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GROUNDWATER MONITORING AND MODELING OF SPATIALLY DISTRIBUTED MANAGEMENT SYSTEMS ON A DEMONSTRATION WATERSHED

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Summary:

Nonpoint pollution of surface and ground water resulting from agricultural management practices is a major water quality problem. A five-year joint project among state and federal agencies was initiated in 1990 to address this problem on a demonstration watershed in the Cape Fear River Basin of North Carolina. Groundwater on twenty farms in the watershed were monitored. Nitrate-N in ground water was highest in the portion of the HMR watershed with the highest concentration of swine and poultry production. The GLEAMS model was used to perform simulations of the monitored fields. Model comparison and validation with groundwater observations will be preformed.

Keywords:

Water quality, Modeling, Groundwater

Groundwater Monitoring and Modeling of Spatially Distributed Management Systems on a Demonstration Watershed

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Introduction

In the Eastern Coastal Plain as well as other areas of the country, nonpoint source pollution of surface and ground waters is a major concern. These factors are especially critical in the Eastern Coastal Plain because of shallow ground water tables and coastal estuaries that can be affected by nonpoint source pollution. Reduction of erosion, runoff, and the discharge of pollutants into surface and ground waters require alternative or improved management practices that have been developed but have not been extensively implemented.

Geographical information systems (GIS) have become essential tools in the presentation and interpretation of spatially distributed information. Information on land use and physical characteristics of study areas can be stored in the GIS database to provide geographical references for interpretation of research data. Location of stream monitoring stations and ground water monitoring wells can be determined precisely using global positioning systems and stored into the GIS. Data from these monitoring sites can then be linked to the geographical features for analysis and interpretation. Data stored in these geographical data bases can then be manipulated and used to generate input data files for simulations models. Simulation models provide a method to investigate the potential impact of the implemention of alternative management practices. Models can evaluate potential management alternatives and provide a basis for guiding management and regulatory decision making.

Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) is a mathematical model developed for field-size areas to evaluate the effects of agricultural management systems on the movement of agricultural chemicals within and through the plant root zone (Leonard et al., 1987). The GLEAMS model utilizes soil input data by soil horizon and can accommodate depth-specific parameters. The original version of GLEAMS consisted of hydrology, erosion, and pesticide components. Recently the model has been extended to include a nutrient component. It includes nitrogen fixation by legumes, land application of animal waste, improved nitrogen and phosphorus cycling, and algorithms to distinguish between ammonium and nitrate fertilizers and their uptake by crops.

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The first objective of this work was to evaluate the levels and spatial distribution of ground water nitrate-N in the Herring Marsh Run Watershed. The second objective was to evaluate the ability of GLEAMS to simulate field observations from a monitored field site. Results from these and additional analyses will be used with the GLEAMS model to evaluate and compare the potential impacts of alternative and conventional production practices. These alternative practices are directed at reducing agricultural nonpoint source pollution from the watershed.

Background

A water quality demonstration project involving private industry, local land owners, and federal, state, and local agencies was initiated in 1990 on a watershed located in the Cape Fear River Basin in Duplin County, North Carolina. The 2044-ha demonstration watershed, Herrings Marsh Run (HMR), is one of eight original demonstration projects funded as part of the USDA Presidential Water Quality Initiative. It is located within the Goshen Swamp Watershed, one of the 37 original Hydrologic Unit Area Projects (United States Department of Agriculture and Cooperating State Agencies, 1989). Duplin County has many characteristics typical of an intensive agricultural county in the eastern Coastal Plain of the USA. It has the highest agricultural revenue of any county in North Carolina. In 1990, it had the highest population of turkeys and the fourth highest population of swine of any county in the United States (North Carolina Dept. of Agriculture, 1990).

