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COMPUTER MAPPING OF SEASONAL GROUNDWATER FLUCTUATIONS FOR TWO DIFFERING SOUTHERN NEW JERSEY SWAMP FORESTS I

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I. ABSTRACT

Computer-generated maps (SYMAP, Harvard) of seasonal groundwater fluctuations for two New Jersey swamp forests, a red maple (Acer rubrum) swamp and an Atlantic white cedar (Chamaecyparis thyoides) swamp, are presented. Notable differences exist in water table behavior for the two swamp forests and are best accounted for by topographic differences. Other factors examined which might affect the hydrologic differences include vegetation and subsurface geologic differences.

II. INTRODUCTION

Little information is currently available concerning the hydrologic features of southern New Jersey wetland forests. These forests vary floristically in composition and are widespread in over half of New Jersey's landscape.[11-19] More importantly, they are typical of forest wetlands distributed throughout most of the eastern United States.[4,10,21,2,3,22,1]

Information on the hydrology of these wetland forests has lagged behind that for other types of forest ecosystems. Much is known concerning the hydrologic characteristics of mountainous forested watersheds.[9,6,8,5] Despite this experience gained in working with other types of forested ecosystems, approaches for obtaining hydrologic data from ecosystems such as the one at Hubbard Brook are useful only in a general way when applied to wetland ecosystems not directly underlain by a bedrock base. New hydrologic approaches need to be and are in the process of being developed for studying forested wetlands.[18,20]

In the last decade, the technique of computer graphics was first utilized to study plant community structure.[23] In this paper, we have used computer graphics to study two differing New Jersey swamp forests with the intent of showing that computer graphics can be used to monitor hydrologic events in wetland ecosystems.

III. METHODS

A. SITE DESCRIPTION

The two swamp sites are located on the Stockton State College campus near Pomona, New Jersey (Fig. 1; latitude 39° 27'N; longitude 74° 33'W), and have been previously described in detail.[11,12] The sites are part of a larger stream ecosystem within the Stockton Ecological Preserve.

Major tree species for the two swamp sites include red maple (Acer rubrum L.), Atlantic white cedar (Chamaecyparis thyoides L.), tupelo (Nyssa sylvatica Marsh.) and sweetbay magnolia (Magnolia virginiana L.). Table 1 summarizes the major vegetative characteristics for the two swamp communities.

Soils for the two swamps have been described as Atsion sand (sandy, siliceous, mesic, typic haplaquod, spodosol) and Muck (histosol).[7]

Table 1. Vegetative characteristics for the two swamp communities.

Species	Density (stems/ha.)	Basal Area (m^2/ha.)	Frequency (% occurrence)	Above-Ground Standing Crop Biomass (kg./ha.)
		HARDWOOD SWAMP		
Red maple	756	11.85	88	295,535
Tupelo	511	3.17	66	13,387
Sweetbay magnolia	361	0.41	67	7,182
Total	1,628	15.43		316,104
		CEDAR SWAMP		
Atlantic white cedar	2,226	47.5	100	181,927
Red maple	424	3.19	93	82,410
Tupelo	77	0.39	37	1,802
Sweetbay magnolia	145	0.12	54	2,284
Total	2,872	51.2		268,423

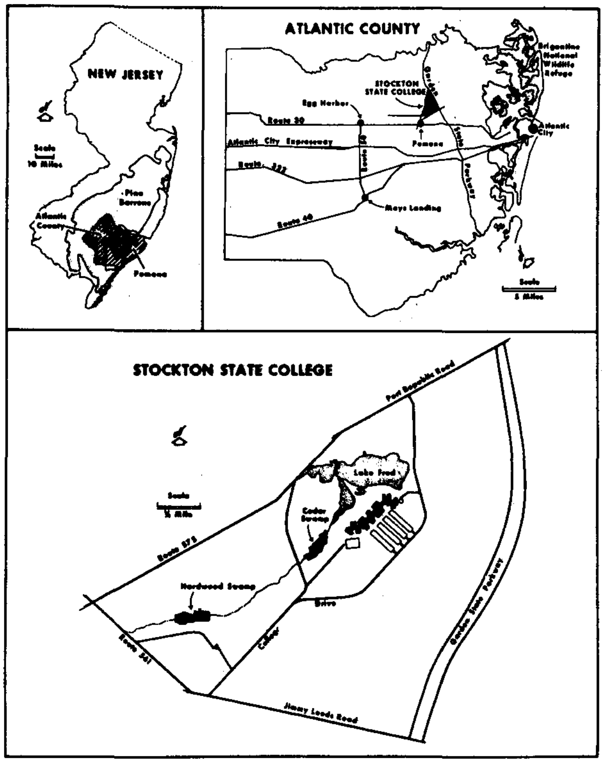

Figure 1. Study site location.

B. ESTABLISHMENT OF PERMANENT GRID SYSTEMS

Approximately one hundred adjoining 10 x 10 meter plots (1.0 ha.) were established for each of the swamp sites. The overall plot systems were carefully laid out to conform to the irregular boundaries between swamp and upland forest vegetation.

