Coastal Ground Water at Risk— Saltwater contamination at Brunswick, Georgia and Hilton Head Island, South Carolina

USGS science for a changing world

Introduction

Saltwater contamination is restricting the development of ground-water supply in coastal Georgia and adjacent parts of South Carolina and Florida. The principal source of water in the coastal area is the Upper Floridan aquifer—an extremely permeable and high-yielding aquifer—which was first developed in the late 1800s. Pumping from the aquifer has resulted in substantial ground-water-level decline and subsequent saltwater intrusion of the aquifer from underlying strata containing highly saline water at Brunswick, Georgia, and with encroachment of sea-water into the aquifer at the northern end of Hilton Head Island, South Carolina. The saltwater contamination at these locations has constrained further development of the Upper Floridan aquifer in the coastal area and has created competing demands for the limited supply of freshwater. The Georgia Department of Natural Resources, Georgia Environmental Protection Division (GaEPD) has restricted permitted withdrawal of water from the Upper Floridan aquifer in parts of the coastal area (including the Savannah and Brunswick areas) to 1997 rates, and also has restricted additional permitted pumpage in all 24 coastal area counties to 36 million gallons per day above 1997 rates. These actions have prompted interest in alternative management of the aquifer and in the development of supplemental sources of water supply including those from the shallower surficial and upper and lower Brunswick aquifers and from the deeper Lower Floridan aquifer.

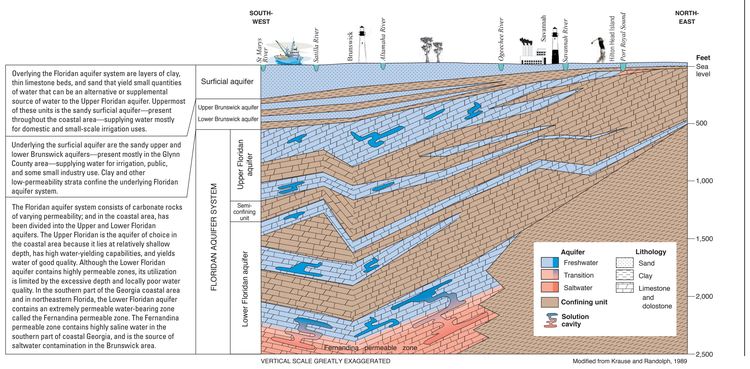
Image from Nickolas L. Faust, Coastal Georgia LANDSAT TM Image, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, Georgia, 1998

Coastal Physical Setting

The coastal area of Georgia and adjacent parts of South Carolina and Florida is part of the Coastal Plain physiographic province of the Atlantic Coastal Plain. The area consists of barrier islands, marshes, plains, a series of terraces, and inland rolling hills and valleys. Land use is urban and industrial in cities such as Savannah and Brunswick; outside these areas, land use is a combination of forest, grazed woodland, cropland with pasture, and marsh and swampland. In 1997, ground-water sources served a population of about 526,600; surface-water sources served about 8,000 (Fanning, 1999). Average annual precipitation ranges from about 46 to 54 inches.

Geology and Ground-Water Resources

The coastal area of Georgia and adjacent parts of Florida and South Carolina is blanketed and underlain by sand, clay, and other clastic rocks that overlie limestone and dolostone at varying depth. The sequence of sedimentary strata is thickest and most deeply buried in the Brunswick area and southward into northeastern Florida, where more than 500 feet of sand and clay overlie more than 2,000 feet of limestone and dolostone. The sequence is thinner and at shallower depths toward the north in the Savannah, Georgia, and Hilton Head Island, South Carolina, areas where the carbonate rocks are 50–150 feet below land surface and are less than 500 feet thick.



