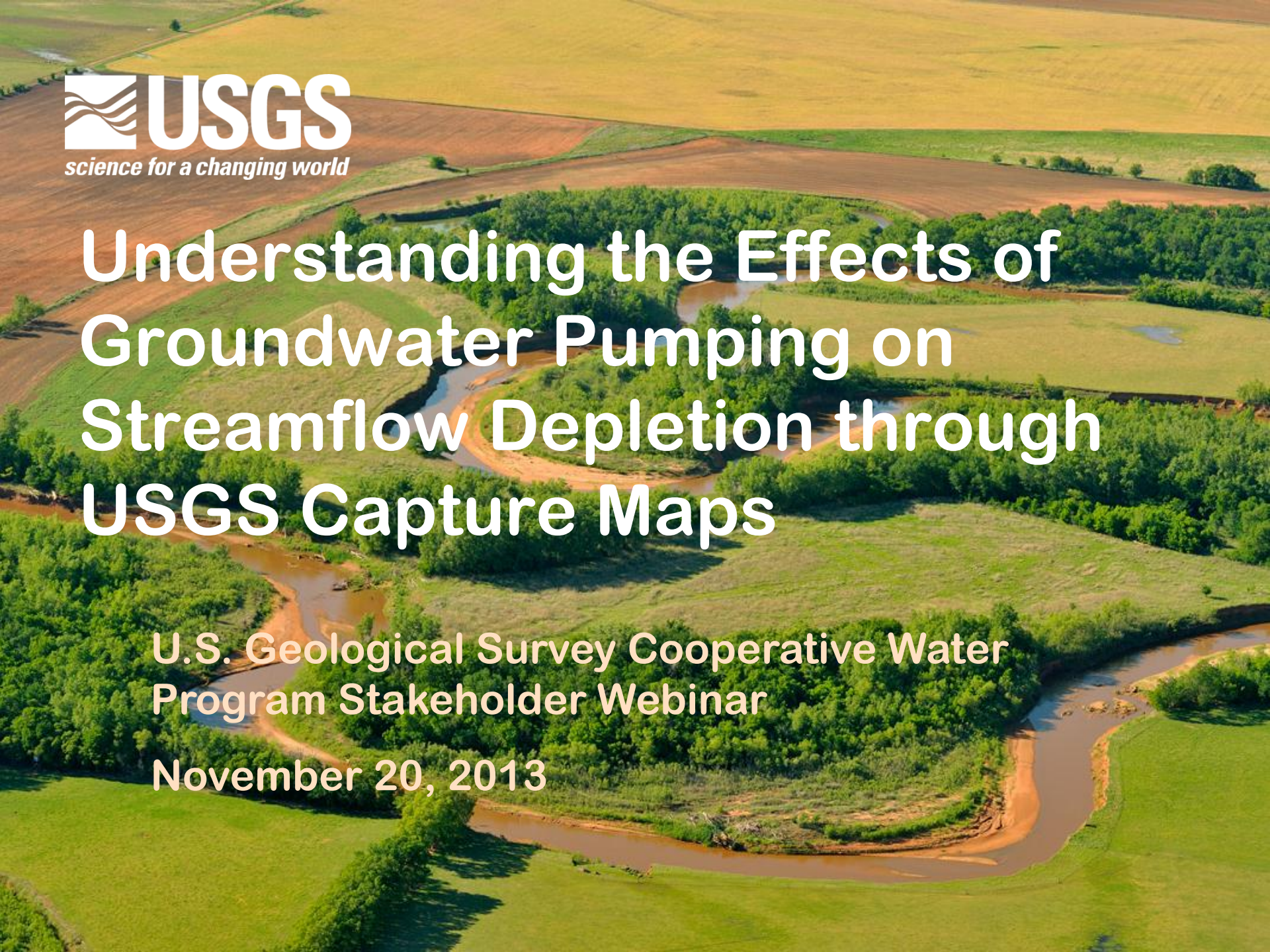



# Understanding the Effects of Groundwater Pumping on Streamflow Depletion through USGS Capture Maps

U.S. Geological Survey Cooperative Water Program Stakeholder Webinar

November 20, 2013

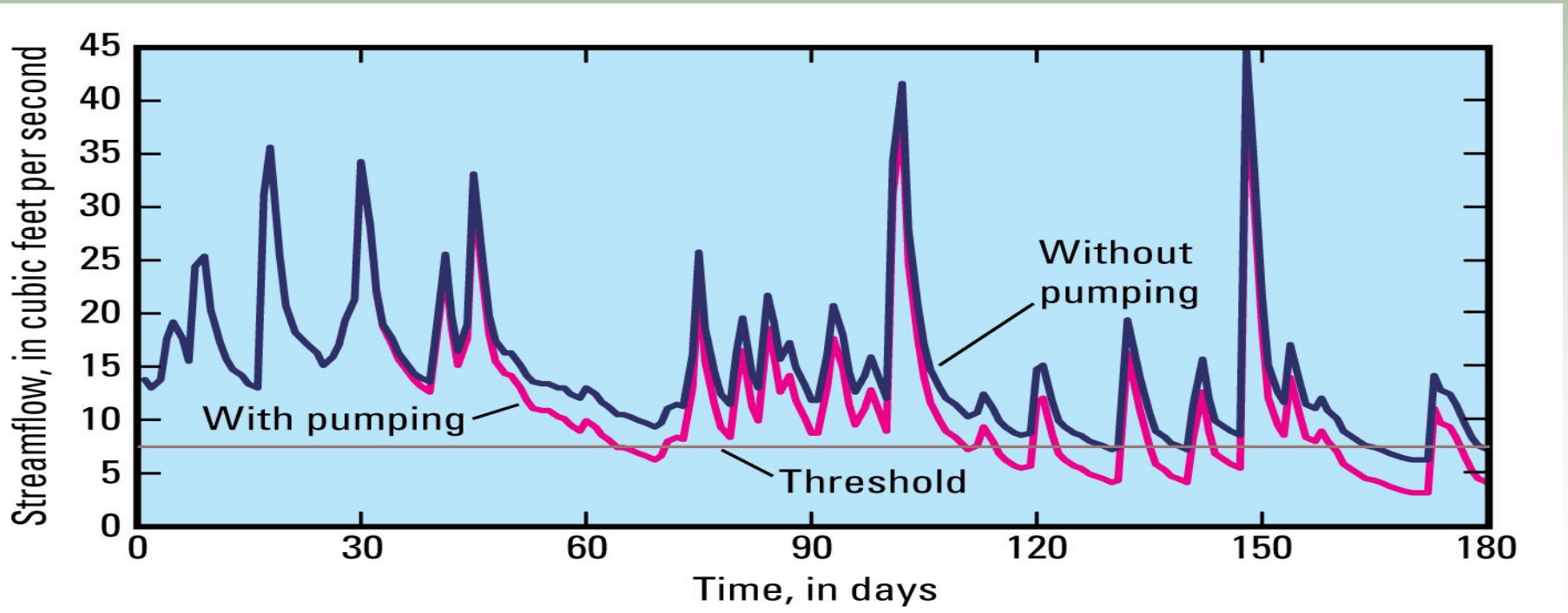
# Presentation Outline

- Streamflow Depletion by Wells: What is it? What factors affect the *rates, locations, and timing* of depletion?
- Capture Maps: What are they? Why are they needed?
- Elkhorn and Loup River Basins, Nebraska, and History of Water Management
- Capture Maps for the Elkhorn and Loup River Basins and how they are used for water management by the Lower Loup Natural Resources District

USGS

# Streamflow Depletion by Wells

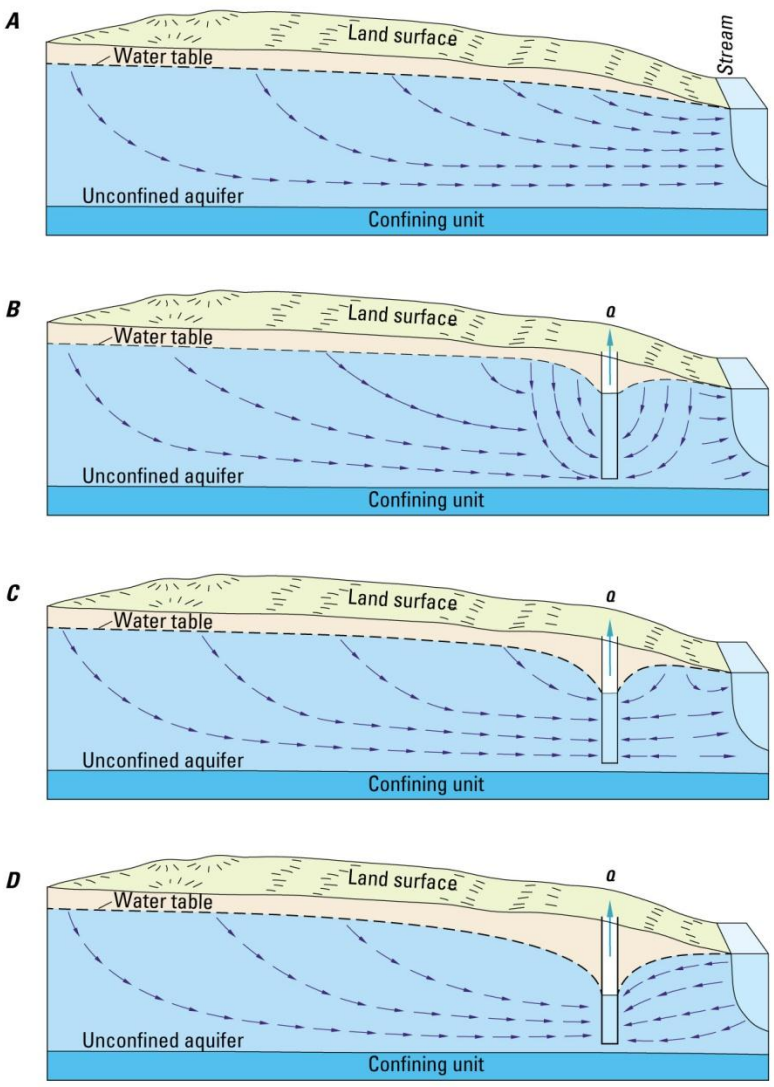
- Reduces streamflow
- Changes the mix of sources of water to streams
- Consequent changes in water quality/temperature
- Impacts aquatic and riparian biota




http://pubs.usgs.gov/circ/1376/

USGS

# The Process of Streamflow Depletion




***A. Prepumping conditions***

***B. Reductions in aquifer storage predominate***

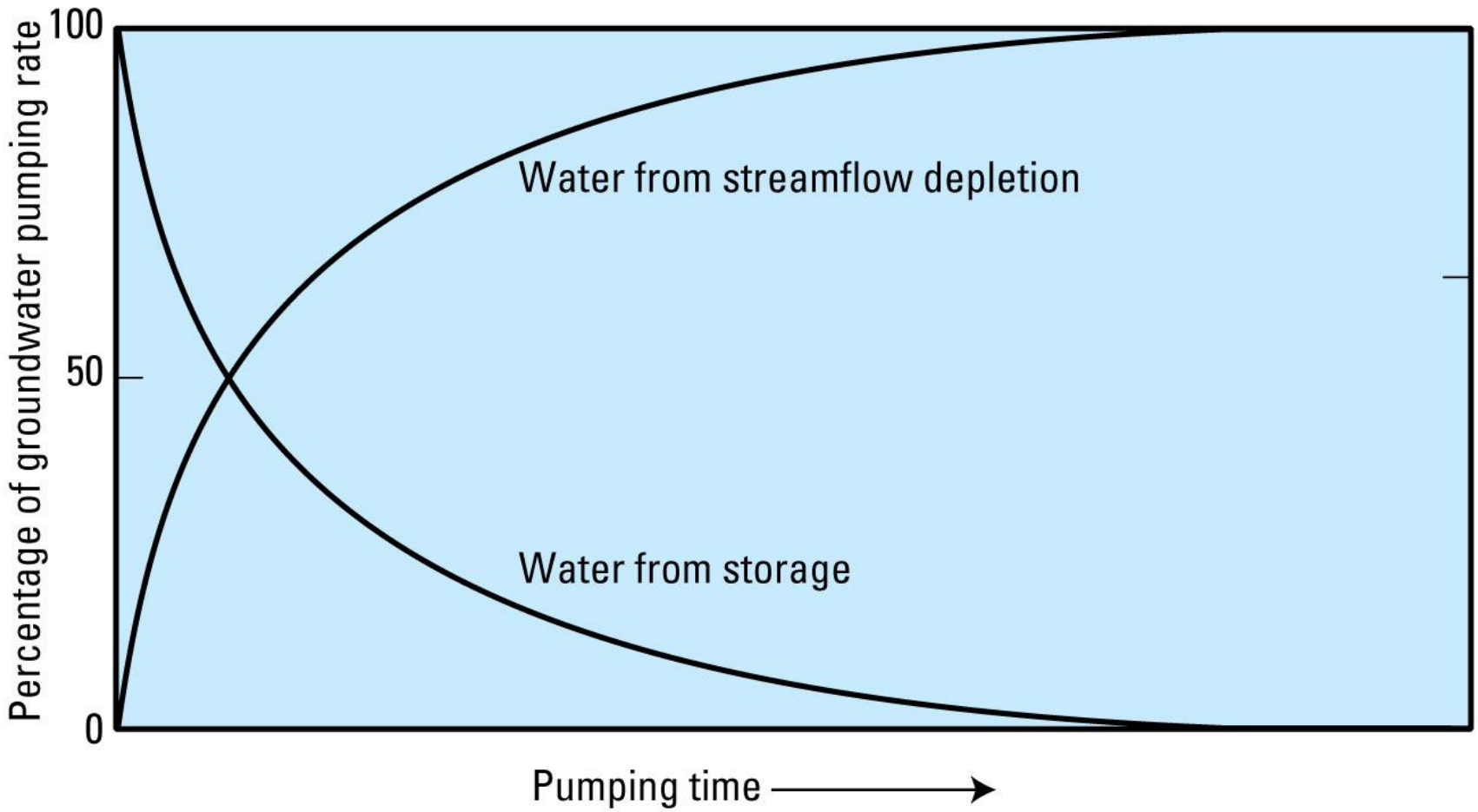
***C. Captured groundwater discharge***

***D. Captured groundwater discharge and induced infiltration***

*Streamflow depletion = captured groundwater discharge + induced infiltration of streamflow*

