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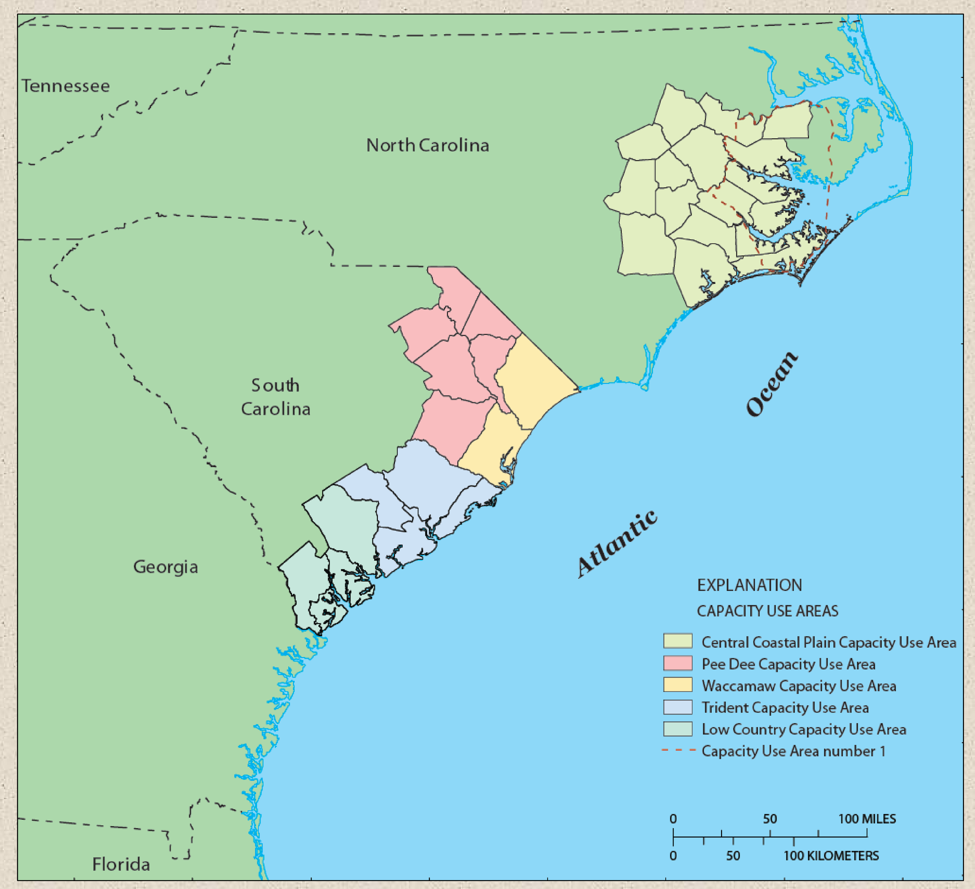
Ground-Water Availability in the Atlantic Coastal Plain of North and South Carolina

BACKGROUND

Ground-water withdrawals from Atlantic Coastal Plain aquifers in North Carolina (NC) and South Carolina (SC) have increased over the past 15 years in response to demands for water for a rapidly growing population. The 2000 census report indicates that the combined populations of the NC and SC Coastal Plain counties totaled nearly 6 million people, representing about 40 percent of NC's total population and about 63 percent of SC's total population. The populations of Coastal Plain counties in both states is expected to increase between 13 and 14 percent by 2015.

Concern about adequate ground-water supplies and declining ground-water levels in the Coastal Plain of the Carolinas dates back to the early part of the 20th century. As a result, Capacity Use Areas (CUA) have been established to regulate ground-water withdrawals.



OBJECTIVES

The current project is one of three studies nationwide funded internally through the USGS Ground Water Resources Program. All three studies are designed to build on the efforts of the original Regional Aquifer System Analysis (RASA) models using new simulation techniques. The Coastal Plain Aquifer study is a combined effort of the NC and SC USGS Water Science Centers and will provide a valuable tool for assessing ground-water availability in the NC and SC Coastal Plain.

The modeling effort will combine and update the original NC and SC RASA computer models. The modeling effort will include new ground-water pumpage, water-level, and hydrogeologic framework data collected since the completion of the earlier RASA models. Conceptual hydrogeologic differences in aquifer and confining units at the NC-SC border will be resolved.

