U.S. Fish & Wildlife Service

DRAFT WATER MANAGEMENT PLAN AND ENVIRONMENTAL ASSESSMENT FOR

POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Hyde, Tyrrell, and Washington Counties, North Carolina

Photo: USFWS

Photo: D Suiter, USFWS

South Atlantic-Gulf Unified Region

Pocosin Lakes National Wildlife Refuge

Draft Water Management Plan and Environmental Assessment

U.S. Department of the Interior
Fish and Wildlife Service
South Atlantic-Gulf Unified Region

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SECTION A: DRAFT WATER MANAGEMENT PLAN

I. INTRODUCTION

This Water Management Plan (WMP, plan) specifies the implementation of the specific goals and objectives of the 2007 Pocosin Lakes National Wildlife Refuge (NWR, refuge) Comprehensive Conservation Plan (CCP) specifically related to water management. The actions presented in this plan are stepped down from and support the goals and objectives in the CCP. Water management is critical to meeting many of those goals including:

- *Wildlife Populations:* Conserve, protect, and maintain healthy and viable populations of migratory birds, wildlife, fish, and plants, including Federal and State endangered and trust species;
- *Habitat:* Restore, protect, and enhance pocosin wetlands and other natural habitats for optimum biodiversity. Intensively manage habitats specific to waterfowl on the Pungo Unit; and
- *Resource Protection:* Protect and perpetuate refuge resources by limiting the adverse effects of human activities and development on refuge resources.

In 1990, Pocosin Lakes NWR was established primarily to conserve the unique pocosin wetlands. The Pungo Unit, originally a separate refuge, was established in the early 1960s as a waterfowl and migratory bird sanctuary. A key component of refuge management is to restore and maintain natural processes and biodiversity of a functional pocosin wetland and provide habitat for threatened, endangered, and other Federal trust species as well as other wildlife that occur in pocosins all or part of the year.

Overall, habitat management at Pocosin Lakes NWR is greatly influenced by two things: fire and water. Because the refuge is located within a rainfall driven system, meaning rainfall is the primary source of water in the system, during extreme weather conditions the refuge can either experience too much or too little water. Too much rain leads to surface runoff, called sheet flow, and potentially flooding issues. Too little water can lead to drought conditions making the landscape more susceptible to large, habitat-destroying wildfire. A water supply is critical to containing and controlling fire; therefore, water management is the most critical management need at the refuge.

The goals established in the Refuge CCP are further refined in the four primary water management goals identified in this plan IV, Water Management Direction and Implementation):

Goal 1. *Manage Water Resources to Provide Optimal Wintering Waterfowl Habitat*.
Provide wintering waterfowl habitat to support not only historic numbers of tundra swans, geese, and ducks but also additional birds that may utilize the refuge due to the loss of habitat on the Albemarle-Pamlico Peninsula from past and future sea level rise and other climate change factors.

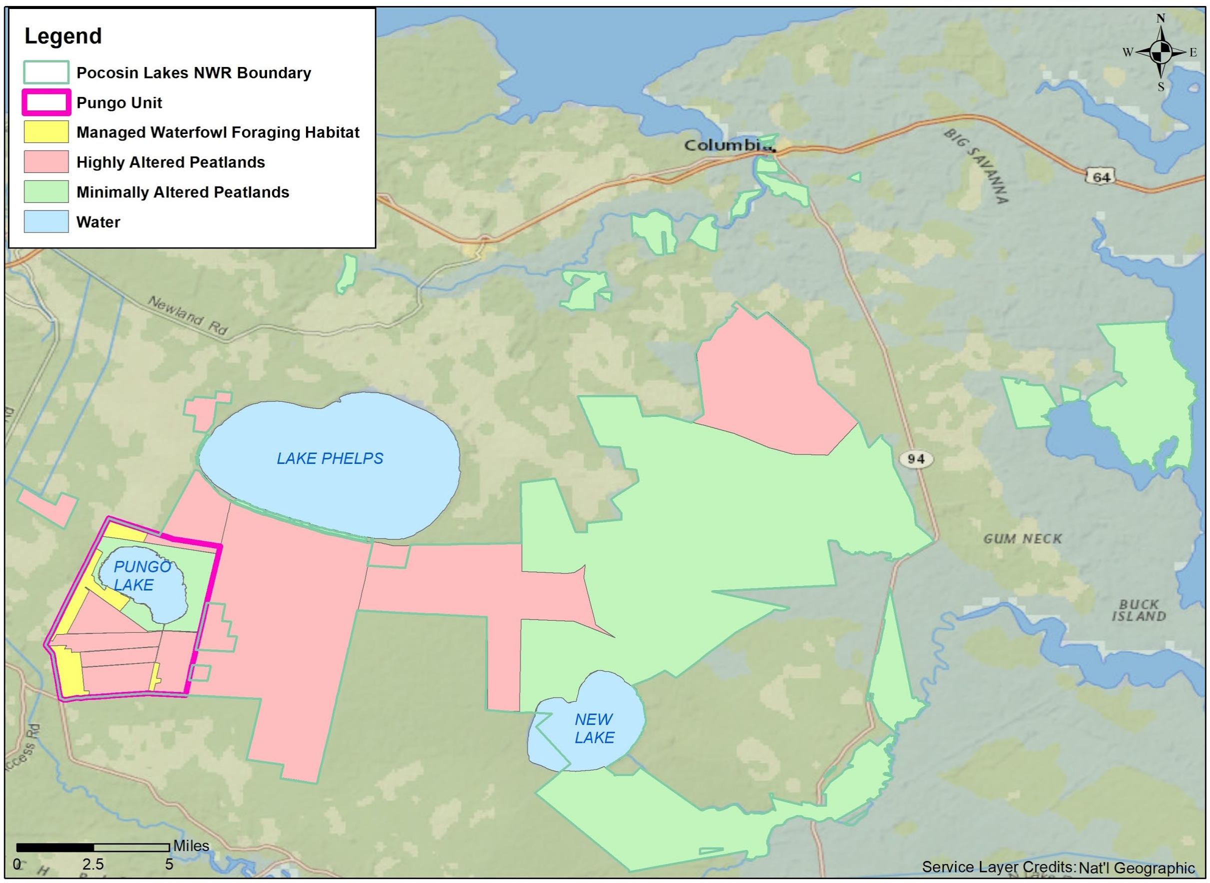
Goal 2. *Restore, Manage, Maintain and Protect Hydrologically Altered Peatlands*.
Restore, or mimic, the natural hydrology of highly altered areas of pocosin wetlands/peatlands to rewet the peat soils and promote natural pocosin vegetation and conditions, enhance wildlife habitat, and prevent the loss of peat via oxidation and wildfire.

Goal 3. *Maintain and Protect Minimally Altered Peatlands*. Protect peatlands with relatively intact natural, minimally altered hydrology from any further alteration; enhance natural hydrologic conditions where practicable without eliminating all existing access for management and other purposes.

Goal 4. *Enhance Fire Management Capabilities*. Minimize and control wildfires as quickly as possible and facilitate prescribed burning for hazardous fuels reduction and wildlife habitat management using any and all water management capabilities.

In order to achieve these goals, management approach will vary within three distinct zones: managed waterfowl habitat, highly altered peatlands, and minimally altered peatlands, which are depicted in Figure A-1. The fourth goal related to fire management cross cuts all three zones.

Figure A-1. Map of Pocosin Lakes NWR showing areas described in the Water Management Plan.



<u>Managed waterfowl habitat</u> includes Pungo Lake and part of New Lake, croplands, and moist soil and forested wetland impoundments which total approximately 8,300 acres or about eight percent of the refuge. Lake Phelps, which is adjacent to the refuge and part of Pettigrew State Park, also provides habitat and sanctuary for waterfowl. All managed waterfowl habitat except for New Lake is located on the Pungo Unit of the refuge. However, much of the rest of the refuge and surrounding areas also provide waterfowl habitat, especially for wood ducks and

other puddle ducks, in the form of marsh, natural shoreline, riparian areas, ephemeral ponds, and other natural wetlands.

Highly altered peatlands include those wetland areas where the land was heavily ditched and drained prior to the establishment of the refuge. Hydrologically altered peatlands total just over 43,000 acres or about 39 percent of the refuge. For purposes of this plan, most of these peatlands are divided into five restoration areas (RAs) based on geographic location and water flow patterns (Section III). To date, the refuge has restored the hydrology on over 37,000 acres or about 86 percent of highly altered peatlands.

Minimally altered peatlands comprise most of the remainder of the refuge. Approximately 58,500 acres or about 53 percent of the refuge are minimally altered, including the Northwest and Southwest Fork of the Alligator River headwater lands, lands surrounding the Frying Pan part of the Alligator River and along the Scuppernong River, and others. Generally, there is limited or no water management capability in the minimally altered peatlands.

PLANNING PROCESS

This Water Management Plan is a step-down management plan that builds upon the information, goals and objectives presented in the CCP with more specific details on management actions to achieve specific outcomes. A CCP describes the desired future conditions of a refuge or planning unit and provides long-range guidance and management direction to achieve the purposes of the refuge, helps fulfill the mission of the Refuge System; maintains and, where appropriate, guides restoration of the biological integrity, diversity, and environmental health of each refuge and the Refuge System; helps achieve the goals of the National Wilderness Preservation System, if appropriate; and meets other mandates. The CCP for Pocosin Lakes NWR was finalized in 2007 (USFWS 2007).

This WMP is a dynamic working document that guides the management of water for the refuge habitats that depend upon it and provides long-term vision, continuity, and consistency for water management for the next 15 years. The plan will be reviewed and adapted as conditions require.

REFUGE PURPOSES

The purposes of each national wildlife refuge, as established by Congress or the Executive Branch, are the barometer by which all actions on that designated public land are measured. Habitat management, public use, and all other programs are conducted as required to fulfill the established purposes of the refuge.

The 12,350-acre Pungo NWR was established in 1963 by the authorities of the Migratory Bird Conservation Act of 1929 and the Fish and Wildlife Act of 1956. The Service established Pocosin Lakes NWR in 1990 and designated Pungo NWR as a unit of Pocosin Lakes.

The purposes of Pocosin Lakes NWR, including the Pungo Unit, as reflected in the legislation under which Congress authorized the refuge and the refuge has acquired land, is to protect and conserve migratory birds and other wildlife resources through the protection of wetlands, in accordance with the following laws:

> … for use as an inviolate sanctuary or for any other management purpose, for migratory birds… 16 U.S.C. Sec. 664 (Migratory Bird Conservation Act of 1929);
>
> … for the conservation of the wetlands of the Nation in order to maintain the public benefits they provide and to help fulfill international obligations contained in various migratory bird treaties and conventions… 16 U.S.C. Sec 3901 (b) 100 Stat. 3583 (Emergency Wetland Resources Act of 1986);
>
> … for the development, advancement, management, conservation, and protection of fish and wildlife resources… 16 U.S.C. Sec 742f(a)(4) (Fish and Wildlife Act of 1956); and
>
> … for the benefit of the United States Fish and Wildlife Service in performing its activities and services. Such acceptance may be subject of the terms of any restriction or affirmative covenant or condition of servitude… 16 U.S.C. Sec 742f(a)(4) (Fish and Wildlife Act of 1956).

REFUGE VISION

The refuge vision was developed for the CCP for Pocosin Lakes NWR (USFWS 2007):

> The Pocosin Lakes National Wildlife Refuge will restore and maintain natural processes and biodiversity of a functional pocosin wetland and provide habitat for threatened, endangered, and other Federal trust species. On the Pungo Unit, the Refuge will provide optimum wintering habitat for migratory waterfowl and breeding habitat for wood ducks throughout the Refuge on suitable habitats in conjunction with other refuges in the National Wildlife Refuge System.
>
> The Refuge will reduce habitat fragmentation by establishing corridors to other protected areas in the central Albemarle-Pamlico Peninsula. The visitor center will be a gateway for visitors to refuges in eastern North Carolina. The Refuge will serve as a destination for nature-based tourism that will contribute to the economic health of rural communities. It will provide opportunities for priority public uses. The Refuge staff will continue to use partnerships to accomplish goals.

RELATIONSHIP TO OTHER PLANS AND PROGRAMS

In order to maintain consistent strategies for managing wildlife and habitats on the refuge, the CCP and several other documents were used in the development of this WMP.

The Water Management Plan was heavily informed by the Pocosin Lakes NWR Hydraulic and Hydrologic Study and Water Management Study (USDA 1994) developed for three of the RAs. According to that document, in 1992 the Service requested assistance from the local Soil and Water Conservation District and the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) (now called the Natural Resources Conservation Service) in developing a restoration approach designed to reverse, to the extent practicable, the effects of the drainage system that was previously installed on lands that had become Pocosin Lakes NWR. The Service request articulated two goals and 13 objectives. The goals were "*a. To raise water levels to restore as much of the land between Allen Road and County Line (Washington-Tyrrell) to pocosin type wetland as possible*" and "*b. To raise water levels to maintain pocosin type wetlands between County Line and the Gum Neck area.*" The SCS completed the hydraulic and hydrologic study in 1994, making recommendations for road maintenance and repair, watershed unit divisions, siting water control structures (e.g., culverts and risers), and management and operations for some of the most heavily altered (ditched and drained) areas of the refuge. Refuge staff relied heavily on the recommended restoration design presented in the 1994 Study for developing the infrastructure needed to restore the three RAs. However, modifications to that design have occurred over the years as a result of changing field conditions and/or observations of efficacy post-installation. Infrastructure installation has been underway for over 20 years as funding and staffing have been available. Infrastructure development is now complete; however, additional modifications may be needed based on adaptive monitoring. Many design elements and recommendations of the 1994 Study regarding water management have been followed and are being incorporated in this plan. Lessons learned post implementation, changing conditions on the ground (e.g., post fire, etc.) and more current technical information have promoted adaptive management actions by the refuge. While the study laid the groundwork for the restoration design, this WMP builds on that design and begins to shift management focus to identifying drainage level targets, establishing reference sites, and building a robust monitoring network.

The Service initiated a Water Resource Inventory Assessment (WRIA) in 2016 with the goal of evaluating pertinent water management information and assessing long-term threats and needs for water management at the refuge. Refuge management also is informed by recovery planning documentation for federally listed species: the red wolf, *Canis rufus* (USFWS 1990) and red-cockaded woodpecker, *Picoides borealis* (USFWS 2003). In addition, the Service's "National Bald Eagle Management Guidelines" (USFWS 2007) were consulted. Where possible, priority actions identified in these plans were incorporated into the strategies of the Water Management Plan.

In 2014, the Service released a Land Protection Plan expanding the acquisition boundary for Pocosin Lakes NWR by 8,105 acres (USFWS 2014). Where possible, objectives of the expansion were incorporated into the objectives of the Water Management Plan.

The Farm Bill programs administered by the USDA provide cost-share funding and technical assistance to private landowners. These programs aid farmers with installing and managing conservation measures on working farms and forests in order to restore cropland to natural habitats. These efforts are complementary to this plan. The programs provide opportunities for landowners in the vicinity of national wildlife refuges to manage their land as wildlife habitat and to protect it with easements. Pocosin Lakes NWR has an active cooperative farming program and is located near many farmlands enrolled in Farm Bill programs.

The following conservation plans and regional reviews address habitat management and resources found on Pocosin Lakes NWR:

- Pocosin Lakes NWR Comprehensive Conservation Plan (USFWS 2007)
- Pocosin Lakes NWR Biological Review (USFWS 2002)
- Pocosin Lakes NWR Fire Management Plan (USFWS 2009)
- Pocosin Lakes NWR Fire Program Review (USFWS 2010)
- Draft Pocosin Lakes NWR Forest Management Plan (USFWS 2002)
- Evans Road Wildfire Burn Area Rehabilitation Plan (USFWS 2010)
- Pocosin Lakes NWR Cropland Management Plan (USFWS 1994)
- North Carolina Wildlife Action Plan (NCWRC 2005)
- North Carolina Division of Water Quality Pasquotank River Basin Water Quality Plan (NCDENR 2007)

- North Carolina Division of Water Quality Tar-Pamlico River Basin Water Quality Plan (NCDENR 2010)
- North Carolina State Water Supply Plan (NCDWR 2001)
- Coastal Habitat Protection Plan (NCDEQ 2016)
- North Carolina River Herring Fishery Management Plan (NCDMF, 2007)
- North American Waterfowl Management Plan
- Southeastern Coastal Plains-Caribbean Region Report, U.S. Shorebird Conservation Plan (Hunter et al. 2002)
- Southeast United States Regional Waterbird Conservation Plan (Hunter et al. 2006)
- Partners in Flight Bird Conservation Plan (Rosenberg et al. 2016)

Landscape level conservation plans incorporated into this Water Management Plan include the South Atlantic Landscape Conservation Cooperative Conservation Blueprint (www.southatlanticlcc.org). For more detailed information on conservation plans consulted, see the Pocosin Lakes NWR CCP (USFWS 2007).

II. REFUGE CHARACTERISTICS

LOCATION AND HISTORY

Pocosin Lakes NWR is located in the Albemarle-Pamlico Peninsula, surrounded by the Albemarle and Pamlico Sounds (Figure A-2). The refuge encompasses approximately 110,106 acres of Washington, Hyde, and Tyrrell Counties in North Carolina. In 1990, through the donation of land from The Conservation Fund in conjunction with the Richard Mellon Foundation, Pocosin Lakes NWR was established. Initially the Service designated 89,658 acres as the land base for Pocosin Lakes NWR. Due to the refuge's proximity to Pungo NWR, the Service incorporated Pungo NWR into Pocosin Lakes NWR in 1991. It is now known as the Pungo Unit of Pocosin Lakes NWR and retains its establishing purpose for waterfowl and migratory birds. Also in 1991, another 5,707 acres in the Frying Pan area were transferred from Alligator River NWR to Pocosin Lakes NWR due to its proximity to the new refuge. Since then the Service has acquired six additional tracts of land expanding Pocosin Lakes NWR to its current size. For a complete acquisition history, see the Pocosin Lakes NWR CCP.

Figure A-2. Pocosin Lakes National Wildlife Refuge and surrounding features.

The Service named the refuge for the pocosin habitat that dominates the landscape and for the natural lakes that occur within the pocosin. Pocosin is a Native American term that means "swamp on a hill." Pocosins are dominated by a dense, shrubby plant community and deep organic soil. The eastern edge of the refuge lies near the Alligator River, just west of Alligator River NWR, and 47 miles west of the Atlantic Ocean. The northern edge of the refuge lies near U.S. Highway 64, four miles south of the Albemarle Sound. The western edge of the refuge is just east of North Carolina Highway 45 and the Pungo River which flows into the Pamlico Sound. The southern edge of the refuge lies near the Intracoastal Waterway, four miles north of Mattamuskeet NWR. This region is part of the physiographic area known as the South Atlantic Coastal Plain and the Service administrative ecosystem known as the Roanoke-Tar-Neuse-Cape Fear Ecosystem.

The Pungo Unit is 12,350 acres with lands in Hyde and Washington Counties. At the time of establishment, Pungo consisted of the approximately 2,500-acre Pungo Lake and pocosin wetlands surrounding the lake. The Service planned to convert most of the peatlands to cropland and other managed waterfowl habitat, and, in fact, in the early stages of the acquisition process the Service required some of the sellers to complete the agricultural drainage system on about 7,000 acres (Kitts, personal communication). But when much of the surrounding private land started being cleared for farming, the approach was changed to retain some diversity of habitat types. Pocosin habitat remains on Pungo, some of which is hydrologically altered, some hydrologically restored, and some minimally altered.

Historic, pre-alteration, land use in the area depended for the most part on the nature of the land. Hydric, or saturated, soils cover 97 percent of Tyrrell County, 99 percent of Hyde County, and 86 percent of Washington County. Deep organic soils are less productive for crops and forest trees than mineral soils, and the depth of organic soil over mineral soil, though not evident at the surface, has a tremendous influence on the potential uses of the land. The hydric soils remained in forest, pocosin (shrubby plant communities), or marsh until the 20th century. The major historic land uses have revolved around hunting upland game and waterfowl. Native Americans and farmers descended from European settlers cultivated crops on the uplands on the shoreline of the Albemarle Sound and Lake Mattamuskeet and terraces of streams for centuries.

Generally, only typical pocosin vegetation (pond pine, Atlantic white cedar, shrub species) will grow on peat soils greater than 30 inches deep while crops can be produced when it is less than 30 inches (Kitts, personal communication). Prior to establishment of the refuge, in the late 1960s and early 1970s, First Colony Farms cleared most of the vegetation and installed the existing drainage system to support agriculture and other uses. Although very little of the land in the RAs was ever actually farmed or used for pasture, in small demonstration areas the upper part of the peat layer was skimmed off to reduce the thickness of the peat layer to less than 30 inches in order to show that farming was possible on the higher parts of the peat dome north of Colburn Road (Kitts, personal communication). Plowing and land preparation proved too difficult on deep organic soils to allow farming, and economic and regulatory restrictions prevented peat mining. In 1981 and 1985, intense wildfires destroyed vegetation and consumed part of the peat soil layer (USDA 1994, Gregory, et. al. 1984).

Today, the major land use on the land surrounding Pocosin Lakes NWR is farming and hunting. There is little residential construction in the wetlands surrounding the refuge. The population of Tyrrell County is 4,136; the population of Washington County is 12,425; and the population of Hyde County is 5,621 (North Carolina OSBM 2016). The area is still predominantly rural, and the largest towns and county seats are Columbia (Tyrrell County), Plymouth (Washington County) and Swan Quarter (Hyde County) (U.S. Department of Commerce 2013). Tyrrell, Hyde, and Washington Counties are 57 percent, 52 percent, and 40 percent forested, respectively, and 26 percent, 24 percent, and 38 percent cropland, respectively. Soybeans, corn, wheat and cotton account for the largest acres of cropland in the counties. From 2007 to 2012, there was a general increase in the land being used for agriculture in Tyrrell and Hyde Counties.

PHYSICAL ENVIRONMENT

Descriptions of components of the physical environment that are pertinent to water management on the refuge follow. More detailed information regarding the broader physical environment at Pocosin Lakes NWR is available in the CCP (USFWS 2007) and the WRIA (USFWS 2020).

SOILS AND HYDROLOGY

Pocosin wetlands are characterized by poorly drained soils consisting primarily of organic matter such as leaves, sticks, and other once-living material. These organic soils are commonly referred to as mucks or peats. Due to a lack of oxygen in these waterlogged environments, the organic material in the soil decomposes very slowly and in time, the peat actually accretes, forming a dome.

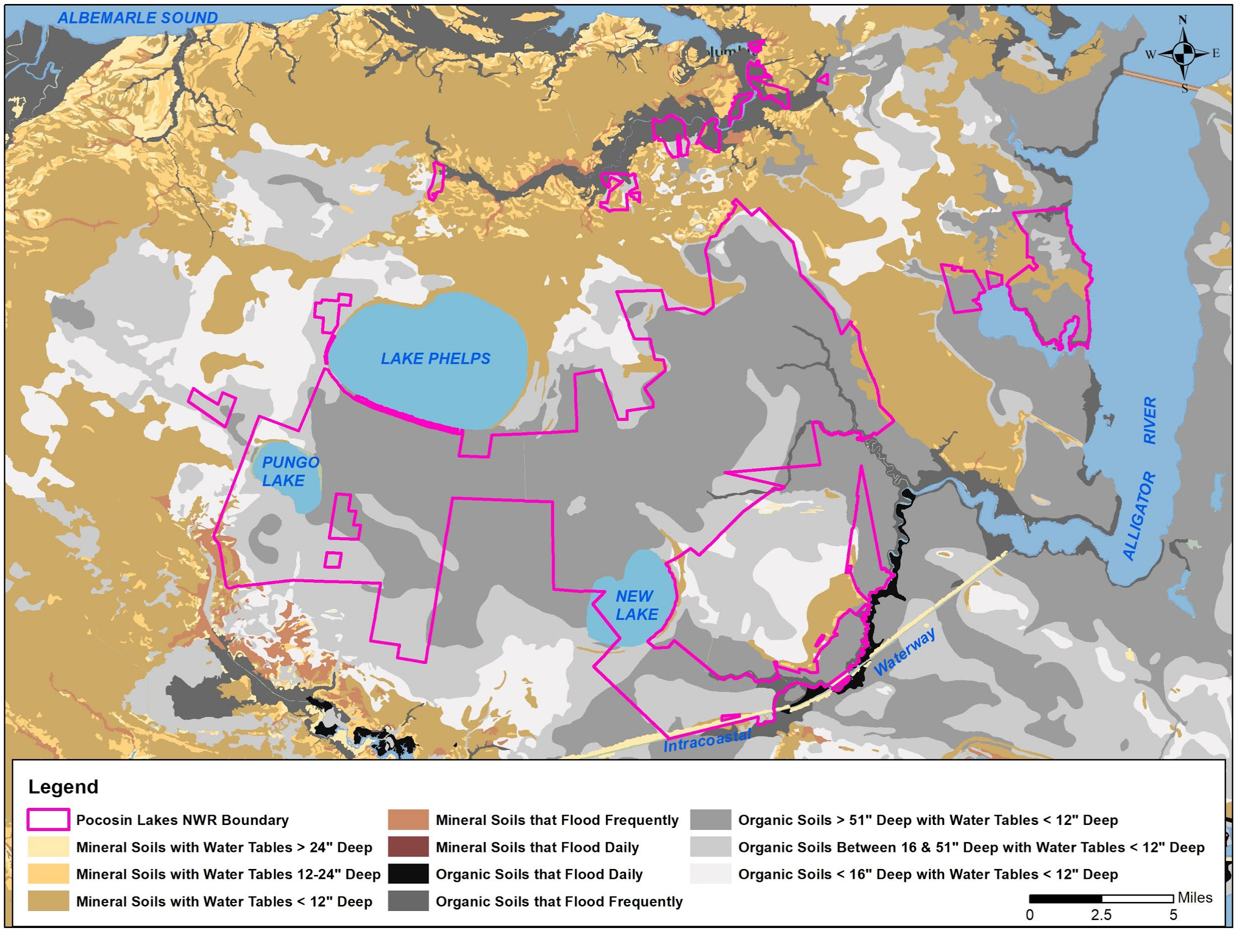
The Albemarle-Pamlico (AP) Peninsula is extremely low and flat; however, the refuge includes some of the highest elevation land in the region, even though those elevations are less than 20 feet above sea level. That topography makes water management on the Refuge extremely complex. Water flows off of the Refuge in several directions; south and west (to the Pungo River), north (to the Scuppernong River), and east (to the Alligator River). Flows to the north, south, and west go through private lands (including productive farmland) on the way to the rivers. Flows to the east generally go to the headwaters of the Alligator River (including the Northwest and Southwest forks of the Alligator River) which are mostly surrounded by Refuge lands.

The somewhat higher elevation lands on the Refuge are the result of the formation of peat domes which occurred over geologic time. The domes consist of high organic content soil which can hold rainwater like a sponge, resulting in wetland hydrology; this is the basis of the Native American term “pocosin,” which means “swamp on a hill.” The term “dome” is commonly used to describe these topographic features; however, the domes are actually very low in elevation and have very wide bases. This results in the domes being nearly unnoticeable in terms of elevation from visual observation. For example, the side slope of the peat dome in RA 1 is only six feet of rise over six miles. But even in this relatively flat landscape, these slight “hills” dictate flow direction. Of course these domes do not occur throughout all of Pocosin Lakes NWR. In other areas, slight changes in topography can add complexity to drainage pathways because slightly higher elevation land located somewhere in the middle of a single canal can cause water to drain down hill toward both ends of the canal.

Formation of peat is an ongoing process in areas sufficiently wet to prevent oxidation of organic matter deposited by plants. According to some estimates, it takes over 100 years for one inch of peat to form. Peat depths on the refuge vary from a couple of inches to 12 feet.

Over 95 percent of the soils on the refuge are high in organic content (Figure A-3; USFWS 2007). According to the National Resources Conservation Service (NRCS) Soil Surveys for the counties in which the refuge is located, all but 17 acres of the refuge’s deep organic soils are classified as mucks (sapric); there are 17 acres of mucky peat (hemic) and no acres of peat (fibric). The differences between mucks and peats include the extent of decomposition of the organic material in the soil and bulk densities. This degree of specificity is not necessary for this plan, and we use the terms “peat” and “muck” interchangeably in reference to the refuge’s deep organic soils. We also use the term “peatlands” in reference to these lands with deep organic soil. Over 68 percent of refuge soils are greater than 51 inches of muck over mineral soils, and about 25 percent are 16 to 51 inches of muck over mineral.

Figure A-3. Characteristics of soils at Pocosin Lakes National Wildlife Refuge



Most of the soil types on the refuge are also considered hydric. Hydric soils are "soils that in their undrained condition are saturated, flooded or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic (water loving) vegetation" (USDA Soil Conservation Service 1985). These soils have seasonally high water tables within a foot of the surface of the soil. On the refuge, these hydric soils contain a mucky organic surface layer that varies in thickness. Typically, the thicker the muck surface layer, the shorter the vegetation growing on the soil. The terms “high pocosin” and “low pocosin” are sometimes used to categorize this variation in vegetation.

Peat domes, or pocosins, are generally higher in elevation than the surrounding areas and the peat soil functions like a big sponge, absorbing rainfall which is the primary source of water to the system. Therefore, despite the fact that the pocosin is ever so slightly higher than its surroundings, drainage is very poor. Any rain water not absorbed by the soil spreads out and moves very slowly across the surface of the land in a manner known as “sheet flow.” Prior to the excavation of ditches and canals to drain the land, excess rainfall drained off the peat dome via sheet flow when the organic soils became inundated. When the rain stopped, inundation conditions gradually lessened due to sheet flow off of the peat dome and a saturated soil condition would return. Without additional rainfall, the water table level and soil moisture would then begin to drop slowly due to evapotranspiration, which is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants (McDonald 1983). With the installation of drainage ditches, water leaves the system through evapotranspiration, ditch system drainage, and sheet flow when the capacity of the ditch system is overwhelmed.

While extreme rainfall events and droughts can have a dramatic impact on the above and below ground water levels, there is a seasonal pattern to the water levels within pocosins under normal conditions. Generally, the water table is higher in the winter and lower during the growing season. This is because evapotranspiration often outpaces rainfall during the growing season when plants are using large amounts of water for photosynthesis (USFWS 2020).

HYDROLOGIC ALTERATIONS

Artificial drainage of peatlands in eastern North Carolina began before 1800, and considerable acreage in the Albemarle peninsula was converted before 1900 (Ashe 1894, Lilly 1981, McMullan 1984). The volume of peat on the Albemarle Peninsula is probably less than half the original amount due to the effects of drainage, agriculture, and fire (Lilly 1995). There are descriptions of subsidence greater or equal to 3 feet as a consequence of drainage and agriculture (Ruffin 1861, Dolman and Buol 1968, Lilly 1981, Roberts and Cruikshank 1941, Whitehead and Oaks 1979). In general, drainage of organic soils results in the loss of at least one-third of the peat (Farnham and Finney 1965), and sometimes more (Dolman and Buol 1968, Lilly 1981). Some of the initial loss in volume is due to subsidence and compaction at the time of ditching (Dolman and Buol 1968, Skaggs et al. 1980). In addition, drainage makes pocosins drier, increasing the frequency and severity of fires. Sharitz and Gibbons (1982) note that wildfires in pocosins during periods of dry weather, and a low water table, can burn enough peat soil to form a lake when the water table returns to normal levels. Lastly, drainage causes peat to oxidize rather than accumulate. If subjected to drainage, fire, and tillage over a long enough period of time, all blackland soils will become mineral soils (Lilly 1981).

Degradation of refuge peatlands commenced when ditching occurred, lowering the water table. Logging and vegetation removal to facilitate agriculture also degraded pocosin habitat. These changes on the landscape significantly altered the natural hydrologic regime and limited two of the critical components of peat formation. After the abandonment of agriculture on refuge land, the drainage system once managed entirely by First Colony Farms is now jointly used by the refuge and adjacent landowners. Accordingly, there is a shared interest in coordination between landowners regarding the condition of drainage canals and adjacent earthen roads. With ditches and canals in place, water leaves the peat dome and accelerates the rate and depth at which the peat soil dries out. Even though rain events can bring water levels in the ditches back up — even to the point of soil saturation and sheet flow — the water levels drop back down to an artificially low level following the event because of the drainage system. These lower water levels result in the pocosin losing its wetland hydrologic characteristics. Counterintuitively, when peat soil is dried out for long periods of time, it loses its ability to function as a sponge and repels water (Dolman and Buol 1968).

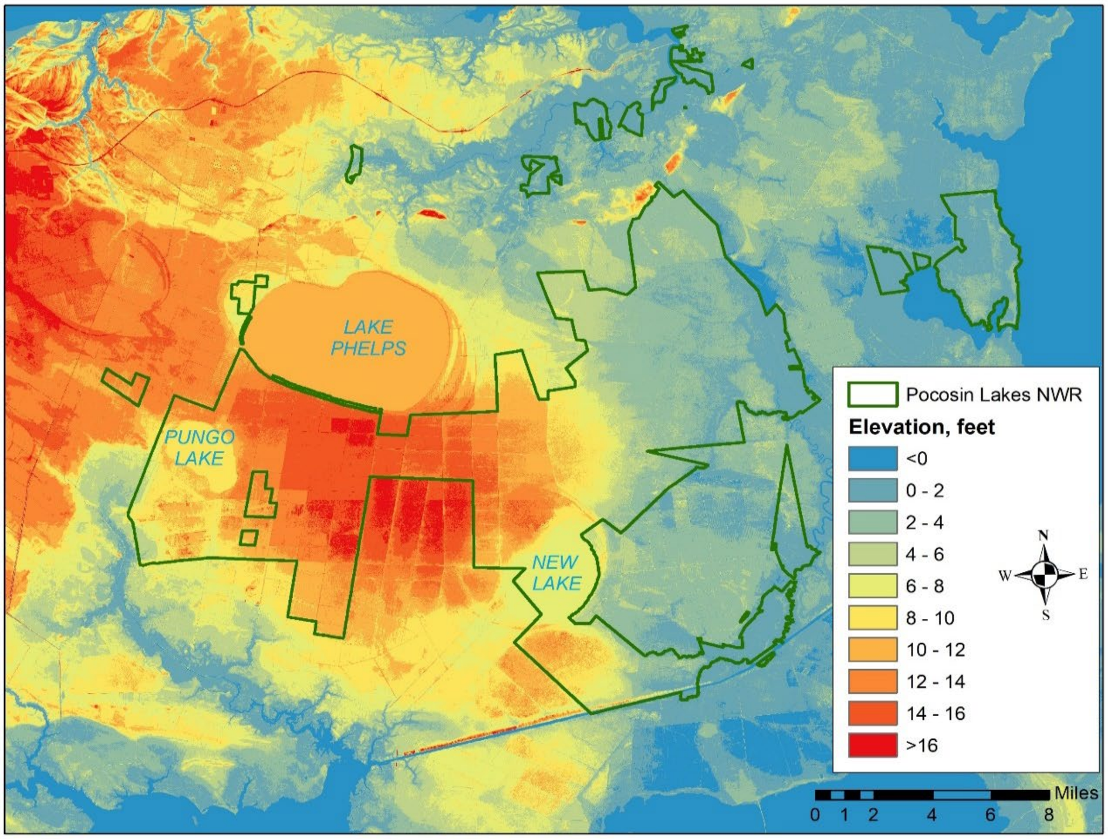
Environmental factors, like the amount of rainfall received and the rate of evapotranspiration, are beyond the control of the refuge. Fortunately, the artificial drainage level in the extensive drainage/ditch systems can be managed with relatively simple infrastructure, allowing the Service to eliminate excessive artificial drainage of water via the ditches from the refuge's peat soils. This allows rainfall to be captured and held in the peat soils, returning their natural sponge-like qualities. Therefore, while evapotranspiration can cause the water table to drop, peat soils in restored areas will retain moisture longer than peat soils in an open drainage system.