USGS

# Timing of Streamflow Depletion




USGS

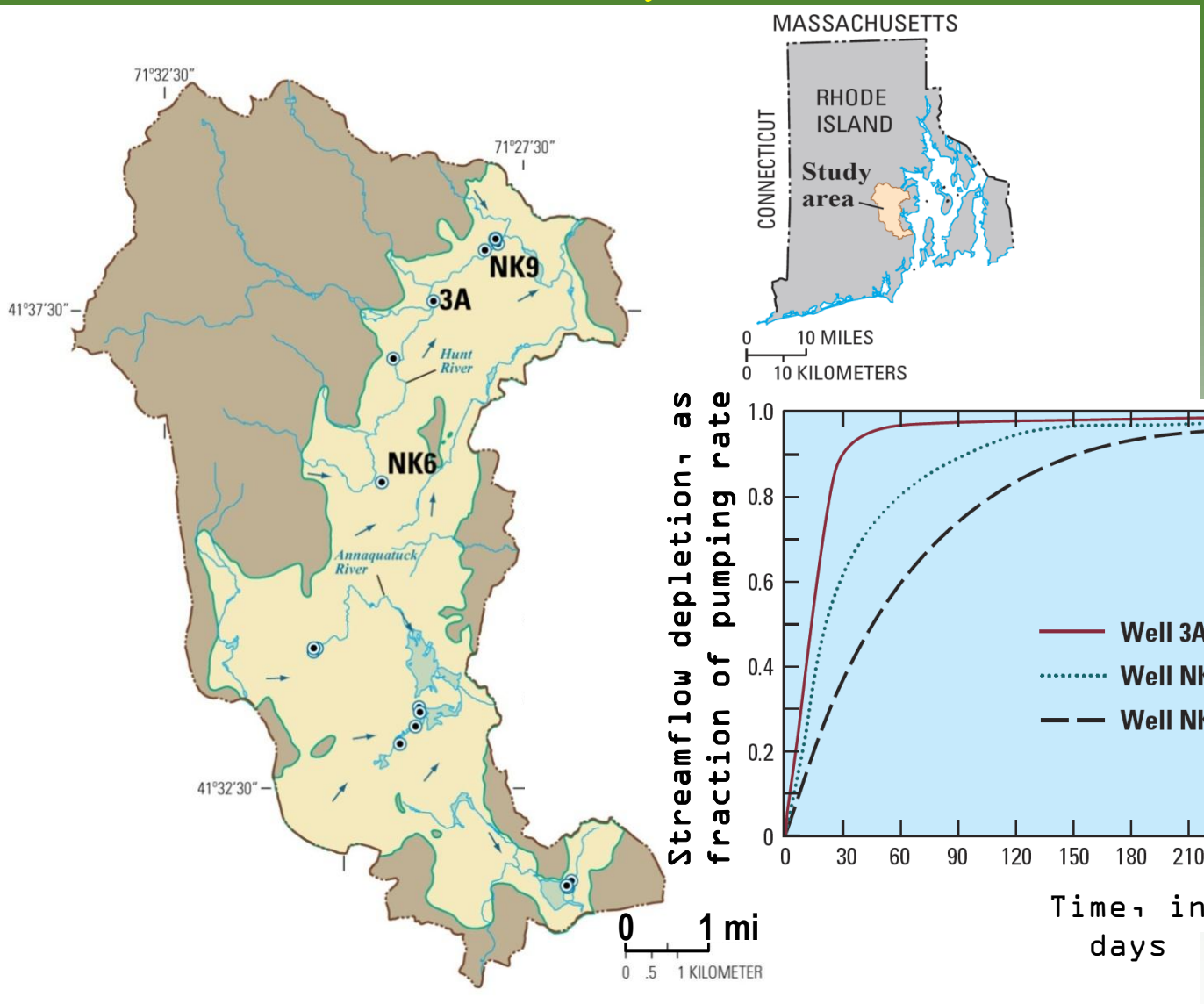
# Factors that Affect the Timing, Rates, and Locations of Streamflow Depletion

- Geology and Hydraulic Properties of Aquifer
- Aquifer Dimensions (size)
- Geometry of the stream network
- Well location (Vertical and Horizontal Distance from Streams)
- Pumping rates and pumping schedules

➢ *The timing of streamflow depletion varies substantially among aquifer systems, and even within aquifer systems.*

USGS

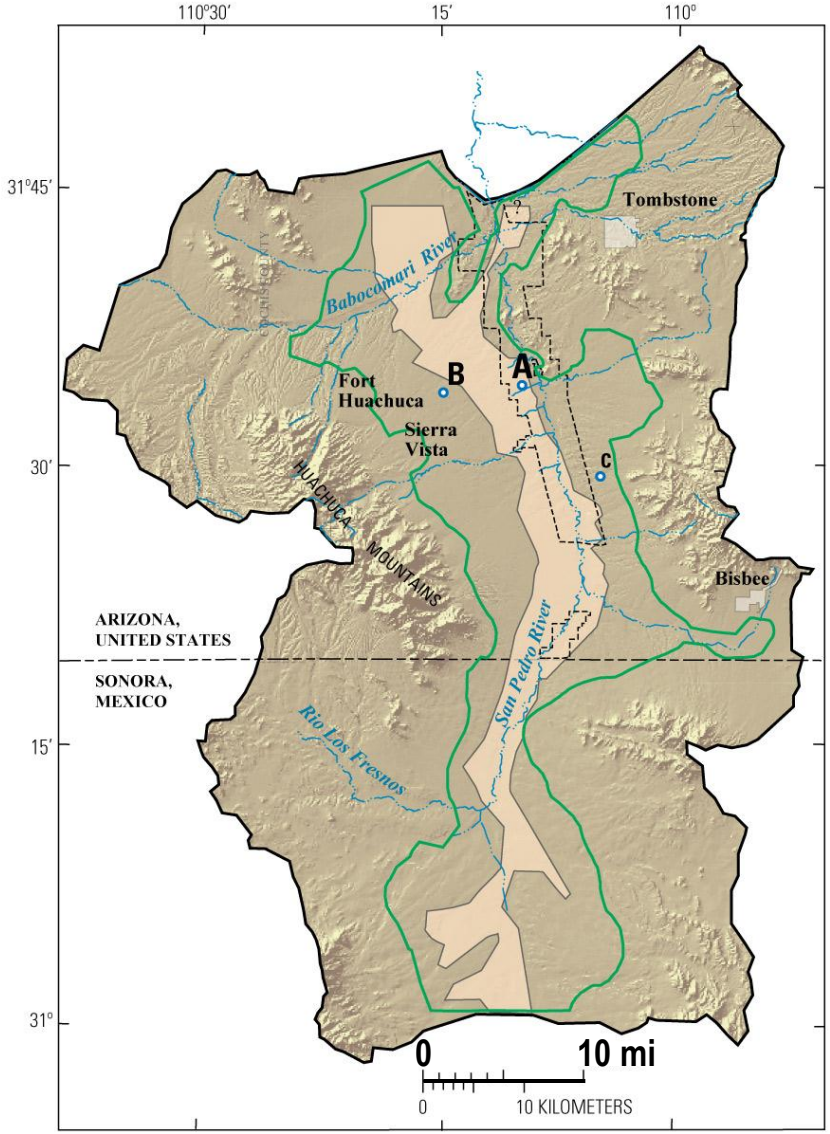
# Hunt River Basin, Rhode Island



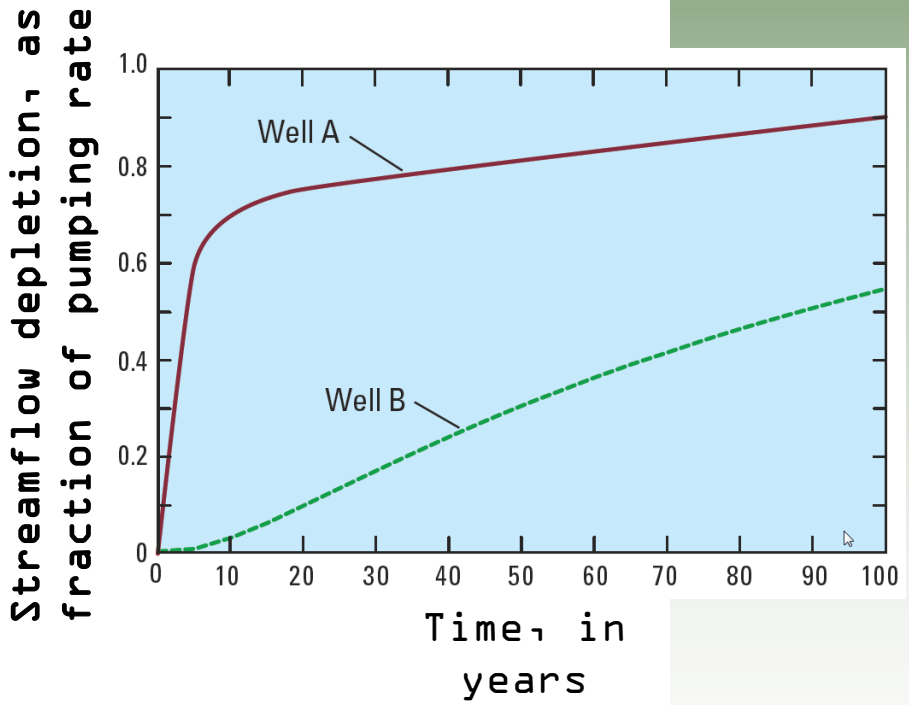

*Streamflow depletion is the primary source of water to the wells in* ***days to months****.*

USGS

# Upper San Pedro Basin, Arizona



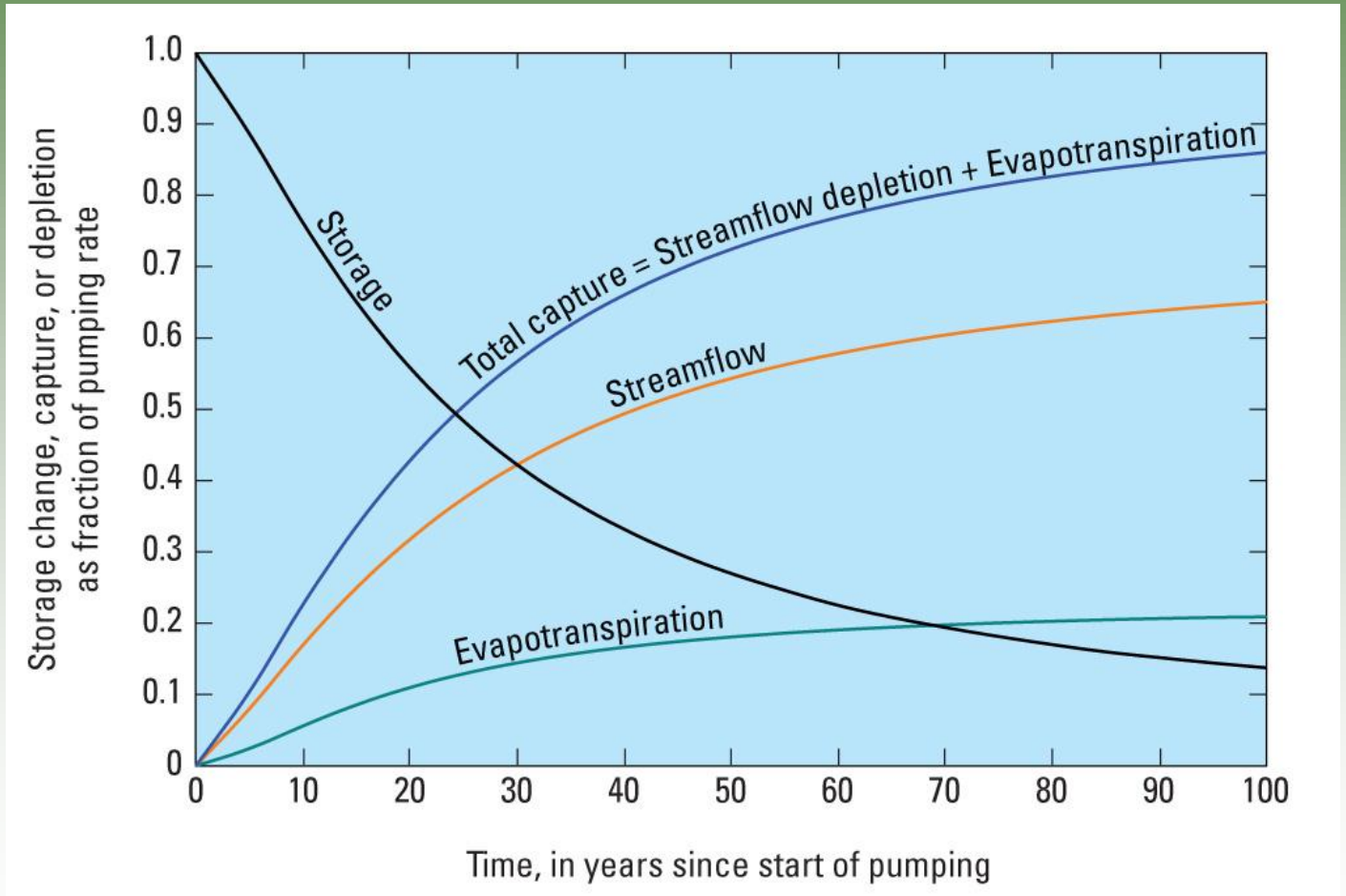





*Streamflow depletion is the primary source of water to the wells in* ***years to decades****.*

