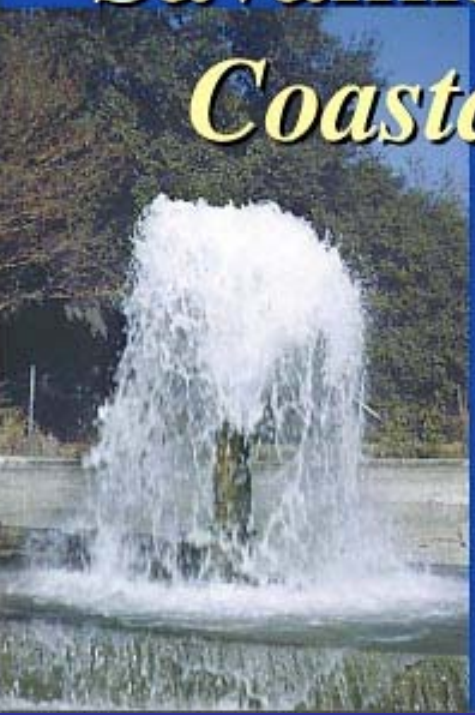
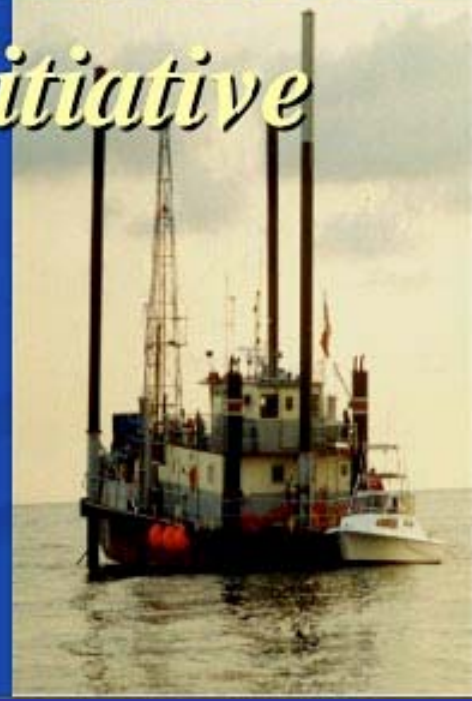
Saltwater Contamination in the Savannah-Hilton Head Island Area

Coastal Sound Science Initiative



U.S. Geological Survey

September 22, 2006



Major Findings

- Local hydrogeology makes the Hilton Head Island area prone to saltwater intrusion
- Pumping in *both* Savannah and Hilton Head Island areas contributes to saltwater intrusion in the Hilton Head Island area
- The science does not lend itself to quantify relative percentage contributions by either area to the existing saltwater intrusion
- Substantial reductions in pumping in Savannah and Hilton Head Island areas would be required to stop plume growth
- If all pumping is eliminated, chloride plumes will continue to exist well into the future

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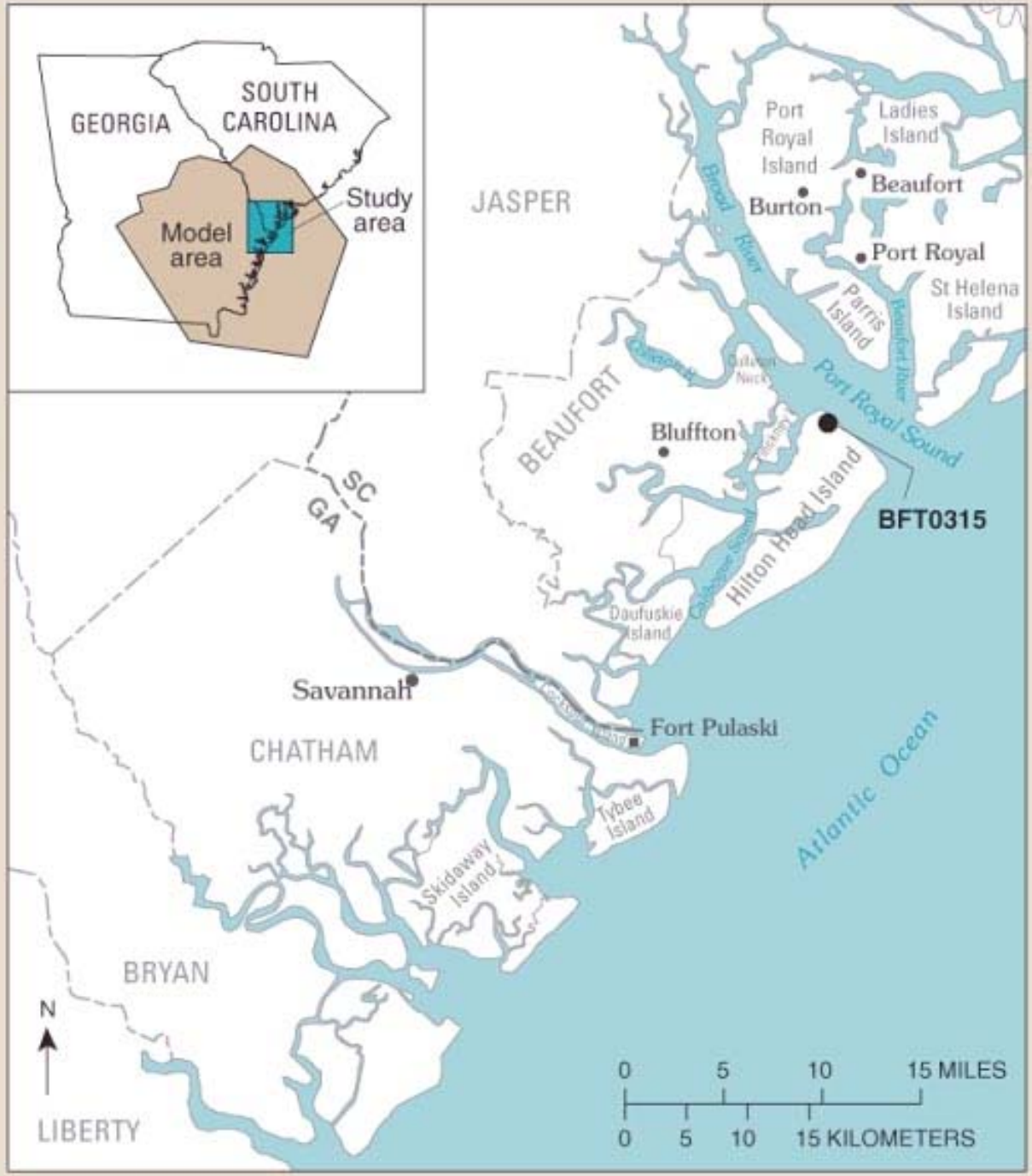
Note: Quantifying percentage contributions by either the Savannah or Hilton Head Island area to the saltwater intrusion is difficult because the system is complex and the processes are non-linear. For example, if pumping in areas A and B contribute to the presence of intruded saltwater in an aquifer, the sum of the amount of saltwater intrusion that pumping in area A causes by itself and the amount that pumping in area B causes by itself, does not necessarily equal the amount caused by pumping in both areas together.

Study Area



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Chronology of Saltwater Contamination

- 1885: First well drilled at Savannah
- 1880s-1890s: Beaufort and Parris Island supply wells drilled
- 1903: Wells on Parris Island abandoned due to saltwater contamination
- 1946: Beaufort supply well abandoned due to saltwater contamination
- 1980: Saltwater contamination exceeds drinking water standard in well BFT-315 on Hilton Head Island

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Coastal Sound Science Initiative

1999–2006

- Offshore drilling—Locate where saltwater enters the aquifer
- Alternative water sources—Reduce demand on the major water source
- Monitoring network and data-base—Assess the effectiveness of water-management policies
- Ground-water flow and solute-transport modeling—Plan for future demands

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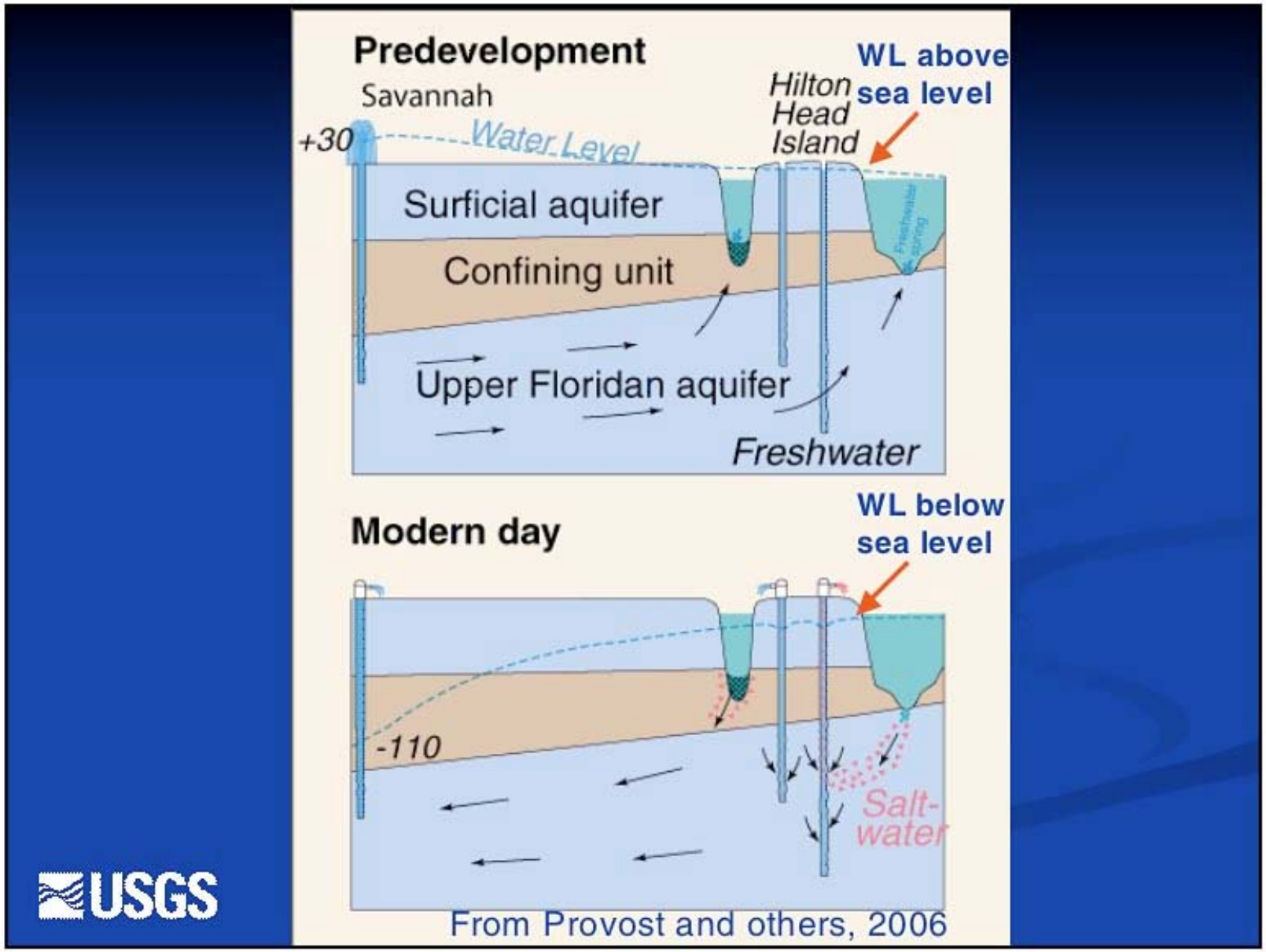
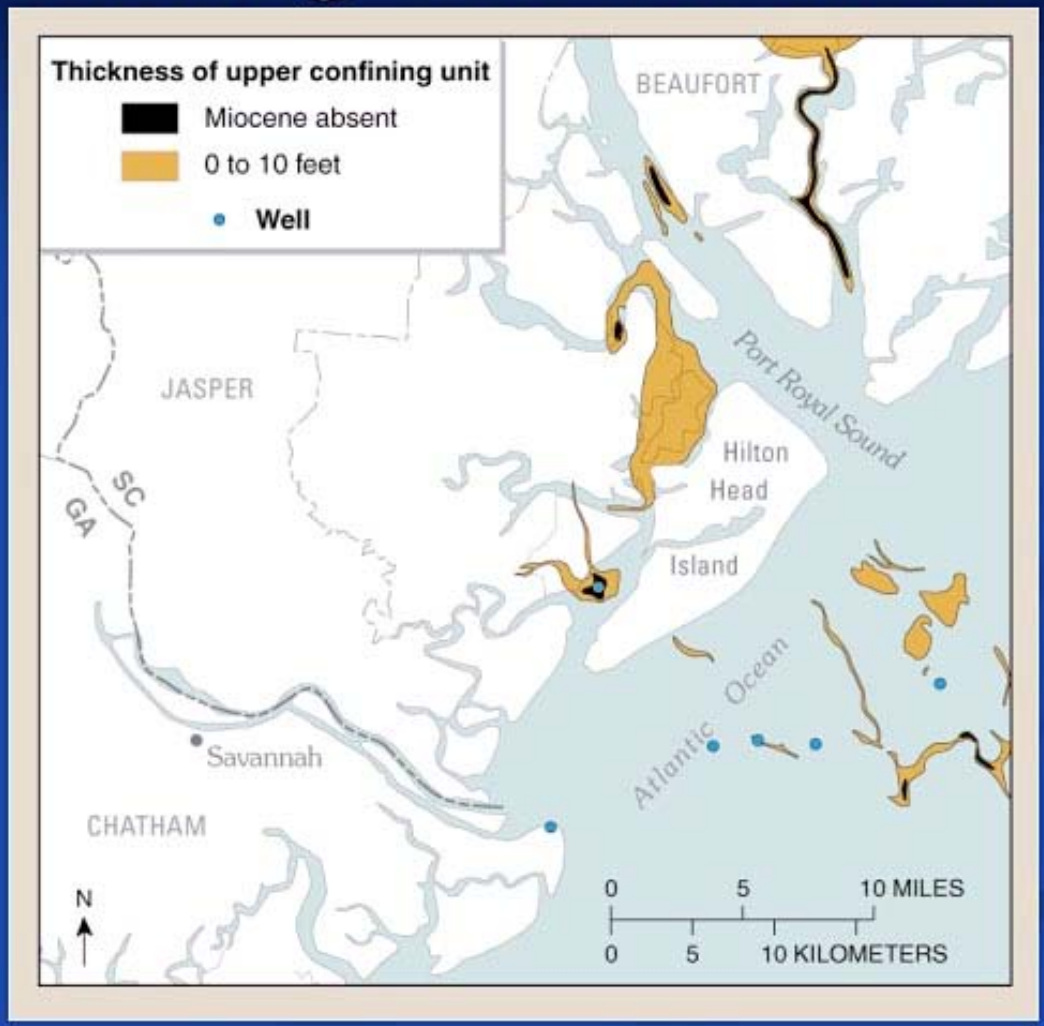
For more information see:

