

texas water development board

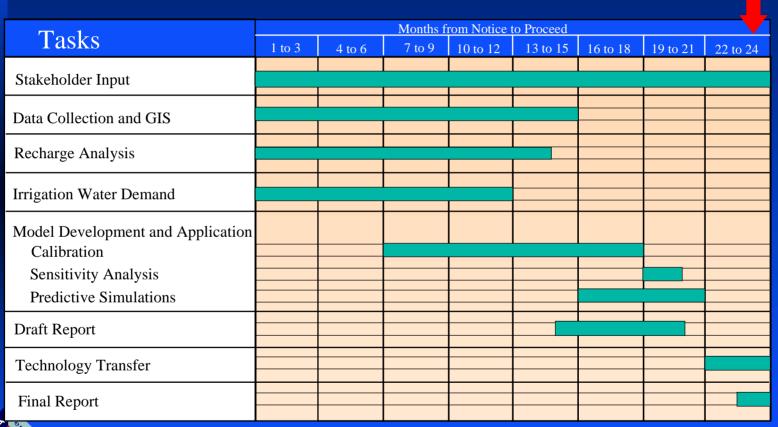
Agenda for Southern Ogallala GAM Model Training - SAF Meeting No. 8 January 10, 2003

- Introduction to groundwater flow modeling and MODFLOW computer code
- Overview of Southern Ogallala GAM model
- Introduction to PMWIN
- Application of PMWIN to GAM model



Project Status

We are here



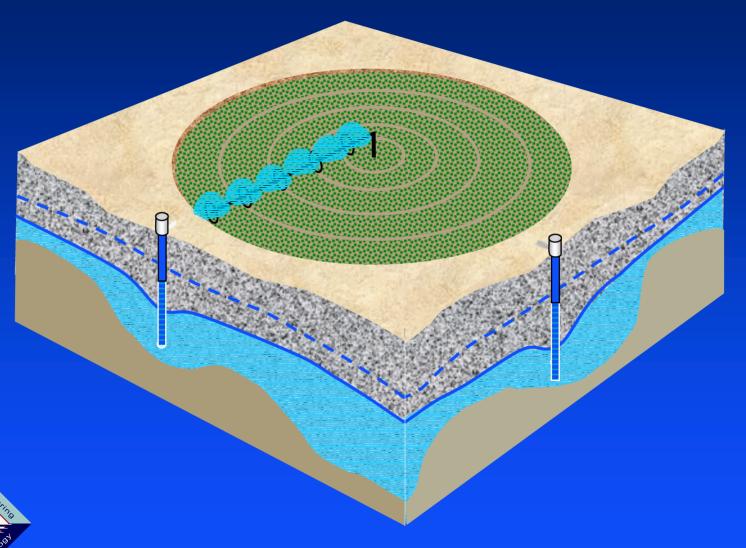
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Modeling Process

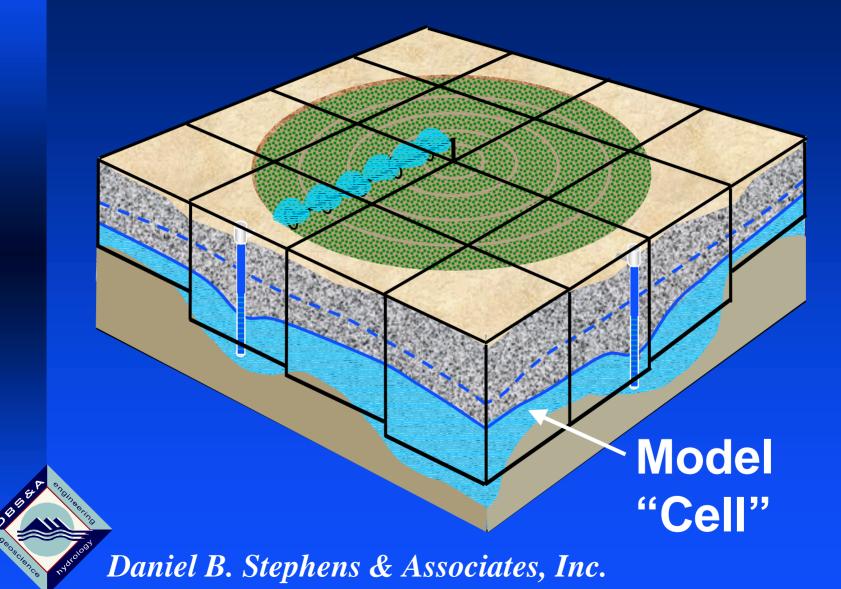
- Develop "conceptual" model
- Incorporate conceptual model into a mathematical model
- Model Calibration (history matching)
- Model validation (optional)
- Post-audit and updating



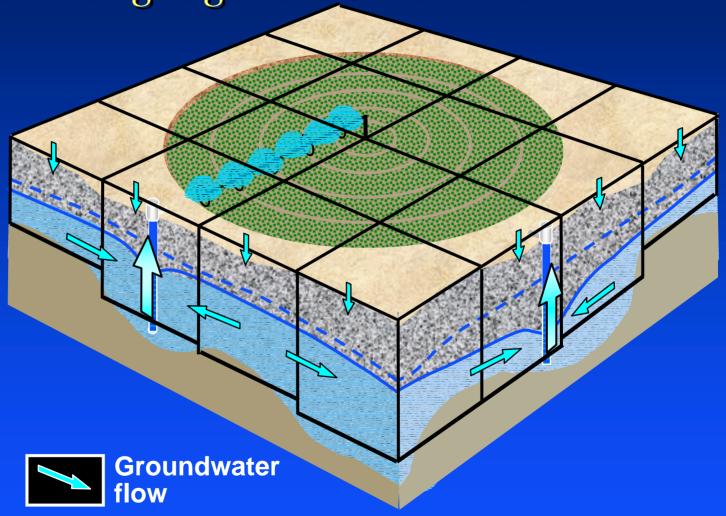
Ogallala Aquifer



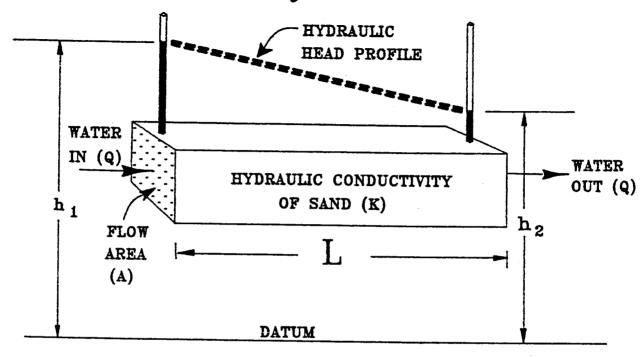
Groundwater Flow Modeling



Cells "Communicate"
Their Language is Mathematics!



Darcy's Law



Hydraulic Gradient $I = (h_1 - h_2)/L$

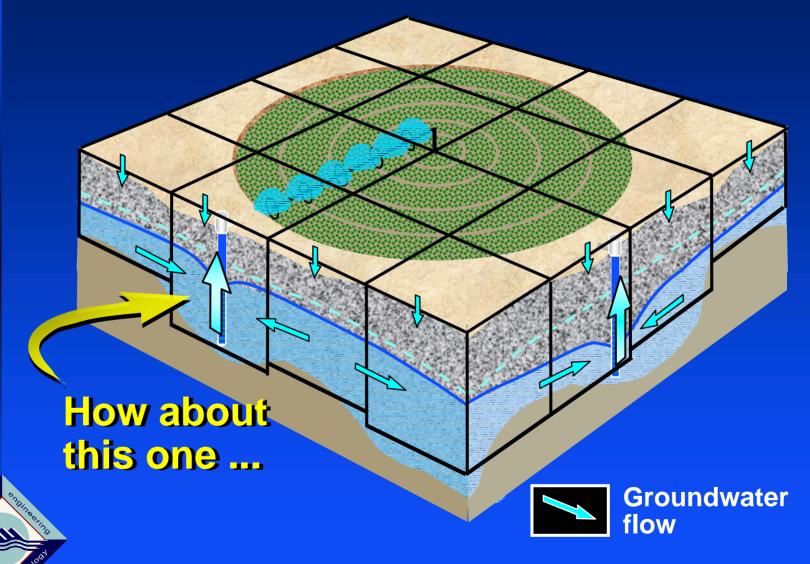
$$Q = KIA$$

$$\frac{PORE}{WATER} v = \frac{KI}{porosity}$$

$$VELOCITY$$



Let's Take a Look at One ...