USGS

# Pumping Can Affect Other Hydrologic Features: Springs, Wetlands, Coastal Discharge, Evapotranspiration




USGS

# Presentation Outline

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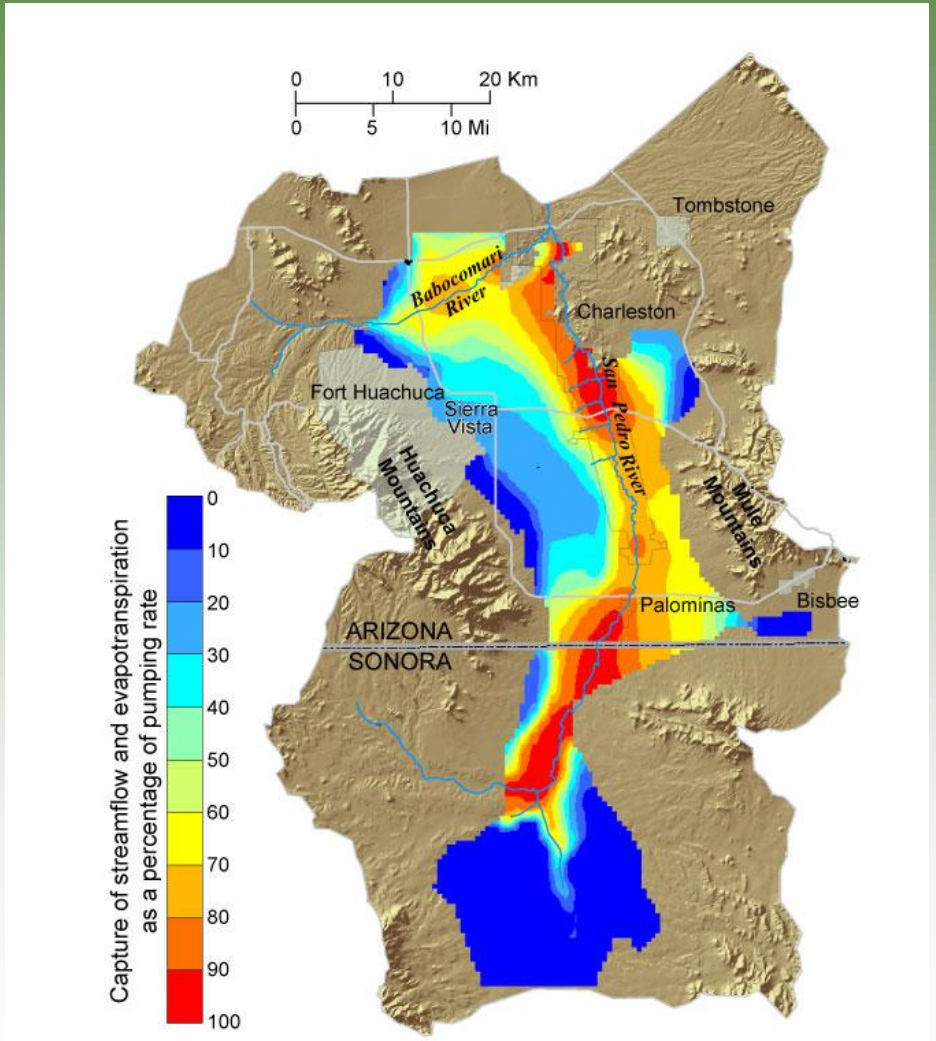
USGS

# A New Tool: Capture Maps

- ✓ Constructed using groundwater models
- ✓ Give a sense of timing of capture by <u>one well</u> as a function of well location
- ✓ Applications: Arizona, Michigan, Nebraska, Oregon

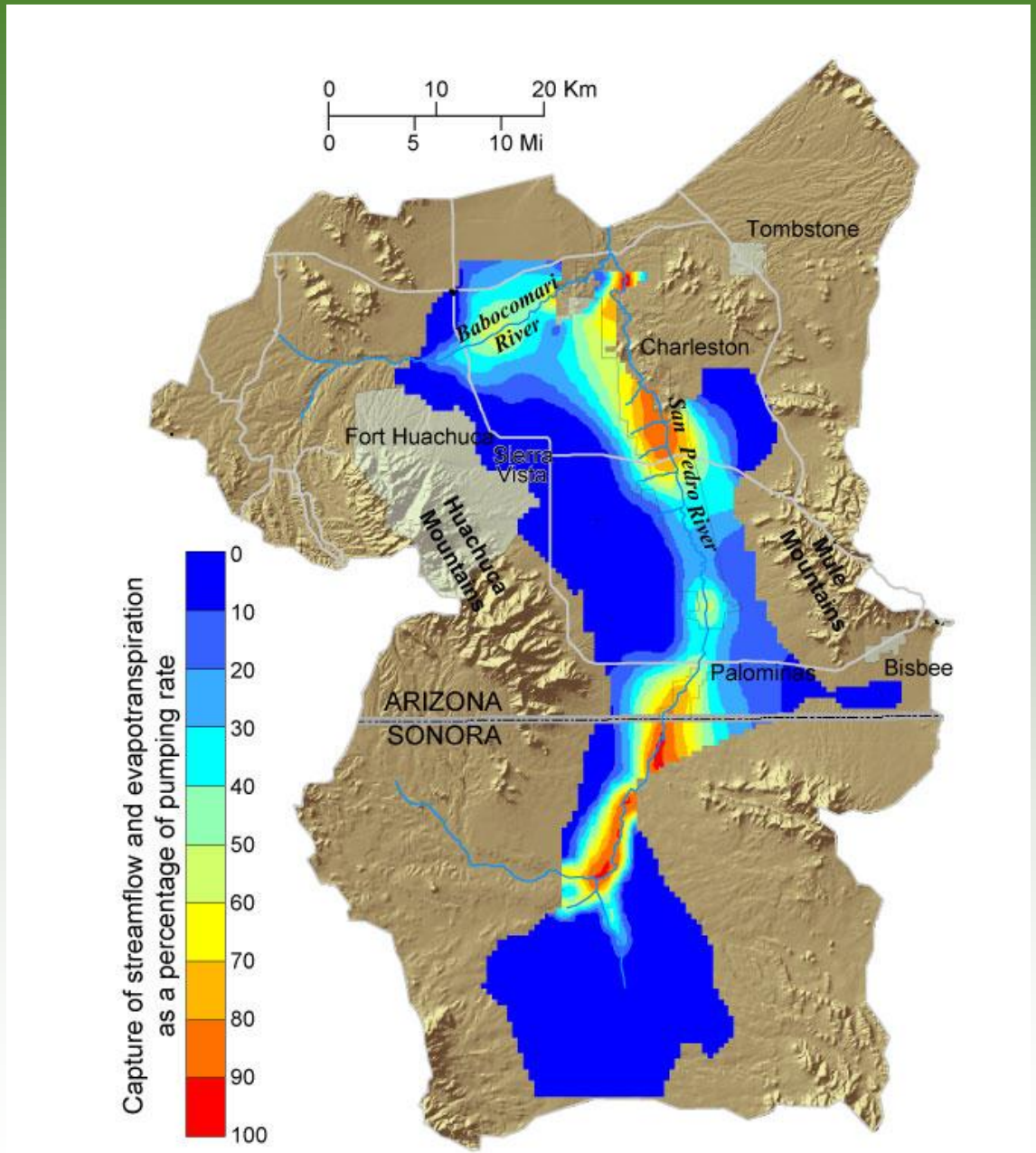


# Why Map Capture?

- To help water managers and other interested parties understand relation between pumping location and the timing of streamflow depletion or other capture
- To help with specific regulations relating to groundwater pumping

