Pocosin Lakes National Wildlife Refuge

Forest Habitat Management Plan

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POCOSIN LAKES NATIONAL WILDLIFE REFUGE

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II. ACKNOWLEDGMENTS

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II. Background

A. Description of Area.

Pocosin Lakes National Wildlife Refuge (PLNWR, or the Refuge) -- formed in 1990 by the combination of Pungo National Wildlife Refuge and land formerly owned by First Colony Farms (FCF) -- contains 19,540 acres in Washington County, 36,091 acres in Hyde County, and 56,369 acres in Tyrrell County. Approximate boundaries are Pungo Lake (west), Phelps Lake (northwest), Scuppernong River (north), Pungo River over to New Lake (south), and Alligator River (east). Surface elevations range from ~ 18 ft at the highest point south of Phelps Lake to ~ 2 ft or less around Northwest Fork and Alligator River (Soil Conservation Service 1994). Climatic data for the Refuge are given in other reports (Soil Conservation Service 1994, Jenkins 1999).

The Refuge is centrally located on the Albemarle-Pamilico peninsula, the site of the greatest pocosin acreage in the United States (Ingram and Otte 1981, Richardson et al. 1981). Ruffin (1839) described Washington County (and perhaps the entire peninsula) as "one immense swamp , except for narrow knolls of firm soil scattered throughout — islands of sand, or of clay, in a sea of black mire". Most land within the Refuge is pallustrine (system); scrub-shrub or forested wetland (sub-class), broad-leaved evergreen or needle-leaved evergreen (dominance type), seasonally flooded (moisture class) (Cowardin et al. 1995). Detailed classification of specific sites can be obtained from maps of the National Wetlands Inventory.

Enabling legislation for the Refuge was the Fish and Wildlife Act of 1956 (16 U.S.C. § 742f (b) (1). The Mission is "to provide optimum habitat for wintering waterfowl and other migratory birds and to restore and manage pocosin and other wetland types and their associated wildlife species". There are five primary goals:

l) Endangered species — to protect and enhance habitat for those species classified as endangered, threatened, or of special concern.

2) Wetland restoration — to protect and restore pocosin and other wetland types, and protect the watershed of nearby lakes, rivers and estuaries.

3) Wildlife managment — to maintain and manage migratory and resident wildlife populations at sustainable levels through law enforecement, hunting, fishing and wildlife surveys.

4) Habitat managment — to maintain adequate habitat types and diversity through management programs including fire, water manipulation, cooperative farming, land acquisition, and protection of organic soils.

5) Environmental education/wildlife recreation — to provide for wildlife-oriented interpretation, outdoor recreation, and environmental education through partnerships, lectures, tours, kiosks, and wildlife viewing areas.

A goal of this plan is to develop recommendations compatible with other Refuge plans (Fire, Hydrology, Wildlife) within the mission and goals of the Refuge. It is very general, allowing managers flexibility in decision making.

Most vegetation on PLNWR is tall pocosin, bay forest, or pond pine woodland (Weakeley and Schafale 1991). Pocosins and swamp forests have unique plant and animal communities, and represent some of the last truly remote and inaccessible wilderness in the state. The vision of this plan is not to convert pocosin communities or to plant the entire Refuge with trees. Large areas should remain intact, without active management, except to contain wildfire, and perhaps prescribe burn occasionally. Planting activities suggested in this plan are meant to create ‘islands’ of forests within a sea of pocosin vegetation -- a concept embracing the idea of biogeographic islands (MacArthur and Wilson 1967, Zeveloff 1985). The resulting increase in horizontal and vertical diversity should benefit wildlife, positively impact other Refuge objectives, and increase the importance of swamp tree species that are only nominally present on the Refuge, compared to earlier times.

Balancing goals and objectives often results in conflicts that require prioritization (Cooper 1981). Intensive forest management is not totally compatible with all Refuge goals and objectives, e.g., maximum water quality. The need to reduce fire hazzard, which requires prescribed burning, might also conflict to some extent with the necessity to exclude fire from stands of Atlantic white cedar (AWC), bald cypress, and oaks. These species are extremely sensitive to fire owing to their thin bark. On the other hand, pines are resistant to fire, and must be burned frequently to favor species such as red-cockaded woodpecker (RCW).

Forest management (burning, planting, thinning, etc.) is a valuable tool to realize various Refuge objectives; e.g., increase diversity, improve habitat for red-cockaded woodpecker or bears. The intent of this plan is to help realize those objectives, with minimal negative impact. The level of permissible activity (intensity, scope, frequency) is lower on organic soils, compared to mineral soils, owing to the more fragile nature of the soil. Where the benefits of modern forestry can be realized, e.g., genetically improved planting stock, without compromising other objectives, these practices should be used.

B. Geology and Peat.

The geology of the region and processes which formed the peat have been discussed by numerous authors (Daniel 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. Organic residues first accumulated in the lowest places; e.g, stream channels, and eventually covered slightly elevated ridges. The resulting landscape appears level and uniform on the surface, yet has considerable undulation and variation in depth of peat. Peat depth over mineral soil, though not evident at the surface, has a tremendous influence on the potential uses of the land. Formation of peat is an ongoing process in areas sufficiently wet to prevent oxidation of organic matter deposited by plants.

C. Anthropogenic Effects

Humans, through drainage, agriculture, logging, and fire have drastically changed the land surrounding and including PLNWR (Ashe 1894, Frost 1981, Hanlon 1972, Lilly 1981, McMullan 1984, Phillips et al. 1998). The two most important industries in the area have been forestry and agriculture. Drainage began before 1800, and considerable acreage in the Albemarle peninsula was converted to agriculture before 1900 (Ashe 1894, Lilly 1981, McMullan 1984). A law was passed in 1909 allowing the formation and financing of drainage districts (Pratt 1909). That law, combined with more efficient logging methods, led to rapid conversion of swamps to agriculture.

The volume of peat on the Albemarle peninsula is probably less than half the original amount owing to the effects of drainage, agriculture, and fire (Lilly 1995). There are descriptions of subsidence ≥3 ft as a consequence of drainage and agriculture (Ruffin 1861, Dolman and Buol 1967, 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 much greater (Dolman and Buol 1967, Lilly 1981). Some of the initial loss in volume is due to mechanical shrinkage (Dolman and Buol 1967, Skaggs et al. 1980). In addition, drainage makes pocosins drier, increasing the frequency and severity of fires. Last, 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).

A. Soils.

Long ago, people on the lower Coastal Plain recognized the association between tree cover and land quality. The best land for agriculture supported gum/cypress forests, and was underlain by clay, or sandy clay (Ashe 1894, Ruffin 1861). In the late 1800's, most good cypress land in the Pamilico Peninsula had already been drained and converted to agriculture (Ashe 1894). Smaller areas of peat (histosols) largely disappeared in response to drainage, fire, and tillage (Dolman and Buol 1967, Lilly 1981, Ruffin 1861). Although most land suitable for farming — mineral soils or shallow organic soils — is still in private ownership, there are inclusions of such soils within the Refuge, as well as additional acreage along the fringe of the Refuge.

Early writers also knew that many Atlantic white cedar (AWC) sites -- characterized by deep peat, or peat over sandy soil -- had little value for agriculture (Ruffin 1861; Pinchot and Ashe 1897), and should be retained for production of AWC. Roberts and Cruikshank (1940) made similar observations concerning pond pine pocosins. Hall and Maxwell (1911) agreed with earlier authors, but correctly speculated that much of the land would be drained for agriculture in the early 20th century. The experience of Norfolk & Southern Land Development Co., Atlantic Farms, and First Colony Farms (FCF) proved the veracity of the earlier observations about site quality.

Site index (i.e., height growth realized in a given number of years, usually 50) for most trees decreases with increasing depth of peat, and also is affected by the texture of the mineral soil (sand or clay) underlying the peat (Buol and Davey 1969, Otte 1981, Weakeley and Schafale 1991). It is important to be cognizant of peat depth across the Refuge to facilitate decisions about where to plant various tree species, or to determine the feasibility of using fire as a management tool.

Peat depth can vary considerably over a short distance, often as a consequence of fire. In other instances, there are ‘ridges’ or ‘islands’ of shallow organic or even mineral soil (Appendix maps). Such areas would likely have a higher site index for cypress, pines, and hardwoods owing to the thinner peat, and closer accessibility of underlying mineral soil to roots. In addition, peat depth often decreases near the boundaries between Refuge land and privately-owned farmland and forest land (see maps). Compared to soils with deep peat, these areas would be more productive for trees. On mineral soil, especially where underlain by clay, other species of bottomland hardwood, e.g., water oak, willow oak, swamp chestnut oak; should grow well.

A knowledge of soils is important in estimating productivity as well as suitability for various tree species. **Table 1** contains names, map symbols, acreage, and texture of all soils within PLNWR as taxonomically identified at the series category. Information was adapted from soil surveys for Hyde, Tyrrell, and Washington County (Tant et al. 1981, 1988; unpublished for Hyde Co.). Acreage values were obtained from Doug Newcomb (USFWS, Raleigh). **Table 2** contains the complete taxonomic classification for each soil series used to identify soil mapping units in the aforementioned county soil surveys.

Eleven of the 31 soil series identified in the Refuge have two or three map symbols, depending on the county (Table 1). Belhaven has four map symbols in the three counties, but only three occur within the Refuge. The opposite also occurs: one map symbol represents more than one soil series; e.g., ‘Pe’ represents Pettigrew soils in Washington Co; in Tyrrell County it represents Perquimans. These differences are the result of independence of individual county publications.

Descriptions also vary for certain named soils. For example, Belhaven soils (BnA, Hyde Co.) And Ba (Washington Co.) are described as having 26 inches of muck on the surface, whereas Ba (Tyrrell Co.) and BmA (Hyde Co.) have 40-43 inches -- a considerable difference that might affect reforestation recommendations. These differences have resulted from the chronologic taxonomic definition. Similarly, the Ponzer soil series is listed as having 42 inches of peat on the surface in Washington Co. (Po), 30 inches in Tyrrell Co., and 21 inches in Hyde Co. (PnA). Again, this is a large difference that might affect reforestation recommendations although 21-42 inches falls within the “terric” classification (organic soils of medium depth). For most other soils, consistency is much better among the three county soil surveys.

A master soils map (p. 62) for the Refuge shows major soil categories (based on depth of peat) by color code. This map has latitudes, longitudes, and boundaries for USGS quadrangle maps (7.5') that contain Refuge property. A separate soil map is included for each of the 14 quadrangles, showing soil types in more detail (p. 63-77).

Total area of the Refuge is 113,720 acres (land = 106,598 acres; water = 7,121 acres). The most common abundant soils identified in the Refuge are Pungo (70,684 acres, 66% of land) and Dorovan (3,676 acres; 3.4%) (≥ 51" to mineral soil), followed by soils with 16 to 51 inches of peat **:** Belhaven (16,351 acres, 15%), Scuppernong (5,973 acres, 5.6%), and Ponzer (3,129 acres, 2.9%). These five soils make up 94% of the terrestrial area of the Refuge. They are excessively wet, characterized by layers of peat over mineral soil, and are mostly unsuitable for agriculture (Skaggs et al. 1980, Lilly 1981). Forest productivity is lower on these soils, compared to mineral soils with ≤16 inches of organic soil. With appropriate drainage and bedding, productivity can be increased. However, the Refuge would not likely engage extensively in such practices on these deep organic soils owing to accelerated oxidation of peat and release of nitrogen and mercury -- a negative impact on water quality. Bedding or mounding on mineral soils would be acceptable.

Mineral soils **(Table 3)** have surface layers of peat ≤ 16 inches thick, and are consequently more productive for plant growth. Included in this group is Pettigrew (539 acres), Conaby (461 acres), Wasda (455 acres), and Roper (218 acres) -- totaling 1673 acres (1.6% of the land area of the Refuge). Most commercially valuable trees — pine, bottomland hardwoods, cypress, AWC — would grow well on these soils.

Mineral soils make up 4440 acres (4.2%) of the Refuge (Table 1). The largest is Hyde (1300 acres in the Frying Pan Unit, 1.2% of land area), followed by Weeksville (779 acres), Cape Fear (648), NewHolland (401), Portsmouth (381), Tomotley (286), Wahee (245), Perquimans (137), Augusta (65), Altavista (59), Argent (41), Roanoke (35), and Arapahoe (33). Six additional mineral soils total 26 acres (0.24%). Mineral soils are the most productive for crops as well as forest trees. All would grow loblolly pine, cypress, white cedar or pond pine, and those underlain by clayey subsoil would be good for bottomland hardwoods such as water oak, willow oak, and swamp white oak.

Where no forests exists, what tree species should be planted, and where? In most places, the current plant community bears little resemblance to earlier communities. Descriptions of various natural areas in the region give insight into the composition of earlier forests and pocosins, and soils where they grew (Frost et al. 1992, Legrand et al. 1992, Lynch and Peacock 1982a, 1982b, McDonald and Ash 1981). It is impossible, however, to predict vegetation type based solely on soil characteristics.

The term ‘pocosin’ includes several distinct plant communities (Richardson 1991, Weakely and Schafale 1991) whose characteristics and dynamics are still poorly understood (Weakely and Schafale 1991). In the great peatlands, fire frequency and depth of peat are two master factors determining the distribution and structure of many plant communities (Frost 1995). Other factors such as soil series, hydrology, fertility gradients, source and chemistry of water, and direction of water movement through the system are also important. Normally, no single factor is the sole determinant. For example, on the basis of peat depth alone, one might expect low pocosin vegetation where peat depth exceeds characteristic species as many pocosin types, and often have gradational boundaries to pocosins” (Weakley and Schafale 1991).

Table 3 contains recommendations for tree species to plant on the various soil series on the Refuge. Recommendations represent a compilation from soil surveys, descriptions of natural areas in the region, observations and descriptions in other literature, and research and observations by ecologists, field foresters, soil scientists and naturalists. Soil surveys suggest loblolly pine on virtually every soil type in the region. However, this is done on the

assumption that landowners are trying to maximize timber production, an effort that in most cases requires intensive site preparation (e.g., drainage, bedding, fertilization, and mounding) (Campbell and Hughes 1981, 1991). Such practices should be avoided on deep organic soils, but are more feasible on mineral soils and shallowest organic soil sites.

Growth of pines is best on well drained mineral soils, decreases with varying degrees of impeded drainage, and is least on excessively wet, deep organic soils. Sites most likely to produce pines large enough for RCW nest trees within a reasonable rotation length will be on mineral soils or shallow organic soils. Most soils on the Refuge are naturally wet.

Because the acreage of mature pines is limited, this plan recommends that pines be established on mineral soils to increase habitat for RCW (Table 3). Loblolly pine is suggested in the table for most soils, but pond pine would also do well. Giving preference to pines on the mineral soils does not mean that AWC and cypress would not also grow well on those sites, or that they should not be planted there. On the contrary, they might grow as well or perhaps better on mineral soils than in the swamps where they are commonly found. This phenomenon is fairly common: species often occur in certain habitats not because they are incapable of growing elsewhere, but because seedlings are unable to become established or are unable to compete with other species that are more competitive on the other sites. Two classic examples are longleaf pine and bald cypress. The exacting moisture conditions required for germination and establishment of cypress can be easily circumvented by using 1-0 planting stock, but the extreme sensitivity of cypress to fire naturally limits it to swamps. Longleaf pine can grow on a wide array of mineral soils, but is often relegated to acidic, xeric, impoverished sandy soils because seedlings are unable to compete with more aggressive, faster growing hardwoods on more fertile land. Suitable weed control can overcome that limitation.

The Tyrrell County soil survey lists a site index of 95 for AWC on Pungo soil, but suggests planting cypress even though no productivity data are given for AWC. This recommendation is puzzling. AWC transplants 15-18" tall have reached 6-8 ft in 3 years (≥400% increase in height) on Pungo soil south of Phelps Lake

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(Hinesley et al., unpublished), and are clearly outgrowing cypress (10-20% increase).

In Dare County, AWC associations most commonly occur on Pungo, Dorovan and Dare soils (McDonald and Ash 1981, Weakley and Schafale 1991). This plan suggests planting AWC and cypress in riparian zones on the deep peat soils. The down-side of AWC is that it suffers severe damage from deer and rabbits if not protected. Cypress growing next to canals in Pungo soil is doing alright, and has many potential advantages, but growth rates are far inferior to those that would occur on shallower organic soils such as Bellhaven, Ponzer, Roper, Pettigrew, or Scuppernong. In the interior of Blocks B5 and B6, where it is drier away from the major canals, growth of cypress is even slower although survival has been good. Cypress appears to be hurt by competition more than AWC. Raising water levels would directly benefit cypress, and also eliminate some of the competition.

E. Hydrology.

The hydrology of wetlands in the Albemarle-Pamilico peninsula has been studied extensively (Chescheir et al. 1990; Daniel 1981; Evans et al. 1989, Gilliam and Skaggs 1981, Heath 1975, Richardson 1981, Skaggs 1980, Skaggs et al. 1980, Treece 1994). The Refuge has a hydrology plan (Soil Conservation Service 1994). Most Refuge land south of Phelps Lake was originally part of a domed pocosin, with rain as the only source of water. Natural movement of water is by sheet flow (Gallup 1954), a pattern strongly altered by an extensive network of canals and roads. Other pocosins are in lower areas, and receive water from surrounding higher ground, often mineral soil. Pocosins generally have a water surplus during the winter months, resulting in high water tables and runoff, whereas in the summer, there is a deficit, resulting in water tables often well below the peat surface. Evapo-transpiration is about 70% of rainfall.

Pocosins are an important source of water in coastal streams and sounds. Their main value appears to be their influence on runoff characteristics, not groundwater recharge (Daniel 1981, Daniels et al. 1984, Gresham 1984). Internal movement of water is extremely slow (Daniel 1981, Daniels et al. 1984, Gilliam and Skaggs 1981). Even in areas where field ditches have been constructed, the water table can be higher than in surrounding canals or drainage ditches owing to the poor internal drainage (Daniels et al. 1984, Gilliam and Skaggs 1981). Owing to extremely slow internal drainage, surface water often has little influence on the groundwater aquifer immediately below (Daniel 1981, Daniels et al. 1984). However, ditches cut into sand sub-soil enhances groundwater discharge, thereby diminishing the storage capacity of the system. The survival of pocosins "depends on the maintenance of a considerable thickness of peat, and that in turn depends on the preservation of a normal water budget and unobstructed patterns of water flow" (Whitehead and Oaks 1979).

Land use strongly influences the the yield and pattern of water flow from pocosin systems. Vegetation acts as a wick which transpires and evaporates much of the rainfall, especially during the growing season. Forested watersheds have less outflow than agricultural areas (Chescheir et al. 1990, Skaggs et al. 1980). Drainage and development causes peak flows to occur quicker (hydrograph is more ’flashy’), and peak flows are taller but more narrow (hydrograph is more ‘intense’) although total discharge might be similar to undeveloped areas in the long-run (Daniel 1981, Gilliam and Skaggs 1981, Gresham 1988, Skaggs et al. 1980).

The most crucial factor in determining the presence of swamp forest, as opposed to other pocosin communities of lower stature, is the origin of water in the system, and its direction of movement (Daniel 1981, Otte 1981). This idea helps explain the distribution of various plant communities in wetlands of eastern North Carolina, and the failure of swamp forests in some locations to convert to pocosin vegetation of less stature (Daniel 1981, Lynch and Peacock 1982a). Water in domed pocosins (example: area south of Phelps Lake) originates only from rain because the area is higher than the surrounding countryside, causing water to flow outward. These systems are nutritionally sterile (ombrotrophic). Other pocosins receive water from surrounding uplands, overland flow, or groundwater seepage; consequently, are more fertile and thus more likely to support forests (Daniel 1981, Daniels et al. 1984, Lynch and Peacock 1982a).

Swamp forests often occur in peat-dominated wetlands adjacent to higher ground. Water runs off the high ground into the swamp. Consequently, swamp forests have a higher mineral content in the peat, largely as clay, which is carried into the wetland as sediment. In addition, runoff also carries nutrients that would not be present in rainwater. Enhanced fertility helps support swamp forests. The presence of considerable AWC in the swamps adjoining Alligator River is probably related more to the nature of the flooding regime than to depth of peat, soil series, or fire history (Lynch and Peacock 1982a, Moore and Laderman 1989). These AWC forests occur in non-alluvial swamps where there is neither heavy sediment load nor high overbank flows, as in brown-water river flood plains where cypress and water tupelo would be more common.

The distribution of AWC in Florida also confirms the importance of water source and movement in determining the occurrence of various plant communities. “AWC stands are most common where the soil is perennially wet as a consequence of seepage from adjacent uplands. Soil moisture within the root zone is high and remains constant in all seasons. AWC is intolerant of flooding during the growing season. Sensitivity to flooding would exclude it from floodplains of the larger rivers (except the back swamps). The rise and fall of water levels is too drastic, plus sedimentation and erosion patterns are deleterious. AWC tends to occupy banks of small streams, where gradual colluvial transport of sediment (i.e., erosion from adjacent uplands) is relatively important, compared to alluvial transport (Ward and Clewell 1989)."

In Refuge land in eastern N. C., the same principle is Illustrated in the vast Upper Alligator River Pocosin in southeastern Tyrrell County (McDonald and Ash 1981), the drainage basin for Northwest Fork, Juniper Creek and Southwest Forks of Alligator River. A 1960 WestVaco map shows AWC on peat ≥6 feet thick north and west of the intersection of Middle Rd and Seagoing Road (Tyrrell Co, upper reaches of Northwest Fork) (Scotia Quadrangle, p. 77). Backwater swamps like this tend to be wet, but not severely flooded, and would receive nutrients and water from surrounding land, thus explaining why peat of such depth might support swamp forests. This does appear to be the situation: overland flow moves into the area from the west, south, and north (Heath 1975, Soil Conservation Service 1994). The area around Frying Pan Lake also illustrates this principle: water moves generally eastward into the areas where AWC was historically abundant.

F. Water Quality.

Drainage patterns on PLNWR have been described (Heath 1975, Soil Conservation Service 1994). Drainage water from Washington Co. and western Hyde County moves south in canals toward Clark-Mill Creek and Pungo River. According to North Carolina standards (Anonymous, 1993) for fresh surface water, Pungo River has a `C' classification. The `Best Usage' of such waters is -- "Aquatic life propagation and maintenance of biological integrity (including fishing, and fish), wildlife, secondary recreation, agriculture and any other usage except for primary recreation or as a source of water supply for drinking, culinary or food processing purposes." The `Conditions Related to Best Usage' are -- "The waters will be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture; sources of water pollution which preclude any of these uses on either a short-term or long-term basis will be considered to be violating a water quality standard." As in all waters draining into the Tar-Pamlico Basin, Clark Mill Creek is also classified as nutrient sensitive (Clark 1994).

Peat Methanol Associates analyzed water quality in this area to determine the potential impact of a proposed peat-methanol plant (Environmental Science and Engineering 1982). Unfiltered water samples in the major canals exceeded North Carolina standards for mercury and iron, presumably a result of seepage from surrounding peat land. Mercury bound to particles suspended in surface water draining the area would be an additional source of mercury that could affect filter feeders (e.g., oysters) in the Pungo River. The Tar-Pamlico River Basinwide Water Quality Management Plan (Clark 1994) also indicated that Clark Mill Creek and the upper end of the Pungo River were non-sustaining for their water use classification. Thus, there was a clear need to bring drainage waters into compliance with state standards and to reduce nitrogen loading.

