Georgia EPD Updates – Floridan Aquifer Groundwater Resource Update

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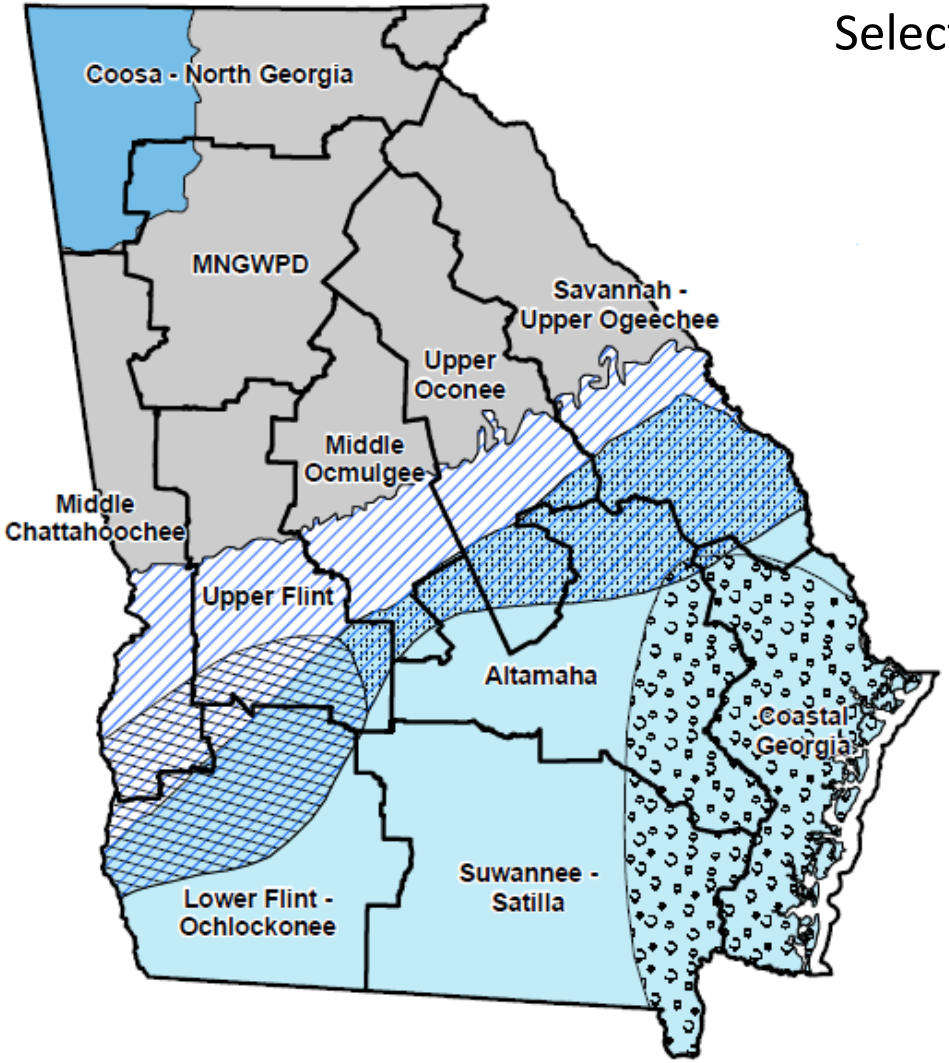
Floridan Aquifer Update

- History of the salt-water encroachment issue
  - Early concerns of salt-water intrusion along Coast
  - History of Coastal Policies regarding permitted withdrawals
    - Model Simulation results of salt-water encroachment into Floridan Aquifer
- Current Permitting in Coastal Area
  - Current and reported withdrawals out to 2025
- Health of Floridan Aquifer System
  - USGS monitoring well data
    - Red Zone, Yellow Zone, and Green Zone
  - SHEP sentinel monitoring wells

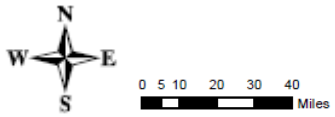
Water Planning Regions and Georgia's Aquifers



Select aquifers were prioritized for assessment.

Legend

- Water Planning Regions
- Brunswick Aquifer System
- Claiborne and Clayton Aquifers
- Cretaceous Aquifer System
- Crystalline-rock Aquifers
- Gordon Aquifer System
- Paleozoic-rock Aquifers
- Upper and Lower Floridan Aquifers



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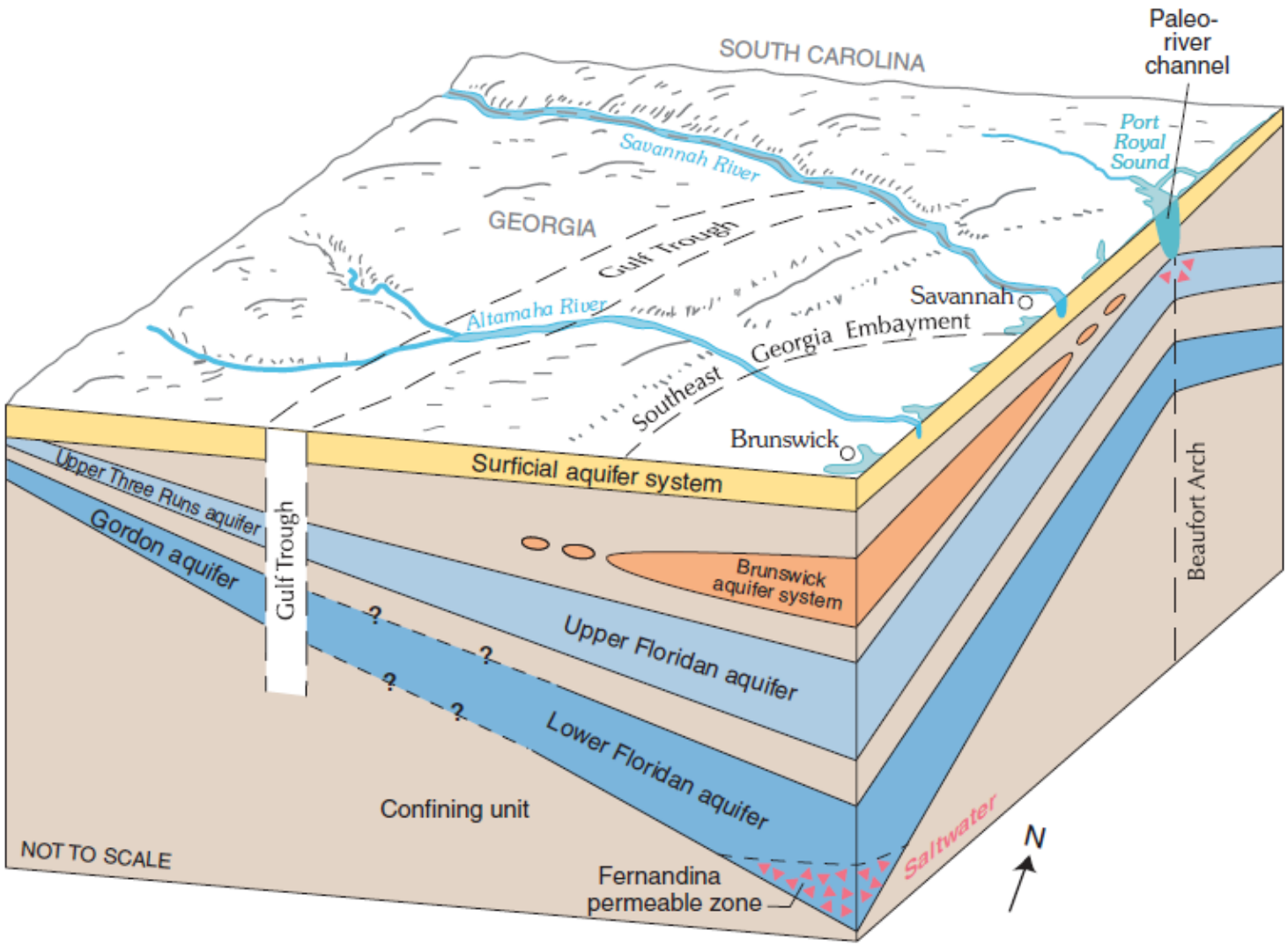
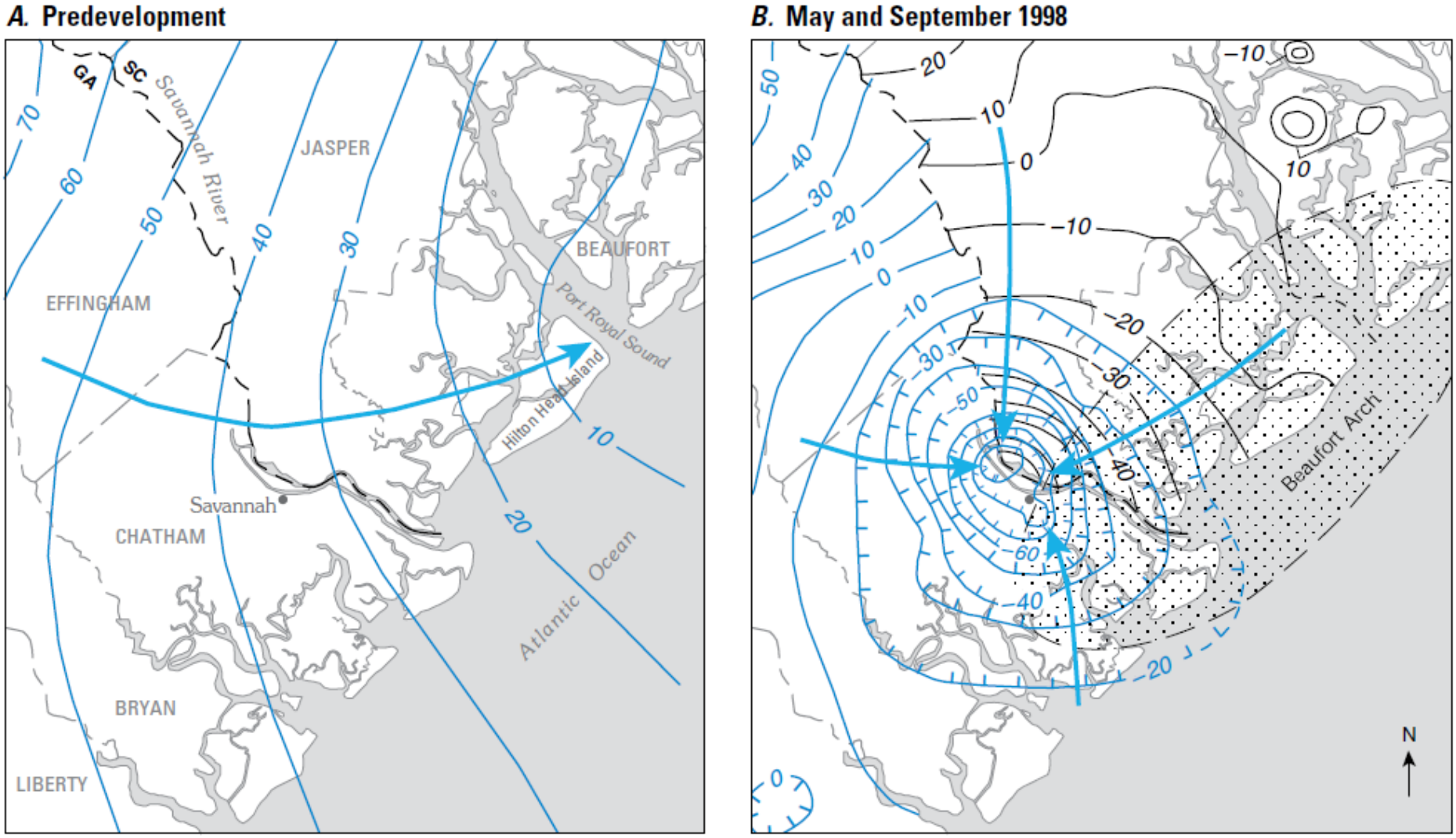
Coastal Georgia Aquifers



USGS SIR 2005-5089

Upper Floridan Potentiometric Surface



USGS SIR 2006-5058

Coastal Groundwater Use History

- 1960s and 1970s
  - Concerns about saltwater intrusion near Savannah and in Brunswick.
  - A saltwater wedge found on northern end of Hilton Head Island.
  - Eastern end of Bull Island – Some wells had higher salinity levels.
  - Saltwater from deeply buried brines was entering the Floridan aquifer in Brunswick, Ga.

- 1980s and Early 1990s
  - South Carolina DHEC and Georgia EPD begin discussions on Floridan Aquifer use.
  - Initial restrictions on withdrawals in Chatham County implemented

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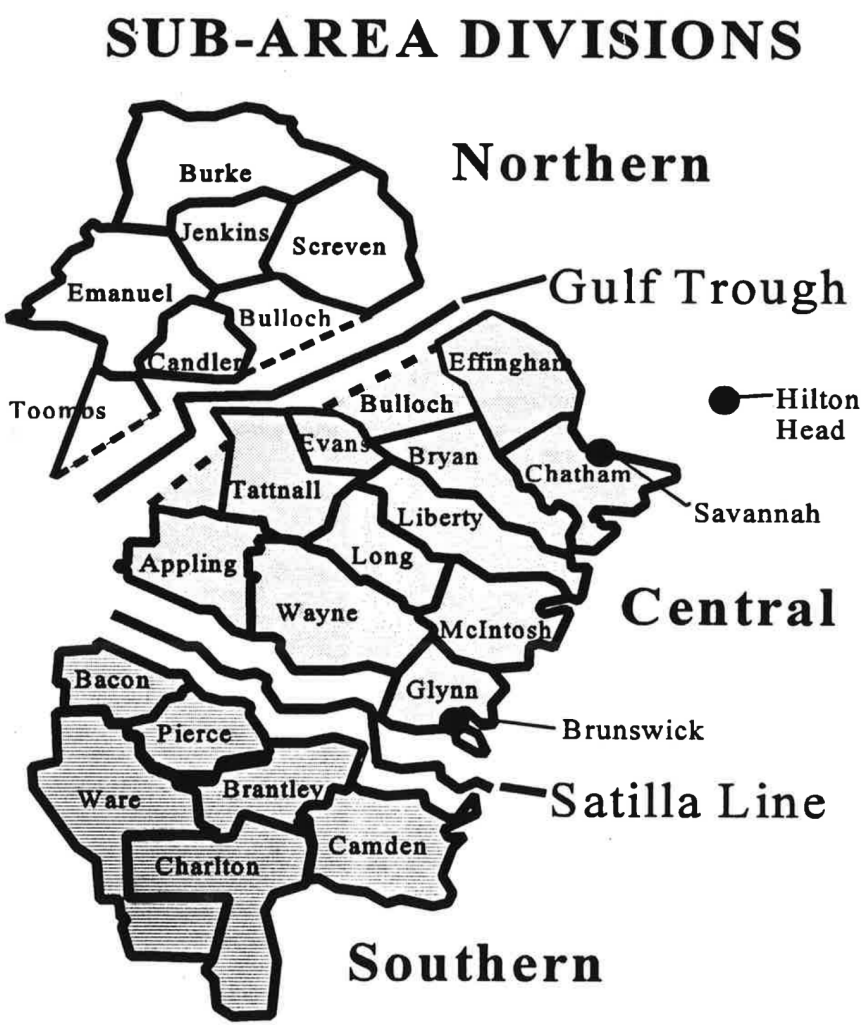
Coastal Groundwater Use History

- 1995 – April 1997 – Development of and Release of the Interim Strategy for Managing Salt-water Intrusion in the Upper Floridan Aquifer in Coastal Georgia (Interim Strategy).
  - Impacted 24 Coastal Counties
  - Imposed caps on groundwater use in Glynn and Chatham Counties, and portions of Bryan and Effingham Counties to avoid worsening the rate of saltwater intrusion.
  - Reduction of groundwater use in Chatham County by at least 10 mgd by December 2005 through conservation and switching to surface water use.
  - Develop information needed to assist Georgia stakeholders with development and implementation of a final strategy that will acceptably address saltwater intrusion and encroachment problems along Georgia's coast.
    - Promote water conservation
    - Develop comprehensive water supply plans
    - Develop expanded scientific studies

Interim Strategy for Managing Saltwater Intrusion

- **Coastal Area divided into 3 subareas:**
  - Northern area – Limited additional withdrawals
  - Central area:
    - Chatham and portions of Bryan and Effingham Co.
      - Withdrawals reduced by 10 mgd by Dec. 2005.
      - No new withdrawals without associated reductions.
    - Glynn County – No additional withdrawals.
    - Other counties in Central area – Some limited increases would be allowed (up to 15 mgd).
  - Southern area – Limited additional withdrawals
  - All three subareas
    - Inactive groundwater permits will be canceled.
    - No new permits for golf course irrigation or non-contact cooling water, where alternate sources exist.
    - Total withdrawal increases would be limited to 36 mgd.

