

# LONG-TERM TRENDS IN NITRATE CONTAMINATION IN FOUR FLINT RIVER SPRINGS

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**Abstract.** Groundwater in the Upper Floridian aquifer is susceptible to nitrate ( $\text{NO}_3^-$ ) contamination, the extent of which may vary depending on land use within different recharge areas. We examined  $\text{NO}_3^-$  concentrations over a five year period in four large springs (Radium, Riverview, Bovine, and Hog Pen Springs) which discharge into the lower Flint River between Albany and Bainbridge, Georgia. Average  $\text{NO}_3^-$  concentrations over the entire study period were 1.7, 2.8, 2.7 and 3.3 mg/L for Radium, Riverview, Bovine, and Hog Pen Spring, respectively. Significantly lower  $\text{NO}_3^-$  in Radium Spring was attributed to differences in land use. The Radium Spring recharge area includes substantial urbanized land cover, whereas the other three springs are recharged in rural locations dominated by agriculture. Positive correlations between groundwater levels and  $\text{NO}_3^-$  concentrations at two springs suggest that recharge water may be more contaminated with  $\text{NO}_3^-$ . Although some of the variability in  $\text{NO}_3^-$  was explained by fluctuations in the water table, long-term trends for all four springs demonstrated a statistically significant increase in groundwater  $\text{NO}_3^-$  with net changes ranging from 0.4 to 1.3 mg/L. This study demonstrates the importance of long-term data for evaluating the effects of anthropogenic activities on regional groundwater quality.

## INTRODUCTION

Widespread nitrate ( $\text{NO}_3^-$ ) contamination of groundwater is an emerging global problem with consequences for both human and ecosystem health (Spalding and Exner, 1993). Elevated  $\text{NO}_3^-$  (above 10 mg/L) levels in drinking water can increase an infant's susceptibility to methemoglobinemia which decreases blood oxygen levels that can result in death (Camargo and Alonso, 2006). In addition, ingestion of  $\text{NO}_3^-$  has been correlated with non-Hodgkins's lymphoma, central nervous system birth defects, and certain cancers (Spalding and Exner, 1993). Elevated  $\text{NO}_3^-$  levels in streams, wetlands, lakes, and coastal waters pose ecological problems such as increased growth of aquatic vegetation, and eutrophication of waters which decreases

the overall health of the aquatic system and may lead to fish kills. Groundwater discharge is often the source of  $\text{NO}_3^-$  loading in rivers and streams (Opsahl et al., 2003).

The Upper Floridian aquifer which underlies most of the Southeast coastal plain is susceptible to  $\text{NO}_3^-$  contamination. Sources for  $\text{NO}_3^-$  contamination include agricultural activities, wastewater discharge, and atmospheric deposition. Agriculture activities are considered the primary source for  $\text{NO}_3^-$  contamination in the Upper Floridian aquifer (Katz et al., 1999). In the lower Flint River Basin, large springs discharge groundwater from the Upper Floridian aquifer into streams elevating  $\text{NO}_3^-$  in this system (Opsahl et al., 2003). However, understanding the sources and timing of  $\text{NO}_3^-$  contamination is challenging because  $\text{NO}_3^-$  may enter spring conduits directly or it may take decades or longer before it is discharged from the aquifer into the river system (Katz et al., 1999). The purpose of this study was to determine the extent and long-term trends of  $\text{NO}_3^-$  contamination in four large springs in the lower Flint River Basin.

