Aquifer Basics and Appropriation Decision-making

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Thresholds for Negative Impacts to Surface Waters
October 21, 2015

What's involved in a groundwater review?

- ❑ Develop a conceptual model of the aquifer system.
- ❑ Quantify potential impacts

- ❑ Determine need for further investigation including aquifer tests and monitoring.
- ❑ Provide a report with results, conclusions, and technical recommendations.

Conceptual Model of the Aquifer System

What was the origin of the aquifers?:

- From glaciers (sand & clay till sediment)
- Ancient seas (sandstone & limestone bedrock)
- Volcanos or cooling of deep magma (igneous & metamorphic bedrock)

Glacial Lobes with Glacial Lakes (From 2.5 million to 12,000 years before present)

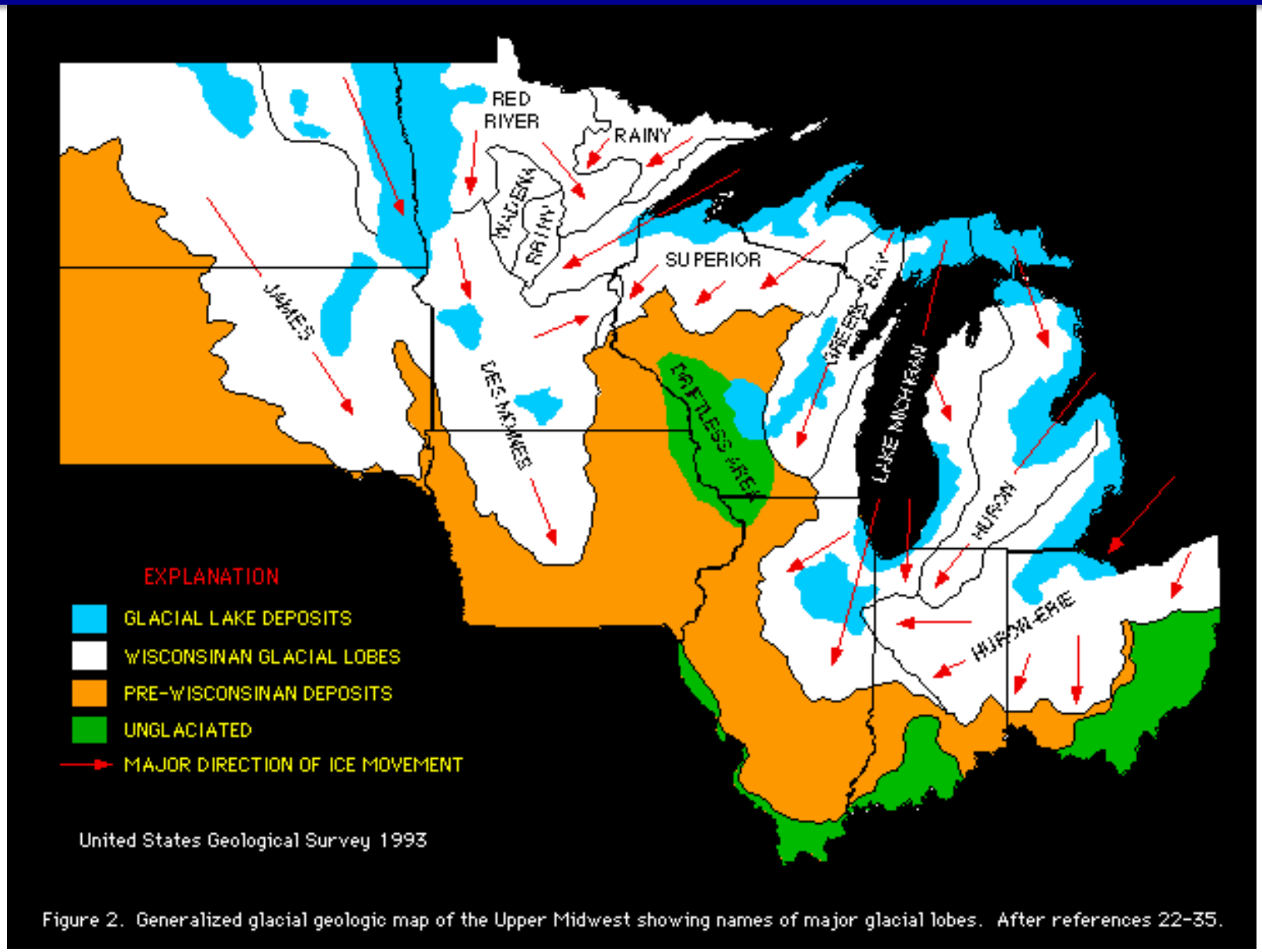
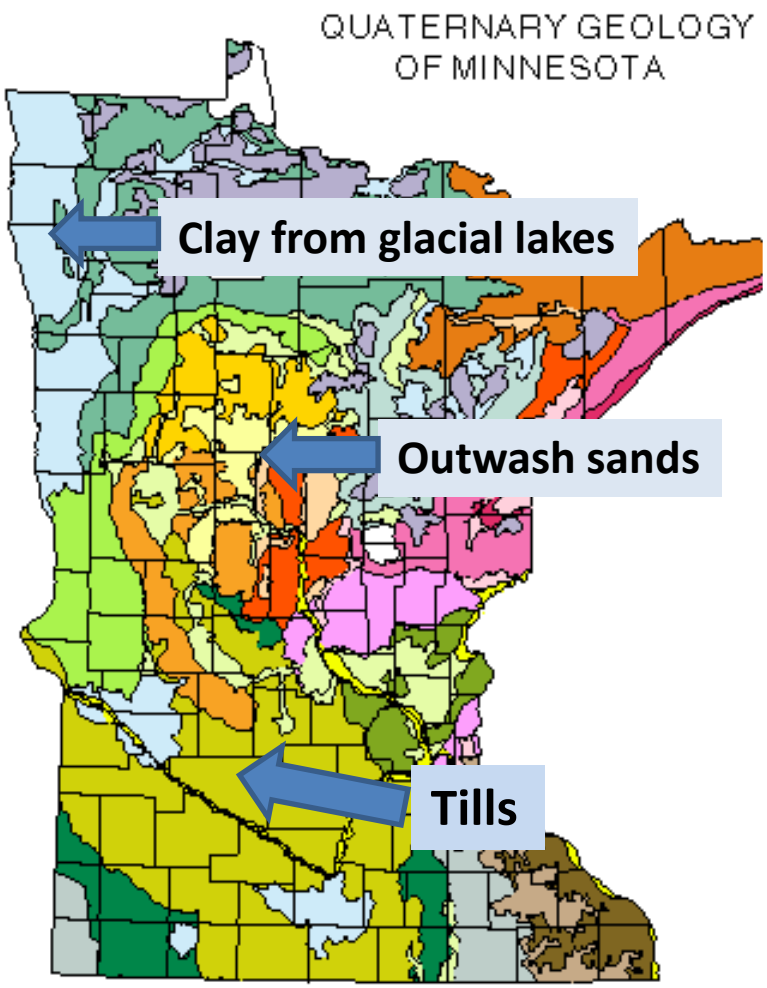


Figure 2. Generalized glacial geologic map of the Upper Midwest showing names of major glacial lobes. After references 22-35.

Quaternary (glacial) Geology (12,000+ years before present)



- Tills (unsorted sand, silt, and clay
- Clay (from glacial lakes)
- Sands (from glacial outwash)

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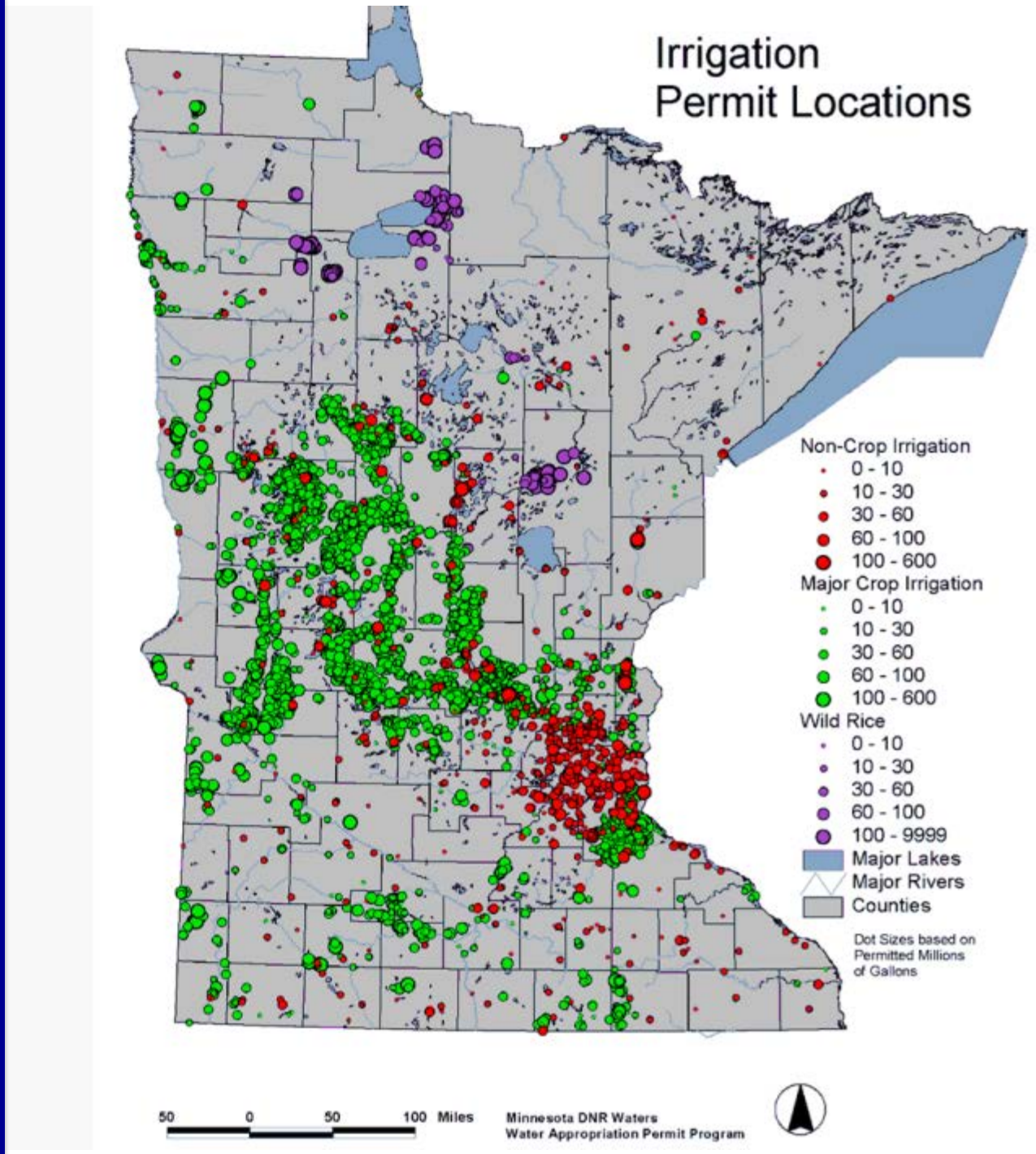
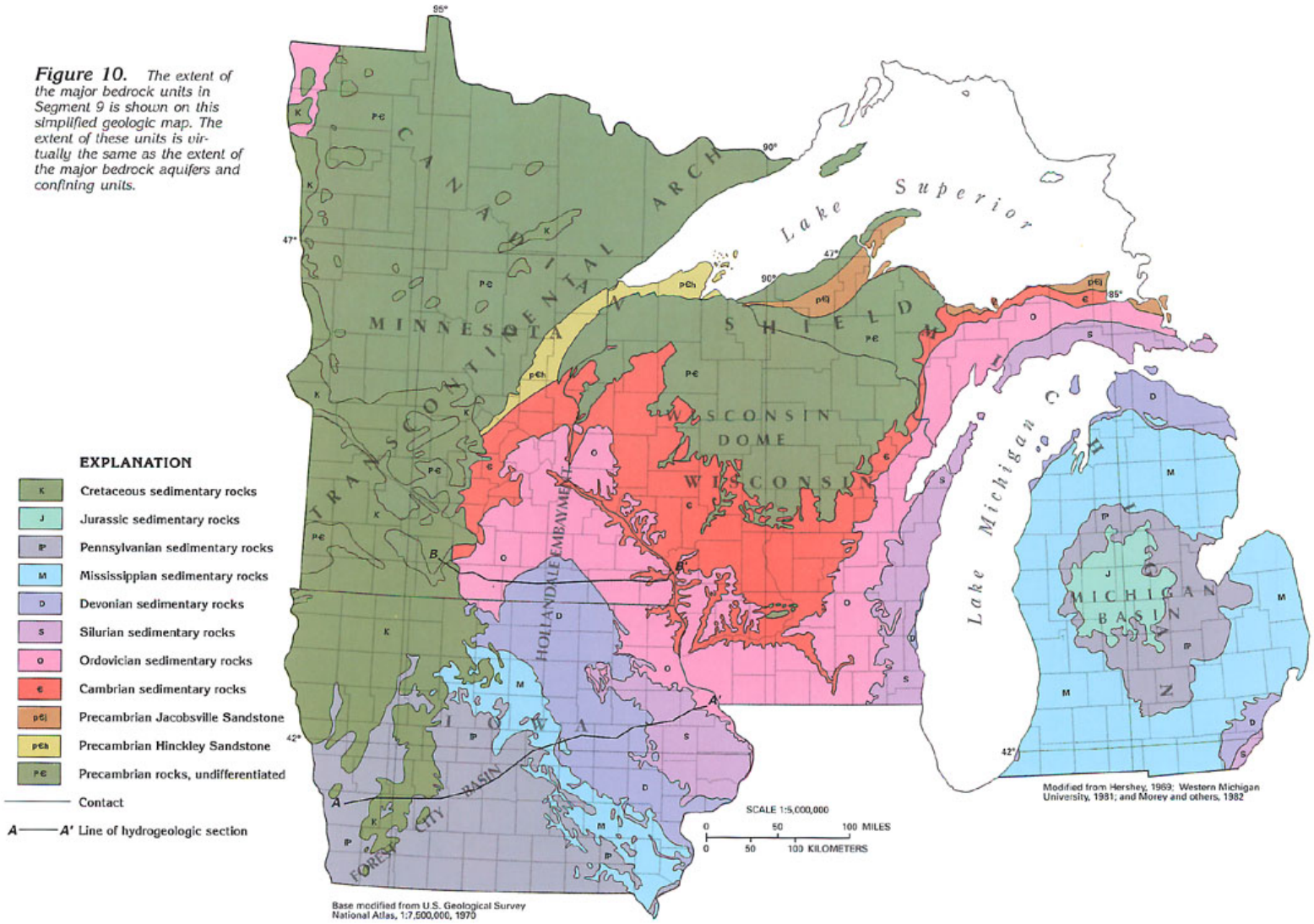
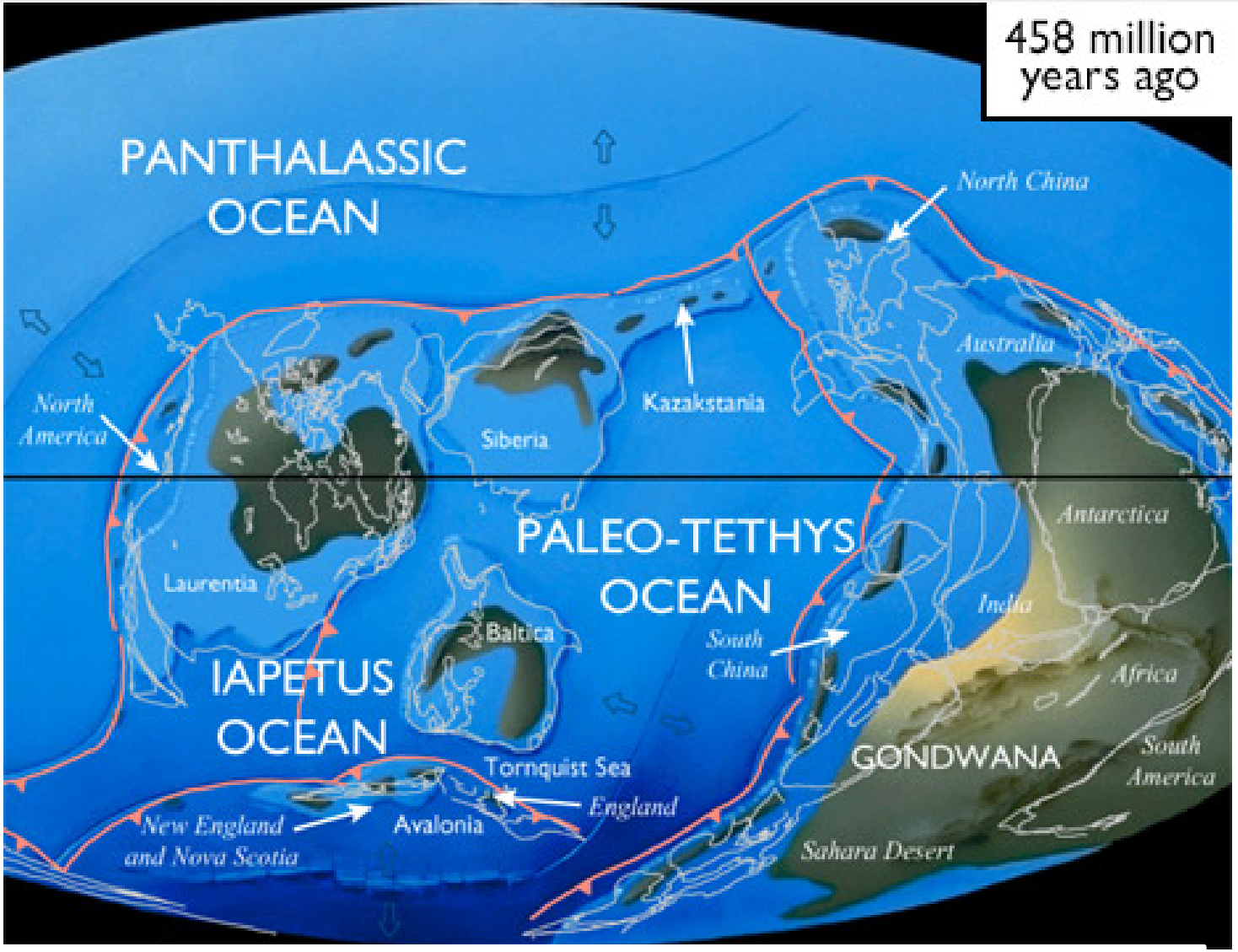
Irrigation Permits