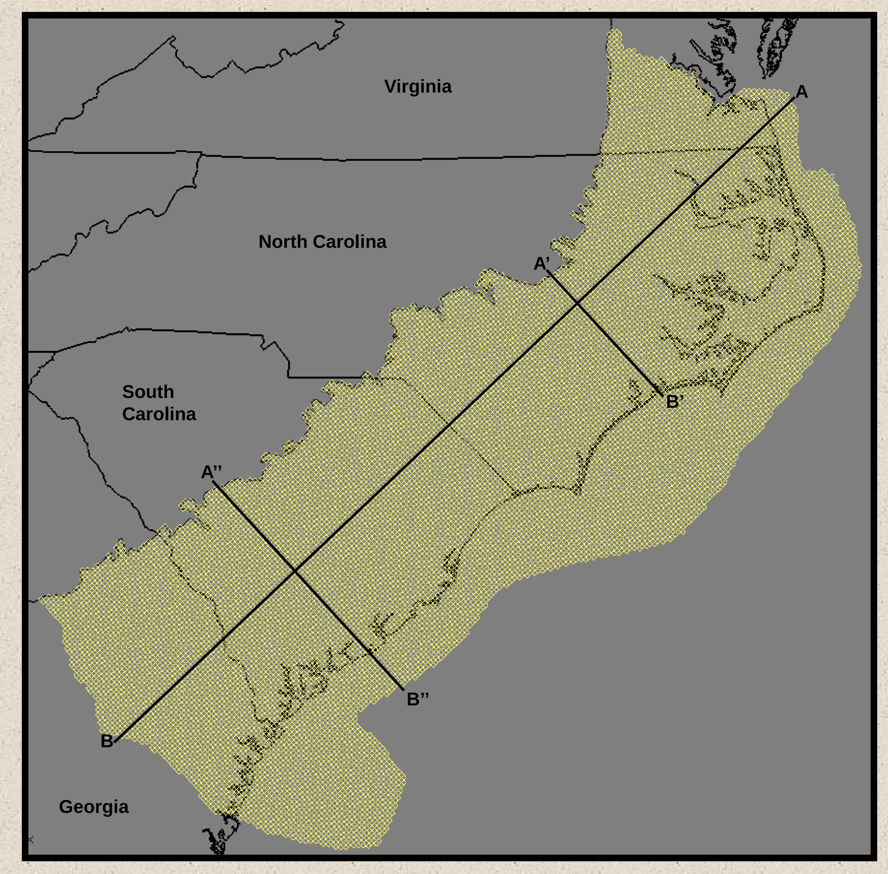
The scope of the modeling effort is the Atlantic Coastal Plain area extending north from eastern Georgia through South and North Carolina and into southern Virginia, including the surficial, Tertiary, and Cretaceous aquifer systems.

