State of Delaware
DELAWARE GEOLOGICAL SURVEY
Robert R. Jordan, State Geologist

REPORT OF INVESTIGATIONS NO. 62

THE CYPRESS SWAMP FORMATION, DELAWARE

by

A. Scott Andres

C. Scott Howard

University of Delaware
Newark, Delaware

2000

State of Delaware
DELAWARE GEOLOGICAL SURVEY
Robert R. Jordan, State Geologist

REPORT OF INVESTIGATIONS NO. 62

THE CYPRESS SWAMP FORMATION, DELAWARE

by

A. Scott Andres

C. Scott Howard

University of Delaware
Newark, Delaware

2000

CONTENTS

ILLUSTRATIONS

TABLES

THE CYPRESS SWAMP FORMATION, DELAWARE

A. Scott Andres and C. Scott Howard

ABSTRACT

The Cypress Swamp of Sussex County, Delaware, is underlain by a body of late Pleistocene- to Holocene-age unconsolidated sediments. They form a mappable geologic unit herein named the Cypress Swamp Formation. Deposits of the formation can be found outside the current boundaries of the Cypress Swamp and record the erosion and redistribution of older Pleistocene coastal and Pliocene sedimentary units.

Deposition of the Cypress Swamp Formation occurred in environments ranging from fresh-water, cold-climate marsh and boreal forest, to fresh-water, temperate climate, forested swamp, and bog. About 22,000 years before present (yrs BP) organic matter began accumulating within the swamp. Silt, clay, and sand eroded from local dunes and surrounding uplands were transported into the Cypress Swamp, and redistributed by small streams and wind, and deposited in marsh, bog, and pond environments. Thin sheet sand deposits likely formed during storms or during seasonal thawing events. This environment persisted until at least about 14,000 yrs BP. In the modern landscape, sandy upland areas (>40 ft elevation) are likely the remnants of these older eolian dunes, stream channel deposits, and shallow pond shoreline deposits. Areas that are now swamp overlie former bogs, marshes, and ponds.

Over the past 10,000 years the climate has warmed, and temperate-forested swamp, bog, and floodplain environments have become more dominant. Erosional and depositional processes continued to level the landscape as organic-rich sediments were deposited in low-lying fresh water swamp, marsh, bog, and pond environments, and mineral-rich sediments were deposited closer to stream channels and along the fringes of higher areas. The construction of the existing network of ditches and roads, as well as timbering and log mining practices, have dramatically altered the environment of the Cypress Swamp.

INTRODUCTION

The Cypress Swamp is located west of Ocean City, Maryland and is one of the largest areas of contiguous forest on the Delmarva Peninsula (Figures 1 and 2). Most of the Cypress Swamp lies within Sussex County, Delaware, and a smaller portion in Worcester County, Maryland. For the purpose of simplifying text, the name Cypress Swamp, unless otherwise noted, will be used to refer to a larger area that includes the Burnt Swamp, and intervening and some surrounding lands.

Recently, there has been increasing interest in the Cypress Swamp in the forms of the Delaware Natural Heritage Program's "An Ecological Characterization of Delmarva's Great Cypress Swamp Conservation Area" (Bennett et al., 1999) and the Delaware Department of Transportation's (DelDOT) Wetland Mitigation Bank project. Because of the importance of geology and hydrology to swamp ecology the Delaware Geological Survey (DGS) participated in the DNHP project by conducting a study to characterize the hydrogeology and Quaternary geologic history of the Delaware portion of the area (Andres and Howard, 1999). One of the results of this work is the recognition of a newly-named lithostratigraphic unit, the Cypress Swamp Formation. This report documents the criteria used to recognize and map this unit. This report also contains our interpretation of the depositional history of the Cypress Swamp Formation.

Acknowledgments

This work was partially supported by the Delaware Natural Heritage Program. A number of student assistants (Lisa J. Donahoe, Kim Gregg, Michael Knobloch, James A. Maio) and DGS staff (Roland E. Bounds, Thomas E. McKenna, C. Thomas Smith, Johan J. Groot, Ralph Orlansky, Scott A. Strohmeier, Kim McKenna) participated in portions of the field and laboratory research activities. Johan J. Groot deserves special recognition for providing invaluable expertise in palynology and paleoenvironmental analysis. We thank Delaware Wildlands, Inc. and DelDOT and its consultant Louis Berger, Inc. (LBI) for their important contributions to our efforts. Jeffrey Halka (Maryland Geological Survey), David S. Powars (U. S. Geological Survey), Kelvin W. Ramsey (DGS), Peter P. McLaughlin (DGS), and Gerald H. Johnson (College of William and Mary) are thanked for their critical reviews and helpful comments.

Previous Geologic Work

On the bases of lithologic and paleontologic data from a relatively small number of boreholes and exposures Jordan (1962, 1964, 1974) and Jordan and Talley (1976) identified and mapped the Columbia, Omar, and Beaverdam formations over much of Sussex County, Delaware, including the area of the Cypress Swamp (boreholes Rg23-01 and Rg22-01). Subsequent publications have supplemented the geographic distributions and stratigraphic interpretations of Jordan (1962, 1964, 1974) and Jordan and Talley (1976). Denny et al. (1979), Owens and Minard (1979), Owens and Denny (1978, 1979a, 1979b, 1986), Ramsey (1992, 1993, 1997), Ramsey and Schenck (1990), Groot et al. (1990), Groot et al. (1995), Andres and Ramsey (1995, 1996), Groot and Jordan (1999), and Groot (written communications, 1992-1999) report additional lithostratigraphic units and a spatially and temporally complex late Tertiary through Holocene depositional history for the section that Jordan (1962, 1964, 1974) and Jordan and Talley (1976) recognized and mapped as the Quaternary-age Columbia, Beaverdam, and Omar formations. Rasmussen and Slaughter (1955), Denny et al. (1979), and Owens and Denny (1978, 1979a) describe and map a surficial deposit, the Quaternary-age Parsonsburg Sand that overlies the Omar Formation in portions of southern Delaware and adja-

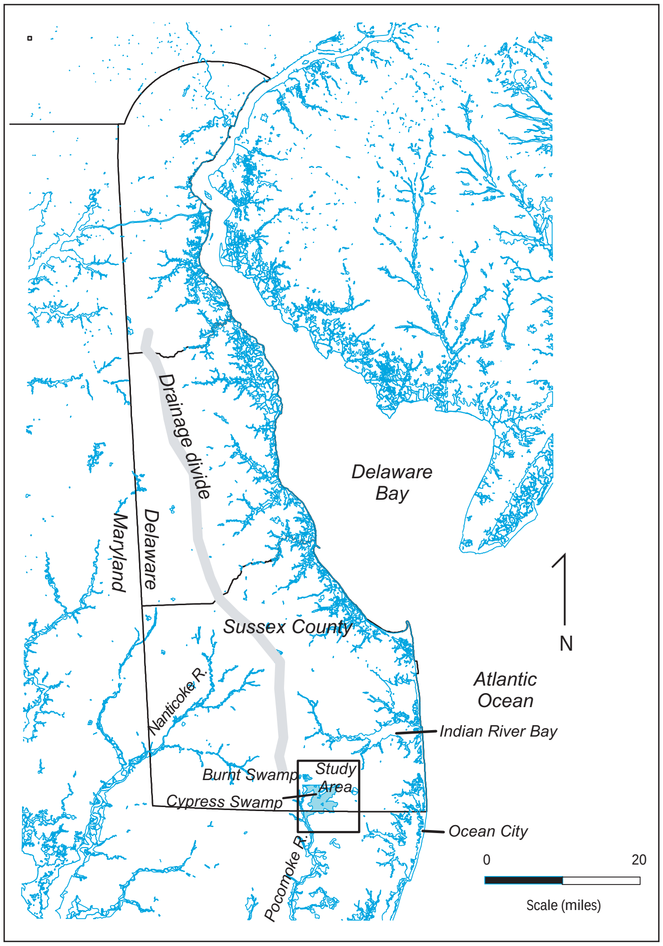

Figure 1. Map of the Delaware and surrounding region with location of the Cypress Swamp study area.

cent Maryland. Ramsey and Schenck (1990) and Andres and Ramsey (1995, 1996) identify and map the Nanticoke deposits, a Quaternary-age surficial deposit in the Nanticoke River basin. Owens and Denny (1978, 1979a, 1979b, 1986), Owens and Minard (1979), Groot et al., (1990), Benson (1990), Ramsey and Schenck (1990), Ramsey (1992), and Andres and Ramsey (1995, 1996) consider the Beaverdam to be of Tertiary age and recognize its presence under large areas of the Delmarva Peninsula. Recent interpretations of palynologic data (Groot et al., 1995; Groot and Jordan, 1999) indicate the Columbia Formation to be of Quaternary age and confirm the unconformable contact between the Beaverdam and Columbia. Detailed 1:24,000-scale lithofacies mapping in and around the Cypress Swamp by Andres (1991a, 1991b, 1992, 1994), Andres and Howard (1995), and Howard and Andres (1998a, 1998b) identify unnamed surficial units deposited in upland swamp, bog, and eolian environments. Groot and Jordan (1999) report pollen assemblages and environmental interpretations of selected samples collected from these unnamed units. These data indicate fresh water, cold to temperate-climate, bog, marsh, swamp, and forest depositional environments. In a compilation of the recent historical record of the area, Bennett et al. (1999) describe timbering, log mining, drainage, and cultivation efforts as well as many large fires.

