Monitoring Potential Water Quality Changes Using Managed Aquifer Recharge: Unlocking the Secrets of a Fractured/Karst Aquifer

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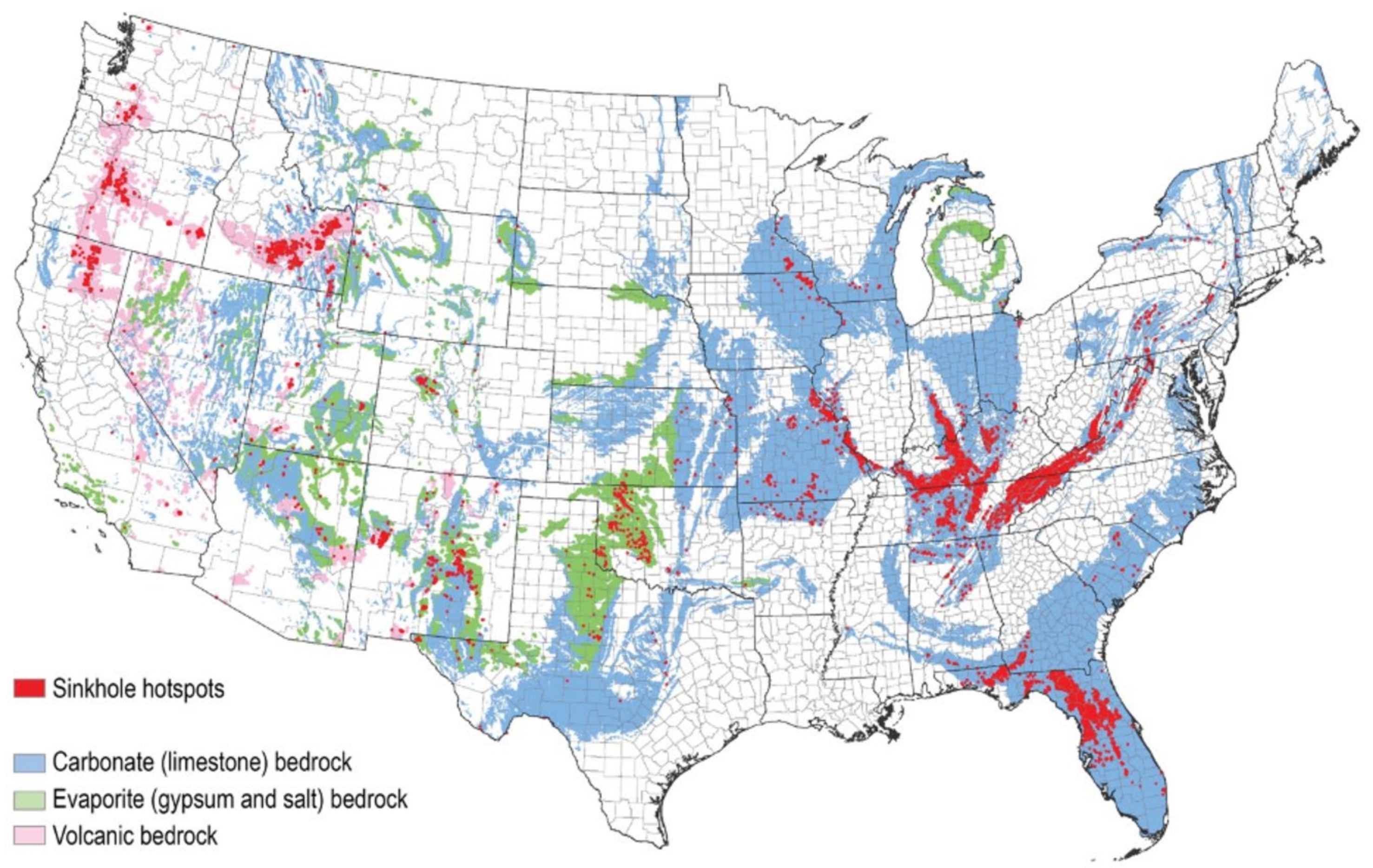
Importance of Karst and Fractured Rock Aquifers

- USGS, 2021
  - 40 % of U.S. groundwater drinking water supplies comes from karst aquifers
  - Groundwater storage is in the rock matrix
  - Groundwater transport is through openings
  - Karst aquifers are highly heterogeneous and anisotropic
  - Research needs: “developing innovative approaches for better understanding and managing these valuable water resources”



Source: USGS. 2021. Karst Aquifers. https://www.usgs.gov/mission-areas/water-resources/science/karst-aquifers

EPA MAR Project

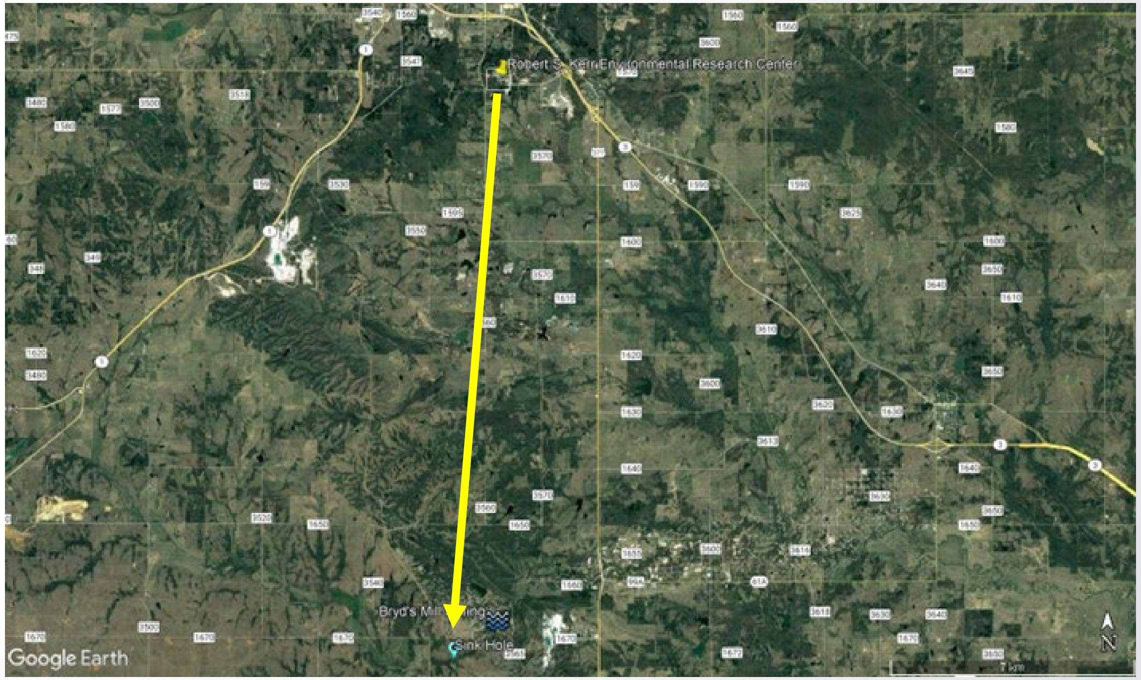
- Location:
  - ~10 miles south of Robert S Kerr Environmental Research Center (RSKERC), Ada, OK
  - ~ 1 mile southwest of Byrds Mill Spring (BMS), the City of Ada Water Supply and much of the surrounding rural area
- Using natural karst features (sink holes) to enhance aquifer recharge
- Source water is stormwater runoff
- Does the use of MAR impact water quality in the Arbuckle Simpson Aquifer or at Byrds Mill Spring?