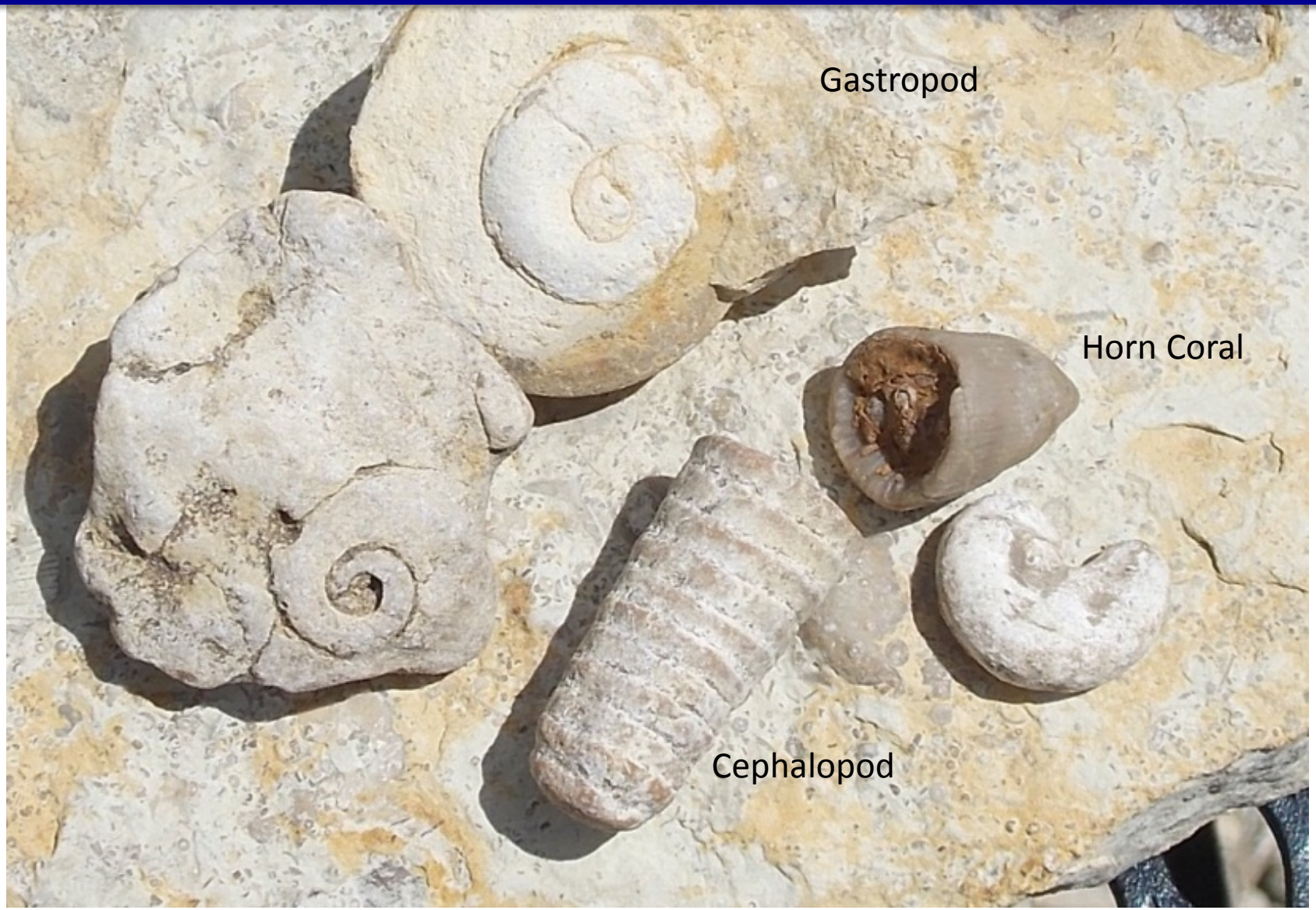
Sedimentary Bedrock Aquifers (650 to 400 million years before present)



