township of Morris, where it is bordered by various residential and commercial developments, recreational fields, and a municipal park. The Loantaka Brook is the most impaired stream in the GSW, primarily due to non-point pollutants, including nitrogen and phosphorus, and excess water volume in the stream channel. The overall water quality in Loantaka Brook during both baseflow and stormflow is "impaired" based on NJDEP Surface Water Quality Standards, EPA reference criteria, and nutrient concentrations as compared to the other watershed streams (Lieb and Browne 2002). In addition, macroinvertebrate studies indicated the brook is ranked "very poor" and along with Black Brook, Loantaka Brook is one of the most biologically impaired streams in the watershed (Lieb and Browne 2002). Stormwater runoff from nearby roadways and effluent from the Woodland Wastewater Treatment Plant is resulting in increased sedimentation, turbidity, scour and channel widening (GSWA 2009). In a 2005-2007 study, the Great Swamp Watershed Association (GSWA) identified elevated concentrations of sodium and chloride in Loantaka Brook during base-flow conditions. Although high concentrations of sodium and chloride were detected at all sample locations, chloride exceeded the NJDEP chronic toxicity standard in the upper reach of the brook (i.e., above the discharge point of the wastewater treatment plant). The study concluded the elevated salt concentrations are most likely a result of the application of deicing agents to nearby roads and parking lots (Edwards and Curran 2008).

Great Swamp Watershed Protection

Extensive research, advocacy, and protection efforts have been actively pursued throughout the GSW since the establishment of the refuge. Watershed research has been conducted by several agencies and conservation groups, including the EPA, the U.S. Department of Agriculture (USDA), GSWA, Ten Towns Great Swamp Watershed Management Committee (Ten Towns Committee), and others.

Research conducted in the 1960s by Vechioli, Gill and Lang (1962) and Miller (1965) evaluated the relationship of the GSW to stream flows and flooding (USDA 1996). Early water quality studies conducted by the refuge primarily evaluated water chemistry and included biweekly water quality sampling between 1976 and 1980. The Great Swamp Research Institute evaluated various parameters of water quality in the early 1980s (USDA 1996).

Throughout the 1980s, studies within GSW became more comprehensive and widespread as various scientific organizations and community partnerships developed and general concern for the watershed's health increased. In 1981, the GSWA was formed and dedicated to the preservation and enhancement of the natural resources within the watershed.

In August 1984, the FWS, in partnership with the Morris County Soil Conservation District, completed a hydrology study of the GSW. The study evaluated potential land use changes within the watershed and associated water quality and quantity impacts on the refuge. The study concluded that the current rates of development in surrounding municipalities would have major implications on the refuge (USFWS 1984). In 1984-1985, an additional comprehensive water quality study was performed as a joint effort between the EPA and NJDEP. This study revealed that upstream land use changes and development since the 1960s were the primary causes of water quality degradation and flow changes, including increased silt load, higher floods, greater pollution loads, faster peak flows and smaller low flow characteristics (USFWS 1987). The study's findings played an important role in the development of the Final Environmental Impact Statement/Master Plan for the refuge in 1987.

During the late 1980s and early 1990s, it became evident that regionwide cooperation would be required to effectively protect the watershed. In September 1989, the Great Swamp Watershed Advisory Committee (GSWAC) was established by Administrative Order #51 of the NJDEP to generate public attention and resources for the refuge, as well as to create a specific program to protect the refuge (GSWAC 1993).

A 5 year study (1991 to 1995), known as the USDA Great Swamp Hydrologic Unit Area (HUA) Project, was conducted by the USDA Natural Resources Conservation Service, Rutgers Cooperative Extension, and Consolidated Farm Services Agency to "provide local public officials and community leaders (i.e., Ten Towns Committee) with the tools to evaluate, recommend, and implement strategies to reduce impacts of existing and proposed development on water quality and quantity as it impacts the Great Swamp NWR" (USDA 1996). A 25-member HUA Technical Advisory Committee was created to provide technical support to the project, review results, and determine logistics for the dissemination of results. The team also coordinates efforts between the USDA, GSWA, GSWAC, and other regional and local efforts.

Several reports in the 1990s, including the 1993 Final Report of the GSWAC and the 1996 Final Report of the USDA Great Swamp HUA Project, provided a foundation of data and a series of recommendations required for watershed protection. The 1993 study provided a series of Federal, State, local regulatory and policy recommendations to be considered. Recommendations were made for wetlands, streams and floodplains, surface water quality and discharge, nonpoint source pollution and stormwater management, soil erosion and sediment control, septic systems, vegetation protection, and environmental analysis. The HUA Project provided data on water quantity, sediment and water quality and included a series of technical, institutional and social recommendations (USDA 1996).

One of the most significant partnerships formed in the 1990s was the creation of the Ten Towns Committee in 1995. The Ten Towns Committee was a 501(c) non-profit organization formed by agreement between the municipalities within the GSW. Participating municipalities included Bernards Township, Bernardsville, Chatham Township, Harding Township, Long Hill Township, Madison Borough, Mendham Township, Mendham Borough, Morris Township, and Morristown. Its primary purpose was to create a Watershed Management Plan for the GSW that would provide guidance and direction for watershed protection. Utilizing the USDA study recommendations and in partnership with the FWS, the Ten Towns Committee developed the Great Swamp Watershed Management Plan developed by F.X. Browne Inc. (Ten Towns 2003). The plan consisted of the following components: Development of Watershed Management Organization, Watershed Based and Open Space Planning, Public Education, Riparian Buffers, Watershed Investigations and Water Quality Monitoring, Stormwater Management, Model Ordinances, and Best Management Practices (BMPs).

The Ten Towns Committee represented a highly successful municipal partnership. Although the Ten Towns Committee disbanded in June 2010, the legislation and protections that resulted from the organization remain in place and are continued to be used by the GSWA. Community efforts through the GSWA led to the development of an extensive volunteer water monitoring network within the GSW and the establishment of specific water quality standards based on those findings in June of 2002 (GSWA 2011). The water quality standards are especially useful in identifying problem locations and targeting areas for restoration. Technical practices and land acquisitions are coupled with extensive outreach, education and advocacy with the watershed by the GSWA, the refuge and their multiple watershed partners.

AMNET Monitoring (Aquatic Invertebrate Populations)

In order to determine the health of the streams that comprise the watersheds, the NJDEP performs monitoring of benthic macroinvertebrate populations using the EPA's Rapid Bio assessment Protocols – Level II procedure. Using this method, aquatic communities are examined for pollution tolerant and intolerant life forms and the results are used to compute a New Jersey Impairment Score and Biological Condition. The program is termed the Ambient Biological Monitoring Network (AMNET). Biological condition of a stream sample is based on 100 organism samples taken at a specific site. The benthic macroinvertebrate samples examined include representatives of various taxonomic families of insects and insect larvae; mollusks, such as mussels, clams and snails; and crustaceans, such as crayfish. Ratings of the stream condition are based on the level of pollution tolerance of the families collected, the ratio of pollution tolerant to pollution intolerant families, and the biodiversity of the system (percentage of single species dominance). In New Jersey, over 800 locations are sampled on a 5-year rotating schedule. Biological impairment of streams may be caused by several major factors, including nonpoint source pollution, point source pollution, and/or a lack of stream corridor (riparian) buffers (NJDEP 2008f).

Non-impaired streams are represented by maximum taxa richness, balanced groups and a good representation of pollution intolerant species. Moderately impaired communities are characterized by reduced richness of what is known as EPT taxa [*Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies)]; reduced community balance of various species; and reduced number of pollution intolerant taxa. Severely impaired communities are benthic communities that are drastically different from those in less impaired situations, including a few dominant pollution tolerant macroinvertebrate taxa (NJDEP 2004 Ambient Stream Metadata). Pollution tolerant groups include worms (*Oligochaeta*), midges (*Simulidae*), leeches (*Hirudinia*), and various snails (*Gastropoda*). The scoring system for impairment is listed in table 2-8 and is based on three basic categories: Non-Impaired (24 to 30), Moderately Impaired (9 to 21) and Severely Impaired (0 to 6).

The second round of sampling of New Jersey streams included a habitat score system developed from recently revised EPA criteria (Barbour 1997). Parameters considered in the evaluation include in-stream substrate, channel morphology, bank structural features, and riparian vegetation. The area evaluated includes the sample site and the adjacent area within a 100- to 200-foot radius. Qualitative habitat assessment scores include four condition categories, rating each parameter as: Optimal (160 to 200), Sub-Optimal (110 to 159), Marginal (60 to 109) and Poor (less than 60). Scores within the State range between 53 and 197.

The habitat conditions in the waterbodies within and immediately surrounding Great Swamp NWR are rated as sub-optimal to optimal (see table 2-4). AMNET results indicate that the streams within and immediately surrounding Great Swamp NWR are moderately to severely impaired, indicating a combination of low macroinvertebrate diversity and high numbers of a few pollution tolerant species.

TABLE 2-4: NJDEP AMNET BIOLOGICAL CONDITION OF STREAMS INFLUENCING GREAT SWAMP NWR

AMNET #	Stream Name	Municipality	Road	1998-1999 Impairment Score/Rating[a]	2003 Impairment Score/Rating[b]	Habitat Score[b]
AN0230	Passaic River	Chatham	Summit Ave	12/Moderately Impaired	21/Moderately Impaired	154
AN0229	Passaic River	Chatham	Stanley Ave	15/Moderately Impaired	15/Moderately Impaired	141
AN0223	Black Brook	Meyersville	New Vernon Rd	12/Moderately Impaired	6/Severely Impaired	151
AN0222	Black Brook	Chatham	Southern Blvd	3/Severely Impaired	12/Moderately Impaired	139
AN0221	Loantaka Brook	Green Village	Green Village Rd	9/Moderately Impaired	15/Moderately Impaired	131
AN0219	Great Brook	Harding	Woodland Rd	9/Moderately Impaired	12/Moderately Impaired	164

Notes:
[a] – Derived from NJDEP Ambient Biomonitoring Network, Watershed Management Areas 3, 4, 5, and 6, Passaic Region, 1998 Benthic Macroinvertebrate Data, Water Monitoring Report, prepared by NJDEP Bureau of Freshwater and Biological Monitoring, updated June 2000 (NJDEP 2000).
[b] – Derived from NJDEP Ambient Biomonitoring Network, Northeast Water Region, Passaic River Drainages, Watershed Management Areas 3, 4, 5, and 6, Round 3 Benthic Macroinvertebrate Data, Volume 1 of 2, Water Monitoring Report, prepared by NJDEP Bureau of Freshwater and Biological Monitoring, updated February 2008 (NJDEP 2008f).

Federal Clean Water Act Section 303(d)

Under the Federal Clean Water Act Section 303(d), each state in the United States is required to list impaired waterbodies. New Jersey is required to list impaired waterbodies as part of the water quality planning process in the State pursuant to the Water Quality Planning Act (N.J.S.A. 58:11A-7). New Jersey uses chemical and biological stream monitoring to determine these impaired waters. Waterbodies cannot be removed from the 303(d) list until the water quality standards are met.

The 303(d) list is divided into *sublists* or *categories* depending on the condition of the waterbody. When a designated use assessment is complete and results for the assessment indicate non-attainment, it is added to Sublist 5 for non-attainment.

The Clean Water Act requires that each Sublist 5 (non-attaining for pollutants) waterbody is given a *priority ranking* of high (H), medium (M), or low (L) with the goal of lowering Total Maximum Daily Load (TMDL). The prioritization process takes into account various environmental, social and political factors. Evaluated criteria include source and parameters of impairment; additional data needs; TMDL complexity and nature; waterbody use and cultural or historic importance; efficiency concerns; watershed management activities; sensitive species concerns; and public interest. Table 2-5 below provides the most recent available (2010) data for waterbody conditions for Sublist 5. Streams or portions of streams surrounding Great Swamp NWR are most impacted by issues related to dissolved solids and sediment levels, low dissolved oxygen, and pathogens.

TABLE 2-5: 2010 303(d) LIST (SUBLIST 5) IMPAIRED WATERS WITHIN AND ADJACENT TO GREAT SWAMP NWR[a]

Assessment Unit #	Location	Parameter	Rank
NJ02030103010020-01	Primrose Brook	*Escherichia coli*	M
NJ02030103010020-01	Primrose Brook	Dissolved Oxygen	M
NJ02030103010020-01	Primrose Brook	pH	M
NJ02030103010020-01	Primrose Brook	Water Temperature	M
NJ02030103010020-01	Primrose Brook	Total Suspended Solids	M
NJ02030103010030-01	Great Brook (above Green Village Road)	Cause Unknown	M
NJ02030103010040-01	Loantaka Brook	Cause Unknown	M
NJ02030103010040-01	Loantaka Brook	*Escherichia coli*	M
NJ02030103010040-01	Loantaka Brook	Total Dissolved Solids	M
NJ02030103010050-01	Great Brook (below Green Village Rd)	Dissolved Oxygen	M
NJ02030103010060-01	Black Brook (Great Swamp NWR)	Dissolved Oxygen	M
NJ02030103010060-01	Black Brook (Great Swamp NWR)	Total Dissolved Solids	M
NJ02030103010070-01	Passaic River - Upper (Dead Rd to Osborn Mills)	Arsenic	L
NJ02030103010070-01	Passaic River - Upper (Dead Rd to Osborn Mills)	Cyanide	L
NJ02030103010070-01	Passaic River - Upper (Dead Rd to Osborn Mills)	Dissolved Oxygen	M

Notes:
[a] – Derived from 2010 New Jersey Integrated Water Quality Monitoring and Assessment Report (appendix B), prepared by NJDEP Division of Water Monitoring and Standards, Bureau of Water Quality Standards and Assessment, dated June 2011.

Chemical Contaminants

Both non-point and point sources of contamination have been and continue to be problematic at Great Swamp NWR.

Non-point sources of contamination originate from suburban and urban stormwater runoff, which can carry nutrients from fertilizers, hydrocarbons, heavy metals, and deicing agents, such as road salts. Ten Towns Committee and GSWA have focused much effort on non-point source contaminant monitoring.

The primary point source of contamination on the refuge is the Rolling Knolls Landfill (formerly known as Miele's Dump), a 200-acre, unlined and uncapped landfill located within the Green Village section of Chatham Township. Approximately 30 to 35 acres of the landfill are located within the Wilderness Area of the refuge. Surface water from the landfill drains to Loantaka Brook, located to the west, and eventually to Black Brook and Great Brook, both of which ultimately drain to the Passaic River. Rolling Knolls Landfill operated from the early 1930s through December 1968, during which time it primarily received municipal solid waste and construction debris, as well as septage and industrial wastes. In 1959, herbicide and pesticide applications were conducted in order to comply with new health code regulations. Additionally, application of oil was performed to minimize dust on facility roadways. Initial remedial investigations conducted in 1999 indicated elevated levels of heavy metals, phthalates, and polychlorinated biphenyls (PCBs) in surface soil, subsurface soil, and wetland sediment. This landfill was included on the National Priorities List (NPL) on September 29, 2003 (EPA ID No. NJD980505192). Remedial investigation of the landfill is ongoing (USEPA 2011a).

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Other point sources of contamination at Great Swamp NWR are several asbestos dumps. These asbestos dumps are collectively part of the Millington Superfund Site, which includes the Millington site and three separate satellite dumps. These satellite dumps were addressed under three operable units, two of which are located in the refuge. Operable Unit 2 (OU2), which includes the New Vernon Road Property and White Bridge Road Site, are adjacent to the refuge on private property and Operable Unit 3 (OU3) is located entirely on the refuge. OU3 was an approximate 7-acre asbestos dump that also contained numerous buried drums of unknown substances. The Department completed remedial action by removing small areas of asbestos contaminated materials, buried drums and heavy metal-impacted soils that may have been a potential exposure threat to refuge visitors. In 1999, the EPA approved the Final Remedial Action Report documenting that all remediation is complete for OU3 (USEPA 2008). OU3 was delisted from Superfund status in 2010 (USEPA 2011b).

The New Vernon Road Property is part of OU2 and was an approximate 30 acre asbestos dump. The EPA conducted remedial action activities on this property in 1998 and 1999. In September 2000, the EPA approved the Final Remedial Action Report. In September 2002, the remediated 25-acre portion of the New Vernon Road property was formally acquired by Great Swamp NWR and was also delisted from Superfund status in 2010 (USEPA 2011b). Concurrently, the remaining 5 acres, which is comprised of a remediated asbestos fill area, was transferred to the State of New Jersey (USEPA 2008).

The White Bridge Road Site is the remaining piece of OU2. These dump sites are located adjacent to the Wilderness Area of Great Swamp NWR. Various remedial investigation and remedial actions were performed between 1991 and 2000. On February 8, 2002, the EPA removed the White Bridge Road property from the NPL list (USEPA 2008).

The Harding Township Landfill, encompassing approximately 1 acre, is located west of Long Hill Road in the management area of the refuge. This landfill primarily received municipal waste, as well as minimal industrial waste, until 1968. Remedial investigation activities revealed sediments contaminated with heavy metals. Remedial action activities were complete in September 2000 (Horne 2009).

Numerous other asbestos fill areas are located throughout the refuge, many of which have been remediated. The remaining non-remediated fill areas are usually buried and rarely encountered (Horne 2009).

2.1.5 The Cultural Landscape Setting and Land Use History

Early Native American and European Influences

Wildlife populations ebb and flow as habitat conditions vary in space and time. Natural and human disturbances intervene, shifting species abundance and diversity. Change is inevitable and natural, although human activities in the last 400 years have significantly altered the landscape compared to the previous 12,000 years when humans first appeared in the Northeast (Foss 1992).

As the Wisconsin Glacier advanced south, ocean levels dropped as increasingly more water was locked into ice formation. As a result, previously submerged land formations surfaced, including *Berengia,* a 1,500 mile-wide land bridge between Siberia and Alaska (NOAA 1999). This land bridge allowed early Paleo-Indians to migrate from Asia to North America possibly as early as approximately 30,000 years ago (Bonatto et al., 1997) with expanded habitation likely occurring across the Americas between 13,500 and 16,000 years ago.

Archaeological evidence gathered from the area confirms that Paleo-Indians occupied the Great Swamp basin as early as 12,000 years ago. The Paleo-Indian men may have hunted species such as mastodon, caribou, and giant beaver in the lower elevations of Great Swamp, while the women collected berries, roots and birds eggs (Parrish and Walmsley 1997). Circa 8,000 B.C., the climate began to warm, causing certain ecological shifts including the predominance of deciduous forests. These changes resulted in an alteration of Native American way of life, including expanding food-gathering techniques to include fishing and gathering of nuts and wild plants. By the Late Woodland Period (900 A.D.-1650), Native Americans began practicing farming (Parrish and Walmsley 1997). During this time period, Native Americans were known as the Lenape or Delaware Indians.

The Lenape Indians occupied various sections of New Jersey, concentrating in areas accessible by water such as the valleys of the Delaware, Passaic, Hackensack, and Raritan Rivers. Prior to European settlement, Native Americans disturbed the natural landscape in order to clear sites for villages and for cultivation of crops, such as maize. Native Americans cut forests to acquire wood and bark to make utensils, weapons, canoes, shelters, and for fuel. The Lenape intentionally burned woods during the spring and fall to improve travel and hunting for game (Collins and Anderson 1994).

Prior to European settlement, the composition and density of forests within the region may have been modified through Indian-set fires; however, fire was likely only a minor factor on the ecology of Great Swamp NWR. Several land surveys were conducted in the early 1700s, which documented tree species such as swamp white oak, maple, poplar, beech, elm, and ash (Harris and Ziesing 2010).

The most significant anthropogenic impact to New Jersey's landscape, including the refuge, was undoubtedly caused by European settlers and their descendents. The first European settlers were living in Great Swamp by 1720 (Cavanaugh 1978). European colonists introduced new land use concepts, such as permanent settlements and political boundaries. Small villages and hamlets were created along the perimeter of the swamp, including New Vernon, Green Village, New Providence, Meyersville, Stirling, Millington, Basking Ridge, and Bernardsville (Cavanaugh 1978).

Prior to the Revolutionary War, early settlers logged the land that presently encompasses the refuge, particularly in the eastern portion (present day Wilderness Area), and farmed much of the open and shrub communities of the western portion of the refuge (Momsen 2007). By the 18th century, farming and logging became so intensive that New Jersey became known as "The Garden of North America." Grassland species, such as Eastern meadowlarks, bobolinks, upland sandpipers, woodchucks, and voles, increased as hayfields and pastures expanded during the early 19th century (Foss 1992; Foster and Motzkin 2003).

Local logging was productive enough to support the wagon wheel manufacturing industry and contributed to the success of the ironworks industry in Morris County. A constant supply of charcoal was required for the furnaces, and as a result, over-logging occurred in the area leading to the closure of some local forges. By 1778, no extensive areas of land well suited for farming remained wooded in the central part of the State (Collins and Anderson 1994). According to a visitor's observation in 1790, Chatham Township was "utterly treeless."

Records suggest that by the mid-1800s, a majority of the lowest elevations in the Great Swamp basin may have been logged. By 1844, farmers were draining the marshlands and began planting crops, such as foul meadow hay; however, logging activities resulted in flooding, which led to crop failure. In a report prepared by the New Jersey State Geologist, dated 1899, "cutting was most severe about 1850, and from 1850 to 1860 was the period of maximum deforestation" (Collins and Anderson 1994). During the late-1800s, Great Swamp's woodlands were further logged in response to the demand for lumber to construct boats for the Morris Canal; pitch, turpentine, and rosin for shipyards; railroad ties, shingles, and fruit baskets; and fuel for mills and iron forges (Cavanaugh 1978).

The 1800s witnessed the demise of many forest wildlife species from loss of habitat (forest clearing), bounty and market hunting, millinery trade, and natural history specimen collecting (Foster et al., 2002). Mountain lion, gray wolf, and elk were extirpated by the mid-1800s or early 1900s and have not re-colonized the region. The passenger pigeon became extinct at the hand of humans during the same period (DeGraaf and Yamasaki 2001; Foster et al., 2002). In contrast, coyotes expanded eastward and were first sighted in New Jersey in the 1950's.

Plant and animal species that prefer open land reached their peak abundance in the mid-1800s; however, the historical record is unclear on the abundance and distribution of these species prior to the surge in farming. Foster and Motzkin (2003) suggest that species that prefer open land were opportunistic, expanding into newly cleared lands from small, scattered populations in the pre-settlement era. Other species expanded their range into New England from the Midwest. DeGraaf and Yamasaki (2001) consider grassland and shrubland birds as specialists that occupied native grasslands and shrublands in the region prior to the massive land clearing.

The soil disturbances resulting from agriculture result in soil homogeny (mixing) and depletion of key elements, such as carbon and nitrogen, that can last for decades or longer (Momsen 2007). In addition, late season harvests left agricultural soils exposed to elements and subject to erosion. These soil impacts may have influenced the current vegetation structure and composition. The dichotomy of vegetation patterns in the eastern (Wilderness Area) and western portions (management area) of the refuge reflect the differences in historic land use and land cover. The eastern portion of the present day refuge, while disturbed through logging, was not subject to the intensive soil and hydrologic alteration that result from agricultural practices. The western portion of the refuge had undergone soil disturbance from the clearing, ditching, and plowing associated with farming. As a result, the present day Wilderness Area vegetation patterns are consistent with the influence of post-glacial deposits that characterize the geologic history of the region. The pin-oak swamps and other vegetation communities of the western portion of the refuge reflect the post-colonization agricultural use (Momsen 2007).

Post–Industrial Influences

Habitat loss, due to post-industrial influences, is the major threat to wildlife in the United States. Habitat loss can be defined by three major components:

- Habitat fragmentation – habitats being divided into smaller land components by roads and other development practices;
- Habitat destruction – the complete loss of a habitat by clearing or other drastic change in land cover and use; or
- Habitat degradation – the compromising of the ecological quality of habitat by exposure to stressors. Examples of stressors include pollutants, invasive species, or climate changes (NWF 2011).

On a global scale, land use and climate changes result in destruction, fragmentation and degradation of habitats (see section 2.1.7). Remaining degraded and fragmented habitats are more conducive to a lower diversity of generalist predators and species (species that can thrive in a wider range of ecological conditions) and less conducive to a higher diversity of habitat specialists (species that thrive in a very narrow range of ecological conditions) (Litvaitis 2003; Devictor et al., 2007). Shifts from many specialist species to fewer generalist species has been specifically studied and identified across taxa of plants and animals within variety of ecosystems ranging from forests to coral reefs (DeVictor et al., 2007; Clavel et al., 2011).

The explosion of population growth during the 20th century drastically altered the landscape of northern New Jersey and resulted in wide-scale habitat loss. A recent dramatic shift in development pressure from urban to rural areas has and continues to result in the development of valuable farmland, forestland, open space and wetlands (Collins and Anderson 1994). The amount of timberland (i.e., forest cover) in New Jersey has increased since 1987; however, an inventory conducted by the U.S. Forest Service, in cooperation with the NJDEP, indicated that forest regeneration is actually declining. Forest succession toward climax stage, white-tailed deer herbivory and invasive species may limit the establishment and growth of many tree species throughout New Jersey (NJDEP 2008c).

Locally, the regional land use shift has caused the refuge to become an "island of habitat" within a highly developed landscape. As with many natural areas within New Jersey, the fragmentation of Great Swamp NWR from similar adjacent landscapes results in various issues associated with habitat degradation from encroaching urban development.

Modern Hydrological Influences

Repeated attempts of draining, ditching and stream alteration of Great Swamp NWR occurred through the mid-1900s. In the 1920s, the U.S. Army Corp of Engineers proposed several flood control plans. In the 1930s, the Works Projects Administration constructed drainage ditches and straightened and deepened the channel of Black Brook; however, the overall wetland character of the swamp remained. Failure to effectively drain and manage flooding of the swamp eventually caused farming to be unprofitable and too difficult to maintain; therefore, many farmers moved away. By the 1940s and 1950s, many of the remaining farmhouses became occupied by non-farming families, commuters, and local business owners, and abandoned farm fields began to succeed to forest.

After being established as a national wildlife refuge in the 1960s, Great Swamp NWR staff began plugging the previously constructed drainage ditches and creating short dikes with small water control structures in attempt to restore more than 1,000 acres of wetlands. Five major impoundments, encompassing a total of approximately 500 acres, were constructed in the 1970s and early 1980s in order to provide wildlife habitat and influence plant composition and abundance. Beginning in 1994, water levels were drawn down annually in an attempt to manage the five impoundments as moist soil units; however, this management technique was not successful as it resulted in a significant invasion of non-native purple loosestrife (*Lythrum salicaria*) and mild water pepper (*Polygonum hydropiperoides*) and was therefore terminated in 2001. The refuge currently manages for marsh habitat to maintain native wetland plant communities (USFWS 2003b).

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Invasive Species, Pests, and Disease

An "invasive species" is defined as a species that is (1) non-native (or alien) to the ecosystem under consideration and (2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112, February 1999). Invasive species have tremendous impacts on ecosystems, and the recreational, agricultural and commercial portions of the economies dependent on these ecosystems (USFWS 2010e).