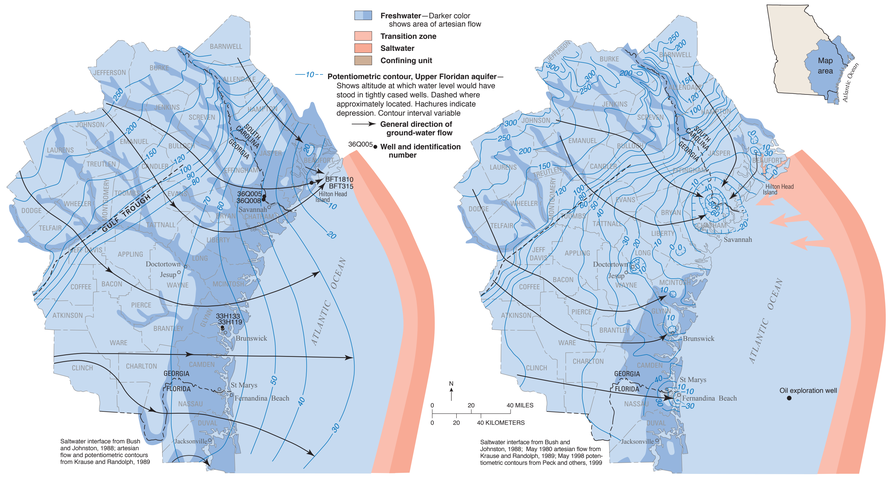
VERTICAL SCALE GREATLY EXAGGERATED — Modified from Krause and Randolph, 1989

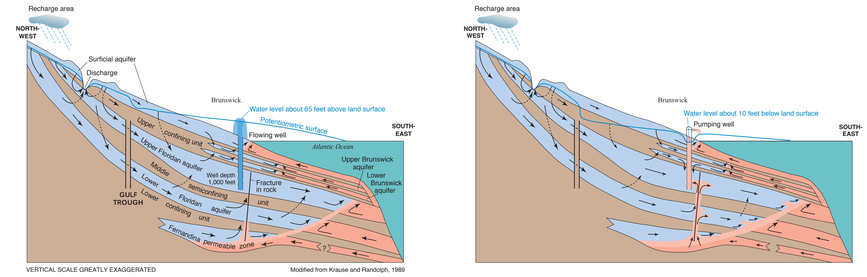
Predevelopment Ground-Water Flow System

Prior to development of the Floridan aquifer system in the 1880s, recharge to the aquifer system was roughly offset by natural discharge. The Floridan aquifer system was replenished (recharged) by rainfall in areas where aquifer sediments are at or near land surface, generally west and northwest of the coast. Ground water flowed from areas of recharge downgradient toward the coast. The aquifer system was under artesian conditions and the pressure in the aquifer system was great enough that wells flowed at land surface throughout most of the coastal area. In some areas, pressure was high enough to elevate water to multi-story buildings without pumping. The artesian water level was about 65 feet above sea level at Brunswick, and 35 feet above sea level at Savannah. Ground water discharged naturally to springs, rivers, ponds, wetlands, and other surface-water bodies; as diffuse upward leakage into overlying adjacent aquifers; and to the Atlantic Ocean. As water flowed coastward, low-permeability sediments in the vicinity of the Gulf Trough inhibited ground-water flow and produced a steep flow gradient.

Modern-Day Ground-Water Flow System

Ground-water pumping has caused the water level in the Upper Floridan aquifer to decline throughout the entire coastal area, resulting in the development of cones of depression in areas of heavy, concentrated pumpage, such as the Savannah, Brunswick, Jesup, and St Marys, Georgia–Fernandina Beach, Florida, areas. Wells have ceased to flow at land surface in much of the coastal area. Many freshwater springs and seeps have ceased to discharge; freshwater wetlands and ponds that prior to development were sustained by flow from the Upper Floridan aquifer are no longer sustained by that flow. Although the cones of depression are deep, they do not intercept the top of the Upper Floridan aquifer; thus, dewatering or mining of water is not occurring. The pressure reduction has caused saltwater that is under higher pressure to flow into and contaminate the freshwater part of the aquifer in at least two locations—Brunswick, Georgia, and Hilton Head Island, South Carolina.