Agricultural management practices on the watershed are typical for the eastern Coastal Plain and include 1093 ha of cropland, 708 ha of woodlands, and 212 ha of farmsteads, poultry facilities, and swine facilities. The major agricultural crops on the watershed include corn (415 ha), soybeans (273 ha), vegetables (162 ha), tobacco (131 ha), and wheat (121 ha). Conventional management practices typically used commercial fertilizers as their main source of nutrients. Some alternative management practices replace many of these commercial fertilizers with animal waste to better utilize nutrients on the watershed. The predominant soil series in the watershed is Autryville (Loamy, siliceous, thermic Arenic Paleudults); secondary soil series are Norfolk (Fine-loamy, siliceous, thermic Typic Kandiudults), Marvyn-Gritney (Clayey, mixed, thermic Typic Hapludults), and Blanton (Loamy siliceous, thermic Grossarenic Paleudults).

Current annual nutrient input for crop production on the watershed is estimated at 145 tons of nitrogen, 64 tons of phosphorus, and 243 tons of potassium. Although swine and poultry operations produce sufficient quantities of waste to supply over half the nutrients needed for crops, 90% of the nutrients are supplied by commercial fertilizers. The application of large quantities of commercial fertilizers, coupled with the production of large quantities of animal waste, provides a potential for nitrogen and phosphorus contamination of surface and ground water.

Field Sites and Descriptions of practices

Ground Water Monitoring

Ground water monitoring wells were installed on 22 farms in the HMR watershed (Fig. 1) beginning in August 1991 and continuing through March 1993. These farms exemplify the agricultural practices used in the watershed. The farms were selected to represent the watershed both on a geographical basis and a farming-practices basis. The majority of farms with monitoring wells produced row crops either with or without implemented nutrient management plans. The main source of nitrogen on two row-crop farms was poultry litter and poultry compost. Practices on two other farms include the application of swine lagoon effluent to pasture and a pasture for hay production.

Ground water monitoring wells were installed using a SIMCO 2800[2] trailer-mounted drill rig equipped with 108-mm inside diameter hollow stem augers. The well casings and screens were 50-mm threaded schedule 40 PVC, and well screens were 1.5 m long. Well bottoms were placed on an impermeable layer or to a depth of 7.6 m if the impermeable layer could not be located above that depth. Water table depths in the watershed were generally 1.5 to 3 m below the soil surface. Monitoring wells were constructed according to N. C. Dept. of Environmental Management regulations. A filter pack of coarse sand was placed around well screens. An annular seal of bentonite was placed above the filter sand. Concrete grout was then placed between the bentonite and the soil surface to prevent contamination from the surface. Locking well covers were installed to prevent unauthorized access. WaTerra foot valves (model D-25) and high density polyethylene tubing were installed in each well to provide dedicated samplers.

Before samples were collected, the static well water depths were measured, and three well volumes were purged. Glass sample collection bottles were rinsed with the well water before sample collection, filled with sample, packed in ice, and transported to the laboratory. Wells were sampled monthly.

All water samples were transported to the USDA-ARS, Soil, Water, and Plant Research Center in Florence, SC, for analysis. Water samples were analyzed using a TRAACS 800 Auto-Analyzer for nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, ortho-phosphorus, and total phosphorus using EPA Methods 353.2, 350.1, 351.2, 365.1, and 365.4, respectively (U.S. EPA, 1983). EPA-certified quality control samples were routinely analyzed to verify results. All statistical analysis of the data was accomplished using SAS version 6.07 (SAS, 1990). A geographical information system (GIS), ARC/INFO (ESRI, 1994), was utilized to store and display the spatial distributed data for interpretation.

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[2]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U. S. Dept. of Agr. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Simulations and Field Validation.

The GLEAMS model was validated on cropland field with Norfolk soil that had two ground water monitoring wells screened from 3 to 5 m. Cropping practices used in the field system were obtained from farm surveys (NCSU, 1993). Soil and land use data were obtained from the county soil survey and annual reports of the demonstration project (USDA-SCS, 1959, and NCSU, 1993). Additional parameters for development of input data for the GLEAMS model were obtained from the GLEAMS manual. Climatological variables for validation of simulations were obtained from Warsaw, NC, and Clinton, NC, weather stations for the two-year period to be simulated. The specific management practices for the simulated field are shown in Table 1. Observed Nitrate-N concentrations from the ground water monitoring wells were compared to the GLEAMS simulated values. No calibration of the GLEAMS model was preformed.

