Coastal Aquifers

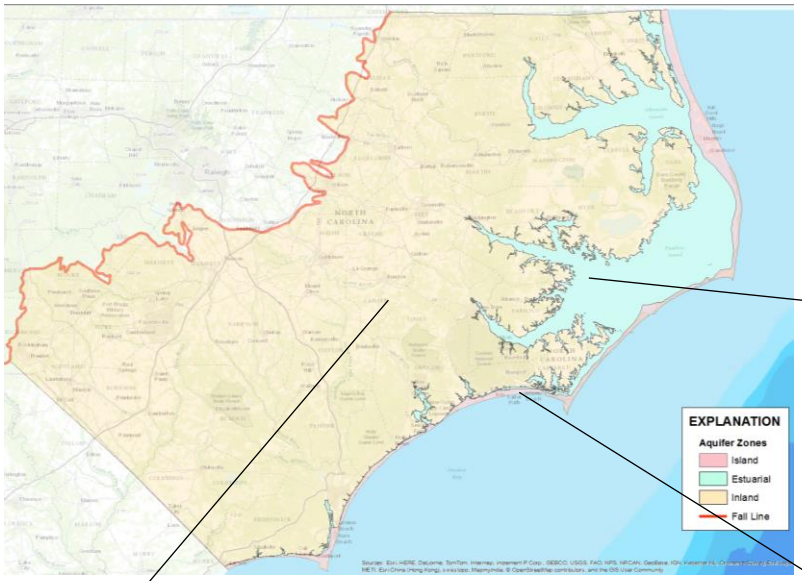
Salt Water Intrusion and other Challenges

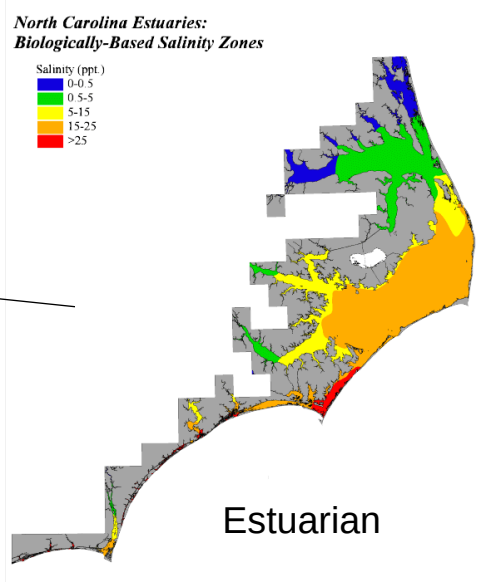
ACEC Wilmington, NC
March 15, 2017

Topics

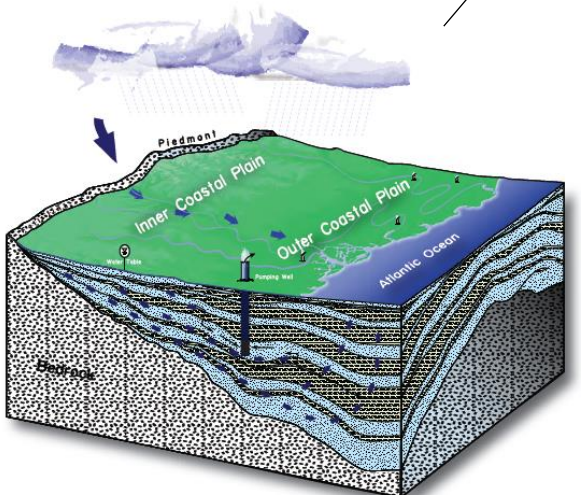
- North Carolina Coastal Aquifers
- Hydrogeology & Hydraulics of Coastal Aquifers
- Development Impacts on Coastal Aquifers
- Management of Impacts to Coastal Aquifers

North Carolina Coastal Aquifer Zones

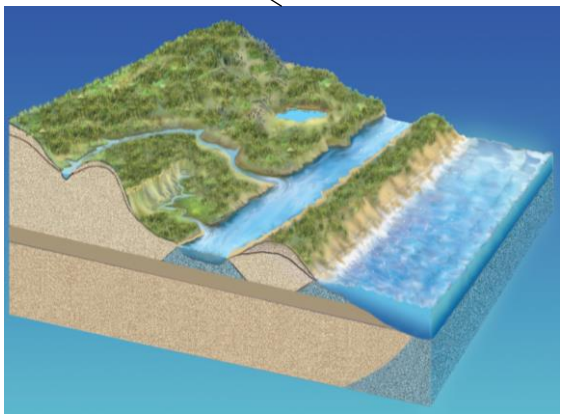




Estuarian

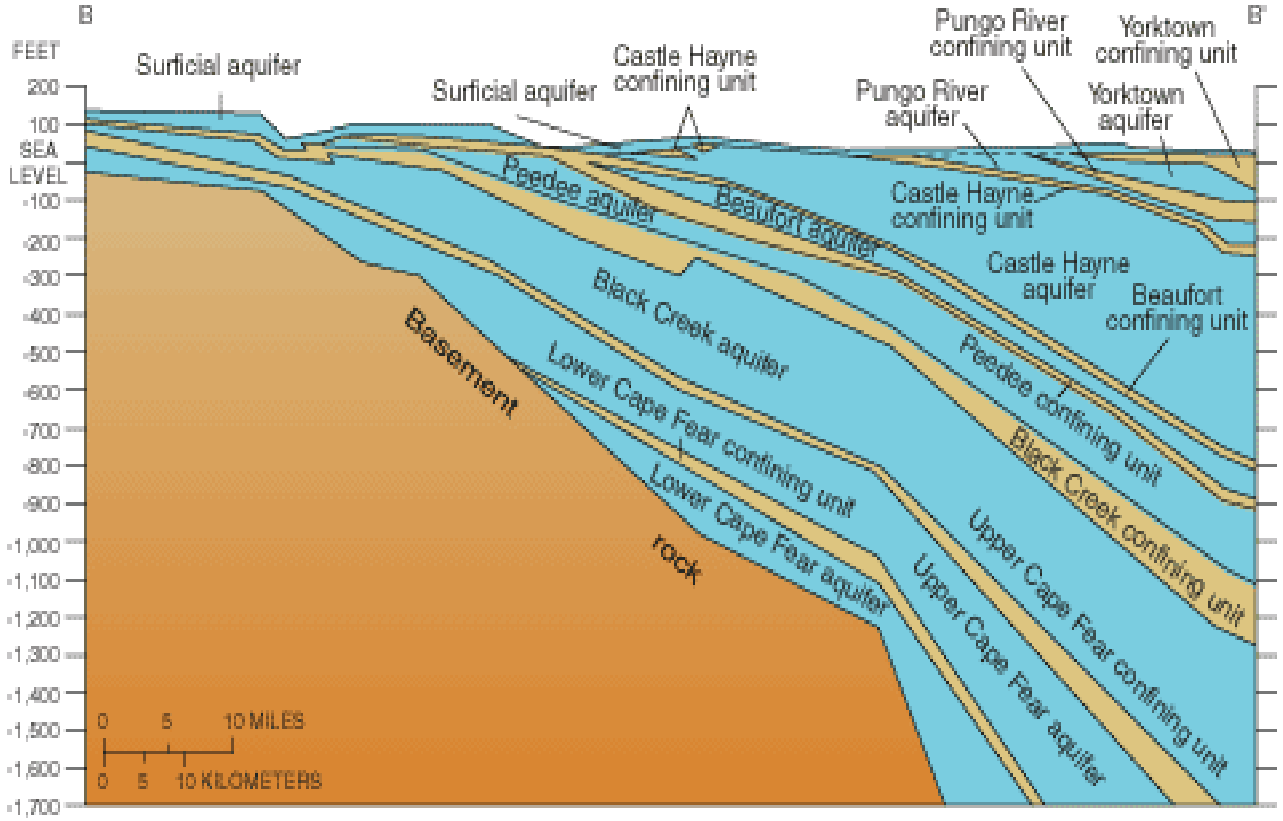


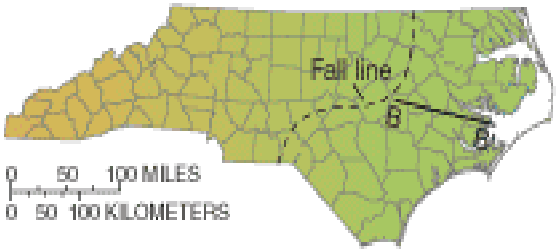
Coastal Plain



Barrier and other Islands

North Carolina Coastal Plain Aquifer System

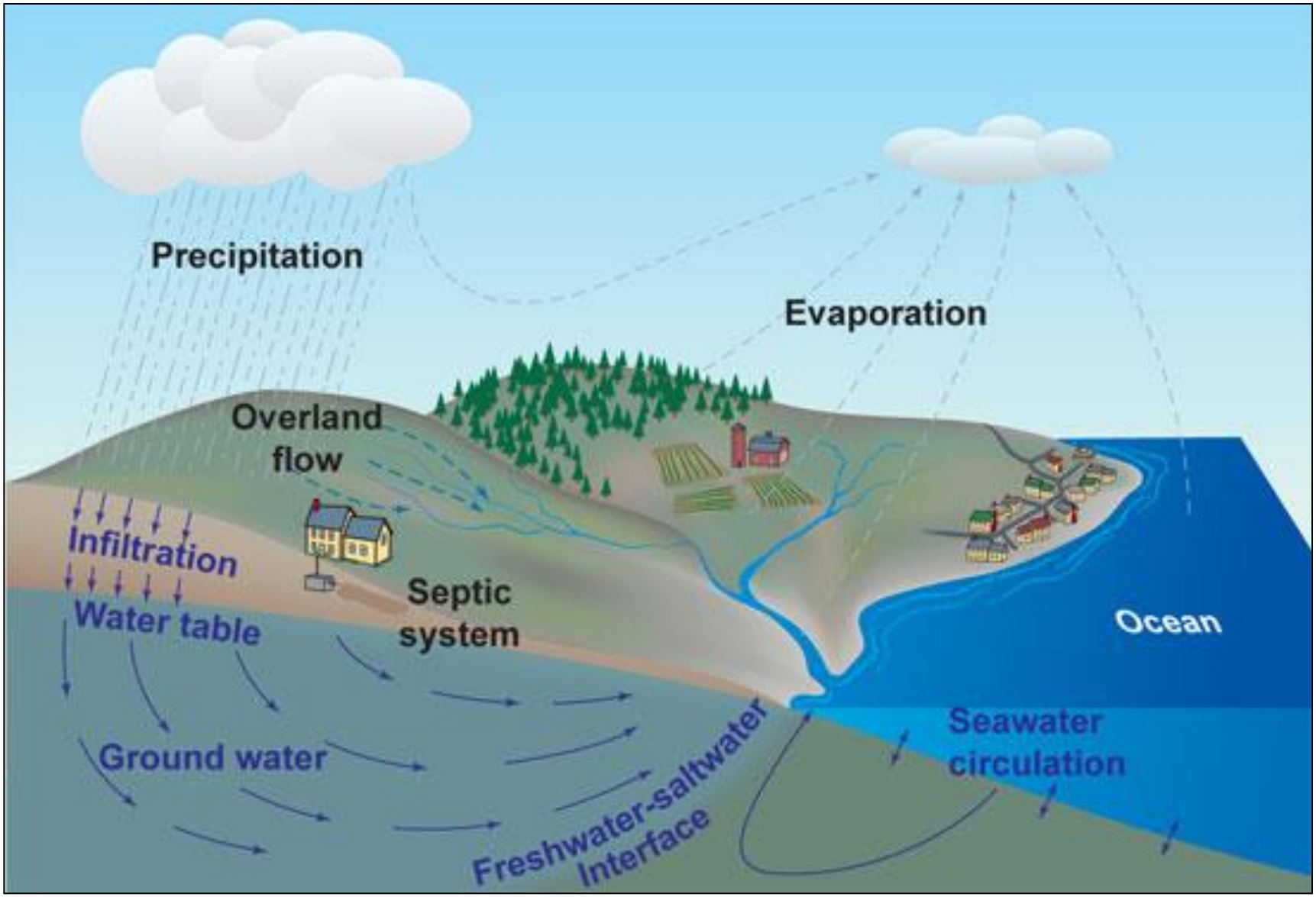




LOCATION OF SECTION B-B'
AND FALL LINE IN NORH CAROLINA

Source: NC DWR

Coastal Hydrologic Cycle



Salt Water Statics

Density Driven Hydraulic Head

- Ghyben-Herzberg Relation:
  - Depth to Interface ~ 40 X Potentiometric Surface Elevation

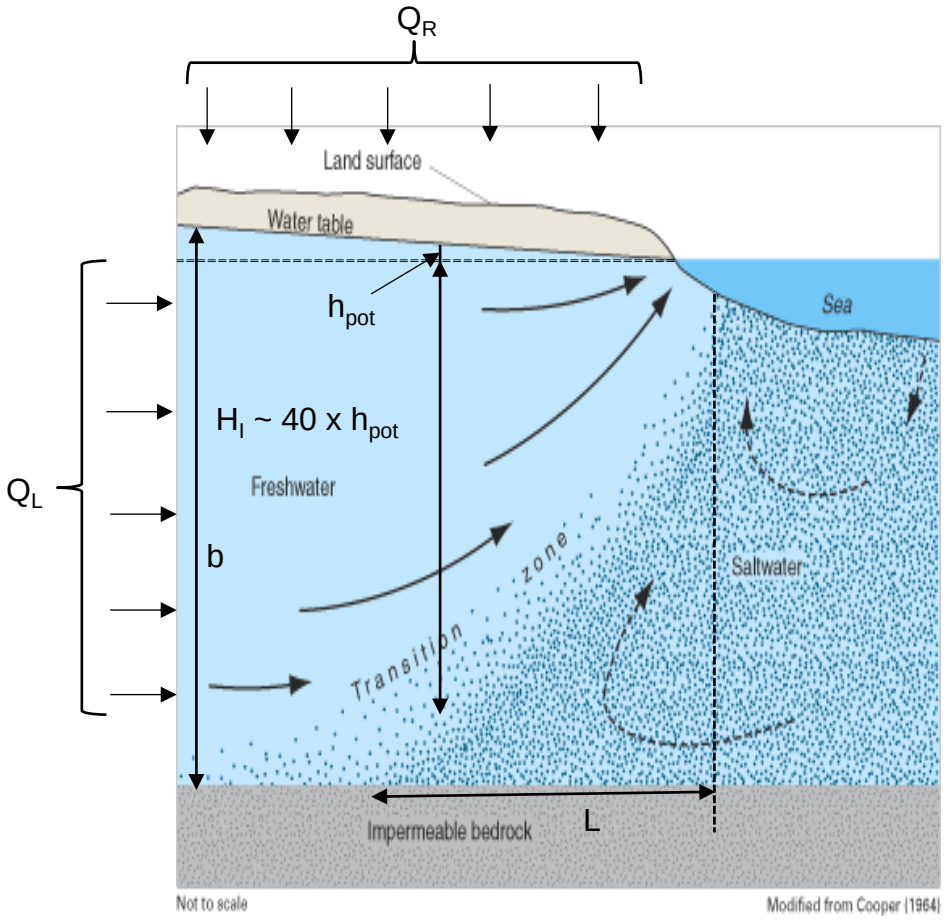
$$H_I = \frac{r_F}{(r_S - r_F)} h_{POT} = 40 h_{POT}$$

  - Intrusion Distance

$$L = \frac{1}{2} \frac{(r_S - r_F)}{(Q_L + Q_R) r_F} K b^2 = 0.0125 \frac{K b^2}{Q_T}$$

Controls on Potentiometric Surface Elevation

- Recharge Rate (***Q_R***)
- Lateral Flow (Q_L)
- Pumping/Injection (Q_P)
- Stratigraphy *(K & b)*

