GAM

Groundwater Availability Modeling

texas water development board

Agenda for Stakeholder Advisory Forum No. 5 - June 17, 2002

- Data collection and analysis update
- Predevelopment modeling status
- Hydraulic conductivity analysis
- Recharge analysis
- Questions/comments/input

Groundwater Availability Modeling (GAM) is the process of

developing and using computer programs to estimate the amount of water available in an aquifer. It is based on

- Hydrogeologic principles
- Actual aquifer measurements
- **Stakeholder guidance**

Purpose of the GAM is to...

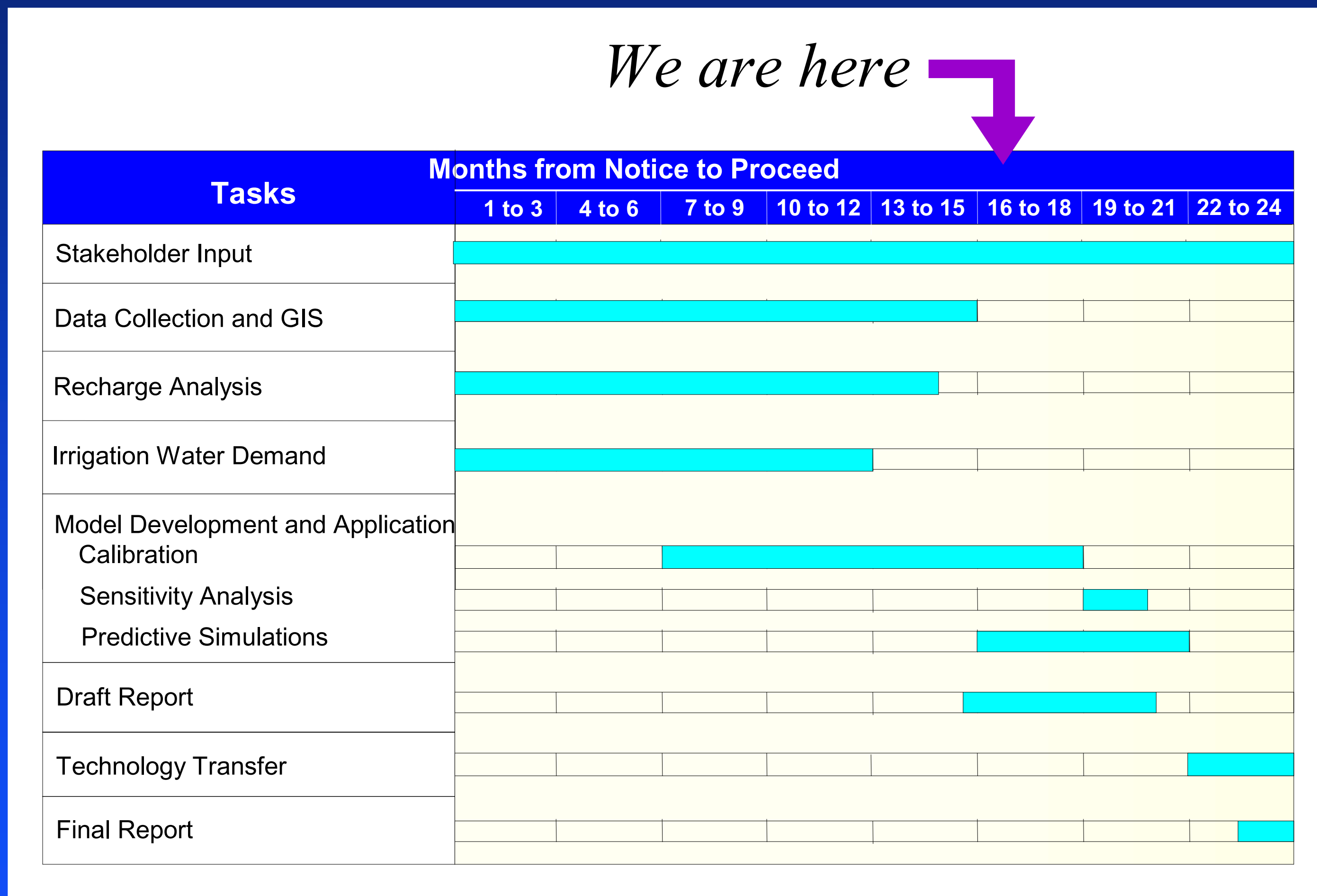
"provide reliable, timely data on groundwater availability ... to ensure adequacy of supplies or recognition of inadequacy of supplies throughout the 50-year planning horizon."

- Pederson, TWDB (1999)

The model will be used by

- Underground Water Conservation Districts (UWCDs), Regional Water Planning Groups (RWPGs), TWDB and other entities to evaluate the effects of water use alternatives
- The model and the data will be available to the public

Project Schedule



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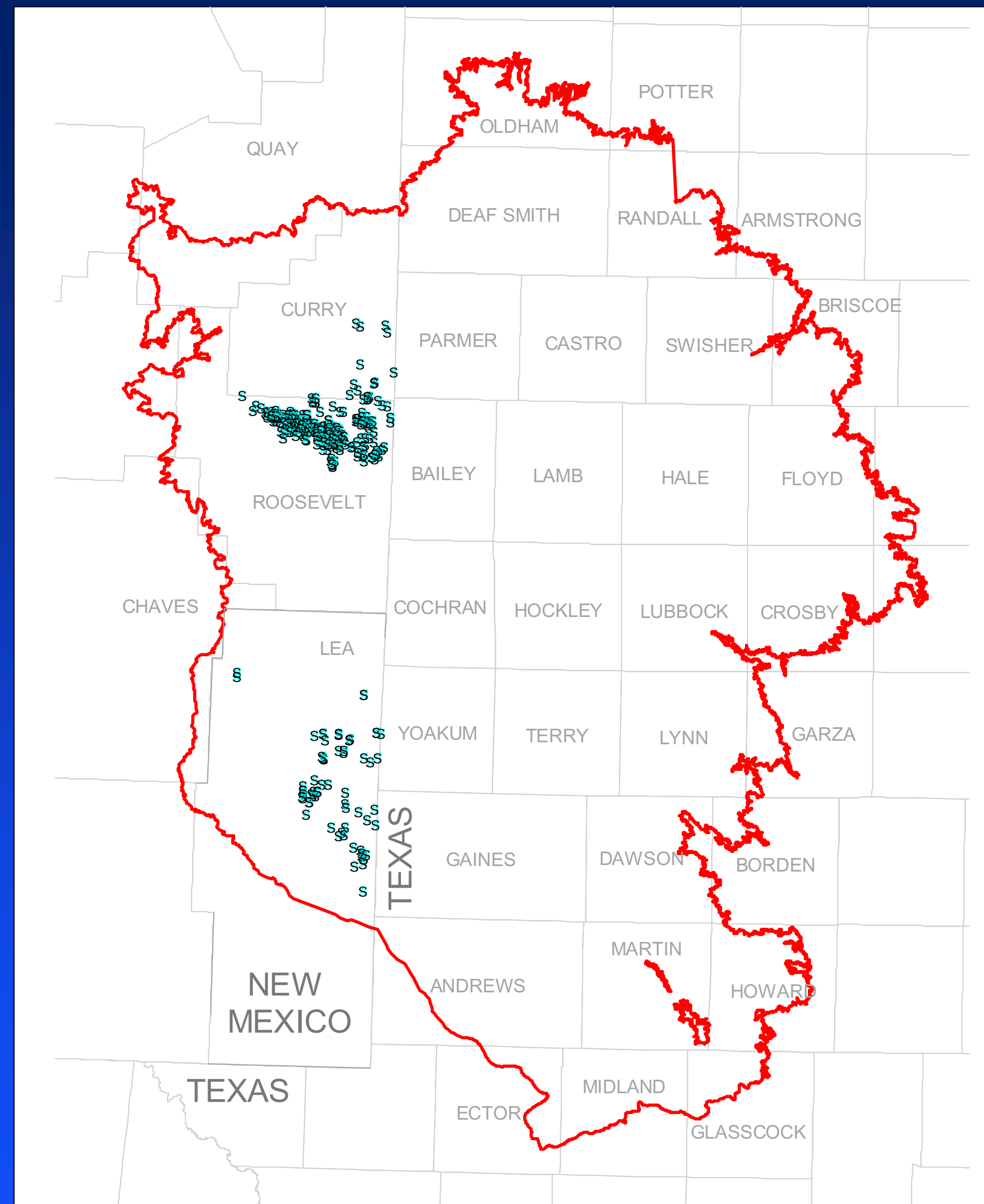
New Mexico Specific Capacity Data Points (349)



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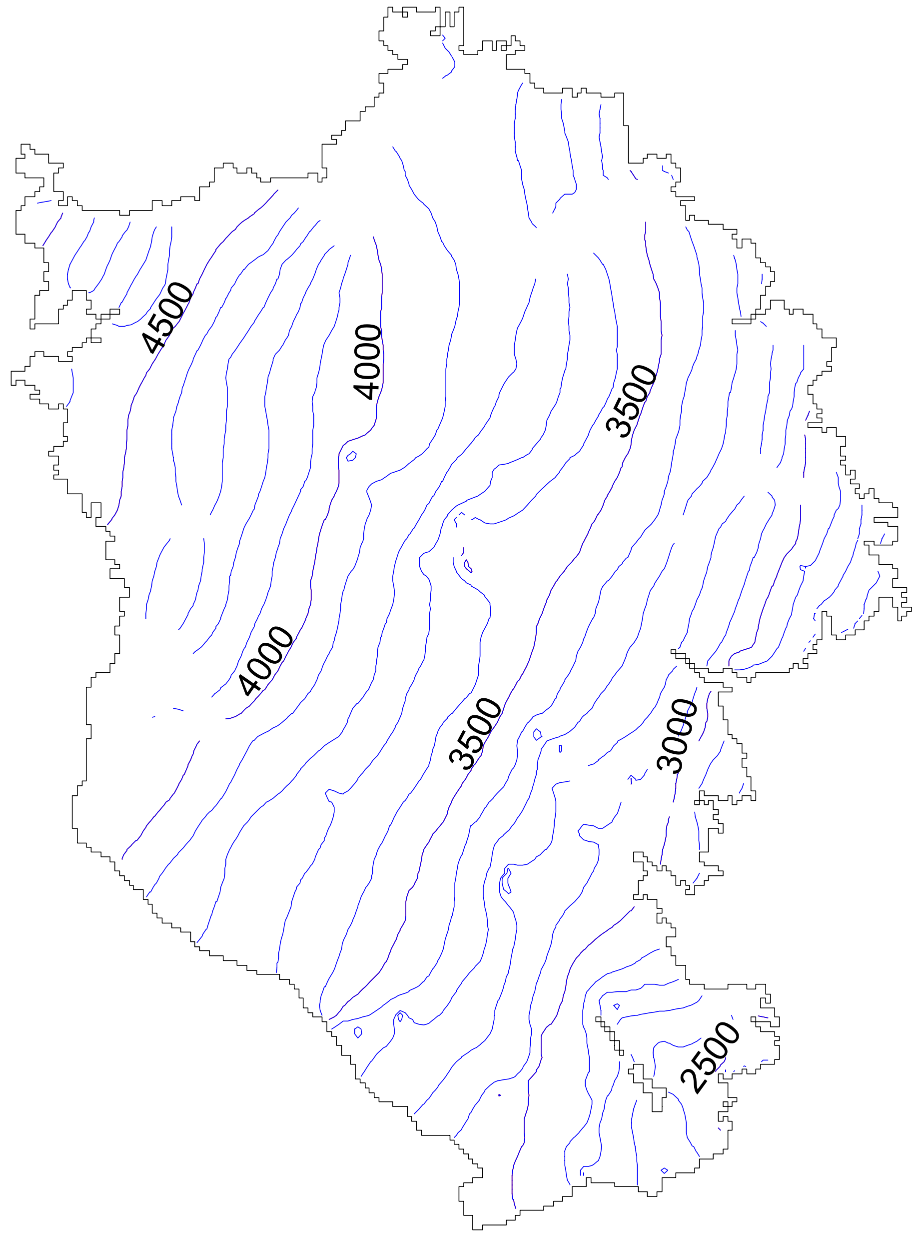
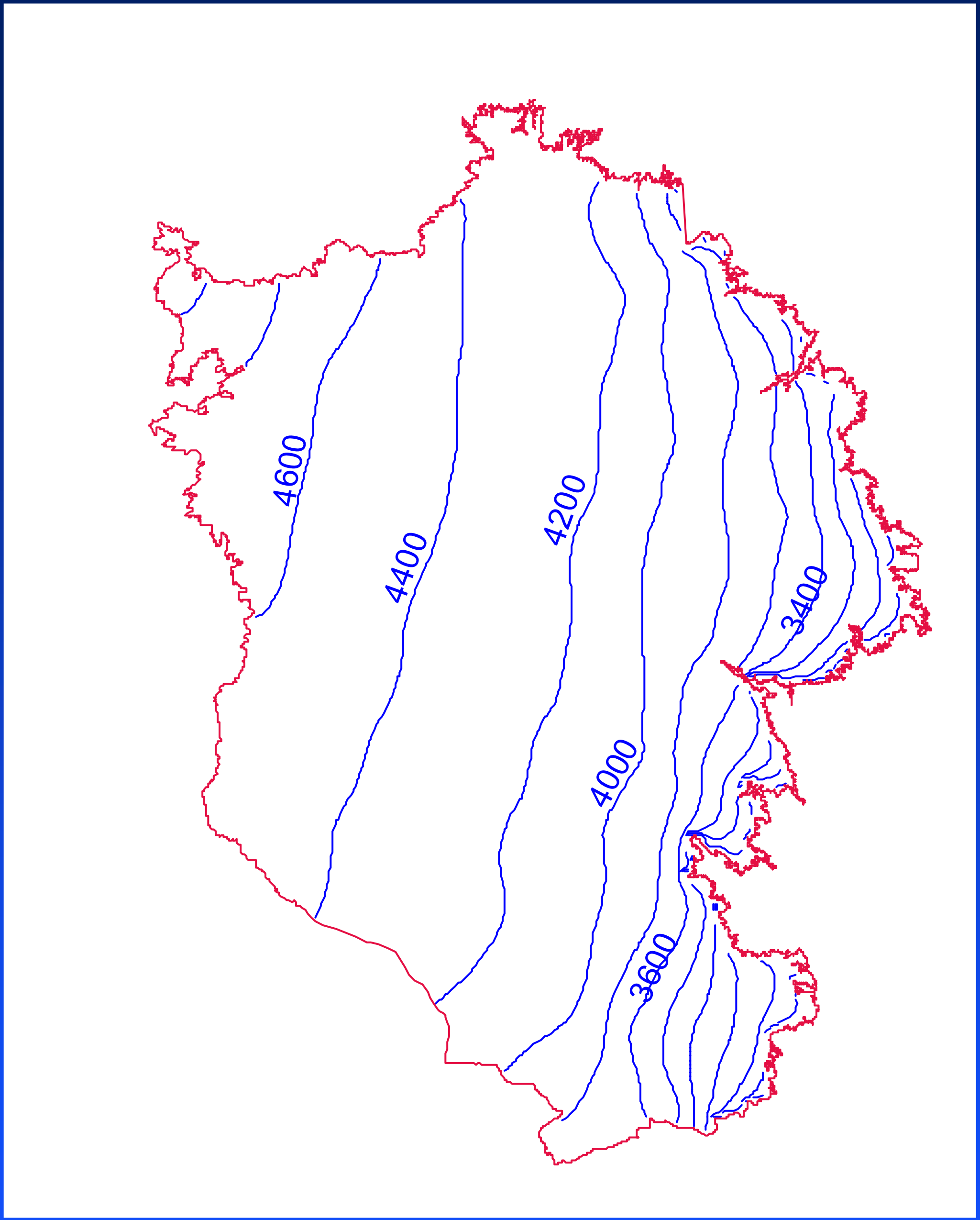
Sample Simulated Water Levels



