PALYNOLOGY AND PALEOHYDROLOGY OF DELAWARE

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August 25, 1989

INTRODUCTION

The sediment records from small basins can yield information on the paleohydrology of an area. Previous work at Walter's Puddle in central Delaware has documented changes in the water level of the basin (Newby, Webb, and Webb in this volume; Figure 21). The pollen record, the sediment stratigraphy, and the radiocarbon dates from a core taken in the center of Walter's Puddle near Townsend, DE, independently confirm the existence of a major hiatus (unconformity) within the basin. We interpret this hiatus, dated from 11,880 to 5820 BP, to be a period of lowered water levels. Under these conditions, the basin dried out and sediments were desiccated and removed. Before 11,900 and after 5800 BP the accumulation of sediment in the basin appears to have been relatively continuous during periods of higher water levels in the basin. After the initial work at Walter's Puddle, important stratigraphic questions concerning the duration, magnitude, and regional extent of this early to mid-Holocene drop in water level remained unresolved, however.

The bracketing dates of 11,880 and 5820 BP have provided a maximum estimate for the period of lowered water levels at Walter's Puddle. The 5820 BP date is a well-constrained estimate for the end of lower water level conditions in the basin, whereas, the 11,880 BP date for the beginning of lowered lake level is less well-constrained. Because the hiatus was probably an erosional surface, the sediments immediately below the hiatus are more likely to represent the stratigraphic depth to which material was removed during lowered water level conditions than the material deposited immediately before the onset of such conditions. Previous work has been unable to resolve whether the lowered water levels at Walter's Puddle lasted 6000 years (11,880 to 5820 BP) or less than 1000 years (6800 to 5820 BP).

The extent and nature of the erosional surface within Walter's Puddle also was not well-constrained from our initial field work. From a single 5 cm diameter sediment core, we were unable to predict whether the erosional surface was continuous and uniform within the basin. We did not find additional evidence that could provide insights into the drying out process such as soil development within the basin, presence of a subsurface bench suggestive of intermediate water levels within the basin, or desiccation surfaces indicative of the maximum drop in water level. Finally, we wanted to know whether the period of lowered water level at Walter's Puddle was unique to the basin or if it represented a regional drop in the water table. If the drop in water level at Walter's Puddle was symptomatic of a regional trend, the archaeological, paleoclimatic, and paleoecological significance of the event would be much more far-reaching.

To address these research interests, Walter's Puddle was recored following Digerfeldt's (1974) method of obtaining a transect of sediment cores within a basin to look for evidence of water level fluctuations. We took a transect of short-cores (1 m or less) from the center of the basin to the edge to sample the erosional surface/hiatus throughout the basin. We also cored three additional basins within the area following the Digerfeldt (1974) method of multiple-core transects. Two of these basins, Longhauser Pond (39°23' 05" N, 75°40' 30" W) and Nowakowski Pond (39°23' 09" N, 75°40' 40" W) were within 500 m of Walter's Puddle. The third basin, Prison Pond (39°20' 20" N, 75°36' 45" W), is located approximately 15 km south of Walter's Puddle in Smyrna, DE. (Figure 21). Evidence for a hiatus was found in each of the cores within the transect at each basin. Correlation of this hiatus between basins verified the regional nature of the water level fluctuation and further constrained the timing of this event.

STUDY DESCRIPTIONS

A total of 10 locations in the Smyrna to Townsend, DE area were surveyed as potential basins to be cored. All the basins were "bay/basins" - small, closed depressions of indeterminate origin (Plate 3). Newby, Webb, and Webb (in this volume) have provided a thorough description and discussion of the origin of this type of basin, the regional vegetation, and the modern climate of the area. For our second phase of field work, we selected three of the basins for coring. The basins, as well as Walter's Puddle, appeared to remain wet throughout the year.

Longhauser Pond

Longhauser Pond is a shallow, elongated oval basin approximately 75 by 40 m (Figure 26) with the long axis trending northeast/southwest. At the time of coring the maximum water depth was 55 cm. The center 30 m of the basin was open water, ringed by 10 m of emergent Cephalanthus (buttonbush), and a ring of 5 to 10 m of open water along the edge of the basin (Figure 26 and 27).

Nowakowski Pond

Nowakowski Pond is a shallow, elongated oval basin approximately 90 by 50 m (Figure 26). This basin, with the long axis trending northwest/southeast, appeared to be made up of two distinct, smaller sub-basins. Emergent Cephalanthus occupied most of the basin with only the center of each sub-basin containing open water. At the time of coring the maximum water depth was 45 cm (Figure 28).

Prison Pond

Prison Pond is a small, shallow, oval basin approximately 25 m in diameter. The maximum water depth at the time of coring was 55 cm. The center 10 m of the basin was open water, ringed by 10 m of emergent Cephalanthus, and an outer ring of 5 m of open water (Figure 26).

Walter's Puddle

Walter's Puddle is a small, oval basin approximately 20 m in diameter and 1 m in depth. The basin had been excavated by the owner since the original core was taken. The northwestern section of the basin was dug out 1 to 2 m with debris fringing the area of primary disturbance (Figure 26).