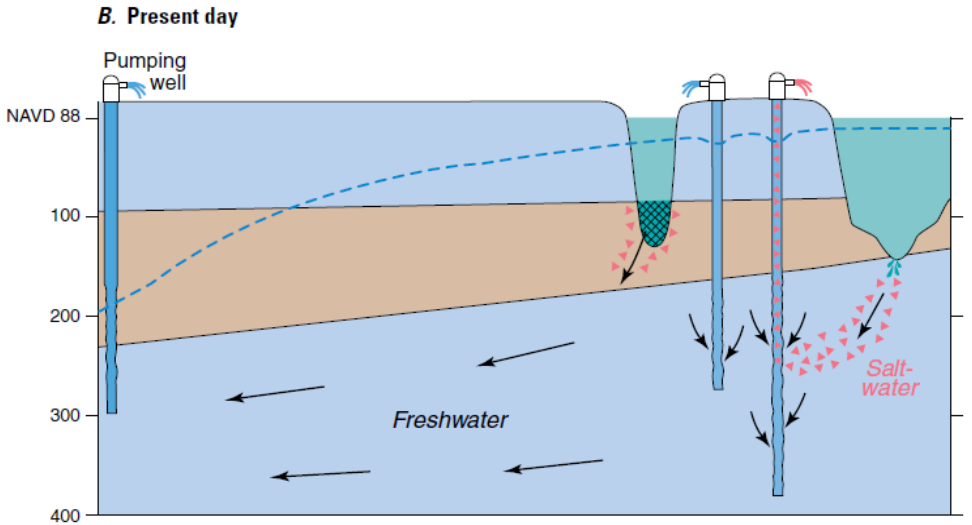


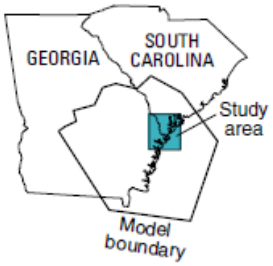
Coastal Sound Science Initiative (CSSI)

- CSSI established by 1997 Interim Strategy.
  - $18 million effort:
    - $11,258,000 – State of Georgia
    - $1,750,000 – USGS
    - $200,000 – Glynn County
    - $1,000,000 – State of South Carolina
    - $500,000 – State of Florida
    - $3,260,415 – Paper Industries in Coastal area
  - Technical Advisory Committee established
    - Included representatives from Georgia EPD, SCDHEC, USGS, and other Georgia stakeholders.
    - Gathered additional scientific data, undertook extensive hydrological modeling and had input on any initiatives and regulatory actions that would be a result of the CSSI.
  - June 2006 – Coastal Georgia Water & Wastewater Permitting Plan for Managing Salt-Water Intrusion (CPP)
    - Replaced the Interim Strategy.
    - Based on the findings of the CSSI.

How and Where is Saltwater Entering the Floridan Aquifer

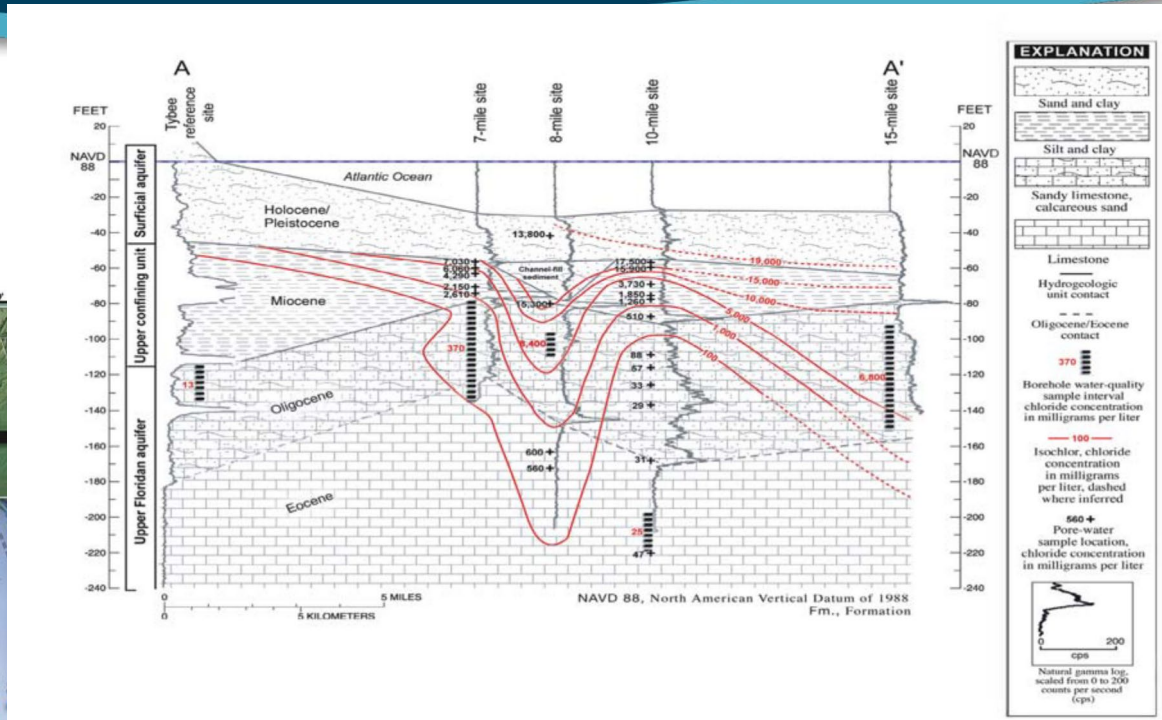
- Where is saltwater entering the Aquifer:
  - T-shaped plume – Brunswick
    - Saltwater entering aquifer through fractures.
  - Hilton Head Island area:
    - Saltwater is entering aquifer along the northern shore of Hilton Head Island, Pinckney Island, and Colleton River.
    - Saltwater is entering the Floridan aquifer through downward leakance through the confining layer where confining unit is thin or absent.

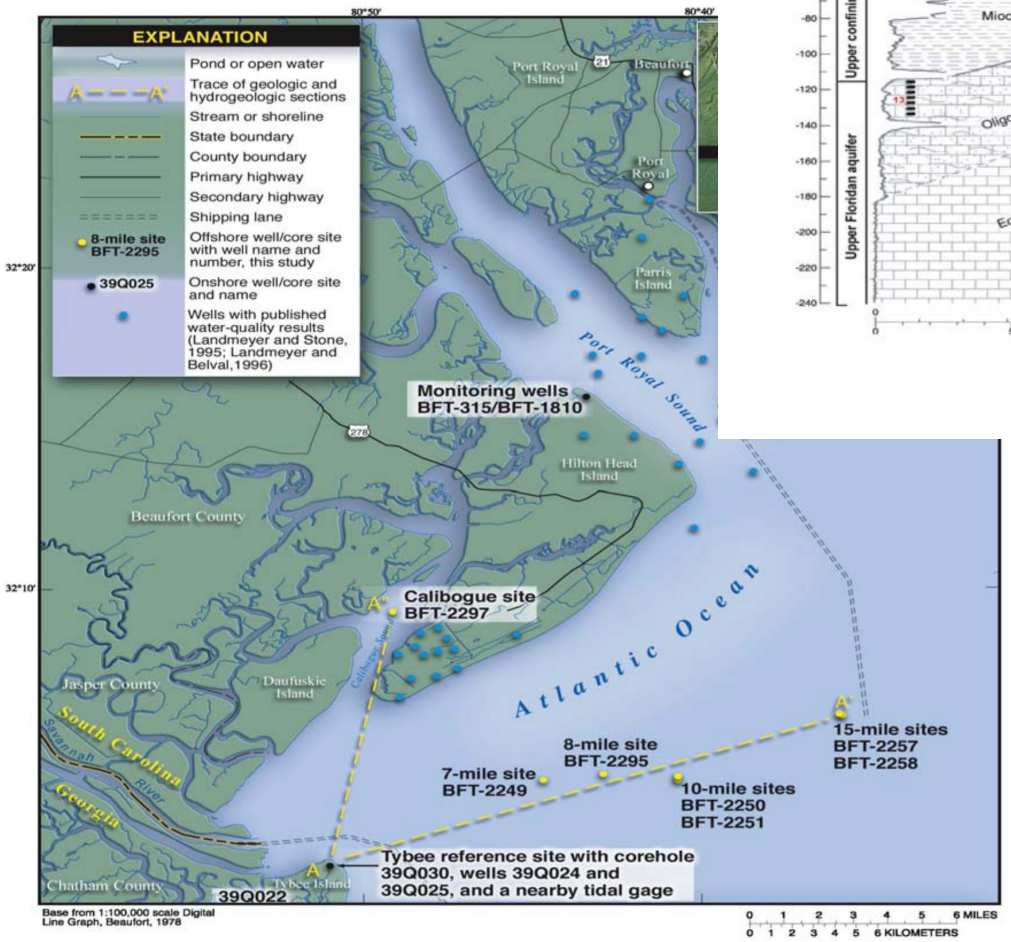




USGS Scientific Investigations Report 2006-5058

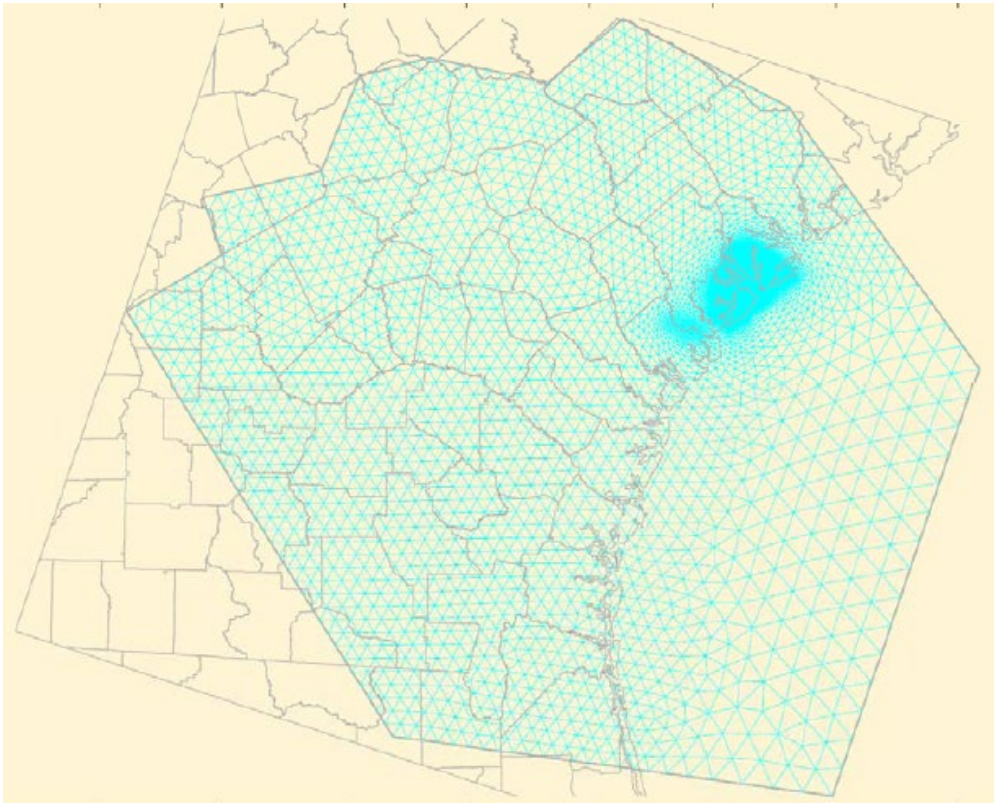
Coastal Georgia Water & Wastewater Permitting Plan for Managing Salt-Water Intrusion





Seismic studies show that east of Hilton Head Island and northeast of Tybee Island, the confining unit is thin.

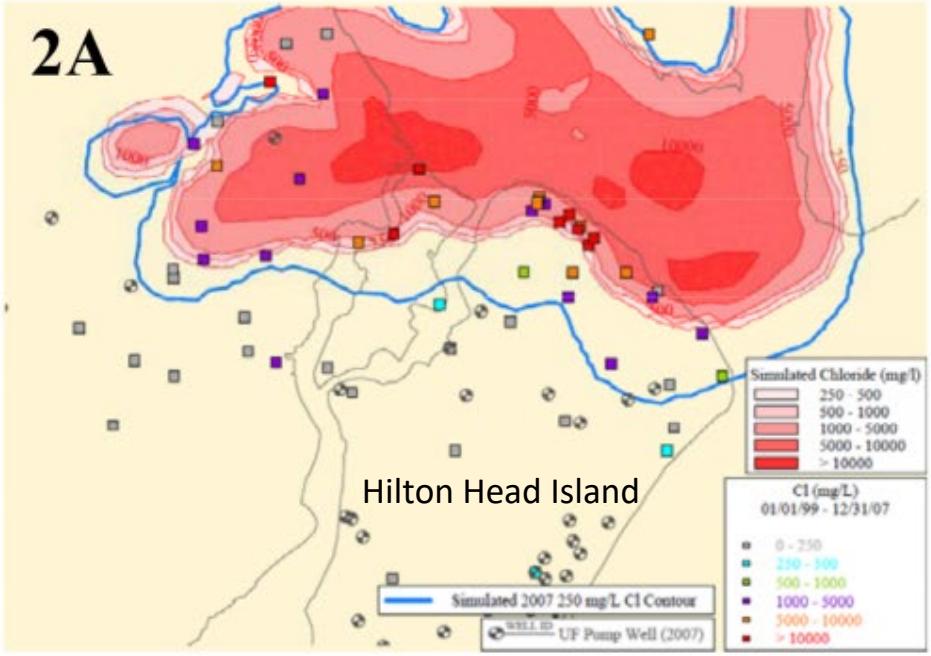
CSSI Hydrologic Modeling



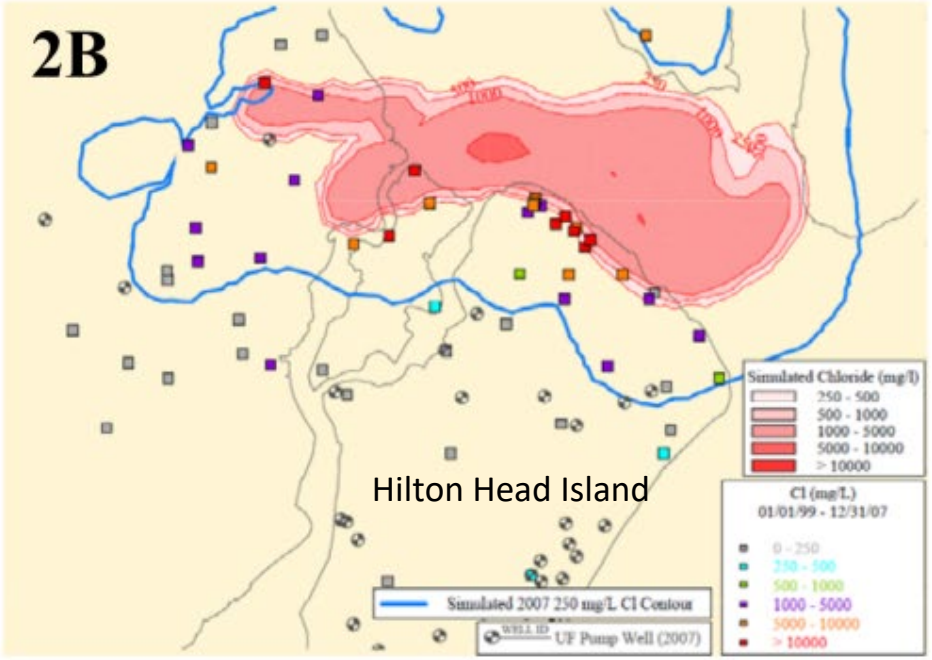
- CSSI model refined from the SHE model
  - Finer grid spacing around Hilton Head
  - Model was calibrated for steady state and transient conditions.
    - Model was calibrated against 2007 chloride contours provided by SCDHEC.
    - Model closely matched historical measurements of plume movement.
    - GA EPD and SCDHEC approved the model for use in the CSSI.
  - Baseline withdrawals (includes Ag, Drinking water systems, and Non-Farm Permitted Withdrawals):
    - Savannah Area – 69 mgd
    - Hilton Head Island – 9 mgd