METHODS

A variety of surface and subsurface investigation methods were used in the field and laboratory to characterize the study area. LBI, under contract to DelDOT, is conducting a hydrologic study of the area in support of construction of a wetlands mitigation bank site. Preliminary reports of the LBI study (LBI, 1999) provided significant resources in the forms of observation locations, borehole logs, and samples. We used these resources and supplemented them with data collected in prior studies, additional boreholes, and field and laboratory measurements. Figure 3 shows the locations of boreholes and outcrops discussed in this report.

Test borings and sampling of subsurface materials were completed by the DGS and LBI with truck-mounted auger drill rigs, and by hand with bucket auger and dutch coring devices. Some of this work was completed during earlier DGS mapping projects (Jordan, 1964; Andres and Howard, 1995). All subsurface observation locations are identified with a DGS site identifier, and all samples collected by the DGS are cataloged, cross-referenced to the site identifiers, and archived in the DGS core and sample library. The locations of most observation sites were determined using differential global positioning systems by DGS or LBI. A few of the sites from previous work were determined by field locating positions on 1:24,000 topographic maps.

Laboratory investigations of selected subsurface samples included standard and accelerator mass spectrometry carbon-14 age dating by Beta Analytic (Miami, FL), and extraction of fossil pollen by the DGS lab and identification by Johan J. Groot. In addition, the DelDOT Materials Laboratory analyzed physical properties of selected sediment samples (grain size, liquid limit, plastic limit, organic carbon loss on ignition). DGS laboratory analyses included grain size analysis and x-ray diffraction analysis of clay-sized minerals.

Investigations of land surface data included digital terrain analysis supplemented with visual interpretation of hydrography, vegetation, and land use on aerial photographs and maps. Digital elevation models (30 m grid) were obtained from John MacKenzie (pers. comm., 1998) who also provided a 5-m sampled raster image of the USGS 1:24,000 hypsography coverage of the swamp area. These data were supplemented with spot elevations from the 1:24,000 USGS topographic sheet and regridded with Surfer (Golden Software, Golden Colo.). Slope and aspect analyses were completed on these data by Surfer and ARCView with the 3D Analyst extension (ESRI, Redlands, Calif.).

RESULTS AND DISCUSSION

Geologic Units and Mapping

Geological investigations and interpretations in southern Delaware commonly use compositional data of sediments (e.g., grain size, mineralogy, age, and fossil components) and geomorphology to characterize, subdivide, and map the surface and subsurface distribution of geologic units. The attributes of individual geologic units provide the bases for interpreting the geologic history, including such things as depositional environments, time of deposition, soil

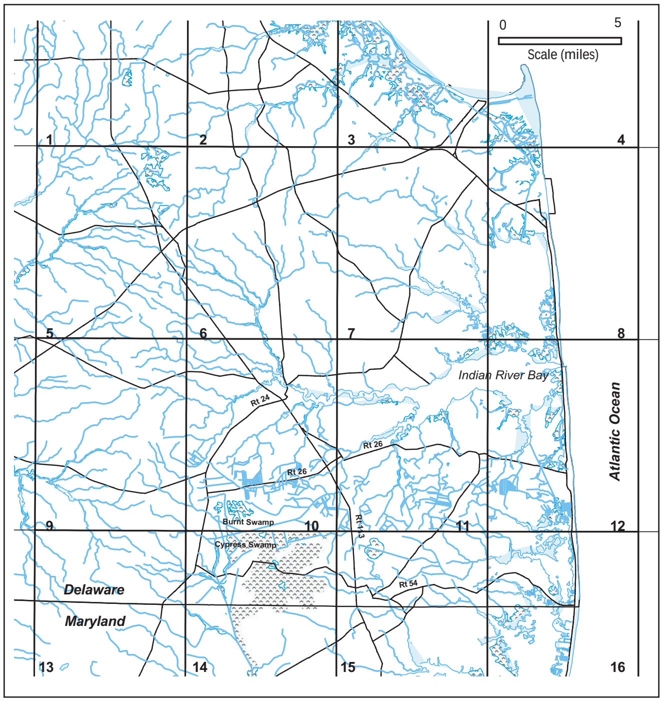

Figure 2. Index map of the study area vicinity showing 7.5-minute quadrangles used in the study. 1 = Ellendale, 2 = Milton, 3 = Lewes, 4 = Cape Henlopen, 5 = Georgetown, 6 = Harbeson, 7 = Fairmount, 8 = Rehoboth Beach, 9 = Trap Pond, 10 = Millsboro, 11 = Frankford, 12 = Bethany Beach, 13 = Pittsville, 14 = Whaleysville, 15 = Selbyville, 16 = Assawoman Bay

formation, and evidence for erosional surfaces. In practice, identification and mapping of geologic units in southern Delaware is difficult because observation and sample locations are limited to excavations and scattered boreholes. Also, there are similarities in the gross composition of the units, and diagnostic fossils are commonly not present. Thus, geologic interpretations are models limited by the data available to the authors.

Table 1 shows the geologic (lithostratigraphic) units present in the shallow subsurface beneath the Cypress Swamp along with interpreted ages and environments of deposition. This study focuses on youngest Pleistocene and Holocene geologic units, thus, the tops of the Beaverdam and Omar formations form the lower boundary of the section of interest. On the bases of new lithologic, palynologic (Groot and Jordan, 1999), and age data, we propose the recognition of a new lithostratigraphic unit, the Cypress Swamp Formation.

In the field, the Cypress Swamp Formation is recognized by its alternating thin (< 5 ft) beds of fine light-colored sand and dark-colored organic silt that contain plant fragments, and lowermost beds of peaty organic and mineral silt. This is distinguished from the Omar Formation which contains fossil *Crassostrea* (oyster) shells and shell fragments and, thick (> 5 ft) dark colored, fine-grained beds. The Beaverdam Formation is recognized as interbedded light colored, gravelly coarse sands and thin fine-grained beds with less common, thicker (20 to 40 ft thick) light- or dark-colored, fine-grained units. The only other potentially diagnostic sedimentary constituents are fossil pollen and spores, which require time-consuming laboratory procedures to extract and identify.

The occurrences of each unit are spatially variable because of complex relationships between original thickness and extent and post-depositional erosion. As a result, in some locations one or more of the units are absent in the uppermost 25 ft below land surface. For example, at Rg14-12 (Figure 3) the Cypress Swamp Formation unconformably overlies the Beaverdam, and the Beaverdam is exposed at locations along the south shore of Indian River Bay (Figure 1).

Cypress Swamp Formation

The Cypress Swamp Formation is the surficial geologic unit in the study area. It unconformably overlies either the Omar or the Beaverdam formations. The type section is corehole Rg14-12 (Figure 4). The reference section is corehole Qg53-15 (Figure 5). The upper part of the Cypress Swamp Formation is a multi-colored, thinly-bedded to laminated, quartzose fine sand to silty fine sand, with areally discontinuous laminae to thin beds of fine to coarse sand, sandy silt, clayey silt, organic silt, and peat. The lowermost 3 to 6 ft of the unit are commonly composed of thin beds of dark-colored, organic-rich, clayey silt with laminae to thin

Table 1. Names, ages, environments of deposition, and generalized composition of lithostratigraphic units in the Cypress Swamp area. Stages refer to oxygen isotope record stage numbers (Shackleton et al., 1984). Dominant climate interpreted from compo sition and pollen assemblages.