http://ga2.er.usgs.gov/coastal/



From: Provost, A.M., Payne, D.F., and Voss, C.I., 2006, Simulation of saltwater movement in the Upper Floridan aquifer in the Savannah, Georgia-Hilton Head Island, South Carolina, area, predevelopment-2004, and projected movement for 2000 pumping conditions: U.S. Geological Survey Scientific Investigations Report 2006-5058, 124 p.

Confining Unit Thickness



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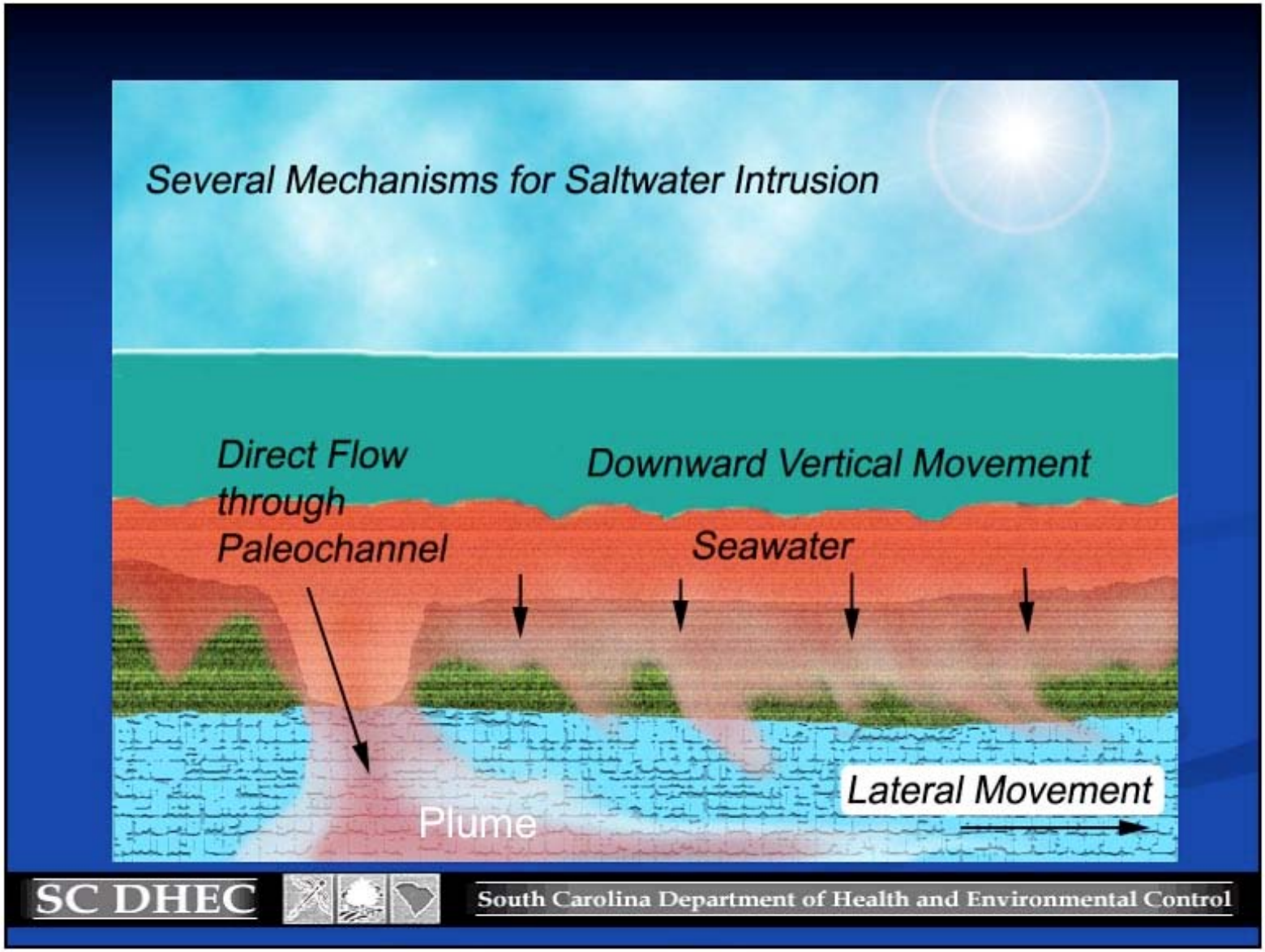
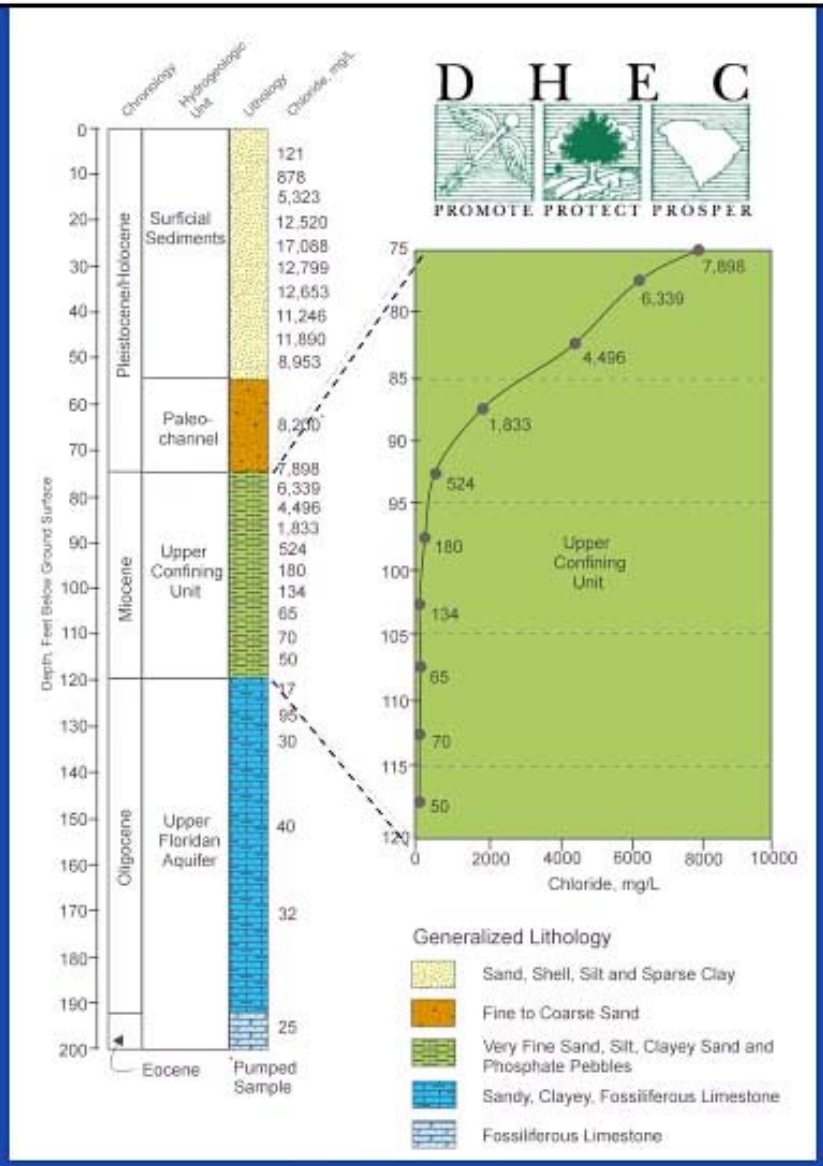
(Modified from Foyle and others, 2001)

Modified from: Foyle, A.M., Henry, V.J., and Alexander, C.R., 2001, The Miocene aquitard and the Floridan aquifer of the Georgia/South Carolina coast: Geophysical mapping of potential seawater intrusion sites: Georgia Geologic Survey Bulletin 132, 61 p.