Major Influences in the Life of a Cell

Natural recharge

Exchange of water with neighboring cells

Permeability

Storage value

Thickness

Irrigation return flow

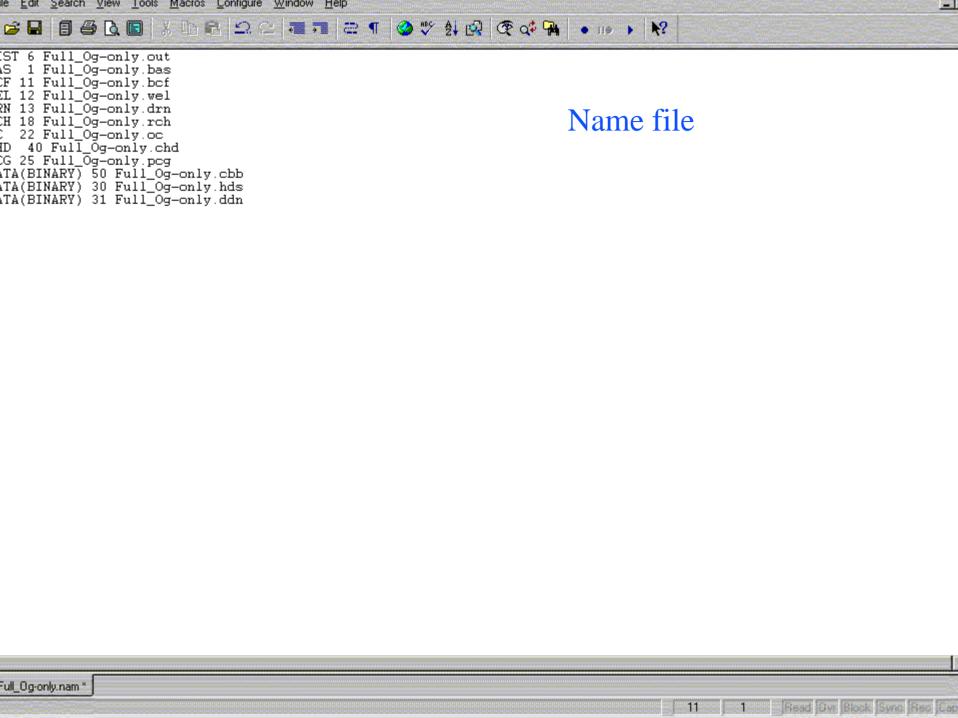
Water removed from storage

Water remaining in storage

MODFLOW Code

- MODFLOW-96 prescribed by TWDB
- USGS computer code for simulating groundwater flow in three-dimensions
- Most commonly used code/industry standard





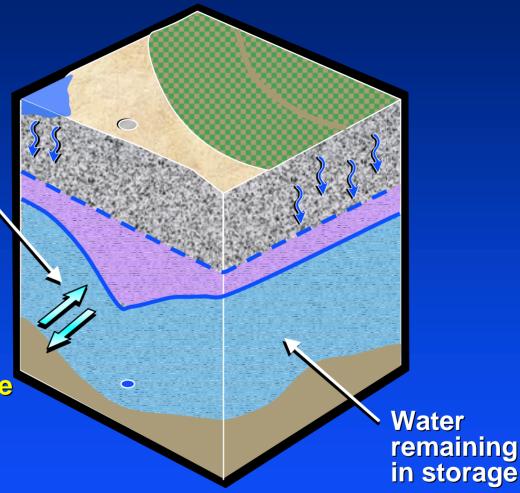
Basic and Block Centered Flow Packages

Exchange of water with neighboring cells

Permeability

Storage value

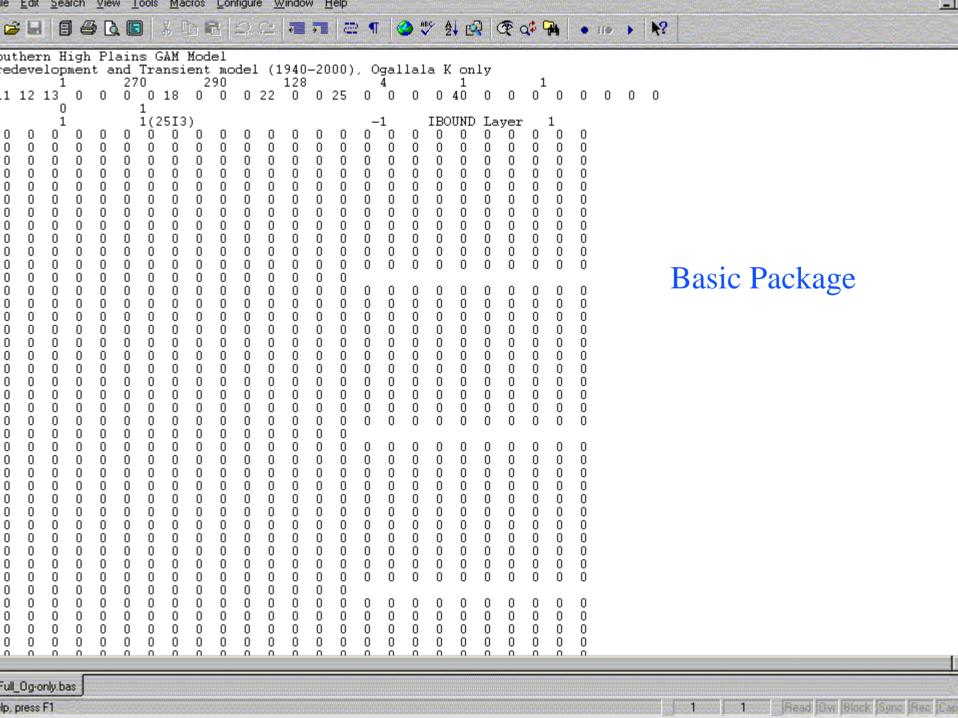
Thickness



Basic Package

- Grid definition
- Time period definition
- Initial conditions
- Boundary conditions

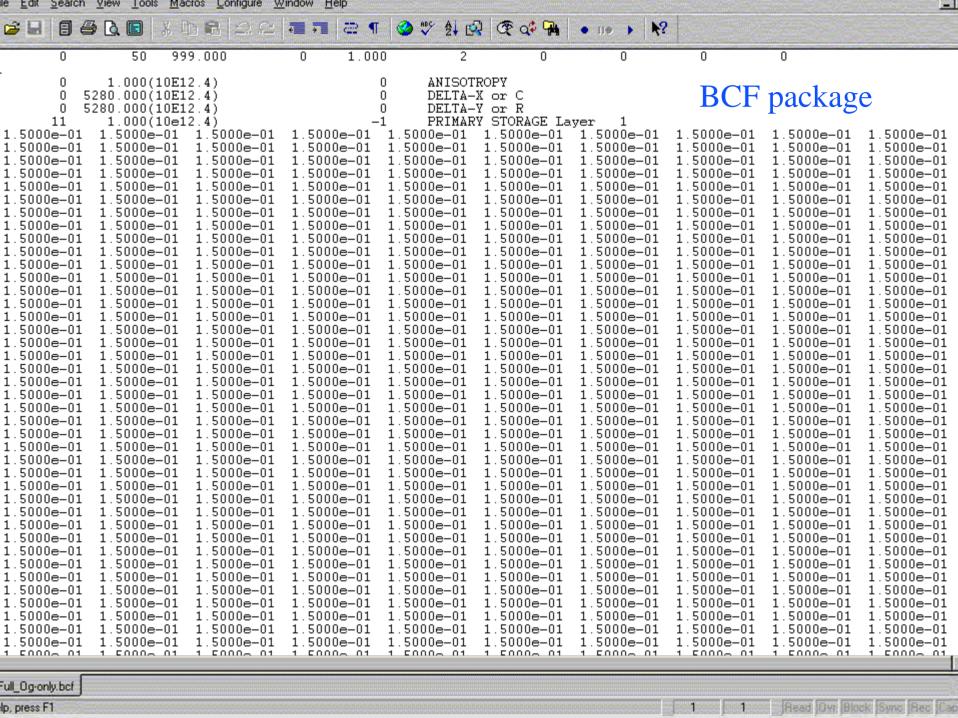




<u>Block Centered Flow Package</u>

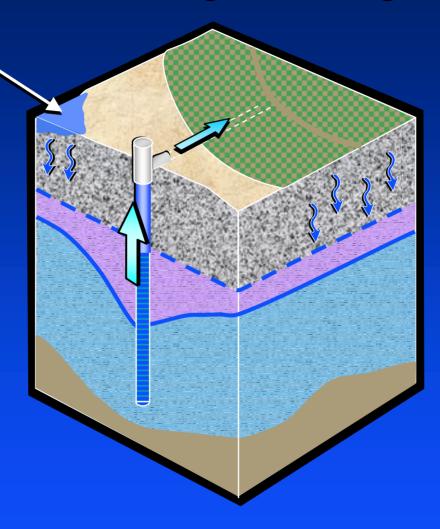
- Grid dimensions
- Hydraulic conductivity
- Storage coefficients
- Bottom/top elevations of model layers