Sink hole during dry conditions

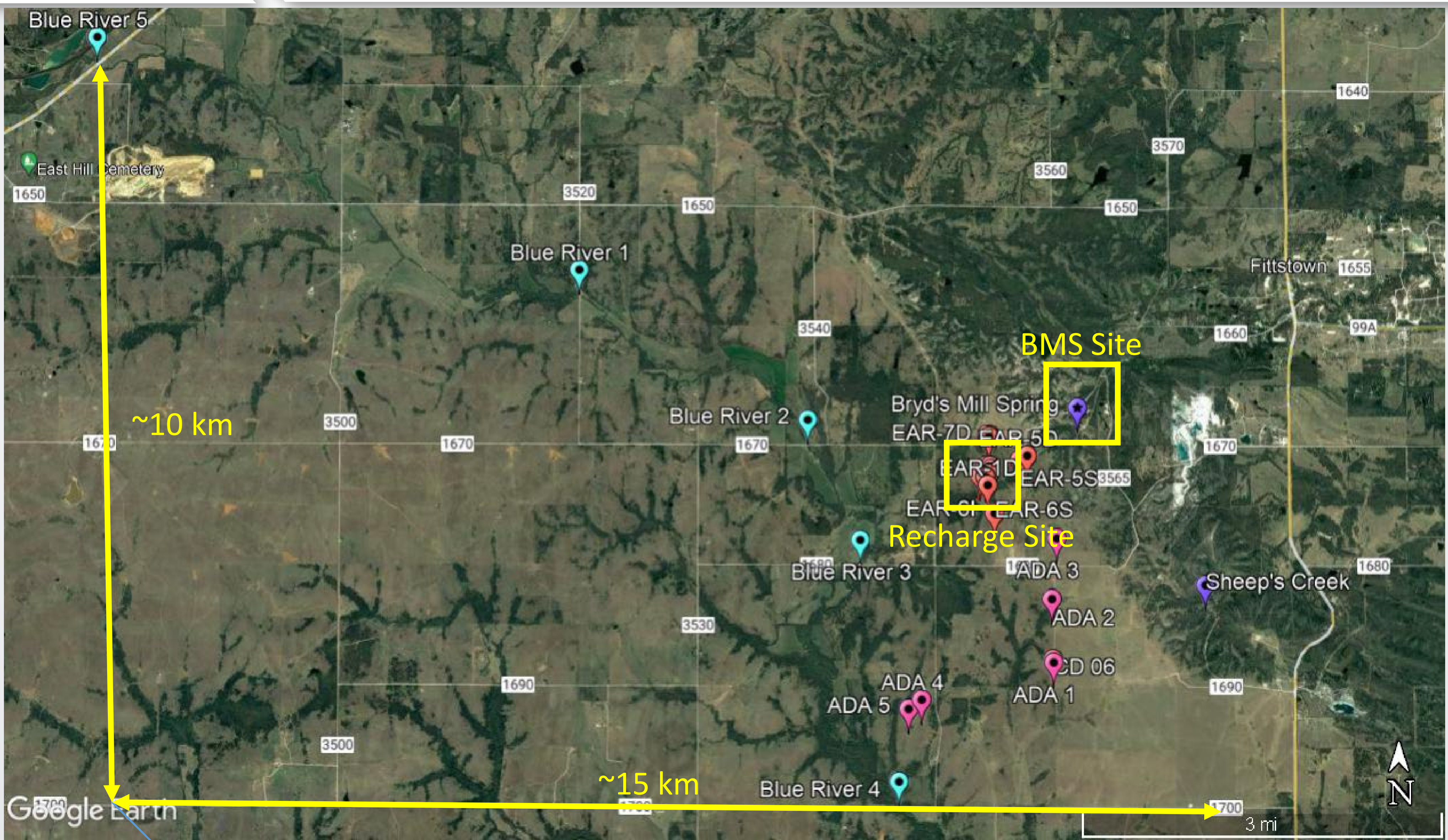
Sink hole during a stormwater infiltration event

MAR Research Site

- Location:
  - ~10 miles south of Robert S Kerr Environmental Research Center (RSKERC)
  - ~ 1 mile southwest of Byrds Mill Spring (BMS)