Water quality is affected by land use (Chescheir et al. 1990, Evans et al. 1989, Gambrell et al. 1974, Skaggs et al. 1980, Treece 1994). Drainage water from undisturbed forested watersheds carries a lower nutrient load than drainage water from developed soils. Development of organic soils results in large increases in the phosphorus (P) content of drainage water if fertilizer P is added, because the the soil does not bind P, as in mineral soils. Losses of N also increase, but not nearly to the extent noted for P. Restoration of wetland conditions in peatlands formerly drained for agriculture would likely reduce nutrient export, and improve water quality.

Prescribed burning will be an essential forest management tool on the Refuge, but care must be used so avoid negative impact on water quality. High-frequency prescribed burning on organic soils would be incompatible with maintaining good water quality for drainage water entering Pamlico Sound owing to loss of organic matter, and release of nitrogen and mercury. The peat on one square mile of Pungo soil contains stored N equal to 75 years of Raleigh's waste water discharge (Hinesley and Wicker 1997). Prescribed burning, if not carried out under ideal conditions of soil moisture, could consume significant amounts of peat, and release large quantities of minerals and metals into the system. In contrast, mineral soils planted with pine could be burned frequently with less negative impact on water quality.

G. Ownership.

Around 1825, swamplands in North Carolina were turned over to the State Board of Education to raise money for public education (Gwynn 1867, Kerr 1883). This model ultimately failed, however, because 1) the land was of so little value for agriculture and 2) establishing true title was extremely difficult, which discouraged potential buyers when the State tried to sell the land. In addition, people feared malaria, which was associated with the "bad air" of swamplands (Heath 1975).

Around 1885, Roper Lumber Co moved into the western end of the Albemarle peninsula and began logging between Roper and Pantego (Hanlon 1981, Lilly 1981). At its zenith, the company owned 600,000 acres of land, with cutting rights on another 200,000 acres. At they time, they boasted of being one of the biggest sawmills in the world, and were cutting over 100,000 board feet of cedar and cypress shingles per day at the Roper plant (Anonymous 1907). Richmond Cedar Works owned or had cutting rights on most land in Tyrrell and Dare Counties.

Roper lumber company owned or controlled virtually all the land from Pungo and Phelps Lakes to Mattamuskeet (Anon 1907; Roper Lumber Co. and Norfolk & Southern Land

Co. map, dated 1928). This tract was bounded by Phelps Lake (north), Pungo Lake (west), Pungo River (south), Lake Mattamuskeet (southeast), and a north/south line from Alligator Lake up to a point east of the lower right corner of Phelps Lake (east). This tract included virtually all of the Refuge land in Washington Co. and Hyde Co, excluding Pungo Lake, and a small acreage in western Tyrrell Co. The eastern boundary appeared to correspond to an "agreement line" established between Roper Lumber Co and Richmond Cedar Works in 1905 (Richmond Cedar Works map for Tyrrell Co., 1921). Both companies were logging the white cedar and cypress in the Albemarle Peninsula, and clashed more frequently as their operations expanded outward and overlapped. After the agreement, Roper Lumber Co logged to the west of the line; Richmond Cedar Works to the east. The line extended generally northward from about the center of Alligator Lake, and southeast from the same point toward Mattamuskeet. Several stone markers were on the line, but I do not know if their location is currently known.

Roper Lumber company was bought in 1906 by Virginia & Carolina Coast Railroad which soon merged with the Norfolk & Southern RR to form the Norfolk & Southern Railway (N & S RR) (Prince 1972). After that, Roper operated as a subsidiary of N & S RR.

In 1912, Roper Lumber Co. Torrenized a 16,000-acre tract immediately south of Phelps Lake, east of Pungo Lake, and north of County Line Rd (Washington Co. Register of Deeds, Map Book 10). The purpose of torrenizing land was to establish clear title. The justification for that action has been elusive because the company already appeared to own the land (Anon 1907). A few years later, it was deeded to N & S Land Co.

Owing to a number of mill fires and other setbacks, N & S RR decided around 1923 to invest no more money in the lumber business, but retained the land (Prince 1972).

Refuge land south of Phelps Lake was sold to West Virginia Pulp and Paper Co. (WestVaco) in the early 1950's. Later, the principle owners were Atlantic Farms (60's and early 70's), and First Colony Farms (FCF) (mid-70's to late 80's). The eastern boundary of Atlantic Farms in Tyrrell Co. was a short distance west of Western Road (Atlantic Farms map, 1961).

WestVaco acquired Richmond Cedar Works land (~160,000 acres) in Tyrrell and Dare Co in 1953 (McMullan 1982). One of their timber maps for the Tyrrell District, dated 1960, shows every stand of trees (by species, site index, age, and stocking) within the county, excluding several blocks in private ownership. Stands of AWC and cypress were scattered across present-day Refuge land in Tyrrell Co. The map also shows isolines for depth of peat.

First Colony Farms (FCF), bought about 375,000 acres in the peninsula around

1973, including virtually all land now in PLNWR (Carter 1975). The acquisition was mostly land previously owned by Atlantic Farms (Washington, Hyde, western Tyrrell) and WestVaco (Dare, Hyde, and Tyrrell). Clearing and drainage expanded on present-day Refuge land in Washington Co. and Hyde Co (McMullan 1984). After a number of years, however, FCF conceded that farming and/or growing livestock on deep peat soils was unprofitable, confirming the conclusions of various people during the previous century.

FCF was also interested in peat mining for production of energy (Carter 1978, Campbell and Hughes 1981), and exploratory operations were carried out south of Phelps Lake. A 200-megawatt power plant was proposed (~ 1 mile north of County Line Rd) in the middle of a 15,000-acre permit area (McCarthy et al. 1985). Peat deposits on the permit area (estimated to be 14 (10^6) tons of dry matter) were to be burned as fuel, lasting for ~20 years (Adams et al. 1985). Total cost to "ramp up" was ~$300 million of private money, with generation of power to span the period 1991-2011 (Adams et al. 1985). At that time, 26,000 acres between Phelps, Pungo, and Alligator Lakes had received permits for peat mining (Rogers et al. 1981). Peat deposits in North Carolina were estimated to be equivalent to 156 days of energy supply for the United States (Winkler 1981).

Detailed studies and reports were developed to determine the potential environmental and cultural impact (Environmental Science and Engineering 1982, Adams and Barnes 1985; Adams et al. 1985, 1986; Anthony and Steen 1982, McCarthy et al. 1985). These studies showed that run-off from drained peat deposits considerably exceeded the state water quality standard for mercury (Environmental Science and Engineering 1982). The mercury problem is addressed in this plan by supporting existing recommendations to restore the hydrology of these wetlands (Soil Conservation Service 1994). Restoration of wetland hydrology results in accretion of peat rather than oxidation, thereby reducing the release of mercury. Currently, total mercury in Boerma Canal near County Line Rd averages 7-8 ppt (Hinesley and Wicker 1999) -- well below the state water quality standard of 13 ppt.
FCF liquidated in the late 1980's. The land was acquired by the Conservation Fund, and later turned over to the USFWS in 1990 (Washington County Register of Deeds, Book 328: 197-221; 13 tracts). It was combined with Pungo National Wildlife Refuge to become Pocosin Lakes National Wildlife Refuge.

H. **Vegetation: past and present**.

Most of the land within PLNWR is not forested; yet, forests clearly grew there in the past. A generalized vegetation map is shown in the Appendix (p. 77). It might be desirable to "restore" some of the wetland acreage on the Refuge, but the question must be asked, "Restore to what ?" It is easy to visualize a static image of pristine cypress-gum and white cedar forests, and conclude that this should be the goal for restoration. However, it is not so simple. Swamp forests are dynamic, not static (Drayton and Hook 1988, Odum 1984). Likewise, pocosin soils are not static, but are also dynamic (Daniel 1981, Otte 1981, Weakeley and Schafale 1991, Whitehead and Oaks 1979).

It is one thing to note the presence of tree residue, but it is more difficult to say exactly when these stands existed. Through the millenia, peat accumulated around these residues as they were deposited. Offsetting the process of accumulation were the effects of subsidence, mostly in response to drainage, as well as loss of peat in fires, both of which left material at the surface that might be very old. Some soil profiles contain strata composed of very different plant species, each group with different requirements for establishment and growth. Ruffin (1861) described a peat profile near Pungo Lake in which there were three major layers of embedded woody material: pond pine (upper), cypress (middle), and white cedar (lower). Peat profiles near Pungo Lake also contain several distinct layers of tree residue Dolman and Buol (1967).

Species composition of the swamp vegetation in eastern North Carolina has undergone several major changes through its history (Dolman and Buol 1968, Lewis and Cocke 1929, Whitehead and Oaks 1979). Otte (1981) said he had never observed a pocosin (underlain by deep peat soils) that had been dominated by a single vegetation type throughout the history of the wetland. This complicates questions concerning what should be the target vegetation for restoration; obviously, no single vegetation type has always existed on these sites. Analysis reveals many localized changes and successional sequences during the last several thousand years, indicating a state of dynamic equilibrium and a modest capacity for self-repair over long periods without disturbance, say several centuries (Whitehead and Oaks 1979). This tenuous equilibrium is constantly threatened by the activities of man. Preserving pocosin systems requires recognition of the many factors that permitted them to develop and of the variety of forces that have maintained them for thousands of years (Whitehead and Oaks 1979).

South of Phelps Lake, in the vicinity of Boerma Rd and County Line Rd, the peat is 7-9 ft thick (Pungo soil) and contains thousands of tons of logs and stumps. The age of the woody material is ~7000 yrs just above the sand at the bottom of the peat ; ~3400 yrs at mid-depth (Courtney Hackney, UNC-Wilmington, personal communication). The woody material throughout the peat is AWC (Hackney, personal communication). I have seen a few logs up to 30 inches in diameter, and the residue of numerous trees is exposed in the surface of the peat.

Despite evidence that AWC once grew on much of the area, modern descriptions are not conclusive about what vegetation actually existed there in the last two centuries. Few references describe the vegetation of this region, largely because people feared swamps and had no reason to go there. Swamps were regarded as vast, forbidding, impenetrable places, harboring dangerous beasts and disease (swamp sickness: malaria?) — a place where a person could easily become lost and die. The threat of disease was often well founded (Morrison 1911). In addition, the water was often non-potable (Krinbill 1956).

In 1839, the vegetation south of Phelps Lake was described as Savannah: Perhaps the largest part of the interior or highest part of the whole region; no trees, except scattered and stunted and ragged pines; undergrowth of evergreen bushes, vines, and reeds — none usually higher than 10-12 ft; extremely dense; almost impenetrable; more susceptible to fire than the cypress- gum swamps; extending from Phelps Lake to Lake Mattamuskeet (Ruffin 1839).

In 1882, Hale published The wood and timber of North Carolina. Questionaires were sent to people around the state, who then replied with descriptions of the timber resources in their local. Strangely, no information was given for Washington County. Tyrrell Co. was about 75% wooded, with 50% accounted for by AWC and cypress; 25% pine and oak. No information was reported for Dare Co. and Hyde Co.

Ashe (1894) stated that there were 1,000,000 acres of swamp in the Albemarle-Pamlico Peninsula, including 40,000 acres of AWC. Most cypress was already gone, except in Tyrrell Co. and Dare Co. Cypress land was the most fertile, and had largely been drained and put in agriculture. Much of the swamp in Washington Co. and Tyrrell Co was thinly timbered with savannah pine (Pond pine).

Ashe and Pinchot (1897) devoted several pages in their book to AWC and cypress, including silviculture and regeneration. They mentioned no AWC in Washington Co, but stated that it was present in Tyrrell and Dare Counties. They also described extensive areas of pine-shrub pocosin in Washington Co. -- almost certainly the area now within PLNWR.

Roper Lumber Company hired a graduate of Biltmore School of Forestry, Howard Krinbill, in 1911 to cruise 500,000 acres of land. Late in his life, Krinbill described this work, and the hardships endured by the men while finishing the cruise in Summer of 1912 on the 38,000-acre Albemarle Swamp (Krinbill 1956). That tract (Washington County Register of Deeds, Map Book 1 & 3, p. 5; Slide Cabinet A, slide 4) stretched from Pungo Lake northwest to Roper, northeast toward Scuppernong, and then south around the west shore of Phelps Lake back to Pungo Lake — outside PLNWR. Volume was 19% cypress, 21% AWC, 34% pine, 22% gum, and 4% yellow-poplar, but no board footage was indicated. Clearly, there was still considerable AWC and cypress in Washington Co in 1910, but it was on land west of PLNWR.

I have found no information from the 1911-12 cruise related to present-day Refuge lands. The absence of such information might suggest that there was too little standing timber volume in that area to justify a cruise, or perhaps it had was already gone before 1911.

Roberts and Cruikshank (1940) classified virtually all the land within PLNWR as “pond pine-hardwoods” except a small north/south strip of “bottomland hardwoods” east of Phelps Lake. The first term referred to pond pine pocosin; the second term “bottomland hardwoods” referred mostly to bays, wax myrtle, etc, but also included AWC. They mentioned no AWC in Washington County, but briefly indicated that commercial stands were in Tyrrell Co and the Great Dismal Swamp. They showed virtually no cypress in Washington Co, although large amounts were certainly there in earlier years.

In 1938, there were seven sawmills in the northern half of Tyrrell Co; none in the southern part (Roberts 1944). In Washington Co, there were four mills in the northern side (mostly north of Phelps Lake), four in the southwestern sector (west of Pungo Lake), and one small mill about mid-way down the west side of Tyrrell County. All these mills, except two in the western part of the county, were cutting less than 10,000 board feet per day.

These references, spanning 100 years (1839 to 1944), indicate that the vegetation south of Phelps Lake on present-day Refuge land (Washington Co, and probably Hyde County, as well) was mostly pond pine pocosin. I have found no reference documenting AWC there in the last 150 years. Based on the literature, it appears that most logging done by Roper Lumber Co was west and southwest of Phelps Lake and Pungo Lake, and perhaps south along the Pungo River. For example, Norfolk & Southern Farms developed a plan to reclaim 45,000 acres of cutover land for farming in Beaufort and Washington Counties in the area of Wenona and Terra-Ceia (Jacobs 1918). The 38,000-acre Albemarle Swamp has already been mentioned. Man’s activities have wrought such huge changes in the entire region that one can only speculate about the appearance of past plant communities.

I. Fire and pocosins.

Many foresters/ecologists have studied the influence of fire on pocosin systems and the plant life found there (Buel and Cain 1943, Christensen 1981, Christensen et al. 1981, Frost 1995, Garren 1943, Kologiski 1977, Otte 1981, Penfound 1952, Wells 1942). Fire frequency profoundly affects the distribution and structure of most wetland plant communities (Frost 1995). Fire is inevitable in these systems, and the absence of fire can probably be regarded as more of a disturbance than fire itself (Christensen et al. 1981, Wells 1946). Many pocosin species have life cycles centered around fire, with various strategies to regenerate afterwards (Christensen et al. 1981, Wells 1946). A well known example is pond pine in which serotinous cones accumulate in the crown over many years; then, open and disperse seeds following a fire. Variations in fire intensity also tend to create diversity in the subsequent plant community -- a benefit to wildlife (Christensen et al. 1981). Furthermore, plant communities recover quickly, and diversity tends to be greater immediately after fires -- another benefit to wildlife (Christensen et al. 1981).

Although fire has always been present, as evidenced by charcoal throughout the peat profile (Dolman and Buol 1967), the frequency of burning accelerated after the arrival of the white man (Whitehead 1972). Historically, major fires occurred in cycles of 100 to 250 years (Frost 1987)— long enough for trees to become merchantable and build up a seed bank in the duff. In the last 100 years, major fires have occurred on PLNWR about once every 9-11 years (Steve Barnes, personal communication). Two fires in the 1980's consumed an average of 1 ft of peat on FCF land (Adams et al. 1986). The age of dominant trees on pocosin sites often reflects the lapsed time since the last fire (Wells 1946).

It is unrealistic, and probably undesirable, to completely eliminate fire, but the frequency of wildfire on the organic soils of PLNWR should be reduced. Otherwise, efforts to regenerate swamp forests might largely fail.

J. Atlantic White Cedar.

1. **Status**. Historically, Atlantic white cedar was the most valuable tree in the Albemarle Peninsula. It had a stumpage value 2 to 5 times greater than other species, and special effort was made to accurately locate all stands so they could be reached with minimum construction of railroad spurs (Krinbill 1956). In addition, severe fires created an economic windfall for lumbermen who would go into the swamps and harvest the abundant supply of sound logs, previously embedded in the peat matrix, which were exposed after the peat had been consumed by fire (Ruffin 1861, Hall and Maxwell 1911).

   The acreage of AWC today is probably ≤ 5% of the original (Davis et al. 1997, Frost 1987). In the late 19th century, the greatest assemblage of AWC was in the Great Dismal Swamp, with large acreage also in Dare, Hyde, Tyrrell and Washington Counties (Ashe 1894). Ashe (1894) estimated 200,000 acres of AWC in eastern North Carolina, with about 40,000 acres in the peninsula and 60,000 acres in Great Dismal Swamp. In 1937 there was an estimated 82,000 acres with AWC, either pure or in mixed stands, in the Northeastern Coastal Plain of North Carolina, including the Great Dismal Swamp (Roberts and Cruikshank 1941). They mentioned no AWC in Washington County, but noted commercial stands in Tyrrell and Dare Counties. In 1990, the combined volume of AWC sawtimber (≥10 inches in diameter) in the northern and southern Coastal Plain of North Carolina was ~210 million board feet (Johnson 1990, Thompson 1990). Less than 10,000 acres of AWC still remain in North Carolina, with more than half in Dare Co. (Davis et al. 1997).

Ashe (1894) concluded that the existing rate of exploitation of forests in eastern North Carolina would exhaust the resource within 20 years. That prophesy never materialized: people realized the need to save the resource, and took steps to do that. Today, Ashe's concerns can be echoed for AWC, which is making its last stand in the eastern end of the Albemarle-Pamilico peninsula and the Great Dismal Swamp.

Several bulletins and books have been written about AWC (Ackerman 1923, Korstian 1924, Korstian and Brush 1932, Little 1950; Laderman 1981, 1989). In general, there is a substantial body of older literature concerning AWC. There has been a strong resurgence of interest in AWC in the last decade, as reflected by several workshops and symposia (Christopher Newport University 1997, N. C. Forest Service 1995, Stockton College 1996), review articles (Kuser and Zimmermann 1995, Laderman 1989, Phillips et al. 1998), and a variety of research publications. Considerable research has been carried out concerning vegetative propagation of AWC from stem cuttings, seed germination, nursery practices, seedling physiology, and establishment in the field. Weyerhaeuser Co. developed a protocol to produce good quality rooted cuttings in greenhouses as well as outdoor nursery beds, but is not currently producing plants. A 12-acre experimental planting of AWC rooted cuttings was installed at the Pungo Unit in the early 1990's, using large rooted cuttings from Weyerhaeuser, and has grown rapidly. Several AWC regeneration experiments are currently underway on PLNWR, Alligator River NWR, and Great Dismal Swamp NWR.

The prospect of growing significant amounts of AWC again on private land now in permanent agriculture or other uses is almost nil. AWC requires at least 70 years, if used for siding and paneling , and larger trees suitable for more profitable boat lumber require much longer (Ward 1989). Thus, "the cedar industry should expect an increasing proportion of its diminishing supply to come from public lands where controlled logging is included within the management plan" (Ward 1989).

Available information is helpful in determining where and how to establish AWC, and how to maintain and perpetuate it, once there. Even among people who spent many years studying AWC, there is not total agreement on all issues. However, certain common themes seem to recur:

2. Ecology

a. **Fire.** The distribution and occurrence of white cedar is affected by the frequency and intensity of fires and other disturbances. Results are often unpredictable, resulting in conversion to hardwood swamps rather than AWC. Where possible, disturbance must be carefully managed or controlled in order to encourage, not deter, cedar regeneration (Roman et al 1990).

Fire can easily destroy AWC, but, if not too severe, also creates conditions that favor establishment of this pioneer species if a seed source is present. However, a second fire within 10-20 years will eliminate it and change the composition of the vegetation, usually more toward pond pine (Korstian 1924, Little 1950?). In another scenario, mild fires often result in conversion to hardwoods such as maple as a result of sprouting from stumps not killed by the fire (Roman et al. 1990).

AWC is sensitive to fire, but without fire it gives way to other species (Christenson 1981, Frost 1987, Korstian 1924, Little 1950, Motzkin et al. 1992). AWC forests can be regarded as "special fire serclimaxes, the special conditions occurring so infrequently . . . as to limit the extent to which these forests have appeared" (Wells 1942). AWC forests "are the product of a low frequency, relatively high intensity fire regime which is probably related to their marginally moist soil conditions. Too frequent fire, either prescribed or the result of lower water tables, will convert such areas to shrub bogs. Infrequent fires result in decreased importance of white cedar and pine" (Christensen 1981).

Quoting Frost (1987): "The known longevity of AWC and its absence from regions which originally burned frequently suggest that AWC was limited to areas having catastrophic fire return intervals ranging from about 25 to 250 years. Repeated logging in the absence of fire leads to step-wise reduction in area and loss of cedar habitat to deciduous swamp forest, with eventual extirpation of the species. This effect, along with widespread hydrologic changes associated with ditching, seems adequate to explain virtually all known cases of white cedar displacement in the Carolinas. It requires periodic catastrophic fire, but with a medium to long fire return interval".

The most extensive development of AWC forests occurred on medium to deep peat soils with fire intervals of 100 - 300 years (Frost 1995). One hundred years allows stands to mature and accumulate an extensive seed bank in the upper few inches of peat. Three hundred years is the approximate longevity of AWC, but at that age, too few trees still remain on the site to maintain a good seed bank or prevent succession to other species (Frost 1995). AWC can occur with fire intervals of 50-100 years **:** sometimes, small patches might appear with fire intervals of 13 to 25 years (Frost 1995).

In Massachusetts, "the burning cycle was 100-200 years before

Europeans came. In the 600-800 years before establishment of the current mature stand, AWC did not persist for more than 100-200 years without stand-regenerating fires. A management policy excluding disturbance would eventually lead to a decline in the importance of cedar" (Motzkin et al. 1991).

Regeneration is favored when fire occurs when the water table is near the surface, thus preventing consumption of the peat, and when a seed source is present, either from nearby trees or stored in the upper few inches of peat (Ackerman 1932, Frost 1995, Little 1950). In other situations, regeneration is successful after severe fires burn down close to the water table, thus creating moisture conditions favorable for seedling establishment (Little 1950). In this situation, however, seed would have to come from adjacent stands.

b. **Water, light, soils, and windthrow.** AWC will not regenerate under flooded conditions. It normally gains footing on sites just above the water table. Like red maple (*Acer rubrum*), it is moderately tolerant of flooding (Hook 1984). AWC grows best where the water table is only a few inches below the surface during the growing season (Korstian and Brush 1932, Ackerman 1932, Little 1950). AWC sites are normally "drier" than cypress/gum sites (Whitehead 1972). AWC occupies a narrow hydrologic position toward the wet end of the moisture gradient, and intermediate between that of deciduous swamp forest and evergreen pocosin (Frost 1987).

Young seedlings easily establish beneath the shade of an overstory, but require more intense sunlight by the third year to continue normal development. Hardwoods such as red maple are more shade tolerant, an important reason why they eventually take over AWC stands that are undisturbed or selectively logged (Roman et al 1990). It is fairly common for a remarkably dense vegetation to claim a site after cedar is logged (Phillips et al. 1998, Whitehead 1972).