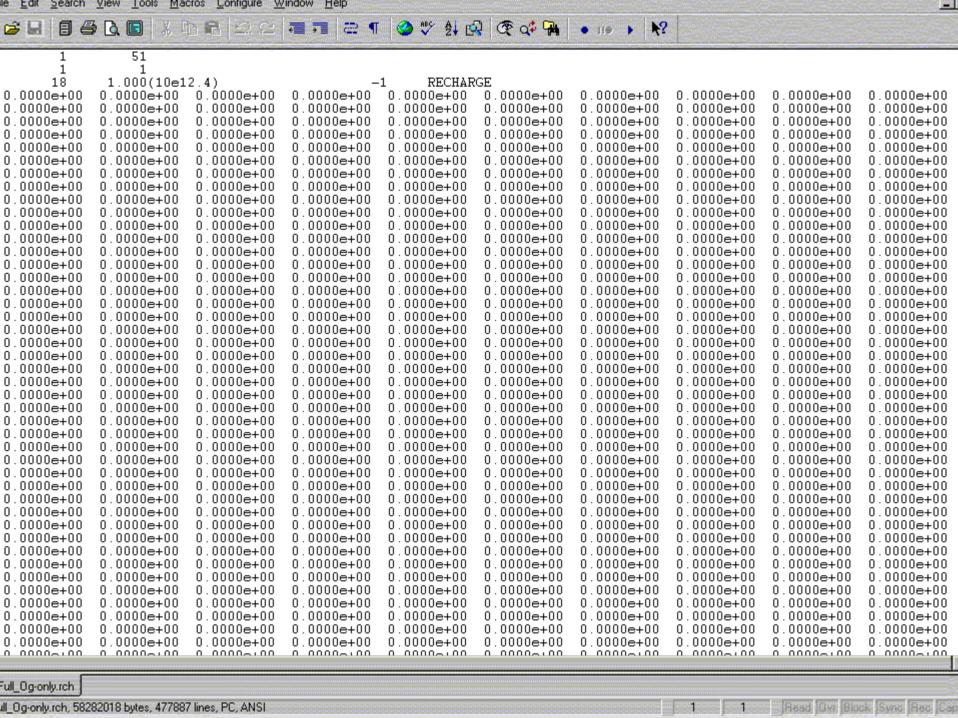




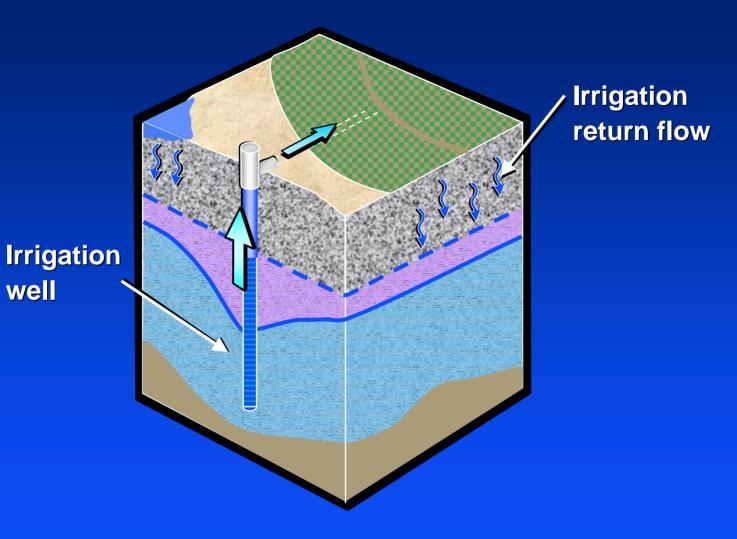
Recharge Package

Natural recharge



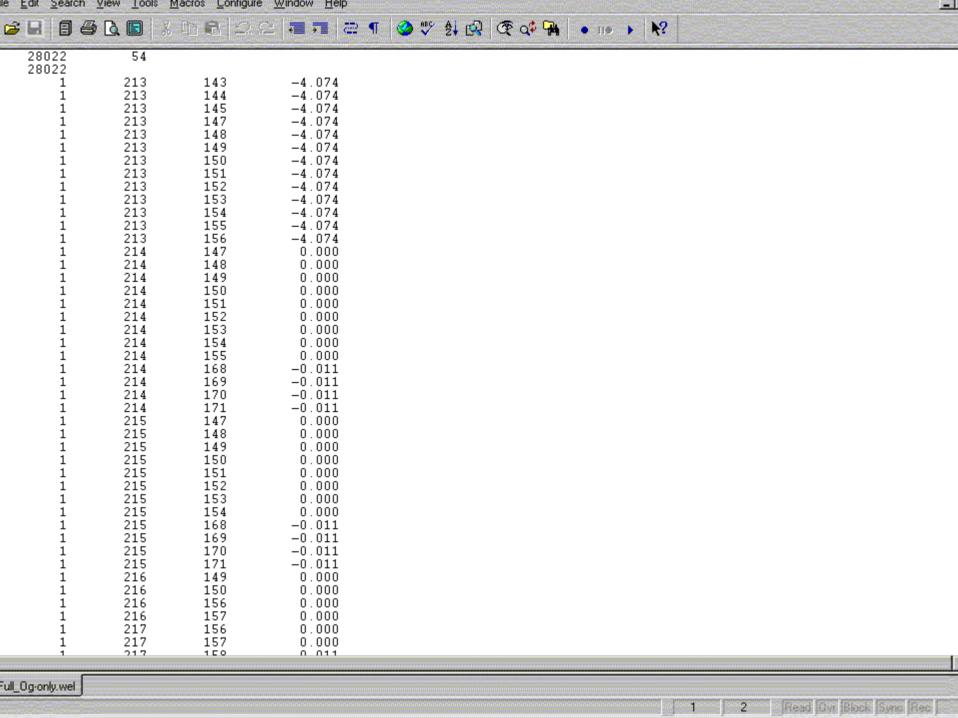


Well Package



Daniel B. Stephens & Associates, Inc.