C. INSTALLATION OF PERMANENT WELL SITES

Figures 2A and 2B show the locations of 29 wells in the hardwood swamp and 36 wells in the cedar swamp. The well pipes consisted of 2.0 meter lengths of 5.1 cm. diameter PVC pipe. Angled slits were cut in the pipe to permit the entrance of water while prohibiting the influx of sediment. The bottom of each pipe was stoppered to prevent clogging with soil during installation. The pipe was installed by drilling 1.5 meter deep holes at the various well locations using a 4-inch power auger bit modified for hand use.

D. DETERMINATION OF TOPOGRAPHY

Following well installation, the absolute elevations of all well locations within the grid system were determined using a theodolite and a leveling rod. Within each swamp site, the theodolite was moved a minimum number of times to minimize elevation error.

E. MONITORING OF WELLS AND ATMOSPHERIC PRECIPITATION

Water table change and precipitation reported here was monitored during the period April 1980 through May 1981. A significant drought affecting the southern New Jersey region began in 1980 and is notable in our data.

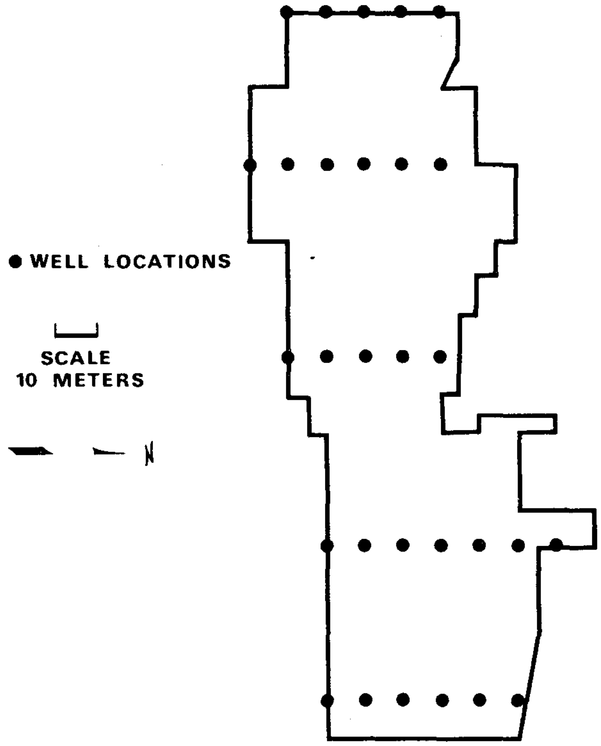

Figure 2A. Map of hardwood swamp showing well locations.

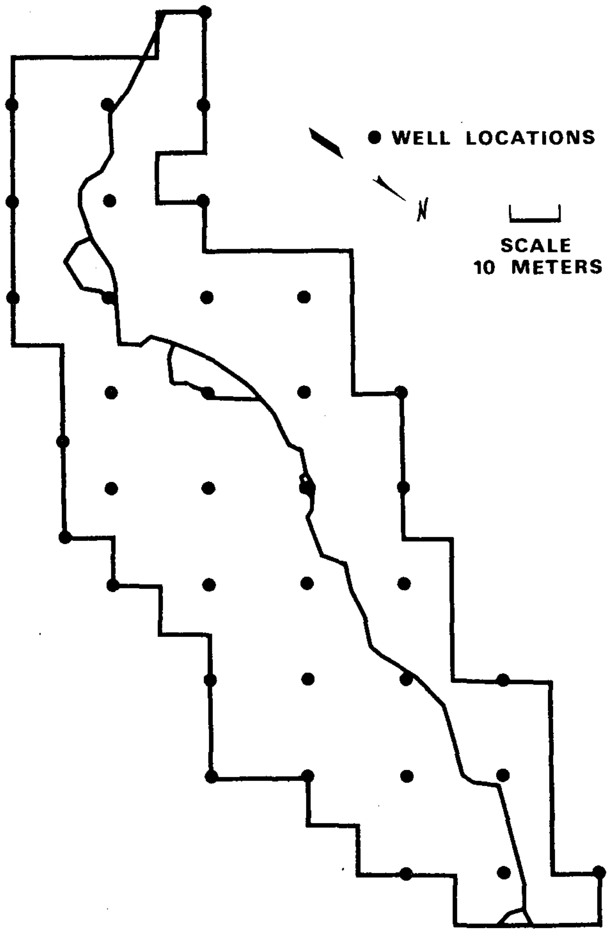

Figure 2B. Map of cedar swamp showing well locations.

F. COMPUTER GRAPHICS

Using SYMAP, a computer mapping program developed by the Harvard School of Graphics and Design, we constructed maps for both sites of (1) topography and (2) absolute water table elevations. This was accomplished by keypunching onto computer cards (1) the coordinates of all wells and (2) the absolute elevations of all wells (meters) and the absolute water table elevations of all wells (meters).

IV. RESULTS

A. TOPOGRAPHIC MAPS

Figure 3A is a topographic map of the Stockton Ecological Preserve showing the location of the hardwood and cedar swamps in reference to each other and to a nearby lake, Lake Fred. From the map it may be noted that a well defined stream channel exists in the cedar swamp; stream flow in the hardwood swamp is intermittent, and no well defined stream channel exists. In general, the cedar swamp has less relief than the hardwood swamp and is located at a lower elevation than the hardwood swamp. The cedar swamp is only slightly elevated on the edge.