AWC can occur on a wide variety of sites, but is usually found on peat overlying sandy soil, or in sandy creek bottoms with soils high in organic matter (refs). It shuns alluvial sites, where cypress and gum tend to dominate. See additional discussion in Section D: Soils (page 4).

AWC is susceptible to windthrow. Typical of many pioneers, it often grows in dense, even-age stands, and has a long bole, narrow crown, and shallow root system. With these characteristics, trees are easily windthrown in the soft peat where they usually grow, especially when a dense stand is suddenly exposed to wind from the side, as after a logging operation in adjoining stands. Storms and hurricanes have played a major role in destroying or altering forest stands in eastern North Carolina. In the last two centuries, for example, hurricanes have struck the South Carolina coast once every 7 years (Conner 1998). If seed is available, either within the peat or from surrounding trees, AWC stands can regenerate following destruction. Bald cypress is rarely windthrown, even by the fiercest storms (Matoon 1915). More than 200 years ago, a German naturalist noted that AWC south of Albemarle Sound (below Edenton) could reach 60-100 ft in height and 12-15 ft in circumference at the base, but only on fertilie swamp soils where trees were protected at the sides by other trees (Morrison 1911).

H. Bald cypress

Like AWC, Bald cypress (*Taxodium distichum*) has been an important tree of commerce in the South, including North Carolina. The total resource is only a fraction of that in earlier years even though demand is still strong. Ashe (1894) noted that the supply of cypress suitable for lumber and shingles in eastern North Carolina was almost gone, but there were still some large tracts in Tyrrell and Washington Co. In the South, harvesting of cypress peaked at 1.3 billion board feet (bbf) in 1913 (Betts 1960). The slack-line technique used by early loggers in southern swamps was described by Bryant (1913). The reserve of cypress sawtimber decreased from 40 bbf in 1913 to 13 bbf in 1953, with 1.2 bbf in North Carolina (Betts 1960). In 1990, there was an estimated 2.1 bbf of cypress sawtimber in the northern Coastal Plain (Thompson 1990) and southern Coastal Plain of North Carolina (Johnson 1990).

The value of cypress lumber is in the heartwood, which is resistant to decay. Cypress, which can live more than 1000 yrs, produces little merchantable heartwood before 200-300 years in age (Betts 1960, Krinbill 1956, Hall and Maxwell 1911). By usual methods of forest valuation, It could be argued that high quality cypress is prohibitively expensive to grow in rotations of 200-300 years (Krinbill 1956). In addition, other factors also affect yield, e.g, the hydro-period influences wood quality; if the site is too dry, or if water levels fluctuate too much, trees tend to develop heart rot, become hollow or pecky, and produce a higher percentage of sapwood (Krinbill 1956; Pinchot and Ashe 1897). Although undesirable for timber quality, defects would benefit wildlife by providing more dens and nest cavities.

Cypress usually occurs in even-aged groups in all-aged stands (Matoon 1915), and rarely constitutes more than 25% of the stand (Pinchot and Ashe 1897). The most common associates are water tupelo on alluvial sites, blackgum on non-alluvial swamps and peat swamps, AWC and bays on muck soils, and AWC on peat soils (Matoon 1915).

Cypress occurs on soils ranging widely in texture, reaction, base saturation and fertility (Coultas and Duever 1984), but is normally confined to swamps where there is abundant moisture throughout the year (Fowells 1965; Matoon 1915). Cypress grows well on drier sites or more fertile sites, but its absence there is likely due to its inability to regenerate and compete with other tree species (Betts 1960. Matoon 1915). It is not demanding nutritionally, but is so exacting in regard to moisture that the area adapted for best growth is extremely limited, amounting to perhaps 300,000 acres in eastern North Carolina (Pinchot and Ashe 1897). Cypress is the dominant tree on alluvial soils, where fertility is augmented by nutrient- and sediment-laden water from outside the system.

Although much of the swampland west of Phelps Lake and Pungo Lake was forested with gum/cypress in the early 1800's (Ruffin 1839), I have found no accounts documenting tracts of cypress/gum in the portions of Washington Co. and Hyde County currently in PLNWR, excluding Pungo Lake and immediate surroundings. However, there were numerous cypress stands in Tyrrell Co. and Dare Co. (Ashe 1894, Roberts and Cruikshank 1940; WestVaco map, 1960).

III. Management Recommendations

A. Restore wetland hydrology, including raising roads.

Much of the Refuge was subjected to drainage and agriculture in the past 40 years. Drainage lowered the water table, thus accelerating the loss of peat by natural decomposition and fire. These mechanisms of oxidation release metals and other ions, which can then find their way into drainage waters. Restoring wetland hydrology would reverse or slow these processes because the peat would be more anaerobic, resulting in net accumulation (Whitehead 1979). The Refuge applied for and received a permits (Section 404 of the Clean Water Act) to install flashboard risers to restore wetland hydrology to about 20,000 acres south of Lake Phelps that had been ditched and drained prior to Service acquisition. To date, 18 culverts with risers have been installed, plus an additional 11 new culverts.

Higher roads would allow more effective manipulation of water levels with flashboard risers, thus creating conditions more like those in typical AWC stands. Godet and Lowry (1967) found that mean annual water (April -Sept.) levels in Rhode Island AWC stands ranged from 4" below to 5" above ground level (average ~ 0.5"), with the soil surface flooded 18% to 76% of the growing season. Little (1950) observed that growth of AWC was best where the growing season water table was 4-5" below the surface, with little fluctuation during the year. In the past 3-4 years, groundwater in Pungo soil south of Phelps Lake (Blocks B5 and B6) has averaged 8-22" below the surface during the growing season (Hinesley and Wicker 1999). Without raising roads, risers cannot attain the levels of wetness indicated above without undermining the road, aggravating maintenance, and hindering access for the public as well as Refuge personnel.

A benefit of restoring AWC and cypress wetlands (using risers and higher roads) is reduction of fire hazzard. The Refuge's history of major wildfire about once per decade is incompatible with regenerating and growing long-lived, swamp forests such as AWC and cypress. Higher water levels would reduce the risk of conflagration, reduce the rate of spread, reduce the risk of fire moving from marsh or pocosin vegetation into forested areas, and reduce the average size of fires — important components in creating a longer fire cycle. Historically, the fire cycle for AWC was 25-300 years forests; for bald cypress, 50 years to "never burned" (Frost 1995).

Broad swamps act as firebreaks, especially when the water table is high (Laderman 1989, Little 1946). Fires rarely originate within wet swamps; rather, they start in adjacent, more flammable vegetation types, and spread into the swamps, especially during periods of drought (Little 1946). Wells (1946) noted that fires in Holly Shelter Pocosin in Pender County often originated in surrounding savannah or pine ridges where the wiregrass could ignite within hours after a rain. In New Jersey, AWC wetlands more than 1,000 feet wide act as firebreaks when approached by headfires (Laederman 1989). However, crown fires can traverse broad swamps, even during times of flooding (Little 1946).

The greatest potential incidence of fire and potential danger to private property adjacent to the Refuge is south of Phelps Lake (Fire Management Unit 1) (Jenkins 1999). This area experiences considerable traffic from the public, and historically has the most ignitions from lightning strikes, probably because it is drier as a result of the previous history of ditching and drainage. There is already an extensive road and canal system. Increasing the elevation of roads in this area would greatly reduce the potential for wildfire by allowing a longer hydro-period.

Higher water levels can be used to bring about changes in vegetation composition that might reduce fire hazzard. For example, flooding killed or seriously damaged red bay (*Persea borbonia*) along Boerma Canal in just one growing season. More information is needed about this subject.

More frequent burning on mineral soils and higher water levels on organic soils will combine to reduce overall fire hazzard for the entire Refuge. As an exception, where there is high risk of fire jumping Refuge boundaries and damaging private property, it might be necessary to more frequently burn these fringe areas, even if they are organic soils, to reduce hazzard. There, every effort should be made to burn under wet conditions to minimize consumption of the soil.

Unpredictable regeneration of AWC following fire is largely a consequence of poor control over the water table. The literature suggests that regeneration should not be difficult after a fire if seed is present and if the soil matrix is wet, but not flooded (Ackerman 1932, Ashe and Pinchot 1897, Korstian 1924). Higher roads, combined with the system of flashboard risers, will allow more control over the water table and hydro-period, thus increasing the probability for successful natural regeneration. However, care must be exercised since AWC is intolerant of flooding during the growing season (Ward and Clewell 1989).

In addition to better fire control, higher roads would positively impact many other goals and objectives of the Refuge. The ability to flood these blocks could be important in future efforts to regulate water discharge, improve water quality, manipulate vegetation, prescribe burn, and regenerate AWC. Controlled release with water control structures is a best management practice (BMP) to reduce outflow and nutrient exports (Chescheir et al. 1990). Raising roads can be accomplished by dredging existing canal channels. This would qualify as maintenance, and not require new permitting.

I. Plant indigenous forest tree species.

Benefits would include increased evapo-transpiration and less runoff, restoration of native trees, improved wildlife habitat, a more effective nutrient sink to reduce movement of nutrients off the site, seed for natural regeneration; reduced subsidence that often occurs when organic soils are exposed to oxidation by exposure and disturbance, leading to discharge of mercury and other metals. The net result should be less runoff and better water quality.

1. **White Cedar**. Resource managers and the people of North Carolina must not allow AWC, a unique and historically important species, to become only a memory, as with several other plant and animal species once indigenous to North Carolina.

   It appears that the most limiting factor to AWC on PLNWR is the absence of a seed source, which prevents it from naturally regenerating after disturbances, including fire. For this reason, stands of AWC should be established across Refuge holdings to serve as a future source of regeneration, and function as a springboard for future observation and research. Later, these stands can also be used for collection of seed, which traditionally comes from sawtimber trees during logging operations — analagous to killing the goose that lays the golden egg.

   One-year-old bare-root seedlings are normally available from the N. C. Forest Service, but demand has recently exceeded the supply. Seedlings are normally planted in the spring, with typical plants ~ 6 inches tall. Several plantings at PLNWR have conclusively shown that large transplants give better results in the field, especially when subjected to browsing and heavy weed competition (Hughes 1995, Hinesley et al. 1999).

The Refuge should develop a source of large transplants for annual planting needs. In addition to the advantages already mentioned, larger plants are adaptable to machine planting, and less likely to be killed by flooding. Recognizing the real-world constraints associated with contracting and managing operations, successful regeneration of AWC may strongly depend upon the use of large planting stock, with no subsequent protection.

About 425 acres south of Phelps Lake have been planted with white cedar.

2. Cypress. Cypress can regenerate from stump sprouts, seed, or by artificial regeneration. Stumps sprout readily, especially young trees ≤ 100 yrs in age and/or 10 to 14 inches in diameter (Matoon 1915), but mortality is heavy, and the quality of surviving sprouts is often poor (Conner et al. 1986). Old, slow-growing trees produce few sprouts, and the best yield of sprouts occurs after logging in fall or winter (Matoon 1915).

   Regeneration from seed is critically tied to the moisture regime after seedfall and during the first year of establishment. Cypress produces seed almost every year, but seeds are not carried far by wind or animals (Matoon 1915). Although seeds will not germinate while submerged (Demaree 1932), they require a moist seedbed for 1-3 months to become established (Matoon 1915). Older trees are very tolerant or tolerant of flooding (Hook 1984), but seedlings drown easily (Demaree 1932, Matoon 1915). To survive, plants must reach a height in the first year sufficient to stay above floods except for very brief periods during the second year (Demaree 1932).

   Regeneration systems for cypress are also debatable. Foresters have long questioned the ability of cypress to regenerate in cut-over swamps (Ashe 1894, Krinbill 1956, Matoon 1915, Pinchot and Ashe 1897). Cypress and gum often grew in association, but the gum and/or other hardwoods would frequently gain dominance after the cypress was logged out (Krinbill 1956, Pinchot and Ashe 1897). Regeneration is best assured with seed-tree or shelterwood cuts (Matoon 1915), whereas clear-cutting often fails to provide adequate regeneration (Conner et al 1986, Matoon 1915). Clear-cutting or selective removal of all the cypress also increases the likelihood of a type conversion to hardwoods (Krinbill 1956 ?, Pinchot and Ashe 1897).

   The easiest method of regeneration is 1-0 planting stock from the N. C. Forest Service or commercial timber companies. Planting is normally in early spring, but Matoon (1915) suggested planting in fall to allow establishment before winter flooding — a practice that should be tested with research. Fall planting has advantages, but it uncertain how it might work considering the deciduous nature of cypress. Overwinter browsing by deer could also be a problem (Matoon 1915).

Cypress is capable of impressive growth on a variety of sites. Much of the Refuge in Washington and Hyde Co. is deep peat — acidic and nutritionally impoverished. In plantings installed since 1994 on Pungo soil south of Phelps Lake, cypress has survived well but is growing slowly, compared to AWC. Growth is better adjacent to canals, where, in addition to being wetter, perhaps water moving past the trees, although having minimal nutrient load, provides a greater "effective" nutrient regime, compared to drier sites toward the middle of the blocks. Trees established next to canals act as a biological filter or scrubber to effectively remove nutrients (e.g., nitrogen) and particulate matter as it moves down canals toward the estuary (Kuenzler 1988). Years will be required to determine the stature that cypress can ultimately attain in these locations. However, even if trees attain only nominal size for the species, they should benefit wildlife and water quality.

About 500 acres have been planted with cypress since Spring 1996.

C. Encourage and maintain plant diversity to benefit wildlife.

Planting AWC, cypress, blackgum, pine, and oak will not only increase the acreage of these species, but will also increase horizontal and vertical diversity — a benefit to wildlife. This is consistent with the idea that the best program for integrating wildlife management and forestry is long-range planning for good age-class distribution in the forest to ensure that areas of young and older plantations are constantly available (Monshein 1981). Historically, the fringe of large pocosins has been bordered by swamp forests, and is valuable for animals moving back and forth between the pocosin and forest.

Owing to the value of AWC for timber, it is easy to overlook its importance to wildlife. Stands are not only utilized by many species of breeding and migratory birds, especially warblers, but also support high bird densities per unit area (Miller et al. 1987, Terwilliger 1967). Particularly with birds, there are distinct species associations along vertical and temporal gradients, e.g., different-aged trees and stands support different species at various heights in and under the canopy in different seasons (Laderman 1989, Terwilliger 1967).

Cypress/gum swamps are also important to wildlife, and acreage should be increased. On a historical note, ivory-billed woodpeckers and Carolina parakeets, both originally found in North Carolina but now extinct, were dependent upon gum/cypress swamps for food, roosting, and nesting (Brewster 1889, Maynard 1881, Ridgeway 1898).

Harris and Vickers (1988) described many attributes of cypress domes in relation to faunal populations in Florida, with many conclusions and observations applicable to cypress/gum stands in general:

1. Cypress ponds, and possibly swamps in general, have an abundance of evergreen, broad-leaved trees and shrub species. Foliage is important to browsing animals throughout the winter and provides escape cover for vertebrates. Foliage is also a food source for arthropods that, in turn, constitute the food base for insectivorous vertebrates.

2. Cypress/hardwood swamps tend to have many winter-fruiting plant species and other species that bear persistent fruit. Consequently, they are important in production of mast in the winter.

4. Bottomland swamps have a high frequency of cavity trees. This is very important since wet conditions preclude ground burrows. Healthy trees can have have several cavities that last for many years. Many breeding birds in swamps are cavity dwellers.

3. Southeastern cypress/hardwood forests have much higher bird populations in winter than in summer, supporting dozens of northern species that are not present in the summer. Conversely, some species present in the summer are absent in winter.

4. Cypress/hardwood stands support about twice the bird density of surrounding pine lands, but fewer species and numbers than bottomland hardwoods. Canopy-feeding, insectivorous passerines are abundant.

5. Edge effect associated with the high contrast of cypress ponds surrounded by clear-cut is superior for breeding passerine birds to that of the lower contrast ecotone between cypress and planted pine. The effect also extends to breeding bird densities in the interior cypress as well.

6. The minimum size of stand for suitable habitat varies by animal species; also by type of surrounding vegetation.

7. Mammal populations are lower than in other ecosystem types, with greatest populations at the periphery or ecotone.

8. Cypress swamps were used more heavily by bear, panther, and red wolf before populations were severely reduced. Stands serve as rookeries and roosting sites for wading birds, and are preferred roosts for turkeys and other birds, possibly because high water assists in predator avoidance. Less common mammals, e.g., bats, also utilize cypress.

D. Maintain hardwood/cypress stands so that they progress towards old growth.

The purpose is to improve habitat quality for bears. Acreage of hardwood is limited, and these stands are important havens for wildlife. The Refuge is not in the timber business, and has no compelling reason to thin or otherwise disturb such stands. There will never be a shortage of tall pocosin and bay forest on the Refuge. These plant communities, plus a mixture of swamp forests (various species) and agricultural areas, will provide diversity that should benefit bear populations.

Currently, there is no bear hunting on PLNWR, effectively making the Refuge a 113,000-acre sanctuary. With the increasing numbers of bears in North Carolina (Foushee 1999), the 1999 hunting season has been lengthened in northeastern N. C. In the future, there might be pressure to open seasons on federal lands. The following discussion, in addition to material concerning forestry and habitat, also includes impacts of hunters on bear populations, and thus might be useful if the Refuge ever considers opening a bear season.

Black bears are “forest dependent species” (Pelton 1986), tending not to venture far from trees (Herrero 1972). They prefer old growth timber, where large trees are more likely to have cavities large enough for a female and her cubs (Pelton 1986). Man has destroyed or fragmented bear habitat, making it more challenging for bears to survive. Fragmentation has several negative effects (Mollohan and LeCount 1989):

1. Increased size of home range; consequently, less carrying capacity.

2. Greater difficulty of moving back and forth among areas that supply food and shelter, which increases the importance of protected travel-ways. Maintaining traditional travel corridors to and from feeding areas is critical in fall when bears move more (Pelton 1986).

3. Inreased hunter efficiency and access; consequently, greater mortality.

4. Concentration of females and cubs in smaller areas, making them more vulnerable.

5. More difficulty in replacing bears lost to hunting or natural mortality, especially females.

Because fragmentation plus accessibility leads to higher mortality, especially of females, a primary goal should be to prevent further fragmentation (Mollohan and LeCount 1989). Limited access remains at the core of the species’ needs, and is critical for survival of remaining populations (Pelton 1986). Reducing human access to bears and their habitat appears crucial, either by making large sanctuaries or by eliminating [closing] roads (Powell et al. 1996).

Pocosins should be viewed as nature refuges rather than nature preserves (Wilbur 1981). Bear and deer are concentrated in these places, not because they are the best habitat, but because they tend to be the last place cleared for human land use (Wilbur 1981). Pocosins provide the last stronghold for the black bear in eastern North Carolina (Monshein 1981).

Male black bears can have extensive home ranges, whereas the range of females is much smaller (Hamilton 1978, Hardy 1974), usually one-fourth to one-third that of males (Powell et al. 1996). This, plus the tendency of females and cubs to tree rather than flee means that they are more easily taken during hunting (Hardy 1974).

Habitat preferences also vary among males and females. In the Great Dismal Swamp, females prefer pocosins and mesic areas, whereas males prefer gum-cypress swamps and stands with a mixture of maple and pine (Hellgren et al. 1991). It is also significant that females prefer roads at all times of the year except early fall (Hellgren et al. 1991).

Large, impenetrable pocosins provide seclusion and protection during denning (Hamilton and Marchinton 1980**,** Landers et al. 1979). In addition, they supply important food items during fall, winter and early spring (Hardy 1974). Maintenance and enhancement of pocosins, mature gum, oak, and disturbed habitats would benefit black bears in southeastern wetlands by providing a wide variety of natural foods throughout the year (Helgren et al. 1991).

Among the requirements of black bears are the following (Pelton 1986):

1. Greater quantity and quality of oaks, with long rotations. “Logging regimes managed to maximize timber volume are incompatible with maintaining viable populations of black bears, in part because of access provided to hunters via logging roads and in part because of habitat change” (Brody and Stone 1987, Powell et al. 1997). Bears need rotations longer than 100 years.

2. Alternate fall foods, either light-seeded hardwoods or berry producers. Range will become larger if food supply fails or decreases. Increased food supply results in decreased fall movements, therefore decreased mortality, increased natality, and consequently an increase in the population.

3. Well-distributed pockets of old growth timber covering 5-10% of the range.

4. Preservation of large trees ($\geq$3 ft in diameter) as potential den trees, especially for

females and cubs. Bald cypress and blackgum are common den trees (Hamilton and Marchinton 1980).

5. Restricted road access (no more than 0.5 km (3000 ft) of roads per square km of forest). Greater access means greater mortality. A high percent of the kill by hunters is within 1 km (3000 ft) of roads accessible to 4-wheel drive vehicles (Powell et al. 1996).

6. Sanctuaries within hunted areas inside or outside designated wilderness to protect breeding age females. Most of these areas have low road densities or no roads at all.

Ideal black bear habitat is remote and inaccessible, with dense understory, and a good year-round food supply (Pelton and Nichols 1972, Powell et al. 1996). Because 95% of the mortality is caused by man, the most critical factor is escape cover -- defined as more than 400 ha (~1000 acres) of conterminous roadless forest (Powell 1997). Even larger areas might be needed in Coastal North Carolina.

Recommendations (Rogers and Allen 1987) for management of black bear in the Upper Great Lakes States are also applicable elsewhere. "Timber management should maintain a diversity of age classes in close proximity. Selective and seed tree prescriptions should preserve and enhance food species. Thinning of pine stands as they mature enhances food production. About 5-25% of the area should be in non-forested cover types to maximize diversity, productivity and availability of food. Stands of hard mast producing species should be protected to the fullest extent" (Rogers and Allen 1987). Because agricultural fields act as "sinks" for black bears, farmland should not exceed 30% of the land area. Otherwise, mortality [author insert: from hunting and road-kill] increases to a level that makes the population non-sustainable (Rogers and Allen 1987).

Sanctuaries, consisting of forested swamplands, help protect female bears and sub-adults (Berringer et al. 1998, Collins 1991, Scott 1991). Since 1970, sanctuaries have been very successful in increasing bear populations in eastern North Carolina to an estimated 6000 animals (Foushee 1999). Optimum size for sanctuaries is debatable partly because home range can vary significantly in size. Bears are opportunists, and unlikely to exert more energy than necessary to acquire food, water, shelter, and mates. Consequently, home range should decrease in size as habitat quality increases, especially for females and sub-adults (Pelton 1986). Zeveloff (1985) suggested 40,000 acres for sanctuaries in eastern North Carolina pocosins -- perhaps too extreme. A mitigation area of ~25,000 acres was recommended in Dare County to offset habitat losses as a consequence of proposed operations of Prulean Farms (Noffsinger et al. 1984). Because there is no bear hunting at present on the Refuge, it is already serving as a huge sanctuary for bears and other animals.

Hardwood forests surrounding Pungo Lake should remain as a sanctuary. Other areas with significant acreage of hardwoods could also be set aside. Where small stands of trees already exist but are too small, the acreage could be expanded by planting swamp blackgum and cypress.

E. Establish riparian zones, and plant with Atlantic white cedar and cypress.

The Refuge has many miles of roads and canals. Roads were built from the spoil that was dredged from canals. Riparian protection zones or streamside forests improve water quality, species diversity, habitat diversity, and reduce outflow rates (see papers by Howard and Allen, Kuenzler, Nutter and Gaskin in the symposium proceedings edited by Hook and Lea, 1988). In addition, forested riparian zones would serve as corridors for movement of bears and other wildlife (Mollohan and LeCount 1989, Noffsinger 1985).