well

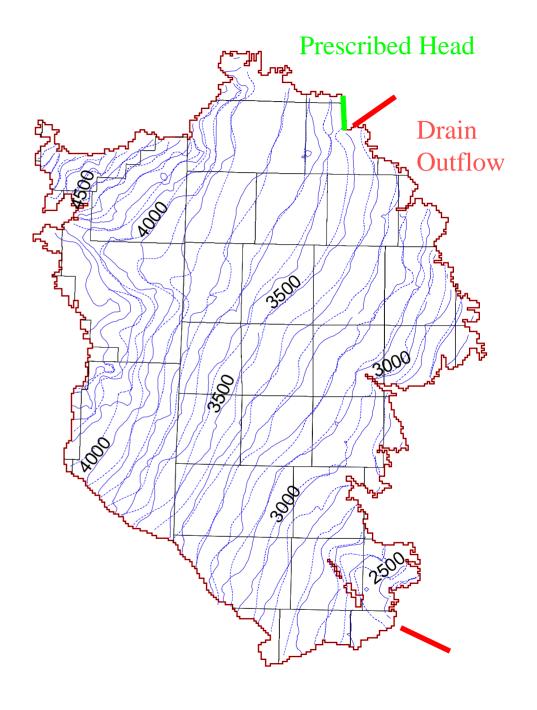


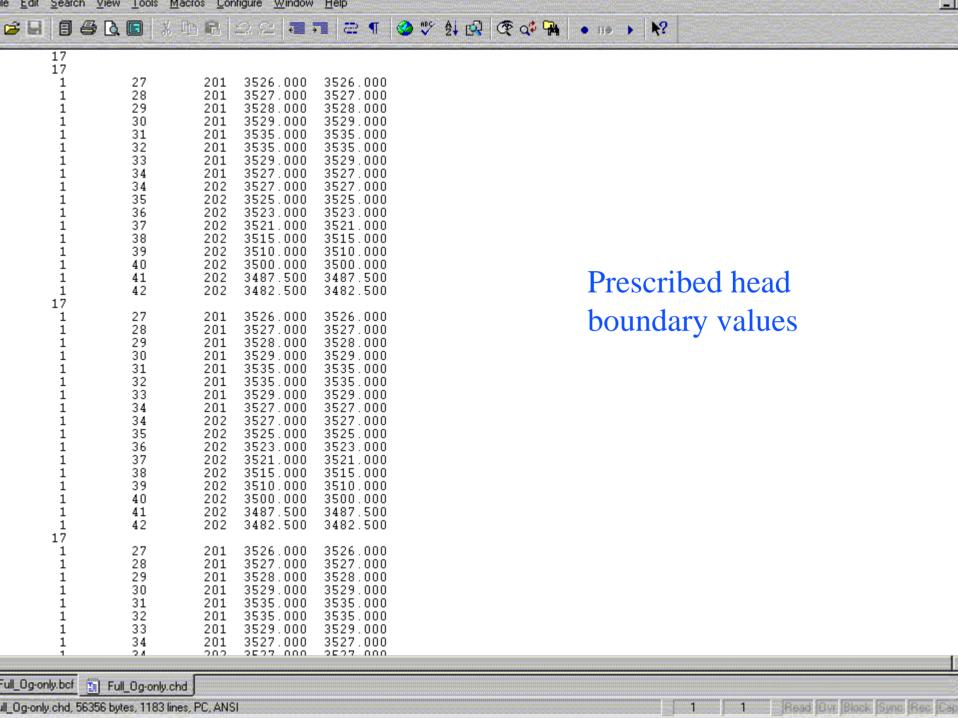
Boundary Conditions

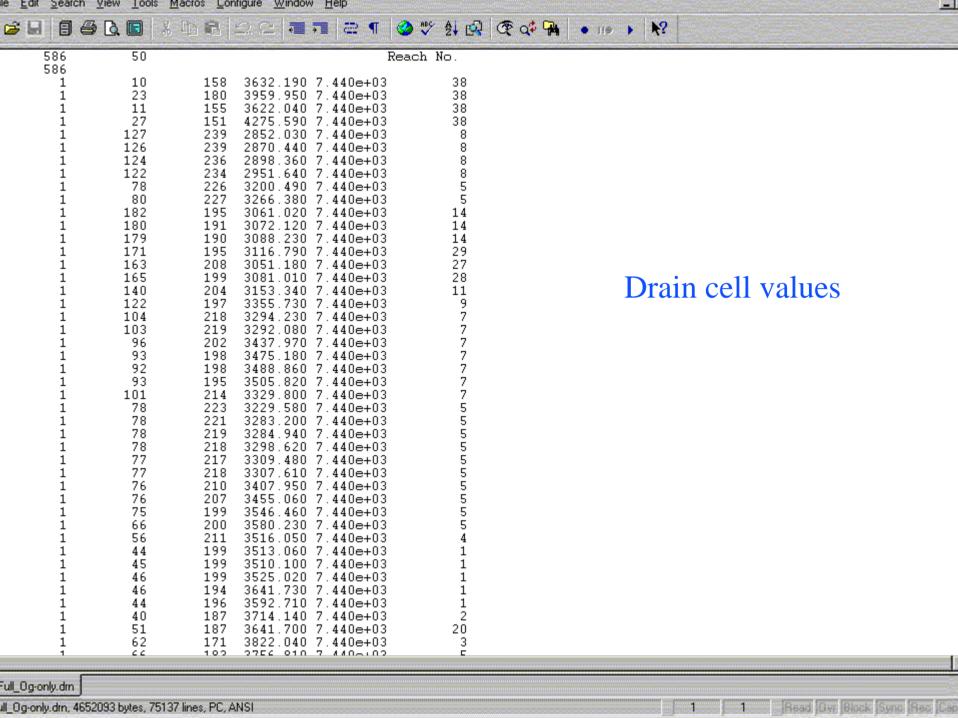
- Prescribed hydraulic head (water levels)
 - Used along northeastern boundary
- Prescribed groundwater flux
 - Not used (some would consider recharge and pumping here)
- Head-dependent flux
 - Used along eastern escarpment and for small reach along western escarpment



Simulated and Observed Hydraulic Heads







GAM Modeling Approach

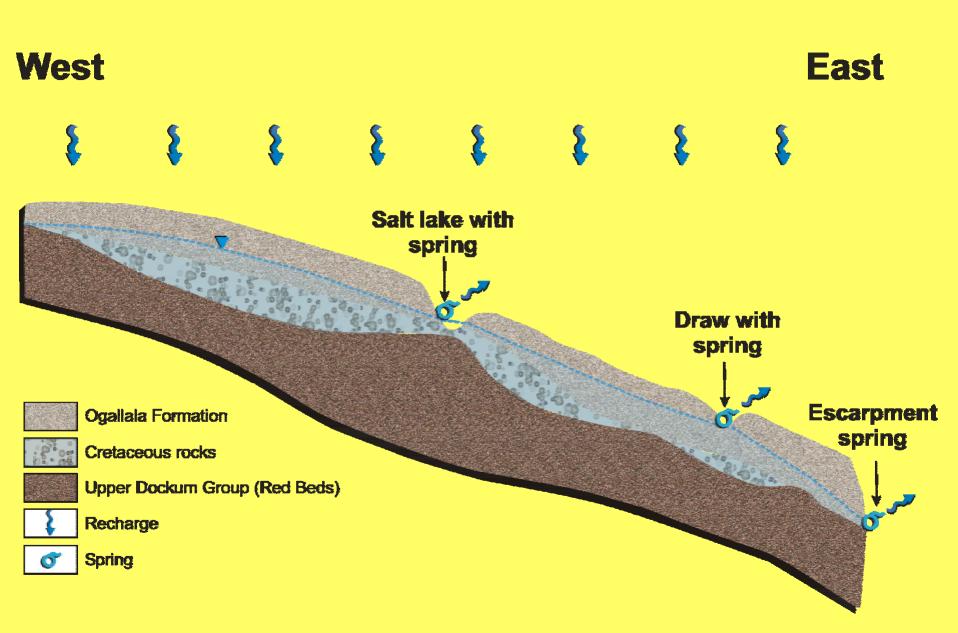
- Quantify recharge terms separately
 - Natural (precipitation)
 - Irrigation return flow
- Refine estimates of agricultural water use
- Update aquifer parameters
 - Specific capacity data
 - Previous field investigations
 - Geological models
- All data sets available electronically