Invasive species tend to be species that occur in high numbers and are therefore more likely to have multiple introductions of many individuals; are adaptable to a wide set of conditions (generalist); and may have greater genetic diversity and therefore more success in ecosystem establishment (Clavel et al., 2011).

Humans have deliberately and inadvertently introduced many species, some of which have had significant effects on native ecosystems (i.e., woolly adelgid, zebra mussel, European starling, and common carp). Some intentional introductions, such as ring-necked pheasant, may have negligible effects on native ecosystems. Other introductions, such as Norway rat, house sparrow, mute swan, and European starling, have adapted well to human habitation after their arrival in the United States.

Approximately 40 percent of the plants and animals federally listed as endangered species have been negatively impacted by invasive species (Pimentel et al*.,* 2005; NJISC 2009). In addition to the ecological costs created by invasive species introductions and establishment, there are tremendous costs to various sectors of the economy including agriculture, recreation and tourism. It is estimated that invasive species cost approximately $120 billion every year in the United States (Pimentel et al*.,* 2005). New Jersey is impacted by a wide variety of invasive plants, animals, insects, fungi, and pathogens. For example, it is estimated that about 1,000 species or 30 percent of the State's vascular flora are non-native and generally believed to cover hundreds of thousands of acres within New Jersey (NJISC 2009). The annual economic impact to New Jersey alone has been estimated at $290 million or 33 percent of the State agricultural cash receipts (NJISC 2009). New Jersey's high number of invasive species is attributable to its long history of colonization and its position as an international commercial and transportation hub (Snyder and Kaufman 2004).

The introduction of exotic disease has significantly altered the character of vegetation communities in New Jersey. One prominent example, the chestnut blight (*Cryphonectria parasitica*), is a parasitic fungus that was accidentally introduced to the United States in 1904 from eastern Asia. This fungus causes disease in the bark of chestnut trees, eventually killing the tree. Within 50 years, the fungus spread over the chestnut's entire range and decimated all mature trees in the northeastern United States. As a result, no fully grown chestnut tree remains in the forests of New Jersey. Although sprouts may develop from diseased tree trunks, they rarely grow more than 15 to 20 feet in height before being killed by the fungus. The massive die-off of the chestnut tree resulted in vast holes in New Jersey's forests, which are now filled by other tree species, such as hickory and oak (including pignut hickory and red oak) as well as other species such as red and sugar maple (McCormick and Platt 1980; Collins and Anderson 1994).

Other destructive fungi include Dutch elm disease, which is spread from tree to tree by the elm bark beetle, and dogwood anthracnose, which is resulting in major declines in native flowering dogwood species. Environmental stresses, such as acid rain and other atmospheric pollution, severe winter weather and drought, may have initially weakened the dogwood, causing it to become more susceptible to a fungus that eventually causes death to the tree (Collins and Anderson 1994).

Bacterial Leaf Scorch (BLS), caused by *Xylella fastidiosa*, is another disease that colonizes and obstructs the xylem of tree species. The disease was initially observed primarily in urban landscape trees; however, in 2001, the disease was sighted in a New Jersey woodland area and then documented in Parvin State Forest in 2003. BLS is now considered widespread in New Jersey and infects various tree species, including oaks, sycamores, maples, dogwoods, American elm, and some agricultural plants. Many other plants, such as numerous shrub species and grasses, become infected with BLS, but do not show symptoms and do not die (US Forest Service 2011).

Invasive wildlife diseases may also have potential impacts at Great Swamp NWR. A potentially disastrous type of chytrid fungus, *Batrachochytrium dendrobatidis* or *Bd,* has been severely impacting amphibian populations worldwide as animals become infected with a disease known as chytridomycosis (USFWS

2010c; Borrell 2009; AARK 2011). The disease attacks the skin of the amphibian and makes trans-dermal respiration difficult and also attacks neurological systems and impacts behavior. As Great Swamp NWR is home to diverse group of New Jersey amphibians, this fungal infection has the potential to have serious implications to the ecology of the refuge. *Bd* has been identified in New Jersey (NJDEP 2011b) and the New Jersey Endangered and Non-Game Species Program (ENSP) is currently testing amphibians throughout New Jersey, including Great Swamp NWR, for disease presence. ENSP is working to determine if it is impacting or has impacted frog and salamander populations within the State.

A variety of exotic animal species, particularly insects, have impacted forests of the northeastern United States. The gypsy moth is one example of a leaf-eating insect that has impacted the forests of Great Swamp NWR. Gypsy moths were imported into Massachusetts from Europe in 1869 by a French scientist attempting to cross gypsy moths with silkworm moths to develop a strong race of silk producing insects; however, a windstorm accidentally blew the gypsy moth eggs out of the laboratory into the surrounding area. The caterpillars that hatched from these eggs had no natural predators and eventually spread into other eastern states. Although gypsy months were first discovered in New Jersey as early as 1919, defoliation in woodlands was not notably reported until after 1966. Since then, an average of 187,000 acres is defoliated annually; however, the highest amount of defoliation occurred in 1981, which resulted in more than 800,000 acres. The gypsy moths typically defoliate oak and pine species, as well as other tree species include beech, birch, willow, poplar, and red maple. Defoliation often weakens trees and impairs natural growth; however, repeated defoliation over subsequent years often kills the tree. Certain oak species, such as red, black, and scarlet, are slightly resistant to gypsy moth defoliation, while pine species are more susceptible and often die after a single severe defoliation (Collins and Anderson 1994).

USFWS

The Asian longhorned beetle (ALB) was imported from China into Brooklyn, New York in 1996. The beetle infestation spread to Long Island, Queens, and Manhattan. In 1998, a separate introduction of the beetle was discovered on trees in the suburbs of Chicago, Illinois. Beetles were also detected in Jersey City (2002), and Middlesex and Union Counties (2004) in New Jersey. ALBs were also discovered on Staten Island and Prall's Island, New York in 2007 and most recently, in Worcester, Massachusetts in August 2008. In April 2008, both the Jersey City and Chicago infestations were declared eradicated. The USDA Animal and Plant Health Inspection Service's (APHIS) Plant Protection and Quarantine is implementing quarantine and control strategies to eradicate this species in New York, New Jersey, and Massachusetts. The ALB is a wood boring beetle that typically prefers several species of maples, box elder, horsechestnut, ash, poplar, buckeye, elm, London plane, birch, and willow as host trees. After mating, the female ALB chews depressions into the bark of various hardwood trees in which they lay their eggs. Once the eggs hatch, the larvae bore through the bark of the tree to feed on the sensitive vascular layer beneath, forming tunnels in the trunk and branches. This weakens the integrity of the tree and will eventually kill the tree if the infestation is severe enough. Over the course of a year, a larva matures and then pupates under the surface of the bark. An adult beetle emerges by chewing its way out of the tree, leaving a characteristic round hole. Beetles typically emerge from June through October (USDA

2010). Current management practices in New Jersey consist of removing infested trees, chipping in place, and burning the chips. The stumps of infested trees are ground to below the ground surface and all potential host trees within one-eighth to one-quarter mile radius of infested trees are removed to stop the spread of ALB (NJDEP 2011).

The Emerald ash borer (EAB; *Agrilus planipennis*) is an exotic beetle that likely arrived in the United States on solid wood packing material carried in cargo ships or airplanes originating from Asia. EAB was discovered in southeastern Michigan near Detroit in 2002 and has since established in Quebec and Ontario; Ohio (2003); Indiana (2004); Illinois and Maryland (2006); Pennsylvania and West Virginia (2007); Wisconsin, Missouri, and Virginia (2008); Minnesota, New York, Kentucky (2009); Iowa and Tennessee (2010); and Connecticut, Kansas, and Massachusetts (2012). EAB was confirmed in Bucks County, Pennsylvania in March 2012. Since its discovery, the EAB has killed tens of millions of ash trees in southeastern Michigan alone with tens of millions more lost in the other affected states. In attempt to slow the spread of EAB, regulatory agencies and the USDA have enforced quarantines and fines in many states to prevent potentially infested ash trees, logs, or hardwood firewood from being moved out of affected areas (USDA et. al 2012). Although not yet documented in New Jersey, the EAB is a serious threat to the State's forests and potentially to Great Swamp NWR due to the common presence of ash species within many refuge forests.

The EAB is a metallic green, wood-boring beetle that only feeds on native ash trees (*Fraxinus* spp.), including white (*F. americana*), green (*F. pennsylvanica),* blue (*F. quadrangulata*), and black (*F. nigra*). Adult EAB beetles leave a "D"-shaped exit hole in the bark when they emerge in the spring. The larva spends its life inside the tree, feeding on the spongy layer of the tree just beneath the bark. The feeding destroys the tissue and prevents the tree from moving water and nutrients back and forth from the roots to the rest of the tree, which eventually causes death in the tree (Wisconsin DATCP 2012). EAB can kill an ash tree in just a few years or a little longer, depending on the size of the tree.

Great Swamp NWR actively manages for a number of invasive plant species impacting the habitats of the refuge. Common shrub invasives of successional areas include multiflora rose, Russian olive, and autumn olive. Within the historically disturbed and successional forested areas, species such as garlic mustard, wineberry, Japanese honeysuckle, multiflora rose, tree-of-heaven, Japanese stiltgrass and long-bristled smartweed may be observed. Common reed, reed canary grass, and purple loosestrife have all developed as monotypic cultures within Great Swamp NWR, primarily along heavily manipulated wetland areas and along utility rights-of-way.

Additional information regarding common invasive plant species of Great Swamp NWR and current management strategies are included in the section 2.5.4.

2.1.6 Current Climatic Conditions

General Description

The dominant feature of the atmospheric circulation over North America, including New Jersey, is a broad, undulating flow from west to east across the middle latitudes of the continent. These "prevailing westerlies" shift from north to south and vary in intensity during the course of the year, exerting a major influence on the weather throughout New Jersey. Geology, distance from the Atlantic Ocean, and prevailing atmospheric flow patterns create distinct variations in the daily weather of New Jersey (OSCNJ 2009).

These variations may influence local ecology and anthropogenic activity. Annual precipitation can range from approximately 43 to 47 inches, but may reach up to 51 inches in the north-central portion of the State. Measureable precipitation typically falls on approximately 120 days per year, although fall months are typically the driest with an average of 8 days of measurable precipitation per month (Rutgers University). July and August typically receive the most precipitation and February receives the least.

New Jersey is located between the 39th and 41st parallels, or about halfway between the equator and the North Pole. Its geographic location results in highly variable daily weather, which is influenced by wet, dry, hot and cold air masses. This type of climate, known as continental climate, is characterized by a significant variation between summer and winter temperatures and by relatively large fluctuations in daily temperature. During the winter, the prevailing winds originate from the northwest, which carry cold air masses from the sub-polar areas of Canada. From May through September, New Jersey is blanketed with moist tropical air originating from the Gulf of Mexico. Average temperatures in northern New Jersey range from 27.9 degrees Fahrenheit in January to 73.2 degrees Fahrenheit in July (Collins and Anderson 1994).

New Jersey is divided into five climate zones, designated as the Northern, Central, Pine Barrens, Southwest and Coastal Zones. Great Swamp NWR is situated between the Northern and Central Climate Zones. Due to Great Swamp NWR's position between the Northern and Central Climate Zones and based upon observations by refuge staff, the growing season at the refuge is estimated to be approximately 195 days (i.e., average between Northern and Central Climate Zones). The growing season is a period in which the daily temperature averages 43 degrees Fahrenheit or more.

The Northern Climate Zone consists primarily of elevated highlands and valleys. This zone generally exhibits colder temperatures than the other zones of the State and has minimal influence from the Atlantic Ocean. Clouds and precipitation are often enhanced by orthographic, or mountain, effects. Thunderstorms are typically responsible for producing most of the precipitation during summer months. The Northern Climate Zone generally has the shortest growing season of about 155 days (OSCNJ 2009).

The Central Climate Zone extends from New York Harbor and the Lower Hudson River to the Delaware River in the vicinity of Trenton. This zone consists of many urban settings with elevated pollutants produced from automobile traffic and industrial processes. Evening temperatures within the urban areas are typically higher than those of surrounding suburban and rural areas since paved and concrete surfaces retain heat, known as "heat islands." The northern perimeter of this zone often defines the boundary between the freezing and non-freezing precipitation during winter months. Approximately 15 to 20 days above 90 degrees Fahrenheit are often observed in central New Jersey. Included in table 2-6 below is a summary of mean precipitation and temperature collected at the Boonton, New Jersey Weather Station (located approximately 12 miles north of Great Swamp NWR) between 1971 and 2000.

TABLE 2-6: MONTHLY AVERAGES FOR TEMPERATURE AND PRECIPITATION AT BOONTON WEATHER STATION (1971-2000)													
Parameter	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual Average
Mean Temperature (°F)	27.4	29.8	38.9	49.6	60.0	68.7	73.6	71.8	64.0	52.1	42.9	32.8	51.0
Mean Precipitation (inches)	4.17	3.05	4.24	4.37	4.83	4.55	4.67	4.05	5.08	3.96	4.19	3.78	50.94

2.1.7 Global Climate Change

Introduction

Increases in ambient temperatures of the earth's surface is expected to cause land-ice to melt and sea levels to rise. The increase of greenhouse gas concentrations emitted due to human activity is believed by science to amplify the earth's natural greenhouse effect and cause global climate change (NCDC 2011). Examples of greenhouse gases include carbon dioxide, methane, nitrous oxide, halocarbon, ozone, and water vapor (Global Climate Change Impacts in the United States 2009). Concentrations of carbon dioxide, a major greenhouse gas, have risen from 280 parts per million (ppm) prior to the industrial revolution to concentrations of approximately 370 ppm today (NCDC 2011). This change represents an atmospheric carbon dioxide increase of over 30 percent during this period. In New Jersey, long-term data documents an increase in average temperature and a rise in sea level that is consistent with observed and predicted global trends (NJDEP 2008d). An anthropogenic radiative forcing (increase of energy) of the atmosphere is estimated at an increase of 1.6 watts per meter (Wm^{-2}) at 2005 levels relative to 1750 preindustrial values (Bates et al 2008). This forcing correlates to a global warming trend of positive 0.74 degrees Celsius between 1906 and 2005. A more rapid acceleration of warming has occurred in the latter fifty years (Bates et al, 2008). These rates of warming have been identified in the lower and mid-troposphere layers of the atmosphere as well as at the earth's surface (Bates et al 2008).

Data indicates that the Northeast has become warmer and wetter over the last century and particularly since 1970, at a rate of 0.45 degrees Fahrenheit per decade. Although is difficult to document the changes in the number of frost-free days in the Northeast, the growing season has increased since 1980 by approximately one week nationally with greater increases in the western U.S. than in the eastern U.S. Average annual precipitation has increased by 0.4 inches over the last century with increases in very heavy daily precipitation and decreases in the percent of precipitation falling as snow (Perschel et al. 2007).

Carbon dioxide emissions due to human activity are projected to further increase global temperatures by 2.5 degrees Fahrenheit to 10.4 degrees Fahrenheit over the period of 1990 to 2100. Global MSL is likely to rise an additional 4 to 35 inches over the same period (NJDEP 2008d). Rising ambient temperatures are expected to have direct and indirect impacts to human health, natural ecosystems, agriculture, and water supply in New Jersey.

The IPCC is a scientific organization developed by the World Meteorological Organization and the United Nations Environmental Program and comprised of hundreds of scientists worldwide. The IPCC evaluates and reports on most current climate change science. IPCC reports in their "Summary for Policymakers of the Synthesis Report of the IPCC Fourth Assessment Report" that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007). The FWS has endorsed IPCC and released a summary of findings from the IPCC fourth assessment report (USFWS 2010a).

In response to accelerating climate change, the FWS prepared a plan entitled "Rising to the Urgent Challenges of a Changing Climate: A Strategic Plan for Responding to Accelerating Climate Change in the 21st Century", which was finalized in September 2010 (USFWS 2010a). The goals and objectives of the Strategic Plan fall under three major strategies:

- *Adaptation – the use of management techniques and strategies, including reactive and anticipatory, to reduce impacts to fish, wildlife and habitats as a result of climate change.*

- *Mitigation – involves reducing the FWS "carbon footprint" by using less energy, consuming fewer materials, and altering land management practices with the ultimate intent to become carbon neutral by the year 2020.*

- Engagement - *reaching out to FWS employees; our local, national, and international partners in the public and private sectors; our key constituencies and stakeholders; and citizens to join forces with them in seeking solutions to the challenges and threats to fish and wildlife conservation posed by climate change* (USFWS 2010a).

The primary purposes of the plan are to present a vision for accomplishing the FWS mission in the face of accelerating climate change and to provide direction for our organization and its employees, defining our role within the context of the Department and the larger conservation community (USFWS 2010a).

In 2009, Congress urged the Council on Environmental Quality (CEQ) and the Department to develop a national, government-wide climate adaptation strategy to assist fish, wildlife, plants, and related ecological processes in becoming more resilient, adapting to, and surviving the impacts of climate change (USFWS et al 2012). In cooperation with the NOAA, the New York Division of Fish, Wildlife & Marine Resources, and with support by the AFWA, the FWS prepared a draft plan entitled "National Fish, Wildlife, and Plants Climate Adaptation Strategy," which was released for public review and comment in January 2012. The purpose and overarching goal of the plan is to provide a nationwide, unified approach, reflecting shared principles and science-based practices, to protect the nation's biodiversity, ecosystem functions, and sustainable human uses of fish, wildlife, and plants in a changing climate (USFWS et al 2012). The plan provides a basis for sensible actions that can be taken now, in spite of uncertainty that exists about the specific impacts of climate change, and presents guidance about what actions are most likely to promote natural resource adaptation. The plan is expected to be finalized in June 2012.

Potential Local and Regional Impacts of Global Climate Change

The information below represents a selection of some significant and scientifically supported climate-based ecological impacts that may occur within the Northeastern United States, including Great Swamp NWR. While it is certain that the climate in the future will be altered throughout the world, precise predictions are difficult due to variation in emission volumes, climate and ecosystem response, and other compensation mechanisms or compounding factors (NABCI 2010). This great potential for variation is reflected in the discussions within this section.

The difficulty of predicting climate induced impact is certainly true at the refuge specific level. Addressing and curtailing potential climate associated problems at the refuge will require extensive monitoring of potentially climate sensitive species, early detection of ecological and species impacts, and innovative and adaptive management strategies. These strategies are further discussed in the later chapters of the CCP.

Water Resources

The earth's hydrological cycles are directly connected to climatic radiation and temperature levels (Bates et al. 2008). As a result it could be expected that changes in global temperature may influence rainfall patterns and subsequent flow and cycling of water within ecological systems. Weather instability (including an increase in short-term droughts and floods) resulting from global climate change may impact water recharge or input timing, reduce storage capacity, and increase drought or flooding (NABCI 2010).

Some studies that compare trends in global climate change to rates of precipitation, runoff and river flow have shown a statistically significant correlation (Bates et al. 2008). Other studies have not identified trends or were not able to separate out the impacts from localized variables such as anthropogenic catchment (Bates et al, 2008). This inconsistency illustrates the influence of localized environmental characteristics on the specific effects of global climate change within a community or ecosystem. On a global scale however, there is fairly consistent pattern of significant runoff increases in the United States and higher elevations, and decreases in other global regions including West Africa and Southern Europe (Bates et al. 2008). Within the Northeast, winter flooding, precipitation and high flow periods are expected to increase by as much as 20 to 30 percent with increased rainfall impacts under varying levels of emissions (Frumhoff et al., 2007).

Some studies have projected two to five fold increases of extremely hot summer days and increases in short-term (one to three month) warm season droughts in the Northeast. Subsequent low flow (least amount of water volume within a stream) periods during summer seasons may be prolonged for northeastern streams. Water demands within ecosystems may also seasonally increase within the region due to increases in plant productivity and subsequent evapotranspiration (Frumhoff et al. 2007).

Forest Community Impacts


Barbara Frankenfield

Climate is a major factor on the range, rate of growth and reproduction of trees. In addition, climate impacts the forest ecological processes involving water and nutrient cycling. A 350 to 500 mile northward shift of forest complexes is expected by the end of the century as a result of global climate change (Iverson et al, 2008). Although these forest shifts are expected, the effect of global climate change on any community is complicated by many variables, including invasive species changes, stress and disease, habitat loss, species competition, deer grazing, seed dispersal and other wildlife influences (Frumhoff et al. 2007).

As with all types of flora and fauna, certain tree species are more likely to adapt to climate shifts while other species will not be as successful. Tree species extinctions not occurring in the last 120,000 years of gradual climate change may rapidly occur as some species may not be able to adapt to this abrupt change. Cool climate coniferous forests of the Northeast are considered particularly vulnerable. Other deciduous hardwood species, such as sugar maple (*Acer saccharum*), American beech (*Fagus grandiflora*), birches (*Betula* spp.), quaking aspen (*Populus tremuloides*), white ash (*Fraxinus americana*), and black cherry (*Prunus serotina*), may be lost in portions of their range (Stout et al., 2008; Frumhoff et al., 2007). Oak–hickory and oak-pine forests may expand northward in the United States (NABCI 2010). Particular species, such as white oak (*Quercus alba*), black oak (*Quercus nigra*), and black gum (*Nyssa sylvatica*), may expand their range northward under various warming scenarios within the Northeast (Stout et al. 2008).

Impacts to red maple (*Acer rubrum*), one of the most dominant forest tree species of Great Swamp NWR, may vary greatly under different warming scenarios. Although this species is projected to be impacted under certain high emissions conditions, red maple is highly adaptable and has expanded its range in the past 100 years (Frumhoff et al 2007; Fei and Steiner 2007). Studies have shown significant growth increases (130 percent) among juvenile red maples corresponding with increases in soil temperature of up to 9 degrees Fahrenheit (Frumhoff et al. 2007). Due to the significant proportions of red maple-dominant communities at Great Swamp NWR, these varying scenarios could have significant implications for the refuge with regard to rates of succession and management responses.

Increased CO_2 driven photosynthesis within some forests may result in increased growth and productivity rates. This increased growth may result in increased water efficiency, demand for soil nutrients, and accelerated decomposition rates and could potentially offset some CO_2 production by providing increases in carbon storage. However, such benefits could be neutralized by forest loss due to land use changes (Frumhoff et al. 2007).

Birds

It has been determined that approximately 36 percent of the 165 wetland breeding birds in the United States show medium or high vulnerability to climate change (NABCI 2010). Wetland birds that occur at Great Swamp NWR projected to decline due to climate driven drought and flood cycles include common loon (*Gavia immer*), sora (*Porzana carolina*), and American bittern (*Botaurus lentiginosus*) (Frumhoff et al. 2007). Waterfowl and wading bird habitat may be affected as climate change results in changes in rainfall and temperature. Potential impacts to the prairie pothole wetlands could have an impact on breeding waterfowl throughout the continent due to their importance as breeding habitat for 50 to 80 percent of North American ducks (NABCI 2010).

Due to their ability to adapt to varying conditions, common generalist resident bird species such as blue jay (*Cyanocitta cristata*), American robin (*Turdus migratorius*), Northern cardinal (*Cardinalis cardinalis*), tufted titmouse (*Baeolophus bicolor*) and red-tailed hawks (*Buteo jamaicensis*) may be less affected or increase under various emissions scenarios. Other common Great Swamp NWR passerines, such as white-throated sparrows (*Zonotrichia albicollis*) and the American goldfinch (*Carduelis tristis*), may be impacted by global climate change as their current ranges continually shift northward (Matthews et al., 2008).

Habitat specific and migratory species, especially northern forest birds, have been determined to be particularly vulnerable to global climate change (NABCI 2010). Approximately one third of the 312 forest breeding birds in the United States have been found to have medium or high susceptibility to global warming (NABCI 2010). A number of less common Great Swamp NWR forest passerines and neotropical migrants, such as wood warblers (*Dendroica* spp.), yellow-bellied flycatcher (*Empidonax flaviventris*), veery (*Catharus fuscenscens*) and hermit thrush (*Catharus gluttatus*) have all been predicted to decline as a result of rising global temperatures (NABCI 2010; Frumhoff et. al 2007). Changes in migratory timing, including the seasonal availability of food resources, would be a major contributing factor to these declines (NABCI, 2010). The FWS suggests monitoring populations of insect eating birds, such as nightjars (Family *Caprimulgidae*) and swifts (Family *Apodidae*), as an early indicator of potential impacts to forest habitats (NABCI 2010). High elevation species, such as the Bicknell's thrush (*Catharus bicknelli*), that rely on a spruce fur habitat, are expected to be more heavily impacted under various emissions scenarios.

Northern grassland areas are expected to become drier with increased evapotranspiration caused by global climate change impacts. It is also suspected that increased atmospheric carbon dioxide may contribute to faster succession of woody species in grassland habitats (NABCI 2010). Approximately 50 percent of grassland bird species of the United States, including the State-listed bobolink (*Dolichonyx oryzivorus*), are expected to be impacted by global climate change (NABCI 2010). Christmas bird count data indicates that grassland birds were the only general group of birds unable to shift north in response to global climate change over the last 40 years. This inflexible response has been attributed to the poor quality of northern grassland habitats (NABCI 2010).

Insects, Pathogens and Invasive Species

As trees become stressed from climate change, introduced Northeastern pests may become more successful at infiltrating populations of trees. Since insects are poikilothermic (cold-blooded) animals and sensitive to temperature fluctuation, climate change may also result in redistributions of pest insects and subsequent forest impacts (Logan et al., 2003). As growing and reproductive seasons are prolonged, some insects, including pest insects, will likely produce more generations per season (Ibanez et al. 2011). Insects that may benefit from warming scenarios may include the wooly adelgid, emerald ash borer, and gypsy moth. Certain parasitic fungi and other diseases, including Dutch elm disease, white pine blister rust and beech bark disease, are also expected to benefit from climate change (Frumhoff et al. 2007).

In addition to pathogens, fungi and insects, certain invasive plants including kudzu, Canada thistle and weedy vines, such as Japanese honeysuckle, appear to respond positively to rising CO_2 and would be expected to expand their range in Northeastern forests (Frumhoff et al. 2007).

Some wildlife diseases' ability to spread and infect hosts may also be connected to climate change. The amphibian-infecting chytrid fungus, *Bd* (see section 2.1), has been potentially linked to climactic changes including variations in temperature and rainfall (Pounds et al. 2006; Rohr et al. 2011); however, the full nature and extent of this connection has not yet been fully determined (Borrell 2009). Efforts have been made to model the effect of climate and anthropogenic activity on *Bd* and predict future infections on a global scale (Rohr et al. 2011).

In addition to changes in parasitic relationships, there is a high potential for global climate change to impact other crucial ecological interactions, such as trophic (feeding) and mutualistic relationships. Climate induced interruptions between angiosperm plant flowering and pollinator flight activity periods (phenology) have the potential to severely impact ecosystems worldwide (Memmott et al. 2007). There is evidence that the first flowering date of some plants has been advanced by an average of four days per degree centigrade over the past 100 years in temperate zones (Memmott et al. 2007). According to some climate change models, phenological shifts resulted in a reduction of floral resources available to 17 to 50 percent of all pollinator species due to a reduced overlap between the pollinators activity period and plant food availability (Memmott et al. 2007). Specialized species with a limited range of food hosts may be especially vulnerable to these climate induced disruptions. As with other ecological predictions related to global climate change, we could expect great variation in responses among different species or the same species in various locations and conditions (Ibanez et al. 2010).