In Washington and Hyde Co, the principle drainage is south toward Clark-Mill Creek and Pungo River. Large canals carrying this water are oriented generally in a north/south direction, parallel to v-ditches in the adjacent blocks formerly used for agriculture and pasture. Roads are on the west side of canals. This plan recommends that riparian zones (area= 600 ft x 0.5 mile = 40 acres) be established along canals on the side opposite the road (east). This corresponds to columns 15 and 16 (each 300 ft wide) at the west end of each block. Along the east/west canals, which carry less water, designate zones at least 300 ft wide on the north side of the canal (opposite the road). Strips 300 ft wide are better for wildlife, especially birds, than extremely narrow strips, and are consistent with recommendations of Noffsinger et al. (1985) for riparian zones along 19 miles of roads in the Prulean Farms project in Dare County in the 1980's.

Plant AWC and cypress in riparian zones using a 12 ft x 12 ft spacing (300 trees per acre) for cypress and 7 ft x 10 ft (623 trees per acre) for AWC. These columns (west end of block) will be mostly flooded during the winter months, but the water table drops below the surface in the summer and fall. South of Phelps Lake, the slope gradient is slightly uphill towards the northeast. Consequently, the eastern end of blocks is drier, and AWC might be more suitable. Areas designated for planting might require rolling & chopping before planting, at least in strips wide enough to reduce competition from woody plants in the first decade after establishment.

Drainage changes toward Tyrrell Co. (Soil Cons. Serv. 1994). About 1 mile east of Washington Co. line, water drains eastward, making these blocks wetter at the east end. Consequently, riparian strip should be positioned according to the existing drainage pattern in each block.

F. Manage pine stands to favor red-cockaded woodpecker (RCW).

An important Refuge goal is to protect and enhance habitat for endangered species including red-cockaded woodpeckers (RCW). RCW is a rare permanent resident of Dare County and other parts of the Albemarle-Pamilico peninsula (Peacock, 1982 letter, p. H-2, *IN* Noffsinger et al. 1985). USFWS Guidelines for assessing habitat quality for RCW suggest the following: mature, open-growing pines, ≥ 30 years in age, clean of undergrowth, with at least 8,500 sq ft of basal area and 6400 stems ≥ 10 inches (Henry 1989). Suggested basal area per acre is about 70 ft^2, translating to 90 trees per acre 10 inches dbh. Meeting the criterion for stem number would require a minimum of 71 acres. However, home ranges and foraging areas are often 2 to 3 times larger (Epting et al. 1995), and vary depending on the quality of habitat (Engstrom and Sanders 1997, Porter and Labisky 1986). In the past, the U. S. Forest Service traditionally managed areas of ~125 acres of pine or pine/hardwood that met certain criteria (Krusac et al. 1995).

For most species, a critical minimum area of habitat is needed. Habitat quality does not increase indefinitely with increasing area, beyond certain limits, e.g., two 100-acre tracts might have more value than a single 200-acre stand. Ross et al. (1997) noted that RCW tend to excavate new cavities in trees near edges, possibly owing to better resin flow, and concluded that a mosaic of patches is preferable to more uniform conditions. Engstrom and Sanders (1997) observed that RCW favored old-growth longleaf pine for foraging, and concluded that quality foraging habitat should have old trees across the landscape. These observations underscore the value of adequately-sized, well distributed islands of suitable habitat across the landscape.

Much literature is devoted to the importance of longleaf pine habitat in management of RCW. Longleaf pine occupied extensive areas of the Coastal Plain when European settlers arrived (Wahlenberg 1946, Ware et al. 1993). It was a very important tree for production of lumber and naval stores, occupying a central place in the history and lore of the South. Today, longleaf pine occupies only 1% of its original range in the Southeast (Ware et al. 1993). Wholesale failure of pine forests [author insert: longleaf pine] to regenerate following early exploitation was a pivotal event in the natural history of the eastern United States, rivaling the loss of chestnut in the Appalachians (Ware et al. 1993). Factors contributing to its demise were 1) destruction of a seed source with extensive clearcutting, often followed by wildfire; 2) depredation by feral hogs, 3) infrequent seed years, 4) inability to compete with loblolly pine (more rapid growth, more reliable seed producer), and programs of fire suppression (since about 1920), which favors a shift towards hardwoods (Ashe 1894, Wahlenberg 1946, Ware et al. 1993).

Longleaf pine has many advantages. It is favored by RCW partly because it maintains resin flow much longer than other southern pines (Conner et al. 1998).

This provides better protection against predators and parasites, and enables birds to use nest cavities much longer without having to excavate new cavities. Seeds are utilized as mast, and insects and arthropods inhabiting bark and foliage provide food for birds. It is a fire ‘sub-climax’ (perpetuated by occasional fire), and seedlings can withstand moderate fires in the juvenile stage. It is relatively immune to Nantucket pine tip moth (*Ryaconia frustrana*), which severely injures and deforms shoots of juvenile pond pine and loblolly pine, often turning them into ‘bushes’. The biggest disadvantage is its inability to endure and outgrow competition during the juvenile stage.

Longleaf pine normally occurs on dry, sandy soils, and does not thrive where there is excessive moisture, as in swamps or pocosins (Wahlenberg 1946). It never occupied the deep organic soils of the Refuge, but was present on sand ridges like the one adjoining the southern shore of Albemarle Sound (Sargent 1880). Plantings have been successful on canal banks (mixture of sand and peat) near County Line Rd. Although site index is unknown, trees appear healthy, with some 6-8 ft tall after 5 years. The acreage that could naturally support longleaf pine is limited, so it might be feasible to bed some mineral soils to make the surface drier and perhaps more suitable. Containerized plants are normally planted in October or November.

Although longleaf pine is important in the world of RCW, over 80% of populations on southern national forests are dominated by species other than longleaf pine, namely loblolly and shortleaf pine (Hedrick et al. 1998). In Dare Co and Tyrrell Co., RCW commonly nests in pond pine and loblolly pine on organic soils in pocosin habitats, sometimes in isolated trees or small clumps of trees, not strictly in large stands (Noffsinger et al. 1985).. In addition, nest sites often have thick undergrowth. The crucial element is large pine trees (≥10" dbh, ≥35 ft tall), which are typically emergents over a dense shrub understory or cane (*Arundinaria)* (Noffsinger et al. 1985). *Arundinaria* (switch-cane) occurs where the fire cycle is 4-12 years (Frost 1995). These observations offer promise for RCW on PLNWR, where mineral soils are limited, and where pond pine occurs naturally across most of the landscape, often as scattered, isolated trees or clumps. Where clumps or stands of pond pine occur, manage to produce trees large enough for nesting sites.

Habitat requirements for RCW have been extensively studied. Even though birds favor older pine stands, they are adaptable and will utilize a variety of habitats. Foraging use increases with increasing pine density, and decreases with hardwood density (Epting et al. 1995). RCW persists in a broad range of conditions for most habitat variables (Wigley and Sweeney 1995). In some locals, RCW is not very selective of forest stands in which they forage: any pine or hardwood stand with a modest number of pines ≥ 10 inches dbh will provide highly usable foraging habitat (Hooper and Harlow 1986). However, requirements for nesting habitat are more stringent (Hedrick et al. 1998, Krusac et al. 1995).

Owing to the limited acreage of pine stands on Refuge property, this plan recommends establish pines on mineral soils throughout the Refuge (4440 acres, 4.8% of land) (Table 1).   These soils correspond to the red areas on the master map for the Refuge (p. 63). The largest is the Hyde series (1,300 acres) in the Frying Pan Unit (p. 71). Several small holdings (Columbia E, Columbia W, and Creswell) across the northern part of the Refuge include areas of Tomotley and Altavista soil, which should be utilized to the fullest extent. Weeksville (650 acres) and Perquimans (137 acres) occur together along the Refuge boundary west of NC94 (Fairfield NW and Scotia quadrangles; pages 70 and 77). About 400 acres of Newholland soil is southwest of Pungo Lake (p. 75). Some inclusions of mineral soil contain only a few acres, but their potential value for RCW justifies managing for that purpose. As additional land comes into the Refuge, perhaps it will contain a greater portion of mineral soil that will be productive both for pines and hardwoods, thus increasing management options.

Sustained yield is central concept of forest management. A forest is an assemblage of individual stands, each of different age and composition. The basic idea is to manage the forest to ensure a steady income through time. Income is derived from individual stands perhaps once every 10-15 years, but at the landscape level (forest), some income is derived practically every year owing to activity in a portion of the stands each year. While the Refuge is not concerned with sustained income as an ongoing forestry concern, it is -- in a manner of speaking -- interested in sustaining the production of usable wildlife habitat; i.e., the product is habitat, not timber. This issue, as well as several other concerns, affects the approach that should be taken to develop and maintain habitat for RCW.

If all the acreage of mineral soil on the Refuge were planted with pines, it would represent only 4% of the area. This task could be accomplished in a few years, leading to a narrow age-class distribution for the pine component. For several reasons, this would not be desirable. Ultimately, these stands will require regeneration, in effect, starting another cycle from ground zero. Such areas would be of little utility to RCW until pines reach 10 inches or more in diameter. Second, if the Refuge were struck by a severe hurricane like Hugo, it might destroy all stands at once (example: Francis Marion National Forest in S. C.) leaving the Refuge with little usable habitat for at least a generation. This would only have to occur once every 30-50 years to prevent pines from reaching the optimum size for RCW. Mature stands favored by the birds are most susceptible to blow-down. Having a distribution of age classes reduces the risk of catastrophic loss**,** and the resulting long-term void in usable habitat. In addition, it provides ingrowth of younger stands into the larger size classes as older stands are lost to decadence, logging, insect infestation, or natural disasters.

An additional threat of significance is southern pine beetle (*Dendroctonus frontalis*), which is most likely to attack older, mature stands with less vigor than younger stands. In reality, managers have little control over this insect **:** the best insurance against potential losses is to keep stands in good vigor with thinning and other management practices. The potential for extensive outbreaks is greater in mono-cultures involving large acreage of even-aged pines : this scenario provides a virtually unlimited source of trees for the spread of an epidemic, another justification for even-aged management, with numerous age classes. Furthermore, it is unlikely that the Refuge would not expend a lot of resources to contain such an outbreak.

How can a diversity of age classes be realized? This plan does not suggest planting every acre of mineral soil with pines. Size and shape of pine stands, and their configuration with other habitat types is important (Wigley and Sweeney 1995, Krusac et al. 1995). The following is suggested : area ≤ 100 acres (plant all with pines), 200-300 acres (two stands, 75 acres each), more than 300 acres (100-acre stands, not more than half the total area). In addition, other forest tree species can be established in adjoining stands, but might require exclusion of fire. In addition, in areas of sufficient size to support multiple stands, planting should be staggered at 10- to 15-year intervals to provide a range of age classes. These areas can be regarded as sub-units or mini-forests within the larger backdrop of pocosin and swampforest vegetation.

Even if a program is undertaken to create diverse age class distribution, it will be challenging owing to the limited area of mineral soils, and the small number of stands of minimum acceptable size that can be planted in a given area. A possible way to expand the available area, thus increasing options, is to include adjoining shallow organic soils in the management unit for RCW. The transition from mineral soil to deep organic is often gradual rather than abrupt, resulting in soils with a shallow organic layer (histic epipedon); e.g., Wasda, Roper, Ponzer, Conaby (Table 2). These soils are good for agriculture, and if drained and bedded, will also grow large pine trees. For example, the 400 acres of Newholland soil south of Pungo Lake is adjoined by or in close proximity to several hundred acres of Wasda, Ponzer, and Conaby. This plan suggests that the combined area of these soils be regarded as a management unit for RCW.

The ability of a pine species to withstand fire determines how early in the rotation that prescribed burning can be used to control hardwood competition. Pond pine and longleaf pine are more resistant to fire than loblolly pine: it is possible to burn those stands earlier than stands of loblolly pine (Russ Lea, personal comm.). This difference can be crucial in the battle to control shrubs and broadleaf trees. In the latter situation, competing vegetation might already be out of control before it would be possible to burn the first time. If the Refuge chooses not to use herbicides or chemical release of young pine stands, this consideration is very important. Careful utilization of these tools would greatly increase the chances for successful regeneration.

Availability of potential cavity trees and forage can vary widely depending on the regeneration system used (Walters 1995). RCW can persist in uneven-aged stands (Wigley and Sweeney 1995), but even-aged stands (plantations) provide the greatest number of potential nest cavity trees; produce faster growing, more windfirm trees; and makes it easier to use prescribed burning to control understory (Hedrick et al. 1998, Walters 1995).

The lack of trees old enough to provide natural cavities is a significant limiting factor (Krusac et al. 1995), and it will take many years to grow mature stands favored by RCW. To bridge this gap in time, this plan recommends the use of artificial cavities to sustain and expand RCW populations. This technique has been highly successful in expanding populations of RCW elsewhere (Krusac et al. 1995). There are several types of artificial cavities (Allen 1991, Copeyon et al. 1991, Taylor 1991). Birds quickly take up residence, but at first, only for roosting (Conner et al. 1998). However, the breeding male is particular in his choice of a nest site, and is unlikely to take over a cavity until after other birds (helpers) have scaled the bark and dug resin wells (Conner et al. 1998).

Use long rotations in pine stands. RCW is not an old-growth obligate, but does need trees with old-growth characteristics (Krusac et al. 1995). Birds favor older trees for nest cavities, but will utilize younger trees ≥10 inches. Cavity trees often have heart rot, which is more common in older stands. In the Southeast, potential cavity trees of loblolly pine are often 80-100 years old; shortleaf pine, 100-120 years old (Hedrick et al. 1998). Longleaf pine is of sufficient size at 70-90 years, but older and larger trees allow construction of cavities at greater heights (Conner et al. 1994). Jackson et al. (1979) indicated that the average age for initiation of cavity activity was ~95 years for longleaf pine; ~75 years for loblolly pine. At age 70, the average dominant or co-dominant tree in a loblolly pine stand with site index (SI)≥ 90 for loblolly pine and ≥ 80 for longleaf pine will contain sufficient heartwood (≥ 5 inches at 22 ft) for RCW cavity excavation (Clark 1993).

Based on these observations, this plan suggests a rotation length not less than 70 years for loblolly pine; 80 years for longleaf pine. Rotations could be longer, depending on site quality. Stand age is important only as it bears on the number of years required to grow pines ≥10 inches dbh. Faster growing trees on better sites will reach the desired size quicker than trees on less productive land, and thus will be available for cavity excavation at an earlier age (Clark 1993).

Use local seed sources for loblolly, longleaf and pond pine. Site prepare (roll & chop, burn) before planting, and use 720 trees per acre (spacing 10 ft x 6 ft). Wider row spacing will allow easier access in later years. Thin to meet the basal area guideline for RCW, and prescribe burn every 3-5 years on mineral soils to maintain open conditions.

G. Replant burned areas after wildfires.

After wildfires, replant with appropriate tree species (See Table 3), using local seed sources and large transplants, if available. Plant 720 trees per acre on the deeper peat soils; 720 per acre on shallow peat soils or mineral soils. This will create a mosaic of stands across the landscape. Record GPS coordinates for the perimeter of each burned/planted area, and submit to the Raleigh office for compilation into a permanent record.

H. Maintain and participate in research.

The Refuge should seize opportunities to participate in research which provides information about pocosin systems, including 1) knowledge of regeneration systems for AWC and cypress, 2) effectiveness of management practices, (3) ecology of various plant and animal species, and 4) monitoring of water quality. Use research as an education and public awareness tool to promote wetland restoration and good resource management practices. Projects, whether short-term or long-term, should be encouraged and maintained to provide baseline data for pocosin systems.

The AWC wetlands restoration project (Hinesley and Wicker in 1995) project encompasses 1 square mile (Blocks B5 and B6), and has monitored 1) water table depth in the peat, and 2) mercury and nitrogen content of water in Boerma Canal four times annually (Hinesley and Wicker 1995, 1996, 1997). Mercury levels in Boerma Canal meet the state water quality limit of 13 ppt (Anonymous 1998 ??, Clark 1995)., and nitrogen levels are 2-3 mg/liter. Improvement is possible. Monitoring should be continued.

Several experiments on the Refuge have compared methods of protection for AWC following transplanting, including wire cages, plastic tree-shelter tubes, electric fences, and total exclosure (Guidry 1998, Hinesley et al., unpublished). All are expensive, but electric fences are cheaper when the enclosure increases to a certain size, say 2-3 acres (Kays 1995). It is easier to keep deer out of small plots, compared to large blocks. Repellents are uncertain, expensive, and not recommended for forest plantations in areas with moderate to high deer pressure (Kays 1995), as at PLNWR. Bill Barber (District Manager, Weyerhaeuser Co) has expressed similar sentiments about repellents. Protection is effective, but all methods are too expensive to be practical on a large-scale. The best alternative is large, robust transplants.

In the area south of Phelps Lake, there is great potential to examine the influence of fire in relation to well managed water regimes, but only after raising the roads and installing flashboard risers. Such information would be useful in habitat management, and site preparation for establishment of AWC and/or other species. It would also increase understanding of pocosin plant communities, thereby improving the potential to actively manage these systems.

J. Use volunteer groups to plant trees.

Even though large-scale planting will be done commercially, the Refuge should utilize volunteer labor when available, especially in areas that might be too wet or too cluttered with woody debris to allow machine planting. In addition to planting trees, this will be a valuable publicity and educational tool. Getting outdoors and planting trees, particularly for young people, can be a satisfying experience, satisfaction, with considerable intangible influence on the voters and policy-makers of tomorrow.

K. Manage designated natural areas to maintain the character of their vegetation and fauna.

In the early 1980's, the Coastal Energy Impact Program (CEIP) funded efforts to construct natural area inventories for Washington, Hyde, and Tyrrell Counties. This work was undertaken partly in anticipation of proposed peat mining activities in the region. Inventories excluded land already within Federal ownership. The mission was ". . . to identify natural areas containing highly unique, endangered, or rare natural features, or high-quality representations of relatively undisturbed natural habitats, and which may be vulnerable to threats and damage from land use changes. The resulting inventory and recommendations were designed to help state and federal agencies, county officials, resource managers, landowners and developers work out effective land management and preservation mechanisms to protect outstanding or exemplary natural areas..." (Lynch and Peacock 1982a, 1982b; McDonald and Ash 1981).

These inventories are useful in developing a picture of plant communities that previously existed in certain areas and/or on certain soil types. Updated inventories of natural areas in the Albemarle-Pamilico peninsula were prepared by Legrand et al. (1992).   Natural areas (page 78, Appendix) total 62,300 acres, representing 58% of the terrestrial area within PLNWR. It is suggested that management activities be directed toward maintaining and/or preserving the unique botanical and faunal character of these areas. Under some situations, prescribed fire might be required. Owing to the inaccessibility of some areas, active management is probably not feasible.

Hyde County.   An area south and southeast of New Lake, extending to the intra-coastal waterway was called New Lake Fork Pocosin (9,300 acres; 7,300 acres in PLNWR) (Lynch and Peacock 1982a). Prior to a severe fire that burned the entire area in 1982, it was mostly high pocosin, with an admixture of pond pine woodland and possibly pond pine forest. LeGrand et al. (1992) also included this area (Site significance ‘C’, regional), and suggested that the USFWS consider prescribed fire to perpetuate the type, especially if wetland hydrology could be restored.

Tyrrell County. The inventory of McDonald and Ashe (1982) included several natural areas within present-day Refuge property in Tyrrell County. The largest was “Upper Alligator River Pocosin” (map quadrangles: Fairfield, New Lake, Scotia, and Creswell) (36,820 acres) — the drainage basin for Northwest Fork and Southwest Forks of Alligator River. The vegetation was mostly pond pine pocosin, The area, described as ‘vast and inaccessible’, was given a State Natural Heritage rating of ‘high’ (statewide significance).

A small area on the western side (Community Type B, Creswell SE quadrangle, bisected by Seagoing Rd) was described as “forest that was cut within the last 15-20 years, but the loggers left behind some huge bald cypress trees (cull remnants of earlier logging), most with their tops blown out, and some as large as 5 ft in diameter.” [Soils: Belhaven-Dare-Dorovan (p26)]. The authors speculated that the area might contain a state record tree. Other trees were mostly small blackgum

Upper Alligator River Marsh and Forest (2,761 acres) is at the SE corner of the Refuge, east of NC 94. This area received a State Natural Heritage rating of 'medium' (regional significance). LeGrand et al. (1992) also included this area (Site Significance 'C', regional), and considered it critical as a migration corridor. They suggested burning the marsh once every 5 years.

Scuppernong River Swamp Forest (7,570 acres; 2,555 acres in PLNWR) lies on both sides of the Scuppernong River from Columbia, extending to approximately where county road 1122 intersects the Washington/Tyrrell County line. It was described as an excellent example of a lower coastal plain river with adjacent swamp. The State Natural Heritage Rating was 'locally significant'.

Harvester Road Tall Pocosin (7,385 acres in PLNWR) is north of County Line Rd, east of the Washington/Tyrrell County line, and west of the Upper Alligator River Pocosin natural area. The State Natural Heritage Rating was 'medium' (regional significance).

PLNWR has 57 acres in Alligator Creek/Second Creek Swamp Forest north of the Frying Pan Unit.

Washington County. Lynch and Peacock 1982b conducted the first natural area inventory for Washington County. Later inventories (Frost et al. 1990 and LeGrand et al. 1992) included Pungo Refuge Natural Area (5,598 acres; site significance "C", regional). Both reports suggested that portions remaining in forest should be allowed to mature.

PLNWR has 3.5 acres in Pettigrew State Park along the south shore of Lake Phelps.