Conceptual Model

- Where water flows and why
- How water enters and exists the aquifer



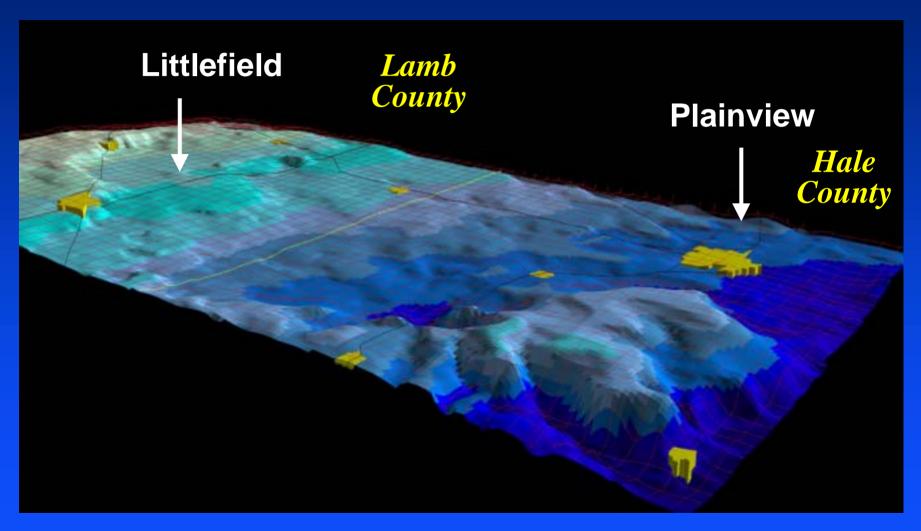


Incorporate Conceptual Model Into a Mathematical Model

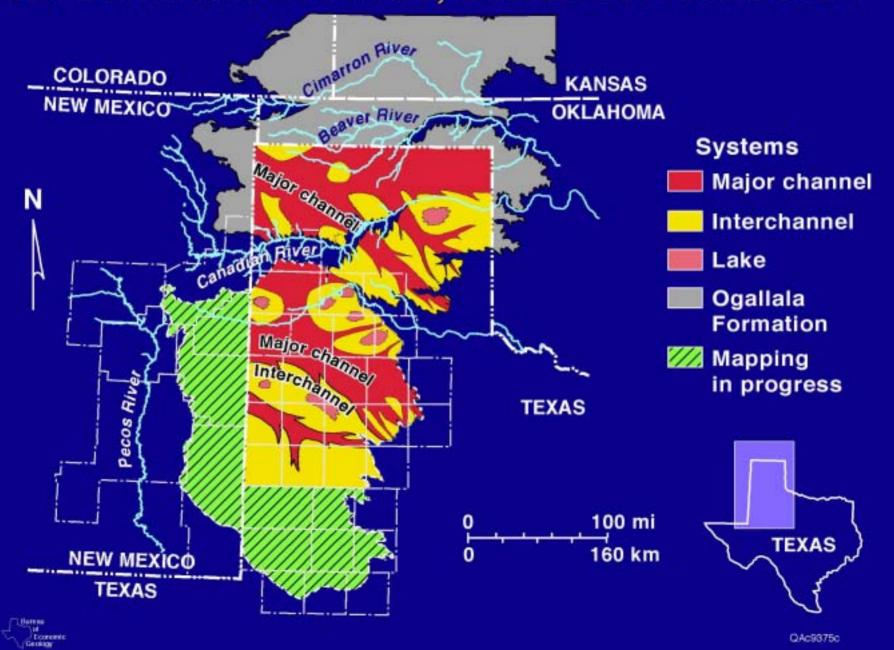
- Model Grid 1 mi x 1 mi; 1 layer
- Boundary conditions along edge of grid and internally around salt lakes
- Assign hydraulic conductivity
- Assign recharge
- Assign specific yield (transient model)
- Assign pumping (transient model)

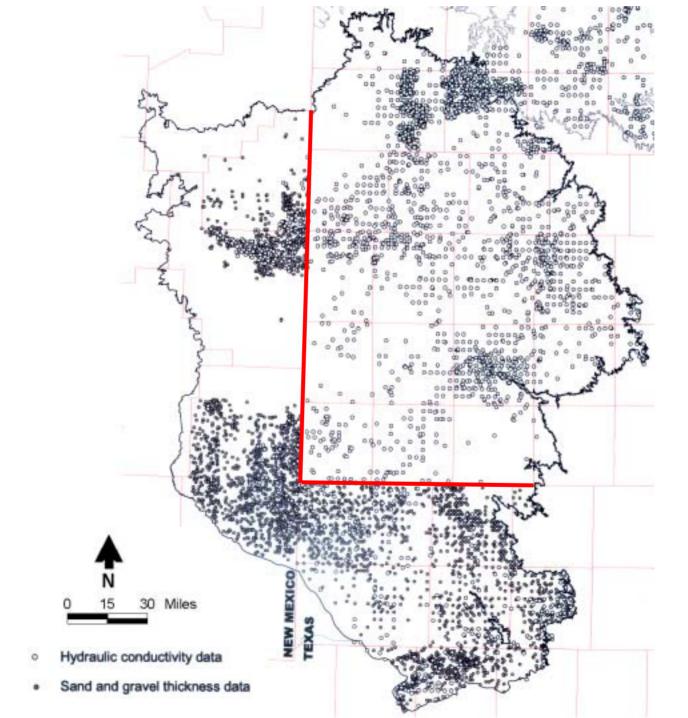


Approximate Altitude of the Base of the Ogallala Aquifer with Model Grid

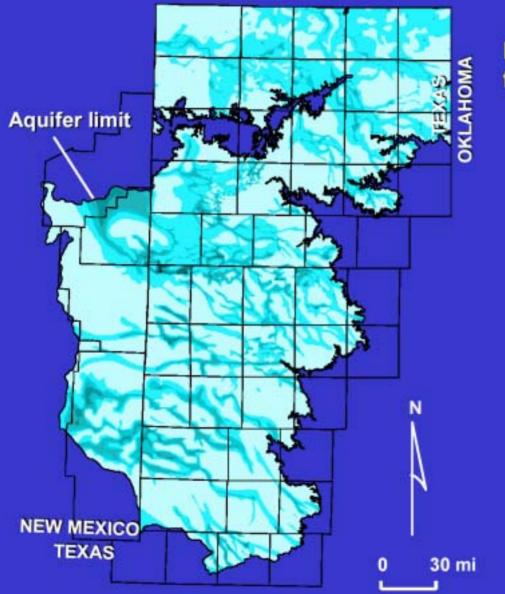


DEPOSITIONAL SYSTEMS, OGALLALA FORMATION



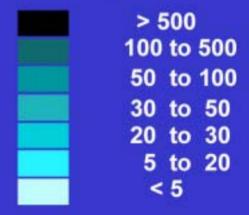


HYDRAULIC CONDUCTIVITY OF OGALLALA AQUIFER



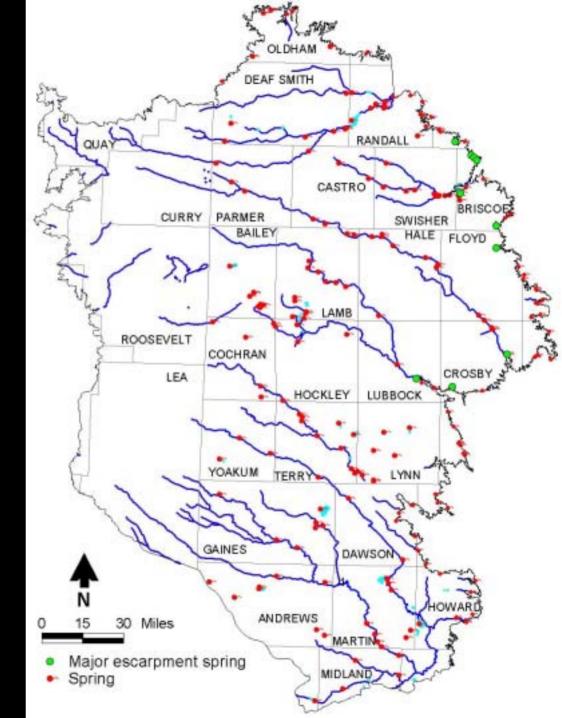
New Mexico trends inferred from sand and gravel percentage

> Hydraulic Conductivity (Feet/day)

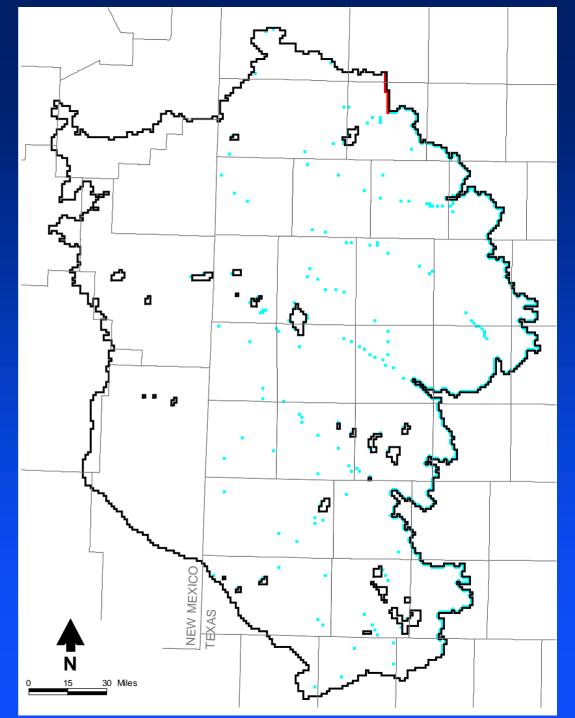


Documented Springs

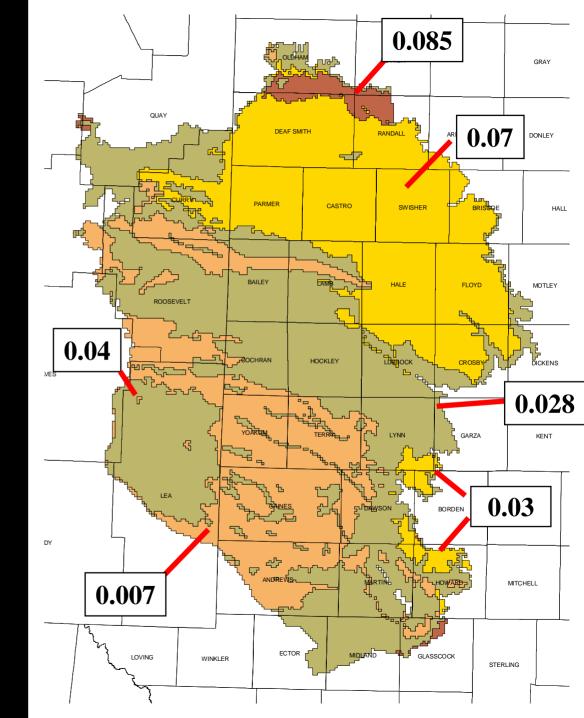
Outflows: Escarpment = 57% 'Interior' = 43%