PLATE 3

Aerial Photograph of Bay/Basin Ponds

Many Bay/Basin ponds occur in central Delaware. Some hold water year round, while others are shallow and are plowed over by farmers.

FIGURE 26

Sketch Maps of Bay/Basin Study Localities

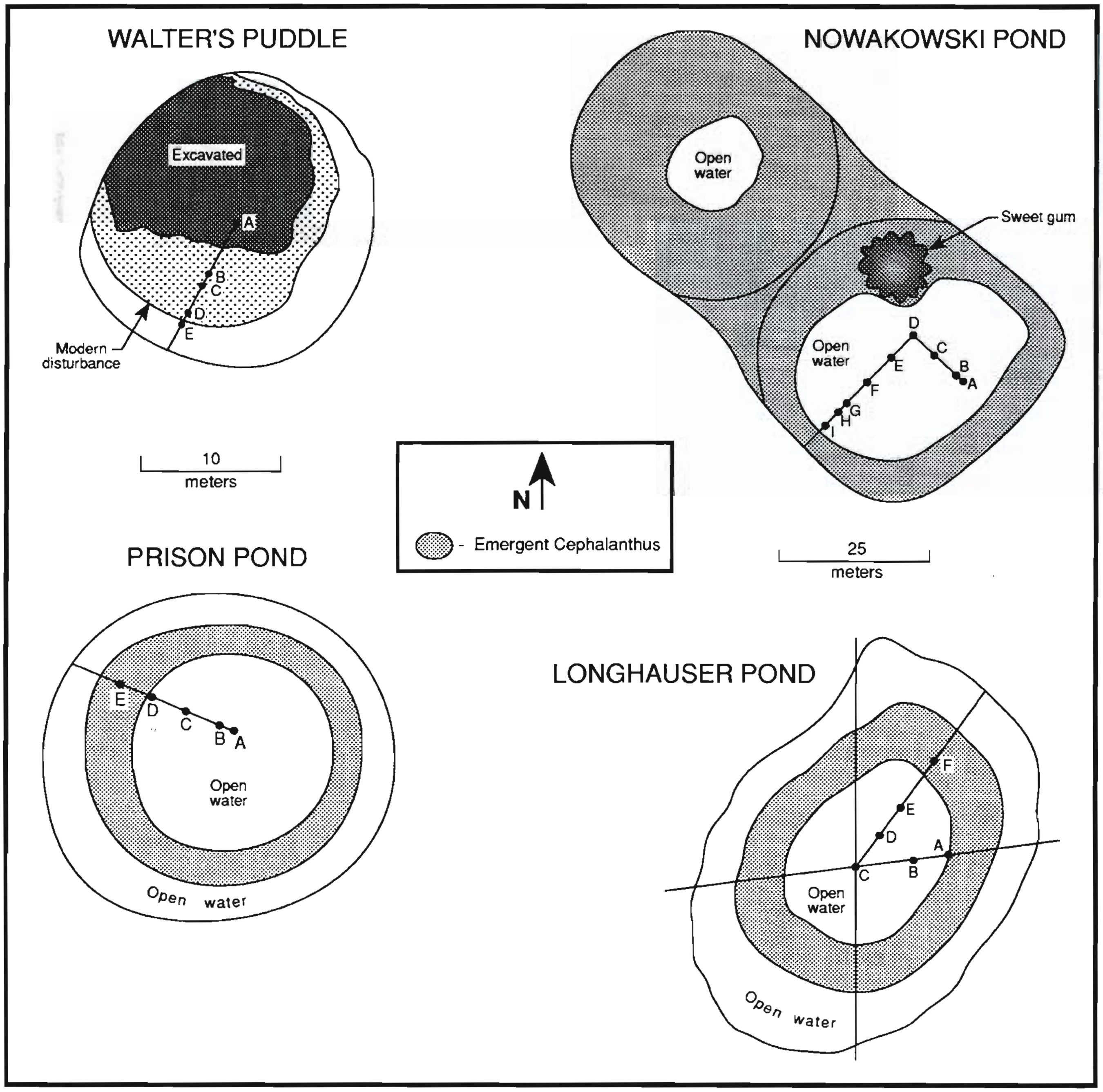


FIGURE 27

Stratigraphic Profile of Longhauser Pond

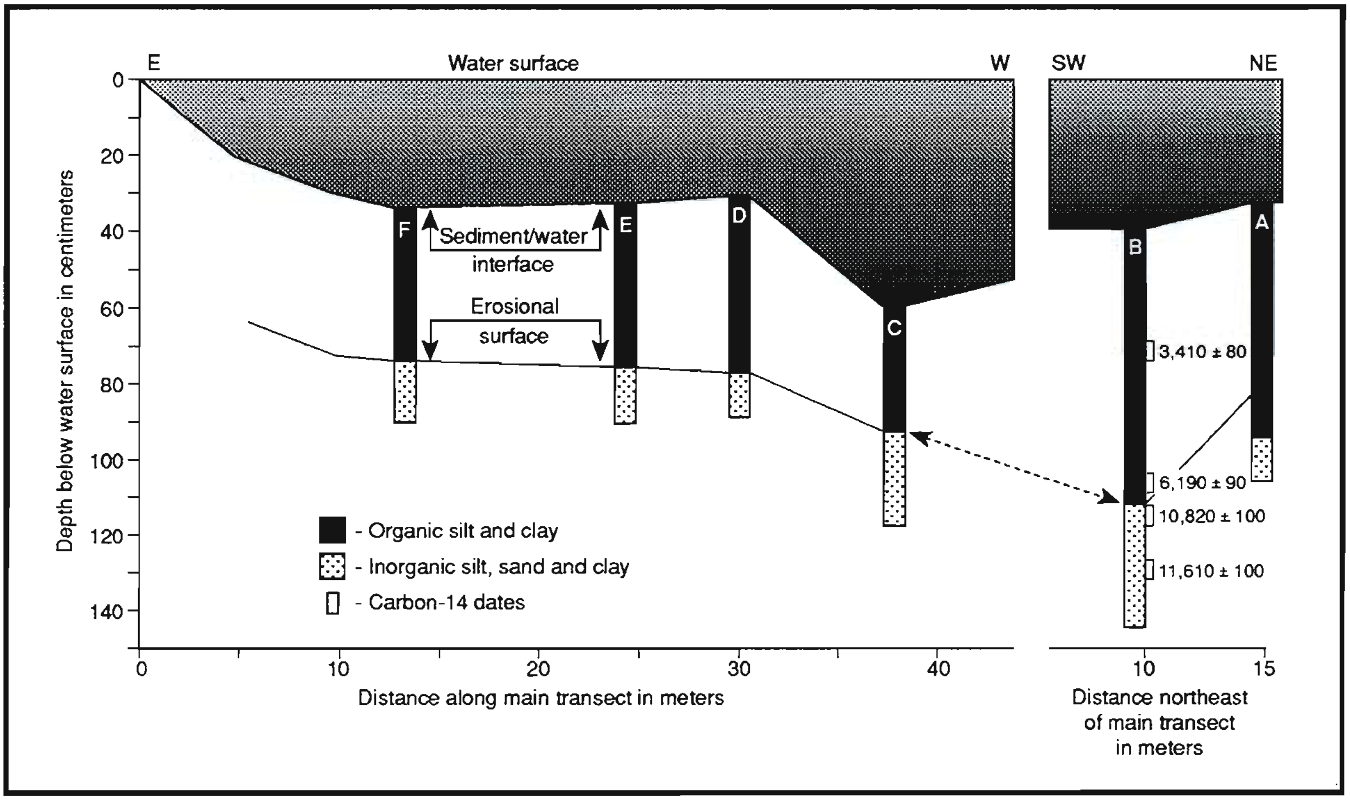
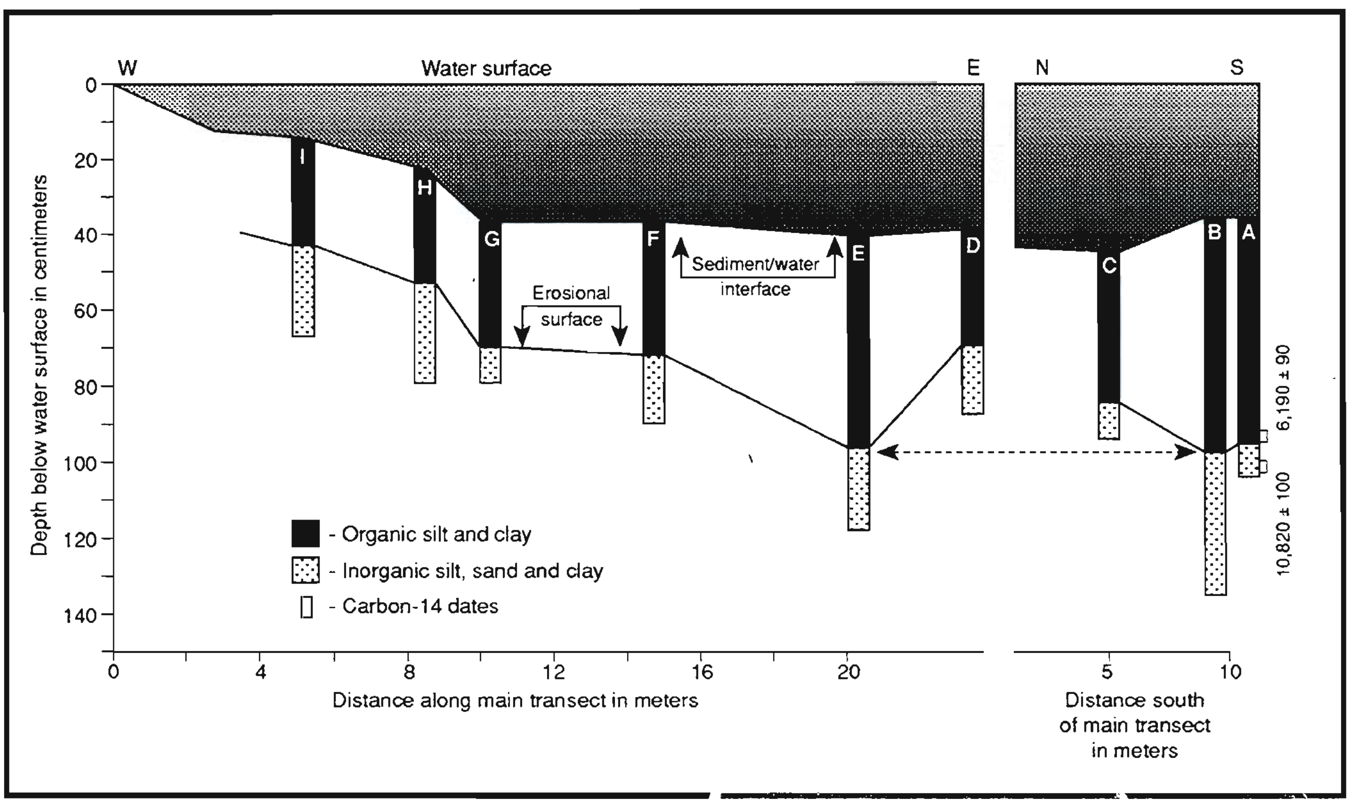