Initial CSSI Model Simulations

Historical Withdrawals in Savannah Area Only



Historical Withdrawals on Hilton Head Island Only

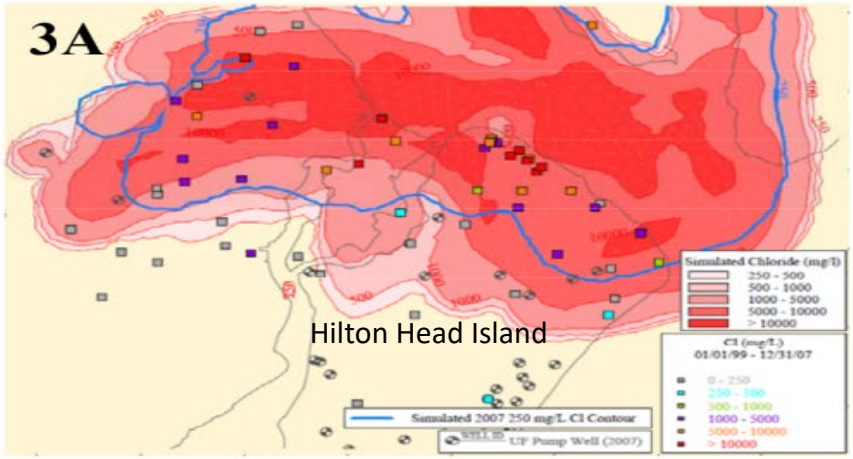


- 2A – Maintain historical withdrawals in Savannah area with no withdrawals on Hilton Head
- 2B – Maintain historical withdrawals on Hilton Head with no withdrawals in Savannah area.

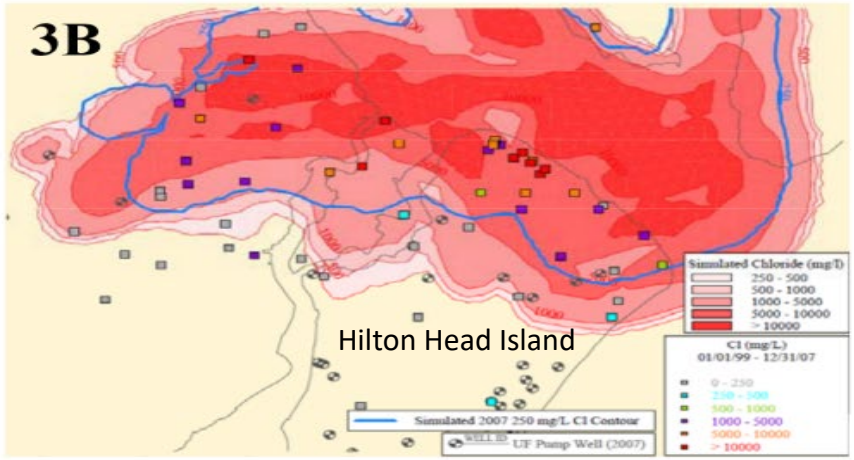
** Neither simulation extended as far inland as the simulated initial plume (2007), so both contribute to the inland extent of the plume.

CSSI – Simulate Aquifer Management Scenarios

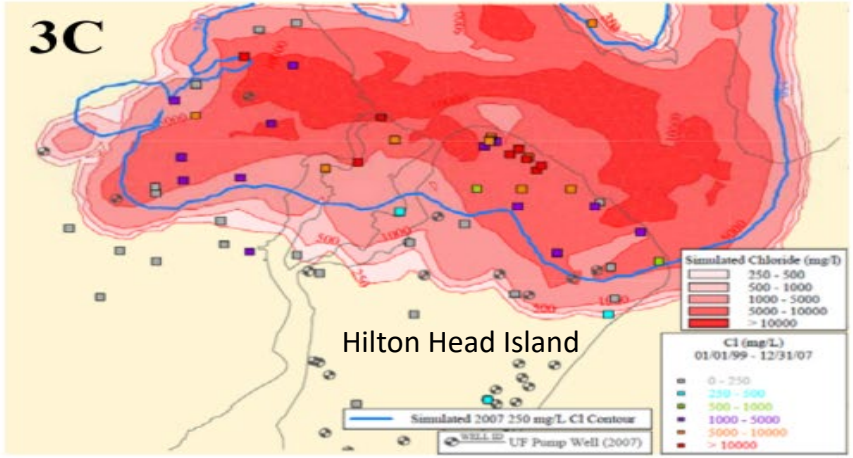
No Reduction of Withdrawals



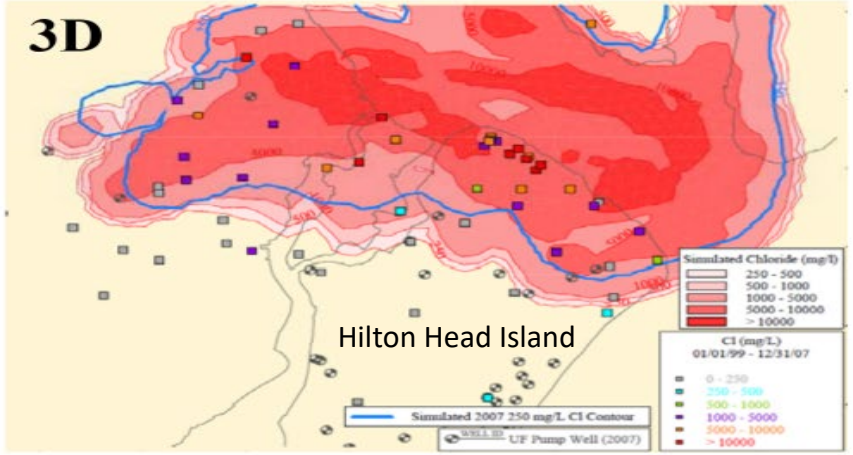
No Reduction of Savannah Area Withdrawals and 50% Reduction of Withdrawals on Hilton Head Island



50% Reduction of Savannah Area Withdrawals and No Reduction of Withdrawals on Hilton Head Island



50% Reduction of Withdrawals in the Savannah Area and on Hilton Head Island



Conclusions of CSSI model simulations

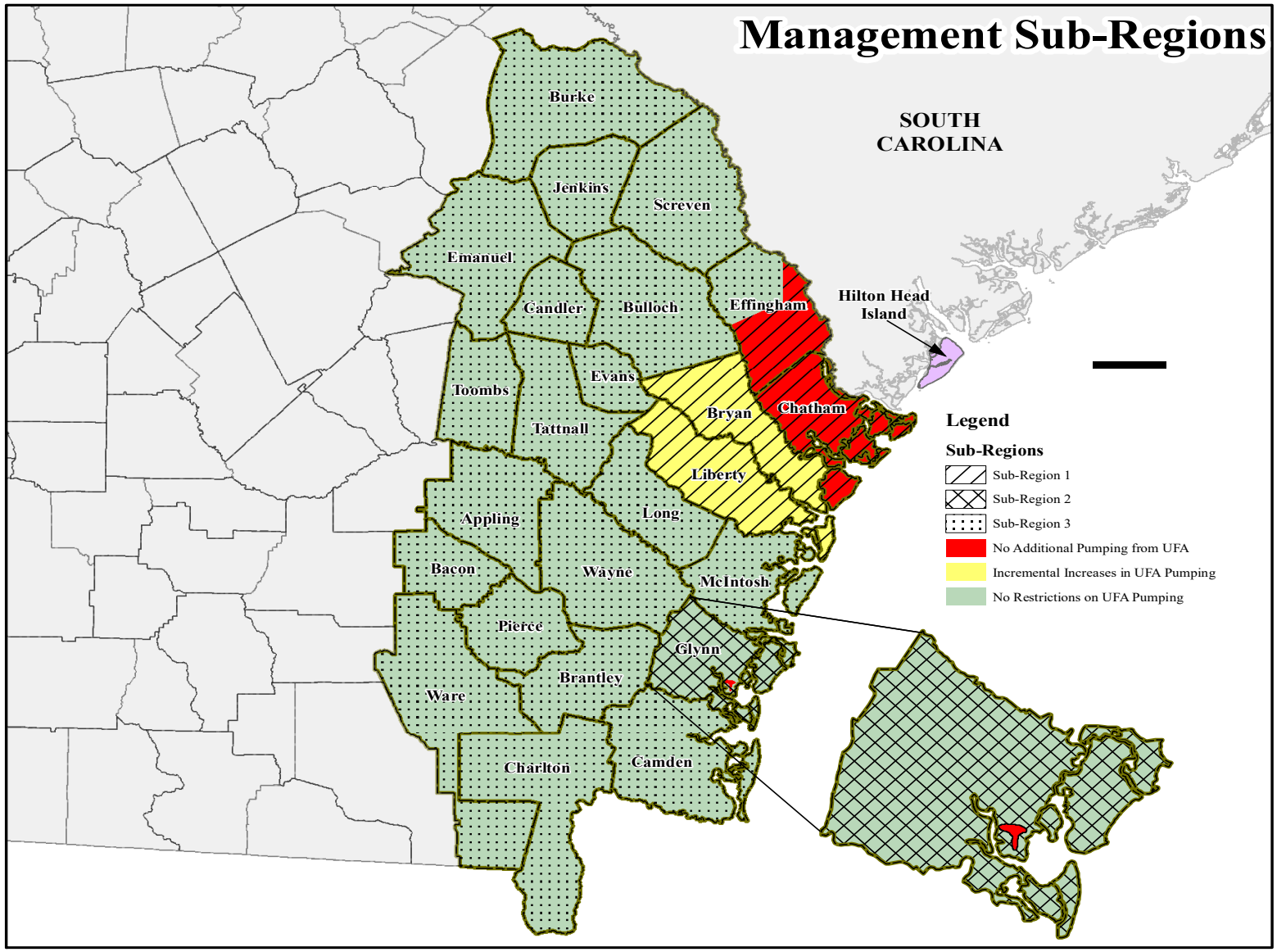
- Groundwater withdrawals in both the Savannah and Hilton Head areas contributed toward the inland extent of the saltwater plume.
- Salt-water plumes would continue to exist into the future even if all groundwater withdrawals were eliminated.
- Reducing groundwater withdrawals from the aquifer, even by large amounts, would not eliminate salt-water intrusion into the aquifer.

CSSI Findings - How Fast is Saltwater Traveling?

- Hilton Head Island area:
  - Since mid 1960s, the saltwater plume has moved about 2 miles south/southwest.
  - If year 2000 pumping rates are maintained – plume will move ~130 feet per year, southwest toward the cone of depression.
  - Offshore investigations indicate some saltwater has migrated into the Floridan aquifer in the area 7-10 miles northeast of Tybee Island.
- Brunswick, Glynn County area:
  - Monitoring data indicate plume at Brunswick is stable and is not moving.

** Modeling shows that increases/decreases in pumping from the Upper Floridan in or near the Savannah/Hilton Head areas will change the potentiometric gradient in these areas and thus change saltwater intrusion velocities.

2006 Sub-Regional Management Areas



- Sub-Region 1:
  - Chatham County
  - Effingham County (south of Hwy 119)
  - Bryan County
  - Liberty County
- Sub-Region 2:
  - Glynn County
- Sub-Region 3:
  - The remaining 19 counties.
  - Effingham County (north of Hwy 119)

No net increases in UF withdrawal amounts

Allow up to 5 mgd to be withdrawn from UF through 2008

No restrictions

Elements of 2006 CPP Management Plan

- Sub-Region 1 Red Zone (Chatham and Southern Effingham County):
  - Restrict withdrawals from Upper Floridan aquifer to 2004 actuals.
  - Reduce withdrawals by at least an additional 5 mgd by 2008.
    - City of Savannah -2.111 mgd
    - International Paper – 1.289 mgd
    - Other users – 1.600 mgd
  - Require implementation of water conservation and reuse measures.

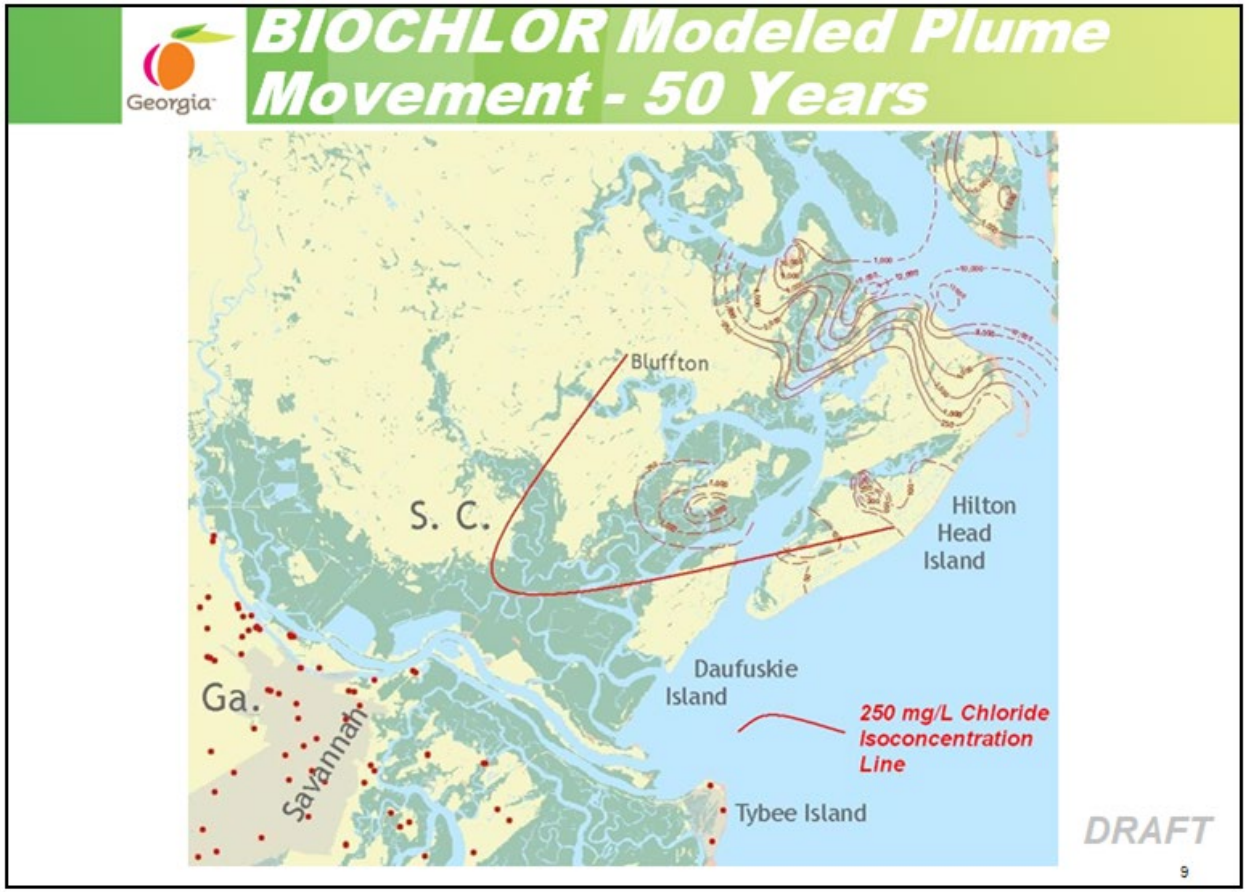
- Sub-Region 1 Yellow Zone (Bryan and Liberty Counties):
  - Allow up to an additional 5 mgd of Upper Floridan aquifer to be withdrawn through 2008.
  - Require implementation of water conservation and reuse measures.