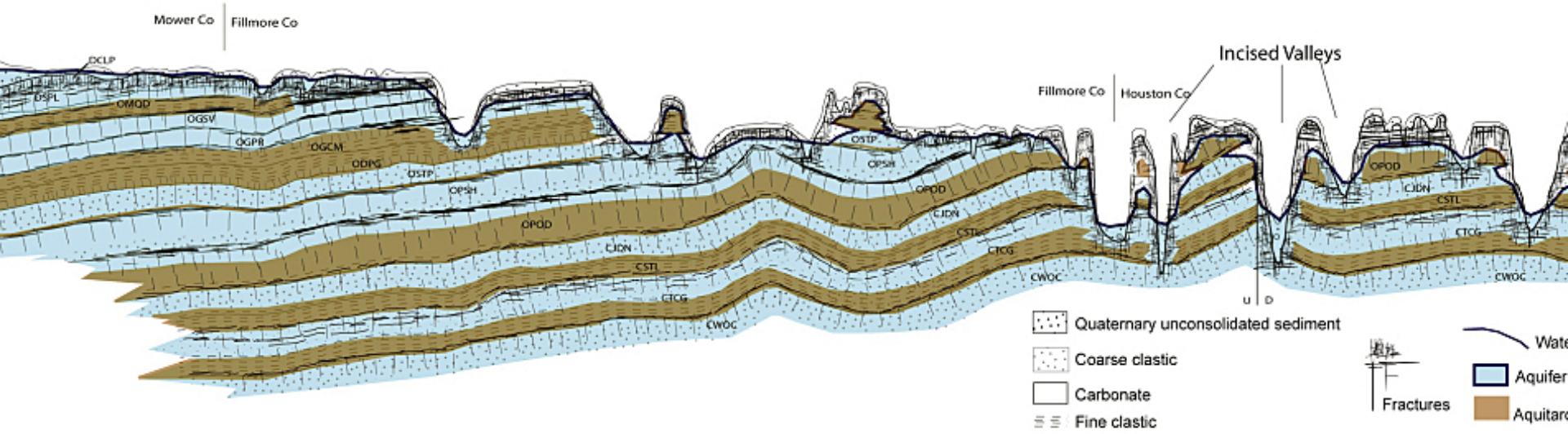
Ancient Sea covering Minnesota



Evidence of ancient sea in Minnesota – Sea Fossils



Sedimentary Aquifers in Southeast Minnesota



Layers of Limestone Aquifers, Sandstone Aquifers, and Shale Confining Units

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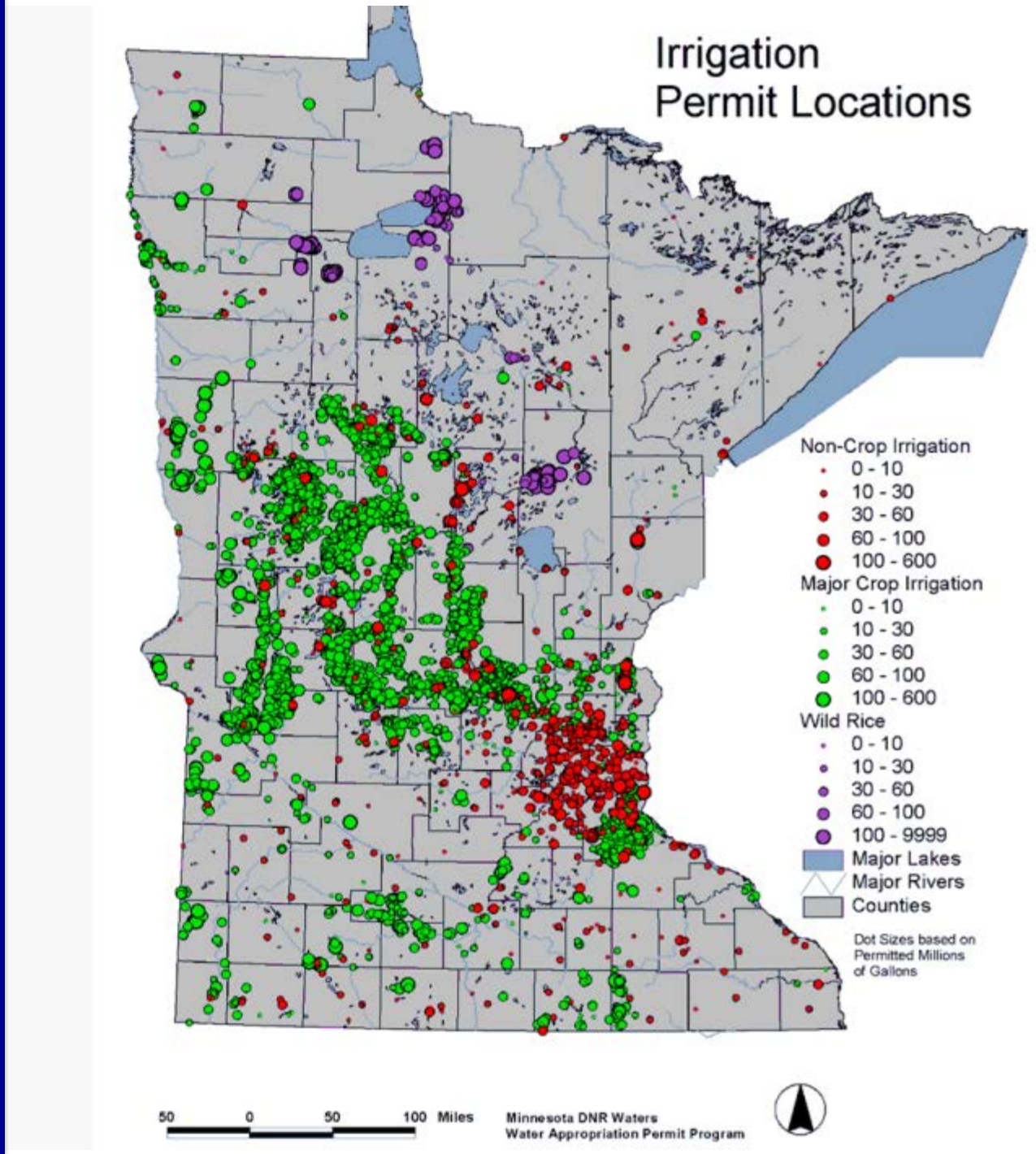
Irrigation Permits



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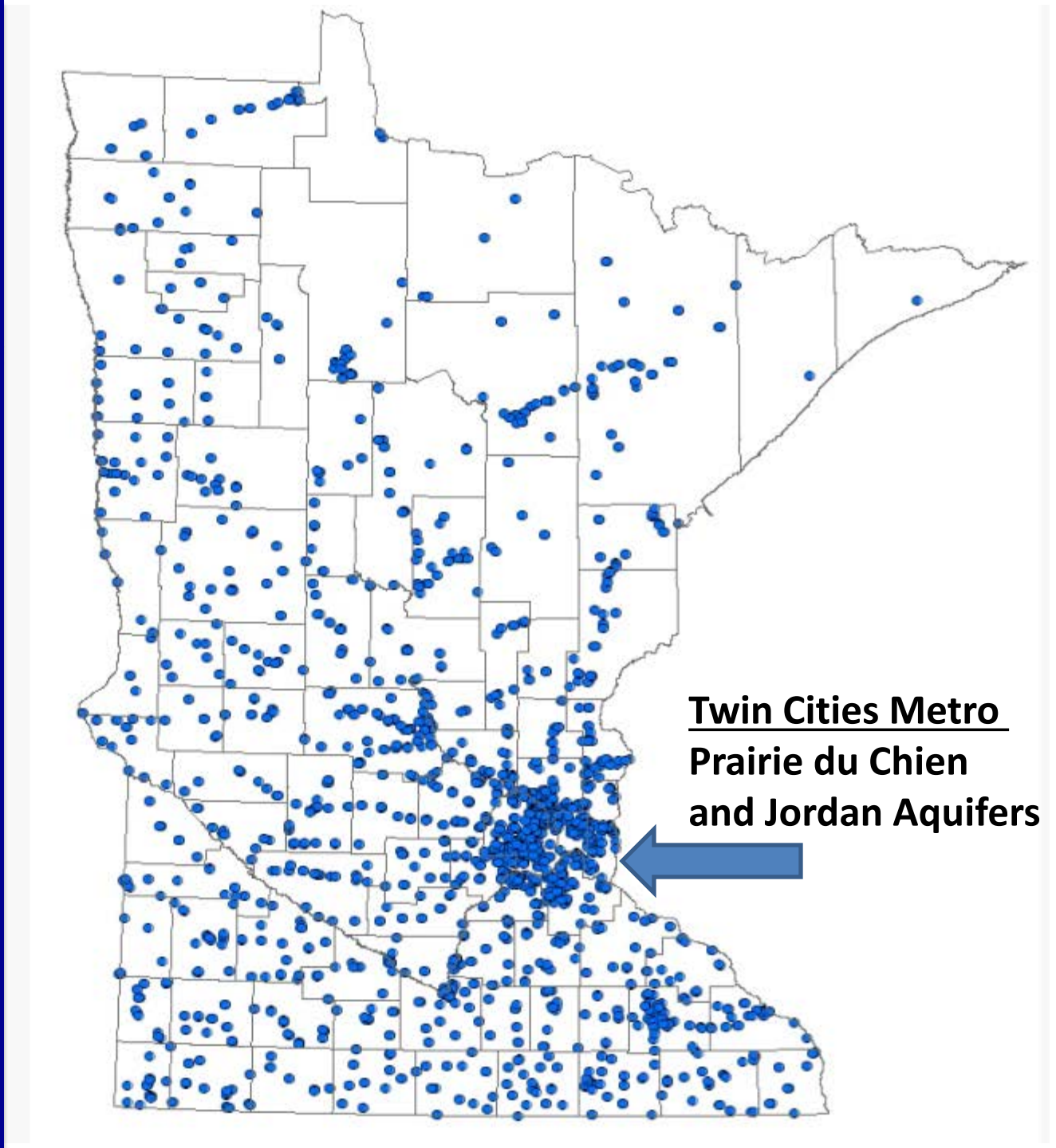
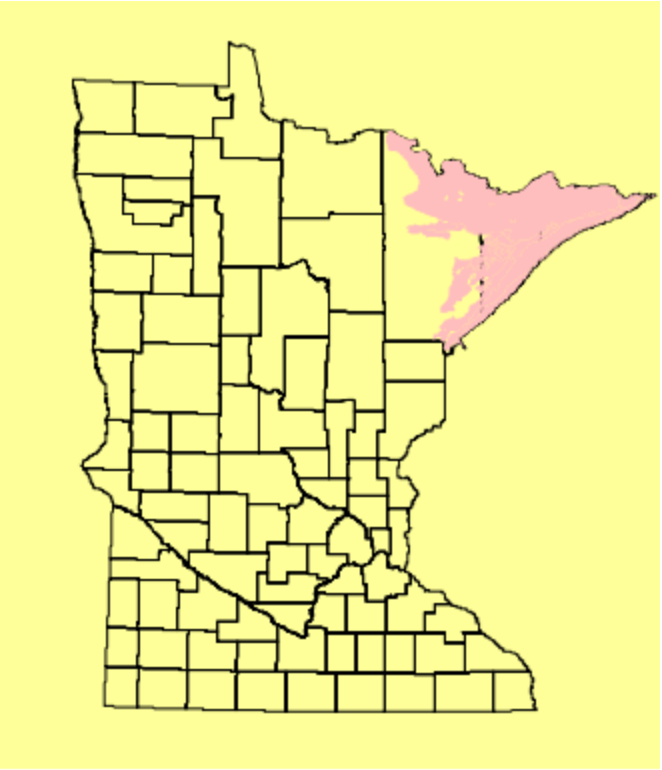
Community Water Supply Wells



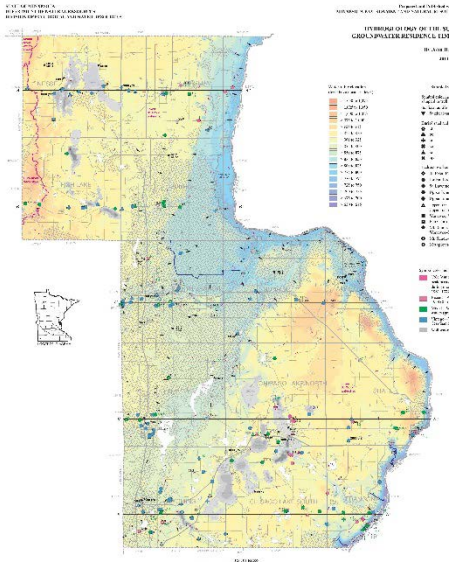
Igneous and Metamorphic Rocks

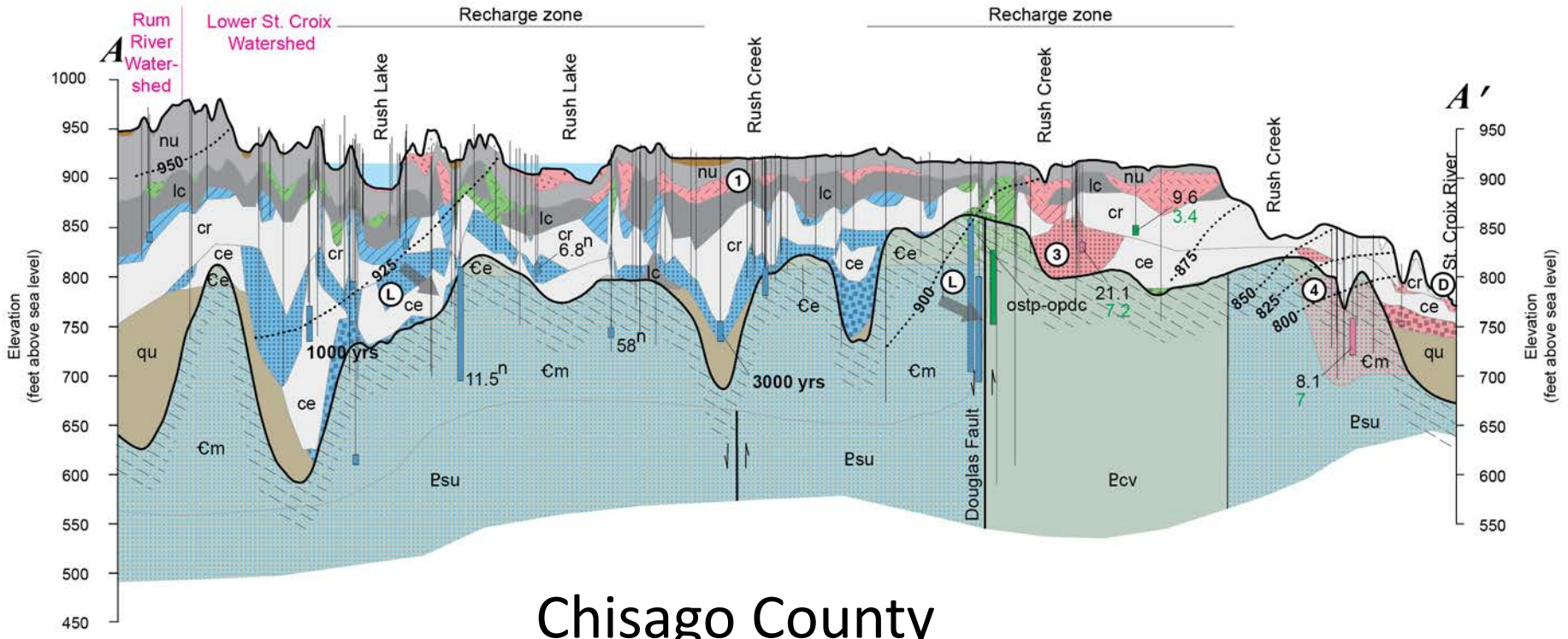
- Used as aquifers where sedimentary and glacial aquifers are absent (NE Minn)
- Limited water availability
- Underlies entire state