FIGURE 28

Stratigraphic Profile of Nowakowski Pond



METHODS

Field Work

Transects of cores were taken in each of the four basins extending from the shoreline to the center of the basins. The location and orientation of the transects of cores were selected to maximize:

1) sampling within each basin; and

2) recovery of as long a section of organic-rich sediments as possible.

Five centimeter diameter polycarbonate tubes with pistons were used to sample the upper 50 to 75 cm section of each core. These polycarbonate tubes were capped and extruded in the laboratory. To recover material below the depth of 50 to 75 cm, a modified 5cm Livingston piston corer was used. A 10 cm PVC tube with piston was also used to take a core along the transect in each basin for higher resolution radiocarbon dating. By increasing the surface area of the core, we hoped to decrease the amount of stratigraphic displacement required for each sample submitted for radiocarbon dating. These cores were also capped and extruded in the laboratory.

A total of six cores was taken at Longhauser Pond: four along a northeast/southwest transect, Cores C-F; and two along an east/west transect, Cores A and B (the 10 cm radiocarbon core; Figure 26). At Nowakowski Pond, nine cores were taken: six along a southeast/northeast transect, Cores D-I; and three along a north/south transect, Cores A (the 10 cm radiocarbon core), B, and C (Figure 26). Five cores were taken at Prison Pond along a east/west transect, Cores A-E (Figure 26). Four more cores were taken at Walter's Puddle along a northeast/southwest transect, Cores B-E (Figure 26).

Laboratory Analyses

Core sediments were described in terms of changes in color, lithology, texture, and relative abundance of macrofossil material. Samples were taken for loss-on-ignition at selected intervals (every 5 to 10 cm) in each of the cores. A total of twelve radiocarbon samples were submitted for analysis: four samples from Longhauser Pond, Core B; two samples from Nowakowski Pond, Core A; two samples from Prison Pond, Core A; and four samples from Walter's Puddle, Core B (Table 4). Each radiocarbon sample was wet-sieved using a 2-4 mm brass sieve to remove potential contaminants, such as rootlets, and then dried at 98°C to remove excess water.

RESULTS

Sediment Stratigraphy

The sediment records of each of the four basins contained evidence for the early to mid-Holocene lowered water level previously observed in Core A of Walter's Puddle. The sediment stratigraphy varied slightly from basin to basin in terms of the composition and amount of material recovered. In each of the basins, between 28 and 70 cm of organic-rich mud overlay oxidized, inorganic clay, silt, and sand. A