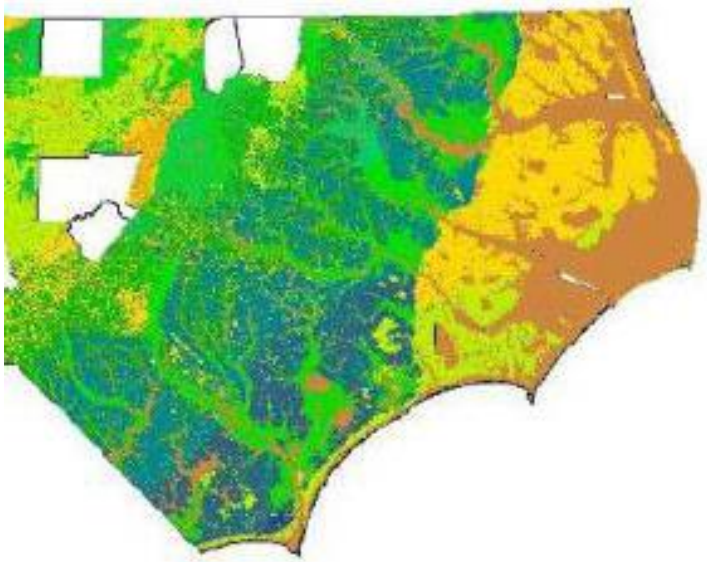


Factors that Affect Saltwater Intrusion

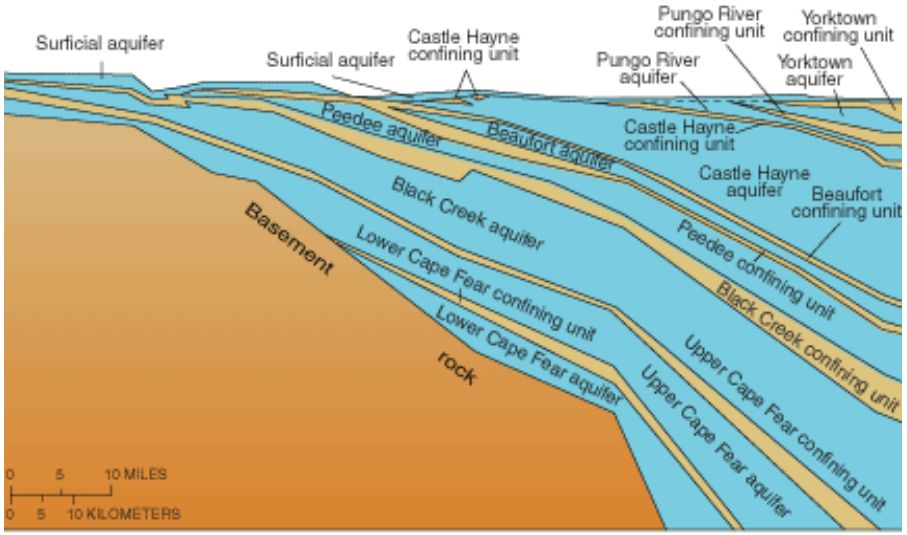
- Climate
  - Variable Recharge Rates (Precipitation – Runoff – Evapotranspiration)
  - Boundary Conditions - Sea Level Rise
- Stratigraphy
  - High and Low Permeability Layers
  - Anisotropy within Single Layers
  - Porosity Differences
- Discharge
  - Pumping
    - Water Level Declines
    - Dewatering
    - Salt Water Encroachment
    - Up-coning by Pumping
- Changes in Recharge
  - Agriculture
  - Urbanization

Hydrologic Controls on Interface Position

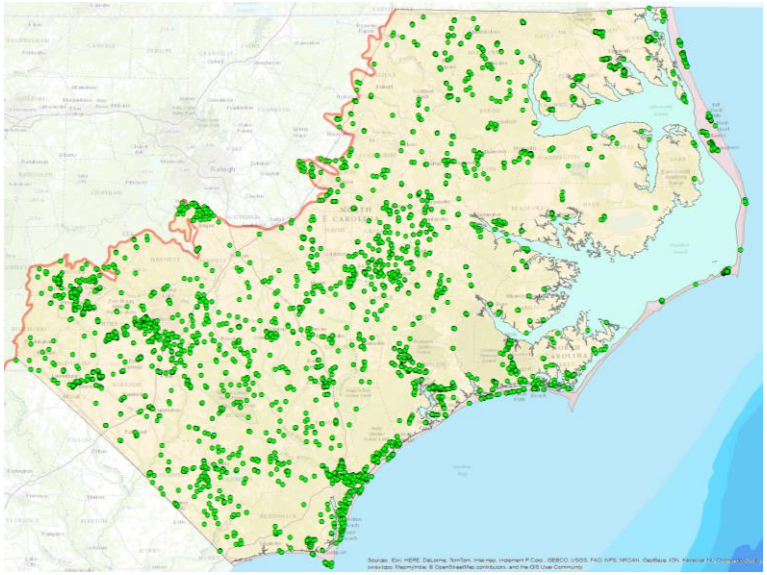
Net Recharge



Stratigraphy (K & b)