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Table 1. Acreage of various soils on PLNWR

Soil Series	Map Symbol	Hyde (acres)	Tyrrell (acres)	Washington (acres)	Total (acres)	% of total	% of land
Altavista	AaA	-	58.7	-	58.7	0.05	0.06
Acredale	AcA	2.1	-	-	2.1	0.00	0.00
Arapahoe	Ap	-	33.4	-	33.4	0.03	0.03
Argent	Ar	-	41.2	-	41.2	0.04	0.04
Augusta	At	-	55.1	10.3	65.4	0.06	0.06
Belhaven	Ba	-	6533.2	1927.5	8460.7	7.44	7.94
"	BmA	7085.5	10.7	3.6	7099.7	6.24	6.66
"	BnA	790.5	-	-	790.5	0.70	0.74
Cape Fear	Cf	-	529.0	118.9	647.9	0.57	0.61
Chowan	Ch	-	2.3	-	2.3	0.00	0.00
Conaby	Co	-	-	43.7	43.7	0.04	0.04
"	CoA	417.6	-	-	417.6	0.37	0.39
Conetoe	CtA	-	7.3	-	7.3	0.01	0.01
Dorovan	Do	0.5	3226.1	26.9	3253.5	2.86	3.05
"	DoA	403.0	19.2		422.2	0.37	0.40
Fortescue	Fo	-	-	4.5	4.5	0.00	0.00
"	FoA	32.3	-	-	32.3	0.03	0.03
Hyde	Hy	-	1292.4	7.8	1300.2	1.14	1.22
Hydeland	HyA	6.9	-	-	6.9	0.01	0.01
Longshoal	LfA	-	12.5	-	12.5	0.01	0.01
Newholland	NeA	401.4	-	-	401.4	0.35	0.38
Perquimans	Pe	-	137.0	-	137.0	0.12	0.13
Pettigrew	Pe	-	-	538.6	538.6	0.47	0.51
Ponzer	PnA	2316.0	1.4	-	2317.5	2.04	2.17
"	Po	-	811.6	-	811.6	0.71	0.76
Portsmouth	PoA	381.2	-	-	381.2	0.34	0.36
"	Pt	-	253.9	0.6	254.4	0.22	0.24
Pungo	Pu	0.6	43720.1	12173.4	55894.0	49.15	52.43
"	PuA	14770.3	15.2	4.5	14790.1	13.01	13.87
Roanoke	Ro	-	-	34.9	34.9	0.03	0.03
Roper	RoA	76.5	-	-	76.5	0.07	0.07
"	Rp	-	141.6	-	141.6	0.12	0.13
Scuppernong	ScA	5378.2	-	2.2	5380.3	4.73	5.05
"	Se	-	-	592.9	592.9	0.52	0.56
Seabrook	SeA	37.3	-	-	37.3	0.03	0.03
State	StB	-	1.7	-	1.7	0.00	0.00
Tomotley	To	-	238.0	47.9	285.8	0.25	0.27
Landfill	Ud	333.6	-	-	333.6	0.29	0.31
Wahee	WaA	244.0	-	1.4	245.3	0.22	0.23
Wasda	Wd	-	312.6	142.2	454.8	0.40	0.43
Weeksville	WeA	126.6	-	-	126.6	0.11	0.12
"	WkA	88.5	563.4	-	651.9	0.57	0.61
Wysocking	WyA	1.5	-	-	1.5	0.00	0.00
Yeopim	YoA	6.3	-	-	6.3	0.01	0.01
	Water:	4720	158	2244	7121	6.3	-
	Land:	32900	58017	15681	106598	93.7	-
	Total:	37620	58175	17925	113720	100.0	-

Table 1. Acreage of various soils on PLNWR

Soil Series	Map Symbol	Hyde (acres)	Tyrrell (acres)	Washington (acres)	Total (acres)	% of total	% of land
Altavista	AaA	-	58.7	-	58.7	0.05	0.06
Acredale	AcA	2.1	-	-	2.1	0.00	0.00
Arapahoe	Ap	-	33.4	-	33.4	0.03	0.03
Argent	Ar	-	41.2	-	41.2	0.04	0.04
Augusta	At	-	55.1	10.3	65.4	0.06	0.06
Belhaven	Ba	-	6533.2	1927.5	8460.7	7.44	7.94
"	BmA	7085.5	10.7	3.6	7099.7	6.24	6.66
"	BnA	790.5	-	-	790.5	0.70	0.74
Cape Fear	Cf	-	529.0	118.9	647.9	0.57	0.61
Chowan	Ch	-	2.3	-	2.3	0.00	0.00
Conaby	Co	-	-	43.7	43.7	0.04	0.04
"	CoA	417.6	-	-	417.6	0.37	0.39
Conetoe	CtA	-	7.3	-	7.3	0.01	0.01
Dorovan	Do	0.5	3226.1	26.9	3253.5	2.86	3.05
"	DoA	403.0	19.2		422.2	0.37	0.40
Fortescue	Fo	-	-	4.5	4.5	0.00	0.00
"	FoA	32.3	-	-	32.3	0.03	0.03
Hyde	Hy	-	1292.4	7.8	1300.2	1.14	1.22
Hydeland	HyA	6.9	-	-	6.9	0.01	0.01
Longshoal	LfA	-	12.5	-	12.5	0.01	0.01
Newholland	NeA	401.4	-	-	401.4	0.35	0.38
Perquimans	Pe	-	137.0	-	137.0	0.12	0.13
Pettigrew	Pe	-	-	538.6	538.6	0.47	0.51
Ponzer	PnA	2316.0	1.4	-	2317.5	2.04	2.17
"	Po	-	811.6	-	811.6	0.71	0.76
Portsmouth	PoA	381.2	-	-	381.2	0.34	0.36
"	Pt	-	253.9	0.6	254.4	0.22	0.24
Pungo	Pu	0.6	43720.1	12173.4	55894.0	49.15	52.43
"	PuA	14770.3	15.2	4.5	14790.1	13.01	13.87
Roanoke	Ro	-	-	34.9	34.9	0.03	0.03
Roper	RoA	76.5	-	-	76.5	0.07	0.07
"	Rp	-	141.6	-	141.6	0.12	0.13
Scuppernong	ScA	5378.2	-	2.2	5380.3	4.73	5.05
"	Se	-	-	592.9	592.9	0.52	0.56
Seabrook	SeA	37.3	-	-	37.3	0.03	0.03
State	StB	-	1.7	-	1.7	0.00	0.00
Tomotley	To	-	238.0	47.9	285.8	0.25	0.27
Landfill	Ud	333.6	-	-	333.6	0.29	0.31
Wahee	WaA	244.0	-	1.4	245.3	0.22	0.23
Wasda	Wd	-	312.6	142.2	454.8	0.40	0.43
Weeksville	WeA	126.6	-	-	126.6	0.11	0.12
"	WkA	88.5	563.4	-	651.9	0.57	0.61
Wysocking	WyA	1.5	-	-	1.5	0.00	0.00
Yeopim	YoA	6.3	-	-	6.3	0.01	0.01
	Water:	4720	158	2244	7121	6.3	-
	Land:	32900	58017	15681	106598	93.7	-
	Total:	37620	58175	17925	113720	100.0	-

Table 2. Classification of Soils on PLNWR

Soil series	***Map symbol***	***Soil Classification***
Acredale	AcA	Fine-silty, mixed, thermic Typic Endoaqualfs
Altavista	AaA	fine-loamy, mixed, semi-active, thermic Aquic Hapludults
Arapahoe	Ap	Coarse-loamy, mixed, nonacid, thermic Typic Humaquepts
Argent	Ar	Fine, mixed, thermic, Typic Endoaqualfs
Augusta	At	Fine-loamy, mixed, thermic, Aeric Endoaquults
Belhaven	Ba BmA BnA	Loamy, mixed, dysic, thermic Terric Medisaprists
Cape Fear	Cf	Fine, mixed, thermic Typic Umbraquults
Chowan	Ch	Fine-silty, mixed, nonacid, thermic Thapto-Histic Fluvaquents
Conaby	Co CoA	Coarse-loamy, mixed, nonacid, thermic Histic Humaquepts
Conetoe	CtA	Loamy, mixed, thermic Arenic Hapludults
Dorovan	Do DoA	Dysic, thermic Typic Haplosaprists
Fortescue	Fo FoA	Fine-silty, mixed, acid, thermic Cumulic Humaquepts
Hyde	Hy	Fine-silty, mixed, active, thermic Typic Umbraquults
Hydeland	HyA	Fine-silty, mixed, thermic Typic Umbraqualfs
Longshoal	LfA	Euic, typic, thermic Medisaprists
Newholland	NeA	Coarse, loamy, mixed, acid, thermic Cumulic Humaquepts
Perquimans	Pe (Tyrrell)	Fine-silty, mixed, thermic Typic Endoaquults
Pettigrew	Pe (Wash.)	Fine, mixed, nonacid, thermic Histic Humaquepts

Table 2 --- continued

Ponzer	Po PnA	Loamy, mixed, dysic, thermic Terric Haplosaprists
Portsmouth	Pt	Fine-loamy over sandy or sandy skeletal, mixed, thermic Typic Umbraquults
Pungo	Pu PuA	Dysic, thermic Medisaprists
Roanoke	Ro	Fine, mixed, semi-active, thermic Typic Endoaquults
Roper	Rp RoA	Fine-silty, mixed, acid, thermic Histic Humaquepts
Scuppernong	ScA Se	Loamy, mixed, dysic, thermic Terric Medisaprists
State	StB	Fine-loamy, mixed, semi-active, thermic Typic Hapudults
Tomotley	To	Fine-loamy, mixed, thermic Typic Endoaquults
Wahee	WaA	Fine, mixed, semi-active, thermic Aeric Endoaquults
Wasda	Wd	Fine-loamy, mixed, acid, thermic Histic Humaquepts
Weeksville	Wk WkA	Coarse-silty, mixed, acid, thermic Typic Humaquepts
Wysocking	WyA	Coarse-silty, mixed, super-active, acid, thermic Thapto-Histic Fluvaquents
Yeopim	YeA	Fine-silty, mixed, thermic Aquic Hapludults

Table 2. Classification of Soils on PLNWR

Soil series	***Map symbol***	***Soil Classification***
Acredale	AcA	Fine-silty, mixed, thermic Typic Endoaqualfs
Altavista	AaA	fine-loamy, mixed, semi-active, thermic Aquic Hapludults
Arapahoe	Ap	Coarse-loamy, mixed, nonacid, thermic Typic Humaquepts
Argent	Ar	Fine, mixed, thermic, Typic Endoaqualfs
Augusta	At	Fine-loamy, mixed, thermic, Aeric Endoaquults
Belhaven	Ba BmA BnA	Loamy, mixed, dysic, thermic Terric Medisaprists
Cape Fear	Cf	Fine, mixed, thermic Typic Umbraquults
Chowan	Ch	Fine-silty, mixed, nonacid, thermic Thapto-Histic Fluvaquents
Conaby	Co CoA	Coarse-loamy, mixed, nonacid, thermic Histic Humaquepts
Conetoe	CtA	Loamy, mixed, thermic Arenic Hapludults
Dorovan	Do DoA	Dysic, thermic Typic Haplosaprists
Fortescue	Fo FoA	Fine-silty, mixed, acid, thermic Cumulic Humaquepts
Hyde	Hy	Fine-silty, mixed, active, thermic Typic Umbraquults
Hydeland	HyA	Fine-silty, mixed, thermic Typic Umbraqualfs
Longshoal	LfA	Euic, typic, thermic Medisaprists
Newholland	NeA	Coarse, loamy, mixed, acid, thermic Cumulic Humaquepts
Perquimans	Pe (Tyrrell)	Fine-silty, mixed, thermic Typic Endoaquults

Table 2 --- continued

Pettigrew	Pe (Wash.)	Fine, mixed, nonacid, thermic Histic Humaquepts
Ponzer	Po PnA	Loamy, mixed, dysic, thermic Terric Haplosaprists
Portsmouth	Pt	Fine-loamy over sandy or sandy skeletal, mixed, thermic Typic Umbraquults
Pungo	Pu PuA	Dysic, thermic Medisaprists
Roanoke	Ro	Fine, mixed, semi-active, thermic Typic Endoaquults
Roper	Rp RoA	Fine-silty, mixed, acid, thermic Histic Humaquepts
Scuppernong	ScA Se	Loamy, mixed, dysic, thermic Terric Medisaprists
State	StB	Fine-loamy, mixed, semi-active, thermic Typic Hapudults
Tomotley	To	Fine-loamy, mixed, thermic Typic Endoaquults
Wahee	WaA	Fine, mixed, semi-active, thermic Aeric Endoaquults
Wasda	Wd	Fine-loamy, mixed, acid, thermic Histic Humaquepts
Weeksville	Wk WkA	Coarse-silty, mixed, acid, thermic Typic Humaquepts
Wysocking	WyA	Coarse-silty, mixed, super-active, acid, thermic Thapto-Histic Fluvaquents
Yeopim	YeA	Fine-silty, mixed, thermic Aquic Hapludults

Table 3. Soils on PLNWR, and recommended tree species

Soil series	*Map symbol*	*Acres*	*Surface texture & depth (in)*	*Subsoil texture*	**Recommended** *species* [1]	*Site index* [2]
Acredale	AcA	2	silty	sandy	LP	96
Altavista	AaA	59	sandy -- 9	loamy	LP, LLP	91
Arapahoe	Ap	33	sandy -- 13	sandy	LP, S	95
Argent	Ar	41	silt loam -- 9	clayey	LP, O, S	96
Augusta	At	65	sandy -- 16	clayey	LP, S, RB	90
Bellhaven	Ba (Tyrrel)	6,533	muck (40-43)	sandy; then clayey	AWC, C, PP	
	BmA	7,086	(")	(")	(")	
	BnA	791	muck -- 26	sandy, then clayey; then sandy	AWC, C, BG	
	Ba (Wash.)	1,928	(")	(")	(")	
Cape Fear	Cf	648	loam -- 14	clayey	LP, O, S, A	100
Chowan (flood plains)	Ch	2	loam -- 25	sapric	C, WT, BG, A	
Conaby	Co CoA	44 418	muck -- 13	sandy	AWC, C, BG	
Conetoe	CtA	7	sandy (22-28)	sandy	LP, LLP	80
Dorovan (flood plains)	Do	3,254	muck (90+)	--	C, BG, WT	
	DoA	422	muck -- 70	--	(")	
Fortescue	Fo FoA	4 32	silt loam -- 10	**???**	LP, O, A	107
Hyde	Hy	1300	loam --24	loamy	LP, O, A	96
Hydeland	HyA	7	silt loam -- 11	variable	LP, O, A	107
Longshoal	LfA	12	mucky peat -- 72	---	AWC, C, PP	
Newholland	NeA	401	mucky loamy sand -- 19	sandy	AWC, C, A	

Perquimans	Pe (Tyrrell)	137	Loam -- 7	loamy	LP, O, A	94
Pettigrew	Pe (Wash.)	539	muck -- 15	clayey	C, AWC, BG	
Ponzer	Po PnA	812 2,318	muck -- 30 muck -- 21	clayey, then sandy loamy	AWC, C, BG (")	
Portsmouth	Pt	254	Loam (14-18)	sandy	LP, O, A	96
Pungo	Pu PuA	55,894 14,770	Muck (65-80)	clayey	AWC, C, PP	95
Roanoke	Ro	35	Loam -- 6	clayey	LP, O, A	86
Roper	Rp RoA	142 77	Muck (10-13)	silty, clayey variable	AWC, C, BG	
Scuppernong	ScA Se	5,378 593	muck (28-33)	silty, clayey	AWC, C, BG, PP	
State	StB	2	sandy -- 7	loamy	O, S, LP	95
Tomotley	To	286	sandy -- 8	clayey	LP, YP, O, A	94
Wahee	WaA	245	Loam-5	clayey	LP, O, A, S	86
Wasda	Wd	455	Muck (12-15)	loamy	AWC, C, BG, O, A	
Weeksville	Wk WkA	563 127	silty; sandy -- 42 loam -- 13	sandy loamy	LP, O, A (")	90
Wysocking	WyA	2	sandy-29	muck	W, Pers, RB	94
Yeopim	YeA	6	silty -- 3	variable	S, A	91

[1] **Species**: white cedar (AWC), bald cypress (C), swamp blackgum (BG), ash (A), loblolly pine (LP); longleaf pine (LLP); pond pine (PP); yellow-poplar (YP); sycamore (S); water tupelo (WT), persimmon (Per), river birch (RB); Oaks, including water oak, willow oak, swamp white oak, and cherrybark (O).

[2] For loblolly pine (50 years).

Table 3. Soils on PLNWR, and recommended tree species

Soil series	***Map symbol***	***Acres***	***Surface texture & depth (in)***	***Subsoil texture***	**Recommended *species*** [1]	***Site index*** [2]
Acredale	AcA	2	silty	sandy	LP	96
Altavista	AaA	59	sandy -- 9	loamy	LP, LLP	91
Arapahoe	Ap	33	sandy -- 13	sandy	LP, S	95
Argent	Ar	41	silt loam -- 9	clayey	LP, O, S	96
Augusta	At	65	sandy -- 16	clayey	LP, S, RB	90
Bellhaven	Ba (Tyrrel)	6,533	muck (40-43)	sandy; then clayey	AWC, C, PP	
	BmA	7,086	(")	(")	(")	
	BnA	791	muck -- 26	sandy, then clayey; then sandy	AWC, C, BG	
	Ba (Wash.)	1,928	(")	(")	(")	
Cape Fear	Cf	648	loam -- 14	clayey	LP, O, S, A	100
Chowan (flood plains)	Ch	2	loam -- 25	sapric	C, WT, BG, A	
Conaby	Co CoA	44 418	muck -- 13	sandy	AWC, C, BG	
Conetoe	CtA	7	sandy (22-28)	sandy	LP, LLP	80
Dorovan (flood plains)	Do	3,254	muck (90+)	--	C, BG, WT	
	DoA	422	muck -- 70	--	(")	
Fortescue	Fo FoA	4 32	silt loam -- 10	**???**	LP, O, A	107
Hyde	Hy	1300	loam --24	loamy	LP, O, A	96
Hydeland	HyA	7	silt loam -- 11	variable	LP, O, A	107
Longshoal	LfA	12	mucky peat -- 72	---	AWC, C, PP	
Newholland	NeA	401	mucky loamy sand -- 19	sandy	AWC, C, A	

Perquimans	Pe (Tyrrell)	137	Loam -- 7	loamy	LP, O, A	94
Pettigrew	Pe (Wash.)	539	muck -- 15	clayey	C, AWC, BG	
Ponzer	Po	812	muck -- 30	clayey, then sandy	AWC, C, BG	
	PnA	2,318	muck -- 21	loamy	(")	
Portsmouth	Pt	254	Loam (14-18)	sandy	LP, O, A	96
Pungo	Pu PuA	55,894 14,770	Muck (65-80)	clayey	AWC, C, PP	95
Roanoke	Ro	35	Loam -- 6	clayey	LP, O, A	86
Roper	Rp RoA	142 77	Muck (10-13)	silty, clayey variable	AWC, C, BG	
Scuppernong	ScA Se	5,378 593	muck (28-33)	silty, clayey	AWC, C, BG, PP	
State	StB	2	sandy -- 7	loamy	O, S, LP	95
Tomotley	To	286	sandy -- 8	clayey	LP, YP, O, A	94
Wahee	WaA	245	Loam-5	clayey	LP, O, A, S	86
Wasda	Wd	455	Muck (12-15)	loamy	AWC, C, BG, O, A	
Weeksville	Wk	563	silty; sandy -- 42	sandy	LP, O, A	90
	WkA	127	loam -- 13	loamy	(")	
Wysocking	WyA	2	sandy-29	muck	W, Pers, RB	94
Yeopim	YeA	6	silty -- 3	variable	S, A	91

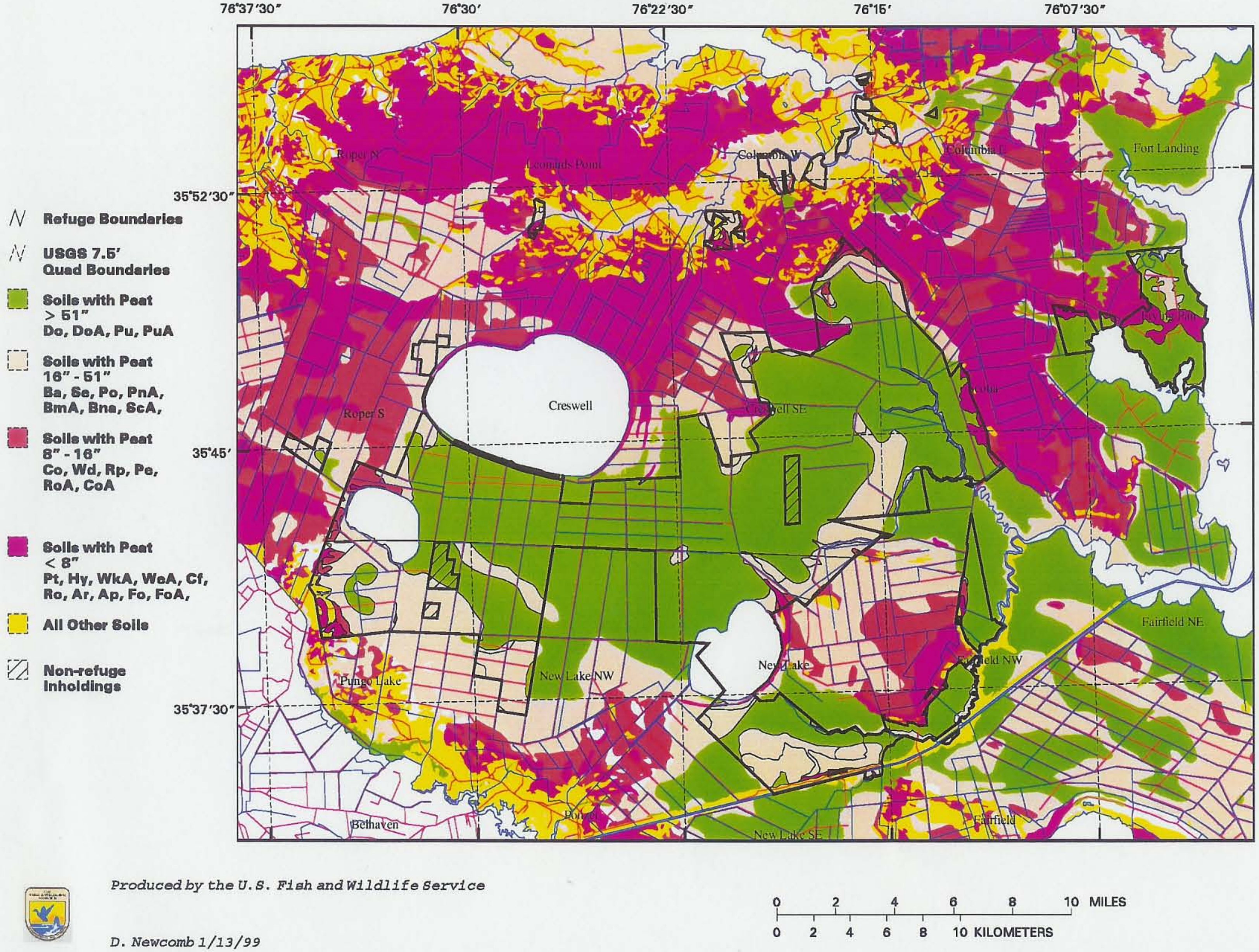
[1] **Species**: white cedar (AWC), bald cypress (C), swamp blackgum (BG), ash (A), loblolly pine (LP); longleaf pine (LLP); pond pine (PP); yellow-poplar (YP); sycamore (S); water tupelo (WT), persimmon (Per), river birch (RB); Oaks, including water oak, willow oak, swamp white oak, and cherrybark (O).

[2] For loblolly pine (50 years).