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Freshwater-Saltwater Interface

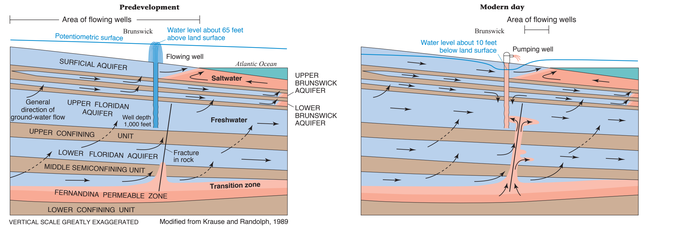
Freshwater in the Floridan aquifer system flows seaward until it comes in contact with seawater along the freshwater-saltwater interface. Freshwater is less dense than saltwater and flows above the saltwater. The interface is not sharp and distinct, but is a diffuse zone where freshwater and saltwater mix through the processes of chemical diffusion and mechanical dispersion. Data from the offshore area, conceptual models, and results of simulation indicate that the freshwater-saltwater interface occurs near the coastline in the Hilton Head Island area, arcs eastward beneath the ocean floor, reaching a maximum distance of about 85 miles offshore, then arcs back westward to the coast south of Jacksonville, Florida.

Freshwater in the aquifer system along the coast also has an interface with saltwater at depth. Saltwater occurs naturally in aquifer-system sediments below the freshwater zone, extending landward from the freshwater-saltwater interface offshore, and underlying freshwater in the aquifer system in the lower part of the Fernandina permeable zone. In the Brunswick area, saltwater in the Fernandina permeable zone was detected at a depth of about 2,400 feet below sea level, and has a maximum chloride concen-tration of about 33,000 milligrams per liter at a depth of 2,700 feet.

Saltwater Contamination at Brunswick, Georgia

Saltwater contamination at Brunswick is the result of upward intrusion of saline water from the lower part of the Fernandina permeable zone into freshwater zones of the Lower Floridan, then Upper Floridan aquifers. Saltwater from the Fernandina permeable zone migrates upward through fractures and conduits in the limestone and dolostone confining units in response to reduced artesian pressure caused by pumping of water from the Upper Floridan aquifer. Upon reaching the aquifers in the southern part of Brunswick, the saltwater moves toward areas of ground-water pumping in the northern part of Brunswick.

Contamination of the Upper Floridan aquifer in the Brunswick area is not due to lateral encroachment nor downward intrusion of seawater because the Upper Floridan aquifer is deeply buried at Brunswick (greater than 500 feet deep); the freshwater-saltwater interface is far from the coastline (more than 50 miles offshore); and perhaps most importantly, pressure in the Upper Floridan aquifer was greater than sea level when saltwater contamination at Brunswick was first detected in the late 1950's. Lateral encroachment or vertical infiltration of saltwater may be possible, however, in the shallower surficial aquifer or in the upper and lower Brunswick aquifers.



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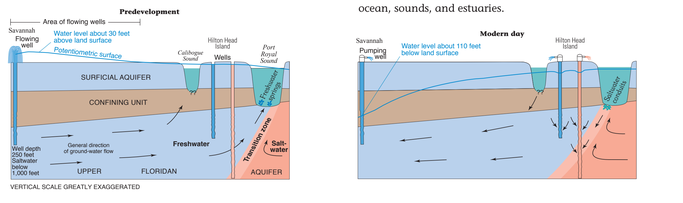
Saltwater Contamination at Hilton Head Island, South Carolina

Saltwater contamination along the northern part of Hilton Head Island probably is a result of lateral encroachment of seawater, combined with some downward vertical leakage of seawater where the Upper Floridan aquifer is exposed or nearly exposed. In the vicinity of Port Royal Sound, and possibly other estuaries, downcutting by ancient river systems during periods of lower ocean levels that existed during the most recent ice age exposed rocks that form the Upper Floridan aquifer, causing direct connection between seawater and fresh ground water.

Regional ground-water pumping, but most importantly, pumping on the island, has locally lowered the pressure in the Upper Floridan aquifer and reversed the natural hydraulic gradient, causing the encroachment of saltwater. Features that formerly were submarine springs prior to development, now are conduits for the encroachment of saltwater from the ocean, sounds, and estuaries.