Groundwater moves in the rock fractures

County Geologic Atlas Program





Chisago County

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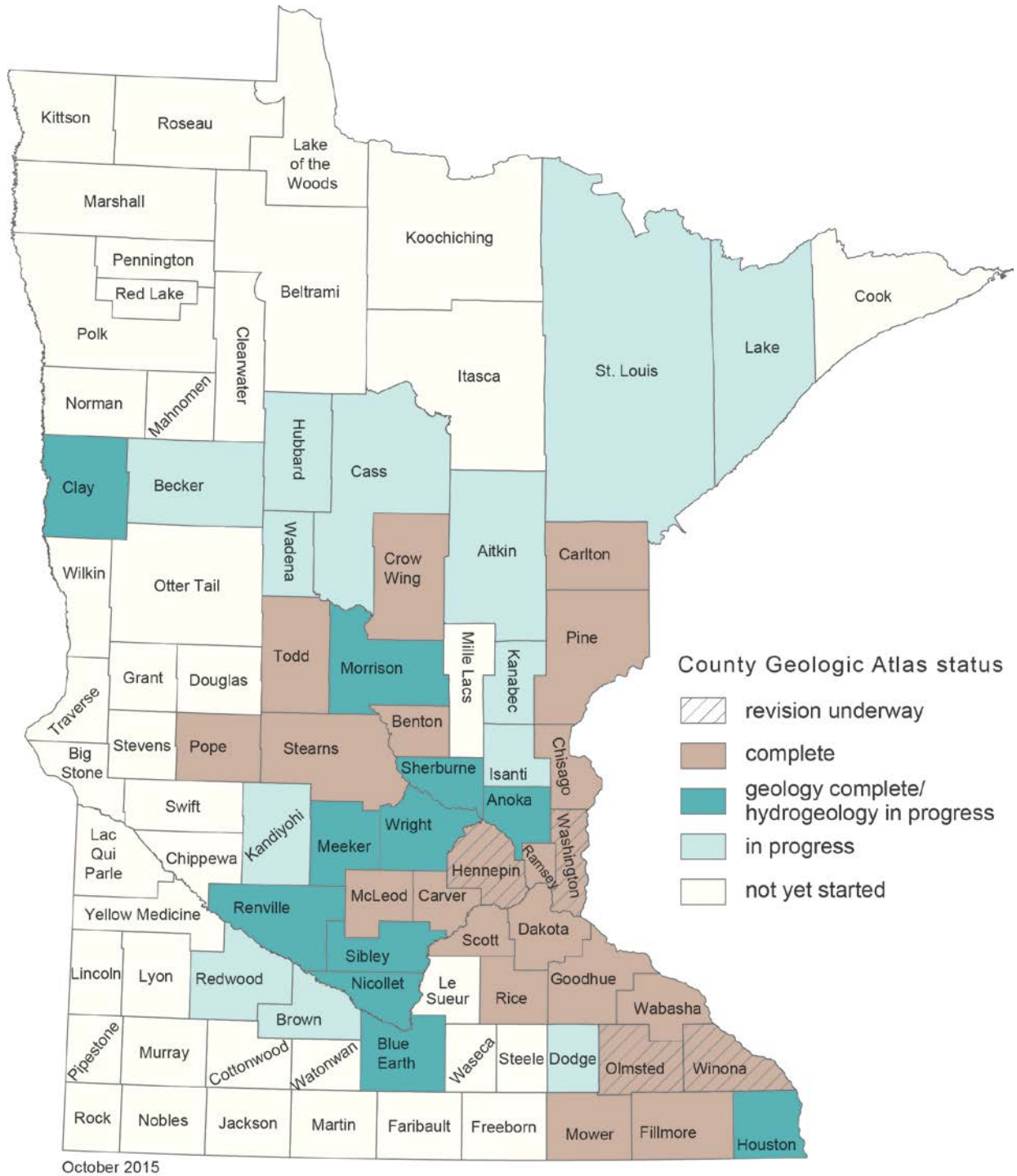
County Geologic Atlas Program

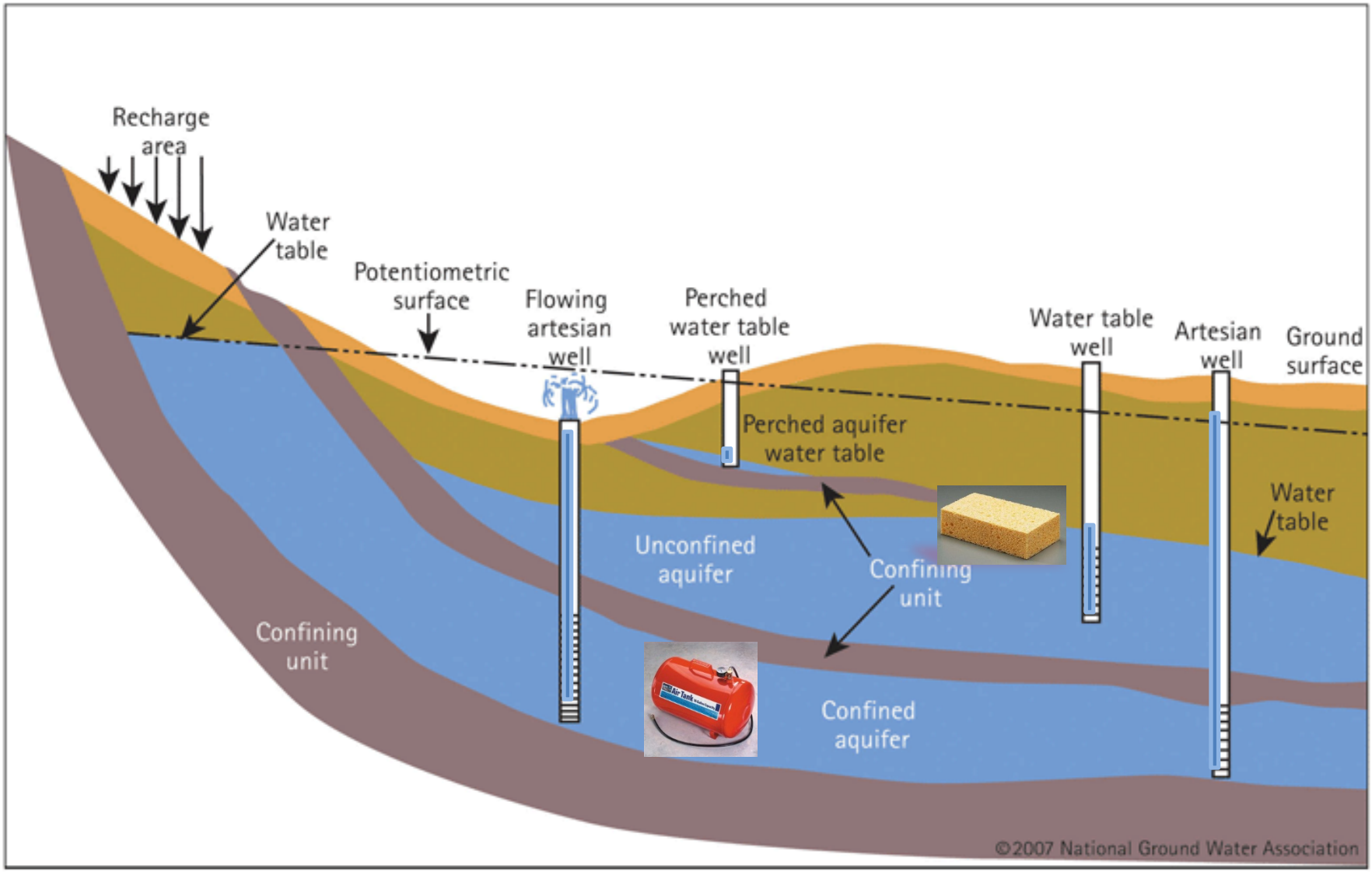


“Limiting” factors for sustainable groundwater pumping

- **Impacts to streams, lakes, wetlands (unconfined or water table aquifers)**

- **Safe yield for confined (buried) aquifers**

Confined and Unconfined Aquifers



“Limiting” factors for sustainable groundwater pumping

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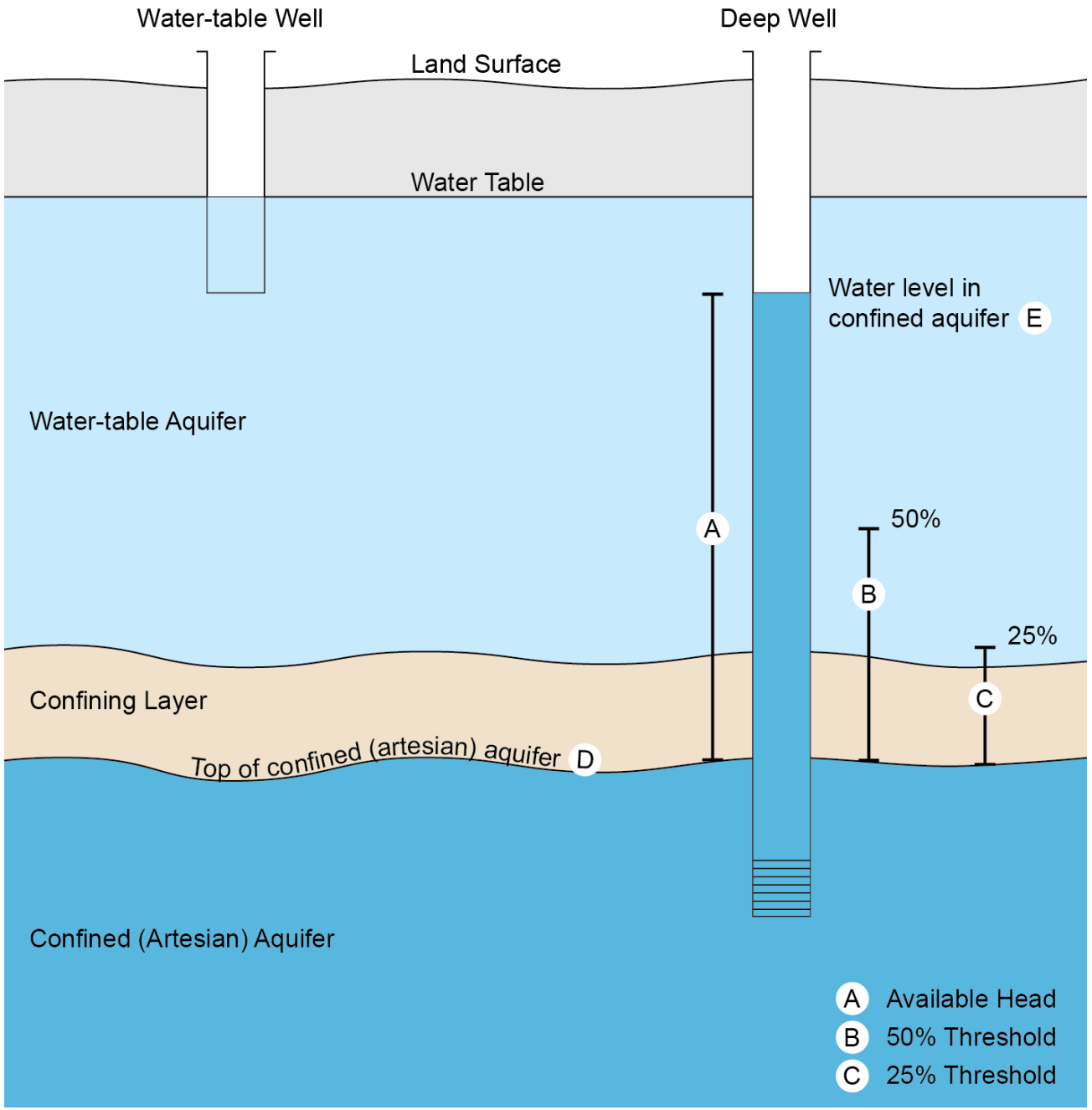
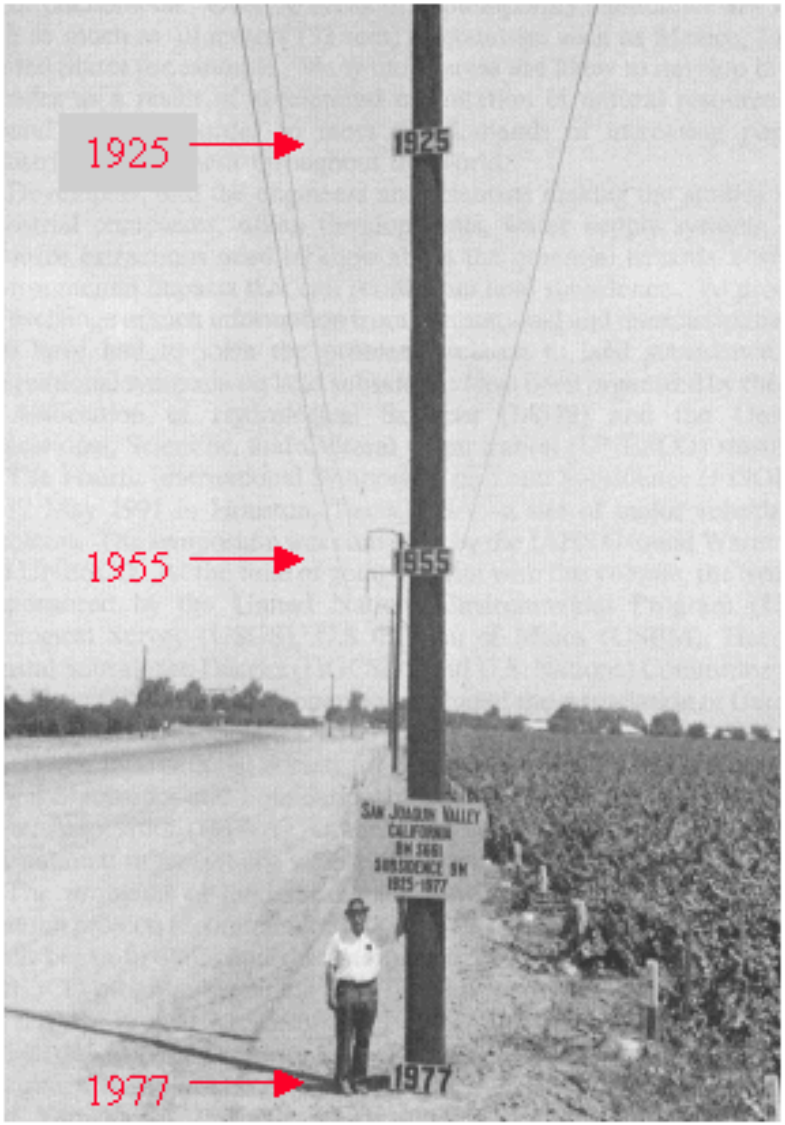
Safe Yield – Confined Aquifer