A large body of scientific evidence indicates that global climate change will result in worldwide ecological consequences in the future. While numerous ecological and anthropogenic variables make the most precise and site specific determinations difficult, certain shifts or impacts have a higher potential of occurring. Some of those changes that could impact the refuge include the following:

- More instability in hydric regimes with increased periods of drought and flood.
- Reductions in water quality or more seasonal changes in water quantities.
- Changes in seasonal temperatures, including increases in extremely hot summer days.
- Potential increases in forest productivity and related ecological processes such as succession.
- Northward shifts of forest communities, including expansions or losses of certain community types.
- Potential increase in opportunities for pests and disease within some forest communities.
- Disruptions to key ecological interactions, such as pollination and timing of migrations.
- Increases of various insect populations.
- Losses of some northern forest breeding, wetland and grassland bird species.
- General stability or increases among generalist species and losses of specialist species.

2.1.8 Air Quality

Regional Air Quality – Criteria Pollutants

The 2007 Air Quality Index Report, published by the NJDEP Bureau of Air Monitoring, provides the most recent report data available. In New Jersey, there are monitoring stations that continually monitor six specific criteria air pollutants, which are used as indicators of air quality and for which National Ambient Air Quality Standards (NAAQS) have been established by the EPA. These pollutants are listed as carbon monoxide (CO), nitrogen oxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), particulate matter (PM) and lead (Pb). Because ambient levels have dropped far below the standard throughout the State, lead is only monitored through the Bureau of Air Quality Monitoring Network at the New Brunswick Station. Ambient air quality data is used as the baseline for evaluating the effect of the construction of new emission sources or of modifications to existing sources. New stationary sources of air contamination require permits from the NJDEP Bureau of Air Quality.

TABLE 2-7: CRITERIA POLLUTANTS MONITORED WITHIN THE SUBURBAN REPORTING REGION (INCLUDING GREAT SWAMP NWR)						
Station	County	CO	SO_2	PM	O_3	NO_2
Chester	Morris	----	X ---	-	X	X
Morristown	Morris	X	----	X ---		----
New Brunswick	Middlesex	----	----	X ---		----
Perth Amboy	Middlesex	X	X	X	----	----
Rutgers University	Middlesex	----	----	----	X	X

Notes:
X = Tested at Station
---- = Not Tested at Station

The air monitoring data is also used to characterize the general air quality within nine distinct Air Quality Index Reporting Regions covering New Jersey. Great Swamp NWR is contained entirely within Reporting Region 3 – Suburban Region. Reporting Region 3 includes five stations for measuring criteria pollutants in Morris, Somerset and Middlesex Counties, including stations in Chester (Route 513) and Morristown in Morris County.

Descriptor ratings, ranging from “Good” to “Very Unhealthy,” have been established to provide a general system of rating the regional air quality. The NAAQS is given a numerical Air Quality Index (AQI) rating. The primary health-based standard AQI rating for each pollutant is generally a value of 100; any pollutant values above 100 are considered unhealthy. The values for each pollutant are as follows: 0 to 50 is considered “good”; 51 to 100 is considered “moderate”; 101 to 150 “is unhealthy for sensitive groups”; 151 to 200 is “unhealthy”; and 200 to 300 is “very unhealthy” air quality.

According to the 2009 AQI Report, the Suburban Region had 327 days of “good” air quality, 37 days of “moderate” air quality and 1 day of air quality considered “unhealthy for sensitive groups.” Based on the NJDEP 2009 Air Quality Monitoring Report, there were no days marked as “unhealthy” or “very unhealthy” overall within the region. Regions with closer proximity to the urban centers of Philadelphia and New York City tended to have less “good” air quality days and more “moderate” air quality days than the Suburban region. These urban areas also tended to have a number of particulate matter exceedances during the course of the year (NJDEP 2009c).

Data for the Suburban Region indicates that excessive ozone is the most common cause of air quality exceedances in the region and most often occur in the summer. Daily AQI Exceedances (above 100) for Region 3 in which ozone levels rise above NAAQS may occur several times annually during warmer months in the vicinity of Great Swamp NWR.

Regional Air Quality - Air Toxics

Air toxics are a large group of pollutants that are likely to be emitted into the atmosphere in large enough quantities to result in adverse health effects, including lung and respiratory conditions, birth defects and cancer. Although there is no Federal air quality standard for these toxicants, Congress in 1990 directed the EPA to begin addressing 200 of these substances by developing technology control standards (NJDEP Department of Air Monitoring).

Some of these toxicants are tested for in Air Quality Monitoring Stations through a manual monitoring network. The data obtained through samples collected are then analyzed in a laboratory. The data collected through manual sampling cannot be monitored in real time as the criteria pollutants are. Seventy volatile organic compounds (VOCs) are air toxics monitored under the manual monitoring network. VOCs are typically emitted from industrial sources, including chemical plants, factories and motor vehicles. In addition to being linked to adverse health effects, VOCs contribute to the development of ground level ozone. Ozone is a gas that forms when nitrogen oxides and VOCs react in the presence of sunlight and heat. Ozone is the most common criteria pollutant exceeding standards in the State. Ozone season is during the summer and ozone formation occurs mainly during daytime. Repeated exposure to ozone results in damage to the lungs and aggravates many respiratory ailments. Children and asthmatics are especially prone to adverse health effects due to exposure to ozone.

VOCs are measured at four monitoring stations in New Jersey. For the purposes of the Great Swamp NWR CCP, data collected at the geographically closest station to the refuge (the Chester Station- Approximately 12.5 miles northwest of Great Swamp) from the most recently available NJDEP Bureau of Air Monitoring Report (2007) are shown in table 2-8. Ten VOCs were found at the Chester Station in mean concentrations above the accepted long-term health benchmark established by NJDEP. These compounds include the following in micrograms per cubic meter (ug/m3). Table 2-8 also includes a risk ratio (RR), which evaluates the potential harm of a chemical by evaluating its concentration in the sample against the established benchmark. If the risk ratio is greater than one, its level of concentration may be of concern (NJDEP 2007).

TABLE 2-8: AIR TOXICANTS EXCEEDING LONG-TERM HEALTH BENCHMARKS CHESTER LABORATORY MONITORING STATIONS (2007)

Pollutant	NJDEP Long-Term Health Benchmark (ug/m^3)	Chester Annual Mean	
		ug/m^3	Risk Ratio (RR)
Acetaldehyde	0.45	1.28	3
Acrolein	0.02	0.67	34
Benzene	0.13	0.45	3
1,3 –Butadieine	0.033	0.10	3
Chloroform	0.043	0.08	2
Carbon tetrachloride	0.067	0.54	8
Chloromethane	0.56	1.16	2
Formaldehyde	0.077	2.32	30
p-Dichlorobenzene	0.19	0.091	2
Tetrachloroethylene	0.17	0.29	1.7

The results indicate that Acrolein and formaldehyde have, by many magnitudes, the highest risk ratio of the chemicals exceeding benchmarks at both stations. These two chemicals have been summarized below.

Acrolein is an industrial VOC typically associated with the production of acrylic acid and is commonly produced in the atmosphere. It vaporizes easily and is released into the atmosphere through the combustion of many different substances including fossil fuels, tobacco smoke, cooking oils and grease, and during residential commercial or industrial fires. It may also be used as an agent to control aquatic weeds, bacteria, algae and mollusks (ASTDR 2011). Exposures to acrolein typically come from breathing in tobacco smoke, automobile exhaust, vapors from cooking grease, or exposure to facilities where acrolein is manufactured or used (ASTDR 2011). Acrolein is found throughout the environment, including soils, water, and air. The chemical dissipates rapidly from soil and water, and breaks down rapidly in the air (50 percent within one day of release) due to interaction with chemicals and sunlight (ASTDR 2011). Little is known about the health effects of acrolein; however, breathing large quantities could cause lung damage or death. Exposure to lesser amounts can cause eye and throat irritation (ASTDR 2011). The EPA has not determined this chemical to be carcinogenic based on the lack of data.

Formaldehyde is a colorless gas with a pungent smell commonly used for a variety of applications. It is used in the production of textiles, resins and other chemicals. It is also used as embalming fluid, disinfectant, fungicide, fertilizer and food preservative. It is also found some cosmetics and medicines. Formaldehyde naturally occurs in low levels in plants and animals, including humans (ASTDR 2011). Releases of formaldehyde into the air may be the result of its industrial production, or release from wood products such as particle board, paints and varnishes, automobile exhaust, cigarette smoke, carpets and some fabrics. Indoor air levels of formaldehyde are generally greater than outdoor air levels. In general formaldehyde breaks down quickly in the air (typically within hours) and dissipates quickly in water. It evaporates rapidly from soils and does not accumulate in plant or animal tissue (ASTDR 2011). The most common exposure to formaldehyde is direct inhalation. Formaldehyde is classified as a carcinogen and a mutagen based on inhalation studies (ASTDR 2011). It is corrosive in nature and can cause eye, ear nose mouth, throat or skin irritation and neurological damage (NJDHSS 2010; ASTDR 2011)

2.2 Regional Demographic and Socioeconomic Setting

2.2.1 Population

As with many undeveloped areas in New Jersey, the refuge is surrounded by suburban and urban landscape. The refuge lies approximately 11 miles south of Morristown, the Morris County seat (see map 2-1). Downtown New York City is less than 30 miles away, and the top five cities or townships in New Jersey with the highest population estimates (i.e., Newark, Jersey City, Paterson City, Elizabeth City, and Edison Township) are less than 25 miles away (US Census Bureau 2010). Many local residents commute to these nearby metropolitan areas for work.

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New Jersey is the most densely populated state in the country with an estimated 1,185 people per square mile (table 2-9). Of the 21 counties in New Jersey, Morris County and Somerset County are the 11th and 12th most densely populated, respectively (US Census Bureau 2011). As with the nation as a whole, the population of New Jersey and both counties has increased over the last 10 to 18 years (table 2-9). However, Somerset County's population has grown more quickly than the Nation's, the State's, or Morris County's growth rates. Between 1990 and 2000, Somerset County's population grew (about 24 percent) more than twice as much as New Jersey's (9 percent) or Morris County's (11.6 percent). Between 2000 and 2010, estimated population in the United States was at 9.7 percent. New Jersey's population growth during this period was 4.5 percent.

Overall, median age in the United States has increased approximately 3 percent between 2000 and 2007 (U.S. Census Bureau 2009b). During this same time span, median age was higher in the State of New Jersey (37.4), Morris County (42.4), and Somerset County (39.0) compared to the United States (38.5).

TABLE 2-9: NATIONAL, REGIONAL, AND LOCAL COMMUNITY FOR AREAS NEAR GREAT SWAMP NWR

Community	Population in 2010				Population Change	
	2010 Population	Land Area (square miles)	Persons per square mile	2000 Population	1990 to 2000	2000 to 2010
United States*	308,745,538	3,537,438.44	87.3	281,424,602	13.15%	9.71%
New Jersey	8,791,894	7,417.34	1185.3	8,414,360	8.85%	4.49%
Morris County	492,276	468.99	1,049.7	470,212	11.60%	4.69%
Chatham Township	10,452	9.36	1,164.2	10,086	7.74%	3.63%
Harding Township	3,838	20.44	192.7	3,180	-12.64%	20.69%
Long Hill Township	8,702	12.14	734.3	8,777	12.15%	-0.85%
Morristown	18,411	3.03	6,284.9	18,544	14.55%	-0.71%
Chatham Borough	8,962	2.41	3,776.1	8,460	5.66%	5.93%
Somerset County	323,444	304.69	1,061.6	297,490	23.81%	8.72%
Bernards Township	26,652	23.93	1,113.6	24,600	--	8.34
Bernardsville Borough	7,707	12.91	597.2	7,345	11.34%	5.51%

Notes:
-- indicates data were not available
* Census 2010 data used for U.S. population
Source: U.S. Census Bureau Population Estimates Program and American Fact Finder. Retrieved September 2011. (http://factfinder.census.gov/home/saff/main.html?_lang=en)

According to the U.S. Census Bureau 2000 Census Data (U.S. Census Bureau 2010), New Jersey's population consisted of 68.6 percent white persons not of Hispanic or Latino origin, slightly lower than the percentage reported for the nation's population as a whole (72.4 percent). Morris County (82 percent) reported higher percentages, while Somerset County (70.1 percent) compared to New Jersey and the United States. The percentages of residents identifying themselves as Black or African American were lower in Morris (3.1 percent) and Somerset (8.9 percent) Counties when compared to New Jersey (13.7 percent) and the U.S. (12 percent) (U.S. Census Bureau 2010). This trend is consistent for residents of other ethnicities, with one exception. Both Morris (9 percent) and Somerset Counties (14.1 percent) had higher percentages of residents identifying themselves as Asian compared to New Jersey (8.3 percent) and the U.S (4.8 percent). (U.S. Census Bureau 2010).

2.2.2 Employment and Income

Data analyses by Headwaters Economics (2009a) show that, based on data from 2006, employment (total jobs) in the State of New Jersey has been dominated almost equally by retail trade (10.8 percent), healthcare and social assistance (10.7 percent), and State and local government positions (11.2 percent). Manufacturing accounted for 6.6 percent of all jobs in the State in 2006, a decrease of about 2 percent compared to 2001. Employment patterns in Morris and Somerset Counties differed slightly from the State's in that professional and technical services (e.g., lawyers, accountants, scientific researchers) comprised the largest number of jobs (about 12 percent of total jobs in both Counties), followed by retail trade and health care and social assistance (Headwaters Economics 2009b, 2009c). Farm employment accounts for less than 0.5 percent of the total employment for Morris County, Somerset County, and New Jersey.

These patterns are similar to national employment by industry figures in 2006. For the United States as a whole, retail trade, state and local government, and health care and social assistance accounted for between 10 and 11 percent of the total jobs each (Headwaters Economics 2009d). The biggest difference between the county and the national employment information was within the professional and technical services category. Nationally, this category only accounted for about 7 percent of the total jobs, compared to about 12 percent for each county, and 8 percent for the State.

Currently, the United States is recovering from its largest recession since the 1930's (e.g., Bull and Felsenthal, 2009). The average national unemployment rate for 2009 was estimated at 9.3 percent, and equaled or exceeded 10 percent in October, November, and December of 2009 (BLS 2010a). National unemployment rates consistently remained near 10 percent throughout 2010 (BLS 2011) and have slowly dropped to the current (April 2012) level at 8.1 percent (BLS 2012). Historically, New Jersey has fared marginally better than the nation as a whole in regards to unemployment, usually experiencing lower unemployment rates (table 2-10). New Jersey was; however, above the national unemployment average for 2011. Over the last ten years or so, Morris and Somerset Counties have had unemployment rates about 1.5 percent lower than the national figures (BLS 2010a, BLS 2010b, and BLS 2011). New Jersey had similar unemployment numbers to the United States as a whole, while unemployment estimates for Morris and Somerset Counties were between 1 and 2 percent lower (BLS 2010b; 2011; 2012). Between 2009 and 2010 the average unemployment rate in New Jersey rose slightly by 0.4 percent and dropped by 0.7 percent in 2011(BLS 2011; 2012).

TABLE 2-10: ANNUAL AVERAGES OF UNEMPLOYMENT RATES FOR THE UNITED STATES, NEW JERSEY, MORRIS COUNTY AND SOMERSET COUNTY BETWEEN 2000 AND 2010				
	Average Annual Unemployment Rate[1]			
Year	U.S.	New Jersey	Morris Co.	Somerset Co.
2001	4.7	4.3	3.3	3.3
2002	5.8	5.8	4.6	4.8
2003	6.0	5.9	4.6	4.6
2004	5.5	4.9	3.7	3.7
2005	5.1	4.5	3.3	3.4
2006	4.6	4.6	3.3	3.4
2007	4.6	4.3	3.0	3.1
2008	5.8	5.5	4.0	4.1
2009	9.3	9.2	7.2	7.4
2010	9.6	9.5	7.3	7.4
2011	8.9	9.3	7.0	7.1
Ten Year Average 2001-2010	6.3	6.2	4.6	4.8

[1] U.S. data from Bureau of Labor Statistics (BLS). Labor Force Statistics from the Current Population Survey. Retrieved 3 May 2010. (http://www.bls.gov/cps/). All other data from Bureau of Labor Statistics (BLS). 2010b. Local Area Unemployment Statistics. [Online] Retrieved 3 May 2010 (http://www.bls.gov/lau/data.htm). 2010 Data retrieved from U.S. Census Data and Bureau of Labor September 2011; 2011 data retrieved May 2012.

In general, New Jersey, Morris County, and Somerset County are affluent compared to the rest of the country (see table 2-11; U.S. Census Bureau 2011). Median family income per year in New Jersey exceeds the national figure by over $21,000 while this value for Morris and Somerset Counties exceeds the national figure by over $50,000. However, median family income and per capita family income, when adjusted for inflation, have decreased in the United States, New Jersey, Morris County, and Somerset County between 1999 and 2005-2009.

TABLE 2-11: CALCULATED ANNUAL MEDIAN FAMILY INCOME AND PER CAPITA INCOME FOR THE UNITED STATES, NEW JERSEY, MORRIS COUNTY AND SOMERSET COUNTY					
Location	Annual Estimate	Census 2000 (1999 dollars)	2000 Adjusted (2009 dollars)	2005-2009 (2009 dollars)	Percentage Change
United States	Median Family Income	50,046	64,466	62,363	-3.26
	Per Capita Income	21,587	27,798	27,041	-2.72
New Jersey	Median Family Income	65,370	84,179	83,957	-0.26
	Per Capita Income	27,006	34,777	34,566	-0.61
Morris County	Median Family Income	89,773	115,604	114,019	-1.37
	Per Capita Income	36,964	47,599	46,764	-1.75
Somerset County	Median Family Income	90,605	116,675	113,873	-2.40
	Per Capita Income	37,970	48,895	46,835	-4.21

[1] Data adjusted for inflation using the Bureau of Labor Statistics inflation calculator (http://www.bls.gov/data/inflation_calculator.htm).
Source: U.S. Census Bureau. 2011. American Fact Finder Page. [Online] Retrieved September 2011. (http://factfinder.census.gov/home/saff/main.html?_lang=en).

2.2.3 Recreation and Tourism

Tourism is an important part of New Jersey's economy. A recent study completed by IHS Global Insight (2009) found that tourism spending in 2008 contributed $27.9 billion to New Jersey's gross State product, accounting for 5.8 percent of the State's total gross state product. The same study found that tourism Sexpenditures were responsible for over 443,000 jobs, about 10.9 percent of the State's total employment. Tourism also generated an estimated $7.7 billion in Federal, State, and local government taxes for 2008 (IHS Global Insight 2009). Activities generating the most tourism dollars included dining, entertainment, gambling, shopping, sightseeing, and similar (DKSA 2009). While tourism is important to the State's economy, it plays a smaller role in the region around Great Swamp NWR. A 2008 regional analysis of tourism in New Jersey shows the northwestern New Jersey Skylands region, including Great Swamp NWR, comprised the smallest share of total statewide tourism spending at 8.5 percent (IHS Global Insight 2009). Morris County itself; however, was listed as ninth out of the 21 New Jersey counties for overall tourism expenditure in 2008 at a total of $1,323,000,000.

Great Swamp NWR has the potential to increase visitation, and associated economic benefits to the area, because of its proximity to highly populated areas. Great Swamp NWR currently attracts an estimated

150,000 to 160,000 visitors per a year to the region from throughout the United States and various countries.

Based on a recent report completed by the FWS, over 34 million people visited refuges for recreation in the lower 48 States (Carver and Caudill 2007). These visits generated almost $1.7 billion in sales in regional economies, supporting 27,000 jobs and nearly $543 million in employment income. Refuge recreation spending generated an additional $185.3 million in tax revenue at the local, county, State, and Federal levels.

2.2.4 Contribution of the Refuge to the Local Economy

Refuges provide many benefits to local economies in addition to tourism dollars. Property values and associated property taxes often increase near open spaces, benefitting local communities (Gies 2009). In addition, land in public ownership requires little in the way of services from municipalities yet it provides valuable recreation opportunities and quality of life benefits for local residents.

National wildlife refuges also contribute to local economies through shared revenue payments. Under the provisions of the *Refuge Revenue Sharing Act* (the Act of June 15, 1935; 16 U.S.C. 715s), the FWS pays an annual refuge revenue sharing payment to counties that contain lands the FWS administers. The exact amount of the annual payment depends on Congressional appropriations, which in recent years have tended to be less than the amount to fully fund the authorized level of payments. Recent FWS revenue sharing payments for Great Swamp NWR are presented in table 2-12.

TABLE 2-12: RECENT GREAT SWAMP NWR REVENUE SHARING PAYMENTS (1986 THROUGH 2012)

Year	Municipality		
	Chatham	Harding	Long Hill
1986	$22,749	$60,364	$37,015
1987	$22,473	$59,821	$37,841
1988	$ 27,096	$ 72,127	$ 46,670
1989	$ 29,676	$ 78,996	$ 51,640
1990	$ 35,656	$ 94,915	$ 64,019
1991	$ 24,182	$ 66,500	$ 49,005
1992	$ 22,160	$ 69,538	$ 45,029
1993	$ 21,135	$ 69,385	$ 45,777
1994	$ 21,011	$ 68,708	$ 48,066
1995	$ 17,905	$ 58,552	$ 43,263
1996	$ 21,195	$107,062	$ 56,520
1997	$ 19,349	$ 97,740	$ 52,398
1998	$ 18,210	$ 91,983	$ 49,311
1999	$ 16,954	$ 85,638	$ 49,258
2000	$ 14,872	$ 75,124	$ 46,212
2001	$ 19,238	$306,479	$107,428
2002	$ 17,972	$286,306	$102,015
2003	$ 17,273	$281,394	$101,726

TABLE 2-12: RECENT GREAT SWAMP NWR REVENUE SHARING PAYMENTS (1986 THROUGH 2012)			
Year	Municipality		
	Chatham	Harding	Long Hill
2004	$ 15,278	$248,959	$ 90,904
2005	$ 17,255	$281,164	$102,663
2006	$ 15,970	$263,458	$ 95,018
2007	$ 16,993	$254,754	$ 92,894
2008	$16,993	$197,652	$72,072
2009	$16,993	$188,461	$67,850
2010	$28,136	$60,436	$118,333
2011	$30,150	$126,803	$64,762
2012	$28,331	$119,154	$60,856

2.3 Refuge Administration

2.3.1 Refuge Establishment and Land Acquisition

In 1959, the Port Authority of New York & New Jersey announced plans to consider Great Swamp as a potential site for a commercial jet airport. As a result of major opposition, local citizens formed the Great Swamp Committee of the North American Wildlife Foundation, and through a national campaign, raised one million dollars to acquire nearly 3,000 acres. The Foundation began acquiring these lands in 1960 with the intention to donate this area to the United States. Great Swamp NWR was established in 1960 in accordance with provisions of the Migratory Bird Conservation Act of 1929, and formally dedicated by the Secretary of the Interior in 1964.

Great Swamp NWR, presently 7,773 acres, comprises the largest land ownership (53 percent) of the GSW area. Remaining lands are predominantly held in private ownership with the exception of the Somerset County Lord Stirling Park and Environmental Education Center (1,027 acres) and the Morris County Outdoor Education Center (40 acres). Additional information regarding establishment and acquisition history is included in section 1.5 of chapter 1.

<u>Helen C. Fenske</u>

Helen C. Fenske was a Green Village resident, who in the early 1960s, led a grassroots effort to prevent the Great Swamp from becoming a commercial jetport, as planned by the Port Authority of New York and New Jersey. Through her skillful community organizing, fundraising and political advocacy, Ms. Fenske worked to raise more than $1 million to purchase and donate nearly 3,000 acres of land to the Department for the establishment of Great Swamp NWR.

After the establishment of Great Swamp NWR, Ms. Fenske's efforts to improve and protect the refuge continued. Ms. Fenske was instrumental in developing Great Swamp NWR's Wilderness Area in 1964, the first NWR wilderness area in the United States.

Ms. Fenske continued conservation efforts throughout her life, including fostering the development environmental commissions, protecting open space and wetlands, and promoting the creation of Wallkill and Cape May NWRs. Ms. Fenske also served as the Assistant Commissioner of NJDEP. The Department of Interior's Conservation Service Award was among the many awards she received during her lifetime. Helen C. Fenske died on January 19, 2007 at the age of 84.

2.3.2 Great Swamp NWR Staffing and Budgets

Great Swamp NWR currently consists of nine permanent staff: a Refuge Manager; Deputy Refuge Manager; Refuge Wildlife Biologist; Refuge Contaminants Biologist; Visitor Services Manager; Visitor Services Specialist; Engineering Equipment Operator; Maintenance Worker; and Refuge Law Enforcement Officer. The refuge also includes two temporary staff: a Biological Technician and Administrative Assistant.

Table 2-13 below summarizes general budget, visitation and volunteer hour data.

TABLE 2-13: GREAT SWAMP NWR STAFFING, BUDGET, VOLUNTEER HOURS AND VISITATION DATA

Category	2010	2009	2008	2007	2006
Refuge Acreage	7,773	7,745	7,735	7,725	7,657
Budget					
Salaries/ops[A] (FTE's)	$1,340,423 (9.5)	$1,394219 (10.5)	$1,333,178 (10.5)	$1,274,293 (9.9)	$965,500 (9.8)
One-time Project Funds[B]	$43,800[C]	$84,220	$289,211	$2,218,119	$396,742
Fees	$3,684	$3,883	$3,490	$4,090	$4,567
Volunteer Hours	15,143	14,584	10,240	12,000	8,148
Visitation	156,500	155,500	151,000	155,000	240,000[D]

Notes:
[A] Includes annual maintenance, utilities, contracts, and other similar salaries.
[B] Includes deferred maintenance, construction, equipment, and biological projects.
[C] In addition, the refuge received $579,000 from the American Recovery and Reinvestment Act
***Apparent drop in visitation between 2006 and 2007 is the result of changes in how visitation was calculated and does not reflect an actual substantial drop in refuge visitation

2.3.3 Refuge Facilities and Maintenance Summary

The following is a summary of current refuge facilities, including wildlife management facilities, maintenance facilities, roads, parking lots and other visitor facilities, and other structures not occupied or in use. Facilities include the following:

- *Refuge Headquarters* is an administrative building that contains offices of staff members, a meeting room, bathrooms, a refuge receptionist desk, and informational displays and materials.

- The *Wildlife Observation Center* (WOC) is an area located off of Long Hill Road ideal for observing wildlife in forested, emergent and scrub-shrub wetland and open water habitats. The WOC consists of 1.5 miles of trails, including interpretive handicapped accessible boardwalk trails, three observation blinds for viewing wildlife, an informational kiosk, a large parking area, a visitor contact station, and all-season restrooms.

- The *Helen C. Fenske Visitor Center* was opened in 2009 and is housed in a century–old farmhouse located on Pleasant Plains Road. The facility provides visitor services and contains exhibits, meeting space, and offices. The Friends of Great Swamp NWR offer public programs and have their nature gift shop, library, and Discovery Den in the Visitor Center. The Visitor Center has an adjacent pavilion that is used for outdoor educational programs, a 0.5 mile loop trail, children's nature trail, outdoor restrooms, and ample parking.