Model Boundaries



Recharge
Zones
Used in
the Model
(inches/yr)

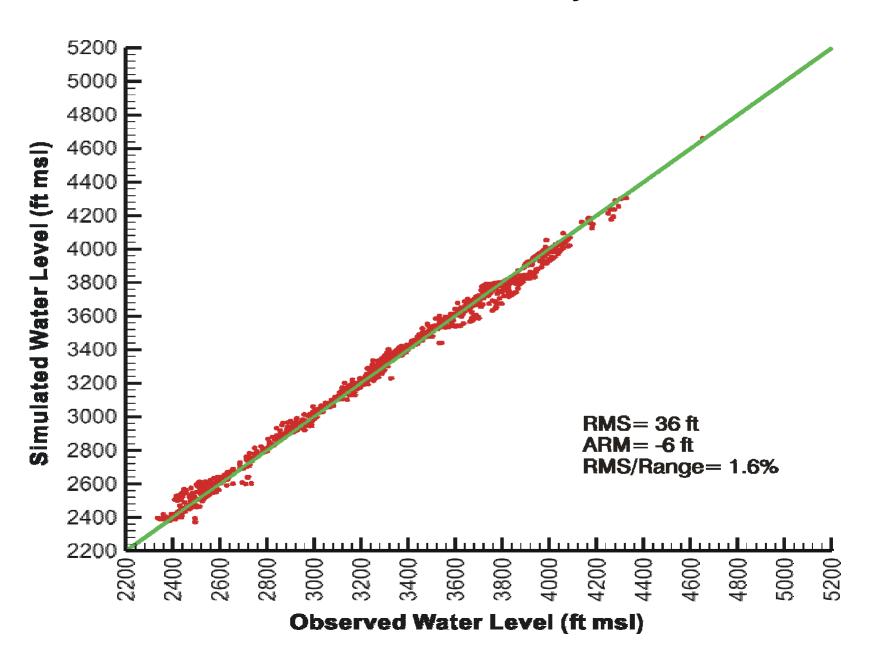


Model Calibration

- Predevelopment (1940) point data and spring discharge
- Transient (1940 2000) 80 well hydrographs and all water levels for 1980, 1990 and 2000



Simulated vs. Observed Hydraulic Head



Comparison With Previous Regional Models

GAM

R = 0.037 inch/yr

K = 17 ft/d

USGS RASA

R = 0.086 inch/yr

K = 10 - 150 ft/d

■ TWDB (begins 1960) R = 0.2 inch/yr

K = 68 ft/d



Model Calibration

- Transient (1940 2000)
 - 80 well hydrographs
 - All water levels for 1980, 1990 and 2000



Return Flow Estimates

1940 - 1960 55%

1961 - 1965 50%

1966 - 1970 45%

1971 - 1975 40%

1976 - 1980 35%

1981 - 1985 25%

1986 - 1990 20%

1991 - 1995 15%

1996 - 2000 10%

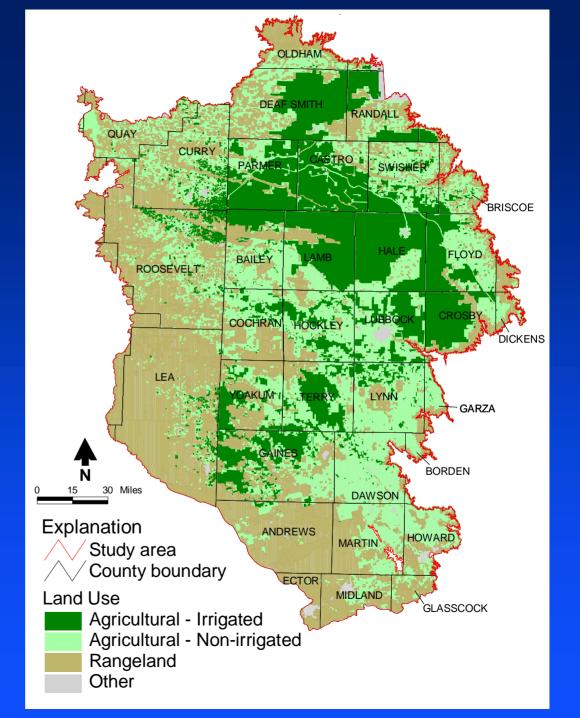


Enhanced Recharge

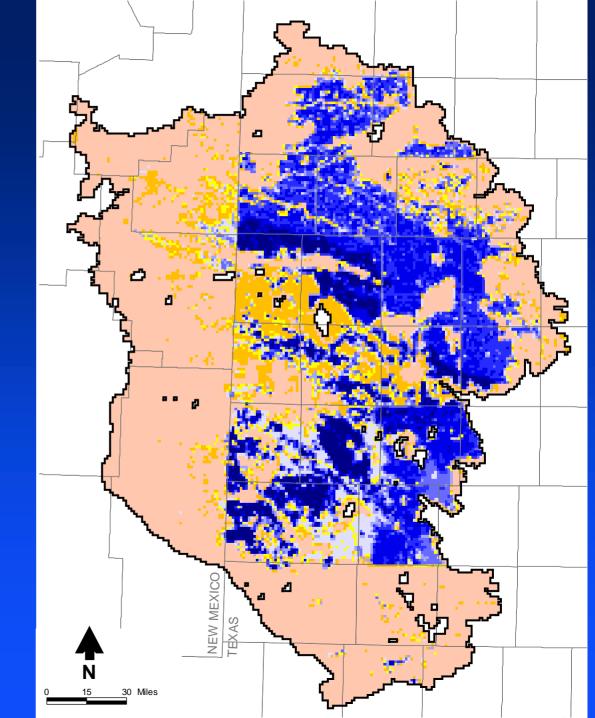
- Irrigated areas; 1.75 2.5 in/yr
- Dry land farming; 0.25 2.0 in/yr
- Non-farmed areas; predevelopment rates