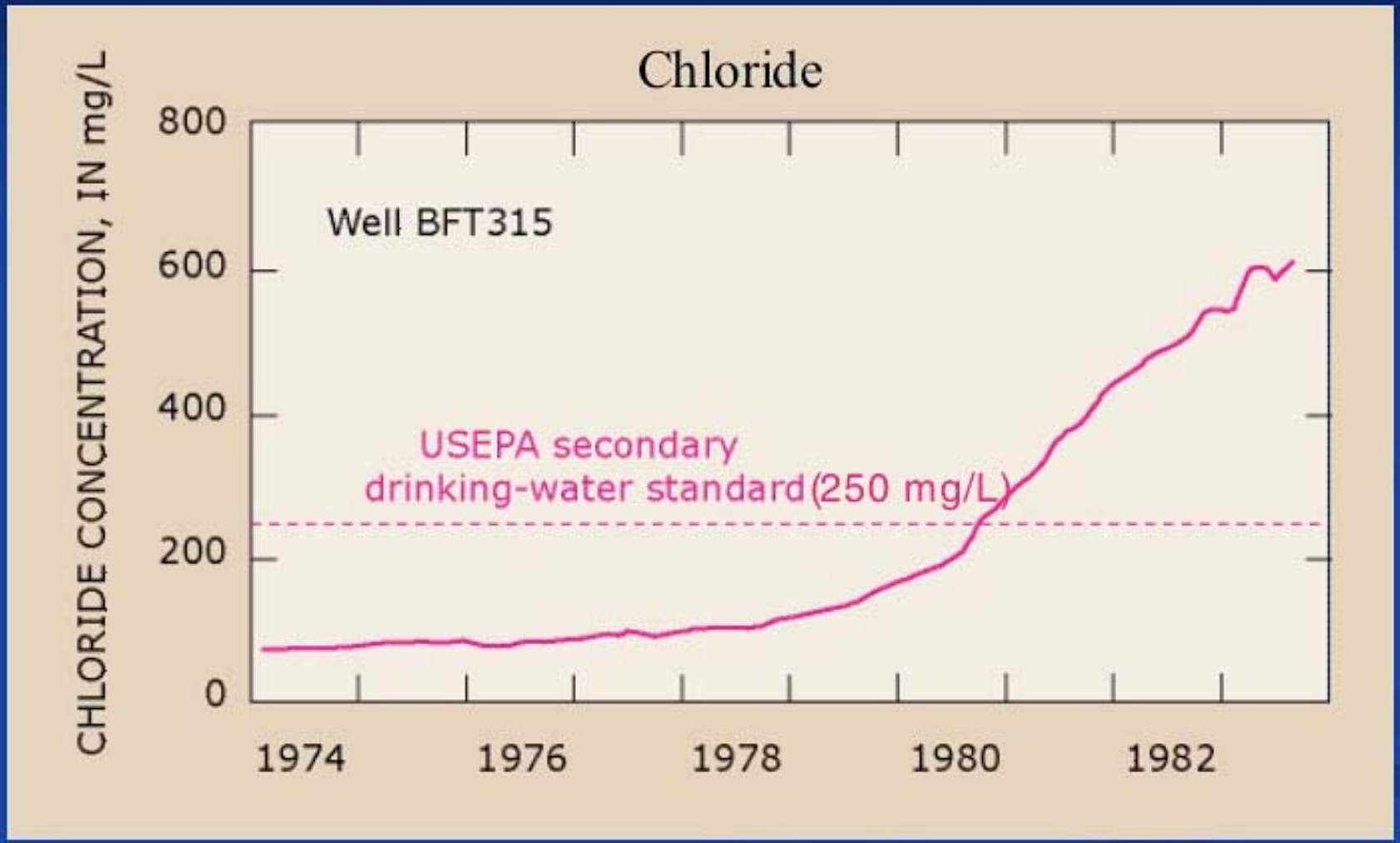
In addition to saltwater migrating into the Upper Floridan aquifer in areas where the confining unit is thin or eroded, it may be leaking downward through the overlying confining unit in other areas as well. At any location, the breakthrough time of saltwater through the confining unit into the Upper Floridan aquifer will be a function of the thickness and hydraulic properties of the confining unit, and the vertical hydraulic gradient.



Documentation of Downward Movement of Saltwater through the Upper Confining Unit near Savannah, Georgia

Although the Upper Floridan aquifer confining unit near Tybee Island, Georgia, is not as thin as at locations near Hilton Head Island, the vertical hydraulic gradient is larger, and saltwater has been observed to be migrating through the confining unit.

BFT-0315 Northern HHI



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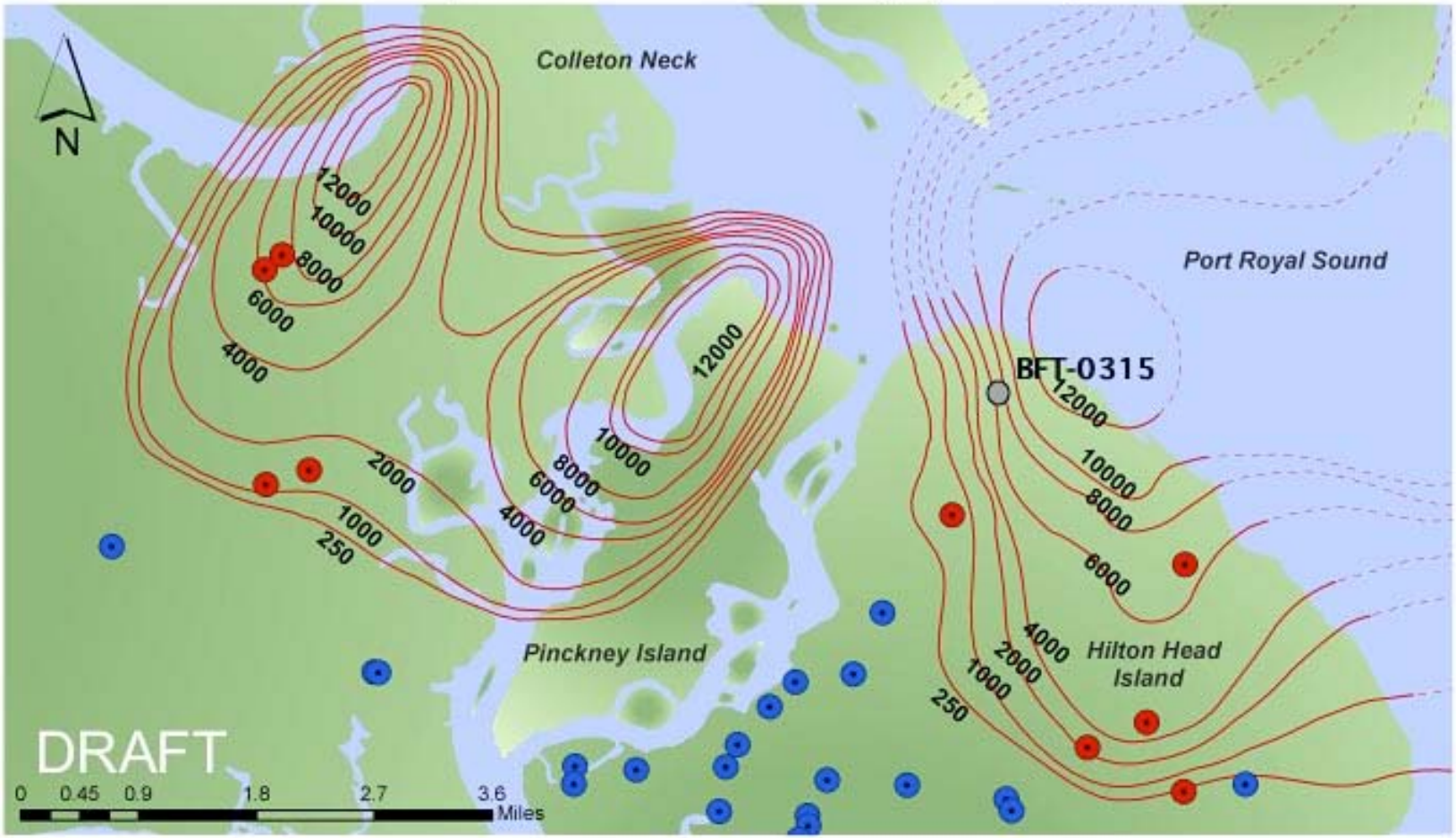
Chloride Distribution and Impacted Public Water Supply Wells, Hilton Head Island Area



Public Water Supply Well Impacted by Salt Water Intrusion

Public Water Supply Well

Approximate Line of Equal Chloride Concentration at the Base of the Upper Floridan Aquifer

4000 Chloride Concentration, in milligrams per liter

D H E C

PROMOTE PROTECT PROSPER

South Carolina Department of Health and Environmental Control

South Carolina Conservation Measures

- 1981 – Beaufort, Colleton, and Jasper Counties were declared a Capacity Use Area

  Within these counties, large groundwater withdrawals require a permit and must be justified during the application process
- 1993 Island Utilities and the State of South Carolina agree to cap withdrawals on Hilton Head Island
- 2002 Full compliance with the mandated 9.77 Mgal/day limit on Hilton Head Island

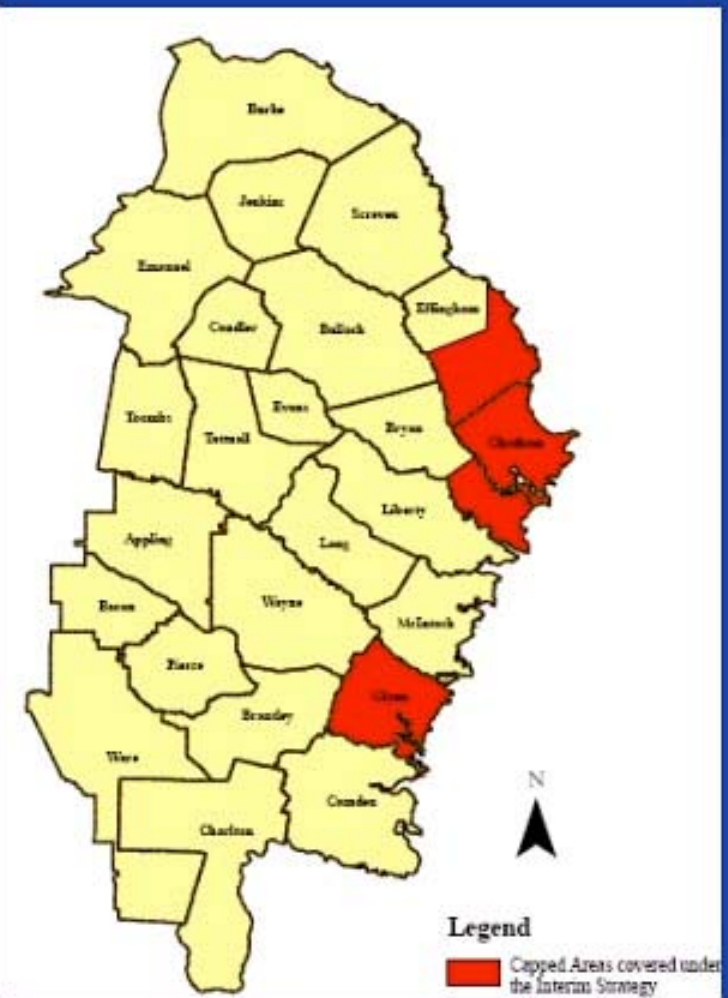
South Carolina Conservation Measures

- Water withdrawals on Hilton Head Island (HHI) reduced from 14 Mgal/D to a cap of 9.77 Mgal/D
- Alternative sources, such as a deep (3800 feet) well and surface water, used on HHI
- Golf courses inland from HHI may not use the Upper Floridan aquifer for irrigation
- Treated effluent used for golf course irrigation throughout the area
- Approximately 90 million dollars has been spent on providing surface water distribution infrastructure and other Upper Floridan alternatives in the area