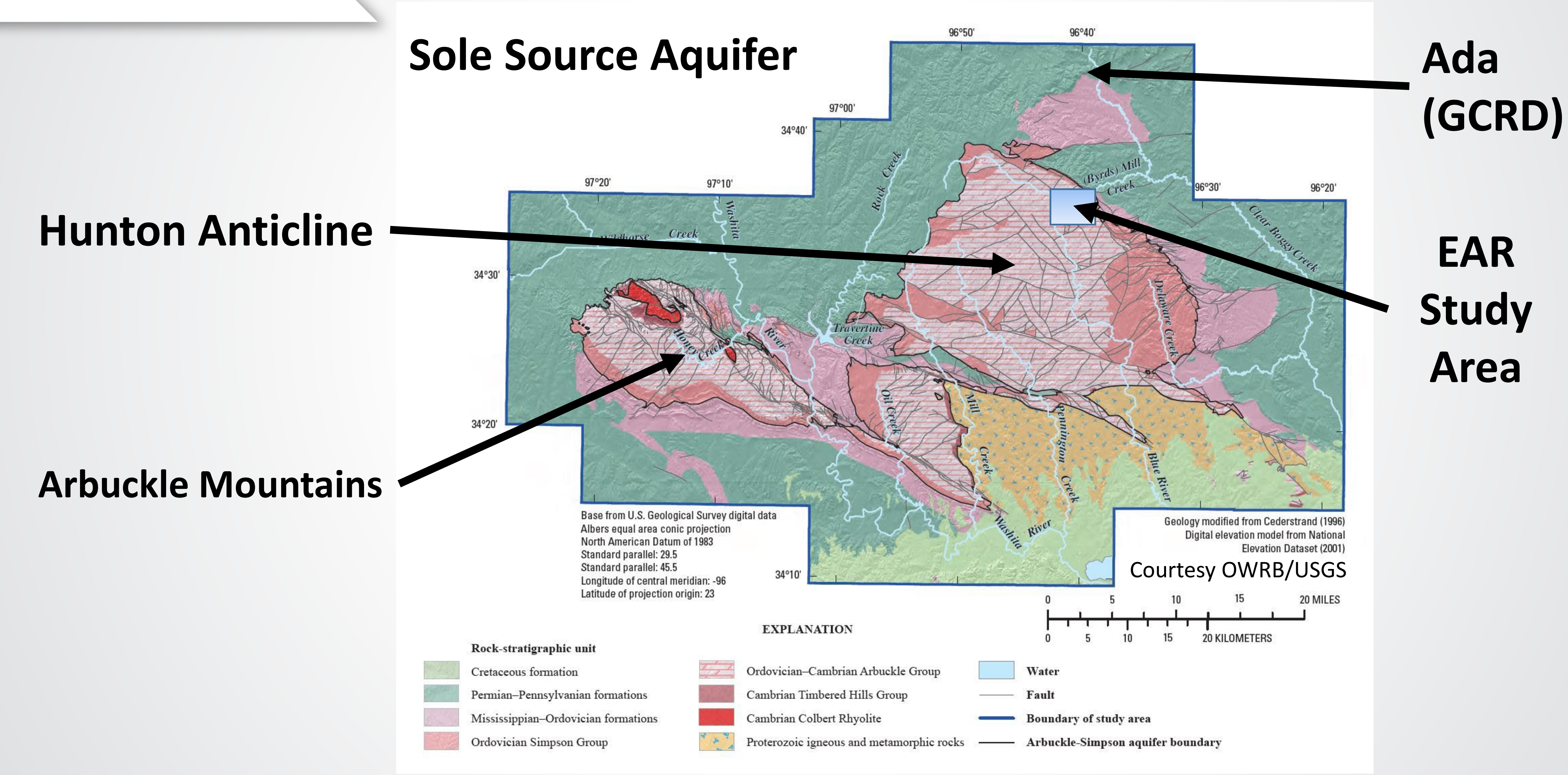


MAR Study Area



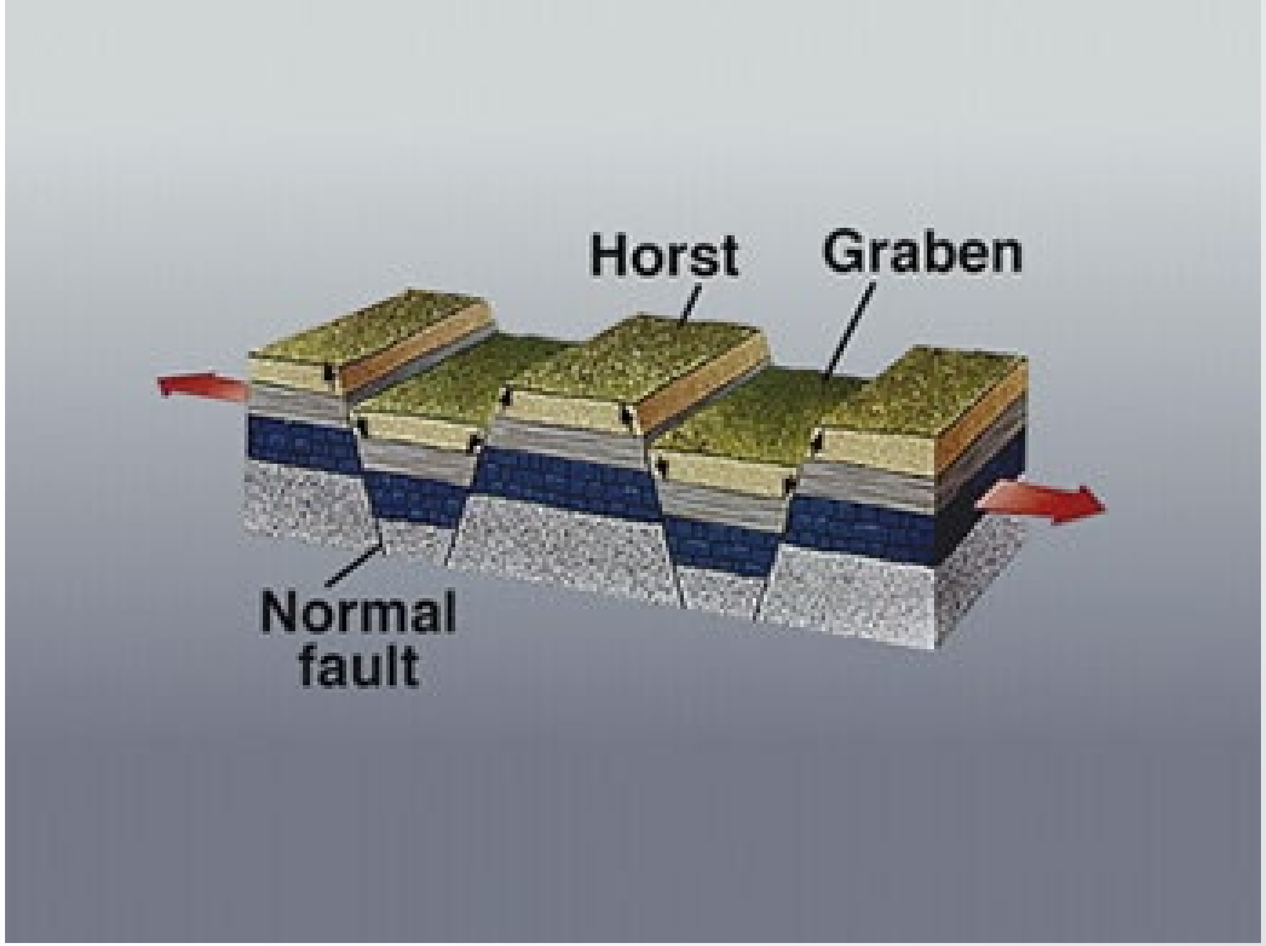
MAR Recharge Site

Arbuckle-Simpson Aquifer



Arbuckle Simpson Geology

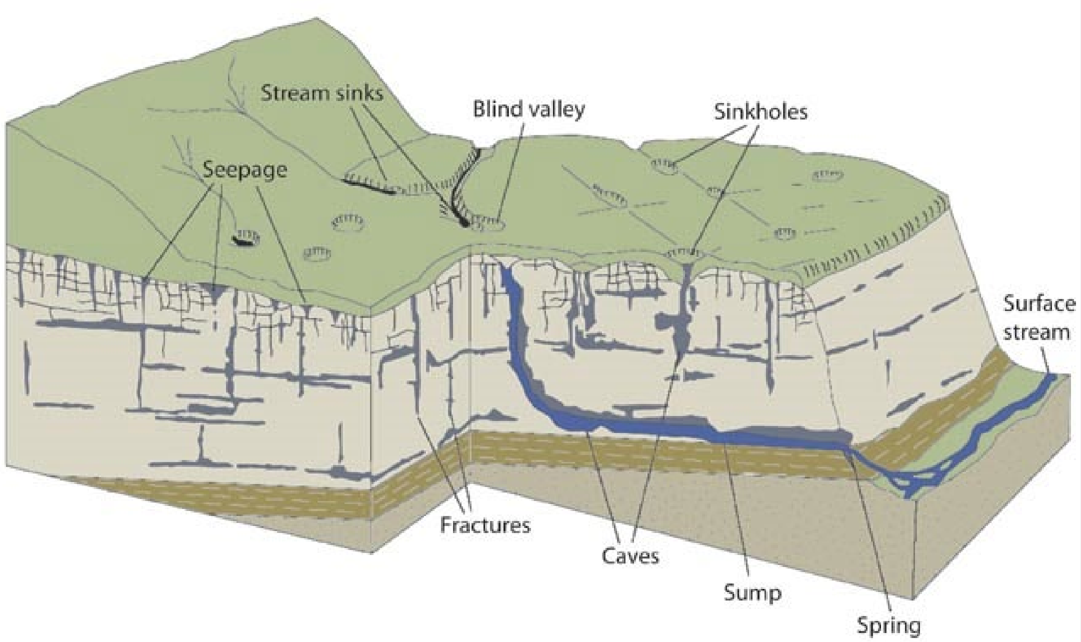
- Complex Geology
- Considerable faulting
- Horst and Graben
- Rock strata is not continuous across aquifer
  - "Blocky"
- Karst



Source: USGS, 2021, Earthquake Hazards Program

Arbuckle-Simpson Geology/ Hydrogeology

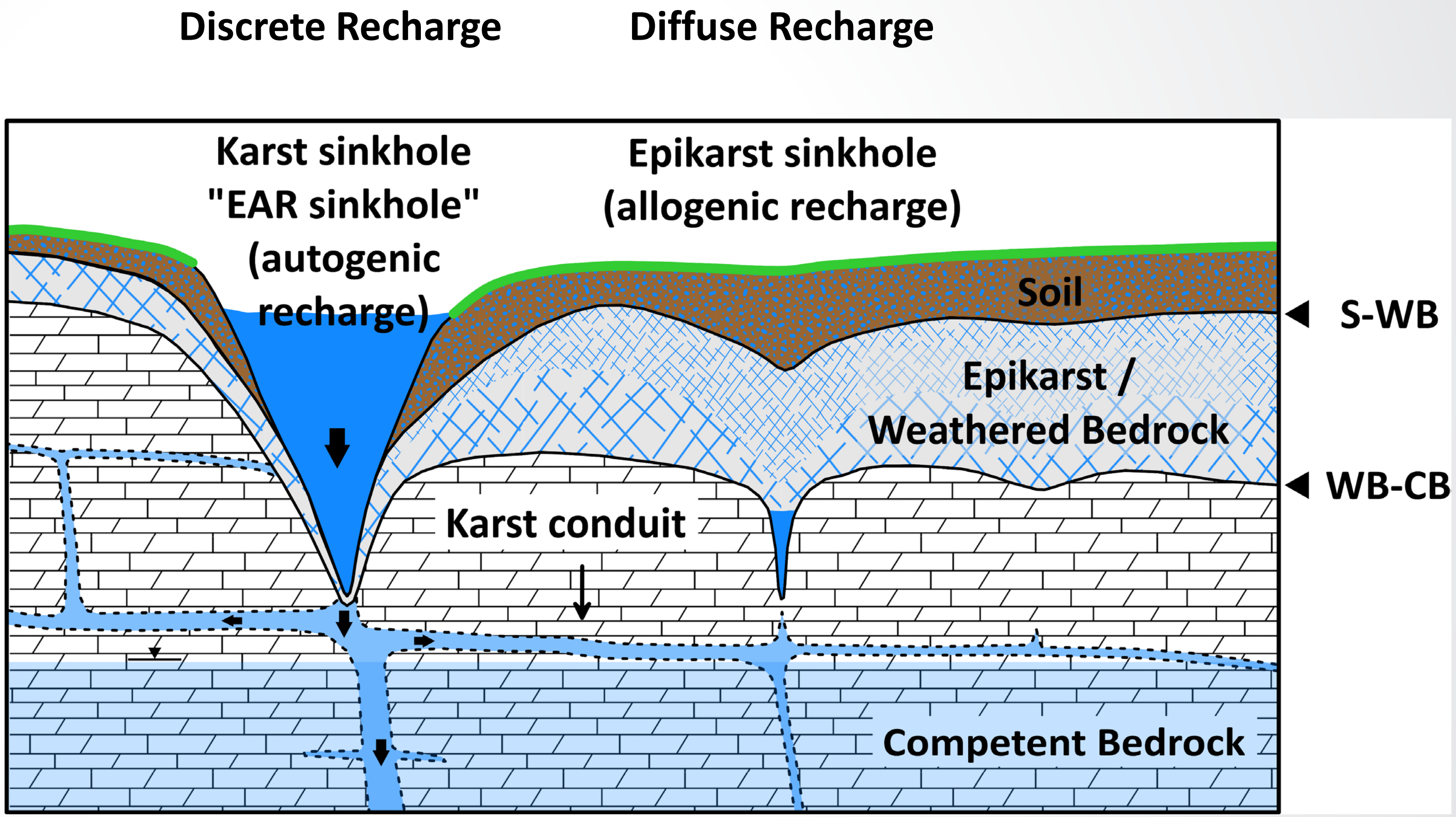
- Primarily composed of carbonates (i.e., limestone and dolomite)
- Karst aquifer
  - Preferential flow paths develop through dissolution and expansion of faults, fractures, bedding planes, etc.
  - Groundwater travel times vary by orders of magnitude (hours to years)



Source: Wisconsin Geological and Natural History Survey, 2021

Recharge Mechanisms

- Epikarst sinkholes (highly fractured bedrock; karst 'skin')
- Karst sinkholes (dissolved bedrock; sinkholes and caves)