Computer-generated maps of topography (mean sea level) for the two swamps based upon elevations obtained at well locations are presented in Figures 3B and 3C. As shown in Figure 3B, elevation for the hardwood swamp ranges from 13.6 to 15.2 meters mean sea level. The hardwood swamp is low in the central portion and elevated on the edges. As shown in Figure 3C, elevation for the cedar swamp ranges from 11.4 to 12.2 meters mean sea level.

B. RELATIONSHIP OF WATER TABLE LEVEL TO PRECIPITATION

Figure 4 shows the relationship between precipitation events in 1980 and 1981 and average water table depth for the two swamps. The two swamps differ in their seasonal groundwater responses to precipitation. The water table in the cedar swamp reaches its highest and lowest levels earlier in the year. However, the rate of rise or fall, and the height or depth reached, are greater in the hardwood swamp.

C. WATER TABLE MAPS

A series of computer-generated maps showing seasonal changes in water table elevation for the hardwood and cedar swamps are shown in Figures 5 and 6. The dates chosen for display reflect water table status immediately following major precipitation.

Based upon water table observations for numerous dates including those shown in Figures 5 and 6, a number of observations may be made. The hardwood swamp water table is highest in May and surface water is present. In early June the water table starts falling with surface water disappearing in early August. The water table reaches its lowest point in late September before beginning to rise in early October. The cedar swamp water table is highest in April and the swamp is flooded. The water table starts falling in early June, with surface water, except that in the stream channel, disappearing in mid-July. The water table reaches its lowest point in early September before beginning to rise in mid-September. In early December 1980, the water table of both swamps began to fall in response to the drought affecting southern New Jersey. By mid-January 1981, the cedar swamp had declined below the lowest level observed in September 1980, while the hardwood swamp had not.

Histogram summaries of Figures 5 and 6 are presented in Figures 7 and 8. Monthly values presented in Figures 7 and 8 were obtained by averaging data for the various dates depicted in Figures 5 and 6. As an example, the June 1980 values presented in Figure 7 are mean values based upon summing and averaging data for the dates June 9, 17 and 30 shown in Figure 5.

As shown in Figure 7, the water table was lowest in the hardwood swamp during September 1980. In response to drought in December 1980, the water table dropped in the hardwood swamp during January 1981 to a level similar to that during September 1980. A brief recovery from this drought began in February 1981. A similar trend for the cedar swamp is shown in Figure 8.

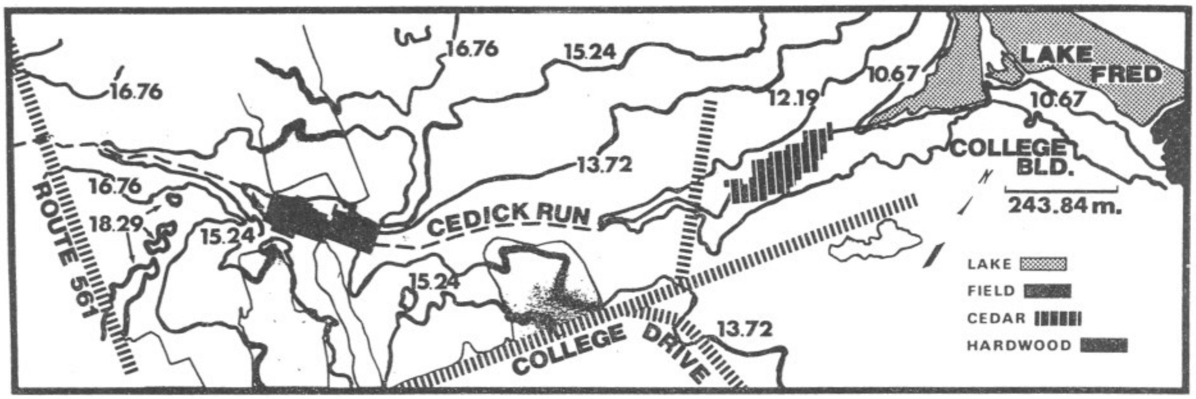

Figure 3A. Topographic map of Stockton Ecological Preserve.

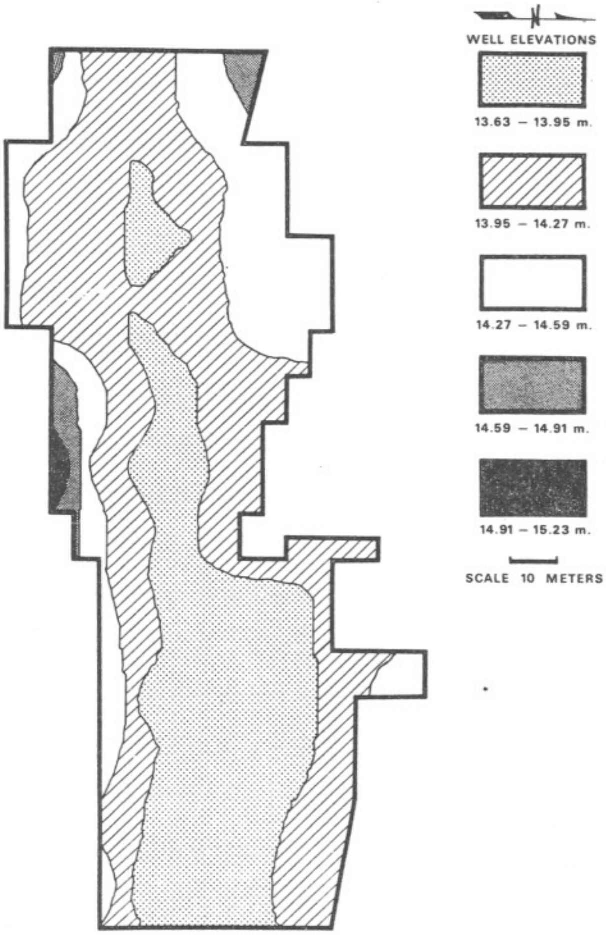

Figure 3B. Computer-generated topographic map of hardwood swamp.