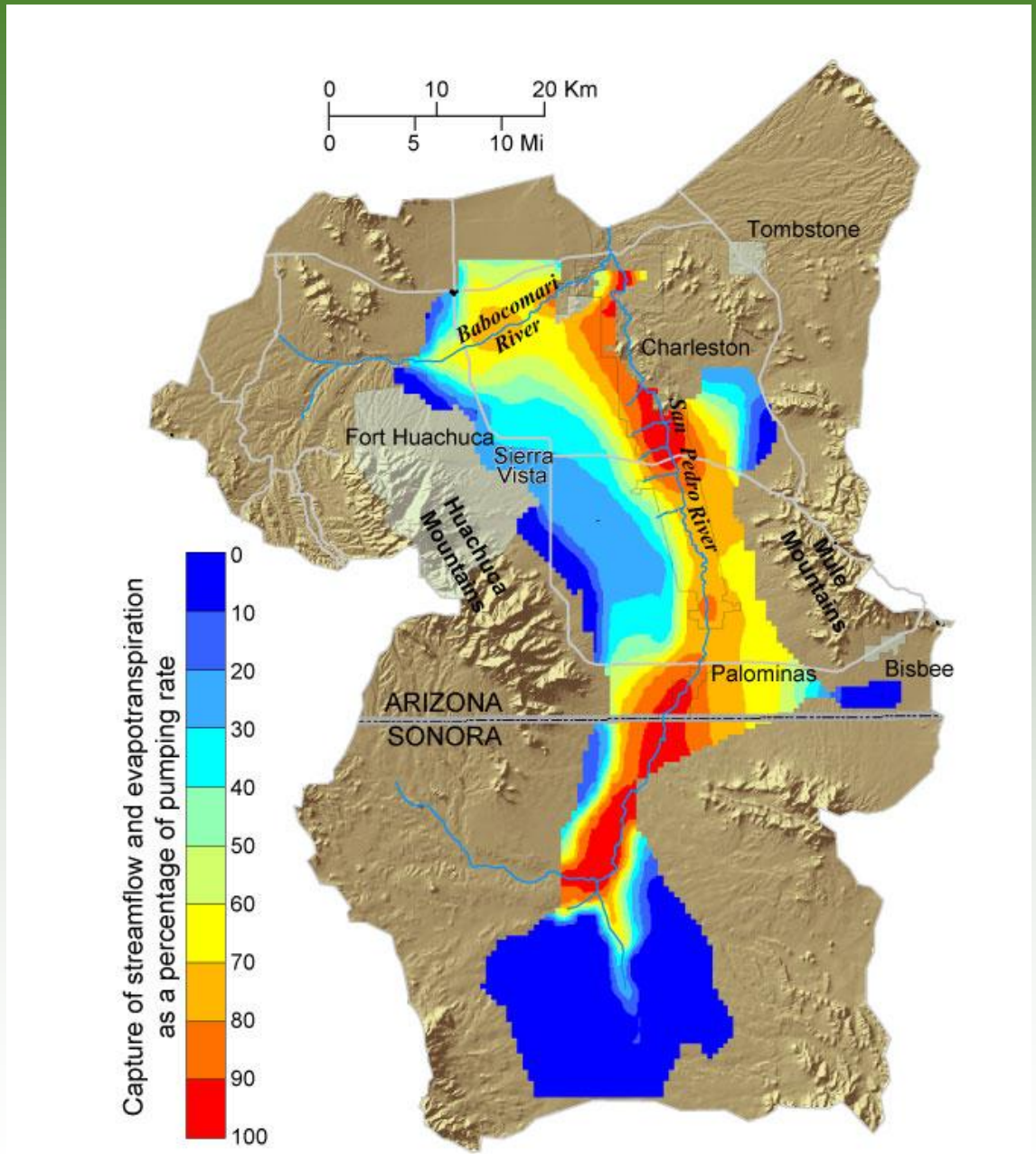
USGS

# Computed capture by pumping in layer 4 for 10 yrs



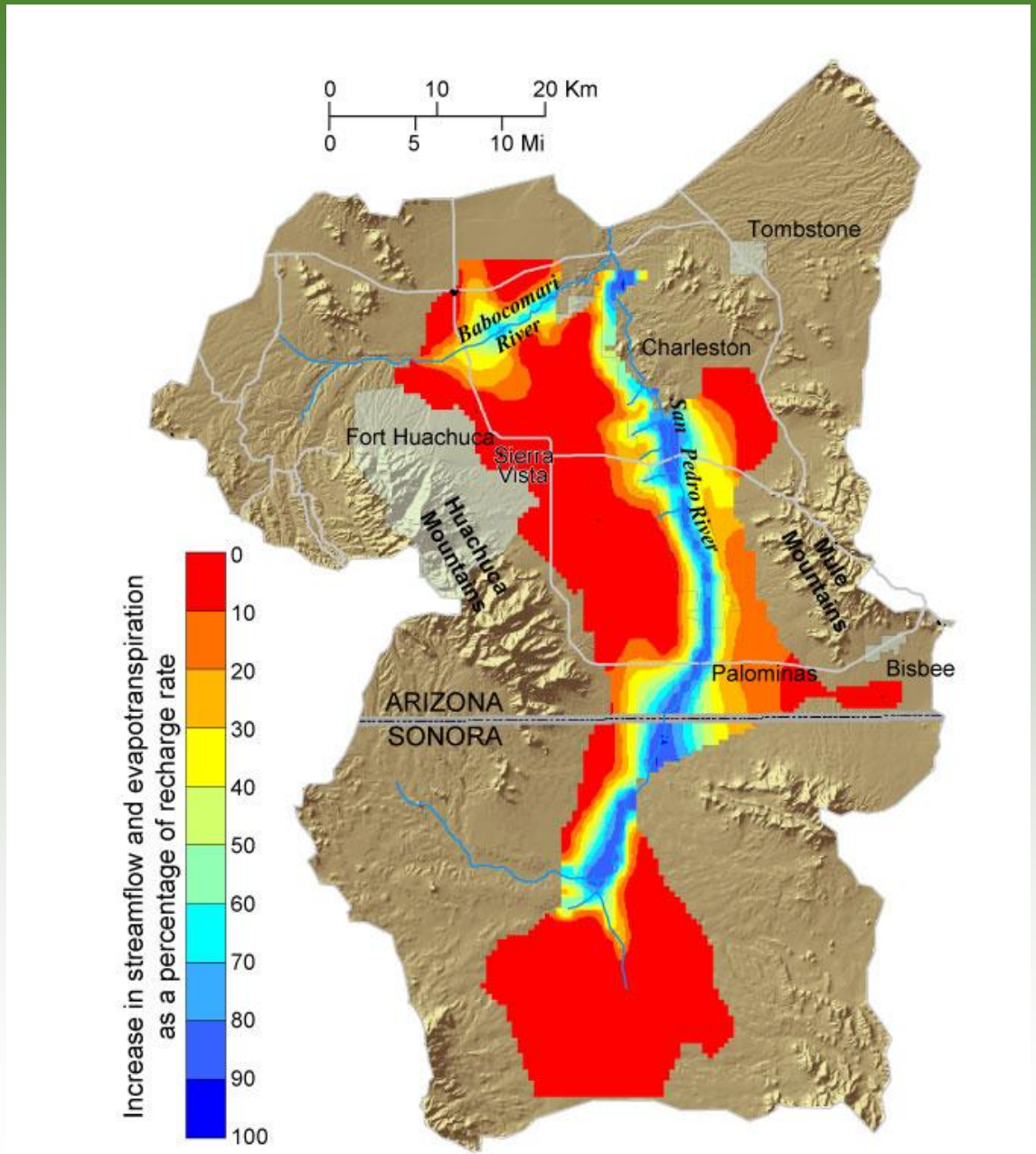

USGS

# Computed capture by pumping in layer 4 for 50 yrs



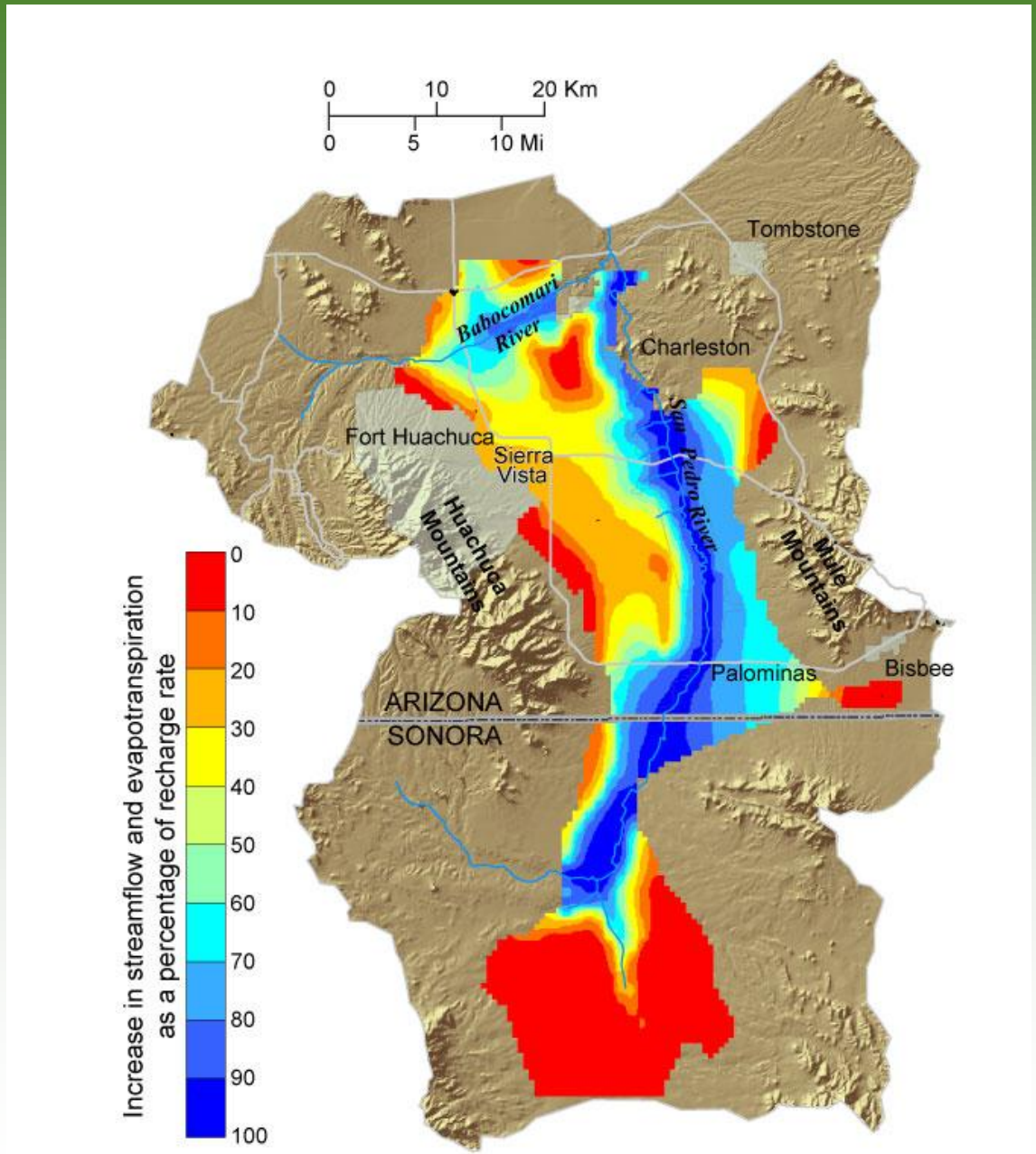

USGS

# Artificial recharge into uppermost layer for 10 yrs




USGS

# Artificial recharge into uppermost layer for 50 yrs




USGS

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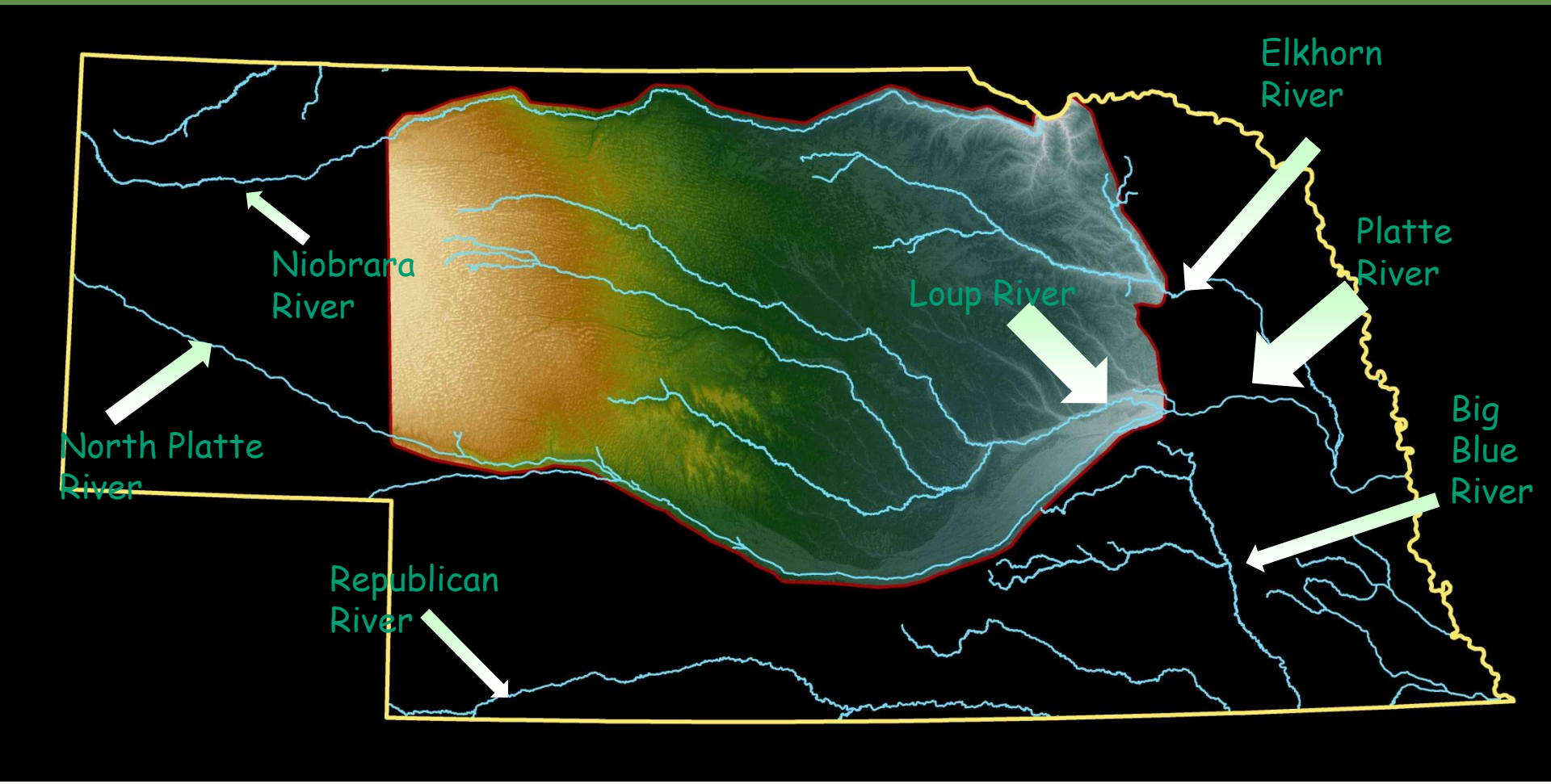
USGS