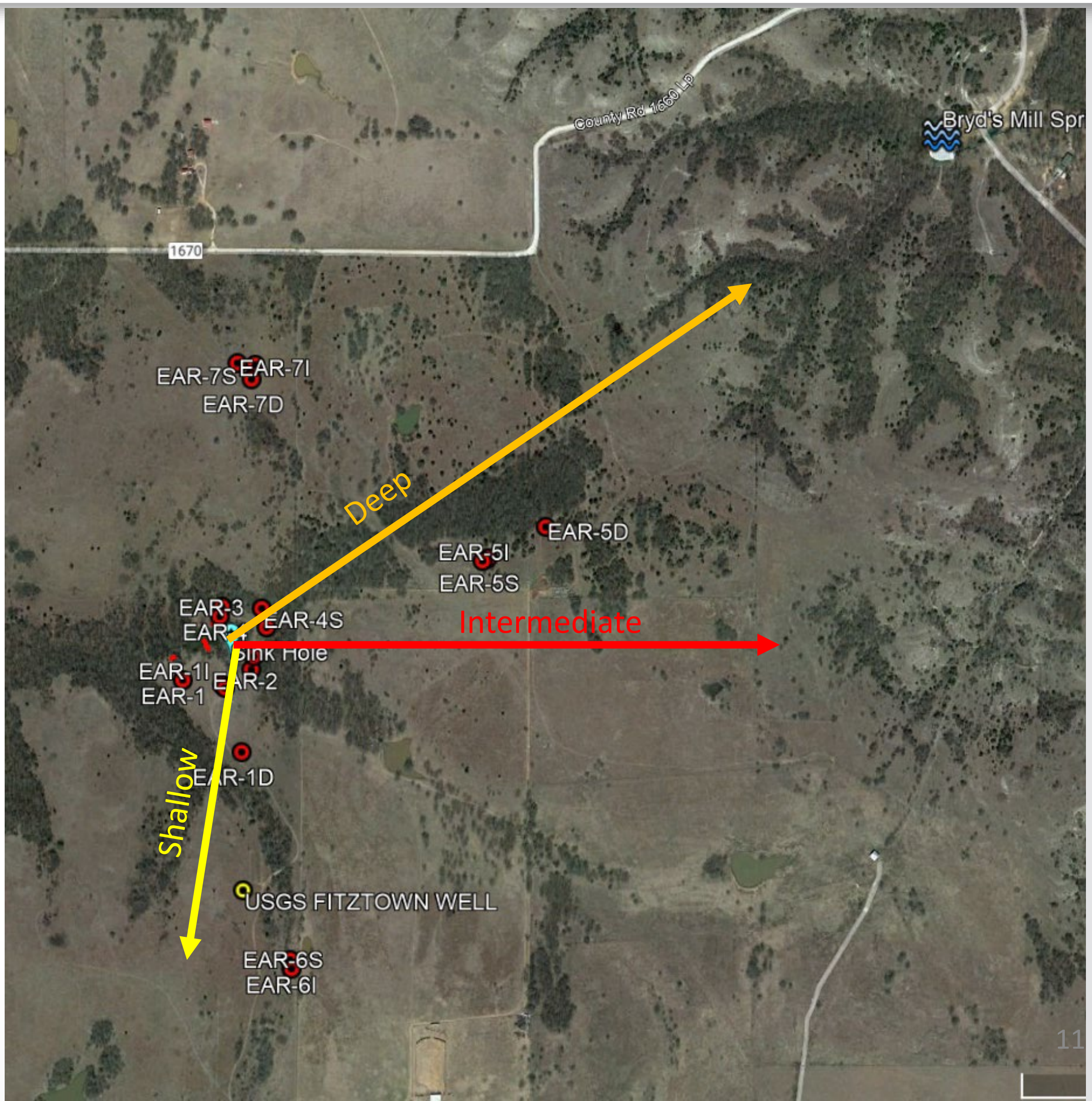


Source: *Fields et al., 2022*

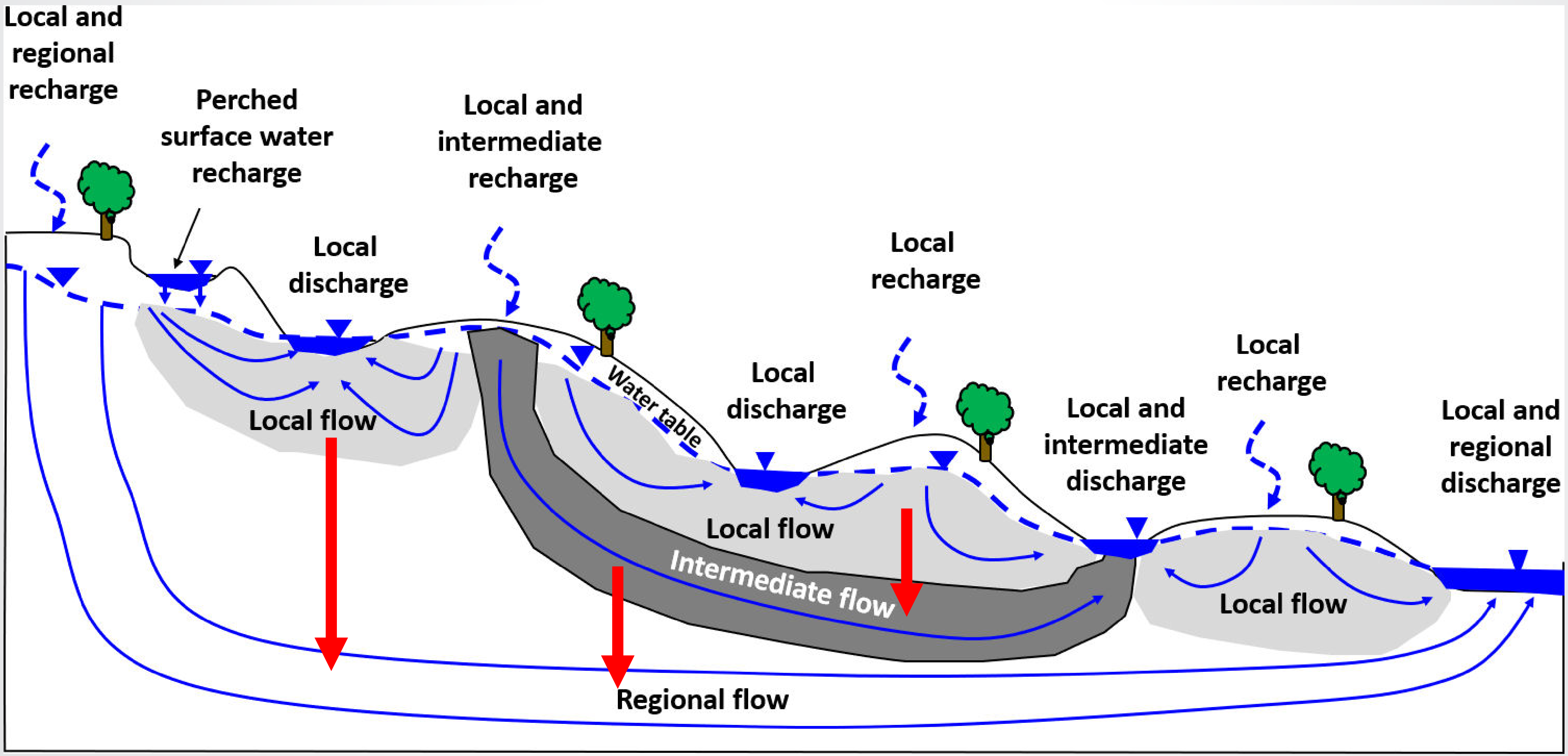
Potential Groundwater Flow Systems

- USGS suggest that groundwater flows towards Byrds Mill Spring (BMS)
- EPA data suggest at least 3 groundwater flow systems
  - Shallow System < 150 ft
  - Intermediate System ~ 250 ft
  - Deep System ~750 ft

- Water age at BMS < 50 yrs
- Vertical groundwater movement needs to be determined