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- Five *Impoundment Areas* are located within the management area of the refuge. Each impoundment includes water control structures.

- An *overlook observation area* located along Pleasant Plains Road, which includes two fixed viewing scopes, a kiosk, benches, and parking for about 10 cars.

- Four major *parking lots.*

- 8.5 miles of primitive, blazed *foot trails* within the Wilderness Area. An information kiosk is located at each Wilderness Area trailhead.

- Numerous interpretive, informational, directional, and administrative *signs*.

- *Maintenance storage facilities* house equipment and tools. Maintenance storage facilities include the pole barn, shop, oil shed, and Cement Plant.

- 11 *houses*, five of which are occupied by staff. Three are scheduled for demolition.

- Three *bridges*, located at Middle Brook, Great Brook, and Amil Gates.

- Gravel and paved *roads*, including 2.3 miles of Pleasant Plains Road. 1.3 miles consists of gravel and 1.0 mile is paved.

- *Additional Structures:* the Bluebird lot (formerly referred to as Q99) includes an outdoor restroom. A kiosk, benches and parking for about 20 cars are planned for the future.

2.3.4 Step-Down Plans, Findings of Appropriateness, and Compatibility Determinations

Step Down Plans

As previously discussed in chapter 1, there are more than 25 step-down management plans that are generally required on refuges. Please refer to section 1.7 for a summary on the requirements for step-down plans, a list of plans that are complete and up-to-date, and a list of plans required upon completion of this CCP.

Findings of Appropriateness and Compatibility Determinations

The *Policy on the Appropriateness of Refuge Uses* (603 FW 1) provides a national framework for determining appropriate refuge uses to prevent or eliminate those that should not occur in the Refuge System (USFWS 2006b). It describes the initial decision process the refuge manager follows when first considering whether to allow a proposed use on a refuge. *Policy on Compatibility* (603 FW 2) complements the *Policy on Appropriateness of Refuge Uses* (603 FW 1). If a refuge manager finds a use appropriate, the use is further evaluated through a CD. The policy provides guidelines for determining the compatibility of uses and procedures for documentation and periodic review of existing uses (USFWS 2000d). Chapter 1 describes parameters used in making Compatibility Determinations and Findings of Appropriateness.

The list below outlines the current CDs and uses that have been approved for the refuge. The list includes original, updated and new determinations completed and reviewed as part of the CCP process. The detailed findings are included in appendix B of this report.

Compatibility Determinations:
- Wildlife Observation, Photography, Environmental Education, and Interpretation
- Public Hunting
- Alternative Forms of Transportation to Access Refuge Lands
- Leashed Dog Walking During Daylight Hours on Pleasant Plains Road
- Research
- Commercial Filming, Motion Picture Production, and Advertisements
- Police and Fire Training
- Maintenance of National Weather Service Automatic Rain Gauge
- World Series of Birding
- Maintenance of Utility Rights of Way

2.3.5 Partnerships

NJDEP Division of Fish and Wildlife

The NJDFW works closely with Great Swamp NWR by assisting in the management of its hunting program and by providing assistance and direction in the management of sensitive wildlife species through ENSP, which has assisted the refuge in management of its endangered species, such as the bog turtle and Indiana bat. The NJWAP, which sets direction for the protection of wildlife within New Jersey, has been utilized by Great Swamp NWR as a planning tool to assist in the prioritization of species for management. ENSP has also assisted with onsite species surveys and inventories of the refuge, including the 2009 Bioblitz.

The *Great Swamp Watershed Association*

The GSWA was established in 1981 by a small group of concerned citizens. GSWA conducts water quality monitoring on streams within the watershed, promotes intelligent land use, provides environmental education, and protects habitat and open space (GSWA 2009).

Ten Towns Committee

The Ten Towns Committee was established in 1995 through an *Intermunicipal Agreement* among the ten GSW townships in Morris and Somerset Counties to manage and improve local water quality (Ten Towns Committee 2009). The Ten Towns Committee also established a macroinvertebrate water quality monitoring program in 2000, which was to be conducted on an annual basis. Since 1998, GSWA, in conjunction with the Ten Towns Committee, had been monitoring the water quality and quantity of the five main streams in the GSW. The Ten Towns Committee was dissolved on June 30, 2010 as many of the organization's initial policy goals had been completed and are still in place.

For more information on the GSWA and Ten towns Committee, see Watershed Advocacy and Protection in section 2.1.4 of this chapter.

Friends of Great Swamp NWR

Friends of Great Swamp NWR is an independent, non-profit organization that was established in 1999 by local citizens in partnership with the FWS. The *Friends* mission is to promote stewardship of the natural resources of the refuge; inspire appreciation of nature through education and outreach; and engage in partnership activities that support and enhance Great Swamp NWR and the Refuge System. The *Friends* program has provided important input on issues related to refuge public use and management during the course of the CCP. Additional information on the *Friends* program is included in the Volunteer section of the CCP (see chapter 2, section 2.4.6).

Somerset County Environmental Center

The Somerset County Environmental Center is located within Lord Sterling Park in Basking Ridge. The park is comprised of 425 acres of the western portion of the GSW Basin and adjacent to Great Swamp NWR. The park provides access from its environmental center to wetland, open water, forest and meadow habitats. The Environmental Center offers a variety of exhibits and educational programming, including a traveling program. The center also offers canoeing and kayaking through portions of the park's open waters (Somerset County Park Commission 2011).

Morris County Park Commission Great Swamp Outdoor Education Center

The Morris County Outdoor Education Center is located along the eastern side of Great Swamp NWR in Chatham Township. The park offers a variety of recreational and educational opportunities for visitors. Facilities include an exhibit based visitor center, including wildlife observation along a boardwalk system, guided hikes, public education, teacher certification, and scout programs (Morris County Park Commission 2011).

The Raptor Trust

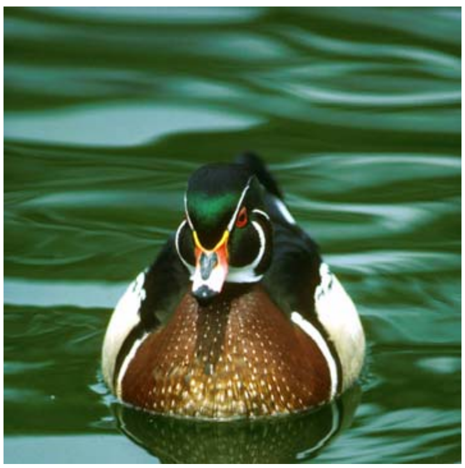
The Raptor Trust is a highly respected and nationally-recognized wild bird rehabilitation center located within the southwestern portion of Great Swamp NWR on White Bridge Road. The Raptor Trust includes a hospital with state-of-the-art medical facilities, adequate housing for hundreds birds, and an education building. The Raptor Trust provides the public with access to view many rehabilitated birds, and offers a variety of raptor-subject programs to the public, schools and scouts (Raptor Trust 2006).

The National Park Service

Morristown National Historical Park is comprised of four geographically separate units located north of Great Swamp NWR. The historical park is associated with the 1777 and 1779 to 1780 winter encampments of the Continental Army and General George Washington's headquarters in Morristown. The park contains 27 miles of hiking trails that wind through mature forests. The park offers curriculum-based programs for 4th and 5th grades on the significance of the parks resources and region during the American Revolution (National Park Service 2011).

New Jersey Audubon Society

The New Jersey Audubon Society was founded in 1897 and is one of the oldest independent Audubon societies. The New Jersey Audubon Society is a privately supported, not-for-profit, statewide membership organization unaffiliated with the National Audubon Society. The New Jersey Audubon Society promotes the conservation of natural lands and protects New Jersey's wildlife and endangered species. The New Jersey Audubon Society manages natural lands within the State, including the 276 acre Scherman-Hoffman Wildlife Sanctuary, which is located approximately 2.5 miles northwest of Great Swamp NWR in Bernardsville, New Jersey (New Jersey Audubon Society 2011).



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Ducks Unlimited, Inc.

Ducks Unlimited conserves, restores, and manages wetlands and associated habitats for North America's waterfowl. The New Jersey Chapter includes more than 5,700 members. Chapters work through partnerships with individuals, landowners, agencies, scientific communities and others to accomplish its conservation work (Ducks Unlimited Inc. 2011).

The Trust for Public Land

The Trust for Public Land is a national nonprofit organization that conserves land for use as parks, gardens, historic sites, rural lands, and other natural places. The trust acquires properties to improve natural areas and quality of life for inner cities. The trust helps to plan solutions, raise funds and complete conservation transactions. Within New Jersey, the Trust has protected nearly 25,000 acres and helped to pass several million dollars in new State spending on conservation. Local Trust lands include the McVickers Brook Preserve in Mendham Borough, which connects into the Patriots Path, and Morristown National Historical Park (Trust for Public Land 2011).

The Land Conservancy of New Jersey

The Land Conservancy of New Jersey is an important organization in State land preservation .The Conservancy has preserved over 17,000 acres and assisted in securing over $206 million in county, State, and Federal grants for their land conservation projects. Land preserved near the refuge includes the 26-acre Passaic River County Park Addition in Long Hill Township, 35-acre Great Swamp NWR Addition in

Long Hill Township, and the 10-acre Loantaka Brook Greenway in Chatham Township (Land Conservancy of New Jersey 2011).

2.4.6 Volunteer Program

In Fiscal Year (FY) 2012, volunteers contributed 13,809 hours to Great Swamp NWR. Volunteers assist with biological projects; maintain of refuge facilities and trails; develop and conduct environmental education programs; assist with special events; create educational exhibits; and staff exhibits during on- and off-site special events. Volunteer orientations are held biannually and a recognition dinner is held annually.

Friends of Great Swamp NWR

The *Friends* provide major coordination of the volunteer program at Great Swamp NWR. The *Friends* currently have a group of volunteers who conduct environmental education and interpretation activities on the refuge. Since the fall of 2008, approximately 5,200 students in Kindergarten through Grade 12 have attended these programs. During bird migration season each year, the *Friends* spend over 500 hours greeting visitors at the Wildlife Observation Center.

Friends of Great Swamp NWR are involved in the following:

Visitor Services
The *Friends* greet visitors and provide general refuge information at the Helen C. Fenske Visitor Center and Wildlife Observation Center.

Work Projects and Refuge Cleanup Activities
The *Friends* assist with maintenance projects, including homestead cleanups and biannual roadside cleanups.

Education & Outreach
The *Friends* conduct or assist with scheduled school, club, scout, or group tours, answer questions, show video programs, and provide orientation to the refuge.

Surveys and Refuge-Specific Projects
The *Friends* work closely with refuge staff on an as–needed basis on various biological and management projects. These projects include wildlife and bird surveys and banding, deer hunt assistance, vernal pool and stream bank restoration projects, or invasive species control.

TABLE 2-14: VOLUNTEER HOURS BY FRIENDS OF GREAT SWAMP NWR							
Category	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Wildlife and Habitat	2,676	2,359	4,200 3,	657 4,958		4,245	6,279
Refuge Maintenance	968	655	500 54	9 669		498	963
Wildlife-Dependent Recreation	2,990	3,905	3,900 6,	025	8,152 6,	113 6,010	
Environmental Education	419	310	100 64	2 280		271	241
"Other" Activities	958	753	1,000	1,278 1,	084	222	316
TOTAL	8,011	7,982	9,700	12,051	14,816	11,349	13,809

2.4.7 Outreach

Public outreach is two-way communication between the FWS and the public to establish mutual understanding, promote involvement, and influence attitudes and actions with the goal of improving joint stewardship of our natural resources (USFWS 2001c). Recognition of the refuge, the Refuge System, and the FWS among neighbors, local leaders, conservation organizations, and elected officials are among the refuge's major purposes for public outreach efforts. These efforts generate support for conservation in the region. Forms of outreach include off-site exhibits and displays; news media relations; internet, intranet, and listservers; partnerships; environmental education; memberships in professional and community organizations; and Congressional relations.

Refuge staff often host or participate in local events which facilitates direct communication with the public and raises the visibility of the refuge. Volunteers also frequently represent the refuge at local events. For example, each fall the refuge participates in a cooperative outreach program with the Morris County Park Commission. Various other municipal, county, state and Federal land management agencies also participate in the event, all of which share a common theme or conservation message. The refuge staff or volunteers distribute information about the refuge, children's nature games, and display material. The mission of the Refuge System and the refuge's purpose are conveyed to the public to raise awareness and recognition. This public event is typically attended by about 500 people.

2.4.8 Research

From its inception, environmental and wildlife education have been an integral component of Great Swamp NWR (see chapter 1). Great Swamp NWR and its academic and organizational partners conduct numerous multi-year wildlife inventories for terrestrial vertebrate groups. This section provides a general list of the types of studies conducted on the refuge. Details on specific studies are included in section 2.6.1 and chapter 3.

Wildlife and Plant Inventories

While most species inventories focus on birds, other species groups, including other vertebrate and some invertebrate groups, have been inventoried on the refuge. Various plant and fungal inventories have also been conducted on the refuge. Examples of Great Swamp NWR species inventories include the following:

- Fungal inventories
- Herbaceous plant inventories
- Breeding grassland and early successional bird surveys
- Inventories of breeding waterfowl populations
- Marsh bird inventories
- Christmas Bird Counts
- World Series of Birding inventories.
- Frog call surveys
- Bog turtle and wood turtle mark-recapture study
- American kestrel nest box breeding data
- Productivity monitoring of great blue heron rookeries
- Woodcock singing ground surveys (refuge and State run)
- Wood duck box breeding data
- Deer population surveys
- Small mammal trapping surveys
- Moth surveys
- Butterfly surveys
- Stream aquatic invertebrate inventory
- Bioblitz (2009 and 2011) – General species diversity inventory)
- Vernal pool surveys
- Mal-formed frog survey

Threatened and Endangered Species Studies

Studies focusing on specific State or federally listed threatened or endangered species are regularly conducted at Great Swamp NWR. The habitat utilization and demography of Indiana bat, bog turtle, wood turtle, and blue-spotted salamander have all been studied on the refuge. Information from these studies is incorporated into management strategies on the refuge. Specific threatened and endangered species studies include the following:

- Roost selection by reproductively active female Indiana bats
- Roost tree selection by male Indiana bats
- Radio telemetry and habitat use by bog turtles and wood turtles
- Wood turtle artificial nesting mound productivity
- Blue-spotted salamander egg mass counts and breeding pool study

Other Ecological Studies

Ecological studies on the effect of wildlife populations, such as white-tailed deer on plant communities, have been conducted at the refuge. Data on deer population structure and trends are maintained by the refuge, which assists with future management decisions and techniques. Hydrologic studies, including water quality monitoring studies, have also been conducted at the refuge.

Plant Communities and Wildlife Habitats

- General plant community evaluation
- Early successional shrub data
- Hedgerow study (avian use)
- Shorebird use of impounded wetlands (part of a larger USFWS Region 5 study)
- Invasive species management data
- Vernal pool studies

USFWS

Wildlife Control and Health

- Frog abnormality study
- White-tailed deer harvest data
- White-tailed deer and forest understory health monitoring
- Mute swan control data
- Avian Influenza monitoring

Abiotic Conditions

- Soil surveys
- Pool and stream elevation data
- Water quality studies

Please refer to the Great Swamp NWR HMP for a spreadsheet of all major studies that are occurring or have occurred at Great Swamp NWR. Specific details on key studies are further discussed within the alternatives analysis and text of chapter 3 of this CCP.

2.4.9 Special Use Permits, Including Research

Special Use Permits (SUPs) are issued to individuals, organizations, institutions, companies, and agencies that request the use of refuge facilities or resources beyond what is available to the public. Permits may or may not be research or education oriented in nature. SUPs commonly issued at Great Swamp NWR include access in restricted areas, entrance after hours, collection or sampling of resources for research or monitoring, and special events or other activities. SUPs are needed to engage in the following activities on a national wildlife refuge (USFWS 2011a):

- Agriculture, such as haying, grazing, crop planting, logging, beekeeping, and other agricultural activities.

- Commercial Activities, including commercial fishing, trapping, and other activities.

- **Research and Monitoring** by students, universities, or other non-FWS organizations.
- **Commercial Filming**, including audio, video, and photographic products with a monetary value.
- **Commercial Visitor Services**, such as outfitters or guides for hunting, fishing, canoeing, kayaking, and other visitor services.
- **Special Events**, including guided birding trips, amateur photography workshops, and special events (for example, BioBlitz).
- **Other** – any activity not mentioned above.

For Great Swamp NWR, these activities typically include public access at night or into the Management (restricted) Area for an approved event or project, access for right-of-way maintenance, and police and fire training in government structures

Approved Evaluations of Appropriateness and Compatibility Determinations (see section 2.4.4) are required before SUPs can be issued under current FWS policy. Special conditions and restrictions are identified for each permit awarded to ensure safety, prevent conflicts with other uses, and minimize disturbance to wildlife and habitats. Specified SUP periods typically range from one day to one year, depending on the nature of the request.

More than 130 permits have been issued at Great Swamp NWR since 2001 and the number of SUPs has generally increased each year. Approximately 11 permits were issued in 2006; 23 in 2007; 24 in 2008; 26 in 2009; and 30 in 2010.

2.5 Soils, Vegetation, and Habitat Types

2.5.1 Soils

Great Swamp NWR lies at the bottom of former glacial Lake Passaic. Terraces of sand and silt were deposited by Great Brook, Loantaka Brook and the Passaic River. The wetland complexes of Great Swamp NWR typically include several feet of peat, alluvial sand and silt, which are underlain by tens to hundreds of feet of accumulated glacial clay and silt. In some places, the clay and silt is underlain by sand and gravel, which was deposited during both the Illinoisan and late Wisconsin glaciations (Stanford 2007). According to the Soil Survey Geographic (SSURGO) Database for Morris County, Great Swamp NWR is comprised of 28 soil units of 16 soil series (refer to table 2-15, Soil Types of Great Swamp NWR and figure 2-3).

TABLE 2-15: SOIL TYPES OF GREAT SWAMP NWR[1]			
Soil Symbol	Soil Name	Description	Acreage[2]
AdrAt	Adrian muck (0-3% slopes, frequently flooded)	Nearly level, very poorly drained organic soils underlain by sandy deposits at a depth of 16-50 inches, which has a permanent high water table and is ponded or flooded in winter and spring.	220.79

TABLE 2-15: SOIL TYPES OF GREAT SWAMP NWR[1]			
Soil Symbol	Soil Name	Description	Acreage[2]
BhdAt	Biddeford silt loam (0-2% slopes, frequently flooded)	Nearly level, deep, very poorly drained soils in depressions, along streams, and in old meander scars on the flat, nearly level bottom of the former glacial Lake Passaic basin. Soils formed in stratified, glacial lacustrine deposits and have a thin mantle of silty and mucky sediment washed from surrounding soil. Very frequently ponded, susceptible to flooding, and slow permeability.	998.55
BohC	Boonton moderately well drained gravelly loam (8-15% slopes)	Gently to strongly sloping, well drained and moderately well drained soils on hills and within the margins of the former glacial Lake Passaic basin. Heavy fine sandy loam and gravelly loam with coarse fragments of stone, cobble and gravel. Soils formed in stony glacial till that overlies fractured basalt or red shale and sandstone bedrock.	6.71
CarAt	Carlisle muck (0-2% slopes, frequently flooded)	Deep, nearly level, very poorly drained organic soils in depressions that were formerly or are now partly occupied by lakes or ponds. Upper 18 inches contains black, highly decomposed muck underlain by about 60 inches of very dark grayish-brown, decomposed muck that contains many fibers and pieces of wood.	2,071.82
EkhhB	Ellington loamy substratum variant fine sandy loam (3-8% slopes)	Gently sloping to steep, moderately well drained and somewhat poorly drained soils formed in somewhat gravelly material that was derived from shale, siltstone, and sandstone, and smaller amount of other material such as granitic gneiss. Fine sandy loam soils underlain by finer textured residual material weathered from trap and or shale bedrock. Soils on sides of Watchung ridges within basins formerly occupied by glacial Lake Passaic.	125.43
EkhhC	Ellington loamy substratum variant fine sandy loam (8-15% slopes)		61.44
EkhhD	Ellington loamy substratum variant fine sandy loam (15-25% slopes)		12.01
MknA	Minoa silt loam (0-3% slopes)	Deep, nearly level to gently sloping, somewhat poorly drained silt and fine sandy soils on slightly elevated areas within and at the margins of former glacial Lake Passaic. Areas are recessional beaches or terraces formed by wave action or currents working on older lake sediment, formed in lacustrine sediment.	24.19
MknB	Minoa silt loam (3-8% slopes)		108.27
NekB	Neshaminy gravelly silt loam (3-8% slopes)	Deep, gently sloping to steep, well-drained gravelly and stony soils on hills south of the terminal moraine of the Wisconsin glaciation. Soils formed in material weathered from the underlying basalt bedrock.	68.14
NekC	Neshaminy gravelly silt loam (8-15% slopes)		12.66

TABLE 2-15: SOIL TYPES OF GREAT SWAMP NWR[1]			
Soil Symbol	Soil Name	Description	Acreage[2]
		Coarse fragments generally increase with depth, and in places, generally contain few cobbles, stones and boulders.	
PHG	Pits, sand and gravel	Open excavations and adjoining areas of fill material removed during mining of sand, gravel, and burrow material, generally 6-20 feet deep with steep to vertical sides. Common in glacial outwash and glacial till areas.	5.08
PafAt	Palms muck (0-2% slopes, frequently flooded)	Very deep, very poorly drained soils formed in herbaceous organic material underlain by loamy deposits on closed depressions on moraines, lake plains, till plains, outwash plains and hillside seep areas, and on backswamps of flood plains.	207.29
PbpAt	Parsippany silt loam (0-3% slopes, frequently flooded)	Deep, nearly level, poorly drained soils that have a moderately fine textured subsoil. The water table is at or near the surface during much of winter, early in spring and after heavy rains. These soils typically occur on the nearly level bottom of the formerly glacial Lake Passaic basin and formed in stratified sediment of lacustrine origin, derived mostly from red and brown shale, basalt, and granitic rock. Coarse fragments are very rare or absent. In PbphAt, a thin substratum of fine sandy loam is present within 40 inches of the surface and is dominantly fine sandy loam or silt loam below a depth of 40 inches.	707.59
PbphAt	Parsippany silt loam, sandy loam substratum (0-3% slopes, frequently flooded)		2,283.94
PbtAt*	Parsippany very poorly drained variant silt loam (0-2% slopes, frequently flooded)	Deep, very poorly drained silt loam and silty clay loam soils on low-lying flats and in depressions in the former glacial Lake Passaic that formed in glacial lake sediment derived mainly from red shale, granite gneiss, and basalt. These areas are subject to frequent flooding and often contain scattered areas of black organic matter on the surface and small areas where water is ponded most of the year.	1.54
PeoB	Penn channery silt loam (3-8% slopes)	Moderately deep, gently sloping to steep, well-drained shaly silt loam soils on hillsides within the Passaic basin. Soils are subject to erosion and have poor stability and compaction characteristics due to high content of silt.	35.02
PeoC	Penn channery silt loam (8-15% slopes)		21.89
PohB	Pompton sandy loam (3-8% slopes)	Deep, nearly level to gently sloping, somewhat poorly drained sandy loam soils in wide, nearly level swales on terraces and on broad, low outwash plains that formed in sandy and gravelly glacial outwash derived mainly from granitic material and in places from red	636.55

TABLE 2-15: SOIL TYPES OF GREAT SWAMP NWR[1]			
Soil Symbol	Soil Name	Description	Acreage[2]
		and brown shale and traprock, and a small amount of other kinds of material, such as quartzite, sandstone, and conglomerate. These soils are underlain by stratified, water-sorted sand and gravel.	
PrkAt	Preakness sandy loam (0-3% slopes, frequently flooded)	Deep, nearly level, poorly drained sandy loam soils on broad outwash plains in the former glacial Lake Passaic basin, subject to annual floods in spring and low-frequency floods in summer. Soils are generally granitic material, with smaller amounts of quartzite, sandstone and shale. The water table is at or near the surface late fall, winter and spring, with many ponded areas in winter.	457.44
PrsdAt	Preakness dark surface variant sandy loam (0-3% slopes, frequently flooded)	Deep, nearly level, very poorly drained, moderately coarse textured soils generally located in small isolated kettles or other undrained depressions on terraces and pitted outwash plains. They occur in sandy and swampy areas in the Great Swamp region, with the water table at or near the surface most of the year, and are formed in stratified and sorted glacial outwash. These soils are underlain by stratified sandy and gravelly material.	158.66
RerB	Reaville deep variant channery silt loam (0-6% slopes)	Deep, nearly level to gently sloping, moderately well drained and somewhat poorly drained shaly soils in waterways, on gently sloping hillsides, and in seep spots at the base of steeper slopes. These soils formed in material weathered from the underlying shale bedrock or in local alluvium of similar material that washed from the surrounding slopes. Shale fragments occur throughout the profile and increase in size and number with increasing depth.	118.75
RksB	Riverhead gravelly sandy loam (3-8% slopes)	Well drained, nearly level to strongly sloping gravelly sandy loam soils on undulating outwash terraces and plains, as well as small isolated moraines. These soils formed in sandy and gravelly outwash derived mainly from granitic material that contains small amount of shale, sandstone, quartzite, and conglomerate.	106.50
RksC	Riverhead gravelly sandy loam (8-15% slopes)		35.68
UdrB	Udorthents, refuse substratum (0-8% slopes)	Deep, somewhat poorly drained, moderately well drained, and well drained loamy soils on flood plains that formed in sediment derived mainly from glacial till, granite gneiss, and limestone, which washed from nearby uplands.	2.19
UR	Urban land	This unit is characterized by areas that have been cut or filled as a result of development and covered	4.92

TABLE 2-15: SOIL TYPES OF GREAT SWAMP NWR[1]			
Soil Symbol	Soil Name	Description	Acreage[2]
		with an impervious surface, such as buildings or pavement. The original soil profile is not distinguishable.	
USRHVB	Urban land-Riverhead complex (3-8% slopes)	This complex consists of well-drained, nearly level to strongly sloping sandy and gravelly soils on undulating outwash terraces and plains in valleys that are underlain by loose, unweathered, stratified and sorted sand and gravel outwash, mostly of granitic material that contains some shale, sandstone, quartzite, and conglomerate. Approximately 55 percent of this complex has been disturbed by man to the extent that the original profiles no longer remains and 35 percent Riverhead soils.	188.25
WATER	Water	Areas mapped as water.	23.27
WhpA	Whippany silt loam (0-3% slopes)	Deep, nearly level to gently sloping, somewhat poorly drained silt loam soils on broad flats and slight rises in former glacial Lake Passaic that formed in glacial lake sediment derived mainly from red shale, granitic gneiss, and basalt. In WhphA and WhphB, a thin stratum of sandy loam is present within 40 inches of the surface and is dominantly sandy loam or silt loam Below a depth of 40 inches.	156.00
WhpB	Whippany silt loam (3-8% slopes)		69.05
WhphA	Whippany silt loam, sandy loam substratum (0-3% slopes)		221.56
WhphB	Whippany silt loam, sandy loam substratum (3-8% slopes)		144.78
WkkAt	Willette muck (0-2% slopes, frequently flooded)	Nearly level to gently sloping, very deep, very poorly drained soils organic soils formed in organic material 16 to 51 inches deep overlying clayey deposits on lake plains, ground moraines, and end moraines.	133.22
		TOTAL	9,429.18

Notes:
1 –SSURGO Database for Morris County, USDA, Natural Resource Conservation Service, Fort Worth, Texas, December 2004.
2 - Acreages include all lands within the approved acquisition refuge boundary.