- Sub-Region 2 (Glynn County):
  - Manage withdrawals from the Upper Floridan aquifer in such a manner so that the current "t-shaped" plume doesn't change.
  - Require implementation of water conservation and reuse measures.

- Sub-Region 3 (19 Counties plus Effingham Co. north of Hwy 119):
  - Require implementation of water conservation and reuse measures.

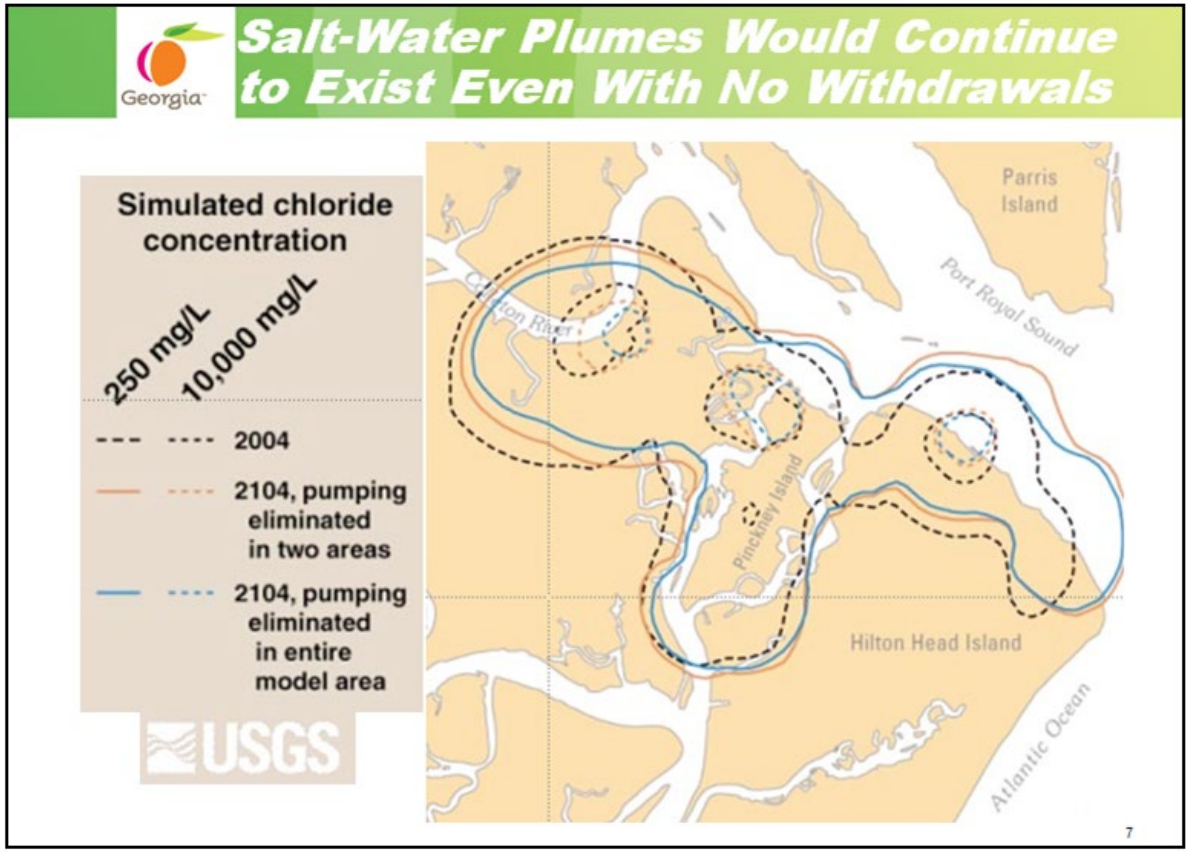
Coastal Activities Since 2008

- In 2011, EPD simulated how long it would take salt-water plumes to reach Savannah:
  - Simulation indicated that in 50 yrs the saltwater plume would move toward Savannah but not yet reach it.
  - Simulations indicated ~125 yrs for saltwater to reach Savannah area wells (2000).
  - Model assumed Savannah area pumping of 69 mgd (2000).
  - **Savannah area pumping in 2022 was 45.6 mgd.**
  - Chlorides are moving toward cone of depression and will not reach Tybee Island.



Saltwater Plume Movement Study

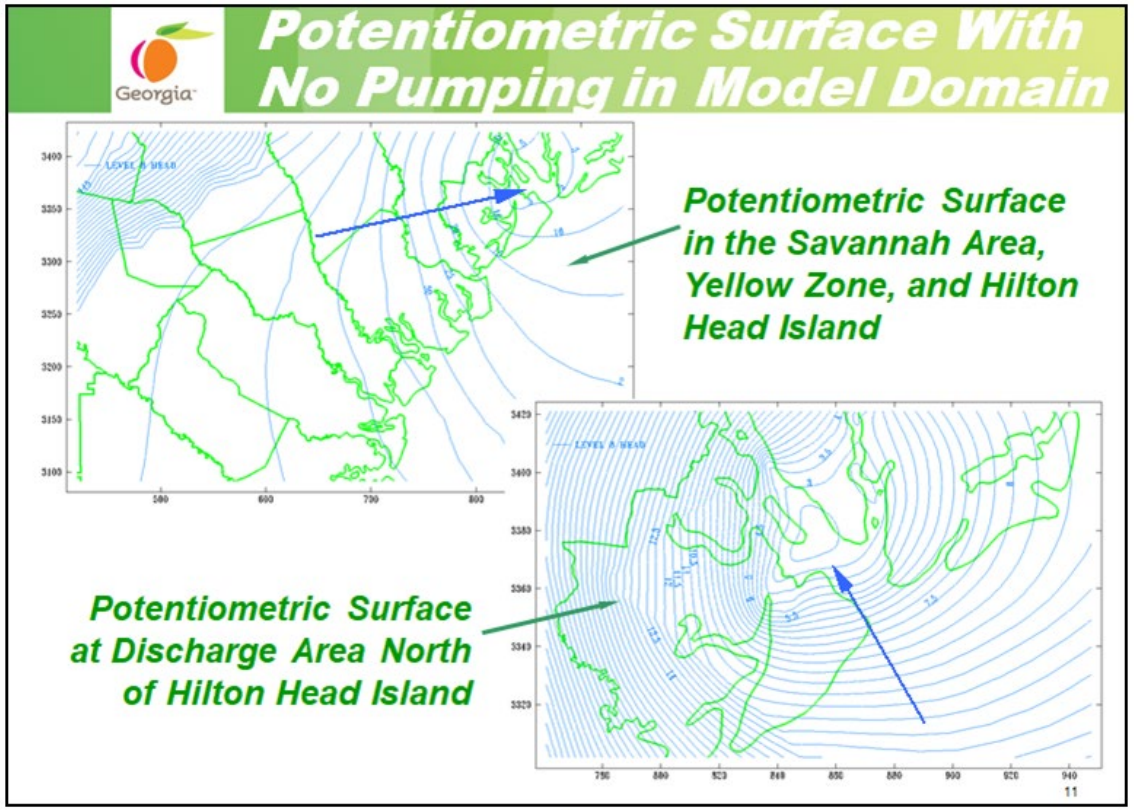
- 2013 – EPD presents modeling work done by USGS:
  - USGS modeling of plume movement when pumping ceases.
    - 100 years of pumping (2004-2104) where pumping in the Savannah area and Hilton Head Island were eliminated.
    - 100 years of pumping (2004-2104) where pumping in the entire model domain was eliminated.
  - USGS simulations show that even with pumping eliminated for 100 years, the saltwater plume continues to exist on Hilton Head Island.



Saltwater Plume Movement Study

- Simulations were done to determine what amount of water could be pumped from the Floridan aquifer without causing movement of the saltwater plume toward the Savannah area.
  - Baseline model was run with no pumping in the Savannah area or on Hilton Head Island.
  - Simulate what amount of water could be pumped from the aquifer and still have the direction of groundwater movement pointing to the north (away from the Savannah area).
  - Pumping scenarios included pumping from the Savannah area, Hilton Head, and the Yellow Zone.

- Hilton Head Island pumping by itself (1.7 mgd)
- Savannah area pumping by itself (10.3 mgd)
- Yellow Zone pumping by itself (34.9 mgd)



Sustainable Yield to Keep the Potentiometric Surface flowing away from Savannah

Combinations of Withdrawals That Do Not Cause the Plume to Move Further Inland

Sustainable Yield Depends on Where Pumping Occurs

Area Withdrawal (mgd)			Total Withdrawal (mgd)
Savannah	Yellow Zone	Hilton Head	
0.000	0.000	1.723	1.723
6.875	0.000	0.861	7.736
10.312	0.000	0.000	10.312
5.158	8.735	0.646	14.539
3.439	13.102	0.431	16.972
1.720	17.468	0.215	19.403
6.880	17.472	0.000	24.352
3.441	26.204	0.000	29.645
0.000	34.934	0.000	34.934

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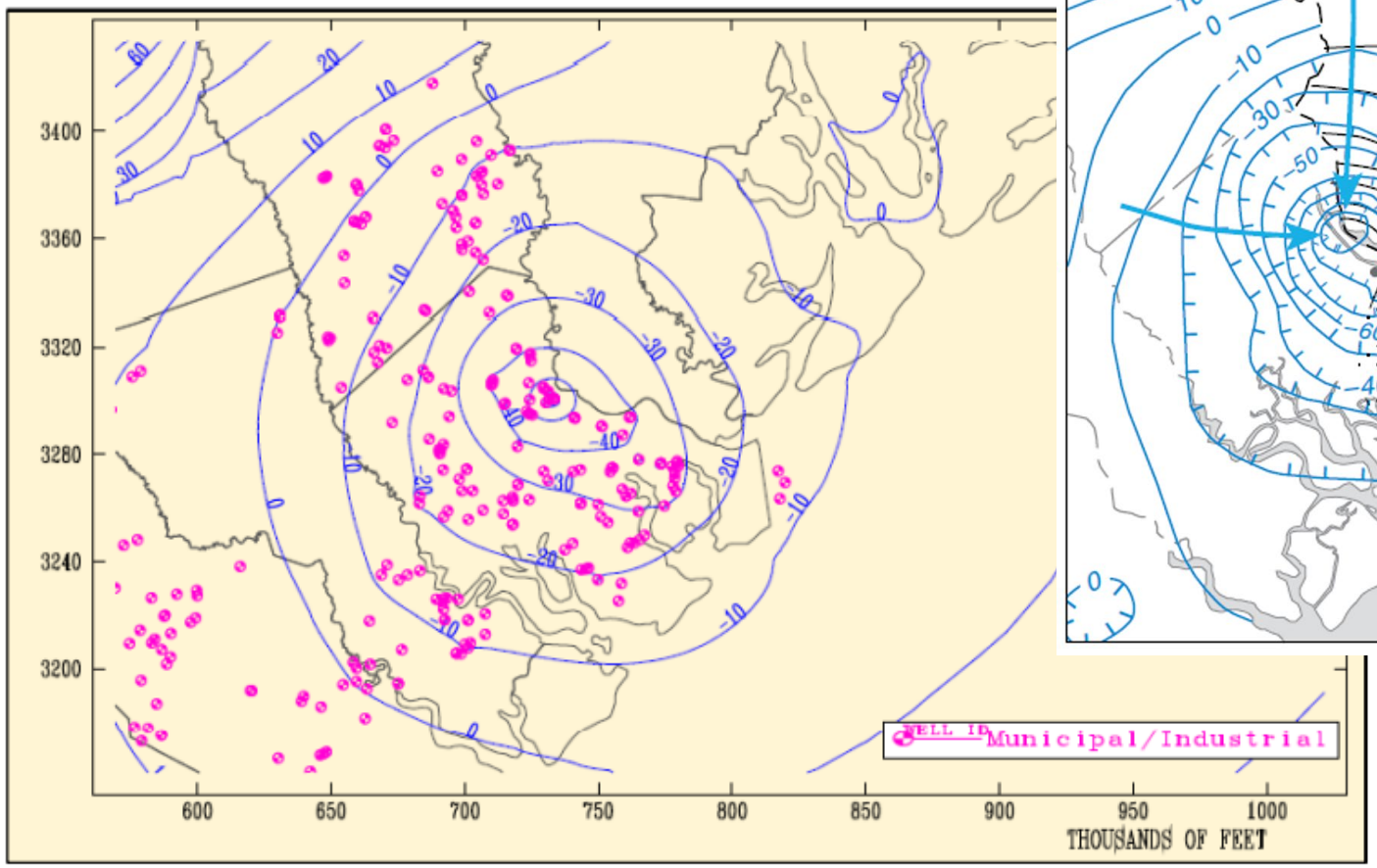
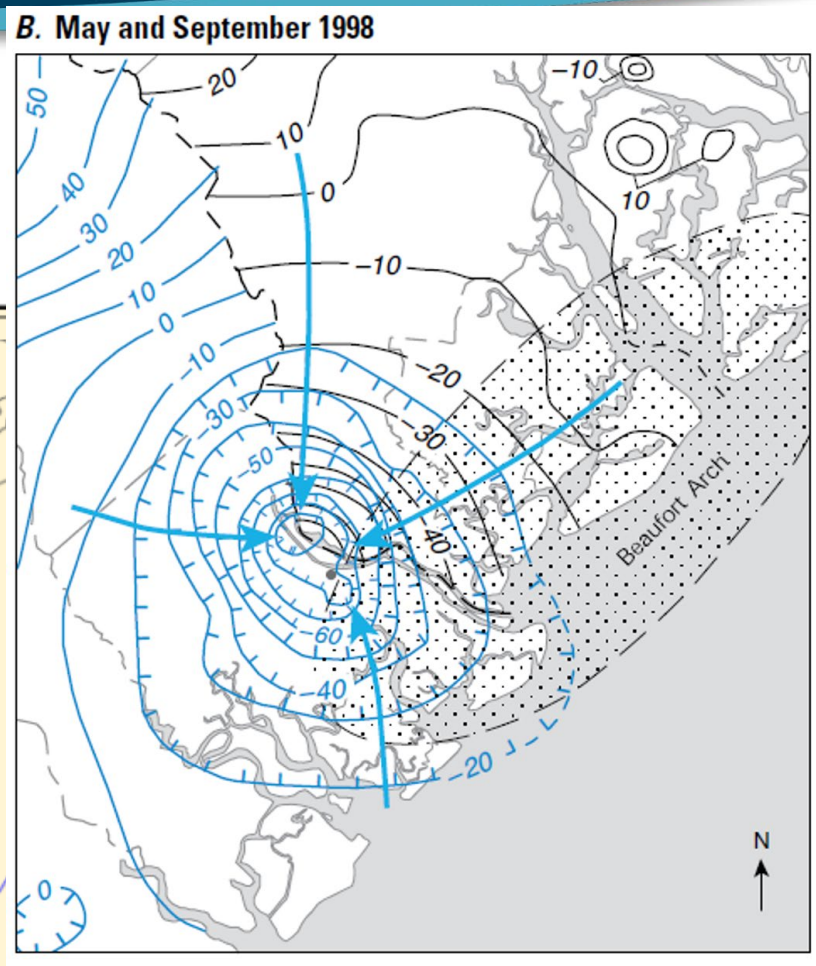
CSSI Model Updates (2017-2018)

- Grid discretization reduced to 1,200 – 1,700 ft:
  - Red Zone
  - Yellow Zone
  - Southern half of Bulloch County, Evans County, Long County, McIntosh County, and eastern portion of Tattnall County.
- Grid spacing for remainder of model adjusted to avoid numerical instability.
- Transient simulation period extended through 2016 (1915-2016). Steady state simulation of 2016 pumping conditions was developed.
- Model updated to include 2008-2016 reported withdrawals (M&I and Ag use):
  - Model update eliminated distributed fluxes for years 2008-2016 in areas where Ag withdrawal information was available. Withdrawals now assigned to coordinates.
    - Appling, Bacon, Brantley, Bryan, Bulloch, Burke, Candler, Chatham, Effingham, Evans, Emanuel, Jenkins, McIntosh, Pierce, Screven, Tattnall, Toombs, Ware, and Wayne)
- Model used to simulate steady state groundwater conditions under December 2015 permitted groundwater withdrawals.