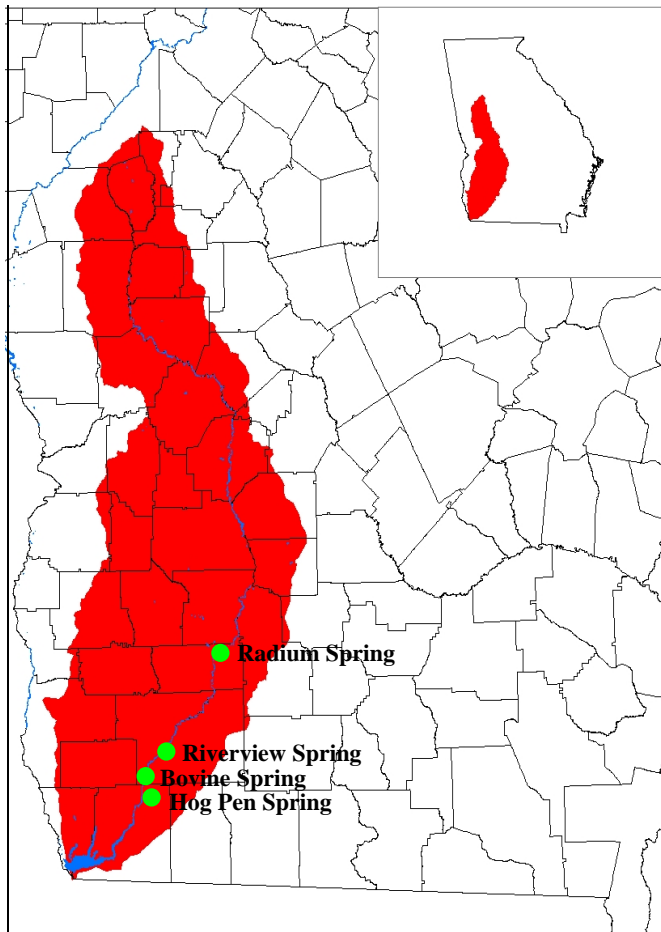
## METHODS

### Site Description

In 2001, a study was implemented to assess the long-term trends in groundwater chemistry in four springs located in the lower Flint River Basin. Radium Spring is an urban spring located in Dougherty County (31° 31' 12.6" latitude 84° 08' 26.4" longitude), Riverview Spring is located in Mitchell County (31° 08' 15.4" latitude 84° 28' 58.8" longitude), Bovine Spring is located in Baker County (31° 06' 09.8" latitude 84° 30' 28.0" longitude), and Hog Pen Spring is located in Decatur County (31° 02' 54.1" latitude 84° 30' 47.7" longitude) (Figure 1).

### Sampling & Analysis

Samples were collected opportunistically between May 2001 and May 2004; although no samples were collected between June 2004 and September 2005. Beginning in April 2006, the springs have been sampled on a monthly basis. Radium Spring was accessed by land.



**Figure 1** The Flint River Basin is indicated by the shaded area. The study sites (●) are located along the lower Flint River between Albany and Bainbridge, Georgia

Bovine, Riverview, and Hog Pen Springs were sampled by boat. Water levels in the river limited accessibility to Bovine, Riverview, and Hog Pen Springs. Triplicate groundwater samples were collected in acid-washed 1-liter polycarbonate bottles and stored on ice until transported to the laboratory. In the laboratory, samples were filtered within 24 hours using 47 mm glass fiber filters with 0.7  $\mu\text{m}$  nominal pore size. A subsample of the filtrate was analyzed for  $\text{NO}_3^-$  on a Lachat QuikChem 8000.

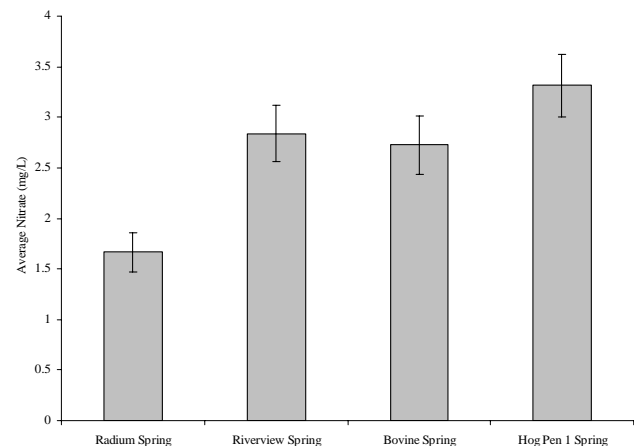
In order to estimate groundwater levels, daily data was obtained from three U.S. Geological Survey (USGS) groundwater monitoring wells that are in close proximity to the four springs sampled for this study. The groundwater data from the USGS wells used as an approximation of groundwater levels was for Radium (USGS 13L012), Riverview (USGS 10G313), Bovine (USGS 09G001), and Hog Pen (USGS 09G001) Springs.

## RESULTS AND DISCUSSION

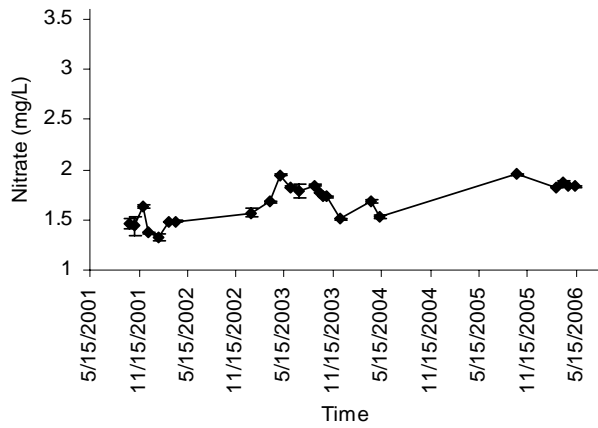
$\text{NO}_3^-$  concentrations averaged over the entire study period were 1.7, 2.8, 2.7, and 3.3 mg/L for Radium, Riverview, Bovine, and Hog Pen Springs, respectively (Figure 2). Radium Spring had significantly lower  $\text{NO}_3^-$  concentrations than the other springs. This difference was attributed to differences in land use. The Radium Spring recharge area includes substantial urbanized land cover; whereas, the other three springs are recharged in rural locations dominated by agriculture. Although current  $\text{NO}_3^-$  concentrations do not pose a significant threat to human health, elevated levels do have consequences for aquatic ecosystems.