2.5.2 Vegetation and Habitat Types

The Refuge System adopted the National Vegetation Classification System (NVCS) developed by The Nature Conservancy and the Natural Heritage Network as its standard system for classifying vegetation communities.

In September of 2008, NatureServ produced the *Vegetation Classification and Mapping of Great Swamp National Wildlife Refuge.* Vegetation mapping of the refuge was undertaken in conjunction with a vegetation mapping project at the Morristown National Historical Park. NatureServ utilized vegetation mapping protocols and standards originally established by the USGS – National Park Service Vegetation

Mapping Program. NatureServ worked with refuge staff to develop an initial vegetation classification for the refuge based on the NVCS and the New Jersey Natural Heritage Program's state types (Breden 1989). In the summers of 2002 and 2003, 55 vegetation plots were sampled to cover the observed range of variation in the vegetation (Sneddon 2008). Based on the 2008 study, 25 Associations were identified at Great Swamp NWR; these Associations are listed along with key species in table 2-16. These combined habitat types are used in the development of habitat objectives in chapter 3.

To facilitate management strategies developed under the CCP, the diverse vegetation categories developed in the 2008 study were incorporated into the 13 broader habitat management/land use-land cover categories listed below. These categories take into account both vegetation types and land use management practices, and were used to develop the alternatives mapping. Table 2-16 represents a crosswalk illustrating how the vegetation types were grouped for the purpose of developing the CCP. In some cases, vegetation communities may fall under more than one of the management category. For example, areas defined as "cattail marsh" fall under the categories "non-forested wetland" and "impoundments" in the CCP mapping.

The General land cover types at Great Swamp NWR include the following types.

Habitat Types

Bottomland Forest

Great Swamp NWR contains approximately 5,028 acres of forested bottomlands that includes floodplains and riparian habitats, including approximately 35 acres of woodland vernal pool habitat. This vegetation cover type is the most dominant on the refuge. Dominant tree types of most of these forests include green ash, red maple, pin oak, and some swamp white oak. This forest type also contains inclusions of mesic forest dominated by white oak, red oak and American beech.

These habitats contain a variety of high priority bird species in BCR 28 and 29, presence of federally listed species (i.e., Indiana bat), and several State-listed species (i.e., barred owl, blue-spotted salamander, and red-shouldered hawk). Bottomland forests are of particular importance to fall migrating songbirds and raptors. Impacts include invasive species, especially Japanese stiltgrass (*Microstegium vimineum*); increased flow and sedimentation from upstream development; altered hydrology due to historic trenching, ditching, and channelization; impaired water quality (i.e., non-point pollution); forest succession and browsing pressure or overgrazing by white-tailed deer (impediment to regeneration); and parasites, disease, and infestation (i.e., gypsy moth, chestnut blight, Dutch elm disease).

Upland Forest

Great Swamp NWR contains approximately 288 acres of upland forest. Upland forest areas are primarily mapped as small inclusions within the bottomland forests of the Wilderness Area in the easternmost portion of the refuge. The NaturServ study primarily identifies these forests as Coastal Plain beech-chestnut oak forest. A number of high priority bird species in BCR 28 and 29, such as wood thrush, several migrating wood warbler species and various neotropical migrants utilize the refuge's upland forests. Refuge upland forests are important for fall migrating raptors, as well as the barred owl. The refuge upland forests require less management and/or limited management capability due to legal constraints within the Wilderness Area. Invasive species are among the greatest threat; particularly Japanese barberry (*Berberis thunbergii*), garlic mustard (*Alliaria petiolata*), tree-of-heaven (*Ailanthus altissima*), multiflora rose (*Rosa multiflora*), Russian olive, Japanese wisteria, and Japanese honeysuckle (*Lonicera japonica*). These species thrive along forest edges and are spread from surrounding residential encroachment. Forest succession and browsing pressure or overgrazing by white-tailed deer (impediment to regeneration) are also threats to this habitat type. Other threats include parasites, disease, and infestations (i.e., gypsy moth, chestnut blight, Dutch elm disease).

Non-Forested Wetlands

Great Swamp NWR contains approximately 692 acres of non-forested emergent wetland habitat. Much of this habitat is identified under the NVCS classification as eastern cattail marsh (see table 2-16). Other marsh areas are dominated by forbs, such as pickerelweed and broadleaf arrowhead, while other areas are dominated by tussock sedge and other *Carex* sedges. Portions of the communities within this general habitat type contain federally listed species (i.e., bog turtle) and support several State-listed species (i.e., wood turtle, American bittern, and Northern harrier). Some of these habits are managed or planned to be managed as habitat restoration for bog turtle. Open marshes and adjacent waters are of high importance to fall migrating waterfowl (average peak fall population = 10,000 waterfowl individuals), including highest priority species in BCR 28 and 29. Threats to these communities include invasive species, particularly purple loosestrife and common reed; increased flow and sedimentation from upstream development; impaired water quality (i.e., non-point pollution); altered hydrology due to historic ditching and channeling; and forest succession. This category contains Floodplain Pool (see table 2-16), identified by NatureServ as a Globally Rare (G2) community (Sneddon 2008). The CCP mapping identifies approximately 0.17 acres of *open water* within a non-forested wetland of the wilderness area (see alternative A, Map 3-1).

Impoundments

Great Swamp NWR contains five artificial impoundments that comprise approximately 479 acres of open water, emergent forb and cattail marsh, and scrub-shrub wetland components. Through the mid-1900s, the hydrology of Great Swamp NWR was historically disturbed by repeated attempts of draining and ditching for farming activities and stream alterations for flood and mosquito control purposes. In the 1960s, refuge staff began plugging the previously constructed drainage ditches and creating short dikes with small water control structures in attempt to restore more than 1,000 acres of previously drained wetlands. Five major impoundments were constructed in the 1970s and early 1980s in order to provide wildlife habitat and influence plant composition and abundance. This resulted in an increase in use by many wetland-dependent wildlife species (USFWS 1987a). Chapter 3, objective 1.2 provides additional information on refuge impoundments and their current management.

Pool 1 consists of approximately 116 acres and receives water from Great Brook, Middle Brook, and direct precipitation. This pool contains primarily herbaceous species with some open water and buttonbush stands. The dominant vegetation in Pool 1 is cattail (*Typha* spp.), burreed (*Sparganium* spp.), mild water pepper (*Polygonum hydropiperoides*), wool grass (*Scirpus cyperinus*), buttonbush (*Cephalanthus occidentalis*), bulrush (*Scirpus* spp.), and willow (*Salix* spp.). The purpose of Pool 1 is to provide waterfowl roosting, brooding, feeding, resting, and loafing habitat during migration (USFWS 1987; USFWS 2003b).

Pool 2 consists of approximately 295 acres and receives water from Primrose Brook, Great Brook, and precipitation (USFWS 2003b). This pool contains persistent herbaceous vegetation, as well as a high diversity of red maple swamp and flooded timber (USFWS 1987). The dominant plants are cattail, swamp rose mallow (*Hibiscus palustris*), burreed, wool grass, smartweeds (*Polygonum* spp.), pickerelweed, common reed grass, willows, and some live and standing dead timber in the northwest section of the impoundment (USFWS 2003b). The purpose of Pool 2 is to provide habitat for wildlife, particularly passerines and waterbirds, as well as roosting and feeding habitat for waterfowl during migration (USFWS 1987; USFWS 2003b).

Pools 3A and 3B encompasses approximately 55 and 88 acres, respectively, and are naturally occurring marshes with a mixture of herbaceous vegetation. Pool 3A is dominated by burreed, cattail, wool grass, buttonbush, and various other shrubs. Pool 3A receives water from Pool 2 via a feeder ditch Water Control Structure (WCS) #23, Pool 3B via WCS #34, and precipitation (USFWS 2003b). The pool was managed as a green timber impoundment favoring mast production of oaks (USFWS 1987). Pool 3B receives water from Pool 3A through WCS #34, Middle Brook via WCS #35, and precipitation. The pool is characterized by stands of cattail, buttonbush, and various other shrubs, ash, willow, red maple, pin oak (*Quercus palustris),* bulrush, swamp rose mallow, burreed, tussock sedge (*Carex* spp.), arrow arum, purple loosestrife, and common reed grass. The purpose of Pools 3A and 3B is to provide feeding and roosting habitat for waterfowl during migration (USFWS 2003b). The pools are frequently used by migratory waterfowl, herons, bitterns, rails and marsh wrens (USFWS 1987).

USFWS

Middle Brook Pool is approximately 17 acres in size and receives water from Pool 1 through WCS #5, and a 100-foot emergency spillway between Pool 1 and Middle Brook, and some small ponds, during times of flooding (USFWS 2003b). The upper reaches of the pool are dominated by tussock sedge. During a draw down, the lower portions of the pool are dominated by smartweeds, millets, sedges, burreed, wool grass, cattail, and swamp rose mallow (USFWS 2003b). Middle Brook Pool is used by nesting waterfowl and as a loafing area for Canada geese (USFWS 1987). The purpose of this pool is to provide feeding and roosting habitat for migratory waterfowl (USFWS 2003b).

In addition to the five major impoundments, a small 4-acre impoundment was constructed near the refuge headquarters to serve as an observation pond for visitors. This pond is particularly popular with visitors in the season following a mechanical set back of plant succession and is often considered a "must stop" for birders (Byland 2001). Early in the season the water is held at a depth of 4 to 6 inches to attract early waterfowl migrants. Every few years, the impoundment is drawn down completely after the shorebirds have left and the soils are disked to set back perennial plants. Water is pumped back into the impoundment a few weeks later to create a moist soil condition. The most common plants observed in the impoundment include sedges, pondweeds (*Potamogeton* spp.), blunt spikerush (*Eleocharis obtusa*), common water plantain (*Altisma plantago-aquatica*), and seedbox (*Ludwigia alternifolia*) (USFWS 2003b). Although much smaller than the impoundments, this pool attracts a variety of shorebirds in numbers that compare to or occasionally exceed the larger impoundments (Byland 2001).

Grassland/Grassland Management

Great Swamp NWR contains approximately 793 acres of maintained open habitats dominated by herbaceous species. Most of these grassland habitats are identified as “successional wet meadow” in the 2008 NaturServ Report. These areas are periodically mowed to suppress woody vegetation growth. Some of the grassland areas are fragmented by narrow hedgerows of trees and woody vegetation. Larger patches of grasslands are utilized by low densities of regionally prioritized bird species, such as bobolink, Northern harrier, and Eastern meadowlark. Larger grassland habitats are also used for interpretive programs, including bluebird box programs run by the Friends of Great Swamp. Chapter 3, objective 2.1 describes the current management practices of grasslands.

In addition, approximately 20 acres of grasslands are designated as administrative grassland have management constraints due to the presence of historic landfills or dump sites and must be maintained as open fields. All of these historic landfills or dump sites have been remediated, are considered “stable” due to depth of contamination, or are in some stage of remedial action or investigation. These sites will continue to be maintained and monitored in the future in accordance with O&M Plans.

Brushland Management

Great Swamp NWR contains approximately 314.5 acres of successional field habitat containing a mix of woody and herbaceous species. The 2008 NaturServ study identified these areas primarily as “Successional Wet Meadow” (see table 2-16). These brushland management areas may contain nesting woodcock, State-listed species such as wood turtle, and support regionally prioritized shrub –nesting species such as blue-winged warbler. Threats to the refuge’s successional habitats include invasive species, particularly multiflora rose (*Rosa multiflora*); forest succession; altered hydrology due to historic trenching, ditching and channelization.

Scrub-Shrub Wetlands

These areas include 58.0 acres of naturally occurring shrub swamps dominated by species such as buttonbush, shadbush, swamp rose and dogwoods (see table 2-16). These habitats are scattered throughout the Wilderness Area and to a lesser extent, portions of the Management Area east of Pleasant Plains Road. These habitats may contain standing water. These habitats support priority bird species in BCR 28 and 29, such as American woodcock, blue-winged warbler and willow flycatcher.

<u>Other Land cover types</u>

Administrative

This land cover type includes the two primary administrative facilities comprising approximately 7.8 acres at the refuge: the Headquarters Buildi ng and the Visitor Center. The m apping cover includes the buildings, associated lots and surroundi ng manicured areas that may inclu de components of cool seas on grasses, hedgerows and shrubs.

Transportation/Utilities

This land cover designation refers to approximately 73 acres of management roads which are currently restricted from public access and utility rights-of-way for power and gas lines. Utility rights of way are generally kept open for maintenance purposes but may contain a variety of sensitive habitats including scrub-shrub and non-forested wetland habitats that support regionally prioritized or threatened and endangered species.

Residences

There are multiple residences on the refuge that are utilized by single families and refuge staff. These areas comprise approximately 27.5 acres of land cover on the refuge. This land cover type includes the structure itself and associated lawns and manicured areas.

Refuge management is most often focused on restoring, managing, or maintaining habitats or certain habitat conditions to benefit a suite of focal species or a suite of plants and animals associated with a particular habitat. The high and moderate priority habitats of Great Swamp NWR were identified based on information compiled (e.g., site capability, historic condition, current vegetation, conservation needs of wildlife associates). As part of this process, any limiting factors that affect the refuge's ability to maintain these habitats were also identified. Since all management activities cannot feasibly be undertaken at the same time, habitats were prioritized based on the following ranking factors:

- Where management actions would provide the greatest conservation benefit to identified priority species;
- Current habitat conditions and the urgency of needs for active management, and
- Landscape level rankings for particular habitats.

Although a habitat may be ranked as a "moderate" priority, this should not be interpreted as meaning that the habitat type does not provide valuable habitat to a variety of species or contribute to the overall biological diversity, integrity, and environmental health of the refuge. In some cases, habitats may not require active management by the refuge, or may represent an area where little management capability is available.

TABLE 2-16: CCP HABITAT TYPES AND NVCS VEGETATION COMMUNITIES

Habitat	NVCS Community identified in NaturServ Report (Sneddon 2008)	Dominant Vegetation
Non-Forested Wetlands	Floodplain Pool	*Peltandra virginica, Dulichium arundinaceum, and Polygonum spp.*
	River Bulrush Marsh*	*Schoenoplectus fluviatilis, Peltandra virginica, Hibiscus spp.*
	Eastern Cattail Marsh	*Typha angustifolia, Typha latifolia, Boehmeria cylindrica, Mikania scandens, Peltandra virginica*

TABLE 2-16: CCP HABITAT TYPES AND NVCS VEGETATION COMMUNITIES		
Habitat	NVCS Community identified in NaturServ Report (Sneddon 2008)	Dominant Vegetation
	Leafy Forb Marsh	*Pontederia cordata, Sagittaria latifolia, Peltandra virginica, Polygonum robustius*
	Eastern Reed Canary Marsh	*Phalaris arundinacea*
	Eastern Tussock Sedge Meadow	*Carex stricta, Boehmeria cylindrica*
	Waterlily Aquatic Wetland	*Nuphar lutea*
Grassland, Grassland Management, Administrative Grasslands	Successional Wet Meadow	*Carex stricta, Euthamia graminifolia, Phalaris arundinacea, Rubus allegheniensis, Spiraea tomentosa, Vernonia noveboracensis*
Brushland Management	Successional Wet Meadow	*Carex stricta, Euthamia graminifolia, Phalaris arundinacea, Rubus allegheniensis, Spiraea tomentosa, Vernonia noveboracensis*
Scrub-Shrub Wetlands	Buttonbush Shrub Swamp	*Cephalanthus occidentalis, Bidens discoidea, Carex comosa, Carex stricta,*
	Blueberry Wetland Thicket*	*Vaccinium corymbosum Clethra alnifolia, Rhododendron viscosum, Carex stricta, Impatiens capensis, Osmunda cinnamomea*
	Successional Shrub Swamp	*Rosa palustris, Cornus amomum, Carex stricta, Typha latifolia, Cornus sericea*
Upland Forest	Coastal Plain Beech–Chestnut Oak Forest	*Prunus serotina, Liriodendron tulipifera, Acer rubrum, Fraxinus americana, Fagus grandifolia, Kalmia latifolia, Quercus prinus*
Impoundments	Isolated Basins NVCS Components of Non-Forested Wetlands and Scrub-Shrub Wetlands	*Spiraea tomentosa, Vaccinium corymbosum, Carex stricta, Phalaris arundinacea, Nuphar lutea* ssp., *Spiraea tomentosa, Vaccinium corymbosum, Carex stricta, Phalaris arundinacea,*

TABLE 2-16: CCP HABITAT TYPES AND NVCS VEGETATION COMMUNITIES		
Habitat	NVCS Community identified in NaturServ Report (Sneddon 2008)	Dominant Vegetation
		Nuphar lutea ssp. *Advena Spiraea tomentosa, Vaccinium corymbosum, Carex stricta, Phalaris arundinacea, Nuphar lutea* ssp.
Bottomland Forest	Beech-Red Maple Subhydric Forest	*Acer rubrum, Fagus grandifolia, Liquidambar styraciflua, Vaccinium corymbosum*
	Red maple –Lizard's Tail Forest	*Acer rubrum, Fraxinus pennsylvanica, Saururus cernuus*
	Red Maple-Black Gum Swamp	*Acer rubrum, Clethra alnifolia, Nyssa sylvatica, Viburnum dentatum*
	Beech-Red Maple Subhydric Forest	*Acer rubrum, Fagus grandifolia, Liquidambar styraciflua, Vaccinium corymbosum*
	Northeastern Modified Successional Forest	*Prunus serotina, Liriodendron tulipifera, Acer rubrum, Fraxinus americana*
	Pin Oak-Swamp White Oak Forest	*Quercus palustris, Quercus bicolor, Liquidambar styraciflua, Viburnum dentatum*
	Pin Oak Small River Floodplain	*Fraxinus pennsylvanica, Quercus palustris, Polygonum virginianum, Lindera benzoin*
	Red Maple Swamp Wooded Marsh, Red Maple Tussock Sedge Wooded Marsh	*Acer rubrum, Carex stricta, Clethra alnifolia, Saururus cernuus, Vaccinium corymbosum Fraxinus pennsylvanica,*
Bottomland Forest	Ash-Red Maple Impoundment	*Fraxinus americana, Acer rubrum, Vaccinium corymbosum*
	Woodland Vernal Pool	*Acer rubrum, Quercus alba (overhanging),Clethra alnifolia, Vaccinium corymbosum*
	Northeastern Modified Successional Forest	*Fagus grandifolia, Betula lenta, Carpinus caroliniana*

Altered Habitats

Prior to FWS ownership and management, the long history of ditching, draining and clearing of the western portion of the refuge has resulted in a variety of altered habitats with plant communities and land formations reflecting past disturbances. Subsequently, the FWS implemented various restoration efforts throughout the refuge, such as plugging ditches and creating approximately 500 acres of impoundments. The linear nature of many vegetation and topographical boundaries in the western portion of the refuge is indicative of historic land manipulation (Sneddon 2008). Aerial photographs of the eastern portion of the refuge (Wilderness Area) show less disturbed vegetation, hydrological and topographic conditions, and the gradients between these habitats and vegetation communities tend to be more subtle and non-linear.

Other altered habitats include areas that are kept in varying stages of vegetation succession by periodic mowing to increase the refuge's overall habitat and wildlife diversity. Fields that were managed for haying when in private ownership are now managed as early-successional wet meadows with shrub cover ranging from 6 to 60 percent, depending on mowing frequency (Sneddon 2008). Areas such as modified successional forest, successional wet meadow and successional shrub swamp are additional altered communities that have historically experienced vegetation clearing.

2.5.3 Rare Plants and Exemplary Natural Communities

A review of the NJDEP's Natural Heritage Program (NHP) database did not indicate the presence of any State or globally rare plant communities on the refuge; however, the 2008 NatureServ study revealed the presence of one rare vegetation association, known as Floodplain Pool (Sneddon 2008). The Floodplain Pool Association is described as an herbaceous community that may form a continuous bed along the side of slowly flowing water in larger streams, or be characteristic of smaller channels within the floodplain of the larger streams. This association is identified as globally imperiled. According to the NatureServ report, the rank of the Floodplain Pool also indicates there are likely to be fewer than 20 viable examples globally. The global rank of this community is still not fully confirmed as additional data is needed to rank the association with greater confidence. Sneddon (2008) identified this habitat in 13 polygons comprising approximately 31 acres on the refuge. The Floodplain Pool Association is mapped along portions of the Passaic River, Black Brook and Great Brook.

Many other refuge associations have not yet been globally ranked due to an overall lack of data on the particular association. Other habitats, including vernal pools and spring fed emergent wetlands, are not known to support rare plants or plant communities at the refuge, but are still important due to their ability to support State or federally listed threatened and endangered wildlife species.

The NHP database revealed three historic records of rare wetland plants on or immediately adjacent to the refuge. These species include the featherfoil (*Hottonia inflate;* G4/S1; recorded 1947 & 2009), water-plantain spearwort (*Ranunculus ambigens;* G4/S2; recorded 1936) and black-girdle woolgrass (*Scirpus atrocinctus;* G5/S1*;* recorded 1951). No other rare plants were recorded on or adjacent to the refuge in the database.

Two field vegetation surveys were conducted by Bowman's Hill Wildflower Preserve in 2008, which revealed the presence of water horehound (*Lycopus americanus* var. *longii*), a State-ranked imperiled or vulnerable plant (S2/S3). The first survey area was located adjacent to the Great Swamp NWR Visitor's

Center on Pleasant Plains Road and situated along the Passaic River. This survey area included riparian woodlands and a vernal pool. Eighty-six plants, 87 percent of which are native to New Jersey, were identified during the survey (Bowman's Hill Wildflower Preserve 2008a). The second survey area was located adjacent to Great Swamp NWR Visitor's Center and situated between Pleasant Plains Road and the Passaic River. This survey area consisted of "damp sedgy field… that has been used for grazing sheep and, more recently horses" (Bowman's Hill Wildflower Preserve 2008b). Collectively, 131 plants, 58 percent of which are native to New Jersey, were identified during the survey (Bowman's Hill Wildflower Preserve 2008b).

2.5.4 Invasive Plant Species

Executive Order 13112 (see section 2.1.5, Invasive Species, Pests and Diseases) requires the National Invasive Species Council (Council) to produce a National Invasive Species Management Plan (Plan) every two years. In January 2001, the Council released the first Plan, which serves as a blueprint for all Federal action on invasive species. Collaboration between the Council and the *Fulfilling the Promise* team, also known as the National Invasive Species Management Strategy Team, furthered the Plan to focus on invasive species control and management efforts in the Refuge System. This National Strategy, developed in 2003, provides precise guidance to regional and field offices, and identifies four primary goals, including 1) increase awareness; 2) reduce impacts to refuge habitats; 3) reduce impacts to neighboring lands; and 4) utilize and develop new integrated pest management approaches (USFWS 2003a). The Plan focuses on those non-native species that cause or may cause significant negative impacts and that do not provide an equivalent benefit to society. A major component of vegetation management within all Great Swamp NWR habitats involves the control of invasive plant species.

TABLE 2-17: COMMON INVASIVE PLANT SPECIES AT GREAT SWAMP NWR AND PAST CONTROL EFFORTS

Common Name	Scientific Name	Control Efforts By the Refuge
Autumn Olive	*Elaeagnus umbellata*	Cut stem application of herbicide application in select areas.
Russian Olive	*Elaeagnus angustifolia*	Cut stem application of herbicide application in select areas.
Japanese Barberry	*Berberis thunbergii*	Started treating herbicide in 2001, killed more than 70,000 plants.
Japanese Knotweed	*Polygonum cuspidatum*	Foliar treatment as well as "snip and drip" application of herbicide
Garlic Mustard	*Alliaria petiolata*	Will be receiving biological control from Cornell.
Multiflora Rose	*Rosa multiflora*	Cutting and herbicide spot treatment in select areas.
Common Reedgrass	*Phragmites australis*	Treatment with herbicide on more than 40 monoculture tracts over three years.

TABLE 2-17: COMMON INVASIVE PLANT SPECIES AT GREAT SWAMP NWR AND PAST CONTROL EFFORTS		
Common Name	Scientific Name	Control Efforts By the Refuge
Purple Loosestrife	*Lythrum salicaria*	Treatment with herbicide from 1985-1995. Beginning in 1995, ½-million Galerucella beetles released, resulting in significant reduction in *L. salicaria* by 2005.
Reed Canary Grass	*Phalaris arundinacea*	Herbicide spot treatment in select areas.
Japanese stiltgrass	*Microstegium vimineum*	Hand pulling by volunteers and some herbicide treatment in select areas.
Bradford pear	*Pyrus calleryana*	Removal of 3,000 trees. Deer killed off 50% of the root systems.
Asiatic Bittersweet	*Celastrus orbiculata*	Cutting and base application of herbicide in select areas.
Wineberry	*Rubus phoenicolasius*	No management to date.
Tree-of-Heaven	*Ailanthus altissima*	Some cutting.
Japanese wisteria	*Wisteria floribunda*	Cut stem
Chinese Lespedeza	*Lespedeza cuneata*	All areas found have been treated with herbicide and monitored regularly.
Long-bristled smartweed	*Polygonum caespitosum*	No management to date.
Mile-a-minute vine	*Polygonum perfoliatum*	Hand-pulling by staff and volunteers and release of weevils for biological control.
Japanese honeysuckle	*Lonicera japonica*	Cut stem application of herbicide in select areas.

The 2008 NatureServ report indicates differences in distribution, abundance and composition of invasive species between the western and eastern portions of the refuge. Pre-refuge land manipulation (i.e., ditching, draining, agriculture, and logging) and some refuge management activities within the western portion of the refuge have resulted in the establishment of several invasive species. The eastern portion of the refuge (Wilderness Area) has undergone less intensive land use manipulations and therefore contains fewer invasive species.

Some invasive species were historically planted as wildlife food plots on the refuge, including multiflora rose, crown vetch, Russian olive, and autumn olive. In addition, birdsfoot trefoil and crown vetch were planted in dikes and fields for soil erosion control and fertility (USFWS 1987).

Within the historically disturbed and successional forested areas, species such as garlic mustard, wineberry, Japanese honeysuckle, multiflora rose, tree-of-heaven, Japanese stiltgrass and long-bristled smartweed may be observed. Certain species, such as reed canary grass, purple loosestrife and common reed, are highly capable of creating monotypic cultures and are most common in heavily manipulated wetland areas and along utility rights-of-way.

The following list briefly describes the common invasive plants of Great Swamp NWR (table 2-17):

Autumn Olive (Europe and Asia) - Autumn olive is a dense shrub or small tree found in old fields, roadsides, pastures and open woodlands. The species may shade out native species and is a nitrogen fixer that may alter soil nitrogen cycling and consequently impact natural plant succession (Swearingen et al. 2002).