NUMERICAL MODEL CONSTRUCTION

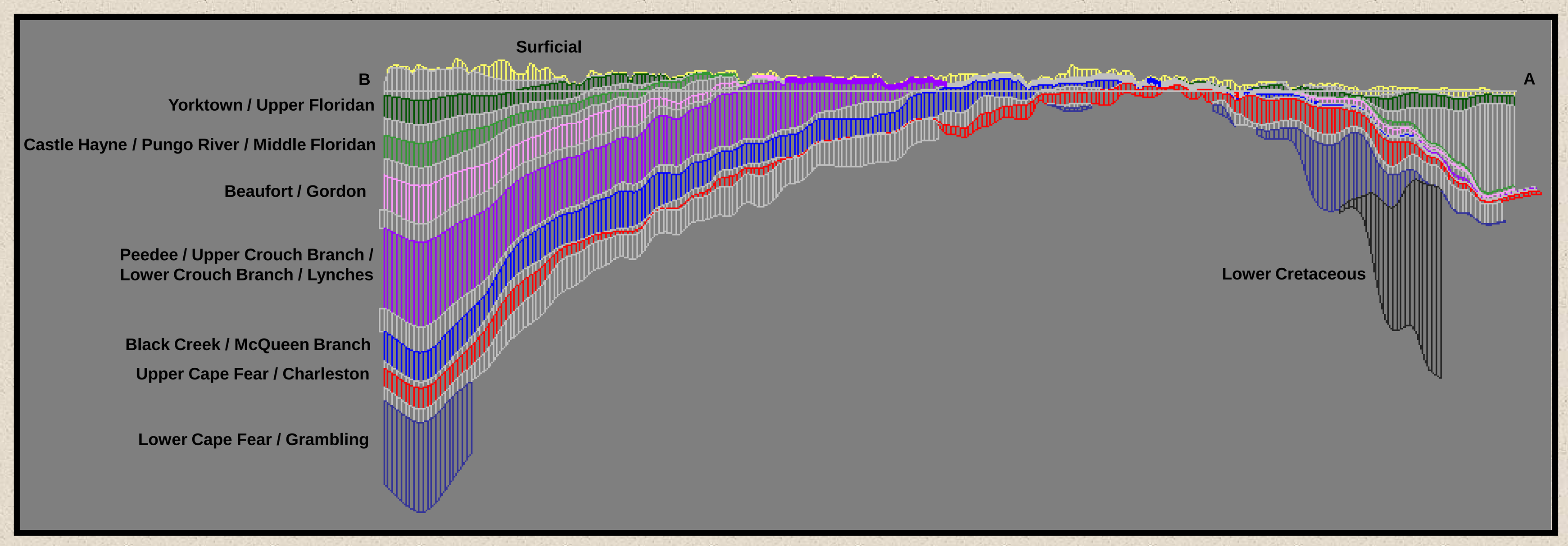
FRAMEWORK
- Over 600 boreholes with complete hydrostratigraphy to basement

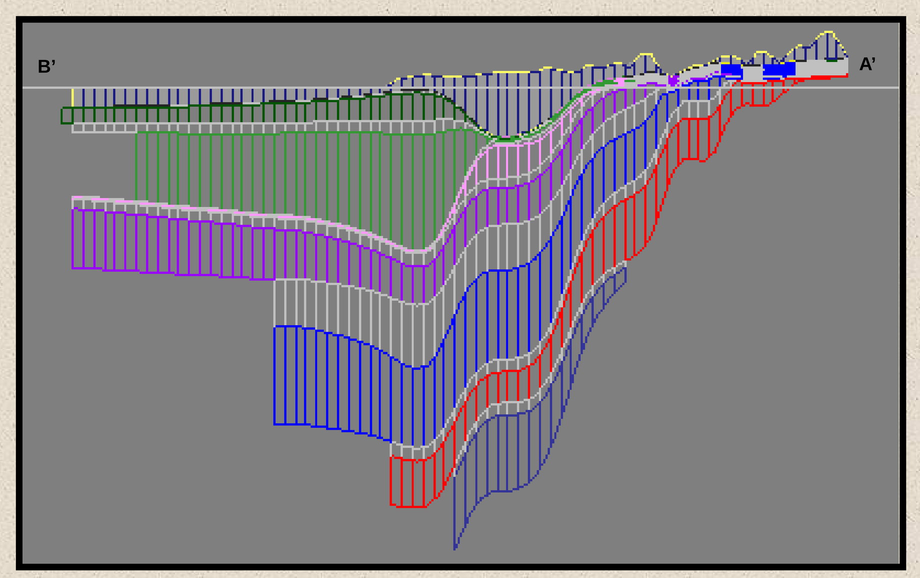
GRID
- 2 x 2 mi cell size
- 16 layers (9 aquifers, 7 confining units)
- 275 columns
- 130 rows