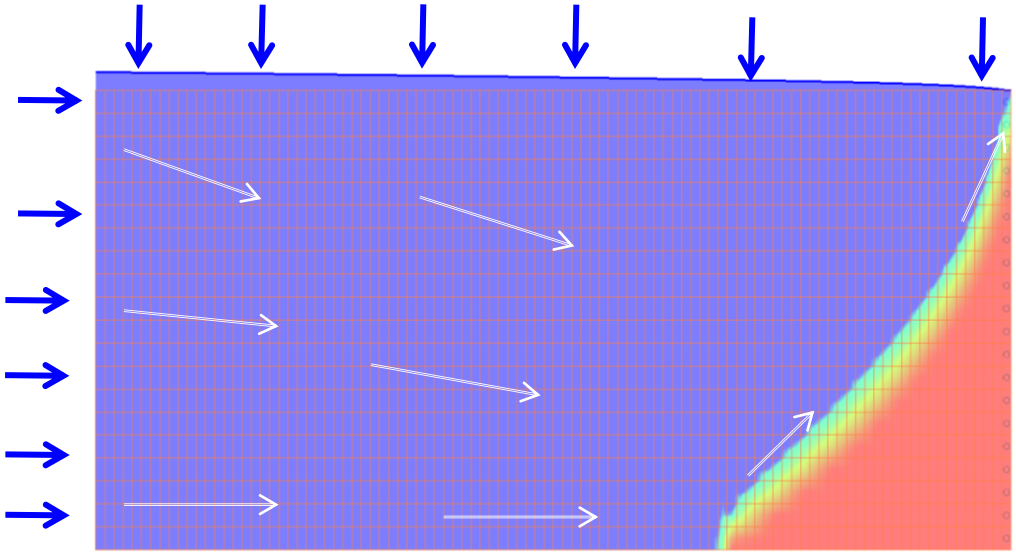


Groundwater Withdrawals

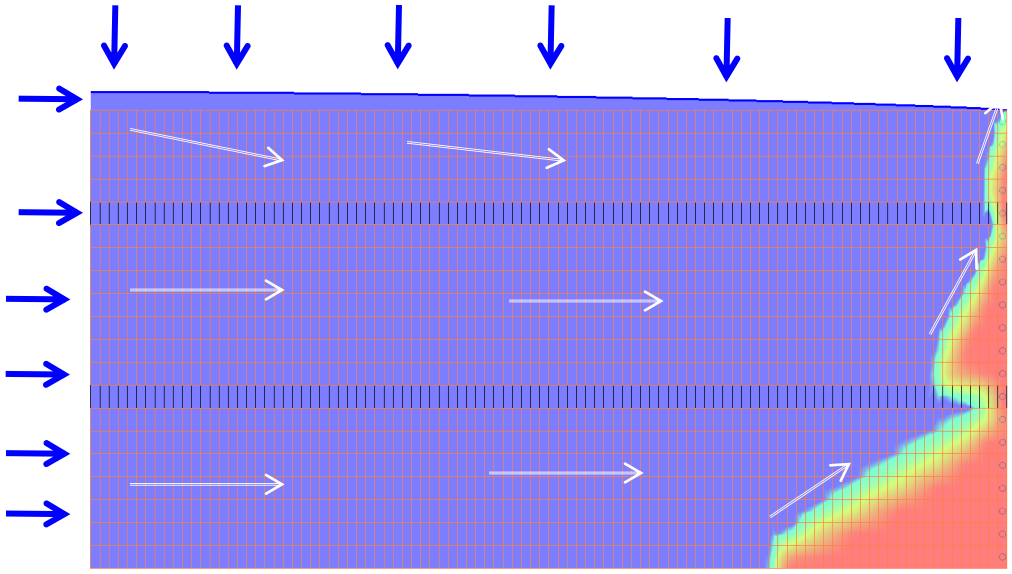


Effect of Hydraulic Conductivity

Non-Layered and Isotropic

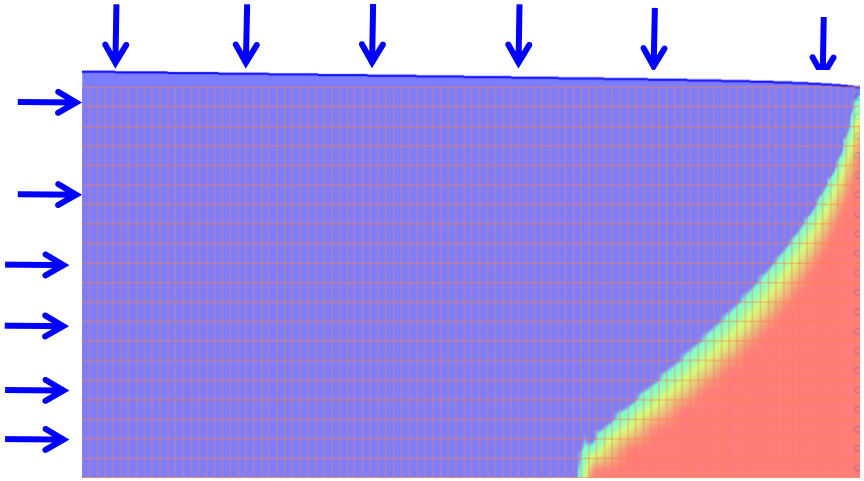


Layered and Anisotropic

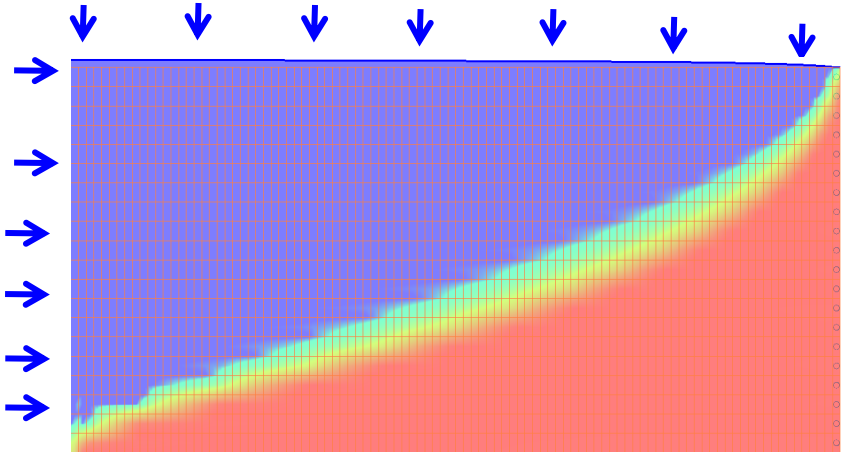


Effect of Changes in Recharge

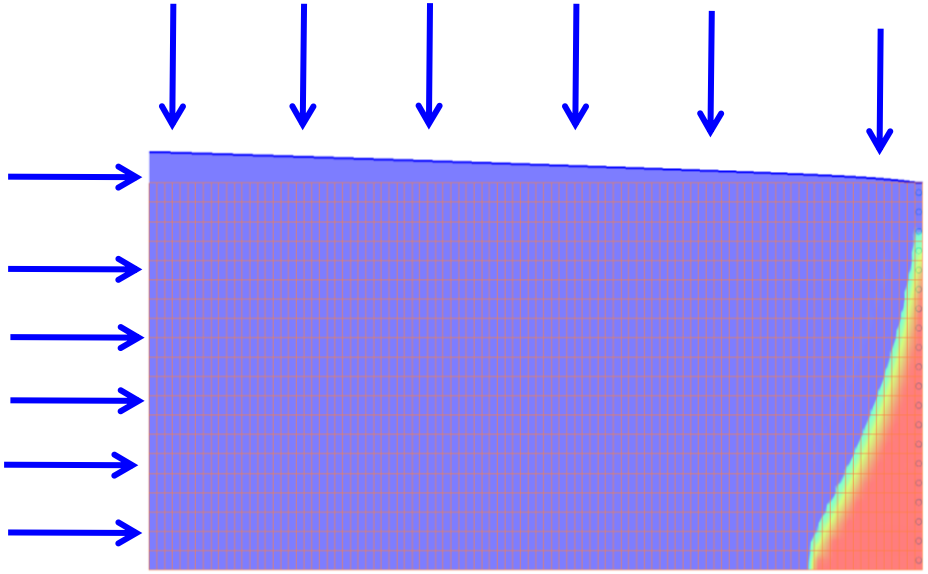
100 % of Natural Recharge and Lateral Q



50% of Natural Recharge & Lateral Q

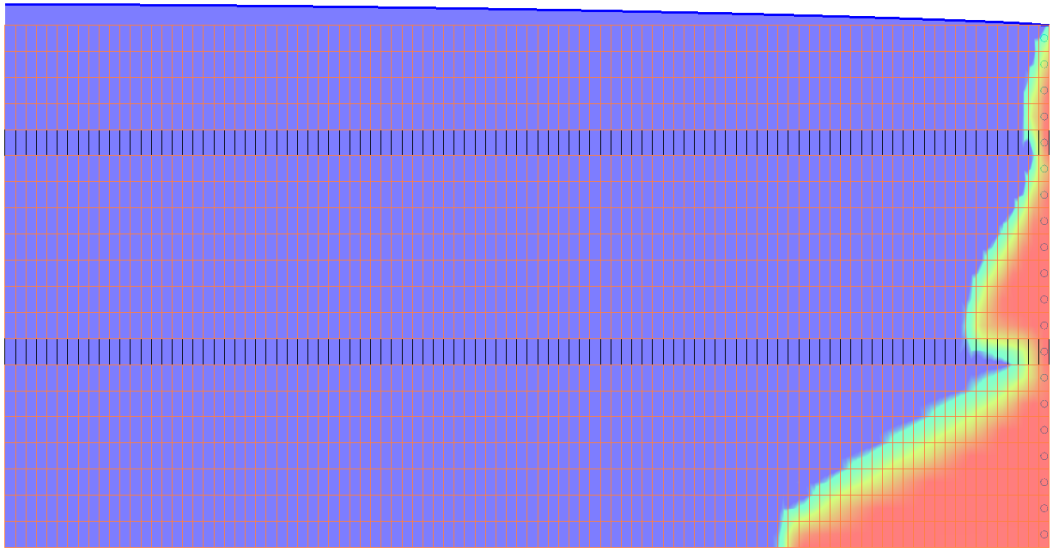


200% of Natural Recharge & Lateral Q

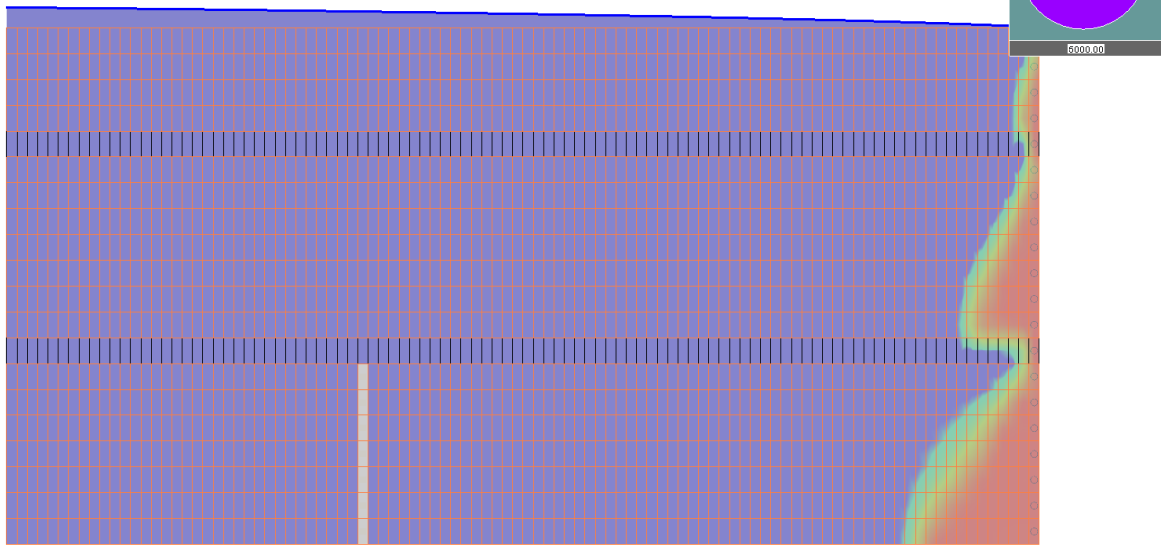


Wells Pumping from One Aquifer

No Pumping

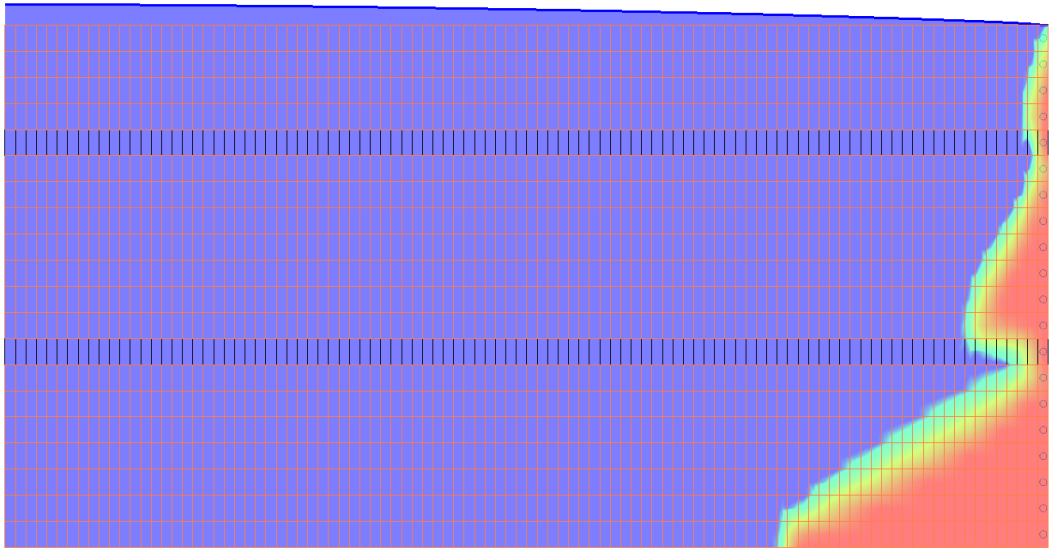


Pumping from
Bottom Aquifer

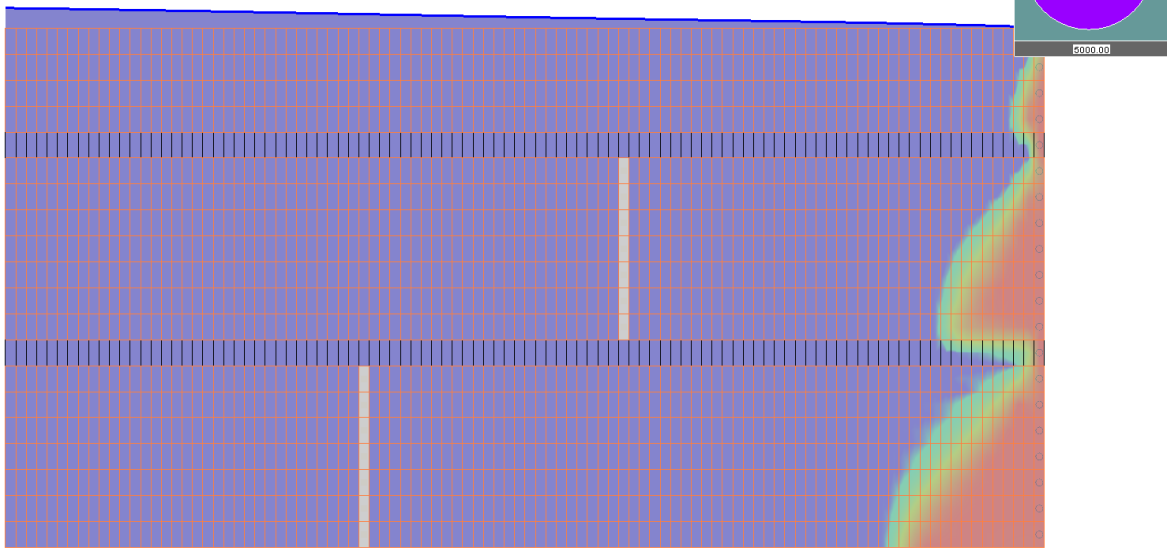