GEOLOGY AND TOPOGRAPHY

The "Dismal Swamp" from which Pocosin Lakes NWR is comprised, originally extended over a million acres, from the James River in southeastern Virginia to the Pamlico Sound in northeastern North Carolina. The Outer Coastal Plain Region of North Carolina where Pocosin Lakes NWR is located generally rests less than 20 feet above sea level. The area gives the appearance of a very low, flat, gently sloping landscape, which was shaped by numerous climate-driven sea level changes associated with glacial cycles over the past 3-4 million years. There are, however, very slight variations in elevation across the refuge caused by the developmental stages of the peat soils underlying the refuge. Saturation allows for continued accrual of soil, while oxidation leads to soil loss and subsidence. The result is a landscape dotted with small potholes across the overlying soils, the depths and locations of which are contingent upon micro-scale conditions over time. Wildfires, which have been a relatively frequent occurrence at Pocosin Lakes NWR due to the susceptibility of dry peat to burn in drained areas, also have the potential to diminish the soil deposits in the region and cause major changes in the surface topography.

Bare earth Light Detection and Ranging (LiDAR) elevation data is available for the refuge with 5-foot point spacing and a vertical resolution of 6-17cm (Figure A-4). Elevation across the refuge alone is low-lying and ranges from 0-23.6 feet above mean sea level (msl). The surface is highest in the central section of the refuge where the deepest peat deposits occur, and is lowest in the eastern sections as the land slopes downward toward the northwest fork of the Alligator River and other outlet drainages. The region comprises a complex set of landforms including the ancient Suffolk shoreline, Carolina Bays, swales, river terraces, drowned-river estuaries, and ancient ocean shorelines (Riggs et al. 2011). Some of these features are evident in the LiDAR data.

Figure A-4. LiDAR elevation data for Pocosin Lakes NWR and surrounding areas. Source (USGS QL2 LIDAR Data, 2014).



The geology of the region and processes which formed the peat has been discussed by numerous authors (Daniels 1981; Daniels et al. 1984; Dolman and Buol 1967, Heath 1975, Lilly 1981, Otte 1981, Whitehead 1972). When glaciers receded after the last ice age 10,000 to 15,000 years ago, water movement was impeded, which led to formation of peat and ultimately, pocosins. Formation of peat is an ongoing process in areas sufficiently wet to prevent oxidation of organic matter deposited by plants.

As the climate began to warm again following the last glacial maximum, sea level on the North Carolina coast rose consistently, although at varying rates, to present day (Riggs et al. 2011). The river valleys created during the last glaciation were drowned by the rising seas, forming the 160-mile-long Outer Banks sand ridge and the Albemarle-Pamlico estuary system (Heath 1975). The sounds' expansion and impingement landward persist today as temperatures and sea level continue to rise.

This long history of fluctuating sea levels and advancing and retreating shorelines over the past 100 million years has led to a complex sequence of aquifers and confining units, making up a wedge-shaped mass of primarily unconsolidated sediments underlying the peninsula.

GROUNDWATER

Water enters the subsurface in recharge areas across the Coastal Plain Region, and flow is dictated by the hydraulic conductivities of aquifer materials and hydraulic gradients to discharge areas, which primarily occur along streams and adjoining floodplains (Heath 1980). A simulated groundwater budget for each formation layer was computed for the region by Campbell and Coes (2010). The upper aquifer is most vulnerable to contamination, since the water table lies so close to the surface in this region (APNEP 2012). About 20 percent of the precipitation across the Coastal Plain enters the shallow groundwater aquifer (Winner and Simmons 1977), and most of that recharged volume remains within shallow aquifers until it is lost to evapotranspiration or discharges to streams. Evapotranspiration and rainfall are primary drivers of the local water table, with about two-thirds of rainfall inputs leaving the system via evapotranspiration (USDA 1994), though this estimate may be slightly conservative.

Groundwater near the refuge is generally within a couple feet of the land surface during the growing season (Hinesley and Wicker 1996). Units within the peatland RAs are managed by maintaining the water levels to promote a seasonal water table near the ground surface in order to maintain saturated conditions necessary for peat accrual. Doing so attempts to mimic natural, pre-ditching hydrologic conditions, thereby reducing peatland drainage and making the system less susceptible to fire.

To evaluate the potential for refuge management of drainage levels at specific water control structure to affect the surficial water table (and corresponding extent of ponding and storage), a recent elevation analysis was conducted (KBE 2017). That study concluded:

> "In general, the mapping results and analysis show that current flashboard elevations do not create large areas of ponded water on the Refuge. At the current flashboard elevations, the normal water table will be at the surface or above in less than 3% of areas analyzed. Every map resulted in the water table being below the ground surface on 97% or more of the affected area. The remaining open water areas are primarily confined to the canal and ditch system."

It is important to note that, due to its position on the topographic landscape, vast portions of "the swamp on the hill" are limited to rainfall as the sole source of water. Accordingly, the surficial water table will necessarily fluctuate based on the amount of precipitation and evapotranspiration.

DRAINMOD is a computer model that tracks rainfall, infiltration, evapotranspiration, and runoff on an hourly basis over long periods of time (Skaggs 1978) to simulate the hydrology of poorly drained, high water table soils drained by drainage ditches or natural channels. DRAINMOD was used for the 1994 studies by the SCS on the refuge (USDA 1994) and was recently updated using more current data (KBE 2017). The model runs focused on soils data from Gregory et al. (1984), who described an organic soil surface with very high infiltration and lateral conductivity overlaying a deep/lower infiltration capacity layer of more decomposed peat. In general, this results in most storms infiltrating the surface and then flowing laterally towards ditches at a shallow depth (KBE 2017). Recent model simulations (KBE 2017) of restored peatlands confirm that they are primarily rainfall and evapotranspiration driven.

FIRE

Fires are a natural part of pocosins, which are characterized by fire-dependent vegetative communities. Because peat soils have a high organic matter content, they will burn (Ash et al. 1983, McDonald et al. 1983). Prior to settlement of the area, fire frequency occurred on a natural return interval determined by soil type, depth, water table, and vegetative community. The severity of peat ground fire was largely dependent on the water table and pre-alteration fires were typically restricted to above ground fire. On soils associated with pocosin wetlands, known as histosols, a fire return interval between 7 and 300 years would have been expected, with peat bogs with plant communities like those at Pocosin Lakes NWR towards the higher end of that range. In particular, Atlantic white cedar plant communities that were historically present at the refuge were associated with a fire return interval exceeding 50 years (Frost 1995).

Prior to 1900, fires in the swamp were uncontrolled and probably occurred mostly during drought periods. Lightning was the main ignition source, but Native American hunting parties and early loggers may have set some fires. Railroad and logging activities appeared to increase the frequency of long duration peat fires from about 1900-1945. Simpson (1990) reported on "The Great Conflagration," a logging slash fire that started in 1923 and did not go out until 1926, eventually burning an area of about 150 square miles. Yellow peat smoke filled the air around Plymouth, Wenona, and Roper for entire summers. Since the mid-1940s, prevention and suppression efforts reduced both the number and magnitude of fires within the pocosins, but ignition from lightning persists, particularly in drought years. This is especially true for formerly common railroad and agriculture-ignited spring wildfires, which ceased being a problem when some local farming practices and the railroad made effective changes. Several large and long duration fires have occurred within and nearby the refuge since the 1940s. Most pocosin wildfires result in the loss of combustible organic soils to depths ranging from a few inches to six feet. In fact, one theory is that Pungo Lake formed from a large, deep burning peat fire (Heath 1975). Frost (1989) hypothesized that fire ceased being a major factor in determining natural vegetation only about 50 years ago for most of this geographic area, originally the most fire prone area in North Carolina.

The creation of ditches and canals artificially drained the land, which dried soils below historic levels. This created a unique fire hazard that increases the frequency and severity of fires and threatens to consume the organic soils, changing the entire ecosystem of the area (USFWS 2008). The refuge has historically had numerous incidences of lightning caused wildland fires that caused significant natural resource damage, especially to the organic soils. During the last 35 years, the refuge has experienced two catastrophic wildfires and deep ground fires due to drought conditions and artificially drier organic soils from drainage practices prior to refuge establishment. These fires are considered catastrophic compared to the historic fire regime associated with pocosin forests (Bailey et al. 2007).

The first catastrophic fire was the 1985 Allen Road Fire on then Pungo NWR and adjacent lands caused by an escaped slash pile debris burn. Under drought conditions, this spring season wildfire roared through then First Colony Farms and was eventually stopped when it reached the Alligator River. This fire burned over 100,000 acres and, in some areas, as much as a meter of peat soil was consumed (USFWS 1990b, Poulter et al. 2006). The Allen Road fire destroyed 26 homes and related buildings. Refuge and state fire personnel worked for at least eight weeks on this incident as it literally shaped the mandate for a future fire program at the refuge. Estimated total carbon emissions ranged from 1 to 3.8 TG (or 1,000,000 to 3,800,000 metric tons of carbon), and a heterogeneous burn pattern resulted in carbon fluxes of 0.2 to 11 kg carbon per square meter (Poutler et al. 2006). The burn area of 40,000 hectares (ha) was classified as being 25,000 ha pine forest (62 percent), 4,225 ha agriculture, 5,548 ha hardwood forest, and 5,466 ha shrub-scrub (Michler and Welch 2010).

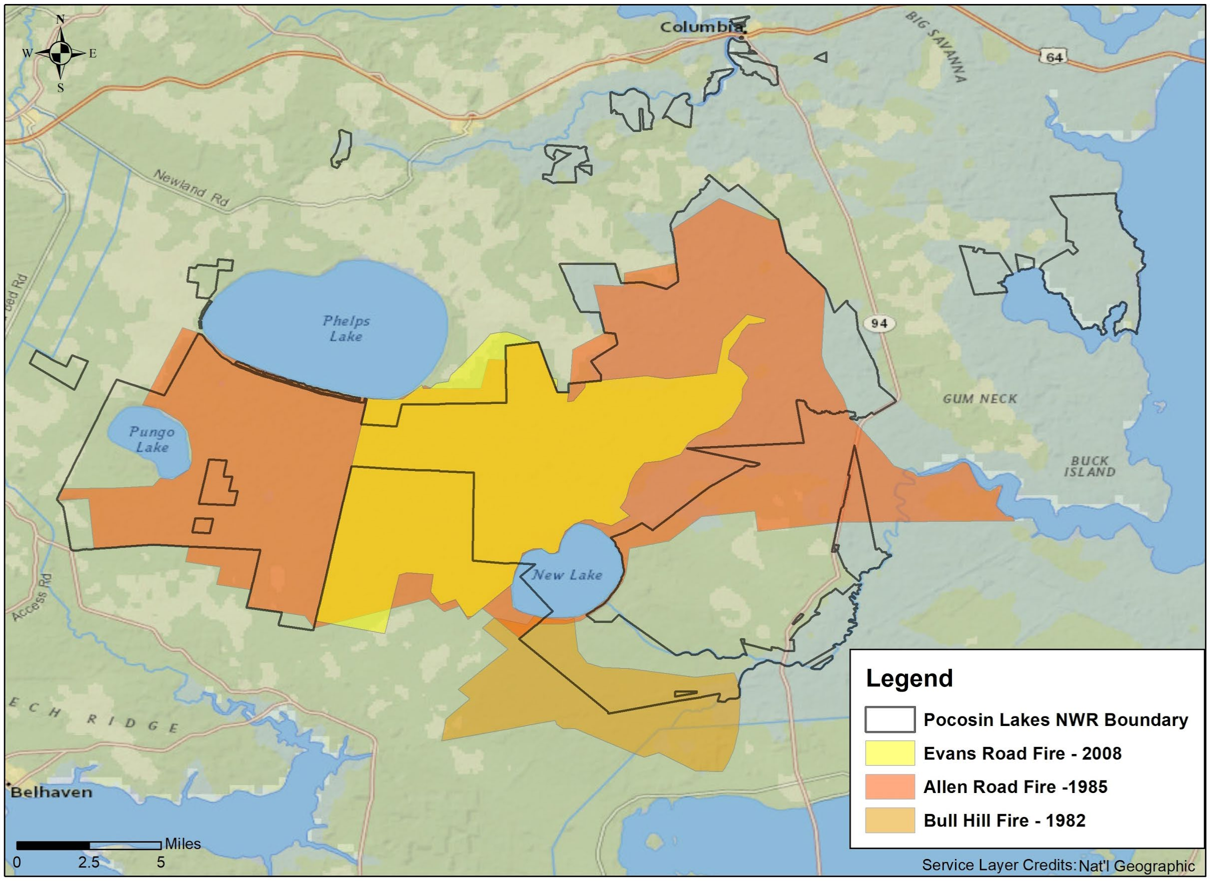
The Evans Road Wildfire was ignited by lightning on private lands on June 1, 2008, and was finally extinguished in January 2009. In total, 40,740 acres burned with the following average depths of soil loss: 24 inches lost over 15,350 acres of non-federal land (private land and Pettigrew State Park), 12 inches lost over 16,100 acres of federal land west of Western Road, and 6 inches lost over 9,650 acres of federal land east of Western Road. The estimated carbon loss was approximately 10 million tons (Mickler and Welch 2010). The areas with drier peat conditions located on adjacent private land experienced severe ground fire resulting in losses of over five feet of peat. The refuge experienced less severe ground fire than on adjacent drained private lands due to wetter peat conditions from the ongoing, but not yet complete, hydrology restoration work. Most of the infrastructure for the hydrology restoration was installed by 2010.

Since 2010, several fires of less than 100 acres have burned on Pocosin Lakes NWR. The majority of these were lightning caused and occurred in the summer months. Most of these required extended mop-up due to ground fire. A wet cycle that started in 2013 has resulted in very few fires since it started.

Prescribed burning is a widely used tool. The habitats of the Albemarle-Pamlico Peninsula depend on fire. Some pine trees rely on fire to trigger seed release. Fire frequency and intensity strongly influence vegetative structure dominance, composition, height, and diversity. Canebrakes and a large portion of the shrub-dominated pocosins on the refuge are fire-maintained pocosins on shallower peat soils. In the absence of fire, the canebrake succeeds to shrub pocosin and eventually to climax community with a pine overstory and a shrub understory. With increased human habitation and modification of the landscape, wildfires cause severe destruction and limit the ability of the habitat to provide its historic functions. Therefore, controlled, prescribed fires are the means by which managers incorporate fire as a management tool while minimizing the negative impacts.

Appropriate water management allows prescribed fire to be utilized with less risk of ground fire occurring. The drainage network limits the seasonal saturation of the peat soils while also lowering the water table. This, in turn, aerates and dries the peat, leading to more frequent ground fire and significant soil loss—in some cases, wildfires are repeated within the same footprint of prior events (Figure A-5). Drainage also limits the ability to control wildfire because any water pumped for suppression purposes or rainfall cannot be retained on the landscape. Saturation of the soils under restored hydrologic conditions reduces the potential for peat ground fires to burn intensely while still allowing the above ground vegetation to burn, which is a necessary component of pocosin ecosystems (USFWS 1990). Pocosin Lakes NWR has an existing Fire Management Plan (USFWS 2008) and prescribed burn plans that describe where and how to manage refuge resources through the use of prescribed fire.

Figure A-5. Peat ground fire footprints at Pocosin Lakes NWR post-drainage.

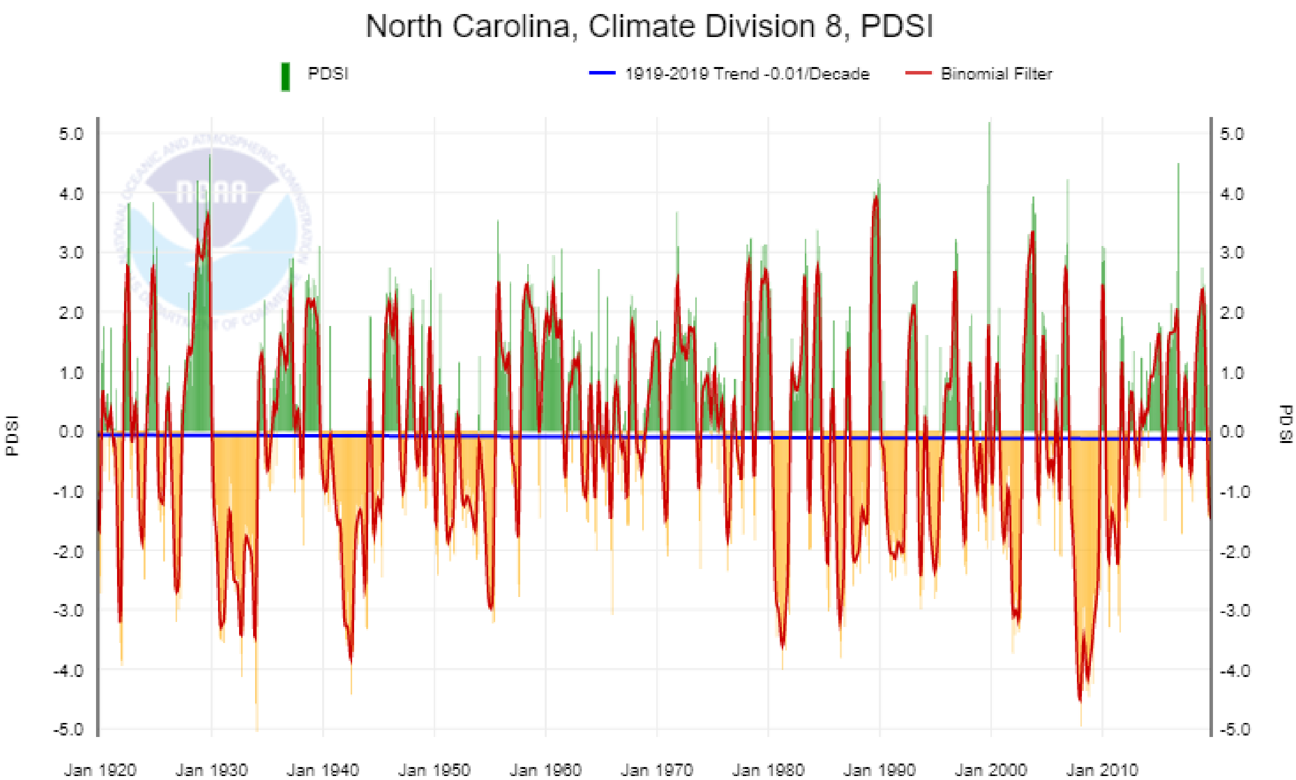


CLIMATE, PRECIPITATION, AND EVAPOTRANSPIRATION

Details about the climate of Pocosin Lakes NWR are available in the Pocosin Lakes NWR CCP.

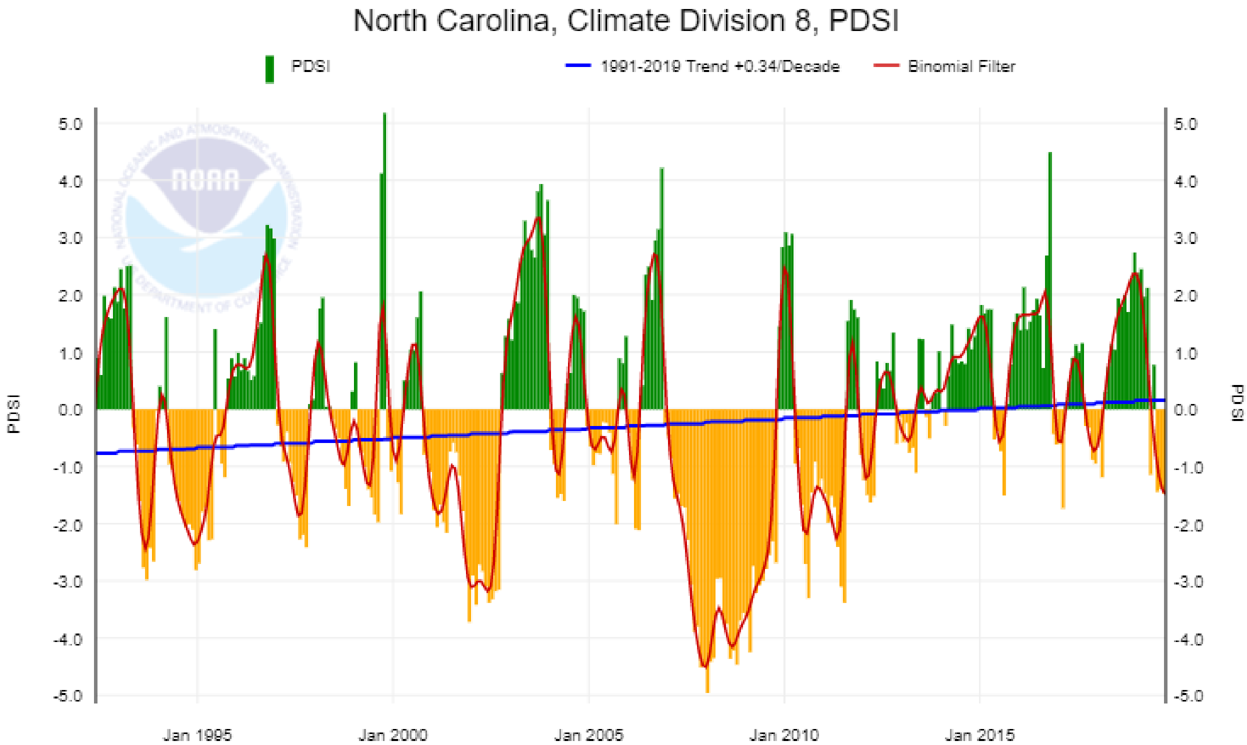
On average, the refuge receives over 50 inches of rainfall annually. Generally, about a third of the rainfall drains off the land. Most of the rainfall, about two thirds, is removed by evapotranspiration. Evapotranspiration normally causes the water table level in pocosins to drop during the growing season, while periodic rainfall events cause upward fluctuations of the water table. During the winter, when plant growth and evapotranspiration slow, water table levels normally rise. This typical seasonal pattern can be drastically changed by atypical precipitation events and patterns. For example, the refuge received much higher rainfall amounts in 2015 and especially in 2016, and a much lower amount in 2007, which was a drought year. Multi-year dry and wet cycles (patterns) have also been documented in the region. Long-term Palmer Drought Severity Index values show those cycles (Figure A-6).

Figure A-6. Monthly Palmer Drought Severity Index values for North Carolina's northern coastal plain from 1919 - October 2019 (NOAA 2019).



In 2013/2014, the Palmer Drought Severity Index data show that the area entered a wet cycle after many years of mostly drier conditions. The wet cycle continued until early to mid 2019 (Figure A-7). During drier periods, there would often be little to no water draining off of the refuge during the growing seasons. But during the recent wetter period, it has been much more common for water to drain from the refuge throughout most of the growing season. Rainfall has a significant effect on field conditions and pocosins are often referred to as a "rainfall driven system."

Figure A-7. Monthly Palmer Drought Severity Index values for North Carolina's northern coastal plain since refuge establishment from 1991 - October 2019 (NOAA 2019).



SEA LEVEL RISE, RESILIENCY, AND ADAPTATION

The Albemarle-Pamlico region is affected by climate changes on the local scale as well as the global scale, most notably by sea level rise. Estimates have also suggested that sea level has risen globally at an increasing rate over the past 15-20 years (USCCSP 2009). In past periods of rapid relative sea level rise, levels rose more quickly in the northern region of the Sound System (including northern Pamlico Sound and northward) compared to the southern region (Horton et al. 2009). Similarly, the frequency of "nuisance-level" flooding, or minor coastal flooding experienced during high tide, has increased since the 1980s in this region (NOAA 2014). Higher sea levels not only exacerbate coastal drainage, flooding, and inundation issues, but also increase the coastline's vulnerability to storm surges and hurricanes (USFWS 2020).

Rising sea level has already visibly impacted the area, especially in the eastern region of the Albemarle-Pamlico Peninsula, by inundating low-elevation peatlands, marshes, and the unique ecosystems that distinguish the region's coastline (Riggs and Ames 2003, USCCSP 2009), and causing saltwater intrusion into inland waterways and over farm fields (Girvetz et al. 2009). Because of the low-lying nature of the entire peninsula, similar effects may soon be felt more directly by the refuge and other inland areas.

A 1-foot rise in sea level in this region, which is likely to be exceeded by the end of the century even under the best-case (low emissions), could significantly alter the landscape, habitat, and hydrology of Pocosin Lakes NWR as the northwest fork of the Alligator River, Pungo River, and other major drainages back up farther into the refuge (Manda 2018, USFWS 2020). Some models predict that within the next century 12-15 percent of the North Carolina coastal plain could be engulfed by the Albemarle-Pamlico estuary, and a much larger proportion will experience saltwater intrusion (Riggs and Ames 2003, Poulter et al. 2009).

Although the specifics about future conditions are uncertain, significant changes in the climate and hydrology of this region are inevitable. Planning for climate change is essential to the effective management of refuge water resources and habitat. Pocosin Lakes NWR has been noted to be particularly sensitive to climate change, due to its location on a biome edge (Magness et al. 2011). Biome edges are generally associated with species range margins where population changes may occur, influencing species' abilities to adapt to climate change. Wildlife communities specific to Pocosin Lakes NWR are therefore more limited in their ability to respond to changing conditions (USFWS 2020).

As sea level rises, there is a corresponding increase in local vulnerabilities to coastal flooding, storms, coastal erosion, threats to coastal structures, saltwater intrusion of freshwater resources, and higher water tables. Erosion presents a particularly complicating factor for predicting sea level rise impacts, with shoreline recession varying drastically based on shoreline types, geometry, composition, location, orientation, size and shape of adjacent waterbody, vegetation, water level, storm frequency, and storm intensity (Riggs and Ames 2003). It is estimated that an average of 1,166 acres per year of estuarine land are eroded away across nearly 1,600 miles of shoreline in northeastern North Carolina (Murphy 2002). An increase in shoreline armoring and stabilization methods across the peninsula in response to these processes could result in increased rates of erosion in undeveloped reaches, and may affect the ecosystem in areas like Pocosin Lakes NWR and adjacent lands in many different ways (USCCSP 2009, Corbett et al. 2008). On top of this, shoreline retreat, peat loss from wildfire, subsidence, slumping and loss of coastal peat due to saltwater intrusion, and other processes all impact the region (Pearsall and Poulter 2005).

Inland development across the peninsula is low, and the broad watershed is well-protected with low road density (Magness et al. 2011). Up-gradient migration of wetlands along the peninsula may provide a response strategy for the ecosystem to gain ground while other areas are lost to the rising seas (Riggs 2003), but as previously noted this adaptive capacity is somewhat limited due to the very low elevation range across the region (Magness et al. 2011). Roughly 50 square miles of coastal environment in northeastern North Carolina have been lost to erosion over the past 25 years due to these low gradients (Riggs and Ames 2003). Higher sea levels additionally increase the likelihood of flooding associated with other hydrologic factors outside of storm events, such as spring tides, and will likely lead to the salinization and inundation of coastal wetlands. Current strategies to alleviate the already-existing flooding issues on the inner Peninsula provide pathways by which saltwater is transferred. Ditches are being excavated or widened across the Peninsula for the purpose of draining floodwaters more quickly, a process which exacerbates the coastal saltwater intrusion issues (Manda 2018).

Identified by the International Panel on Climate Change as one of the most vulnerable ecosystems to climate change due to sea level rise, coastal wetlands are valuable features of the landscape and local economy for the Peninsula (CIER 2008, Darnell 2008). Unfortunately, it is not clear to what degree these wetlands in particular will be able to adapt to sea level rise. Modeled projections of coastal wetland responses to rising seas are unsuited for wetlands across the Albemarle-Pamlico Peninsula because of several characteristics that set the region apart, including low elevation and very low land surface slopes, absence of lunar tides, and lack of large sediment sources (Moorhead and Brinson 1995). Unlike tidal marshes that can migrate overland at a rate controlled by the sediment supply, land surface slope and the rate of sea level rise, the pocosin wetlands on the Albemarle-Pamlico Peninsula are the result of an in situ process of vertical accretion in an area where there is negligible land surface slope. Therefore, the ability for coastal wetlands to adapt to sea level rise may be limited. If the rate of sea level rise exceeds the vertical accumulation rate of peat in these wetlands, extensive areas could be submerged within a relatively short time (Moorhead and Brinson 1995).

EXTREME WEATHER EVENTS

Extreme weather events can have significant impacts on refuge and adjacent lands, infrastructure, and water drainage. The drainage of water throughout the region is relatively slow because of the flat nature of the landscape. Rising sea levels have resulted in higher average sound and coastal river levels, thus impeding drainage from the low-elevation lands to the rivers. Likewise, hurricanes and other coastal storms can bring large amounts of rainfall in a short period of time while wind tides or storm surge can push waters even higher in the rivers. The combination of high rainfall and hindered drainage into the rivers can result in extensive flooding on the landscape (Figure A-8). Alternatively, during droughts, when there is a lack of water supply, evapotranspiration can dry out the peat soils, and the region can become more susceptible to large, catastrophic wildfires. Consistent with the refuge mission and purpose, the focus of management is on restoring hydrology and reducing the risk of catastrophic wildfire; however, there are circumstances where refuge infrastructure may provide some potential to ameliorate extreme weather impacts as described below.

Figure A-8. Flooding in Columbia, North Carolina

Precipitation in the Albemarle-Pamlico region averages about 50 inches per year, but is highly variable across the region and across years (Heath 1975). More recent annual precipitation data from NOAA's weather station in Gum Neck, which is located just east of the main body of the refuge, indicates that average annual rainfall from 2009 to 2013 was 55.9 inches and from 2014 to 2018 it was 64.9 inches. In 2016, that weather station recorded 82.7 inches of rainfall (NOAA 2019a).

The Palmer Drought Severity Index data indicating that the cyclical wet and dry cycles are trending towards wetter conditions in recent years (Figure A-7) coincides with altered frequency patterns of more intense storms. Although the total number of tropical cyclones that have impacted the Atlantic Basin (IPCC 2007) and North Carolina (Eastin 2012) has increased between 1900 and the present, an analysis by Eastin (2012) concludes that it is likely that North Carolina will be impacted by roughly 2-3 fewer tropical cyclones or hurricanes per decade in the future. However, it is likely that a larger percentage of those storms that make landfall will be more intense on average than in the past (Eastin 2012, USGCRP 2009). In contrast, a general increase in hurricane frequency is predicted by some models over broader spatial scales (IPCC 2007). An increase in storm intensity along the North Carolina coast, combined with sea level rise projections, has the potential to increase the frequency of extreme (100-year) coastal floods by 3-4 times by the end of the 21st century (UNCW 2008).

Restoration infrastructure (see Section III) allows for maintenance of higher soil moisture conditions to a point; however, inundation and sheet flow or flooding resulting from large amounts of rainfall cannot be managed. Modeling studies show that peak flow rates from fully drained and controlled drainage (restoration) areas are nearly identical during high rainfall events (KBE 2017). Once rainfall fills up the ditches (i.e. the capacity of the drainage system is exceeded) sheet flow starts occurring. The 24-hour capacity of the ditch system on the Refuge can easily be exceeded during large storm events like hurricanes, requiring just 1.0 to 1.5 inches of rain during a wet period or 2.0 to 5.0 inches of rain during a dry period (USDA 1994). Although not the primary purpose of the restoration design, some stormwater retention occurs in the RAs from simply installing and using the restoration infrastructure and managing drainage. For example, a modeling study demonstrated that the overall amount of water draining off the refuge annually is reduced by managing drainage (USDA 1994, KBE 2017). Furthermore, whenever a lack of rainfall and evapotranspiration prior to a storm reduces water levels below the board levels set in a riser, stormwater runoff is prevented until the water level reaches the top of the boards and drainage flow resumes. This provides a limited stormwater retention benefit for downstream lands. However, when rainfall amounts prior to a storm are higher, causing water levels to rise above the top of the boards and water to drain from the refuge, little stormwater retention capacity exists.

While the refuge has previously received requests to use the riser and levee system as a catchment during major storm events, setting lower drainage levels is contrary to the goal of restoring pocosin wetland hydrology and would increase wildfire risks. Maximizing stormwater retention benefits would require setting lower drainage levels well in advance of storms and adding boards to risers to catch as much rainwater as possible during or after a storm. Reducing the drainage level by removing boards from risers to drain water from the refuge to create stormwater storage capacity when hurricanes or other storms are forecasted for the area also has several inherent drawbacks:

- First, there is usually not enough time, once a storm is forecasted to strike the area, to drain enough water off the refuge to create a significant amount of stormwater retention capacity. The concept of drawing down water levels across the Refuge to create storage for large rain events is a complicated one. The timing of a forecasted storm event, the time it takes to move water downstream, and the potential benefits of an action must be a part of a decision making strategy. Initial calculations indicate that it would take several days for water levels to drop within the Refuge after a lowering board levels. It will take over a week for water from the uppermost areas of the Refuge to travel through downstream canals and to the Pungo River (pers comm Kris Bass 2019). This timing not only limits the potential storage benefits, but could create unintended consequences downstream. If waters from the Refuge meet storm surges, the combination could make flooding worse in some places. Consequently, managers must consider the potential unintended consequences of pre-storm drainage on lands in storm surge vulnerable areas.

- Second, there is the risk of a forecasted storm changing direction. In this case, the water released from the refuge might not be replenished by the storm, which could lead to drier soil conditions until sufficient rainfall occurs, thus increasing wildfire risk and negatively impacting wetland conditions.
- Third, stormwater retention benefits are realized only if boards can be reinstalled either prior to, during, or immediately following significant rainfall events. There is a risk with very large storms causing widespread damage that refuge staff will not be able to access the risers and reinstall boards removed prior to the storm in a timely fashion.

Because of these drawbacks, drawing down RAs prior to forecasted storms will be considered on a case-by-case basis and at a limited geographic scope considering the best available information about each storm, including water levels prior to possible draw down, the storm's projected path and intensity, projected timing and intensity of storm surge, confidence in projections, and other factors. Given the associated risks, decisions regarding if and when to modify drainage settings during a pre-storm window will be weighed carefully.

Another extreme weather event is prolonged drought, which, in addition to creating some stormwater retention capacity at risers, can lead to low groundwater levels. While peat soils will retain moisture as the water table drops, over time during a prolonged drought the soils will begin to lose moisture and become dry. Above ground vegetation will become dry more quickly than the soil. The combination of dry above ground vegetation and drying soils increases the risk of wildfire above and below the ground surface level (Figure A-9). Surveillance of water control structures is important during droughts to ensure that little or no water is lost via the artificial drainage system.

Figure A-9. Firefighting at Pocosin Lakes NWR

While Palmer Drought Severity Index values indicate the refuge experienced a wet cycle in recent years, it experienced very dry conditions for most of 2007 - 2011 (Figure A-7). This was the setting for the 2008 Evans Road Fire, which burned in the peat soils in and around the refuge for more than six months and cost nearly $19M to manage. To supply water to contain the fire on some of the fully drained private lands, water was initially pumped from Lake Phelps and later, it was pumped uphill through the ditch system from the Alligator River. This was very costly and is cost-prohibitive during non-emergency prolonged droughts.

On rare occasions during prolonged droughts, the refuge has received requests to release water. However, unless appropriate infrastructure is already in place downstream to hold released water, it would simply drain on to the river and be ineffective. Additionally, releasing water during a drought would further dry the peat soil and increase wildfire risks on the refuge. If drainage management infrastructure were to be installed downstream, it could be used to manage rainfall and drainage from upstream prior to a drought, thereby lessening the need for water during the drought.

WATER QUALITY

The water quality on portions of Pocosin Lakes NWR can be affected by the water quality in Albemarle Sound, Scuppernong River, Lake Phelps, and Alligator River. Nutrient loading in the Albemarle Sound, Scuppernong River, and Alligator River and related non-point source pollution has the potential to affect the water quality on portions of the refuge in the future. There are 16 facilities in the counties around the refuge in the National Pollution Discharge Elimination System. The State of North Carolina has classified the water bodies around Pocosin Lakes NWR for minimum water quality standards. All the water bodies and streams meet the standards established for the minimum uses. The high water tables in the soils in the three counties represent a great potential for non-point pollution. The residences in the three counties have onsite treatment of domestic wastewater (i.e., septic systems). Those systems are more likely to fail on soils with high water tables. Agricultural operations are also more likely to generate elevated nutrient and pesticide concentrations capable of reaching the water table before plants utilize the nutrients or the pesticides break down.