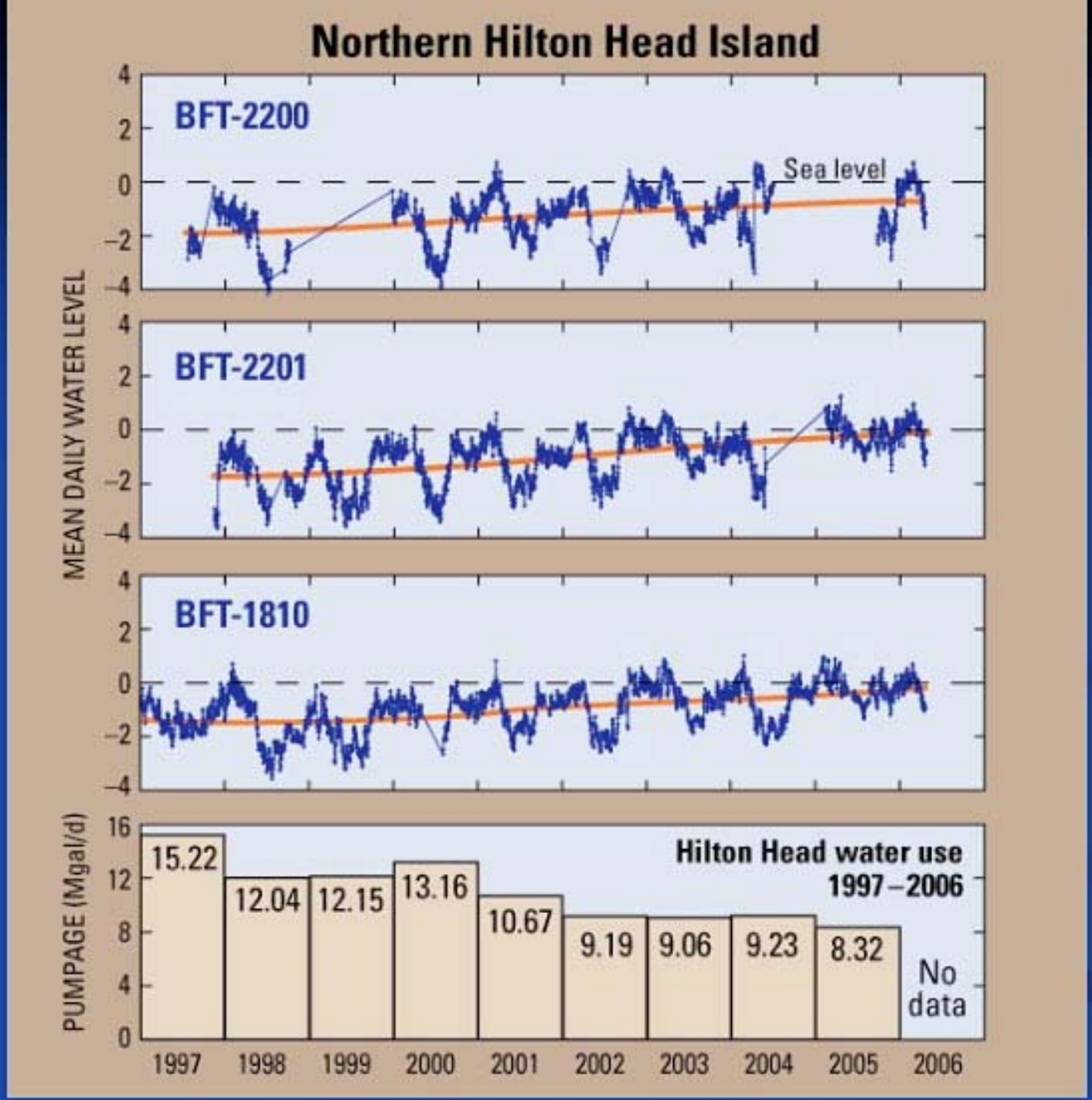
South Carolina Conservation Measures

- All new residential developments along Highway 278 (inland from HHI) are served by surface water from Beaufort-Jasper Water & Sewer Authority
- Aquifer storage and recovery (ASR) was implemented near HHI with treated surface water
- Upper Floridan aquifer usage continues to decline in Beaufort County as a result of serious conservation measures

Interim Water-Management Strategy for Coastal Georgia, *Ga EPD April 1997*



- Caps on ground-water use in areas that have most pronounced effect on salt water contamination
- Reduce ground-water use in Chatham County by *at least* 10 MGD before 2006
- Allow on an interim basis increases in ground-water withdrawals in areas with little impact on salt-water contamination
- Encourage and promote water conservation and reduced usage



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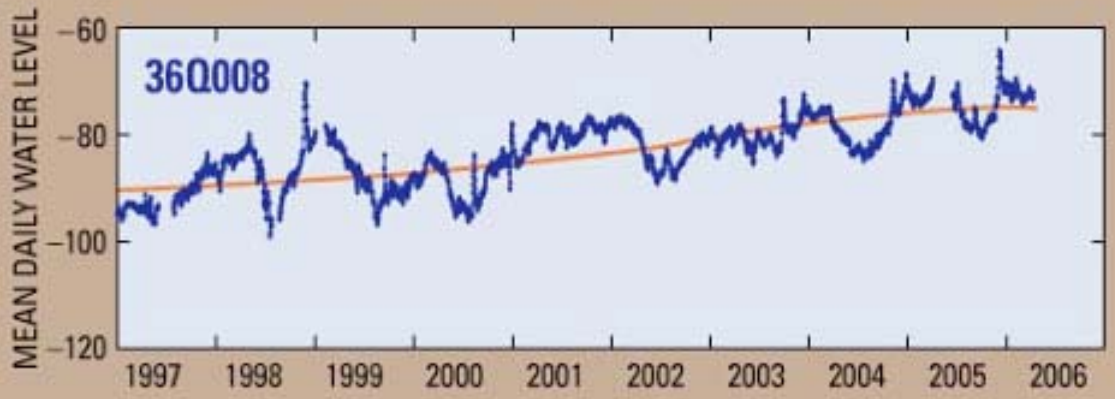
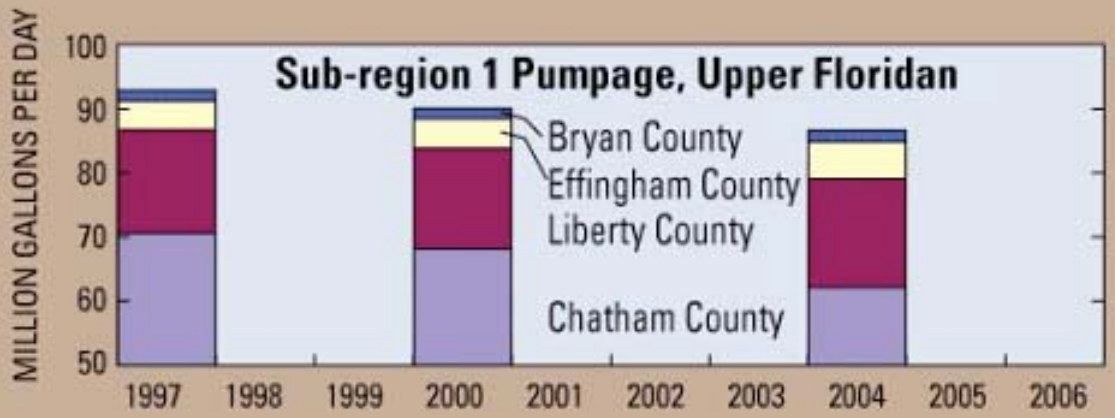
Data courtesy of Jack Childress, SC DHEC

Savannah Area





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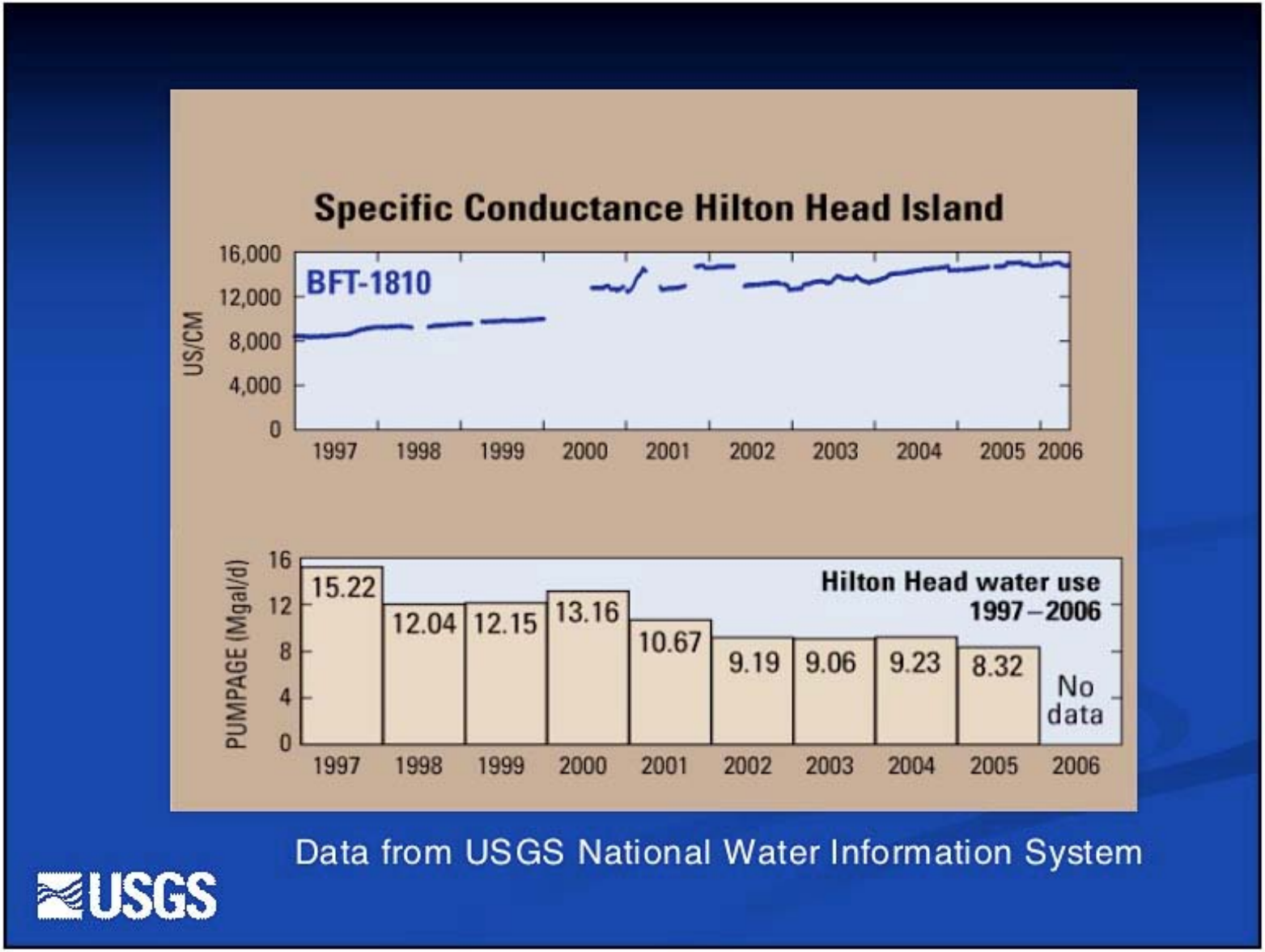
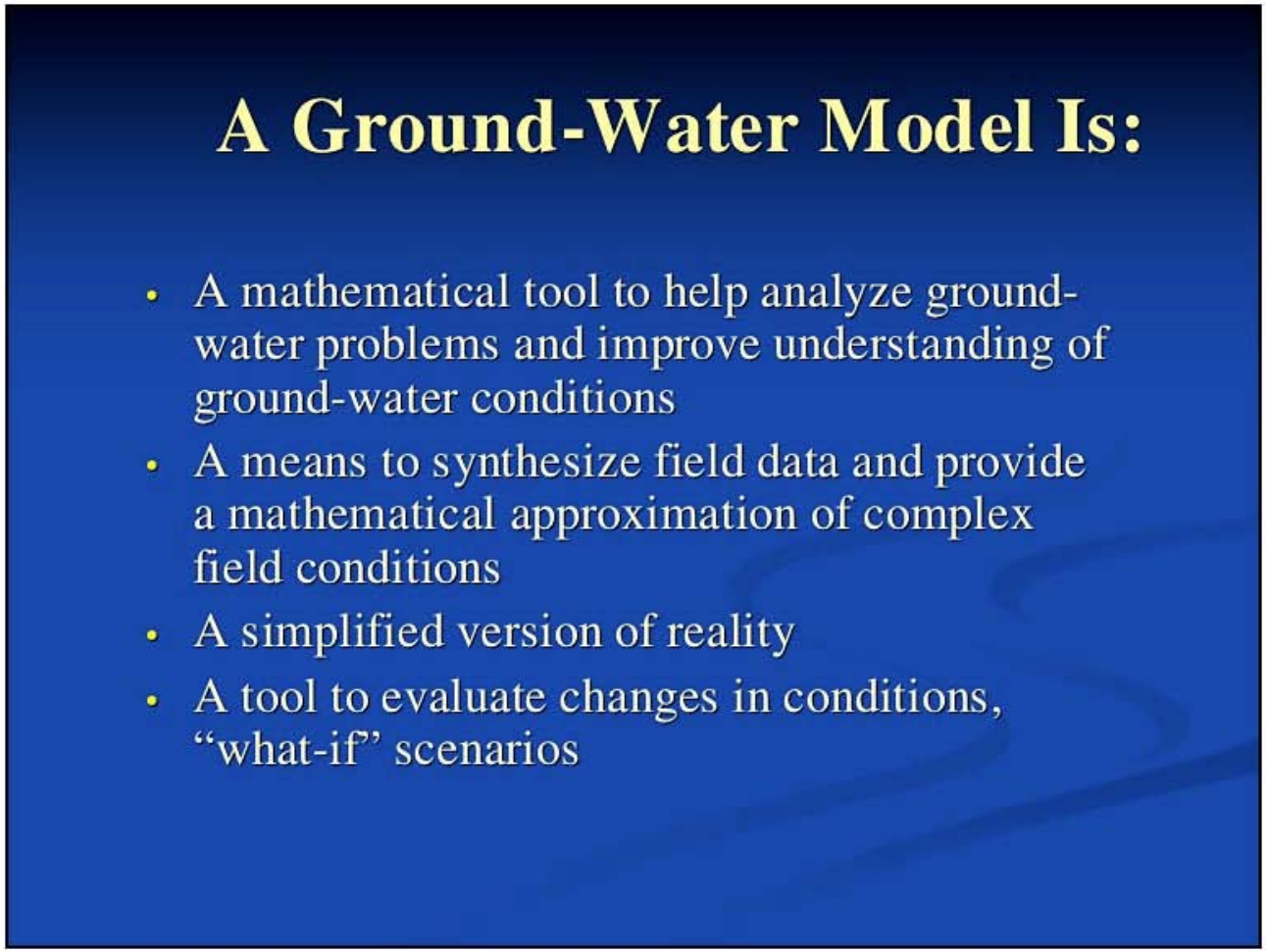
Data from USGS National Water Information System



Even with implementation of conservation measures that result in rising ground-water levels, chloride concentrations may continue to rise (specific conductance is a surrogate for chloride concentration) because: 1) the response of chloride con-centrations to changes in stress is sluggish compared with the response of water levels; and 2) the reductions in stress may not be enough to prevent saltwater from continuing to enter the aquifer and migrate toward pumping centers.