Lithostratigraphic Unit	Age	Environments	Composition	Dominant climates
Cypress Swamp Fm. (=Parsonsburg Sand?)	Late Pleistocene - Holocene (Stages 2 - 1)	Fresh-water bog, swamp, marsh, pond, forest, floodplain, dunes	Fine sand, mixtures of sand and silt, organic material, clayey silt	Cold to temperate
Omar Fm.	Pleistocene (Stages 13 - 5a)	Fresh- to brackish-water lagoon, estuary, marsh, swamp, bog	Beds and/or mixtures of silt, clay, sand, shell	Temperate to cool
Beaverdam Fm.	Pliocene	Fresh- to brackish-water, tidal channel, estuary, lagoon, river, and floodplain	Sand, gravel, silt, clay	Temperate and warm temperate

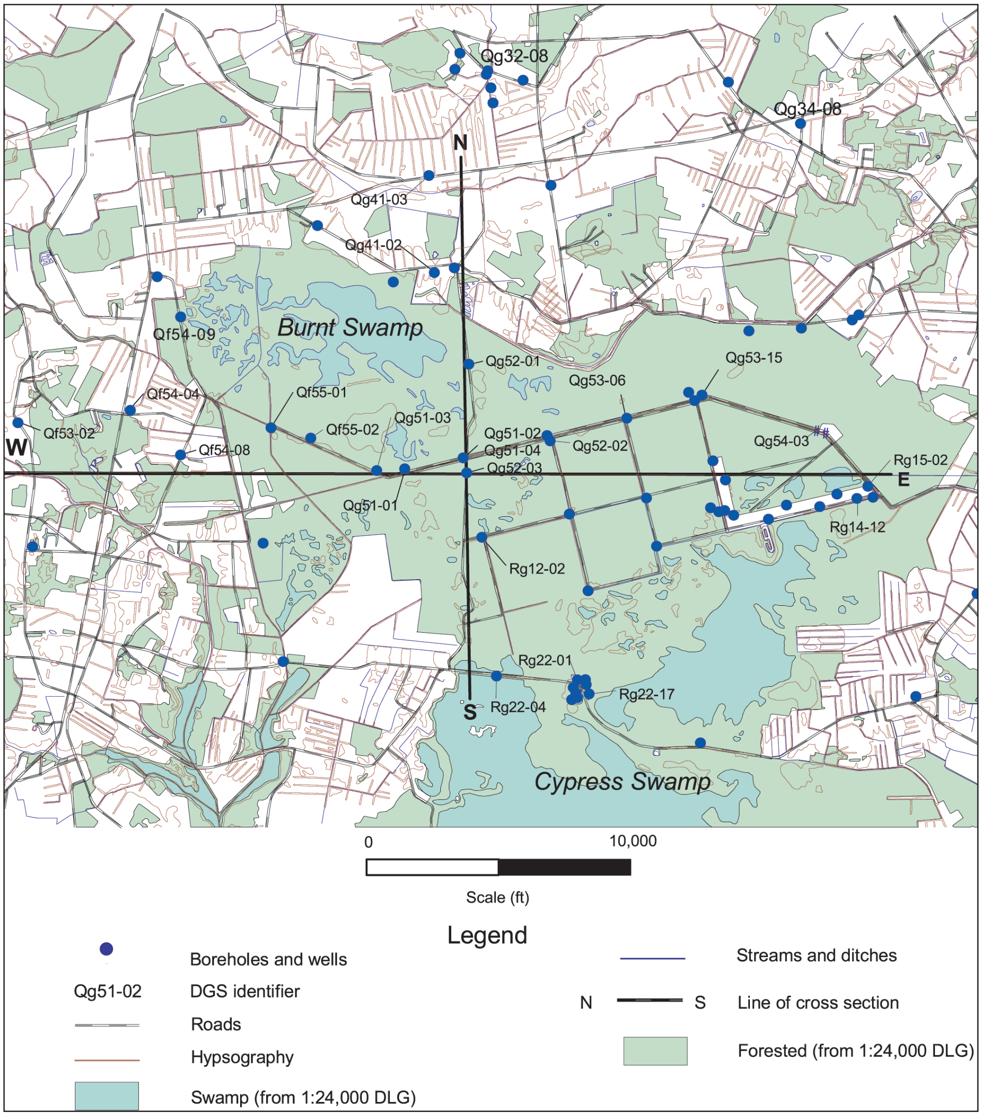

Figure 3. Map of study area showing locations of boreholes and outcrops used in this study. Base map compiled from 1:24,000 digital line graph data from Millsboro and Whaleysville 7.5-minute topographic maps.

beds of fine sand and peat. Fine sand to fine sandy silt are present at the base of the unit in boreholes where the lower organic-rich beds are absent. Dark-colored, peaty, organic-rich silt and clayey silt with laminae of fine to medium sand as much as 4.5 ft thick are common within 5 ft of land surface but may be absent in some locations. Colors are shades of brown, gray, and green where the unit contains visible organic matter, and orange, yellow, and red at shallow depths where the organic-rich beds are absent. The clay-sized minerals from 9 samples are a mixed suite that includes kaolinite, chlorite, illite, and vermiculite.

Cross-sectional views of the distribution of subsurface units are shown in Figures 6 and 7. Thickness of the Cypress Swamp Formation is variable, ranging from a few feet to as much as 20 ft. Available data indicate that the unit thins to the east, west, and north. Data are not adequate to resolve thickness trends to the south. Thicker organic-rich beds occur more commonly within a few feet of land surface in the current Cypress Swamp area where there has not been intensive ditching.

The results of radiocarbon analyses are shown in Table 2. Radiocarbon determined dates of samples between 14,000 and 21,500 years before present (yrs BP) have pollen assemblages representative of cold-climate, fresh-water bogs, marshes, and swamps typical of taiga and boreal forest environments. The oldest dates occur in the lowermost beds of peaty organic silt, the youngest of this group from a sample collected at an elevation of about 30.9 ft in the middle of the unit (sample 26373-3, Qg53-15). A calibrated date of 4585 yrs BP is reported for a wood fragment from the same depth (sample 26373-1). The near vertical orientation of the wood, the erosional unconformity present just above the wood, and the younger date indicate that the wood is a root that had grown down into the older sediment. The older date is also consistent with the cold-climate pollen assemblage in samples 26373-1 and 26373-3.

At the type and reference sections (Qg53-15, Rg14-12), the shallowest (1-3 ft below land surface) organic-rich horizons yielded calibrated radiocarbon dates of 2959 to 3712 yrs BP, respectively. The pollen assemblage at Rg14-12 indicates a temperate-climate forested swamp. The environmental interpretation is consistent with the radiocarbon age and with environmental interpretations in Webb et al. (1994), Newby et al. (1994), and Rogers and Pizzuto (1994). At Qg53-15, however, the pollen assemblage indicates a cold forested swamp environment. This incompatible combination of age and environment are interpreted to be the result of mixing of older and younger carbon through natural or human activities.

Site Rg22-17 (Figure 3) is located in the area identified on 1:24,000 topographic maps as the Cypress Swamp. The site is in a seasonally flooded forested swamp where water depths range from 2.5 ft above ground in the winter and spring, to 1 ft below surface in the summer (Andres and Howard, 1999). Artificial drainage is not intensively developed in this area, and many boreholes in this area have thicker accumulations of organic-rich sediment than boreholes located in more intensively drained areas. The uppermost 4.3 ft of sediment at Rg22-17 is a peaty, woody, organic silt with scattered laminae of fine sand and silt. A calibrated radiocarbon date of 12,028 yrs BP from a sample

Table 2. Radiocarbon dates for samples collected in the Cypress Swamp area. Elevations are in ft NVD 1988. The radiocarbon sample IDs are from the DGS radiocarbon database. See Ramsey and Baxter (1996) for a discussion of calibrated versus uncalibrated dates.

DGS site identifier	Radiocarbon Sample ID	Sample Number	Elevation (ft NGVD 29)	Calibrated RC date (yrs BP)	Calibrated Range (yrs BP)	RC date 5568 (yrs BP)	+/- (yrs)	Sample composition
Qf54-09	RC236	26343	30.7			21400	220	peat
Qg32-08	RC232	85595	27.3			19330	100	peaty organic silt
Qg34-08	RC219	84908	31.5			19470	110	peaty organic silt
Qg53-15	RC239	26370-1	36.2	2959	3082 - 2836	2840	60	organic silt
Qg53-15	RC240	26373-1	30.9	4585	4415 - 4075	3840	60	wood (root)
Qg53-15	RC263	26373-3	30.9	15099	15578 - 14619	14210	50	peaty organic silt
Qg53-15	RC241	26375-1	27.1			18440	100	peaty organic silt
Rg14-12	RC237	26363-1	33.6	3712	3839 - 3584	3460	50	peaty, woody, organic silt
Rg14-12	RC238	26367-1	26			20280	130	wood
Rg22-17	RC262	26378-3	32.5	12028	12324 - 11732	10230	40	peat and wood

(No. 26378-3) collected at the base of this interval is similar to ages of sediments found beneath the floodplain of the Nanticoke River near Seaford (Andres and Ramsey, 1996) in which the pollen assemblages indicate a temperate-climate forested swamp environment. Additional radiocarbon and pollen analyses of shallower intervals of this core or other cores collected in this area would likely yield a good record of environmental changes in the Cypress Swamp over the past 12,000 years.

Recent (< 25 yrs BP) deposition in undrained areas of the Cypress Swamp is limited to a thin (< 0.5 ft) layer dominated by organic matter, wood, leaves, and moss, with minor amounts of silt, clay, fine sand, and floatable trash (i.e., paper and plastic). Sediment deposition in non-ditched areas near the Pocomoke River is a mix of mineral and organic matter deposited during flood stage as thin (< 1 ft) discontinuous sand waves and bars. These deposits are most common near unpaved roads indicating that the source of the sand and silt is the roads. There also are accumulations of organic muck in abandoned ditches and voids left from tree falls.