One of the most significant water quality issues on the refuge is related to the prior drainage of refuge peat soils. Peat in the area of the old East Dismal Swamp formed over the last 9,000 years; its high organic content and poor drainage resulted in retention of metals and nutrients over geologic time (similar to the way an activated charcoal filter cleans water by accumulating contaminants). The wetland hydrology that allowed for peat accumulation also provided the conditions for accumulation of atmospheric mercury and nutrients over geologic time (Zillioux et al. 1993). Mercury concentrations in peat from the area south of Lake Phelps ranged from 40 to 193 ng/g (dry weight) with a geometric mean in surface samples of 71 ng/g (Evans et al. 1984; DiGiulio and Ryan 1987).

When peat bogs are ditched, the water table is lowered and the peat is aerated, which accelerates soil oxidation and nutrient (Brinson 1991) and metal (Lodenius et al. 1987) release. South of Lake Phelps, extensive drainage prior to Service acquisition enhances off-site run-off of metals and nutrients, and these are known parameters of concern in regional water quality impairment (NCDWQ 1999). The impacts of drainage in the area have been concisely stated by Daniels (1980, 1981):

> "…drainage and development of wetlands, particularly wetlands underlain by deep organic soils, will result in some rather substantial changes to water quality. When the increased amounts of nutrients, sediment, and other dissolved constituents are rapidly carried by canal runoff to coastal waters, the resulting drop in salinity and increase in nutrients can result in algal growth and eutrophication and ultimate disruption of marine habitat along the coastal fringe."

Artificial drainage also contributes to off-site water quality impacts by speeding the pace of run-off and increasing discharge peaks (Kirby-Smith and Barber 1979, Daniel 1980, Gregory et al. 1984). An unintended consequence of drainage is enhanced fire intensity, leading to soil loss and off-site transport of constituents previously immobilized in the soil matrix. Wildfires are more intense in the drained peatlands than the natural state, and they exacerbate soil loss and mobilization of soil constituents that can degrade the quality of run-off water following fires.

Work to restore the wetlands has demonstrable benefits to water quality, both estimated from the published literature as well as measured through site-specific research. Restoration of wetland conditions in peatlands formerly drained for agriculture will reduce nutrient export, and improve water quality (USFWS 2002).

AIR QUALITY

In North Carolina, the impacts of agricultural nutrient, and specifically nitrogen, releases have been the subject of great concern. Like European regions with intensive animal production, the human population in North Carolina is significantly outnumbered by animals in production facilities (NC DWQ 1999). As a result of a series of significant environmental problems caused by nitrogen over-enrichment, including algal blooms and fish kills in the lower rivers and sounds in the State, research efforts here have focused on links between confined animal feeding operations (CAFOs) in the eastern portion of the State and observed environmental degradation. Nitrogen-sensitive Albemarle and Pamlico Sounds receives a total nitrogen load of approximately 23 million kilograms annually, of which, about 40 percent is estimated to result from atmospheric deposition (USEPA 2000). In recognition of these nutrient stresses to local waters, the North Carolina Department of Environment and Natural Resources (NCDENR) designated waters on and surrounding the refuge as “nutrient sensitive.”

In 2003, a large CAFO was proposed within a mile of the southern boundary of the refuge. Based on concerns related to the potential for nutrients and other wastes to impact local fish and wildlife resources, nearby sensitive habitats, and the quality of the refuge visitor experience, the environmental fate of emissions from the facility was assessed. That study concluded that the refuge is downwind of the large poultry operation 45 percent, 66 percent, 57 percent, and 46 percent of time during winter, spring, summer, and fall, respectively. Ammonia nitrogen loading via dry deposition to the refuge was determined between 41 percent and 79 percent higher downwind of the CAFO than background dry ammonia deposition alone (Robarge et al. 2013). Ambient atmospheric chemistry was also measured at the refuge prior to and following the start of operations at the CAFO. Compared to background gaseous ammonia monitoring during 2005–2006, a consistent increase in ambient weekly concentrations of atmospheric ammonia was evident after late fall/early winter of 2008; however, the extent to which the CAFO facility which began operating in August 2006 contributed to the increase could not be determined with atmospheric monitoring alone (Robarge et al. 2013). In addition, changes in weekly wet atmospheric nitrogen and phosphorus measured at monitoring stations located 0.8, 7.9, and 10.3 km downwind pre- and post operation of the indicate significant doubling in mean wet ammonia concentrations at the closest wet deposition monitoring station with no change at the other sites (Rossignol et al. 2011). This increased load coupled with nutrient enrichment bioassay results indicating co-limitation of nitrogen and phosphorus in local waters suggest downwind deposition or runoff from the facility has the potential to impact receiving waters via phytoplankton productivity and biomass (Rossignol et al. 2011).

Catastrophic fire and ignition of the highly combustible carbon-rich soils can impact air quality. Soil moisture is a major factor contributing to the likelihood that the peat soils of pocosin will smolder when ignited during a fire; lower soil moisture results in higher chances for soil smoldering (Reardon et al. 2007). Following even a low intensity peat fire, up to 90 percent of soil mass can be consumed in an hour in burnt layers of peat (Rein et al. 2008). Four catastrophic wildfires have occurred in northeast North Carolina and southeast Virginia since 2008: Evans Road Fire 2008 (Pocosin Lakes NWR), South One Fire 2008 (Great Dismal Swamp NWR), Lateral West Fire 2011 (Great Dismal Swamp NWR), and Pains Bay Fire 2011 (Alligator River NWR). These wildfires also had a negative effect on air quality, human health, and safety. During the Evans Road Fire, emergency room visits for cardiopulmonary complications increased significantly in counties exposed to the smoke (Rappold et al. 2011). While drained peatlands can be a source of air quality impacts due to oxidation and burning of soil associated contaminants, rewetting these previously drained peatlands is anticipated to greatly reduce air quality impacts as ground fire risks are reduced.

BIOLOGICAL ENVIRONMENT

Pocosin Lakes NWR is comprised mostly of pocosin habitat but also consists of bottomland hardwood forests, agricultural farm fields, moist soil units, lakes, ponds, and impoundments, Atlantic white cedar, and cypress gum swamp. These habitats support over 200 species of birds occur on Pocosin Lakes NWR including neotropical migrants and large concentrations of wintering waterfowl. The refuge supports over 40 species of mammals, including a large population of black bears and white-tailed deer. Wildlife diversity also includes numerous species of reptiles, amphibians, and fish. Detailed information regarding wildlife species that use the refuge can be found in the Pocosin Lakes NWR CCP (USFWS 2007). Maintenance of appropriate hydrology conditions on the refuge supports healthy habitat which, in turn, promotes rich biodiversity conditions. Descriptions of biological resources that will benefit from water management actions are included below.

SHOREBIRDS AND MARSH AND WADING BIRDS

The canal banks, riparian areas, marshes, and perimeters of Pungo Lake, New Lake, Frying Pan Lake and Phelps Lake provide important habitat for shorebirds and marsh and wading birds. Marsh habitats along Alligator River and the Intracoastal Waterway provide habitat to yellow rail, king rail, American bittern and least bittern. The rails are considered a secretive family of birds that prefer wet habitat such as tidal and brackish marshes, nontidal freshwater marshes and swamp. Their diet is primarily small insects and crustaceans with some seed (Bookhout 1995, Eddleman 1994, Poole 2005). The rails are particularly vulnerable to habitat loss in the region due to the draining of wetlands for development or agriculture as has occurred on Pocosin Lakes NWR.

More intensive surveys are required to further document shorebird and marsh and wading bird use on the refuge. Climatic conditions, especially rainfall, determine habitat availability to support most shorebird species on the refuge. The most abundant and diverse shorebird species occur during drought years. The staff conducts shorebird surveys depending on habitat availability (exposed mudflats) around the lake, firebreaks, and moist-soil units.

WATERFOWL

Waterfowl require food and cover, and for nesting species, adequate nest cavities in suitable locations (NCCES 1994). A variety of habitats are managed on the Refuge for wintering migratory waterfowl and breeding wood ducks. These habitat types include open water, moist soil (Strader and Stinson 2005), farmlands, flooded wetlands, and wood duck nest boxes. Intensive surveys, including bimonthly ground surveys and bimonthly aerial surveys, have documented waterfowl peak use and use days since the establishment of the Pungo Unit as Pungo NWR in 1963. Over 1,000 acres of moist-soil units, other managed wetlands, and three lakes provide abundant wintering habitat for migratory waterfowl. The refuge provides breeding habitat for wood ducks, hooded mergansers, American black ducks, and mallards. The refuge also hosts large numbers of wintering snow geese and tundra swans. Annual peak numbers of waterfowl using the refuge is approximately 100,000 individuals.

Foraging habitat on the Pungo Unit includes agricultural lands, moist soil impoundments, and impounded forested wetlands. Agricultural lands are managed to provide supplemental grain, such as corn, and green browse, such as winter wheat. Moist soil impoundments are managed to provide high-quality natural waterfowl foods in the form of seeds, tubers, and browse from native emergent wetland plants. Impounded forested wetlands provide some tree mast, invertebrates, and other food, as well as sanctuary areas where waterfowl are protected from hunting and other human-caused disturbance.

The Refuge's farmlands provide important high carbohydrate forage for many species of waterfowl, but in particular the tundra swans, snow geese, and Canada geese. Moist-soil impoundments are intensely managed for early succession emergent wetland plants. The seeds, leaves, roots, and tubers of these plants provide important foods for migratory wintering waterfowl. In addition, the wetland habitat supports diverse invertebrate populations which provide protein sources for waterfowl and other migratory birds, including shorebirds and marsh and wading birds. Wood ducks nest in large trees with cavities in or adjacent to flooded habitats. On the Refuge, the majority of these cavity trees have been lost due to timber harvests prior to refuge ownership and catastrophic wildfires. Wood duck nest boxes have been used to supplement the number of natural cavity trees on the refuge. Pungo Lake on the Pungo Unit and the refuge's portion of New Lake located to the east of the Pungo Unit provide roosting and sanctuary habitat for wintering waterfowl. These areas are protected from excessive human-caused disturbance through regulations and law enforcement thereby creating sanctuary areas. Lakes are managed to maintain, to the extent practicable, full-lake water levels and, therefore, provide the maximum acreage of habitat and sanctuary.

NEOTROPICAL MIGRATORY BIRDS AND OTHER LAND BIRDS

The Partners In Flight North American Landbird Conservation Plan states; "The most imperiled Watch List and Stewardship Species are or were birds of the original bottomland-hardwood or southeastern pine forests that require conditions that are rare or absent today," (Rich et al. 2004, Meyer 1995). Pocosin Lakes NWR is located along the Atlantic Flyway for numerous Neotropical bird species and provides breeding, wintering, and stopover habitat for neotropical migratory birds and other land bird species. The various stages of ecological succession and the diversity and range of structure within the vegetative communities on the Refuge benefit many Neotropical migratory birds and other land bird species. This diversity of habitats is particularly important for stop-over sites for these species.

Key neotropical migratory bird and other land bird species of management concern on the refuge include the endangered red-cockaded woodpecker, brown-headed nuthatch, red-headed woodpecker, Chuck-will's-widow, American woodcock, prairie warbler, northern bobwhite quail, prothonotary warbler, black-throated-green warbler, wood thrush, northern parula, rusty blackbird, hooded warbler, Kentucky warbler, Swainson's warbler, and pine warbler. Pocosins, with their variety of vegetative species and structure, provide habitat for these key neotropical and other land bird species of management concern. In particular, the importance of the shrubland stage pocosin cannot be overstated. Pocosin, as detailed earlier in this document, is characterized by very wet, peat substrate that supports different species in different locations depending on the depth of peat and the amount of water within the substrate. Therefore, some areas have a dense shrub layer, others support grass stage communities or cane dominated habitat, and others still may be forested with pine, Atlantic white cedar, hardwoods or a mix of species.

A particular benefit to Neotropical migrants and other land bird species is the inaccessibility by humans to many areas of the Refuge. For those species that are sensitive to human activity such as the red-cockaded woodpecker and the rusty blackbird, this isolation of habitat is critical.

The very presence of the habitat on Pocosin Lakes NWR is critical for some species that are dependent on certain types. For instance, the black-throated green warbler is specific to Atlantic white cedar forests. The Refuge protects this particular habitat in several areas and in turn supporting this habitat specific bird. Since the mid-1980s, the once abundant northern bobwhite quail have significantly declined in North Carolina due to habitat loss. These birds inhabit a variety of early successional stage and edge habitats on the Refuge including firebreaks, open forests, croplands, overgrown fields and vegetated roads.

Intensive long-term monitoring should be conducted in the vegetative communities on the Refuge to more accurately document population parameters for the various species that occur on the refuge throughout the year.

THREATENED AND ENDANGERED SPECIES AND OTHER SPECIAL STATUS SPECIES

Two federally listed species occur on the refuge: the endangered red wolf and the endangered red-cockaded woodpecker. On Pocosin Lakes Refuge, managing the native habitats and restoring a healthy functional peatland ecosystem will benefit the red wolf. In addition, the farmlands on the refuge provide important habitat for prey species including raccoon, rabbit, nutria, rodents, small mammals and white-tailed deer. Habitat requirements for red-cockaded woodpeckers have been extensively studied; however, the majority of that research has been conducted in the typical longleaf pine, savannah habitat which does not always correspond with red-cockaded woodpecker populations in pocosin habitat. The red-cockaded woodpeckers that inhabit pocosin habitat are likely genetically unique and appear to have a higher tolerance to midstory encroachment on the cavity trees than their counterparts in longleaf pine savannah habitats. Additional research is needed to fill in these knowledge gaps to provide best management practices for these unique pocosin populations.

The bald eagle was removed from the list of threatened and endangered species in 2007 and is still protected under Bald and Gold Eagle Protection Act. Biologists have documented the presence of American alligators on land adjacent to the refuge. This species is listed as “threatened” due to similarity of appearance to other endangered crocodilian species.

State listed species that do or could occur on the refuge include: star-nosed mole, Rafinesque’s bigeared bat, Southern dismal swamp shrew, southern bald eagle, loggerhead shrike, Bachman’s sparrow, black vulture, red-cockaded woodpecker, little blue heron, tri-colored heron, Cooper’s hawk, American eastern peregrine falcon, glossy ibis, and American alligator.

VEGETATION

The majority of land in Pocosin Lakes NWR is defined as pocosin habitat. The refuge CCP (USFWS 2007) discusses four categories of pocosin habitat: high pocosin (comprising approximately 41,400 or 36.5 percent of refuge lands), high pocosin grass stage (comprising approximately 9,000 acres or eight percent of refuge lands), high shrub pocosin (comprising approximately 19,200 acres or 17 percent of refuge lands), and low pocosin (comprising approximately 360 acres or 0.3 percent of refuge lands). High pocosin habitats are characterized by shallow peat soils and taller vegetation while low pocosin habitats are characterized by deep peat soils and typically shorter vegetation.

The vegetative types found on these organic soils include pocosin (58 percent), bay forest (3.9 percent), peatland Atlantic white cedar (2.8 percent), mix pine flatwoods (12.4 percent), hardwood swamp forest (12.8 percent), and cypress/gum swamp (0.9 percent). Bay forest and peatland Atlantic white cedar are special types of pocosin. Mixed pine flatwoods are also pocosin wetlands, and are characterized by peats deeper than 16 inches. Typically, this habitat supports vegetation such as loblolly pine, pond pine, red maple, wax myrtle, and red bay

(USFWS 2012). The non-riverine swamp forests of Pocosin Lakes NWR exhibit shallower peat deposits compared to pocosins, and flood regimes are variable. They often support species such as bald cypress, red maple, and swamp tupelo.

Historically, cypress stands were extensive in the area of the refuge; however, clear-cutting has limited the extent of these habitats. Cypress/gum swamp habitat is dominated by blackgum (tupelo) and bald cypress which typically occurs in the wettest parts of the floodplain. Coastal plain bottomland hardwoods habitat is dominated by various combinations of bottomland hardwoods such as water oak, willow oak, other mast producing tree species, and conifers which occur in relatively high parts of the floodplain. Bottomland hardwood swamps are typically a little higher and less wet than cypress/gum swamps, and are flooded occasionally. The land is more productive in these areas due to the shallower peat soils. In and around the refuge, many of these areas have been cleared for agriculture, if flooding could be controlled.

The Atlantic white cedar forest on the refuge is a special type of peatland wetland. Atlantic white cedar, also known locally as juniper, is considered a globally threatened ecosystem due to the relatively few remaining stands of this species. Atlantic white cedar is an early successional species that often grows in dense, even-aged stands. Atlantic white cedar forests are the product of a low frequency, relatively high intensity fire regime that is probably related to their marginally moist-soil conditions. Over time a seed bank accumulates in the surface layer of peat which can regenerate following catastrophic events (fire or blow-down from a hurricane) when seed sources are available. However, severe wildfires destroy the seed bank when the peat is consumed in ground fire. As a result, there is no remaining seed source to regenerate Atlantic white cedar naturally. Several plantings at Pocosin Lakes National Wildlife Refuge have conclusively shown that seedlings grown to large transplants (three feet in height) give better results in the field, especially when subjected to browsing and heavy weed competition (Hughes 1995, Hinesley 1999). Today, Pocosin Lakes NWR is fostering Atlantic white cedar restoration and research.

Vegetative communities in pocosins rely on peat soils and appropriate hydrology conditions. It is anticipated that vegetative communities on the refuge will experience positive changes over time in areas where rewetting has occurred.

INVASIVE SPECIES

There are several invasive and/or exotic plant species found on the refuge. These include common reed or Phragmites, alligatorweed, Japanese stiltgrass, parrot feather, Sesbania, Japanese honeysuckle, Canada thistle, and Chinese privet.

Alligatorweed and parrot feather are exotic aquatic plants which out-compete native vegetation. Alligatorweed has significantly spread and can be found in the majority of the refuge canals located on the east side of the refuge and, for the first time in 2005, on the Pungo Unit. Large mats of this weed are found floating in the Alligator River, Scuppernong River, and their tributaries, sometimes limiting or preventing accessibility to remote locations of the rivers and impacting drainage through the system. Parrot feather, originally an ornamental aquarium plant, is spreading at a slower rate but is becoming more frequently prevalent in refuge canals and small ponds. Small patches of Sesbania were first observed while conducting the 1999 vegetation surveys in the Smartweed impoundment. The presence of common reed will require continued early detection and rapid response to its detection through active management.

SOCIOECONOMIC ENVIRONMENT

The current area of Pocosin Lakes NWR lies in Tyrrell, Washington, and Hyde Counties, North Carolina. Tyrrell, Washington, and Hyde Counties are in northeastern North Carolina with Dare County and the Atlantic Ocean to the east, Pamlico Sound to the south, Martin and Beaufort Counties, North Carolina, to the west, and the Albemarle Sound to the north. The areas have had little growth since 1900 despite rapid growth in Dare County on the coast to the east and the major highway to the coast passing through Tyrrell and Washington Counties. The lack of growth is due in large part to the poorly drained, deep organic soil that makes development expensive and environmentally hazardous. Unemployment and poverty rates are much higher than the State average.

Like other rural areas throughout the country, outdoor activities are both popular and traditional uses of the area. Hunting and recreational fishing are popular pastimes and farming, commercial fishing, and forestry are important elements of the economy.

CULTURAL RESOURCES

Any archaeological sites and artifacts within the refuge are protected under the provisions of the National Historic Preservation Act, Archaeological Resources Protection Act, and other laws. There have been limited archaeological investigations within the refuge. No significant artifacts have been found. The wetland environment makes it unlikely that there are many cultural resources on the refuge. The small area of uplands (170 acres of the 110,106 acres on the refuge) is the most likely site of settlements or encampments.

Formal Phase I field investigations involving surface collections, shovel testing, and metal detection to identify and define the boundaries of archaeological resources within the refuge have not been conducted by the Service. Refuge staff conduct management activities so as to avoid compromising potentially sensitive sites.

III. DESCRIPTION OF EXISTING WATER MANAGEMENT INFRASTRUCTURE AND WATER MANAGEMENT UNITS (WMUs)

Because Refuge lands are generally higher in elevation than surrounding lands and rainfall on the refuge supplies almost all of the water, much of the refuge's water management consists of conserving that rainfall. A big part of conserving rainfall is stopping excessive drainage via the drainage systems that were constructed prior to the establishment of the refuge. So in many places, the refuge's water management consists of managing the level to which the drainage system is allowed to drain water from Refuge lands.

Each of the drainage systems are different, but have some common components. When the ditches and canals were dug, the excavated material was placed beside the ditch/canal creating a dike (Figure A-10) or elevated embankment. The terms "dike," "berm," and "levee" are sometimes used interchangeably, but a berm is often considered smaller than a dike and a dike smaller than a levee. Likewise, "ditch" and "canal" are sometimes used interchangeably, but often a ditch is considered smaller in size than a canal.

Figure A-10. Canal maintenance with excavated material placed on top of adjacent dike.

The infrastructure used in the drainage system canals to manage water includes water control structures (WCSs). There are several types of WCSs; flashboard riser WCSs (risers) are used extensively on the refuge (Figure A-11). A flashboard riser consists of a culvert pipe with a half standpipe welded to one end. The face of half standpipe is equipped with one or more "slots" consisting of two pieces of channel iron designed to hold the ends of wooden or metal boards. The ends of boards slide into the channels and stack upon each other in each slot to establish a higher drainage level.

Figure A-11. Flashboard riser water control structures, before and after installation.

The height to which the boards are stacked sets the level to which the water drains down via the ditch or canal. When rainfall causes the water level in the canals to exceed the board level, the artificial drainage system is engaged. When there is not enough rainfall to raise the water level above the board level, the artificial drainage system is disengaged and water does not drain via the canal.

Figure A-12. Risers with water flow and with no flow over the top of the boards.

There are currently 71 riser locations on the refuge, many of which have two risers installed side by side as shown in Figure A-12 above. The size and number of risers at a location determines flow capacity, which corresponds to the flow capacity of the ditch or canal.

Tidegates, also called flap gates, are sometimes installed on the outlet end of risers and culverts. The gate opens when the water is higher on the inlet side of the structure allowing flow. When the water level is higher on the outlet side of the structure, head pressure closes the gate and stops flow in that direction. There are currently only a few tidegates used on the refuge.

Plugs are also sometimes used to control drainage in ditches or canals. A plug is simply earthen fill material used to completely block a ditch or canal (Figure A-13). The plug may be an extension of a dike or berm, in which case it is elevated above ground level. Alternatively, it may be stand alone, in which case it is often the same elevation as the adjacent ground level because water could simply flow around a higher elevation plug across the adjacent ground surface. There are currently 16 earthen plugs used for water management in ditches and canals on the refuge.

Figure A-13. Earthen plugs used to block water flow in a ditch/canal.

Culverts are installed when a dike extends through a canal for vehicular travel and water flow in the canal needs to be maintained (Figure A-14). While culverts do not serve a water management function, they can become clogged and have an impact on water management. Currently, there are 84 culverts on the refuge in 83 different locations.

Figure A-14. Culvert installation.

The term “impoundment” is used to describe certain types of waterfowl habitat management areas. Impoundments consist of land that is completely enclosed by a dike or berm. There is typically a water control structure draining water into the impoundment and one or more structures for controlling the drainage level for water leaving the impoundment. Surface water can also be pumped into or out of the impoundment. There are currently four managed impoundments on the refuge, all of them on the Pungo Unit. Two of the impoundments have wells that allow groundwater to be pumped into them.

INFRASTRUCTURE MAINTENANCE

As with all infrastructure, water management infrastructure must be routinely checked and maintained. Debris (logs, aquatic vegetation, etc.) floating in the canals constantly blocks risers and culverts (Figure A-15). During periods of high rainfall, these blockages have to be removed to maintain ditch system drainage. When rainfall is low and water levels drop below board levels due to evapotranspiration, clearing the debris is less urgent. When mowing or performing other maintenance operations, risers are sometimes hit by heavy equipment and must be repaired. In addition, risers and culverts deteriorate over time and must be replaced; however, the life span of these structures is usually several decades.

Figure A-15. Obstructed and unobstructed riser water control structures.

Dikes/roads and canal banks are mowed or treated with herbicides annually to prevent tree roots from compromising the berms and to facilitate observation of water levels in the WMUs. As is common in earthen dike systems, leaks sometimes develop. For instance, woody debris cannot always be eliminated during dike construction. If a log is left in the dike during construction, water can run along it and eventually erode a path creating a noticeable leak and even a breach. Leaks are repaired by coring the dike in the affected area, which means a trench is dug in the center of the dike and the dirt is repacked in the trench resealing the dike.

MONITORING EQUIPMENT

Equipment used to monitor hydrologic conditions on the refuge include surface water level gauges and flow meters, groundwater monitoring wells, and soil moisture monitoring stations. Working with the refuge, USGS, Duke University Wetland Center, The Nature Conservancy, Kris Bass Engineering, NCSU's North Carolina Climate Office, and others have installed this type of equipment and collected data from the refuge. Staff maintain a fire weather station on the refuge that provides rainfall information in addition to weather stations surrounding the refuge. The Service has partnered with the NC Department of Public Safety to add monitoring stations on the three rivers that receive drainage from the refuge - the Alligator, Pungo, and Scuppernong Rivers - as part of their Flood Inundation Mapping and Alert Network (FIMAN) in order to better monitor and understand the effects of storm surge in those rivers on hydrologic conditions on and around the refuge.

MANAGED WATERFOWL HABITAT

Managed waterfowl habitat includes Pungo Lake, part of New Lake, crop fields and moist soil, forested wetland, and farmed impoundments. The impoundments are named (see Figure A-19). The agricultural fields have numeric designations used primarily to delineate which local producer is farming the fields under a Cooperative Farming Program agreement. All of the managed waterfowl habitat, except for New Lake, is located on the Pungo Unit. Therefore, water management to facilitate the management of waterfowl habitat occurs primarily on the Pungo Unit.

Much of the water management that occurs at Pungo is very different than in the refuge's other water management areas (peatlands). To utilize water for habitat management to support waterfowl needs, board levels in risers are seasonally changed in order 1) to drain water down during the growing season to enable crop, moist soil plant, and tree mast production and 2) to raise water levels by holding water during the fall and winter to make foraging and other habitat available to wintering waterfowl. Other active water management techniques, such as surface and groundwater pumping, are also used on a small scale for waterfowl habitat water management. Often, the fall season can be dry (low rainfall) making raising water levels difficult. Pumping is one solution, but it is expensive because of fuel and labor costs.

The portion of New Lake that lies within the boundary of the refuge is included in this section because of its value as additional waterfowl habitat. However, its value as a natural feature of the pocosin habitat is also recognized. The water management objectives and strategies for pocosin habitat at New Lake would generally be the same as those for waterfowl.

PUNGO UNIT DRAINAGE SYSTEM

Water draining off of the Pungo Unit flows to the Pungo River via two main routes. Most of the drainage water flows down Hyde Park Canal to the river. Some of the land on the west side of the unit, however, drains down D Canal and under Pat's Road to a couple of other canals on adjacent private land; these canals enter the river well upstream of Hyde Park Canal confluence.

The main drainage routes for water headed to the Pungo River via Hyde Park Canal is: 1) Property Line Canal - which is one of only a few refuge canals that receives drainage water from adjacent lands - to Pungo Lake, which empties into Hyde Park Canal, or 2) the water goes around the lake via West Lake Canal and South Lake Canal, which also empties into Hyde Park Canal (Figure A-16). Drainage infrastructure for these Hyde Park drainage routes includes: 1) a large double riser in Hyde Park Canal located about a mile north of the southern refuge boundary, 2) a riser under Hyde Park Road/Dike in South Lake Canal, and 3) a riser on the Lake Outfall Canal under South Lake Road/Dike that sets the drainage level for Pungo Lake (Figure A-17).

Figure A-16. Pungo Unit drainage routes to the Pungo River.

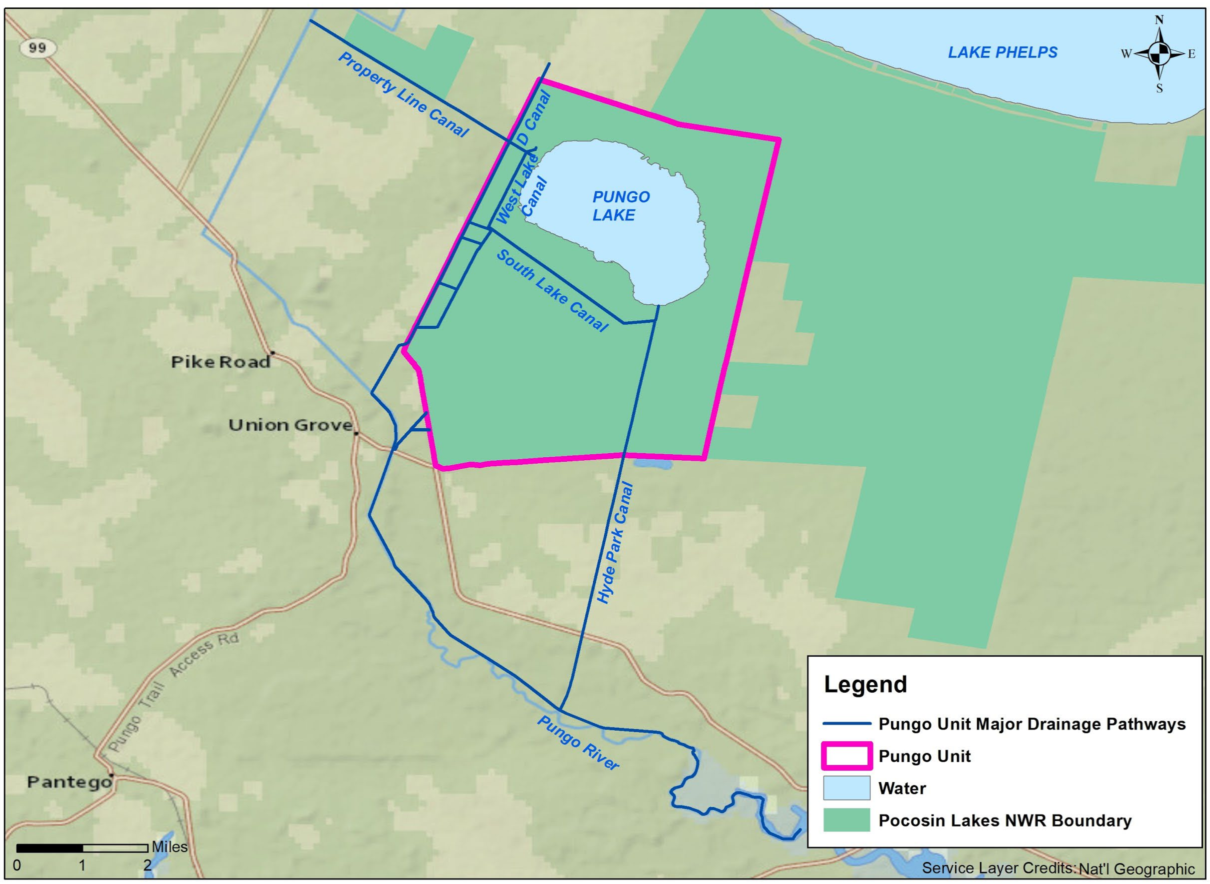
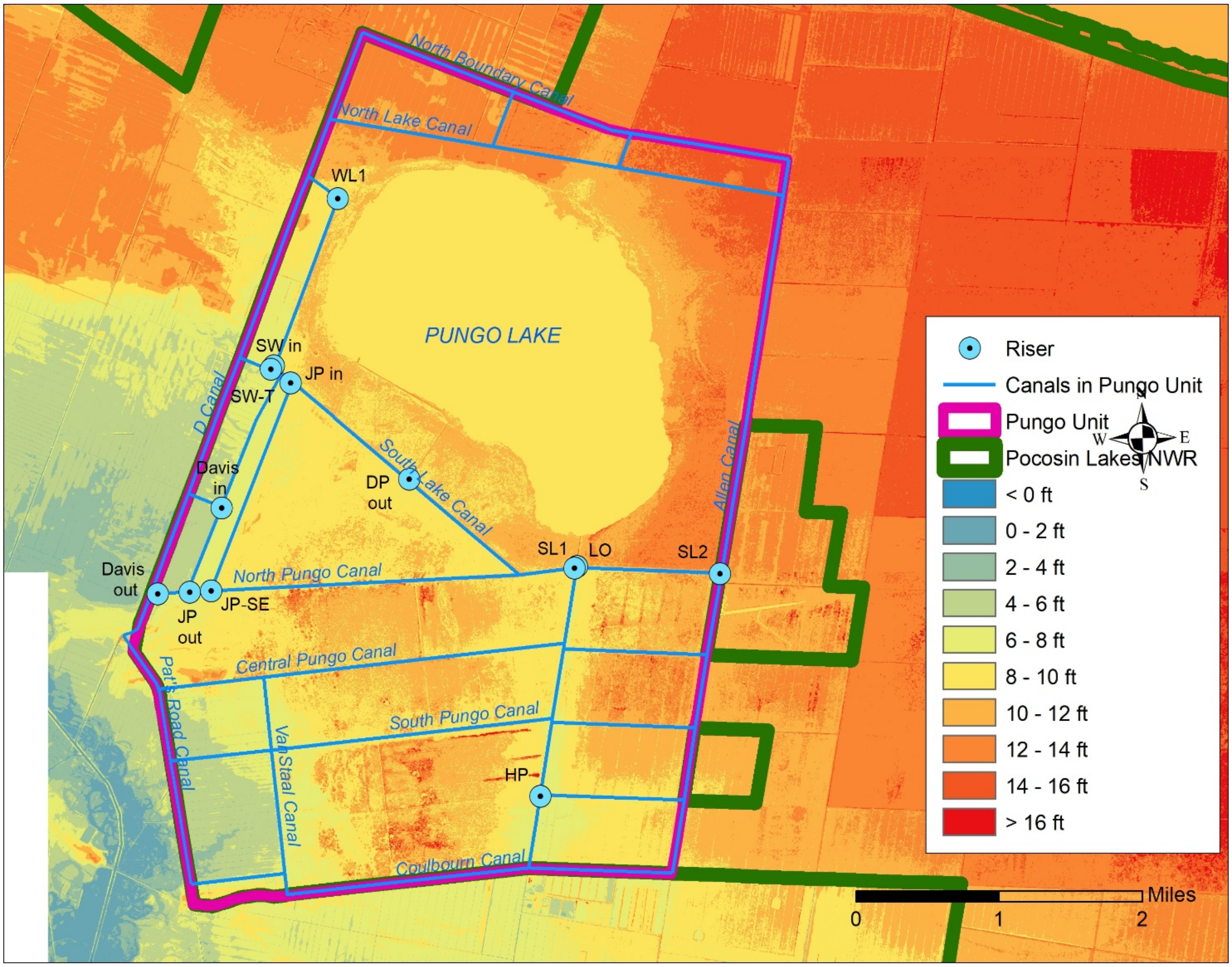


Figure A-17. LiDAR elevation data and managed waterfowl habitat water management infrastructure on the Pungo Unit.



