Hydrologic Model of a Wetland Forest

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A workable schematic model of the hydrologic cycle in a wetland forest has been designed and constructed at the Southeastern Forest Experiment Station in Charleston, South Carolina, as a teaching aid for visitors (Figure 1). We use the model to illustrate and discuss (1) specific research problems being investigated, (2) the movement of water in the hydrologic cycle through a wetland forest, and (3) the impact of management practices on forest hydrology.

The idea of constructing the model came from a magazine article by Green and Halpenny (*1*). Details of its construction and a complete list of materials are presented in Forest Service Research Note SE-166 (*2*).

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The model consists of five watertight plastic boxes fastened on a board to represent the various media (forest surface, soil mantle, etc.) that water moves through in the hydrologic cycle. Outlet holes bored in each box represent the processes (overland flow, seepage, etc.) that regulate water movement from one medium to the next. The amount and timing of water transferred are governed by the height of an outlet from the bottom of a box and by a valve in the plastic tubing going from an outlet to another box. Several of the processes have two or more outlet levels to represent the effects certain management practices have on hydrology. The model operates by gravity flow once water has been pumped to the top by the "sun." Colored water effectively illustrates water distribution through the model.

Demonstrating Research Problems

The model demonstrates three general categories of research on coastal plain wetlands. First, it defines the major components of the hydrologic cycle. To understand the hydrology, we must study the properties and var-

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iations in properties of the media (forest surface, etc.) found in the different wetland types throughout the Southeast as well as the processes governing water movement in the hydrologic cycle. We strive to quantify these processes and to explain how and why they operate as they do.

Second, the model determines the effects of selected water and land management practices on the hydrology of coastal wetlands. The different outlets on the left side of the boxes simulate these effects.

Third, the model determines the effects of vegetative manipulation on hydrology, primarily evapotranspiration (illustrated by the outlets on the right side of the model).

Cycling Water Through the Model

A unique feature of the model is its ability to illustrate water quantitatively cycling through it. We strive only to approximate the quantities of water dissipated by the various processes because the model is used for educational and not research purposes. The action "on the board" is supplemented with a verbal explanation.

The model is dry when its operation begins (*1*). This may seem strange for a wetland forest, but it is a condition that can occur, usually in late spring or fall. Also, outlet levels are set for an undisturbed watershed with a mature forest cover. Rubber stoppers are placed in the nonappropriate outlet holes.

Water is first withdrawn from the rivers, lakes, and oceans external to the watershed by evaporation (Figure 2, reference point 1). Then the meteorological phenomena necessary to convert this moisture into precipitation occur (2-2). As rain first falls on the forest surface, a portion is intercepted by the trees and litter and eventually returned to the atmosphere by evaporation (2-3). Once the process of interception has been satisfied, any additional rainfall is available for infiltration into the soil (2-4). If the rainfall intensity is greater than the infiltration rate, a head of water builds up on the forest surface and overland flow occurs before the water table is recharged to ground surface (2-5). However, overland flow usually does not occur until the soil mantle is completely recharged.

As the water table rises, the trees and atmosphere begin to remove water by evapotranspiration (Figure 3, reference point 1). A head difference also develops between the water table and the stream channel. This gradient produces seepage through the soil into the stream channel (3-2). Some portion of the groundwater also seeps vertically into deeper aquifers (3-3).

Once the water table has reached ground surface, the amount of water entering the soil mantle by infiltration can be no greater than that leaving by the various processes. Consequently, a large portion of any additional

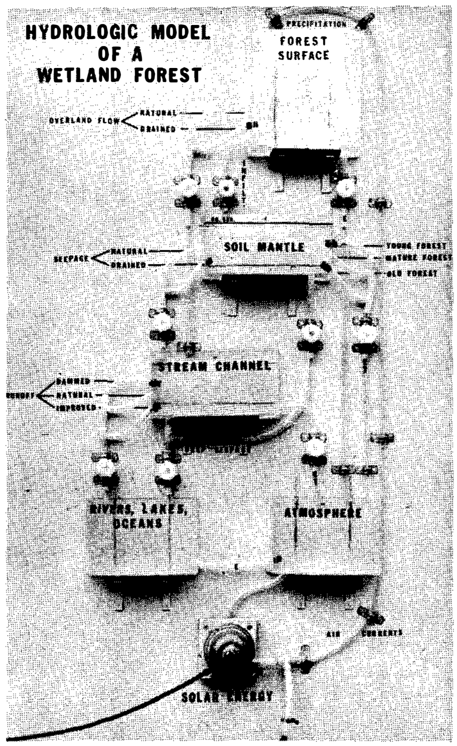

Figure 1. Hydrologic model of a wetland forest.

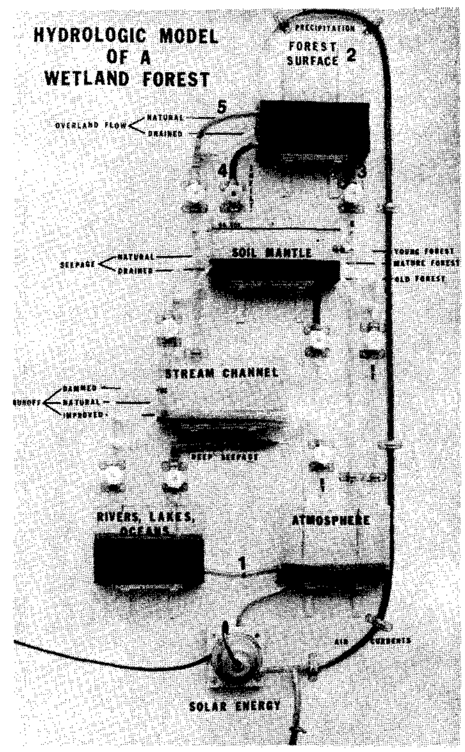

Figure 2. Hydrologic model during recharge.