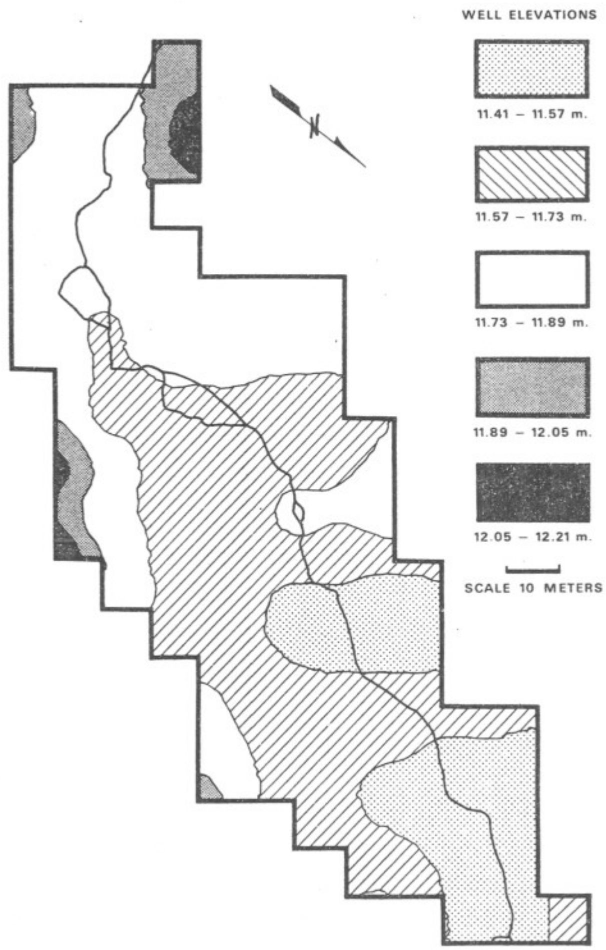

Figure 3C. Computer-generated topographic map of cedar swamp.

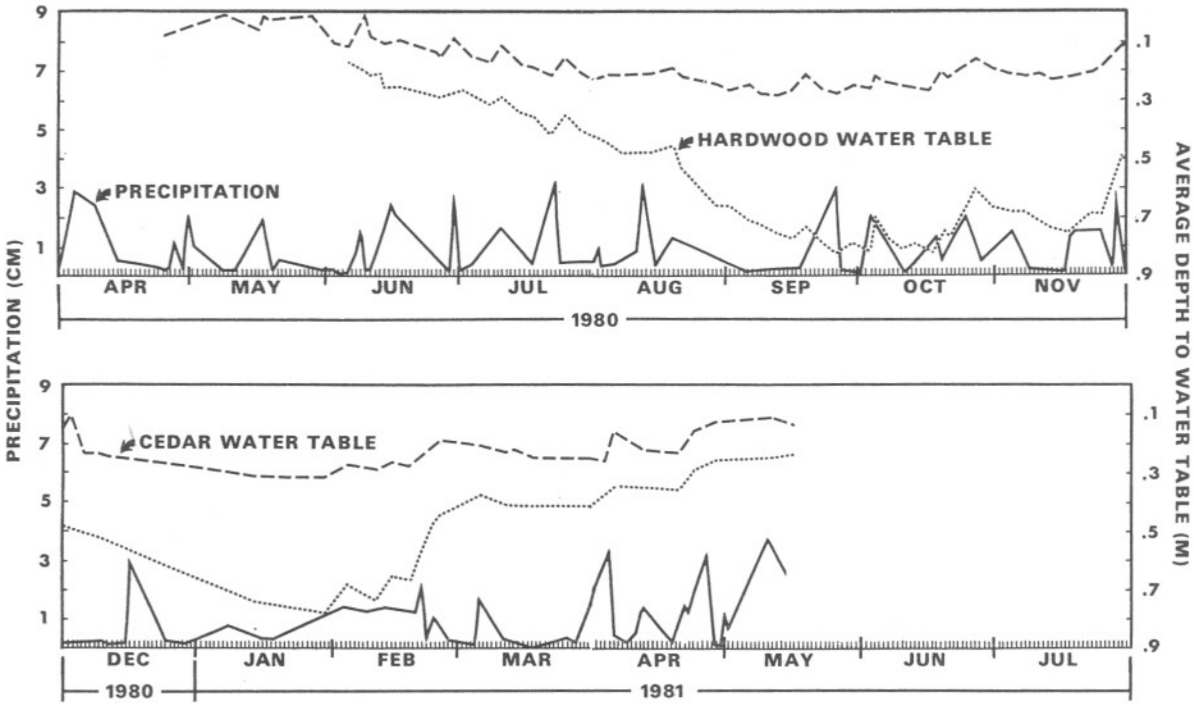

Figure 4. Water table depth and precipitation versus time.