Japanese Barberry (Asia) - This thorny shrub is found in alluvial woods and open forest understory. Barberry can grow densely in the understory, reducing habitat quality for birds and other wildlife and displacing native forest understory species (Swearingen et al., 2002). It may also raise the pH of soils and reduce litter layers in forests (DCNR 2002).

Japanese Knotweed (eastern Asia) -This species is a large herbaceous perennial that reaches heights of over 12 feet. It is a highly adaptable species tolerant of extreme conditions, such as high heat or shade (Swearingen et al., 2002). It is found in disturbed areas, roadsides, floodplain forests, and often along streams and other waterbodies. The species forms monoculture stands that impact riparian habitat by reducing plant and wildlife diversity (Swearingen et al., 2002; Snyder and Kaufman 2004). It may also alter water flow along streams and contribute to flooding.

Garlic Mustard (Europe) - Garlic mustard occurs in moist woodlands, floodplains, along trails and forest edges. The species reduces native herbaceous diversity and lowers habitat quality. As with many other invasive plants, it can suppress growth of native seedlings through allopathic chemicals (Snyder and Kaufman, 2004). The species displaces many native spring wildflower species of woodland habitats. It is also avoided by white-tailed deer (Swearingen et al., 2002).

Multiflora Rose (Asia) - Multiflora rose is found in a variety of habitats, including forest edges and gaps, floodplains, utility rights-of-way, roadside edges and other disturbed areas, grasslands and open wetlands. This thorny shrub produces dense monocultures that are impenetrable to humans and wildlife. This species outcompetes native species and reduces overall native species diversity (Snyder and Kaufman, 2004).

Common Reed or Phragmites (Europe) – The range of Common reed is pan-global (USDA : however, European strains have replaced much of the native common reed in the United States (Swearingen et al., 2002). Phragmites inhabits a variety of brackish and freshwater marsh habitats, as well as riverbanks, ditches, and dredge spoil areas. Large marsh areas, such as areas around the Newark Basin (including the Meadowlands, Great Meadows, Troy Meadows, and Great Swamp) are subject to *Phragmites* monocultures that reduce native plant species diversity and wildlife use.

Purple Loosestrife (Eurasia) - Purple loosestrife is a perennial herb with woody stems that produces a large purplish showy spike. It occupies open habitats, including sedge meadows, cattail marshes, streamside areas, floodplains, bogs, ditches and other disturbed wetlands. It is an aggressive reproducer that grows in monotypic stands that can alter wetland hydrology, reduce native plant diversity, impact sensitive wildlife, and decline overall production of the wetland (Snyder and Kaufman 2004).

Reed Canary Grass is a large fast growing wetland grass that occurs throughout the temperate northern hemisphere. It is found in a variety of moist environments, including wet meadows, marshes, pastures and riparian habitats (DCNR 2002). Possibly native strains may have crossed with European and other exotic strains to produce a more robust genetically diverse and invasive strain. Reed canary grass creates a dense monoculture that outcompetes and smothers native species and drastically drops wetland diversity (DCNR 2002).

Japanese Stiltgrass (Asia) – Japanese stiltgrass grows in a wide variety of habitats, including wetland floodplains, forested uplands, forested and open wetlands, roadside ditches and other disturbed areas. This species grows rapidly and often in large dense patches. As with many other invasive plants, it forms a monoculture that reduces overall diversity and plant production (Snyder and Kaufman 2004).

Bradford Pear (Asia) – Bradford pear, a 30 to 50 foot tree, is planted as an ornamental and is popular for its showy white spring flowers. Bradford pear has become invasive as new strains have naturalized in the northeast (Swearingen et al., 2002). The species displaces native vegetation in open areas and interrupts succession processes (Swearingen et al., 2002).

Asiatic Bittersweet (eastern Asia) – Asiatic bittersweet is aggressive vine inhabits forest edges, open woodlands, fields, hedgerows and other disturbed lands. Asiatic bittersweet grows over native vegetation and kills trees by shading, girdling and uprooting them (Swearingen et al., 2002).

Wineberry (Asia) - Wineberry is a shrubby vine that grows along forest habitats that include wooded ravines and floodplains, shale bluffs and successional fields. The species can grow in impenetrable thickets that threaten certain rare plant communities (Snyder and Kaufman 2004).

Tree-of-Heaven (central China) - Tree-of-heaven may be found in a variety of disturbed sites with rocky or poor soils, including vacant lots, forest edges, roadsides, and other disturbed areas. It also sometimes establishes itself in old growth forest gaps created by fallen trees. It may also occur on trap rock or basalt cliff faces, such as those found along the Northern Watchungs or Palisades. The species breeds rapidly and can through chemical means, suppress the growth of native species and interfere with natural forest succession (Snyder and Kaufman 2004).

Japanese Wisteria (Japan) - Japanese wisteria is a woody vine introduced to North America in the early 19th century as an ornamental. It primarily spreads by vegetative growth and is capable of growing to a height of 35 feet. Japanese wisteria impacts native forest by girdling and killing trees as it grows. This can ultimately change the structure of a forest by altering sunlight penetration to the forest floor (CISEH 2010).

Chinese Lespedeza or Chinese Bush-Clover (eastern Asia) - Bush-clover is an erect perennial legume that grows in dense stands. Chinese bush-clover tolerates varying soil conditions, including very nutrient poor soils. Habitats vary widely, including forest edges, fields, open woodlands and wetland edges (Snyder and Kaufman 2004).

Long-bristled Smartweed (Oriental Lady's Thumb) (Asia) - This smartweed is a small herbaceous plant reaching 30 inches (CISEH 2010). It grows in disturbed habitats, such as pastures, yards, meadows, rights-of-way, and roadsides. It is also found in forests and shaded areas. Its ability to tolerate extreme shaded areas and a range of pH make it potential problem in moist shaded habitats, such as damp forests (Mehrhoff et al., 2003).

Japanese Honeysuckle (Eurasia) – Japanese honeysuckle is an aggressive vine that grows in a variety of disturbed habitats, including forest understories, old fields, roadsides, thickets, fence rows and rocky bluffs.

The vines can grow dense mats that smother and collapse native plants and result in a loss of plant regeneration (Snyder and Kaufman 2004).

Mile-a-Minute Weed (Asia) - Mile-a-minute weed is spreading northward throughout New Jersey from the south. This vine invades open and disturbed areas including roadsides, forest edges, wetlands, and stream edges. It is a sprawling plant that grows rapidly overtop of native plants, shading from light exposure (Snyder and Kaufman 2004).

2.6 Wildlife Resources

2.6.1 Federally Listed Threatened and Endangered Species

There are currently two federally listed species that have established populations at Great Swamp NWR, the federally listed threatened bog turtle and the federally listed endangered Indiana bat. Both of these species utilize specific habitats at Great Swamp NWR. The bog turtle is a year-round resident that utilizes certain open wetlands at the refuge. Reproductively active female and juvenile Indiana bats were first identified on the refuge in 2005. The Indiana bat uses refuge swamp forests and riparian corridors for maternal roosts and as foraging habitat during warmer months. Both of these species have been studied extensively on the refuge and are given primary consideration in the CCP and in wildlife management decisions. Summaries of the FWS recovery plans for these species are included in chapter 1 of the CCP.

Bog Turtle

The Northern population of the bog turtle is a federally listed threatened species and listed as Endangered in the State of New Jersey. The New Jersey NHP's ranking system identifies the bog turtle as G3 (globally, either very rare and local throughout its range or found locally in restricted range or because of other factors making it vulnerable to extinction throughout its range) and S1 (critically imperiled in New Jersey because of extreme rarity; Natural Heritage Program 2008).

The NJWAP lists the species as a high priority with a goal to increase and stabilize the population in the Piedmont Region of New Jersey. Protection of this species' habitat would benefit other key refuge resources of concern, such as spotted turtle (*Clemmys guttata*), American woodcock (*Scolopax minor*), and various passerines, including but not limited to, common yellowthroat (*Geothlypis trichas*), golden-winged warbler (*Vermivora chrysoptera*), song sparrow (*Melospiza melodia*), swamp sparrow (*Melospiza georgiana*), and blue-winged warbler (*Vermivora pinus*).

Among the contributing factors to the decline of bog turtles is habitat destruction due to development; illegal collection; wetland ditching, flooding and filling; water quality degradation; and forest succession or invasive species encroachment (Beans and Niles 2003). Bog turtles require open wetlands, generally with a scrub-shrub component, with perennial groundwater seepage and typically several inches of mucky substrate (generally greater than 4"). Bog turtle populations inhabit areas on the refuge, which are locally uncommon and unique.

The bog turtle utilizes calcareous (limestone) fens, sphagnum bogs, and wet, grassy pastures and occasionally linear drainage ditches characterized by soft, muddy substrates and perennial groundwater seepage (Conant 1975; Behler and King 1979; Ernst et al., 1994). Habitats regularly utilized typically contain water depths no greater than 4 inches (10 cm) above the substrates with some deeper portions. The bog turtle favors open areas for basking and nesting. Vegetation can include cattails (*Typha latifolia, T. angustifolia*), tussock sedge (*Carex stricta)*, other sedge species *(Carex* spp., *Cyperus* spp., *Dulichium* spp.), rushes (*Juncus* spp.), bulrushes (*Scirpus* spp.), spikerushes (*Eleocharis* spp.), spotted jewelweed (*Impatiens capensis*), red maple (*Acer rubrum*), alders (*Alnus* spp.), skunk cabbage (*Symplocarpus foetidus*), arrow-leaved tearthumb (*Polygonum sagittatum*), rice cut-grass (*Leersia oryzoides*), and other open canopy wetland species (Cromartie, et al. 1982). In addition to soft mucky substrates for burrowing and hibernation sites may have an interspersion of wet and dry areas, often with the presence of muskrat and meadow vole runways for travel corridors and cryptic basking sites (USFWS 1997d).

The diet of the bog turtle generally consists of insect larvae, crayfish, mollusks, worms, snails, slugs, seeds, berries, and shoots, as well as amphibians and carrion. Eggs are deposited on raised hummocks in open areas from mid-June to early July; incubation occurs for 48 to 58 days. Eggs and young bog turtles are highly susceptible to predation by a number of animals, including raccoons, opossums, foxes, mink, skunks, muskrats, shrews, large birds (i.e., egrets, herons, crows, birds of prey), bull frogs, snapping turtles, and water snakes (USFWS 2012i). Summer home ranges average about 3.2 acres (1.3 ha). Hibernation occurs within subterranean burrows (2 to 22 inches deep), where springs ensure that water flows through winter (Beans and Niles 2003).

In the early 1960s, Rutgers University researchers were the first to raise awareness about bog turtles being located in the newly established refuge. The refuge is one of three NWRs in the Northeast in which populations of the bog turtle are known to occur. Several sites on the refuge have either had recent or historic bog turtle activity (USFWS 2012j). In May 2004, active monitoring of the refuge's bog turtle populations began using methods such as radio-telemetry, mark recapture, and nest protection (Schmuck 2012). These studies provide important information on bog turtle habitat use, home-range size, and population density, as well as identifying new subpopulations on the refuge (USFWS 2012j).

Bog turtles were initially captured by visual surveys, which consisted of locating suitable habitat and looking for tracks, feeling along the base of mature tussock sedges, and probing muck sections with a walking stick or snake stick and listening for the distinctive tap that occurs when a turtle shell is struck. If a gravid female was located, she would be kept in a nest tub until she laid her eggs. A nest tub is an enclosed area, such as a buried Rubbermaid container, that mimics their habitat. Nests in a tub are protected from predators and the elements, such as excessive shade from thick vegetation growth or flooding. The hatchlings were then marked and released on site (Schmuck 2012).

When a turtle is captured, its location is recorded using a global positioning system (GPS) along with a description of the microhabitat, its age, gender, and whether or not a female was gravid. Measurements of the carapace and plastron, weight, maximum width, and maximum height are also recorded. If a turtle is fitted with a transmitter, an additional weight is taken of the turtle with the transmitter affixed. On average, the weight on the transmitter and adhesive is approximately six grams. All turtles that are captured are marked with notches on their marginal scutes, creating a unique permanent identifying code. The code for each individual turtle is recorded and a drawing of the marked carapace is recorded on the data sheet. Any distinguishing physical characteristics and behavior when captured are also recorded (Schmuck 2012).

Since May 2004, a total of 31 bog turtles have been captured at three sites on the refuge. Of these, 17 were captured during visual surveys, three in live catch box traps, two captured while copulating with a radio-tracked turtle, four captured in nest tubs as hatchlings, and five captured as hatchlings in nest cages after the nest was located by thread spooling, a technique used to locate a bog turtle nest of known gravid females. Of the bog turtles captured, two male and eight females were classified as breeding age, which is over the age of eight (Schmuck 2012).

Beginning in 2009, the refuge began monitoring nest sites to measure clutch size and nesting success at the refuge. In 2009, the refuge monitored two nests containing three eggs each, which had 33 percent and 100 percent nest success rates. Of the eggs that did not hatch, one egg was determined to be infertile and the second contained a developing embryo, which appeared to have drowned due the egg being located at the bottom of the nest. No nests were monitored in 2010. In 2011, the refuge monitored one nest containing five eggs; however, the nest failed due to flooding associated with Hurricane Irene. In 2012, the refuge monitored two nests, which contained three and five eggs each. The nest success rate was determined to be 100 percent and 40 percent, respectively, resulting in a total of five new hatchlings. The unhatched eggs were found to be infertile. All hatchlings were marked, measured, and released on site for future monitoring (Schmuck 2012).

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In addition to active monitoring, habitat management and restoration efforts also began in 2004. Informal habitat assessments indicated a considerable portion of historic bog turtle habitat has degraded in quality due to encroachment of invasive plants and natural succession of tussock sedge-dominated wetlands to red maple swamps. Limited habitat restoration activities were conducted in select areas to open the canopy by girdling trees, cutting pole-sized trees and applying glyphosate to the stump to prevent re-growth, or injecting imazapyr into trunks of larger diameter trees. Habitat management activities also included the control of invasive plant species, such as Japanese stilt grass and common reed grass (USFWS 2012j).

The refuge will continue to conduct habitat restoration activities while also documenting the effects of habitat restoration practices, including herbicide application, on the refuge's bog turtle population and its habitat (USFWS 2012j).

Indiana Bat

The Indiana bat, a State and federally listed endangered species, utilizes riparian corridors at Great Swamp NWR for foraging and warm season roosting.

In 1967, the FWS listed the Indiana bat as federally endangered due to significant population declines documented at their seven major hibernacula in the Midwest (Beans and Niles 2003). At the time of their listing, the Indiana bat population was approximately 883,300 (USFWS 2007). Surveys conducted in 2007 estimated the range wide population at approximately 468,184. Winter surveys conducted in 2007 at known Priority 1 and 2 hibernacula sites in New Jersey estimated the population at 659 (USFWS 2008i). As of October 2006, the FWS had records of existing winter populations at approximately 281 hibernacula in 19 states and 269 maternity colonies in 16 states (USFWS 2007). In 1992, Indiana bats were found hibernating in three areas near Hibernia, New Jersey. Great Swamp NWR recently confirmed the occurrence of maternity colonies in 2005 and is the only known national wildlife refuge with Indiana bat maternity colonies.

Similar to the original recovery plan, the 2007 Revised Draft Indiana Bat Recovery Plan continues to emphasize protection of hibernacula, but also increases the focus on summer habitat and proposes use of four Recovery Units: Ozark-Central, Midwest, Appalachian Mountains, and Northeast. Great Swamp NWR is located within the Northeast Recovery Unit and within the Eastern Broadleaf Forest Ecoregion Division (USFWS 2007).

The primary goal of the recovery plan is to reclassify the Indiana bat to federally listed threatened, with an ultimate goal of removing the species from the Federal List of Threatened and Endangered Wildlife. The reclassification of the Indiana bat will be attained through the achievement of the following objectives: (1) permanent protection of 80 percent of Priority 1 hibernacula; (2) a minimum overall population number equal to the 2005 estimate (457,000); and (3) documentation of a positive population growth rate over five sequential survey periods. Similarly, delisting of the Indiana bat will be attained by addressing the following: (1) permanent protection of 50 percent of Priority 2 hibernacula, (2) a minimum overall population number equal to the 2005 estimate; and (3) continued documentation of a positive population growth rate over an additional five sequential survey periods (USFWS 2007).

A goal for increasing this population was also set for the Piedmont Region under the NJWAP. Great Swamp NWR is documented as having one or more maternal roost colonies for Indiana bat in New Jersey (Kitchell 2008). Maternal roosts are typically established in agricultural areas with fragmented forests. Roosting by Indiana bat occurs within the Management and Wilderness Areas of the refuge, where an interspersion of forests, shrubland, open water, and wet meadow exists (Kitchell 2008). Roost trees are found within a variety of forested habitats, including wetlands and riparian areas, and primarily include snags or nearly dead trees with peeling or exfoliating bark. Primary roost trees are of large diameter [greater than 22 inches diameter at breast height (dbh)] in open areas with high exposure to sunlight, while alternate roosts are generally smaller in diameter and located within the forest interior (Kitchell 2008). Foraging occurs primarily in and around forested habitats that include pole-stage mixed-oak forest, floodplain forest, upland forest, and forested wetlands (Butchkoski and Hassinger 2002; Gardner et al., 1991; Humphrey et al., 1977; Murray and Kurta 2004; Romme et al., 2002, Sparks et al., 2005). Pregnant or lactating bats forage primarily within wooded or riparian corridors, streams, associated floodplain forests and impounded bodies of water; however, they will sometimes use hedgerows, upland forest, early successional fields and along croplands (Kitchell 2008).

White-Nose Syndrome

As discussed in chapter 1, the first documented case of WNS was reported near Albany, New York in the winter of 2006 to 2007. WNS is characterized by the colonization of a psychrophilic, or “cold-loving,” fungus on the muzzle, ears, and flight membranes of hibernating bats (Blehert, et al., 2008); however, the presence of the fungus is typically only observable on approximately half of bats affected. The fungus has been identified as *Geomyces destructans.* Affected bats may exhibit low body weights and abnormal behaviors, including early emergence from hibernation and movement to colder areas of caves. WNS quickly spread to hibernacula of several other New England states the following winter. In 2008-2009, the syndrome spread as far south as Virginia and included the states of New Jersey and Pennsylvania. Since it was first documented, WNS has been confirmed in 20 states and 4 Canadian providences (USFWS 2012d). WNS has been confirmed in states as far west as Oklahoma. More than 5.5 million hibernating bats have died since WNS was documented in 2006-2007 (USFWS 2012d). In some hibernacula (caves or mines where bats hibernate in winter), approximately 90 to 100 percent of bats are dying (USFWS 2010c). The majority of bats dying in the Northeast have been little brown bats; however, WNS has also affected tri-colored, Northern long-eared, big brown, Eastern small footed, and Indiana bats (USFWS 2010c).

In 2009, WNS was confirmed in five hibernacula in New Jersey, including Hibernia mine, both Mount Hope mines, and Upper and Lower Copper mines (NJDEP 2009a). Data suggests that at least some of the refuge's Indiana bats winter in Hibernia and Mount Hope mines (Kitchell 2011). A majority of the bats hibernating in Hibernia mine are little brown bats, with lesser amounts of Indiana bats and Northern long-eared bats (Valent 2011). Visual signs of the fungus and behavioral changes were observed in Hibernia mine in January 2009 and mortality was evident in March to April 2009 (Valent 2011). In February 2010, NJDFW estimated 93 percent mortality in Hibernia mine (Valent 2011). The presence of WNS in New Jersey has resulted in at least a 50 percent decline in *Myotis* species (Valent 2011). Data indicate substantial changes in the bat population and the proportion of maternal females (see chapter 1, section 1.4.14).

Pre- and Post-WNS Research: Population Trends

The refuge has accumulated six summers of intensive bat population and roosting ecology data. Mist-netting and banding of captured bats occurred from May 15 through August 15 from 2006 to 2010 and from June to August 2012. While previous years' netting targeted flight corridors expected to yield Indiana bats, netting in 2012 aimed to comprise foraging habitat of all native, cave-dwelling bats on the refuge and assess the impacts of WNS on species populations. These combined datasets may represent the richest pre- and post-WNS population monitoring database of any refuge in the Region (USFWS 2012g).

Prior to the discovery of WNS in New Jersey, research was conducted at the refuge during the summers of 2006 and 2007 to determine roost selection and landscape movements of Indiana bats (USFWS 2012g; M. Kitchell 2008). The primary goal of the study was to identify and characterize roosts selected by reproductively active female Indiana bats, although all bats captured during mist netting efforts were identified to species, examined to assess general health, and fitted with numbered aluminum bands. Research was continued for another three field seasons (from 2008 to 2010), collecting similar information, except that both sexes of Indiana bats were studied (USFWS 2012g; L. White, In Prep.). Thus, 3 years of data were collected on bats at the refuge prior to detection of WNS in the State.

During the first two years of the study (2006 to 2007), a total of 520 bats representing six species were captured, including Indiana bat, little brown bat, big brown bat, Northern long-eared bat, red bat, and tri-colored bat (USFWS 2012f). Twenty four female Indiana bats were radio-tracked to 74 roost sites, representing three colonies, and peak emergence counts of Indiana bats at four primary trees were 252, 164, 52, and 55 bats (M. Kitchell 2008). During the following three summers (2008 to 2010), a total of 680 bats representing seven species were captured, including the aforementioned species as well as hoary bat (*Lasiurus cinereus*) (USFWS 2012f; L. White, In Prep). However, the number of bats captured among the three years differed ($P < 0.05$). For example, in 2008, 276 bats (representing 40.6 percent of all captures from 2008 to 2010) were captured; in 2009, the number was 231 (34.0 percent of all captures); and in 2010, 173 bats (25.4 percent of all captures) were captured. Decreasing numbers of captures over the three-year period were attributed to the emergence of WNS in New Jersey (USFWS 2012f; L. White, In Prep.).


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No research was conducted in 2011. However, the 2012 bat inventory and monitoring effort at the refuge comprised mist netting at a level of effort comparable to previous years (2006 to 2010), radio-telemetry, and both mobile and stationary acoustic surveys. Nine mist net sites were sampled across the refuge, seven of which were netted historically. Demographic and morphometric data were gathered for all captured bats. A combination of swab sample collection and wing score indexing was used to detect evidence of WNS, and individuals were fitted with numbered aluminum bands. Select bats were radio-tagged and tracked to roosts daily for the lifespan of the transmitters.

During the summer 2012, a total of 215 bats representing five species were captured. Proportions of little brown, Indiana, and big brown bats continued the trend from 2008-2010, with little brown bat captures dropping by an additional 3.8 percent and Indiana bat captures by 5.9 percent from 2010 to 2012, while big brown bat captures increased from 68.2 percent in 2010 to 82.8 percent in 2012. Relative proportions of Northern long-eared bats and tri-colored bats also declined, with Northern long-eared bat captures decreasing by 4.5 percent and tri-colored bat captures by 5.2 percent. Additionally, the proportion of Eastern red bats captured in mist-nets increased by 5.5 percent (USFWS 2012g). The results of swab sample collection and Wing Score Indexing from 2012 have yet to be analyzed (USFWS 2012g).

The complete data from 2006 to 2012 demonstrate total declines of 39.9 percent in little brown bat captures, 16.6 percent in Indiana bat captures, 6.6 percent in Northern long-eared bat captures, 3.4 percent tri-colored bat captures, and total increases of 57.7 percent in big brown bat captures and 9.2 percent in Eastern red bat captures since 2006 (USFWS 2012g). These trends suggest that WNS has caused a marked reduction in the number of *Myotis* species on the refuge, particularly little brown bat. Recent increases in the proportion of big brown bat and Eastern red bat captures suggest that these species are resistant or resilient to the fungus and may be experiencing population increases or range expansions, potentially resulting from recent niche vacancies or reduced roosting and foraging competition by *Myotis.*

Table 2-18: Number of Each Bat Species Captured at Great Swamp NWR (2006-2010 and 2012)						
Species	Pre-WNS			Post-WNS		
	2006	2007	2008	2009	2010	2012
Little brown bat	98	133	114	3	9	3
Big brown bat	60	74	82	151	118	174
Indiana bat	40	46 35 26 11				1
Northern long-eared bat	20	28 24 33 11				4
Tri-colored batF	8	5 8 8 9 0				
Eastern red bat (*Lasiurus borealis*)	9	9	13	8	13	32
Hoary bat (*Lasiurus cinereus*)	0	0 0 2 2 0				

Source: Kitchell, M.E. and L.A. White. "Community Ecology of Bats on the Maternity Range: A Comparison Pre- and Post-White-Nose Syndrome." 2010.

Further research will be useful in documenting the extent that WNS is impacting both sexes of all cave-dwelling bat species that use the refuge. Data will be compared to that collected pre-WNS to aid in understanding the severity of bat population declines.

Roost Selection

Evaluation of bat roosting ecology was performed from 2006 to 2010, which involved locating roosts (typically through radio-telemetry), and then measuring the characteristics of those roosts and surrounding areas. Roost tree and surrounding habitat characteristics (e.g., roost species, dbh, height, decay stage, canopy cover, habitat type, dominant vegetation, etc.) were analyzed and compared to other roost locations in order to depict habitat requirements or preferences within a given area. Roost fidelity and longevity were also assessed through the potential recapture of previously banded individuals or the use of previously marked roosts by newly radio-tagged individuals (USFWS 2012g; L. White, In Prep).

During 2006 and 2007, reproductively active female Indiana bats were fitted with radio-transmitters and tracked daily to identify roosts and foraging areas. Once roost trees were identified, standardized measurements were taken for each identified roost tree as well as randomly selected trees and their surrounding habitats (0.1 hectare). Emergence counts were conducted during 2007 at all trees containing radio-tagged bats. All known locations for radio-tagged bats (capture site, roosts, and estimated foraging points) were combined to produce home range estimates (USFWS 2012g; Kitchell 2008).

During 2006 and 2007, 24 female Indiana bats were tracked to 74 roosts, representing three colonies. Only two roosts were used by more than one transmitted bat. Four primary roost trees yielded peak emergence counts of 252, 164, 52 and 55 bats. Selected roosts were comparable to those documented in the literature in terms of recorded characteristics (species, decay stage, dbh, height, canopy closure); however, certain roost tree parameters varied significantly between 2006 and 2007 (dbh, height, and canopy closure). Reproductive female Indiana bats selected shagbark hickory (*Carya ovata*) and American elm (*Ulmus americana*) as roosts more often than would be expected based on comparisons with randomly selected trees. Moreover, roost plots were characterized by fewer, larger trees and a greater proportion of suitable roost trees than random plots.

The variation in roost characteristics observed between years emphasizes that Indiana bats may be flexible in their roost requirements, and the large home ranges identified suggest that bats may range widely across the habitats available to them, even if roosting and foraging habitat is not limiting. Furthermore, the number of colonies found, the number of roosts identified, and the average distance moved between roosts during 2006 and 2007 suggest that the refuge represented ideal maternity habitat for Indiana bats (USFWS 2012g; Kitchell 2008).