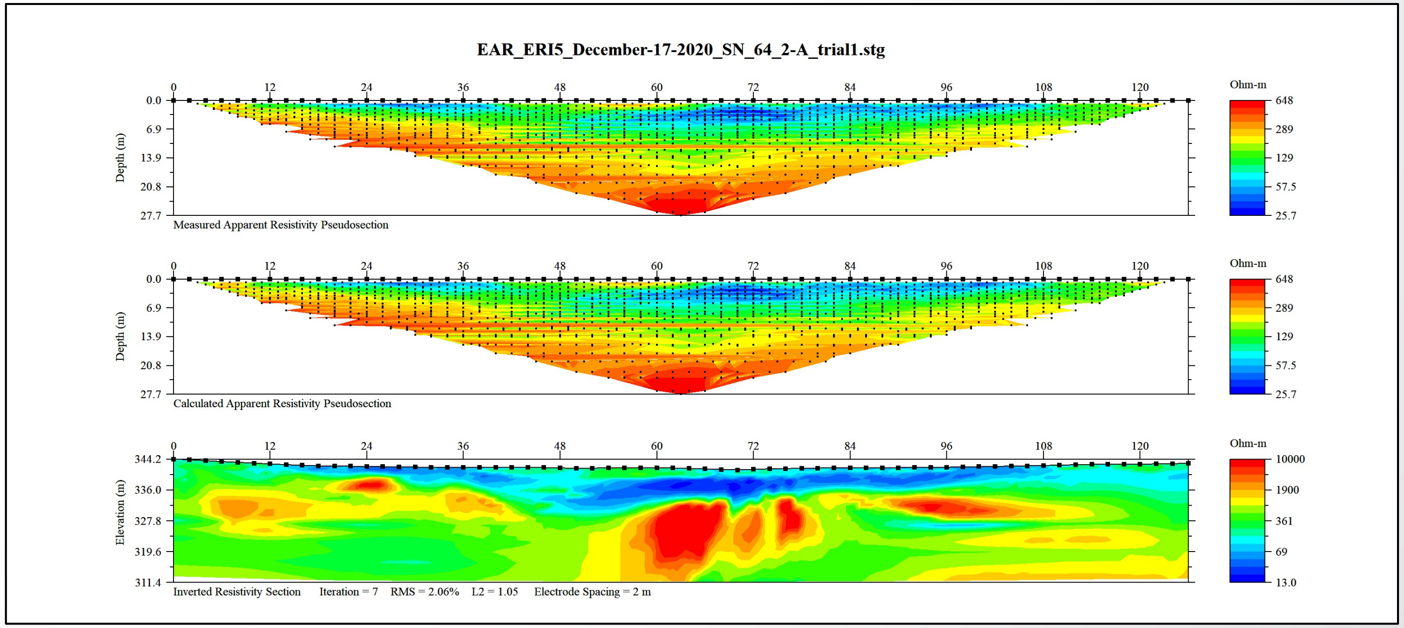


Groundwater Flow Systems



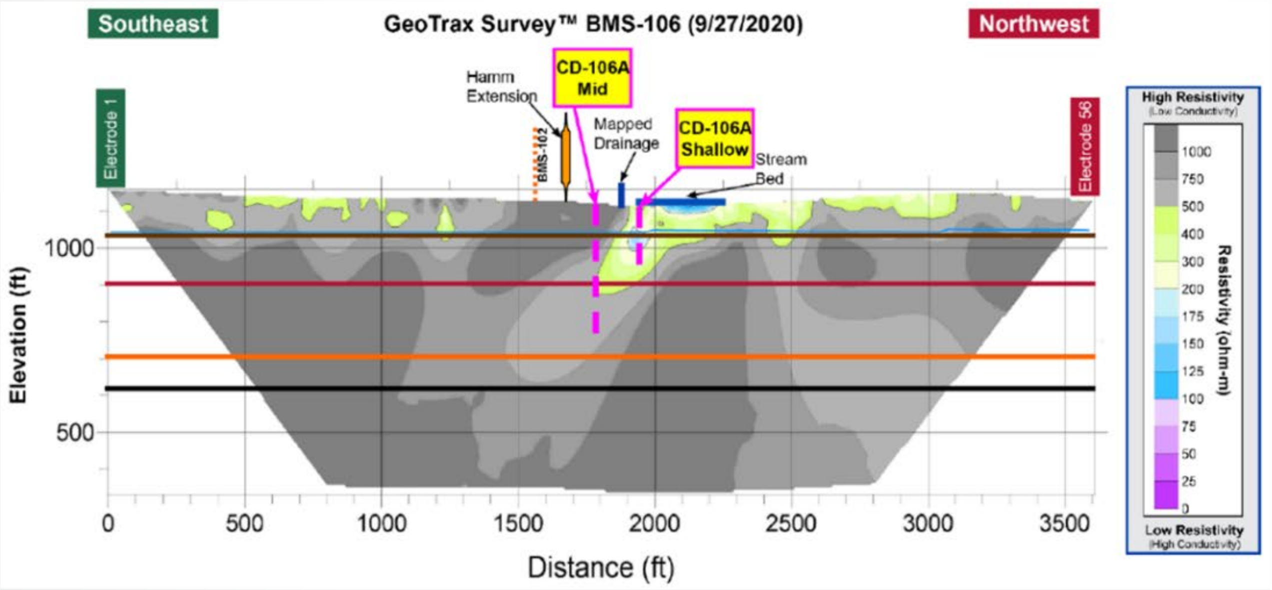
Electrical Resistivity Imaging (ERI)

- ERI is a geophysical technique which measures the apparent electrical resistivity of the subsurface in order to create a 2D image of these measurements.
- ERI is regularly used for high resolution site characterization of:
  - contaminated sites,
  - groundwater presence,
  - flow and transport, and
  - geologic structures.