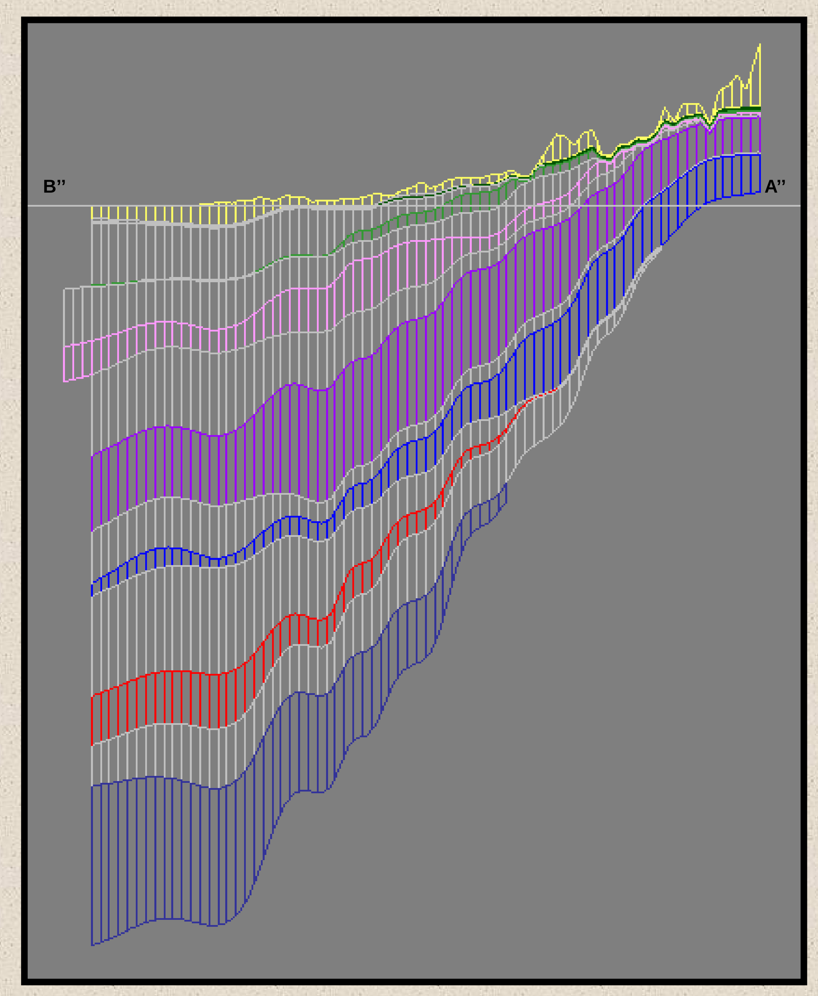
BOUNDARY CONDITIONS
- East – No flow at the Saltwater/Freshwater interface
- West – No flow at the fall line
- North – Specified head at the James River, VA
- South – Specified head at the Oconee River, GA
- Upper – Recharge and specified head
- Lower – No-Flow -- Basement



PARAMETERS
- Hydraulic Conductivity – Over 500 transmissivity values from aquifer pump tests
- Recharge – Constant to the top layer in their outcrop areas
- Streambed Conductance – Highly variable and obtained from calibration
- Groundwater Withdrawals – Annual pumping rates from over 3,000 wells between 1900 and 2004







References

Doherty, John, 2003, Ground water model calibration using pilot points and regularization: Ground Water, v. 41, no. 2, p. 170-177.

Doherty, J., 2005, PEST, model independent parameter estimation user manual: 5th edition: Watermark Numerical Computing, 336p.

Kuniansky and others, 2003, Effects of aquifer development and changes in irrigation practices on ground-water availability in the Santa Isabel Area, Puerto Rico: U.S. Geological Survey Water Resources Investigation Report 2003-4303, 65 pp.

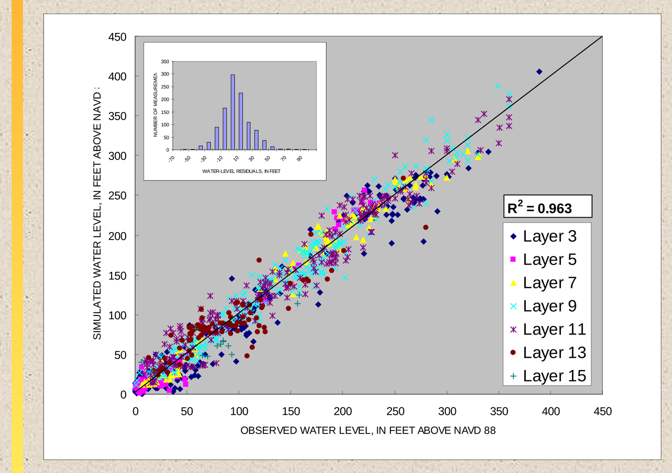
MODEL CALIBRATION

STEADY STATE
- Pre-Development ground-water-level conditions

TRANSIENT
- 28 stress periods: 10-year time steps from 1900 – 1980; 2-year time steps from 1980 – 1990; 1-year time steps from 1990 – 2004