Multiple Pumping Wells

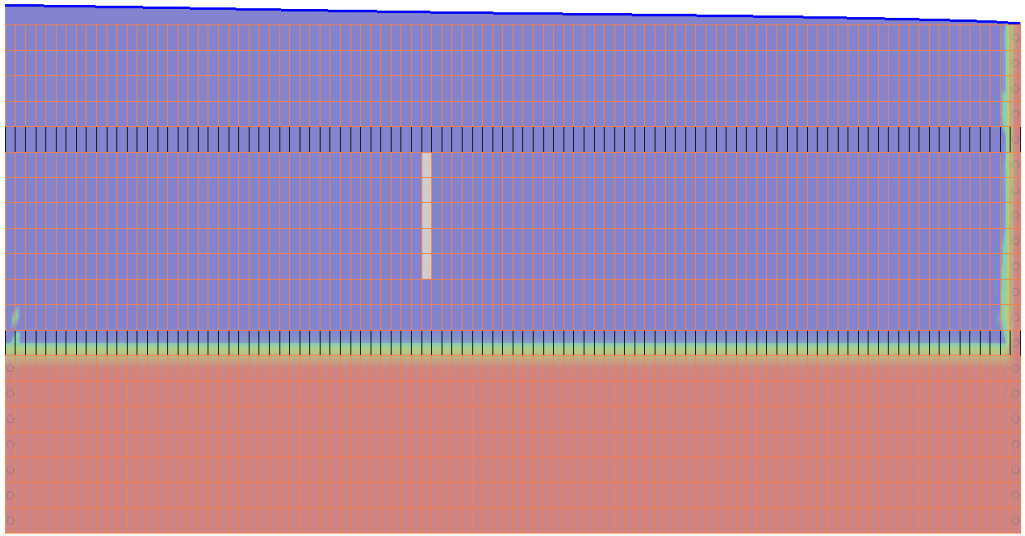
No Pumping



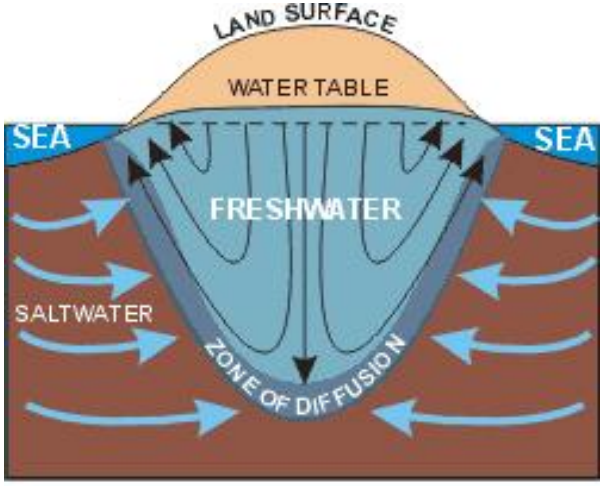
Pumping from Middle and Bottom Aquifers

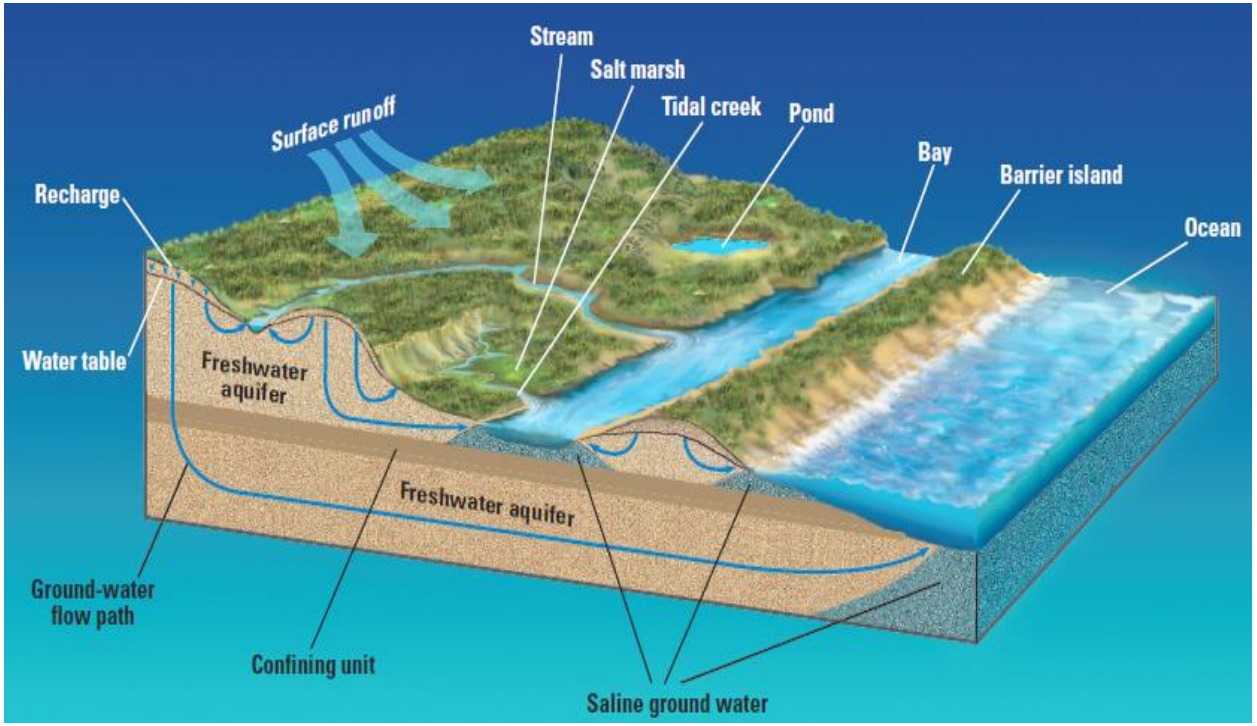


Up-coning from Pumping

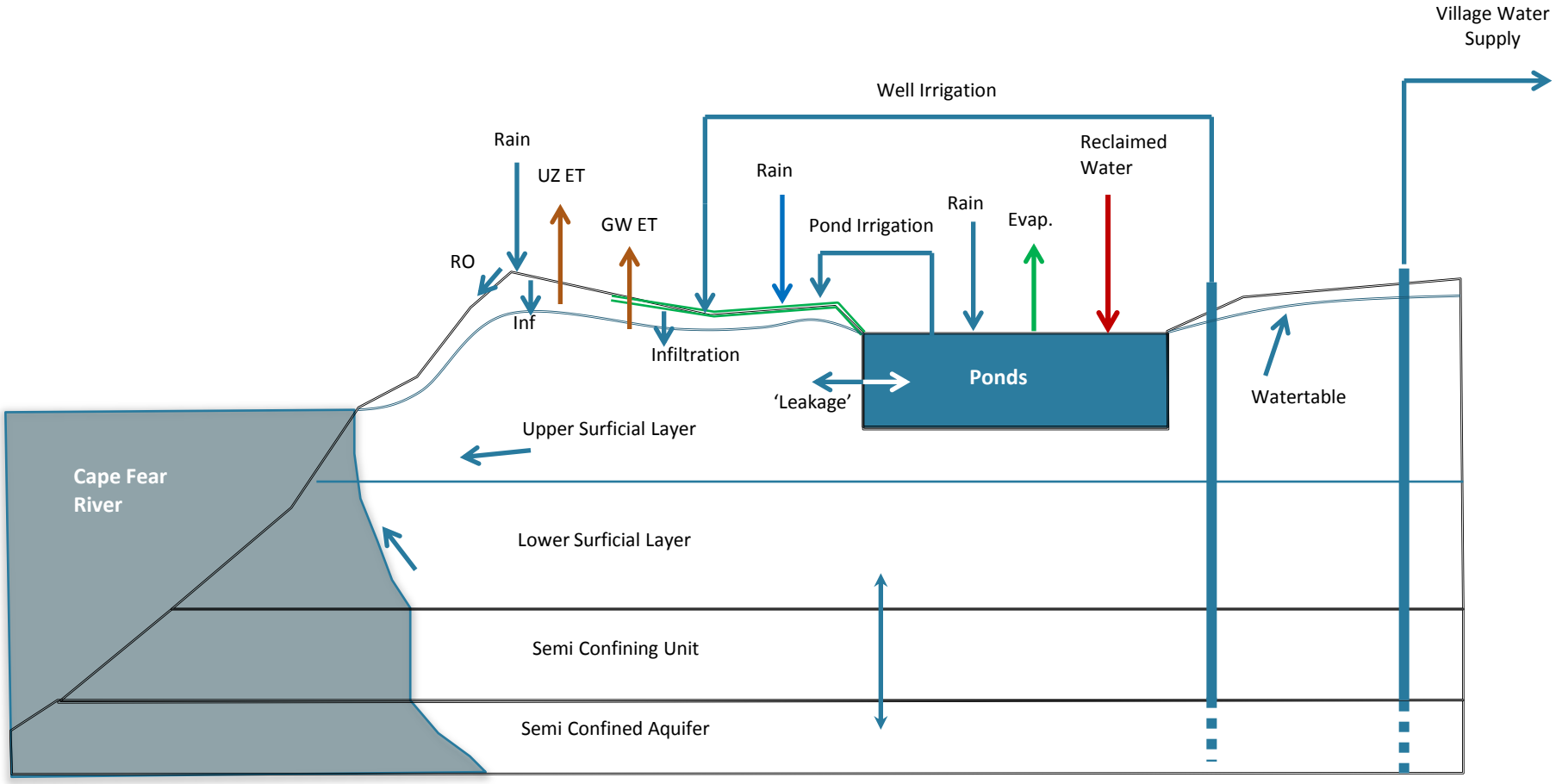


Island Aquifers





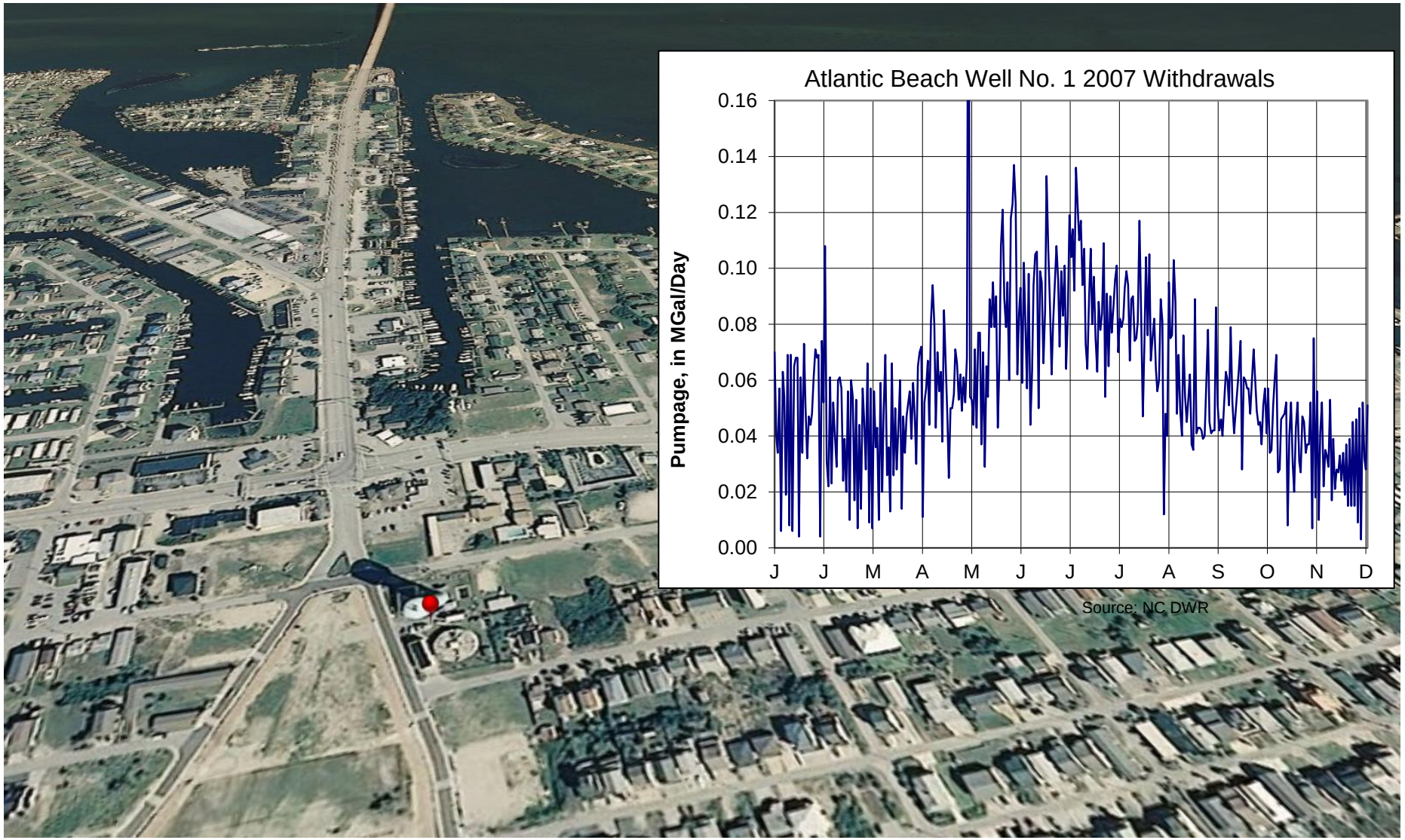
Bald Head Island Hydrologic System



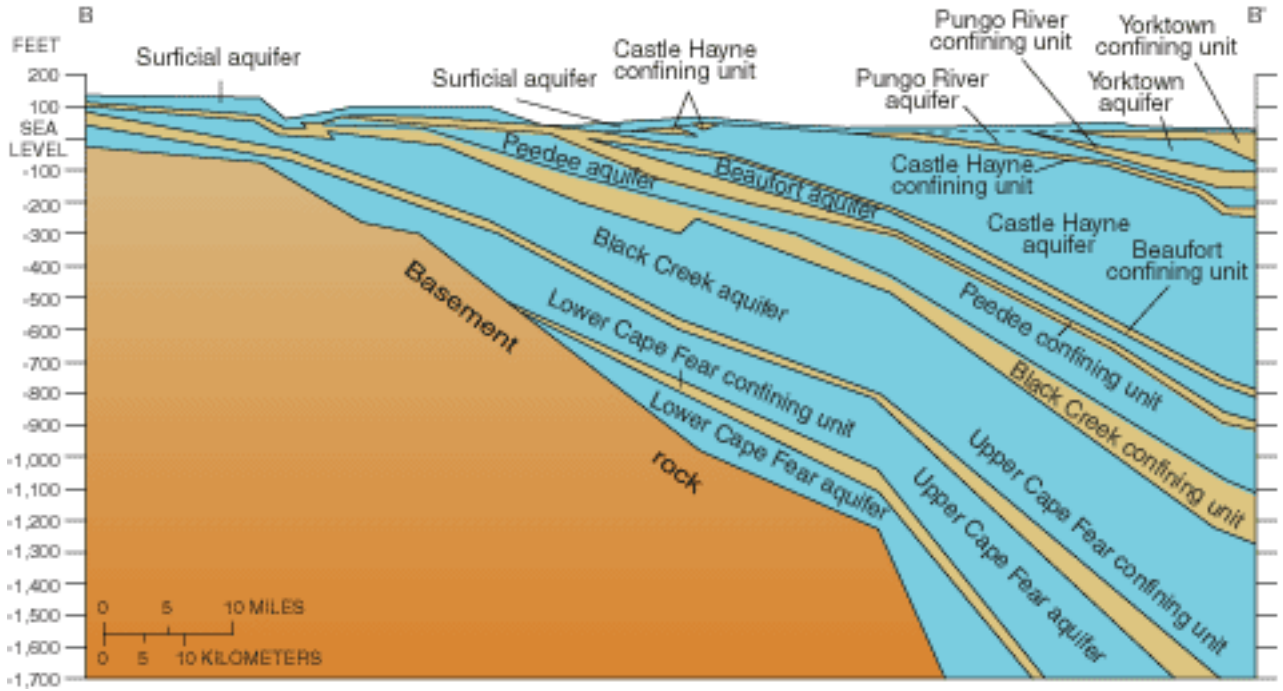
Eagle Resources

Bald Head Island Water Supply & Irrigation Wells

Island Aquifers & Seasonal Demand



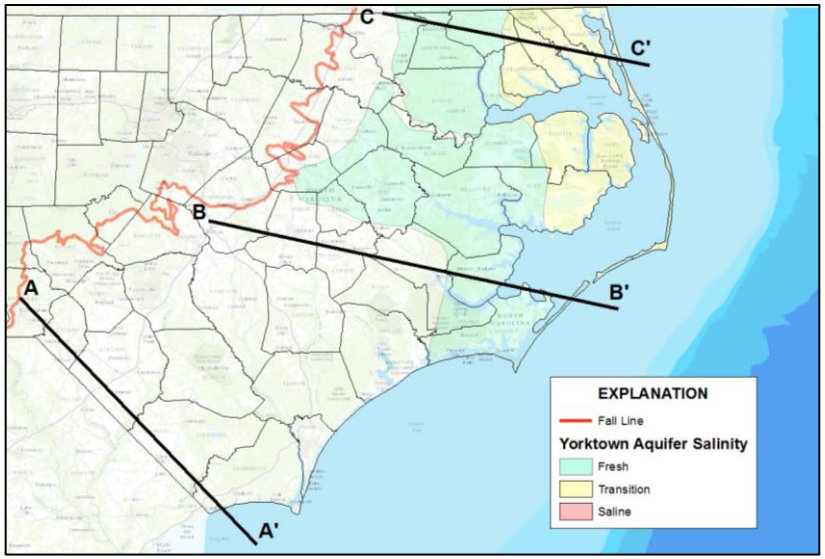
North Carolina Coastal Plain Aquifer System



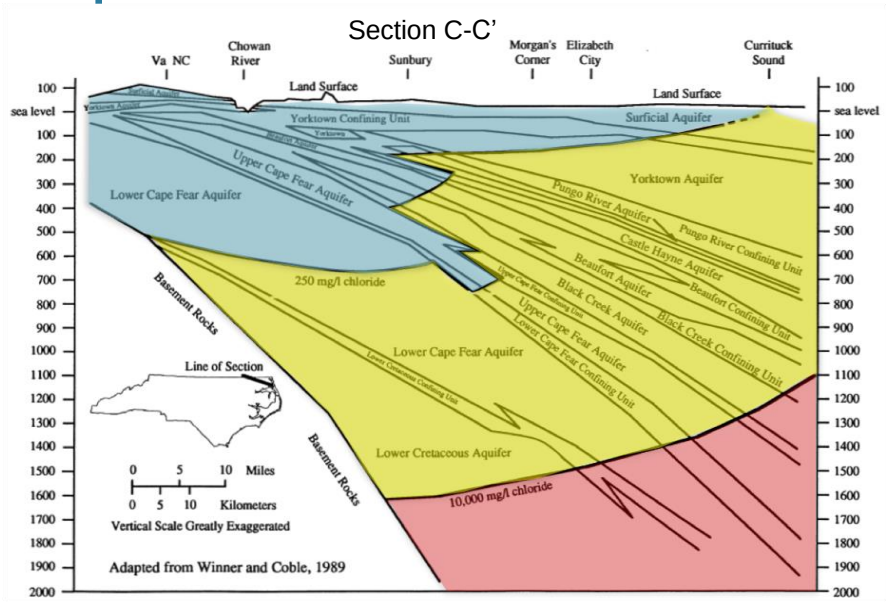
LOCATION OF SECTION B-B'
AND FALL LINE IN NORH CAROLINA