CSSI Model Updates (2017-2018)

- Red Zone – 50.1 mgd
- Yellow Zone - 19.6 mgd





Red and Yellow Zone Permitted and Reported Annual Averages

Annual Average Permitted Limits (mgd)

Zone	1995	2000	2005	2010	2015	2020	2022
Red Zone	93.937	87.172	80.772	60.391	62.213	52.348	52.321
Yellow Zone	21.847	24.563	26.625	26.695	28.872	29.836	30.144
Totals	115.784	111.735	107.397	87.086	91.085	82.184	83.465

Annual Average Reported Withdrawals (mgd)

Zone	1995	2000	2005	2010	2015	2020	2022
Red Zone	66.274	64.358	57.102	53.370	48.149	44.823	45.576
Yellow Zone	12.084	15.061	15.893	17.387	18.848	19.005	20.774
Totals	78.358	79.419	72.995	70.757	66.997	63.828	66.350

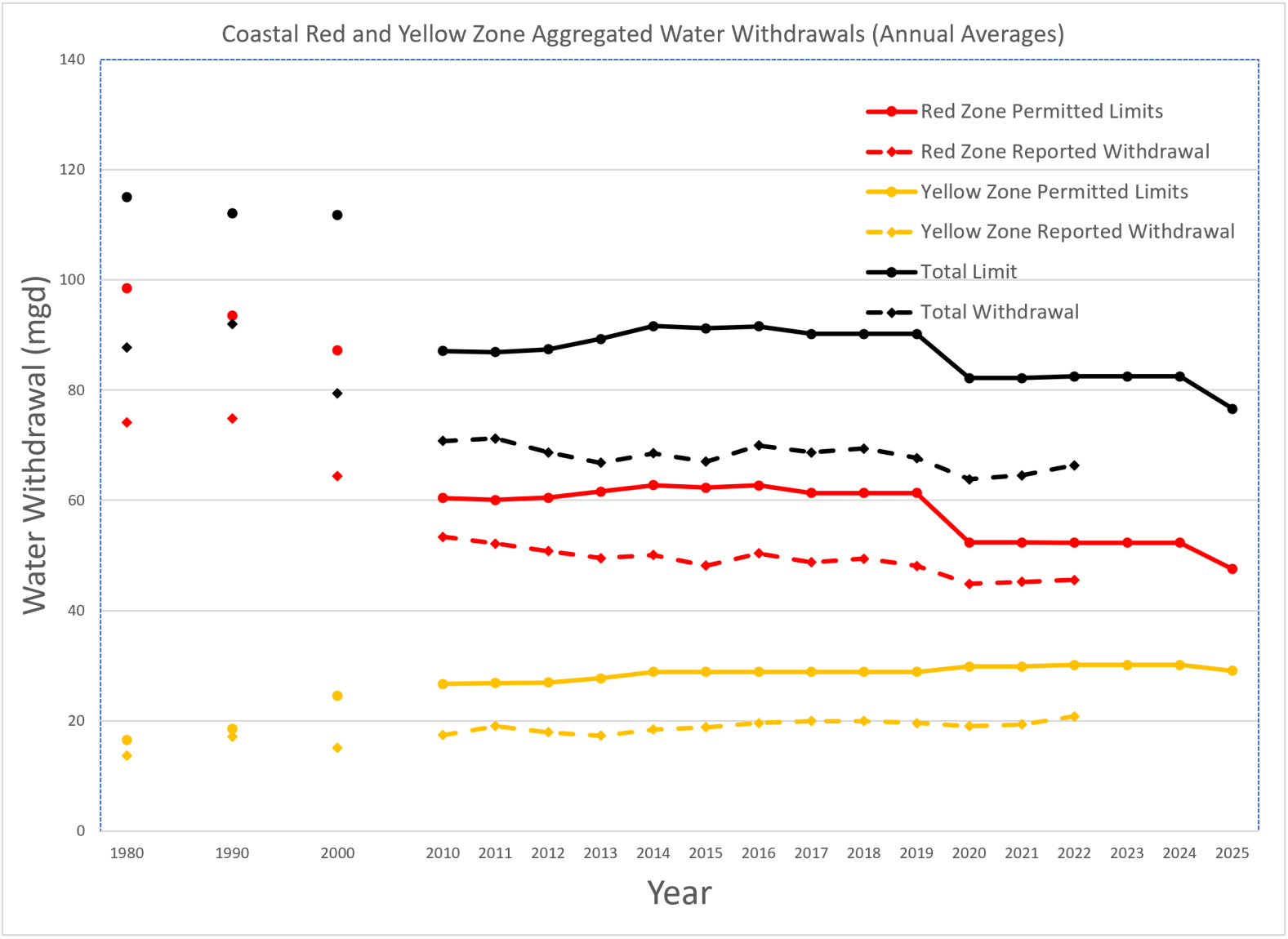
Scheduled 2025 annual permitted limits:

Red Zone - 47.522 mgd

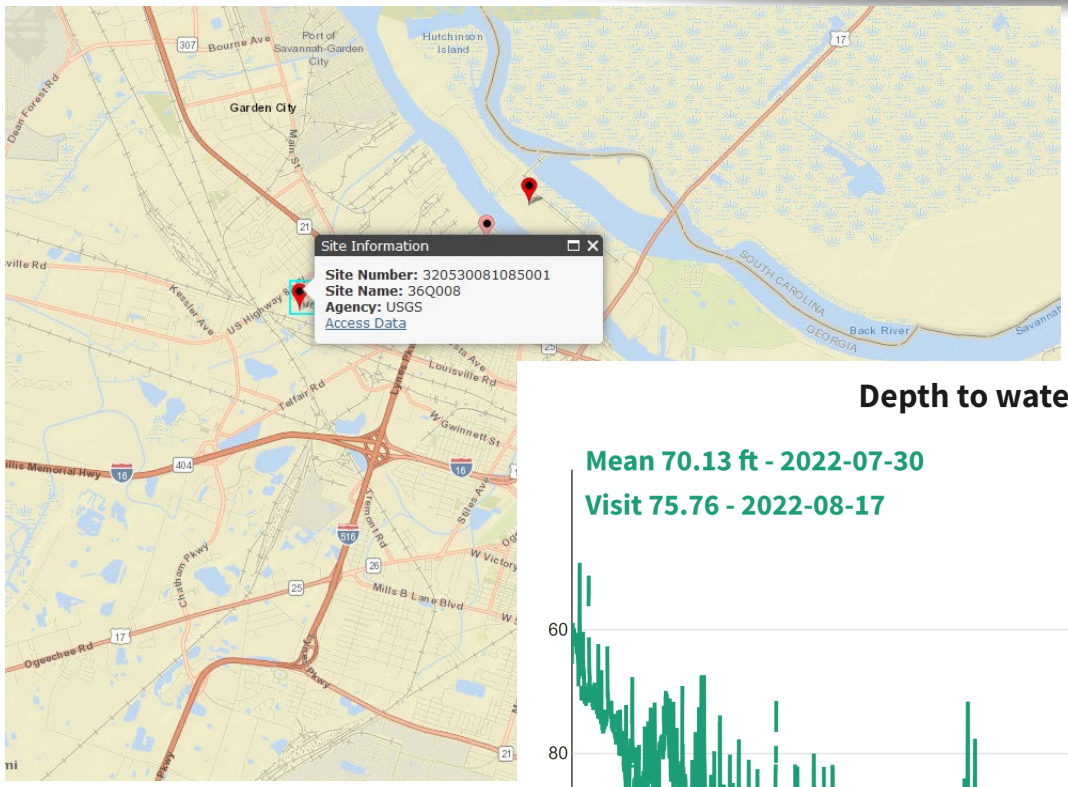
Yellow Zone - 29.092 mgd

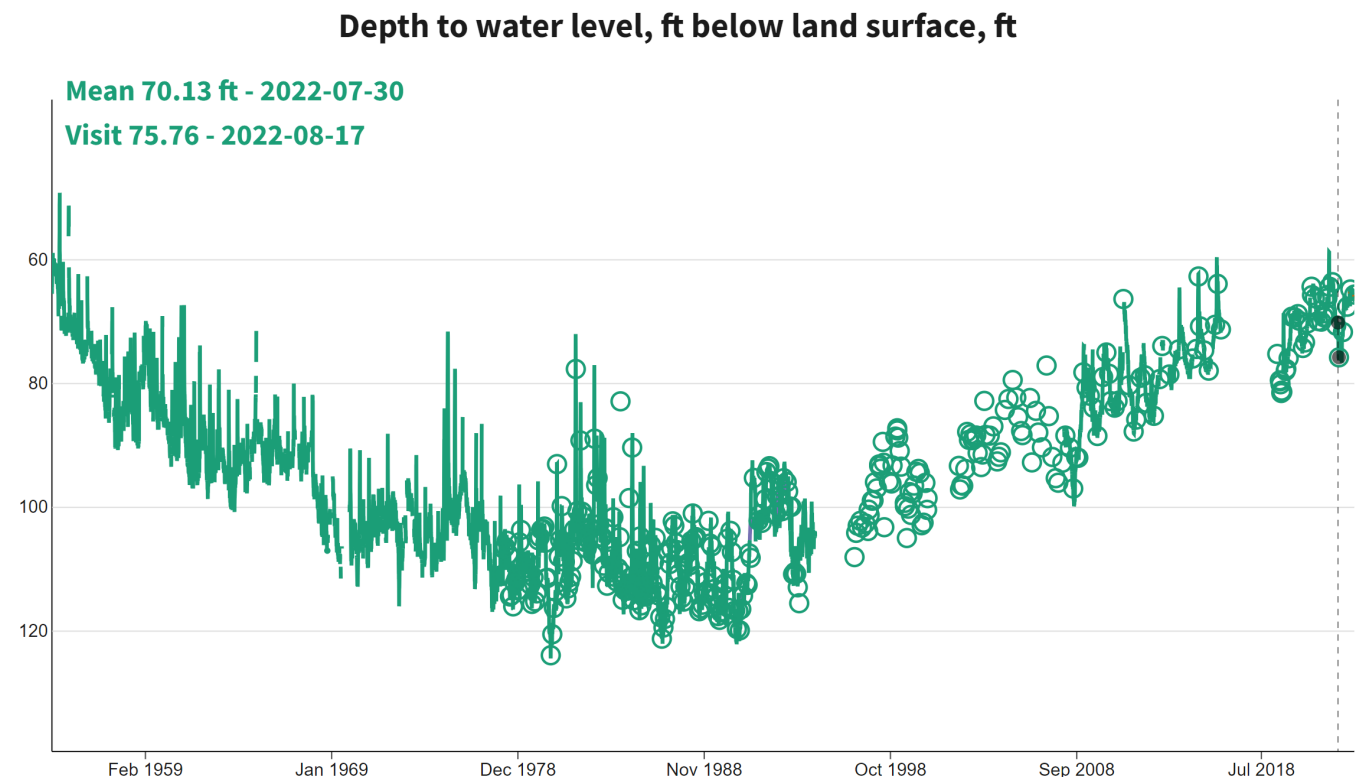
Totals – 76.614 mgd

Red and Yellow Zone Permitted Annual Averages

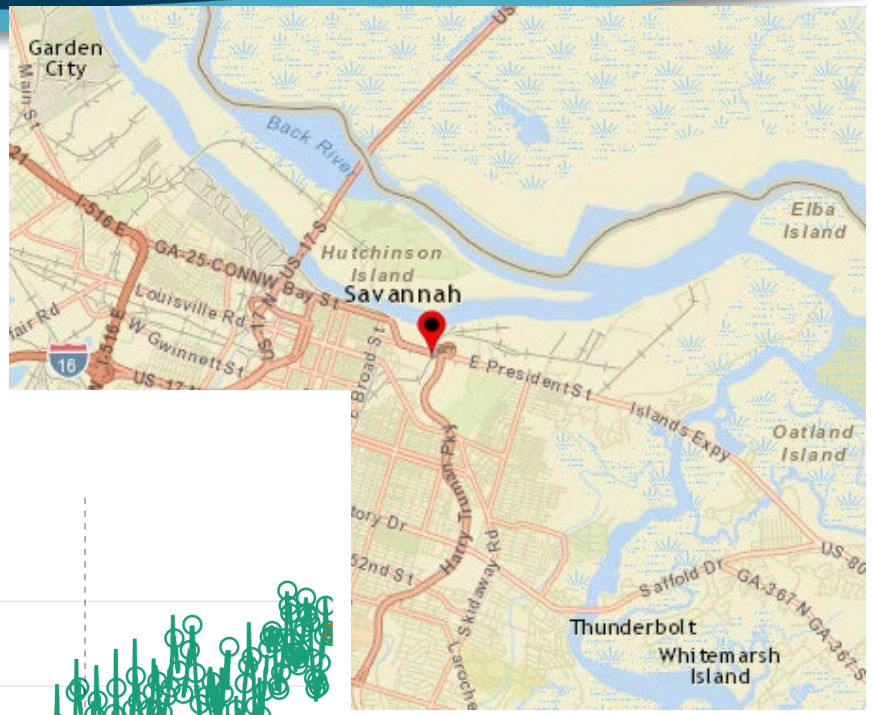


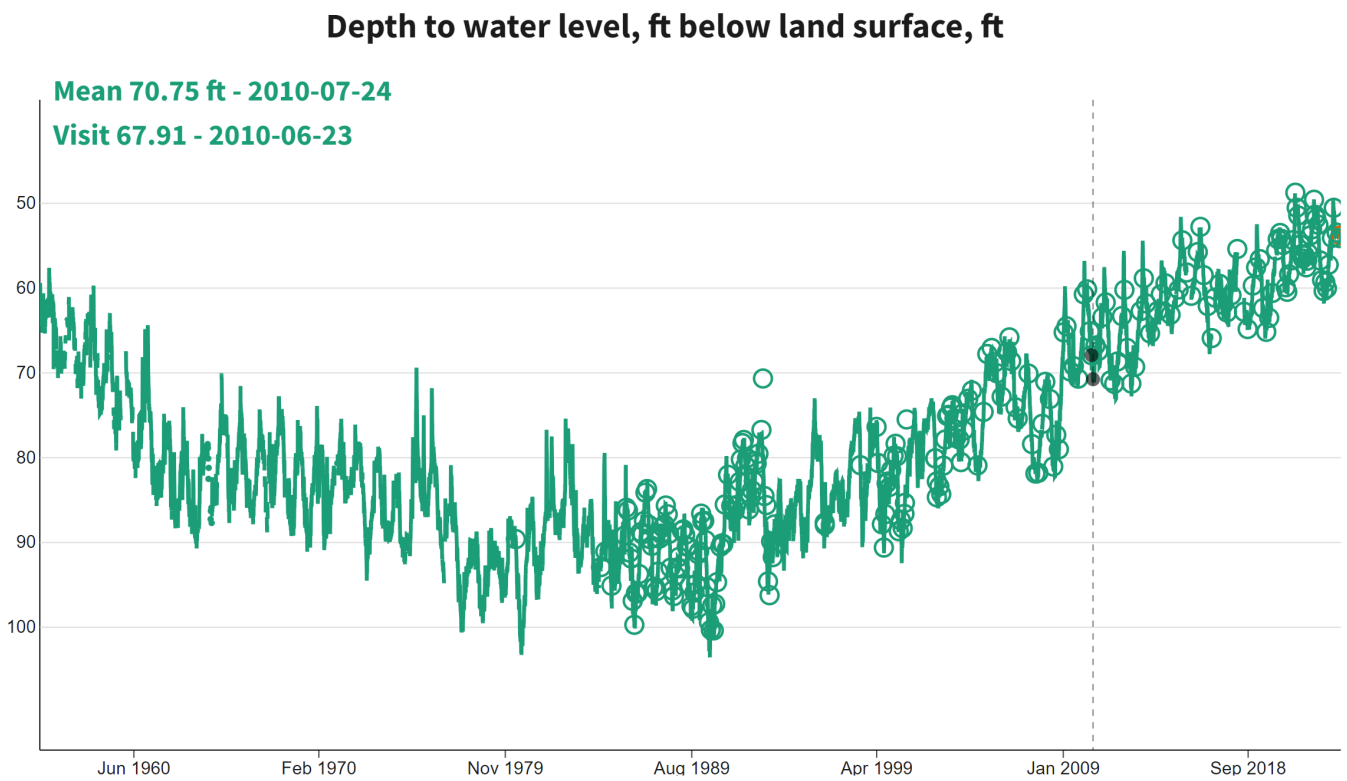
USGS Groundwater Level Measurements – Savannah Area