# Study Area




USGS

# A common conception of Nebraska…

USGS

# But it's different in the Sand Hills…

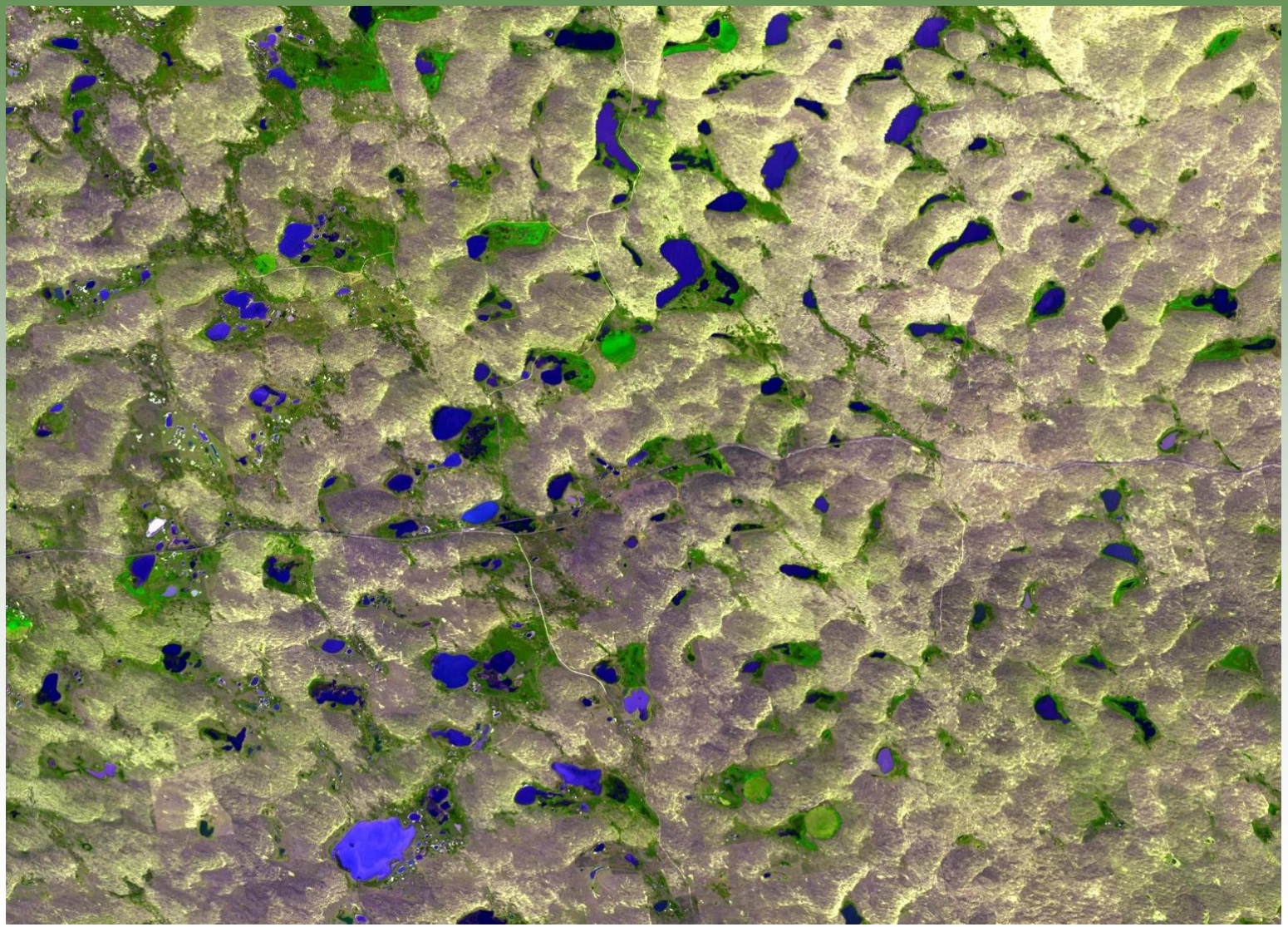


USGS

# With baseflow-dominated streams,

USGS

# … and inter-dunal lakes



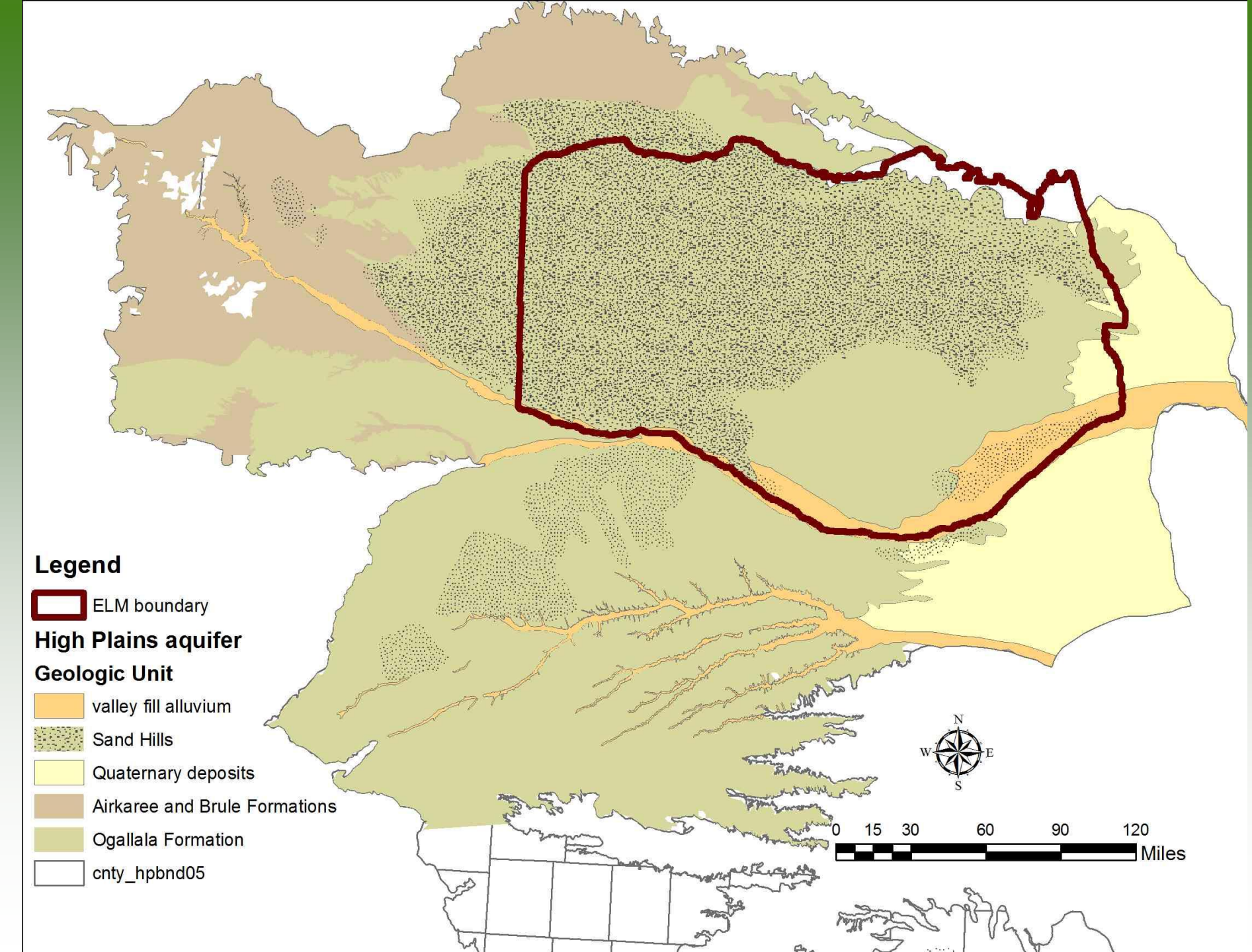
USGS

# Sand Hills Characteristics

- Largely undeveloped, other than pasture and rangeland
- High infiltration rates = high rates of recharge, low runoff
- Predominantly base flow streams
  - Groundwater discharge is the major source of stream flow (up to 90% of stream flow)

*Highly inter-connected surface-water and groundwater!*

USGS


Legend
ELM boundary
High Plains aquifer
Geologic Unit
valley fill alluvium
Sand Hills
Quaternary deposits
Airkaree and Brule Formations
Ogallala Formation
cnty_hpbnd05
N
W
E
S
0 15 30 60 90 120
Miles

# Background – Nebraska Water Management and Law

- Surface-water Rights
  - Prior appropriations, administered at the State level
- Groundwater Rights
  - Correlative Rights, administered by 23 Natural Resources Districts
- Under this system, no recognized connection between surface-water and groundwater

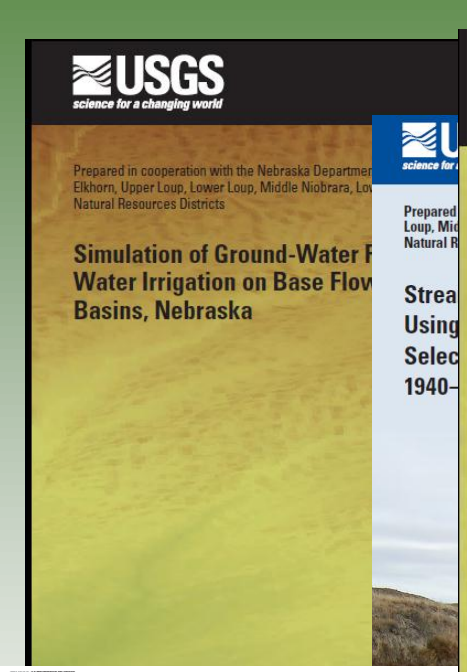
USGS

# Legislative Bill (LB) 962, 2004

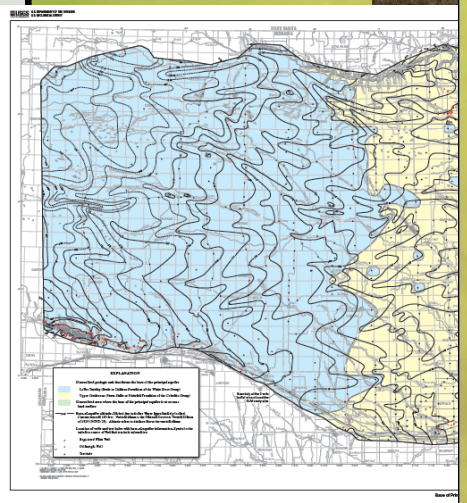
- First recognition of connection between surface-water and groundwater resources
- Legal recognition of connection directly led to increased need for stream depletion capture maps, many completed through cooperative studies
- ELM is a cooperative study with the USGS and several state and regional agencies

USGS

# Elkhorn-Loup Model (ELM) Reports 2005-2012



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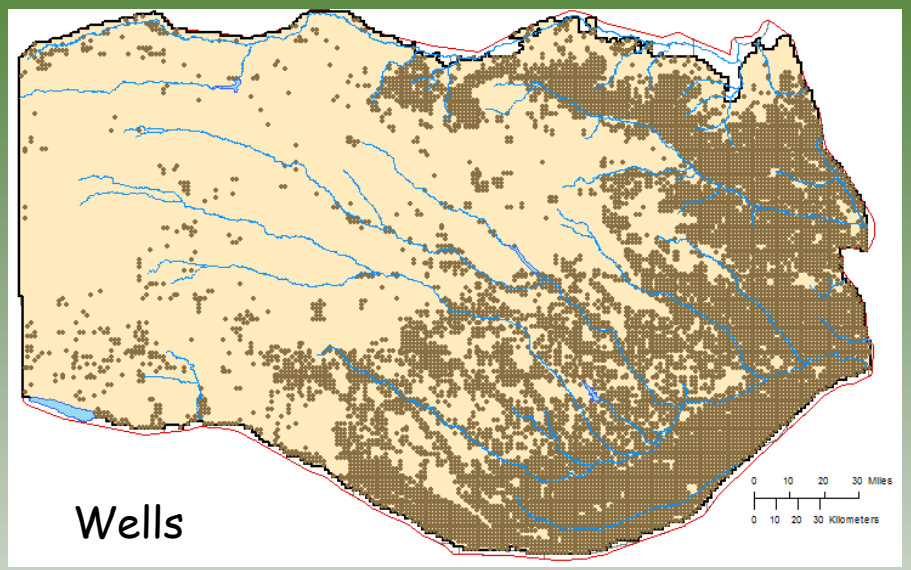
USGS

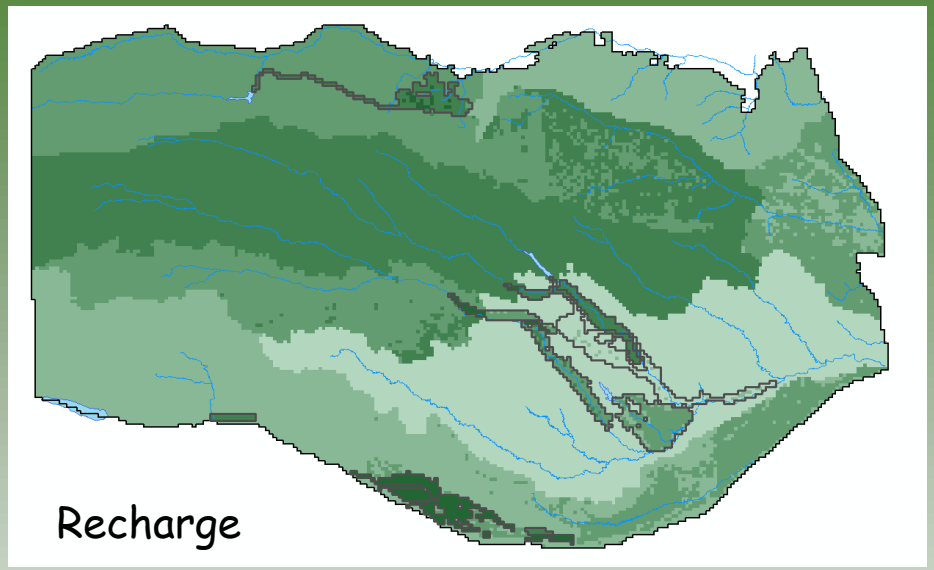
# Elkhorn-Loup Model (ELM) Construction and Capture Maps