Subsidence due to GW pumping

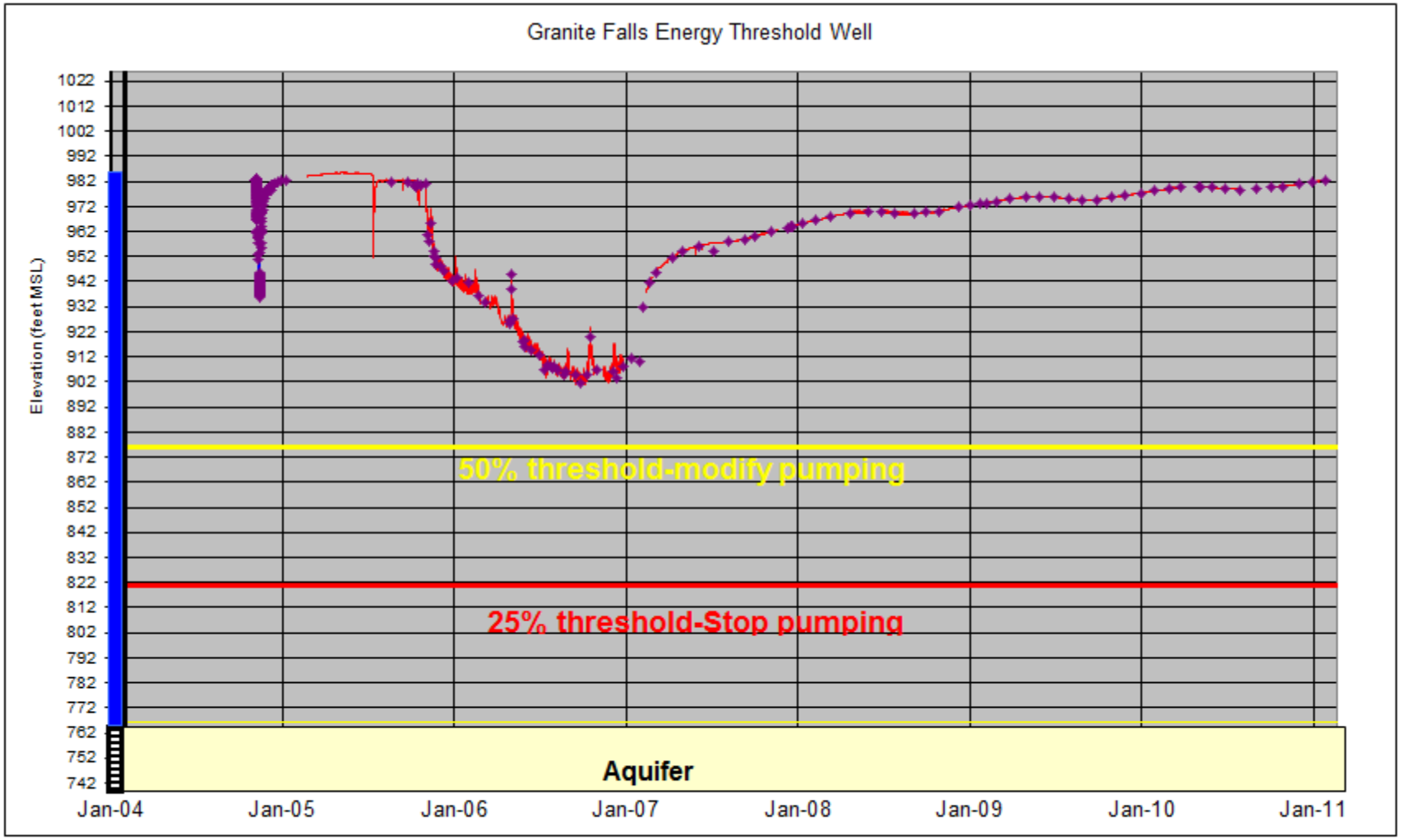


29 feet of subsidence

San Joaquin Valley, Cal.
Between 1925-1977

Dr Joseph F. Poland (Sacramento, CA) retired USGS Senior scientist for land subsidence research, stands at a site near benchmark S661 in the San Joaquin Valley SW of Mendota, CA. The benchmark subsided 8.93m between 1925 and 1977 as a result of heavy pumping of ground water.
Photograph by Richard L. Ireland, USGS.

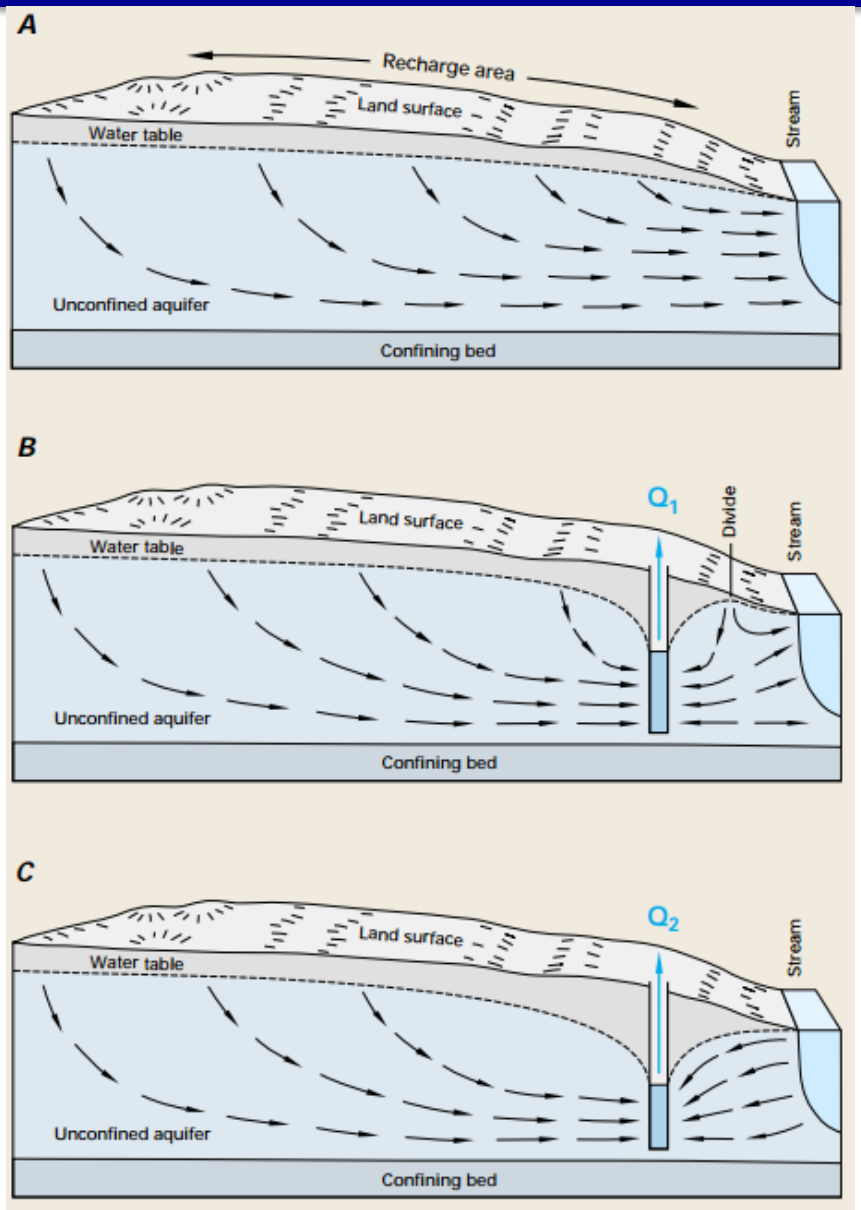
Aquifer Test – Confined Aquifer



“Limiting” factors for sustainable groundwater pumping

- **Safe yield for confined aquifers**
- **Impacts to streams, lakes, wetlands (water table or unconfined aquifers)**

How GW pumping affects streams

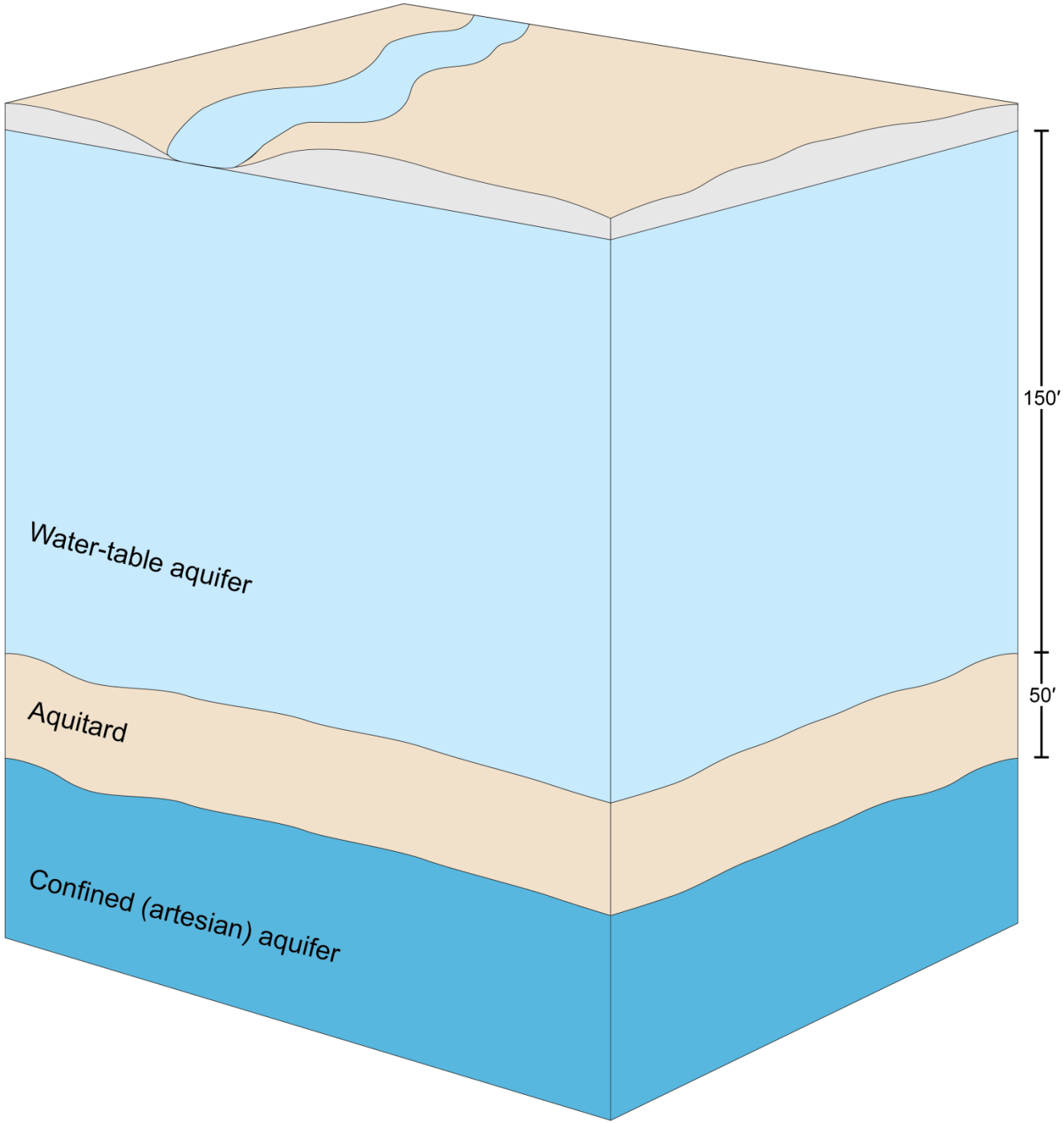


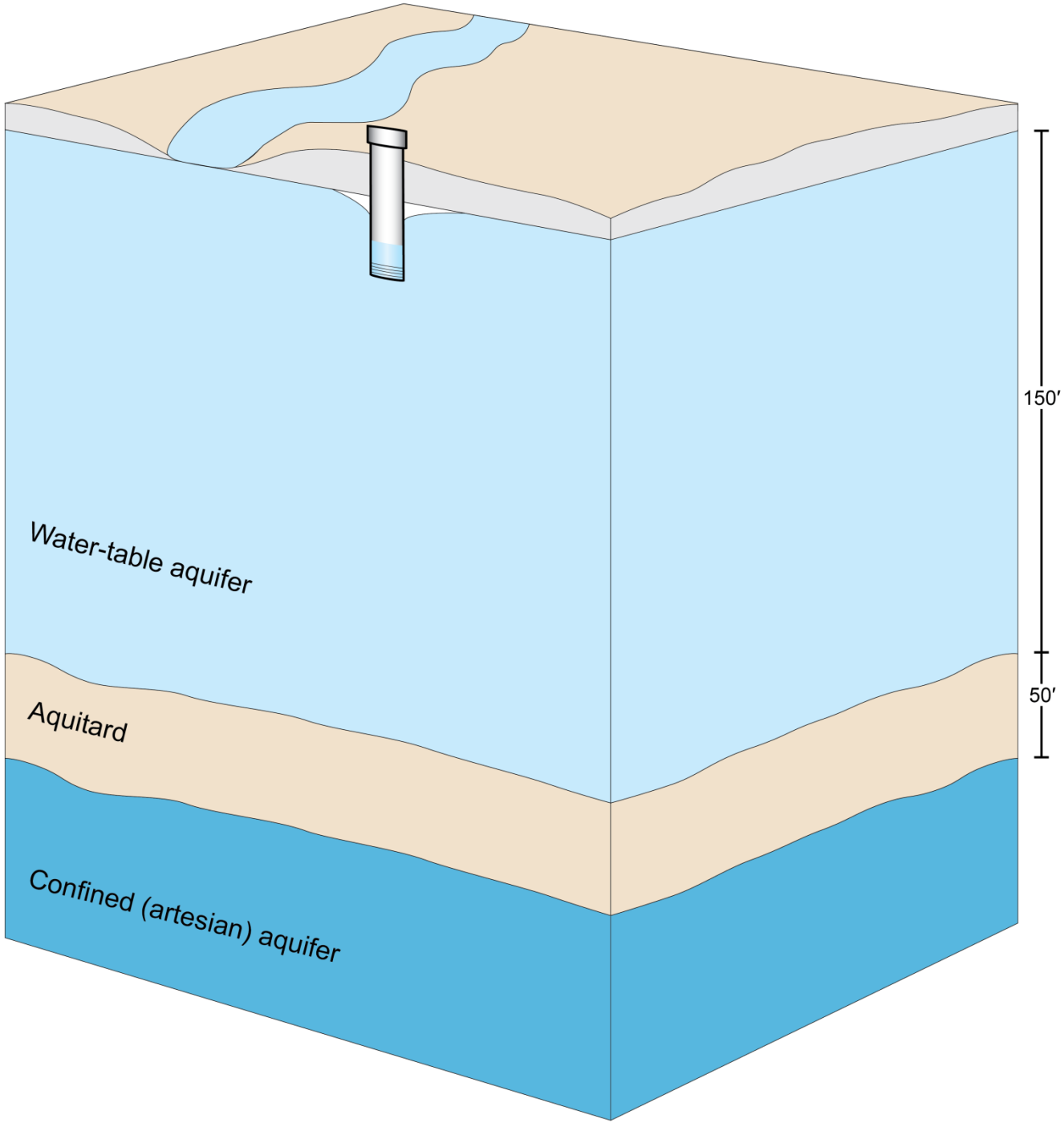
A. Natural groundwater flow replenishes stream flow