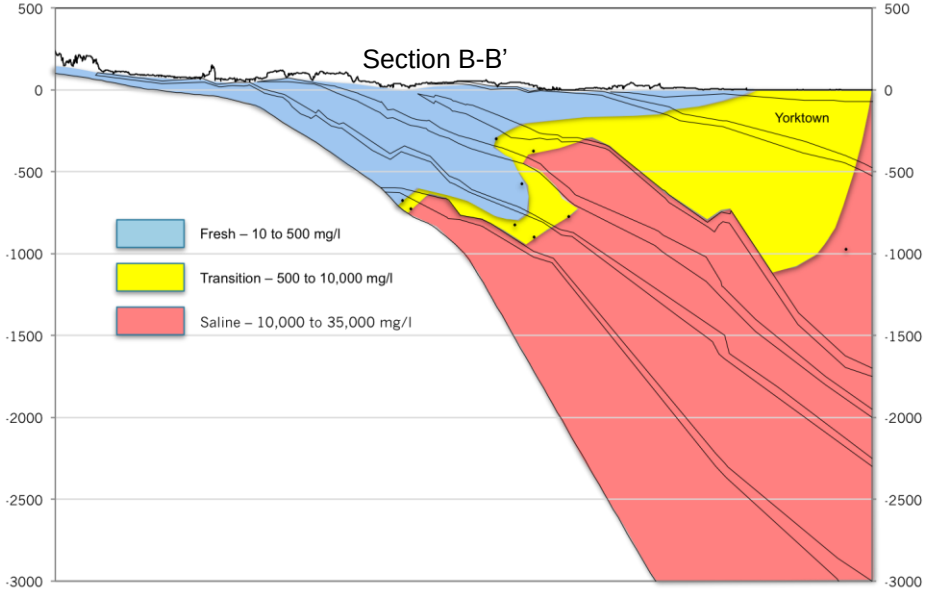
Source: NC DWR

Yorktown Aquifer

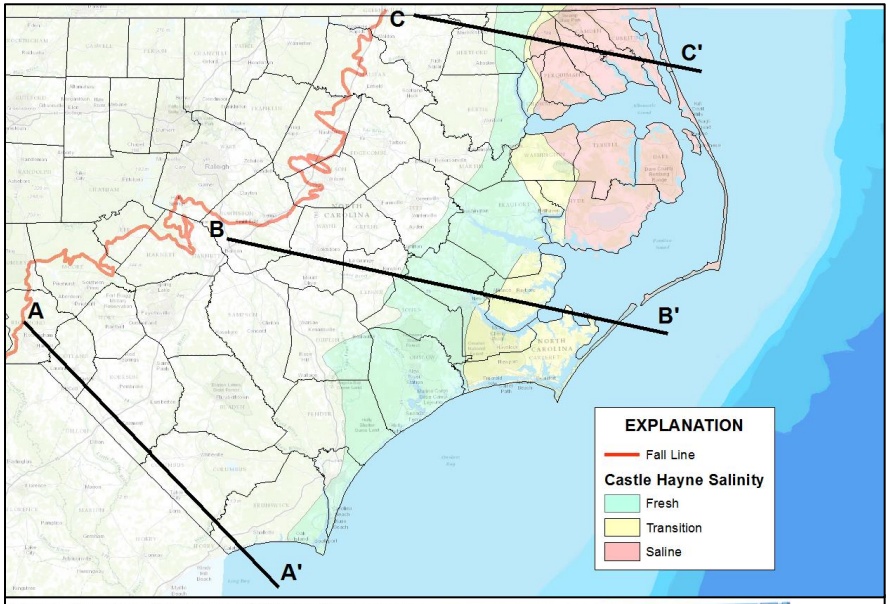


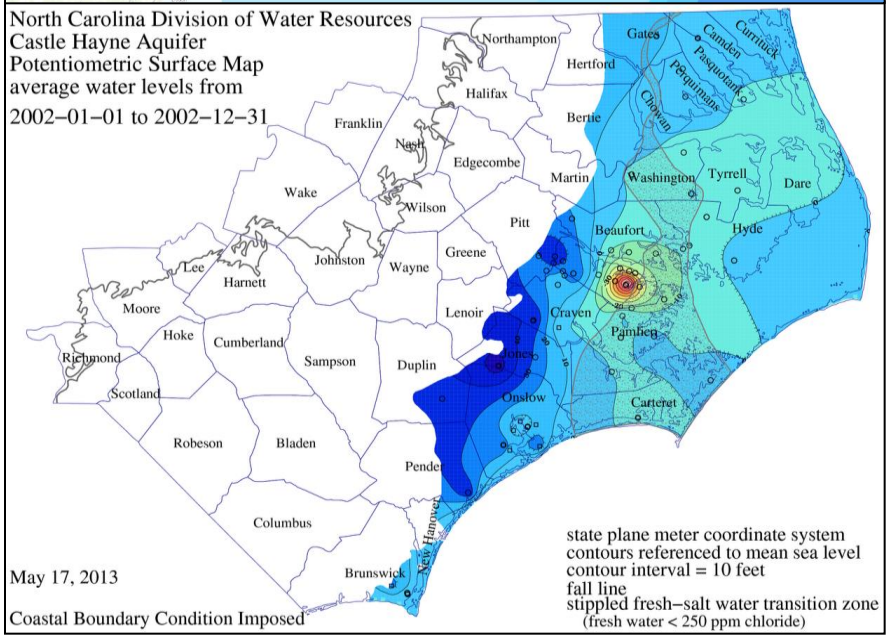
Source: NC DWR

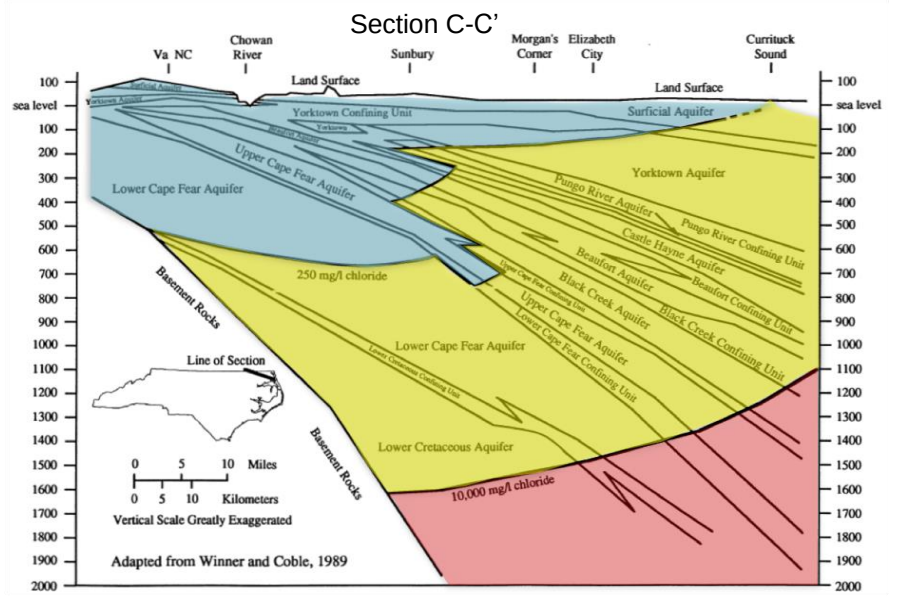


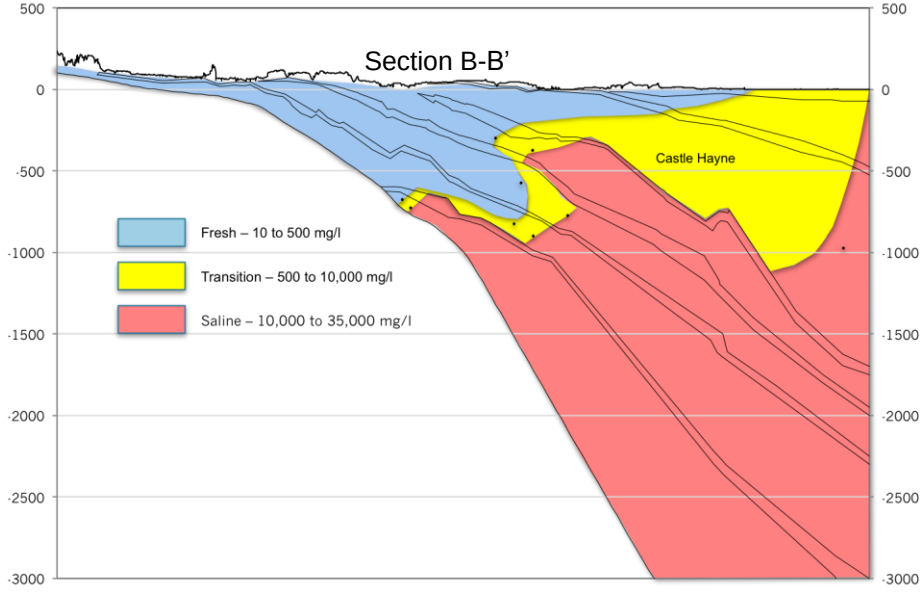


Castle Hayne Aquifer





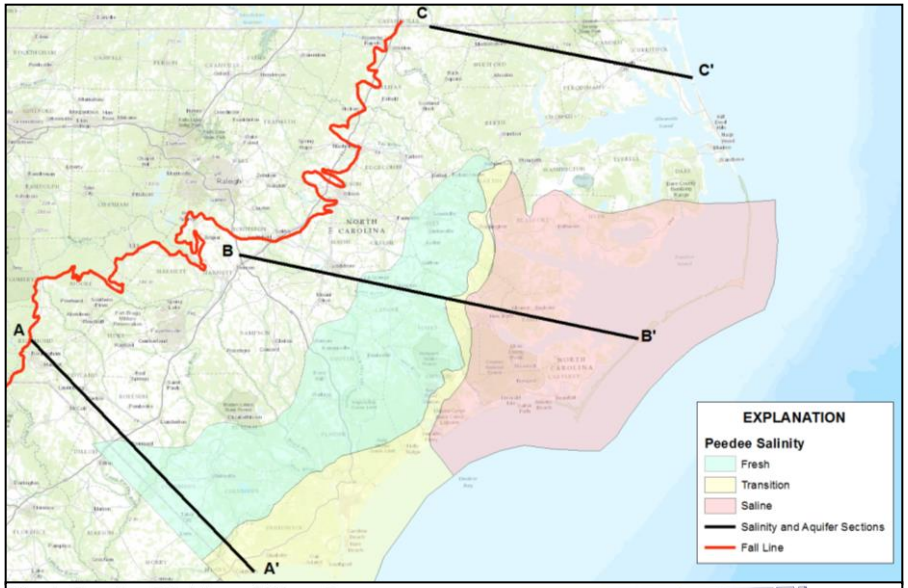


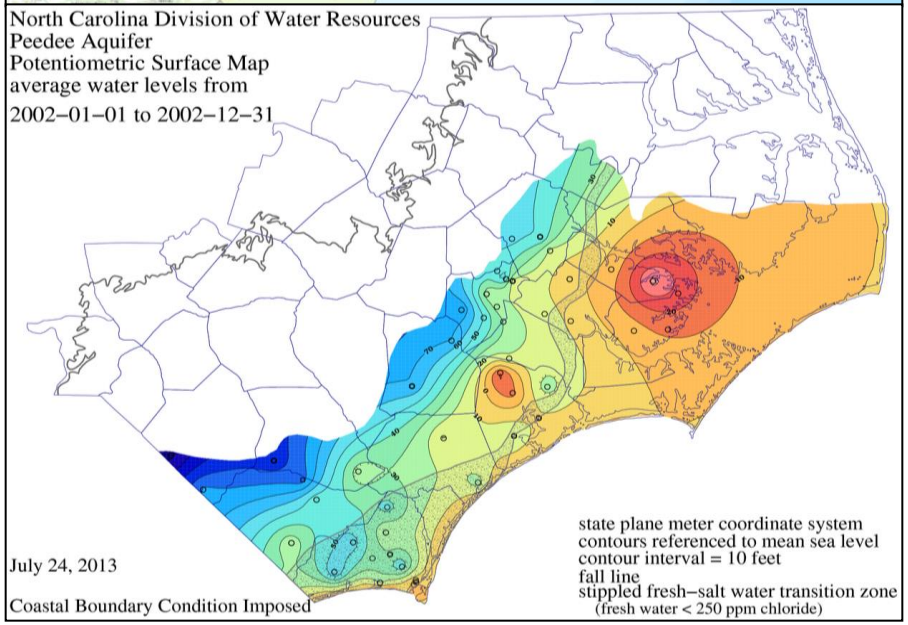


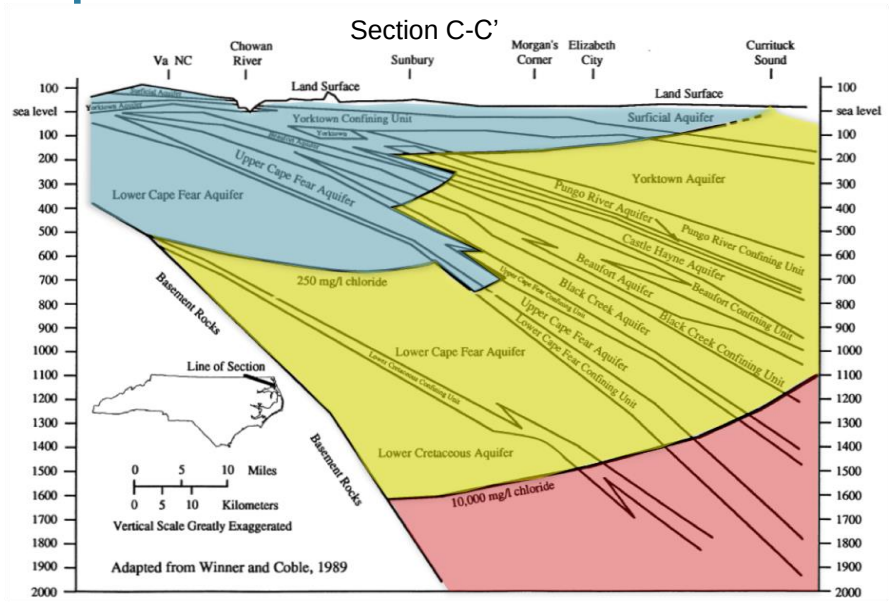
Source: NC DWR

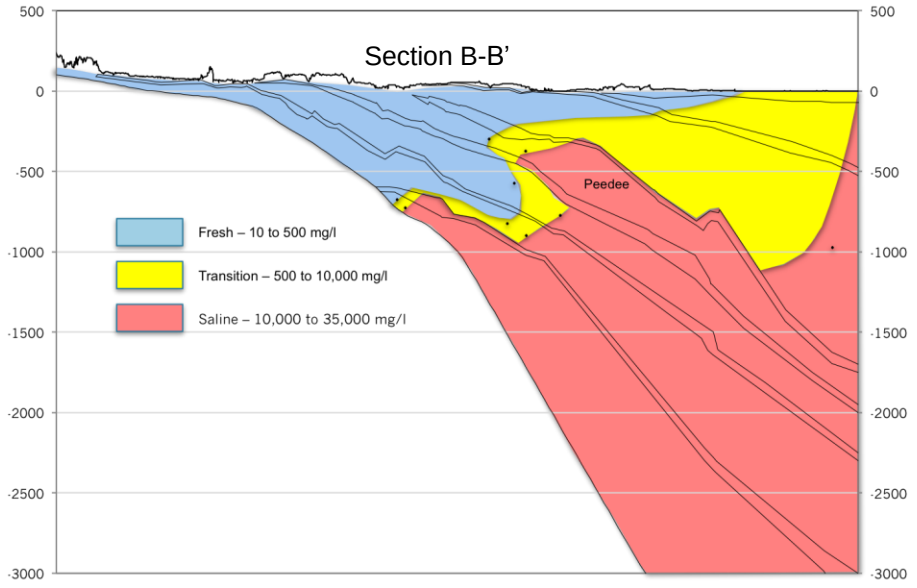
PCS Castle Hayne Depressurization Wells

Peedee Aquifer