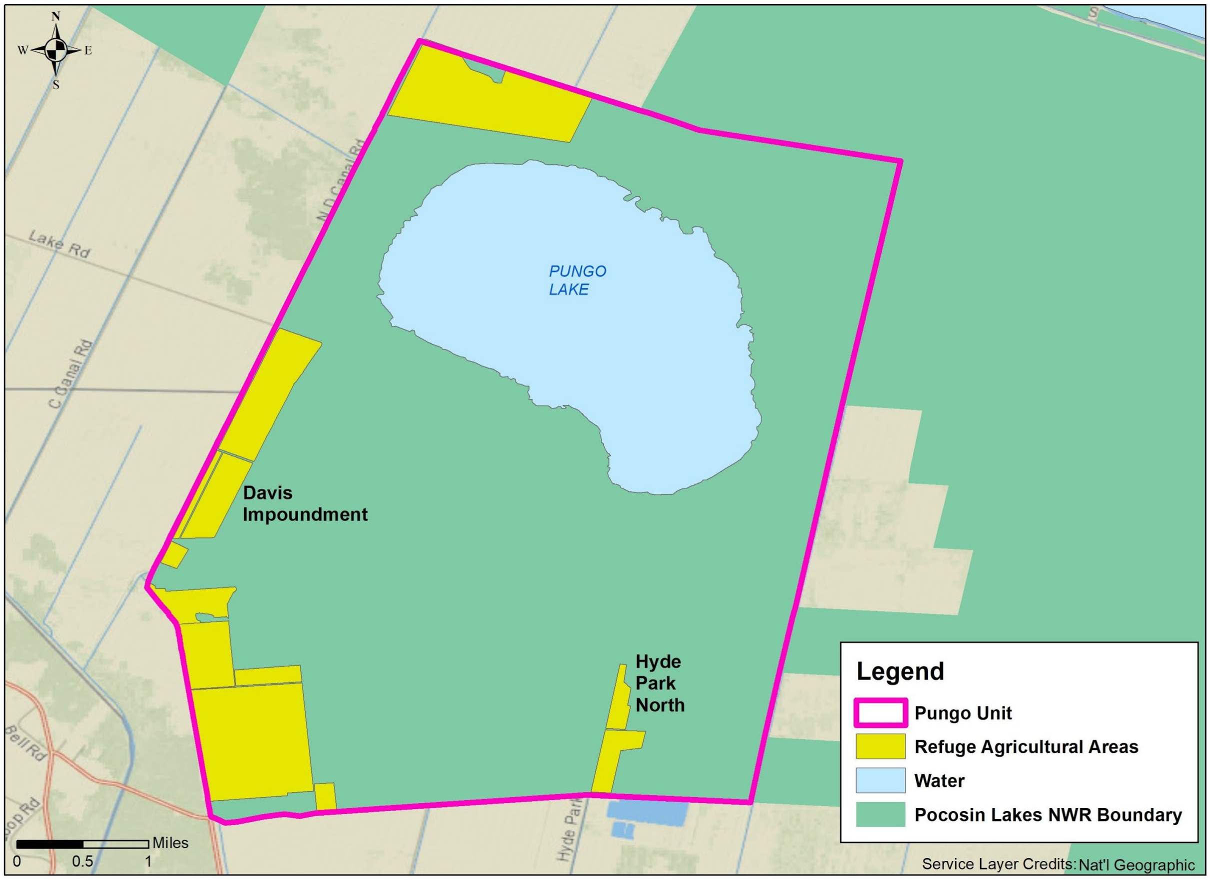
WATERFOWL FORAGING HABITAT

Managed waterfowl foraging habitat includes: agricultural lands where supplemental grain and browse are produced; moist soil impoundments where native plants that produce high-quality waterfowl food are grown; and forested wetland impoundments where tree mast and other natural duck foods are provided.

Agricultural Lands

There are approximately 1,250 acres of agricultural lands on the Pungo Unit (Figure A-18) that are managed through the Service's Cooperative Farming Program. Cooperative farmers, through agreements with the Service, maintain and plant crops on these acres and leave 20 percent of the crop standing in the fields for waterfowl and other wildlife; the farmers leave the standing crops in lieu of paying rent for the farmland. Generally, about half of the acres are planted in corn each year and half in soybeans. Only corn, approximately 250 acres annually, is left standing. Up to 150 acres of winter wheat are planted behind corn or soybeans to be available as green browse for waterfowl. The standing corn left in the fields is mowed or otherwise knocked over a little at a time throughout the fall/winter to make it more available to waterfowl.

Figure A-18. Agricultural lands on the Pungo Unit of Pocosin Lakes NWR.

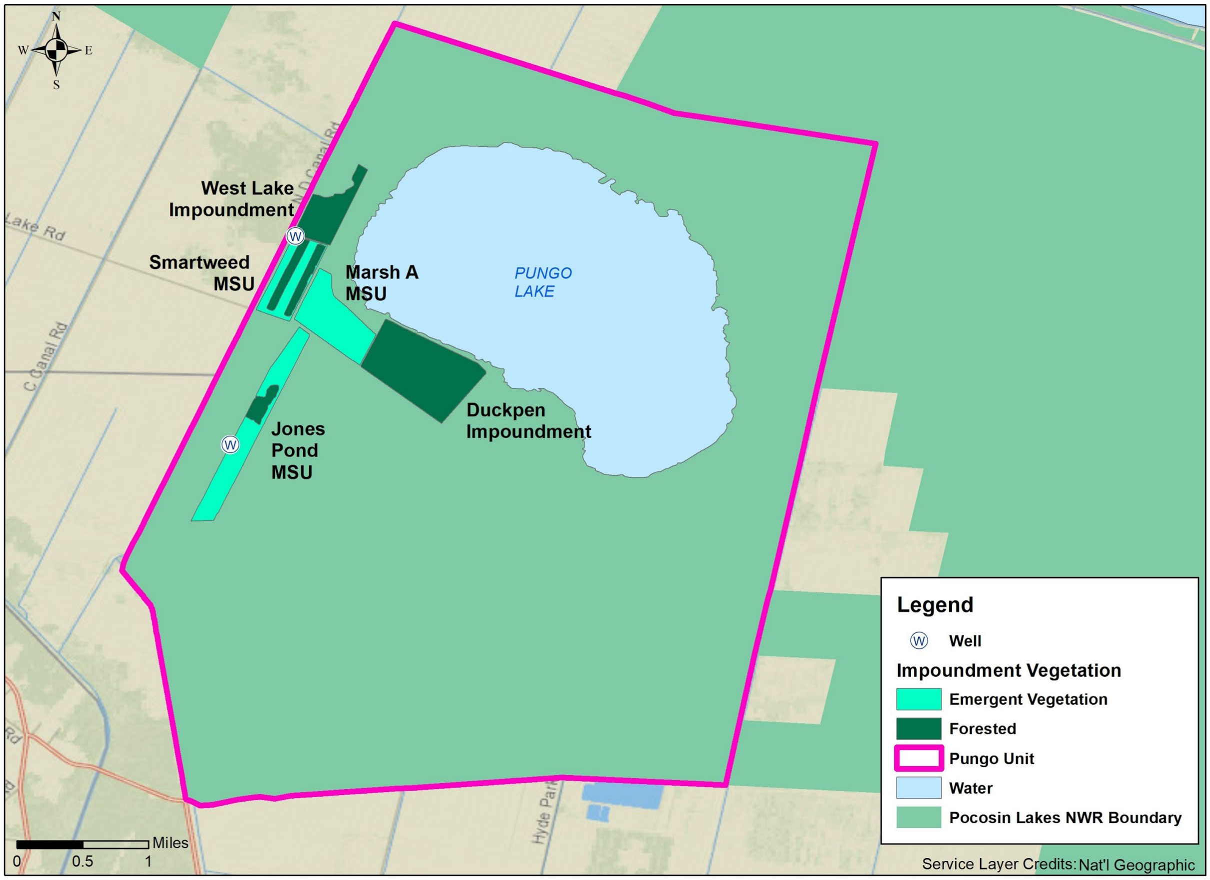


Infrastructure for the agricultural lands includes numerous drainage ditches and culverts. There are no associated water control structures because management is aimed at "dry field" waterfowl foraging, except in Davis and Hyde Park North Impoundments. Unlike the moist soil and forested wetland impoundments, there is not dense vegetation in the farm fields obscuring vision and hiding predators, so the grain is made available to the birds even when not flooded.

Moist Soil Impoundments

Moist soil management, for the production of native, high-quality waterfowl foods (seeds, tubers, browse, insects, etc.) is done in all or most of three impounded moist soil areas on the Pungo Unit: Jones Pond (approximately 115 acres), Smartweed (approximately 57 acres), and Marsh A (approximately 109 acres) (Figure A-19). Parts of the Smartweed (approximately 38 acres) and Jones Pond (approximately 17 acres) impoundments are forested and function the same as the other forested wetland impoundments (see Forested Wetlands Impoundment section below); however, water management in these units is dictated by the moist soil vegetation production requirements outside of the forested parts. The Van Staalduinen Impoundment (approximately 10 acres, located within the Pungo Unit) and the Evans Pond Impoundment (approximately 40 acres, located within the D16 Block in RA 1) became dilapidated and non-functional years ago. Because of their small size and the high estimated cost to rebuild the dikes, there are no plans to reestablish these two moist soil impoundments.

Figure A-19. Five impoundments on the Pungo Unit of Pocosin Lakes NWR.



Generally, water is lowered in the moist soil units during the growing season, aided by lower drainage levels in South Lake and Hyde Park Canals at that time (see Pungo Unit Drainage System section above). The water level is then periodically raised through the fall and winter, aided by the higher drainage levels in South Lake and Hyde Park Canals at that time, to make the waterfowl foods produced in these units more available to the birds. The vegetation in the units is monitored using integrated waterbird monitoring and management protocol (USFWS 2016). When the percentage of high quality waterfowl foods declines and the percentage of undesirable vegetation increases to threshold levels, succession is "set back" in the units by burning, disking, herbicide application, or other disturbance, or a combination of disturbances. Drainage levels are held lower into the growing season when vegetation disturbance is planned.

Infrastructure at the Jones Pond Impoundment includes a small riser at the northeast corner used to gravity flow water in from South Lake Canal, a riser at the southeast corner that can sometimes be used to gravity flow water in from the North Pungo Canal, and a riser at the southwest corner for setting the drainage level of the impoundment.

Infrastructure at the Smartweed Impoundment includes a riser just north of the southeast corner used to gravity flow water in from West Lake Canal, a riser (with a "T" pipe at the outlet end) just west of the southeast corner of the impoundment that is used to set the drainage level of the impoundment, and a well/pump in the northwest corner that is infrequently used to pump water into the impoundment from the aquifer below ground.

Infrastructure at the Marsh A Impoundment includes a dilapidated water control structure with a tidegate in the northeast corner (that needs to be replaced with 24" riser). The dike on the north side of the impoundment, next to Pungo Lake, leaks and needs to be repaired.

Forested Wetland Impoundments

Most of the Duckpen (approximately 205 acres) and West Lake (approximately 69 acres) impoundments consist of forested wetlands. Forested wetlands also occur in part of the Smartweed (approximately 38 acres) and Jones Pond (approximately 17 acres) Moist Soil Impoundments (see Figure A-19). Prescribed burning is sometimes conducted in these forested wetland units.

Infrastructure at Duckpen Impoundment includes a small riser at the southeast corner that is used to set the drainage level of the impoundment and a dilapidated structure with a tidegate at the northwest corner that was at one time used to gravity flow water in from Pungo Lake. This second structure needs to be replaced. Water supply to the Duckpen impoundment is currently via rainfall only.

West Lake Impoundment has no closely associated water control structures. Water supply is from rainfall and drainage from Property Line Canal. The drainage level is dictated by broader management needs for the Pungo Unit overall because the drainage level is set by the riser in South Lake Canal at Hyde Park Canal (see Figure A-17). As part of this plan, the dike that forms the north side of the Smartweed Impoundment will be extended to West Lake Road with a riser installed in West Lake Canal under the new section of dike.

WATERFOWL ROOSTING/RESTING HABITAT AND SANCTUARY

Managed roosting and resting habitat includes Pungo Lake and the refuge's portion of New Lake. These areas protect waterfowl from excessive human-caused disturbance through regulations and law enforcement, thereby creating sanctuary areas. Drainage in the lakes is managed to maintain, to the extent practicable, full-lake water levels during the fall/winter waterfowl period and, therefore, provide the maximum acreage of habitat and sanctuary.

Pungo Lake

Pungo Lake is approximately 2,474 acres located entirely within the Pungo Unit of the refuge. It is a dark water lake, and submerged aquatic plants do not grow well due to a lack of sunlight. Water supply is via rainfall and drainage from Property Line Canal on the northwest side of the lake. Infrastructure at Pungo Lake includes a riser in Lake Outfall Canal that is used to set the lake drainage level.

Soon after Pungo National Wildlife Refuge was established in the early 1960s, managers began implementing a partial drawdown of Pungo Lake during the growing season with the objective of growing waterfowl food plants in the lake bottom around the perimeter, primarily for ducks.

While plant production was successful, in most years fall rainfall amounts were not adequate to bring the lake level back up and flood the emergent vegetation, which meant the food was not available to wintering waterfowl. Adequate rainfall was received during only four out of twenty years of drawdowns. Therefore, the management goal for Pungo Lake was changed to target holding the lake full (as rainfall amounts allow) to maximize roosting/resting habitat and sanctuary for waterfowl in the fall/winter. Since then, prolonged droughts have resulted in the drawdown of the lake water level. In those years, plants that produce excellent waterfowl forage grew in the exposed lake bottom, but the forage was not available to wintering waterfowl because rainfall did not refill the lake until well into the winter, after the birds departed, if at all.

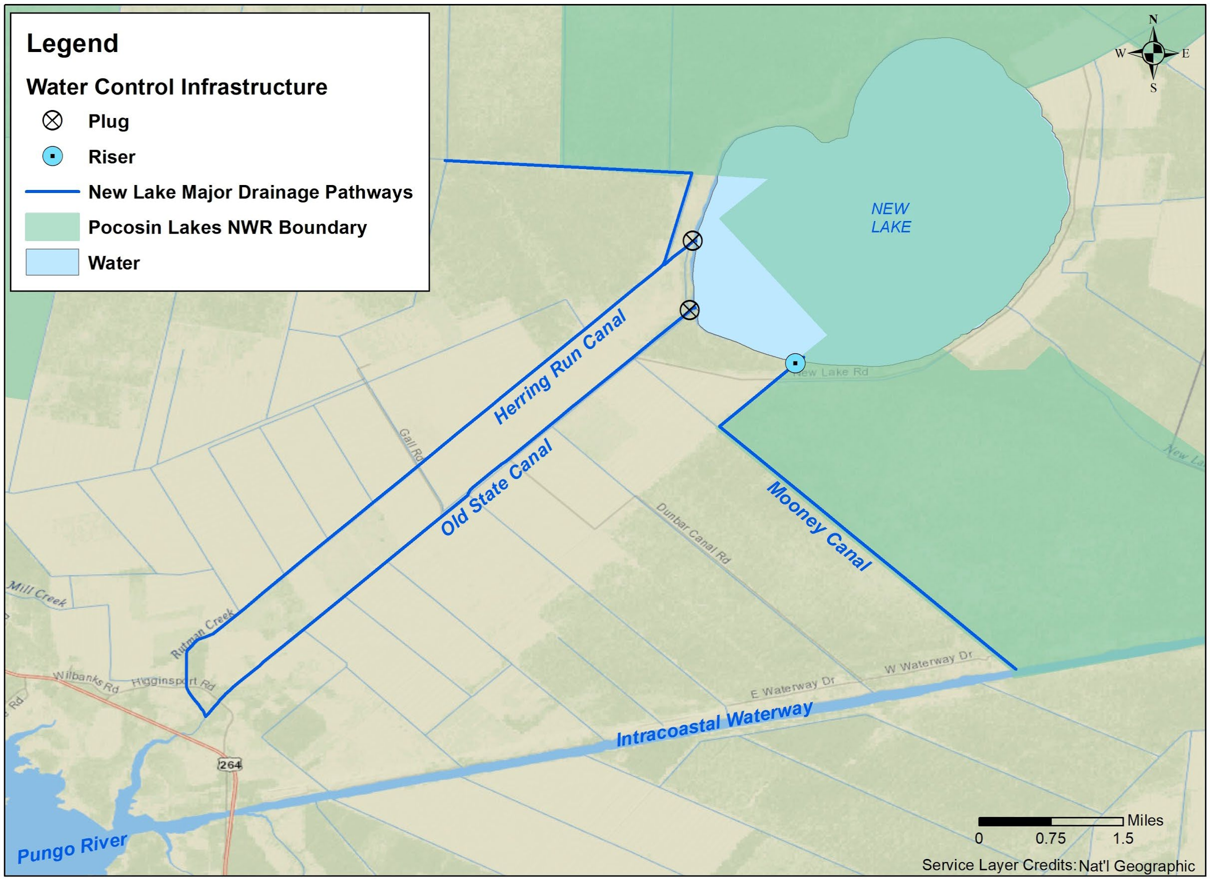
New Lake

New Lake is approximately 4,673 acres in size. Approximately 3,972 acres (85 percent) of the lake bottom is part of the refuge while the other approximately 701 acres (15 percent) of lake bottom are privately owned. Like Pungo, it is a dark water lake, and submerged aquatic plants do not grow well.

New Lake is located in a very remote area and water management is extremely complex because of the large number of owners and stakeholders in and around the lake combined with limited capabilities to manage water drainage. The privately owned lake bottom is divided among 14 tracts with many different owners. Besides the Service's interest in providing waterfowl habitat and sanctuary on the refuge part of the lake, other stakeholder interests include farming agricultural land and maintaining houses immediately adjacent to the lake on its east side, hunting waterfowl in the privately-owned parts of the lake, and hunting other species on the adjacent private lands associated with the lake bottom tracts. There is also a relatively small interest in fishing in the lake. Given these diverse interests, there is presently a lack of consensus among stakeholders regarding a desired lake level.

There are no ditches/canals draining water into the lake, but overland sheet flow during high rainfall events from the north likely occurs. There are three canals connected to the lake that could drain water out of the lake, but only one of them—Mooney Canal—is normally functional (Figure A-20).

Figure A-20. New Lake drainage features.



Infrastructure at New Lake includes a plug in Mooney Canal with an undersized riser. The riser is located about 550 feet downstream of the lake shoreline. About a quarter mile downstream of the riser, New Lake Road crosses Mooney Canal. New Lake Road is maintained by the State of North Carolina and has a large culvert under it in Mooney Canal. Mooney Canal ultimately drains to the Intracoastal Waterway. The centerline of Mooney Canal is the boundary of the refuge and the adjacent private land.

Old State Canal is on private land. It has one or two non-functioning structures adjacent to the lake, but the canal in that area is mostly silted in and does not drain the lake.

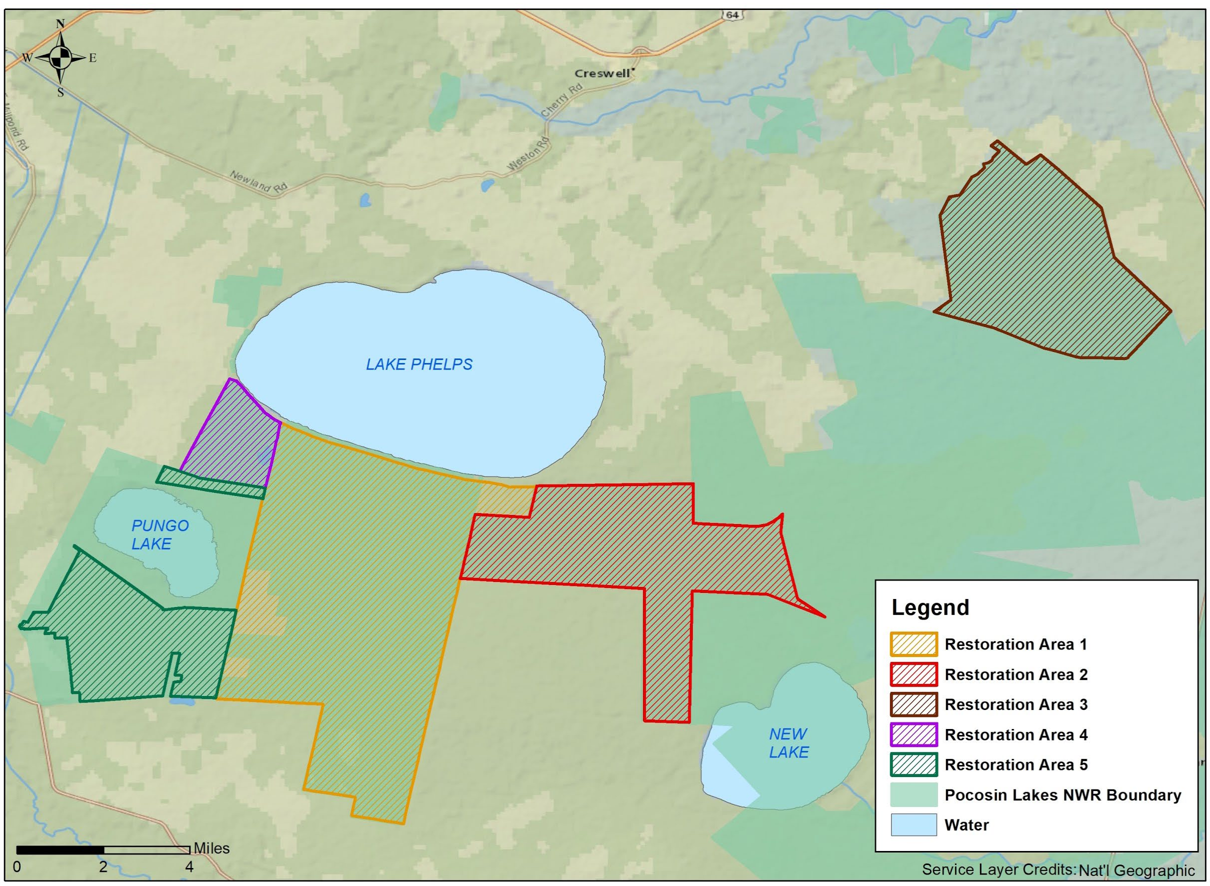
There is normally a plug in the Herring Run Canal extension, which is located on private land. The canal extension was probably built during a wildfire emergency response operation to get water from the lake to fight the fire. It was used for that purpose during the 2008 Evans Road Fire, and the plug was reinstalled following that emergency operation. The plug is located a short distance from the lake shoreline; however, it has reportedly blown out at least twice in the last few years during periods of high rainfall. It was reportedly rebuilt at least once but is currently believed to be missing. When the plug is missing, Herring Run Canal is a source of uncontrolled drainage from the lake and can significantly lower the lake water level when rainfall amounts are normal or, especially, below normal.

There does not appear to be adequate artificial drainage capacity to prevent natural, overland flow out of New Lake during big storms. This overland flow floods surrounding crop and other private lands. Lake drainage is usually slow due to the limited capacity of the Mooney Canal riser structure and canal. Monitoring data indicates that precipitation probably has a much greater and faster impact on lake water levels than current drainage infrastructure.

HYDROLOGICALLY ALTERED PEATLANDS

Refuge areas considered to be extensively hydrologically altered are shown in pink in Figure A-1 and total just over 43,000 acres. Most of these peatlands are located within five designated "Restoration Areas" (RAs). The designations are based on geographic location and water flow patterns (Figure A-21). Restoration work has occurred on over 37,000 refuge acres (about 86% of the highly altered peatlands) and approximately 465 acres on adjacent Pettigrew State Park lands. Additional restoration is planned on approximately 4,800 acres (about 11%) of the highly altered peatlands. The remaining highly altered peatlands (approximately 1,178 ac or 3% of all highly altered peatlands) consist of small tracts such as the outlier tracts located west of Lake Phelps and the "Bear Block" on the northern boundary of the Pungo Unit. Restoring these small tracts is considered a low priority for the limited restoration funding currently available.

Figure A-21. Hydrology Restoration Areas on Pocosin Lakes NWR.



RAs 1, 2, and 3 were the focus of the 1994 Study (USDA 1994). RA 4 lies north of the Pungo Unit and between F1 Canal and Allen Road, it is also known as the North Pungo Area. Some of the altered peatlands in RA 4 have been restored while additional work may be planned and implemented in the future in a manner that is compatible with adjacent private, drained lands. RA 5 includes the hydrologically altered peatlands within the Pungo Unit. Some of these peatlands have been restored while restoration work is pending in others.

As described earlier, each RA is subdivided into WMUs, which are areas of land whose drainage level is set by one or more specific water control structures. RA 3 is an exception, with the WMU designations being based more on geographic features than drainage-level-controlling water control structures.

Where hydrologically altered peatlands are restored, water management infrastructure is used to stop excessive artificial drainage to rewet the soil and mimic more natural hydrology conditions than existed prior to restoration activities. The use of this type of infrastructure to attenuate flows and mitigate off-site water quality impacts is well documented; it is among the most frequently used and encouraged best management practices in the highly altered hydrologic network of eastern North Carolina.

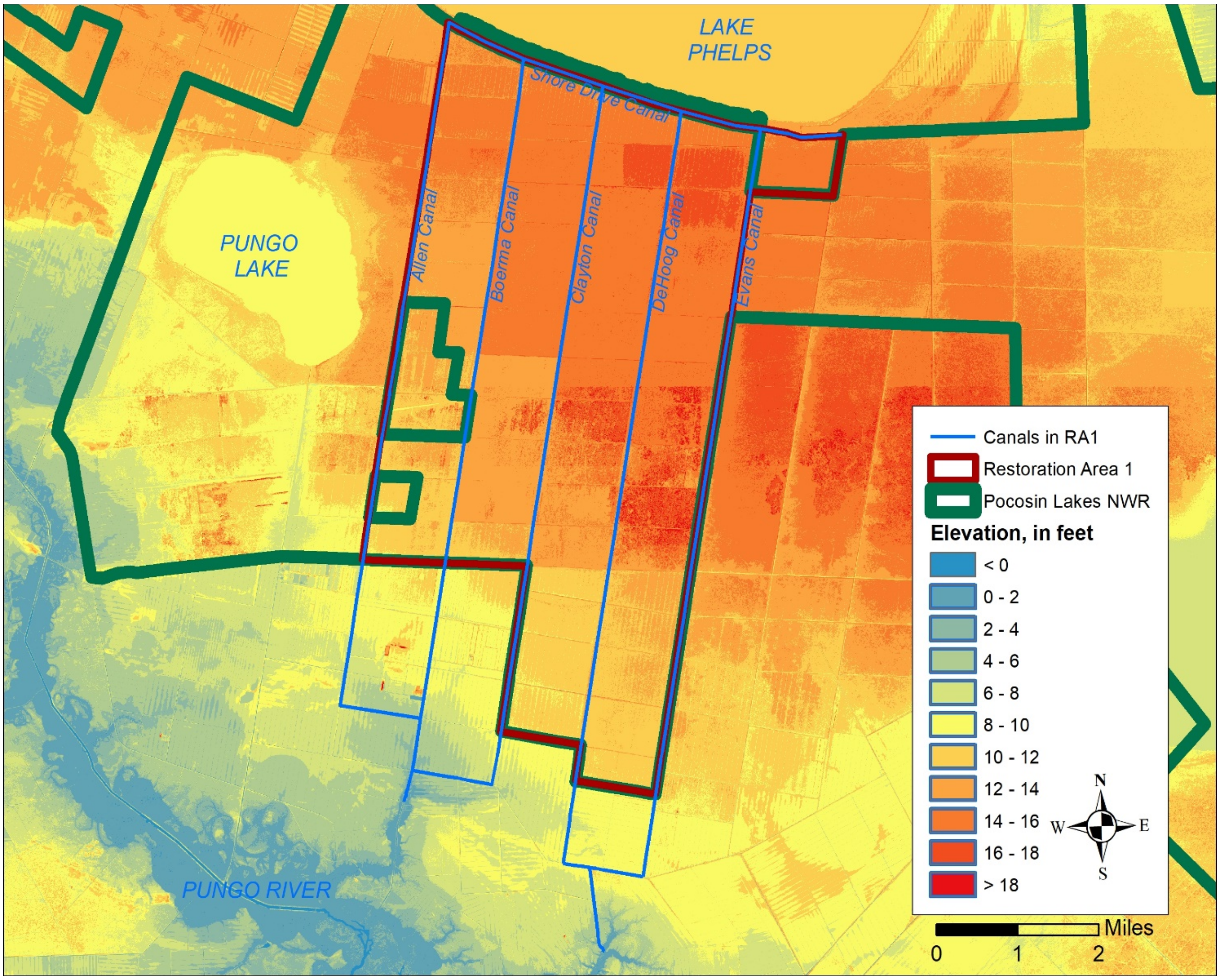
Restoration often involves fully or partially blocking drainage systems by inserting water control structures such as risers or plugs in canals, thus raising the average water level across the changing elevation of the landscape (peat dome). The highest elevation areas receive input only from rainfall, while those at the mid and lower elevations receive a combination of rainfall and drainage water from upgradient refuge lands.

RESTORATION AREA 1

Restoration Area (RA 1) is approximately 17,000 acres. It is bounded by Allen Road, Shore Drive, Evans Road (except for the inclusion of Pettigrew State Park's Pocosin Natural Area), and the southern Refuge boundary in that area (Figure A-22). Some of the highest ground is near the northeast corner and there is a "ridge" of higher ground running across the northern part of the RA. The majority of the land in the RA slopes from northeast to southwest, but about 10 percent slopes down to the north from the ridge.

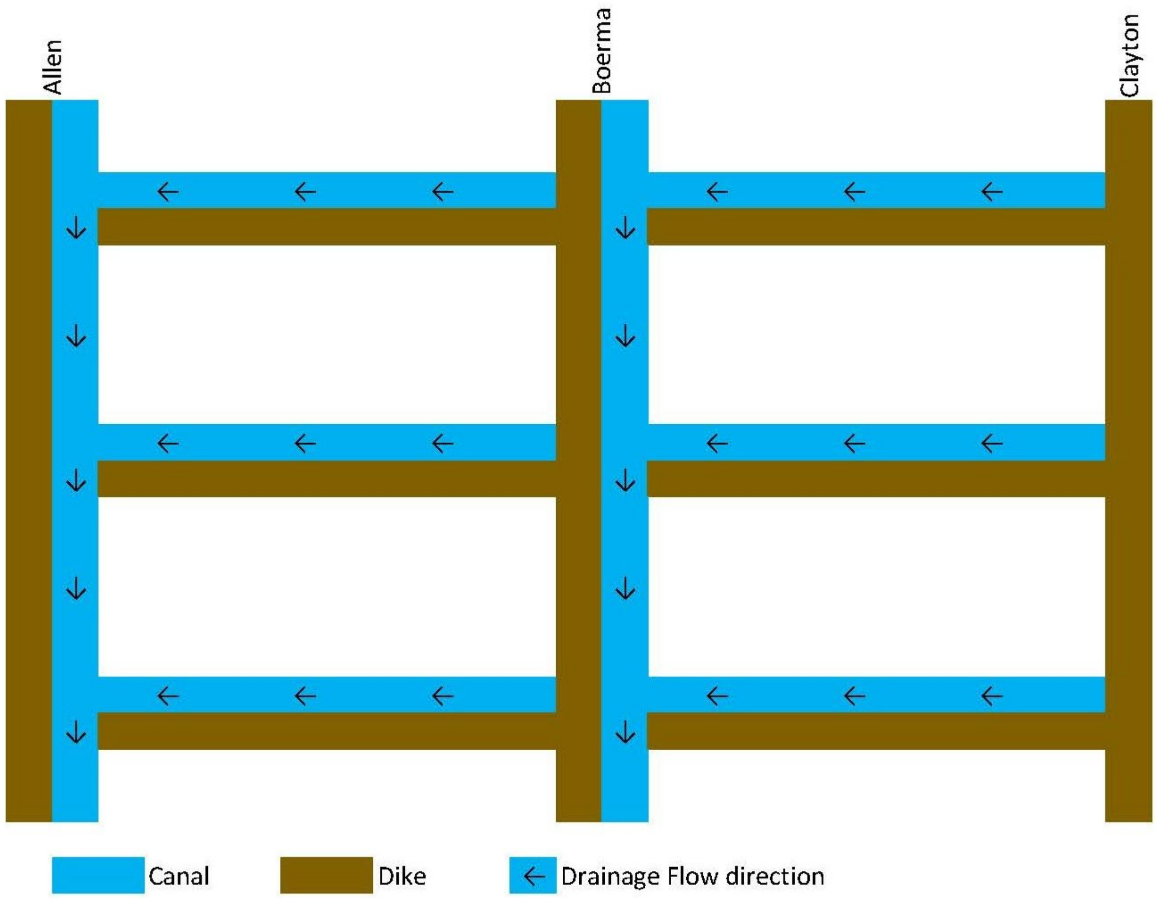
Rain that falls on RA 1 ultimately drains to the Pungo River primarily through five major or "outfall" canals — Allen, Boerma, Clayton, DeHoog, and Evans Canals. Allen, Boerma, and Clayton Canals merge into one canal on private land to the south of the refuge. DeHoog and Evans Canals also merge into one canal south of the refuge. Both merged canals drain to different locations along the Pungo River. The outfall canals lie about one mile apart from each other. There is a dike along the west side of each outfall canal that is comprised of the excavated material from the canal. The tops of the dikes have been graded to serve as roads. DeHoog and part of Evans Roads have also been surfaced with rock while the others are dirt roads.

Figure A-22. LiDAR elevation data for Restoration Area 1 (RA1).



Collector canals running approximately east-west and approximately one half mile apart are another legacy of the drainage network that pre-dated refuge establishment. They also have an associated dike and road on the south side of the canals; these roads are referred to as "headland roads." This system of canals and dikes divides most of the land in RA 1 into one mile by one half mile (320 acre) rectangles, or "blocks" of land. But a few of the southernmost blocks between Clayton and Evans are odd shaped or sized. The collector canals were connected to the outfall canals only on the west side of the blocks; that is, the collector canals dead end at the outfall dike/road on the east side. In most of the RA drainage, water entering a collector canal flows west to the outlet canal and then flows south in the outlet canal to the Pungo River (Figure A-23).

Figure A-23. Illustration of typical section of Restoration Area 1 drainage system.

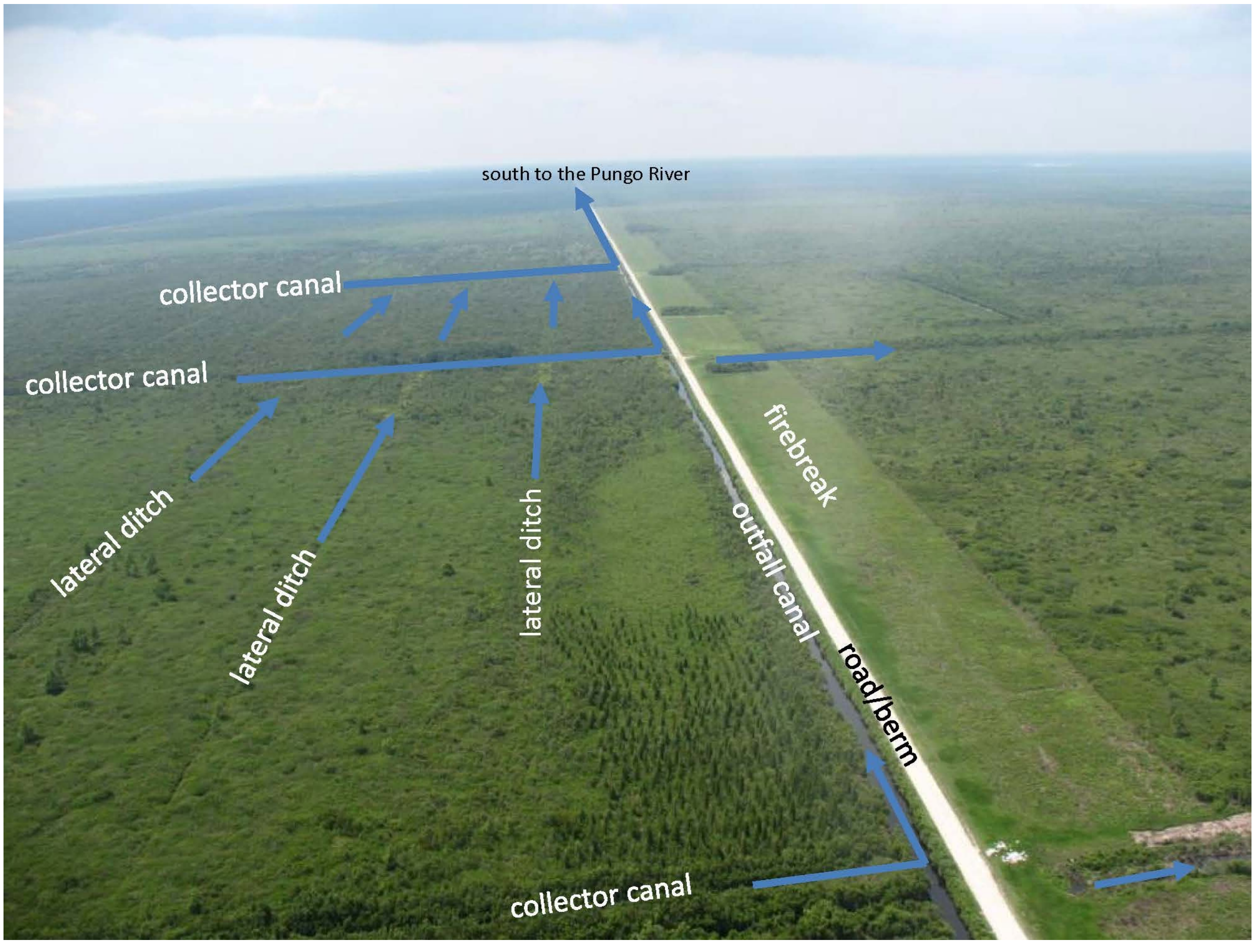


It should be noted that in a few locations (see Figure A-25 below) the headland road/dike was extended all the way to outlet canal dike to the west side, but culverts were installed under them to maintain drainage in the outlet canal and to accommodate vehicle and equipment movement over the canal. These culverts do not play a role in water management except that periodic maintenance is required to prevent drainage obstructions.