B. Pumping of groundwater diverts some, but not all groundwater from reaching the stream

C. Pumping diverts all groundwater which would have entered stream. Greatest impact during drought conditions.

USGS Circular 1139, Thomas Winter, et. al., 1998


Water-table aquifer
Aquitard
Confined (artesian) aquifer
150′
50′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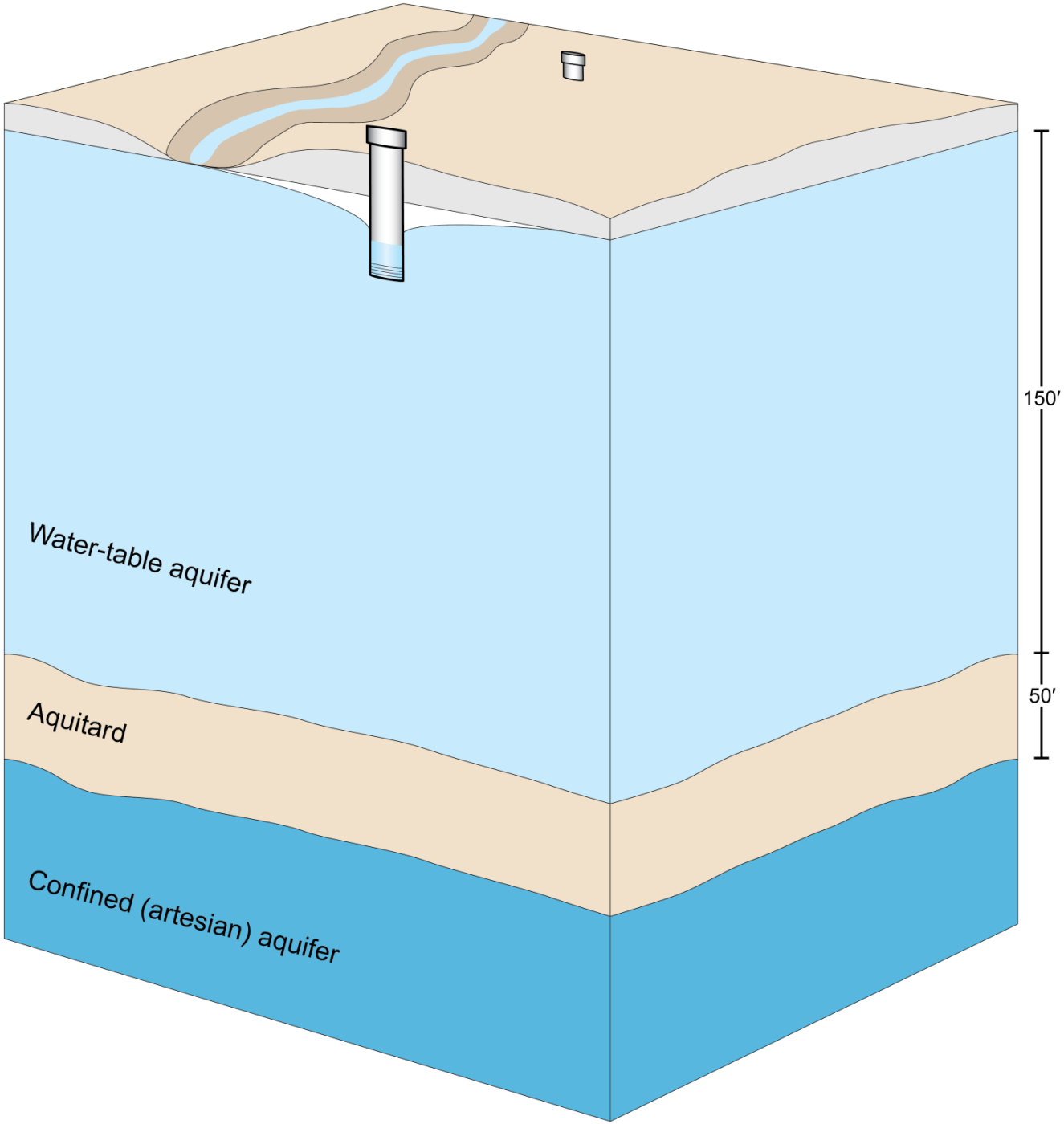
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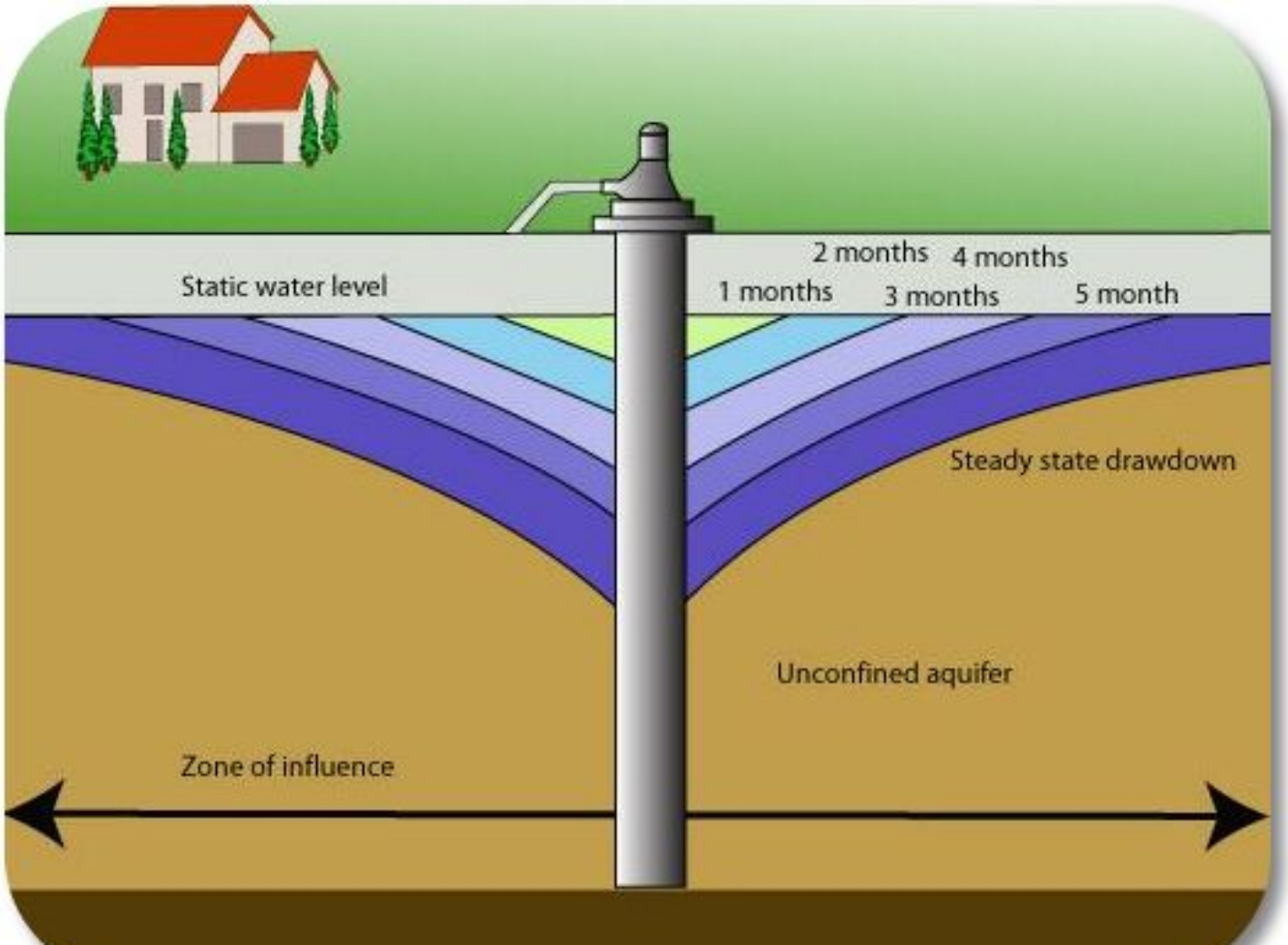
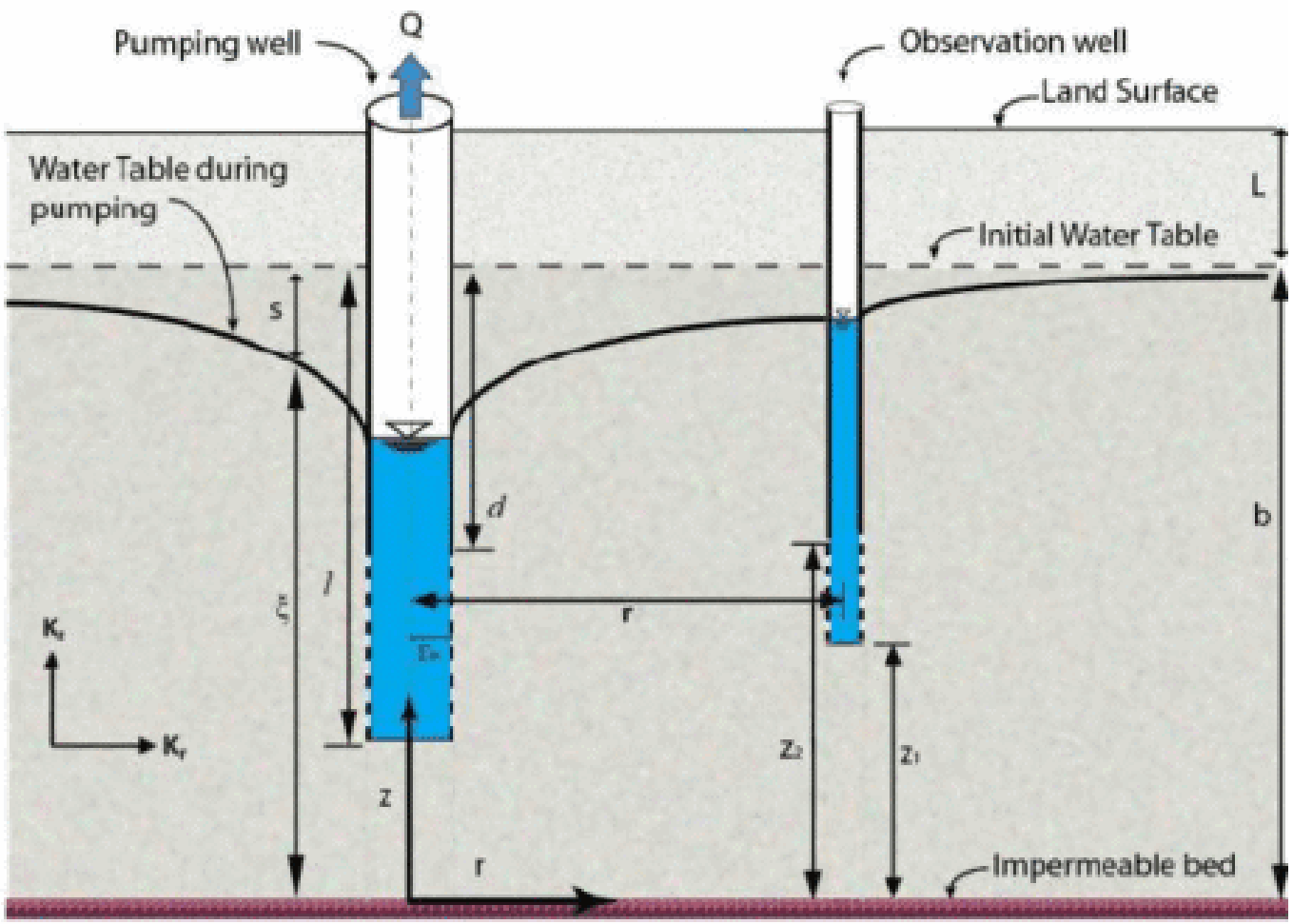
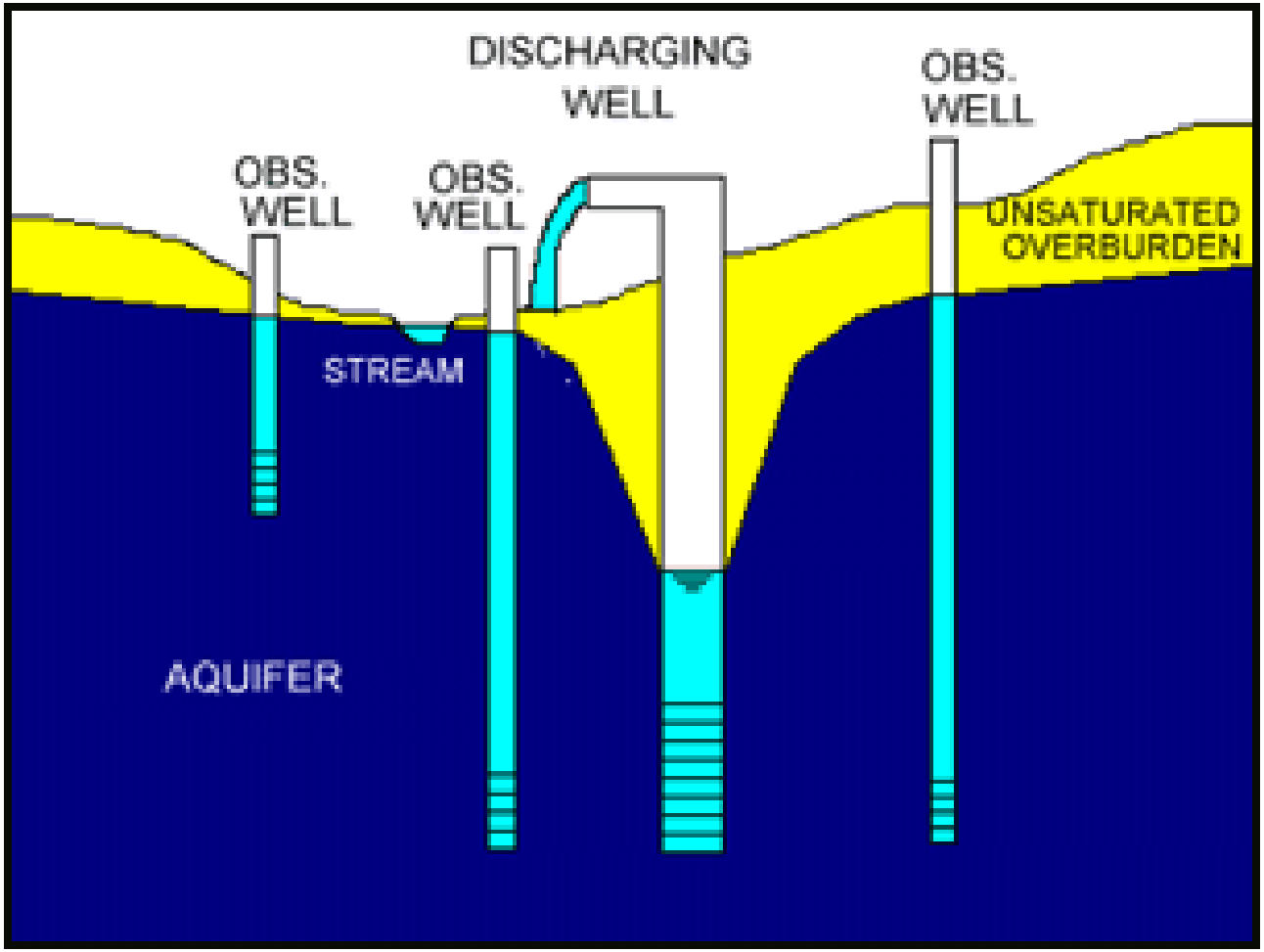
Cone of Depression caused by Groundwater Pumping