The long-term trends demonstrated a statistically significant increase in groundwater  $\text{NO}_3^-$  for Radium ( $r^2 = 0.5016$ ;  $p < 0.0001$ ), Riverview ( $r^2 = 0.9105$ ;  $p < 0.0001$ ), Bovine ( $r^2 = 0.4507$ ;  $p < 0.0051$ ), and Hog Pen ( $r^2 = 0.8845$ ;  $p < 0.0001$ ) Springs (Figure 3 a-d). Over the five year period, the net change in  $\text{NO}_3^-$  concentrations for each spring were 0.4, 0.7, 0.7, and 1.3 mg/L for Radium, Riverview, Hog Pen, and Bovine Springs, respectively. All four springs demonstrated a trend towards increasing  $\text{NO}_3^-$  concentrations which will continue to pose both environmental and health concerns if the trend continues.

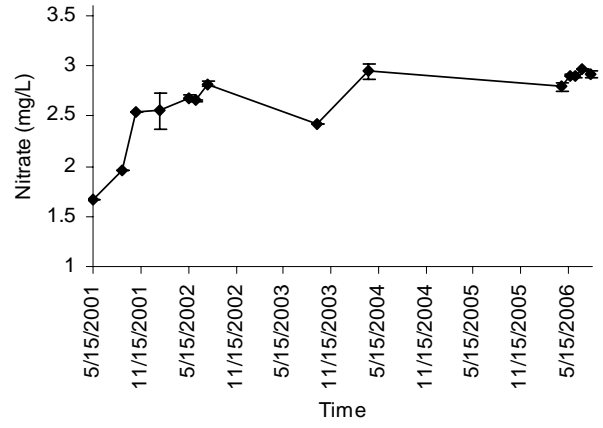
Groundwater levels and  $\text{NO}_3^-$  concentrations were positively correlated at Riverview ( $r^2 = 0.4486$ ;  $p = 0.0289$ ) and Radium ( $r^2 = 0.3552$ ;  $p = 0.0013$ ) Springs (Figure 4 a-b). There was not a significant relationship between groundwater levels and  $\text{NO}_3^-$  concentrations at Bovine ( $r^2 = 0.0000$ ;  $p = 0.8429$ ) and Hog Pen Springs ( $r^2 = 0.2762$ ;  $p = 0.1038$ ). The results for Radium and Riverview Springs indicate that as the groundwater water levels decreased, nitrate levels in spring water discharge decreased as well. This suggests that recharge water coming into the aquifer may be more contaminated with  $\text{NO}_3^-$  than groundwater already present in the system at these two springs. The results for Riverview and Radium Springs indicate that some of the variability in  $\text{NO}_3^-$  concentrations may be attributed to  $\text{NO}_3^-$  contamination in the recharge water at these two springsheds.



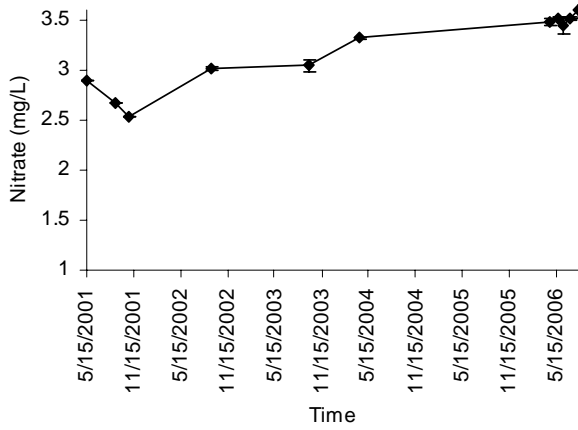
**Figure 2.** Average nitrate concentrations (mg/L).



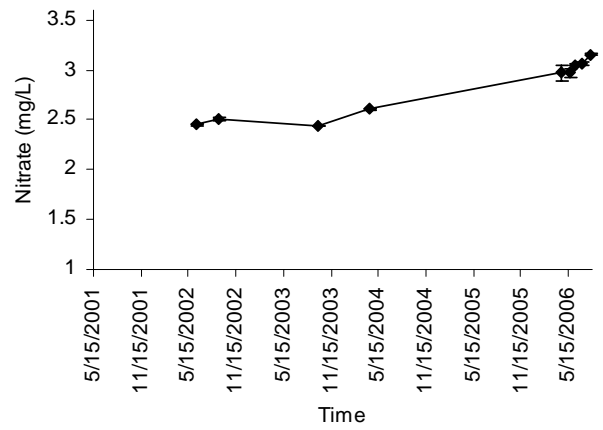
**a) Radium Spring**



**b) Riverview Spring**

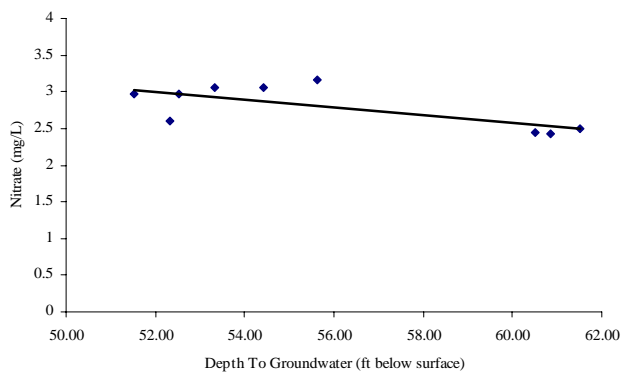


**c) Bovine Spring**

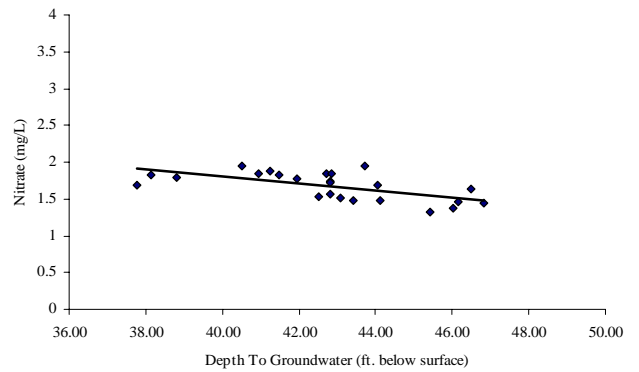


**d) Hog Pen Spring**

**Figure 3 a-d Changes in nitrate concentration (mg/L) over time.**



**a) Riverview Spring**



**b) Radium Spring**

**Figure 4 a-b Nitrate concentration (mg/L) versus groundwater depth (feet below surface).**

## CONCLUSIONS

All four springs demonstrated a trend towards increasing  $\text{NO}_3^-$  concentrations. However, average  $\text{NO}_3^-$  concentrations in Radium Spring were significantly less than the concentrations found in the three rural springs. Therefore, the extent of  $\text{NO}_3^-$  enrichment in springs may depend on surrounding land use. The potential source for  $\text{NO}_3^-$  may differ between the urban and rural springs. The source of contamination at Riverview, Bovine, and Hog Pen Springs is most likely various agriculture activities surrounding the springs. Radium Spring is located within an urban area.  $\text{NO}_3^-$  contamination in this spring may be attributed to septic tank leakage or surface water runoff into sinkholes in the surrounding residential area. Factors that would enable us to better understand the source and extent of  $\text{NO}_3^-$  loading into springs are land-use data and estimates of fertilizer application rates and timing. In addition, knowledge of the springshed boundaries would provide information about where recharge water is entering the aquifer; therefore, allowing us to better understand the sources of  $\text{NO}_3^-$  and how the sources relate to surrounding land-use.

The increasing concentration of  $\text{NO}_3^-$  in the springs indicates that nitrogen inputs are exceeding the capacity of the natural system to assimilate nitrogen that is entering the aquifer. Groundwater quality is an indicator of the region's drinking water supply. Therefore, the increasing  $\text{NO}_3^-$  levels in groundwater are problematic due to the potential health complications associated with ingestion of  $\text{NO}_3^-$  from water. The available technologies for removing  $\text{NO}_3^-$  are limited. Therefore, increasing  $\text{NO}_3^-$  levels in water may prove to be an economic hardship if municipalities and homeowners are required to locate other drinking water sources.

$\text{NO}_3^-$  discharging into rivers from springs may have detrimental consequences downstream from the discharge site. Elevated  $\text{NO}_3^-$  concentrations can sustain invasive aquatic vegetation such as *Hydrilla* which is found in Lake Seminole, Bainbridge, Georgia. In addition, nutrient loading from  $\text{NO}_3^-$  can lead to widespread hypoxia in coastal waters which stresses aquatic species and degrades suitable habitat for fishes and aquatic invertebrates (Rabalais et al., 2002). However, the potential effects of elevated  $\text{NO}_3^-$  concentrations from the lower Flint River Basin on Apalachicola Bay are currently unknown.

## ACKNOWLEDGEMENTS

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