Within each block, lateral ditches were dug about every 330 feet consistent with agricultural practice and pre-refuge plans for use of these lands. These lateral ditches were oriented approximately north/south. The lateral ditches connect to the collector canal on the south side of the block. The land in between the lateral ditches was, in most cases, crowned in the middle to enhance drainage to the laterals. The lateral ditches, being much smaller with much lower flows than the collector and outfall canals, are silting in, but are still largely evident in LiDAR and aerial imagery (Figures A-22 and A-24).

In summary, the drainage system in most of the blocks in RA 1 would drain rainwater that fell on the block to the lateral ditches, which flowed south to the collector canals, which flowed west to the outfall canals, which flowed south to the Pungo River (Figure A-24).

Figure A-24. Rainwater drainage through outfall and collector canals and lateral ditches.

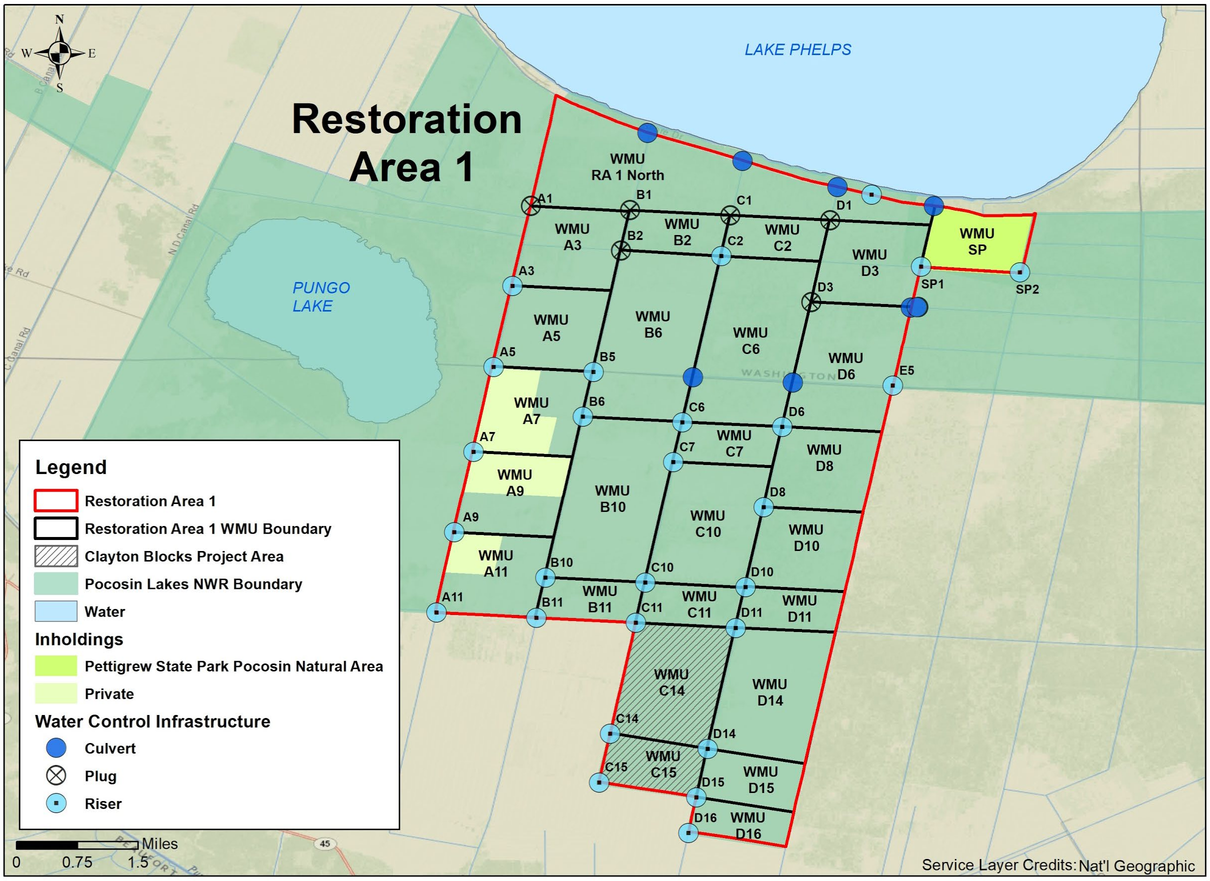


RA 1 Restoration Design

To reverse the effects of the artificial drying of the peat soils from the drainage system, the restoration design for RA 1 included some infrastructure improvements, such as raising some of the existing dikes to increase freeboard and installation of new infrastructure (e.g., water control structures like risers and plugs) (Figure A-25). Flashboard risers were installed in the outfall canals at strategic locations based on elevation change across the peat dome.

Generally, water control structures were installed in the drainage system based on one foot changes in elevation across the RA; therefore, each water control structure affects the drainage of a part of the RA that has an approximate one foot change in elevation from its high end to its low end. The one foot change in elevation is approximate and not uniform because of the variable topography across the landscape and the need to use the existing headland road dikes as locations for the riser structures. Most of the water control structures were installed based on elevation data collection and extrapolation done for the 1994 Study (USDA 1994).

Figure A-25. Restoration Area 1 (RA 1) restoration infrastructure and Water Management Units (WMUs).



WMUs can range in size from one to four blocks (approximately 320 to 1,280 acres) depending on the slope of the land in the unit. A steeper slope means that an approximate one foot drop in elevation occurs over a shorter distance and, therefore, the WMU has a smaller number of blocks. Conversely, an approximately one foot drop in elevation on a flatter slope occurs over a longer distance and the WMU includes a greater number of blocks (Figure A-25). Except for WMU RA 1 North (see below), the riser or plug affecting the drainage of a WMU is located in its southwest corner.

All of the WMUs, except RA 1 North, generally slope down from the northeast to the southwest (Figure A-22). All of the dikes (except DeHoog Dike - see below) on the west and south sides of each of these WMUs were "raised," which means they were elevated in height by adding material excavated from the adjacent canal on top of the dike (see Figure A-10). Because the south and west sides of one WMU are also the north and east sides of the WMU below it, the WMUs are completely surrounded by raised dikes (Figure A-25), but they are not, nor are they managed like, impoundments. The board level in the risers was increased, or raised, to reduce the effect of the artificial drainage system on below ground water levels. The dikes were raised to create additional freeboard to accommodate these higher average water levels in the soil.

Unlike the Allen, Boerma, Clayton, and Evans Dikes, the DeHoog Dike was not initially elevated because the refuge only received funding to rock DeHoog Road. While the lower elevation dike functions adequately for the higher land elevation WMUs east of DeHoog, it was considered inadequate for the lower land elevation WMUs. Additional funding became available in 2017 to address this issue and raise the road (referred to as the DeHoog Road/Dike Project). To the extent practicable, rock was reclaimed from a 3.6 mile section of the road and the dike in the lowest portion of the road was elevated.

The infrastructure is used to “stage” water in the soil up the southwestwardly sloping gradient, which makes up most of the RA, in a terrace-like manner. Except during extreme droughts, the restoration and management results in at least some standing water on the low ends of the WMUs, particularly adjacent to the canals where soil elevation has been lowered due to oxidation and subsidence. Standing water may also be seen in other areas including sites where the peat soil has been compacted by heavy equipment operation, such as within firebreaks alongside parts of Boerma, Clayton, DeHoog, and Evans Roads, and where past fires have burned some of the peat away. Topographic differences (microtopography) across the WMUs, especially the flatter units, can also lead to scattered instances of inundation. Based on a recent evaluation of the aerial extent of inundation based on drainage settings and detailed LiDAR in formation, on average, less than five percent of the WMU acreage would be expected to experience standing water. In other words, the water table was at or below the ground surface on about 97 percent of area in WMUs evaluated (KBE 2017).

If pocosin wetlands are inundated for long enough, they convert to marsh vegetation; but they also begin the slow process of peat soil formation and accumulation which only occurs with inundation. Periods of high rainfall can expand the area converted. Conversion of pocosin vegetation to marsh vegetation is occurring on a small percentage of some of the RA 1 WMUs. While this change in habitat type is not a management objective, it is inevitable when working on a slope. This change in small portions of the RA increases habitat diversity which increases wildlife diversity on the refuge.

When rainfall causes the water level in the canals to exceed the board level, the artificial drainage system is engaged. When there is not enough rainfall to raise the water level above the board level, the artificial drainage system is disengaged, and water does not drain from the WMU. Artificial drainage in the B2 and D3 WMUs (Figure A-25) was stopped completely by installing earthen plugs (Figure A-13) in the outfall canal where a riser would normally have been located. Because they are located on some of the highest elevation lands and do not receive drainage from any other lands, it is likely that almost all of the rain that falls on these units is stored within the berms until it is naturally removed, primarily via evapotranspiration.

WMU RA 1 North

A very different situation exists for the northern tenth (approximately 1,800 acres) of the RA, which is referred to as WMU RA 1 North. Earthen plugs were installed in the outfall canals roughly along the “ridge,” or watershed boundary, to separate drainage in this section from the rest of the RA. Because the land slopes down to the north in this WMU, water flows north in the Allen, Boerma, Clayton, and DeHoog Canals until it encounters the Shore Drive canal and berm. Water in the Shore Drive Canal drains eastward through culverts under Boerma, Clayton, DeHoog and Evans Roads because there is no culvert under Allen Road to allow water drain to the west. The Shore Drive Canal conveys water from the RA 1 North WMU to Evans Canal, which carries the water south to the Pungo River. The drainage level of the ditch system in RA 1 North is controlled by Riser E5, which is located in Evans Canal approximately two miles south of the southeast corner of the WMU. Evans Canal is not plugged and cuts through the “ridge,” while Allen, Boerma, Clayton, and DeHoog Canals no longer do because of the plugs.

Note that eastward drainage through canals from Evans Canal has been stopped (see RA 2 section below).

Pettigrew State Park Pocosin Natural Area

Pettigrew State Park's Pocosin Natural Area (SP Area) is bordered by and hydrologically connected to the refuge via drainage ditches and restoration infrastructure. At the request of the Park, restoration of the SP Area was implemented by refuge staff in concert with RA 1. Accordingly, it is described in this plan even though it is not within the boundary of the refuge. The SP Area, comprised of approximately 465 acres, is bounded by berms on the north, south, and east sides and by Evans Canal on the west side. From a hydrologic perspective, it is an extension of the RA 1 North WMU. The ground is lower along its west and south sides (Figure A-22). The Shore Drive Canal extends across the north side of the area, but it dead ends at Huber Road Dike. Riser E5, which is used primarily to manage drainage in the WMU RA 1 North, also affects the drainage level in the Pocosin Natural Area because Shore Drive Canal extends across its north side. The drainage level set in Riser SP1 (Figure A-25) is similar to Riser E5 to help retain water in the Pocosin Natural Area when water levels drop in Evans Canal. Riser SP2 is used to stop most of the drainage from the Pocosin Natural Area into Furbee Canal in RA 2.

Allen/Boerma Inholdings

Approximately 905 acres of privately owned lands between Allen and Boerma Roads are completely surrounded by refuge lands and, for the most part, are hydrologically linked to the surrounding refuge lands. USDA-NRCS Wetland Reserve Program (WRP) easements were placed on approximately 565 of those acres to help facilitate the refuge's hydrology restoration. These inholding lands are not commercially farmed, and their use for hunting is compatible with hydrology restoration goals. The northernmost inholding has impoundments for waterfowl hunting, and so hydrology restoration on surrounding refuge lands is desirable for water supply. The southernmost inholding lies in the northwest corner of WMU A11. Drainage settings for WMUs that encompass Allen/Boerma inholdings are determined in coordination with neighboring landowners or the USDA for consistency with WRP easements.

WMUs Adjacent to Drained Private Lands

Most of the dikes in RA 1 are a byproduct of the construction of the drainage canals. The borrow material was simply placed on the ground beside the canal as a spoil pile. The dikes were not designed to hold water and seepage through the dikes can occur. On most of the refuge, seepage is not a concern because the lands downgradient of the dikes are also maintained in a restored state, resulting in a low water gradient between the two areas. However, if the land immediately below the dike is drained, the water gradient between the two areas is higher and seepage can make the adjacent drained land wetter up to about 200 to 300 feet from the dike.

WMUs A11, B11, and D16 lie just north of drained private lands. Because of the potential for seepage issues on these adjacent lands, these units are managed in coordination with the adjacent landowners. This essentially creates "buffer" areas on refuge lands to prevent seepage onto adjacent private lands. The refuge's goal is to have the drainage/board level set to achieve targeted restoration conditions as close as possible without causing unacceptable seepage on the adjacent private lands. For the most part, the drainage/board levels set in these units have been lower than what is needed to achieve desired hydrologic conditions in upgradient refuge lands.

Clayton Blocks Project

WMUs C14 and C15, often referred to as the Clayton Blocks, are comprised of approximately 1,325 acres that lie adjacent to drained private lands. These units were once managed as seepage buffer areas in a manner similar to the description in the preceding section. In order to fully restore most of the area within these WMUs, a new cored, seepage-resistant dike was built in 2016 just inside the refuge boundary on the west sides of WMUs C14 and C15 and the south side of WMU C15.

The new dike sections were built by digging a new canal and side-casting the excavated material. To prevent seepage, the new berm was built by first digging a core trench through the entire peat layer to the underlying mineral soil in the middle of the new dike's footprint. Mineral material from the new borrow canal was then packed into the trench and all the way up to the top of the berm through its center (Figure A-26). The peat material from the borrow canal was used to build the sides of the berm. In the unlikely event that seepage through the cored dike were to occur, the narrow strip of refuge land between the new berm and the old canals (Clayton Outfall and the C15 collector) would intercept it and drain it to the Pungo River, thus avoiding alteration of the water table on adjacent private lands. Note that the centerline of the old canals is the refuge boundary in this area.

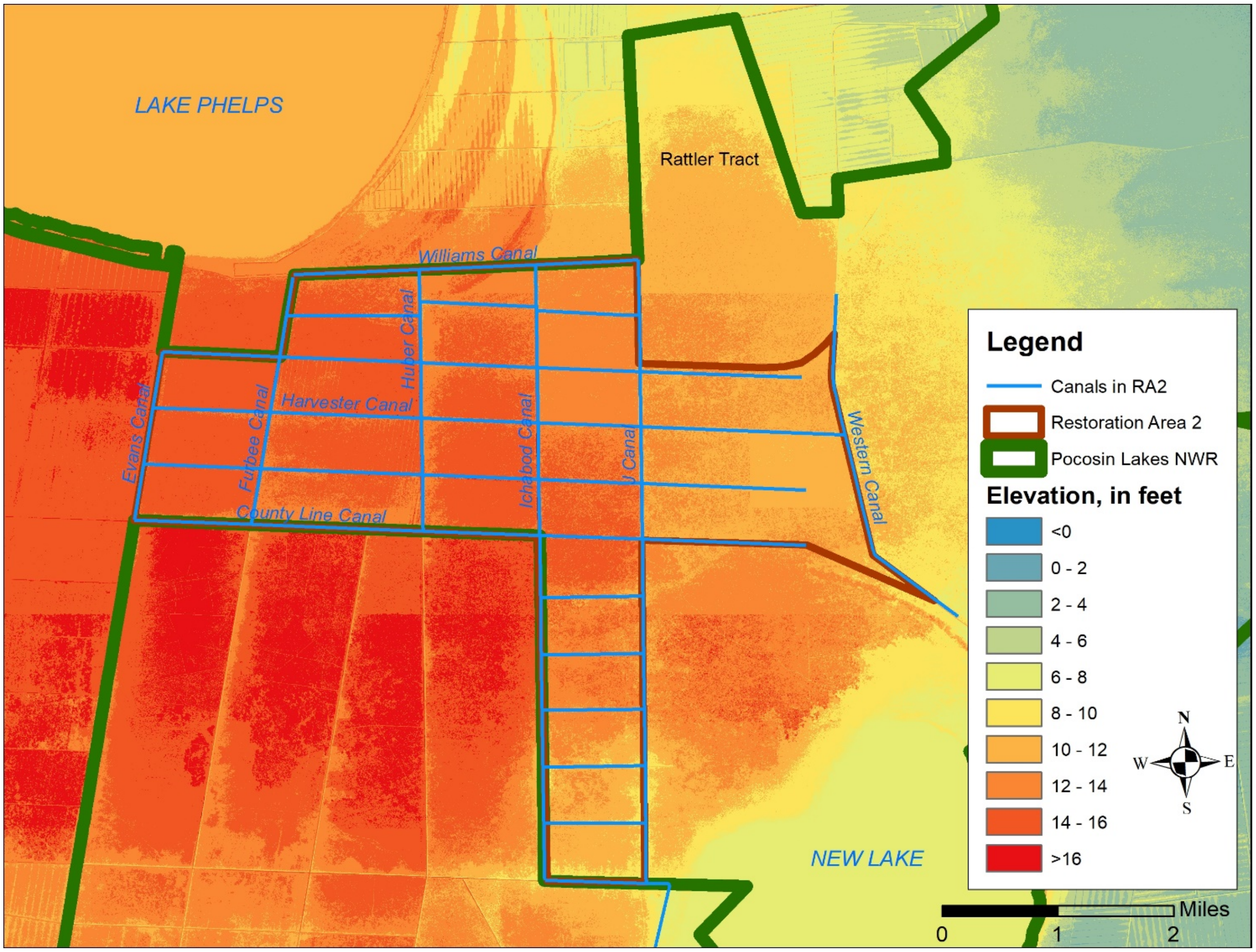
Figure A-26. Clayton Blocks Project cored dike during construction.

New risers were installed to stop artificial drainage of the refuge soils in WMUs C14 and C15 and to supply excess water from upstream WMUs to the new WMUs if needed. Like most of the other WMUs, the drainage level is set with risers near the southwest corners of C14 and C15. Water from WMU C11 can be drained into WMUs C14 and then C15 from the riser near the northwest corner of C14 or can be drained into Clayton Canal, thus bypassing WMUs C14 and C15.

RESTORATION AREA 2

Restoration Area 2 (RA 2) is approximately 9,400 acres (Figure A-27). It is bounded on the west by the by the SP Area and Evans Canal and on the east by Western Canal; other refuge lands lie immediately adjacent to RA 2 along Evans and Western Canals. There are private lands on the north and south sides of RA 2.

Figure A-27. LiDAR elevation data for Restoration Area (RA 2).



East of the park area, the northern boundary of RA 2 coincides with the boundary between refuge and private lands to J Canal. From J Canal to Western Canal, the northern boundary of RA 2 is an inexact line through refuge pocosin.

From Evans Canal to Ichabod Canal, RA 2 is bound on the south by County Line Canal, the centerline of which is the refuge boundary with adjacent private lands. East of there, RA 2 includes six blocks of land between Ichabod and J Canals south of County Line Canal; these blocks are called WMU D. To the East of WMU D, the southern boundary of RA 2 runs with County Line Canal. From the east end of County Line Canal, the southern boundary runs through refuge pocosin to the southernmost riser in Western Canal.

For management purposes, we divide RA 2 into four WMUs: A, B, C, and D (Figure A-28). The canal system in and below WMUs A and B was designed to drain rainfall primarily south via six major drainage canals, toward New Lake and the Pungo River (USDA 1994). The pattern of north-south oriented outfall canals seen in RA 1 (Allen, Boerma, Clayton, Dehoog, Evans) was continued in WMU A and B i.e., Furbee, Huber, Ichabod, and J Canal.

Some of the refuge lands in the Rattler Tract, which lies just north of RA 2, slope down in a northward direction and drain to the upper section of J Canal and to the Nylen Canal (Figure A-27), both of which ultimately drain to the Scuppernong River. J Canal has been plugged near Williams Canal (called the J Canal Plug) to prevent, to the extent practicable, drainage from WMU B from going north towards the Nylen Canal. However, during periods of high rainfall a relatively small amount of water may flow around the plug to the north.

Williams Canal was connected to J Canal in the past, but at some point was plugged just west of J Canal and north of the J Canal Plug. It is also plugged on the west end (by Furbee Dike). Since Williams Canal did not connect to another canal on either end, it would fill often up and overflow during rain events. The lowest point along Williams Canal is on the east end near J Canal. In 2013, storm water from Williams Canal cut a channel through Refuge lands to J Canal just south of the J Canal plug. The refuge made the new canal connection permanent by adding a culvert for access to the J Canal Plug. Therefore, most of the water from Williams Canal now drains through the refuge.

Furbee, Huber, and Ichabod Canals each end approximately 70 to 85 feet south of Williams Canal. During storms, water may run overland from these canals to Williams Canal because the land in that area slopes northward. The 1994 Study documents the occurrence of these “small” flows, describing them as “several inches deep” and ranging “from 20 to 50 feet wide” (USDA 1994).

The higher elevation lands in RA 2 occur toward the upper center in WMUs A and B (Figures A-27 and A-28). This means that downgradient drainage occurs in almost all directions including west, south, east, and even some to the north as described above. Lateral ditches, like those seen throughout RA 1, occur only in blocks on the southwest part of WMU A (Blocks E3, E4, E5, part of F3, F4, and F5). The ground elevation in WMU C drops in an eastward direction taking drainage water towards Western Canal. The ground elevation in WMU D generally drops from the northwest to southeast. The 1994 Study states that in RA 2 “drainage problems have occurred with adjacent landowners because of the erratic drainage patterns created when the canals were dug” (USDA 1994).

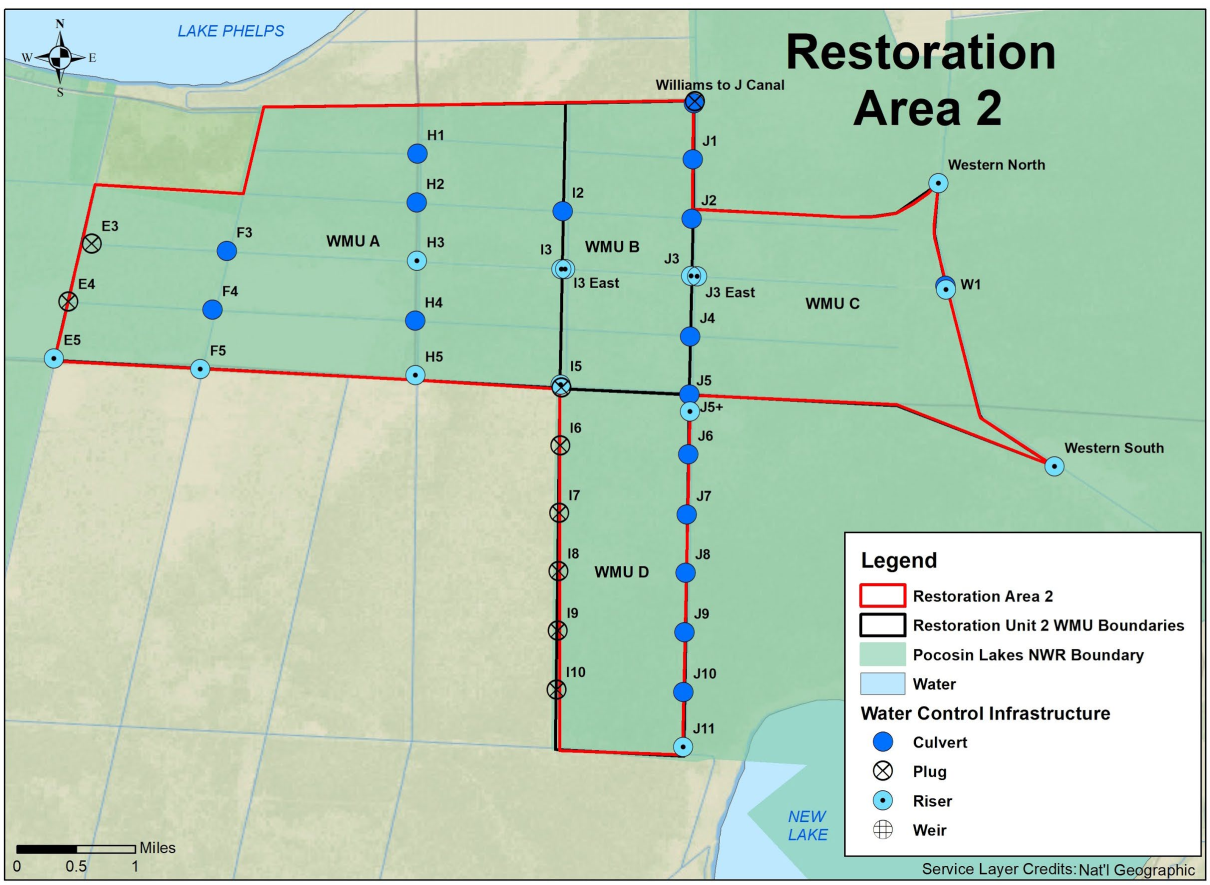
RA 2 Restoration Design

Because of the topography and erratic drainage system patterns, restoration of more natural hydrologic conditions in RA 2 is complex. As stated previously, the highest ground is in the upper middle of WMUs A and B, and, therefore, water flows off this dome in all directions. Broadly speaking, the restoration design includes blocking the westward flow in to Evans Canal with canal plugs and partially blocking flow to the south using risers with the board levels set at or below the corresponding ground levels on the north side of RA 2 to avoid driving additional water north in to Williams Canal. Any water that does drain north to Williams Canal flows east to the refuge portion of J Canal. Thus, most of the drainage in WMUs A and B is managed to flow east into the lower elevation refuge lands in WMU C. From WMU C, water management infrastructure is used to encourage overland flow of water further east to the very low refuge lands at the headwaters of the Northwest and Southwest Forks of the Alligator River. WMU D is similar to RA 1 in that it generally slopes down in one direction (southeast), and, like much of RA 1, the restoration design is to stage water back up the slope.

WMUs A & B

WMU A is approximately 4,300 acres and WMU B is approximately 1,400 acres. Most of the westward canal drainage flow, towards Evans Canal, has been blocked by dikes and plugs; however, water can still move laterally through and over the ground from the refuge lands south of the State Park Natural Area. On the south side, the drainage levels in Risers F5, H5, I5, and J5+ (Figure A-28) are set at or below the corresponding ground levels on the north side of RA 2. Thus, eastward drainage is encouraged, but flow to the north and south still happen during high rainfall events. Northward drainage can go overland into Williams Canal, which is now routed into the Refuge part of J Canal. Southward drainage, through Risers F5, H5, and I5, flows into County Line Canal; the centerline of this canal is the refuge boundary in that area. County Line Canal drains into Evans and Ichabod Canals, which flow south towards the Pungo River.

Figure A-28. Restoration Area 2 (RA 2) restoration infrastructure and water management units (WMUs).



Drainage into County Line Canal via the lateral ditches in Blocks E5 and F5 is now prevented by a small berm, constructed in 2016, on the north side of County Line Canal. The restoration design in the 1994 Study called for simply plugging the lateral ditches in those blocks (USDA

1994). However, the 2008 Evans Road Fire burned away too much of the peat soil adjacent to County Line Canal and between the lateral ditches for just plugging them to adequately reduce southward drainage.

The restoration design for WMUs A and B has been modified from what was recommended in the 1994 Study (USDA 1994). The 1994 design called for plugs in the east/west canals, but on the opposite (east) side of the Icabond and J Canals from their associated dikes (Figure A-29), with risers through those plugs in Harvester Canal. Since heavy equipment could not reach many of these locations, other than in Harvester Canal, many of the plugs had to be installed by hand using boats to get across the canals. Many of those plugs have failed. The new design calls for adding risers in Harvester Canal through the Huber, Icabod, and J Canal Dikes, removing most of the culverts under Huber, Icabod, and J Canal Dikes, and removing most of the plugs that were installed by hand in the eastward draining canals on the east side of Icabod and J Canals.

Figure A-29. Earthen plug, built with hand tools, on the far side of J Canal.

The drainage levels in Risers H3, I3, and J3 will be set to stage water in the soil of lands associated with those dikes, to the extent practicable. Note the ground generally slopes down in an easterly direction starting at Huber Road (Figure A-27).

WMU C

WMU C is approximately 1,900 acres. Land elevation in WMU C is much lower than WMUs A and B (Figures A-27 and A-28). Drainage from those WMUs mostly passes through WMU C, primarily via Harvester Canal. Riser W1 was installed for firefighting and is used to hold some water back in WMU C soils; however, its effect on most of the WMU is minimal. Riser J3-E is used to spread drainage water through as much of WMU C as possible via the other three eastward draining canals lying north and south of Harvester Canal. Risers WN and WS are used to prevent most of the flow to the north and south in Western Canal and facilitate the water flowing from WMUs A, B, and C to flow overland into the lower elevation Refuge lands to the east.

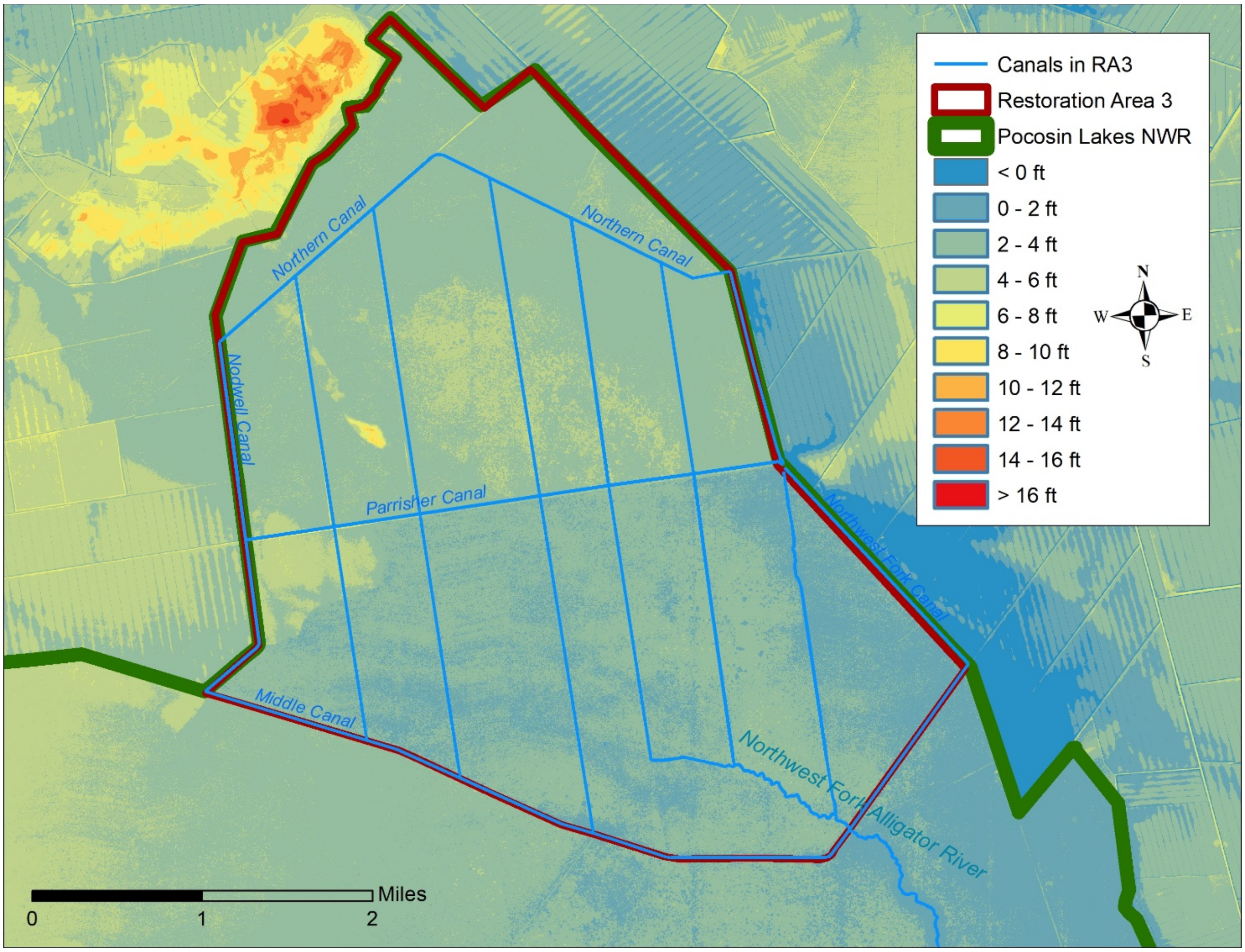
WMU D

WMU D is approximately 1,700 acres. This WMU is much more similar to RA 1 than the other WMUs in RA 2. Ground elevation in the WMU generally falls from northwest to southeast (Figures A-27 and A-28). Plugs were installed in the east-west oriented ditches on the west side of the WMU to stop canal drainage into Ichabod Canal. Some of these plugs have failed and need to be repaired or replaced. The only apparent way to access the plugs is by boat in Ichabod Canal. When the plugs are functioning, Riser J11 provides the only drainage level control for most of this WMU. The 1994 study suggests that additional risers could be added in the future to move more towards a one foot staging interval (USDA 1994). Risers J8, once it is installed, and J11 are used to stage water in the soil along the southeasterly downward gradient, which is similar to the design for most of RA 1.

RESTORATION AREA 3

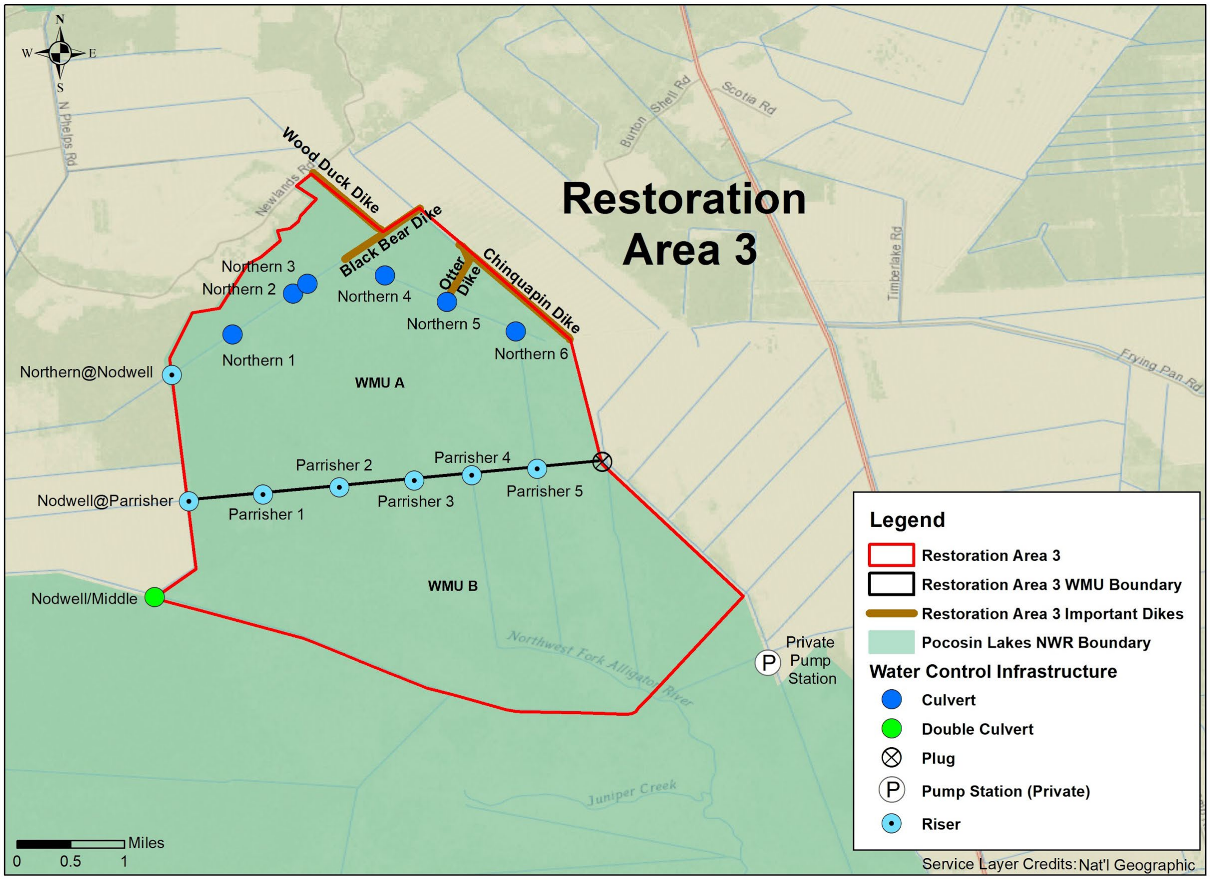
RA 3 is approximately 8,500 acres. It is much closer to the Alligator River and much lower in elevation than RA 1 and RA 2. Generally, the land elevation drops slightly from north to south (Figure A-30). The RA is surrounded by private and state-managed lands on all sides but the south. South of the RA are more refuge lands and the Northwest Fork of the Alligator River. The North Carolina Wildlife Resources Commission's Lantern Acres Game Lands lie adjacent to the upper west side of the RA.