The saltwater transport simulations were run using the SUTRA simulator (Voss, 1984; and Voss and Provost, 2002), which accounts for variable density flow in three dimensions. Details regarding model construction, calibration and testing are reported in Provost and others (2006).

References:

Provost, A.M., Payne, D.F., and Voss, C.I., 2006, Simulation of saltwater movement in the Upper Floridan aquifer in the Savannah, Georgia–Hilton Head Island, South Carolina, area, predevelopment–2004, and projected movement for 2000 pumping conditions: U.S. Geological Survey Scientific Investigations Report, 2006-5058, 124 p.

Voss, C.I., 1984, A finite-element simulation model for saturated-unsaturated, fluid-density-dependent ground-water flow with energy transport or chemically-reactive single-species solute transport: U.S. Geological Survey Water Resources Investigations Report 84-4369, 409 p.

Voss, C.I., and Provost, A.M., 2002, SUTRA: A model for saturated-unsaturated, variable-density ground-water flow with solute or energy transport: U.S. Geological Survey Water-Resources Investigations Report 02-4231, 250 p.

Limitations

- Models are limited by the amount and quality of data, and understanding of the system
- Model results must be interpreted in light of model limitations
- These models use the best available and most current data

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Even with limitations inherent in numerical models, the model used in this study is based on the best and most current data and conceptual model of the flow system. The critical assumptions have been tested.

How does pumping in each of the Savannah and Hilton Head Island areas affect the current extent of saltwater intrusion?

- Simulations run from predevelopment (1885) to 2000 (Base Case)
- Scenario C1: no pumpage in Savannah area
- Scenario C2: no pumpage in Hilton Head Island area
- Results presented in Payne and others (2006)

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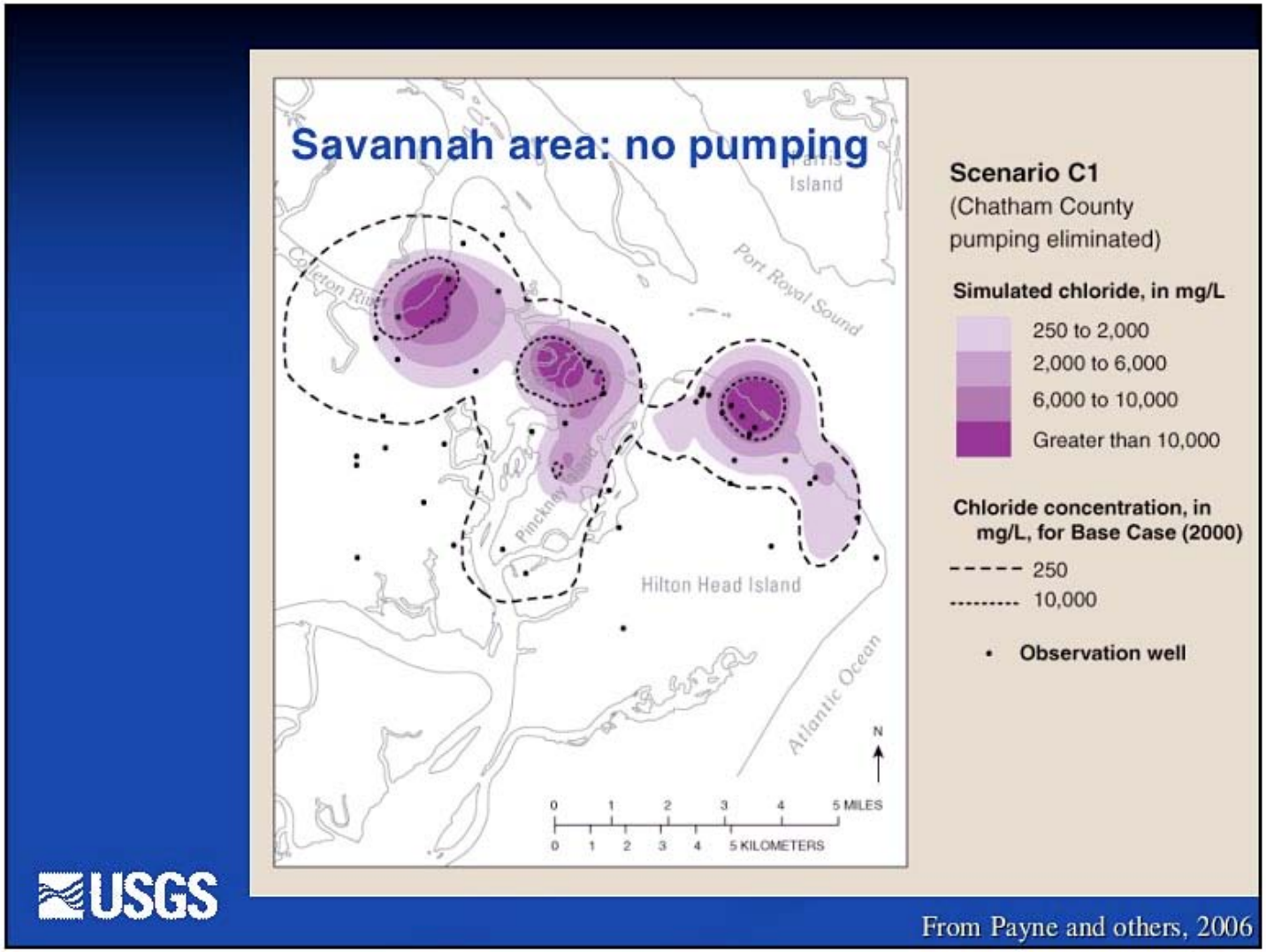
Scenario C1 simulates the pumping history as if pumping had never occurred in the Savannah area. Scenario C2 simulates the pumping history as if pumping had never occurred in the Hilton Head Island area.

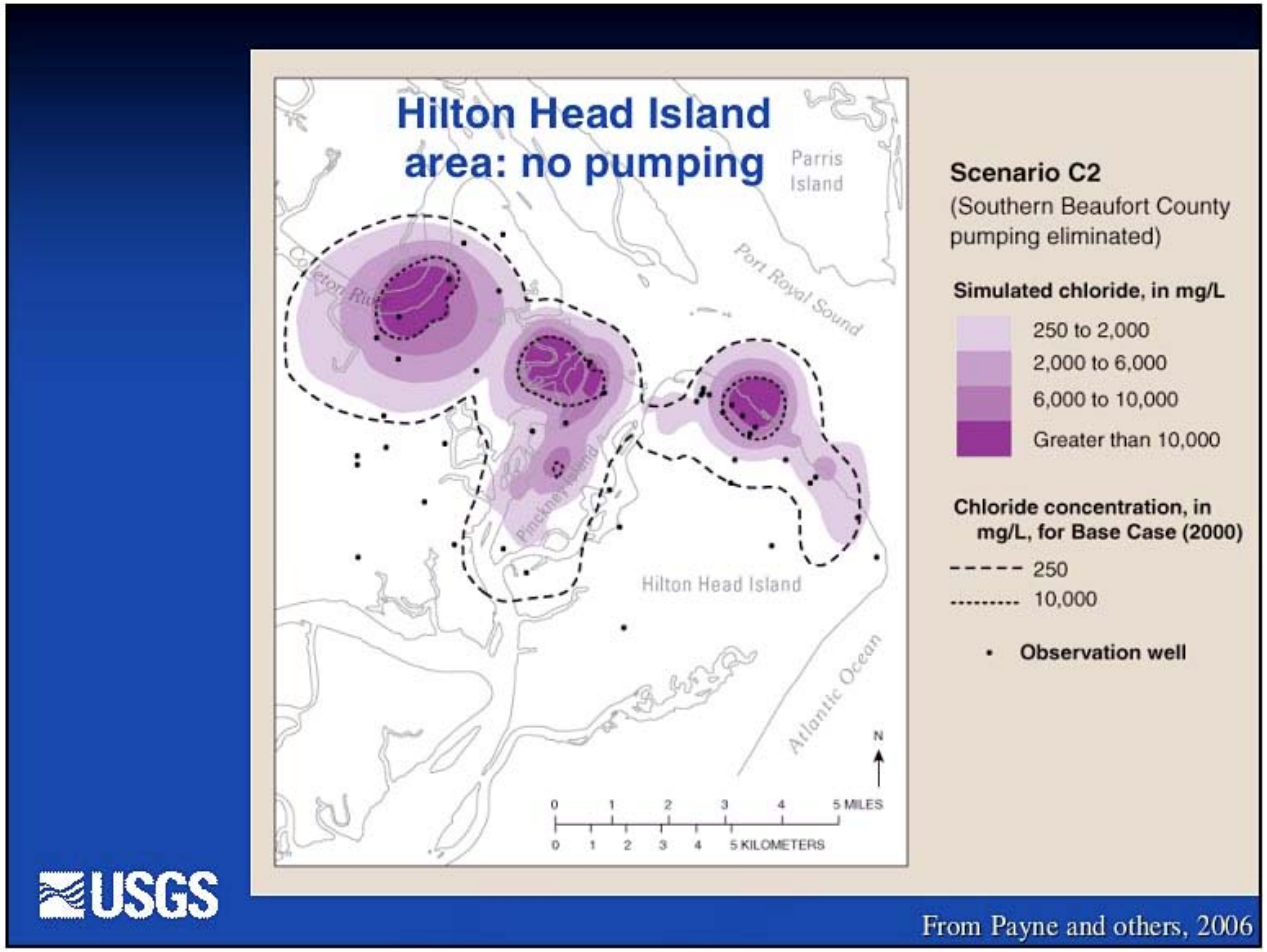
These scenarios are reported in:

Payne, D.F., Provost, A.M., Painter, J.A., Abu Rumman, M., and Cherry, G., 2006, Application of ground-water flow and solute transport models to simulate selected water-management scenarios in coastal Georgia and adjacent parts of South Carolina and Florida, 2000–2100: U.S. Geological Survey Scientific Investigations Report, 2006-5077, 78 p.



Results of scenario C1 indicate that if pumping in Chatham County is eliminated, chloride plumes still develop. The extent of the plumes is not as great as under simulated 2000 conditions, particularly for the Colleton River and Pinckney Island plumes. The plume on the northern end of Hilton Head Island appears to be less affected by elimination of pumping in Chatham County than the other plumes.

Payne, D.F., Provost, A.M., Painter, J.A., Abu Rumman, M., and Cherry, G., 2006, Application of ground-water flow and solute transport models to simulate selected water-management scenarios in coastal Georgia and adjacent parts of South Carolina and Florida, 2000–2100: U.S. Geological Survey Scientific Investigations Report, 2006-5077, 78 p.