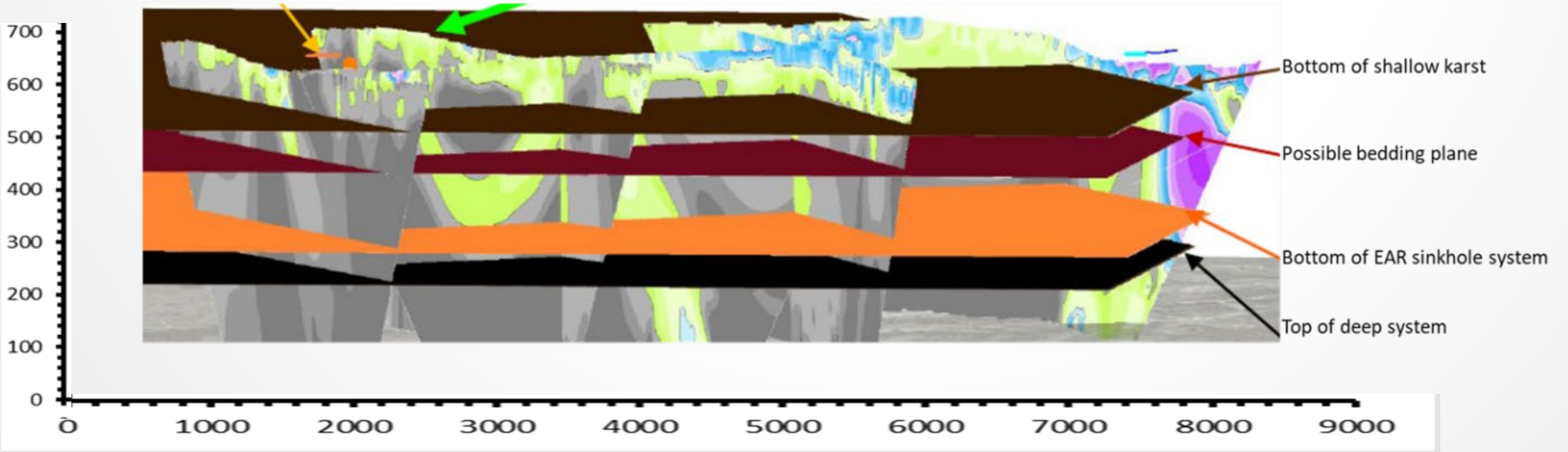


Screenshot of data processing

ERI Investigations ("Plumbing")



Figures from Aestus, Inc., 2020



ERI Investigations (Well Siting)

- Doctors don't operate without prior knowledge (scan)

Photo at EAR site

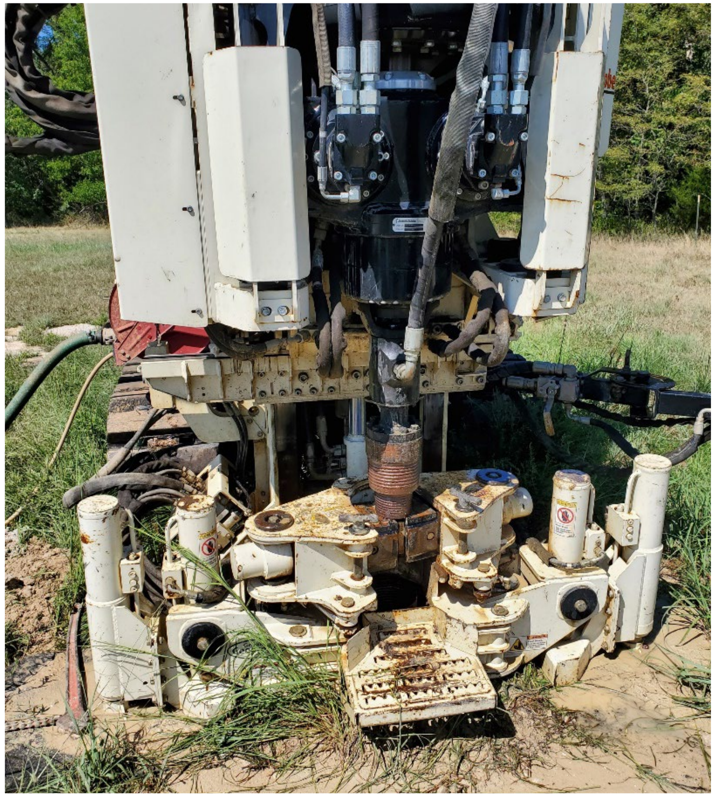
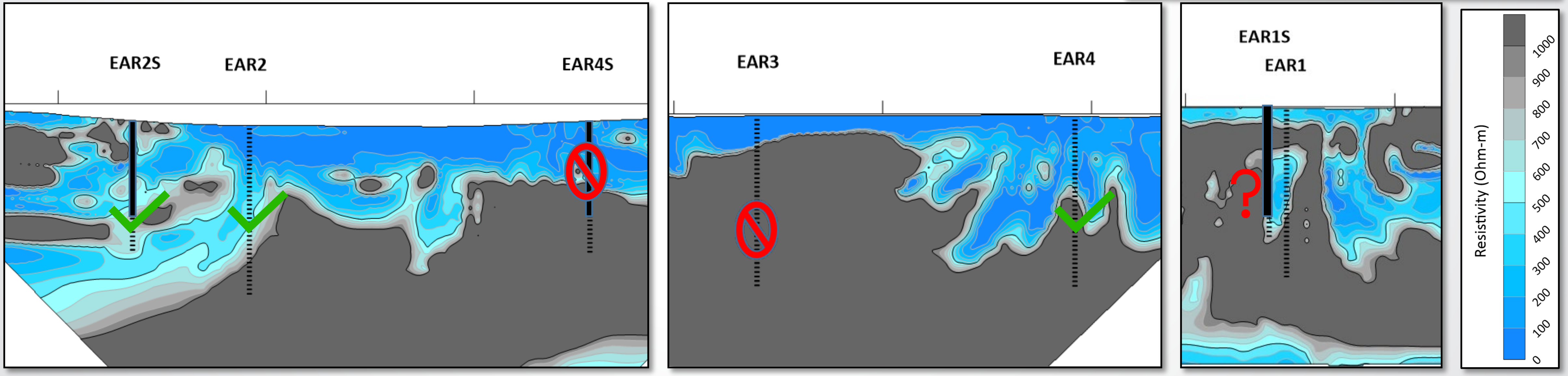


Photo at EAR site

- ERI surveys at the EAR site can indicate potential targets for high flow (drill)

ERI - Well Siting

- Installed without prior use of electrical resistivity imaging to site wells: mixed bag of results
- Low-flow and high-flow wells
- Pre-drilling plan can more efficiently place wells