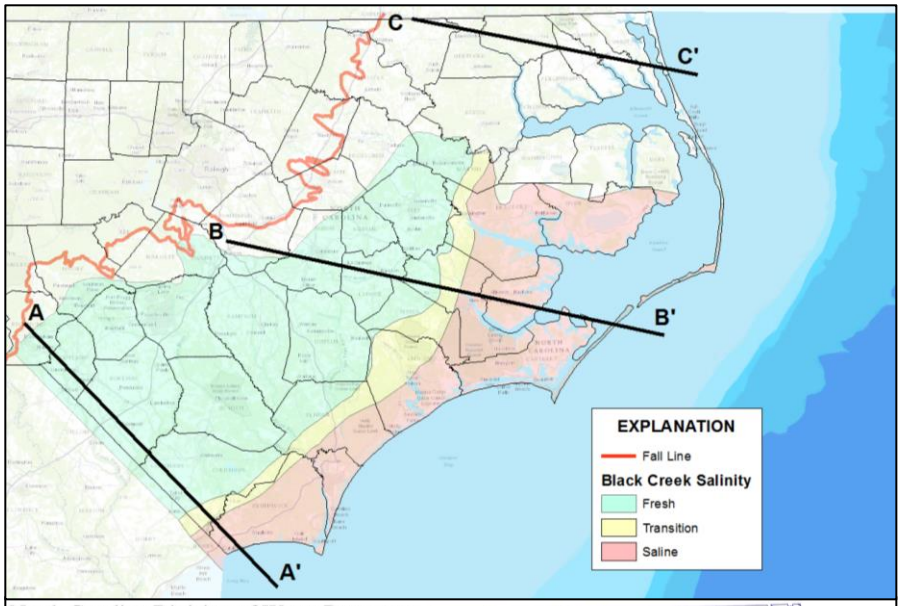


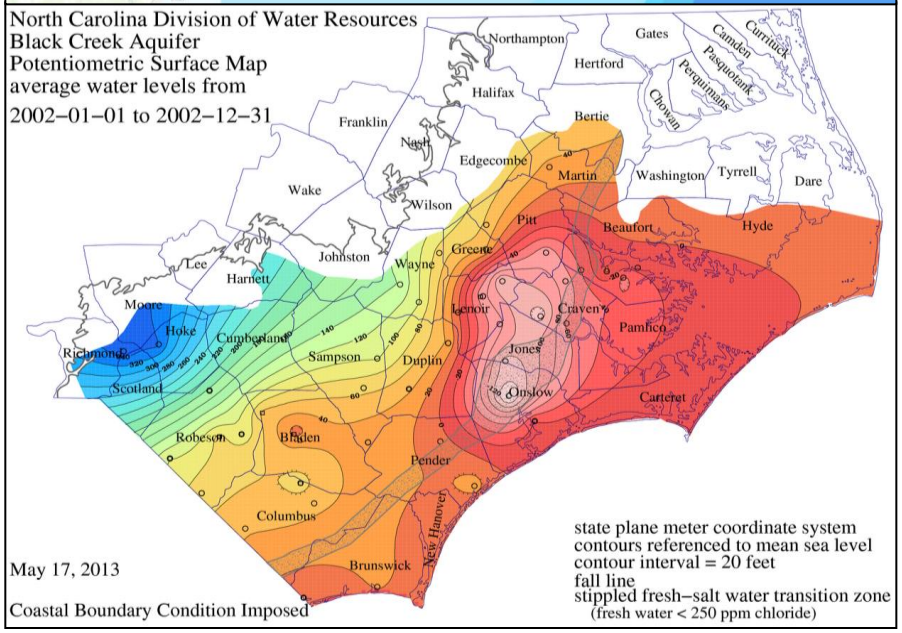


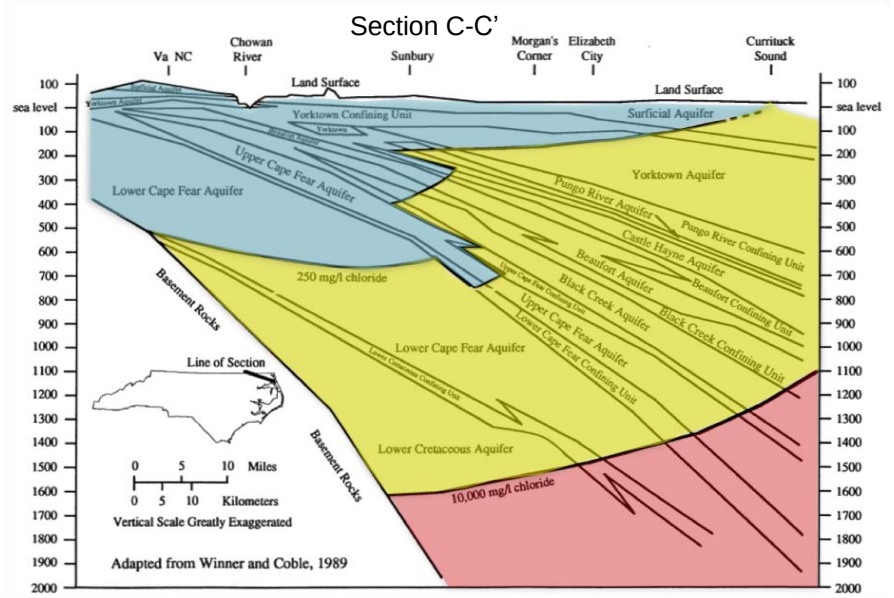


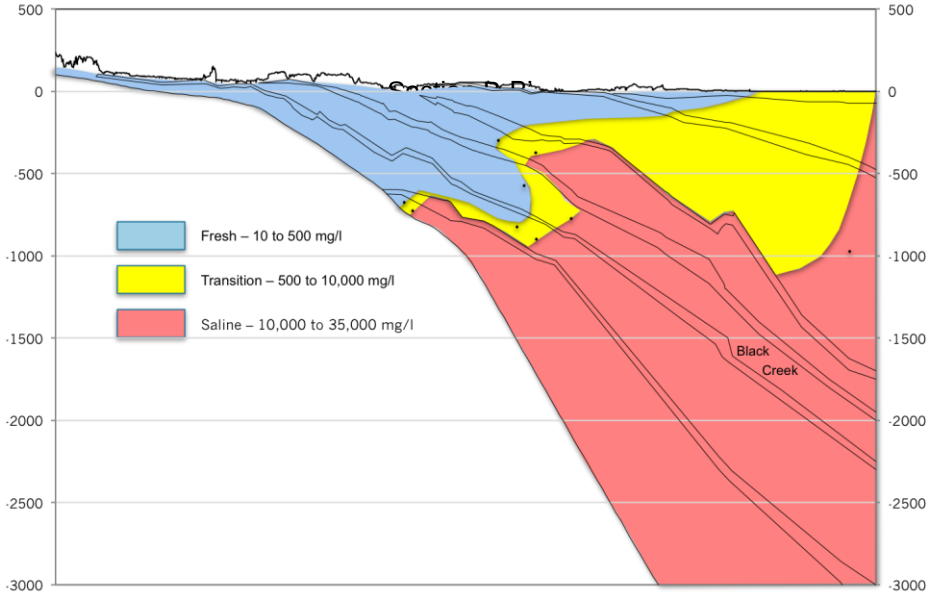


Black Creek Aquifer



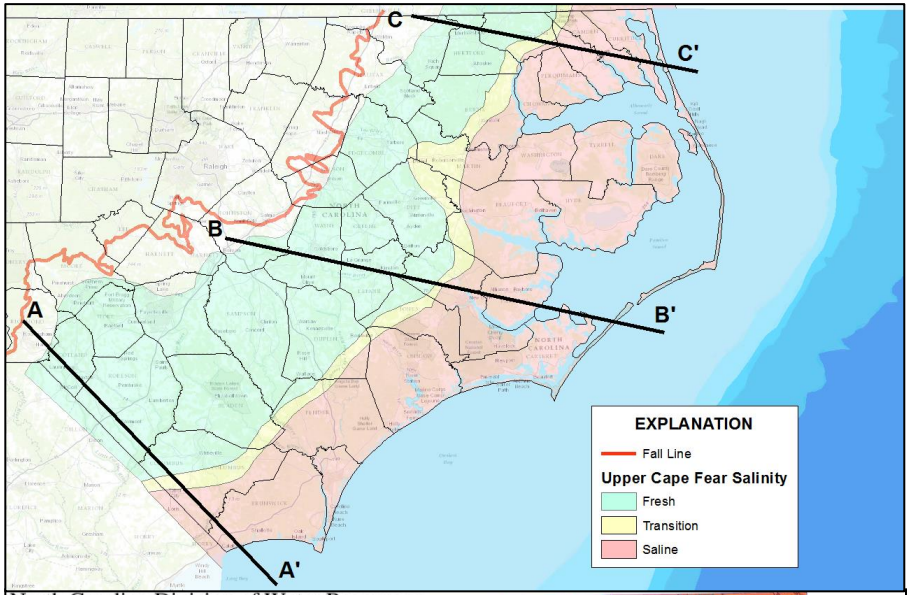


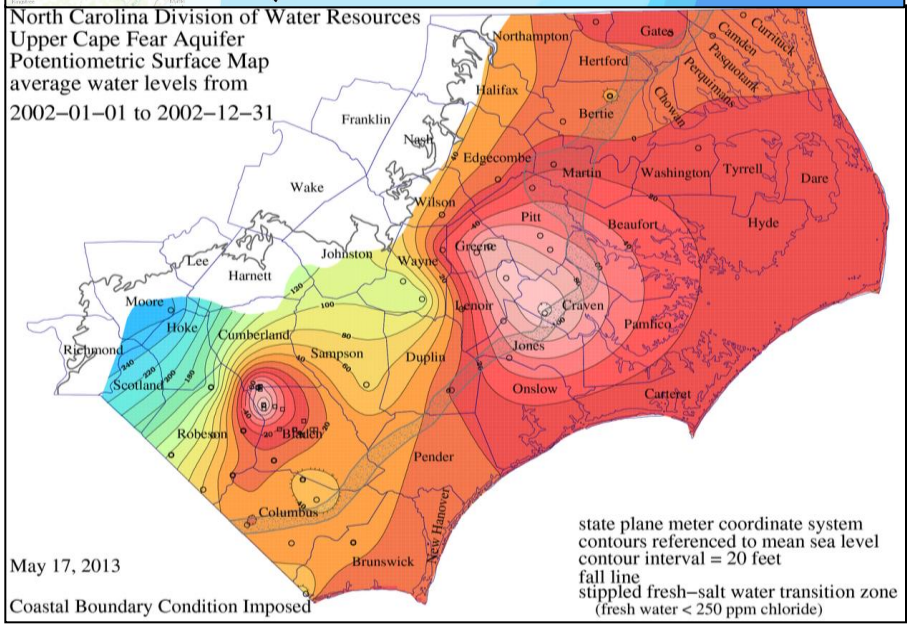




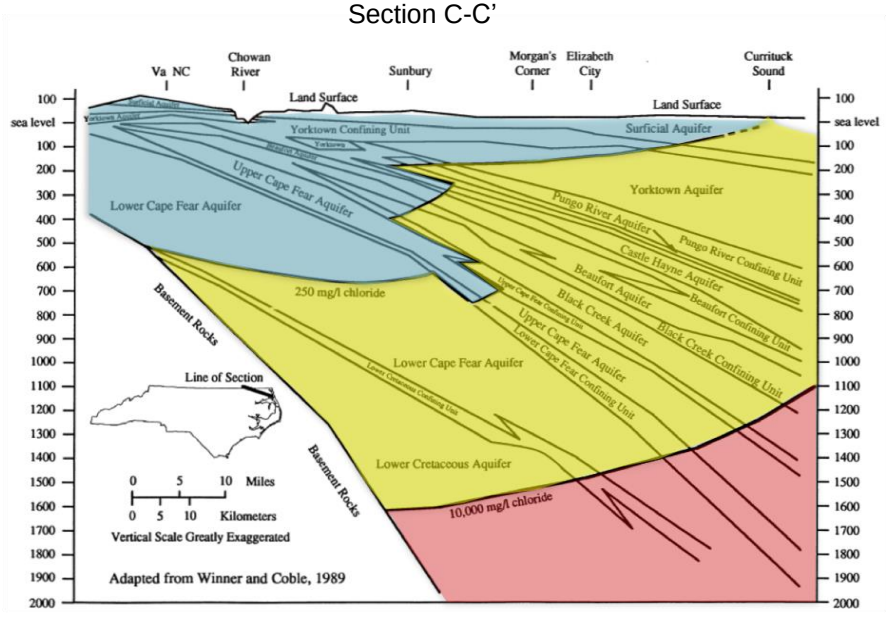
Source: NC DWR

Upper Cape Fear Aquifer

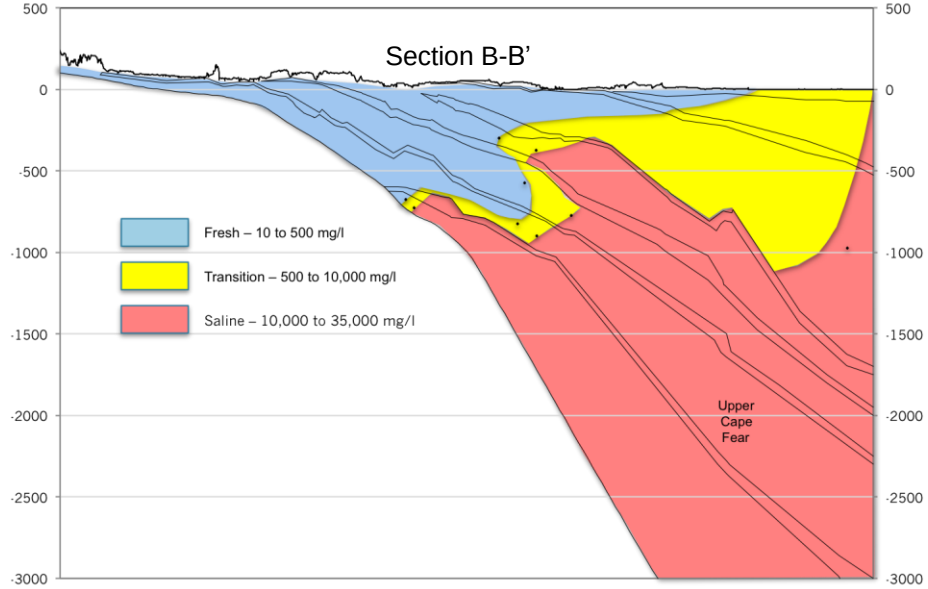




Section C-C’

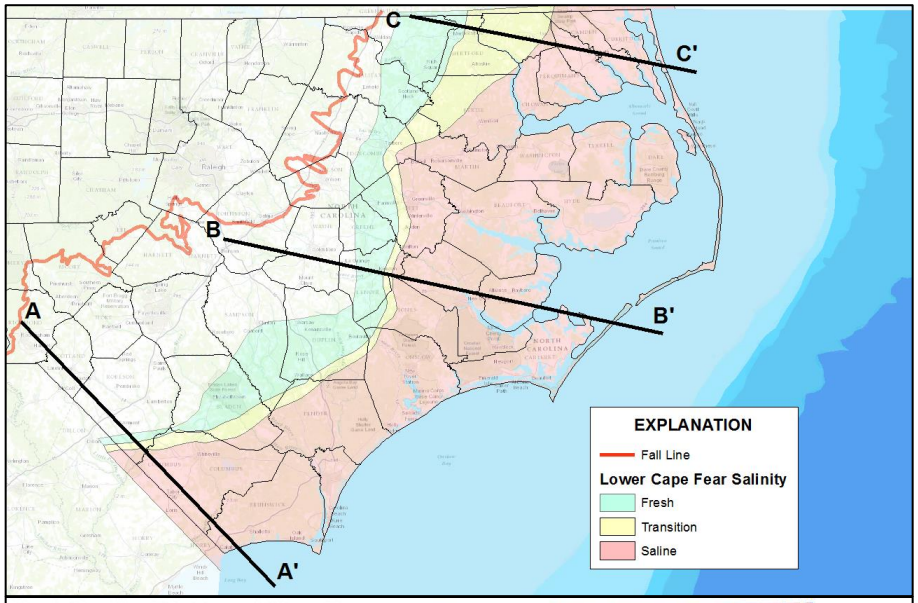


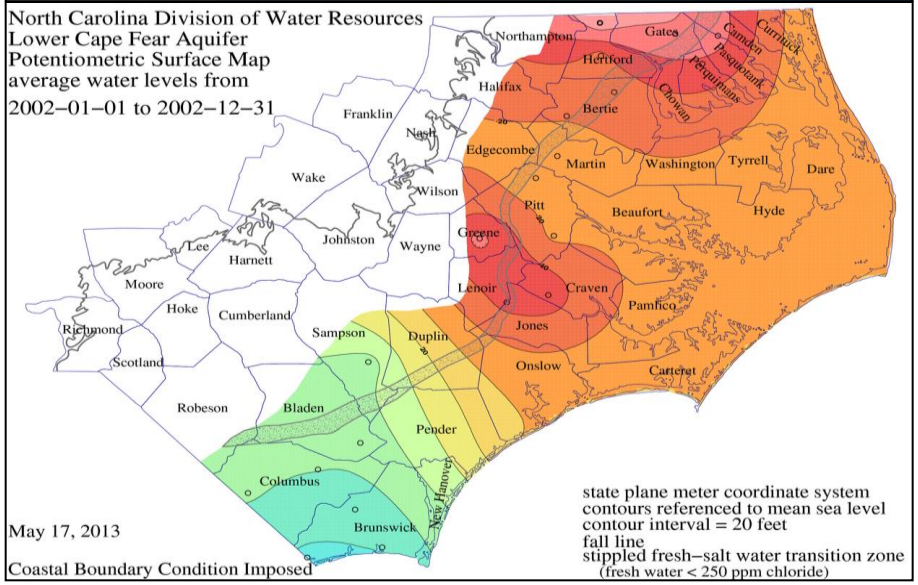
Section B-B’

