# IMPACTS OF CONVENTIONAL AGRICULTURAL PRACTICES ON AQUIFER WATER QUALITY: AN OVERVIEW OF THE PLAINS, GEORGIA WATER QUALITY STUDY

Dr. David Bosch[1], Dr. Ralph Leonard[1], Dr. Clint Truman[1], Dr. Larry West[2], and Dr. David Hicks[3]

*AUTHORS:* [1] Hydraulic Engineer and Soil Scientists, USDA-ARS, Southeast Watershed Research Laboratory, PO Box 946, Tifton, GA 31793; Soil Scientist, Crop and Soil Science Dept., Univ. of Georgia, Athens, GA 30602; and Hydrogeologist, USGS, Water Resources Division, Doraville, GA 30360.
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**Abstract.** Pesticide leaching to groundwater is a potential problem in agricultural production areas of South Georgia where sandy soils predominate. The aquifers in this region are an important resource for South Georgia and North Florida. High soil hydraulic conductivity, coupled with high water-table conditions and high precipitation, can lead to groundwater contamination in the area. A field study near Plains, GA, was initiated in 1988, with the objective of establishing a better understanding of agrichemical transport in this area. Data was collected from 1988 to 1994 on a 0.81 ha research plot. Data indicate under normal climatic conditions nutrient and pesticide transport to groundwater is minimal. However, high precipitation soon after chemical application, combined with a saturated root zone, can lead to groundwater contamination. Thus, extreme care must be used to properly manage the application and soil-water regime. Chemical application during periods of excess precipitation and saturated soil-water conditions must be avoided.

## INTRODUCTION

Groundwater contamination by agrichemicals is a potential problem in South Georgia as well as much of the U.S. Unpublished data collected during a South Georgia groundwater survey indicate significant concentrations of common herbicides in area aquifers. The survey found 6 out of 35 wells contained pesticide concentrations over health advisory levels, with all 6 of these within the Claiborne aquifer recharge area (personal communication, Leonard, 1996). Groundwater quality in Coastal Plain agricultural areas is of interest because the Upper Floridan and Claiborne aquifers, aquifers which supply several municipalities with their drinking water, are recharged there.

As a response to the groundwater survey, the U.S. Geological Survey (USGS); Southeast Watershed Research Laboratory (SEWRL), U.S. Department of Agriculture, Agricultural Research Service (ARS); U.S. Environmental Protection Agency (USEPA), and University of Georgia began a cooperative study of chemical transport in an agricultural area near Plains, Georgia in 1988. The study site included a mixed use watershed as well as two 1 ha fields. Information collected include soil degradation of pesticides, saturated and unsaturated zone transport, physical characterization, and basic climatic and hydrologic data. The study area is in the recharge area of the Claiborne aquifer system (Hicks et al., 1991). This paper provides a summary of data collected at one of the research fields. The objectives of this report are to (1) report water quality measurements taken at the site and (2) examine trends in the water quality data and relate these to management practices. Information provided will be useful in answering questions regarding the impact of agriculture on Claiborne aquifer water quality and for answering questions of regional agri-managers.

## METHODS

### Management

The study area was a 0.81 ha field located approximately 3 km Southwest of Plains, Georgia, in the west-central Coastal Plain Region. The soil is a Eustis loamy sand (sandy, silicious thermic Psammentic Paleudult). A soil berm was constructed around the perimeter of the plot to confine runoff and prevent run on. A H-flume, 0.46 m height, was installed to facilitate measurement of sediment and chemical transport in surface runoff.