Appendix — 62

POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries



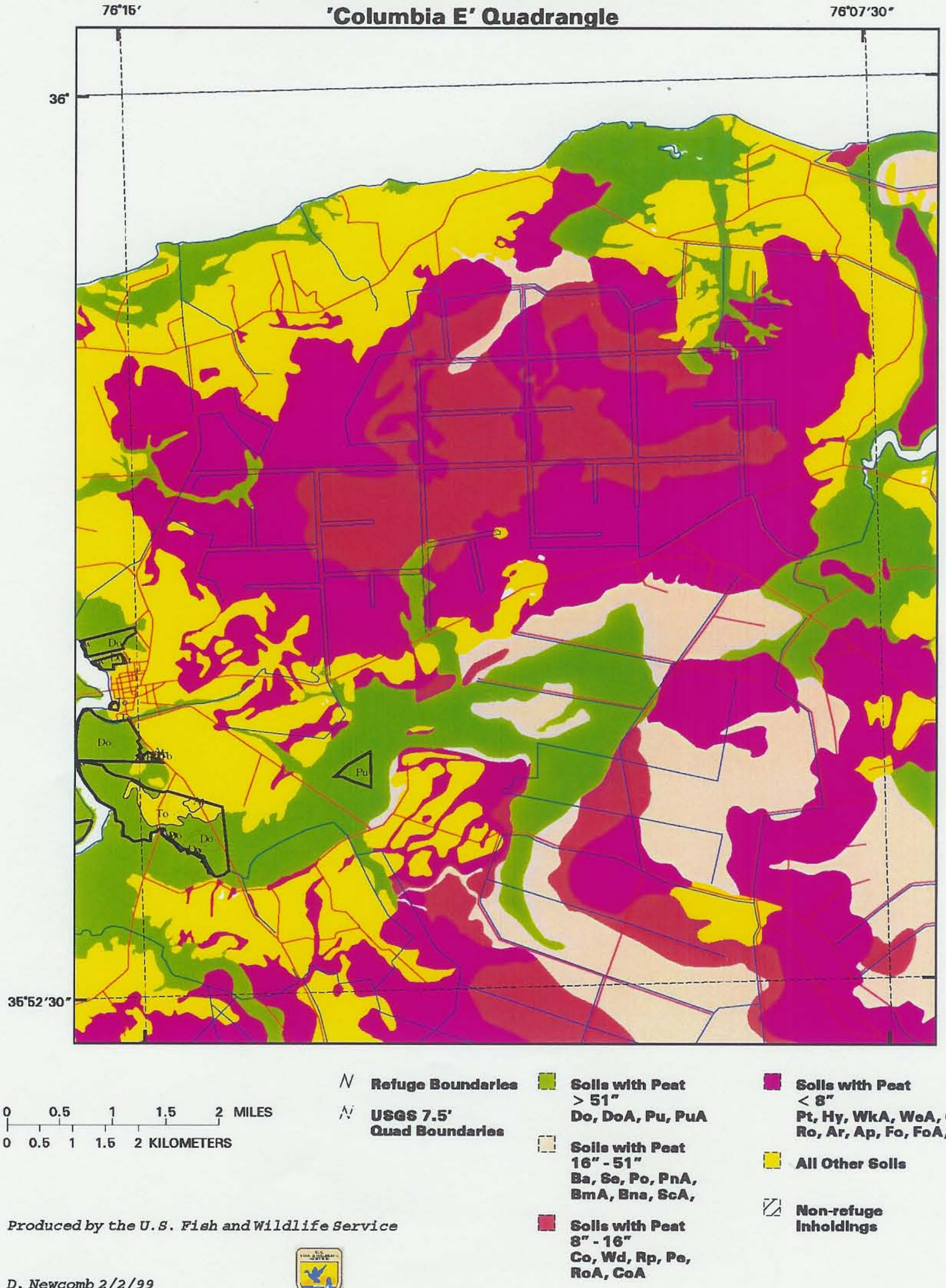
Produced by the U. S. Fish and Wildlife Service

D. Newcomb 1/13/99

POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Columbia E' Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

- Refuge Boundaries
- USGS 7.5' Quad Boundaries
- Soils with Peat > 51" — Do, DoA, Pu, PuA
- Soils with Peat 16" - 51" — Ba, Se, Po, PnA, BmA, Bna, ScA,
- Soils with Peat 8" - 16" — Co, Wd, Rp, Pe, RoA, CoA
- Soils with Peat < 8" — Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
- All Other Soils
- Non-refuge Inholdings

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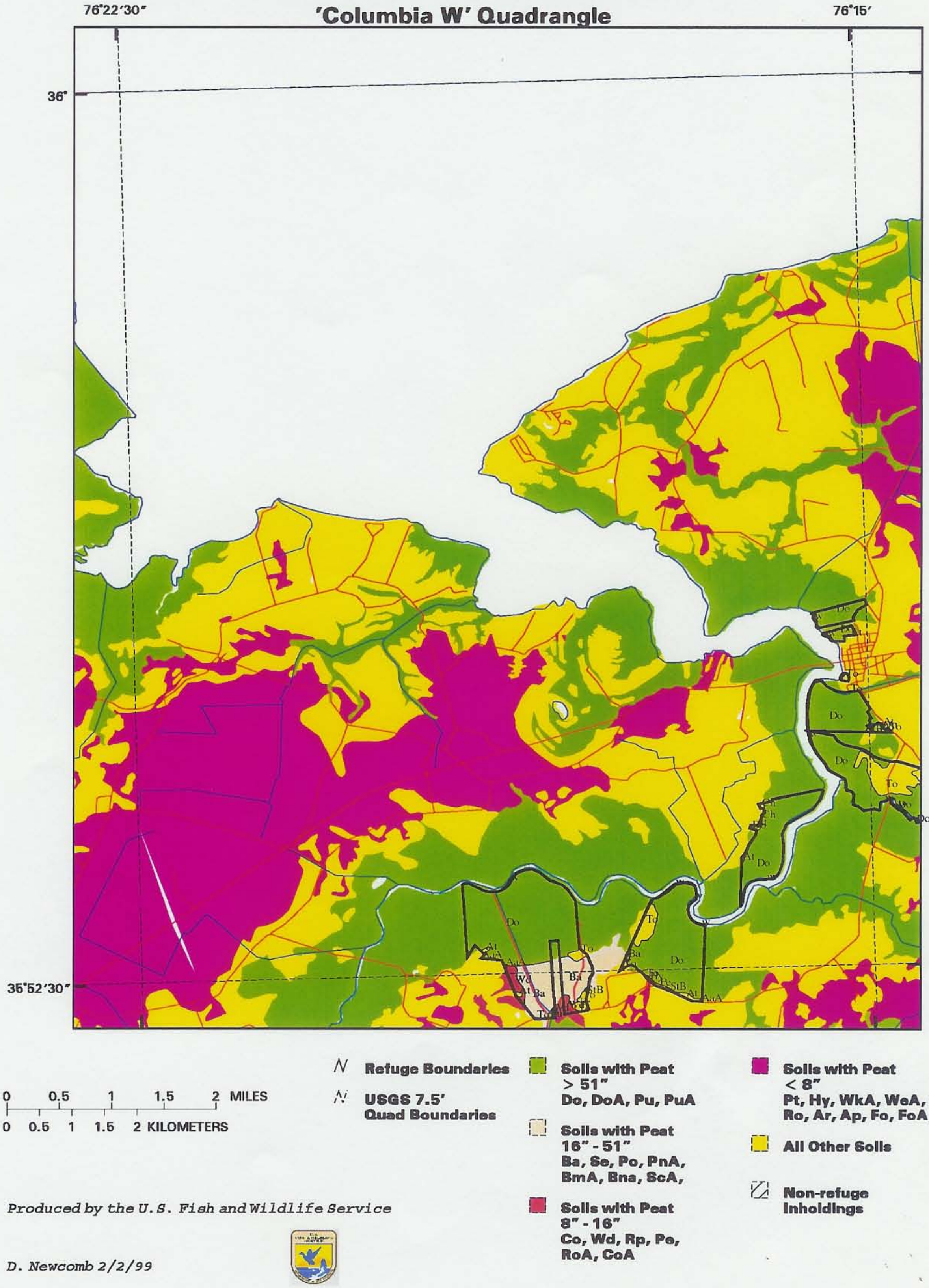
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Columbia W' Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Refuge Boundaries

USGS 7.5' Quad Boundaries

Soils with Peat > 51"
Do, DoA, Pu, PuA

Soils with Peat 16" - 51"
Ba, Se, Po, PnA, BmA, Bna, ScA,

Soils with Peat 8" - 16"
Co, Wd, Rp, Pe, RoA, CoA

Soils with Peat < 8"
Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,

All Other Soils

Non-refuge Inholdings

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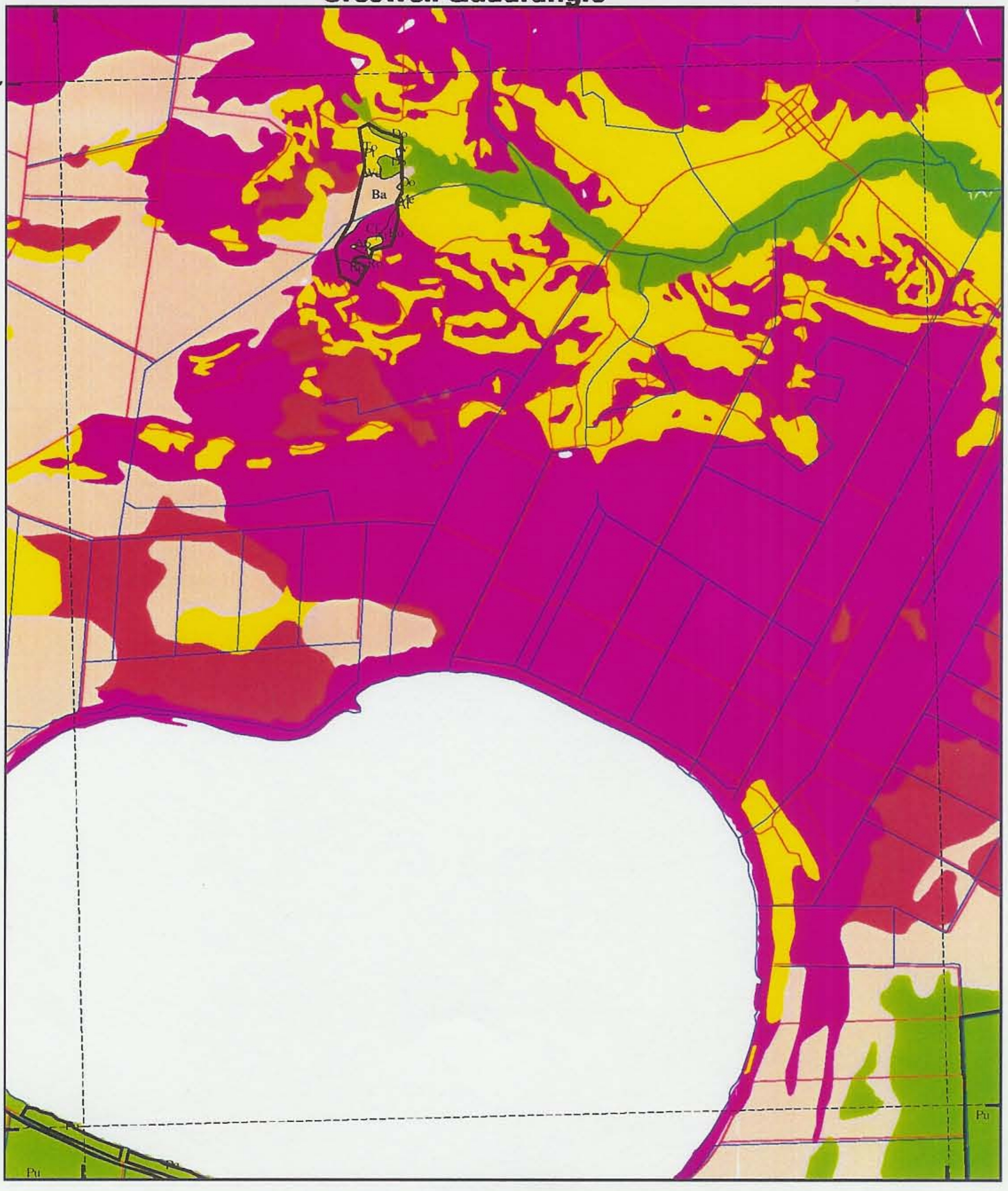
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

Creswell Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

- Refuge Boundaries
- USGS 7.5′ Quad Boundaries
- **Soils with Peat > 51″** Do, DoA, Pu, PuA
- **Soils with Peat 16″ - 51″** Ba, Se, Po, PnA, BmA, Bna, ScA,
- **Soils with Peat 8″ - 16″** Co, Wd, Rp, Pe, RoA, CoA
- **Soils with Peat < 8″** Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
- **All Other Soils**
- **Non-refuge Inholdings**

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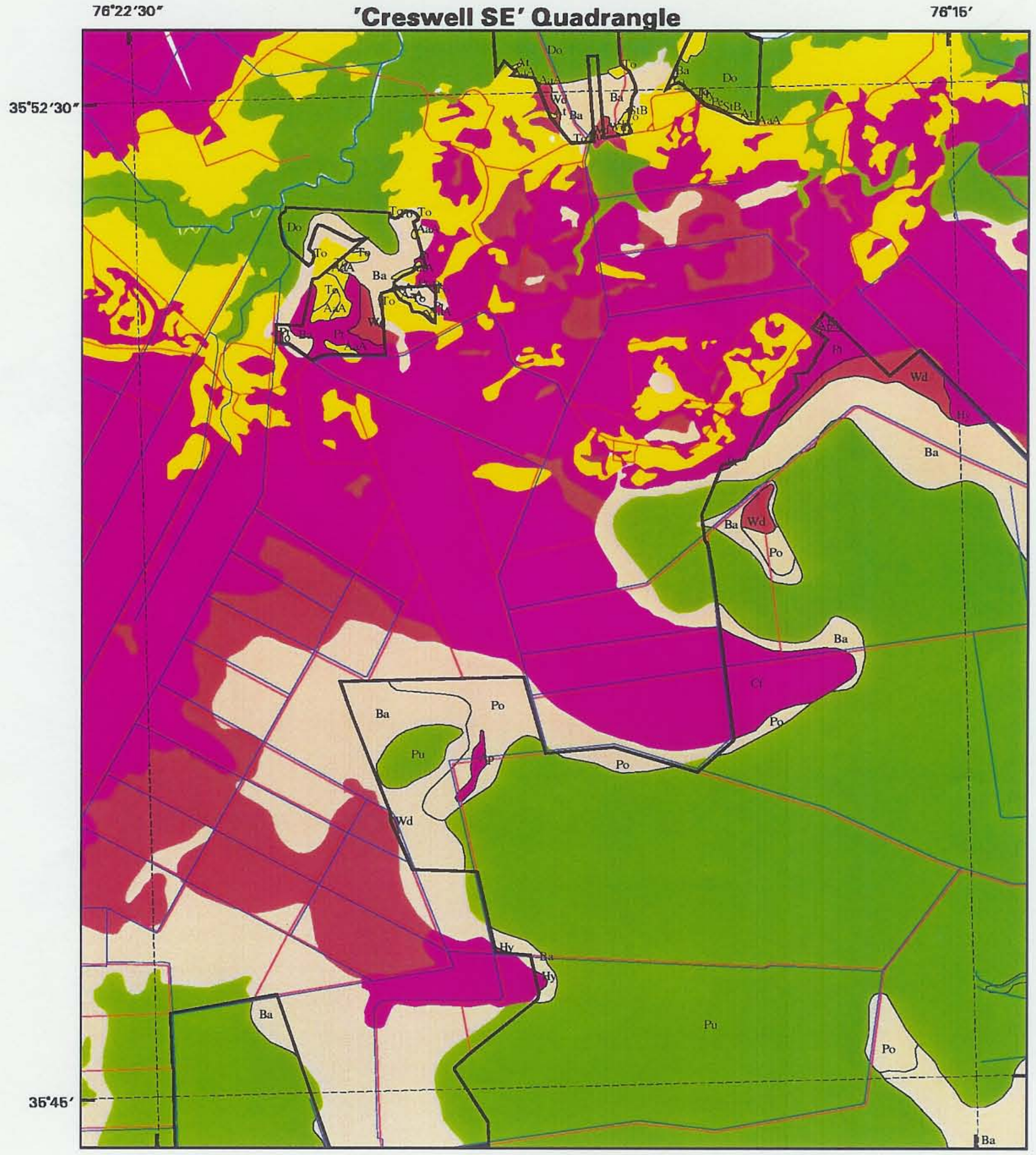
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Creswell SE' Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Refuge Boundaries

USGS 7.5' Quad Boundaries

Soils with Peat > 51"
Do, DoA, Pu, PuA

Soils with Peat 16" - 51"
Ba, Se, Po, PnA, BmA, Bna, ScA,

Soils with Peat 8" - 16"
Co, Wd, Rp, Pe, RoA, CoA

Soils with Peat < 8"
Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,

All Other Soils

Non-refuge Inholdings

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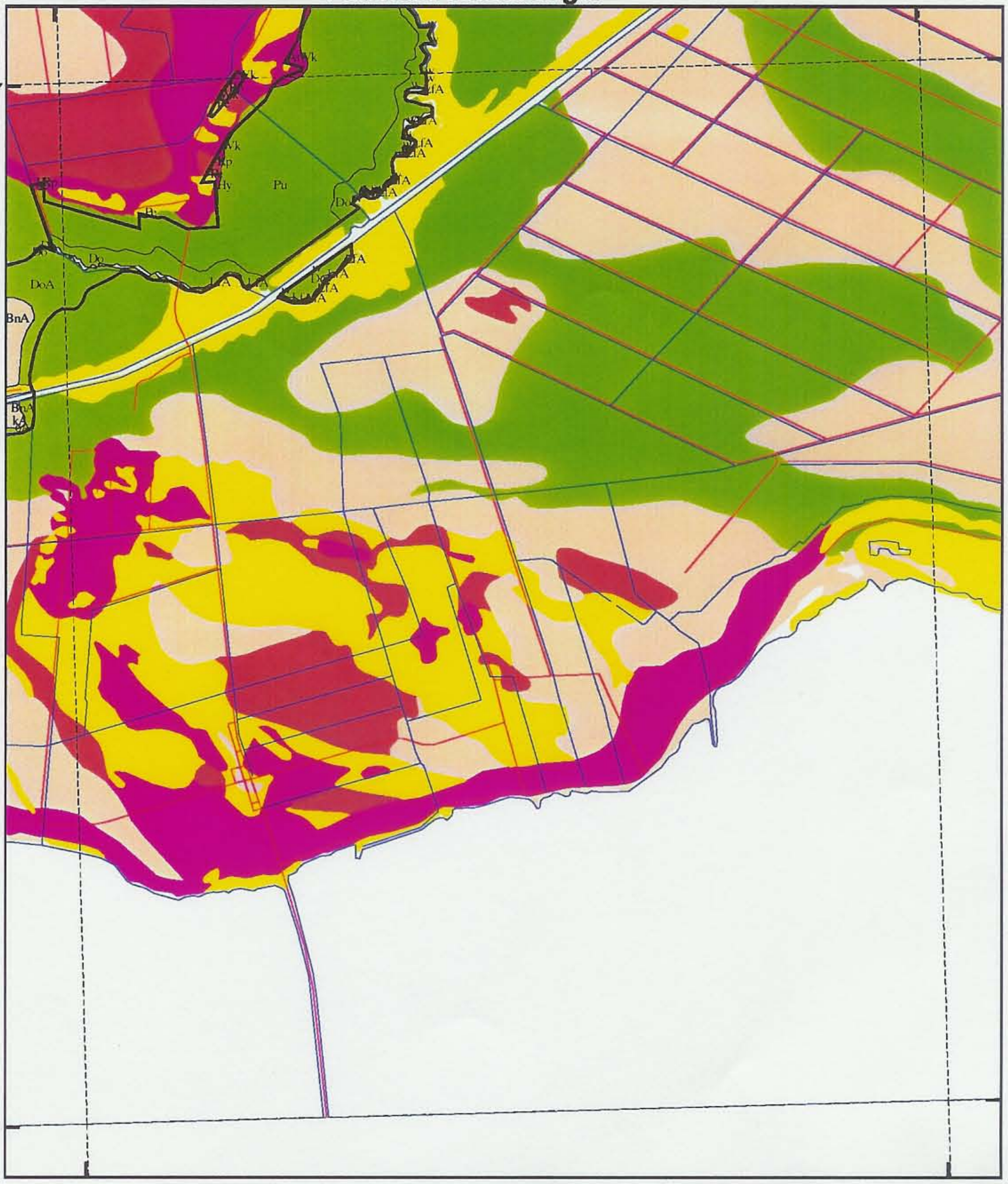
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

Fairfield Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

- Refuge Boundaries
- USGS 7.5' Quad Boundaries
- **Soils with Peat > 51"** Do, DoA, Pu, PuA
- **Soils with Peat 16" - 51"** Ba, Se, Po, PnA, BmA, Bna, ScA,
- **Soils with Peat 8" - 16"** Co, Wd, Rp, Pe, RoA, CoA
- **Soils with Peat < 8"** Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
- **All Other Soils**
- **Non-refuge Inholdings**

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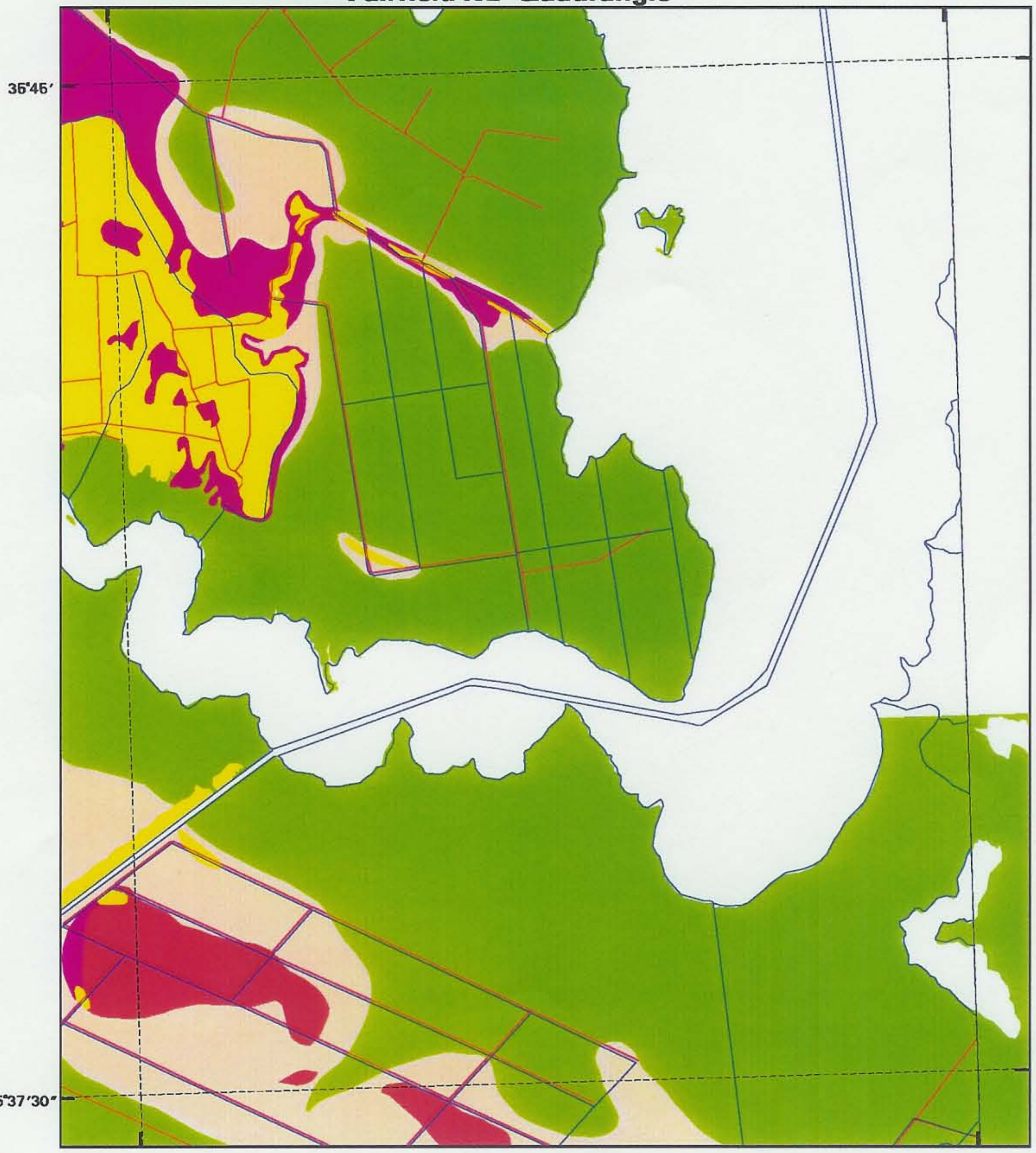
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Fairfield NE' Quadrangle