Geomorphology

The geomorphic attributes of areas underlain by the Cypress Swamp Formation are important to predicting and mapping the distribution and interpreting the geologic history of the unit. In the area around Rg22-17 and Rg22-04 (Figure 3), which is currently identified as the Cypress Swamp, land surface elevations are between 35 and 40 ft. Lower lying areas are seasonally flooded, forested swamps covered with living mosses and underlain by 3 or more ft of dark-colored, organic-rich sediment. Slightly higher areas (2 to 4 ft higher) are not seasonally flooded, have no moss cover, and are underlain by light-colored sand and silty sand. Andres (1991b, 1994), Andres and Howard (1995, 1999), and Sims et al. (1996) found correlative features and sediments outside of the current area of the Cypress Swamp. In these areas, the Cypress Swamp Formation deposits are typically associated with intensive ditching, land surface elevations between 30 and 45 ft, low topographic relief, little to no slope, and irregularly-shaped light and dark colored areas on land surface (Figures 8, 9, and 10). In general, the light colored areas are underlain by sand and silty sand, and the dark colored areas are underlain by mixtures of silt, sand, and organic matter. Dark colored areas tend to be wetter and many are seasonally flooded. Where exposed in ditches dark colored features typically show a lenticular cross section. Soils maps (Ireland and Matthews, 1974) show that these more poorly drained areas are usually assigned to Pocomoke and Muck classes. The land surface elevations of sandy areas can be 1 to 5 ft higher than adjacent areas underlain by organic matter. Soils maps (Ireland and Matthews, 1974) show that the sandier areas are usually assigned to Evesboro, Osier, Woodstown, and Rutledge classes.

By means of these lithologic and geomorphic criteria, we place the western limit of the Cypress Swamp Formation at land surface elevations between 45 and 50 ft along the eastern edge of the drainage divide of the Delmarva Peninsula (Figures 1, 8, and 9). To the north and east, the Cypress Swamp Formation underlies intensively ditched, flat areas with land surface elevations between 25 and 45 ft. Data are not sufficient to map the unit to the south down the valley of the Pocomoke River. It appears that most of the area underlain by the Cypress Swamp Formation is surrounded by land surface elevations between 40 and 45 feet. Scattered borehole and outcrop data indicate that deposits having similar lithologic and palynologic compositions also occur at lower elevations to the east. More detailed field work is need to better identify the stratigraphic relationships between these units and the Cypress Swamp Formation.

Relationships to Parsonsburg Sand, Nanticoke Deposits, and Upland Bog and Swamp Deposits

The Cypress Swamp Formation is similar in age and composition to the Parsonsburg Sand as described by Rasmussen and Slaughter (1955) and mapped by Owens and Denny (1979a, 1979b, 1986) and Denny et al. (1979) in adjacent Maryland. Nonetheless, we assign the name Cypress Swamp Formation to the Delaware unit for two reasons: (1) the word “sand” does not accurately reflect the composition of the unit, and (2) detailed 1:24,000-scale mapping (Andres and Ramsey, 1995, 1996; Andres and Howard, 1995) has found that the Parsonsburg Sand and the Cypress Swamp Formation do not form an areally continuous unit.

The Cypress Swamp Formation has gross compositional and palynologic similarities with near surface units mapped in the Seaford area as Nanticoke, upland bog, and upland swamp deposits by Andres and Ramsey (1995,

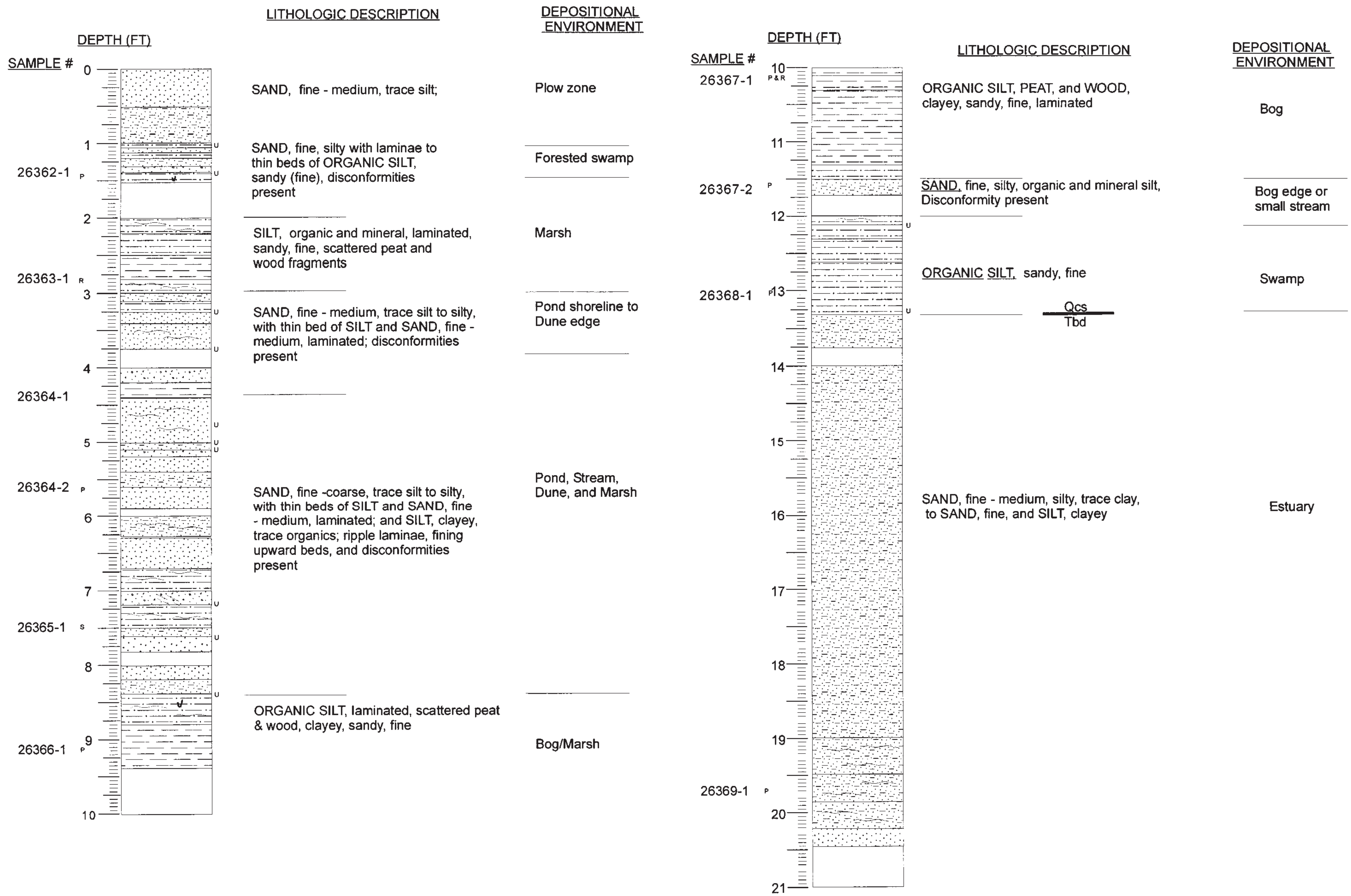

Figure 4. Descriptive log of corehole Rg14-12, type section of the Cypress Swamp Formation. See Figure 5 for key to symbols.