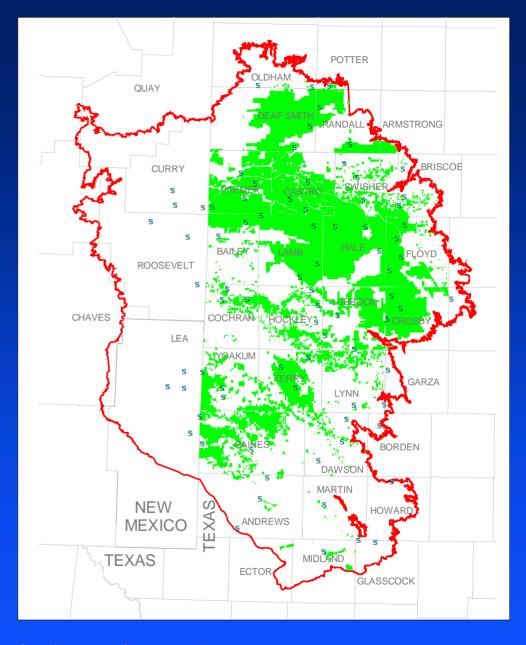
Land Use



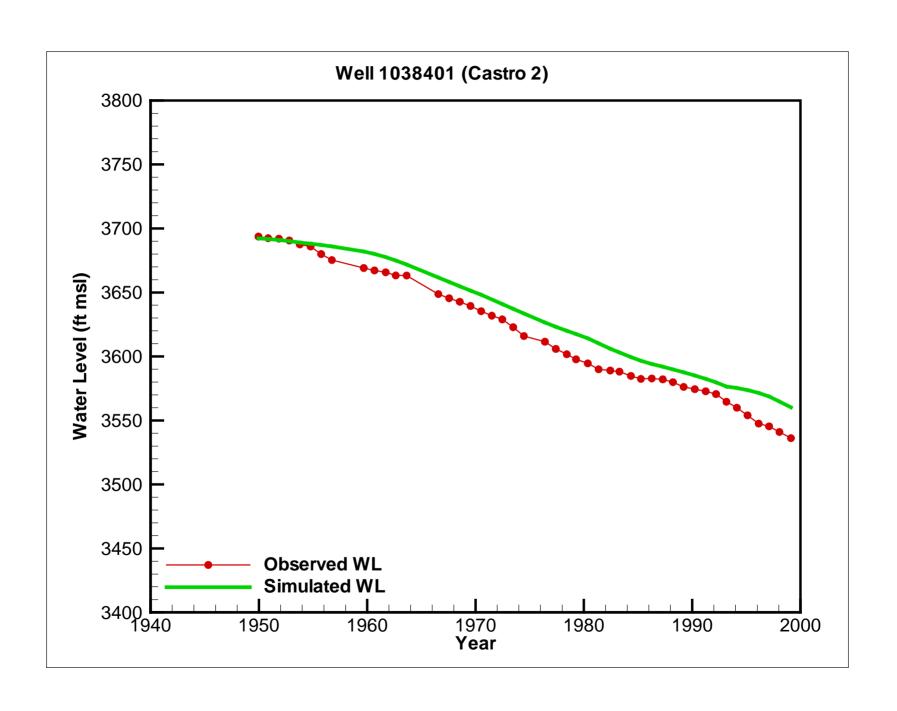
PostDevelopment Recharge Rates

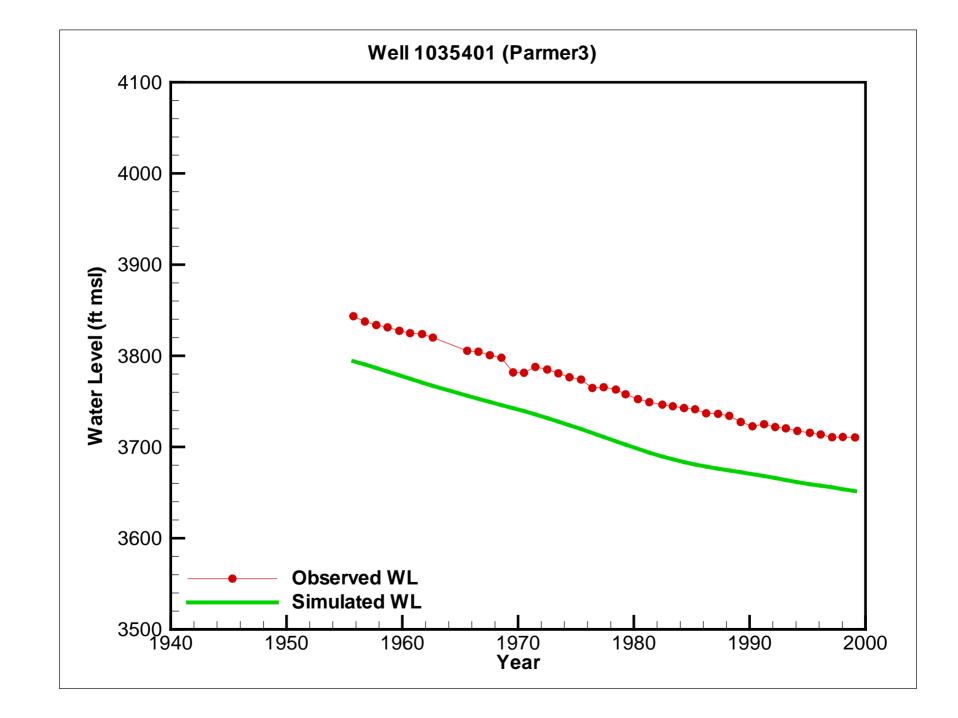


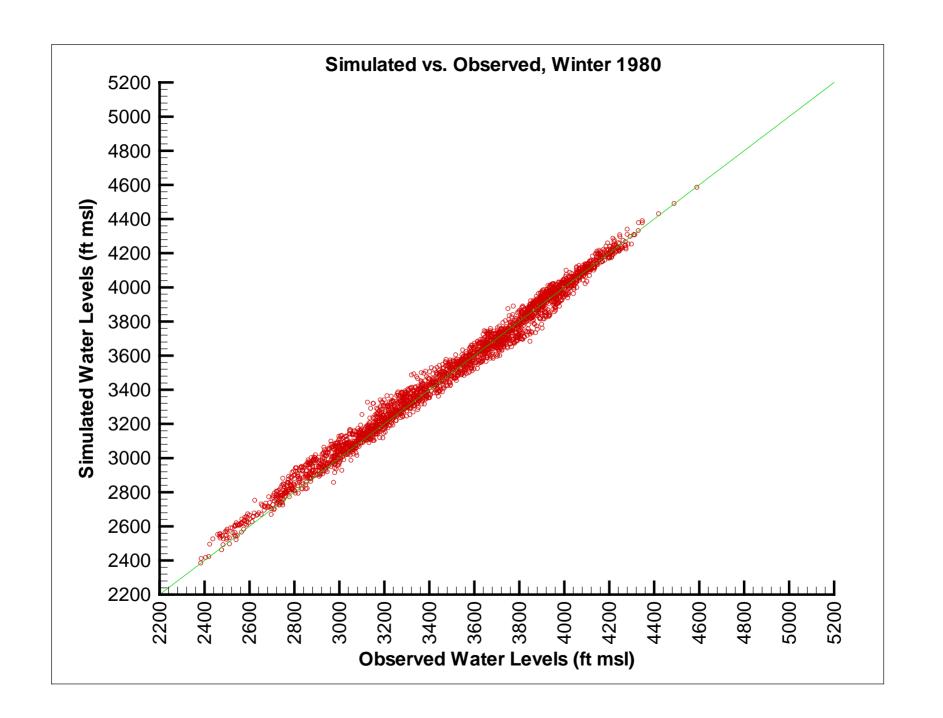
1994 Irrigated
Lands with
Hydrograph
Locations