Results of scenario C2 indicate that if pumping in southern Beaufort County is eliminated, chloride plumes still develop. The extent of the plumes is not as great as under simulated 2000 conditions, particularly for the northern Hilton Head Island and Pinckney Island plumes. The plume at Colleton River appears to be less affected by elimination of pumping in southern Beaufort County than the other plumes.

Results of scenarios C1 and C2 indicate that pumping in Chatham County may have a greater effect on plume development at the Colleton River than pumping in southern Beaufort County, and that pumping in southern Beaufort County may have a greater effect on plume development at the northern end of Hilton Head Island than pumping in Chatham County. The simulated plume at Pinckney Island is affected by pumping at both locations, with a somewhat greater effect from pumping at Chatham County.

Payne, D.F., Provost, A.M., Painter, J.A., Abu Rumman, M., and Cherry, G., 2006, Application of ground-water flow and solute transport models to simulate selected water-management scenarios in coastal Georgia and adjacent parts of South Carolina and Florida, 2000–2100: U.S. Geological Survey Scientific Investigations Report, 2006-5077, 78 p.

- Pumping in Savannah area may contribute more to plume growth in the Colleton River and Pinckney Island areas than pumping in the Hilton Head Island area
- Local pumping may contribute more to plume growth at the northern end of Hilton Head Island than pumping in the Savannah area

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What reductions would be required to stop plume growth?

- Simulations run from 2004 (Base Case) to 2104
- Scenarios represent variety of pumping reductions in Savannah and Hilton Head Island areas, from 0% to 100%
- Model used is reported in Provost and others (2006)

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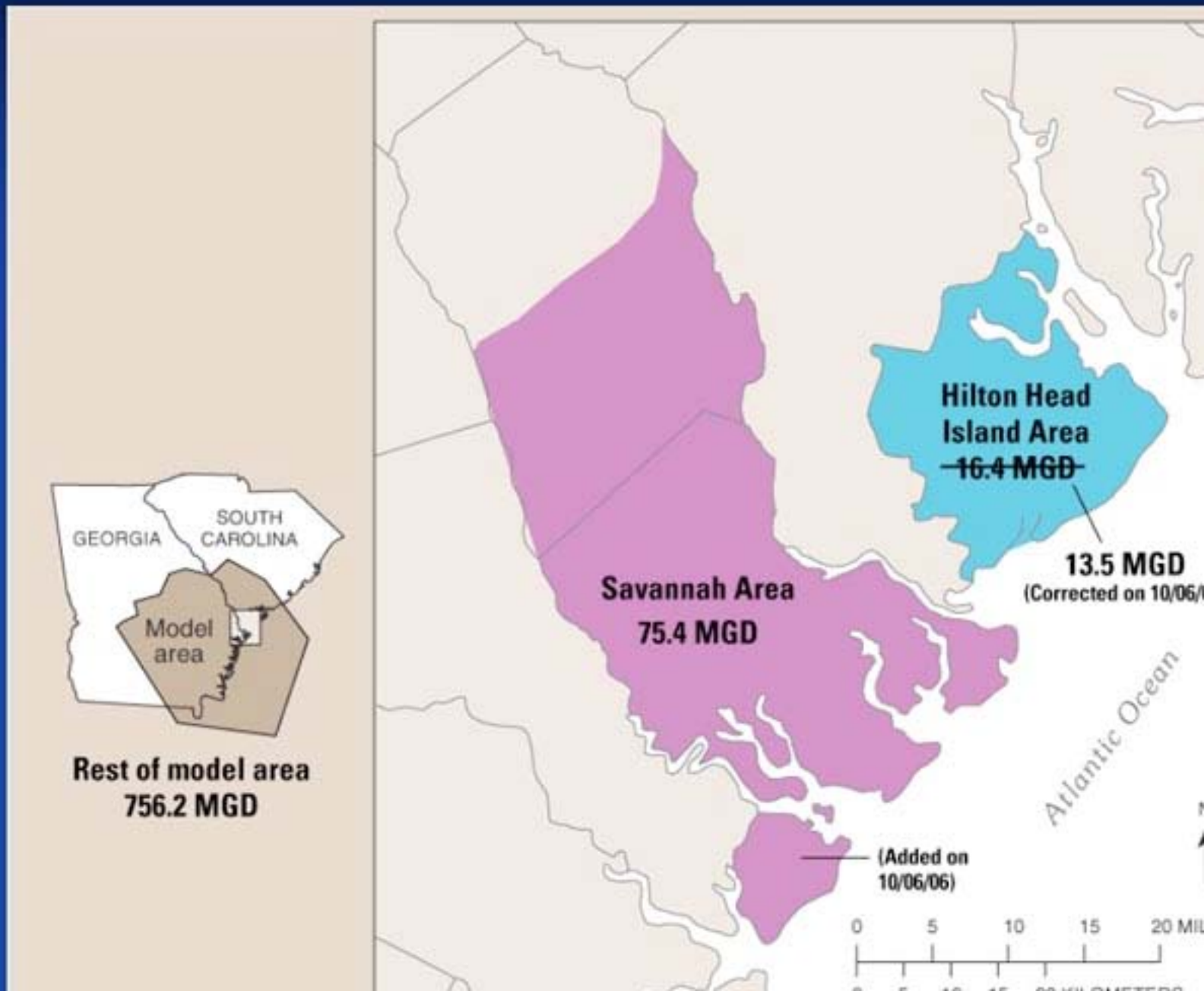
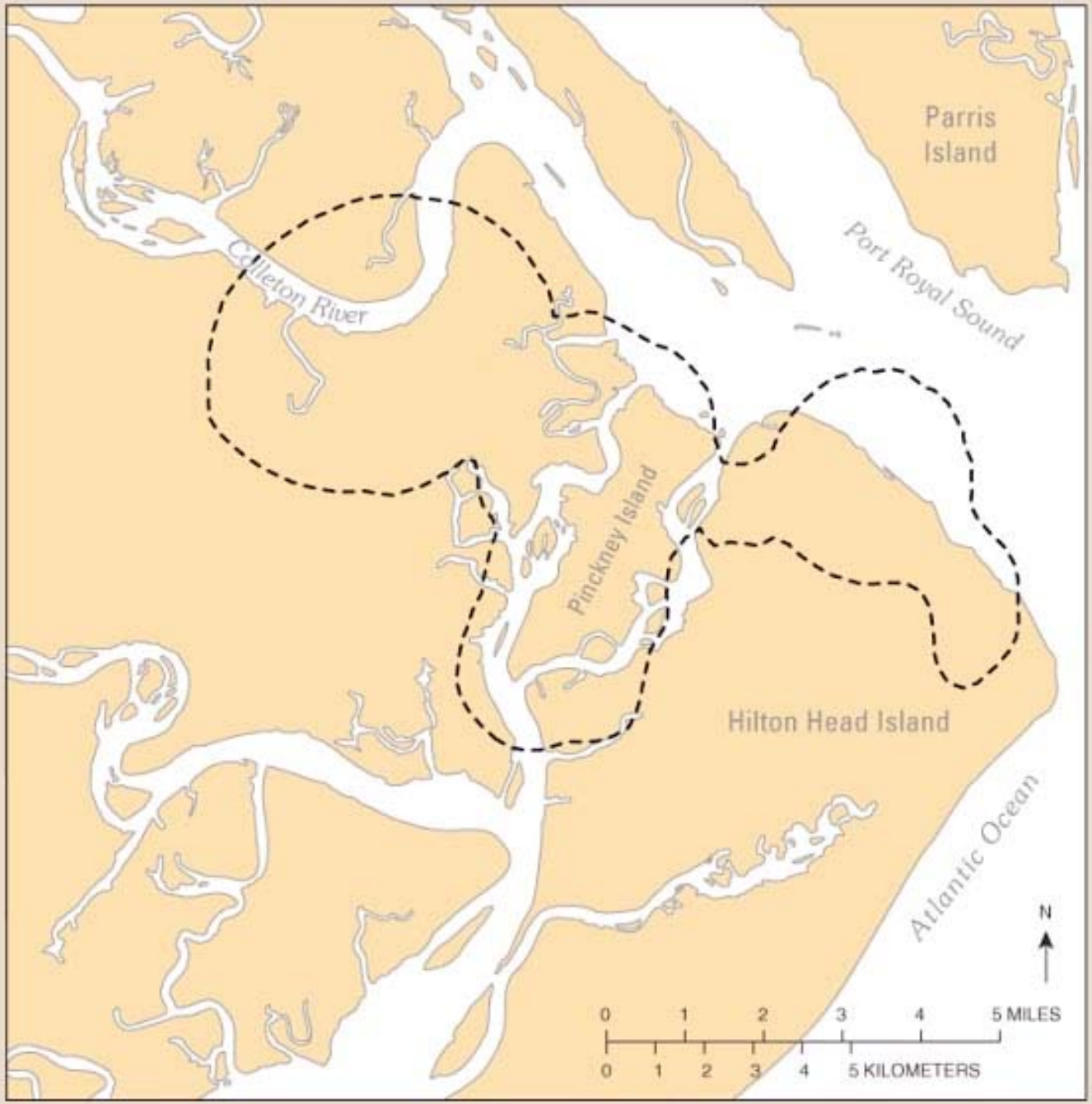
The following simulation results were based on estimated 2004 conditions, and hypothetical conditions thereafter. For these simulations, the model was updated to 2004 conditions using updated pumping data for the Upper Floridan aquifer from the Georgia EPD and from the SCDHEC. For the period 2004 to 2104, pumping was adjusted in the Savannah area, which includes Chatham and southern Effingham Counties, GA, in the Hilton Head Island area, which includes southern Beaufort County, SC, or in the entire rest of the model area.