USGS

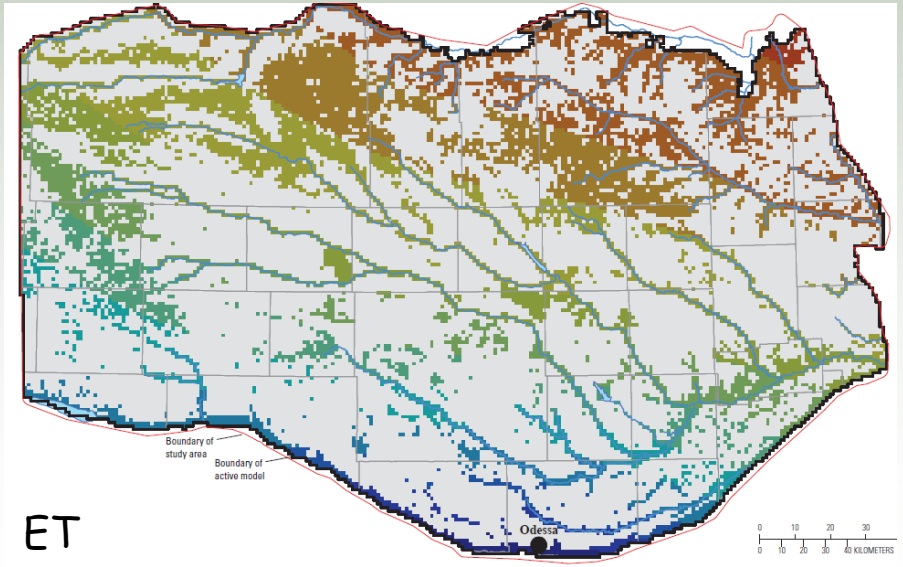
# Model Construction and Calibration



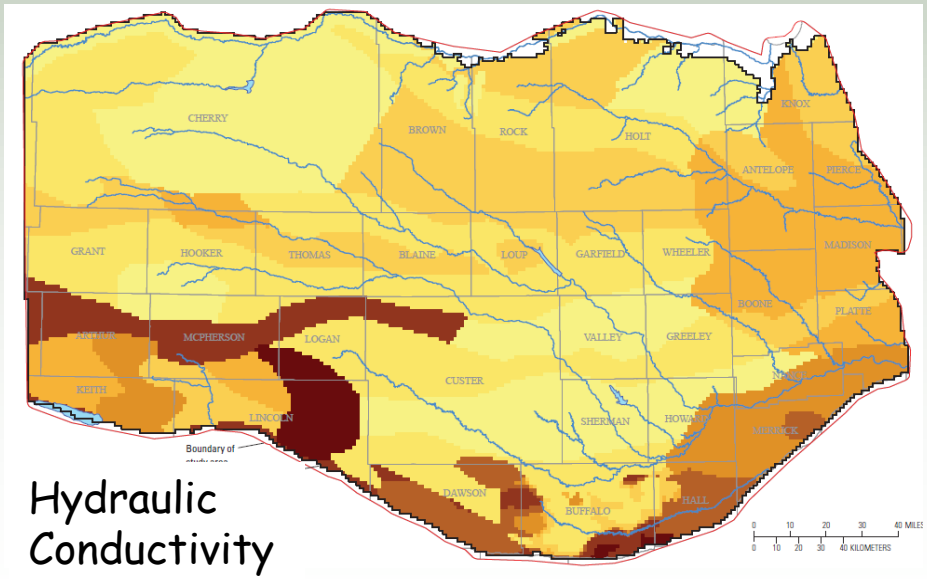

Wells



Recharge




ET



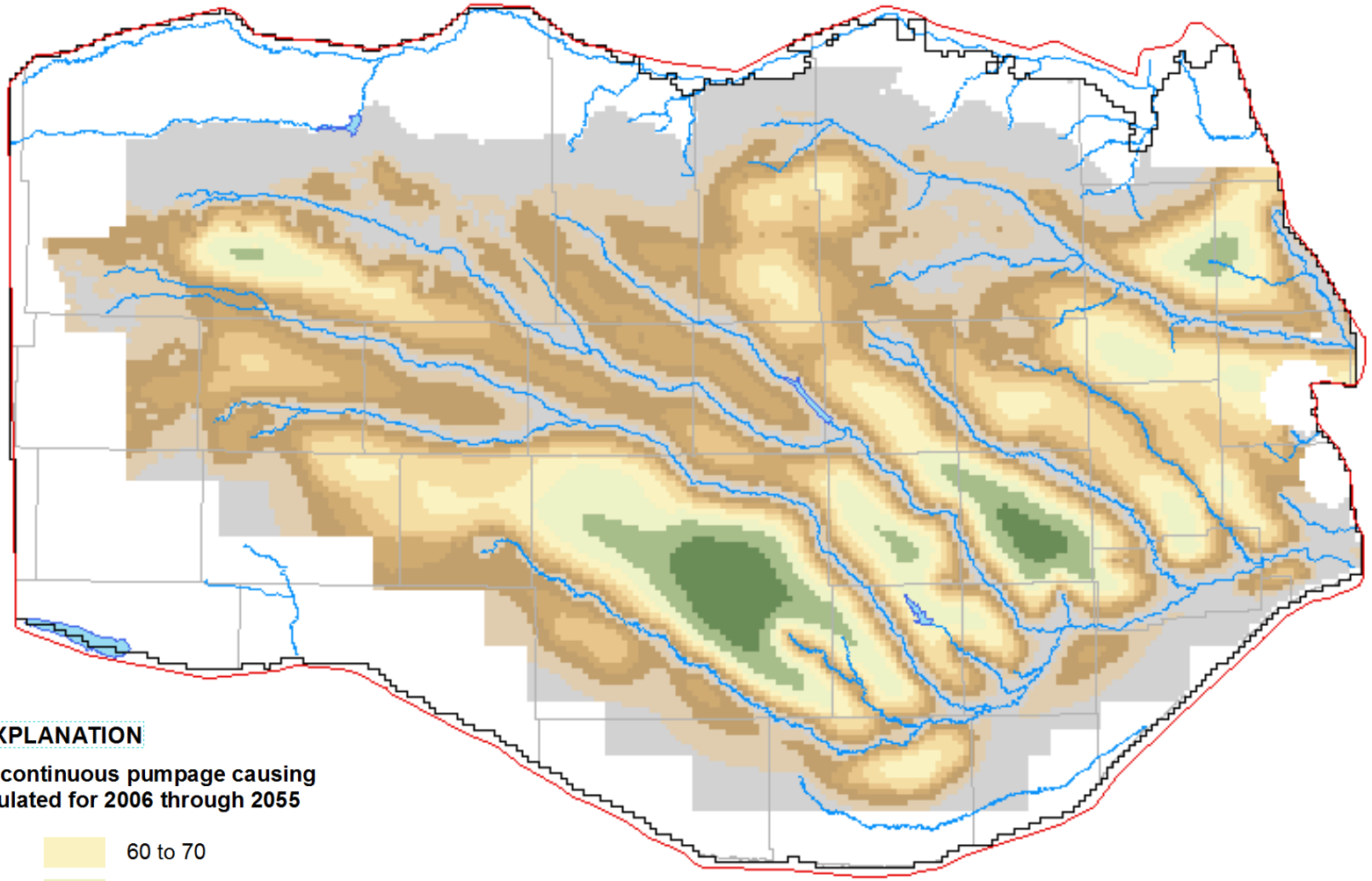

Hydraulic Conductivity

# From Model to Capture Maps

- Run a baseline simulation for a 50-year period (2006 to 2055)
- Make 22,000 additional simulations for the 50-year period, each time simulating pumping from a single, hypothetical well location
- For each run, compute the volumetric fractions of pumped water from the well derived from groundwater storage, base flow, and evapotranspiration (ET)
- Create capture maps of groundwater storage, base flow, and ET for all pumping well locations

USGS

# Computed Capture by Pumping for 50 years



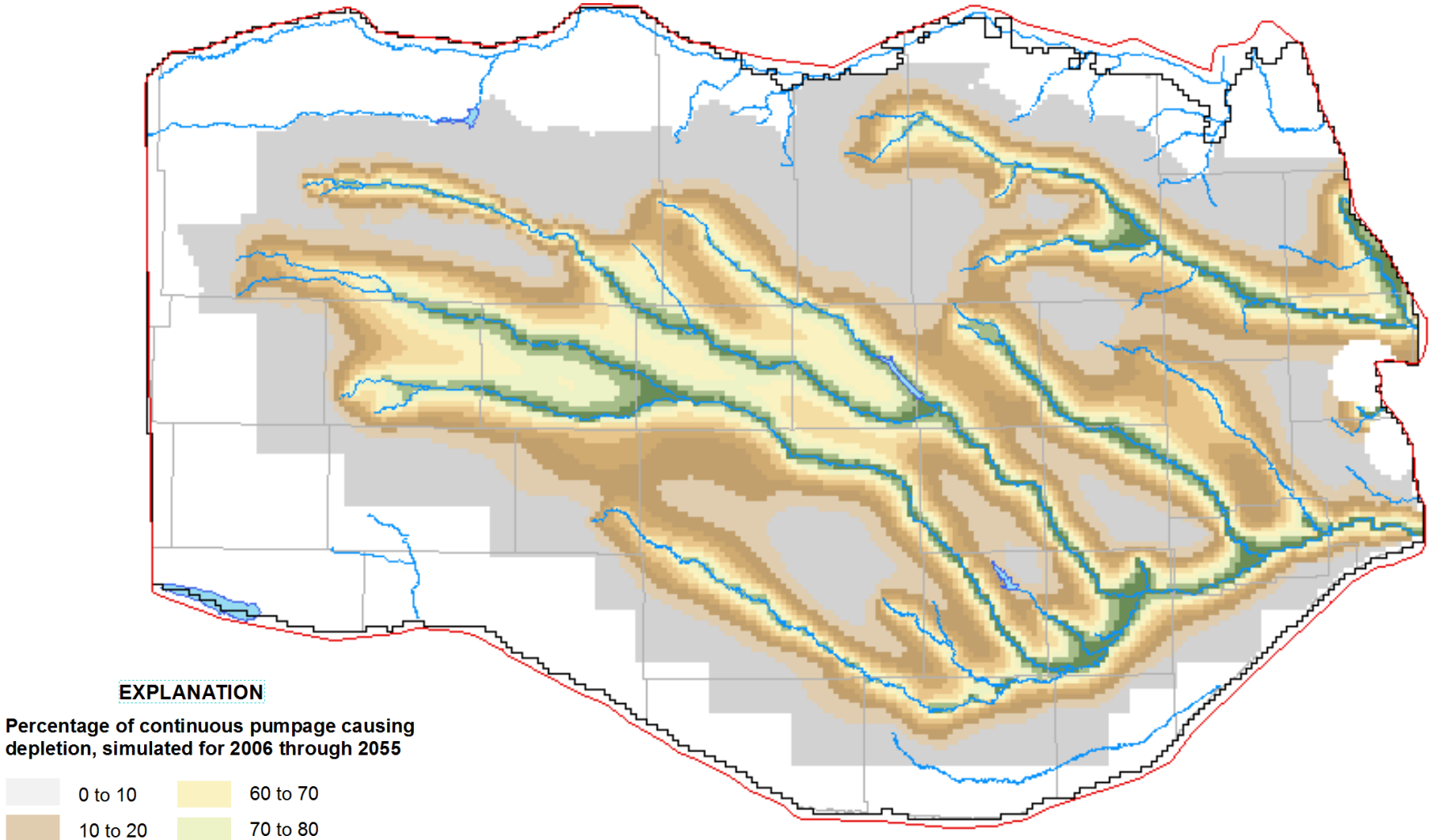
**EXPLANATION**

**Percentage of continuous pumpage causing depletion, simulated for 2006 through 2055**

- 0 to 10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 to 100
- Depletion not calculated