Steady-State Simulation Example



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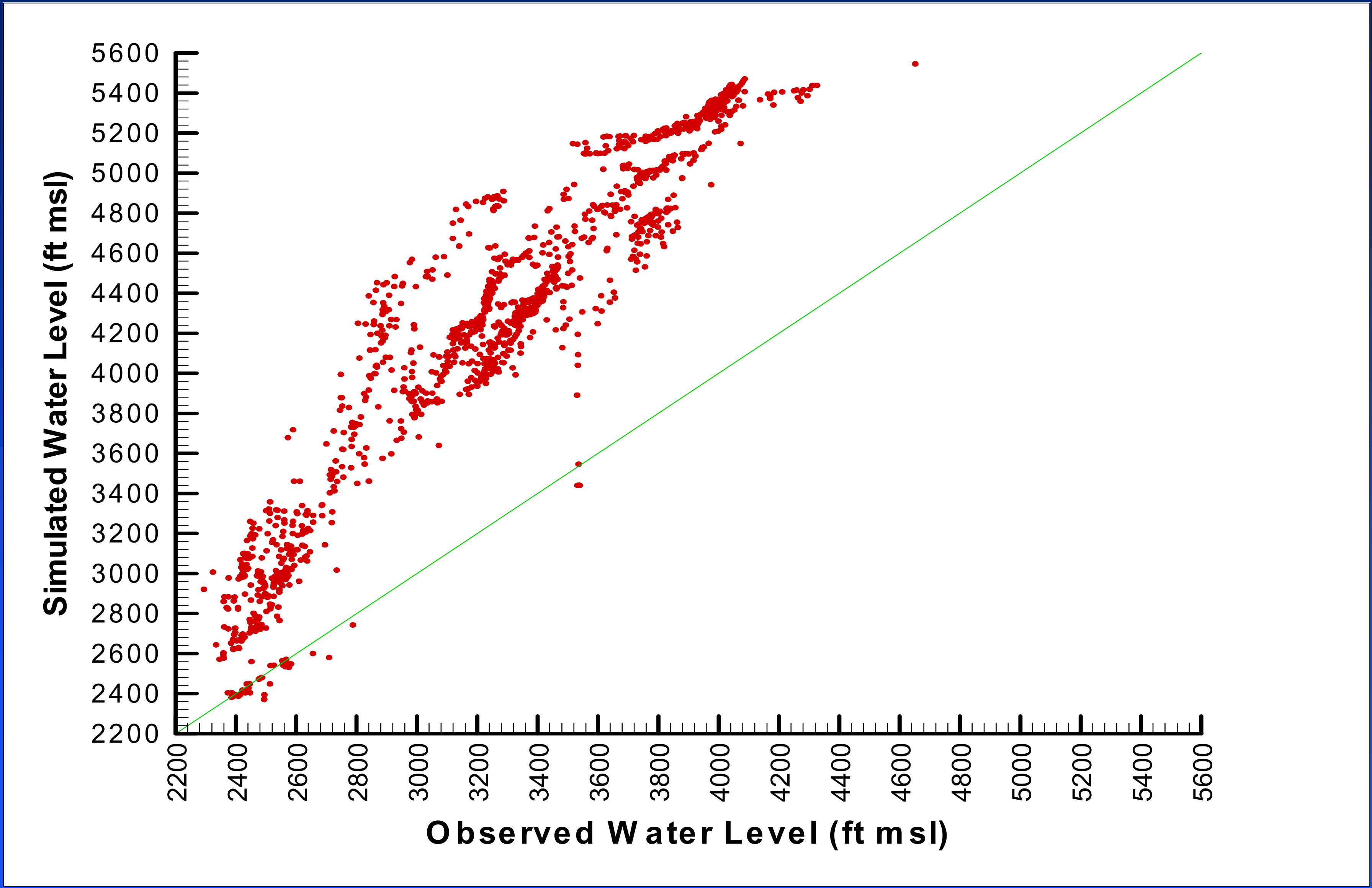
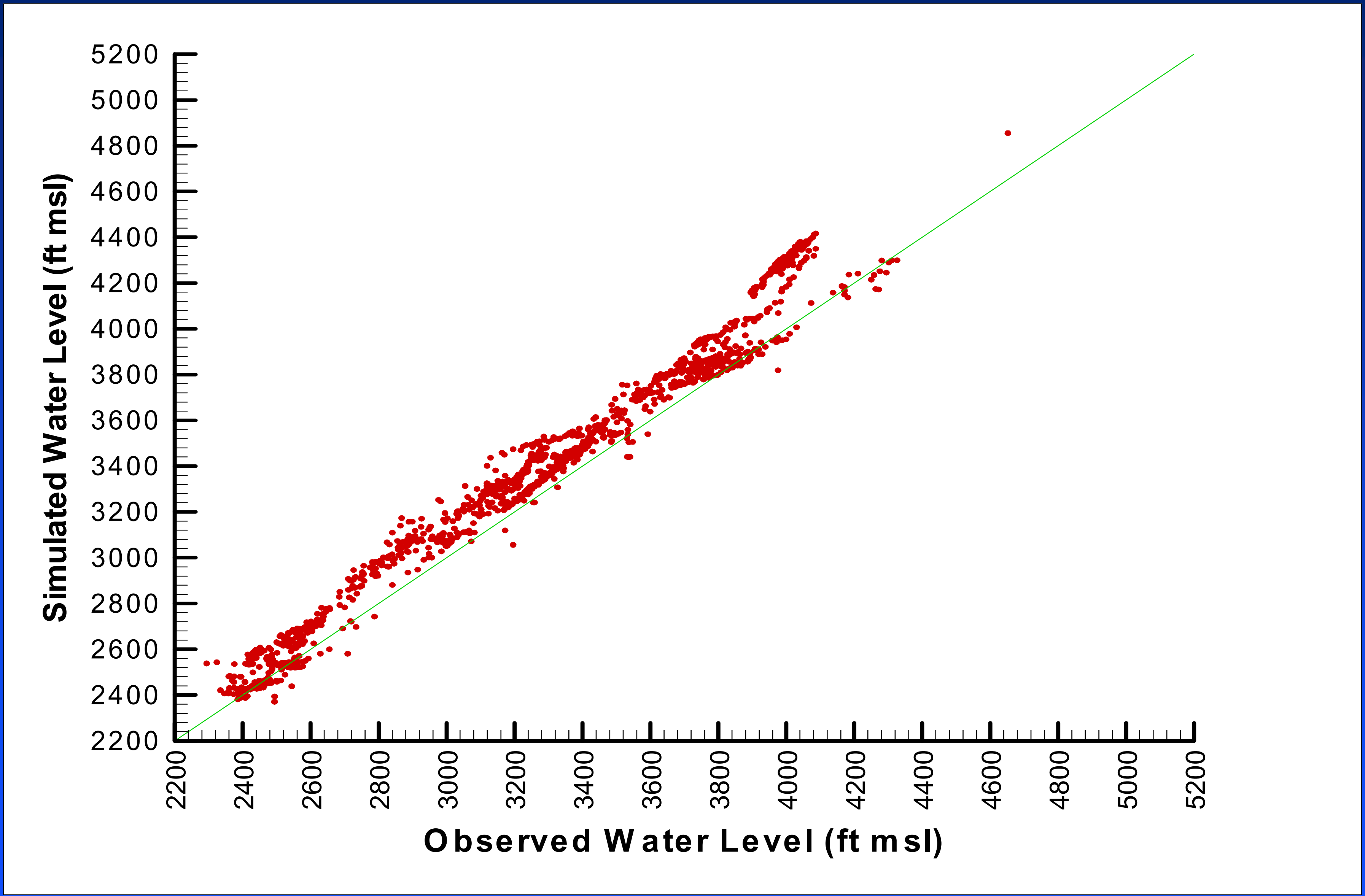
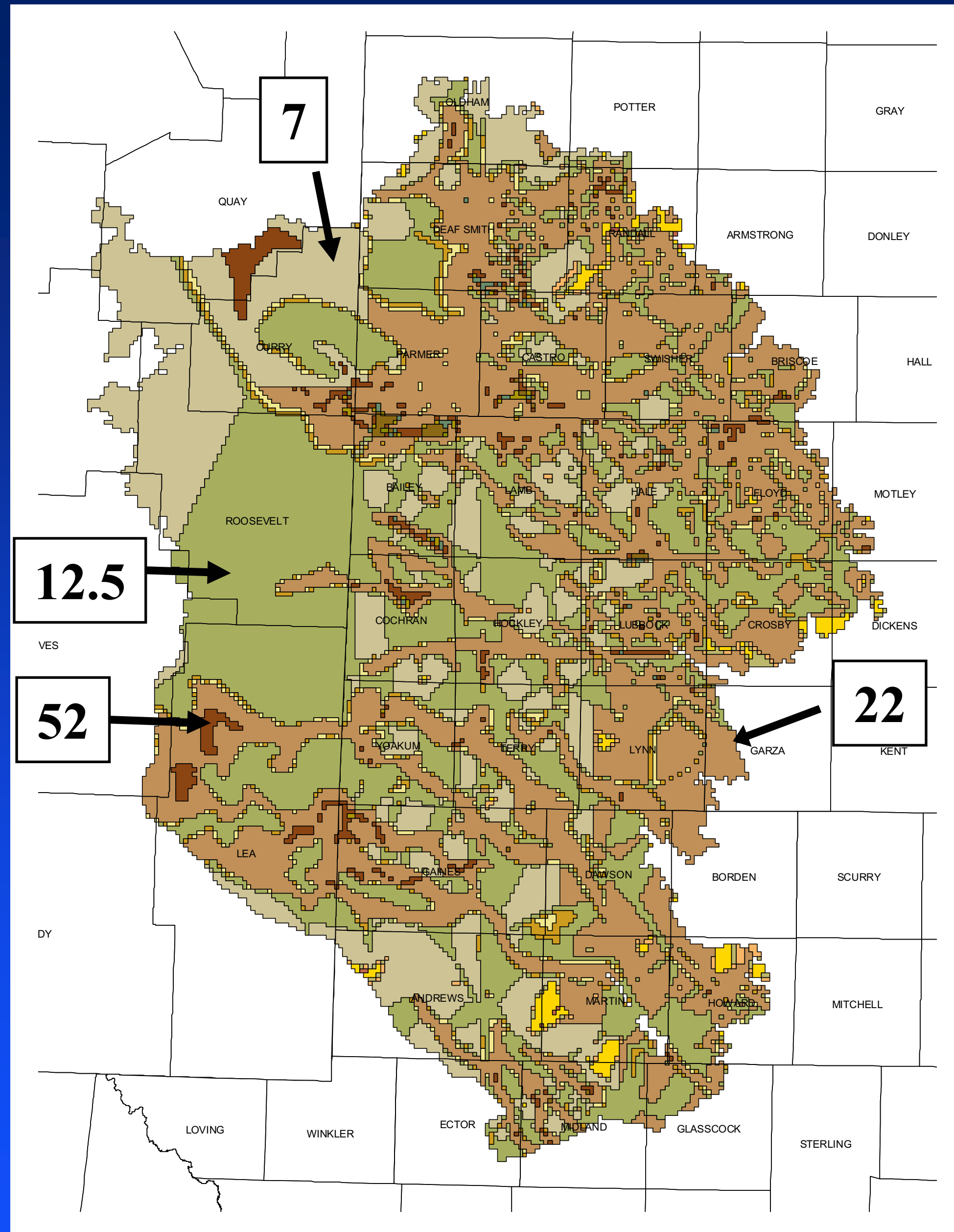
Early Calibration to Water Levels



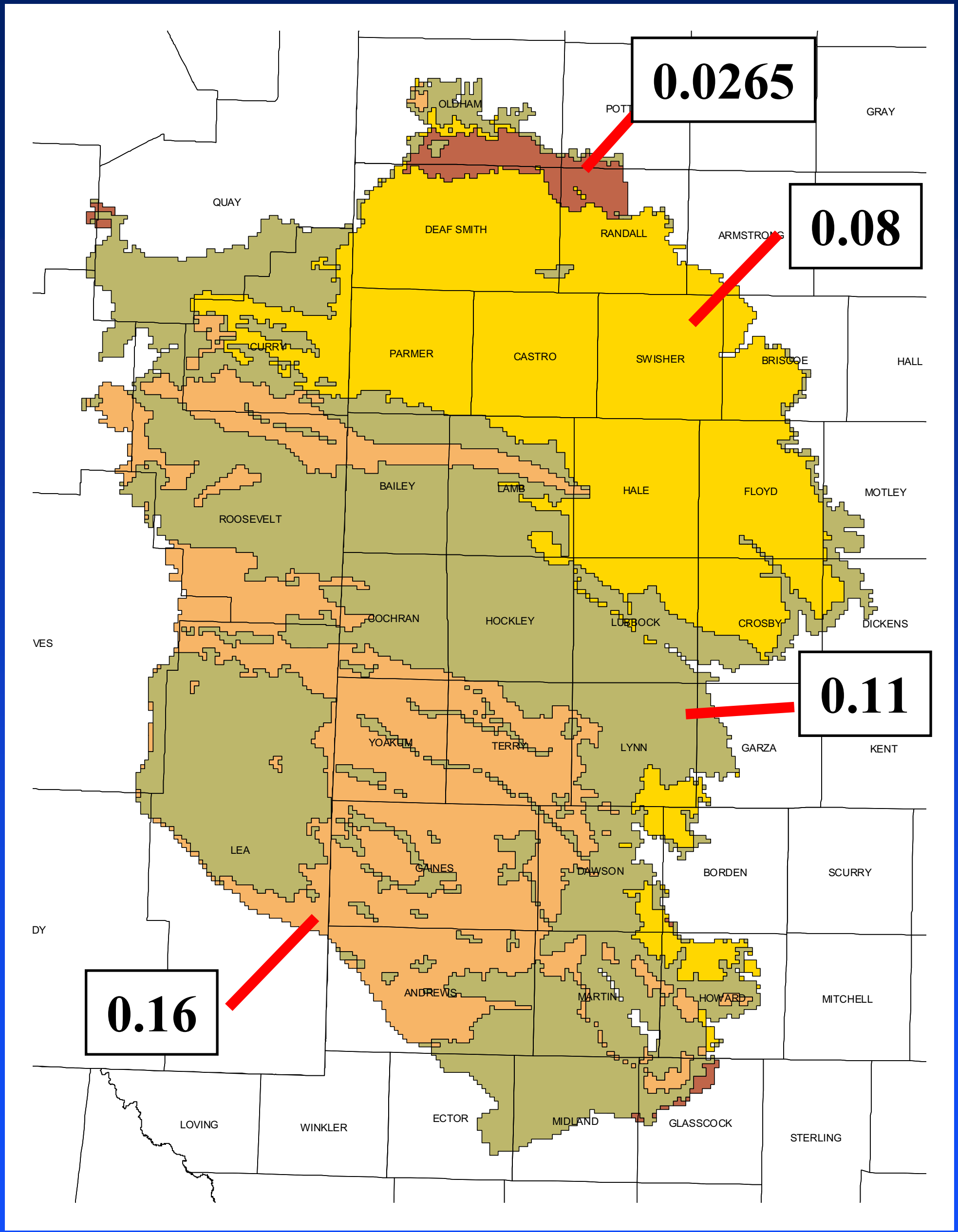
Recent Calibration to Water Levels



Hydraulic Conductivity Used in the Model (ft/d)



Recharge Zones Used in the Model (inches/yr)



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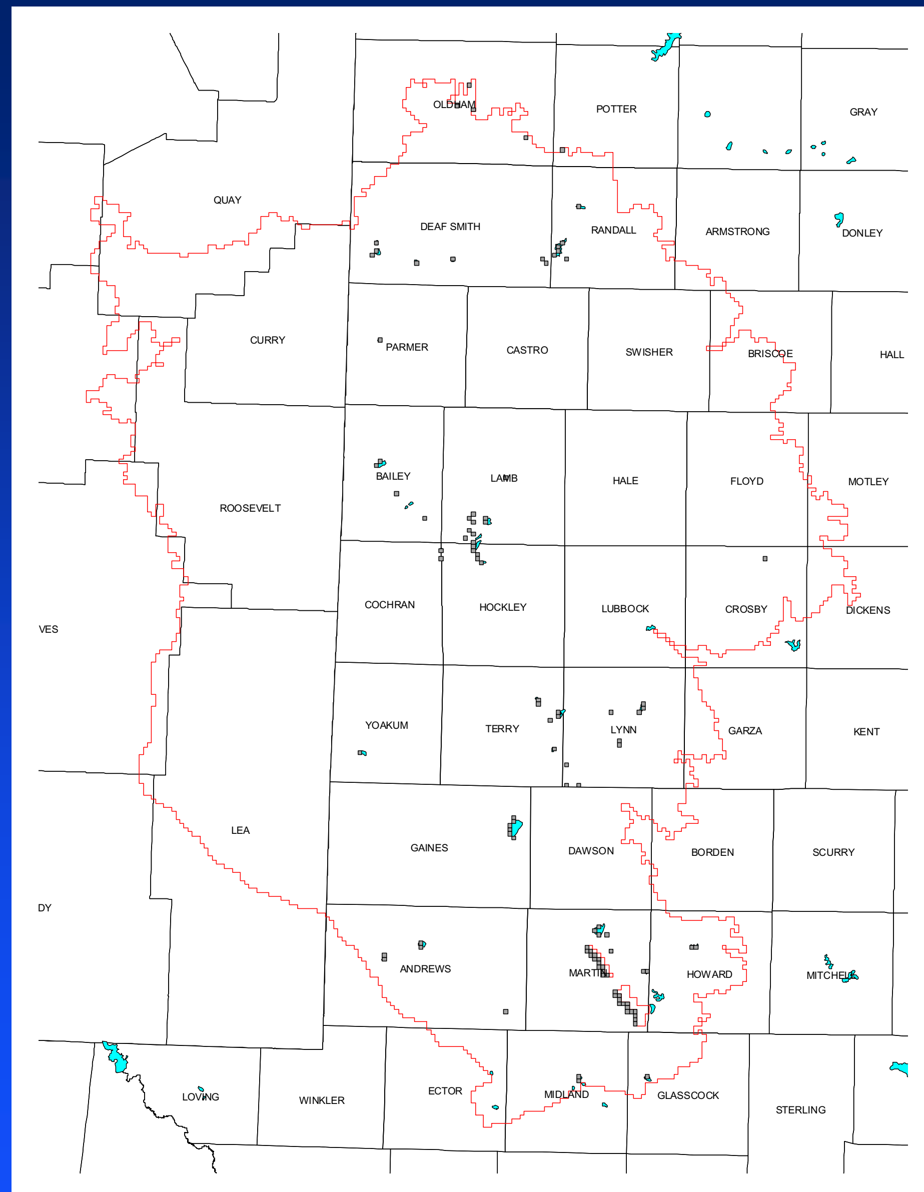
"Interior" Discharge Points