Conventional-till corn (Zea Maize L.) was planted on the plot for four consecutive years, 1989-1992. Conventional agricultural management practices were used for tillage, fertilization, and planting. A center-pivot irrigation system was used for irrigation. The plot was treated with the agricultural herbicides atrazine and alachlor, and the insecticide carbofuran at planting (Table 1). Herbicides were surface applied as a spray at recommended rates and moved into the profile with irrigation. Carbofuran was broadcast applied at the recommended rate for banding in 1989 and at the broadcast application rate the remaining years. The plot was tilled and

**Table 1. Planting dates and target chemical application rates for the 1989 to 1994 dy period.**

| Year | Planting Date | Target Application Rates (kg/ha) Bromide | Alachlor | Atrazine | Carbofuran | Nitrogen[a] |
|---|---|---|---|---|---|---|
| 1989 | June 12 | 112 | 2.8 | 2.2 | 2.2 | 180 |
| 1990 | March 14 | 0 | 0 | 2.2 | 6.7 | 192 |
| 1991 | March 26 | 112 | 0 | 2.2 | 6.7 | 187 |
| 1992 | March 17 | 0 | 0 | 2.2 | 6.7 | 186 |
| 1993 | April 12 | 0 | 0 | 2.2 | 0 | 100 |
| 1994 | March 21 | 0 | 0 | 0 | | 100[a] |

[a]Ammonium nitrate, distributed throughout the year.

a crop grown in 1993 and 1994, with chemicals applied at reduced rates. The June 13, 1989 planting date was about 70 days later than normal for southern Georgia due to difficulty instrumenting the plot. A bromide ($Br^-$) tracer was surface applied in solution in 1989 and again in 1991. Fertilizer was broadcast applied prior to planting, banded next to the plant approximately one month after planting, and broadcast again in the fall, each year. Approximately 60% of the N was applied during the second application with 60% applied at planting and 20% in the fall. A wheat cover-crop was planted each fall.

## Climate

Two automated rain gauges installed at the site measured continuous rainfall on five minute intervals. The variability and volume of irrigation was measured using stationary rain gauges located throughout the plot. A weather station located at the site from 1989 to 1993 measured pan evaporation, wind speed, air temperature, and barometric pressure.

## Soil Samples

Numerous soil cores were collected for evaluation of physical and hydraulic characteristics. Among the properties evaluated were 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 unsaturated zone is approximately 9 m deep in the plot area. The upper saturated zone is the Claiborne aquifer.

Soil cores were collected by hand auger to depths of 2 m several times each growing season. In addition, twice a year soil cores were collected down to the water table (9 m) using a drill rig equipped with a continuous-coring device. Soil samples were analyzed in the laboratory for nitrate nitrogen ($NO_3^-$ N), chloride ($Cl^-$), and $Br^-$ concentrations using an ion chromatograph. Pesticide concentrations were evaluated using gas chromatography (GC), high performance liquid chromatography (HPLC), and enzyme linked immunosorbent assay (ELISA) techniques. Pesticide analysis for soil samples collected from 1989 to 1991 was performed by the U.S. EPA, and only the 1989 results have been released at this time. Samples collected from 1992 to 1994 analyzed by the SEWRL are summarized here.

## Water Samples

The test plot contained 12 permanent monitoring sites. Each site contained three wells extending to different depths in the aquifer. Well samples were collected approximately each month, beginning in 1989. All water samples were analyzed in the laboratory for $NO_3^-$ N, $Cl^-$, and $Br^-$ concentrations. Beginning in 1992, when pesticides were first observed in the deep soil profile, pesticide concentrations in the well water were evaluated using GC, HPLC, and ELISA techniques.

# RESULTS AND DISCUSSION

## Precipitation

During the six years of observation, the plot received an annual average of 163 cm total water (precipitation + irrigation) (Table 2). The long-term average precipitation is 124 cm/year. Total plot water was unusually high in 1989, 1991, and 1994. This is particularly important because much of this was received soon after chemical application. In 1989, planting and application did not occur until mid June and a large part of the total water was likely lost to evaporation. However, during 1991 when planting occurred at a normal time for the area (late March), much of the total water in the period 30 days after application likely percolated through the root zone. During 1991 a large rainfall event combined with a saturated initial soil condition led to increased loading to the aquifer (Fig. 1). Recharge normally occurs in February to June. The relative annual rate at which water is being received in the area appears to be a good indicator of recharge (Bosch and Hicks, 1993). Thus, 1989, 1991, and 1994 were expected to produce more aquifer recharge.