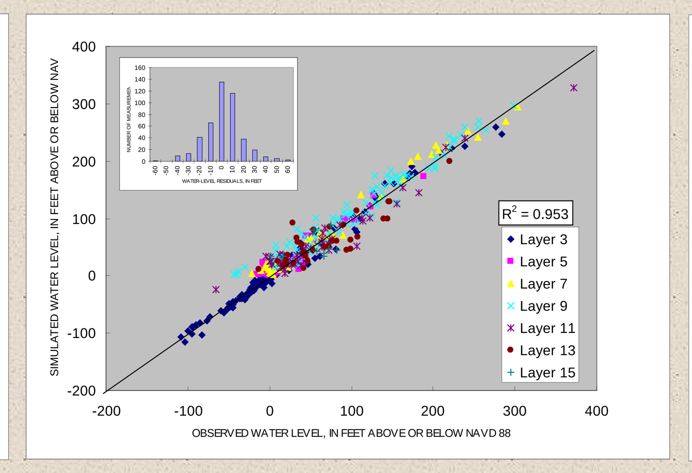
Parameter estimation program PEST (Doherty 2005, 2003) used to calibrate the model. Pilot points and regularization techniques used to estimate aquifer horizontal hydraulic conductivity values.

Predevelopment



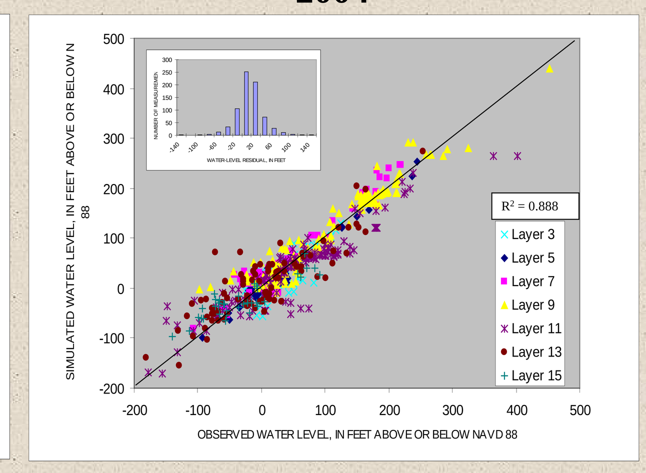
	Layer 3	Layer 5	Layer 7	Layer 9	Layer 11	Layer 13	Layer 15
Number of Observations	278	133	99	231	233	86	13
Range of Observations (feet)	389	236	324	359	351	389	152
Minimum Residual (feet)	-51.62	-36.93	-34.94	-60.34	-51.15	-47.69	-34.39
Maximum Residual (feet)	85.75	37.04	31.78	55.76	39.66	70.90	42.82
Mean Residual (feet)	3.77	-2.19	-2.18	-2.87	-4.24	-0.61	14.58
Standard Deviation of Residuals (feet)	18.65	10.57	13.87	16.73	19.61	23.67	24.03
Root-Mean Square Error of Residuals (feet)	19	10	14	16	21	23	27
Percentage of vaules within 20-foot error criteria	65	86	70	69	52	52	7
Calibration fit: Standard deviation of residuals divided by the range of observations (Kuniansky and others, 2003)	0.05	0.04	0.04	0.05	0.06	0.06	0.16