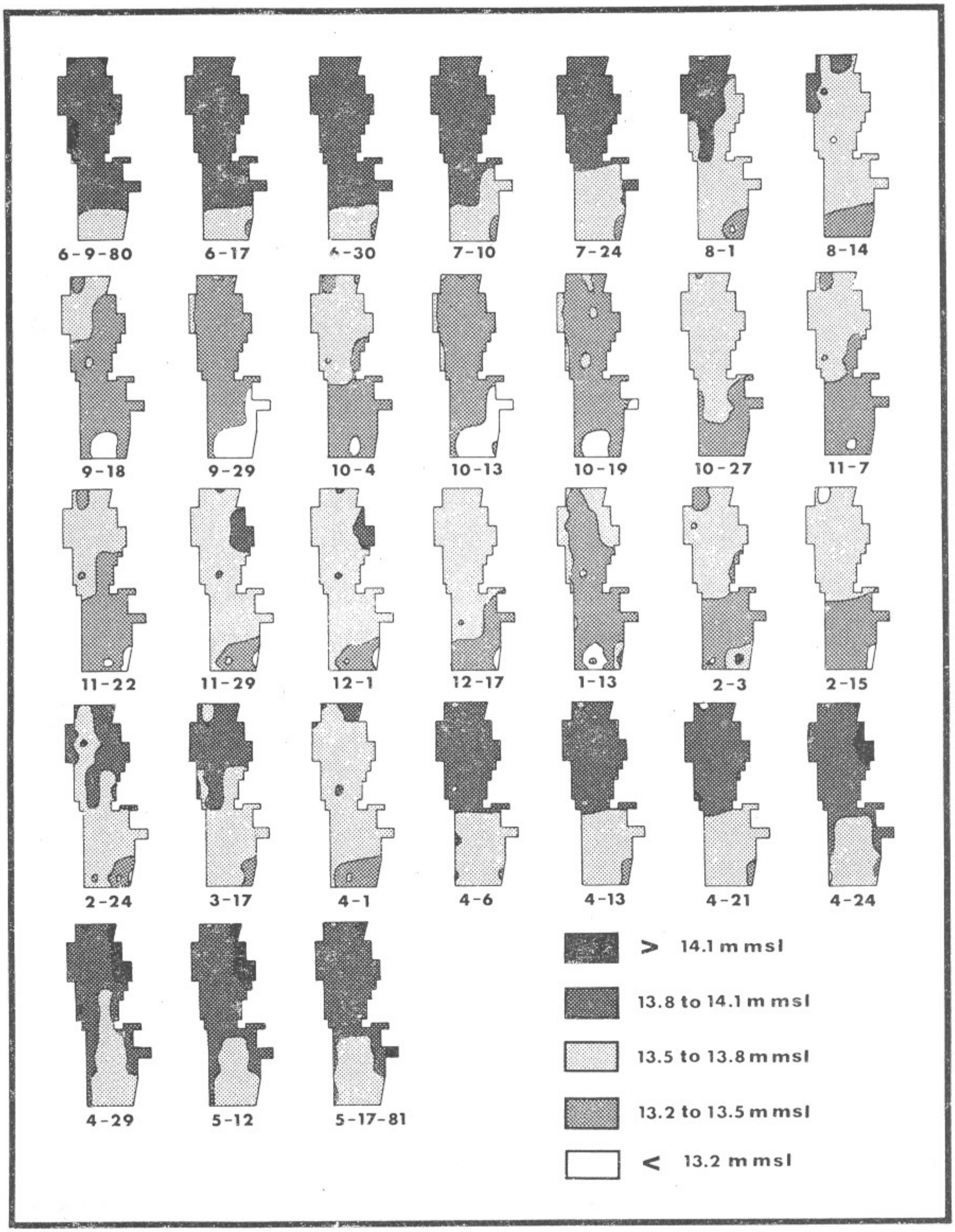

Figure 5. Computer-generated maps of water table elevation, hardwood swamp.