Results and Discussion

Nitrate-N was less than 10.0 mg/L in wells on 17 of the 22 farms (Stone et al., 1994). In the five farms with wells that exceeded 10 mg/L of nitrate-N, only one had wells with nitrate-N that exceeded 20 mg/L. A mean concentration of 65 mg/L nitrate-N was measured in samples from wells in a bermudagrass field on this farm. This field had been overloaded with swine wastewater prior to the initiation of the Water Quality Demonstration Project. The wastewater spray field was expanded in area, but the ground water quality has not yet improved. It is anticipated that lower wastewater application rates, denitrification, and coastal bermuda hay uptake of nitrogen this site will be reclaimed. Three of the other four high-nitrate-N farms were also located in subwatershed 2. Thus, stream and ground water nitrate levels are highest in the portion of the watershed with the highest level of animal waste production.

On an individual well basis 64% of the 95 monitoring wells had nitrate-N concentrations less than 10 mg/L. Twenty monitoring wells had concentration between 10 and 20 mg/L. Fourteen monitoring wells had concentrations greater than 20 mg/L. The high nitrate-N concentrations wells are skewed because all wells on the overloaded swine waste sprayfield had concentrations greater than 10 mg/L and 11 of the 14 wells with concentrations greater than 20 mg/L were located on this farm.

Simulations

Figure 3 shows a comparison of the GLEAMS simulations and observed nitrate-N concentration in ground water monitoring wells from the Norfolk field site. The model results show that the simulation values compared satisfactorily with the field data. These simulations were made utilizing parameters estimated from field observations and best estimates from literature. Using sensitivity analysis and parameter estimation methods, the model could provide much better estimates. A paired comparison t-test indicated that differences between the observed and simulated values were not significant.

Conclusions

Nitrate-N concentration in ground water monitoring wells was greatest in the portion of the HMR watershed with the highest concentration of swine and poultry production with Four of the five farms with high nitrate-N in this subwatershed. However, only five of the 24 tested farms had ground water nitrate-N concentrations in excess of 10 mg/L, and only one of the farms had nitrate-N concentrations in excess of 20 mg/L.

The GLEAMS model was not calibrated, but was verified using measured values to simulate cropping systems currently in practice. The use of mathematical models to simulate the long-term impact of alternative nutrient management practices can provide a means of supplementing field observations of BMP implementation. Long-term simulations of alternative nutrient management practices show that reductions in surface runoff and ground water loading of nutrients can be achieved.

References

ESRI. 1994. Arc/Info version 6.1. Environmental Systems Research Institute Inc., 380 New York St., Redlands, CA.

Leonard, R. A., W. G. Knisel, and D. A. Still. 1987. GLEAMS: Groundwater loading effects of agricultural management systems. Trans of ASAE 30:1403-1418.

North Carolina Department of Agriculture. 1990. Annual agricultural survey. Raleigh, NC.

NCSU. 1993. Annual progress report for USDA Water Quality Demonstration Project in Herrings Marsh Run, Duplin County, North Carolina. North Carolina Cooperative Extension Service, N. C. State University, Raleigh, NC.

SAS. 1990. SAS version 6.07. SAS Institute, Cary, NC.

Stone, K.C., Hunt, P.G., Coffey, S.W., and Matheny, T.A. 1994. Water Quality Status of a USDA Water Quality Demonstration Project in the Eastern Coastal Plain. J. Soil and Water Conservation. (In Press).

USDA-SCS. 1959. Soil survey of Duplin County, North Carolina. Soil Conservation Service, Washington, D.C.

United States Department of Agriculture and Cooperating State Agencies. 1989. Water quality program plan to support the President's water quality initiative. USDA, Washington, D.C. 29pp.

U.S. EPA. 1983. Methods for chemical analysis of water and wastes. USEPA-600/4-79-020. J. F. Kopp and G. D. McKee. Environmental Monitoring and Support Lab. Cincinnati, OH. Office of Research and Development. Cincinnati, OH.

Table 1. Cropping practices for cropland field with Norfolk soil used to validate the GLEAMS model.