**Table 2. Observed and 39 year average total plot water (precipitation + irrigation) for the 30, 60, and 90 days after chemical application and for the year, and plot runoff from 1989 to 1994.**

| Year | Total Plot Water (cm) Days After Chemical Application 30 | 60 | 90 | Annual | Annual Runoff (cm) |
|---|---|---|---|---|---|
| 1989 | 33 | 52 | 73 | 177 | 8 |
| 1990 | 14 | 24 | 38 | 107 | 4 |
| 1991 | 49 | 77 | 101 | 184 | 9[a] |
| 1992 | 11 | 19 | 44 | 147 | 2 |
| 1993 | 14 | 27 | 48 | 154 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 1994 | - | - | - | 211 | not measured |
| 39 year average precipitation | 11 | 19 | 29 | 124 | not available |

[a] Missing runoff data from 3/29/91 to 4/16/91
[b] No chemical application in 1994

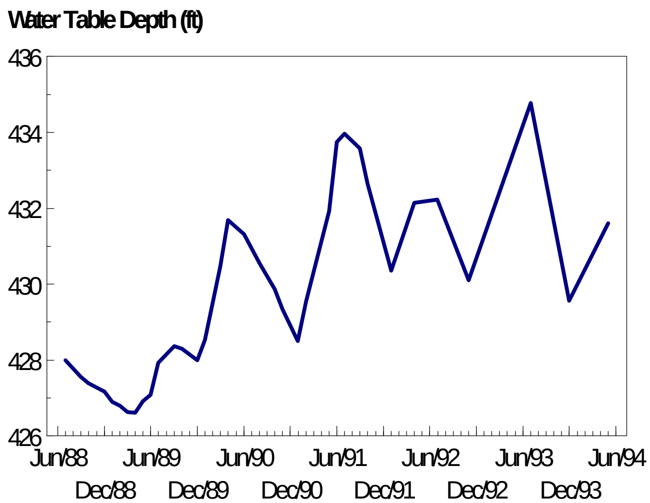


**Figure 1. Water table responses observed over the study period.**

## Soil Samples

Results of the $Br^-$ analysis have been presented elsewhere (Bosch et al., 1993). Examination of the 1989 data indicates the $Br^-$ plume moved to 1.5 m by October of the same year, but slowly thereafter. On November 8, 1990, while low concentrations were observed down to the water table, the center of mass remained at approximately 2 m (Fig. 2). When the 1991 $Br^-$ application was made, the first $Br^-$ plume had concentrated near 2 m depth. Soils data indicate the maximum $Br^-$ concentration in the profile near the water table occurred on July 1991. The 1991 application of $Br^-$ behaved similar to the 1989 application, although, there was a fairly rapid movement early in 1991 due to the excess water. Maximum concentrations in the vadose zone decreased dramatically with time due to dilution and diffusion.