VERTICAL SCALE GREATLY EXAGGERATED

Ground-Water Management and Scientific Studies

Water-resource managers in Georgia and South Carolina are interested in minimizing further contamination of the Floridan aquifer system and allocating water from the aquifer system for current use and for future demands. To this end, the GaEPD released an interim strategy in April 1997, which is described in the document: "Interim Strategy for Managing Salt Water Intrusion in the Upper Floridan Aquifer of Southeast Georgia" (Georgia Environmental Protection Division, 1997). The intent of this Interim Strategy is to protect the Upper Floridan aquifer from saltwater contamination.

To better understand the processes of saltwater contamination and to monitor ground-water conditions in coastal Georgia, the USGS is participating in cooperative studies with the GaEPD, and the City of Brunswick and Glynn County, Georgia.

The Coastal Georgia Sound Science Initiative is a program of scientific and feasibility studies to support development of GaEPD's final strategy to protect the Upper Floridan aquifer from saltwater contamination. Implementation of the final strategy is proposed for January 2006.

In support of the Sound Science Initiative, the USGS is working on a comprehensive program to evaluate ground-water conditions in the coastal area of Georgia and adjacent parts of South Carolina and Florida. The study is being conducted in cooperation with GaEPD. Other participants include the U.S. Army Corps of Engineers; Georgia Institute of Technology; The Georgia Conservancy; Georgia State University; Georgia Southern University; Skidaway Institute of Oceanography; The University of Georgia, Cooperative Extension Service; the South Carolina Department of Health and Environmental Control; and several private consulting firms.

Objectives of the Sound Science Initiative

- Conduct expanded scientific and feasibility studies to determine how to prevent saltwater from moving toward Hilton Head Island, South Carolina, and how to prevent the existing saltwater contamination at Brunswick, Georgia, from worsening.
- Develop a digital ground-water flow model to more completely simulate the flow system by incorporating additional layers in the surficial aquifer, the upper and lower Brunswick aquifers, and the Fernandina permeable zone. Use the calibrated flow model to simulate water-management scenarios and provide input data necessary to simulate chloride movement.
- Investigate paths and rates of ground-water flow and intrusion of saltwater into the Upper Floridan aquifer by developing solute-transport models for the Brunswick and Savannah–Hilton Head Island areas. Use the calibrated models to evaluate rates of saltwater contamination under a variety of water-management scenarios.
- Delineate areas where saltwater enters the Floridan aquifer system by constructing offshore test wells near Savannah–Hilton Head Island, and test wells onshore along the coast.
- Assess alternative and supplemental sources of water supply by conducting studies to evaluate the water-supply potential of (1) seepage ponds connected to the surficial aquifer; (2) the upper and lower Brunswick aquifers; (3) the Lower Floridan aquifer; (4) rivers and streams; (5) off mainstream impoundments; (6) reclaimed water; (7) reverse osmosis; and (8) conservation.
- Develop and maintain an expanded monitoring network to assess ground-water levels and quality.
- Conduct feasibility studies and assessments of engineered and non-engineered methods that could be used to prevent saltwater intrusion.
- Provide scientific rationale to support development of a final strategy to protect ground water in coastal Georgia from saltwater intrusion.

Timeline of Ground-Water Development, Water Quality, and Scientific Studies and State Legislation

TEXT COLORS USED IN TIMELINE
- Ground-water development
- Water-quality information
- Scientific studies and State legislation

ABBREVIATIONS USED IN TIMELINE
- gal/d, gallons per day
- mg/L, milligrams per liter
- Mgal/d, million gallons per day
- s/cm, microsiemens per centimeter

Selected References, Sources of Information, and Contacts

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Data for all water-level and chloride concentration graphs from the U.S. Geological Survey National Water Information System.

1995 water-use data for South Carolina and Florida from the U.S. Geological Survey Aggregate Water-Use Data System (AWUDS).

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Prepared in cooperation with the Georgia Department of Natural Resources, Georgia Environmental Protection Division, Georgia Geologic Survey; the City of Brunswick, and Glynn County

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