Refuge Boundaries

USGS 7.5' Quad Boundaries

Soils with Peat > 51" Do, DoA, Pu, PuA

Soils with Peat 16" - 51" Ba, Se, Po, PnA, BmA, Bna, ScA,

Soils with Peat 8" - 16" Co, Wd, Rp, Pe, RoA, CoA

Soils with Peat < 8" Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,

All Other Soils

Non-refuge Inholdings

0 0.5 1 1.5 2 MILES

0 0.5 1 1.5 2 KILOMETERS

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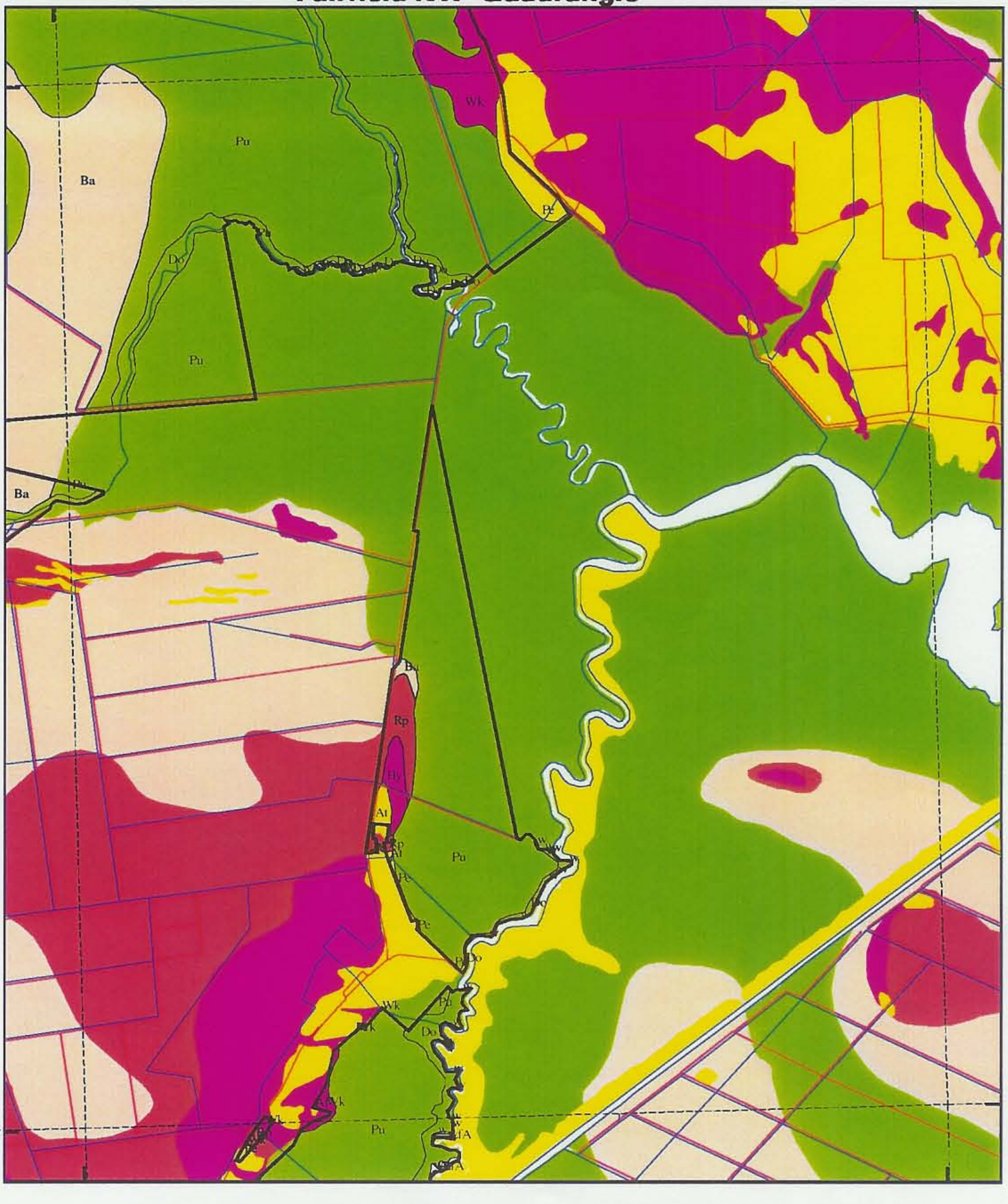
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Fairfield NW' Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Refuge Boundaries

USGS 7.5′ Quad Boundaries

Soils with Peat > 51″
Do, DoA, Pu, PuA

Soils with Peat 16″ - 51″
Ba, Se, Po, PnA, BmA, Bna, ScA,

Soils with Peat 8″ - 16″
Co, Wd, Rp, Pe, RoA, CoA

Soils with Peat < 8″
Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,

All Other Soils

Non-refuge Inholdings

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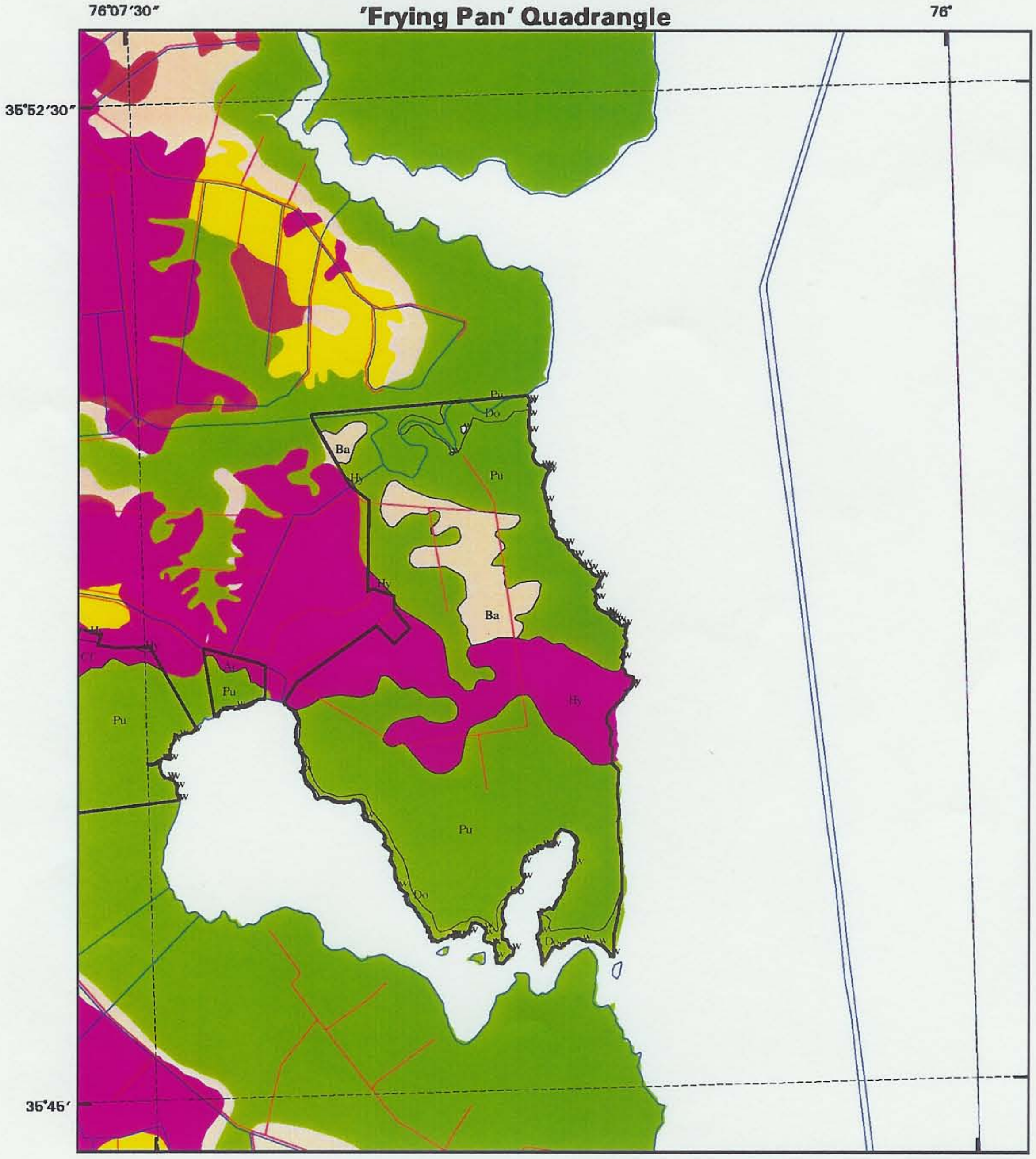
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Frying Pan' Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

- Refuge Boundaries
- USGS 7.5' Quad Boundaries
- **Soils with Peat > 51"** Do, DoA, Pu, PuA
- **Soils with Peat 16" - 51"** Ba, Se, Po, PnA, BmA, Bna, ScA,
- **Soils with Peat 8" - 16"** Co, Wd, Rp, Pe, RoA, CoA
- **Soils with Peat < 8"** Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
- **All Other Soils**
- **Non-refuge Inholdings**

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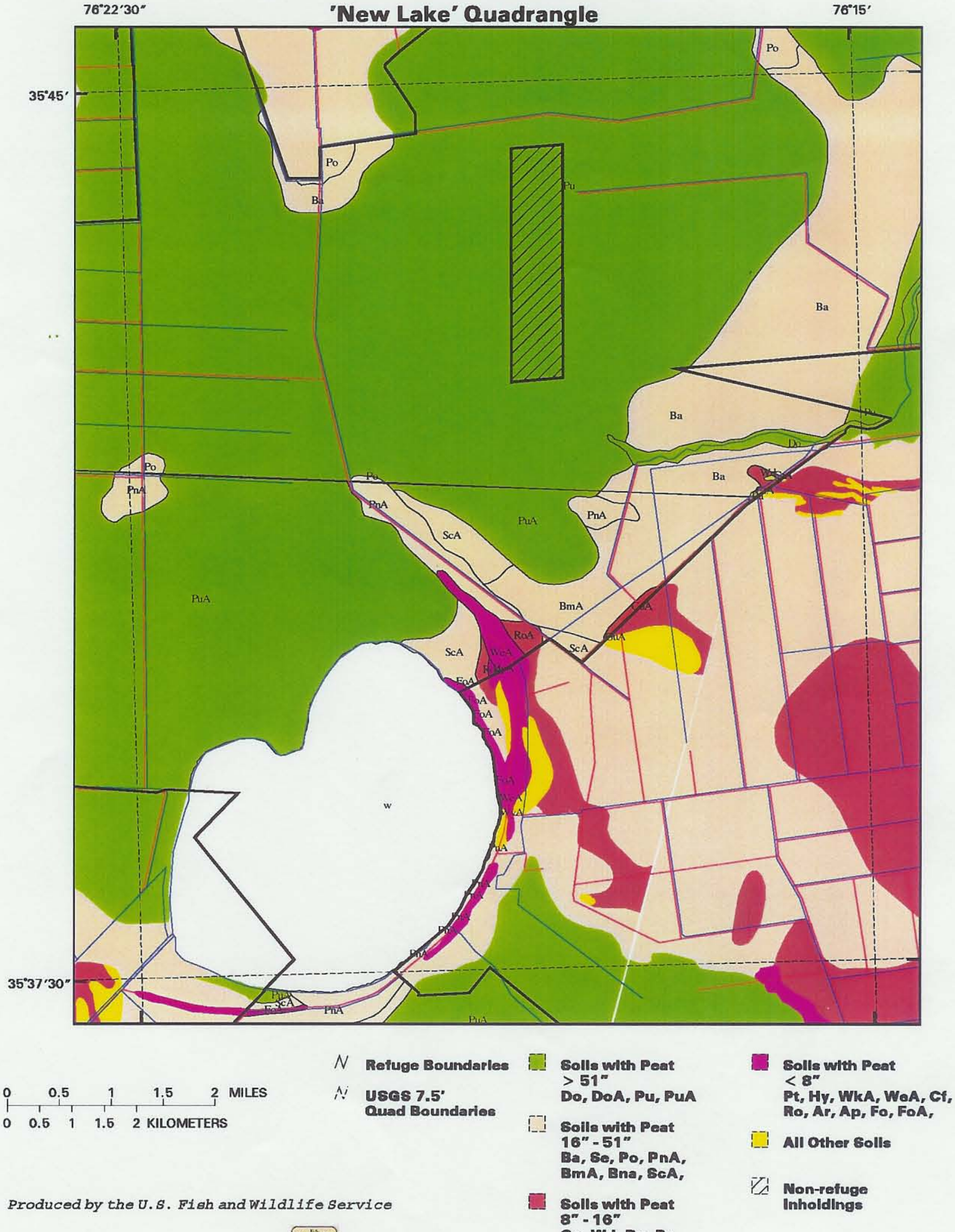
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'New Lake' Quadrangle



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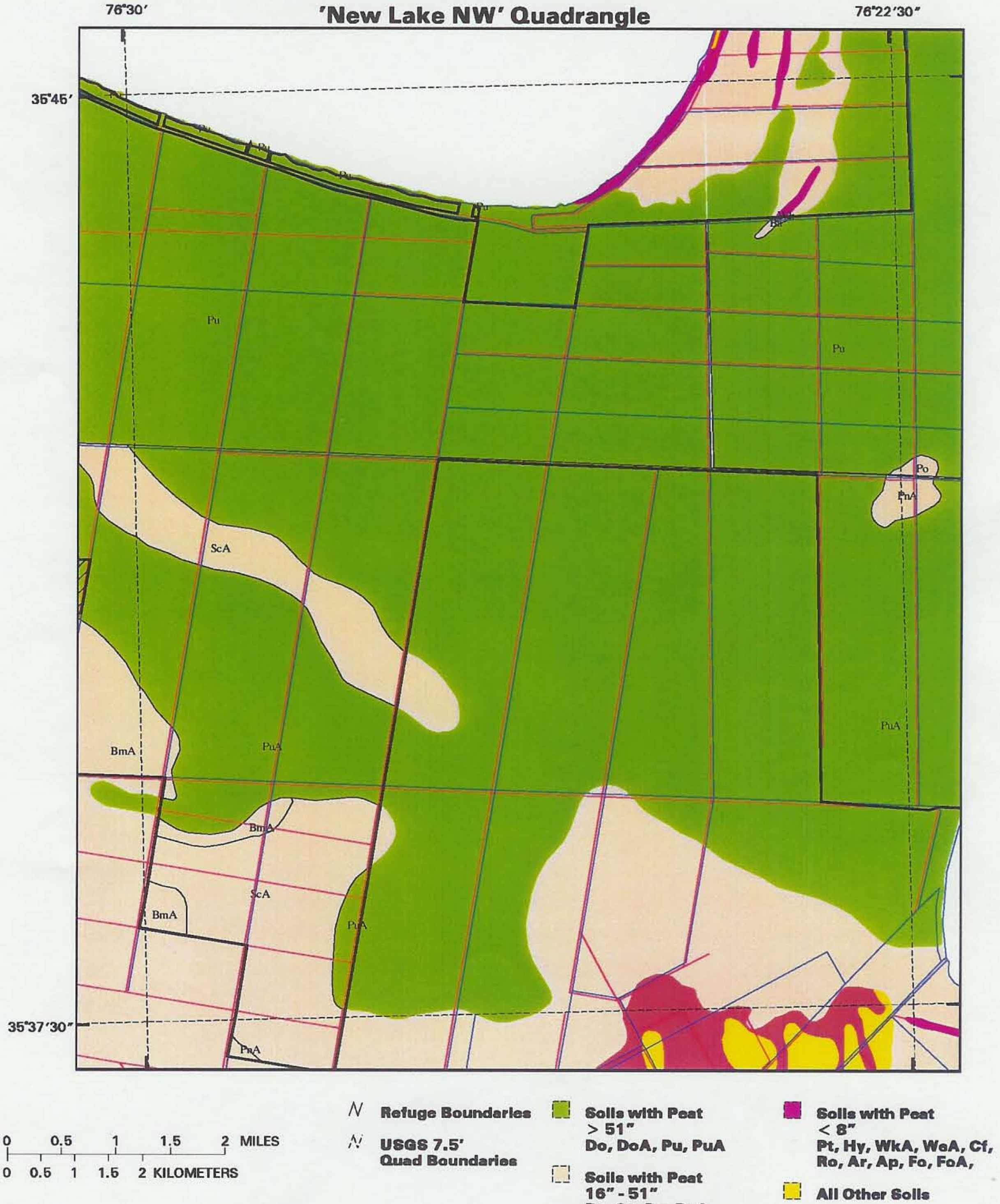
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'New Lake NW' Quadrangle



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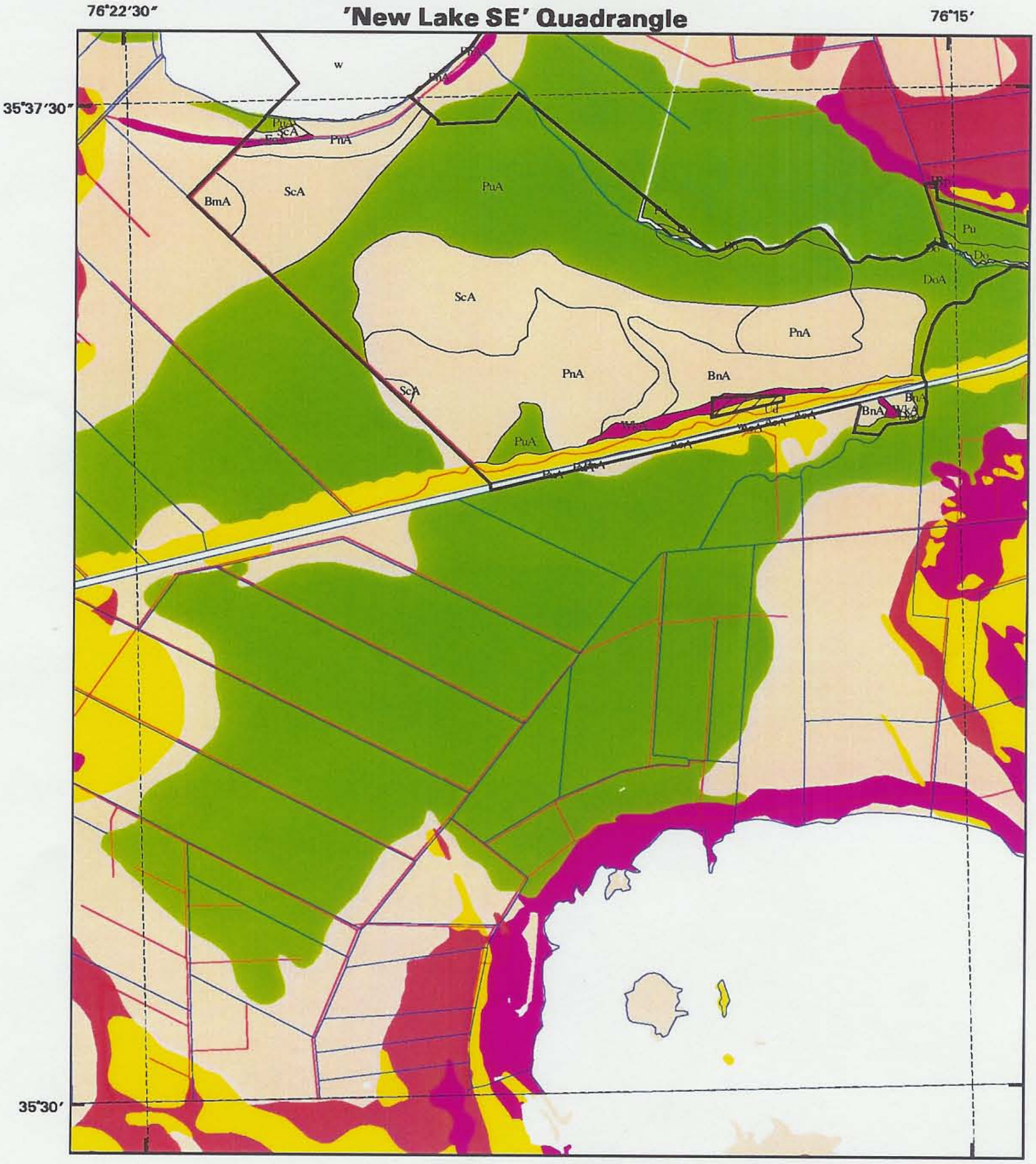
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'New Lake SE' Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Refuge Boundaries

USGS 7.5' Quad Boundaries

Soils with Peat > 51"
Do, DoA, Pu, PuA

Soils with Peat 16" - 51"
Ba, Se, Po, PnA, BmA, Bna, ScA,

Soils with Peat 8" - 16"
Co, Wd, Rp, Pe, RoA, CoA

Soils with Peat < 8"
Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,

All Other Soils

Non-refuge Inholdings

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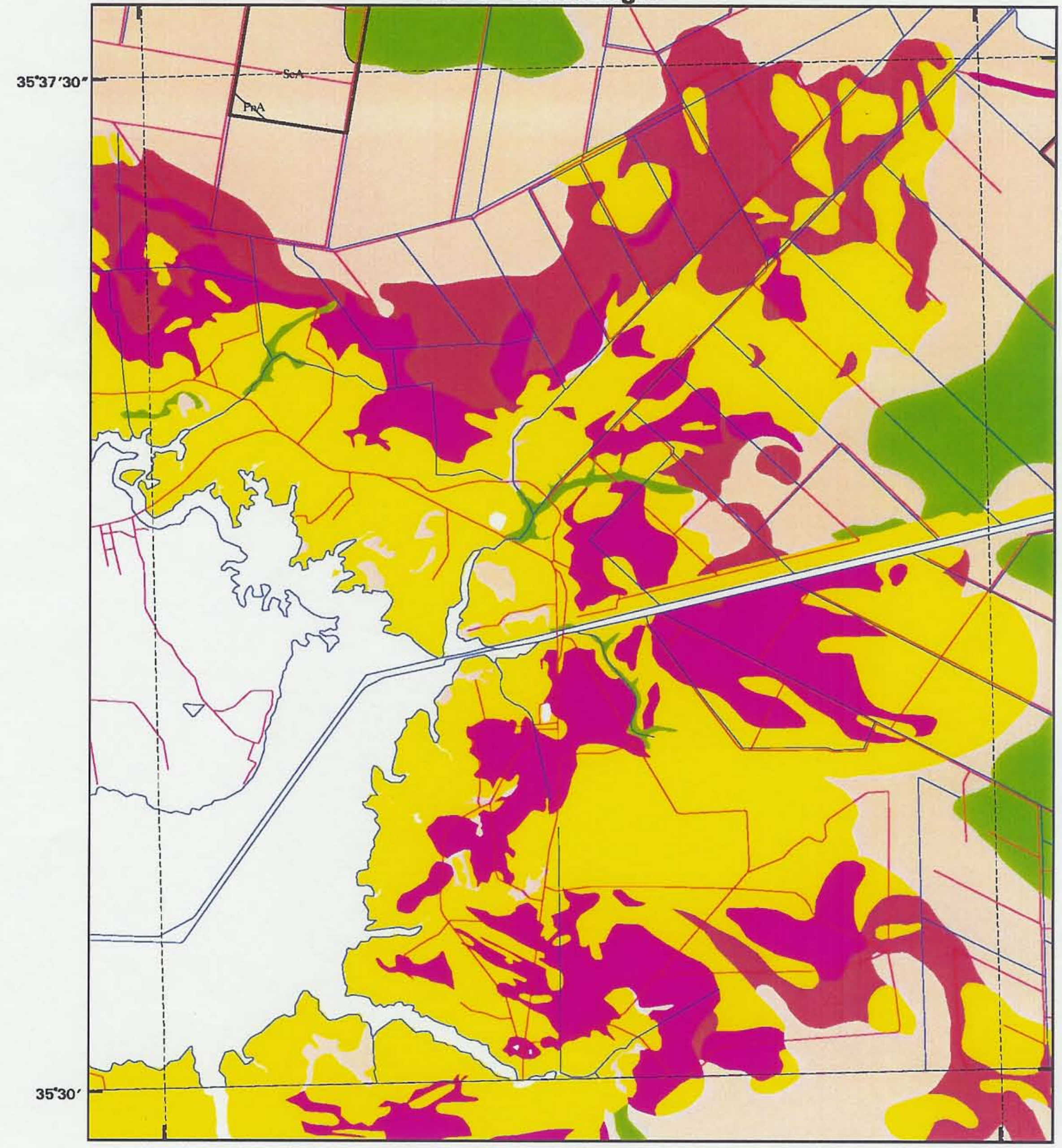
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