Aquifer Test in Water Table Aquifer



Aquifer Test in Water Table Aquifer With nearby stream



Pumping from Water Table Aquifer

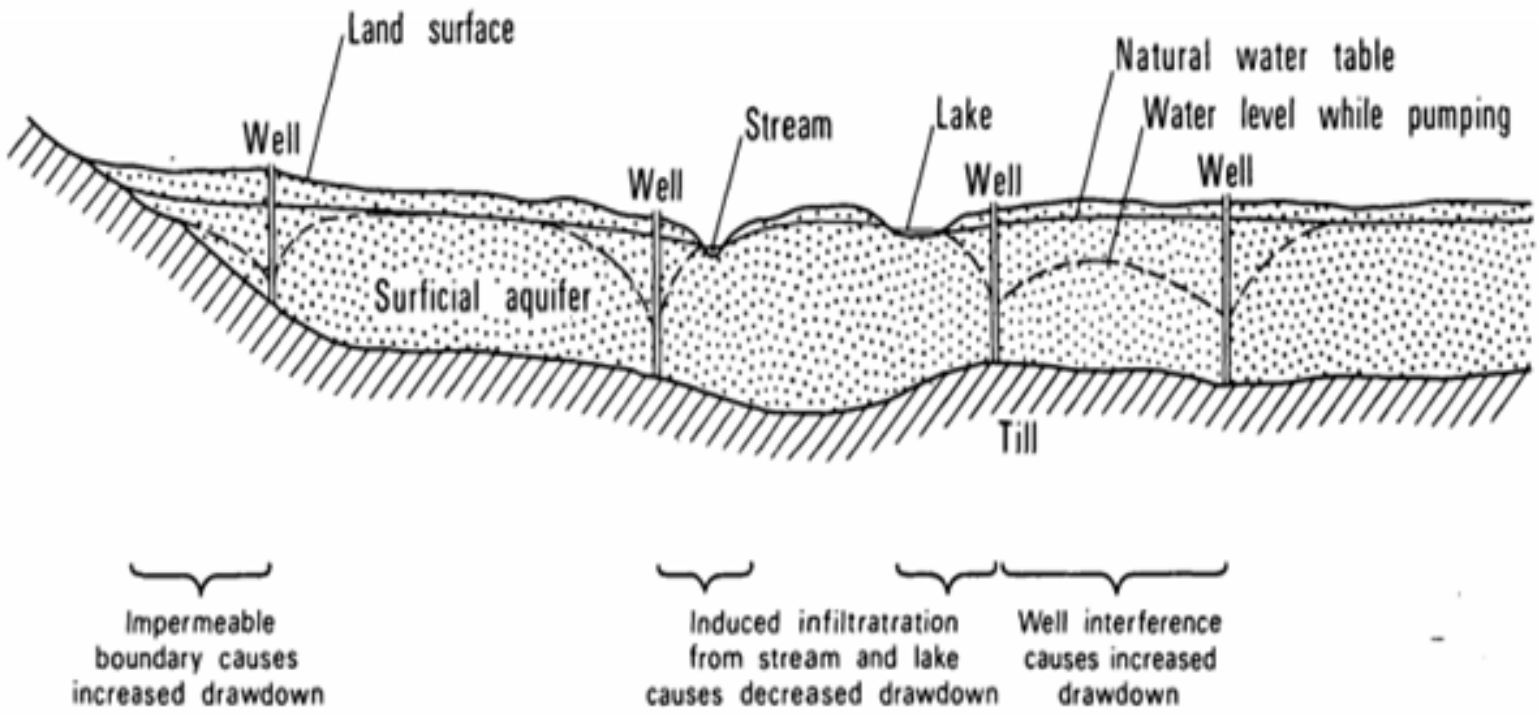
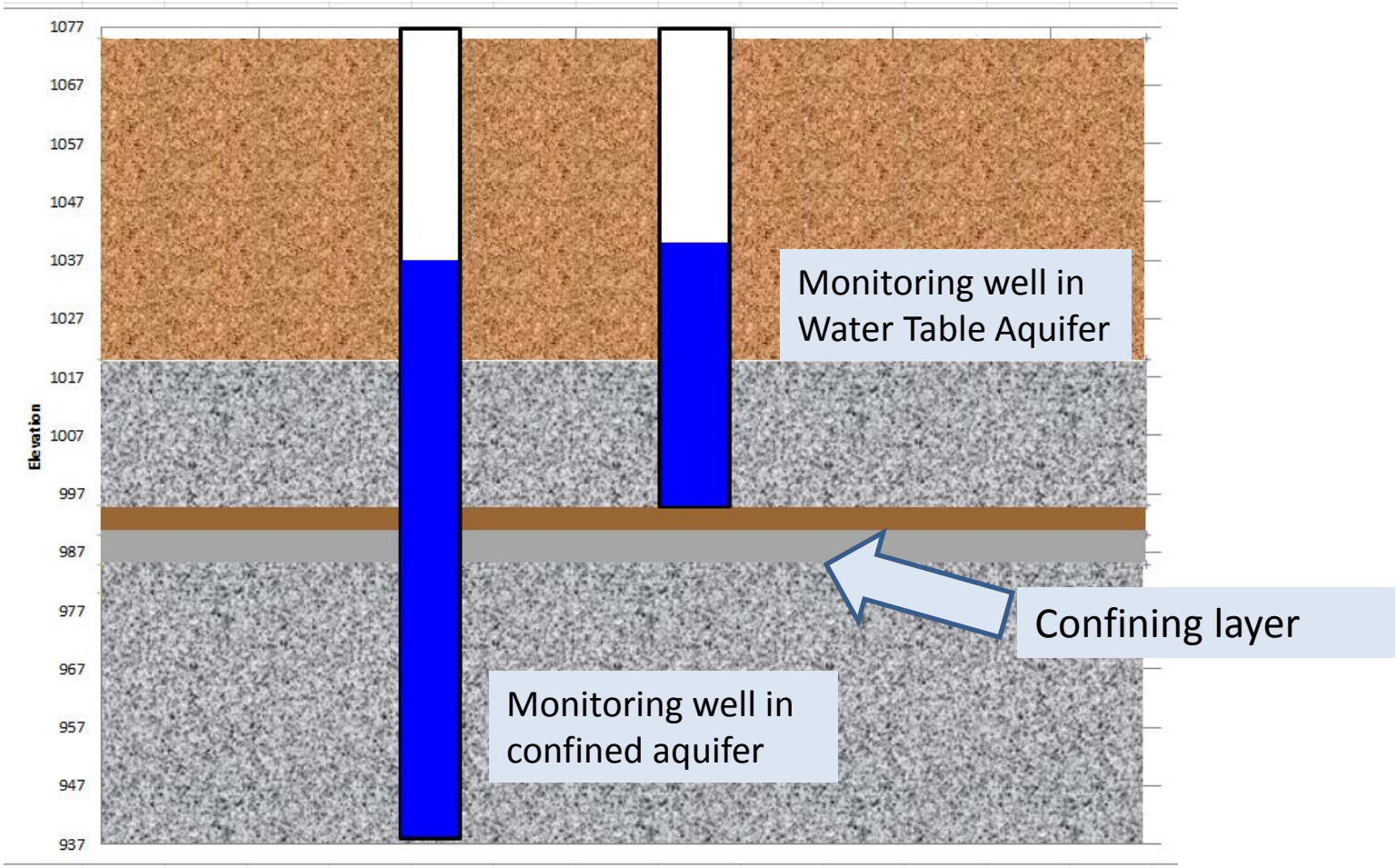
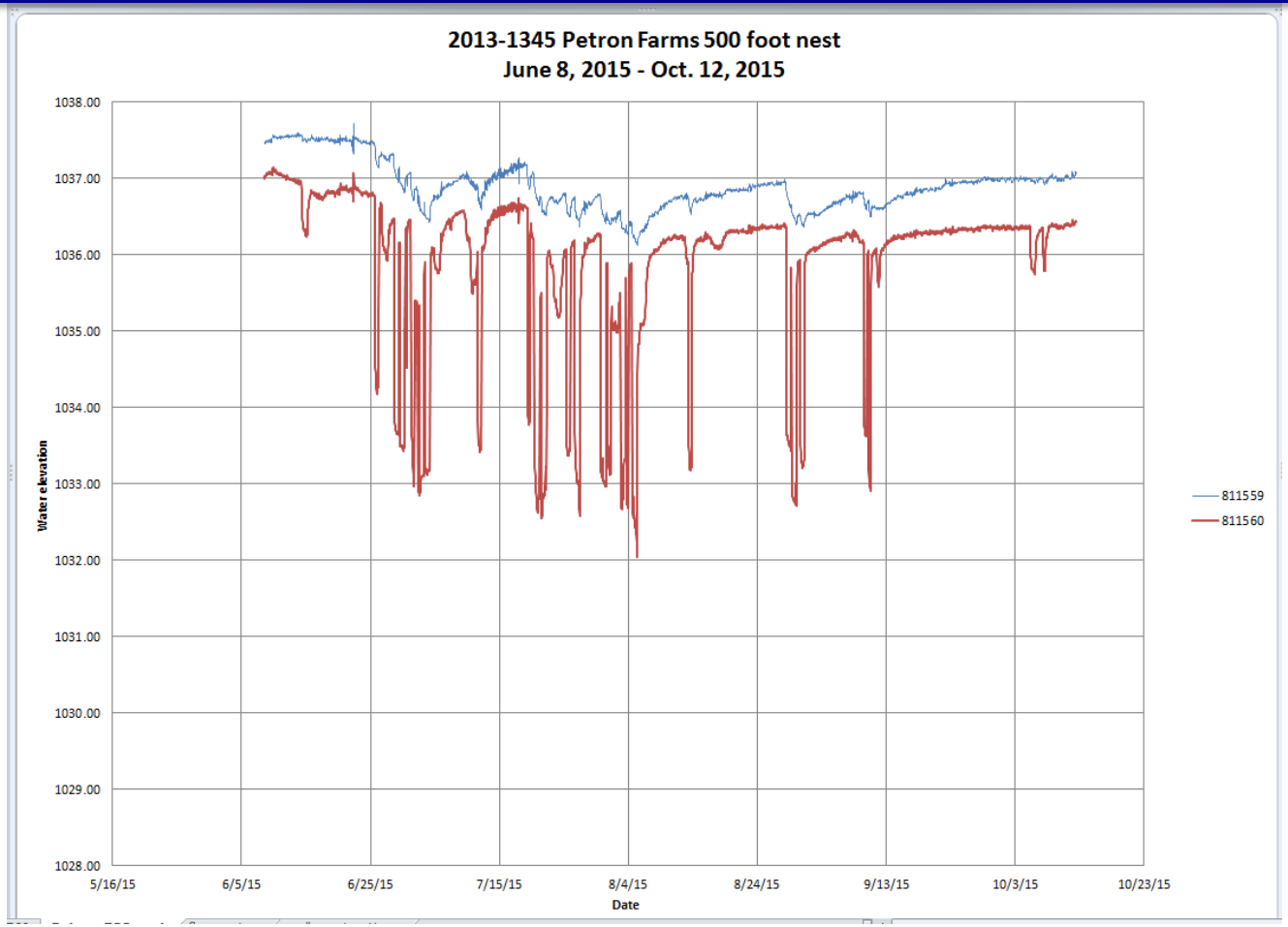