Estimated Pumpage, 2004



Simulated chloride concentration of 250 mg/L

----- 2004



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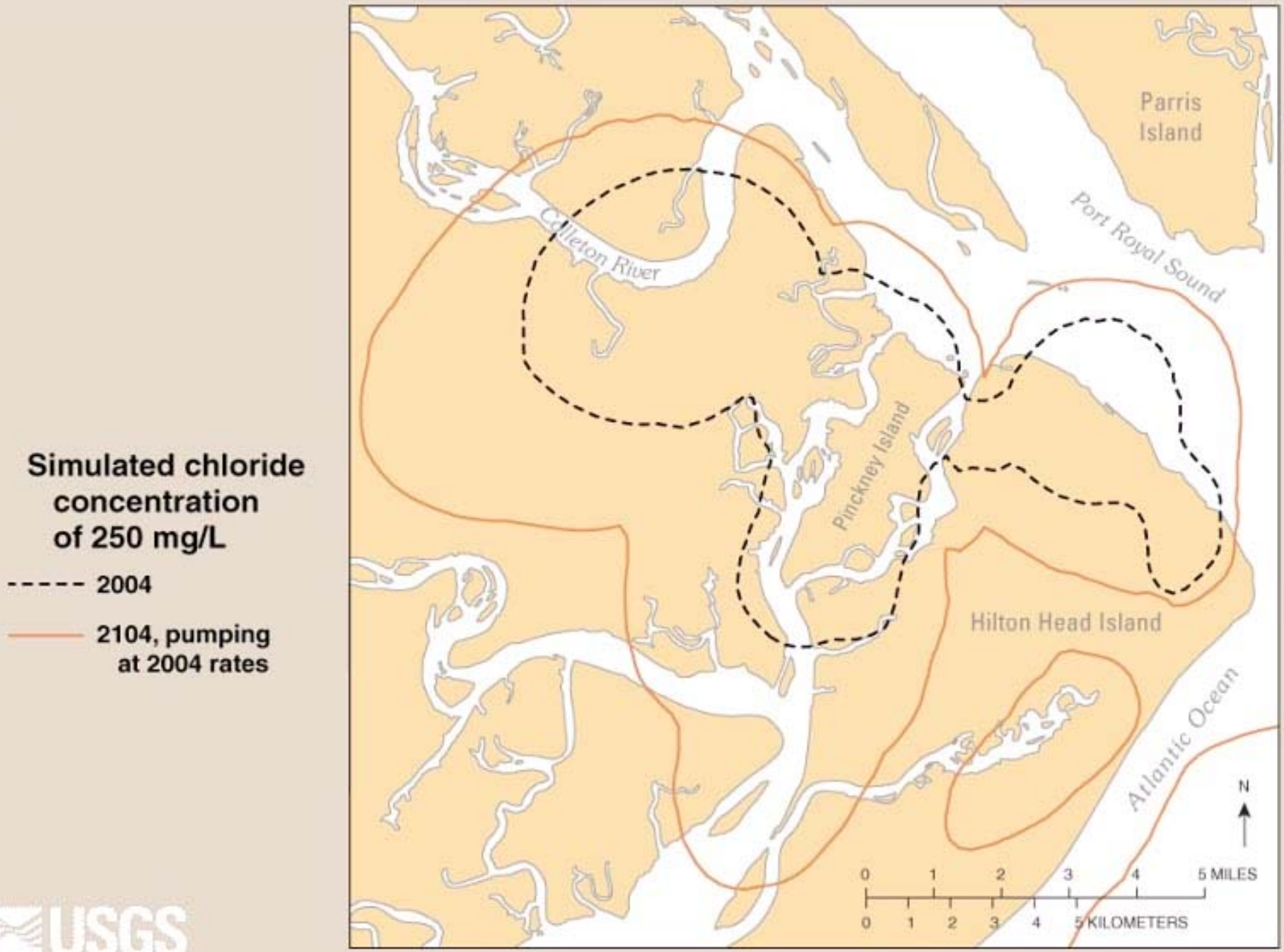
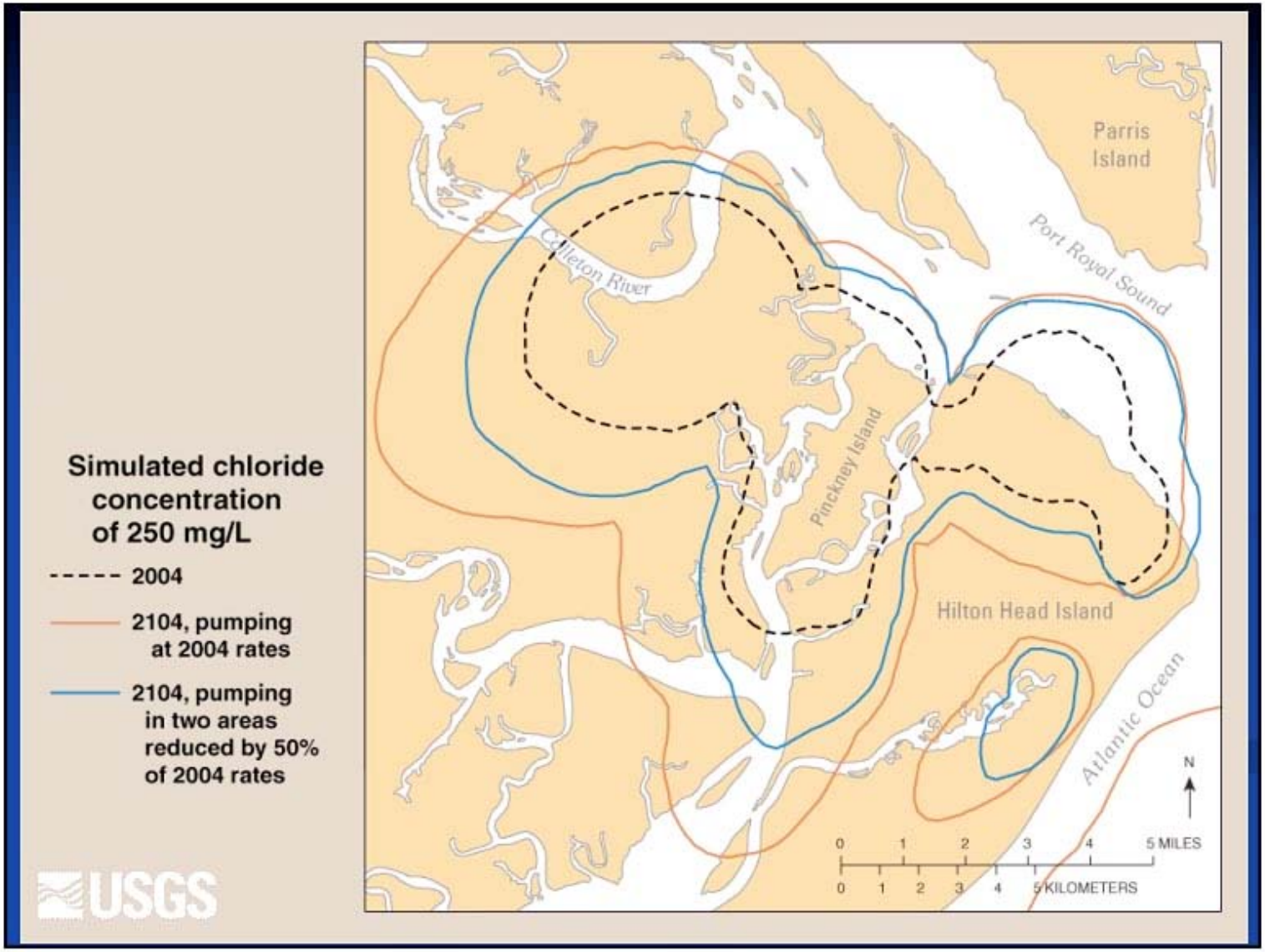
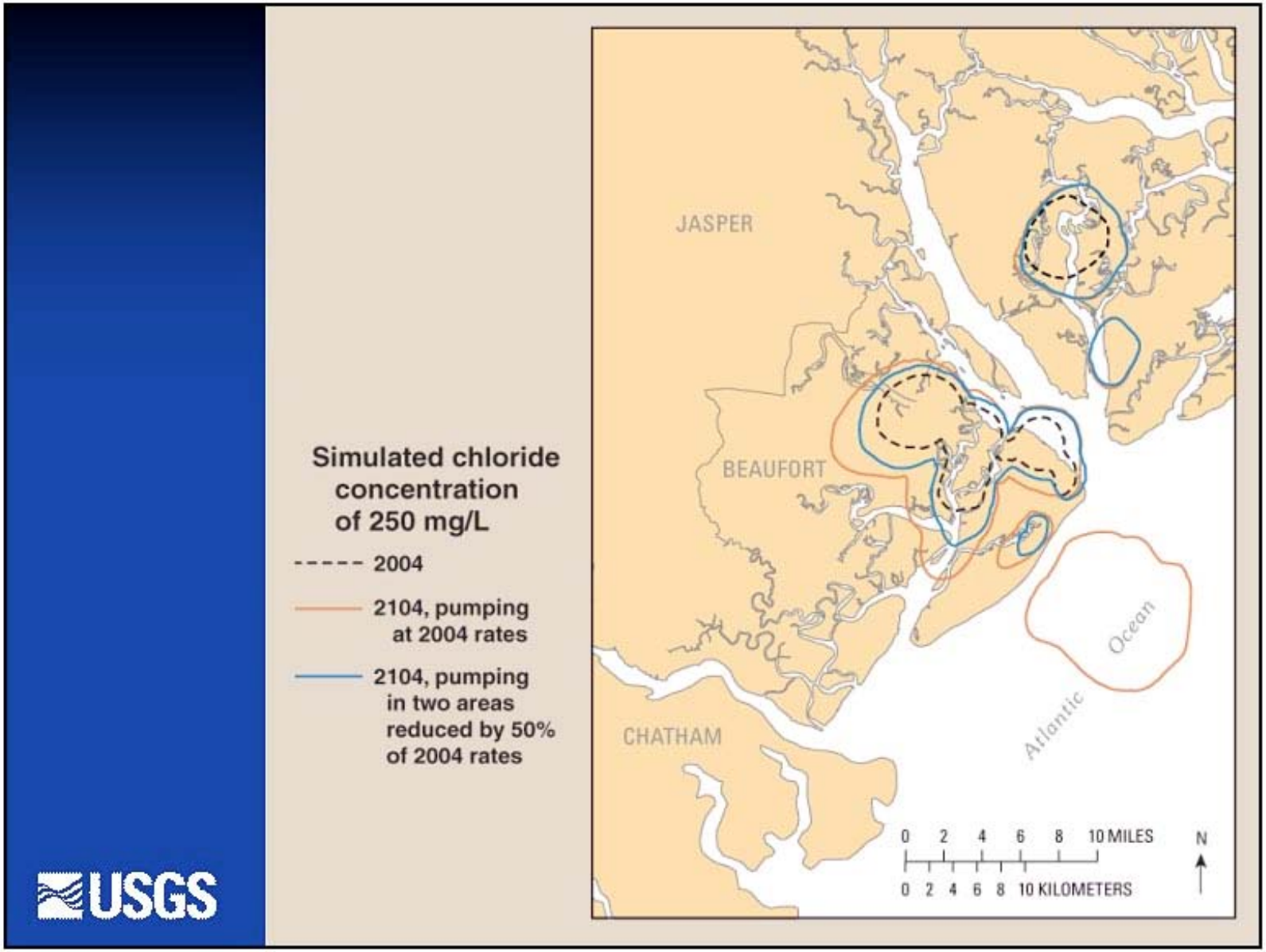
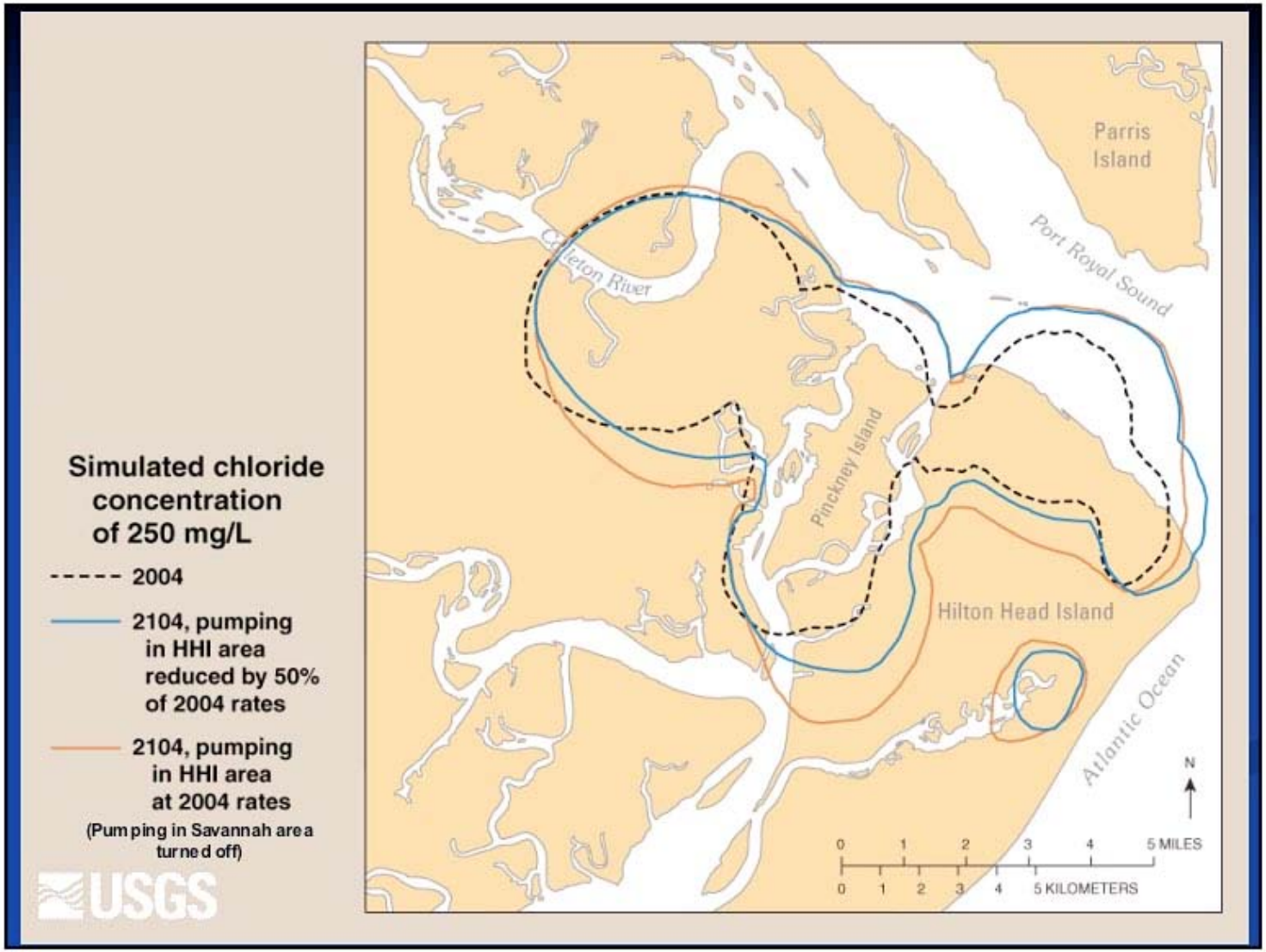