Year 1	Year 2
March: Applied 9kg N starter	Feb: Applied 84 kg N
March: Applied 4667 kg litter (84 kg N)	June: harvested wheat
March: planted corn	June: planted soybeans
May: Sidedressed with 112 kg N	Nov: harvested soybeans
Sept: Harvested corn	
Nov: Planted wheat	

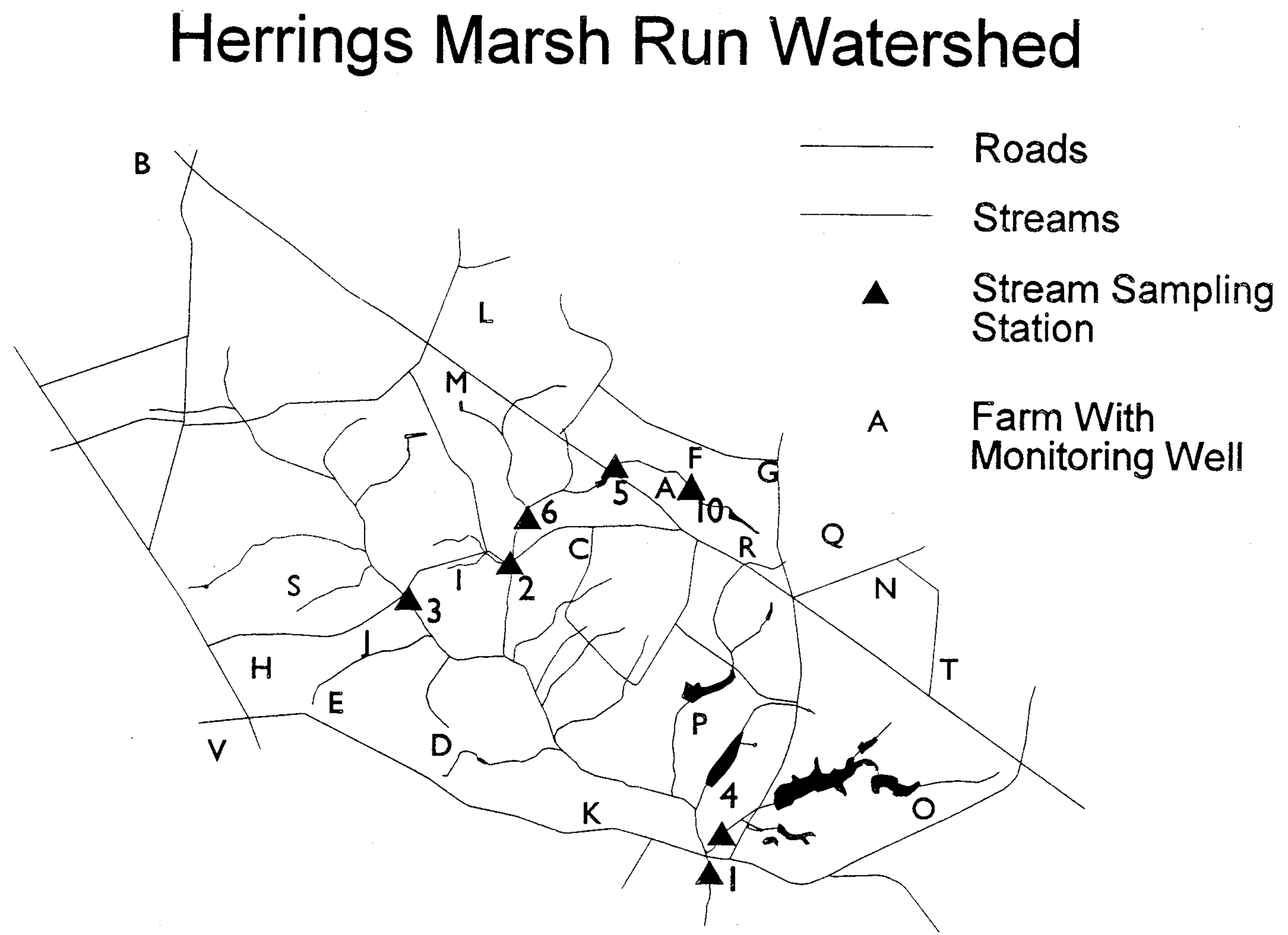

Figure 1. Location of stream sampling stations and farms with monitoring wells on the Herrings Marsh Run Demonstration Watershed.