Figure 14 from Helgesen 1977- USGS 77-102

Leakage from Water Table Aquifer to "Confined Aquifer"



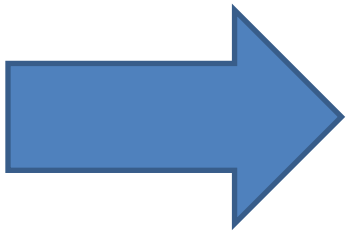
Leakage Water Table Aquifer to "Confined Aquifer"



Challenge

Translate sustainability thresholds

- Streams
- Lakes
- Wetlands
- Confined aquifers



Volume allowed for each groundwater use permit

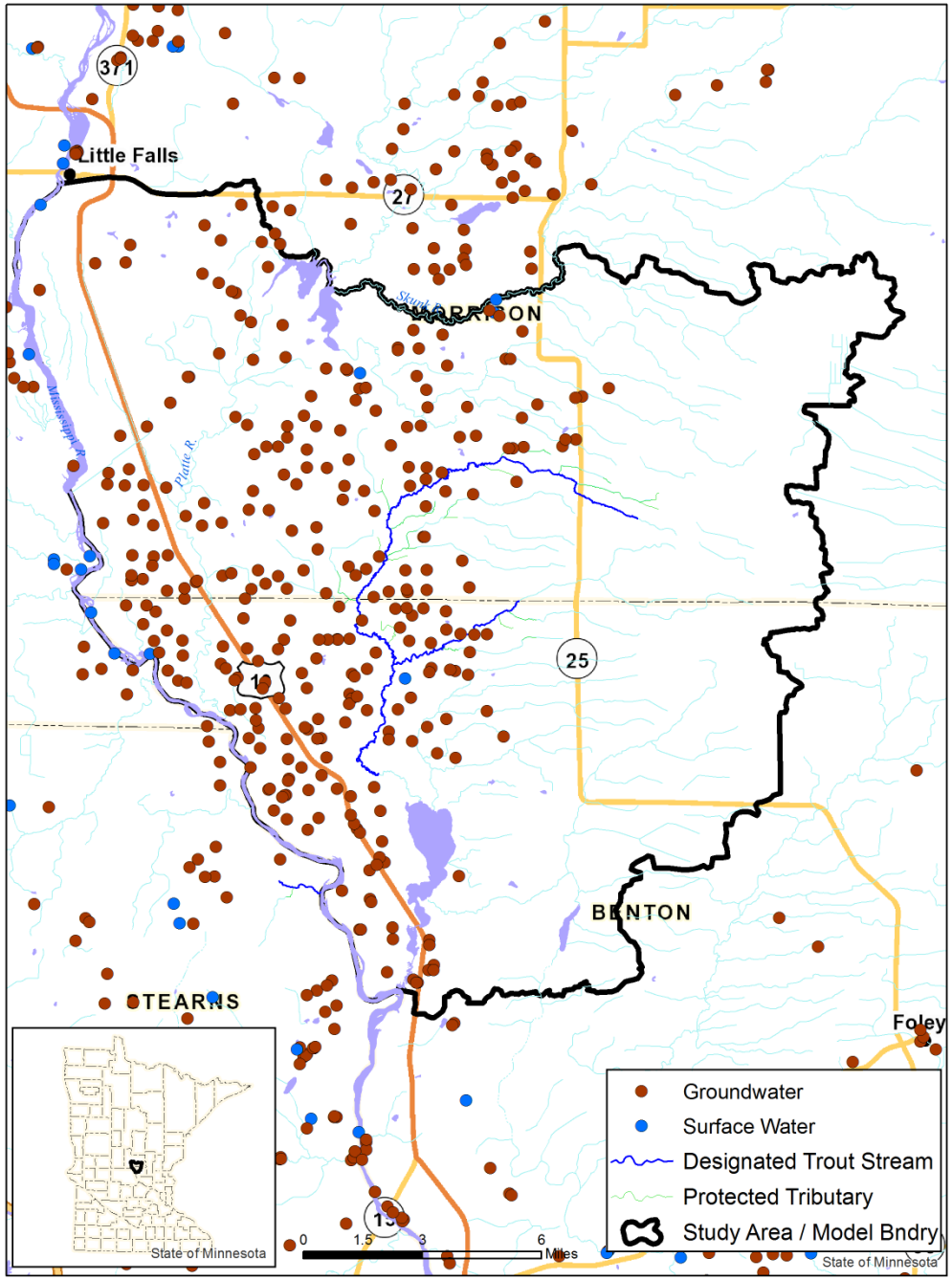
Decision-making criteria and needs

- Quantifiable and fair
- Quick decision-making
- Technically and scientifically sound
- Accounts for cumulative GW use
- Predictive
- Adaptive

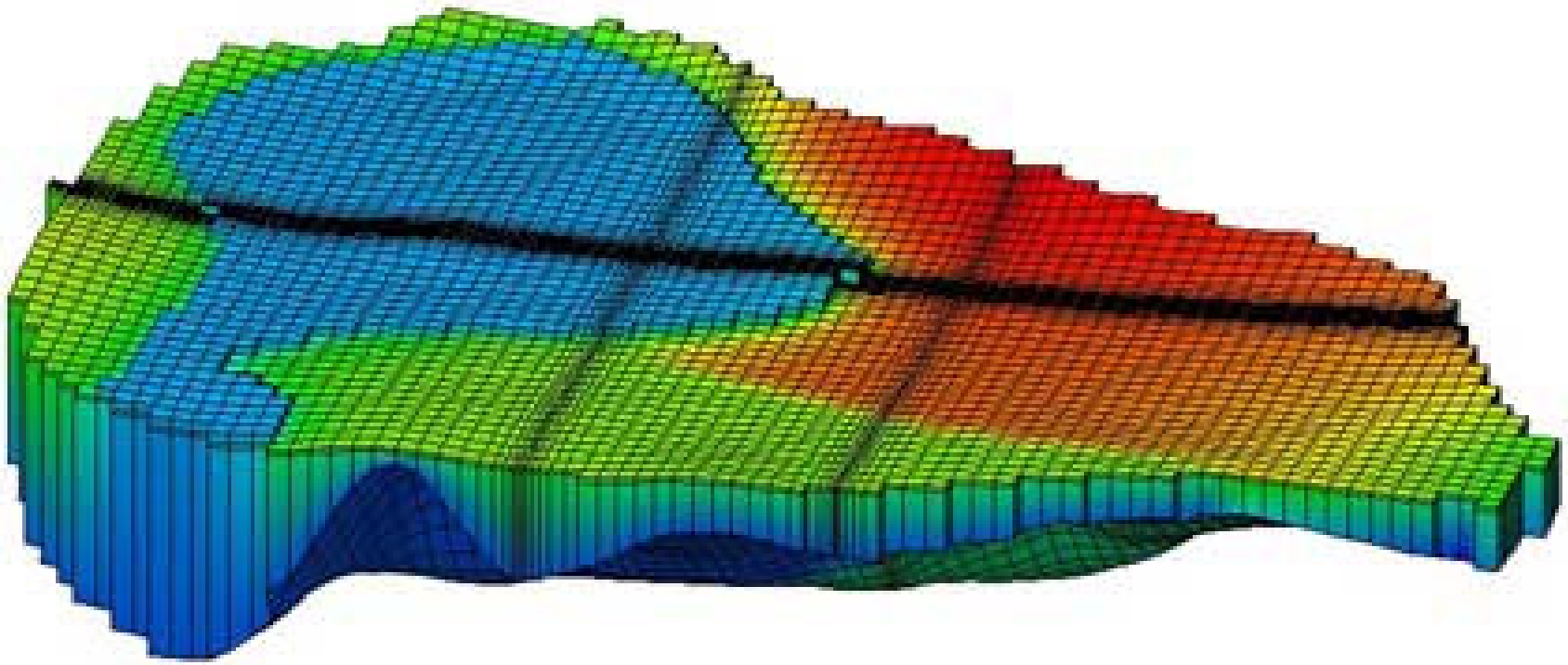
Groundwater Models

Little Rock Creek

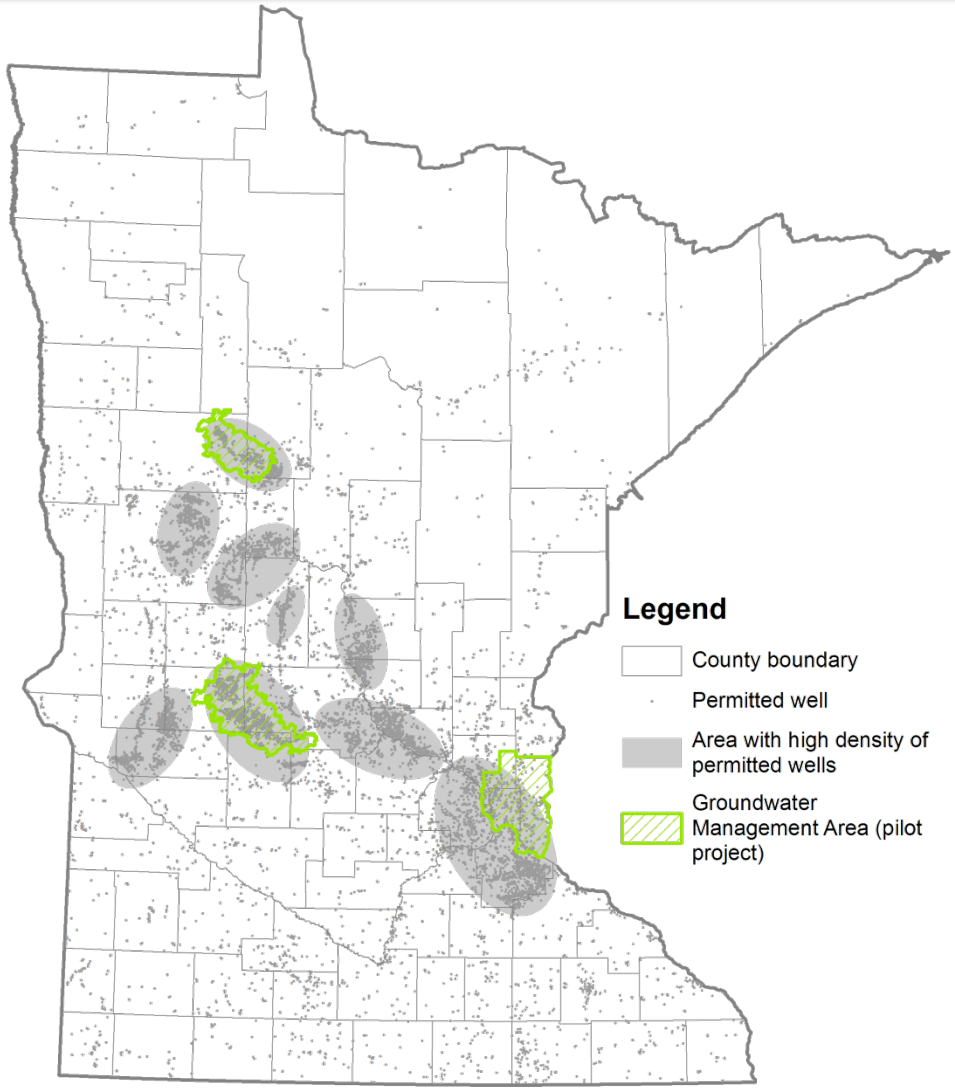
- Proposed model boundary
- Permitted Groundwater wells
- Partnering with USGS



Groundwater Modeling: Modflow Grid



Areas with High Density of Permitted Wells



Questions?