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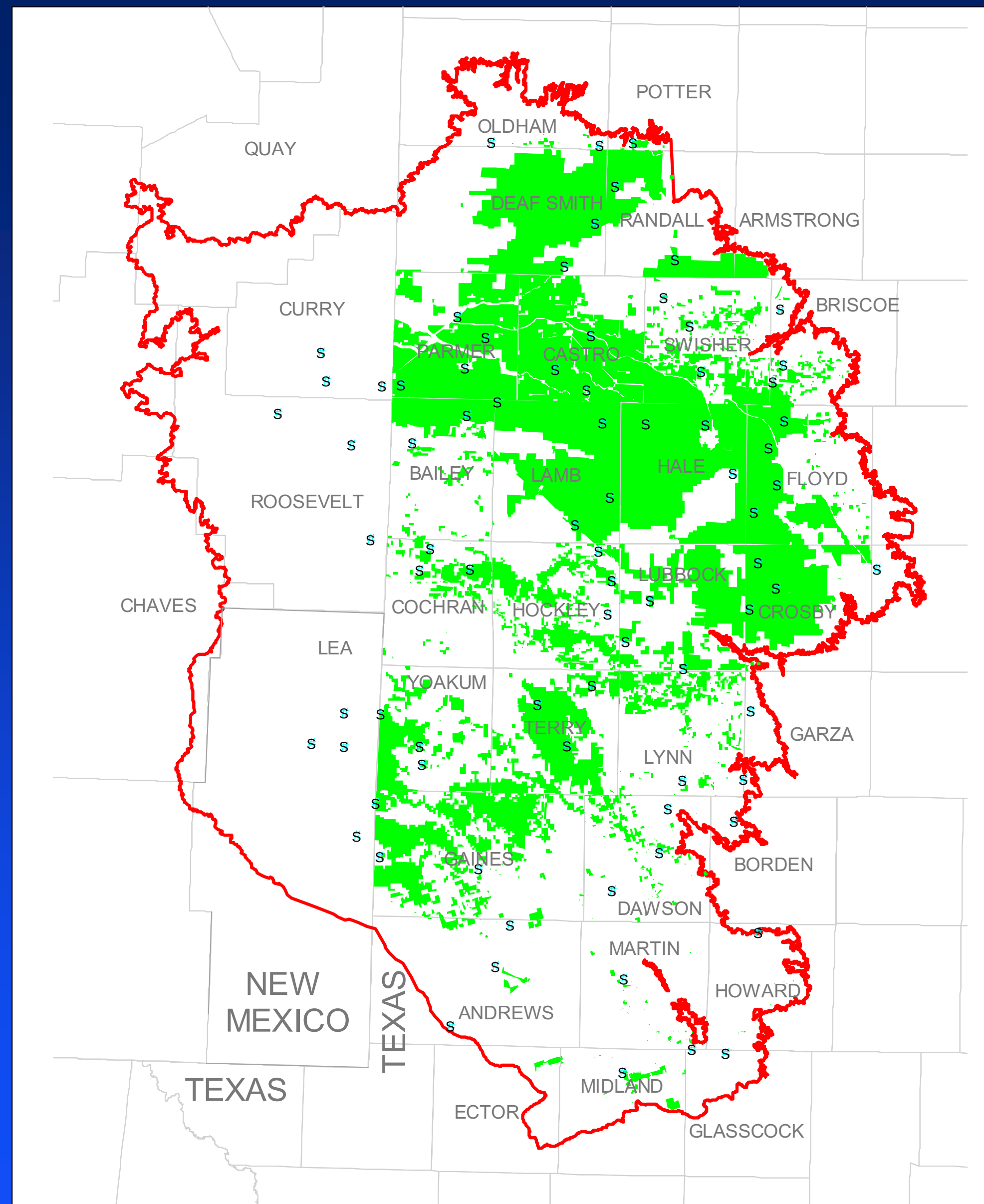
1994 Irrigated Lands with Hydrograph Locations



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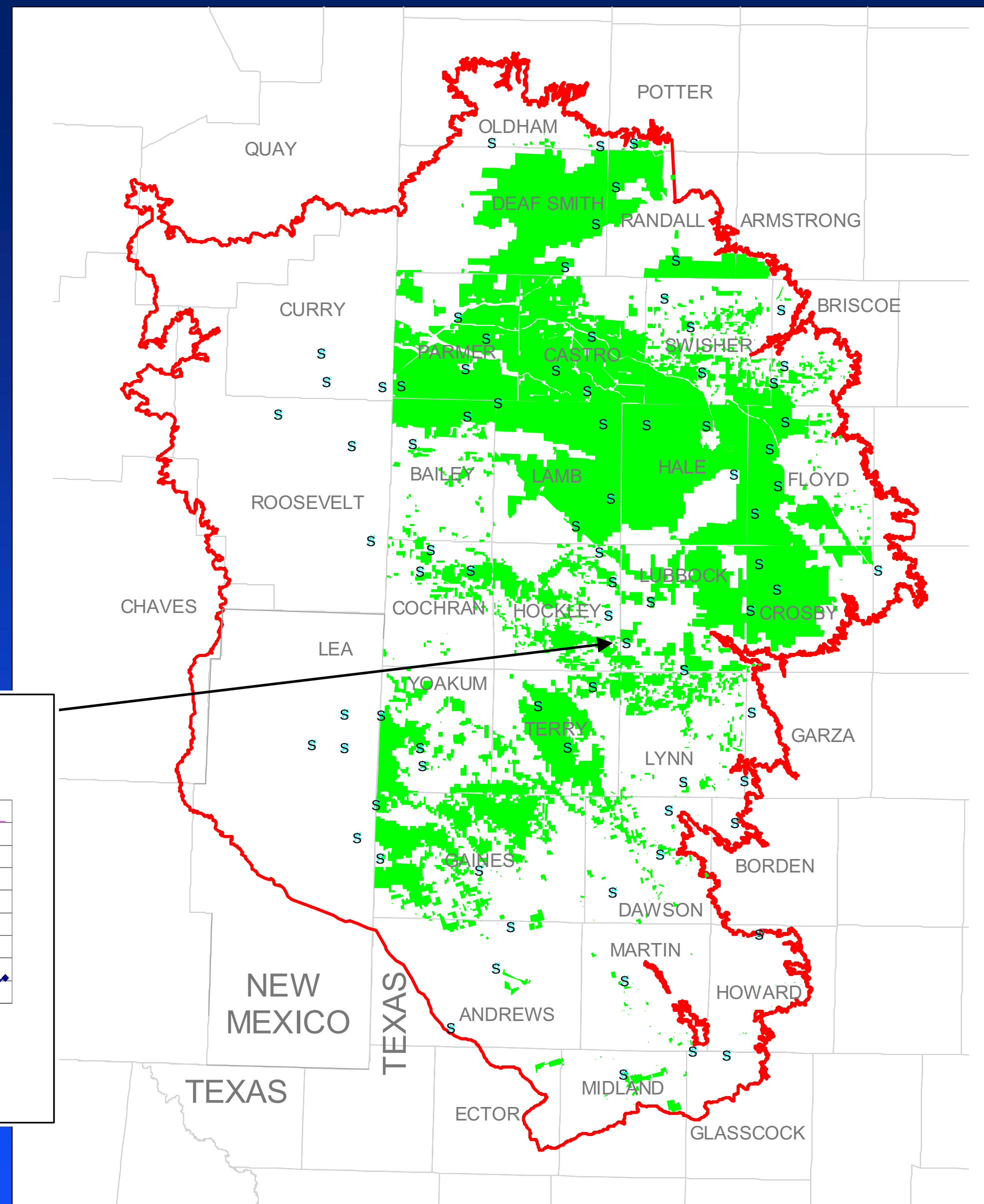

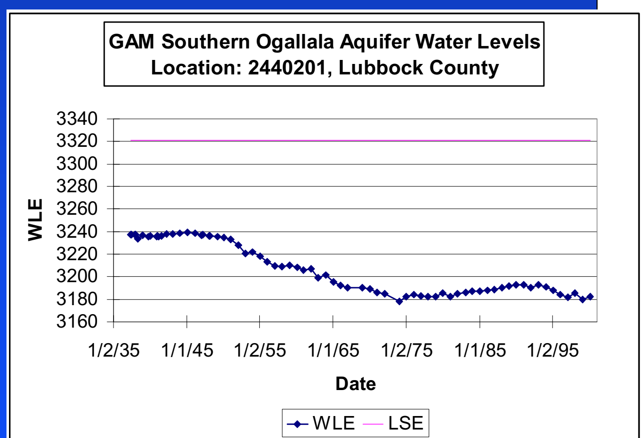

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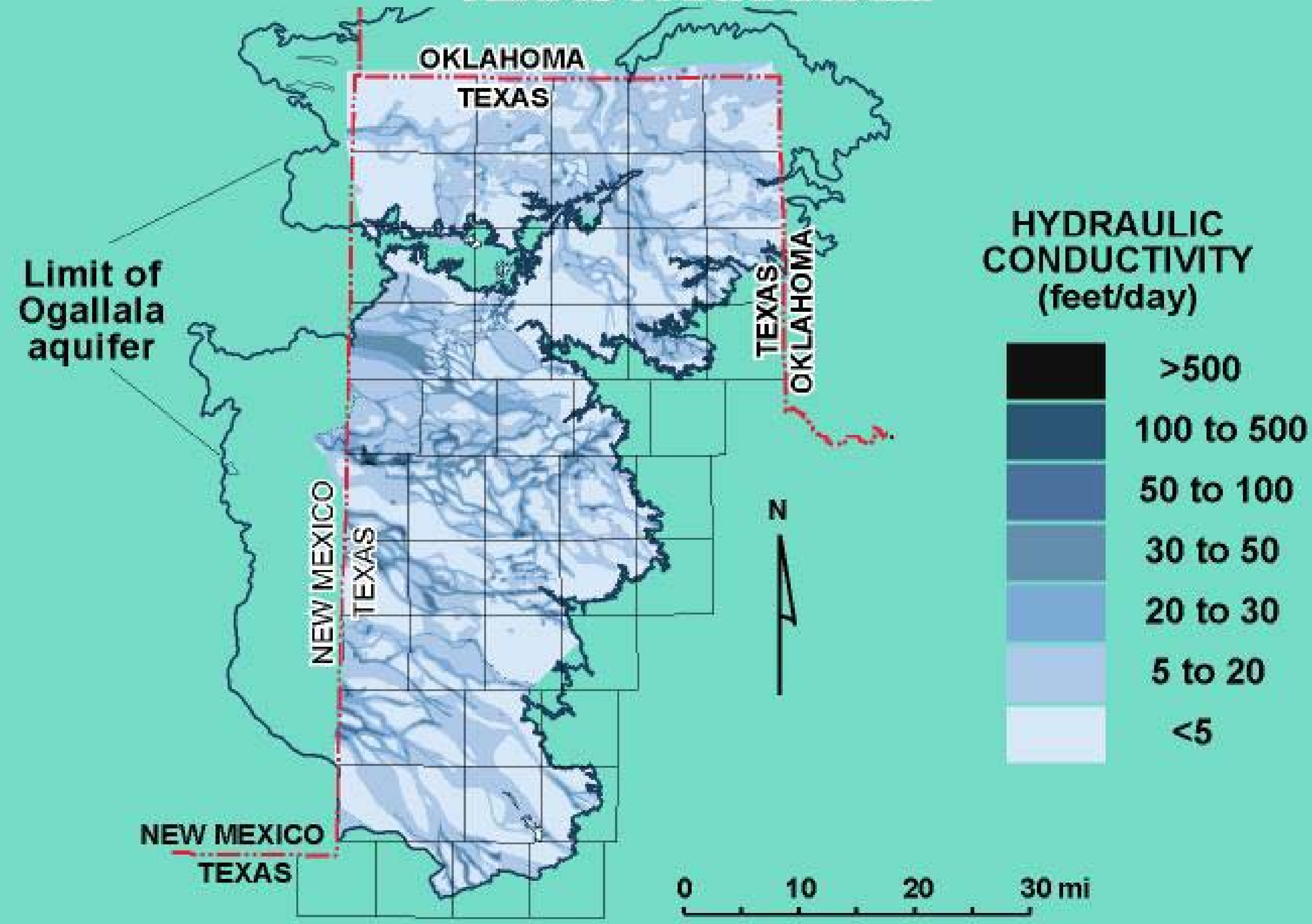
MODEL INPUT

- Hydraulic conductivity
- Recharge rate

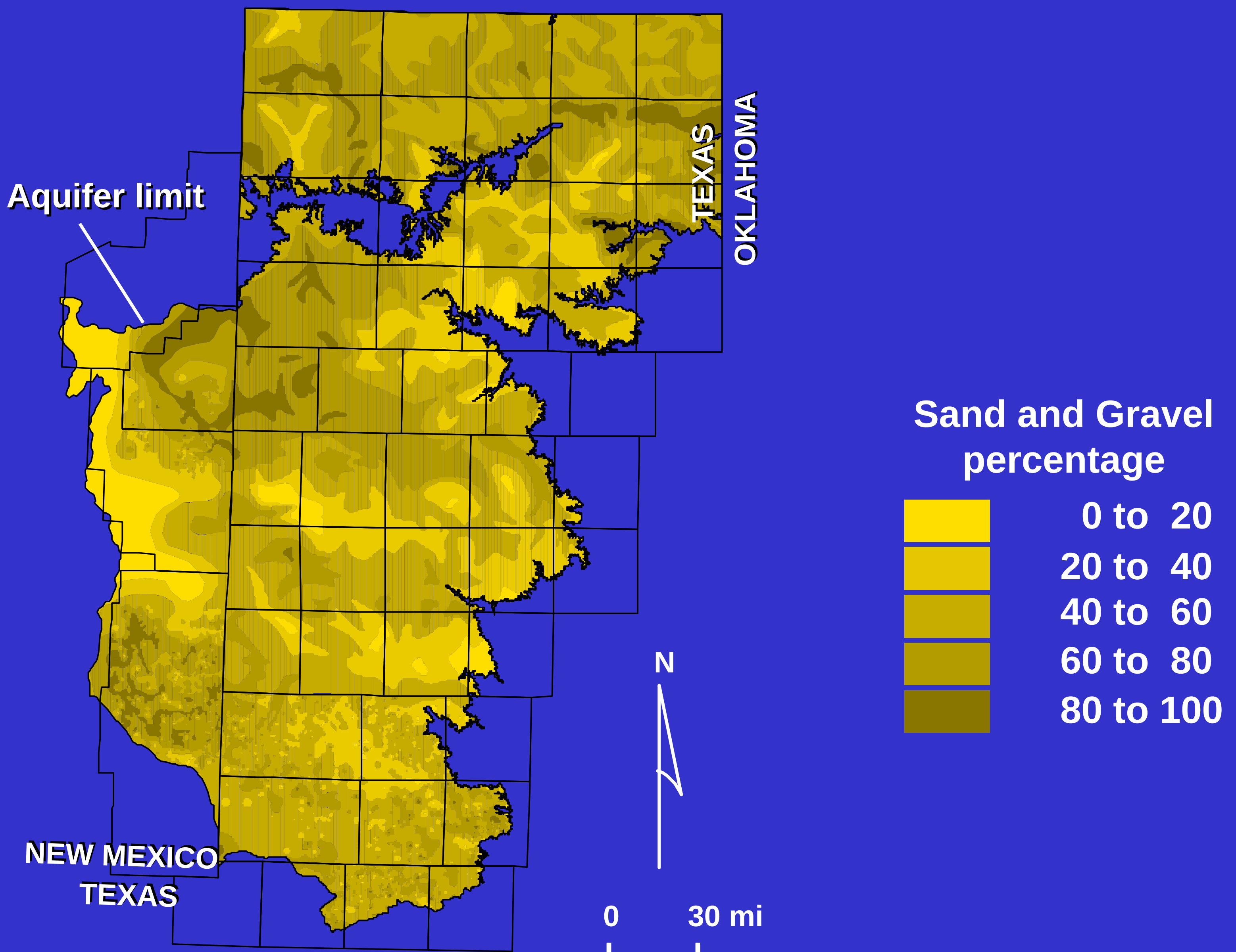
HYDRAULIC CONDUCTIVITY OF THE OGALLALA AQUIFER, TEXAS PANHANDLE



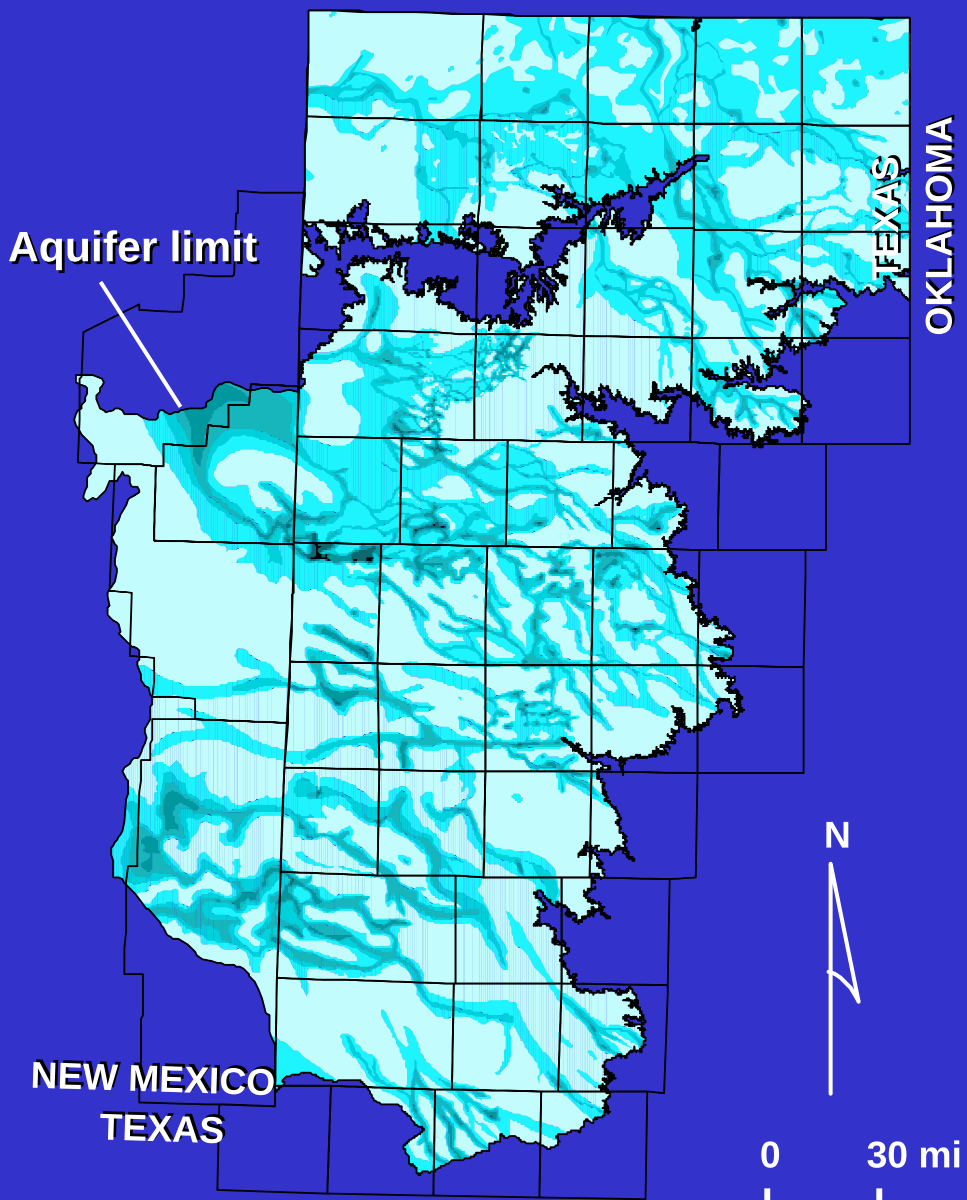
PROGRESS IN MAPPING HYDRAULIC CONDUCTIVITY