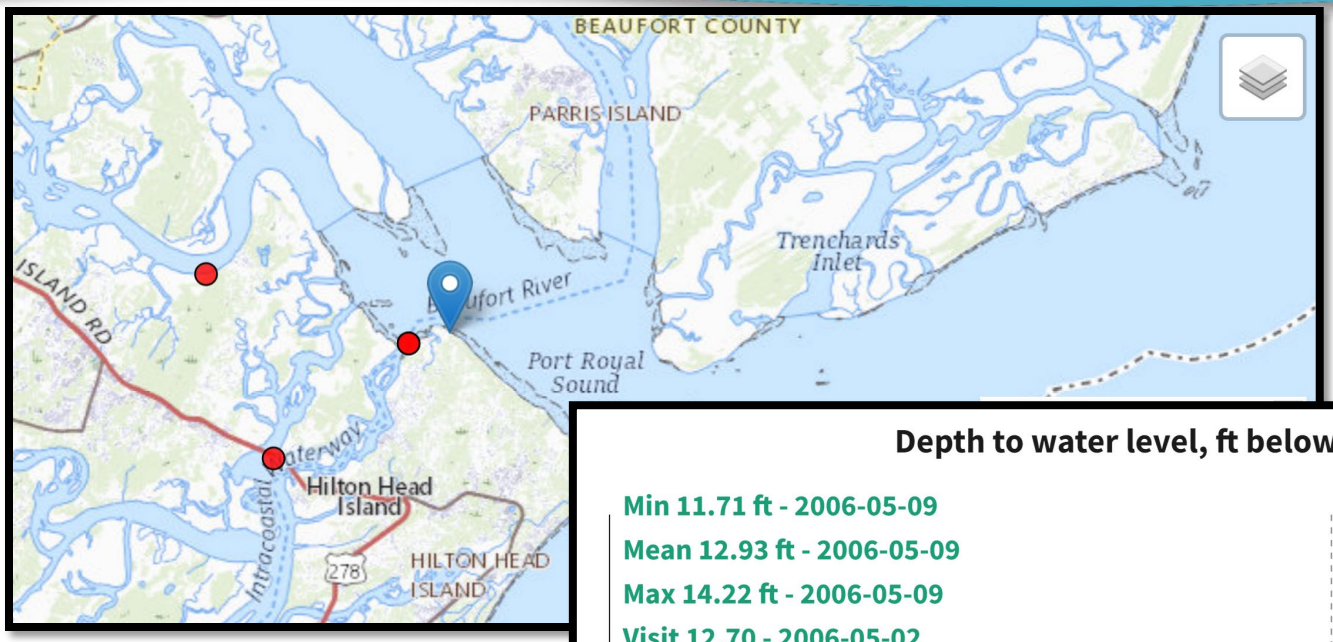


USGS Groundwater Level Measurements – Savannah Area

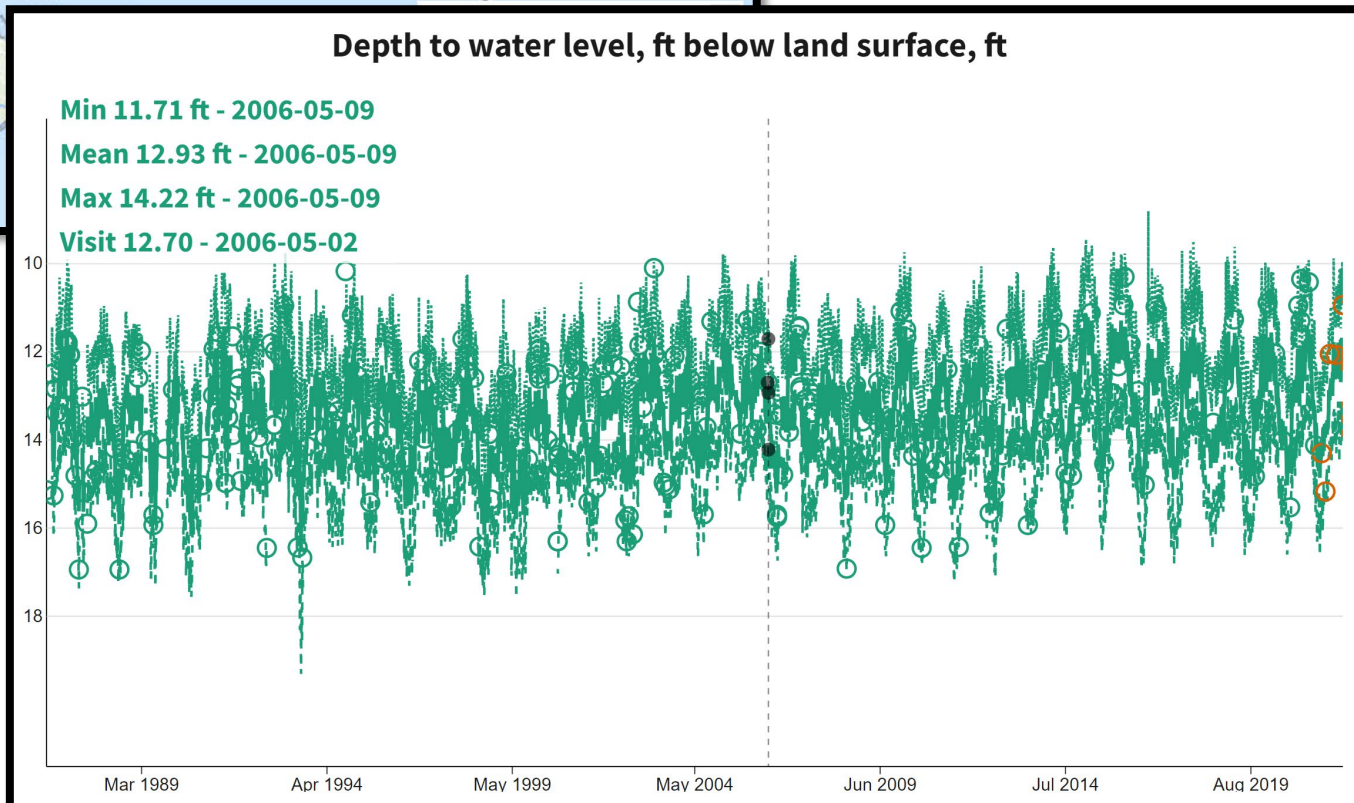




USGS Groundwater Level Measurements – Hilton Head Island Area

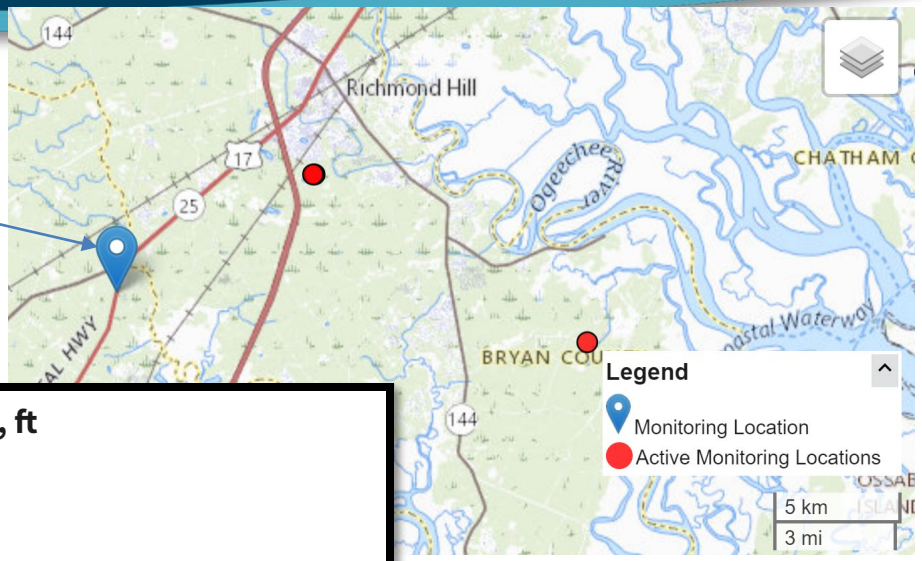


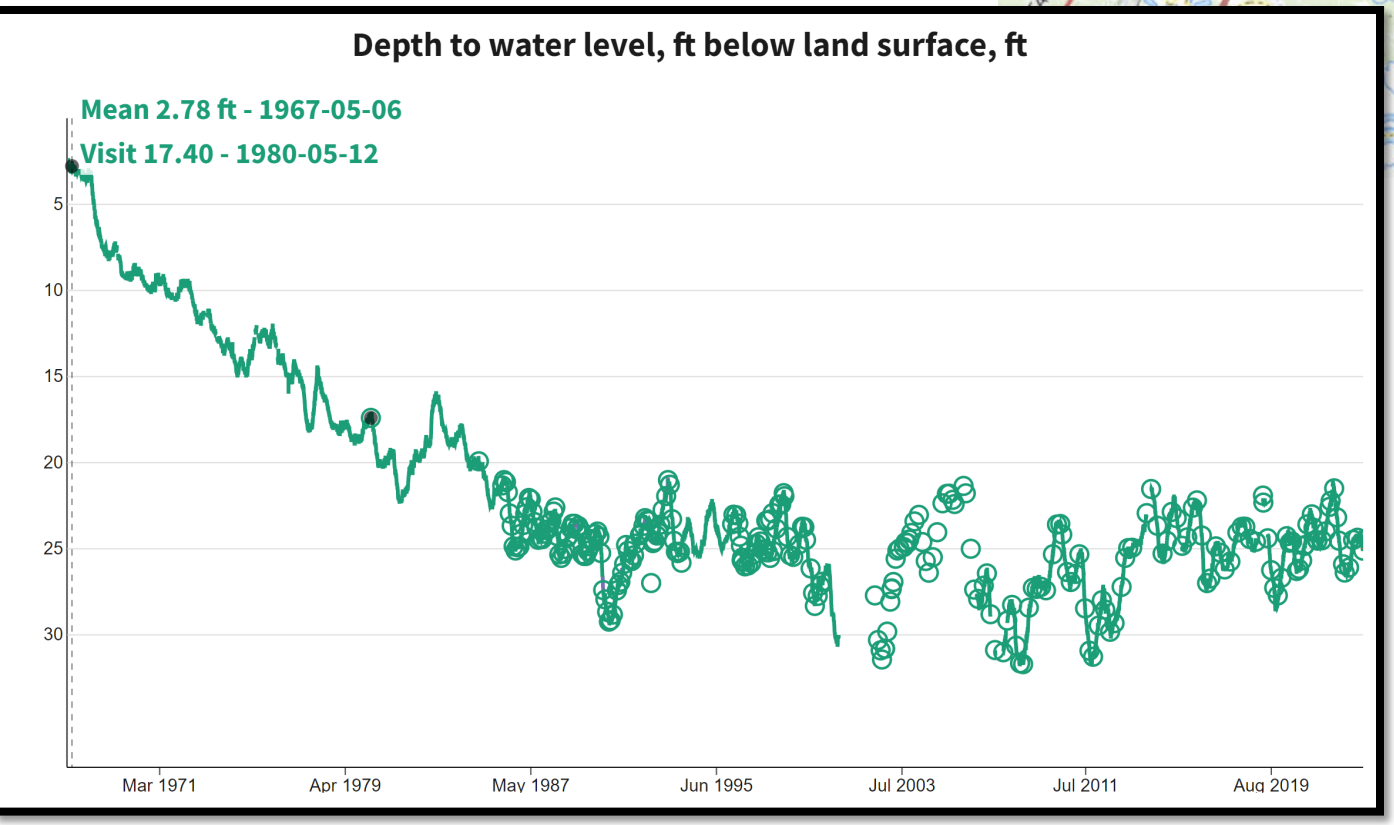
USGS Well – BFT-1810 - 321603080432202



USGS Groundwater Level Measurements – Liberty County (Yellow Zone)