TABLE 4

Radiocarbon Dates from Bay/ Basin Cores

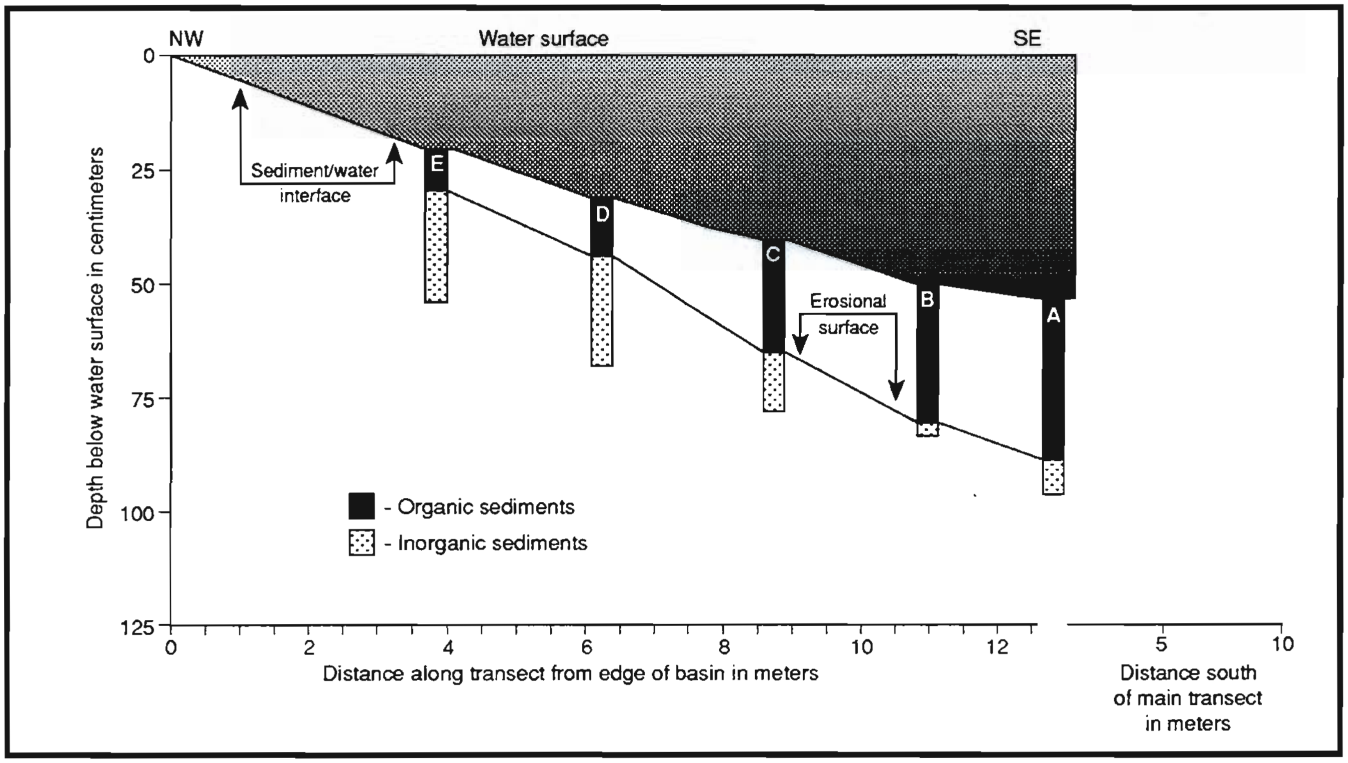
Site	Core	Depth (cm)	Date (BP)	Lab number
	B	30 - 35.5	3410 ± 80	WIS-2007
Longhauser	B	64 - 69	6190 ± 90	WIS-2008
Pond	B	71 - 78	10820 ±100	WIS-2009
	B	86 - 92	11610 ±100	WIS-2010
Nowakowski	A	57 - 59	6190 ±100	WIS-2007
Pond	A	64 - 67	10580 ±100	WIS-2008
Prison	A	24 - 26.5	2650±80	WIS-2022
Pond	A	34 - 41	11760 ±150	WIS-2023
	A	52 - 61	5820 ± 80	WIS-1802
Walters	A	63 - 69	11880 ±160	WIS-1803
Puddle	A	109 - 116	14400 ±150	WIS-1804
	B	25 - 30	2370 ± 80	WIS-2024

distinct hiatus with erosional features marked the transition from organic to inorganic-rich sediment in each of the cores. Color differences across the hiatus were observed with dark brown to black material above and yellow to blue/gray material below the hiatus.

Longhauser Pond. The sediment stratigraphies of the six cores from Longhauser Pond are summarized in Figure 27 and Appendix II. In each of the inner five cores, A-E, the upper most sediment unit was a fibrous peat ranging in thickness between less than 5 cm at Core C to 30 cm in Core B. The surface sediments of the outermost and shallowest core, F, were finer grain and more decomposed. Underlying the upper unit in each of the cores was a fine organic clay and silt unit, close to 30 cm thick with some macrofossils. The third sedimentary unit, a dark organic lake mud ranging in thickness between 10 and 15 cm directly overlay the hiatus. Clasts of material similar to that directly below the hiatus were present at the base of this unit along with occasional well-rounded pebbles. The hiatus separating the organic material above and inorganic material below was uneven and sharp. The sediments below the hiatus were a mixture of inorganic clays, silts, and sand. A thin coarse grain sand layer was present in Core A. The large diameter of Core B facilitated the identification of mud cracks in three dimensions. These mud cracks extended 10 to 15 cm below the hiatus from 70 to 85 cm and were filled by organic-rich material from above. Immediately below the hiatus in Core B the sediments was a dark, fine grain clay and silt. The depth of the hiatus followed the present basin morphometry (Figure 27) and is close to 30 cm deeper in the center of the basin. The loss-on-ignition data from these cores matched the sediment description with higher percent organic material above and lower percent organic below the hiatus (Appendix II).