- **Digitized drillers' logs and mapped percentage of sand and gravel in Ogallala aquifer for New Mexico**
- **Extrapolated hydraulic conductvity across aquifer in New Mexico on the basis of percentage of sand and gravel**
- **Digitized additional specific capacity data for New Mexico**
- **Analyzed changes in hydraulic conductivity through time**
- **Provided alternate versions of hydraulic conductivity maps as input for model calibration**

SAND AND GRAVEL PERCENTAGE OF OGALLALA AQUIFER



HYDRAULIC CONDUCTIVITY OF OGALLALA AQUIFER

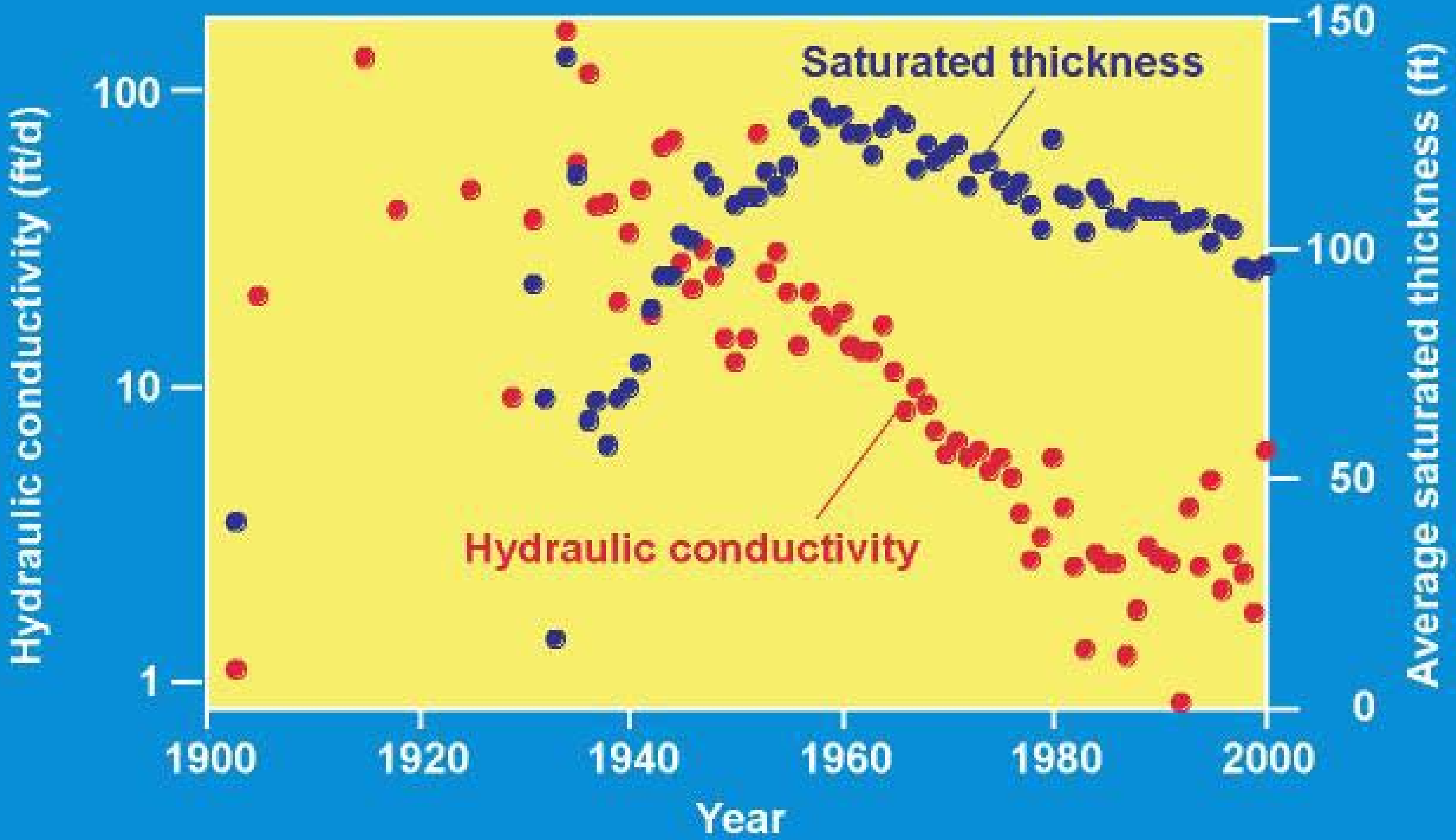


New Mexico trends inferred from sand and gravel percentage

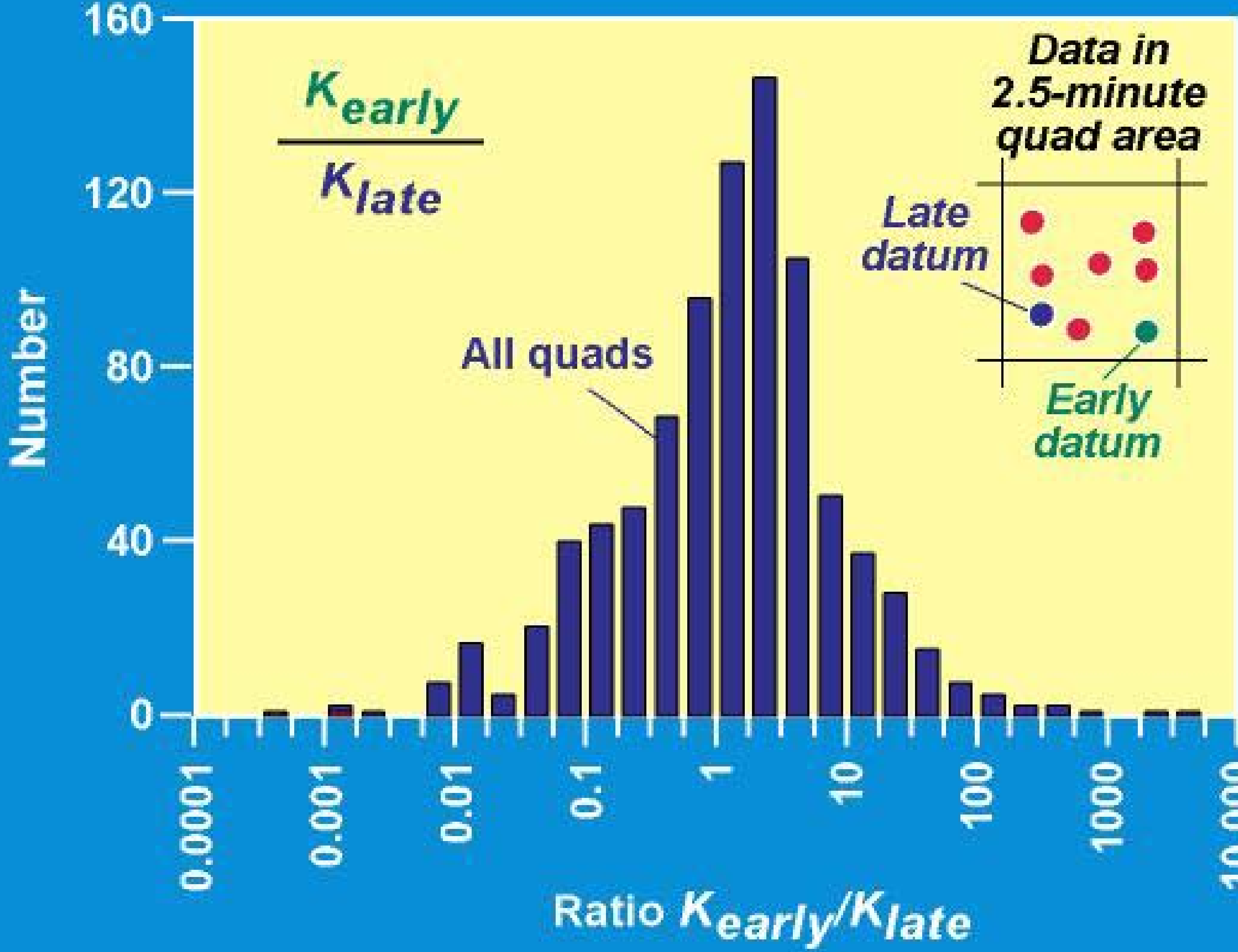
Hydraulic Conductivity (Feet/day)

- > 500
- 100 to 500
- 50 to 100
- 30 to 50
- 20 to 30
- 5 to 20
- < 5

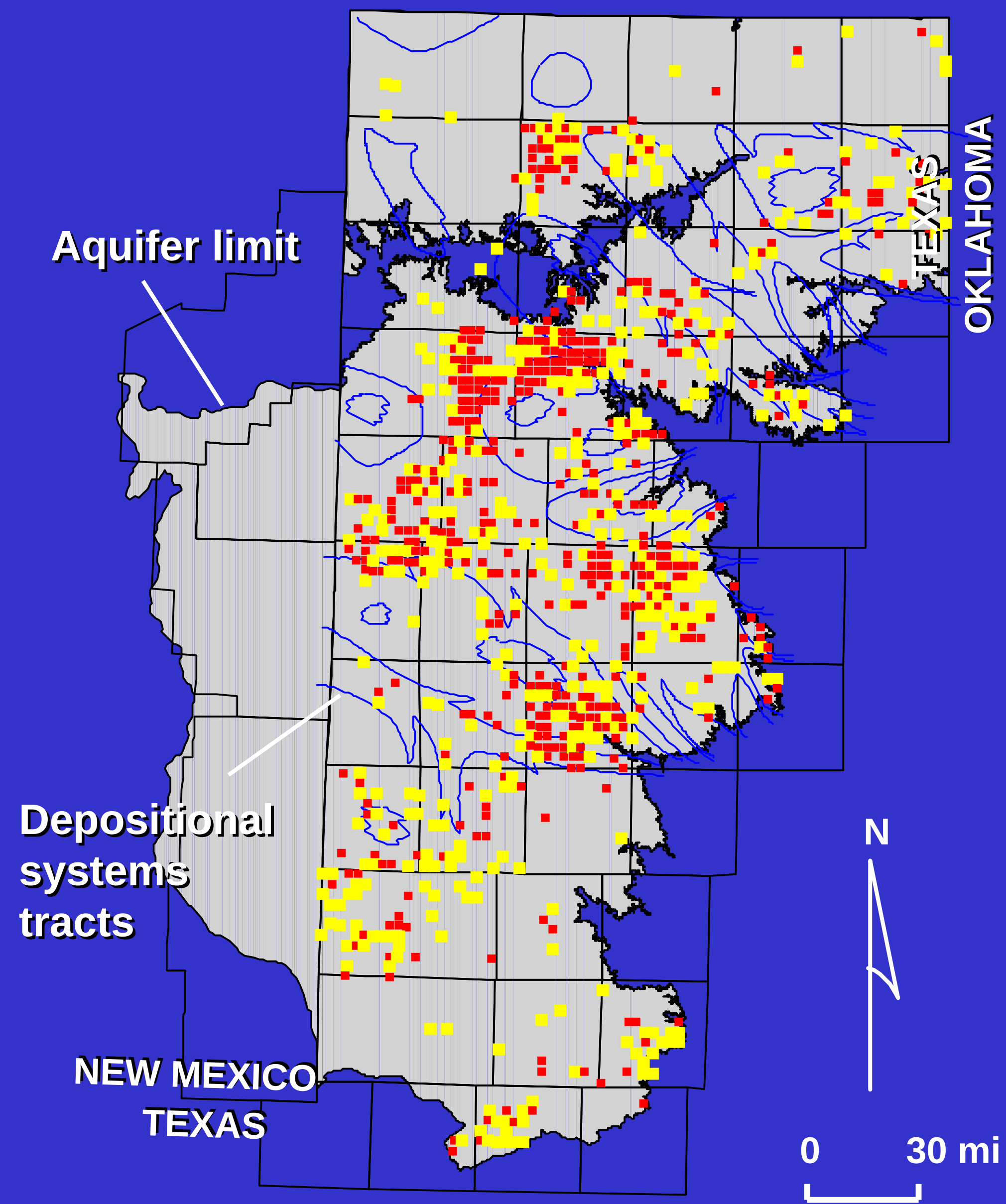
CHANGES IN HYDRAULIC CONDUCTIVITY AND SATURATED THICKNESS



RATIO OF EARLY/LATE MEASUREMENTS OF HYDRAULIC CONDUCTIVITY



CHANGE IN HYDRAULIC CONDUCTIVITY

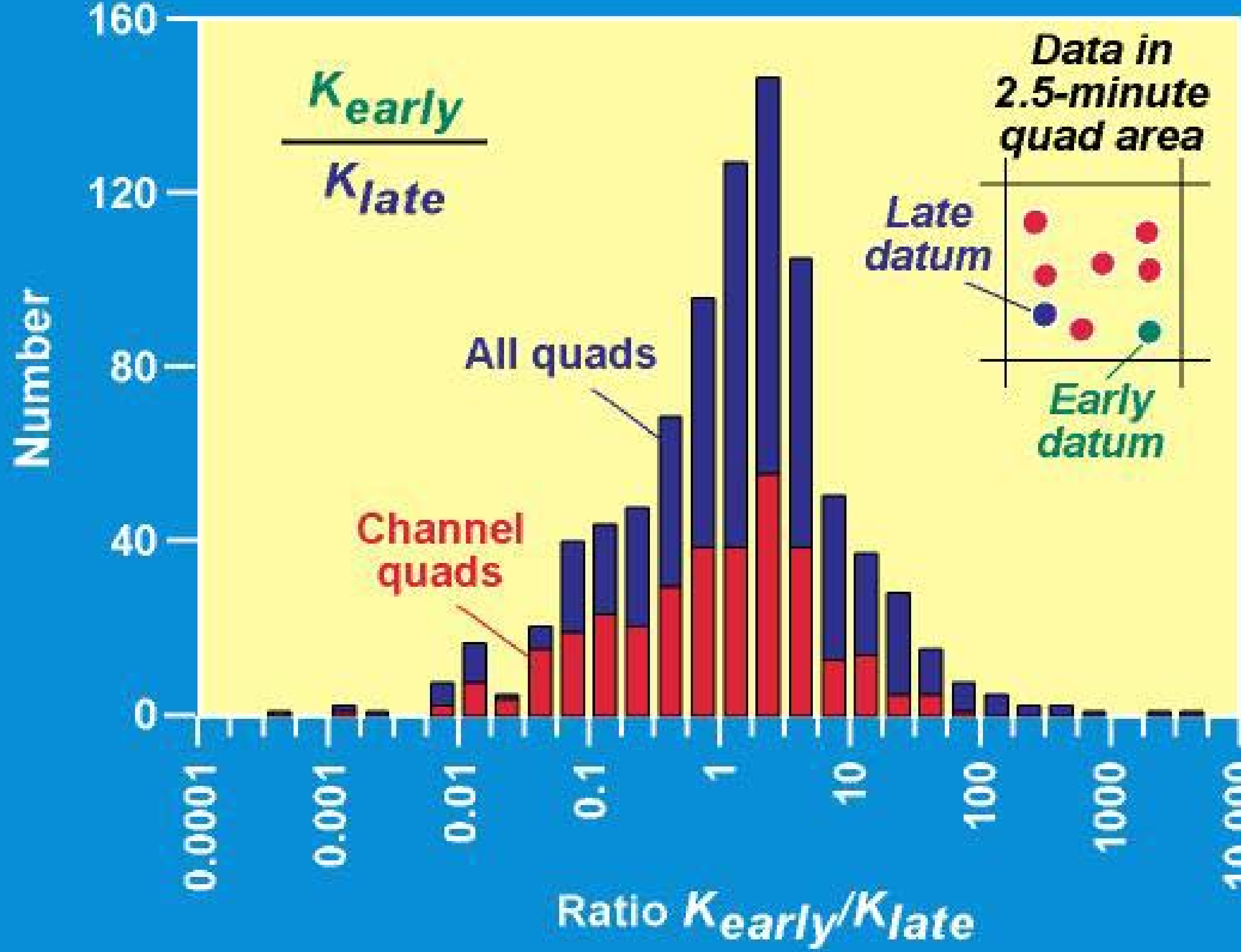


Change in hydraulic conductivity between earliest and latest measurements in 2.5-minute areas