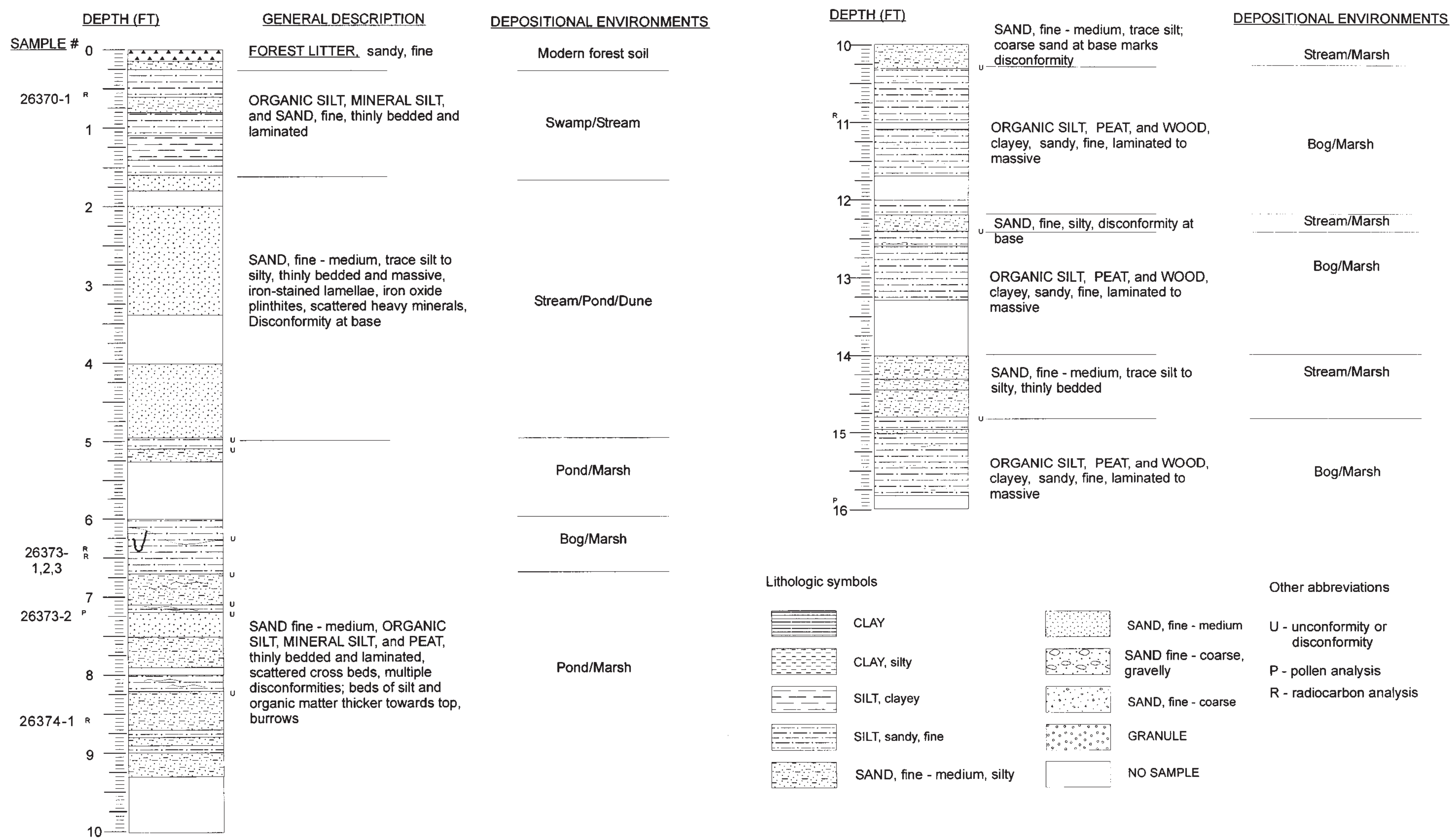

Figure 5. Descriptive log of corehole Qg53-15, reference section of the Cypress Swamp Formation.

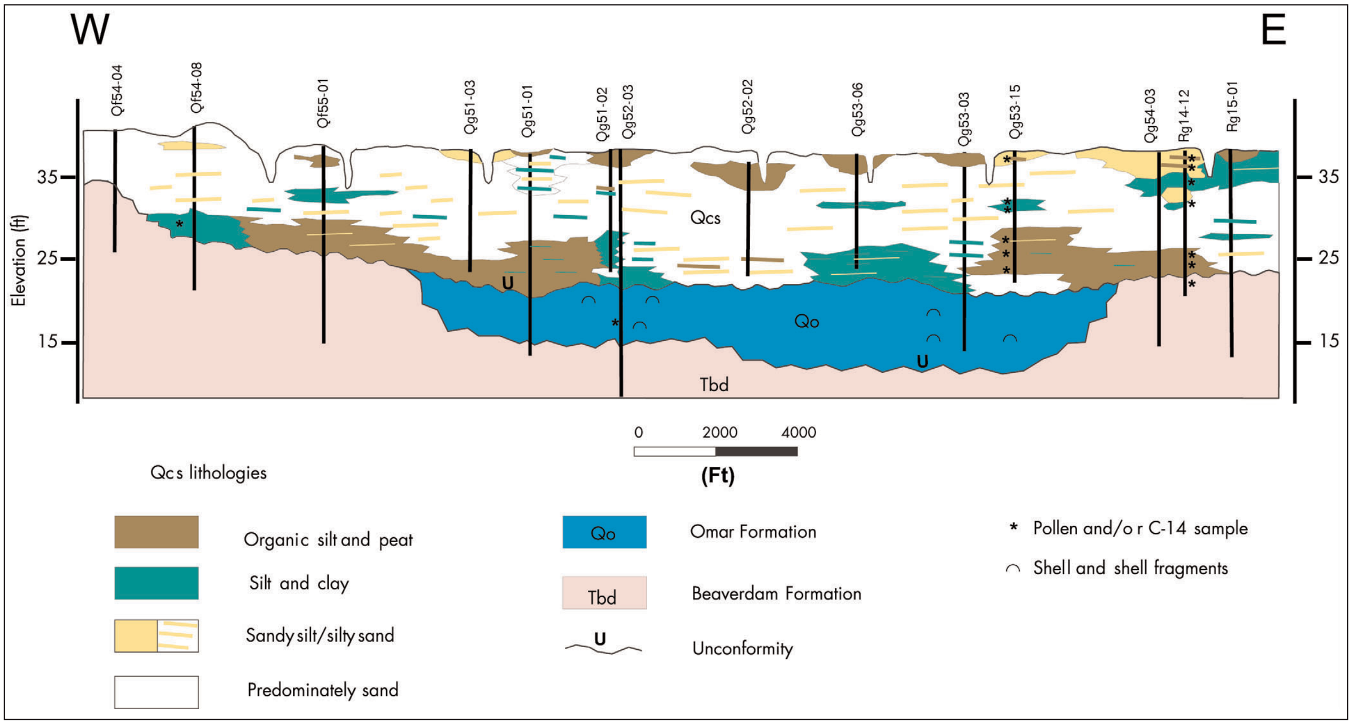

Figure 6. West to east cross section showing Cypress Swamp Formation(Qcs) lithologies. Lithologic details of Omar and Beaverdam formations are not shown. Vertical scale in ft NAVD 1983.

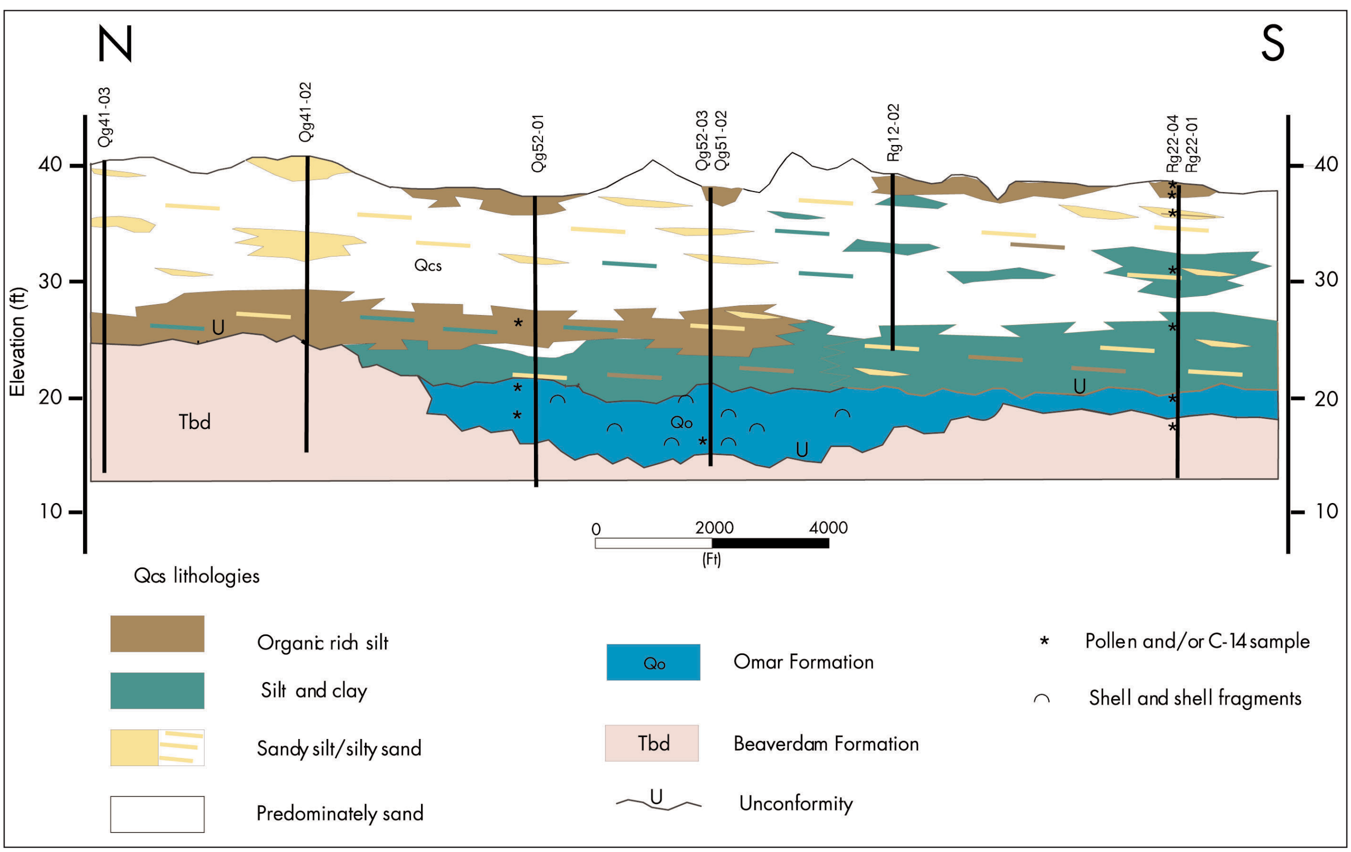

Figure 7. North to south cross section showing Cypress Swamp Formation lithologies. Lithologic details of Omar and Beaverdam formations are not shown. Vertical scale in ft NAVD 1983.