FIGURE 29

Stratigraphic Profile of Prison Pond



Nowakowski Pond. The sediment stratigraphies of the nine cores from Nowakowski Pond are shown in Figures 28 and Appendix II. The upper-most sediments in each of the cores were fine-grained, decomposed organic silt between 3 (Core I) and 15 cm thick (Core B). Underlying the upper unit in each of the cores was a transition unit of fine organic clay and silt up to 35 cm thick with some macrofossils. Dark, organic lake mud ranging between 10 and 20 cm in thickness directly overlay the hiatus. As in Longhauser Pond, there were clasts of the underlying material at the base of this unit immediately above the hiatus. The hiatus was sharp, but uneven in most of the cores. The sediments below the hiatus were a mixture of inorganic clays, silts, and sand. Mud cracks, filled by organic-rich material from above, were also observed below the hiatus in the large diameter core, A. The depth of the hiatus followed the present basin morphometry in all the cores except in Cores C and D (Figure 28), and was 30 cm deeper in the center of the basin. The loss-on-ignition data from these cores also matched the sediment description with higher percent organic material above and lower percent organic below the hiatus (Appendix II).

Prison Pond. The sediment stratigraphies of the five cores from Prison Pond are summarized in Figures 29 and Appendix II. The upper-most sediments in each of the cores was an organic-rich silt. Directly underlying this organic-rich silt was a hiatus that separated the organic material above and inorganic clays, silts, and sand, below. The depth of the hiatus followed the present basin morphometry (Figure 29). The loss-on-ignition data from the cores did not consistently follow the sediment description of higher percent organic material above and lower percent organic below the hiatus (Appendix II).

Walter's Puddle. The sediment stratigraphies of the five cores from Walter's Puddle indicate that the upper most sediments in the three middle cores, B, C, and D, were a modern disturbance mishmash of sands and silts (Figure 30 and Appendix II). Core A, taken two years earlier, had was undisturbed, and

FIGURE 30

Stratigraphic Profile of Walter's Puddle

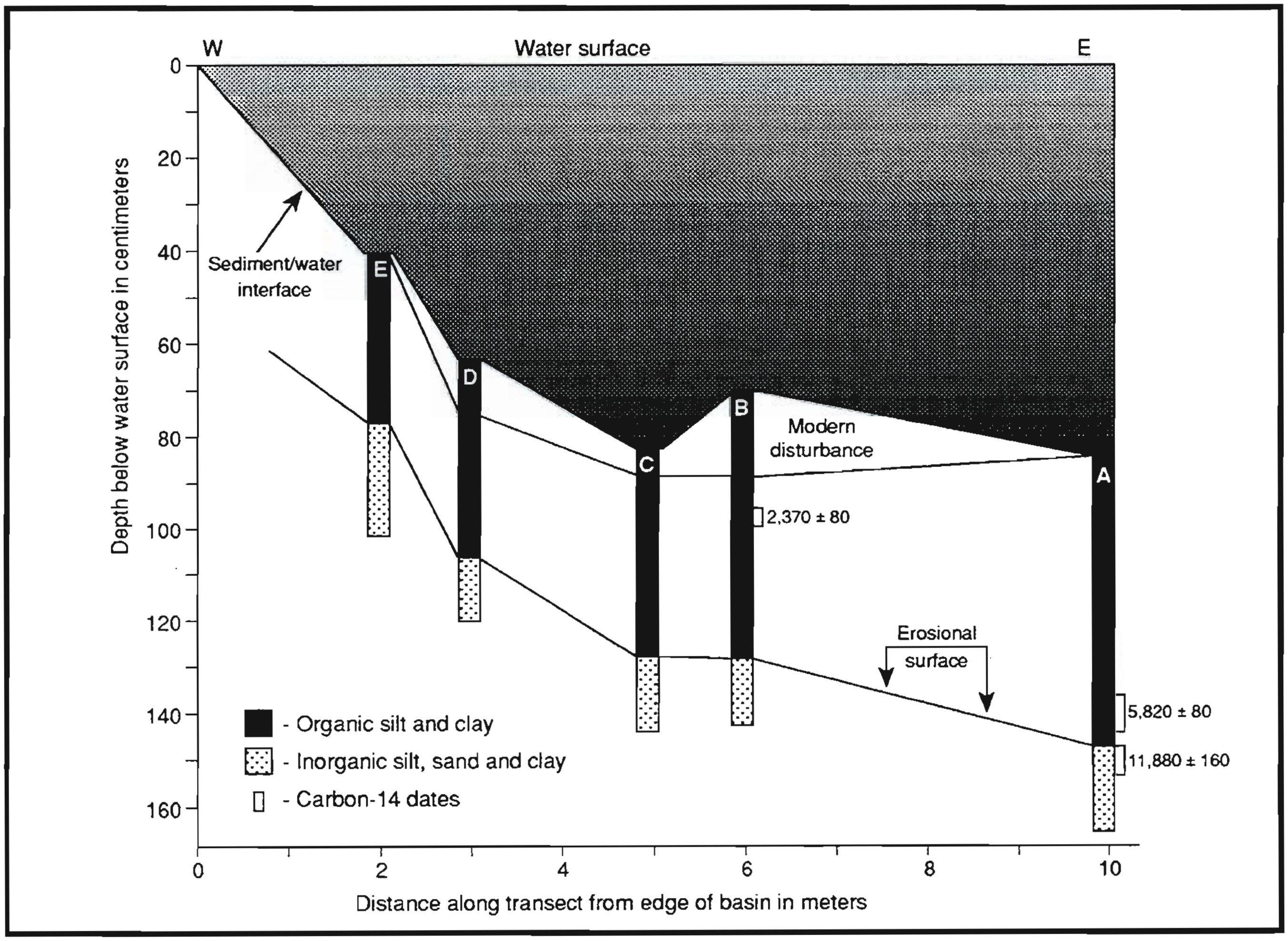
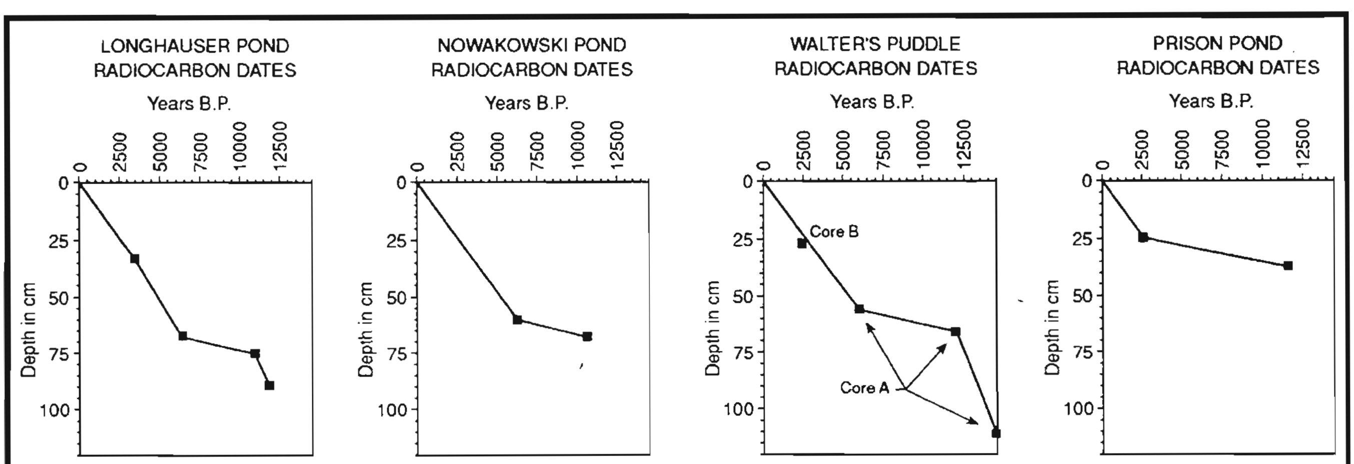