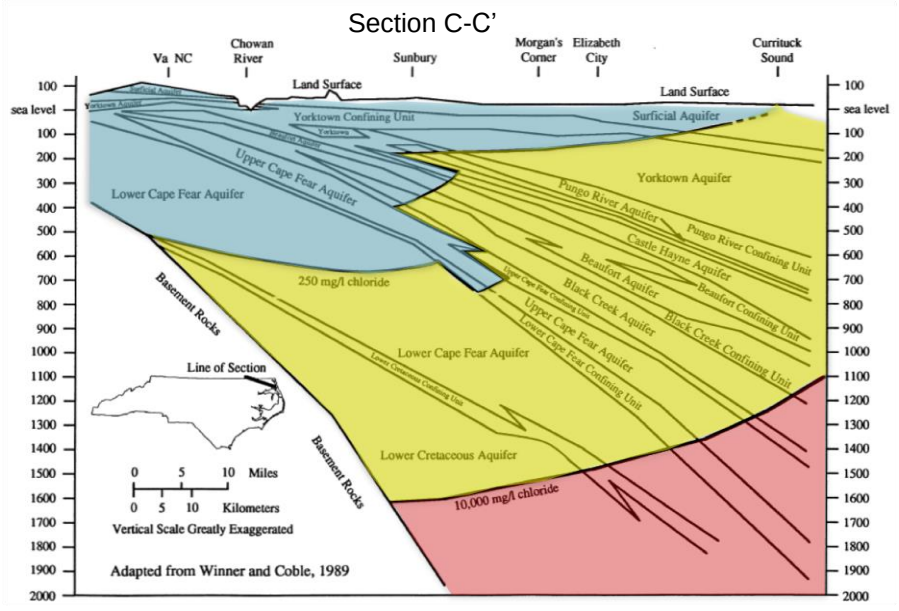


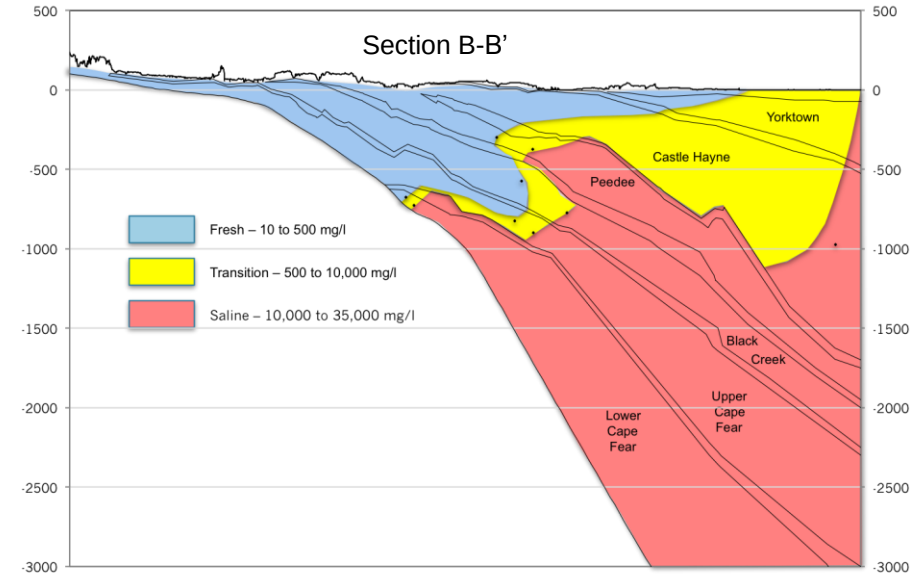
Source: NC DWR

Lower Cape Fear Aquifer





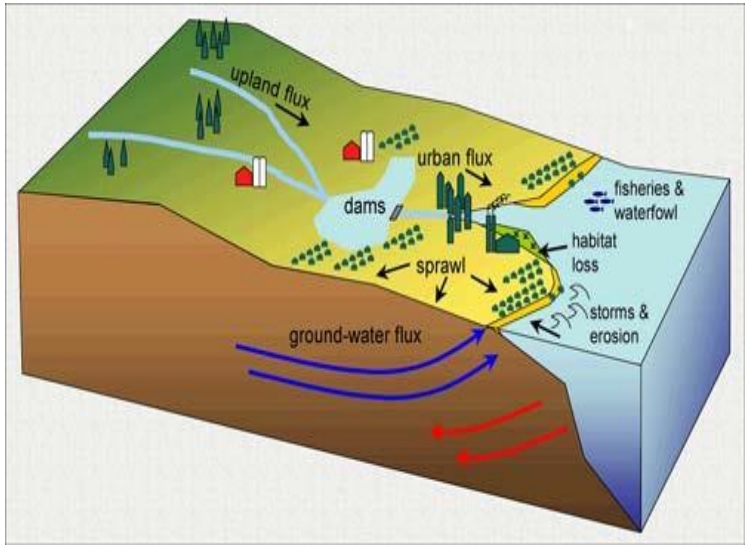


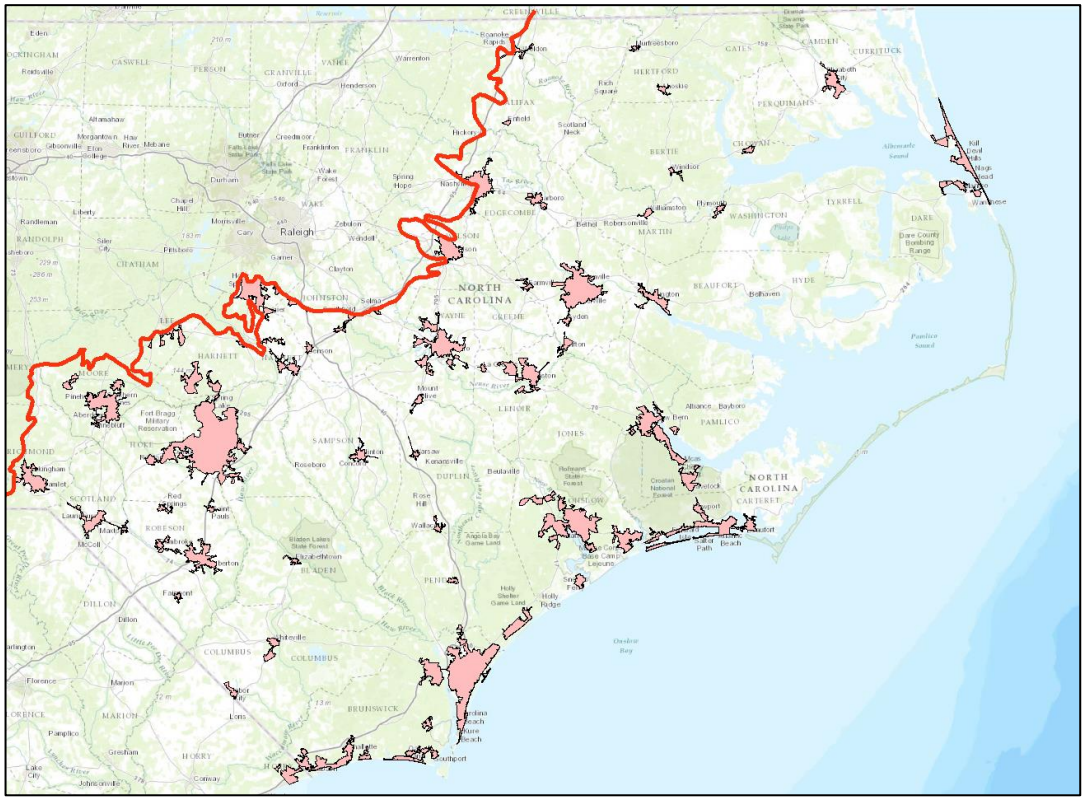


Source: NC DWR

Urbanization Effects

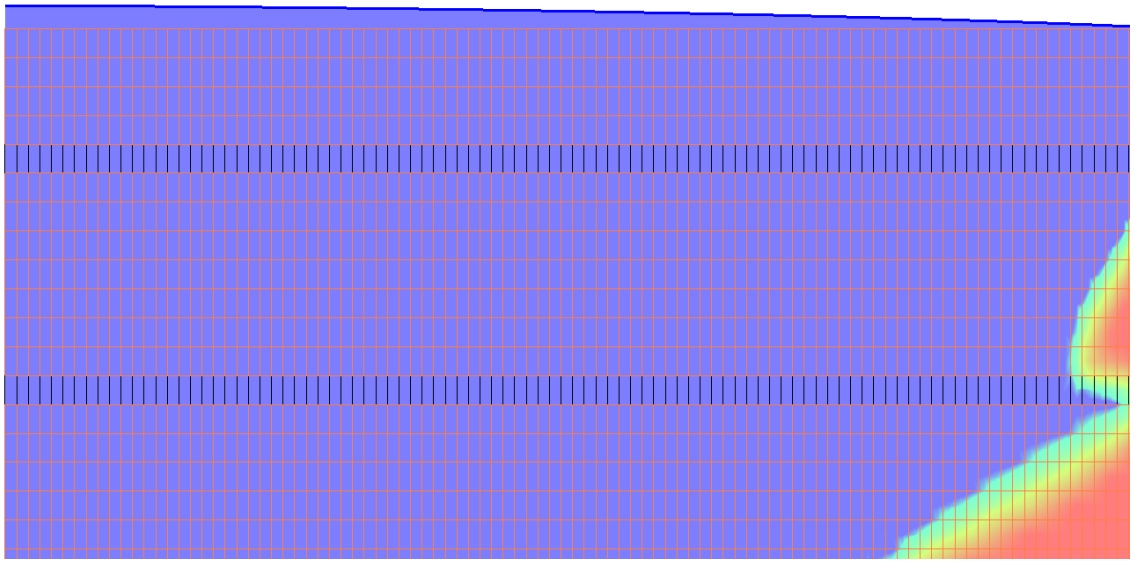
- Increased Recharge from Water & Sewer Main Leaks
- Increased Recharge from Lawn & Landscape Watering
- Withdrawals for Water Supply



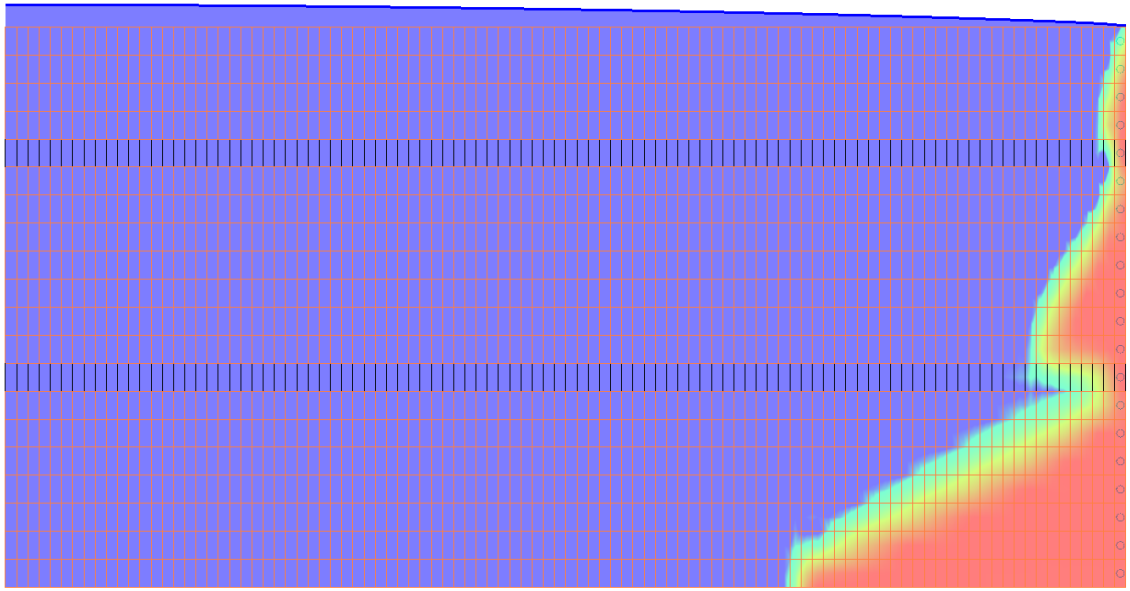


Effect of Sea Level Rise

Sea Level
=
0 Meters



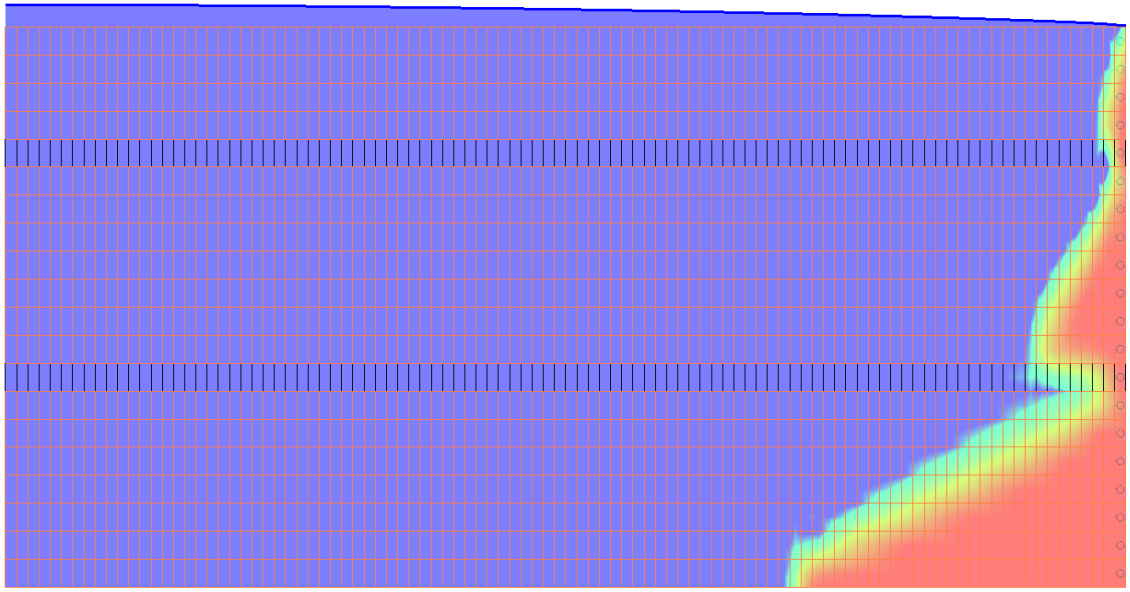
Sea Level
=
1.5 Meters



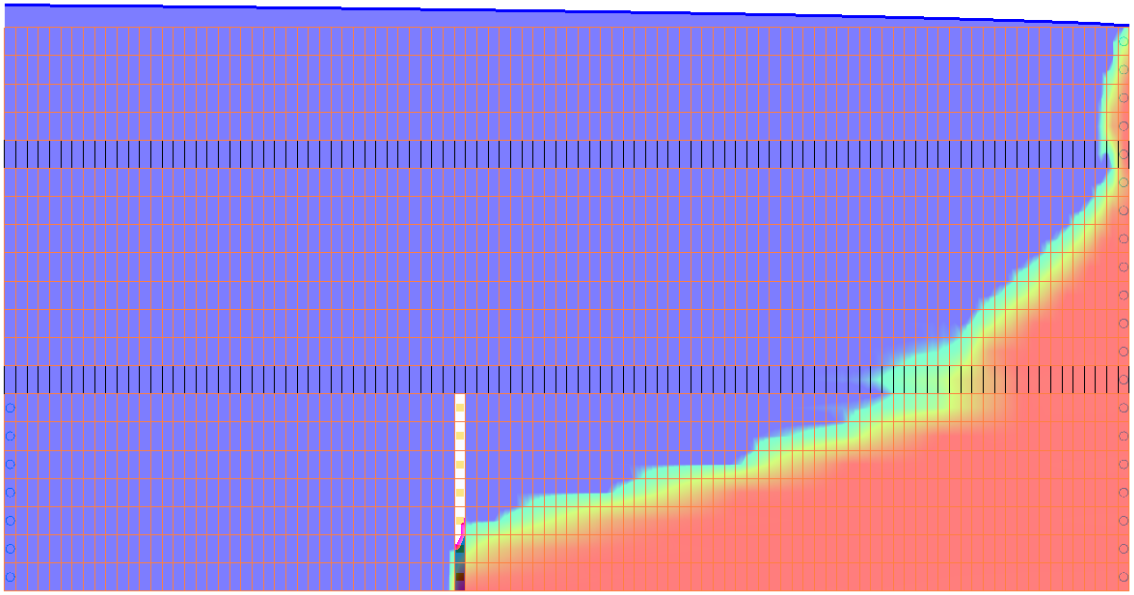
Model: USGS SEAWAT

Sea Level Rise vs. Pumping Effects

Steady State Sea Level Rise of 1.5 Meters



Steady State Pumping Plus Sea Level Rise of 1.5 Meters



Model: USGS SEAWAT

Managing Effects on Coastal Aquifers

- Treat Brackish Water
- Reduce Withdrawals
- Wells in Aquifers not Subject to Regulated Reductions
- New Surface Water Sources
- Connect to Higher Quality Water Source
- Aquifer Storage and Retrieval of Treated Surface Water
- Salt Water Barriers
- Use Water from Mining Withdrawals

Brackish Water as a Water Supply

Dare County Water System

- 4 of 5 Water Plants are RO
- 5th uses Water Softening

Reverse Osmosis & Nanofiltration

Source: Dare County

- CFPUA Nanofiltration Plant
  - Aqufers: Castle Hayne & Peedee
  - Supplies Norther New Hanover Co
  - 6 mgd Treatment Capacity
  - No additional home treatment

Source: CFPUA

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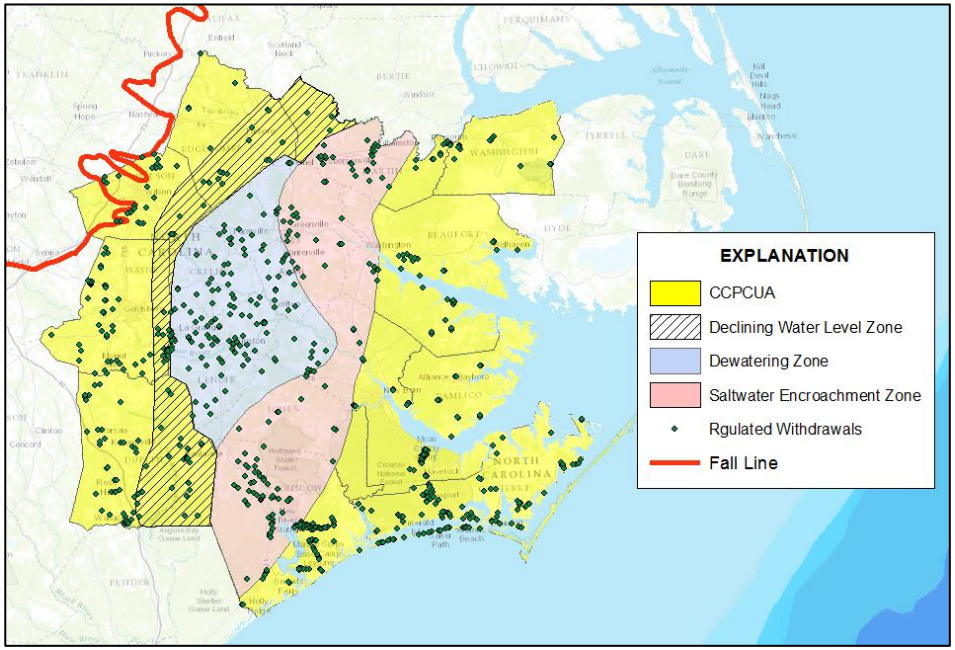
Managing Development Effects