Increase

Decrease

RATIO OF EARLY/LATE MEASUREMENTS OF HYDRAULIC CONDUCTIVITY



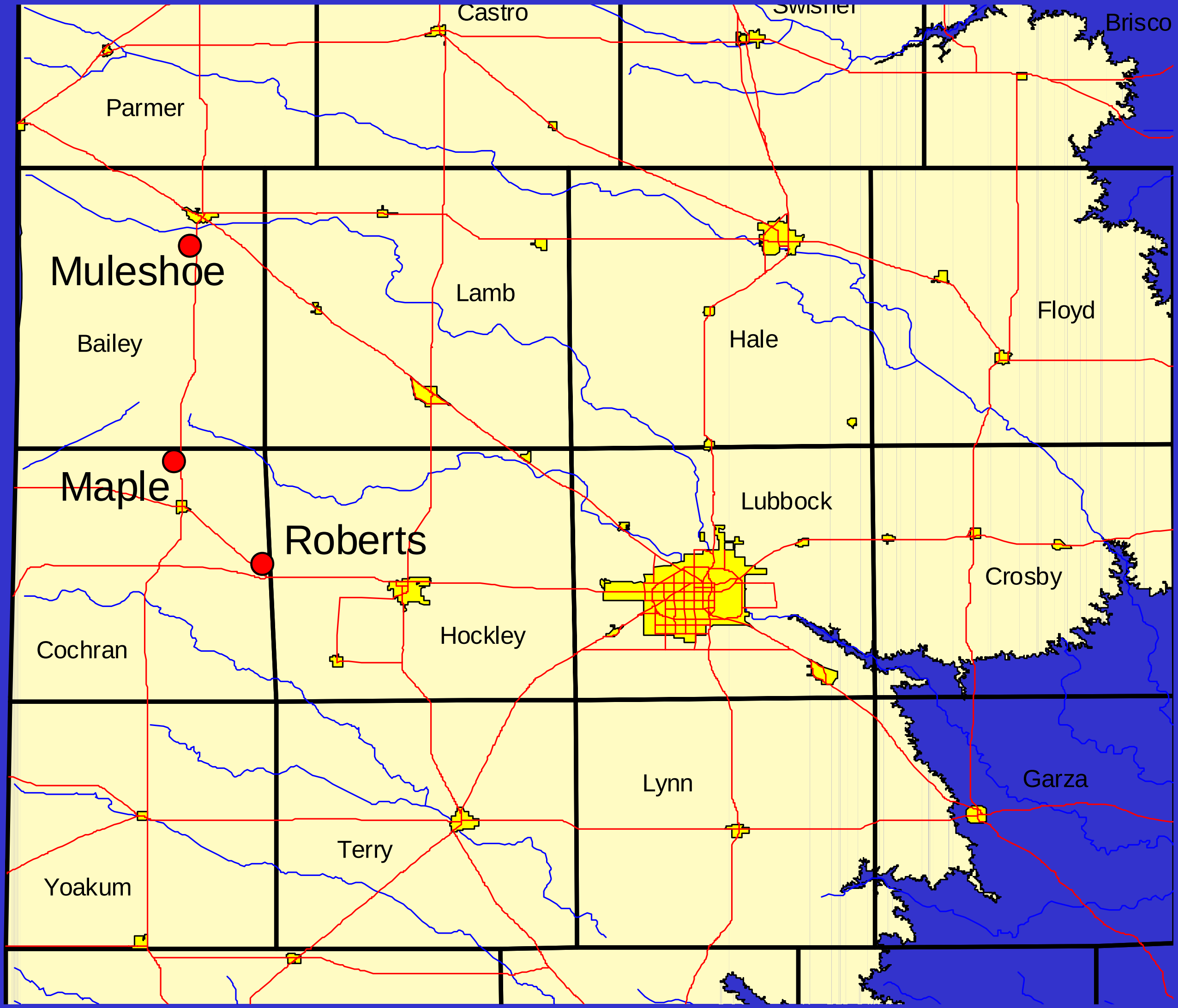
GROUNDWATER RECHARGE

- Purpose: estimate rates of groundwater recharge and return flow in non-playa areas
- Nonirrigated and irrigated agricultural land
- Qualitative and quantitative estimates
- Instrumentation and field tests
- Analysis of water-level changes

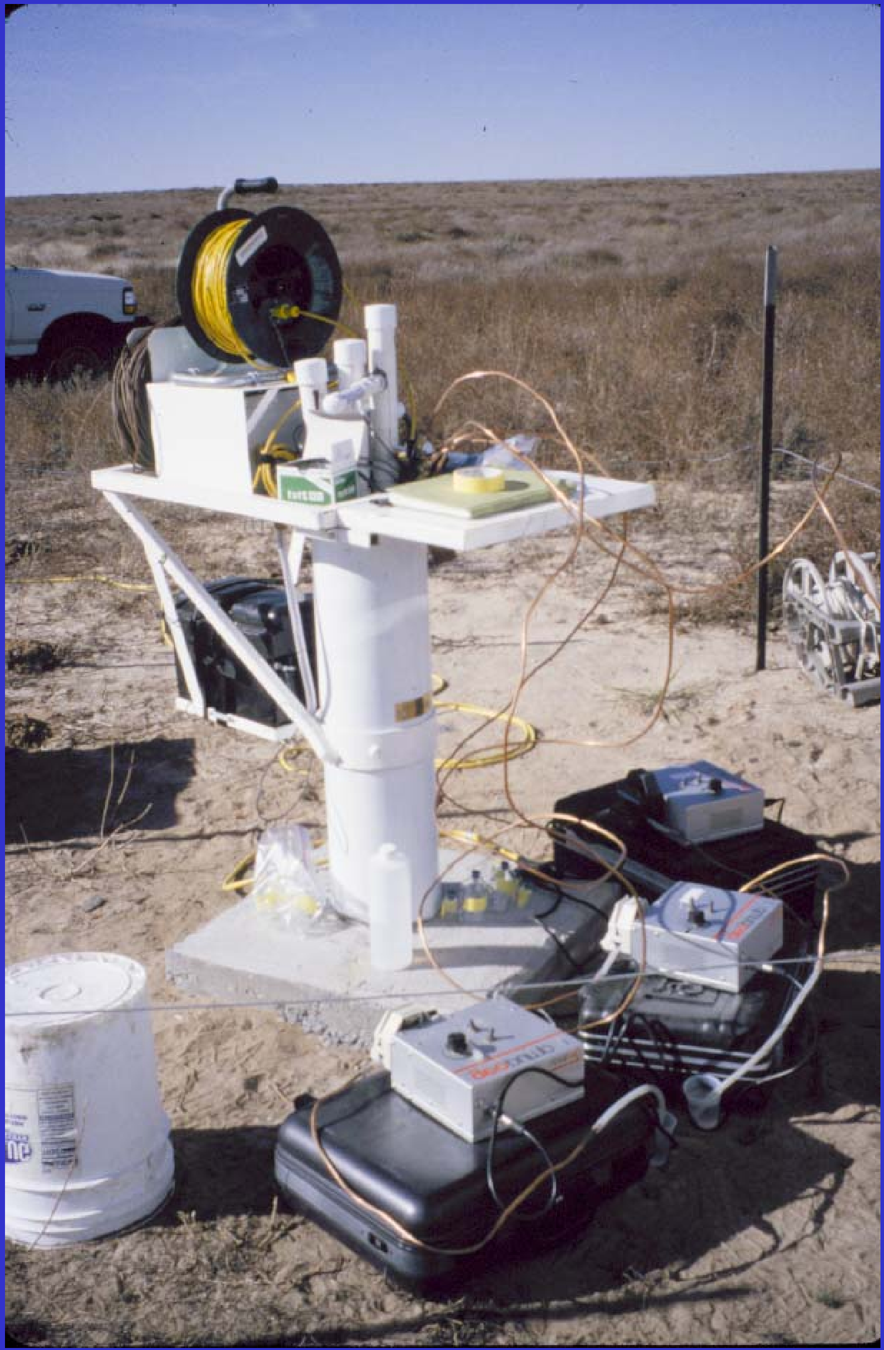
FIELD INSTRUMENTATION

- Two irrigated sites, one non-irrigated site
- Three boreholes, 85 ft, 140 ft, and 150 ft deep
- Instrumentation in each borehole:
  - 6 heat-dissipation sensors (HDS)
  - 6 soil-solution samplers
  - 6 gas ports
- Additional 6 heat-dissipation sensors at shallow depths of 0.5 to 10 ft
- Soil samples: soil texture, water content, chloride, sulfate, nitrate, bomb pulse tritium, and pesticides

SHP MONITORING LOCATIONS



Instrumentation at borehole sites includes water level recorders and data loggers for monitoring soil-water pressures



POTENTIAL ENERGY MEASUREMENT

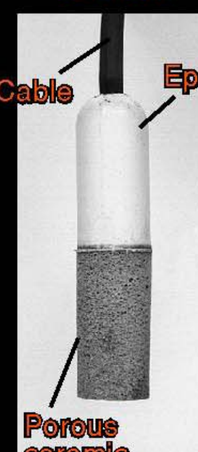
Water activity meter

Thermocouple psychrometer sample changer

Tensiometer

Thermocouple psychrometer

Heat dissipation sensor



Bureau of Economic Geology

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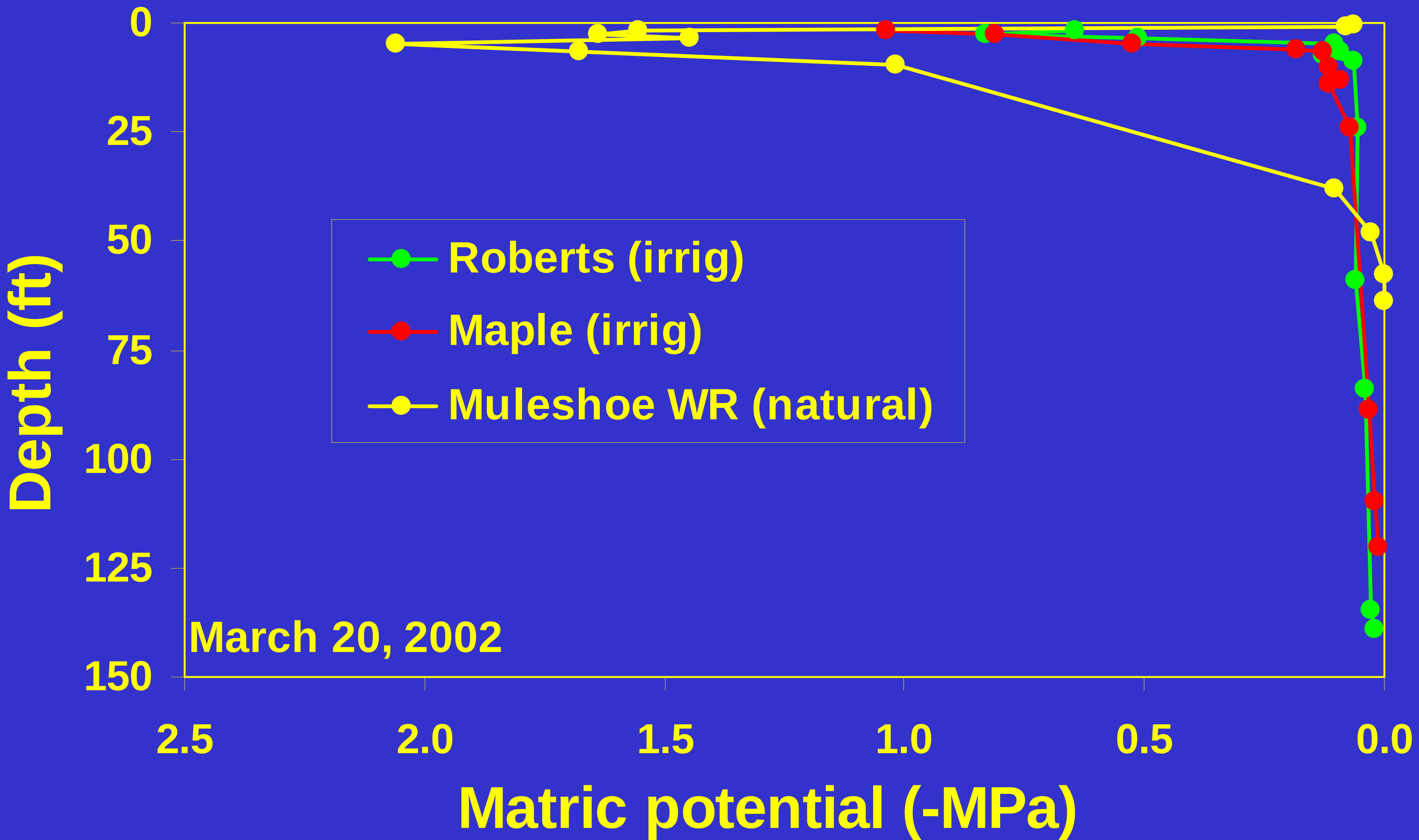
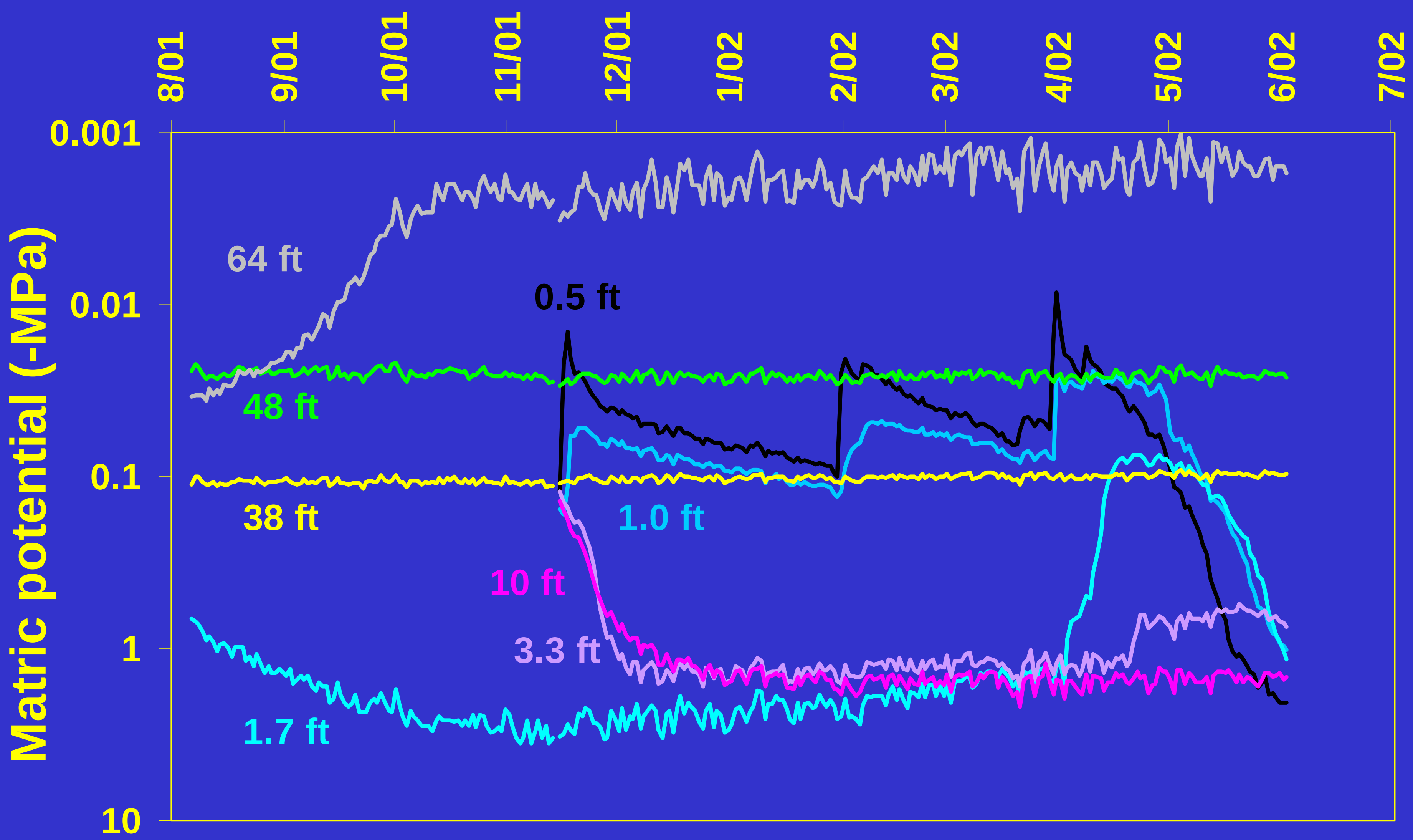
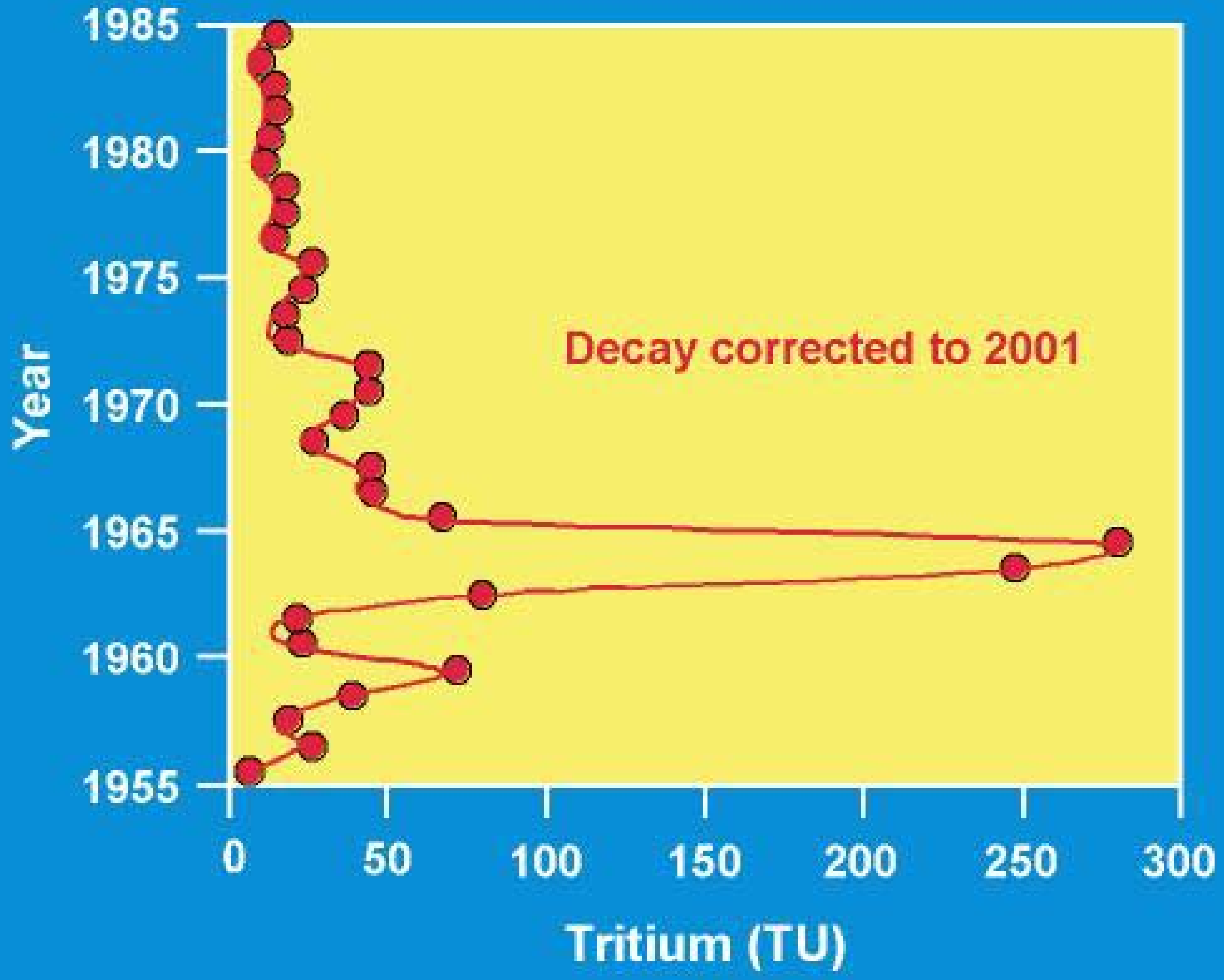
MATRIC POTENTIAL PROFILES