FIGURE 31

Age vs. Depth Plots for the Bay/Basin Cores



Core E was far enough removed to remain undisturbed. The surface sediments from Cores A and E were a coarse, detrital-rich, organic silt. Underlying the upper sediments of each of the cores was transition unit of fine organic clay and silt unit. Dark, organic lake mud, ranging between 10 and 15 cm in thickness, directly overlay the hiatus. Rip-up clasts were found immediately above the hiatus. The sediments below the hiatus were a mixture of inorganic silts and sand grading into a silty, inorganic clay. The depth of the hiatus (Figure 30) is consistently deeper going from the edge of the basin at Core E towards the center of the basin at Core B. Stratigraphic correlation of these cores to Core A can be made although they are complicated by the modern disturbance. We cannot yet say whether the hiatus in Core A was significantly deeper than in Core B or relate the present morphometry of the basin to the depth of the hiatus. The loss-on-ignition data from these cores also matched the sediment description with higher percent organic material above and lower percent organic below the hiatus (Appendix II).

Radiocarbon Dates

Bracketing radiocarbon dates from three of the basins, Longhauser Pond, Nowakowski Pond, and Walter's Puddle, consistently date the break in sediment accumulation within the basins to be from 11,000 to 6,000 BP (Table 4; Figure 31). Discrepancies in the dates from one basin to the next can be explained as a combination of:

1) differences in the deposition/erosion history at each of the basins; and

2) differences in the composition and sample size of the material dated.

The 3410 BP date at a depth of 33 cm from Longhauser Pond confirms that accumulation rates in the basin have remained fairly constant over the last 6,000 years (10 cm/10^3 yr). The basal dates from Longhauser Pond (11,610 BP) and Walter's Puddle (14,400 BP) suggest that sediment accumulated at a higher rate in the late glacial in these basins (20 cm/10^3 yr) than during the latter part of the Holocene (Table 4). Even the mid to late-Holocene and late-glacial rates of sediment accumulation in these basins are low compared with the rates of accumulation in most continuously wet basins during the Holocene. Webb and Webb (1988) show that rates below 10 to 15 cm/10^3 yr are frequently associated with discontinuous sediment accumulation processes.