Simulated chloride concentration of 250 mg/L
2004
2104, pumping at 2004 rates
Parris Island
Port Royal Sound
Colleton River
Pinckney Island
Hilton Head Island
Atlantic Ocean
N
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS
USGS



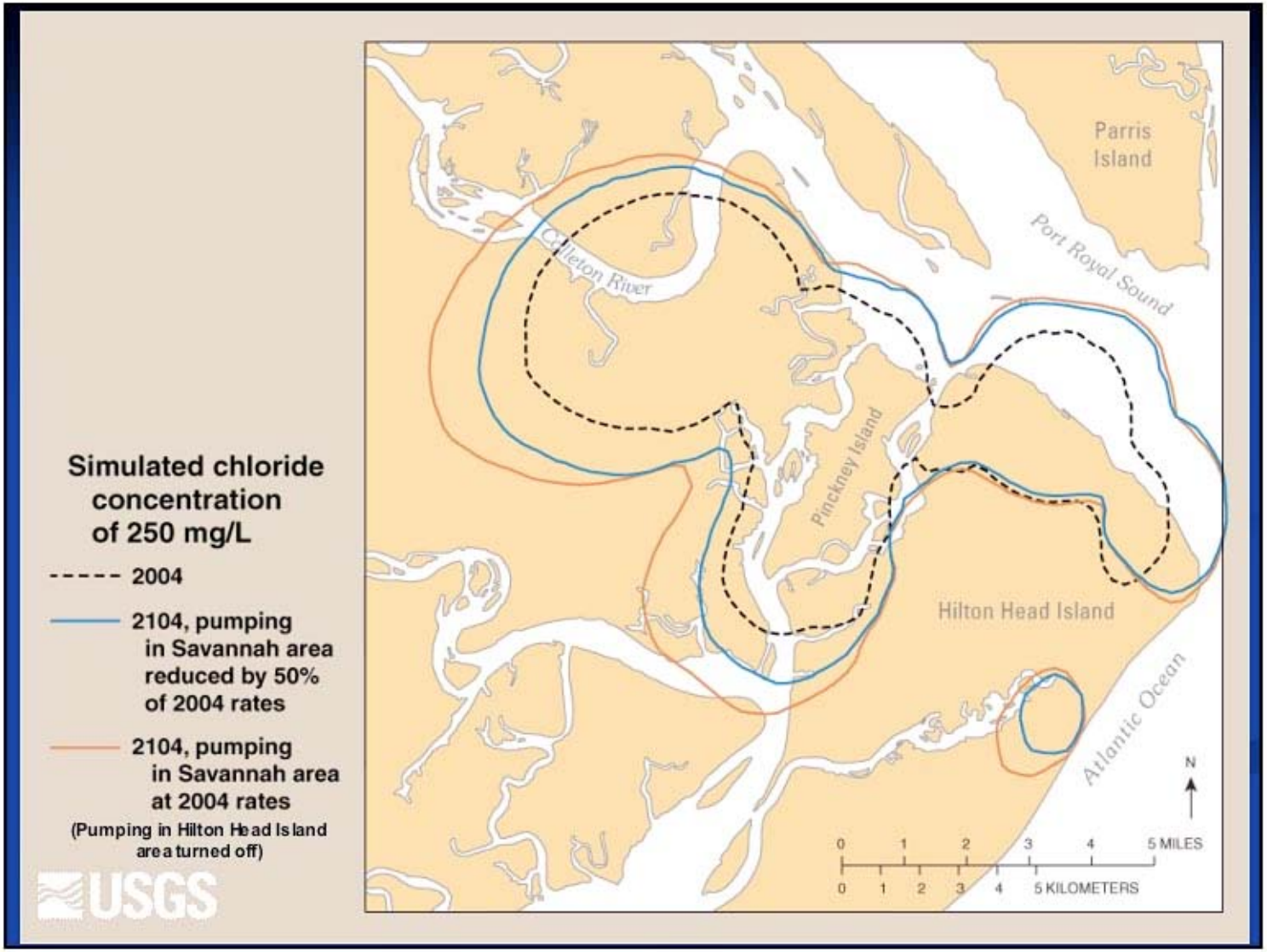
This map shows the simulated 250 mg/L isochlor (chloride contour) for the Base Case, representing 2004 conditions, and for two simulations during 2104. For one simulation, the pumping was left at 2004 rates; for the other simulation, pumping in the Savannah and Hilton Head Island areas were reduced by 50% of 2004 rates: 37.7 Mgal/d for the Savannah area and 8.2 Mgal/d for the Hilton Head Island area. In both simulations, the 250 mg/L isochlor has moved beyond the extent of that in 2004. Even with a 50% reduction in pumping in both areas, the plume will continue to expand.



At this scale, simulation results also show other areas prone to saltwater intrusion with continued pumpage. In particular, a saltwater plume appears in the area offshore of Hilton Head Island with continued pumping at 2004 rates. Saltwater intrusion had been observed in the Parris Island and Beaufort area before the 1950s, and ground water is generally not used for public supply in this area.



This map shows the simulated 250 mg/L isochlor for the Base Case, and for two simulations during 2104. For one simulation, the pumping was eliminated in the Savannah area, and pumping in the Hilton Head Island area was left at 2004 levels; for the other simulation, pumping was eliminated in the Savannah area, and pumping in the Hilton Head Island area was reduced by 50% of 2004 levels: 0 Mgal/d for the Savannah area and 8.2 Mgal/d for the Hilton Head Island area. In both simulations, the 250 mg/L isochlor has moved beyond the extent of that in 2004. With elimination of pumping in the Savannah area and a 50% reduction in the Hilton Head Island area, the plumes will continue to expand.



This map shows the simulated 250 mg/L isochlor for the Base Case, and for two simulations during 2104. For one simulation, the pumping was eliminated in the Hilton Head Island area, and pumping in the Savannah area was left at 2004 levels; for the other simulation, pumping was eliminated in Hilton Head Island area, and pumping in the Savannah area was reduced by 50% of 2004 levels: 37.7 Mgal/d for the Savannah area and 0 Mgal/d for Hilton Head Island area. In both simulations, the 250 mg/L isochlor has moved beyond the extent of that in 2004. With elimination of pumping in Hilton Head Island area and a 50% reduction in the Savannah area, the plumes will continue to expand.

Almost all pumping would need to be eliminated in the Savannah and Hilton Head Island areas to stop plume growth

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Can saltwater plumes be eliminated?

- Simulations run from 2004 to 2200
- Scenarios represent 100% pumpage reductions in the Savannah and Hilton Head Island areas, and 100% reduction of pumpage everywhere
- Model used is reported in Provost and others (2006)

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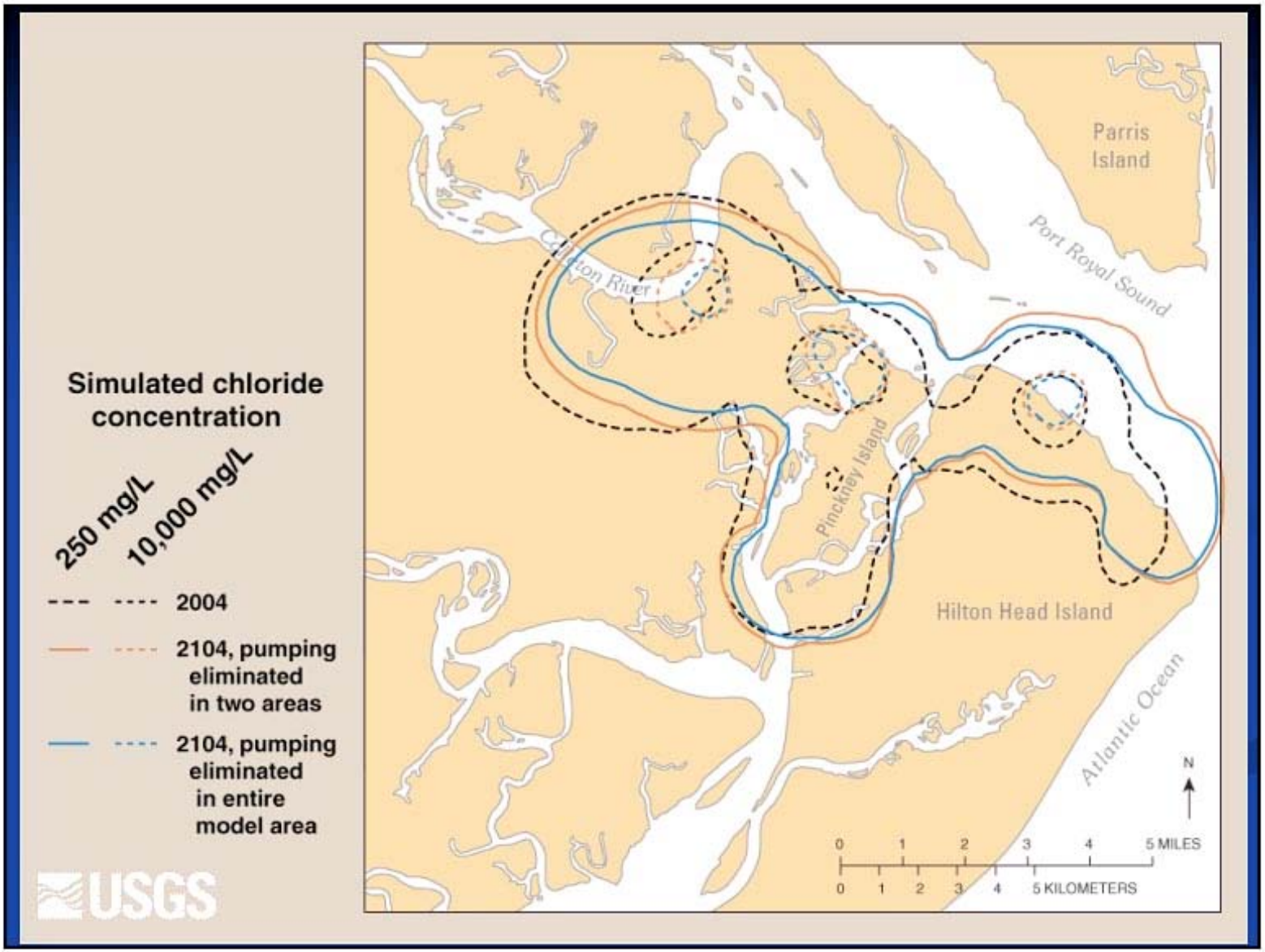

These results show the simulated difference in 2104 between the scenario in which pumping in both the Savannah and Hilton Head Island areas are turned off and the scenario in which all pumping in the model area is turned off after 2004. In general, the plume extent and concentration distribution is similar for the two scenarios. The plume extent and extent of large concentration is smaller, particularly at the westernmost part of the plume area, for the scenario in which all pumping in the model is turned off.

- Modeling results indicate that if all pumping is eliminated, saltwater plumes will continue to exist well into the future
  - Plumes move slowly with large reductions in pumpage
  - Effects of removing regional pumpage on plume growth are minimal

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Summary

- The Hilton Head Island area is prone to saltwater intrusion
- Pumping in *both* Savannah and Hilton Head Island areas contributes to saltwater intrusion in the Hilton Head Island area
- Substantial reductions in pumping in Savannah and Hilton Head Island areas would be required to stop plume growth
- If all pumping is eliminated, chloride plumes will continue to exist well into the future
- Monitoring and modeling are critical elements for development of effective water-management strategies and require continued funding

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