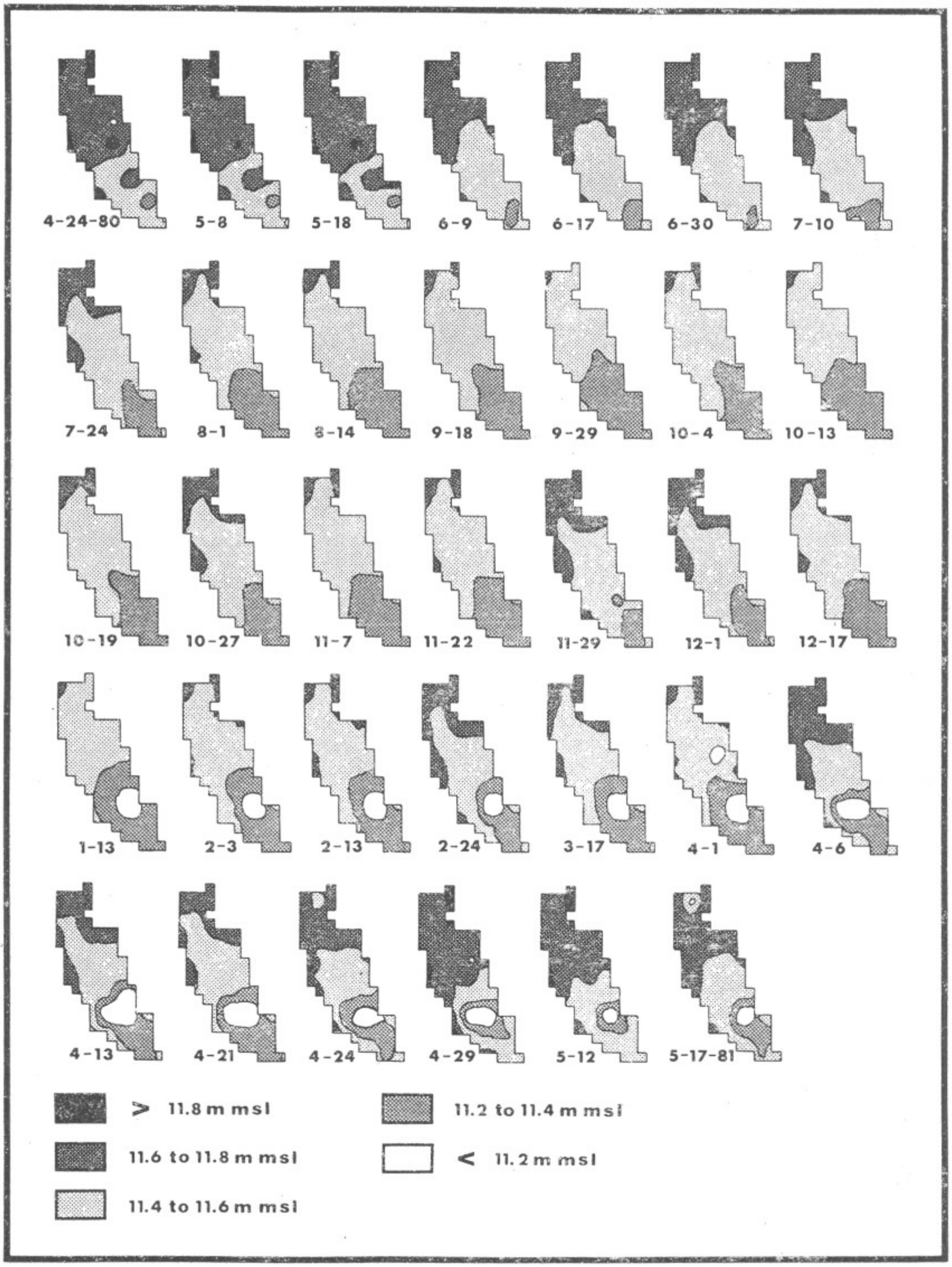

Figure 6. Computer-generated maps of water table elevation, cedar swamp.

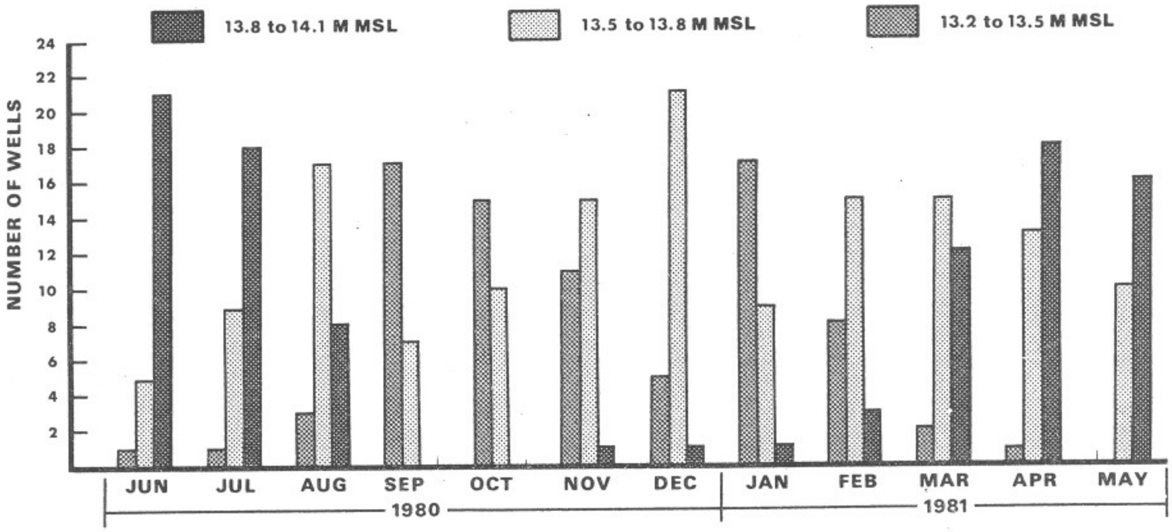

Figure 7. Histograms of water table elevation, hardwood swamp.