Figure A-30. LiDAR elevation data for Restoration Area 3 (RA 3).



There is private farmland east of RA 3 and much of it is very low in elevation and water is pumped to accommodate farming. A large privately-owned and operated pump station located about 3.5 miles south of Northern Road in the Northwest Fork Road/Dike pumps water from the private land into the refuge where it drains to the Northwest Fork of the Alligator River (Figure A-31). This pumping creates a sizable head difference between water on two sides; therefore, several large dikes on the north and east sides of RA 3 separate the farmland from refuge wetlands. The north end of Chinquipin Dike ends at higher land just past the intersection with Otter Dike. During big storm events, water may run across that higher land and into the pumped canal. The centerline of the canal on the east side is the refuge boundary.

Figure A-31. Restoration Area 3 (RA 3) proposed restoration infrastructure and water management units (WMUs).



There are state game lands and private farmland on the west side of RA 3, which are also low in elevation but not as low as those on the east side. The lands on the west side are not pumped. However, the farmland and some of the game lands also drain through the refuge to the Northwest Fork via Nodwell and Middle Canals (Figure A-30). The centerlines of these canals form the Refuge boundary with adjacent private lands. Nodwell Canal intersects with Middle Canal, and all of the drainage water from both canals has to go through two six-foot diameter culverts under Nodwell Road. Beavers often block these culverts creating drainage problems. Middle Canal connects directly to the Northwest Fork; there are no risers, culverts, or other structures in Middle Canal downstream of Nodwell Road.

Some of the highest land in Tyrrell County is located along the RA's northwest side (Figure A-30), which precludes drainage from RA 3 in that direction. There is no dike, canal, or other feature delineating the refuge boundary on the northwest side of RA 3 (i.e., north of Northern/Nodwell). While the high ground prevents drainage to the north, nothing prevents drainage to the west—into Lantern Acres Game Lands—in that small section of boundary north of Northern/Nodwell.

There are remnants of five drainage canals, running from Northern Road/Dike to Parrisher Canal and from Parrisher Road/Dike to the Northwest Fork. They are located about one half to three-fourths of a mile apart. These canals have not been maintained, and their level of functionality is unknown. The intersections of the two westernmost canals between Northern and Parrisher can be seen from each end. Only the westernmost canal between Parrisher and the Northwest Fork can be seen from Parrisher Road. The intersections of the two easternmost canals have been seen from a boat in the Northwest Fork.

Parrisher 1 Riser connects to the canal on the south side of the road/dike. The Parrisher 2 through Parrisher 5 Risers were likely installed so as to connect to other canals on the south side of the road/dike, but they are no longer in place - see RA 3 Restoration Design below - and those south-side canals are no longer visible from Parrisher Road.

Parrisher Canal dead ends at the Northwest Fork Road/Dike on its east end but connects to Nodwell Canal via a small riser on its west end.

RA 3 Restoration Design

We divide RA 3 into two WMUs. WMU A includes lands north of Parrisher Road, and WMU B includes lands between Parrisher and Middle Roads. The original restoration design (1994 Study: USDA, 1994) called for riser structures in the Parrisher Road Berm where the interior canals in WMU B intersect and for culverts under Northern Road, connecting Northern Canal to the WMU A interior Canals. The drainage level in WMU A would have been set by the board levels in the five riser structures. The 1994 design called for removing the culvert connecting the west end of Parrisher Canal to Nodwell Canal. However, that culvert was replaced with a small riser for use as an emergency outlet during storm events. The outlet pipe on that riser is smaller in diameter than the culvert it replaced.

While the risers in Parrisher were installed years ago, they never functioned properly, potentially because of the downstream ditches being blocked. Of the five risers, only Parrisher 1 can still be located with the disappearance of the remaining four likely due to beaver activity, impact by heavy equipment during mowing or other operations, and other causes. Only a small amount of water drains through Parrisher 1 due to the higher ground elevations in that area, beaver activity, pine straw clogging the structure, and possibly blockage of the ditch somewhere below.

The 1994 restoration design for WMU B included blocking the Northwest Fork near the Middle Road Bridge, which was destroyed by fire, and installing large riser structures there. This project was never initiated. In addition, multiple 18-inch culverts were to be installed through the Middle Road Dike at multiple locations on either side of the Northwest Fork risers. Culverts were installed, but only in the dike west of the Northwest Fork.

Changing Conditions at RA 3

The water level in the Northwest Fork appears to be increasing. This may be a result of multiple factors including sea level rise and invasive alligatorweed and other materials impeding flow. Tree mortality appears to be increasing north of Middle Canal in its lower section near the Northwest Fork. In addition, a recent study (KBE 2019) found that actual land elevations in RA 3 are lower than previously indicated by LiDAR. These new data confirm that most of the land in RA 3 is less than two feet in elevation. Overall, conditions seem to be getting much wetter in RA 3 than was evident or anticipated in 1994 when restoration of the area was first planned. A multiyear wet cycle began in 2013; as a result, tree mortality began increasing in WMU A. In response, all boards were removed from the Parrisher/Nodwell riser to maximize drainage and Parrisher Road/Dike was breached in two locations in an attempt to increase drainage in WMU

A. Water level readings taken at the riser indicate that these actions have had a limited effect. The changing conditions at, and new information coming from, RA 3 have caused a shift in management direction from raising drainage levels to rewet peat soils to enhancing floodplain connectivity to reduce standing water and tree mortality (see section IV below). These changing conditions, coupled with refuge management actions, have essentially allowed for restoration goals in RA 3 to be met and, in some cases, exceeded necessitating management actions to promote more natural drainage to the Northwest Fork of the Alligator River.

RESTORATION AREA 4

RA 4, also referred to as the North Pungo Area, is approximately 1,800 acres. It is bounded by Shore Drive on the north side, the Pungo Unit on the south side, RA 1 on the east side, and private lands on the west side (Figure A-32). USDA-NRCS bought a WRP easement on private land immediately adjacent to the west side of RA 4 and implemented a wetland restoration project there with the cooperation of the refuge. The infrastructure needed to restore part of RA 4 is in place and rewetting goals have been achieved. Additional restoration on the remainder of the area is a possibility that can be explored in the future.

WMU NP 3 is approximately 640 acres and is the only restored portion of RA 4 at this time. There is a riser in the northwest, southwest, and southeast corners of the WMU (Figure A-32). The F2 Canal lies along the west sides of WMUs NP 1 and NP 3. Drainage in Canal F2 is both northward and southward with the elevation break point somewhere within the northern half of the WMP NP 3. Risers NP 1 and NP 3 are used to set the drainage level for the WMU under most conditions. Riser NP 3A connects to Allen Road Canal in RA 1. Drainage through Riser NP 3 flows west in North Boundary Canal, which ultimately drains to D Canal on the west side of the Pungo Unit. Drainage through Riser NP 1 flows north in Canal F2 which connects to the Shore Drive Canal which drains to the Scuppernong River via other canals.

Figure A-32. Restoration Area 4 (RA 4) restoration infrastructure and current and potential water management units (WMUs).

There is a canal between F2 and Allen Road in the middle of WMU NP 3. The canal connects to Allen Canal via Culvert NP 2A, but the water in Allen Canal is blocked by Plug NP 2 from entering the F2 Canal; essentially, it is a blind end canal that normally stays at the same water level as the Allen Canal and serves no water management purpose.

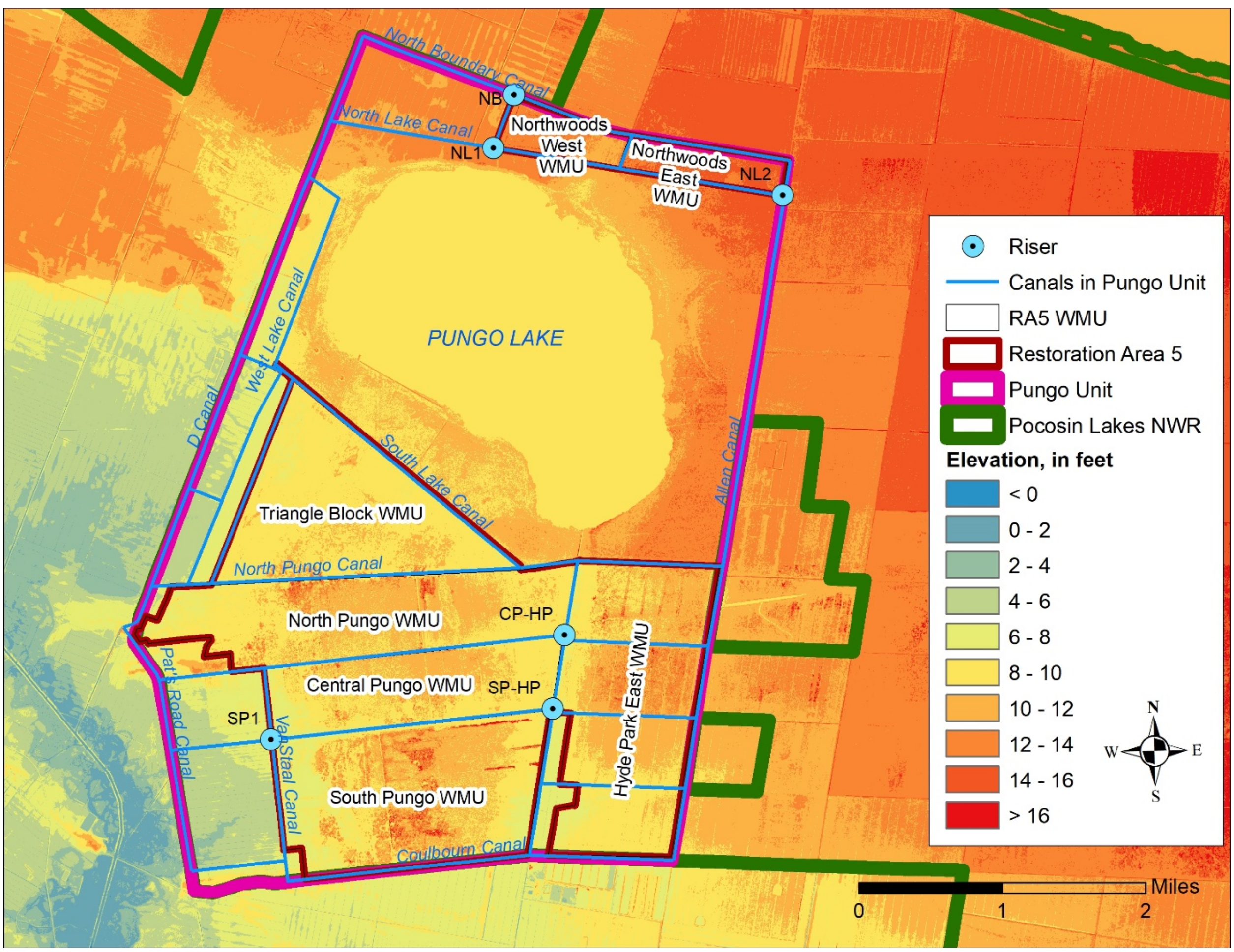
WMU NP 1 is approximately 400 acres. Attempts to restore this block have not been successful to date because of ownership patterns and drainage issues. Improving soil moisture conditions here would have valuable wetland and catastrophic fire prevention benefits. Accordingly, alternatives that might allow restoration of at least a portion of the block should be evaluated for possible future implementation.

WMU NP 4 is approximately 760 acres. Restoration in this block was not considered feasible due to the private farmland located immediately adjacent to the 2.3 mile long western boundary of the block. However, with the WRP easement and restoration project that have been placed on some of the private tract immediately adjacent to the refuge, alternatives that might allow restoration of at least a portion of the WMU should be evaluated for possible future implementation.

RESTORATION AREA 5

RA 5 includes approximately 5,300 acres of hydrologically altered peatlands in the Pungo Unit of the refuge (Figure A-33). In the early 1960s, the plan for Pungo National Wildlife Refuge was to convert most of the peatlands to croplands for Canada goose foraging habitat because Canada goose numbers were declining more slowly around Pungo than other areas. However, as habitat for the species increased in areas surrounding the refuge at that time, the Service decided to retain these areas on the Pungo Unit as vegetated peatlands to retain some diversity of habitat types. Many of these peatlands, by virtue of their hydrologic connection to infrastructure maintained for waterfowl management, were either drained year round or partially drained during the growing season for waterfowl habitat management purposes (see the Managed Waterfowl Habitat section above). Approximately 1,960 acres of altered peatlands on Pungo have been restored including the Northwoods 1 & 2, North Pungo, and Central Pungo WMUs. The approximately 980-acre Triangle Block WMU has been partially restored. Plans have been developed for the infrastructure needed to restore the South Pungo and Hyde Park blocks (approximately 2,330 acres). These peatlands are still subject to drainage because of the waterfowl management activities on the Pungo Unit.

Figure A-33. LiDAR elevation data and water management infrastructure on Restoration Area 5 (RA 5) within the Pungo Unit.



Northwoods 1 & 2 WMUs

The drainage level in the Northwoods 1 WMU (approximately 170 acres) is set with the risers in North Boundary Canal and North Lake Canal on the west side of the WMU. These canals drain west from the risers to D Canal.

The drainage level in the Northwoods 2 WMU is set with the riser in North Lake Canal, which connects to Allen Canal, on the east side of the WMU. The F2 Road/Dike bisects North Boundary and North Lake Canals, making this riser the only outlet. The Northwoods 2 WMU is only approximately 187 acres and sits fairly high in the landscape. Water is rarely seen draining through the riser, and it is likely that almost all of the rain that falls on this unit is stored within the dikes until it is naturally removed—primarily via evapotranspiration. For fire management purposes, refuge staff considers the southwest corner of Northwoods 2 to be a good indicator of how wet or dry the pocosins are across the refuge, and it is relatively easy to access.

North & Central Pungo WMUs

The drainage level in the North Pungo WMU (approximately 960 acres) is set with the riser located in the southeast corner. Water drains through that riser into Hyde Park Canal. The drainage level in the Central Pungo WMU (approximately 1,130 acres) is set with risers located in the southwest and southeast corners of the unit. The highest elevation land is in the north-central part of the unit, resulting in water draining to both of these corners. Water draining east goes in to Hyde Park Canal. There are two risers in the southwest corner of the WMU: one in Van Staalduinen Canal under South Pungo Road/Dike and another in the South Pungo Canal under the Van Staalduinen Road/Dike. The former riser is larger, but is usually left open with no board added. The latter, smaller riser drains water via a smaller farmfield ditch to the Pats Road Canal.

Triangle Block WMU

The drainage level in the Triangle Block WMU (approximately 980 acres) is influenced by the riser (JP-SE) in the southwest corner of the unit and the riser (SL1) in the combined South Lake/North Pungo Canal at Hyde Park. There is higher elevation ground spread out in the middle of the unit so water tends to drain in all directions. While Riser JP-SE can be used to set a drainage level for the unit, Riser SL1 is used for waterfowl habitat management (see the Managed Waterfowl Habitat section above). In addition, water along the northeast side of the unit can drain in South Lake Canal unchecked and is also affected by Riser SP1. To stop this unchecked drainage, a new dike would have to be constructed.

Hyde Park and South Pungo Blocks

Conceptual plans have been developed to construct the infrastructure needed to restore peatland hydrology on the Hyde Park and South Pungo Blocks (approximately 2,330 acres). More detailed evaluation of these restoration options and coordination with downgradient land owners will be needed in the future.

MINIMALLY HYDROLOGICALLY ALTERED PEATLANDS

Limited infrastructure exists within the minimally altered refuge peatlands (approximately 58,500 acres; 53% of the refuge). Pre-existing drainage ditches are generally not so extensive in these areas to allow for significant dewatering of adjacent wetlands or lowering of water tables. Accordingly, the refuge has limited water management capability within these areas and does not divide them into management units.

FIRE MANAGEMENT

Fire management activities, like wildfire fighting and prescribed burning, generally rely on maintenance of soil moisture conditions, achieved through the restoration infrastructure described above for the hydrologically altered peatlands, as well as strategically located firebreaks and access points. Because even the ground will burn in pocosins, “firebreaks” here are not barriers to fire, but are lanes along roads and canals where vegetation is managed to maintain open space from which to work with heavy equipment to defend against an approaching wildfire (Figure A-34).

Figure A-34. Fire management operations on Pocosin Lakes NWR.

The refuge uses any of the restoration infrastructure described above, and the water managed by it, for fire management purposes on and around the refuge.

IV. WATER MANAGEMENT DIRECTION AND IMPLEMENTATION

There are four primary goals with associated objectives identified in this Water Management Plan. Table A-1 lists the refuge water management goals and objectives. In order to accomplish the goals and objectives, the refuge will rely on a series of supportive strategies. These strategies will need to be modified adaptively based on conditions observed on the ground. As such, the strategies will be regularly updated by refuge staff. While refinement will be necessary over time, it is expected that general overarching strategies related to management, monitoring and research, and stakeholder engagement will be commonly used "tools in the toolbox." Strategies for accomplishing specific goals and objectives are described under the appropriate objective. The ability to continue implementing certain strategies or to embark on implementing new strategies will be contingent upon adequate resources and staffing levels. The refuge will continue to maintain water management infrastructure to help meet all of these goals and objectives.

Table A-1. Pocosin Lakes NWR water management goals and objectives.

Goal/ Objective	Description
Goal 1	**Managed Waterfowl Habitat** Manage water resources to provide optimal wintering waterfowl habitat to support not only historic numbers of tundra swans, geese, and ducks but also additional numbers of birds expected due to the loss of habitat on the Albemarle-Pamlico Peninsula from past and future sea level rise and other climate change factors.
Objective 1.1	Manage approximately 2,000 acres of agricultural land to provide supplemental grain (up to 400 acres corn) and green browse (up to 300 acres winter wheat), flood up to half of the corn acreage in the fall/winter.
Objective 1.2	Manage 593 acres of moist soil impoundments to annually achieve at least 70 percent coverage of waterfowl food plants rated as "good" or better and make it available to wintering waterfowl by shallowly flooding.
Objective 1.3	Manage approximately 1,500 acres of seasonally flooded forested wetland habitat in impoundments.
Objective 1.4	Maximize the amount of waterfowl roosting/resting habitat and sanctuary provided at Pungo Lake and provide up to 250 acres of inundated, emergent waterfowl food plants around the perimeter of the lake during the waterfowl season (November - February).
Objective 1.5	Maximize the amount of waterfowl roosting/resting habitat and sanctuary provided in the Refuge portion of New Lake for species such as tundra swan, Canada goose, and gadwall.
Goal 2	**Hydrologically Altered Peatlands** Restore, or mimic, the natural hydrology of highly altered areas of pocosin wetlands/peatlands and rewet the peat soils to promote natural pocosin vegetation and conditions, enhance wildlife habitat, and prevent the loss of peat via oxidation and wildfire.
Objective 2.1	Rewet the organic soils on up to 43,000 acres using a target drainage (riser board) level that mimics, as closely as possible, the water levels in an intact pocosin wetland in terms of relationship to ground surface and natural fluctuation based primarily on rainfall and evapotranspiration (recognizing that some inundation will occur in the lowest elevations of the WMUs).
Objective 2.2	In RA 3 (~8,500 acres), promote natural drainage to the Northwest Fork of the Alligator River.
Objective 2.3	Conserve and maintain approximately 43,000 acres of hydrologically restored peatlands.

Goal/ Objective	Description
Goal 3	**Minimally Hydrologically Altered Peatlands** Protect peatlands with relatively intact natural, minimally altered hydrology from any further alteration; enhance natural hydrologic conditions where practicable without eliminating existing access for management and other purposes.
Objective 3.1	Conserve and maintain approximately 58,500 acres of minimally altered, relatively hydrologically intact peatlands.
Objective 3.2	Increase floodplain connectivity while maintaining most of the current access to minimally altered peatlands.
Goal 4	**Enhance Fire Management Capabilities** Minimize and control wildfires as quickly as possible and facilitate prescribed burning for hazardous fuels reduction and wildlife habitat management using any and all water management capabilities.
Objective 4.1	Contain and extinguish all wildfires at the smallest acreage possible.
Objective 4.2	Supply sufficient water to units, prior to prescribed burning, to encourage appropriate soil moisture conditions and preclude all or most ground fire.

MANAGED WATERFOWL HABITAT

As described earlier, the former Pungo National Wildlife Refuge (established in the early 1960s and now called the Pungo Unit of Pocosin Lakes NWR) retains the establishing purpose as a waterfowl and migratory bird sanctuary for the 12,350-acre unit. Pocosin wetland restoration and conservation is the purpose of the remainder of Pocosin Lakes NWR. Some blending of these two missions has occurred since 1990. For example, waterfowl roosting/resting habitat and sanctuary is an important consideration in the management of the refuge portion of New Lake in addition to its importance as a component of the refuge's pocosin wetlands. Similarly, because much of the Pungo Unit was never converted to agriculture or impoundments, some pocosin restoration, along with conservation of relatively intact pocosin habitat, occurs there as compatible with the waterfowl purpose of the Pungo Unit. Public access is curtailed, at least during the wintering waterfowl season, on all managed waterfowl habitat to reduce bird disturbance. New waterfowl objectives are being developed across the southeast refuge program utilizing a new process for stepping-down objectives from the North American Waterfowl Management Plan. These objectives are not fully developed and were not used to inform the development of this plan. The objectives under Goal 1 will be adapted, if necessary, based on the development of the new waterfowl objectives.

Goal 1: Provide wintering waterfowl habitat to support not only historic numbers of tundra swans, geese, and ducks but also additional numbers of birds expected due to the loss of habitat on the Albemarle-Pamlico Peninsula from past and future sea level rise and other climate change factors.

AGRICULTURAL LANDS

Objective 1.1: To the extent practicable, manage water on up to approximately 2,000 acres of agricultural land to provide supplemental grain (up to 400 acres corn) and green browse (up to 300 acres winter wheat), flood up to half of the corn acreage in the fall/winter.

Rationale: The agricultural lands at Pocosin Lakes NWR provide high quality food for wildlife. Crops such as corn and winter wheat are left in the farm fields after harvesting for browsing. Seasonally flooding farm fields enhances access for wintering waterfowl, such as mallards, pintails, and wigeon, to the remaining crops. The refuge currently manages 1,250 acres of cropland through cooperative farming agreements with local farmers. The result is 250 acres of standing corn and 200 acres of winter wheat for wintering waterfowl. Increased waterfowl use necessitates an increase in available foraging habitat in this program. The amount of grain (corn) made available to wintering waterfowl can be increased by adding acres through land acquisition along with cooperative farming or switching to contract or force account farming on existing refuge lands.

The refuge will continue to:

- Manage drainage on approximately 1,250 acres of existing agricultural lands to produce supplement grain and green browse to make it available to wintering waterfowl through the Service's Cooperative Farming Program.
- Manage drainage in all fields for crop production during the growing season; this requires lowering the drainage levels in Hyde Park and South Lake Canals.
- Maintain drainage in all fields except Davis Impoundment and the Hyde Park North Field for dry field waterfowl foraging during the fall/winter.
- Prohibit public access on agricultural lands during most of the wintering waterfowl season (Nov - Dec).
- Shallowly flood Davis Impoundment and/or the Hyde Park North Field during the fall/winter when corn or other suitable waterfowl foraging crops are grown and avoid flooding when these fields have been planted in soybeans or winter wheat; field inundation requires raising the drainage levels in Hyde Park and South Lake Canals.
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise.
- Conduct waterfowl surveys annually.
- Periodically monitor water and board elevations at water control structures.

In addition, under this plan the refuge will:

- Determine and implement the most practicable means to manage water to meet our goals and objectives on new agricultural lands, if they are needed, to increase standing corn by 150 acres and winter wheat browse by 150 acres.

MOIST SOIL IMPOUNDMENTS

Objective 1.2: Manage water on up to 593 acres of moist soil impoundments to annually achieve at least 70 percent coverage of waterfowl food plants rated as "good" or better and make it available to wintering waterfowl by shallowly flooding.

Rationale: Moist-soil units provide plants that produce high-quality seeds and other foods for waterfowl in the fall and winter and mudflats that produce invertebrates for shorebird food in the spring and late summer. Shallowly flooding the moist-soil units provides foraging habitat for wintering waterfowl, such as teal, shovelers, and wigeon.

The refuge will continue to:

- Lower drainage levels in Smartweed, Jones Pond, and Marsh A Impoundments during the growing season; this requires lowering the drainage levels in Hyde Park and South Lake Canals.
- Shallowly flood these impoundments during the fall/winter; this requires raising the drainage levels in Hyde Park and South Lake Canals.
- Pump surface water to flood impoundments as needed.
- Pump from the wells to flood Smartweed and Jones Pond Impoundments as needed.
- Prohibit public access in all waterfowl impoundments during most of the wintering waterfowl season (Nov - Feb).
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case by case basis as issues arise.
- Conduct vegetation surveys in each unit annually.
- Conduct waterfowl count and habitat condition surveys annually.
- Periodically monitor water and board elevations at water control structures.

In addition, under this plan the refuge will:

- Determine and implement the most practicable means to manage water to meet our goals and objectives on up to 312 additional acres of moist soil impoundments. This requires construction of new impoundments which may require acquisition of additional lands.
- Explore options and execute projects to enhance water management capability in Marsh A. Possible projects include coring the berm to better separate the unit hydrologically from the lake and replacing dilapidated water control structures.
- Periodically conduct surveys for migratory shorebirds.
- Develop innovative, web-based tools for engagement with stakeholders and for education purposes.
- Expand the monitoring network by establishing new water monitoring sites.

IMPOUNDED FORESTED WETLANDS

Objective 1.3: To the extent practicable, manage water to provide approximately 1,500 acres of seasonally flooded forested wetland habitat in impoundments.

Rationale: Shallowly flooding forested wetlands during the dormant season attracts waterfowl by making tree mast, as well as understory food plants such as wild millet and smartweed, available to wintering waterfowl such as wood ducks, mallards, and black ducks. Additionally, it increases diversity by providing a unique habitat type for waterfowl and other species.

The refuge will continue to:

- Lower drainage levels in Duckpen and West Lake Impoundments during the growing season; this requires lowering the drainage levels in Hyde Park and South Lake Canals.
- Shallowly flood these waterfowl impoundments during the fall/winter; this requires raising the drainage levels in Hyde Park and South Lake Canals.
- Prohibit public access in all impoundments during most of the wintering waterfowl season (Nov - Dec).
- Periodically monitor water and board elevations at water control structures.

In addition, under this plan the refuge will:

- Enhance water management capability in West Lake Impoundment by extending the Smartweed Impoundment's northern dike through West Lake Canal and to West Lake Road; and installing a riser in the canal section.
- Determine and implement the most practicable means to manage water to meet our goals and objectives on up to 1,171 additional acres of forested wetland impoundments. This requires construction of new impoundments and may require acquisition of additional lands.
- Conduct vegetation surveys in each unit annually.
- Conduct bird surveys (e.g., breeding bird point counts or indices).
- Develop innovative, web-based tools for engagement with stakeholders and for education purposes.
- Expand the monitoring network by establishing new water monitoring sites.

PUNGO LAKE

Objective 1.4: Maximize the amount of waterfowl roosting/resting habitat and sanctuary provided at Pungo Lake and provide up to 250 acres of inundated, emergent waterfowl food plants around the perimeter of the lake during the waterfowl season (November - February).

Rationale: To date, the refuge has maintained a drainage level for Pungo Lake that attempts to maximize roosting and loafing habitat and sanctuary for tundra swans, Canada geese, snow geese, and many species of duck. If the refuge had the ability via a well and pump system to refill the lake following a drawdown, then a drawdown during the growing season could produce emergent wetland plants around the perimeter of the lake suitable for waterfowl foraging. In years when rainfall amounts are inadequate, the well and pump system could be used to refill the lake, making the foraging habitat accessible to waterfowl by shallowly flooding it. The goal would be to expose up to 10% of the lake bottom around the perimeter of the lake during the growing season thus allowing emergent wetland plants to grow and produce waterfowl forage and reflood this foraging habitat in the fall. This would be accomplished by lowering the lake drainage level at the outfall riser during the growing season, returning to the higher drainage level in the fall, and, if necessary due to lack of adequate rainfall, using the pump system to return the water level in the lake to full.

The refuge will continue to:

- Maintain a drainage level for the lake that corresponds to a water level that fills the lake and maximizes roosting and loafing habitat/sanctuary.
- Prohibit public access on/in the lake year round.
- Conduct waterfowl count surveys annually.
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case by case basis as issues arise.
- Periodically monitor water and board elevations at water control structures.

In addition, under this plan the refuge will:

- Determine if it is feasible to install a well and pump system that could refill the lake following a partial lake water drawdown during the growing season.

- If deemed feasible and within the station's capacity, construct and operate the system.
- Develop innovative, web-based tools for engagement with stakeholders and for education purposes.
- Expand the monitoring network by establishing new water monitoring sites.

NEW LAKE

Objective 1.5: Maximize the amount of waterfowl roosting/resting habitat and sanctuary provided in the Refuge portion of New Lake for species such as tundra swan, Canada goose, and gadwall.

Rationale: New Lake's primary benefit to waterfowl is for roosting and resting; therefore, maximizing the roosting and resting habitat will increase the number of birds that New Lake can accommodate.

The refuge will continue to:

- Engage stakeholders in discussions about lake water management and work towards consensus regarding a drainage level setting in the Mooney Canal riser that provides as much waterfowl roosting and resting habitat and sanctuary as possible given all stakeholder interests.
- Seek to develop consensus regarding overall lake water/drainage levels among stakeholders.
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case by case basis as specific issues arise.
- Prohibit public access on/in the refuge portion of the lake during most of the wintering waterfowl season (Nov - Feb).
- Periodically monitor water and board elevations at water control structures.
- Conduct waterfowl count surveys annually.
- Visually monitor the shoreline for early detection and rapid response of invasive species.

In addition, under this plan the refuge will:

- Work with other stakeholders to develop and execute projects to increase the artificial drainage capacity of the lake with the objective of creating the ability to drain water more quickly following storms and thereby allow higher drainage levels to be set without significantly impacting agricultural and hunting lands adjacent to the lake. Possible projects for evaluation include adding a second riser in Mooney Canal or replacing the riser with a larger structure, working with NCDOT to replace the culvert under New Lake Road with a larger one, replacing the plug in Herring Run Canal with a riser, installing a low water crossing in New Lake Road and/or constructing canals with risers on the east side of the lake creating drainage pathways to the Southwest and New Lake Forks of the Alligator River.
- Develop innovative, web-based tools for engagement with stakeholders and for education purposes.
- Expand the monitoring network by establishing new water monitoring sites.

HYDROLOGICALLY ALTERED PEATLANDS

Some of the most highly hydrologically altered (ditched and drained) peatlands on the refuge are on peat domes. Refuge efforts to manage drainage will focus on RA 1, 2, 3, 4 and 5. New species-specific objectives are being developed across the southeast refuge program. These objectives are not fully developed and were not used to inform the development of this plan. The objectives under Goal 2 will be adapted, if necessary, based on the development of the new objectives.

Goal 2: Restore, or mimic, the natural hydrology of highly altered areas of pocosin wetlands/peatlands and rewet the peat soils to promote natural pocosin vegetation and conditions, enhance wildlife habitat, and prevent the loss of peat via oxidation and wildfire.

The goal of water (drainage) management in the highly hydrologically altered peatland areas of the refuge is to reverse, to the extent possible without causing negative impacts to adjacent lands, excessive drying of the peat soil via the ditch system and to reestablish pocosin wetland hydrologic characteristics and vegetation. This is accomplished by raising the range of water levels that occur in the peat soil and allowing them to naturally fluctuate like those seen in unaltered pocosin wetlands. The refuge manages for rewetted soil conditions over as much of a WMU as possible, recognizing that these WMUs are often on the slope of a peat dome and that some of the lower elevation portions may experience more frequent inundation while the upper ends may experience suboptimal soil moisture conditions. This rewetting approach is described in detail in Section III.

Objective 2.1: To the extent practicable, stop excessive artificial drainage of water from, and rewet, the organic soils on up to 43,000 acres using a target drainage (riser board) level that results in water levels that mimic, as closely as possible, the water levels in an intact pocosin wetland in terms of relationship to ground surface and natural fluctuation based primarily on rainfall and evapotranspiration (recognizing that some inundation will occur in the lowest elevations of the WMUs).

Rationale: As described earlier, the slope of the land that has been restored is not uniform and water levels are constantly fluctuating because of rainfall and evapotranspiration. Drainage settings in risers are currently modified adaptively by refuge managers based on professional observation and judgement, informed by 1) collecting water level data at the riser and evaluating its response to rainfall and other factors and 2) by analysis of other research and monitoring data collected in recent years. In the years following restoration, drainage setting adjustments were made incrementally until optimum levels were reached to achieve desired wetland habitat conditions. When desirable habitat conditions are met, drainage levels are maintained, except for infrequent minor adjustments, promoting natural fluctuation of water levels. Under this plan, the refuge will install wells at strategic locations to monitor groundwater levels in “reference” pocosins (i.e., areas with naturally functioning pocosin hydrology). This data will then be used to adjust drainage levels as needed to mimic natural hydrologic conditions in the WMUs as closely as possible on as much of the WMU area as possible. The refuge will shift towards using more comprehensive monitoring data to guide drainage level management. Achieving naturally fluctuating wetland hydrology conditions will foster the growth of native plant species, such as Atlantic white cedar and bald cypress, which in turn will benefit native fauna. Species that will benefit from these activities include red-cockaded woodpecker, brown-headed nuthatch, red-headed woodpecker, Chuck-wills-widow, American woodcock, prairie warbler, northern bobwhite quail, Swainson’s warbler, and black-throated-green warbler. Consistent with the refuge goal of achieving naturally fluctuating wetland hydrology conditions and nullifying the impacts of artificial drainage, the refuge will rarely modify drainage settings during specific events, such as rainfall extremes, and only on a case-by-case basis when conditions warrant (also see "Extreme Weather Events" in Section II).

The refuge will continue to:

- Use the infrastructure in the following WMUs as described in Section III to raise drainage levels to reach the objective target.
  - RA 1: WMUs A3, A5, A7, A9, A11, B2, B6, B10, B11, C2, C6, C7, C10, C11, C14, C15, D3, D6, D8, D10, D11, D14, D15, RA1 North, and the State Park Pocosin Natural Area
  - RA 2: WMUs A, B, C, D
  - RA 4: WMU NP3
  - RA 5: WMUs Northwoods 1 & 2, North Pungo, Central Pungo, South Pungo, and Triangle Block
- RA 1: Improve/raise elevation of DeHoog Road/Dike.
- RA 2: Drain water from WMUs A & B through WMU C and, subsequently, in to Western Canal and continue to use infrastructure in Western Canal to encourage overland sheet flow or drainage water to the Northwest & Southwest Forks.
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise.
- Develop innovative, web-based tools for engagement with stakeholders and for education purposes.
- Periodically monitor water and board elevations at water control structures.
- Monitor ground and surface water at existing monitoring sites in restored peatlands to ensure restoration targets are being met.

