OBSERVED AND SIMULATED RECHARGE TO THE CLAIBORNE AQUIFER AT THE PLAINS, GEORGIA RESEARCH SITE

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Abstract. Water-table measurements taken at a 0.81 ha research plot in the Claiborne aquifer recharge area over a three-year period from 1989 to 1991 are reported. Analysis indicates the rate of total applied water can be used to accurately predict whether aquifer recharge is taking place. Simulations of root-zone percolation and aquifer recharge using the GLEAMS-FEST model predict the temporal trends of observed data, but do not provide good estimates of absolute values.

INTRODUCTION

Groundwater contamination by agrichemicals is a potential problem in southern Georgia as well as much of the United States. Aquifer recharge in Coastal Plain agricultural areas is of interest because recharge to the Upper Floridan and Claiborne aquifers may contain agrichemicals that degrade water quality. By studying recharge mechanisms to these aquifer systems, we can learn how agrichemicals reach groundwater and perhaps infer transport rates.

This paper (1) presents the results of an investigation of recharge within the study area and (2) evaluates application of a physically based hydrologic model to recharge simulation. The study area is in the west-central Coastal Plain southwest of Plains, Georgia. Results from the analysis presented here will be useful in examining recharge patterns throughout the Claiborne aquifer recharge area. This information will be useful in addressing water-quality issues for this area.

BACKGROUND

In 1988, the U.S. Geological Survey, the U.S. Department of Agriculture-Agricultural Research Service, the U.S. Environmental Protection Agency, and the University of Georgia began a cooperative study of chemical transport on a 0.81 hectare agricultural field approximately 3 km southwest of Plains, Georgia. The study area is in the recharge area of the Claiborne aquifer system (Hicks et al., 1991). The soil is a Eustis loamy sand (sandy, silicious thermic Psammentic Paleudult).

A soil berm was constructed around the plot perimeter to prevent runon and confine runoff. An H-flume was installed to measure surface runoff for determination of sediment and chemical transport. Corn (Zea Maize L.) has been planted seasonally since 1989. Conventional agricultural management practices have been used for tillage, fertilization, and planting. A center-pivot irrigation system was installed to ensure normal crop growth.

Data collected during installation of monitor wells on and surrounding the plot indicate the important geologic units are the Tuscahoma Formation (Paleocene), the Tallahatta Formation (Eocene), and the undifferentiated residuum and alluvium (Hicks et al., 1991). The Tuscahoma Formation begins at a depth of approximately 13 m and consists of homogeneous, well sorted, very fine-to-fine quartz sand. The Tallahatta Formation extends from approximately 4 m to 13 m and is composed of fine-to-coarse quartz sand. The undifferentiated residuum and alluvium consists of alternating and intermittent layers of sand, clayey sand, and clay. The unsaturated zone is approximately 10 m deep in the plot area. The upper saturated zone is the Claiborne aquifer (named for the Claiborne Group which includes the Tallahatta Formation). The aquifer is restricted to the lower part of the Tallahatta and is underlain and vertically confined by the less permeable Tuscahoma Formation. The Claiborne aquifer is generally unconfined in this region.

The test plot contains 12 permanent monitoring sites. Each site contains three wells extending to different depths in the aquifer, stainless steel vacuum lysimeters, soil-moisture sensors, thermo- couples, and soil-moisture access tubes.

Numerous soil cores have been collected from the land surface to the aquifer for evaluation of physical and hydraulic characteristics. Among the properties evaluated are vertical saturated hydraulic conductivity, residual and saturated moisture content, particle-size distribution, bulk density, organic carbon content, and porosity. Estimates of aquifer hydraulic conductivity and transmissivity have been made.

The objectives of this research are to (1) report water-table measurements taken at the Plains, Georgia research site from 1989 to 1991, (2) examine trends in the water-table data and relate these to climatic data collected at the site, and (3) evaluate application of a physically based hydrologic model to recharge simulation.