1980



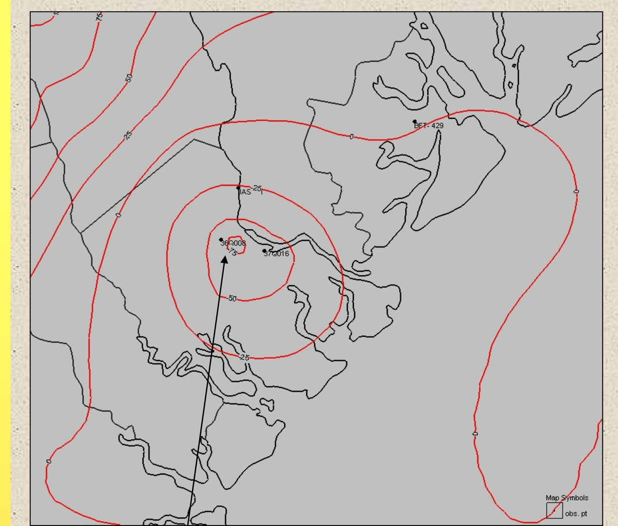
	Layer 3	Layer 5	Layer 7	Layer 9	Layer 11	Layer 13	Layer 15
Number of Observations	163	52	44	101	48	35	10
Range of Observations (feet)	392	205	325	343	438	233	80
Minimum Residual (feet)	-25.47	-31.73	-30.11	-47.86	-42.65	-64.17	-33.11
Maximum Residual (feet)	36.64	25.37	19.11	25.45	54.64	53.43	37.81
Mean Residual (feet)	0.74	-3.04	-9.39	-10.74	1.18	7.34	5.26
Standard Deviation of Residuals (feet)	10.35	10.98	12.92	17.00	20.17	25.51	26.03
Root-Mean Square Error of Residuals (feet)	11	11	15	20	20	24	25
Percentage of vaules within 20-foot error criteria	85	86	66	59	56	40	30
Calibration fit: Standard deviation of residuals divided by the range of observations (Kuniansky and others, 2003)	0.03	0.05	0.04	0.05	0.05	0.11	0.32