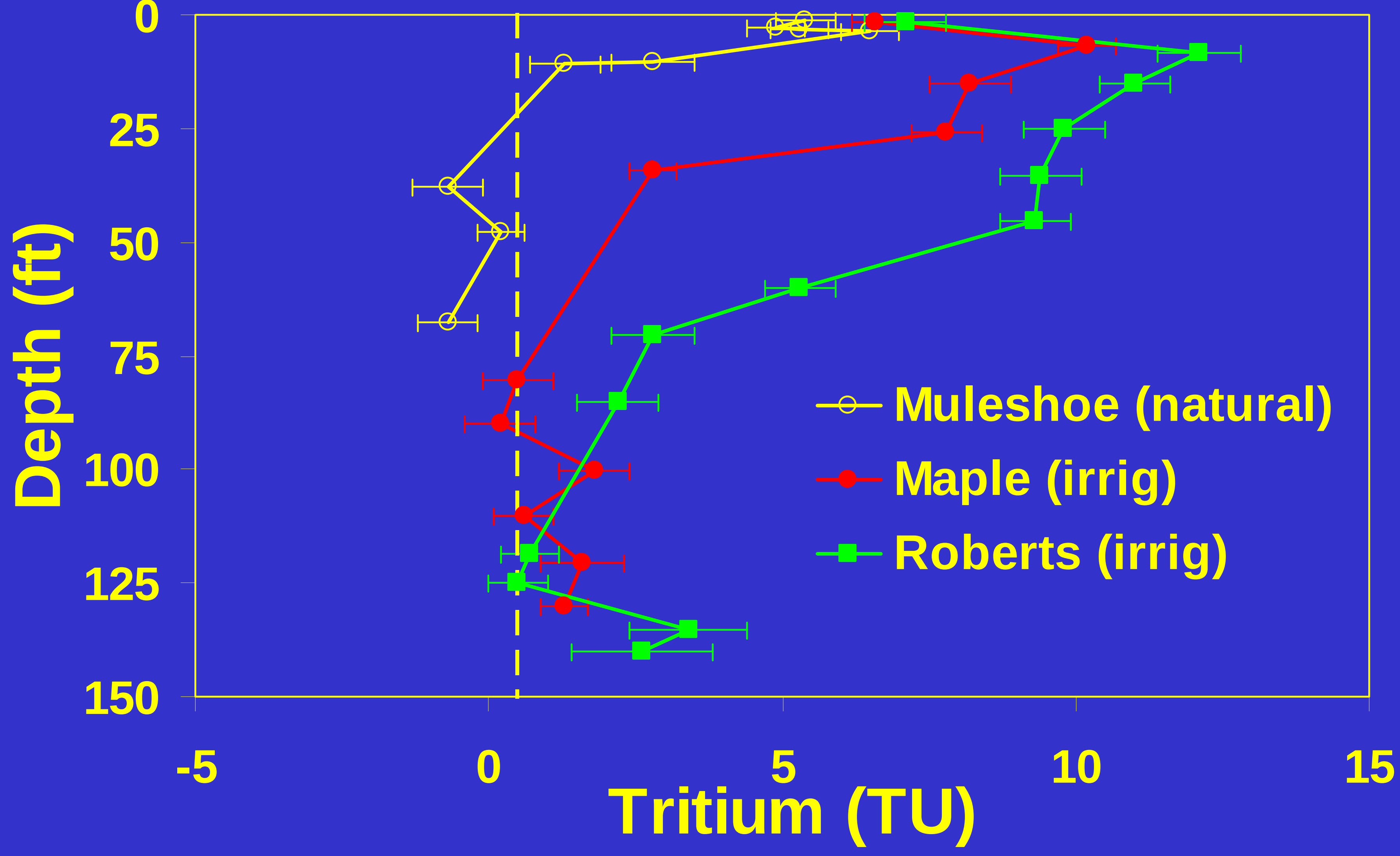
HDS TIME SERIES DATA



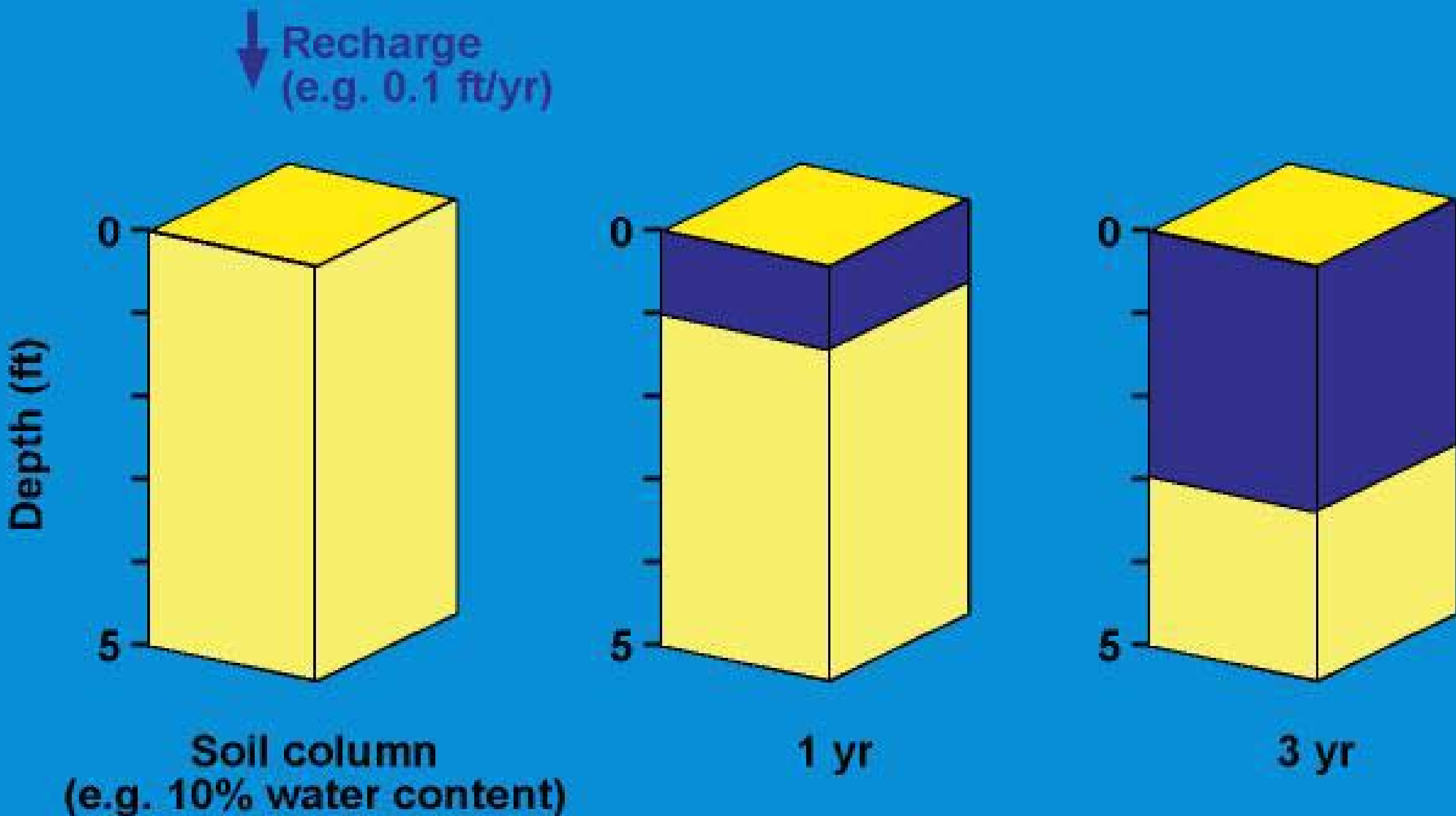
BOMB PULSE TRITIUM



TRITIUM RESULTS



RECHARGE AND VELOCITY



Velocity = Recharge rate / Water content

Recharge rate = Velocity x Water content

RECHARGE CALCULATION BASED ON BOMB TRITIUM

- Water velocity =

  Depth of bomb-pulse tritium in subsurface

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  Time (38 yr) since peak bomb fallout
  to sample date (1963 to 2001)

RECHARGE CALCULATION BASED ON BOMB TRITIUM

- **Water velocity (<u>center of mass)</u>**
  - **Roberts Irrigated Site: 10.5 m / 38 yrs**

    = 0.28 m/yr = 10.9 inches/yr
  - **Maple Irrigated Site: 4.9 m / 38 yrs**

    = 0.13 m/yr = 5.1 inches/yr

RECHARGE CALCULATION BASED ON BOMB TRITIUM

- Recharge rate = water velocity x average water content in soil profile:
  - Roberts Irrigated Site: 0.28 m/yr x 0.12 m^3/m^3

    = 0.03 m/yr = 1.2 inches/yr
  - Maple Irrigated Site: 0.13 m/yr x 0.15 m^3/m^3

    = 0.02 m/yr = 0.8 inches/yr

RECHARGE CALCULATION BASED ON BOMB TRITIUM

- **Water velocity (deepest occurrence of bomb-pulse tritium >0.5 TU)**
  - **Roberts Irrigated Site: 45.1 m / 48 yrs**

    = 0.94 m/yr = 37 inches/yr)
  - **Maple Irrigated Site: 41.5 m / 48 yrs**

    = 0.86 m/yr = 34 inches/yr)

RECHARGE CALCULATION BASED ON BOMB TRITIUM

- Recharge rate = water velocity x average water content in soil profile:
  - Roberts Irrigated Site: 0.94 m/yr x 0.12 m^3/m^3

    = 0.11 m/yr = 4.3 inches/yr)
  - Maple Irrigated Site: 0.86 m/yr x 0.15 m^3/m^3

    = 0.13 m/yr = 5.1 inches/yr)

RECHARGE ESTIMATE

Muleshoe Wildlife Refuge (Nonirrigated)

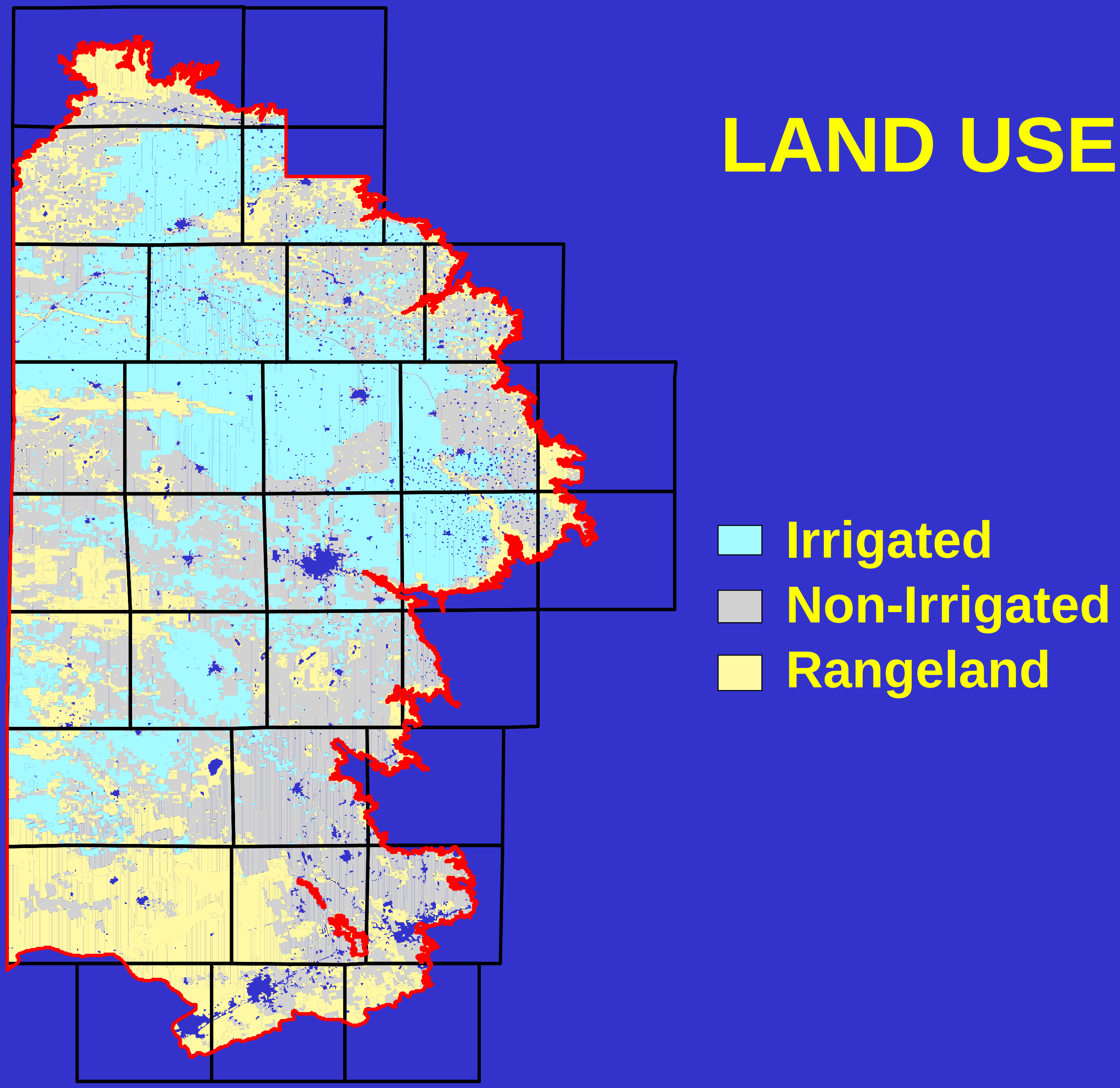
- Bomb ^3H in root zone at Muleshoe (natural) site
- Negligible recharge rate