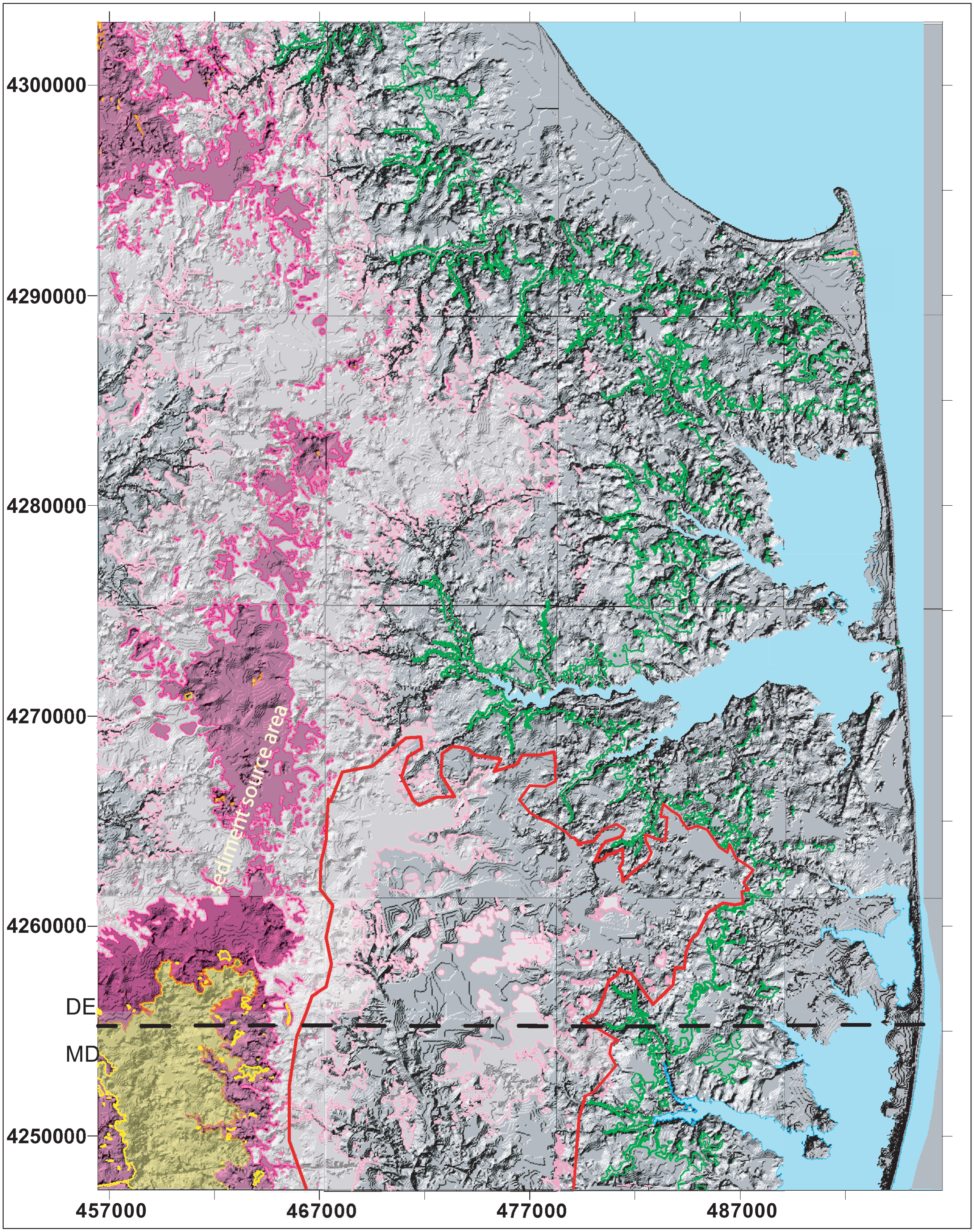

Figure 8. Combination shaded relief and topographic contour map of southeastern Delaware and adjacent Maryland showing where the Cypress Swamp Formation is likely to be found (thick red line). Sediment source areas for the Cypress Swamp Formation are the higher areas to the north and west. The green line is the 20-ft contour, the pink line is the 40-ft contour, pink shading denotes elevations between 40 and 50 ft, magenta shading denotes elevations between 50 and 60 ft, and yellow shading denotes elevations greater than 60 ft. 30 m DEM data from John MacKenzie (pers. commun., 1998) Map coordinates are UTM-18-1983 in meters. See Figure 2 for index map.

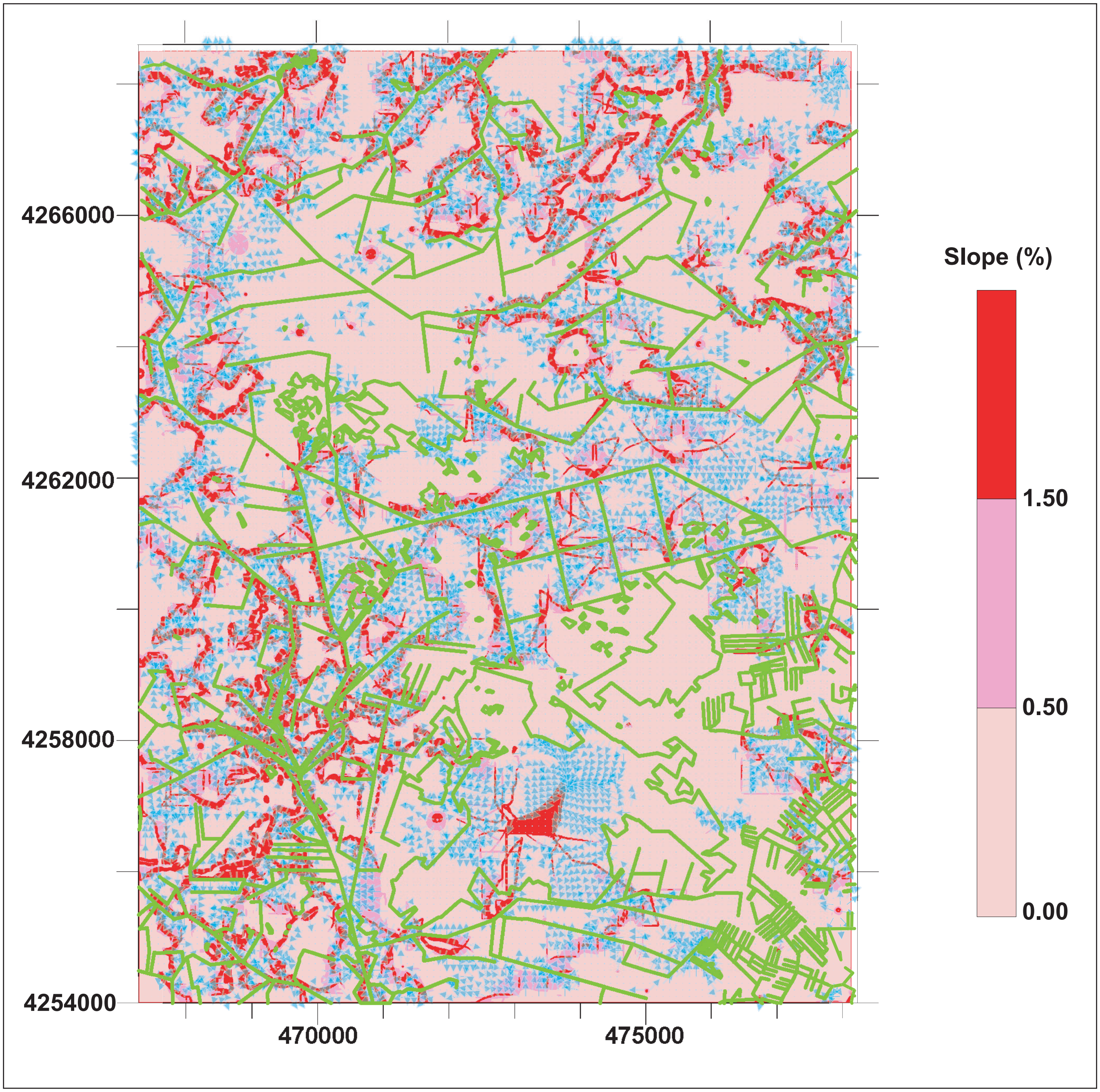

Figure 9. Slope and aspect map (blue arrows) of the Cypress Swamp area computed on 5 m DEM. Map area is southern third of the Millsboro and the northern third of the Whaleysville 7.5-minute 1:24,000 maps. Map coordinates are UTM-18-1983 in meters. Drainage features are depicted in green and show how most topographic relief is due to the extensive ditch network. Areas with no arrows have no calculable slope.