USGS Well –34N039
315214081235301
Liberty County

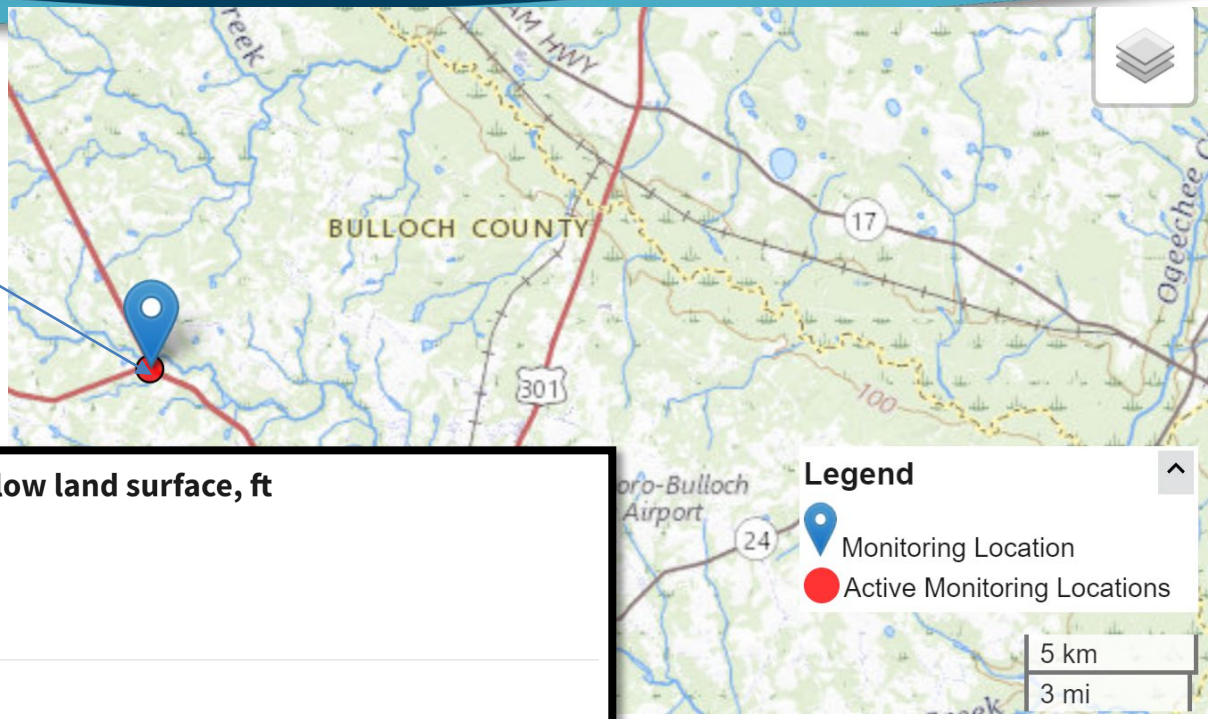


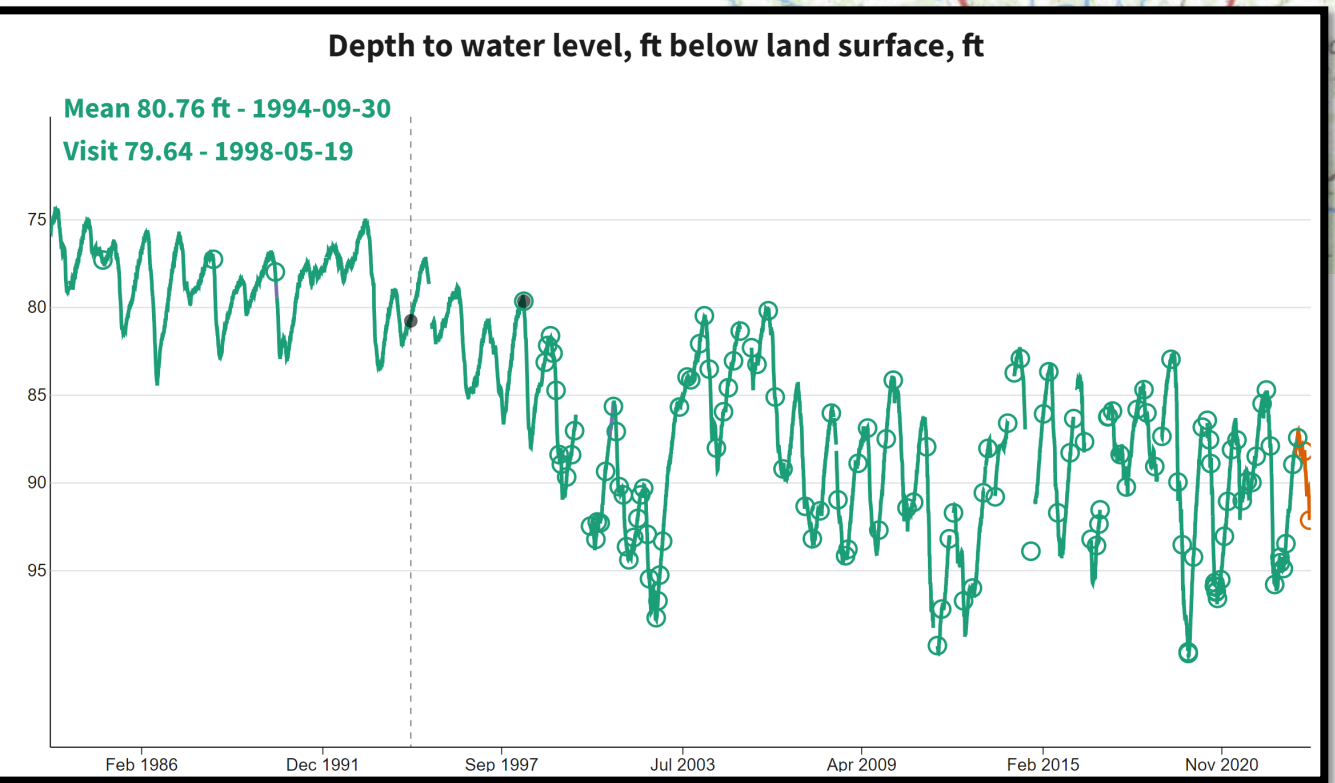


USGS Groundwater Level Measurements – Bulloch County (Green Zone)

USGS Well –31U008 - 323123081511601

Bulloch County

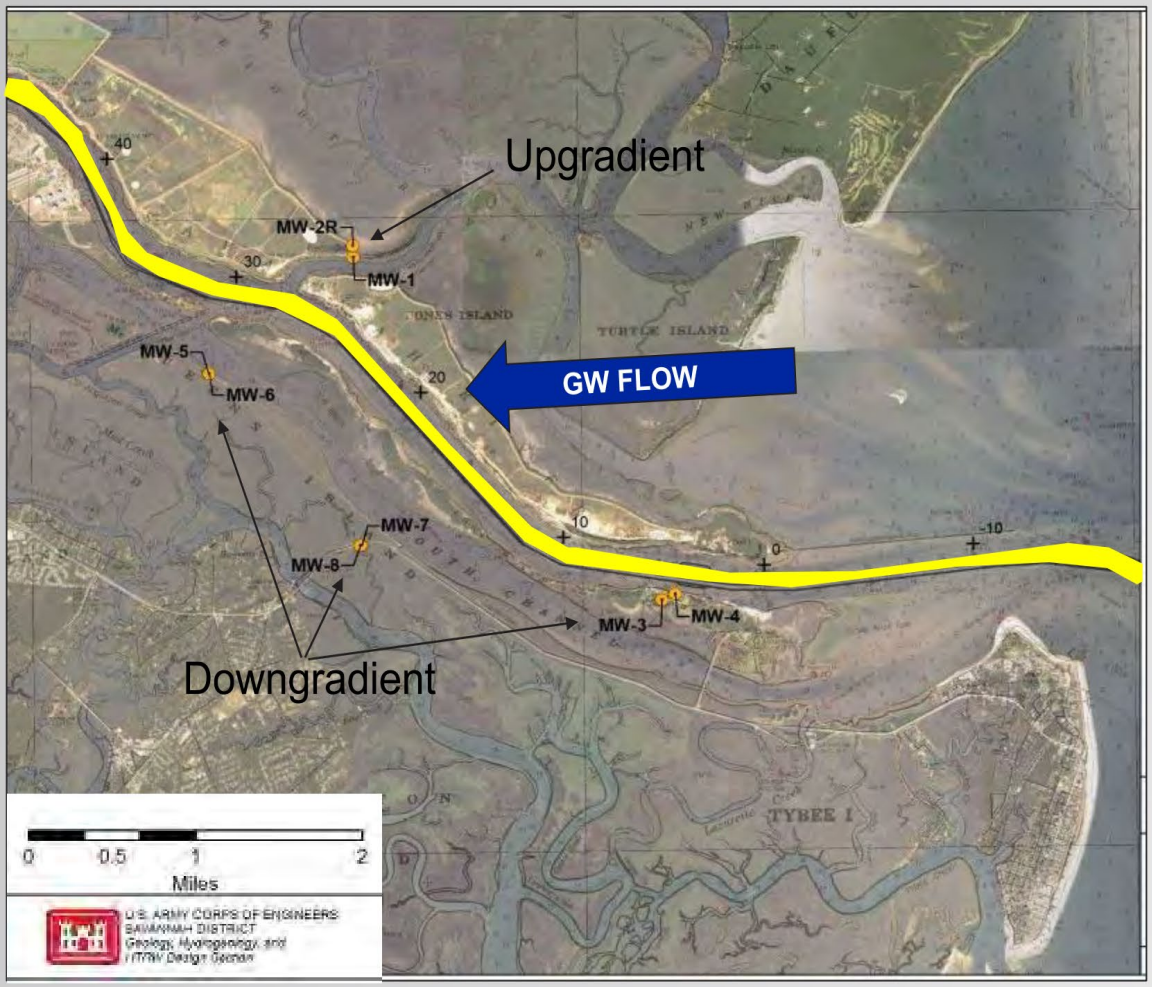


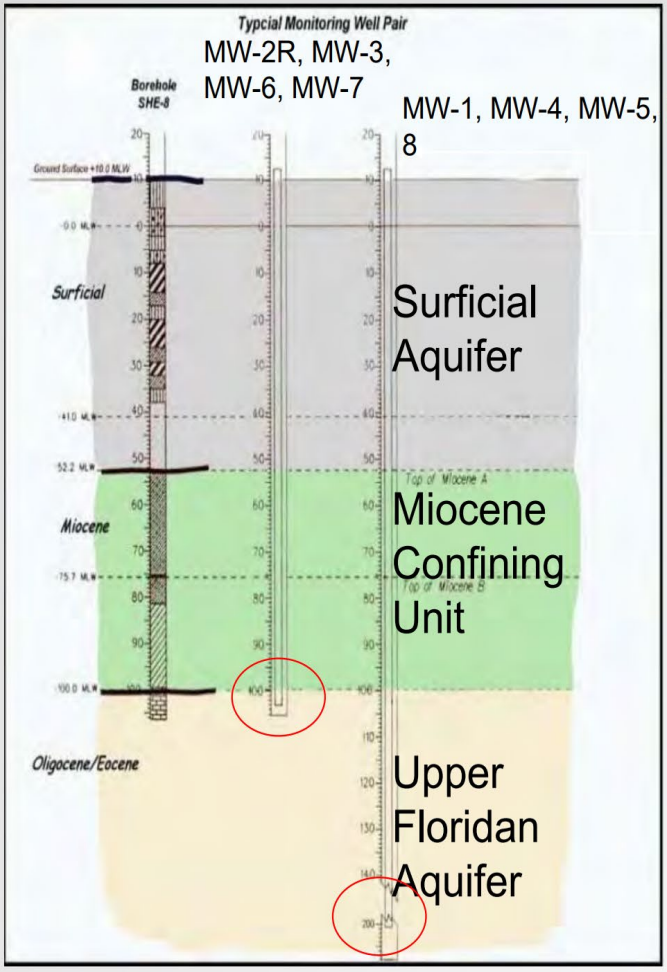


SHEP Groundwater Chloride Monitoring

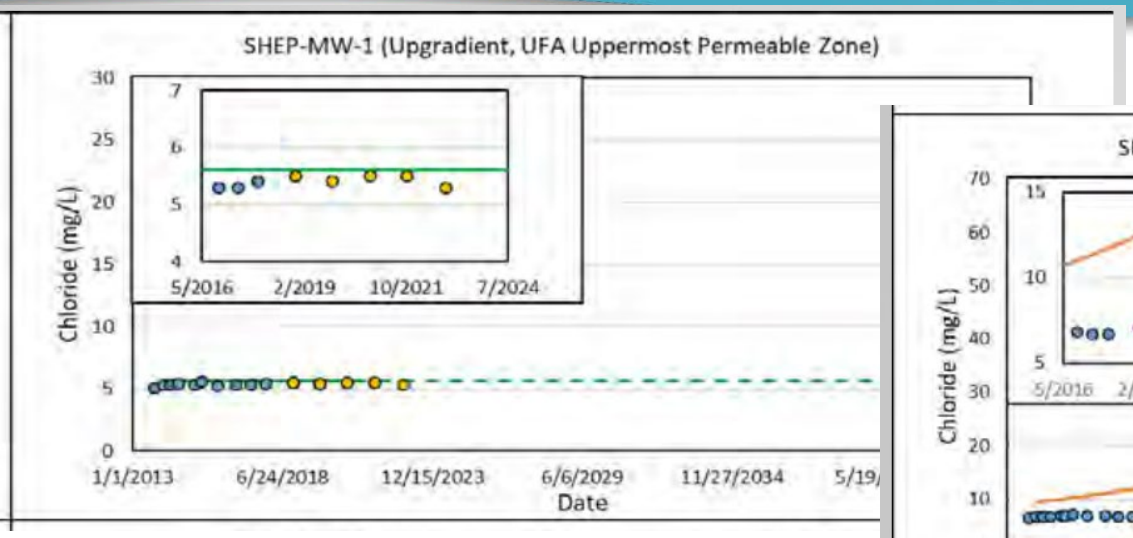
- US Army Corps has 8 sentinel monitoring wells installed to track potential chloride impacts to Floridan aquifer as a result of the Savannah Harbor Expansion Project (SHEP).
- Monitor wells sampled annually for 10 years post construction (Sampling projected out to 2045).
- Last sampling event was November 2022.
- US Army Corps uses a groundwater flow model to project future chloride concentrations at the well locations.