RECHARGE ESTIMATE

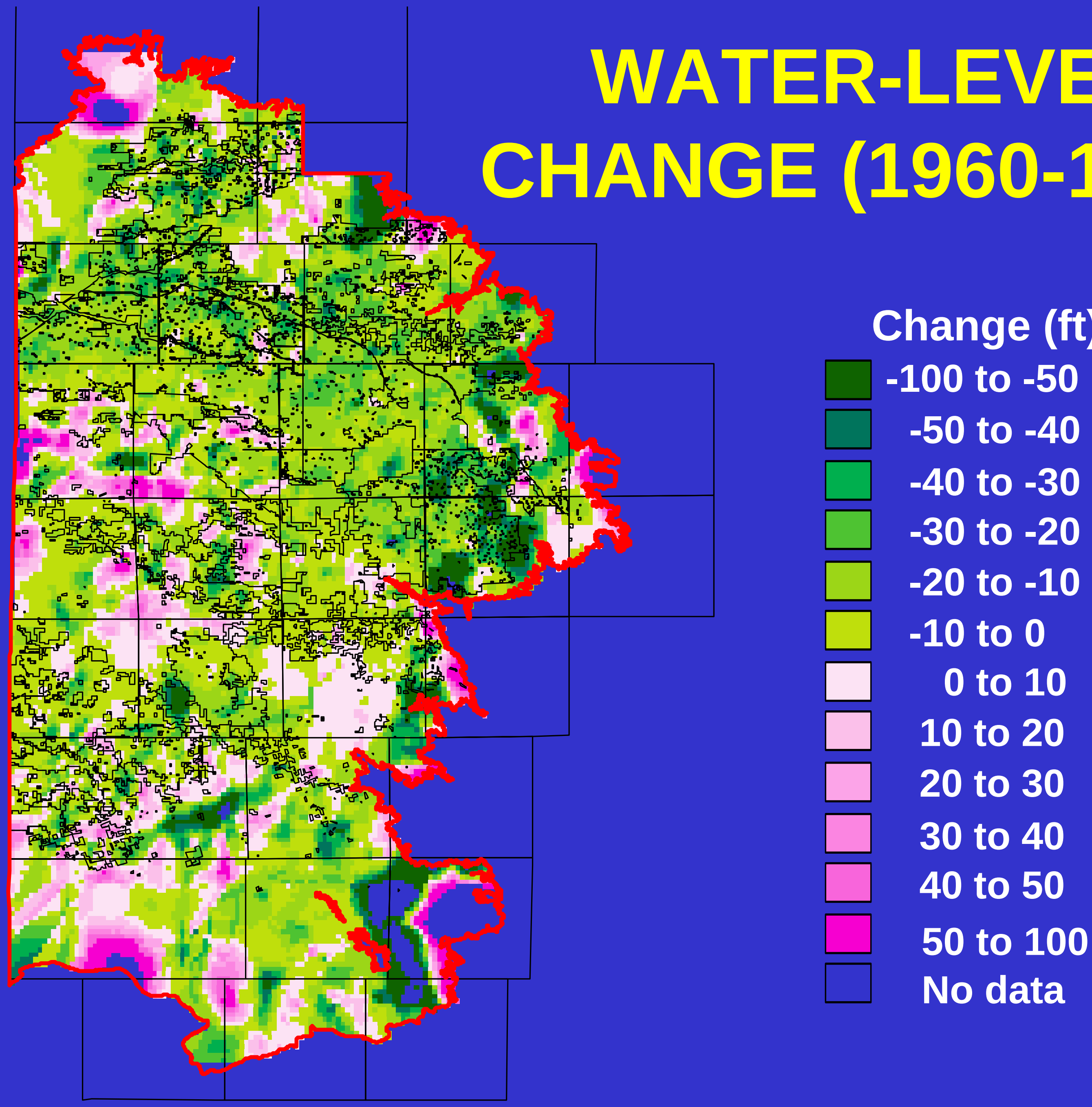
Roberts and Maple Sites (Irrigated)

- Center of mass method
  - 0.8 to 1.2 inches/yr
- Deepest occurrence of tritium method
  - 4.3 to 5.1 inches/yr

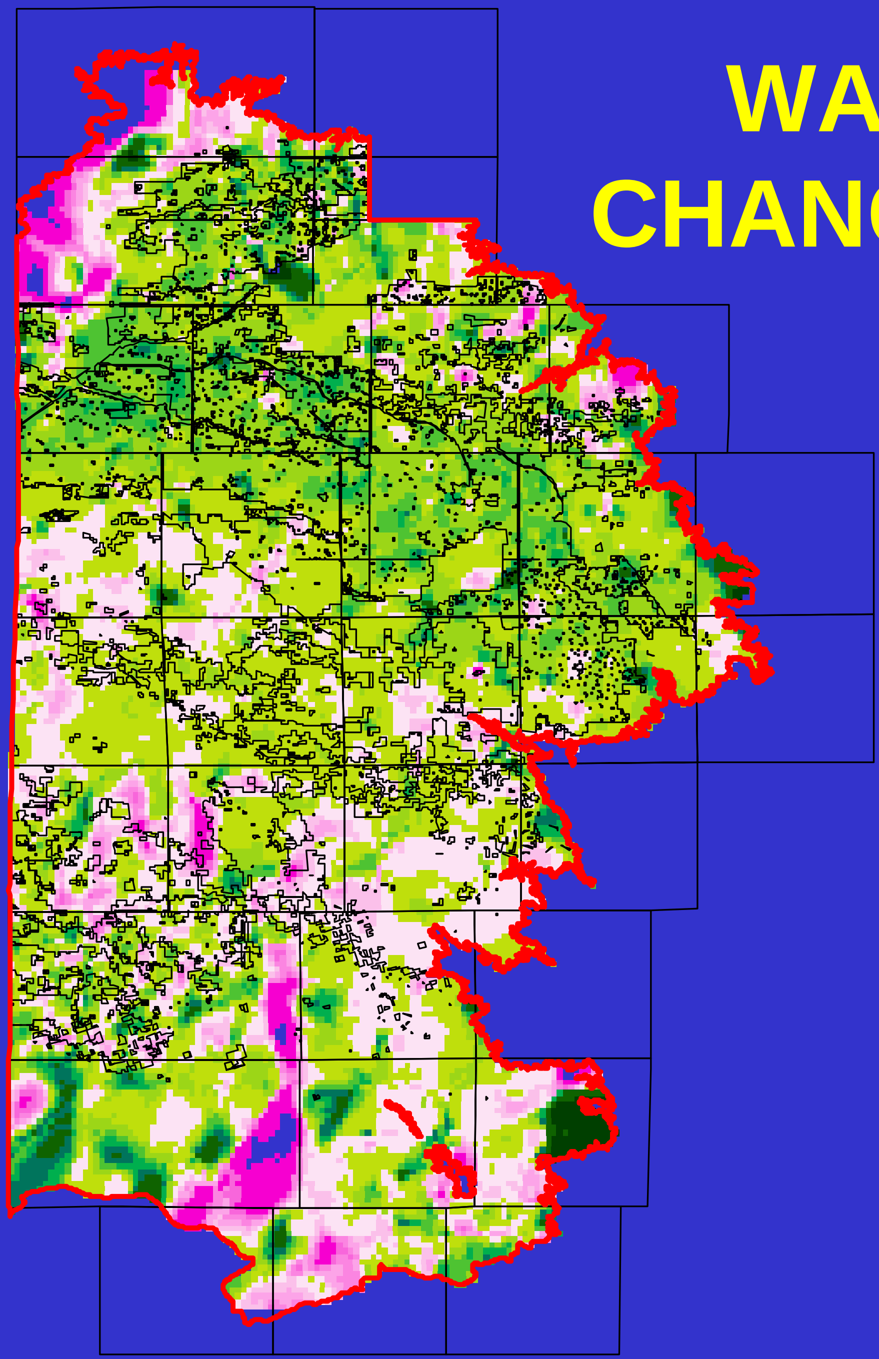
LAND USE



WATER-LEVEL CHANGE (1960-1965)



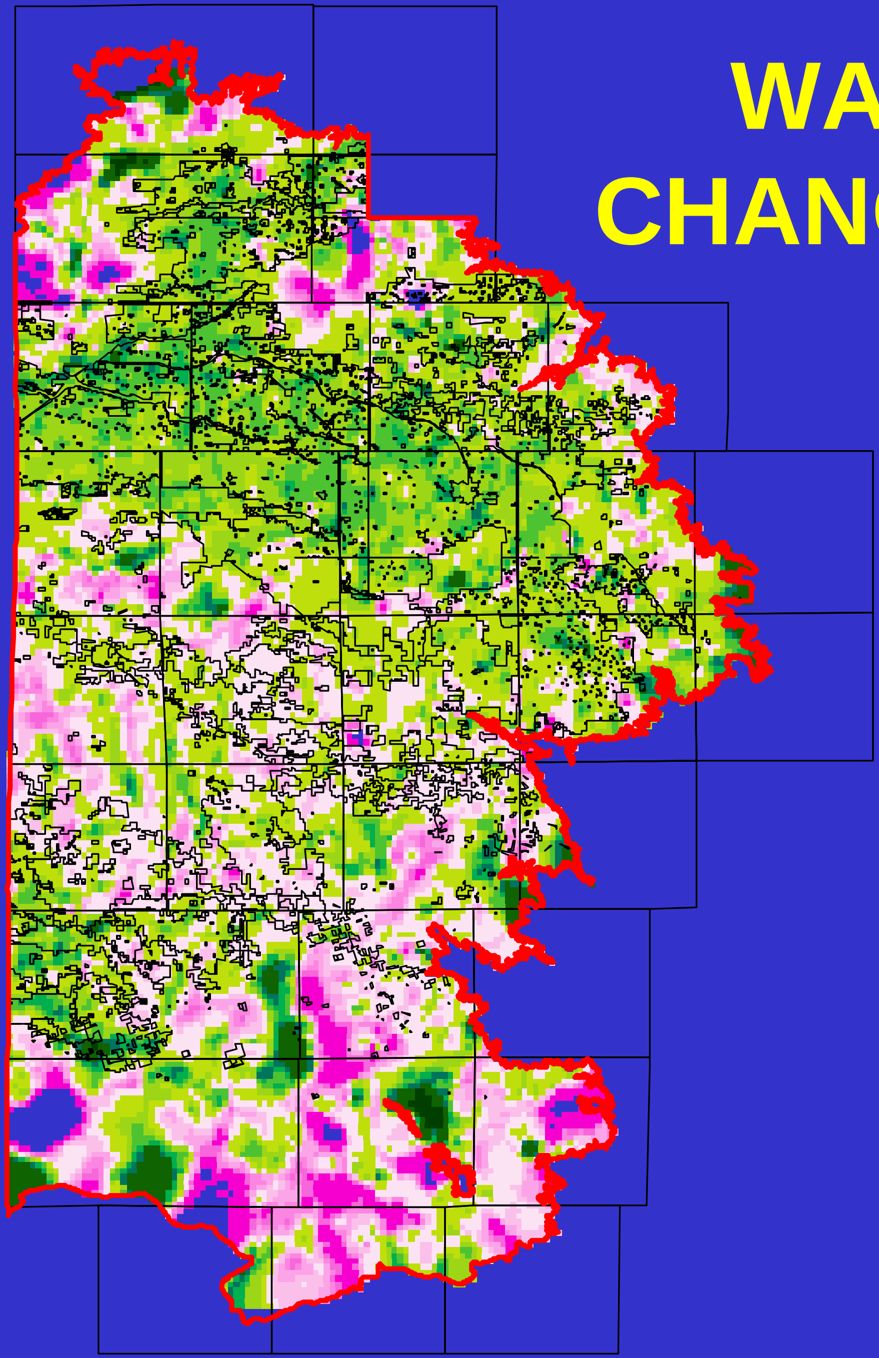
WATER-LEVEL CHANGE (1965-1970)



Change (ft)

- -100 to -50
- -50 to -40
- -40 to -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- No data

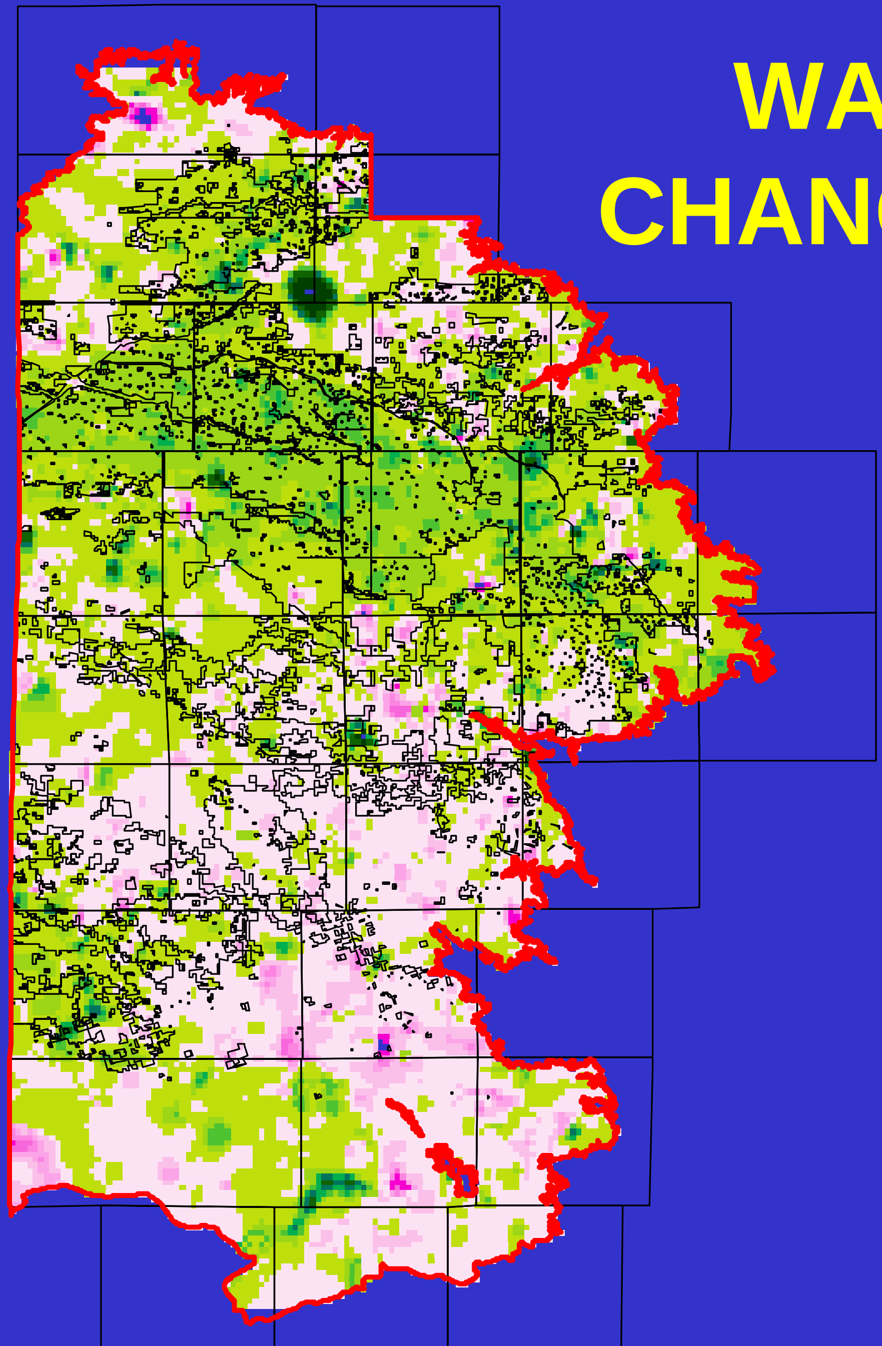
WATER-LEVEL CHANGE (1975-1980)



Change (ft)

- -100 to -50
- -50 to -40
- -40 to -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- No data

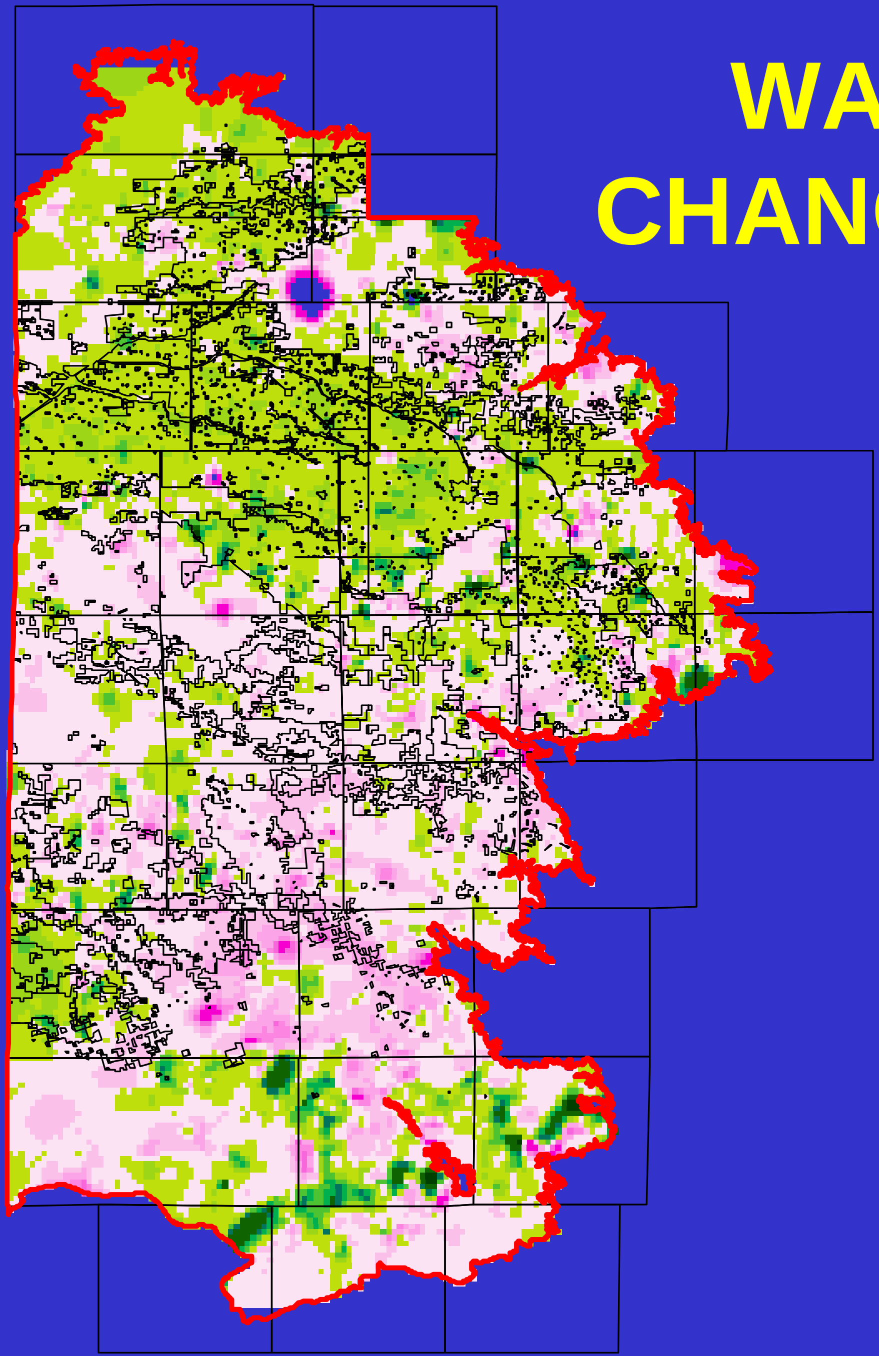
WATER-LEVEL CHANGE (1980-1985)