1996), and with near surface units in other drainage basins (Ramsey, 1997, 2000; Andres and Howard, 1995; Howard and Andres, 1998a, 1998b; Groot and Jordan, 1999, Table 9). However, the Cypress Swamp Formation does not form a continuous cover westward over the Delmarva Peninsula drainage divide or northward into other drainage basins.

Depositional History

The following discussion records our current interpretations of the geologic data as they relate to the erosional and depositional history of the area of the Cypress Swamp. This model of geologic history for the Cypress Swamp Formation is based on interpretations of palynologic, lithologic, and radiocarbon data collected in the study area, published geologic histories of the Milford and Seaford, Delaware, areas (Ramsey, 1997; Andres and Ramsey, 1996) and New Castle and Kent counties (Newby et al., 1994, Webb et al., 1994), and interpretations of the Parsonsburg Sand (Owens and Denny 1979a, 1979b, 1986; Denny et al., 1979; Sirkin et al., 1977), Great Dismal Swamp deposits (Oaks and Whitehead, 1979; Whitehead and Oaks, 1979; Johnson et al., 1985), and similar units in North Carolina

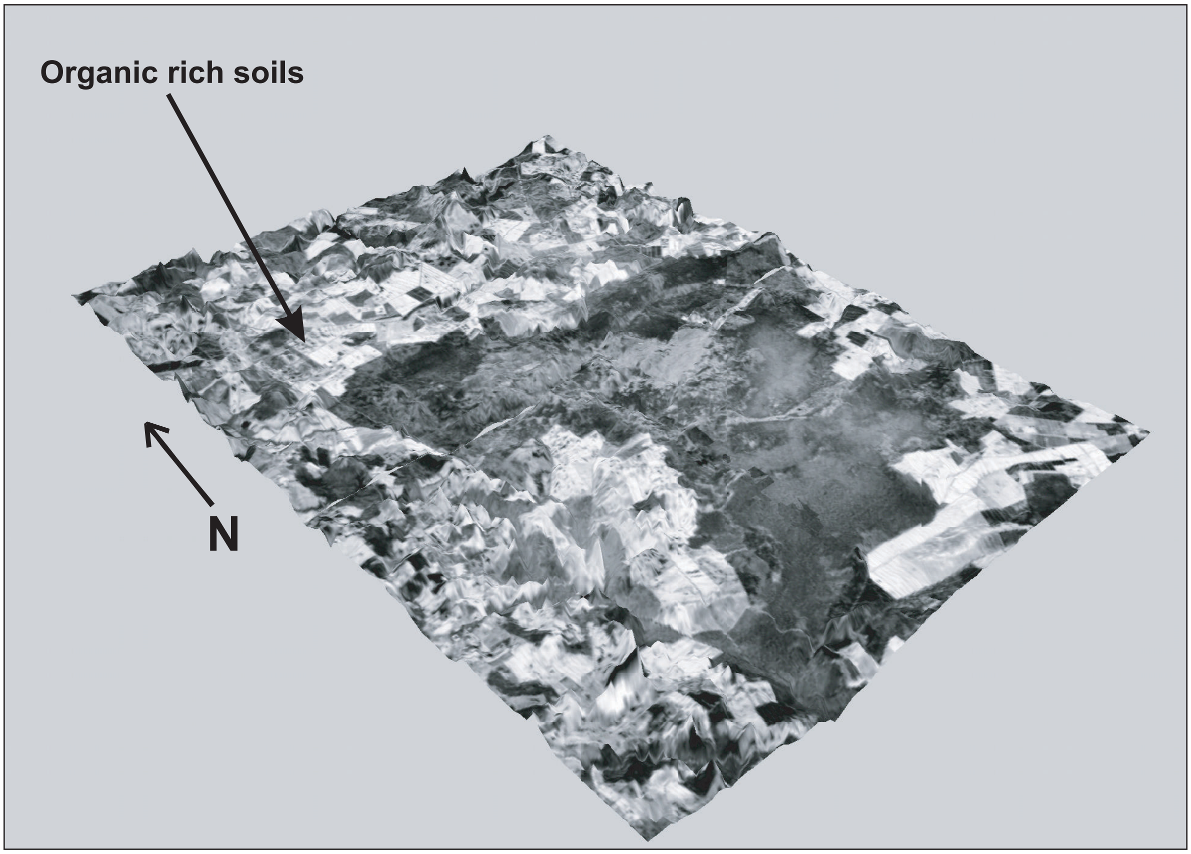

Figure 10. Three-dimensional view of orthophotographs of Cypress Swamp area draped on a 30 meter digital elevation model. The image area is the southern half of the Millsboro and the northern half of the Whaleysville 7.5-minute 1:24,000 maps. The 50 x vertical exageration enhances view of the Cypress Swamp as an internally drained depression. The mottled surface present over much of the image is characteristic of interspersed sandy and organic-rich soils.

and South Carolina (Markewich and Markewich, 1994).

At the time of the beginning of deposition near the end of the Wisconsinan glacial period, the landscape had low irregular, topographic relief, with land surface elevations as much as 20 ft lower than present. Environments in and around the Cypress Swamp ranged from poorly drained, relatively treeless taiga with small streams, marshes, ponds, and bogs in low-lying areas, to boreal forests on better drained uplands. Low topographic relief coupled with a dry cold climate caused overall sedimentation rates to be low. Sparse vegetation and low precipitation allowed eolian processes to form sand dunes and/or dune fields. Sediment transport due to seasonal cryoturbation (freeze-thaw) forces and slope wash eroded sediment from high ground and deposited sediment in local depressions.

Starting about 22,000 yrs BP organic matter, silt, clay, and sand began accumulating more rapidly. The apparent increase in sedimentation rate is probably due to several factors associated with the late Pleistocene global warming trend, increased precipitation, melting and release of water from seasonally frozen ground, and increased plant growth. Sediment eroded from local dunes and surrounding uplands was transported into the Cypress Swamp, redistributed by small streams and wind, and deposited in marsh, bog, and pond environments. Thin sheet sand deposits likely formed during storms or by seasonal thawing events. This environment persisted until about 14,000 yrs BP. In the modern landscape, sandy upland areas (>40 ft) are likely the remnants of older eolian dunes, stream channel deposits, and shallow pond shoreline deposits. Areas that are now swamp overlie former bogs, marshes, and ponds.

Over the past 10,000 years the climate has warmed, and temperate forested swamp, bog, and floodplain environments have become dominant. These were the environments present prior to settlement of the area by Europeans. Erosional and depositional processes continued to reduce topographic relief. Organic-rich sediments were deposited in low-lying fresh water swamp, marsh, bog, and pond environments. Mineral-rich sediments were deposited closer to stream channels and along the fringes of higher areas.

The network of ditches and roads, timbering, and log mining practices have dramatically altered the erosion, transport, and deposition of mineral and organic matter. Excavations and placement of spoil piles have created topography that has altered previous naturally developed drainage and exposed sand and silt to redistribution. Sand and silt are being eroded from the ditch banks and bottoms and from adjacent roads and spoil piles during overland runoff events that generate enough flow to transport sand and silt. The amount of this material that is transported out of the area is unknown. In the ditched portion of the

Cypress Swamp, deposition of organic matter is occurring only in small bogs and in low spots in the ditches. In contrast, deposition of organic matter is occurring over much of the low-lying boggy areas of the Cypress Swamp. Deposition of sand and silt appears to be limited to areas around dirt roads and small streams near the Pocomoke River.

CONCLUSIONS

During the late Quaternary, the environment of the Cypress Swamp area has gradually changed from a coastal, temperate-climate, fluvial-estuary-lagoon system to a freshwater, cold-climate taiga to boreal forest system, to a freshwater, temperate climate, forested swamp and bog system. Sediments deposited during the past 22,000 years form a mappable geologic unit that is named the Cypress Swamp Formation which occurs well outside the current area of the Cypress Swamp. Sediments of the Cypress Swamp Formation record the erosion and redistribution of older Pleistocene coastal and Pliocene sedimentary units.

Human activities such as timbering, log mining, ditching, and cultivation have dramatically changed the environment of the Cypress Swamp. Artificial drainage significantly lowered the water table, and drainage has been redirected from the Pocomoke River watershed to the Indian River watershed. Additionally, sedimentary and erosional processes are very different between the ditched northern portion of the Cypress Swamp and the relatively undrained southern portion of the Cypress Swamp. These drainage modifications have reduced the size of the Cypress Swamp significantly.

REFERENCES CITED

Andres, A. S., 1991a, Ground-water recharge potential map, Fairmount 7.5 minute Quadrangle, Delaware Geological Survey, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24,000.

___1991b, Ground-water recharge potential map, Frankford 7.5 minute Quadrangle, Delaware Geological Survey, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24,000.