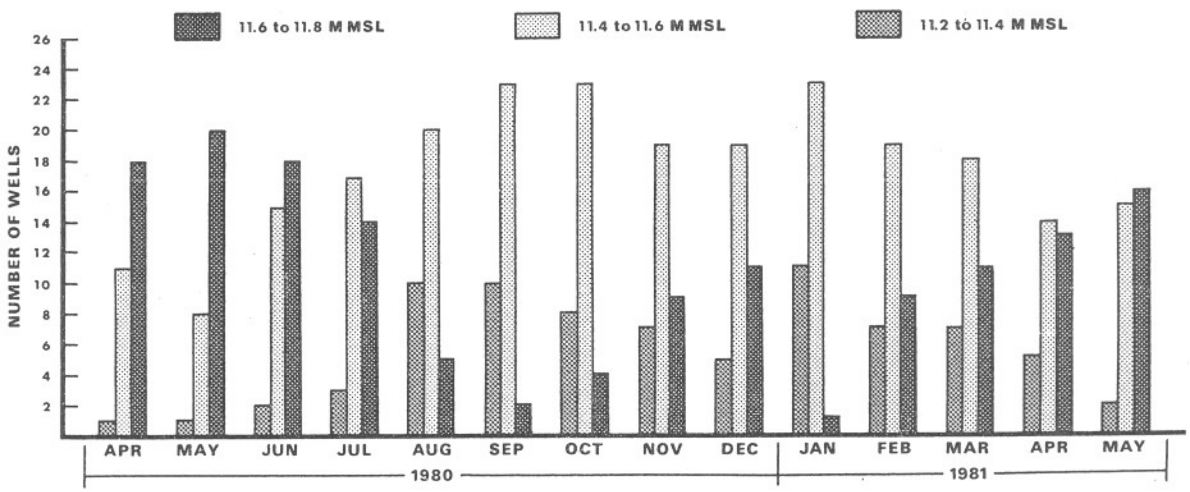

Figure 8. Histograms of water table elevation, cedar swamp.

V. DISCUSSION

As demonstrated in this paper, notable differences exist in water table behavior for two swamp forest types studied: hardwood and cedar. If hydrologic events in swamp forests are to be fully understood, it is important that a viable explanation of these be provided. Differences between the two swamps are especially interesting since they are both a part of the same larger stream ecosystem. Differences in seasonal water table behavior, surface water flow and groundwater flow can in part be explained by (1) vegetation differences, (2) subsurface geologic differences and (3) topographic differences.

Vegetation for the two swamps is significantly different: one is deciduous, the other primarily coniferous. Transpiration differences for the two swamps could account for differences in seasonal water table behavior. As a result of autumn leaf drop, one might expect autumn recharge of the water table to commence slightly earlier in the hardwood swamp than in the cedar swamp. Examination of seasonal water table rise for the two swamps does not support this hypothesis. In fact, autumn recharge of the water table occurs first in the cedar swamp, and not in the hardwood swamp.

A number of subsurface geologic features may affect groundwater flow. Figure 9 has been prepared to illustrate these. As illustrated in Figure 9, differing geologic units may be expected to possess differing hydrologic characteristics resulting in differences in groundwater flow. Extensive coring in both swamps (unpublished data) has revealed that the same geologic units occur in both swamps. Since identified geologic units of the Cedick Run ecosystem are traceable over considerable distance, only slight differences in their relative proportions for the two swamps could be expected to contribute to differences in groundwater flow. Such proportional differences are thought to be negligible. However, differences in groundwater flow ascribable to differences in geologic units are thought to be greatest when comparing the edges of the swamps with their central portions. As schematically shown in Figure 9, the swamp edges may possess geologic unit number 5 whereas only units 1 through 4 occur in the central swamp. Such a qualitative difference could affect groundwater flow and probably would have its greatest impact in the hardwood swamp where topographic relief is greater than that in the cedar swamp.

Extensive corings reveal that numerous clay, gravel and muck lenses occur in both swamps (unpublished data). These are schematically illustrated in Figure 9. It is our belief that these lenses are local features, and probably account for most localized surficial and subsurface water table phenomena. Clay lenses, in particular, appear to be more prevalent in the hardwood swamp and may account for certain groundwater flow differences for the two swamps. Based upon numerous corings, it appears that for both swamps water is held near the surface in beds of sand and gravel extending approximately 1.68 meters deep. Below this a pervasive dense bed of white clay acts as an aquaclude preventing further downward movement of water. This clay bed is 0.05 to 0.1 meters thick and has the consistency of modeling clay.

Surface topographic features including hummocks and depressions will affect surface water flow. Since both swamps have numerous hummocks and depressions, it is probably reasonable to assume that neither of these features contributes significantly to observable hydrologic differences for the two swamps. Within each swamp, however, hummocks and depressions cause significant local ponding of water. It is also noteworthy that the cedar swamp has a well-defined stream channel with year-round flow, whereas the hardwood does not.