Change (ft)

- -100 to -50
- -50 to -40
- -40 to -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- No data

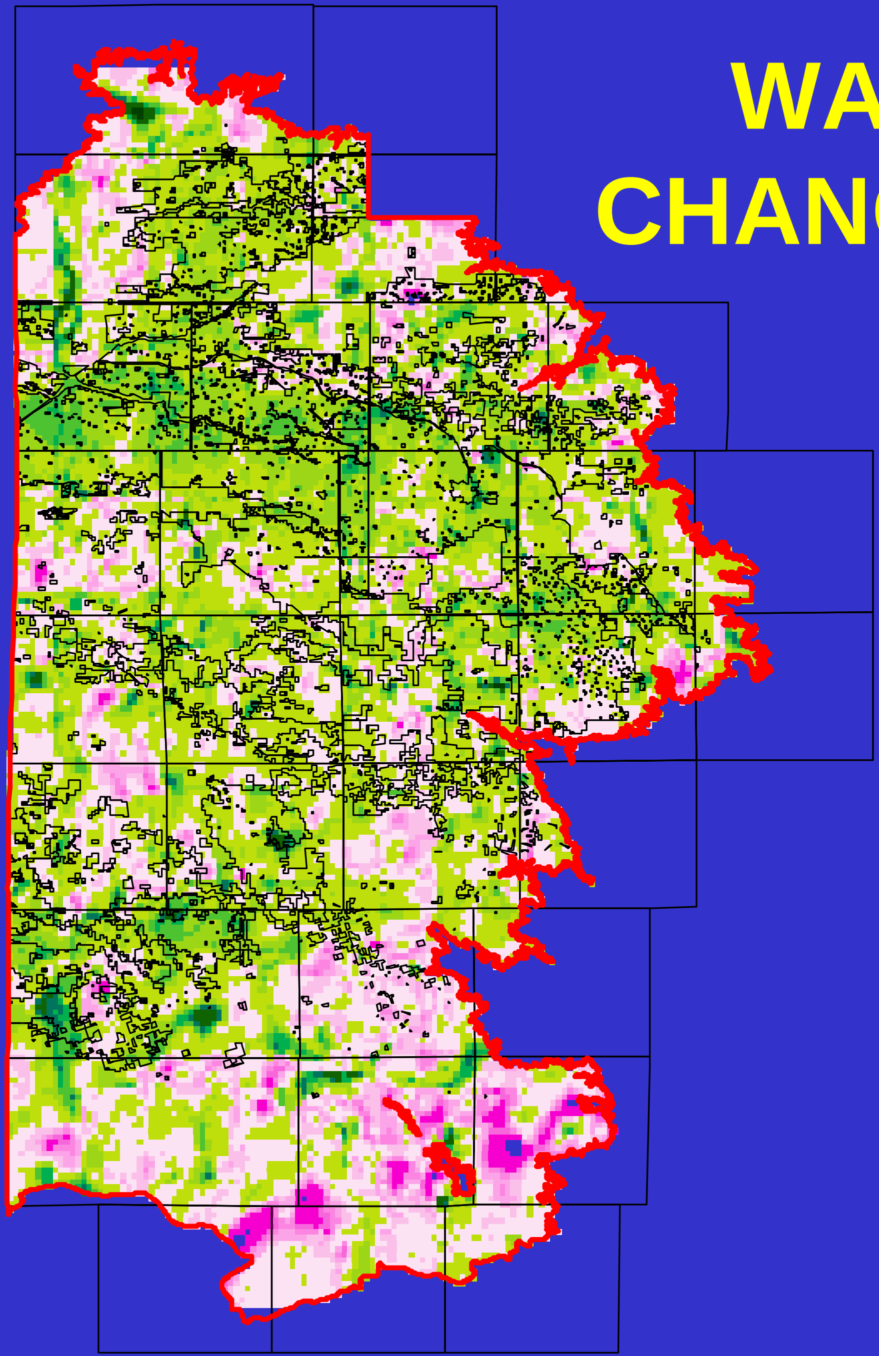
WATER-LEVEL CHANGE (1985-1990)



Change (ft)

- -100 to -50
- -50 to -40
- -40 to -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- No data

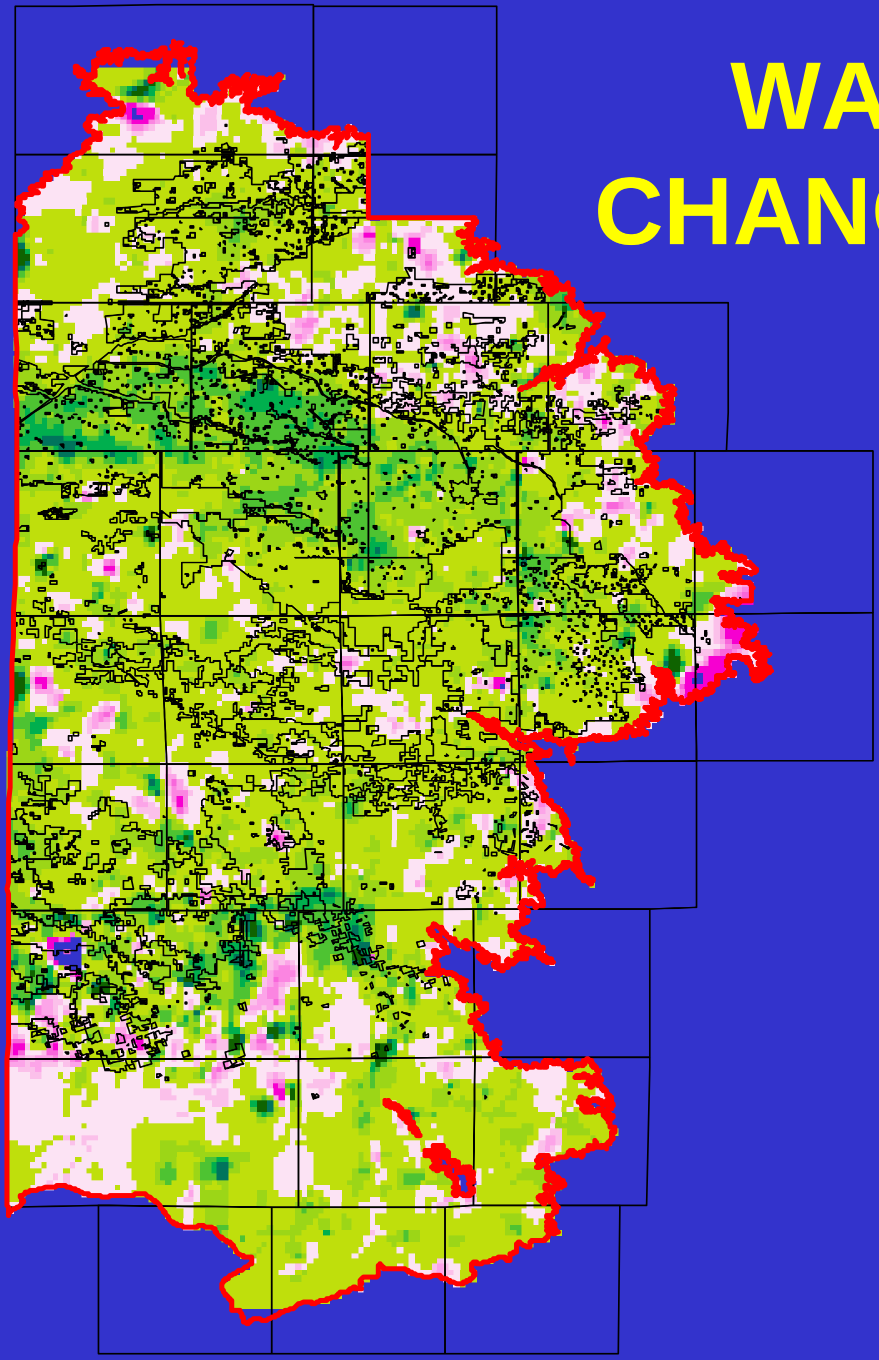
WATER-LEVEL CHANGE (1990-1995)



Change (ft)

- -100 to -50
- -50 to -40
- -40 to -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- No data

WATER-LEVEL CHANGE (1995-2001)



Change (ft)

- -100 to -50
- -50 to -40
- -40 to -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- No data

Southern Ogallala Stakeholder Advisory Forum No. 5
June 17, 2002

List of Attendees

Name	Affiliation
Gary L. Walker	Sandy Land UWCD
Duncan Axisa	Sandy Land UWCD
Richard Smith	TWDB
Stefan Schustor	TWDB
Alan Dutton	Bureau of Economic Geology (presenter)
Jason Coleman	South Plains UWCD
Ronald Bertrand	Texas Department of Agriculture
Scott Orr	High Plains UWCD No. 1
Don McReynolds	High Plains UWCD No. 1
Carmon McCain	High Plains UWCD No. 1
Clyde R. Crumley	LEUWCD
Jim Conkwright	High Plains UWCD No. 1
Harvey Everheart	Mesa UWCD
Neil Blandford	Daniel B. Stephens & Associates, Inc. (presenter)
David Boes	Daniel B. Stephens & Associates, Inc.

Stakeholder Advisory Forum No. 5
June 17, 2002
High Plains Underground Water Conservation District No. 1
Lubbock, Texas

Questions & Answers Concerning Groundwater Availability Modeling (GAM) of the Southern Ogallala

1. What is the largest piece of the GAM project that is not making sense?

Response: *The largest piece of the GAM project that is not making sense thus far, is the contour spacing toward the eastern edge of the model. As recharge occurs across the model, the hydraulic gradient, or the "steepness" of the water table surface, should increase significantly near the escarpment along the eastern edge of the study. When we develop the observed map, we really don't see that. The distance between the contours from the west to the east doesn't really change that much. What we need to have within the aquifer boundary itself, is some type of discharge. There are various springs and salt lakes that exist on the Southern High Plains. We have these lakes put on the model as points for discharge within the model. For instance, rain that percolates in the west may discharge into one of these lakes, rather than moving all the way over to the escarpment. There is not a lot of information on these lakes, so we would be interested in getting some of your observations on the lakes, springs, or any other mechanisms in the area we may not be aware of. We need to establish some form of discharge within the study area before water moves all the way to the escarpment.*

2. What is the Brune *Springs of Texas* report?

Response: *The Brune "Springs of Texas" report is a publication from the early 80's, listing values of discharge for some springs that were current values. In some instances Brune has tried to estimate early discharge values in a qualitative fashion. It's not highly accurate for all locations, but it gives us an idea of discharge increase or decrease over time.*

3. What kind of boundary limits are you using in the modeling equations?

Response: *We have a no-flow boundary on the bottom, a no-flow boundary on the western and southern sides, and right now along the east and the north we are using prescribed head, which will be changed to be drain conditions for the transient modeling. We will back-calculate a conductance for the drains based on the prescribed head boundary. The top of the model is defined by the simulated water level.*

4. The agenda states that you were going to talk about the addition of Cretaceous units. Does that have some correlation with what hydraulic conductivity investigation you have done so far?

Response: *On the original map we showed you in February, we hadn't factored out the Cretaceous units. So, there are some hydraulic conductivity specific capacity tests in the investigation that were completed in both the Ogallala Aquifer and the Cretaceous units. Since then, we have gone through and identified those. We have taken out those in the Cretaceous, so that the newest version of the map is based solely on measurements of the Ogallala. The USGS recognizes that there is groundwater within the Cretaceous rocks that has a hydrologic connection with the Ogallala. The USGS refers to the aquifer as the High Plains Aquifer, including the Ogallala, the Cretaceous rocks, and some Jurassic rocks. The model is going to include all the units within the entire aquifer, which are hydrologically connected. We have maps of the base of the Cretaceous and the base of the Ogallala, so we know pretty well what the thickness of the Cretaceous formation is, from the various drillers logs. For the hydraulic conductivity of the Cretaceous itself, we have too few measurements of the hydraulic conductivity for us to reliably characterize what it is. For that we drew on a study of the Edward's Trinity Plateau Aquifer being done by the Water Development Board. The Edward's Trinity is stratigraphically equivalent to what underlies the Ogallala in this area. We have extensive statistical characterization of the hydraulic conductivity of the Cretaceous from the Edward's Trinity study. We have generated another hydraulic conductivity map as a two-layer model. It's a simple weighted average of hydraulic conductivity of the saturated thickness of the Ogallala and the hydraulic conductivity of the saturated formational thickness of the Cretaceous. This will be used as a sensitivity analysis on the model.*

5. The GAM model has gone beyond the Ogallala to include the Cretaceous. Is that a fair statement?

Response: *I believe it was included as a specification by the Water Development Boards in their request for proposals. It has long been assumed, if not known, that the groundwater in the Cretaceous, beneath the High Plains and the Ogallala were in some sort of hydrologic connection. The water levels are fairly close as comparing them to the Ogallala and the underlying Santa Rosa, which generally has a much greater difference in water levels than that of the Ogallala. The Water Development Board requested that the two, Cretaceous and the Ogallala, to be grouped together.*

6. Did that same proposal include any work on the Santa Rosa?

Response: *No. The Santa Rosa was not slated to be part of this model. I would expect sometime down the road that when the Water Development Board and the Legislature get around to it there will be addition of the Santa Rosa to the model. The Santa Rosa is included in the Dockum Group, which is a minor aquifer. It is going to be modeled at some point in time.*

7. Will the recharge study results be used to enhance the values shown for inter-playa recharge?

Response: *I anticipate that we will use, below the irrigated acreage, a higher value of recharge at least for some early period where the less efficient irrigation methods were used. Then we would eventually phase that out. The big question is; number one how much do you use, and number two when do you phase it out or at least reduce it. That's something we will be looking at during the transient model calibration. You have to remember that at Muleshoe we had zero recharge. Beneath a playa you may have four or five inches of recharge, but the playas are a small area. So, when you take all the recharge beneath playas and divide that volume of water by the whole area, you come up with the smaller number with the averaging involved. We will be looking at some type of time variation and recharge to look at this.*

8. Does the rainfall amount over time account for the rise in water levels from the 1975 to 1990?

Response: *There is no reason, as far as we can see, to believe that rainfall is responsible for the rise in water levels.*

9. What type of velocities were you getting from the Roberts irrigation site?

Response: *The highest velocity was about a meter, or three feet per year. This is how far the water travels in a year. We then we multiply this number by the quantity of water to get a recharge rate.*

10. In your opinion, is the aquifer in the Southern Ogallala region, where you are having these rises, is there any other type of recharge other than percolation from the surface?

Response: *I don't think there is any water coming from the bottom or the sides of the aquifer.*

11. Could it come from the sides? We had a pretty good earthquake in early 90's. After that earthquake centered in western Gaines County, in Dawson

County we started finding irrigation water in areas that in the past we only had domestic water. Now out in that area we have some nice irrigation wells.

Response: *The draw down in Gaines County has not reversed the gradient. They are not pulling water from Dawson County back over to Gaines County. The water is still flowing east. I haven't looked at the map in that great of detail, but I would assume the gradient is less steep than it used to be. I would assume that we have a greater total change in water level in the last 50 years in Gaines County than in Dawson County. If anything, the potential for water to move from west to east across the County line is less than it used to be. It appears that whatever has caused the rise in water levels is now finished. From a water budgeting standpoint, something has come to and end, in the 20-year period of water level rise.*

12. In 1993, we reached a benchmark high. In January of 1993 we had more water in our Dawson County monitoring wells than we did in 1938 when the first one was drilled. All of our monitoring wells showed this. Were all of these water level rises in our monitoring wells caused by rainfall? You have to realize in the mid to later 80's we reached 100 year rains. We had 56 inches of rain in after May 15th to the end of the year.

Response: *I think we need better rainfall data. We don't see this information in the records.*