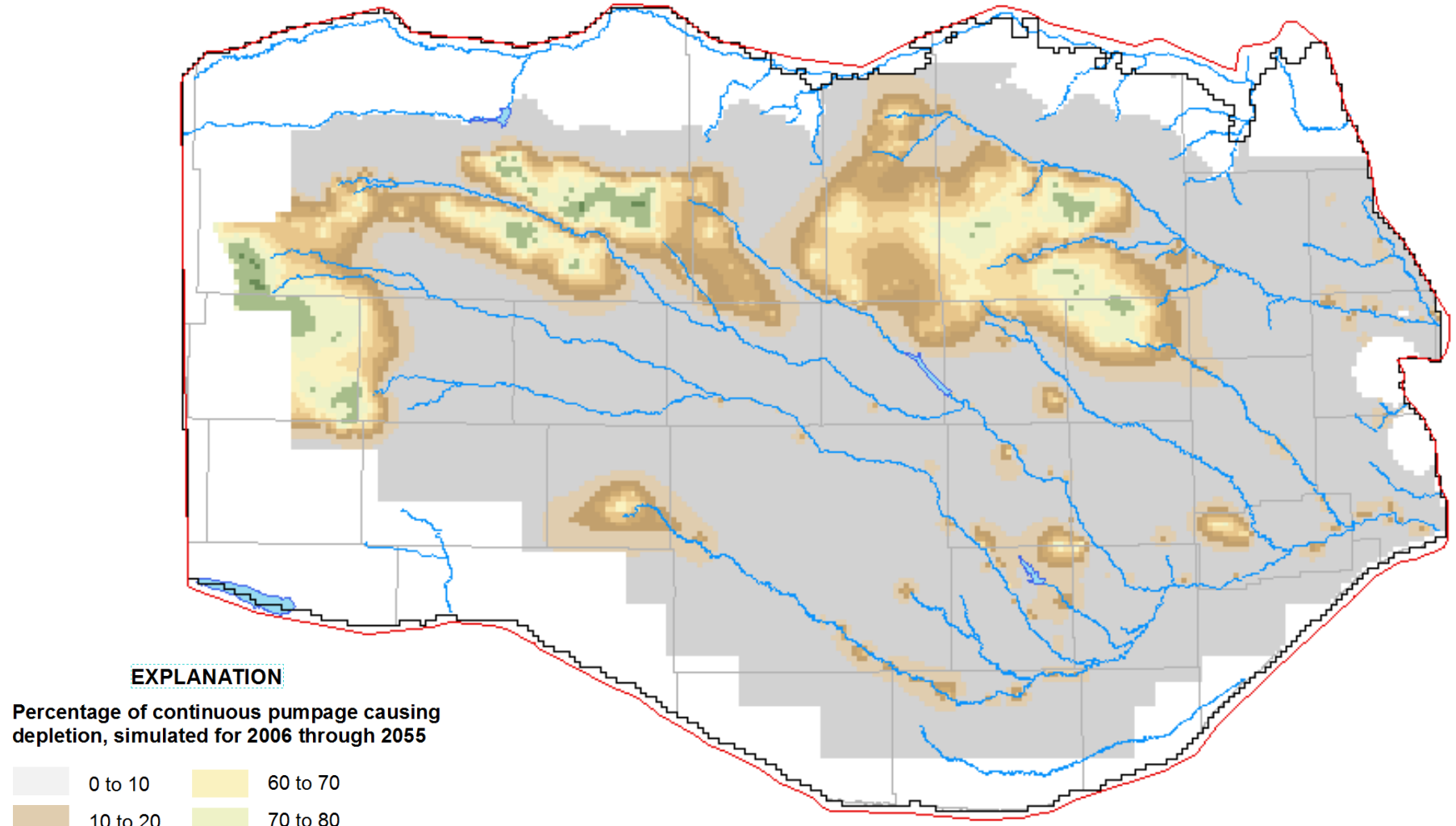
## Groundwater Storage

# Computed Capture by Pumping for 50 years




## Stream Base Flow

# Computed Capture by Pumping for 50 years




## Evapotranspiration

# Groundwater Management Issues, Lower Loup Natural Resources District, Nebraska

Tylr Naprstek
Water-Modeling Coordinator

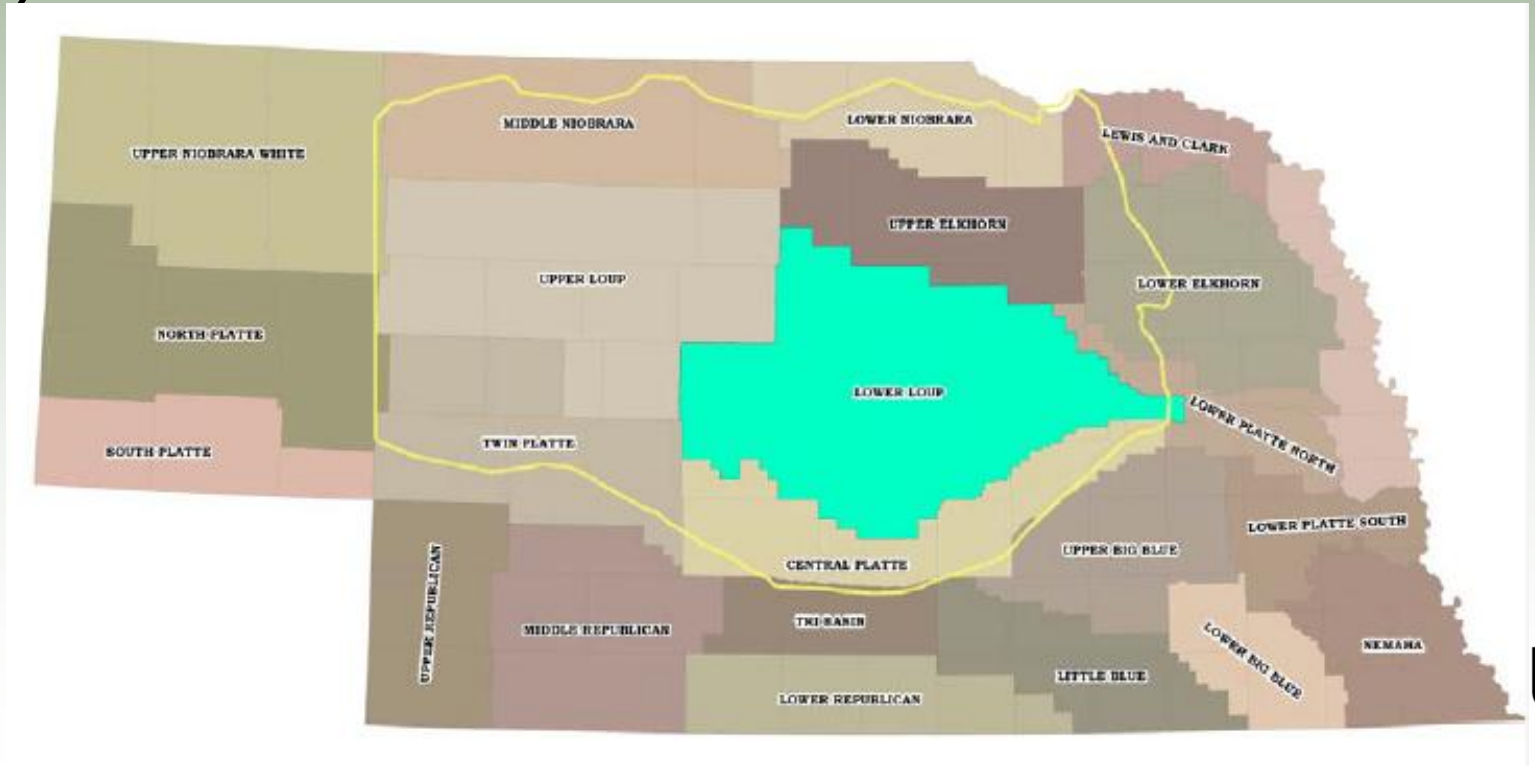
# Overview of Lower Loup NRD's Management using ELM capture maps:

(1) Irrigated Acre Transfer Rule

(2) Irrigation Right Banking Program

(3) New Acre Allocation

(4) Variance Committee & Conclusion




USGS

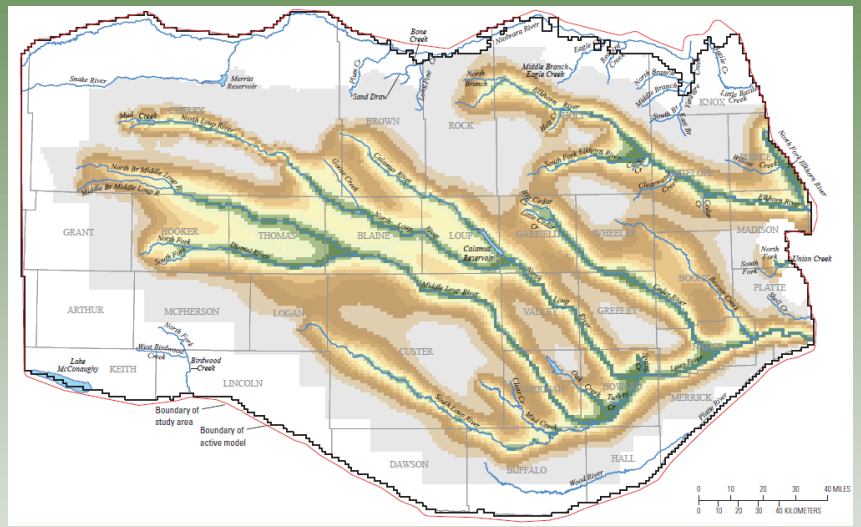
# Background on Irrigation Management

- Lower Loup NRD (LLNRD) management implemented:
  - Well Moratorium January 1st, 2007
  - Acre Moratorium January 1st, 2008
- Required landowners to certify all irrigated acres
- LLNRD creates GIS shapefile of each certification
- Currently:
  - 1.2 million acres certified

USGS

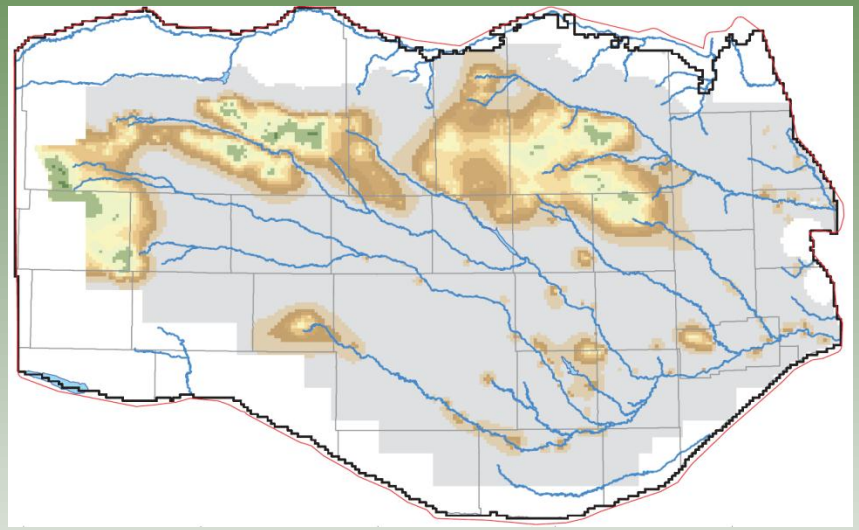
# ‘Stream-Depletion Factor (SDF)’map = Stream Base Flow + ET maps

**Stream Base Flow**




+

**Evapotranspiration**



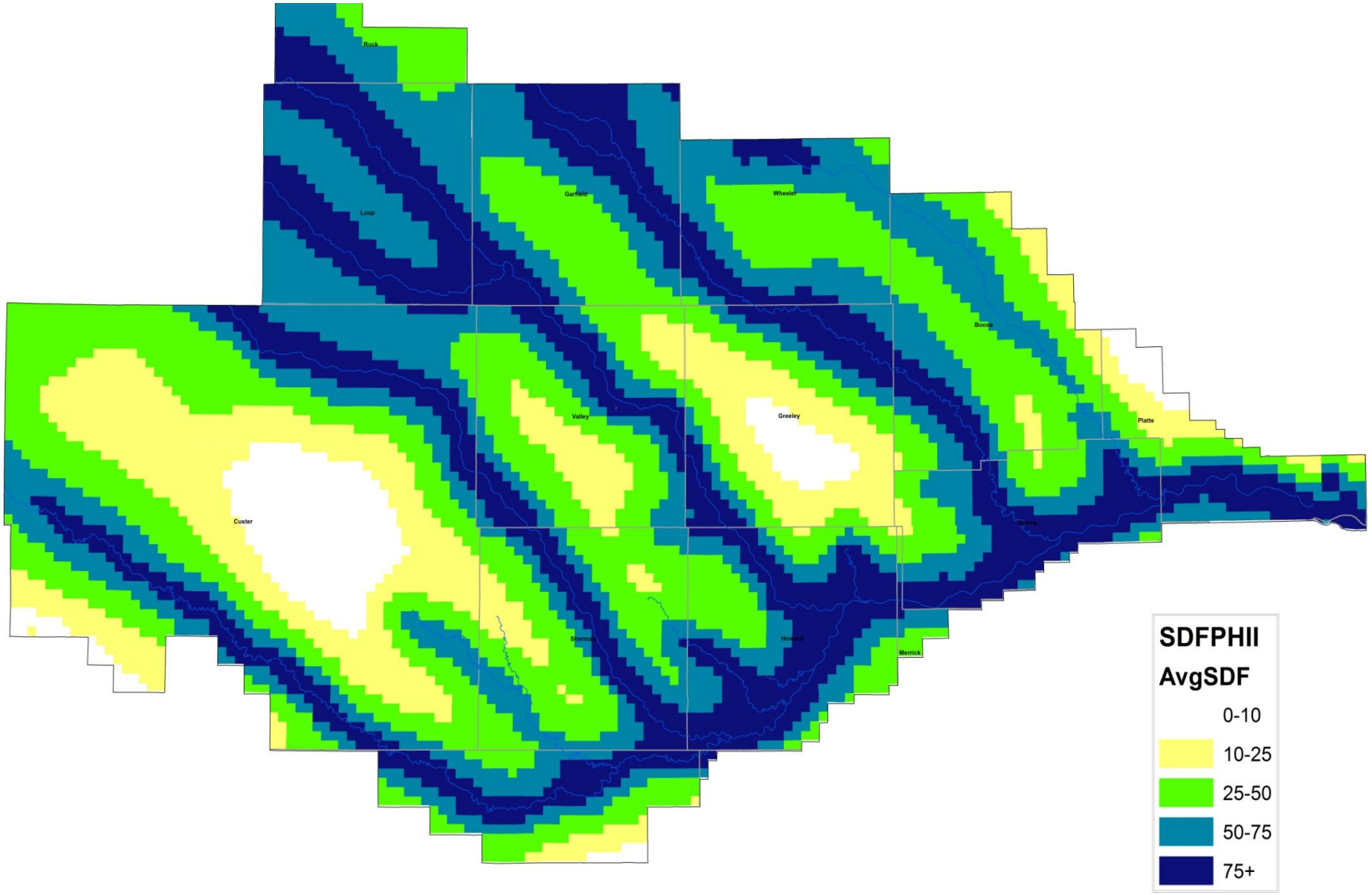
- State of Nebraska (Department of NR)
  - Used in determination of water appropriation
- Accounts for all potential “sinks” to stream flow