In addition, under this plan the refuge will:

- Use more comprehensive monitoring data to guide drainage level management.
- RA 2: In WMUs A and B,
  - Remove the plugs in the eastward draining canals on the east side of Ichabod and J Canal Dikes that are no longer needed with the revised restoration design for the units.
  - Remove the culverts through Furbee, Huber, Ichabod, and J Canal Dikes that are no longer needed with the revised restoration design for the units.
  - Add or remove and use other infrastructure in the units as necessary to achieve drainage level targets.
  - Encourage water draining from the units to spread out as much as possible while draining through WMU C using the riser in Harvester Canal just east of J Canal.
- RA 2: In WMU D, install and manage an additional plug and riser in J Canal.
- RA 2: In WMU D, repair or replace the plugs at the west end of the J5, J6, J7, J8, J9, J10, and J11 east/west oriented canals.
- RA 4: In WMU NP1, evaluate, and implement as appropriate, projects that restore all or part of the unit without negatively impacting adjacent drained private lands.
- RA 4: In WMU NP4, evaluate, and implement as appropriate, projects that restore all or part of the unit without negatively impacting adjacent drained private lands.
- RA 5: Construct the infrastructure needed to restore peatland hydrology on the Hyde Park and South Pungo Blocks (approximately 2,333 acres),
- RA 5: Construct a dike on the northeast side of the Triangle WMU to enhance restoration effectiveness.

- Evaluate opportunities to establish new plantings of Atlantic white-cedar and bald cypress in appropriate locations on an ongoing basis.
- Expand the monitoring network by establishing new ground and surface water monitoring sites in the RAs.
- Periodically conduct vegetation surveys, including surveys to determine and monitor the acreage of Atlantic white-cedar in restored areas.
- Periodically conduct aerial surveys to detect red-cockaded woodpecker nest cavities.
- Periodically conduct bird surveys (e.g., breeding bird point counts or indices).

Objective 2.2: In RA 3 (~8,500 acres) restore natural drainage to the Northwest Fork of the Alligator River to the extent possible.

Rationale: The higher average river levels controlling conditions at RA 3, especially WMU 3A (see Section III), necessitate a change in our water management approach from one of rewetting previously drained soils to one of facilitating water drainage off the land to area rivers. This will be achieved in WMU 3A by breaching the Parrisher Dike and reducing drainage from Parrisher Canal in to Nodwell Canal; thus encouraging drainage water from WMU 3A to flow overland through WMU 3B to the Northwest Fork of the Alligator River. It will be accomplished in WMU 3B by removing impediments to flow in parts of the Northwest Fork and removing portions of the Middle Dike which will increase floodplain connectivity. It is clear that holding water back during periods of normal and above normal rainfall is not needed to retain moist soil conditions in RA 3. It is probable, the same is true for below normal rainfall periods, but the refuge will monitor conditions in WMU 3A and adaptively manage drainage through the Parrisher Dike breach if needed to retain water and soil moisture in WMU 3A.

Achieving naturally fluctuating wetland hydrology conditions will foster the growth of native plant species, such as Atlantic white cedar and bald cypress, which in turn will benefit native fauna. Species that will benefit from these activities include red-cockaded woodpecker, brown-headed nuthatch, red-headed woodpecker, Chuck-wills-widow, American woodcock, prairie warbler, northern bobwhite quail, Swainson’s warbler, and black-throated-green warbler.

The refuge will continue to:

- Maintain the culverts in Middle Dike, west of the Northwest Fork.
- Periodically monitor water and board elevations at water control structures.
- Monitor ground and surface water at existing monitoring sites in restored peatlands to ensure restoration targets are being met.

In addition, under this plan the refuge will:

- Close both existing breaches in the Parrisher Dike and dig a single breach, 100 to 150 feet wide in the dike.
- Manage the riser on the west end of Parrisher Canal to encourage flow through the breach and for “emergency” drainage flow into Nodwell Canal, if needed, during periods of high rainfall.
- Develop and implement plans for:
    - removing the remnants of the Middle Road bridge over the Northwest Fork.
    - removing all or portions of the Middle Road Dike for up to 3,000 feet on each side of the Northwest Fork, to increase floodplain connectivity.
    - potential snagging and clearing, and invasive plant control, in the Northwest Fork downstream of the Middle Canal intersection.

  - replacing the culverts in Middle Canal under Nodwell Road with a bridge or other infrastructure less likely to be repeatedly blocked by beaver activity.
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise.
- Develop web based information for engagement with stakeholders and education purposes.
- Evaluate opportunities to establish new plantings of Atlantic white-cedar and bald cypress in appropriate locations on an ongoing basis.
- Expand the monitoring network by establishing new ground and surface water monitoring sites in RA 3.
- Periodically conduct vegetation surveys, including surveys to determine and monitor the acreage of Atlantic white-cedar in restored areas.
- Periodically conduct aerial surveys to detect red-cockaded woodpecker nest cavities.
- Periodically conduct bird surveys (e.g., breeding bird point counts or indices).

Objective 2.3: Protect approximately 43,000 acres of hydrologically altered peatlands that have been or may be restored from ditching and draining.

Rationale: Once the infrastructure needed for restoration is completed, management activities shift from restoring the peatlands to protecting restored peatlands from further ditching or draining.

The refuge will continue to:

- Protect hydrologically altered peatlands that have been or may be restored from any further ditching/draining.
- Maintain current roads for access to the extent practicable.

MINIMALLY HYDROLOGICALLY ALTERED PEATLANDS

New species-specific objectives are being developed across the southeast refuge program. These objectives are not fully developed and were not used to inform the development of this plan. The objectives under Goal 3 will be adapted, if necessary, based on the development of the new objectives.

Goal 3: Protect peatlands with relatively intact natural hydrology from any further alteration; enhance natural hydrologic conditions where practicable without eliminating existing access for management and other purposes.

Objective 3.1: Protect approximately 58,500 acres of minimally altered peatlands from ditching or draining.

Rationale: The hydrology of the majority of the rest of the refuge (see Figure A-1) is considered to be relatively intact in that it is much less thoroughly or comprehensively ditched and drained than the Hydrologically Altered Peatland areas. Included in the minimally hydrologically altered peatlands are the headwater areas of the Alligator River around the Northwest and Southwest Forks, the portion of the Refuge lying north of the Intracoastal Waterway, the Scuppernong River tracts, the Frying Pan area adjacent to the main stem of the Alligator River, and the peatlands surrounding Pungo Lake. Management in this habitat focuses on preventing further alterations, detecting and responding to invasive species presence early, and researching various aspects of minimally hydrologically altered peatlands.

The refuge will continue to:

- Protect these areas from any further ditching or draining, but will, to the extent practicable, maintain most of the current roads for access.
- Control invasive species in natural waterways to protect minimally altered peatlands from infestation.
- Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise.
- Develop web based information for engagement with stakeholders and education purposes.

In addition, under this plan the refuge will:

- Evaluate the potential for conserving additional intact peatlands to serve as corridors for wildlife use.
- Expand monitoring of flora/fauna associated with the intact peatland community.
- Expand water level monitoring in intact and minimally altered pocosins and assess the potential to apply these data to inform management of restored pocosin areas.
- Evaluate and implement, as feasible, resiliency measures and infrastructure to prevent loss of intact pocosins, particularly in low elevation areas near the Alligator and Scuppernong Rivers.
- Periodically conduct vegetation surveys, including surveys to determine and monitor the acreage of Atlantic white-cedar in minimally altered areas.
- Periodically conduct aerial surveys to detect red-cockaded woodpecker nest cavities.
- Periodically conduct bird surveys (e.g., breeding bird point counts or indices).

Objective 3.2: Enhance floodplain connectivity to the extent possible while maintaining most of the current access to minimally altered intact peatlands.

Rationale: During the recent wet cycle, tree mortality appeared to increase in parts of the refuge, including in areas that are close to and drain into the Northwest Fork of the Alligator River. Although there are only a few dikes/roads in low lying areas such as this, during periods of high water they obstruct flow in the floodplains adjacent to the natural waterways by forcing all the flow through the main channel that is or was bridged for the road, i.e. they create a “pinch point.” Reducing these obstructions, i.e. increasing floodplain connectivity, can help reduce the amount of time upstream trees are inundated during wet periods and reduce tree mortality. Enhanced floodplain connectivity can also improve water quality, provide recreational opportunities, provide habitat for fish and wildlife, and it can help better convey flood water.

Under this plan, the refuge will:

- Explore, evaluate, and execute projects that increase floodplain connectivity where practicable. One possible project would be the removal or perforation of the section of Davis Road located in the floodplain and west of the Southwest Fork of the Alligator River and the remains of dilapidated Davis Road Bridge in the Southwest Fork. This section of road is expected to become part of the Refuge soon through donation.

FIRE MANAGEMENT

Installing the infrastructure to manage drainage and rewet refuge soils not only reduces the risk of catastrophic wildfire (frequency, duration, and intensity), but it may also make some water available for fighting wildfire should an incident occur. Water is essential for containing and extinguishing peatland ground fire. The big, long-duration fires usually occur during a drought when the peat soil dries out and water becomes scarce, especially in heavily ditched and drained areas. These fires can destroy habitat and consume peat soil down to the water table or the mineral soil beneath the peat layer. By raising drainage levels prior to a drought, as has been done in the Restoration Areas, it should take longer for the peat soil to dry out and water should be available in the canals for longer into the drought period.

Prescribed burning helps reduce above ground fuel (vegetation) which reduces the risk of wildfire development. Hydrology restoration also helps make water available to facilitate burning in the pocosin.

Goal 4: Minimize and control wildfires as quickly as possible and facilitate prescribed burning for hazardous fuels reduction and wildlife habitat management using any and all water management capabilities.

Objective 4.1: Contain and extinguish all wildfires at the smallest acreage possible.

Rationale: When a wildfire emergency develops, the refuge will suspend all other strategies to meet all other water management goals and objectives as necessary, and use any available water to contain or extinguish the wildfire at the smallest acreage possible. Strategies may include, but are not limited to, holding more water, if possible, in the area of the fire and moving available water from on-refuge sources and, with permission, off-refuge sources to the fire area by gravity flow, pumping, or other means.

In addition, during prolonged droughts, the refuge may increase drainage settings in riser water control structures to retain extra moisture from any passing storms to help with potential wildfire fighting efforts.

The refuge will continue to:

- Retain and use available water to contain or extinguish wildfire at the smallest acreage possible.
- Facilitate gravity flow and/or active pumping of water to meet wildfire suppression needs.
- Conduct soil moisture, Estimated Smoldering Potential (ESP), and water level monitoring refuge-wide.
- Evaluate the relationship between soil and water level conditions refuge-wide.
- Measure and document fire related soil loss.
- Maintain all fire suppression and monitoring equipment to facilitate rapid response and containment.
- Evaluate habitat response to wildfire.
- Coordinate with state and federal wildfire response agencies.
- Provide proactive communication with and be responsive to adjacent landowners regarding wildfire response and safety.
- Develop web based information for engagement with stakeholders and the public.

In addition, under this plan the refuge will:

- Expand soil moisture, ESP, and water level monitoring.
- Expand research on habitat response to wildfire.

Objective 4.2: To the extent practicable, supply enough water to units, prior to prescribed burning, to preclude all or most ground fire.

Rationale: For planned prescribed burning operations, the refuge can adapt water management strategies to meet all other water management goals and objectives and use available water to prevent all or most ground fire during burning operations, but not to the point of creating a wildfire hazard. For example, it would not be acceptable to drain one area, artificially drying out the peat soil, in order to prescribe burn another area. Minor amounts of ground fire can be tolerated in burn units as long as the amount does not exceed the burn team's capacity to extinguish it in a reasonable amount of time.

In addition, during prolonged droughts, the refuge may increase drainage settings in riser water control structures to retain extra moisture from any passing storms to allow resumption of prescribed burning operations as quickly as possible.

The refuge will continue to:

- Make water available by releasing water from a rewetted WMU to allow for safer prescribed fire on the landscape that prevents all or most ground fire during burning operations.
- Conduct fuel reduction activities, such as prescribed burning and fire break maintenance.
- Develop innovative, web-based tools for engagement with stakeholders and for education purposes.

In addition, under this plan the refuge will:

- Explore and assess opportunities to increase drainage settings in order to temporarily retain extra moisture from passing storms to facilitate appropriate conditions for resuming prescribed burning operations.

V. SUPPORTIVE AND COMPLEMENTARY STRATEGIES

In order to accomplish the Goals, Objectives, and Strategies outlined above, the refuge will rely on a series of supportive and complementary strategies in partnership with others. Refuge management authority rests solely within the boundary of the refuge; however, the refuge is part of a larger landscape of interconnected lands and waters. Many of the strategies described above will be more successfully achieved when completed in coordination with other land managers across the landscape. This is particularly important given the interconnectedness of the drainage network. Therefore, taking a more comprehensive approach will benefit both the refuge and landowners surrounding the refuge. While the refuge will not lead many of these strategies, there is an opportunity to contribute significantly to accomplishing them through partnerships with adjacent landowners; educational institutions; non-governmental organizations; local, State, and Federal governments and agencies; private corporations; and others. These supportive and complementary strategies aim to broaden the understanding of water movement on the landscape, identify barriers to water movement or other issues across the landscape, and identify opportunities for incentive programs and other possible solutions for addressing barriers and issues identified. Tentative examples of supportive and complementary strategies are described below, but potential strategies are not limited to those included here.

- **Regional water management studies:** The need for regional water management studies has long been recognized in various portions of the Albemarle-Pamlico Peninsula by land managers in the region. In the northern portion of the Albemarle-Pamlico Peninsula, the North Carolina Division of Parks and Recreation, the Service, and other partners have been pursuing the idea of developing a collaborative approach for a hydrologic study that can be utilized in a variety of potential future applications. These applications include developing a regional water management strategy, informing management actions on and off of conservation lands, or updating existing plans. The hydrologic study would provide an important information tool to guide potential implementation actions but can also be implemented in collaboration with other regional stakeholders, including local governments and private landowners. The Service could establish similar partnerships or otherwise contribute to the development of regional studies in other geographies of the Albemarle-Pamlico Peninsula. Specific issues that could be addressed by regional studies include:
    - Expanded water level monitoring at major drainage outlets to area rivers and the Sound to evaluate the potential effect of rising river levels on water management on the refuge;
    - Developing a water budget for the refuge and surrounding areas on the Albemarle-Pamlico Peninsula connected by the ditch system;
    - Identifying and prioritizing areas for intervention to prevent saltwater impacts on low elevation peatlands;
    - Exploring the effects of hydroperiod on changing land and habitat conditions; and
    - Identifying potential flow restrictions or under-capacity drainage networks and associated remedies where needed.
- **Cooperation with landowners on mutually beneficial efforts:**
    - Given the complexity of the drainage network surrounding the refuge, there are a number of issues that complicate or serve as barriers to drainage. The Service can contribute to efforts to identify and evaluate these barriers and, in some cases, aid in the resolution of the issues. In 2017, the Service funded a study to conduct a field assessment evaluating outlet restrictions in downstream canals. The assessment resulted in recommendations that identified priorities for debris snagging and removal in Hyde Park Canal, Boerma Canal, and Shallop Creek south of NC Highway 45 (since sediment deposits are greatest at the debris collection points). The Service can help to identify additional opportunities to evaluate outlet restrictions and other priorities for improving drainage downstream of the refuge.
    - The Service's Partners for Fish and Wildlife Program (Partners Program) works with private landowners to help them achieve their conservation goals. This program provides financial and technical assistance through a voluntary partnership agreement aimed at restoring and protecting wetlands, uplands, and riparian habitats. Partners Program staff are also available to assist landowners adjacent to and near the refuge with identifying other resources and programs that can address their conservation challenges. These resources may include the Emergency Watershed Protection Program, the Regional Conservation Partnership Program, the Wetlands Reserve Program, and other Farm Bill and Service programs.

- If adjacent landowners express interest in restoring pocosins, the Service may contribute by providing technical support. The Service has an extensive amount of relevant data and continues collecting data on hydrology restoration and peat rewetting. The Service can support off-refuge pocosin restoration through sharing data and providing technical expertise to those restoration efforts. This effort may assist in establishing wildlife corridors that may provide the dual benefit of enhancing hunting opportunities on private lands and connectivity of publicly managed pocosin areas.
- The Service can facilitate partnerships and share technical expertise in several areas that may allow for improved resiliency of lands adjacent to the man-made ditch network. In particular, areas where increased ecological function is complementary with existing land use may benefit from reconnecting floodplain areas (e.g., along NC-94) and installation of levee banks within ditches (e.g., two stage ditch practice) to allow for flood attenuation.
- The Service can support additional monitoring information including off refuge data collection sites (e.g., tide gauges) to inform management decisions by local land managers and property owners.
- In areas where there is a common interest in canal improvements and anadromous fish habitat expansion, the Service may be able to provide assistance in ditch work that allows for improved flow for both private land managers and native fish.

SECTION B: DRAFT ENVIRONMENTAL ASSESSMENT

I. Purpose and Need for Action

INTRODUCTION

The U.S. Fish and Wildlife Service (Service) proposes to manage water resources to help achieve specific goals and objectives stepped down from the 2007 Pocosin Lakes National Wildlife Refuge (NWR, refuge) Comprehensive Conservation Plan (CCP). Water management is critical to meeting many of those goals including conserving, protecting, and maintaining healthy populations of wildlife; restoring and managing pocosin and other natural habitats on the refuge; intensively managing waterfowl habitat; and providing public use opportunities. In 1990, Pocosin Lakes NWR was established primarily to conserve the unique pocosin wetlands. The Pungo Unit, originally a separate refuge, was established in the early 1960s as a waterfowl and migratory bird sanctuary.

This Environmental Assessment (EA) is being prepared to evaluate the effects associated with water management activities at Pocosin Lakes NWR and complies with the National Environmental Policy Act (NEPA) in accordance with Council on Environmental Quality regulations (40 CFR 1500-1509) and Department of the Interior (43 CFR 46; 516 DM 8) and Service (550 FW 3) regulations and policies. NEPA requires examination of the effects of proposed actions on the natural and human environment.

PURPOSE AND NEED

A CCP describes the desired future conditions of a refuge or planning unit and provides long-range guidance and management direction to achieve the purposes of the refuge, helps fulfill the mission of the Refuge System; maintains and, where appropriate, guides restoration of the biological integrity, diversity, and environmental health of each refuge and the Refuge System; helps achieve the goals of the National Wilderness Preservation System, if appropriate; and meets other mandates. The CCP for Pocosin Lakes NWR was finalized in 2007 (USFWS 2007). The Draft Water Management Plan (WMP) is a step-down management plan that builds upon the information, goals and objectives presented in the CCP with more specific details on management actions to achieve specific outcomes.

The purpose of the Draft Water Management Plan is to provide management direction for water resources on the refuge to ensure that refuge habitat goals and objectives are achieved by depicting current water management practices; describing existing management units and water management infrastructure; establishing specific habitat and species goals and objectives that rely on water management activities; and identifying future refuge water management strategies, data collection needs, and monitoring efforts. The Draft Water Management Plan is a detailed program of action to implement water management policies and objectives as defined by the Service and the Pocosin Lakes NWR. The Draft Environmental Assessment evaluates alternatives to provide wintering waterfowl habitat, restore natural seasonal hydrology in highly altered pocosin wetlands, maintain and protect relatively intact pocosin wetlands, and use water management capabilities to promote fire management activities on Pocosin Lakes NWR.

The WMP is a dynamic working document that guides the management of water for the refuge habitats that depend upon it and provides long-term vision, continuity, and consistency for water management for the next 15 years. The plan will be reviewed every five years and adapted as conditions require.

In 1992, the Service requested assistance from the local Soil and Water Conservation District and the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) (now called the Natural Resources Conservation Service) in developing a restoration approach designed to reverse, to the extent practicable, the effects of the drainage system that was previously installed on lands that had become Pocosin Lakes NWR. The Service request articulated two goals and 13 objectives. The goals were "*a. To raise water levels to restore as much of the land between Allen Road and County Line (Washington-Tyrrell) to pocosin type wetland as possible*" and "*b. To raise water levels to maintain pocosin type wetlands between County Line and the Gum Neck area.*" The SCS completed the hydraulic and hydrologic study in 1994, making recommendations for road maintenance and repair, watershed unit divisions, siting water control structures (e.g., culverts and risers), and management and operations for some of the most heavily altered (ditched and drained) areas of the refuge (USDA 1994). Refuge staff relied heavily on the recommended restoration design presented in the 1994 Study for developing the infrastructure needed to restore three RAs. However, modifications to that design have occurred over the years as a result of changing field conditions and/or observations of efficacy post-installation. Infrastructure installation has spanned a 20+ year period because of funding and other resource limitations. After many years, infrastructure development is now complete; however, additional modifications may be needed based on adaptive monitoring. As with the 1994 Study recommended design elements, many of the study's recommendations regarding water management have been followed and are being incorporated in the Draft Water Management Plan. Again, lessons learned post implementation, changing conditions on the ground (e.g., post fire, etc.), and more current technical information have promoted adaptive management actions by the refuge. While the study laid the groundwork for the restoration design, the Draft Water Management Plan builds on that design and begins to shift management focus to identifying drainage level targets, establishing reference sites, and building a robust monitoring network.

The need for the proposed action is to meet the Service's priorities and mandates as outlined by the National Wildlife Refuge System Administration Act, which mandates the Secretary of the Interior in administering the System to:

- Provide for the conservation of fish, wildlife, and plants, and their habitats within the National Wildlife Refuge System;
- Ensure that the biological integrity, diversity, and environmental health of the National Wildlife Refuge System are maintained for the benefit of present and future generations of Americans;
- Ensure that the mission of the National Wildlife Refuge System described at 16 U.S.C. 668dd(a)(2) and the purposes of each refuge are carried out;
- Ensure effective coordination, interaction, and cooperation with owners of land adjoining refuges and the fish and wildlife agency of the states in which the units of the National Wildlife Refuge System are located;
- Assist in the maintenance of adequate water quantity and water quality to fulfill the mission of the National Wildlife Refuge System and the purposes of each refuge;
- Recognize compatible wildlife-dependent recreational uses as the priority general public uses of the National Wildlife Refuge System through which the American public can develop an appreciation for fish and wildlife;
- Ensure that opportunities are provided within the National Wildlife Refuge System for compatible wildlife-dependent recreational uses; and
- Monitor the status and trends of fish, wildlife, and plants in each refuge.

Based on this EA, if no significant impacts on the human environment are identified, a Finding of No Significant Impact will be prepared. This determination will be based on an evaluation of the purposes for which the refuge was established, the missions of the Service and the National Wildlife Refuge System, and other legal mandates. Assuming that no significant impacts are found, implementation of the plan will begin, and the plan will be monitored on an annual basis and revised when necessary.
This proposed action is often iterative and evolves over time during the process as the agency refines its proposal and learns more from the public, tribes, and other agencies. Therefore, the final proposed action may be different from the original. The final decision on the proposed action will be made at the conclusion of the public comment period for the EA.

BACKGROUND

National wildlife refuges are guided by the mission and goals of the National Wildlife Refuge System, the purposes of an individual refuge, Service policy, and laws and international treaties. Relevant guidance includes the National Wildlife Refuge System Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997, Refuge Recreation Act of 1962, and selected portions of the Code of Federal Regulations and Fish and Wildlife Service Manual.

Pocosin Lakes NWR was established pursuant to the Migratory Bird Conservation Act of 1929, the Emergency Wetland Resources Act of 1986, and the Fish and Wildlife Act of 1956. The primary purposes of the refuge are:

> … for use as an inviolate sanctuary or for any other management purpose, for migratory birds… 16 U.S.C. Sec. 664 (Migratory Bird Conservation Act of 1929);
>
> … for the conservation of the wetlands of the Nation in order to maintain the public benefits they provide and to help fulfill international obligations contained in various migratory bird treaties and conventions… 16 U.S.C. Sec 3901 (b) 100 Stat. 3583 (Emergency Wetland Resources Act of 1986);
>
> … for the development, advancement, management, conservation, and protection of fish and wildlife resources… 16U.S.C. Sec 742f(a)(4) (Fish and Wildlife Act of 1956); and
>
> … for the benefit of the United States Fish and Wildlife Service in performing its activities and services. Such acceptance may be subject of the terms of any restriction or affirmative covenant or condition of servitude… 16 U.S.C. Sec 742f(a)(4) (Fish and Wildlife Act of 1956).

The mission of the National Wildlife Refuge System, as outlined by the National Wildlife Refuge System Administration Act, as amended by the National Wildlife Refuge System Improvement Act (16 U.S.C. 668dd et seq.), is to:

"... to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans."

The CCP emphasizes the importance of the Pungo Unit of the refuge for wintering waterfowl. Managing water resources is necessary for ensuring the availability of foraging and roosting habitat for wintering. The CCP also identifies hydrologic alterations as one of the key ecological threats facing the refuge, and as a major concern for refuge management, planners, and the community.

Hydrologic restoration and water management is necessary for meeting many of the refuge's habitat goals and is the most critical overarching habitat management strategy for refuge pocosins. Protecting minimally altered pocosins from further degradation requires habitat management strategies as well.

PROPOSED ACTION

The Service proposes to manage water resources to achieve refuge habitat goals and objectives to provide wintering waterfowl habitat, restore natural seasonal hydrology in highly altered pocosin wetlands, maintain and protect relatively intact pocosin wetlands, and use water management capabilities to promote fire management activities on Pocosin Lakes NWR. There are four primary goals identified in the Draft Water Management Plan (Chapter IV, Management Direction and Implementation):

Goal 1. *Manage Water Resources to Provide Optimal Wintering Waterfowl Habitat*
Provide wintering waterfowl habitat to support not only historic numbers of tundra swans, geese, and ducks but also additional numbers of birds expected due to the loss of habitat on the Albemarle-Pamlico Peninsula from past and future sea level rise and other climate change factors.

Goal 2. *Restore, Manage, Maintain and Protect Hydrologically Altered Peatlands*
Restore, or mimic, the natural hydrology of highly altered areas of pocosin wetlands/peatlands and rewet the peat soils to promote natural pocosin vegetation and conditions, enhance wildlife habitat, and prevent the loss of peat via oxidation and wildfire.

Goal 3. *Maintain and Protect Minimally Hydrologically Altered Peatlands*
Protect peatlands with relatively intact natural, minimally altered hydrology from any further alteration; enhance natural hydrologic conditions where practicable without eliminating all existing access for management and other purposes.

Goal 4. *Enhance Fire Management Capabilities*. Minimize and control wildfires as quickly as possible and facilitate prescribed burning for hazardous fuels reduction and wildlife habitat management using any and all water management capabilities.

II. AFFECTED ENVIRONMENT

For a complete description of affected resources, see Chapter II, Refuge Characteristics of the Draft Water Management Plan for Pocosin Lakes NWR.

III. ALTERNATIVES, INCLUDING THE PROPOSED ACTION

This chapter presents the alternatives considered, including the Service's preferred alternative, and the process for formulating alternatives.

FORMULATING ALTERNATIVES

Under NEPA, the Service developed and evaluated a reasonable range of alternatives. The Proposed Action defines what the Service plans to do or recommend, but cannot implement without considering other reasonable, environmentally sensitive alternatives. Other reasonable alternatives to the Proposed Action that could also be viewed as fulfilling the purposes of the refuge are described in this Draft EA. This offers the Service and the reviewing public an opportunity to consider a range of reasonable alternatives for the Proposed Action, thus fulfilling one of the key tenets of NEPA.

Alternatives describe complementary management approaches for achieving the missions of the Service and Refuge System, the purposes for which the refuge was established, and its vision and goals, while responding to issues and opportunities identified during the planning process.

DESCRIPTION OF ALTERNATIVES

Based on this process to identify and evaluate alternatives, the Service selected two alternatives, including the NEPA-required No Action Alternative, to provide a baseline for comparing the action alternative. At the end of this chapter, a matrix compares each alternative and its objectives. We also describe alternatives or actions considered but determined to be infeasible to carry forward. The alternatives considered are:

- **Alternative A – Current Management.** This alternative fulfills the NEPA requirement for a no action alternative, one that proposes no change in the current water management at the refuge. Alternative A is to continue to manage the refuge as we do at the present time.
- **Alternative B – Expanded Adaptive Management Framework (Proposed Alternative).** This alternative shifts to an expanded adaptive management framework to evaluate the efficacy of water management actions relative to reference (unaltered, or hydrologically functioning) pocosin wetlands. This alternative also expands water management capability in the Pungo unit habitats, evaluates the potential for additional RAs, explores mechanisms to improve drainage conditions in low lying portions of the refuge, and assesses floodplain connectivity to enhance intact peatlands.

ALTERNATIVES OR ACTIONS CONSIDERED BUT INFEASIBLE TO CARRY FORWARD

Some of the most highly altered (ditched and drained) peatlands on the refuge are on peat domes. Since a peat dome is higher in elevation than the surrounding area, rainfall is the only source of water to the system, and water leaves the system via evapotranspiration and drainage (via the ditches and via sheet flow when the capacity of the ditch system is overwhelmed). Therefore, it is a “rainfall-driven system.” Almost all of the refuge is dependent on rainfall for water, with few parts of the refuge that receive water from other, higher elevation lands or surface waters.

In unaltered pocosin wetlands, excess rainfall drains off the peat dome via “sheet flow,” or water flow down-gradient over the surface of the ground. Once the organic soil would soak up as much water as it could hold, the ground would become inundated and sheet flow would begin. When the rain stopped, inundation would subside as sheet flow transported rainfall off of the peat dome. Without additional rainfall, the water table level and soil moisture would then begin to drop slowly due to evapotranspiration. Per the refuge purpose, the Service is striving to maintain or restore (in areas where the pocosin wetland functions were lost due to historic ditching and draining) these natural pocosin wetland functions to the extent possible.

The goal of water (drainage) management in the highly altered (ditched and drained) areas of the refuge is to reverse the excessive drying of the peat soil via the ditch system and reestablish pocosin wetland hydrologic characteristics. This is done by installing infrastructure (a series of raised levees and risers or earthen plugs) to raise the range of water levels that occur in the peat soil from what they are with fully open ditches and canals to levels that are more consistent with unaltered (i.e., not ditched and drained) pocosin wetlands, while maintaining the natural (based primarily of rainfall and evapotranspiration) fluctuations of water table levels seen in unaltered pocosin wetlands. In effect, this process stops much of the artificial drainage via the ditch network on the refuge, i.e. water is drained to the level set in the riser structures rather than to the bottom of the ditch. Water from what are now refuge lands has, and always will, flow down-gradient, including through adjacent private lands, to the surrounding rivers. Reducing the extent of artificial drainage of water from refuge peatlands does not add any drainage water to the system, it simply holds some of the water that would otherwise drain out.

A common request of the Service from neighboring downstream landowners and others—either on event specific occasions, during stakeholder meetings, or during the open houses for this draft water management plan and EA—is to manage drainage levels actively to retain stormwater in response to changing weather conditions and rainfall events, particularly during the crop growing and harvest seasons. While some stormwater retention occurs in the restoration and waterfowl management areas from simply installing and using the restoration infrastructure and controlling excessive drainage, setting lower drainage levels is contrary to the refuge purposes and goals and would increase wildfire risks. Maximizing stormwater retention benefits would require setting lower drainage levels well in advance of storms and adding boards to risers to catch as much rainwater as possible during or after a storm. Reducing the drainage level by removing boards from risers to drain water from the refuge to create stormwater storage capacity when hurricanes or other storms are forecasted for the area also has several inherent drawbacks. These practices, if implemented, would allow peat soils to artificially dry out, resulting in a loss of wetland functions and values and increasing the risk for and impacts of catastrophic wildfire. Consequently, the Service considered an active drainage level management alternative and determined it to be infeasible to carry forward because it is not consistent with satisfying the purpose and need for which the EA is being prepared.

Although the Service has determined that active drainage management to increase stormwater retention capacity is infeasible to implement as an alternative in this EA, we are exploring and implementing mechanisms to support more favorable off-refuge conditions while protecting restored pocosins. The Service is amenable to utilizing refuge infrastructure to facilitate beneficial off-refuge outcomes while also meeting the refuge purpose and goals. For example, input from stakeholders and adjacent landowners prompted a demonstration project to reconfigure water staging at the on-refuge weirs to enhance temporary on-refuge storage of water from large rain events and reduce peak flow rates off-refuge. This project is intended to benefit neighboring farmlands by allowing downstream canals to drain before the bulk of refuge outflow during storms arrives under certain rain events.

ALTERNATIVE A – CURRENT MANAGEMENT (NO ACTION)

The No Action Alternative required by NEPA serves as a baseline to which any other alternatives are compared. Under the No Action Alternative, the status quo (i.e., no change from current management of the refuge) would continue. The Service would protect, maintain, restore, and enhance 110,106 acres of refuge lands using water management capability for resident wildlife, waterfowl, migratory nongame birds, and threatened and endangered species. The refuge staff would implement water management with little baseline monitoring information except for limited data collection at previously established water monitoring wells and measurements taken at the water control structures regularly. The staff would direct all water management actions toward achieving the refuge’s primary purposes: to protect organic soils and pocosin wetlands from wildfires; to protect the watershed of nearby lakes, rivers, and estuaries; to protect and restore wetlands; to protect and enhance habitat for threatened and endangered species; to protect and enhance production habitat for wood ducks, songbirds, and winter habitat for other waterfowl; and to provide opportunities for wildlife-dependent public use.

The role of Alternative A in terms of its ability to meet each of the four overarching conservation goals is detailed below.

***Goal 1*. Manage Water Resources to Provide Optimal Wintering Waterfowl Habitat**

Under this alternative, the refuge would continue to manage 1,250 acres of cropland through cooperative farming agreements with local farmers, to manage water on 281 acres of moist soil impoundments, and to manage water to provide seasonally flooded forested wetland habitat. The result would continue to be 250 acres of standing corn and 200 acres of winter wheat for wintering waterfowl in the managed cropland units. The refuge would continue to manage drainage to promote crop production in agricultural fields and native plants in moist soil impoundments and impounded forested wetlands during the growing season. Following the growing season, the refuge would also continue to shallowly flood impoundments to make the crops and plants available to wintering waterfowl. The refuge would maintain a drainage level for Pungo Lake that attempts to maximize roosting and loafing habitat and sanctuary for tundra swans, Canada geese, snow geese, and many species of duck. The refuge would continue to conduct vegetation surveys and waterfowl surveys annually.

***Goal 2*. Restore, Manage, Maintain and Protect Hydrologically Altered Peatlands**

The goal of water (drainage) management in the highly hydrologically altered peatland areas of the refuge is to reverse, to the extent possible without causing negative impacts to adjacent lands, excessive drying of the peat soil via the ditch system and to reestablish pocosin wetland hydrologic characteristics and vegetation. This is accomplished by raising the range of water levels that occur in the peat soil and allowing them to naturally fluctuate like those seen in unaltered pocosin wetlands. The refuge manages for rewetted soil conditions over as much of a Water Management Unit (WMU) as possible, recognizing that these WMUs are often on the slope of a peat dome and that some of the lower elevation portions may experience more frequent inundation while the upper ends may experience suboptimal soil moisture conditions. Under this alternative, drainage settings in risers would continue to be modified adaptively by refuge staff based on professional observation and judgement, informed by 1) collecting water level data at the riser and evaluating its response to rainfall and other factors and 2) analysis of other research and monitoring data collected in recent years. The refuge would continue to protect restored peatlands from further ditching or draining.

***Goal 3*. Maintain and Protect Minimally Hydrologically Altered Peatlands**

Management in this habitat focuses on preventing further alterations, detecting and responding to invasive species presence early, and researching various aspects of minimally hydrologically altered peatlands. Under this alternative, the refuge would continue to protect these areas from any further ditching or draining while, to the extent practicable, maintaining most of the current roads for access. The refuge would also treat invasive species in natural waterways to protect minimally altered peatlands from infestation.