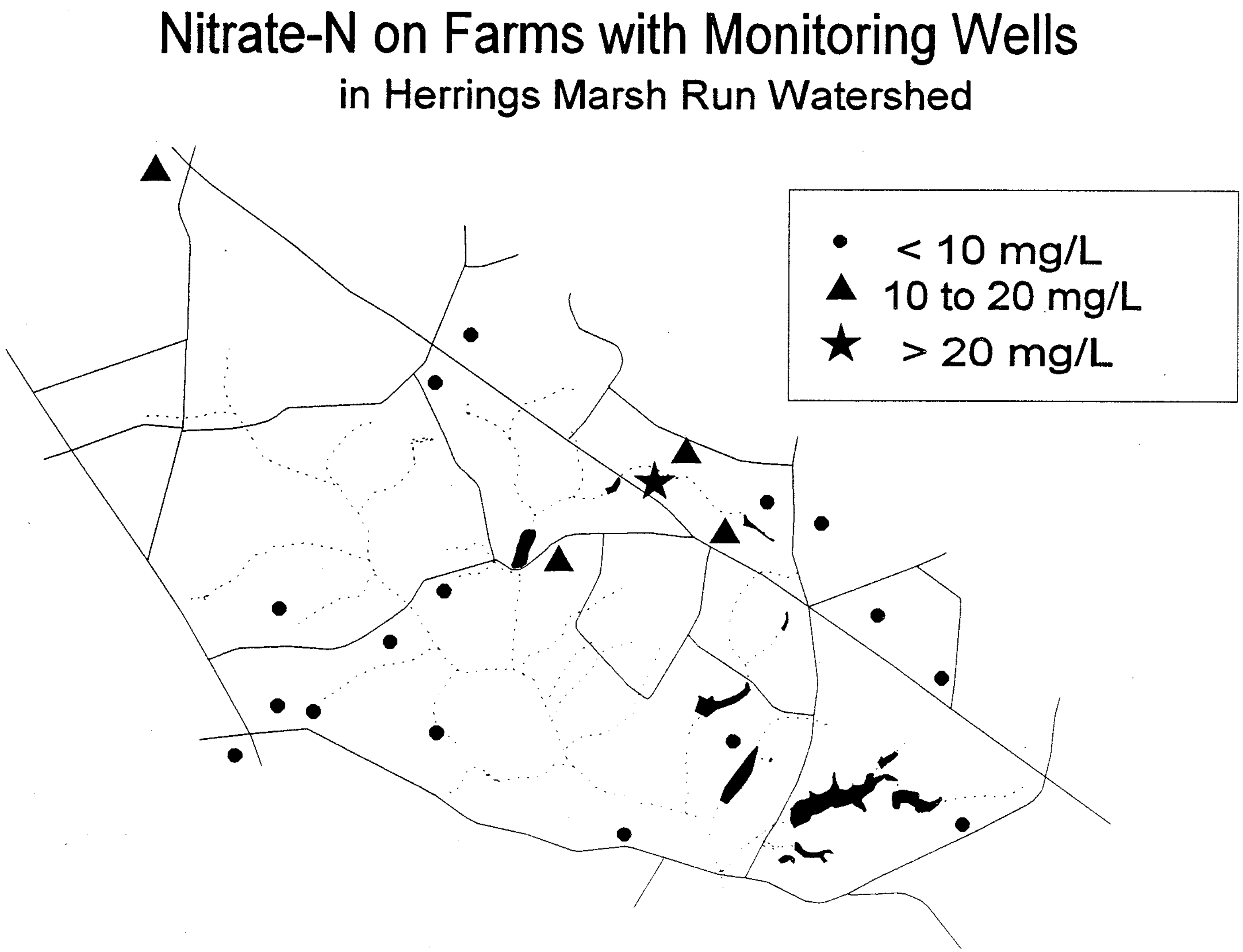

Figure 2. Location of farms with elevated Nitrate-N concentration in the Herring Marsh Run Demonstration Watershed.