From 2008 to 2010, male and female Indiana bats were fitted with radio-transmitters in order to identify and compare roosts and foraging areas of both sexes. Prior to this investigation, male Indiana bats were assumed to have less restrictive habitat requirements than females; however, roost selection and foraging habitat had not been thoroughly documented for males (L. White, Prep). The results of this three-year assessment are still being analyzed (USFWS 2012g).

During 2012, 14 bats were fitted with radio-transmitters. Preference was given to reproductively active female *Myotis*; however, due to the rarity of such captures, additional individuals (a male Indiana bat, juvenile female little brown bat, five adult female big brown bat, one juvenile female big brown bat, and one adult female Eastern red bat) were also radio-tagged. Bats were tracked to roosts daily for the lifespan of their transmitters (approximately 12 days), roost characteristics were recorded, and emergence counts were performed at each identified roost. A total of 39 roosts were identified during 2012. This included 19 trees of six species (pin oak, red maple, Northern red oak, swamp white oak, American beech, and black cherry), 19 buildings (barns and houses), and one bat box. None of the roosts identified in 2012 matched any previously documented Indiana bat roosts. Three primary roosts (two barns and one house) yielded peak emergence counts of 69, 67, and 35 (USFWS 2012g).

Acoustic Monitoring

The 2012 study used mobile and stationary acoustic surveys in combination to further document the extent to which different areas of the refuge are being used by foraging bats. Bat activity (sightings and recorded calls) were documented at each of the six mobile acoustic survey sites across the Management Area, as well as each of the nine stationary survey locations across the refuge. Although these acoustic data have yet to be thoroughly evaluated, preliminary analyses suggest that numbers of recorded *Eptesicus* calls versus *Myotis* calls are comparable to relative mist-net captures for each genus, further emphasizing the shift in species abundances since pre-WNS (USFWS 2012g). Acoustic data are expected to yield a higher proportion of Eastern red bat calls than those obtained from mist-netting. Hoary bats are not known to be affected by WNS and thus should not have experienced recent population declines on the refuge; however, the species tends to forage at heights exceeding those of mist-nets, which limits their chances of being captured in mist-nets (USFWS 2012g).

2.6.2 State-listed and Other Priority Species

In addition to the two Federally listed wildlife populations, approximately 67 State-listed species (see appendix A) have been identified on the refuge, including 26 State-endangered or threatened species. Terrestrial vertebrate and some insect populations have been heavily studied and well documented on the refuge.

There are many national, regional, State, and local plans and reports that have identified species for conservation concern in and around Great Swamp NWR. For development of the Draft HMP, the myriad of species provided in each plan and potentially occurring at the refuge was compiled into a Comprehensive List of Resources of Concern. The list cross references each species that has been identified, or may be expected to occur, on the refuge with the relevant plans where it has been prioritized. Nearly 160 species are identified in the comprehensive list, including 19 waterbird species; 14 shorebird species; 87 landbirds, including 17 owls and raptors; 18 waterfowl species; 6 mammals, including 5 bat species; 5 reptile species; 4 amphibian species; 4 fish species; and 1 butterfly, Harris' checkerspot (*Chlosyne harrisii*).

Sources utilized in the development of the Great Swamp NWR Comprehensive Resources of Concern list include the following: USFWS Endangered Species List; New Jersey Threatened, Endangered and Special Concern List; Appalachian Mountains Joint Venture; ACJV; Appalachian Mountains BCR 28; Piedmont Region BCR 29; Priority Bird Species in PIF Bird Conservation Plan Physiographic Area 9; Priority Bird Species in PIF Bird Conservation Plan Physiographic Area 10; NJWAP; Federal Trust Fish Species List; Waterbird Conservation for the Americas; North American Waterbird Conservation Plan; North American Shorebird Plan Atlantic Flyway Priorities; Northeast Partners in Amphibian & Reptile Conservation (NEPARC); and Amphibians and Reptiles of the Northeast.

2.6.3 Birds

More than 240 species of birds have been recorded during various times of the year at Great Swamp NWR. The refuge provides significant migratory, wintering and nesting habitat for numerous waterfowl, waterbirds, and landbird species, particularly within the regional context of the urbanized New York City Metropolitan Area. Approximately 109 bird species have been recorded nesting within or near the refuge.

Waterfowl

Waterfowl breeding and foraging habitat has traditionally been a major focus of management at Great Swamp NWR and protection of waterfowl is defined in the original refuge purpose. Land uses that predate the refuge resulted in extensive wetland draining and ditching in the Great Swamp. Since the late 1960s, the FWS plugged many ditches to restore these drained wetlands. Over time, nature has also blocked many ditches with tree roots, dropped branches and accumulated leaf and other vegetative matter. In addition, between the early 1970s and early 1980s, five impoundments with low level dikes and water control structures were constructed. The five impoundments, encompassing 485 acres, have integrated spillways to prevent undesirable high water levels during periods of heavy precipitation and runoff. A small four-acre impoundment was also constructed near refuge headquarters as a moist soil management area for wildlife observation. This shallow pond is particularly popular with visitors during the season following a mechanical set back of plant succession. Seasonally, the water is held at a depth of 4 to 6 inches to attract dabbling ducks. Subsequently, the water is drawn down in May and June and becomes highly attractive to shorebirds. The resultant emergent wetlands and open waters of Great Swamp NWR provide vital wintering and breeding habitat for a variety of waterfowl. For additional information on impoundments and impoundment management, refer to section 2.5.2 above.

Waterfowl species that utilize the refuge for foraging or resting during migration include mallard (*Anas platyrhynchos*), American black duck (*Anas rupripes*), green-winged teal (*Anas carolinensis*), American wigeon (*Anas americana*), Northern pintail (*Anas acuta*), gadwall (*Anas strepera*), Northern shoveler (*Anas clypeata*), blue-winged teal (*Anas discors*), Canada goose (*Branta* Canadensis), Ring-necked ducks (scientific name), and bufflehead (*Bucephala albeola*). The most common waterfowl nesting on the refuge are wood duck (*Aix sponsa*), mallard, Canada goose (*Branta canadensis*), and an occasional hooded merganser (*Lophodytes cucullatus*), a State-listed Special Concern species.

Monitoring data was collected for waterfowl located in or around pools 1 and 2, pools 3a and 3b, and occasionally other locations between 1993 and 2006. The data is typically collected on a once a week basis between during the fall, winter and spring. Birds are identified as a fly over, within the waterbody or adjacent to the waterbody. The average number of waterfowl (number of observed waterfowl per single survey event) annually is presented for each species that occurs on the refuge in table 2-19 below.

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The averages presented in table 2-19 indicate that the most common spring and fall migrant waterfowl are mallards (37 percent of counted waterfowl) and wood duck (31 percent of counted waterfowl). American black duck, Canada goose and Northern shoveler all represent about 10 percent of the annual waterfowl counted. Northern pintail and American wigeon represent approximately 2 percent of the waterfowl counted. Other species noted in table 2-19 represent less than 2 percent of the waterfowl counted during annual surveys.

Average fall count of total waterfowl is approximately 1,061.1 per survey event as opposed to approximately 790.5 waterfowl per survey event in the spring. This difference is primarily driven by higher fall mallard and wood duck migratory counts which respectively average approximately 30 percent and 23 percent more birds in the fall than in the in the spring. Canada geese also have a similar percentage difference between fall and spring migratory counts.

TABLE 2-19: AVERAGE ANNUAL WATERFOWL COUNTS 1993-2006*															
Species	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Total Avg.**
Mallard	635.6	143.6	361.3	334.1	679.9	436.3	262.9	N/D	170.8	145.2	72.9	477.1	535.7	99.0	**334.9**
Wood Duck	402.0	269.4	396.1	397.8	627.8	329.8	444.1	N/D	138.6	54.6	52.5	192.8	429.7	63.0	**292.2**
Canada Goose	109.5	59.3	123.2	112.6	252.0	71.0	90.5	N/D	46.8	92.5	43.2	40.8	150.3	38.0	**94.6**
American Black Duck	106.4	19.5	109.4	111.5	209.1	162.6	102.8	N/D	41.4	36.0	12.4	76.2	104.0	27.0	**86.0**
Green-winged Teal	160.0	5.2	102.3	69.1	112.2	46.5	53.3	N/D	8.5	3.9	7.6	52.8	50.5	464.0	**87.4**
Northern Pintail	48.4	1.2	13.4	33.3	45.8	8.9	5.7	N/D	3.5	4.8	1.6	25.8	10.7	38.0	**18.5**
American Wigeon	76.9	4.1	12.1	10.2	24.5	1.7	6.5	N/D	0.0	3.2	0.0	8.3	11.0	71.0	**17.7**
Blue-winged Teal	18.1	36.0	1.3	3.1	0.0	0.1	0.7	N/D	0.0	0.0	0.3	0.0	0.0	0.0	**4.6**
Gadwall	8.2	0.3	0.0	0.0	0.8	0.4	0.0	N/D	0.1	0.2	0.3	0.8	0.0	0.0	**0.9**
Hooded merganser	2.1	0.0	0.0	0.6	0.0	0.2	0.2	N/D	0.2	0.2	0.1	0.3	1.7	0.0	**0.4**
Northern Shoveler	0.9	0.0	0.9	0.0	0.0	0.0	0.0	N/D	0.1	0.1	0.2	0.0	0.3	0.0	**0.2**
Ring Necked Duck	0.0	0.0	0.0	0.3	0.4	0.0	0.0	N/D	0.1	0.1	0.5	0.7	0.0	0.0	**0.2**
Greater/Lesser Scaup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.0	0.0	0.0	1.3	0.0	**0.1**
Mute Swan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.3	0.3	0.0	0.0	0.0	**0.0**
Bufflehead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.1	0.1	0.0	0.0	0.0	0.0	**0.0**
Common Merganser	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.1	0.0	0.0	0.0	0.0	**0.0**
Snow Goose	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.1	0.0	0.0	0.0	0.0	**0.0**
Canvasback	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Common Goldeneye	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Tundra Swan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N/D	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
TOTAL	**1567.8**	**538.5**	**1120.0**	**1072.3**	**1952.6**	**1057.5**	**966.5**	**N/D**	**410.1**	**341.4**	**192.0**	**875.5**	**1295.2**	**800.0**	**937.6**

Notes:
N/D – no data available
* - Annual waterfowl counts are based on the number of observed waterfowl at a location during a single survey event (day)

Land Birds

Approximately 87 species of land birds with varying levels of regional priority have been identified on the refuge. Of these priority land birds, approximately 42 have been identified as nesting species in the various habitats of the refuge. These nesting birds include a large variety of passerines (perching birds), owls, raptors, woodpeckers, doves and cuckoos, swallows and swifts, and wild turkey. Neotropical migrant passerines are the most diverse group of priority birds nesting or migrating at the refuge. Neotropical migrant birds are those species which summer in North America and winter in Latin America or the Caribbean (USFWS 2011e).

The wood thrush (*Hylocichla mustelina*) is a high regional priority neotropical migrant passerine commonly nesting in the forests at Great Swamp NWR. Wood thrush is one of the refuge's and region's most important indicator species with respect to forest management. Although wood thrush is considered a common species, their overall range-wide population has been found to have declined by 43 percent since 1966 (Rosenberg et al 2003).

Wood thrushes prefer to nest in often moist deciduous or mixed forests with a dense tree canopy and a generally well-developed understory. The most common tree species in wood thrush habitat within the eastern region are oaks and maples and to a lesser extent American beech, pines and hickories (Rosenberg et al. 2003). Wood thrush will utilize a wide variety of fragmented habitats with relatively small patch sizes. The reproductive success of wood thrush; however, decreases rapidly in patch sizes less than 100 acres (Rosenberg et al. 2003). In general studies have shown that nest predation and cowbird brood parasitism of wood thrush occur at higher rates in fragmented habitat areas (Rosenberg 2003) and contribute to this correlation.

Other prioritized interior forest, forest edge and shrub nesting species at the refuge include veery (*Catharus fuscescens*), scarlet tanager (*Piranga olivacea*), rose-breasted grosbeak (*Pheucticus ludovicianus*), black-billed cuckoo (*Coccyzus erythropthalmus*), and yellow-billed cuckoo (*Coccyzus americanus*). Approximately 11 warbler species nest on or near Great Swamp NWR. Key nesting warblers include the prothonotary warbler (*Protonotaria citrea*), blue-winged warbler (*Vermivora pinus*), yellow-breasted chat (*Icteria virens*), and the Louisiana waterthrush (*Seiurus motacilla*). All three local mimic thrushes, including the prioritized brown thrasher (*Toxostoma rufum*), nest on the refuge. Eight species of flycatchers nest at Great Swamp NWR. High regional priority forest-nesting flycatchers include the Acadian flycatcher and the Eastern wood pewee. The willow flycatcher is a prioritized shrub-nesting species at the refuge. Six species of woodpecker, including the State-threatened red-headed woodpecker (*Melanerpes erythrocephalus*), also nest on the refuge.

Two sparrow species with regional priority, the field sparrow and the Eastern towhee, are very common and nest in the shrub and successional habitat on the refuge. Important grassland passerines that nest on the refuge include the State-threatened bobolink and the Eastern meadowlark (*Sturnella magna*).

Several State-listed forest-nesting raptors are documented to nest on or near the refuge. These include the State threatened [State endangered (breeding)] red-shouldered hawk (*Buteo lineatus*); State-listed Special Concern Cooper's hawk (*Accipiter cooperii*); the State endangered Northern goshawk (*Accipiter gentilis*); the State threatened barred owl (*Strix varia*); and the State listed Special Concern broad-winged hawk (*Buteo platypterus*). The American kestrel (*Falco sparverius, Statethreatened*), an open field cavity-nesting species, also nests on the refuge.

In addition to providing land bird nesting habitat, the forested, successional and wetland complexes of Great Swamp NWR provide vital migratory habitat for thousands of land birds in the spring and fall. Great Swamp is important as a migratory stopover, particularly in the context of its urban setting. Loss of migratory stopover habitats, such as those provided at Great Swamp NWR, has been identified as a potential contributing factor to population declines of neotropical migrant passerines (NJDEP 2010c).

The refuge's fields and shrub habitats host a large variety of spring neotropical migrant passerines during April and May (Boyle 1986). Common spring migrant passerines include 10 species of flycatcher, including the eight that nest at the refuge; three prioritized vireo species; all six eastern swallows; and approximately 30 species of warblers. Wooded swamps and other wetlands at the refuge provide important migratory habitat for the regional priority rusty blackbird (*Euphagus carolinus*) during the spring and fall.

The highest priority warbler species that occasionally utilize the refuge for migration include two species that have been given consideration for federal listing, the cerulean warbler (*Dendroica cerulea*) and the golden-winged warbler (*Vermivora chrysoptera*). Other high priority warblers that utilize the refuge for migration include Canada warbler (*Cardellina canadensis*), Kentucky warbler (*Geothlypis formosa*), prairie warbler (*Cardellina canadensis*), and worm-eating warbler (*Helmitheros vermivorum*). Other prioritized warbler species commonly observed at the refuge during spring and fall migration include black-throated blue warbler (*Dendroica caerulescens*), black-throated green warbler (*Dendroica virens*), Northern parula (*Setophaga americana*), and blackburnian warbler (*Dendroica fusca*).


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Three rare New Jersey grassland sparrows [the savannah (*Passerculus sandwichensis*), vesper (*Pooecetes gramineus*) and grasshopper (*Ammodramus savannarum*)] are spring and fall migrants on the refuge.

In addition to the nesting owls and raptors that migrate through Great Swamp NWR, the refuge also provides wintering and migratory habitat for other State-listed owl species, including the long-eared (*Asio otus*) and short-eared (*Asio flammeus*) owls. State endangered (nesting) Northern harriers (*Circus cyaneus*) are commonly observed foraging in open fields during summer, winter and migratory periods.

Waterbirds

A number of rare waterbirds utilize the refuge, including several key nesting species. Great blue heron (*Ardea herodias*) rookeries found within the refuge are regularly monitored for productivity. In recent years, as many as four separate rookeries existed at once, but at the current time only one remains active. Other nesting heron species include American bittern (*Botaurus lentiginosus*), least bittern (*Ixobrychus exilis*) and green heron (*Butorides virescens*). Other herons use the refuge for forage or during migration primarily in spring through the fall. Key foraging heron species include the black-crowned (*Nycticorax nycticorax*) and yellow-crowned (*Nyctanassa violacea)* night heron, cattle egret (*Bubulcus ibis*), snowy egret (*Egretta thula*) and little blue heron (*Egretta caerulea*). Four rail species, including the king rail (*Rallus elegans*), Virginia rail (*Rallus limocola*), sora (*Porzana carolina*) and common moorhen (*Gallinula chloropus*), nest within the marsh habitats at Great Swamp NWR.

Shorebirds

The term shorebird refers to diverse groups of bird species under the order *Charadriiformes* that are represented by members of the sandpiper, plover, tern and gull families at Great Swamp NWR. Breeding shorebird species at Great Swamp NWR include the killdeer (*Charadrius vociferus*), spotted sandpiper (*Actitis macularia*), and common snipe (*Gallinago delicate*). In addition, a number of migratory sandpiper species utilize the refuge primarily during the spring and through the fall. Solitary (*Tringa solitaria*) and least (*Calidris minutilla*) sandpipers are common in the spring. Semipalmated sandpiper (*Calidris pusilla*), greater (*Tringa melanoleuca*) and lesser yellowlegs (*Tringa flavipes),* dunlin (*Calidris alpine*), and short-billed dowitcher (*Limnodromus griseus*) are primarily observed in the spring or summer. The State endangered upland sandpiper (*Bartramia longicauda*) is a rare spring visitor to the refuge.

American woodcock (*Scolopax minor*), a member of the sandpiper family, is a well-established breeding bird at Great Swamp and is the most important shorebird at the refuge from the management and regional priority perspective. Long-term regional declines (New Jersey and surrounding Northeastern states) of American woodcock observed by the USFWS between 1968 and 2012. According to the American Woodcock Conservation Plan, New Jersey's population of singing males has declined by 83 percent since the early 1970's (Palmer 2008). There has been no significant Northeastern regional decline, however, between 2000 and 2012 (Cooper and Rau 2012).

The woodcock benefits significantly from the management of fields and successional habitats at the refuge. The species utilizes the refuge's patchwork of grassland, scrub-shrub, forest, and wetland habitats for courtship, roosting, nesting, and foraging. Male woodcock may be regularly observed performing courtship displays throughout the open fields of the refuge between March and May. Courtship habitats for woodcock are preferably at least 2.9 acres (1.2 hectares) in size and consist of open fields, meadows, pastures or brushland and forest clearings (USFWS 2001c). American woodcock nesting cover is ideally located within 300 feet of the male's courtship habitat (USFWS 2001c). Nesting and brood rearing occur in young, open, second-growth deciduous forests with well-drained soils.

Since 1968, the State of New Jersey has collected data on breeding woodcock populations (peenting [singing] males) shortly after sunset during late April and early May at Great Swamp NWR. The State data has been collected once annually with the exception of 1991 and 1992 when no State data was collected due to a Division of Fish and Wildlife reporting error. In addition to the State data, Great Swamp NWR staff has collected peenting male woodcock data on the refuge since 1983. Both surveys have continued concurrently and are conducted by stopping at set point locations along established routes within the western portion (Management Area) of the refuge.

Table 2-20 below lists every year that the woodcock survey was conducted by either the New Jersey Division of Fish and Wildlife or the FWS along with the average number of peenting woodcocks per stop that each agency reported hearing. The last column quantifies the difference between the State and FWS data as a percentage for each given year. Numbers highlighted in red represent years when FWS average numbers of peenting woodcock were below State findings. Both agencies did not conduct surveys on all years listed. Discrepancies between State and refuge derived data may be explained in part by differences in the frequency of survey sessions (USFWS 2012k). The NJDFW only conducts their survey once annually. The refuge's survey may include multiple survey sessions within a single season.

The routes of the two surveys differ from each other but cover much of the same general area in the western portions of the refuge. The survey routes currently utilized today by both FWS and NJDFW span much of the managed (mowed and hydroaxed) fields along Pleasant Plains Road, north of White Bridge Road, where the greatest concentrations of peenting woodcock occur. The State survey also includes five stops along White Bridge Road, east of Pleasant Plains Road, to the western end of the Wilderness Area. The refuge routes utilized by FWS between 1983 and 2004 were altered in 2005 to eliminate route portions that do not contain areas regularly utilized by peenting woodcock (USFWS 2012k).

Table 2-20: COMPARISON OF PEENTING WOODCOCK SURVEYS CONDUCTED AT GREAT SWAMP NWR BY USFWS AND NJDEP DIVISION OF FISH AND WILDLIFE

Year	# of Peenting Woodcocks / Total # of Stops		% Difference
	NJDFW	USFWS	
1968	0.10*	---	-10.00
1969	0.00*	---	0.00
1970	0.40*	---	-40.00
1971	0.80	---	-80.00
1972	1.10	---	-110.00
1973	1.50	---	-150.00
1974	1.70	---	-170.00
1975	1.10	---	-110.00
1976	0.70	---	-70.00
1977	0.30*	---	-30.00
1978	0.30*	---	-30.00
1979	0.40*	---	-40.00
1980	0.30*	---	-30.00
1981	0.40*	---	-40.00
1982	0.20*	---	-20.00
1983	0.10*	0.50*	40.00
1984	0.10*	1.67	156.67
1985	0.40*	1.25	85.00
1986	0.00*	0.75	75.00
1987	0.00*	1.42	141.67
1988	0.20*	2.21	200.83
1989	0.20*	1.79	159.17
1990	0.60	1.56	95.56
1991	---	1.67	166.67

Table 2-20: COMPARISON OF PEENTING WOODCOCK SURVEYS CONDUCTED AT GREAT SWAMP NWR BY USFWS AND NJDEP DIVISION OF FISH AND WILDLIFE			
Year	# of Peenting Woodcocks / Total # of Stops		% Difference
	NJDFW	USFWS	
1992	---	0.96	95.83
1993	0.20*	0.79*	59.17
1994	0.00*	1.11	111.11
1995	0.30*	2.03	172.78
1996	0.20*	1.00	80.00
1997	0.40*	1.42	101.67
1998	0.10*	0.83*	73.33
1999	0.20*	0.73*	53.33
2000	0.10*	0.82*	71.67
2001	0.20*	0.19*	-0.56
2002	0.20*	0.28*	7.78
2003	0.30*	0.17*	-13.33
2004	0.00*	0.67*	66.67
2005	0.30*	0.27*	-3.00
2006	0.60	0.67*	7.00
2007	0.50	0.87*	37.00
2008	0.40*	0.36*	-4.00
2009	0.80	0.36*	-44.00
2010	0.10*	0.33*	23.00
2011	0.80	0.76*	-4.00
2012	1.20	0.44*	-76.00

Notes:
* Indicates below respective means (0.41 for New Jersey Division of Fish and Wildlife and 0.93 for the U.S. Fish and Wildlife Service)
--- Indicates no survey conducted

The 43 years of annual State data at Great Swamp NWR contains an overall mean of 0.41 peenting woodcock per stop. The range of peenting woodcocks has ranged from 0 to 17 per year. During the period between 1971 and 1976, the State consistently recorded the highest frequency of peenting males per stop. A peak number of 17 (mean of 1.7 peenting woodcock per stop) was recorded in 1974. Until the 2012 season, a mean value greater than one peenting male per stop had not been recorded during State surveys at Great Swamp NWR since 1975 (USFWS 2012k).

U.S. Fish and Wildlife Service data contains a mean value of is 0.93 woodcocks heard per stop during the 30 years of surveying. Since 1983, the number peenting woodcocks has ranged from 0 to 35 during a single survey visit. During the period between 1984 and 1997, the FWS generally recorded the highest frequency of peenting males per stop. With the exception of 1993, all years in this period were above the overall FWS mean of 0.93. The high of 35 peenting woodcocks (mean of 2.12 peenting woodcock per stop) was heard in 1988 (USFWS 2012k).

2.6.4 Mammals

Approximately 39 mammalian species have been identified at Great Swamp NWR. Common species include white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), striped skunk (*Mephitis mephitis*), masked shrew (*Sorex cinereus*), smoky shrew (*Sorex fumeus*), and starnose mole (*Condylura christata*).

Common rodents and lagomorphs include the Eastern cottontail (*Sylvilagus floridanus*), Eastern chipmunk (*Tamias striatus*), woodchuck (*Marmota monax*), Eastern gray squirrel (*Sciurus carolinensis*), red squirrel (*Sciurus vulgaris*), Southern flying squirrel (*Glaucomys volans*), beaver (*Castor canadensis*), white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), woodland vole (*Microtus pinetorum*), muskrat (*Ondatra zibethicus*), meadow jumping mouse (*Zapus hudsonius*), and woodland jumping mouse (*Napaeozapus insignis*).

Small and medium–sized predatory mustelids common at Great Swamp NWR include river otter (*Lutra canadensis*), mink (*Mustela vison*), and longtail weasel (*Mustela frenata*). Other *Carnivora* predators include coyote (*Canis latrans*), gray fox (*Urocyon cinereoargentueus*), and red fox (*Vulpes vulpes*). Transient black bears (*Ursus americanus*) have also been observed on the refuge.

White-tailed deer (*Odocoileus virginianus*) are common on the refuge and the numbers are managed with an annual hunting program. Harvest data for white-tailed deer has been recorded since the first refuge hunt in 1974. Raccoons (*Procyon lotor*) are also extremely common. Sightings of two locally rare predatory species, the fisher (*Martes pennanti*) and the State-endangered bobcat (*Lynx rufus*), have been reported on the refuge, but have not been confirmed.

Eight bat species, including the federally listed endangered Indiana bat, have been identified at the refuge. Other species of concern identified include Eastern red bat (*Lasiurus borealis*), Eastern small-footed bat, and hoary bat (*Lasiurus cinereus*). In addition to Indiana bat, certain bat species documented at the refuge including Northern long-eared bat, tri-colored bat and the little brown bat may be threatened by white-nose syndrome (see white-nose syndrome discussion in section 2.6.1).

2.6.5 Reptiles and Amphibians

The first herptile list for Great Swamp NWR was created in 1967 by J.D. Anderson. Since then, many reptile and amphibian populations have been well documented and studied on the refuge. This includes the inventory and/or study of seven State-listed Threatened, Endangered, or Special Concern species, including the federally listed turtle.

Frog call surveys are regularly conducted in the spring and summer on the refuge. Common species identified include Northern cricket frog (*Acris crepitans*), Northern gray treefrog (*Hyla versicolor*), Northern spring peeper (*Pseudacris crucifer*), green frog (*Lithobates clamitans melanotus*), bull frog (*Lithobates catesbeianus*), and Southern leopard frog (*Lithobates sphenocephalus utricularius*). Frog species less frequently encountered at the refuge include the State-listed Special Concern Fowler's toad (*Anaxyrus* *fowlerii*), the American Toad (*Anaxyrus americanus*), New Jersey chorus frog (*Pseudacris triseriata kalmi*), upland chorus frog (*Pseudacris triseriata feriarum*), and pickerel frog (*Lithobates palustris*).