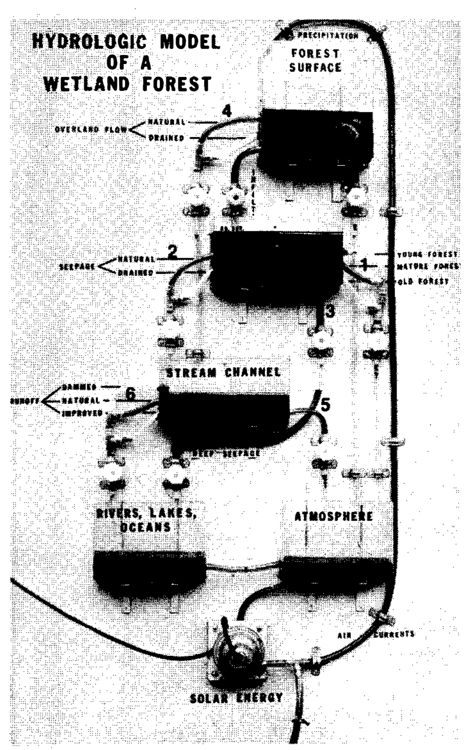

Figure 3. Model fully recharged with all processes moving water.

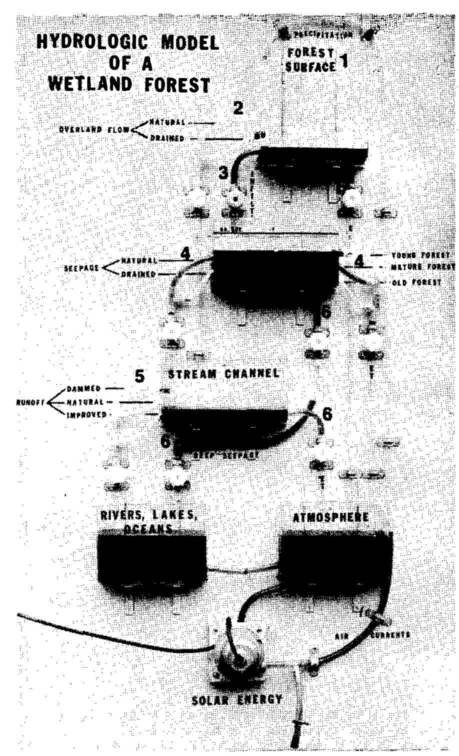

Figure 4. Hydrologic model during discharge.

rainfall moves across the surface as overland flow (3-4).

Water quickly fills depressions in the stream channel by seepage and by overland flow. Some of this water is removed by evapotranspiration (3-5), but most is available for surface runoff (3-6).

The final portion of the demonstration illustrates what happens within the hydrologic cycle when precipitation ceases (Figure 4, reference point 1). Overland flow is the next process to cease as water falls within the depressions of the forest surface (4-2). From then on the dewatering of the watershed is a slow process. Water slowly soaks into the ground (4-3), and the water table gradually recedes as water is removed by seepage and evapotranspiration (4-4). Finally, streamflow stops (4-5), and the water remaining in the soil and stream channel is removed slowly by evapotranspiration and deep seepage (4-6).

Impact of Management Practices

Management practices can alter considerably the natural hydrology of wetland forests. The effects of land treatment are illustrated on the left side of the model. For example, there would be less water ponded on the forest surface if drainage ditches were present. Overland flow would occur sooner and, in some instances, in larger quantities. With drainage, water table levels would decline because of the increased gradient between the water table and water in the ditch. This increased soil water storage potential could act as a buffer to hold excess precipitation from large storms. However, this would be somewhat offset by a decreased storage potential in the stream channels if they were cleaned out. Conversely, stream channel storage could be increased by damming the channel to form reservoirs for consumptive use, recreation, and/or wildlife.

Manipulation of vegetation can also affect water distribution, as indicated by the outlets on the right side of the model. Forests consisting of old trees with deep, extensive root systems could be expected to maintain lower average groundwater levels than young forests with shallow root systems. Higher average water tables would produce less storage capacity in the soil and increase the probability of quicker surface runoff. Some species of trees remove more water by evapotranspiration than others; thus the groundwater drawdown rate could be affected. Also, some species have more intercepting surface and affect the amount of water reaching the soil.

The model's operation as well as the accompanying verbal explanation can be adapted to the interests of various groups, the time available, and the message we want to get across. Also, the model can readily be used by resource managers as a frame of reference for discussing specific research results and the practical applications of these results.

REFERENCES CITED

1. Green, D. K., and L. C. Halpenny. 1965. *Qualitative hydrologic models.* Ground Water 3(1):21-23.
2. Young, C. E., Jr., R. A. Klawitter, and J. E. Henderson. 1971. *Hydrologic model of a wetland forest—details of construction.* Res. Note SE-166. Southeastern Forest Exp. Sta., Asheville, N. C. 4 pp. □