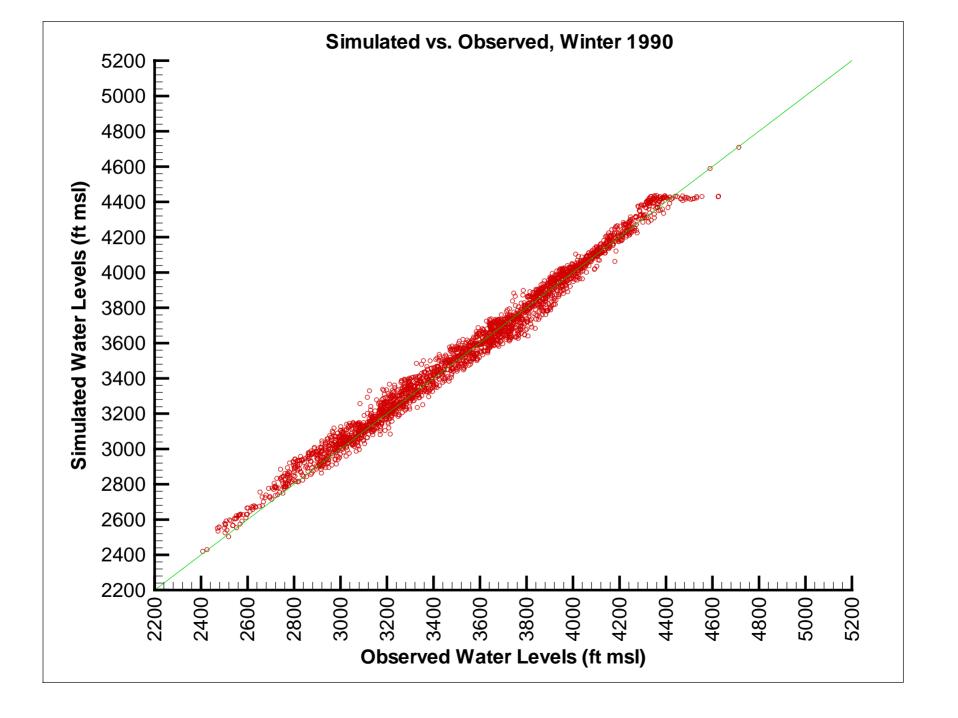


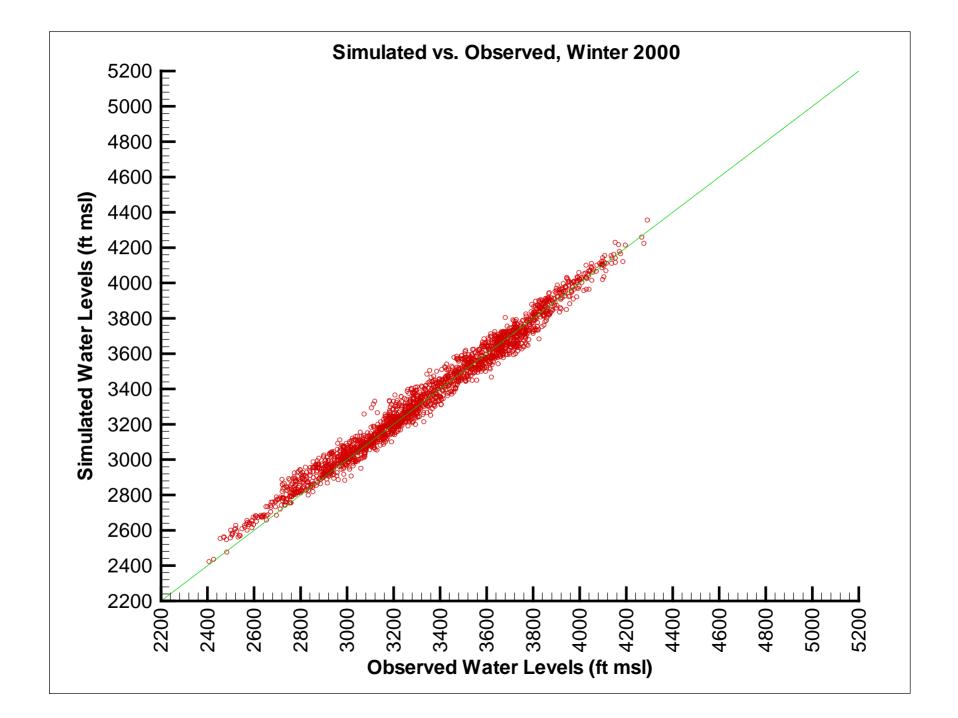








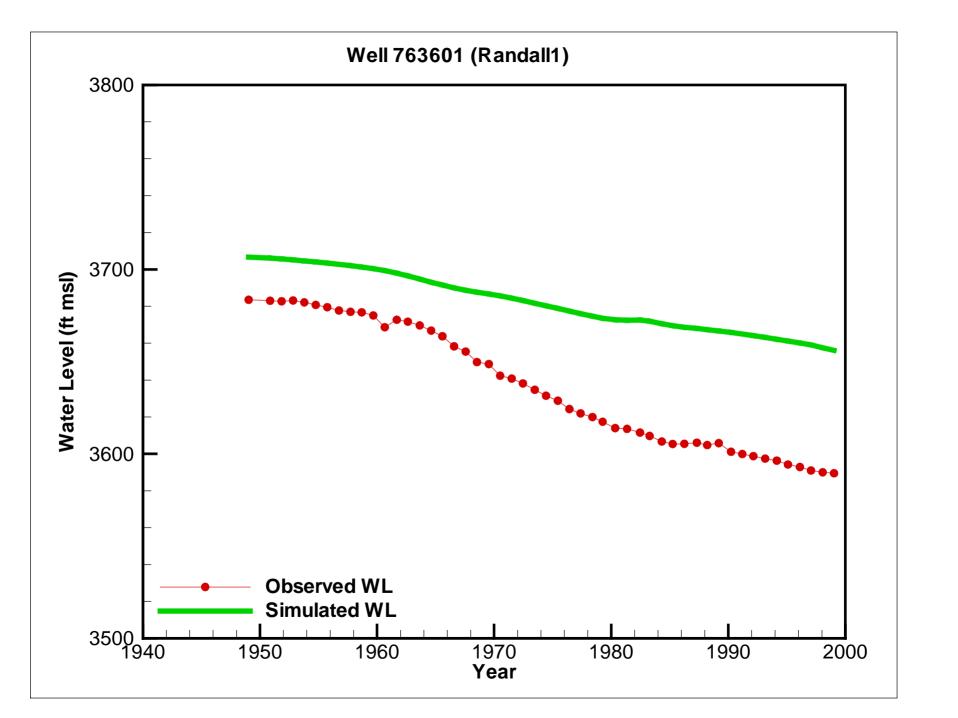


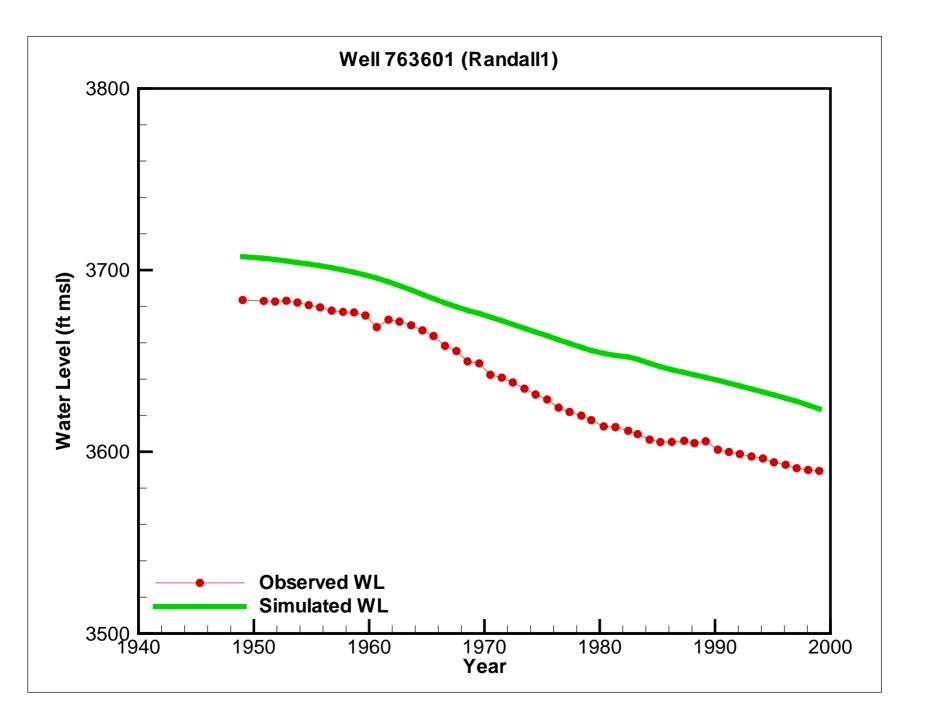


Model Validation

Transient (1940 - 2000) - 10 well hydrographs







Predictive Simulations

- 2001-2050 Average conditions
- Last 5 yrs drought of record
 - ◆ 2001-2010
 - 2001-2020
 - 2001-2030
 - ◆ 2001-2040
 - 2001-2050
- 2001-2050 Reduced pumping, 45-55%

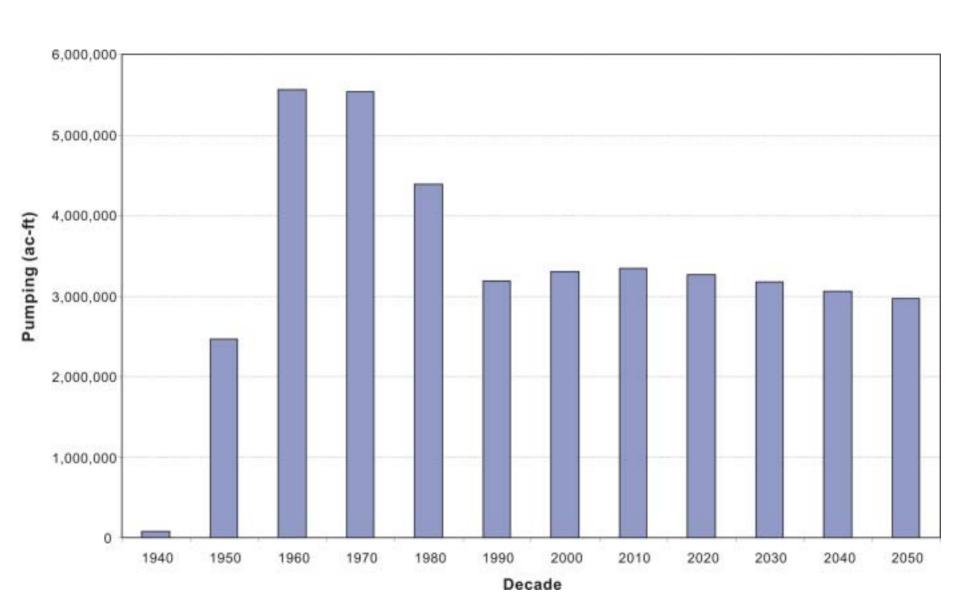


Predictive Simulations

- Agricultural pumping from TWDB spreadsheet
- Applied to 1994 "footprint"
- Drought period = 5 years; increase in Q
 from Amosson calculations
- Non-ag pumping: use year 2000 footprint



Historical and Future Pumping



Simulated 2020 Saturated Thickness