As with other similar habitat complexes in northern New Jersey, the redback salamander (*Plethodon cinereus*) is the most common salamander on the refuge. Other less common salamanders include Northern slimy salamander (*Plethodon glutinosus*), the four-toed salamander (*Hemidactylium scutatum*), red-spotted newt (*Notopthalmus viridescens viridescens*), and the Northern dusky salamander (*Desmognathus fuscus*). Although known to occur in the area, the Northern two-lined salamander (*Eurycea bislineata*) was not confirmed on the refuge until its discovery by refuge biologists in June 2009. The refuge also provides important vernal breeding habitat for two obligate vernal breeders: the wood frog (*Lithobates sylvatica*) and the State-endangered blue-spotted salamander. Populations of the blue-spotted salamander, though fairly common on the refuge, are extremely rare in New Jersey.

Great Swamp NWR hosts populations of two threatened and endangered turtle species: the bog turtle and wood turtle. Management efforts to monitor, sustain and expand refuge populations are ongoing for both of these species. Two State-listed Special Concern species, including the box turtle (*Terrapene carolina*) and spotted turtle, remain common at the refuge. Additional species include the snapping turtle (*Chelydra serpentina*), Eastern painted turtle (*Chrysemys picta*), musk turtle (*Sternotherus odoratus*), and Eastern mud turtle (*Kinosternon subrubrum*). Introduced species, such as the red-eared slider (*Trachemys scripta*), red-belly turtle (*Pseudemys rubriventris*), and Eastern river cooter (*Chrysemys concinna*), have also been reported at the refuge.

Great Swamp NWR is host to a variety of common snake species, including Northern water snake (*Nerodia sipedon*), brown snake (*Storeria dekayi*), common garter snake (*Thamnophis sirtalis*), Northern black racer (*Coluber constrictor*), and the Eastern milk snake (*Lampropeltis triangulum*). One State-listed Special Concern species, the ribbon snake (*Thamnophis sauritis*), is also common at the refuge. Species less common at the refuge include Eastern worm snake (*Carphophis amoenus*), black rat snake (*Scotophis alleghaniensis*), smooth green snake (*Opheodrys vernalis*), ringneck snake (*Diadophis punctatus*), and Eastern smooth earth snake (*Virginia valeriae*). One additional State-listed Special Concern species, the Eastern hognose snake (*Heterodon platyrhinos*), was identified during earlier surveys (Anderson 1967-76), but has not been observed on the refuge in recent years.

R Allen Simpson

A comprehensive study of reptiles and amphibians was conducted at the refuge in 1993 to 1994 with a focus on endangered and threatened species (Record 1995). Ongoing studies have been conducted for endangered and threatened turtle habitat and populations, specifically for bog turtles, beginning in 2004 (see section 2.6.1), and wood turtles, beginning in 2006.

The wood turtle study involves the mark and recapture, and radio tracking of individuals throughout the refuge to understand the movements and reproductive success of wood turtles on the refuge. Each year, mature adult, juvenile and hatchling wood turtles are identified along the open waters and a within a wide variety of vegetated habitats throughout Great Swamp NWR. Specific habitats utilized at the refuge include stream banks and beds; vegetated riparian habitats; sphagnum bogs and other wetlands; floodplain forests; and successional fields dominated by reed canary grass, goldenrods and shrubs. They are also occasionally found in disturbed and non-habitat areas, such as along roads and around buildings.

The wood turtle population at the refuge is actively reproducing and multiple gravid females are tracked on the refuge each season. The refuge facilitates the development of eggs and has been successful in providing quality nesting mound habitat for the species, which produces multiple clutches of hatchlings annually.

2.6.6 Fish

Great Swamp NWR is located within the GSW, which is located within the southern portion of the Upper Passaic River watershed (refer to section 2.1 and figure 2.4). Although a comprehensive inventory of fish species inhabiting the refuge has not been conducted recently; studies of the Lower Passaic-Hackensack River watershed have been conducted. Approximately 39 species of freshwater fish have been reported in or immediately adjacent to Great Swamp NWR within the Passaic-Hackensack River watershed. No anadromous (Clupeids or striped bass) species have been reported within the refuge, as there are significant migratory impediments along major downstream waters (i.e., Great Falls). The refuge is primarily host to a warmwater fishery, with some cold water species existing near the refuge border (i.e., within Primrose Brook). Among the coldwater species identified are the non-native brown trout (*Salmo trutta*) and native brook trout (*Salvelinus fontinalis*).

Two common darter species, the tessellated darter (*Etherostoma olmstedi*) and the Johnny darter (*Etherostoma nigrum*), have been identified within the watershed. Fallfish (*Cyprinella spp. and Notropis spp.*) shiners and blacknose dace (*Rhinichthys atratulus*) are some of the stream fish identified at the refuge. Refuge waters also contain the American brook lamprey (*Lampetra appendix*), banded sunfish (*Enneacanthus obesus*) and bridle shiner (*Notropsis bifrenatus*), all of which will be considered for management in the NJWAP.

A number of larger warmwater predatory species exist within the refuge waters, including chain pickerel (*Esox niger*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis migromaculatus*), and yellow perch (*Perca flavescens).*

A total of seven fish surveys were conducted within the Passaic River (1990), Black Brook (1969), Loantaka Brook (2007) and Primrose Brook (1992/1999) by the New Jersey Division of Fish & Game, Bureau of Freshwater Fisheries. During these surveys, an overall total of 21 species of fish were identified, including longnose dace (*Rhinichthys cataractae*), rainbow trout (*Oncorhynchus mykiss*), and slimy sculpin (*Cottus cognatus*).

Fourteen species of fish were identified within Great Brook and Primrose Brook on the refuge during an electro-shock inventory as part of the *2009 BioBlitz*.

2.6.7 Invertebrates

A complete inventory of invertebrates has not been conducted at the refuge. Certain groups of species, including *Odonata* (dragonflies) and *Lepidoptera* (butterflies and moths), have been recorded more consistently at Great Swamp NWR.

Butterflies have been recorded at the refuge during single-day July counts from 1994 to 2005. Over 45 species of butterflies from 11 families have been identified at the refuge. Families include swallowtails, sulphurs, whites, skippers, hairstreaks, blues, brushfoots, satyrs, and wood nymphs. Common species identified during the surveys include common wood nymph (*Cercyonis pegala)*, little wood satyr (*Megisto cymela*), least skipper (*Ancyloxypha numitor*), silver-spotted skipper (*Epargyreus clarus*), little glassywing (*Pompeius verna*), great spangled fritillary (*Speyeria cybele*) and pearl crescent (*Phyciodes tharos*). Some introduced exotic butterflies, including cabbage white (*Pieris rapae*) and European skipper (*Thymelicus lineola*), are among the most common species identified. Rare moths of the genus *Papaipema* have also recently been identified on the refuge.

Aquatic invertebrate studies conducted in 2001 revealed the presence of 26 insect families, 2 amphipod families, mollusks including gastropods and bivalves, ostracods, isopods, acari and annelids. Gastropods (snails) represented the greatest biomass of invertebrates from more than 5,800 invertebrate individuals collected from two sites.

2.7 Refuge Visitor Services Program

The primary focus of the Refuge System is to protect wildlife and habitat; however, refuges also provide opportunities to "connect people with nature" by providing unique opportunities for people to learn about and enjoy the natural environment. This section highlights overall visitation data collected over recent years at the refuge. The USGS study completed in 2011 illustrated that visitors were generally satisfied with their experiences and the facilities available at Great Swamp NWR. Chapter 3, alternative A of the CCP identifies specific trends regarding visitor attitudes that were determined from the USGS study.

2.7.1 Visitation

Based on data collected from 2001 through 2010, refuge visitation ranges between approximately 140,000 and 162,000 visitors per year (T. McFadden, USFWS Great Swamp NWR, pers. com. 2009). The most recent visitation information from the refuge is for October 1, 2009 through September 30, 2010. During this time, the refuge reported an estimated 156,500 visitors. Onsite interpretation and nature observation account for the largest proportion of visitor days (65,684).

Visitor Hours

Great Swamp NWR is open every day from sunrise to sunset. The only current exception is during the 5-day deer hunt. During the deer hunt, the refuge is closed to any visitors who are not authorized to participate in the hunt. The refuge headquarters is open 8:00 a.m. to 4:30 p.m. Monday through Friday excluding Federal holidays. During seasonal bird migration in spring and fall, volunteers staff the WOC from Wednesday through Sunday. Staff and members of the Friends of Great Swamp NWR run the Visitor Center, which includes the "Friends Nature Shop." It is currently open Thursday and Friday from noon to

4:00 p.m. and Saturday and Sunday from 10:00 a.m. to 4:00 p.m. Regular "Second Sunday" programs and occasional special events, such as the annual Fall Festival, are also scheduled.

2.7.2 Priority Public Uses

The Improvement Act identifies six wildlife dependent public uses for national wildlife refuges: hunting, fishing, wildlife observation, photography, environmental education, and interpretation. (Public Law 105-57 1997). The Act further directs that these public uses receive "enhanced consideration over other public uses in planning and management" within the Refuge System when they are determined to be compatible with the refuge purpose(s). In one way or another, five of the six priority public uses are authorized on Great Swamp NWR. The only priority public use not currently authorized on the refuge is fishing.

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Hunting

Currently, the only hunting authorized on Great Swamp NWR is the annual 5-day deer hunt, which occurs every fall. The annual white-tailed deer firearm hunt has been conducted on the refuge since 1974 to maintain the refuge deer population at or below a level that will not negatively impact wildlife habitat and the integrity of ecological communities, while providing a safe, high quality outdoor experience for hunters (USFWS 2012h). The annual hunt includes a 1-day youth hunt followed shortly thereafter by a 4-day general hunt. Hunting generally follows the New Jersey State guidelines, and detailed regulations and information are included in handouts sent to each of the hunters that purchase hunting permits on the refuge. Regulations are also published in the State's annual hunting digest.

The goals of the refuge's Deer Hunt Program are to: (1) Maintain a white-tailed deer population that allows a diverse and healthy forest understory and assures continuing production of tree seedlings to maintain forest cover in perpetuity; (2) Avoid a truncated buck age class structure and maintain a more natural buck age class distribution; and (3) Provide a safe and high quality outdoor experience for refuge deer hunters (USFWS 2012h). To achieve these goals, harvest strategies and regulations are implemented, evaluated annually, and adjusted when necessary to carry out the objectives of the Program. Program objectives are to: (1) maintain deer at a moderate density of 20 deer per square mile; (2) Maintain a male age class structure where at least 30 percent of the bucks are greater than or equal to 3 years old; and (3) Implement necessary safety precautions to prevent accidents (USFWS 2012h).

In 2011, 194 hunters, including 13 youth hunters, purchased refuge deer hunting permits. The hunter density was one hunter to 35 acres (USFWS 2012h). According to the Draft Deer Hunting Plan (USFWS 2009a), deer hunting is allowed on approximately 82 percent of the total refuge area with the remaining area designated as Safety Zones. There are 31 parking lots available throughout the refuge to distribute hunters and facilitate access for this public use.

Table 2-21 below illustrates relative trends of seasonal bag limits, number of hunters, number of deer harvested, and total hunt days from 1974 to 2011.

TABLE 2-21: COMPARISON OF HUNT STATISTICS FROM 1974-2010				
Year	Bag Limit	No. Hunters	Deer Harvested	Total Hunt Days
1974	1 Deer / Permit	371	127	6
1975	1 Deer / Permit	329	106	6
1976	1 Deer / Permit	354	128	6
1977	1 Deer / Permit	351	106	6
1978	1 Deer / Permit	350	100	6
1979	2 Deer / Permit	502	178	10
1980	2 Deer / Permit	523	148	10
1981	2 Deer / Permit	543	152	8
1982	2 Deer / Permit	491	126	7
1983	2 Deer / Permit	407	116	7
1984	1 Deer / Day / Permit; 2 Max. (a)	408	144	6
1985	1 Deer / Day / Permit; 2 Max. (a)	486	150	6
1986	1 Deer / Day / Permit; 2 Max. (a)	527	179	6
1987	1 Deer / Day / Permit; 3 Max.	439	149	5
1988	1 Deer / Day / Permit; 6 Max.	420	143	6
1989	1 Deer / Day / Permit; 6 Max.	382	153	6
1990	1 Deer / Day / Permit; 6 Max.	331	164	6
1991	2 Deer / Day / Permit	420	212	5
1992	2 Deer / Day / Permit	410	210	5
1993	2 Deer / Day / Permit	392	214	5
1994	2 Deer / Day / Permit	404	252	4
1995	2 Deer / Day / Permit	383	257	4
1996	2 Deer / Day / Permit	408	152	4
1997	2 Deer / Day / Permit	322	184	4
1998	2 Deer / Day / Permit	267	181	4
1999	2 Antlerless / Day, 1 Buck / Season (b)	283	198	4
2000	2 Antlerless / Day, 1 Buck / Season (c)	285	215	4
2001	2 Antlerless / Day, 1 Buck / Season (c)	274	190	4
2002	Unlimited Antlerless, 1 Buck (c)	264	271	4
2003	Unlimited Antlerless, 1 Buck (b)	274	178	4
2004	Unlimited Antlerless, 1 Buck (b)	275	187	5 (e)
2005	Unlimited Antlerless, 1 Buck (b)	275	150	5 (e)
2006	Unlimited Antlerless, 1 Buck (b)	222	102	5 (e)
2007	2 Antlerless or 1 Antlerless and 1 Buck (d)	186	85	5 (e)
2008	2 Antlerless or 1 Antlerless and 1 Buck (d)	161	79	5 (e)
2009	2 Antlerless or 1 Antlerless and 1 Buck (f)	183	113	5 (e)
2010	2 Antlerless or 1 Antlerless and 1 Buck (f)	230	121	5 (e)
2011	2 Antlerless or 1 Antlerless and 1 Buck (f)	194	42	5 (e)
2012	1 Either sex	98	18	3(e)

TABLE 2-21: COMPARISON OF HUNT STATISTICS FROM 1974-2010				
Year	Bag Limit	No. Hunters	Deer Harvested	Total Hunt Days
2013	1 Either sex	107	37	5(e)

Notes:
(a) – Indicates one bonus deer available if deer is harvested in the Wilderness Area.
(b) – Adult doe must be checked in before buck permit is issued.
(c) – First antlerless deer harvested must be an adult doe to obtain a buck permit.
(d) – First deer must be antlerless.
(e) – Youth hunt on first day.
(f) – First deer antlerless for shotgun and either sex for muzzleloader.

Despite a comparable number of deer hunters to hunts in the recent years (2007 to 2010), the 2011 hunt resulted in the fewest number of harvested deer and the lowest hunter success rate (22 percent) ever recorded on the refuge since the deer hunt began in 1974. The reduced number of deer harvested was attributed to population declines due to the EHD outbreak earlier in the season. As a result, the 2012 hunt program was reevaluated and adjusted to reduce the bag limit to one deer of either sex (USFWS 2012h).

Fishing

Fishing is currently not an authorized activity on Great Swamp NWR and no infrastructure specifically supports fishing access. However, refuge staff have found evidence (i.e., fishing line, lures, and bait) that unauthorized fishing is occurring at certain locations within the refuge. The refuge has sponsored offsite fishing derbies in the past and the Somerset County Park Commission provides fishing opportunities on waters adjacent to the refuge on the Passaic River.

Wildlife Observation and Photography

Wildlife observation and photography are popular public uses on the refuge and contributed to 174,132 visitor days in 2010. The refuge has established an informal 1.5 mile auto tour along Pleasant Plains Road. The auto tour includes the Bluebird parking area and the Overlook area. The Overlook focuses on an impoundment, and includes two mounted spotting scopes (one is wheelchair accessible), benches, a three-panel kiosk, and a small parking area with six designated parking spaces (including one designated handicap space). The Bluebird parking area has an outdoor restroom, kiosk, bench, and parking for 20 cars. In addition, the refuge Visitor Center provides opportunities to view wildlife associated with the butterfly garden, a nature trail and varied habitats adjacent to the center.

The refuge also has a WOC located off Long Hill Road. This facility includes all-season public restrooms, an eight-paneled kiosk, a seasonally-staffed visitor contact station, one-mile of ADA-compliant boardwalk that ends in two wildlife viewing blinds, and a 0.5 mile stone dust and wood chip trail that ends in a viewing platform. There is also a parking lot for 40 vehicles.

The western portion of the refuge, which includes 3,360 acres, has been designated by Congress as Wilderness. There are about 8.5 miles of primitive hiking trails in this area and off-trail use is allowed. Except for public roads, the remainder of the refuge is usually closed to the public. Friends of Great Swamp NWR offer occasional interpretive walks in the restricted Management Area and the refuge may authorize access through a SUP.

Environmental Education

There are two well-established county environmental education centers (see Partnerships in this chapter) located on either side of the refuge: the Morris County Great Swamp Outdoor Education Center to the east and the Somerset County Environmental Education Center to the west.

Refuge staff participates in 5 to 10 events each year; however, limitations in funding and time have prevented more extensive efforts. The Friends of Great Swamp NWR provide guided walks and are developing a loan library of refuge and wildlife-related materials for area schools such as the "Swamp in a Box" and education needs. Binoculars are also available for loan to educational institutions that visit the refuge. The *Friends* also set up educational displays at local libraries and schools, and represent the refuge at local environmental fairs.

Environmental Interpretation

The refuge provides many opportunities for environmental interpretation. Visitor information is provided at the reception area in refuge headquarters, the Visitor Center, the WOC, and the Overlook and Bluebird Lot on Pleasant Plains Road. The WOC has an eight-paneled kiosk to help orient visitors to the refuge and describes relevant activities, wildlife, and habitats. The Overlook, Bluebird Lot, the WOC, and each of the four wilderness trailheads also have three-paneled kiosks. Refuge staff participate in several outreach events each year; however, limitations in funding and staff availability impeded participation in more events. Refuge staff and members of the *Friends* group are available at the Helen C. Fenske Visitor Center to answer questions and assist visitors. In addition, during certain times of year (e.g., spring and fall bird migration), refuge staff or members of the Friends of Great Swamp NWR are available at the WOCto assist visitors. Members of the *Friends* group also provide guided bird walks and work closely with staff to organize an annual Fall Festival event.

The refuge has two traveling displays for outreach events, one prefabricated refuge exhibit and one folding display that can be customized. The *Friends* group has also worked with refuge staff to develop a slide presentation and has a number of videos available.

2.7.3 Authorized Other Public Uses

Some specific non-wildlife public uses have been determined to be compatible with refuge purposes and are authorized with certain restrictions on the refuge. Examples include pedestrian travel (e.g., walking or hiking, snow-shoeing, cross country skiing) to facilitate priority public uses; recreational berry, fruit, and nut picking; Landowner access to private inholdings; bicycling and Dog Walking and horseback riding on Pleasant Plains Road. For further discussion on these non-wildlife uses, see section 2.3.4, Step-Down Plans, Findings of Appropriateness, and Compatibility Determinations

2.8 Cultural, Archaeological, and Historic Resources

2.8.1 Introduction and Historic Registers

To assist in developing the CCP for Great Swamp NWR and to ensure compliance with the NHPA, FWS contracted with JMA to complete a detailed updated overview of the cultural resources of the refuge. Building off a previous overview completed in 1978 (Thomas 1978), JMA completed a document describing the current status of known cultural resources (JMA 2010). Unless otherwise cited, the information presented in the cultural resources section has been summarized from this report.

The JMA report (2010) identified 123 cultural resources within the refuge's approved acquisition boundary. According to the report, 100 are within or intersect parcels FWS has acquired interest in or currently owns. The remaining 23 are located within parcels that have not been acquired by FWS at this time. Thirty-two of the identified cultural resources are considered prehistoric sites (i.e., before 1750), 57 are from the historic era (1750 to mid-1900s), 3 have prehistoric and historic components, and 31 are standing structures. To date, no sites within the acquisition boundary are listed on the National Register of Historic Places (NRHP) or the New Jersey Register of Historic Places. Two sites within the acquisition boundary have been characterized as eligible for listing on the NRHP, one pre-historic site and one standing structure. The pre-historic site (GRS-097P; 28-MR-212) was recommended for eligibility based on a single Munsee-incised ceramic shard of the Late woodland period [1300 Before Current Era (BCE) – European Settlement] (Harris and Ziesing 2010). The structure, Baird Tenant House (GRS-077S), is a rare intact example of a once locally common house type, the East Jersey cottage and was therefore recommended for eligibility (Harris and Ziesing 2010).

2.8.2 Onsite History and Resources

Prehistoric Resources

Analysis of artifacts recovered within and around Great Swamp NWR demonstrates that prehistoric use by people likely began in the Paleo-Indian Period and continued through the Woodland Period (the last prehistoric period). The Paleo-Indians at this time may have hunted such species as mastodon, caribou, and giant beaver in the lower elevations of the swamp, while the women collected berries, roots and bird's eggs (Parrish and Walmsley 1997). Of the 35 prehistoric sites identified, only 7 have had radiocarbon dating. Dates from these artifacts range from between 2576 BCE to 2151 BCE; however, professional analysis of another artifact indicates that people have used the Great Swamp since about 10,000 years ago (about 8,000 BCE). Most of the artifacts recovered are flakes (i.e., knives and points), although other artifacts include pottery and steatite bowls. Because of the agricultural history of the area, it is not surprising that all of the known prehistoric sites have experienced some level of disturbance, primarily from plowing.

Circa 8,000 BCE, the climate began to warm, causing certain species, such as the mastodon, to become extinct and deciduous forests to flourish. These changes resulted in an alteration of the Native American's way of life, including expanding food-gathering techniques to include fishing and gathering of nuts and wild plants. The main time span represented on the refuge is Late Archaic to the Transitional Archaic (4000 BCE to 1000 BCE). Prehistorically, much of the refuge was a combination of peat, swamp, and grasslands. Based on this information, known site locations, and artifacts recovered, researchers believe that Late

Archaic and Woodland groups were likely using the area seasonally to exploit available resources (plants and animals) with only transient or semi-permanent camps. Late Archaic sites appear to be located on areas of high ground within the lowlands, while Late Woodland sites appear to be associated with navigable waterways.

Native peoples in the area belonged to the Lenape (or Delaware people), an association of tribal groups connected by shared culture and language. They were known as peace keepers and were often called upon by other tribes to help settle disputes (Delaware Tribe of Indians 2009). The Lenape were divided into three major groups, the Munsee (Wolf clan), Unami (Turtle clan), and Unalachtigo (Turkey clan) (Mauser 2009). Local Native Americans began practicing farming by the Late Woodland Period (900 to 1650) (Parrish and Walmsley 1997). They raised crops such as maize, beans and squash, gathered wild plants, and hunted both for food and to sell fur to European traders (Mauser 2009). Typically, women were in charge of crops and gathering while men were responsible for hunting, fishing, and preparing the fields for planting (Mauser 2009).

As with other Native Americans, the Lenape were forced to move west as European settlers arrived. Over the last 300 plus years, most of the Lenape moved through Pennsylvania, Ohio, and Indiana before dividing into two groups in Illinois (Delaware Tribe of Indians 2009). Both groups eventually settled in Oklahoma, the majority with the Cherokee in Bartlesville and the rest in Anadarko. A third group split off early and moved north through New York, settling in Ontario, Canada where there are currently several settlements. Federally recognized Lenape Tribes from the New Jersey area include the Stockbridge Munsee Community of Wisconsin and the Delaware Nation (from Anadarko, OK) (Small 2009). In May of 2009, the Delaware Tribe of Indians voted in a secretarial election to re-establish its status as an independent federally recognized Tribe (Delaware Tribe of Indians 2010).

Early European Historic Resources

Circa 1600, the first European settlers arrived in the Great Swamp region. Upon arrival, they encountered the Lenape Indians. The Lenape coexisted with the settlers and often traded furs in exchange for knives, glass beads, scissors and cloth (Parrish and Walmsley 1997). Consequently, the Lenape were decimated by diseases, such as smallpox, cholera, and measles, to which they had no immunity. In addition, they were often forced to sell their land and move west as European establishment increased. The first recorded transaction between the Lenape and Europeans occurred near Great Swamp in 1708. According to the "Old Indian Deed," (dated August 13, 1708) 30,000 acres were purchased by British investors for:

> "*…ye Summe of thirty pounds of cash, ten stran'd-water blankets, half a barr'l of wine, one barrel of rum, two barrels of sider, three files, one gun-boer, one auger, four pistolls, four cutlasses, ten gunnes, one hundred barros of lead, half a barrel of powder, ten white blankets, twenty shirts, and one hundred knives*".

European settlement began in the area during the last decade of the 1600s with the Dutch, followed by the English. However, there is no documentation or evidence of European settlement in the Great Swamp area prior to 1708. In fact, Great Swamp remained largely a swamp until the middle of the 18th century. It was heavily wooded by this time, and the land was more valued for its timber than for farming. The desolate nature and rich resources of Great Swamp played an important strategic role during the American Revolution. The Crossroads of the American Revolution Study conducted by the National Park Service and the State of New Jersey recognized it as a truly significant site of the American Revolution (NPS 2002; Harris and Ziesing 2010). During the winters of 1777 and 1779 to 1782, George Washington used the high ground areas immediately around Great Swamp for his camp sites. The Morristown area was chosen by Washington because of its strategic location between New York and Philadelphia and the natural fortifications that surround Morristown including the Watchung Mountains, Long Hill and surrounding swamplands (Harris and Ziesing 2010). The rich natural timber and agricultural resources of the region, including those of Great Swamp, also factored into his decision to utilize the Morristown Area for winter encampments. Timber from the Great Swamp was likely used to make wagon wheel rims and log cabins for the army during the winter campaigns (NPS 2002a; Harris and Ziesing 2010).

As the 19th century approached, local populations expanded and economic demand for agricultural products increased (Momsen 2007). Settlement within the present-day Great Swamp NWR likely began at this time as did the conversion of refuge's western swamplands to agricultural fields. Records suggest that by the mid-1800s, a majority of the lowest elevations in the basin may have been logged. By 1844, farmers were draining the marshlands and began planting crops such as foul meadow hay; however, logging activities resulted in flooding, which lead to crop failure. In a report prepared by the New Jersey State Geologist, dated 1899, "cutting was most severe about 1850, and from 1850 to 1860 was the period of maximum deforestation" (Collins and Anderson 1994). During the late-1800s, Great Swamp's woodlands were further logged in response to the demand for lumber to construct boats for the Morris Canal, railroad ties, and fruit baskets; fuel for mills and iron forges; shingles; and pitch, turpentine, and rosin for shipyards (Cavanaugh 1978). In spite of these intense land pressures during this period, Pleasant Plains remained only known settlement within Great Swamp through the early 1900s.

During the early 1900s, local land use patterns again underwent change, as agricultural land was converted to country or vacation homes and estates for the affluent urban population. This appears to have protected the northern portion of the swamp from being suburbanized. In the 1950s land use was further altered by middle-class expansion and the advent of subdivisions and suburban commuters.

Dumping and asbestos disposal also became an issue in the 1900s. Two landfills were created, a large landfill on the north side near Green Village and a smaller landfill on the southern edge of the refuge. Of the 60 historic sites currently identified, 5 are thought to date from the 18th century or have 18th century components (all farms), 27 are thought to date from the 19th century (26 farms or farmsteads along roads), the remainder are thought to be from the 20th century.