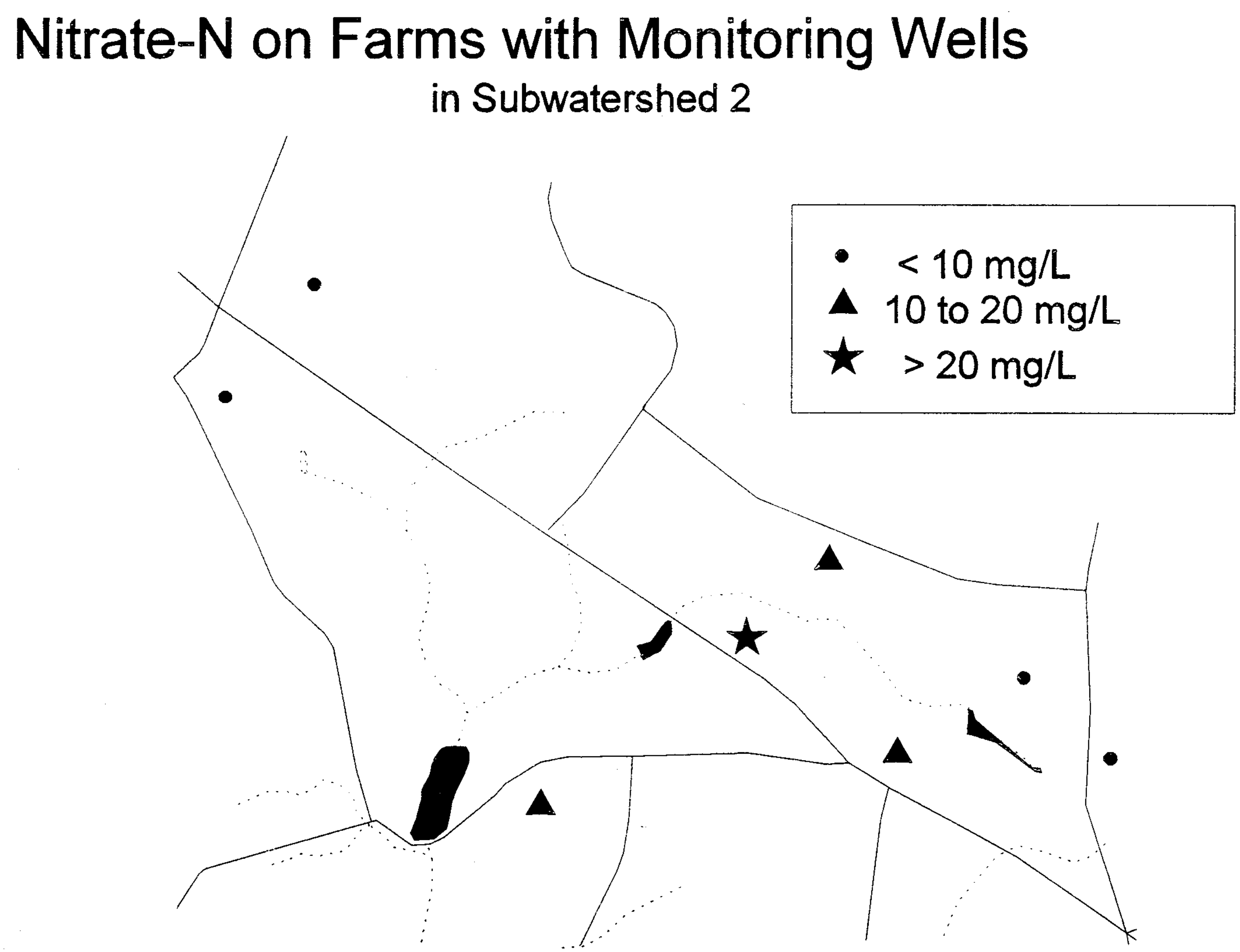

Figure 3. Location of farms with elevated Nitrate-N concentrations in subwatershed 2 of the Herring Marsh Run Demonstration Watershed.