USGS

# Resulting SDF Map

## (Phase 2, ELM results)

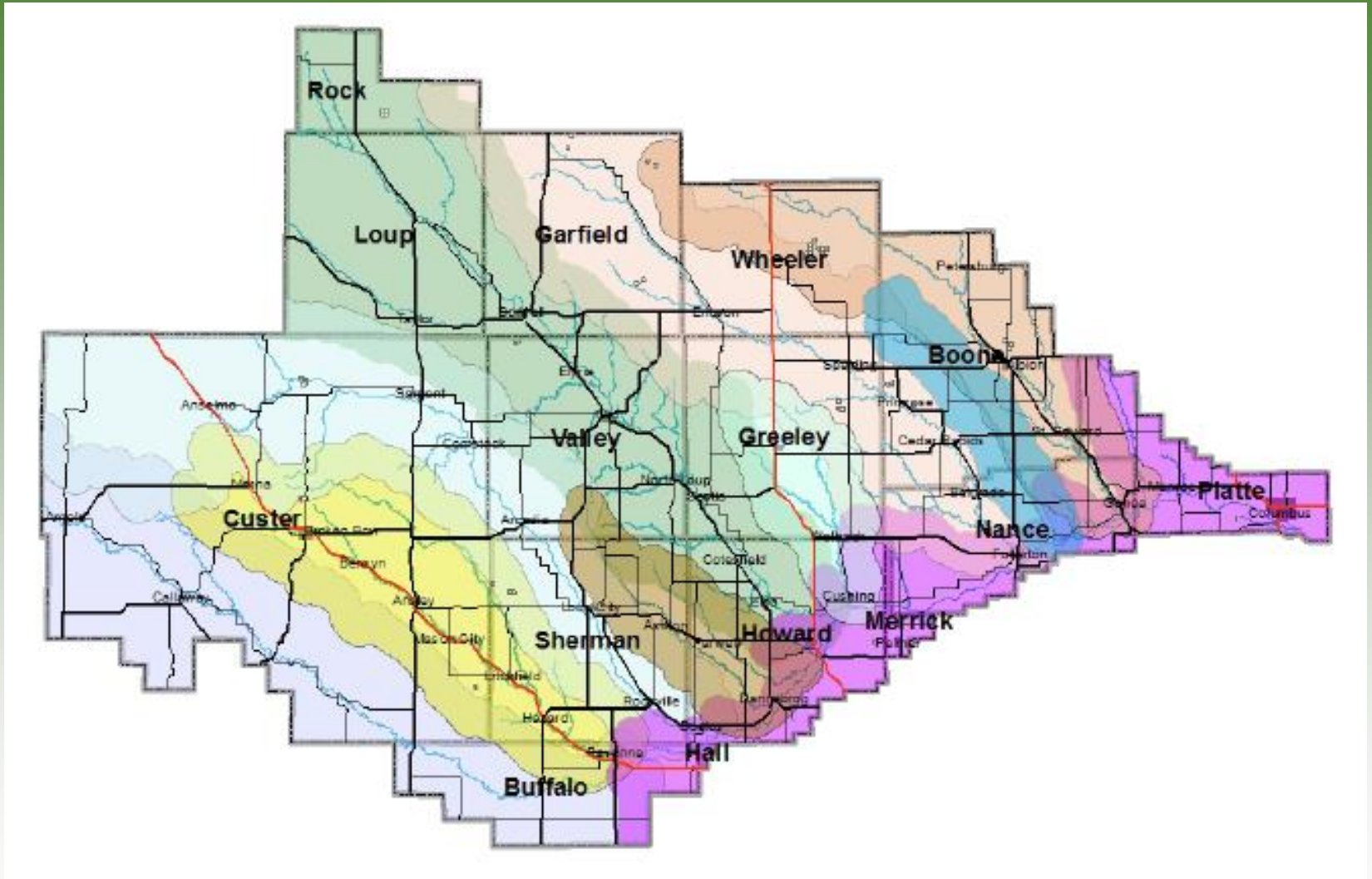
Each section is assigned an SDF as a percent (%) depletion. Results from the COHYST study were also included in the final number.



# (1) Irrigated Acre Transfer

- LLNRD acknowledges the need for changes in farming operations
- New use (depletion) should not impact different watershed nor cause increase depletion to a stream
- Downstream transfers only

# Watershed-USGS Hydrologic Units




- USGS HUC's plus 2 mile buffer
- Overlap can transfer to either basin

USGS

# Transfer Rules Continued

- Transfers shall be based on stream-depletion factors (with no net increase in irrigated acres):
  - Transfers to a lower stream-depletion factor result in 1:1 acre exchange and addition to bank
  - Transfers to a higher stream-depletion factor result in decreased acres transferred. Example:
    - 55 Acres requested @ 90% SDF
    - Requires 100 Acres transferred from 50% SDF
    - This offsets the increased impact to stream

USGS

# Total Transfers Processed

| YEAR | TRANSFERS Processed (#) | ACRES TRANSFERRED TO | ACRES TRANSFERRED FROM (removed) |
|---|---|---|---|
| 2010 | 30 | 1,790 | 1,920 |
| 2011 | 77 | 4,990 | 5,180 |
| 2012 | 174 | 9,640 | 9,600 |
| 2013 | 225 | 7,530 | 7,860 |
| To Date 2014 | 14 | 630 | 640 |
| **TOTALS** | **520** | **24,580** | **25,200** |

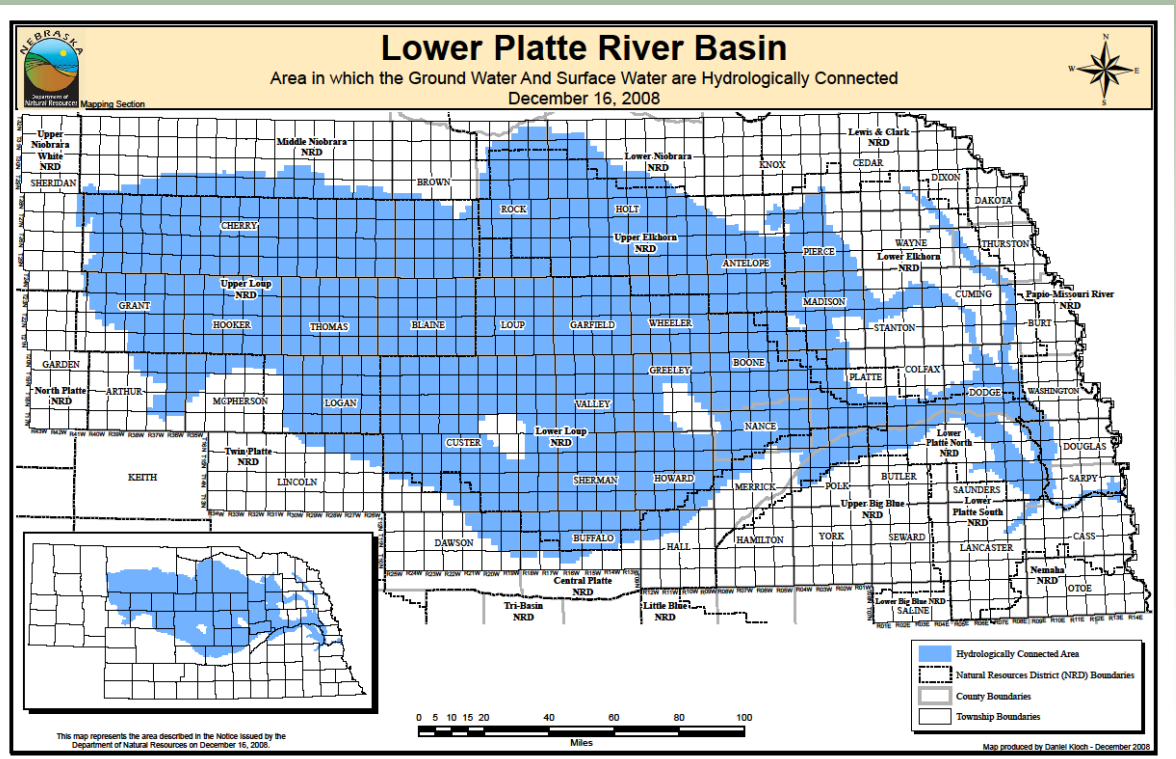
USGS

# (2) Irrigated Acre Banking Program

- Acres that are removed from the initial certification and are not re-used as offset are declared “Banked” by the NRD
- SDF provides a weighted value for these acres should they be applied elsewhere
- Transfers to a lower stream depletion factor result in 1:1 acre exchange and addition to bank

# (3) New Acre Allocation

- Nebraska LB483 allowed an additional 10,000 irrigated acres over 4 years per NRD
- Encompasses Areas that were erroneously declared “Fully Appropriated” by Nebraska State Department of Natural Resources
- Most of ELM Area
  - Phase I



# Lower Loup Natural Resources District

## Ranking Sheet APP

| APPLICATION NUMBER | LEGAL (SEC,TNSP,RNG,(W/E) | | NUMBER |
|---|---|---|---|
| | | | |
| **Description** | **Criteria** | **Rating** | **Rank #** |
| This area would be set by information presented to the water committee to outline areas | | | |
| of the district that show rises or declines in groundwater or surface water. | | | |
| Groundwater / Surface water status | GW/SW Increase Area | 50 | |
| | Not Specified | 20 | |
| | GW/SW Decrease Area | 0 | 20 |
| This section would represent the amount of irrigated acre concentration. | | | |
| Irrigated acre concentration | 5 thru 50 | | |
| | Based on 10 classes | | |
| Based on the ELM % depletion to stream map. | | | |
| Include Platte River depletions | | | |
| 100 - (% Depletion)= | | | |
| Based on highest percent in field | | | |
| This would look at the number of acres being developed. | | | |
| The application would get the points assigned to each catagory that is met. | | | |
| Number of acres being developed | Addition Field<10 Acres | 70 | |
| | Addition Field 10-25 Acres | 50 | |
| | Addition Field 25-150 Acres | 20 | |
| | Addition Field >150 Acres | 0 | |
| Based on soil classification in the USDA soills book and how it would rank according to the | | | |
| classification | | | |
| Soil classification | Factors | | |
| Based on percent of irrigated soil class | Class 1 =32 | | |
| Within the delineated field boundary | Class 2 = 18 | | |
| Multiplied by the soil class factor | Class 3 = 8 | | |
| Then multiplied by 10 | Class 4 = 2 | | |
| | all other classes = 0 | | |
| | Factor x % per class x 10 | | |
| | TOTAL RANKING | | |
| | TOTAL ACRES | | |

2011-1

## ICATION FOR NEW IRRIGATED ACRES

Loup
ces District

2620 Airport Drive, P.O. Box 210
Ord, Nebraska 68862
Phone (308) 728-3221 FAX (308) 728-5669
www.llnrd.org

Application period is September 1-20, 2012 only.
ist be postmarked or received in the NRD office in Ord by 5 pm, September 20, 2012.

_____ Phone:_____

_____

_____Phone:_____

_____

ld:

ection(s)_____, Township_____North, Range_____East/West, _____County

d Acres Being Reqested

)00

f Wells Serving This Field (list below - if none, leave blank):

_____

ield Delineated: Yes_____ No_____

_____

_____

lso attests that all their irrigated acres are certified with the Lower Loup NRD.

_____Date_____

_____Date_____

_____ Required Documentation

FSA Aerial Photo with Field Delineated____

# (4) Constituents, Committees & Conclusion

- 
- 
- 


***The presentation with audio is posted at:***
***http://water.usgs.gov/coop/***

**Speakers and Contacts for More Information:**


- Paul Barlow, Hydrologist, USGS, Office of Groundwater, Northborough, MA (508) 490-5070
- Stanley Leake, Research Hydrologist, USGS, Arizona Water Science Center, Tucson, AZ (520) 670-6671 x259
- Steven Peterson, Lead Hydrologist, USGS Nebraska Water Science Center, Lincoln, NE (402) 328-4151
- Jennifer Stanton, Hydrologist, USGS Nebraska Water Science Center, Lincoln, NE (402) 261-0458
- Tylr Naprstek, Water Modeling Coordinator, Lower Loup Natural Resources District, Ord, Nebraska (308) 728-3221


USGS