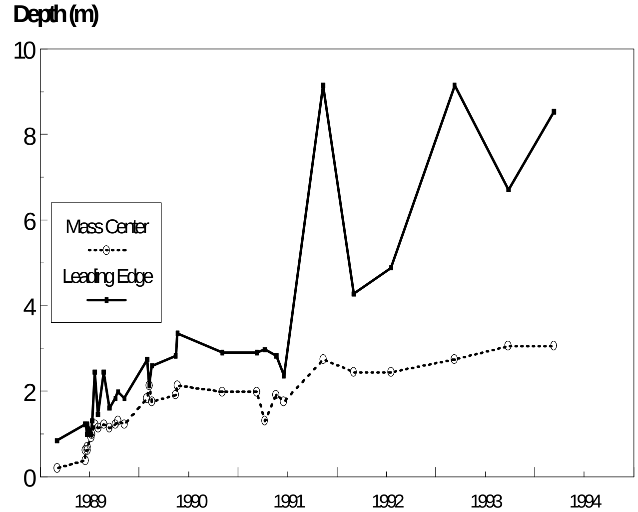


**Figure 2. Observed center of mass and the leading edge of the p plume in the soil over time.**

Atrazine and alachlor normally decayed in the upper 2 m of the soil profile within 4 months after application. This was indicated by the 93 and 94 data as well as 1989 data presented by Smith and Parrish (1991). Carbofuran, because of it's greater mobility and persistence, was observed later in the season and at higher concentrations. Significant fractions of the applied pesticides were transported out of the root zone into the deeper vadose zone in 1991 and possibly in 1989. The maximum concentrations observed near the water table (within 2 m) were 3.4 ppb on March 18, 1993 for atrazine and 12 ppb also on March 18, 1993 for carbofuran. Examination of upper profile data indicate both of these resulted from the 1991 applications. This appears to have been a consequence of higher than normal total water in this year.

## Water Samples

Because of dilution and diffusion, the concentrations of $Br^-$ measured in the groundwater were very low. The maximum values were observed in July 1991 when 0.65 ppm was observed and in June 1994 when 0.5 ppm was observed. Pulses of $Br^-$ were observed in June 1989, July 1991, August 1992, May 1993, and June 1994. Concentrations of $NO_3^-$ N remained below 10 ppm throughout the study, with concentrations peaking at 6.4 ppm in September 1991. A similar pulsing pattern was observed with the $NO_3^-$ N.

The maximum atrazine and carbofuran transport to the groundwater at the site occurred at the end of 1992 and early 1993 (Fig. 3). Carbofuran concentrations as high as 89 ppb were observed in December 1992 and 67 ppb was observed in June 1993. This appears to have resulted from excess water in 1991. Observed atrazine groundwater concentrations remained low throughought most of the study. However, a plume of atrazine entered the groundwater from December 1992 through June 1993 (Fig. 3). During this period, concentrations peaked at 11.5 ppb on February 1993. This slug of atrazine appeared to be a result of the 1991 application and weather pattern.

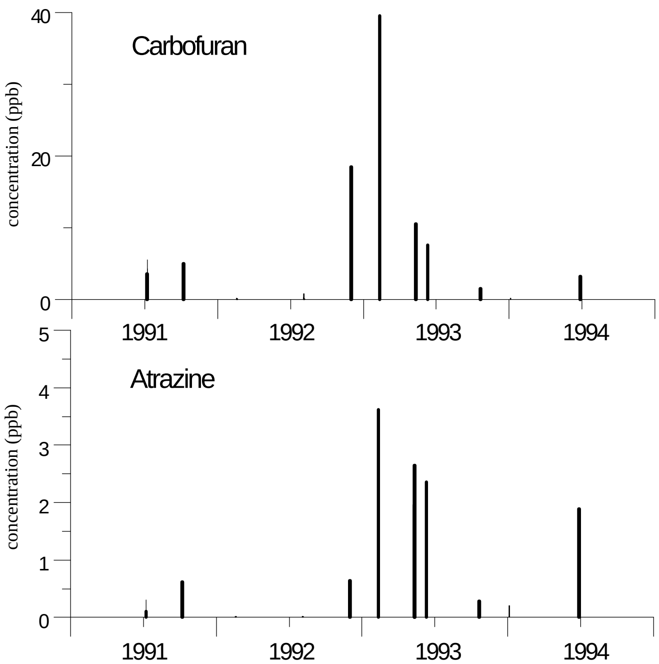


**Figure 3. Mean observed Carbofuran and Atrazine concentration in the groundwater over time.**

## CONCLUSIONS

The results of this study indicate that through proper agricultural management the impact of agricultural practices on the regional groundwater can be minimized. However, if large spring thunderstorms occur soon after chemical application, the chance of groundwater contamination by agrichemicals is high. With the sandy soils and high infiltration rates at the studied site, proper water management was very important. The saturated profile combined with a large rainfall soon after chemical application led to high groundwater pesticide concentrations. The periods of maximum loading coincide with groundwater recharge periods. At this time the quality of the local aquifer is expected to be at its worst. Our data indicate the importance of proper chemical and water management in this area.

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