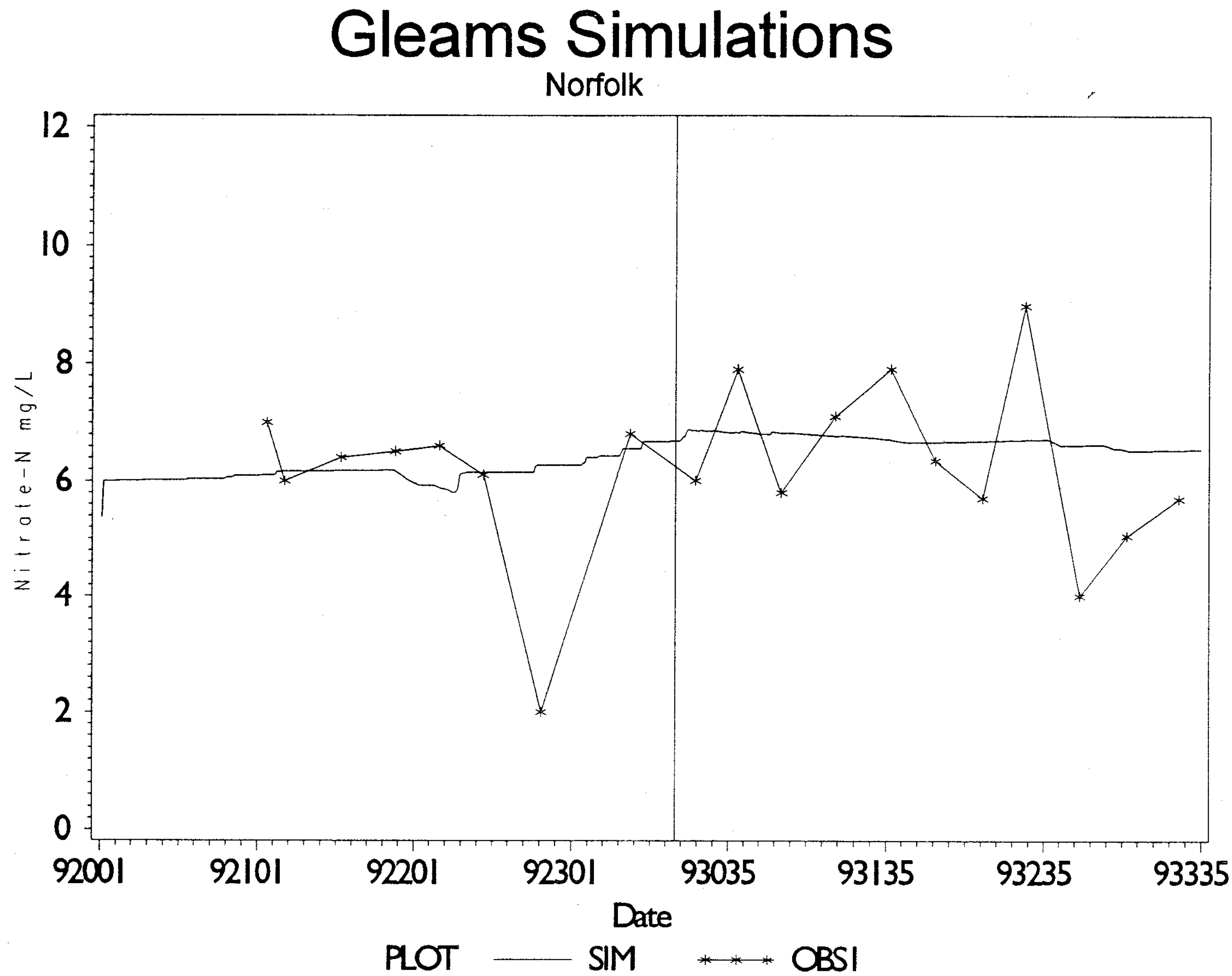

Figure 4. Comparison of GLEAMS simulated to measured ground water nitrate-N.