DISCUSSION

Regional Stratigraphy

We have been able to develop a regional chronology for the area based upon the similar sedimentary records and consistent chronology observed at each of the four basins (Table 5). The appearance of a major stratigraphic break in each of the cores from the four basins demonstrates that the hiatus that had been observed at Walter's Puddle is not unique. The presence of this feature at Prison Pond, 15 km to the south and in a different drainage system suggests that this is a regional change in effective moisture rather then a local hydrologic event. The multiple core transects record the erosional surface as a continuous and uniform feature within each of the basins. The bracketing radiocarbon dates consistently estimate the period of depressed water level to be from 11,000 to 6,000 BP. Prior to 11,000 BP the water levels were high enough to allow sediment accumulation at rates of nearly 20 cm/1000 yr. Depressed temperatures and a reduced nutrient supply are possible explanations for the organic-poor nature of these sediments.

TABLE 5

Regional Lake Sediment Chronology Chart for Central Delaware

Regional History (years BP)	Sediment Accumulation Rate (cm/ 1000 yr) Longhauser Pond	Nowakowski Pond	Prison Pond	Walters Puddle	Walters Puddle Pollen Zone	Interpretation
	9.6					
3400	12.5	9.3	4.7*	9.6	Zone 1 Oak-Buttonbush	- accumulation of organic-rich detrital sediments in shallow intermittantly dry basins - gradual rise in water table to modern level
6000						
	1.6	1.7	2.1*	1.6		- haitus, erosional surface with sessication and sediment removal - water table close to 140 cm below modern level
11000	18.9			18.4	Zone 2 Spruce-Pine-Birch-Sedge	- water depths sufficient to permit the deposition and accumulation of inorganic clays, silts, and sands
14500						
>20000*					Zone 3 Spruce-Oak-Sedge	- inorganic sediment accumulation in low productivity, cold/ wet environment

* estimated

Between 11,000 and 6,000 BP, water levels dropped resulting in desiccation and deflation of previously deposited material as well as inhibiting the accumulation of any additional sediments. After 6000 BP, water levels rose sufficiently to permit the production and accumulation of organic-rich sediments.

The presence of rip-up clasts at Longhauser Pond, and mud cracks at Nowakowski Pond, and Walter's Puddle confirm that the hiatus is an erosional feature in each of the basins. The mud cracks extend the minimum depth of the water level drop below the depth of the hiatus. Water levels dropped at least 10 to 15 cm below the depth of the hiatus in Cores A and B at Nowakowski Pond and Longhauser Pond, respectively. The minimum estimates for the late-glacial to mid-Holocene drop in water level ranges from as little as 83 cm at Prison Pond to 147 cm at Walter's Puddle. The drops in water levels at Longhauser and Nowakowski Ponds are estimated to be 91 and 125 cm, respectively. Maximum seasonal fluctuations in the water table elevation of central Delaware between 1950 and 1960 approach plus-or-minus 50 cm relative to the long term average elevation (Boggess and Adams 1964). The estimated magnitudes of water level lowering during the early Holocene in each of the basins investigated exceed this range of observed values and suggest that the hydrologic conditions were significantly different from those today. Modeling of the present and the paleohydrologic budgets of these basins should provide insight into the climatic conditions that would have caused such a water table lowering.

Archaeological Implications

The existence of a consistently dated hiatus (ca. 11,000 to 6000 BP) in sediment records of each of the four basins provides information that can be used to interpret regional changes in the prehistoric human settlement patterns in central Delaware during the Holocene. The period of most intensive use of this type of basin in central Delaware occurred between 4500 and 1900 BP. Archaeological evidence for activity around these basins prior to 4500 and after 1900 BP is not as well documented (Custer and Bachman 1986b). Archaeological investigations in New Jersey by Bonfiglio and Cresson (1981) suggest that this type of basin was actively used by humans during the early to mid-Holocene. The use of these basins by prehistoric groups may be related to sustained water levels within the basins and the resources available around them. Our data indicate that at least some of the basins were dry for some period between 11,000 and 6000 BP. The timing of this event may be at least a partial explanation for the absence of Paleo-Indian archaeological sites near the basins in central Delaware during the early Holocene. The regional increase in effective moisture, as suggested by our data, could provide an explanation for the observed evidence for greater human activity around and use of the basins after 6000 BP. If activity around, and use of the basins is shown to be related to 'wet' periods, additional analysis will be needed to explain the decline in archaeological sites near the basins after 1900 BP. Nevertheless, preliminary results suggest a correlation between regional changes in water levels of these basins and the timing and intensity of human activity in and around the basins.

SUMMARY

The stratigraphic records from four basins in Central Delaware contain evidence for a regional drop in water levels starting at the end of the late Pleistocene and extending into the early to mid-Holocene. Water levels appear to have been as low as 140 cm below the modern levels in the basins at some time between 11,000 and 6000 BP. Correlation of this event with the timing and intensity of human activity in and around this type of basin suggests that the observed patterns of human settlement in central Delaware during the early to mid-Holocene may be in response to changes in the effective moisture of the region.