METHODS

Groundwater recharge in the plot area was estimated using water-level measurements taken at each of the 12 wells within and five wells around the perimeter of the plot. Water-level measurements taken approximately every two months, from April 1989 through October 1991, were used in this analysis. Changes in atmospheric pressure can produce significant fluctuations in wells penetrating confined aquifers (Clark, 1967). Since this aquifer is unconfined, these effects (as well as other meteorological phenomena) were assumed negligible. Air-entrapment in the unsaturated zone is known to effect water-table elevations in unconfined aquifers. Because the observations in this study were made over a period of years rather than days, these effects were also assumed negligible.

Water-level measurements were compared to those observed on April 5, 1989 in order to calculate recharge. Spatial coordinates of the wells and measured water-levels were used to construct a water-table surface using the SURFER computer software package[1,2]. Change in storage volume within the saturated zone between April 5, 1989 and each observation date was then calculated from the gridded surfaces. Aquifer recharge was estimated as the change in water-table altitude multiplied by the specific yield of the aquifer. Specific yield for the aquifer, a fine-to-coarse sand, was estimated as 0.28 (Todd, 1976).

Simulations of recharge were made using the GLEAMS-FEST (Groundwater Loading Effects of Agricultural Management Systems-Finite Element Solute Transport) model (Bosch, 1989). Soil hydraulic properties were estimated from collected particle size information and saturated hydraulic conductivity measurements (Table 1). Other simulation parameters were determined from management records. Precipitation inputs were obtained from measurements taken at the site. Irrigation over the simulation period was added with precipitation.

RESULTS

Data collected over the observation period, along with simulations performed, were examined for temporal trends. Observed precipitation, irrigation, runoff, and calc-

Table 1. Selected Hydraulic Characteristics Estimated from Particle Size information and Hydraulic Measurements for the Plains, Georgia, Field Site.

Parameter	Applicable Depth	Value	Units
field area	-	0.81	ha
SCS curve number	-	67.0	-
hydraulic slope	-	0.014	m/m
effective rooting depth	-	102.0	cm
effective saturated hydraulic conductivity	0-102 cm	0.76	cm/hr
porosity	0-33 cm	0.40	cm^3/cm^3
field capacity	0-33 cm	0.37	cm/cm
wilting point	0-33 cm	0.05	cm/cm
porosity	33-102 cm	0.40	cm^3/cm^3
field capacity	33-102 cm	0.30	cm/cm
wilting point	33-102 cm	0.18	cm/cm
saturated moisture content	102-502 cm	0.35	cm/cm
residual moisture content	102-502 cm	0.08	cm/cm
saturated hydraulic conductivity	102-502 cm	0.50	cm/hr
n[a]	102-502 cm	1.50	-
alpha[a]	102-502 cm	0.02	-
saturated moisture content	502-1000 cm	0.27	cm/cm
residual moisture content	502-1000 cm	0.05	cm/cm
saturated hydraulic conductivity	502-1000 cm	4.00	cm/hr
n[a]	502-1000 cm	2.00	-
alpha[a]	502-1000 cm	0.03	-

[a] Coefficients for the van Genuchten (1980) soil moisture function

Table 2. Observed Total Precipitation, Irrigation, Runoff, and Calculated Recharge at the Plains, Georgia, Research Site from 1989 to 1991.

	Observed			Calculated
Year	Precipitation (cm)	Irrigation (cm)	Runoff (cm)	Recharge (cm)
1989	25	26	5	15
1990	71	29	3	7
1991	115	70	5[1]	24[2]
Total	311	125	13	46

[1] Missing data from 3/29/91 to 4/16/91

[2] Up to 10/08/91

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[1] Golden Software, Inc., 807 14th St., P. O. Box 281, Golden, Colorado 80402

[2] Trade names are included for information of the reader and do not constitute endorsement by the U.S. Department of Agriculture or the U.S. Geological Survey.

ulated recharge volumes are shown in Table 2. Change in storage and total water (precipitation + irrigation) were calculated on a relative basis, the value on a given day divided by the total on day 1012 (the last day water-level measurements were taken), and are presented in Figure 1. Data indicate a relationship between the rate of total water applied and the change in storage. Relative derivatives of the total water and the change in storage (Figure 2) were calculated as follows: (1) average rate of change in storage and total water were determined by regression through the three years of data, (2) rate of change between two observation dates was calculated, and (3) relative derivatives were determined by dividing the derivative on a given date by the average derivative.