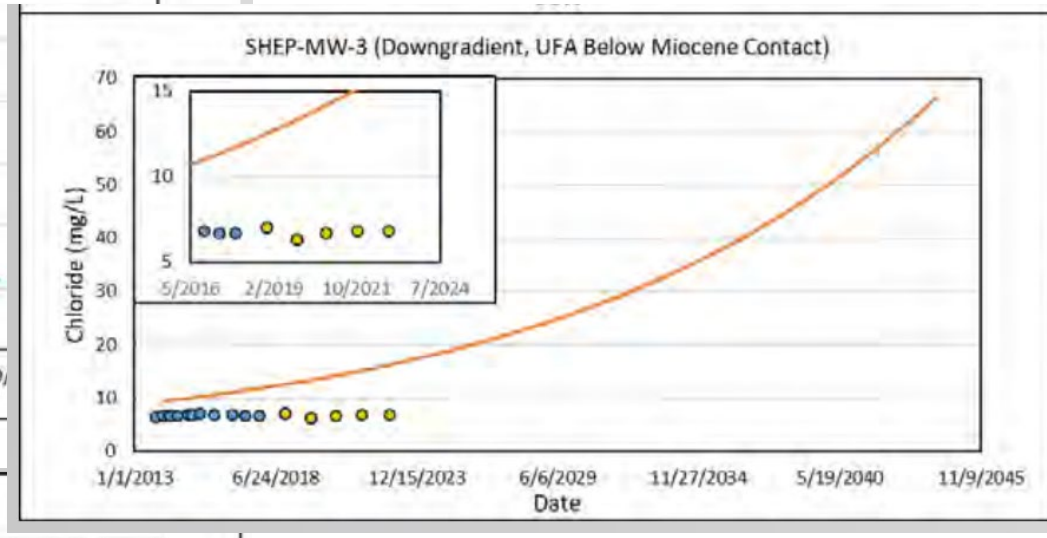
Monitoring Well Locations

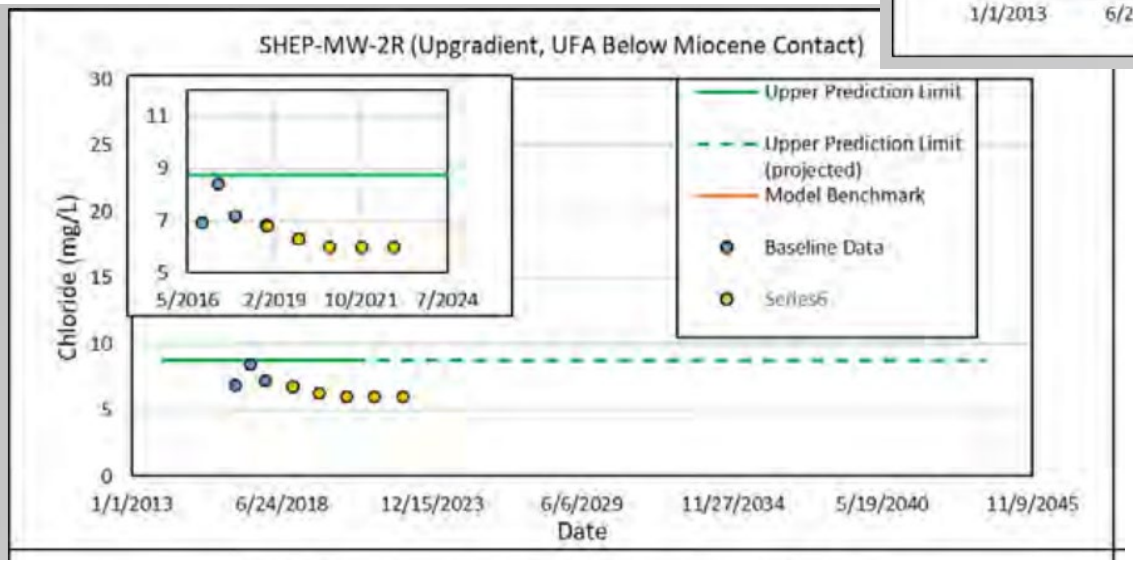


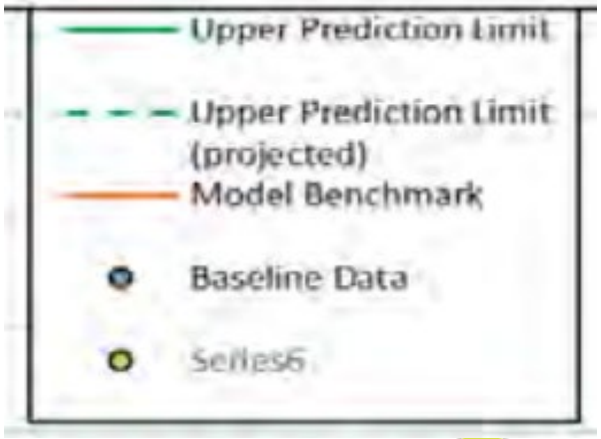


Groundwater Monitoring Results

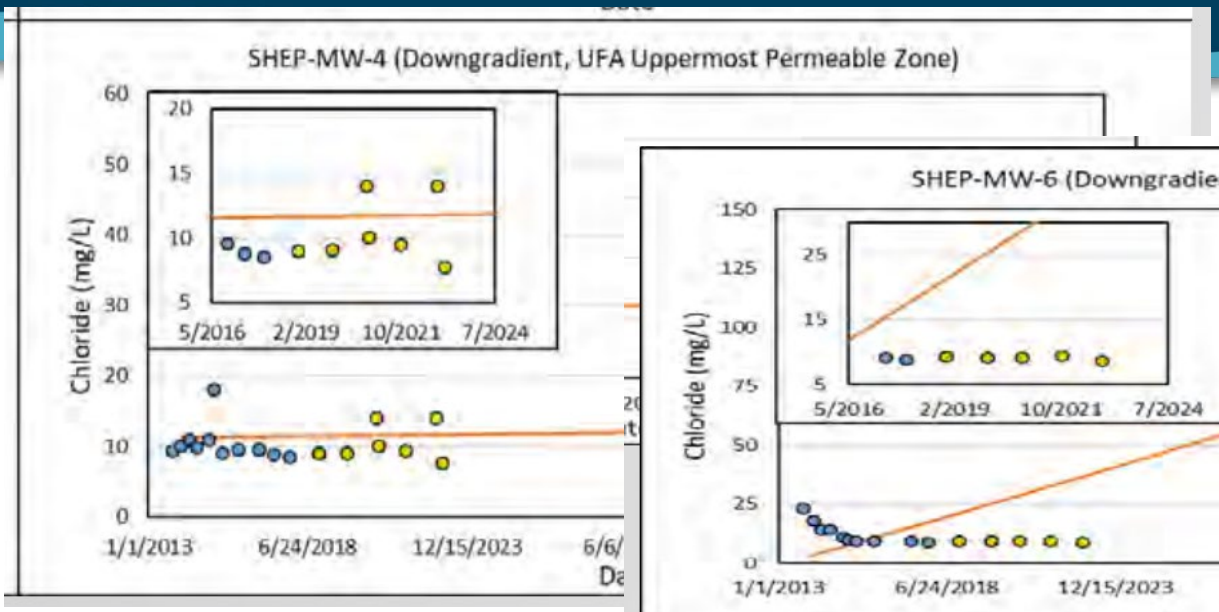


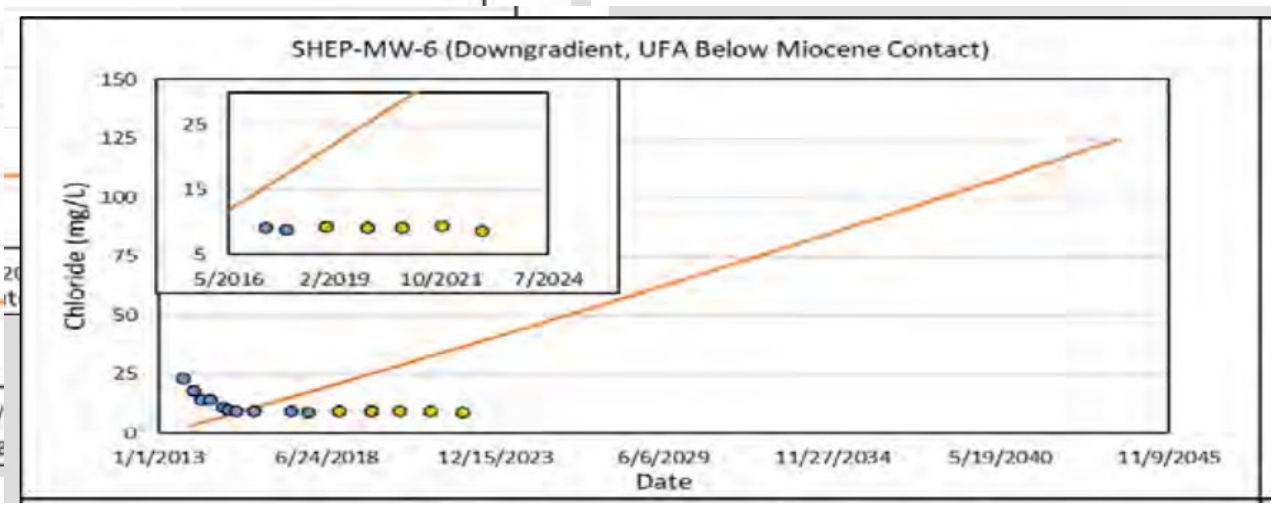


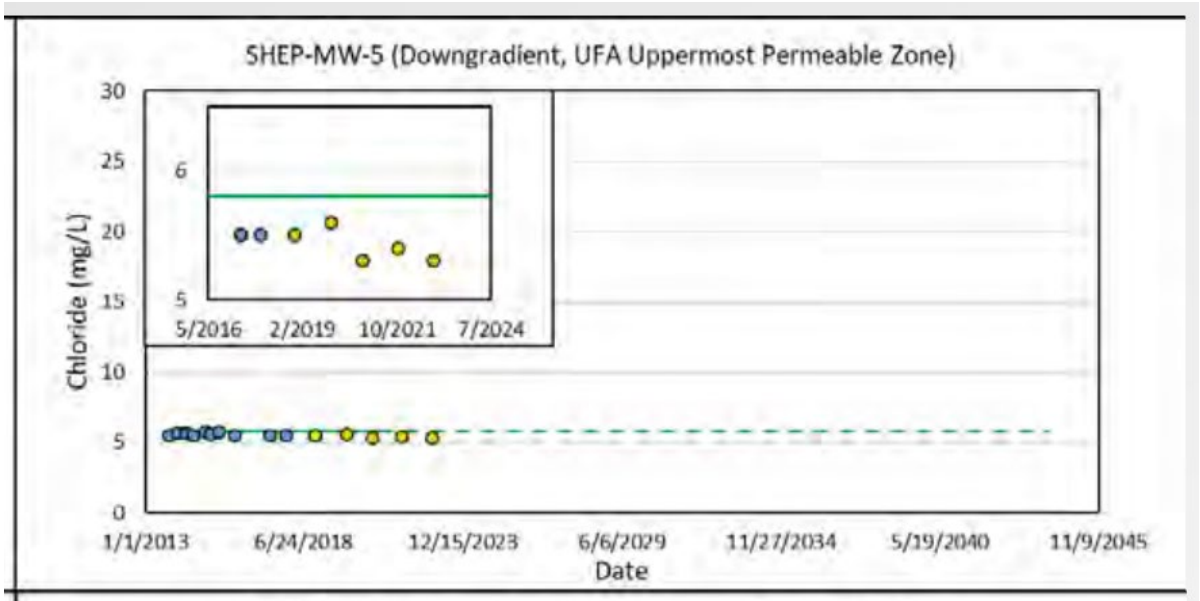


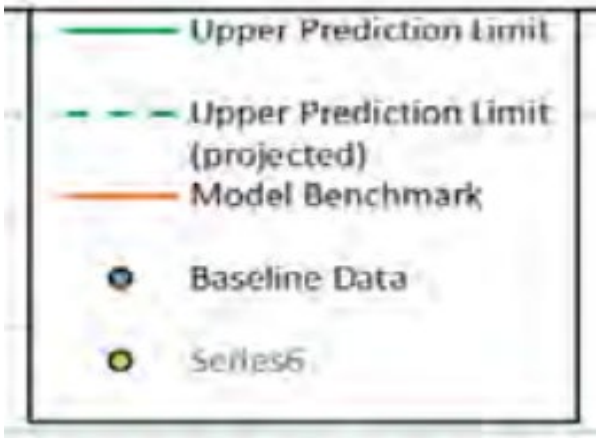


Groundwater Monitoring Results

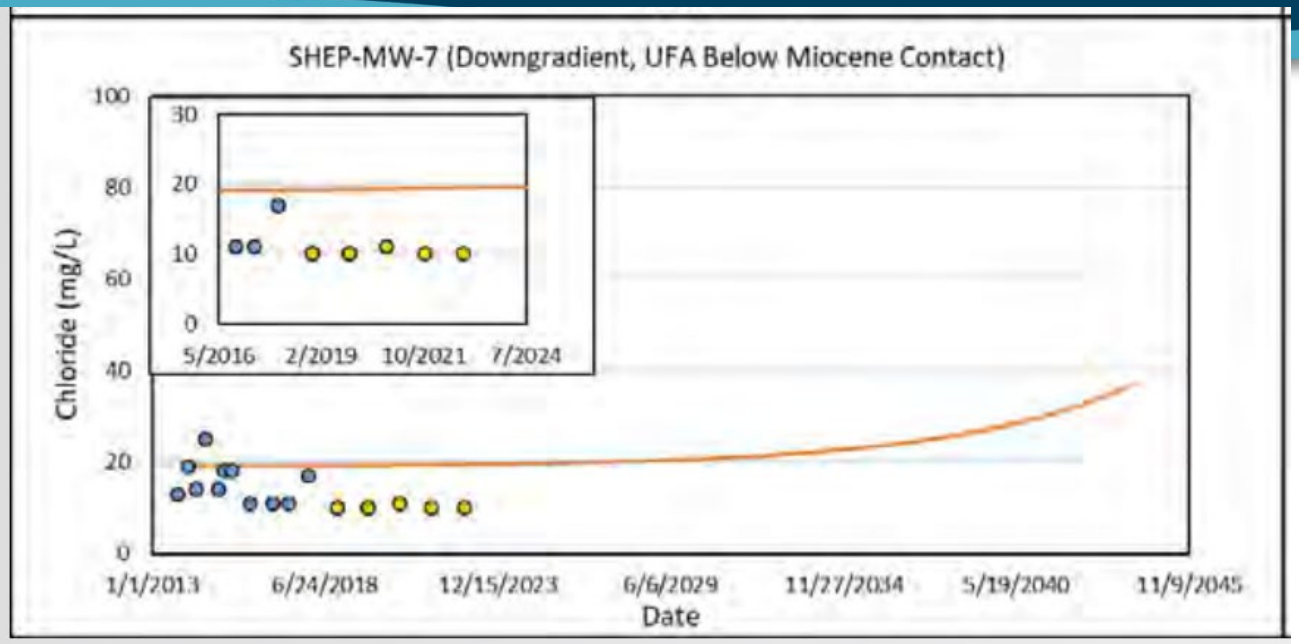


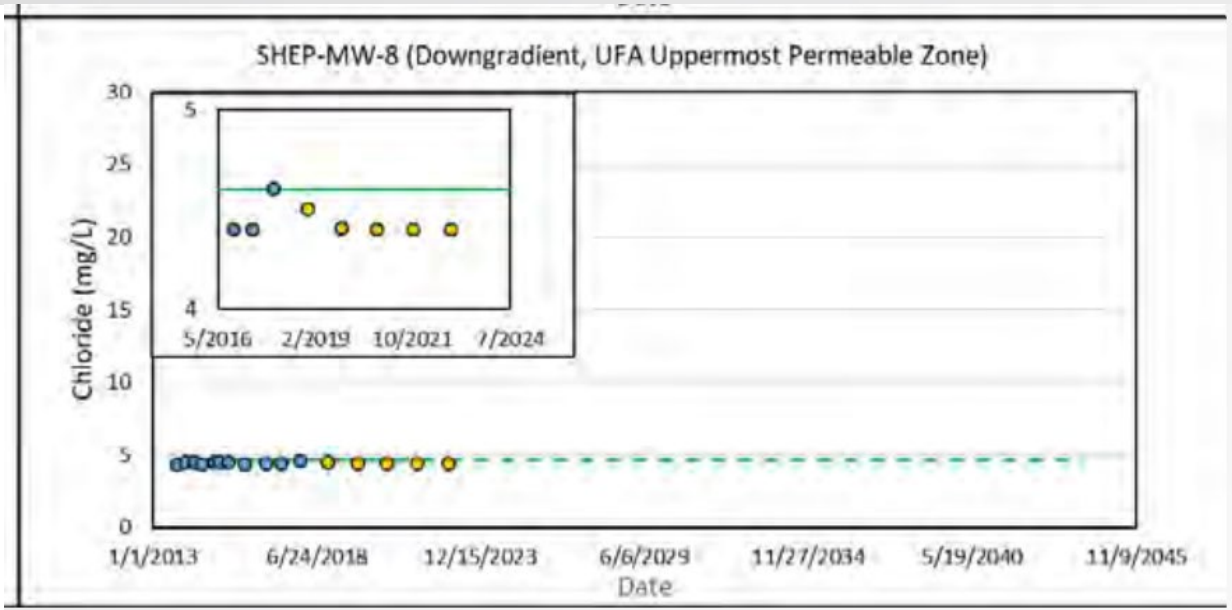


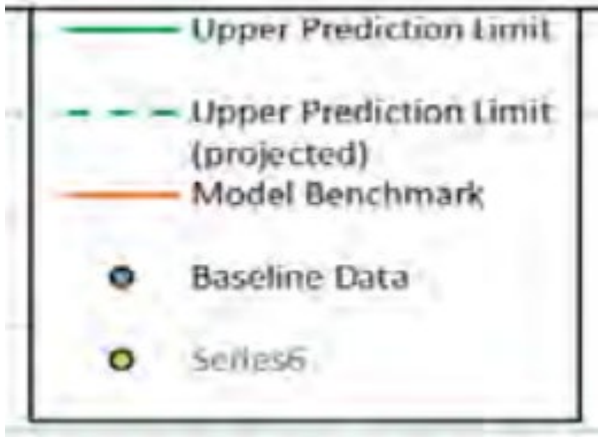




Groundwater Monitoring Results







Conclusions from US Army Corps

- No Cl- concentrations exceeded benchmark values established during the 2017 Background GW Monitoring Report.

- No evidence of Cl- migration to the Upper Floridan Aquifer due to SHEP.

Ongoing Information of Coastal Resources

- Georgia EPD – Coastal Water Study
  - https://epd.Georgia.gov/coastal-water-study
  - Background information and Coastal Permitting Plan Guidance documents
  - Information on the Technical Advisory Committee work
  - Information on the Sound Science Initiative

- US Army Corps of Engineers SHEP Monitoring Reports
  - http://shep.uga.edu/reports.html
  - Information on the Sentinel monitoring wells
  - Other monitoring data associated with the SHEP

- USGS South Atlantic Water Science Center – Coastal Sound Science Initiative:
  - https://www2.usgs.gov/water/southatlantic/ga/projects/coastal/index.html
  - Real Time monitoring of wells in Coastal Georgia
  - Background information on Coastal history
  - Coastal Sound Science Initiative Publications

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Summary

- Monitoring results affirm effectiveness of management practices put in place.
  - Water conservation efforts have contributed to reductions in water use over time.
  - Voluntary/mandatory reductions in permitted withdrawals have also contributed to overall usage declining.
- Challenges continue to exist
  - Reducing groundwater withdrawals from the aquifer, even by large amounts, would not eliminate salt-water intrusion into the aquifer.
  - Even if pumping was eliminated, the chloride plume will exist on Hilton Head Island.
- Foresight and Continuous Effective Management of the Resource is needed
  - Measure and monitor the health of the Floridan Aquifer system as a whole to address future challenges

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