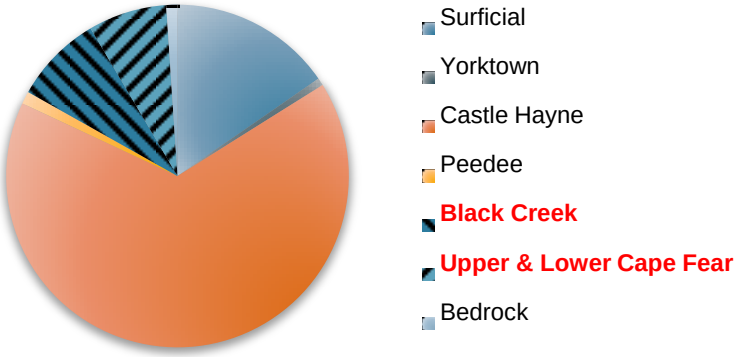
Regulation: Central Coastal Plain Capacity Use Area

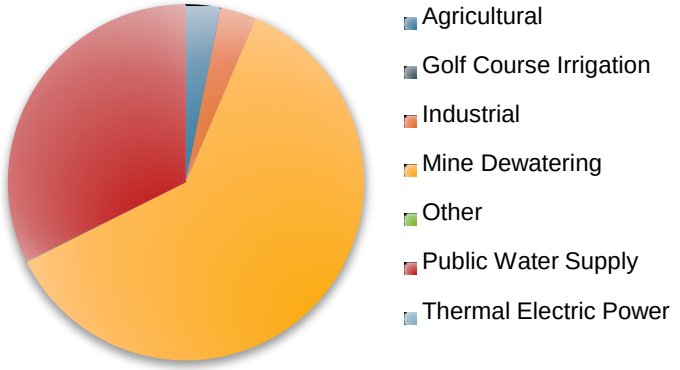
- Permitting for GW users o > = 100,000 gal/day
- Requires reductions from Cretaceous Aquifers

	Declining Zone	Dewatering & Encroachment Zone
2008	10%	25%
2013	20%	50%
2018	30%	75%

- Reporting of all users of 10,000 gal/day
  - Farmers can report to NCDA&CS
  - Individual farm data is confidential







Source: NC DWR

Effect of Pumping Reductions CCPCUA

Regulation: Central Coastal Plain Capacity Use Area

Source: NC DWR

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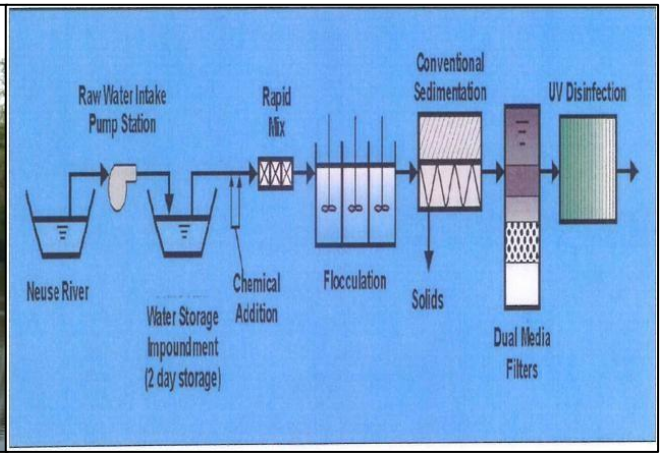
Replacement for Cretaceous Reductions

- Moving to Castle Hayne
  - (ONWASA)
  - Craven County

Source: ONWASA & McKim & Creed

- Surface Water Treatm Plants
  - (NRWASA)



Source: NRWASA

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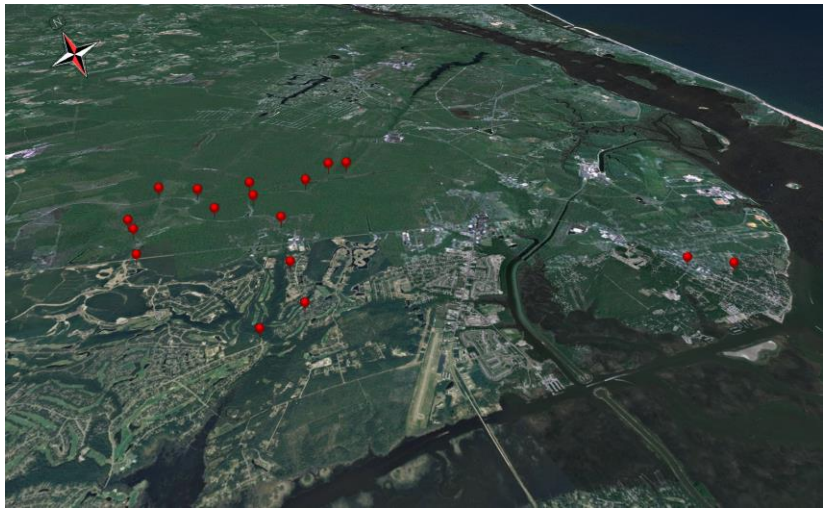
Managing Effects on Coastal Aquifers

Connect to Higher Quality Water Source

Brunswick County Wellfield and Highway 211 Softening plant



Southport

Bald Head Island

Managing Effects on Coastal Aquifers

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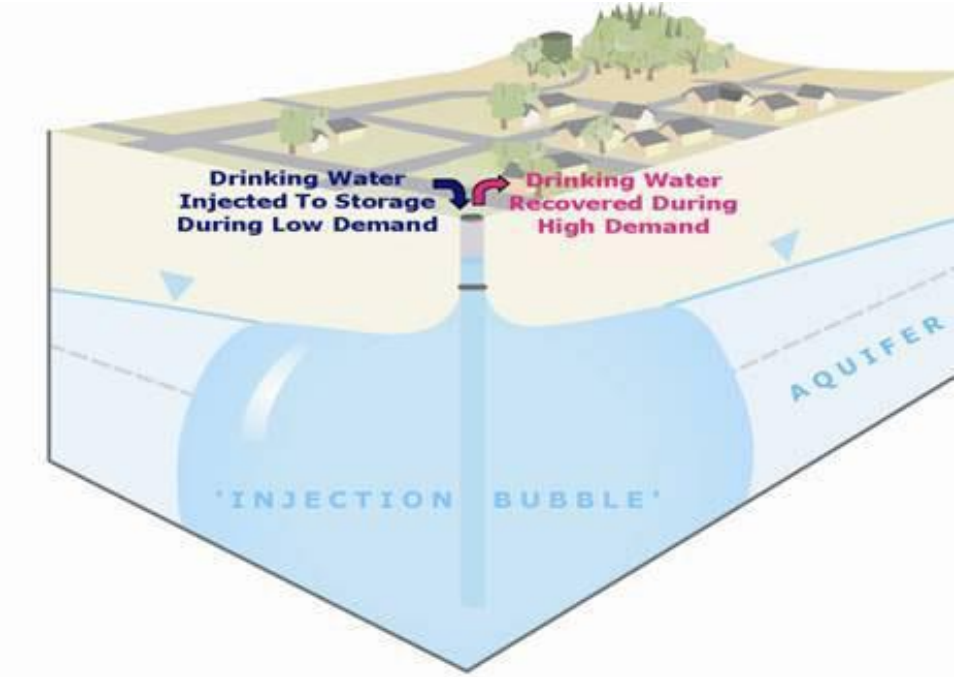
Aquifer Storage & Retrieval

Greenville Utilities
- Permitted
- Black Creek Aquifer
- Treated Surface Water (Tar River)
- Cycle Testing

Cape Fear Public Utilities Authority
- Feasibility Study
- 2 MGD Castle Hayne Aquifer

Brunswick County
- 3 MGD for Seasonal Demand
- Feasibility Study 2014
- 2 Locations in Peedee Aquifer
- Source – Treated Water



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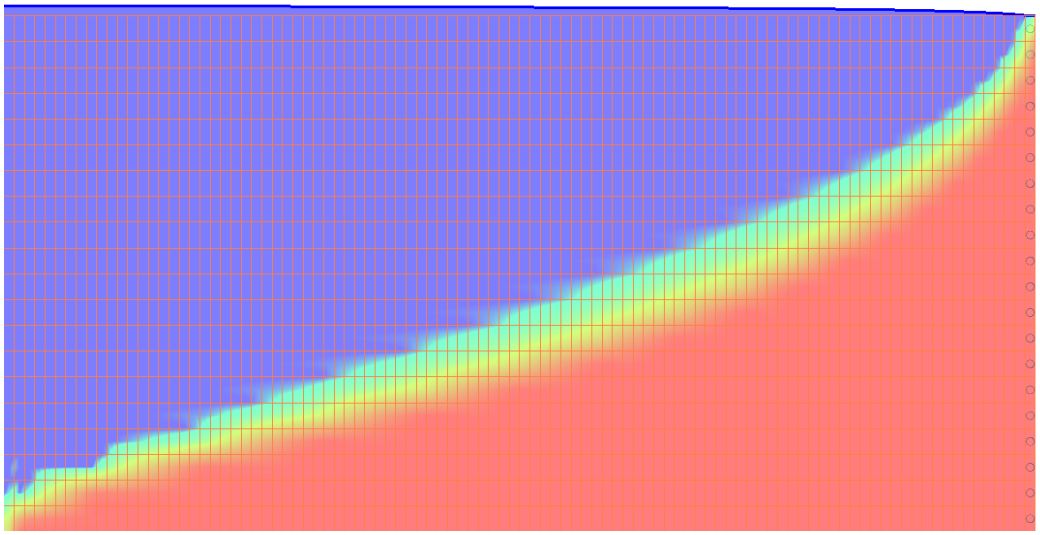
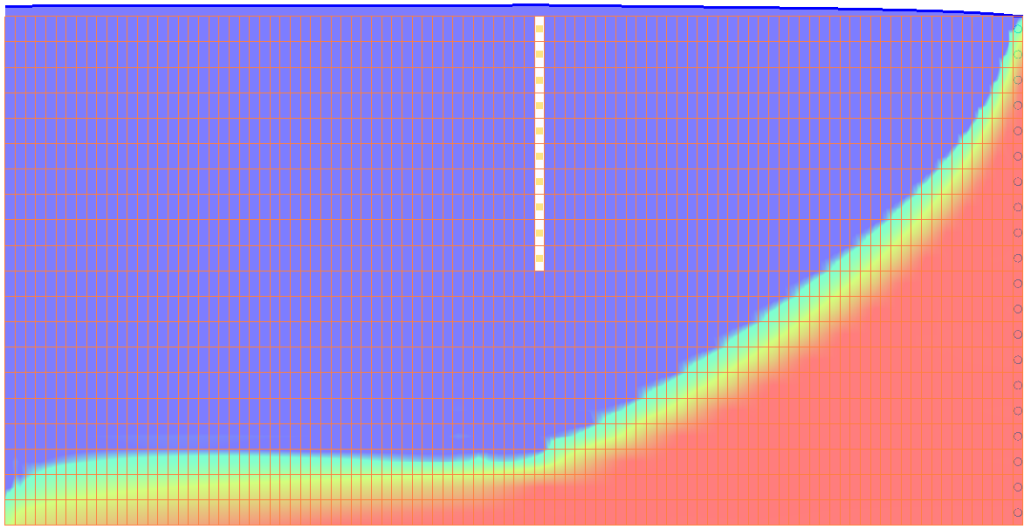
- Additional Use of Water from Mining Withdrawals

Injection Barriers to Encroachment

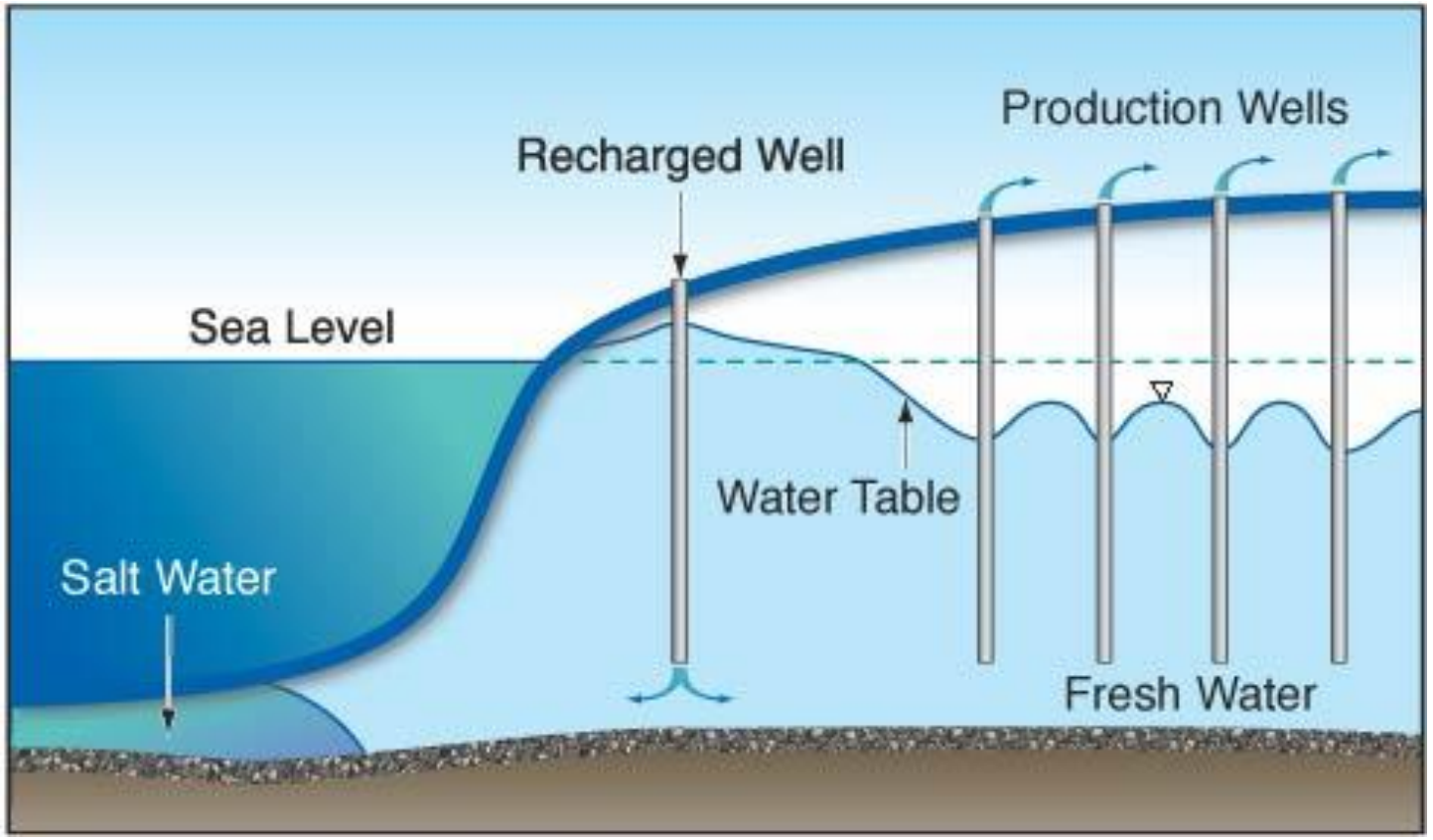
No Injection



Injection
In
Upper Half
of Aquifer



Salt Water Intrusion Barrier Systems



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Take Away Points

- Salt Water Encroachment
  - Magnitude is a function of
    - Balance between Inland Recharge and Discharge
    - Hydrostratigraphy
  - Can be (and has been) induced by Inland Pumping
  - Regulatory Limits exist on pumping (CCPCUA)
  - Pumping has more of an effect than Sea Level Rise

- Salinity Can be Managed
  - Treat Brackish Water
  - Alternative Sources (Surface Water, Non-impacted Aquifers)
  - Intrusion Barriers

- Coastal Aquifers are part of a Total Water Management Strategy
  - Local and Regional Sources
  - ASR Using Potable Water
  - ASR Using Reclaimed Water???

Contact Information

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Link to presentation: