Water Chemistry of the Upper Floridan Aquifer Along a Groundwater Flowpath on St. Catherines Island, Georgia

James S. Reichard[1]; Brock R. Nelson[1]; Brian K. Meyer[2]; R. Kelly Vance[1]; and Gale A. Bishop[3]

(1) Department of Geology and Geography, Georgia Southern University, Statesboro, GA 30460
(2) Department of Geosciences, Georgia State University, Atlanta, GA 30302
(3) St. Catherines Island Sea Turtle Program, Georgia Southern University, Statesboro, 30460

Abstract

St. Catherines Island is a 20 km by 2 to 4 km barrier island located on the Georgia coast between the Savannah and Altamaha Rivers. Hydraulic head and general water chemistry are being monitored on the island's Pleistocene core along a north-south transect of four wells completed in the upper Floridan Aquifer, the principal artesian aquifer for the region. Head data show that the transect lies completely within a major drawdown cone centered near Savannah, Georgia, located 50 km to the north. Previous studies have documented both lateral and vertical saltwater intrusion in coastal Georgia due to the post-industrialization loss of artesian pressure within the upper Floridan.

The 8 km long transect in this study lies along a south to north groundwater flowpath within the drawdown cone of the upper Floridan aquifer. The hydraulic head averages 3.4 and 9.1 meters below sea level at the southern and northern ends of the transect, respectively. The groundwater is slightly alkaline (pH 7.6 to 7.9), has a low dissolved oxygen content (10 to 30%), and is under reducing conditions (-0.28 to -0.32 relative V). Trends in water chemistry along the flowpath consistently show a decrease in total dissolved solids; ranging from an average of 367 mg/l in the south to 310 mg/l in the north. For individual chemical species, south to north decreases were found in average chloride concentrations (13.8 to 9.2 mg/l) and in sulfate (124 to 78 mg/l). Decreases in sulfate concentration along the flowpath, which make up 81% of the decline in total dissolved solids, can largely be explained by sulfate reduction. However, since chloride is a conservative tracer, decreasing chloride concentrations along the flowpath are difficult to account for through chemical reactions. The chloride decline can most easily be explained by saltwater intrusion, with the source being located up-gradient (south) of the transect. Possible mechanisms include the downward movement of seawater through confining beds in the adjacent sound, and by the upwards flow of saline water from deep aquifers along vertical conduits. Additional sampling will be performed in an attempt to determine the source of the saline water.

Study Area

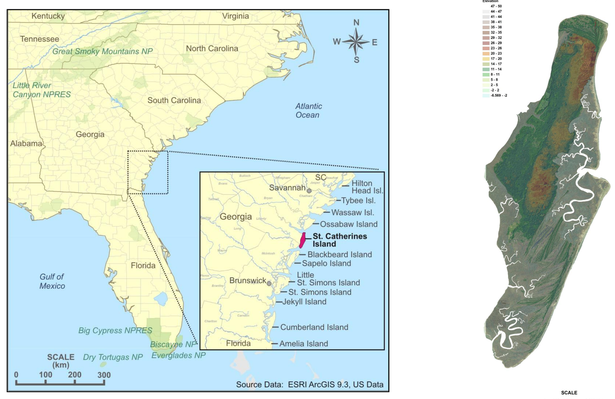


Figure 1. Location of St. Catherines Island on the Georgia coast. LIDAR image (right) from Meyer et. al. 2009.

Floridan Aquifer System

- Three main permeable zones (Fig 2):
  - Upper Floridan aquifer
  - Lower Floridan aquifer
  - Fernandina permeable zone
- Vertical conduit (red line) beneath Brunswick drawdown cone is allowing hypersaline water from the Fernandina to move into the Upper Floridan aquifer (Fig 2).

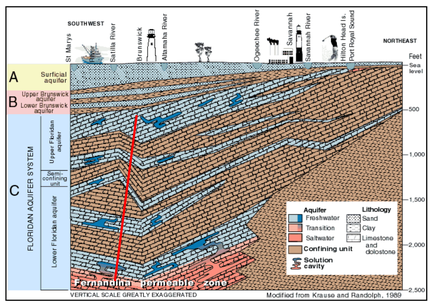


Figure 2. SW-NE hydrogeologic cross-section along the Georgia coast. (modified after Krause and Clarke, 2001).

- Savannah drawdown cone is causing saltwater from Port Royal to enter the Upper Floridan and flow laterally beneath Hilton Head Island (Fig 3).
- Potential for lateral saltwater intrusion exists at numerous other locations, including St. Catherines Island – outlined in black (Fig 3).

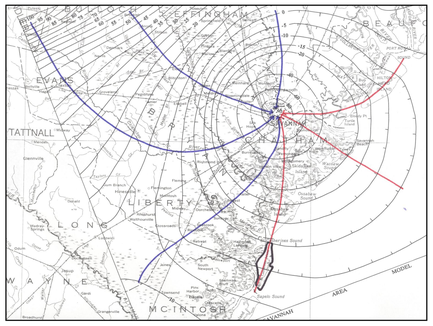


Figure 3. Lateral groundwater flowpaths within the upper Floridan aquifer based on a 1985 configuration of the potentiometric surface (modified after Garza and Krause, 1996).

Purpose and Objectives

The purpose of this study is to determine whether saltwater intrusion is occurring in the upper Floridan aquifer beneath St. Catherines Island. The objective is to use a south to north transect of four pumping wells to characterize the water chemistry along a groundwater flowpath within the aquifer.

South-North Upper Floridan Transect

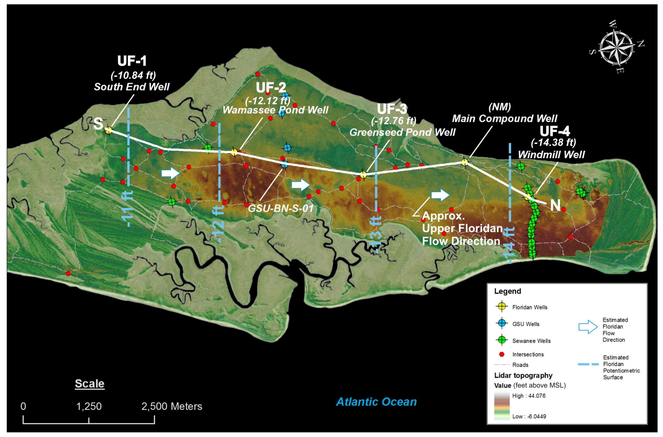


Figure 4. LIDAR map showing the south-north transect of four Upper Floridan pumping wells on St. Catherines Island (modified after Meyer et. al. 2009).

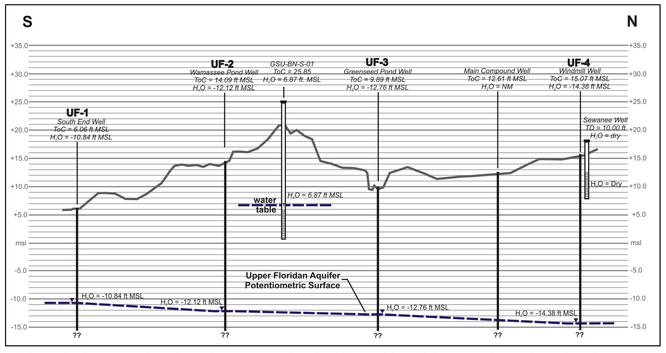
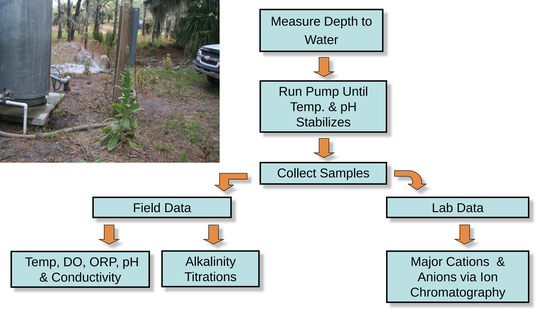


Figure 5. Cross-section along the transect showing the position of the potentiometric surface in each of the four wells on July 26, 2011.

Methodology



Preliminary Results

- Rebound in head (Fig. 6) after December 2011 possibly due to withdrawal reductions by major industrial and municipal users in the Savannah area.

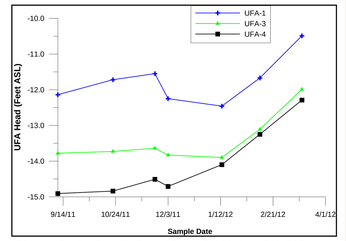


Figure 6. Hydraulic head from 9/11/11 to 3/14/12. Casing collapse has prevented head from being measured in UFA-2 after 8/3/11.

- Both Cl^- & SO_4^{2-} decrease along the Upper Floridan flowpath on St. Catherines Island (Fig. 7).
- SO_4^{2-} decline best explained by chemical reduction.
- Cl^- decline explained by dilution from surficial aquifer, or by saltwater intrusion up-gradient of the transect.
- Dilution along flowpath ruled out as Cl^- concentration of surficial is 2-4x greater than Upper Floridan.
- Seawater chemistry (magenta) on piper diagram (Fig. 8) eliminates modern ocean water.
- Most likely source is Lower Floridan aquifer (magenta on Fig. 8) as its chemistry is consistent with the observed UFA mixing line.
- Wells in tidal wetlands along the Ogeechee River (green) and in surficial aquifer on St. Catherines (red) have chemical signature of modern seawater (Fig. 8).

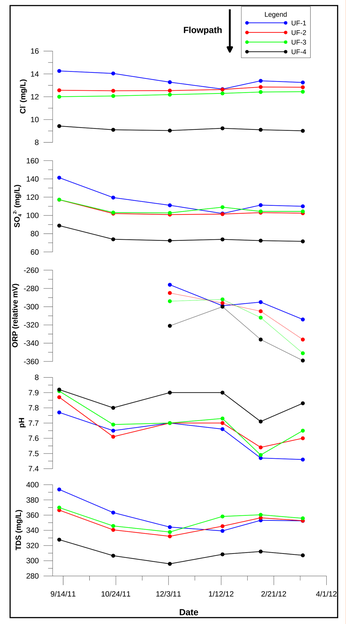


Figure 7. Time series of selected chemical parameters along UFA well transect.

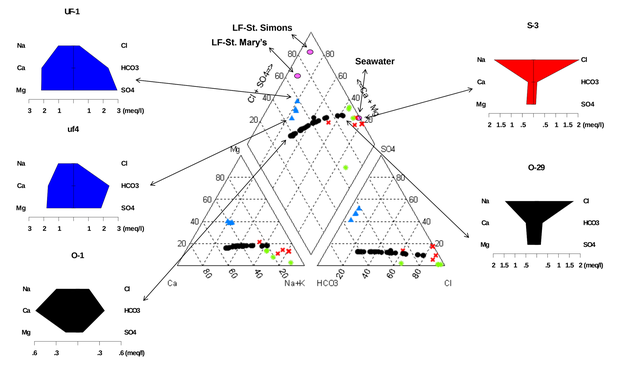


Figure 8. Water chemistry of surficial (red) & upper Floridan (blue) aquifers on St. Catherines along with Ogeechee River (black) & tidal wetland (green) samples. Lower Floridan & seawater data (magenta) from Falls et. al. 2005.

Acknowledgements

Support for this project was provided by grants from the St. Catherine's Island Foundation and Georgia Southern University's College of Undergraduate Research (COUR) Program. Special thanks goes to Royce Hayes, St. Catherines Island Superintendent, for providing logistical support that makes this research possible.

References

Falls, W. Fred Harrelson, Larry G., Conlon, Kevin J., and Petkewich, Matthew D. , 2005, Hydrogeology, Water Quality, and Water-Supply Potential of the Lower Floridan Aquifer, Coastal Georgia, 1999-2002: Scientific Investigations Report 2005-5124, 98 p.

Garza, R., and Krause, R.E., 1996. Water-Supply Potential of Major Streams and the Upper Floridan Aquifer in the Vicinity of Savannah, Georgia. U.S. Geological Survey Water-Supply Paper 2411, 38 p.

Krause, R.E., and Clarke, J.S., 2001. Coastal Ground Water at Risk - Saltwater Contamination at Brunswick, GA and Hilton Head Island, SC: U.S. Geological Survey Water Resources Investigations Report 01-4107, 1 oversize sheet.

Meyer, B.K., Keith-Lucas, T., Bishop, G.A., Thomas, D.H., Hayes, R.H., Sanger, M., and Vance, R.K., 2009. Digital Atlas of St. Catherines Island, Georgia. St. Catherines Research Consortium Publication CD-1