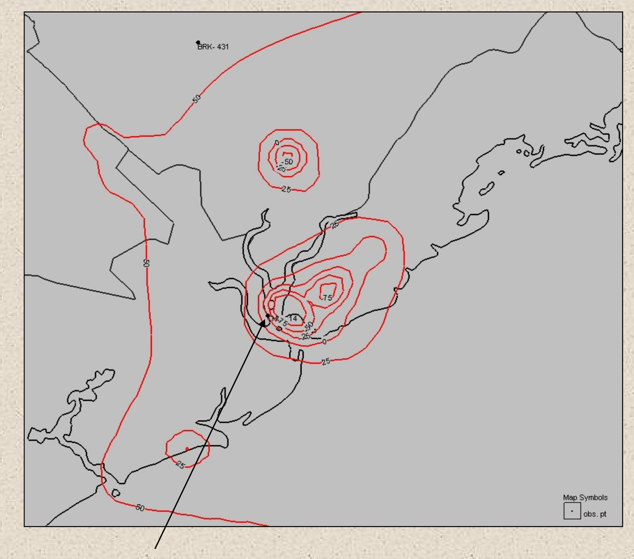
2004

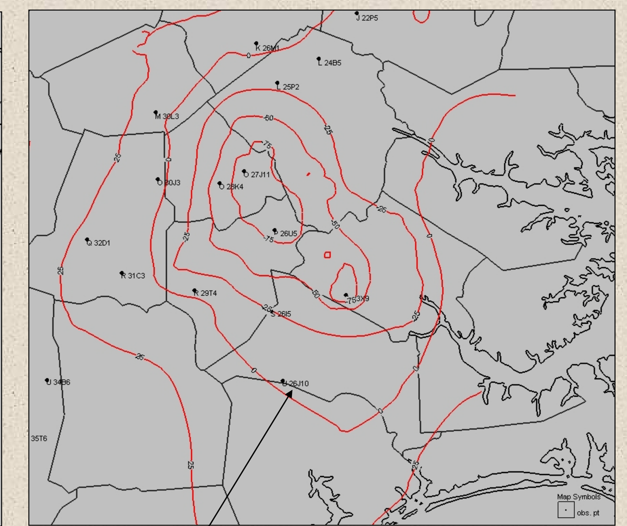


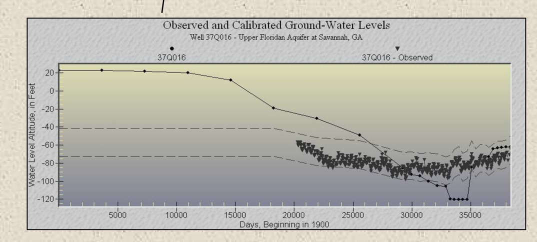
	Layer 3	Layer 5	Layer 7	Layer 9	Layer 11	Layer 13	Layer 15
Number of Observations	131	108	80	160	129	94	36
Range of Observations (feet)	183.65	336.28	326.55	548.95	581.03	435.51	231.40
Minimum Residual (feet)	-39.58	-30.42	-67.96	-94.12	-113.06	-144.93	-61.96
Maximum Residual (feet)	70.40	27.87	35.64	44.60	137.09	80.59	64.07
Mean Residual (feet)	1.21	1.27	-15.86	-8.90	11.98	-7.42	-7.33
Standard Deviation of Residuals (feet)	18.17	9.90	19.25	23.52	37.77	38.67	31.43
Root-Mean Square Error of Residuals (feet)	18	10	24	24	39	39	32
Percentage of vaules within 20-foot error criteria	77	81	48	57	56	57	33
Calibration fit: Standard deviation of residuals divided by the range of observations (Kuniansky and others, 2003)	0.098952	0.029445	0.05896	0.04285	0.06501	0.088789	0.135813

Example Observed and Simulated Hydrograph Comparison

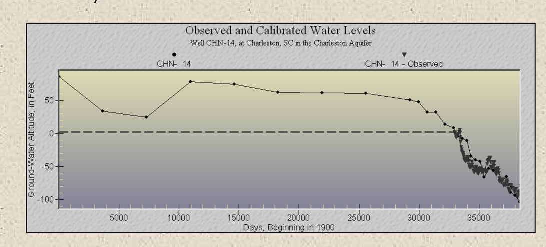




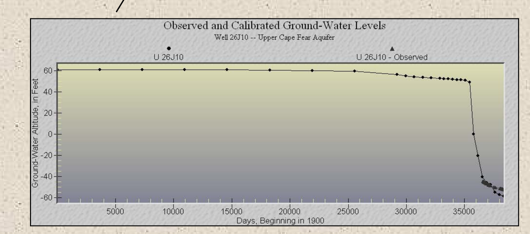




Savannah, GA Area – Upper Floridan Aquifer 1900 - 2004

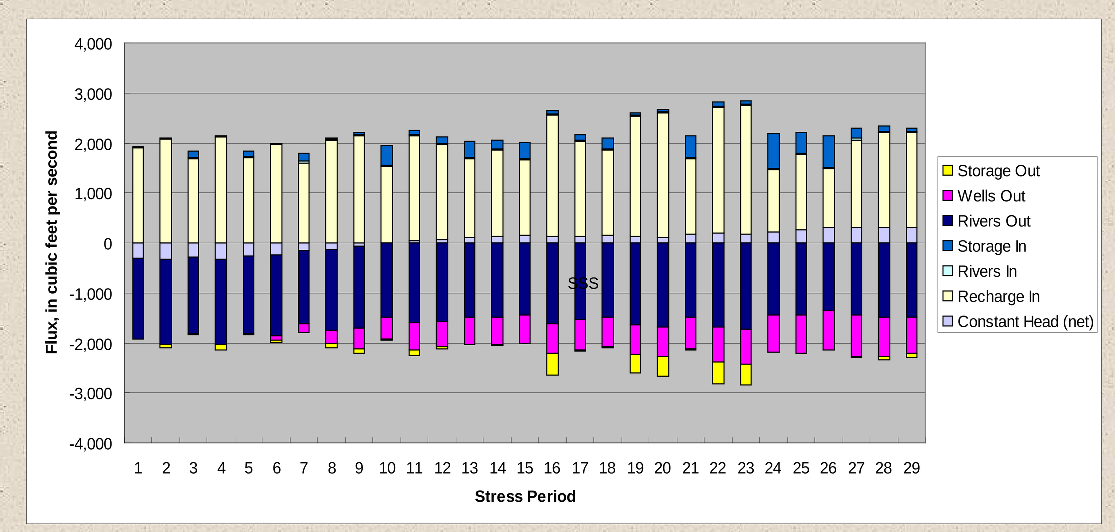


Charleston, SC Area – Charleston Aquifer 1900 - 2004



NC Central Coastal Plain Area Upper Cape Fear Aquifer 1900 - 2004

Model Water Budget



The overall water budget includes net change in specified heads, rivers, recharge, wells, and storage. As significant quantities of water were pumped from the aquifers, the constant heads changed from a sink to a source of water about stress period 10 (1980). During wetter stress periods (for example 22 – 1997) water is replaced as net storage.

USGS Ground-Water Resources Program

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