***Goal 4*. Enhance Fire Management Capabilities**

Under this alternative, the refuge would continue to use any available water to contain or extinguish a wildfire at the smallest acreage possible and to adapt water management strategies to prevent all or most ground fire during burning operations.

Specific strategies for accomplishing the goals under Alternative A are described in greater detail in Chapter IV, Water Management Direction and Implementation of the Draft Water Management Plan. Strategies specific to Alternative A are included under each objective with the heading “The Refuge will continue to.”

ALTERNATIVE B – EXPANDED ADAPTIVE MANAGEMENT FRAMEWORK

Under the proposed action, the refuge would increase the amount of habitat available to wintering waterfowl and expand water management capability in the Pungo Unit habitats. The refuge also would use more comprehensive monitoring data to guide drainage level management, evaluate the potential for additional RAs, explore mechanisms to improve drainage conditions in low lying portions of the refuge (RA 3), and assess floodplain connectivity to enhance intact peatlands.

***Goal 1*. Manage Water Resources to Provide Optimal Wintering Waterfowl Habitat**

Under the proposed alternative, the refuge would increase the amount of grain (corn), the acreage of moist soil impoundments, and the acreage of forested wetland impoundments available to wintering waterfowl by adding acres through land acquisition along with cooperative farming, switching to contract or force account farming on existing refuge lands, and constructing new impoundments. The refuge would expand water management capability in existing impoundments. If feasible, the refuge would install a well and pump system on Pungo Lake that could refill the lake following a partial lake water drawdown during the growing season. Under this alternative, the refuge would work with stakeholders with an interest in New Lake to develop and execute projects to increase the artificial drainage capacity of the lake with the objective of creating the ability to drain water more quickly following storms and thereby allow higher drainage levels to be set without significantly impacting agricultural and hunting lands adjacent to the lake. Additionally, the refuge would develop innovative, web-based tools for engagement with stakeholders and for education purposes and expand the monitoring network by establishing new water monitoring sites.

***Goal 2*. Restore, Manage, Maintain and Protect Hydrologically Altered Peatlands**

Under the proposed alternative, the refuge would install wells at strategic locations to monitor groundwater levels in “reference” pocosins that are areas with naturally functioning pocosin hydrology. This data would then be used to adjust drainage levels as needed to mimic natural hydrologic conditions in the WMUs as closely as possible on as much of the WMU area as possible. The refuge would shift towards using more comprehensive monitoring data to guide drainage level management. Achieving naturally fluctuating wetland hydrology conditions will foster the growth of native plant species, such as Atlantic white-cedar and bald cypress, which in turn will benefit native fauna. The refuge would also evaluate, and implement as appropriate, projects that restore all or part of altered pocosins without negatively impacting adjacent drained private lands. The higher average river levels controlling conditions at specific locations necessitate a change in water management approach from one of rewetting previously drained soils to one of facilitating a water drainage off the land to area rivers. The refuge would develop and implement plans for encouraging the drainage of water and removing impediments to flow in these locations. Under this alternative, the refuge would evaluate opportunities to establish new plantings of Atlantic white-cedar and bald cypress in appropriate locations; expand the monitoring network by establishing new ground and surface water monitoring sites; and periodically conduct vegetation surveys, aerial surveys to detect red-cockaded woodpecker nest cavities, and bird surveys.

***Goal 3*. Maintain and Protect Minimally Hydrologically Altered Peatlands**

In addition to the management strategies under Alternative A, under the proposed alternative, the refuge would expand water level monitoring in intact and minimally altered pocosins and assess the potential to apply these data to inform management of restored pocosin areas. The refuge would evaluate and implement, as feasible, resiliency measures and infrastructure to prevent loss of intact pocosins, particularly in low elevation areas near the Alligator and Scuppernong Rivers. Under this alternative, the refuge would expand the monitoring network by establishing new ground and surface water monitoring sites and periodically conduct vegetation surveys, aerial surveys to detect red-cockaded woodpecker nest cavities, and bird surveys.

***Goal 4*. Enhance Fire Management Capabilities**

In addition to the management activities described under Alternative A, under the proposed alternative, the refuge would expand soil moisture, estimated smoldering potential, and water level monitoring and expand research on habitat response to wildfire. The refuge would also explore and assess opportunities to increase drainage settings in order to temporarily retain extra moisture from passing storms to facilitate appropriate conditions for resuming prescribed burning operations.

Specific strategies for accomplishing the goals under Alternative B are described in greater detail in Chapter IV, Water Management Direction and Implementation of the Draft Water Management Plan. Strategies specific to Alternative B are included under each objective with the heading “In addition, under this plan the refuge will.”

SUMMARY OF ALTERNATIVES

Similarities and distinctions between Alternatives in this EA are presented in Table B-1.

Table B-1. A comparison of evaluated alternatives.

Goal 1. Manage Water Resources to Provide Optimal Wintering Waterfowl Habitat
Provide wintering waterfowl habitat to support not only historic numbers of tundra swans, geese, and ducks but also additional numbers of birds expected due to the loss of habitat on the Albemarle-Pamlico Peninsula from past and future sea level rise and other climate change factors.

AREA	Alternative A	Alternative B
PUNGO UNIT	• Manage drainage on 1,250 acres of cropland (250 acres corn and 150 acres winter wheat) • Manage water on 298 acres of moist soil units with 70 percent coverage of forage; pumps/wells for fall water supply • Manage water to provide 347 acres seasonally flooded forested wetlands • Maintain a drainage level for the lake that corresponds to a water level that fills the lake and maximizes roosting and loafing habitat/sanctuary • Periodically monitor water and board elevations at water control structures	• Manage drainage on new agricultural lands to increase standing corn by 150 acres and winter wheat browse by 150 acres • Expand moist soil acreage to 593 acres and expand pumps/wells • Explore options and execute projects to enhance water management capability • Expand forested wetlands to 1,500 acres; plus install infrastructure • If feasible, install and operate a well and pump system that could refill Pungo Lake following a partial lake water drawdown during the growing season • Develop innovative, web-based tools for engagement with stakeholders and for education purposes. • Expand the monitoring network by establishing new water monitoring sites
NEW LAKE	• Engage stakeholders in discussions about lake water management and work towards consensus regarding a drainage level setting in the Mooney Canal riser that provides as much waterfowl roosting and resting habitat and sanctuary as possible given all stakeholder interests	• Work with other stakeholders at New Lake to develop and execute projects to increase the artificial drainage capacity of the lake with the objective of creating the ability to drain water more quickly following storms and thereby allow higher drainage levels to be set without significantly impacting agricultural and hunting lands adjacent to the lake • Develop innovative, web-based tools for engagement with stakeholders and for education purposes. • Expand the monitoring network by establishing new water monitoring sites.

Goal 2. Restore, Manage, Maintain and Protect Hydrologically Altered Peatlands
Restore, or mimic, the natural hydrology of highly altered areas of pocosin wetlands/peatlands and rewet the peat soils to promote natural pocosin vegetation and conditions, enhance wildlife habitat, and prevent the loss of peat via oxidation and wildfire.

AREA	Alternative A	Alternative B
RESTORATION AREA 1	• Use infrastructure to raise drainage levels to reach the objective target using median-elevation approach • Improve DeHoog Road/Dike	• Use more comprehensive monitoring data to guide drainage level management.

AREA	Alternative A	Alternative B
RESTORATION AREA 2	• Use infrastructure to raise drainage levels to reach the objective target using median-elevation approach • Drain water from RA2 into Western Canal and continue to use infrastructure in Western Canal to encourage overland sheet flow or drainage water to the Northwest & Southwest Forks	• Use more comprehensive monitoring data to guide drainage level management • In Water Management Units A and B: ○ Remove the plugs in the eastward draining canals on the east side of Icabod and J Canal Dikes that are no longer needed with the revised restoration design for the units ○ Remove the culverts through Furbee, Huber, Icabod, and J Canal Dikes that are no longer needed with the revised restoration design for the units ○ Add or remove and use other infrastructure in the units as necessary to achieve drainage level targets ○ Encourage water draining from the units to spread out as much as possible while draining through WMU C using the riser in Harvester Canal just east of J Canal
RESTORATION AREA 3	• Restore natural drainage to the Northwest Fork of the Alligator River to the extent possible • Maintain the culverts in Middle Dike, west of the Northwest Fork • Periodically monitor water and board elevations at water control structures • Monitor ground and surface water at existing monitoring sites in restored peatlands to ensure restoration targets are being met	• Close both existing breaches in the Parrisher Dike and dig a single breach, 100 to 150 feet wide in the dike • Manage the riser on the west end of Parrisher Canal to encourage flow through the breach and for "emergency" drainage flow into Nodwell Canal, if needed, during periods of high rainfall • Develop and implement plans for: ○ Removing the remnants of the Middle Road bridge over the Northwest Fork ○ Removing all or portions of the Middle Road Dike for up to 2,000 feet on either side of the Northwest Fork, to increase floodplain connectivity ○ Snagging and clearing, and invasive plant control, in the Northwest Fork downstream of the Middle Canal intersection ○ Replacing the culverts in Middle Canal under Nodwell Road with a bridge or other infrastructure less likely to be repeatedly blocked by beaver activity • Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise • Develop web based information for engagement with stakeholders and education purposes
RESTORATION AREA 4	• Use infrastructure to raise drainage levels to reach the objective target using median-elevation approach	• Use more comprehensive monitoring data to guide drainage level management • Evaluate, and implement as appropriate, projects that restore all or part of altered pocosins without negatively impacting adjacent drained private lands

AREA	Alternative A	Alternative B
RESTORATION AREA 5	• Use infrastructure to raise drainage levels to reach the objective target using median-elevation approach	• Use more comprehensive monitoring data to guide drainage level management • Construct the infrastructure needed to restore peatland hydrology on the Hyde Park and South Pungo Blocks • Construct a dike on the northeast side of the Triangle Water Management Unit to enhance restoration effectiveness
ALL RESTORATION AREAS	• Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise • Develop innovative, web-based tools for engagement with stakeholders and for education purposes • Periodically monitor water and board elevations at water control structures • Monitor ground and surface water at existing monitoring sites in restored peatlands to ensure restoration targets are being met • Protect hydrologically altered peatlands that have been or may be restored from any further ditching/draining • Maintain current roads for access to the extent practicable	• Evaluate opportunities to establish new plantings of Atlantic white-cedar and bald cypress in appropriate locations on an ongoing basis • Expand the monitoring network by establishing new ground and surface water monitoring sites in the restoration areas • Periodically conduct vegetation surveys, including surveys to determine and monitor the acreage of Atlantic white-cedar in restored areas • Periodically conduct aerial surveys to detect red-cockaded woodpecker nest cavities • Periodically conduct bird surveys (e.g., breeding bird point counts or indices)

Goal 3. Maintain and Protect Minimally Hydrologically Altered Peatlands
Protect peatlands with relatively intact natural, minimally altered hydrology from any further alteration; enhance natural hydrologic conditions where practicable without eliminating all existing access for management and other purposes.

AREA	Alternative A	Alternative B
THROUGHOUT REFUGE	• Protect approximately 58,500 acres from ditching/draining • Maintain all current access to intact peatland areas • Control invasive species in natural waterways to protect minimally altered peatlands from infestation • Engage, coordinate with, and respond to stakeholders and adjacent landowners on a case-by-case basis as issues arise. • Develop web based information for engagement with stakeholders and education purposes	• Evaluate the potential for conserving additional intact peatlands to serve as corridors for wildlife use • Expand monitoring of flora/fauna associated with the intact peatland community • Expand water level monitoring in intact and minimally altered pocosins and assess the potential to apply these data to inform management of restored pocosin areas • Evaluate and implement, as feasible, resiliency measures and infrastructure to prevent loss of intact pocosins, particularly in low elevation areas near the Alligator and Scuppernong Rivers • Periodically conduct vegetation surveys, including surveys to determine and monitor the acreage of Atlantic white-cedar in minimally altered areas. • Periodically conduct aerial surveys to detect red-cockaded woodpecker nest cavities. • Periodically conduct bird surveys (e.g., breeding bird point counts or indices) • Explore, evaluate, and execute projects that increase floodplain connectivity where practicable

AREA	Alternative A	Alternative B
Goal 4. *Enhance Fire Management Capabilities*. Minimize and control wildfires as quickly as possible and facilitate prescribed burning for hazardous fuels reduction and wildlife habitat management using any and all water management capabilities.		
AREA	**Alternative A**	**Alternative B**
THROUGHOUT REFUGE	• Retain and use available water to contain or extinguish wildfire at the smallest acreage possible • Facilitate gravity flow and/or active pumping of water to meet wildfire suppression needs. • Conduct soil moisture, Estimated Smoldering Potential, and water level monitoring refuge-wide • Evaluate the relationship between soil and water level conditions refuge-wide • Measure and document fire related soil loss • Maintain all fire suppression and monitoring equipment to facilitate rapid response and containment • Evaluate habitat response to wildfire • Make water available by releasing water from a rewetted WMU to allow for safer prescribed fire on the landscape that prevents all or most ground fire during burning operations • Conduct fuel reduction activities, such as prescribed burning and fire break maintenance • Develop innovative, web-based tools for engagement with stakeholders and for education purposes • Coordinate with state and federal wildfire response agencies • Provide proactive communication with and be responsive to adjacent landowners regarding wildfire response and safety • Develop web-based information for engagement with stakeholders and the public	• Expand soil moisture, Estimated Smoldering Potential, and water level monitoring • Expand research on habitat response to wildfire • Explore and assess opportunities to increase drainage settings in order to temporarily retain extra moisture from passing storms to facilitate appropriate conditions for resuming prescribed burning operations

Compared to the No Action Alternative, the Service believes that implementing Alternative B (Proposed Action) would provide a more focused, collaborative, comprehensive, landscape-level approach to water management at Pocosin Lakes NWR. It represents a moderate increase in the level of water management of the refuge, particularly in monitoring capability to support adaptive management needs.

IV. ENVIRONMENTAL CONSEQUENCES

This section analyzes the environmental consequences of the action on each affected resource, including direct and indirect effects. This EA only includes the written analyses of the environmental consequences on a resource when the impacts on that resource could be more than negligible and therefore considered an “affected resource” or are otherwise considered important as related to the proposed action. Any resources that will not be more than negligibly impacted by the action and have been identified as not otherwise important as related to the proposed action have been dismissed from further analyses.

The following analysis provides impacts of the proposed action and any alternatives on resources described in the Affected Environment section, including direct and indirect effects. Direct effects are those which are caused by the action and occur at the same time and place. Indirect effects are those which are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Cumulative impacts are effects on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative effects are discussed in a separate section following the analysis of Alternatives A and B.

Potential effects or impacts, either positive (beneficial) or negative (adverse), to resources resulting from the implementation of the two alternatives were identified and placed into one of the listed categories, where possible.

- None - no effects expected
- Minimal - impacts are not expected to be measurable, or are too small to cause any discernible degradation to the environment
- Minor - impacts would be measurable, but not substantial, because the impacted system is capable of absorbing the change
- Moderate - effects would be measurable, but could be reduced through appropriate mitigation
- Major - impacts would be measurable and individually or cumulatively significant; an Environmental Impact Statement would be required to analyze these impacts

EFFECTS COMMON TO BOTH ALTERNATIVES

ENVIRONMENTAL JUSTICE

Executive Order 12898 " Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" requires that federal agencies consider as part of their action, any disproportionately high and adverse human health or environmental effects to minority and low income populations. Agencies are required to ensure that these potential effects are identified and addressed. The Service has not identified any potential high and adverse environmental or human health impacts from this proposed action or either of the alternatives. The Service has identified no minority or low income communities within the impact area. Minority or low income communities will not be disproportionately affected by any impacts from this proposed action or any of the alternatives.

EFFECTS ON THE PHYSICAL ENVIRONMENT

This section discusses potential effects to physical resources (e.g., topography, soils, water resources, etc.) common to both alternatives.

Geology and Topography

Beneficial

Both alternatives would have minimal positive impacts with regard to topography and geology through peat formation processes, which occur over geologic time. Therefore, there would be little to no difference in the benefits obtained between the two alternatives.

Adverse

Neither alternative is anticipated to have adverse impacts on geology and topography.

Air Quality

Beneficial

Both alternatives would have moderate, long-term beneficial impacts on air quality through increased carbon sequestration and by reducing the risk of catastrophic wildfires, which have a negative effect on air quality.

Adverse

Both alternatives would involve activities that could have localized, short-term impacts on air quality including emissions from mechanical equipment used for maintaining ditches and canals, replacing water control structures, conducting cooperative farming activities, and maintaining other infrastructure. Regardless of the alternative selected, we would implement refuge management activities in compliance with the Clean Air Act, and none of the alternatives would violate U.S. Environmental Protection Agency standards for criteria air pollutants. As necessary, the Service would consult with North Carolina Department of Environmental Quality for guidance.

EFFECTS ON THE BIOLOGICAL ENVIRONMENT

This section discusses potential effects on biological resources (e.g., habitats, wildlife, and federal and state listed species) common to both alternatives.

Threatened and Endangered Species and Other Special Status Species

Neither of the alternatives would impact threatened and endangered species and other special status species.

EFFECTS ON THE SOCIOECONOMIC ENVIRONMENT

This section discusses potential effects to socioeconomic resources common to both alternatives.

Local and Regional Economies

Neither alternative would impact local and regional economies.

Sector of the Economy

Neither alternative would impact growth of the area, unemployment rates, or poverty rates.

EFFECTS ON CULTURAL RESOURCES

Neither alternative would affect cultural resources on the refuge.

ALTERNATIVE A: NO ACTION ALTERNATIVE

EFFECTS ON THE PHYSICAL ENVIRONMENT
This section discusses potential effects to physical resources (e.g., topography, soils, water resources, etc.) under the No Action alternative.

Soils & Hydrology

Beneficial

Under this alternative, moderate long-term effects are expected on soil formation processes on refuge lands by rewetting soils and allowing for continued accrual of soil. Beneficial effects are also expected on hydrology as more natural movement patterns are restored. Peat soils in restored areas will retain moisture longer than peat soils in an open drainage system, thereby restoring the pocosin's wetland hydrologic characteristics.

Adverse

Minor disturbances to surface soils and topography would occur to support maintenance operations and management of infrastructure used to set drainage levels. Adverse impacts are anticipated to be minimal.

Groundwater

Beneficial

Under this alternative, units within the peatland restoration areas will be managed by promoting a seasonal water table near the ground surface in order to maintain soil conditions necessary for peat accrual. Doing so attempts to mimic natural, pre-ditching hydrologic conditions, thereby reducing peatland drainage and making the system less susceptible to fire. This alternative would have positive benefits by protecting groundwater recharge areas, preventing runoff, retaining sediment, and minimizing non-point source pollution. Beneficial impacts from this alternative would be moderate.

Adverse

This alternative is not anticipated to have adverse impacts on groundwater.

Fire

Beneficial

Fires are a natural part of pocosins, which are characterized by fire-dependent vegetative communities. Alternative A will have minor, long-term impacts on the fire regime on the refuge. Appropriate water management allows prescribed fire to be utilized with less risk of ground fire to occur, enabling the above ground vegetation to burn, which is a necessary component of pocosin ecosystems (USFWS 1990). Saturation of the soils under restored hydrologic conditions reduces the potential for peat ground fires to burn intensely. Wildfire suppression capabilities will also be enhanced by maintaining firebreaks and infrastructure to support water movement during a wildfire.

Adverse

This alternative is not anticipated to have adverse impacts on fire.

Sea Level Rise, Resiliency, and Adaptation

Beneficial

Restoring hydrology in the peatlands stops the loss of peat soils while allowing soil generation and biomass accumulation to resume. Over time, this results in increasing elevation of previously drained pocosins. By preventing incremental (via oxidation) and catastrophic (via burning) soil loss while generating a deeper soil layer, hydrology restoration in drained peatlands, like those on the Albemarle-Pamlico peninsula, provides an adaptive mechanism to sea level rise. The re-accumulation of soil also helps mitigate the impacts of flooding and storm events. By rewetting altered peatlands and maintaining intact wetlands, freshwater head is retained providing a protective against potential impacts of rising river levels and associated saltwater intrusion.

Adverse

This alternative is not anticipated to have adverse impacts on sea level rise, habitat resiliency, or adaptation.

Extreme Weather Events

Beneficial

Some indirect benefits on the impacts of extreme weather events from current water management are anticipated, including a reduction in wildfire frequency and intensity during below normal rainfall and some stormwater retention capacity during above normal rainfall.

Adverse

Under Alternative A, water management capability has been added to the refuge resulting in some stormwater retention in comparison to the free drainage system present prior to restoration efforts; however, the capacity of the drainage system is limited and often exceeded during big storm events. As such, Alternative A is not anticipated to have an additive effect on the impacts of extreme weather events.

Water Quality

Beneficial

Restoration of peat wetlands is known to have a direct improvement on water quality in the tributaries, rivers, and estuaries that receive waters from the pocosins. Hydrated peat soils sequester significant quantities of carbon and nitrogen and trace amounts of mercury and other elements; therefore, refuge efforts to restore the wetlands has demonstrable benefits to water quality. The relatively low level of soil disturbance under this alternative would have a minor beneficial impact on the water quality in individual streams and wetlands. This alternative would also have minimal to minor impacts from the protection of groundwater recharge areas, reduction of stormwater runoff, sediment retention, and minimization of non-point source pollution.

Adverse

Minimal impacts to water quality under Alternative A would result from sedimentation resulting from activities to support maintenance operations and management of infrastructure used to set drainage levels.

EFFECTS ON THE BIOLOGICAL ENVIRONMENT

This section discusses potential effects on biological resources (e.g., habitats, wildlife, and federal and state listed species) under the No Action alternative.

Wildlife

Beneficial

This alternative will have minor to moderate impacts on wildlife on the refuge. Shorebirds and marsh and wading birds, such as the yellow rail, king rail, American bittern and least bittern will benefit from water management providing canal banks, riparian areas, marshes, and perimeters of lakes as habitat. Water management that provides open water, moist soil, farmlands, flooded wetland habitats will benefit wintering migratory waterfowl and breeding wood ducks, hooded mergansers, American black ducks, and mallards by providing forage and sanctuary areas protected from excessive human-caused disturbances. Restoring altered pocosins and protecting minimally disturbed pocosins will provide habitat for key neotropical and other land bird species of management concern. A particular benefit to Neotropical migrants and other land bird species is the inaccessibility by humans to many areas of the refuge. For those species that are sensitive to human activity such as the red-cockaded woodpecker and the rusty blackbird, this isolation of habitat is critical.

Adverse

Minimal impacts to wildlife are anticipated under this alternative from disturbance resulting from management activities.

Vegetation

Beneficial

Vegetative communities in pocosins rely on peat soils and appropriate hydrology conditions. It is anticipated that vegetative communities on the refuge will return to more natural species presence and densities over time in areas where rewetting has occurred. This will result in a minor beneficial impact on vegetation on the refuge.

Adverse

Minimal impacts to vegetation are anticipated under this alternative from disturbance resulting from management activities.

Invasive Species

Beneficial

Given the Service's policy that most exotic species are undesirable, there would be no positive consequences under this alternative.

Adverse

Many exotic species often thrive in habitats that have been disturbed (Byers 2002). By minimizing disturbance in restored pocosins and minimally altered pocosins, the chance of spreading invasive species will be reduced. Invasive species in managed waterfowl habitats will be detected and treated early to minimize and reduce impacts.

ALTERNATIVE B: PROPOSED ACTION

EFFECTS ON THE PHYSICAL ENVIRONMENT

This section discusses potential effects to physical resources (e.g., topography, soils, water resources, etc.) under Alternative B.

Soils & Hydrology

Beneficial

Under this alternative, moderate long-term effects are expected on soil formation processes on refuge lands by saturating the soils and allowing for continued accrual of soil. In addition to the beneficial impacts described under Alternative A, this alternative is anticipated to have expanded benefits to soil and hydrology through expanded water management capability and additional pocosin restoration efforts.

Adverse

Some disturbances to surface soils and topography would occur to support maintenance operations, installation of new infrastructure, and management of existing infrastructure used to set drainage levels. Adverse impacts are anticipated to be minimal to minor.

Groundwater

Beneficial

In addition to the beneficial impacts described under Alternative A, this alternative is anticipated to have expanded benefits to groundwater through expanded water management capability and additional pocosin restoration efforts. Beneficial impacts from this alternative would be moderate.

Adverse

This alternative is not anticipated to have adverse impacts on groundwater.

Fire

Beneficial

Alternative B would have moderate, long-term impacts on the fire regime on the refuge. Expanding water management capability and restoring hydrology in additional areas would enhance wildfire suppression efforts and further enable prescribed fire to be utilized by reducing the risk and intensity of peat ground fires.

Adverse

This alternative is not anticipated to have adverse impacts on fire.

Sea Level Rise, Resiliency, and Adaptation

Beneficial

In addition to the beneficial impacts described under Alternative A, this alternative is anticipated to have expanded benefits through expanded water management capability and additional pocosin restoration efforts.

Adverse

This alternative is not anticipated to have adverse impacts on sea level rise, resiliency, and adaptation.

Extreme Weather Events

Beneficial

In addition to the benefits described under Alternative A, supportive and complementary strategies under this alternative could provide beneficial impacts through regional water management studies and cooperation with landowners on mutually beneficial efforts. While Alternative B will not have direct beneficial impacts on extreme weather events, efforts to broaden the understanding of water movement on the landscape, identify barriers to water movement or other issues across the landscape, and identify opportunities for incentive programs and other possible solutions for addressing identified barriers and issues could make significant contributions to lessening the impacts of extreme weather events. However, flood and wildfire events can and will occur in this system when rainfall amounts are excessively high or excessively low, regardless of any management actions taken, or not taken, on the refuge.

Adverse

The impacts of extreme weather events under Alternative B are anticipated to be similar to the impacts under Alternative A.

Water Quality

Beneficial

This alternative is not anticipated to affect the water quality from sources off the refuge; however, refuge efforts to restore the wetlands has demonstrable benefits to water quality. This alternative would have a moderate beneficial impact on the water quality in individual streams and wetlands by expanding the protection of groundwater recharge areas, reduction of stormwater runoff, sediment retention, and minimization of non-point source pollution.

Adverse

The impacts to water quality under Alternative B are anticipated to be similar to the impacts under Alternative A.

EFFECTS ON THE BIOLOGICAL ENVIRONMENT

This section discusses potential effects on biological resources (e.g., habitats, wildlife, and federal and state listed species) under Alternative B.

Wildlife

Beneficial

This alternative will have moderate impacts on wildlife on the refuge. Shorebirds and marsh and wading birds, such as the yellow rail, king rail, American bittern and least bittern will benefit from expanded water management capability providing canal banks, riparian areas, marshes, and perimeters of lakes as habitat. Alternative B would have moderate, long-term beneficial impacts to wintering waterfowl by improving existing and increasing the amount and quality of resting and foraging habitat. Restoring additional altered pocosins will increase available habitat for key neotropical and other land bird species of management concern.

Adverse

Minimal impacts to wildlife are anticipated under this alternative from disturbance resulting from management activities.

Vegetation

Beneficial

Alternative B will have a moderate beneficial impact on the vegetative communities on the refuge. Under Alternative B, increased vegetation surveys will provide additional information to enhance adaptive management techniques. Atlantic white-cedar and bald cypress plantings will restore native vegetative communities. Under Alternative B, data collected through established reference sites could result in changes to drainage level settings, thereby causing an individual management unit to be rewetted on a greater area of the unit or on a smaller area of the unit. This would have a negligible to moderate indirect impact on vegetation by causing a shift in vegetation present in that unit. Overall, this would create a mosaic of habitat types available across the refuge.

Adverse

Minimal impacts to vegetation are anticipated under this alternative from disturbance resulting from management activities.

Invasive Species

Beneficial

Given the Service's policy that most exotic species are undesirable, there would be no positive consequences under this alternative.

Adverse

In addition to the impacts described under Alternative A, under Alternative B there would be expanded protection of restored pocosins and minimally altered pocosins, thereby further minimizing the risk of the spread of invasive species. Early detection and rapid response efforts would also increase under this alternative.

CUMULATIVE EFFECTS

According to the Council on Environmental Quality NEPA implementing regulations in 40 CFR 1508.7, "cumulative impact" is the impact on the environment which results from the incremental impact of the Proposed Action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. For the purposes of this EA, the cumulative effects from the Proposed Alternative on each resource are discussed in terms of the net positive or negative impact, if any. The implementation of either of the two alternatives described in this document includes actions relating to fish and wildlife habitat management and water management. These actions would have both direct and indirect effects; however, the cumulative effects of these actions over the 15-year planning period are not expected to be significant.

PHYSICAL RESOURCES

Some minimal and minor impacts on physical resources are expected, under the Proposed Alternative, but none of these are anticipated to be cumulatively significant. Cumulative effects on individual physical resource categories are further discussed below.

Topography and Geology

Under the Proposed Action, no adverse cumulative effects are predicted to this resource.

Soils & Hydrology

The Proposed Action is expected to have net beneficial effects on soils and hydrology by restoring natural processes both in the movement of water and in the accretion of soils.

Air Quality

The Proposed Action is not expected to have significant cumulative adverse impacts on air quality, locally or regionally.

Water Quality

Overall, the Proposed Action alternative is predicted to have a net positive cumulative impact to water quality, as it would restore wetlands and natural hydrology.

Groundwater

Overall, the Proposed Action alternative is predicted to have a net positive cumulative impact to groundwater, as it would restore wetlands and natural hydrology.

Fire

Overall, the Proposed Action alternative is predicted to have a net positive cumulative impact to fire by enabling the expanded use of prescribed fire while reducing the risk of catastrophic wildfire and enhancing wildfire suppression efforts.

Extreme Weather Events

Under the Proposed Action, no adverse cumulative effects are predicted to this resource.

BIOLOGICAL RESOURCES

Wildlife

Overall, the Proposed Action alternative is predicted to have a net positive cumulative impact to wildlife by providing additional habitat opportunities and by increasing the quality of existing habitats.

Vegetation

Overall, the Proposed Action alternative is predicted to have a net positive cumulative impact to vegetation through native species plantings and additional vegetation surveys.

SOCIOECONOMIC ENVIRONMENT

Under the Proposed Action, no adverse cumulative effects are predicted to this resource.

CULTURAL RESOURCES

Under the Proposed Action, no adverse cumulative effects are predicted to this resource.

UNAVOIDABLE ADVERSE EFFECTS

Unavoidable adverse effects are the effects of those actions that could cause significant harm to the human environment and that cannot be avoided, even with mitigation measures. There would be some minor, localized unavoidable adverse effects under all the alternatives. Under the Proposed Action alternative, there could be, for example, localized adverse effects of installing new water management structures. However, none of these effects rises to the level of significance. All would be mitigated, so there would be no significant unavoidable adverse impacts under the Proposed Action.

V. MONITORING

Implicit in the preferred alternative is expansion of the existing monitoring network on the refuge to develop a refuge-wide adaptive management monitoring framework. The purpose of the expanded monitoring network is to provide a more robust understanding of changes in conditions on the refuge in response to refuge water management actions and to establish a science based approach to setting drainage targets to mimic intact or hydrologically functional pocosin wetlands (in the altered peatlands and restoration areas). As resources allow, monitoring will include, but not be limited to, water level, soil moisture, and habitat metrics. In addition, to inform how refuge water management capability is affected by water levels at drainage outlets to the river systems, water level gauges can be installed. Data from these monitoring sites, while useful to inform water management decisions on refuge, may also provide ancillary benefits to other stakeholders.

VI. SUMMARY OF ANALYSIS

The purpose of this EA is to briefly provide sufficient evidence and analysis for determining whether to prepare an environmental impact statement or a Finding of No Significant Impact. The term “significantly” as used in NEPA requires consideration of both the context of the action and the intensity of effects. This section summarizes the findings and conclusions of the analyses above so that we may determine the likely significance of the effects.

Based on the nature of the proposal, the Proposed Action would not have any significant adverse effects on the quality of the human environment including public health and safety. Further, because the purpose of the proposal is to manage water resources to provide optimal wintering waterfowl habitat; restore, manage, maintain, and protect hydrologically altered peatlands; maintain and protect minimally hydrologically altered peatlands; and use water management capability to enhance fire management capabilities, the proposal is not expected to have any significant adverse effects on the area’s wetlands and floodplains, pursuant to Executive Orders 11990 and 11988.

The Proposed Action is not expected to result in significant cumulative impacts on the human environment since it alone, or in combination with other current and future activities in the vicinity, would not significantly change the larger current hydrological patterns of discharge, recreational use, economic activity or land-use. The Proposed Action would not establish a precedent for future actions with significant effects, nor would it represent a decision in principle about a future consideration. No cumulatively significant impacts on the environment would be anticipated. In addition, the proposal would not significantly affect any unique characteristic of the geographic area, such as historical or cultural resources, wild and scenic rivers, or ecologically critical areas. The proposal would not significantly affect any site listed in or eligible for listing in the National Register of Historic Places, nor would it cause loss or destruction of significant scientific, cultural, or historic resources. The area’s cultural resources would be protected under the regulations of the National

Historic Preservation Act of 1966, as amended, the Archaeological Resources Protection Act, and the Advisory Council on Historic Preservation (36 CFR 800). The NC State Historic Preservation Office would be contacted whenever any future management activities have the potential to affect cultural resource sites.

No measures would be taken that would lead to a violation of federal, state, or local laws imposed for the protection of the environment.

VII. LIST OF SOURCES, AGENCIES, AND PERSONS CONSULTED

This section describes how we engaged others in developing the Draft Water Management Plan and EA. It details our efforts to encourage the involvement of the public and partners, including other Federal and State agencies, county officials, non-governmental organizations, and user groups. It also identifies who contributed significantly to the content or writing of the plan.

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The Service hosted a technical workshop on pocosin ecology, restoration and water management on July 14, 2016, in Columbia, North Carolina, where 30 scientists and land managers with pocosin ecology expertise gathered to provide feedback on water management to promote healthy peatlands. The input during the workshop informed Draft Water Management Plan development. Organizations represented included: the Service, U.S. Geological Survey, Natural Resources Conservation Service, North Carolina State Parks, The Nature Conservancy, and scientists from North Carolina State University, Duke University, and East Carolina University.

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STATE COORDINATION

The Service solicited comments from State agencies during the public comment period. Refuge staff also met with staff from the North Carolina Wildlife Resources Commission (NCWRC) during a tour of the refuge in December 2017 focused on hydrology restoration efforts. Additionally, the Service has provided periodic updates to NCWRC leadership as well as keeping NCWRC staff informed of water management activities through their participation in the stakeholder meetings.

TRIBAL CONSULTATION

Pursuant to the NEPA, the National Historic Preservation Act, the Fish and Wildlife Service's Native American Policy, Secretarial Order 3206 (American Indian Tribal Rights, Federal-Trust Responsibilities, and the Endangered Species Act), and Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments), the Service sent letters requesting involvement from the United Keetoowah Band of Cherokee and the Tuscarora Nation of New York in the planning process for this water management plan. The Service did not receive a response and has not had additional communications with the Tribes.

PUBLIC OUTREACH

The Service solicited public input on the issues to be addressed by a water management plan during a public comment period in the summer of 2017. The Service hosted two open houses in July 2019 to provide opportunities for the public to inform the development of the plan. The Draft Water Management Plan and EA will be made available for public review and comment, which will include a public meeting opportunity.

VIII. Recommendation

The Service recommends Alternative B as the Proposed Action because it better serves the outlined purpose and need, stated goals and objectives, and vision and purposes of the refuge. Through the goals, objectives, and strategies described in Alternative B, the Service would be able to fully achieve refuge goals of providing habitat for wintering waterfowl, restoring unique pocosin wetlands, protecting minimally altered pocosins, and enhancing fire management capabilities.

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APPENDIX: LIST OF ACRONYMS

AP	Albemarle-Pamlico
CCP	Comprehensive Conservation Plan
EA	Environmental Assessment
LiDAR	Light Detection and Ranging
NEPA	National Environmental Policy Act
NCWRC	North Carolina Wildlife Resources Commission
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
RA	Restoration area
SCS	Soil Conservation Service
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WMP	Water Management Plan
WMU	Water management unit