The average derivative for total water was 0.41 cm/-day,and 0.05 cm/day for recharge. When the relative derivative for total water between any two observation dates exceeds 1 (application greater than the average rate), the recharge rate is generally positive and water levels are increasing (Figure 2). When the relative derivative is less than 1, the water level is generally declining.

Simulations were performed using the GLEAMS-FEST model to evaluate the feasibility of predicting long-term trends in recharge for the study area. Figure 3 compares observed and simulated recharge. Predictions for root zone percolation are also presented. The model accurately predicts total recharge but does not account for water-level decline. Due to the one-dimensional nature of the GLEAMS-FEST model, there is no mechanism for removing recharge water. Lateral flow within the aquifer is not accounted for. If there is a significant difference between aquifer flow into and out of the simulation area, errors can be expected.

Simulated runoff (Table 3) was generally greater than observed runoff (Table 2), probably due to an underestimate in surface hydraulic conductivity. Knisel et al.(1991) evaluated ET on a small plot near Tifton, Georgia. They reported the average annual ET rate for a corn-peanuts-soybeans rotation was 86 cm. Annual ET rates simulated (Table 3) are within this range.

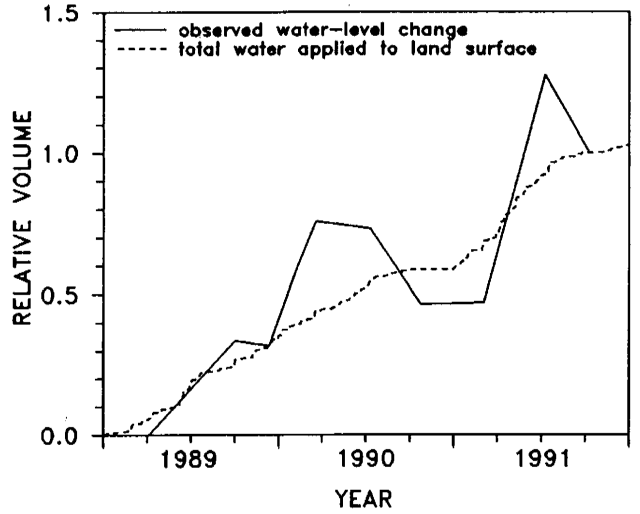

Figure 1. Relative volume of observed water-level change and total water (precipitation + irrigation) at the Plains, Georgia, research site, 1989-91.

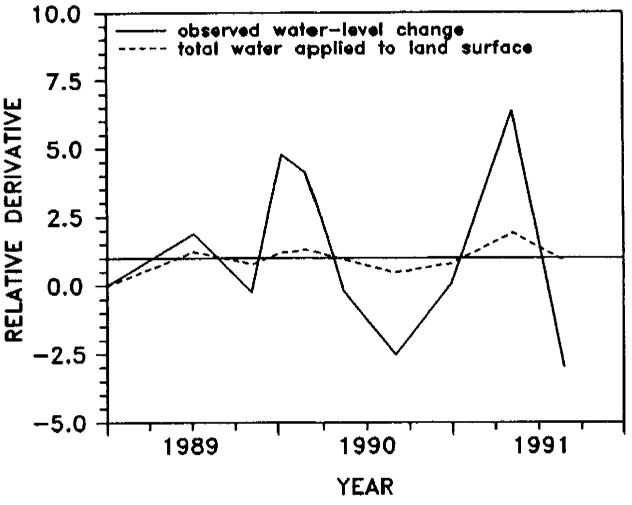

Figure 2. Relative derivative of the observed water-level change and the total water (precipitation + irrigation) at the Plains, Georgia, research site 1989-91.

Table 3. Simulated Runoff, Evapotranspiration, Root-zone percolation, and Recharge at the Plains, Georgia, Research Site from 1989 to 1991.

Recharge Year	Runoff (cm)	Evapotranspiration (cm)	Root-Zone Percolation (cm)	(cm)
1989	14	84	43	21
1990	6	97	15	34
1991	23	112	48	39
Total	43	293	106	94

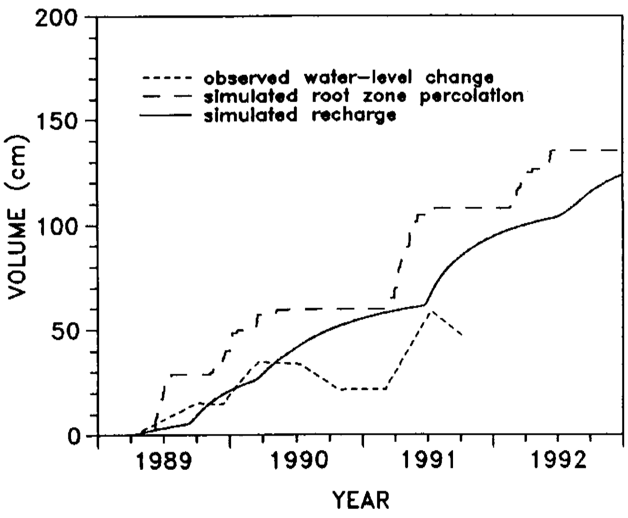

Figure 3. Simulation results and observed water-level change at the Plains, Georgia, research site, 1989-92.

DISCUSSION

During the three years of observation, the plot received 436 cm of total water. During the same three years, 13 cm of runoff were observed, 46 cm of recharge were calculated from well data (not including recharge which may have occurred after October 8, 1991), and 293 cm of ET were simulated. During the two week period in 1991 where runoff data were missing, three runoff events were simulated with a total of 5 cm of runoff predicted. Assuming recharge at a rate of 0.05 cm/day for the remainder of 1991, 4 cm of additional recharge would be predicted for the period from October 8, 1991 to the end of 1991. Including these estimates, and assuming the specific yield and ET values are accurate, 75 cm of water are unaccounted for.

One explanation is that increased recharge in the plot area produced a mounding effect which increased the hydraulic gradient and caused water to flow off-site before it could be detected as recharge. Water-level data recorded in wells located just above and below the plot indicate the primary direction of flow was consistently from the north side of the plot to the south side and the overall gradient was relatively unchanged throughout the study period. This may indicate water moving off the plot laterally through unsaturated flow which would not show up directly in the well data.

Our hypothesis is that irrigation increased the volume of recharge in the plot area. In 1991, irrigation accounted for 40 % of total water applied. The observed average precipitation rate for the three-year simulation period was 104 cm/year. The long-term average for this area is 120 cm/year. Because the three-year average precipitation rate was below the long-term average and recharge was still being observed, it appears that recharge was influenced by irrigation. Water-level data from wells located upgradient from the plot indicate less recharge upgradient in 1989 and 1991, but greater recharge in 1990. These data do not conclusively support our hypothesis.

Data indicate that water-levels in the Claiborne aquifer respond to increases in total water (Figure 1). The response rate cannot be determined due to the coarse interval between water-level measurements, however it appears to be approximately 45 days. Using this time lag, the average infiltration rate from the surface to the water-table at 10 m is 0.93 cm/hr. Simulated root-zone percolation, Figure 3, indicates a rapid response to precipitation and irrigation. However, simulated recharge lags behind water application and root-zone percolation by approximately 90 days. The GLEAMS-FEST model simulates matrix flow only. Because of this, the lag is expected. The more rapid response in recharge may indicate preferential recharge, a phenomena which cannot be accounted for with this model.

CONCLUSIONS

Data collected at the research plot indicate water levels in the Claiborne aquifer respond rapidly to precipitation and irrigation, possibly due to preferential flow. Additional water-table measurements collected more frequently are required to verify this hypothesis. The relative annual rate at which water is being received in the area appears to be a good indicator of recharge. One-dimensional simulation results using the GLEAMS-FEST model predict temporal trends in recharge. However, periods of falling water-level cannot be accounted for by the model. In addition, mass balance discrepancies between observations and simulations indicate model modifications are necessary to more accurately represent the system.

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