76°30′ **Ponzer Quadrangle** 76°22′30″



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

Refuge Boundaries

USGS 7.5′ Quad Boundaries

Soils with Peat > 51″
Do, DoA, Pu, PuA

Soils with Peat 16″ - 51″
Ba, Se, Po, PnA, BmA, Bna, ScA,

Soils with Peat 8″ - 16″
Co, Wd, Rp, Pe, RoA, CoA

Soils with Peat < 8″
Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,

All Other Soils

Non-refuge Inholdings

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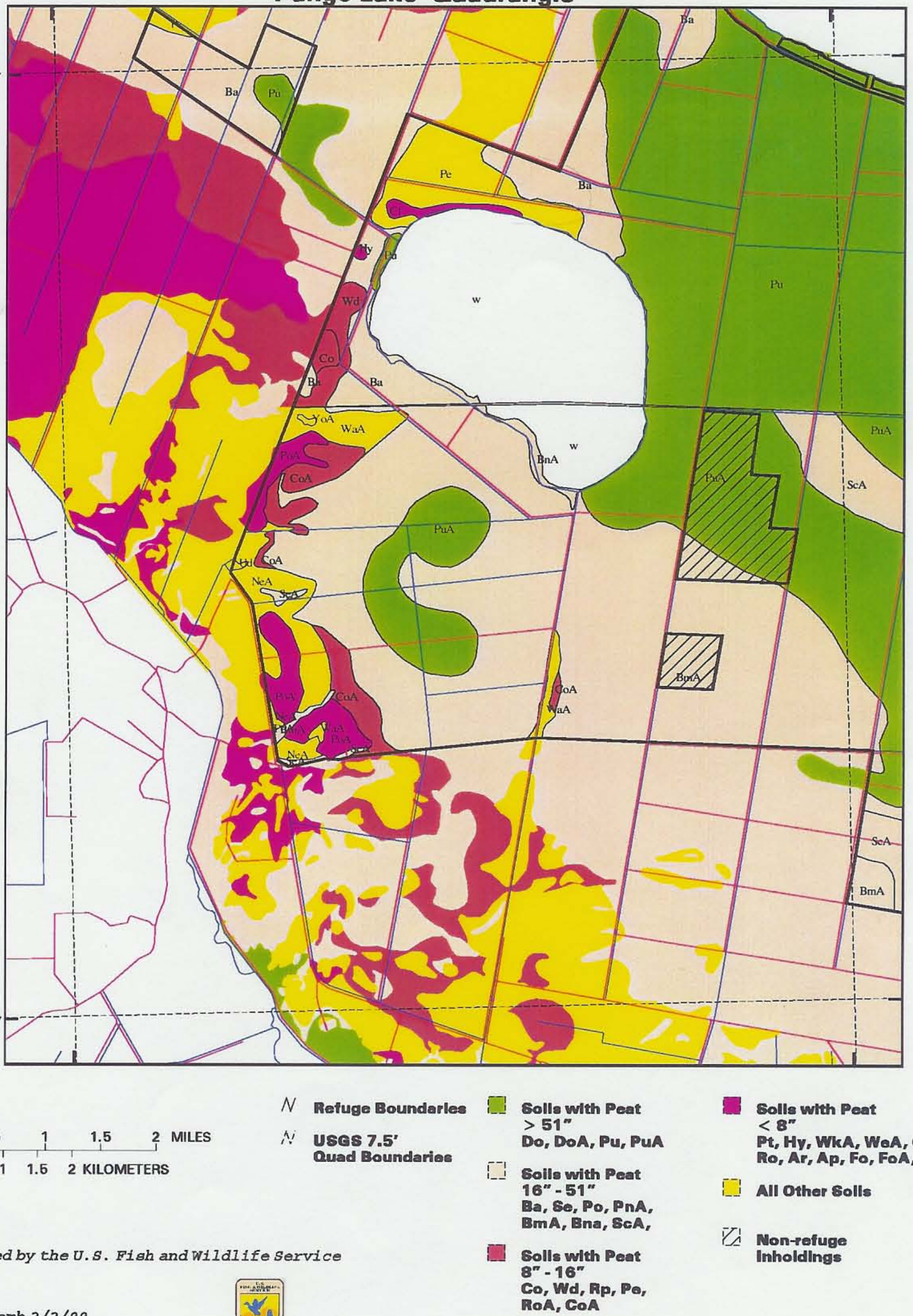
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Pungo Lake' Quadrangle



Symbol	Legend
N	**Refuge Boundaries**
N	**USGS 7.5' Quad Boundaries**
(green)	**Soils with Peat > 51"** Do, DoA, Pu, PuA
(tan)	**Soils with Peat 16" - 51"** Ba, Se, Po, PnA, BmA, Bna, ScA,
(red)	**Soils with Peat 8" - 16"** Co, Wd, Rp, Pe, RoA, CoA
(magenta)	**Soils with Peat < 8"** Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
(yellow)	**All Other Soils**
(hatched)	**Non-refuge Inholdings**

0 0.5 1 1.5 2 MILES

0 0.5 1 1.5 2 KILOMETERS

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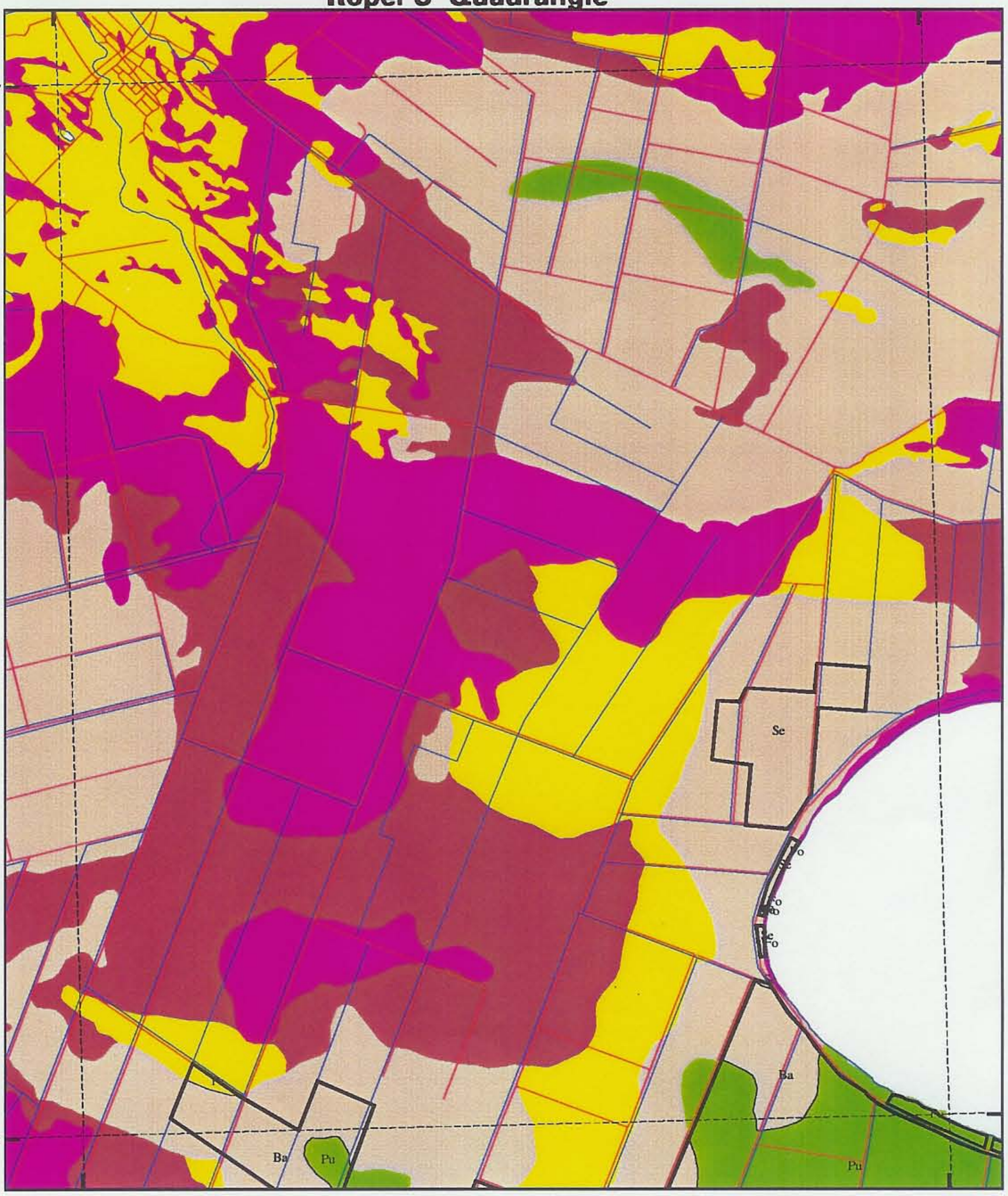
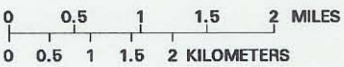
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

'Roper S' Quadrangle





- Refuge Boundaries
- USGS 7.5' Quad Boundaries
- Soils with Peat > 51" Do, DoA, Pu, PuA
- Soils with Peat 16" - 51" Ba, Se, Po, PnA, BmA, Bna, ScA,
- Soils with Peat 8" - 16" Co, Wd, Rp, Pe, RoA, CoA
- Soils with Peat < 8" Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
- All Other Soils
- Non-refuge Inholdings

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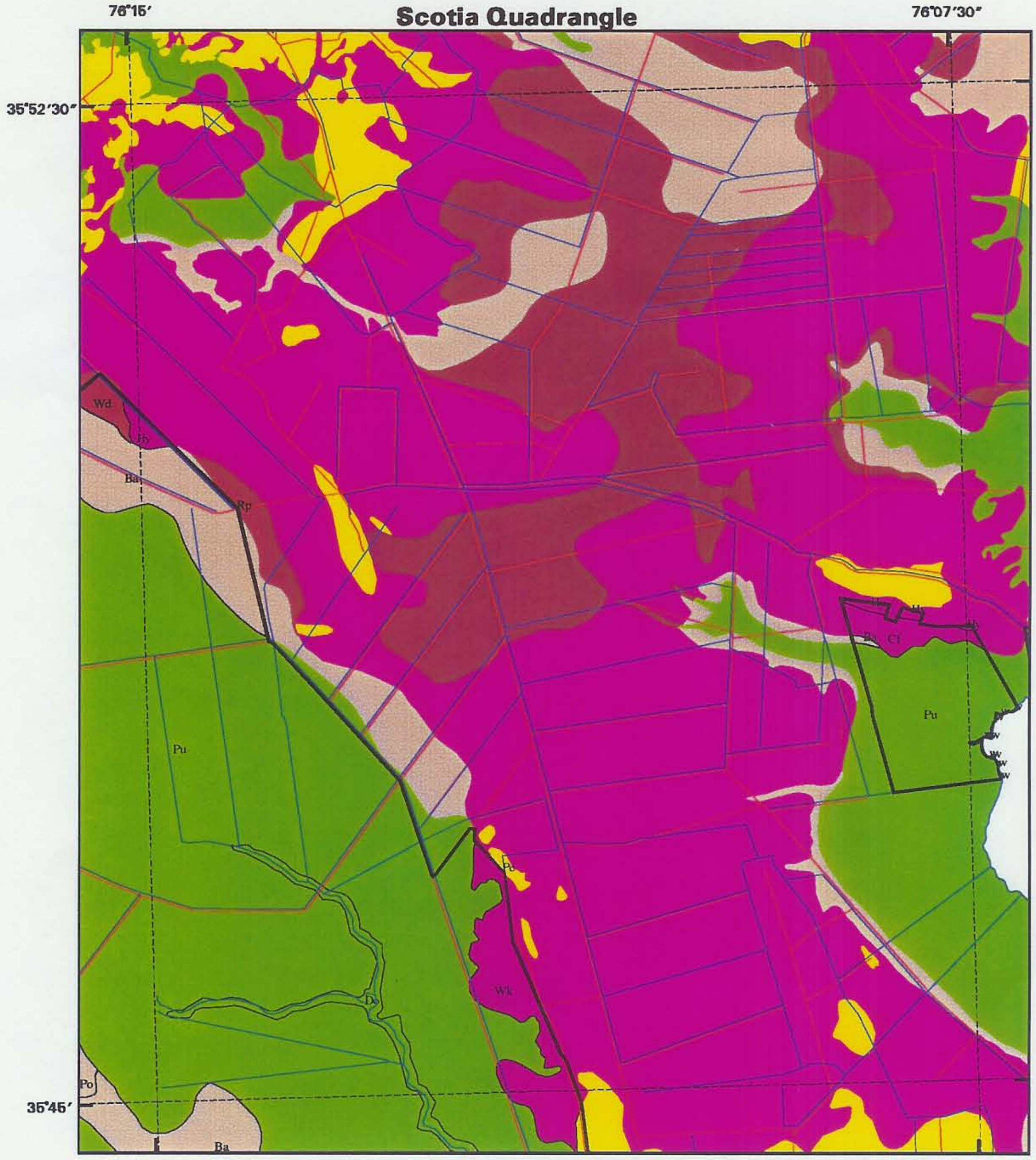
POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Soils, Refuge Boundaries, Quad Boundaries

Scotia Quadrangle



0 0.5 1 1.5 2 MILES
0 0.5 1 1.5 2 KILOMETERS

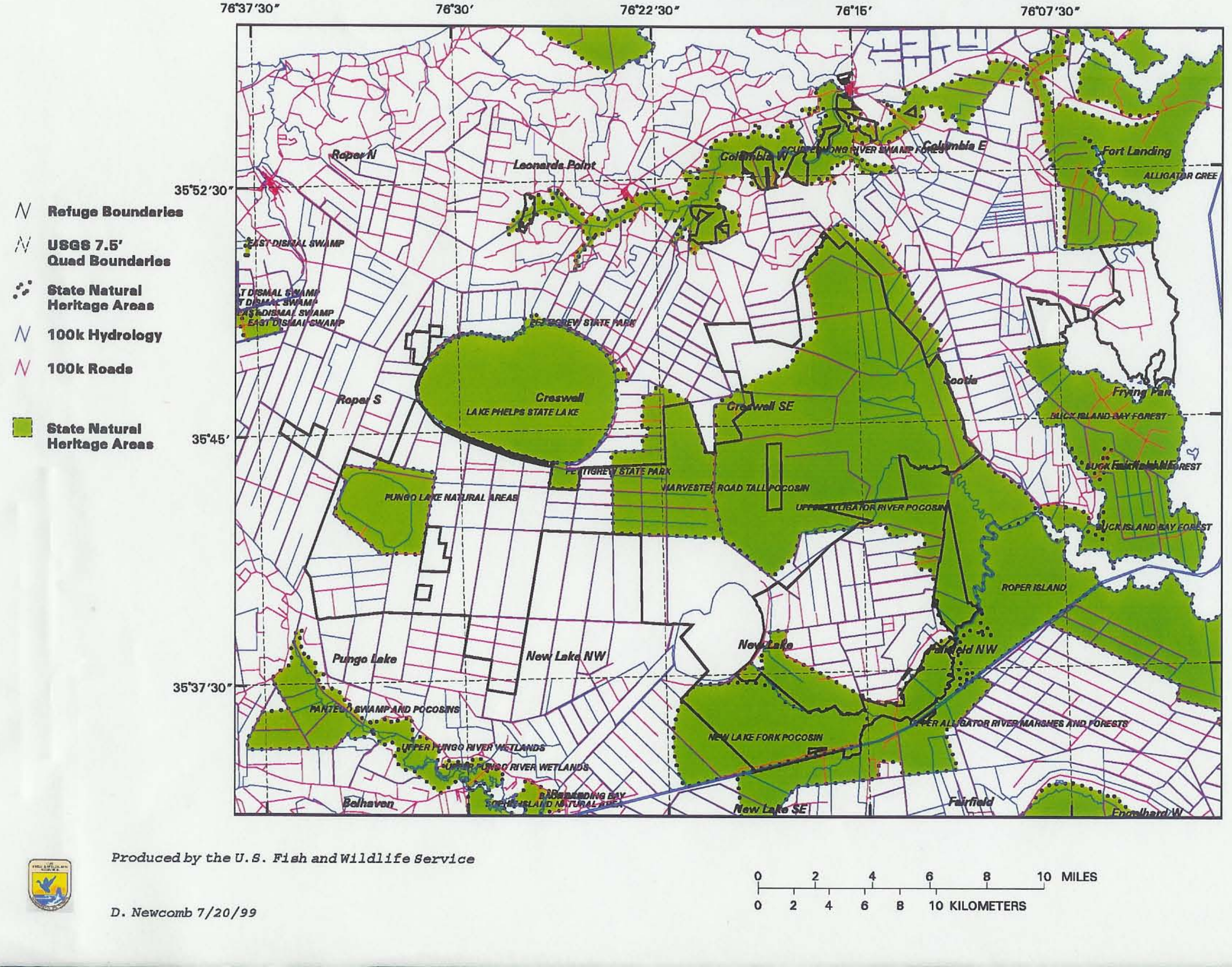
- **Refuge Boundaries**
- **USGS 7.5' Quad Boundaries**
- **Soils with Peat > 51"** Do, DoA, Pu, PuA
- **Soils with Peat 16" - 51"** Ba, Se, Po, PnA, BmA, Bna, ScA,
- **Soils with Peat 8" - 16"** Co, Wd, Rp, Pe, RoA, CoA
- **Soils with Peat < 8"** Pt, Hy, WkA, WeA, Cf, Ro, Ar, Ap, Fo, FoA,
- **All Other Soils**
- **Non-refuge Inholdings**

Produced by the U.S. Fish and Wildlife Service

D. Newcomb 2/2/99

POCOSIN LAKES NATIONAL WILDLIFE REFUGE

State Natural Heritage Areas, Refuge Boundaries, Quad Boundaries

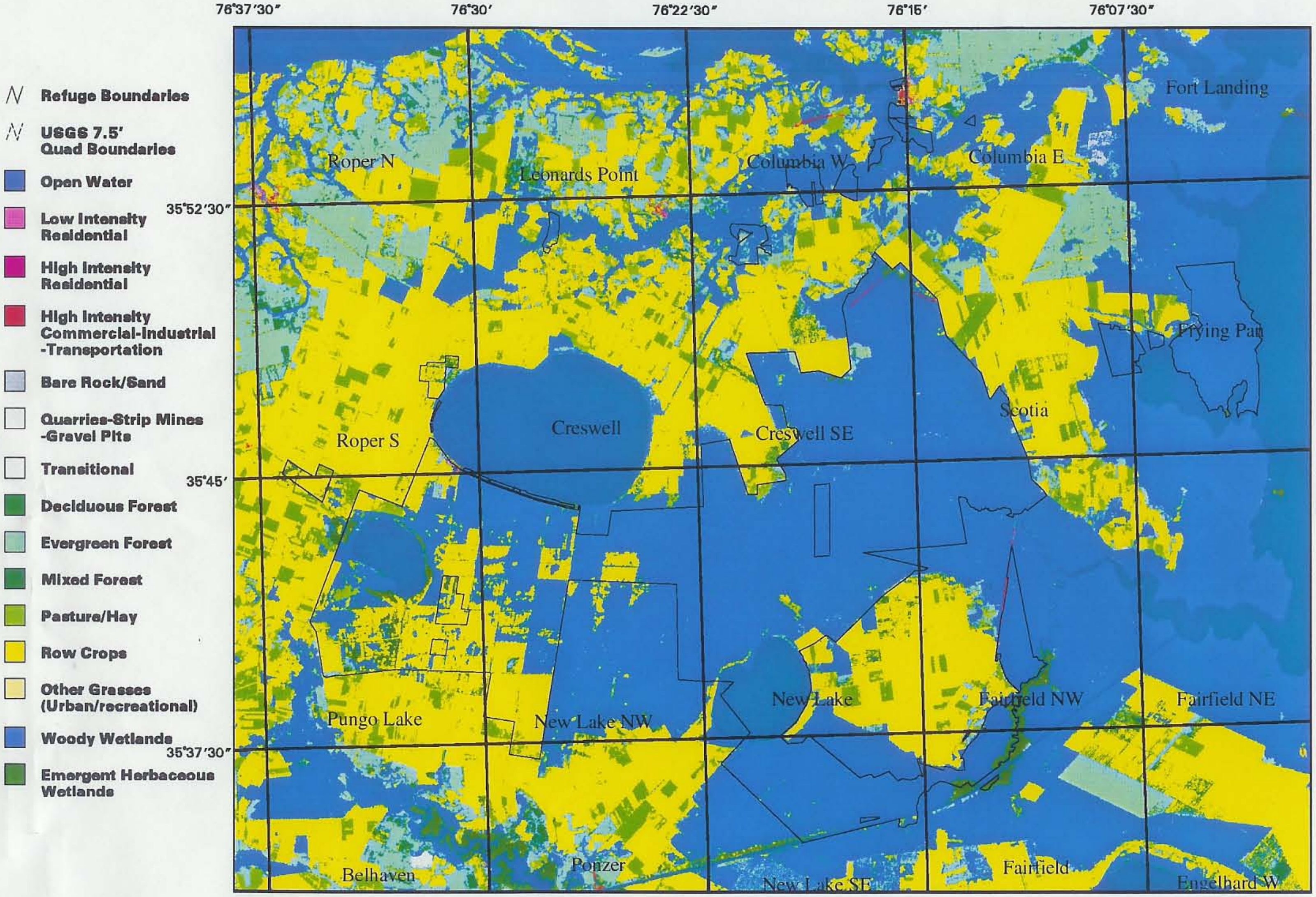


Produced by the U.S. Fish and Wildlife Service

D. Newcomb 7/20/99

POCOSIN LAKES NATIONAL WILDLIFE REFUGE

Land use/ Land Cover, Quad Boundaries, Refuge Boundaries



Produced by the U. S. Fish and Wildlife Service

Based on the MRLC Landuse dataset from 1991, 1992, and 1993

Satellite Imagery

D. Newcomb 12/15/99