___1992, Ground-water recharge potential map, Dover Area: Delaware Geological Survey, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24,000.

___1994, Ground-water recharge potential map, Sharptown, Laurel, and Trap Pond quadrangles: Delaware Geological Survey, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24,000.

Andres, A. S., and Howard, C. S., 1995, Ground-water recharge potential map, Millsboro and Harbeson quadrangles, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24,000.

___1999, Geologic history and hydrogeology of the Great Cypress Swamp: unpublished report to the Delaware Natural Heritage Program, 50 p.

Andres, A. S., and Ramsey, K. W., 1995, Geologic map of the Seaford area, Delaware: Delaware Geological Survey Geologic Map Series No. 9, 1:24,000.

___1996, Geology of the Seaford area, Delaware: Delaware Geological Survey Report of Investigations No. 53, 22 p.

Bennett, K. A., Bolwman, P. J., Heckscher, C. M., McAvoy, W. A., and Zuelke, E. F., 1999, An ecological characterization of Delmarva's Great Cypress Swamp Conservation Area: Delaware Natuaral Heritage Progam, Document No. 40-05990902, 124 p.

Benson, R. N., 1990, Geologic and hydrologic studies of Oligocene-Pleistocene section near Lewes, Delaware: Delaware Geological Survey Report of Investigations No. 48, 34 p.

Denny, C. S., Owens, J. P., Sirken, L. A., and Rubin, M., 1979, The Parsonsburg Sand in the central Delmarva Peninsula, Maryland and Delaware: U.S. Geological Survey Professional Paper 1067-B, 16 p.

Groot, J. J., Ramsey, K. W., and Wehmiller, J. F., 1990, Ages of the Bethany, Beaverdam, and Omar formations of southern Delaware. Delaware Geological Survey Report of Investigations No. 47, 19 p.

Groot, J. J., Benson, R. N., and Wehmiller, J. F. 1995, Palynological, foraminiferal, and aminostratigraphic studies of Quaternary sediments from the U.S. middle Atlantic upper continental slope, continental shelf, and Coastal Plain: Quaternary Science Reviews, v. 14, p. 17-49

Groot, J. J., and Jordan, R. R., 1999, The Pliocene and Quaternary deposits of Delaware: palynology, ages, and paleoenvironments: Delaware Geological Survey Report of Investigations No. 58, 36 p.

Howard, C. S., and Andres, A. S., 1998a, Ground-water recharge potential map, Milton 7.5 minute Quadrangle, Delaware Geological Survey, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24000.

___1998b, Ground-water recharge potential map, Ellendale, Georgetown 7.5 minute Quadrangle, Delaware Geological Survey, unpublished report and map to the Delaware Department of Natural Resources and Environmental Control, scale 1:24000.

Ireland, W., and Matthew, E. D., 1974, Soil survey of Sussex County, Delaware: U. S. Department of Agriculture Soil Conservation Service, 74 p.

Johnson, G. H., Peebles, P. C., Otte, L. J., and Smith, B. J., 1985, The late Cenozoic geology of southeastern Virginia and the Great Dismal Swamp: Eastern Section American Association of Petroleum Geologists Field Trip Guidebook, 67 p.

Jordan, R. R., 1962, Stratigraphy of the sedimentary rocks of Delaware: Delaware Geological Survey Bulletin No. 9, 51 p.

___1964, Columbia (Pleistocene) deposits of Delaware: Delaware Geological Survey Bulletin No. 12, 69 p.

___1974, Pleistocene deposits of Delaware, *in* Oaks, R. Q., Jr., and DuBar, J. R., eds., Post-Miocene stratigraphy, Central and southern Atlantic Coastal Plain: Utah State University Press, p. 30-52.

Jordan, R. R., and Talley J. H., 1976, Guidebook, Columbia deposits of Delaware: Delaware Geological Survey Open File Report No. 8, 49 p.

Louis Berger and Associates, Inc. (LBI), 1999, Southern Delaware wetlands mitigation bank, Great Cypress Swamp, unpublished data report to Delware Department of Transportation.

Markewich, H. W. and Markewich, W., 1994, An overview of Pleistocene and Holocene inland dunes in Georgia and the Carolinas — morphology, distribution, age, and paleoclimate: U.S. Geological Survey Bulletin 2069, 32 p.

Newby, P., Webb, R. S., and Webb, T., 1994, Pollen and sediment records from Walter's Puddle in central Delaware, *in* Kellogg, D. C., and Custer, J. F., eds., Paleoenvironmental studies of the State Route 1 corridor: contexts for prehistoric settlement, New Castle and Kent counties, Delaware: Delaware Department of Transportation Archeology Series No. 114, p. 27-35.

Oaks, R. Q., and Whitehead, D. R., 1979, Geologic setting and origin of the Dismal Swamp, southeastern Virginia and northeastern North Carolina, *in* Kirk, P. W., ed., The Great Dismal Swamp: The University Press of Virginia, p. 1-24.

Owens, J. P. and Denny, C. S., 1978, Geologic map of Wicomico County, Maryland: Maryland Geological Survey, 1:62500.

___1979a, Geologic map of Worcester County, Maryland: Maryland Geological Survey, 1:62500.

___1979b, Upper Cenozoic deposits of the central Delmarva Peninsula, Maryland and Delaware: U.S. Geological Survey Professional Paper 1067-A, 28 p.

___1986, Geologic map of Dorchester County, Maryland: Maryland Geological Survey, 1:62500.

Owens, J. P., and Minard, J. P., 1979, Upper Cenozoic sediments of the lower Delaware Valley and northern Delaware Peninsula, New Jersey, Pennsylvania, and Maryland: U. S. Geological Survey Professional Paper 1067-D, 47 p.

Ramsey, K. W., 1992, Coastal response to late Pliocene climate change: Middle Atlantic Coastal Plain, Virginia and Delaware, *in* Fletcher, C. H. and Wehmiller, J. W., eds., Quaternary coasts of the United States: Marine and lacustrine systems: Society of Economic Paleontologists and Mineralogists (Society for Sedimentary Geology) Special Publication No. 48, p. 121-127.

___1993, Geologic map of the Milford and Mispillion River quadrangles: Delaware Geological Survey Geologic Map Series No. 8, 1:24,000.

___1997, Geology of the Milford and Mispillion River quadrangles: Delaware Geological Survey Report of Investigations No. 55, 40 p.

___2000, Geologic map of the Ellendale quadrangle, Delaware Geological Survey unpublished map to the U.S. Geological Survey, 1:24,000.

Ramsey, K. W., and Baxter S. J., 1996, Radiocarbon dates from Delaware: A compilation: Delaware Geological Survey Report of Investigations No. 54, 18 p.

Ramsey, K. W. and Schenck, W. S., 1990, Geologic Map of southern Delaware: Delaware Geological Survey Open File Report No. 32, 1:100,000.

Rasmussen, W. C., and Slaughter, T. H., 1955, The water resources of Somerset, Wicomico, and Worcester counties: Maryland Department of Geology, Mines and Water Resources, Bulletin 16, 114 p.

Rogers, E. E., and Pizzuto, J. P., 1994, The Holocene stratigraphy of three freshwater to brackish wetlands, Kent County, Delaware, *in* Kellogg, D. C. and Custer, J. F., eds., Paleoenvironmental studies of the State Route 1 corridor: contexts for prehistoric settlement, New Castle and Kent counties, Delaware: Delaware Department of Transportation Archeology Series No. 114, p. 48-81.

Shackleton, N. J., Backman, J., Zimmerman, H., Kent, D. V., Hall, M. A., Roberts, D. G., Schnitker, D., Baldauf, J. G., Despraries, A., Homrighausen, R., Huddleston, P., Keene, J. B., Kaltenback, A. J., Krumsiek, K.A., Morton, A. C., Murray, J. W., and Westberg-Smith, J., 1984, Oxygen isotope calibration of the onset of ice-rafting and history of glaciation in the North Atlantic region: Nature, v. 307, p. 620-623.

Sims, J. T., Andres, A. S., Denver, J. M., and Gangloff, W. J., 1996, Assessing the impact of agricultural drainage on ground and surface water quality in Delaware: University of Delaware, Department of Plant and Soil Science, 185 p.

Sirkin, L. A., Denny, C. S., and Rubin, M., 1977, Late Pleistocene environment of the central Delmarva Peninsula: Geological Society of America Bulletin, v. 88, p. 139-142.

Webb, R. S., Newby, P., and Webb, T., 1994, Palynology and paleohydrology of Delaware, *in* Kellogg, D. C. and Custer, J. F., eds., Paleoenvironmental studies of the State Route 1 corridor: contexts for prehistoric settlement, New Castle and Kent counties, Delaware: Delaware Department of Transportation Archeology Series No. 114, p. 36-47

Whitehead, D. R., and Oaks, R. J., 1979, Developmental history of the Dismal Swamp, *in* Kirk, P. W., ed., The Great Dismal Swamp: The University Press of Virginia, p. 25-43.

Delaware Geological Survey
University of Delaware
Newark, Delaware 19716