It is our belief that Lake Fred is the major factor contributing to major seasonal hydrologic differences between the two swamps. As schematically shown in Figure 10, the cedar swamp is approxi-

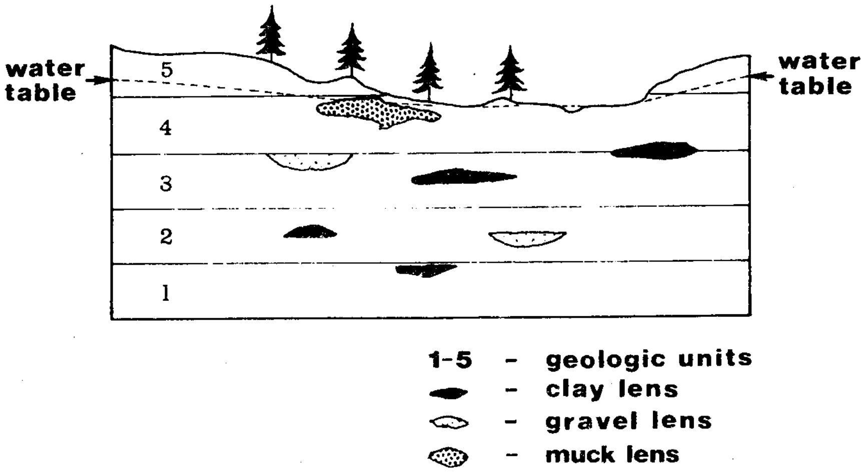

Figure 9. Schematic cross-section of cedar swamp.

mately 0.25 km. upstream from the lake; the hardwood swamp is approximately 1.7 km. upstream from the lake. This locational difference of the two swamps in reference to the lake (local base level) coupled with an elevation difference is believed to explain most observed differences in seasonal water table behavior for the two sites.

In order to properly focus on these cause-and-effect differences, it is desirable to briefly restate the fundamental seasonal hydrologic difference for the two swamps. The water table in the cedar swamp reaches its highest and lowest levels earlier in the year. Since the cedar swamp is of lower elevation and is closer to local base level (Lake Fred), the water table in the swamp is closer to the ground surface year-round. As a result, the water table has less distance to rise or fall in order for the swamp to flood or to reach its lowest water level. Conversely, the significantly greater distance of the hardwood swamp from local base level (Lake Fred) accounts for its lack of a well-defined stream channel and its greater tendency to dry out in the late summer and early autumn.

Relative wetness of the two swamps, due to their location in reference to Lake Fred (local base level), is probably the best explanation of why the two swamps differ floristically. Since cedar is more tolerant of flooding than the other hardwood species found growing along Cedick Run, it possesses a greater potential for growing near the lake than the other species. Similarly, the greater year-round dryness of the hardwood swamp helps to explain why no evidence of previous cedar growth at this site has been found. Although it is possible to hypothesize that vegetation differences for the two swamps have caused the significant hydrologic differences, it seems more likely that the hydrologic differences observed have caused the fundamental vegetation differences.

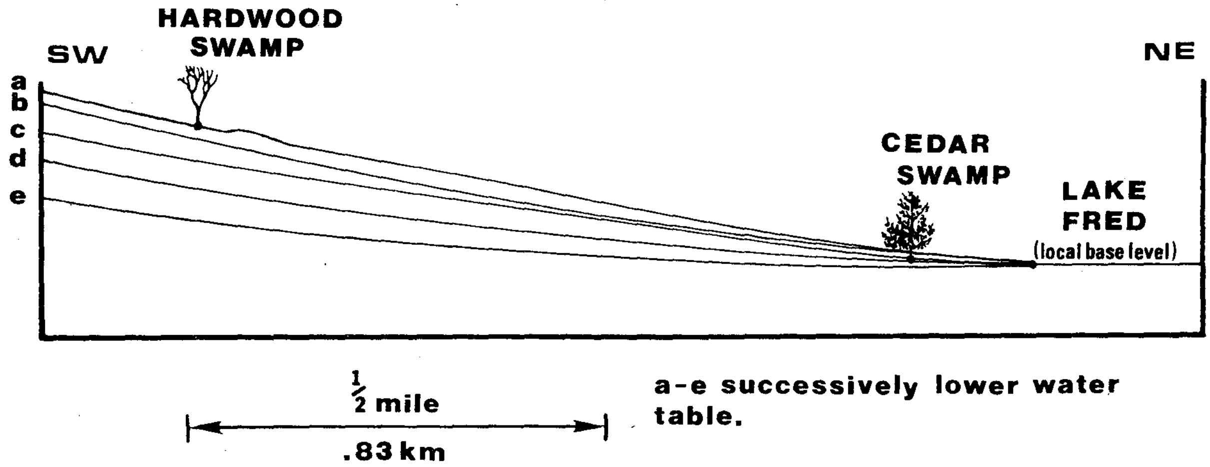

Figure 10. Schematic transverse profile of Stockton Ecological Preserve.

VI. SUMMARY

New information on seasonal hydrologic differences for two differing southern New Jersey swamp forests was obtained by systematic monitoring of the water table fluctuations and computer-generated mapping of this information. Significant differences in hydrologic characteristics were detected in terms of water table configuration and groundwater flow. It is believed that topographic elevational and positional differences (regarding local base level) account for the fundamental hydrologic differences observed for the two swamp sites. Subsurface geologic features are believed to play an insignificant role in explaining differences between the two swamps, but are thought to provide a better explanation of local hydrologic phenomena within each of the swamps. Similarly, it has been concluded that a significant vegetation difference for the two swamps does not explain notable hydrologic differences for the two swamps. Rather, observable hydrologic differences for the two swamps have caused the significant vegetation difference.

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John R. Maurer. Mr. Maurer is currently a senior geology student at Stockton State College and is expected to receive his B.S. degree in geology in 1981. His studies have been concentrated in mineralogy, petrology and hydrology.