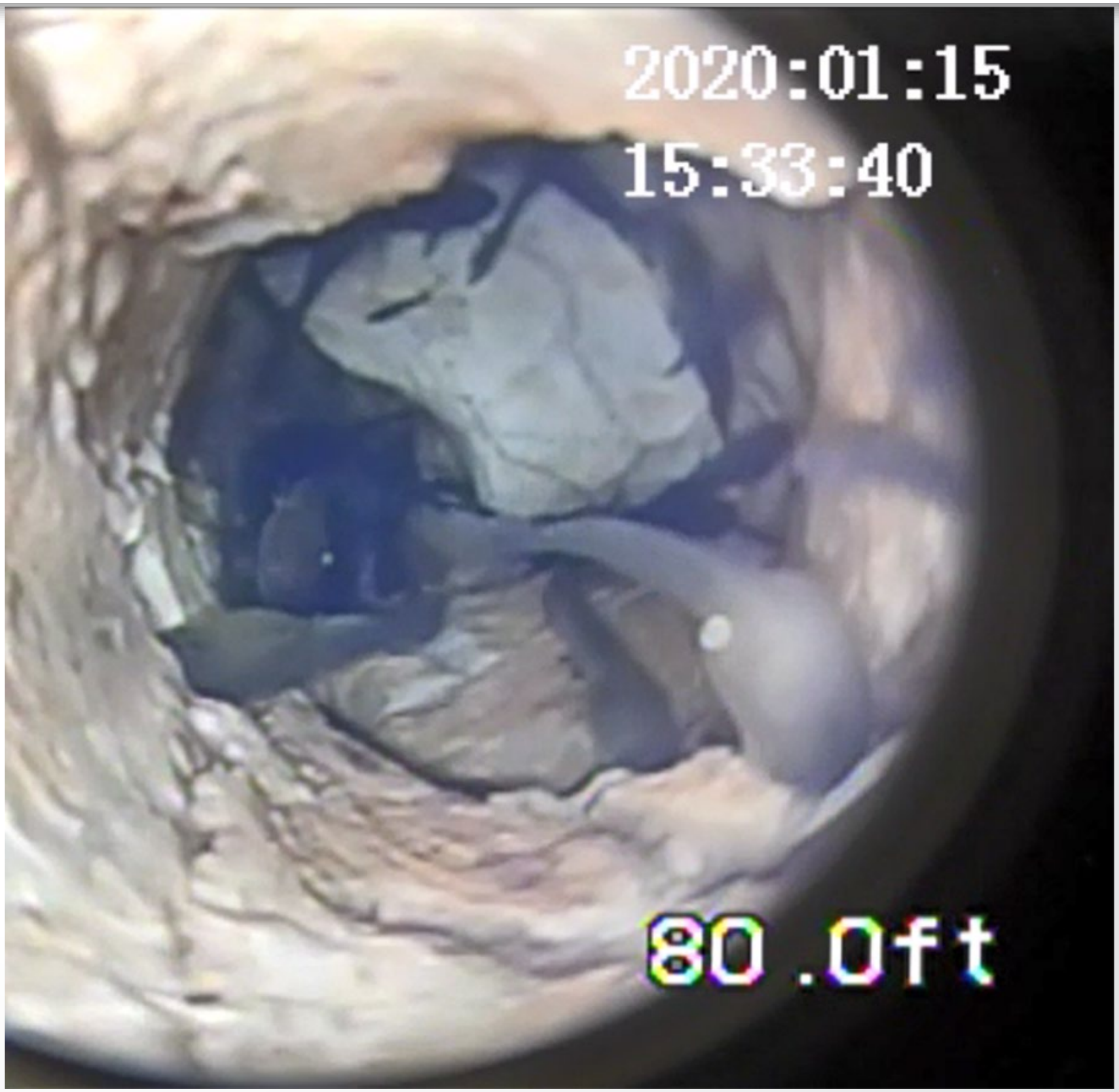
June 2022 Overland Flow Event

- June 6, 2022
  - 64.6 mm (2.54 in) of total precipitation
  - Precipitation over 0.75 hr (45 min)
  - Intensity: 86.0 mm/hr (3.39 in/hr)
- June 7, 2022
  - 26.4 mm (1.04 in) of total precipitation
  - Precipitation over 2.42 hr (145 min)
  - Intensity: 10.9 mm/hr (0.43 in/hr)

Source: Unsplashed.com/s/photos/rain

Groundwater Observations Overland Flow

- Rapid water level response to overland flow events in 4 wells.
- Direct connection between sinkhole and EAR-1 (i.e., fish & tadpoles).
- In EAR-1 there will be little attenuation of any contamination.



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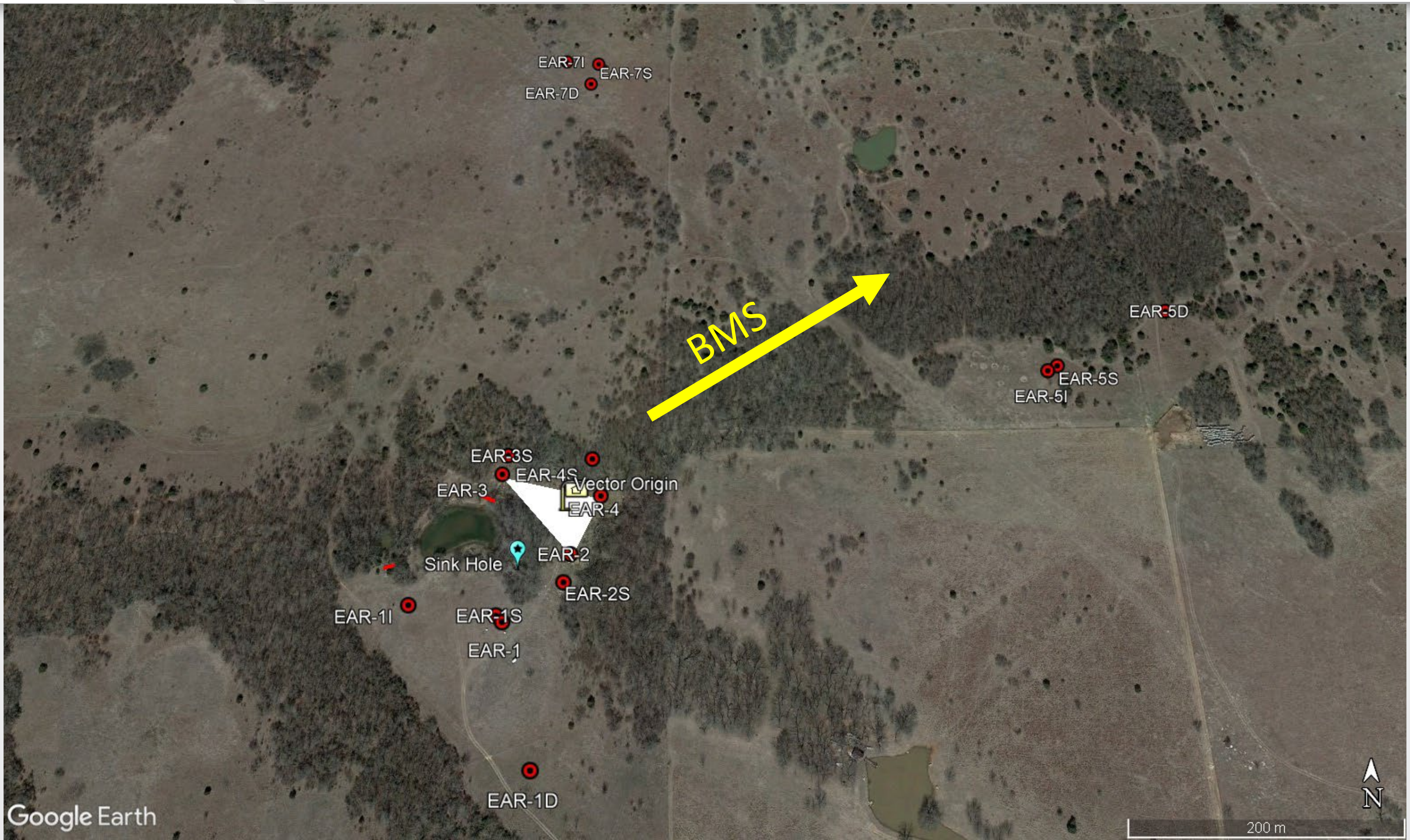

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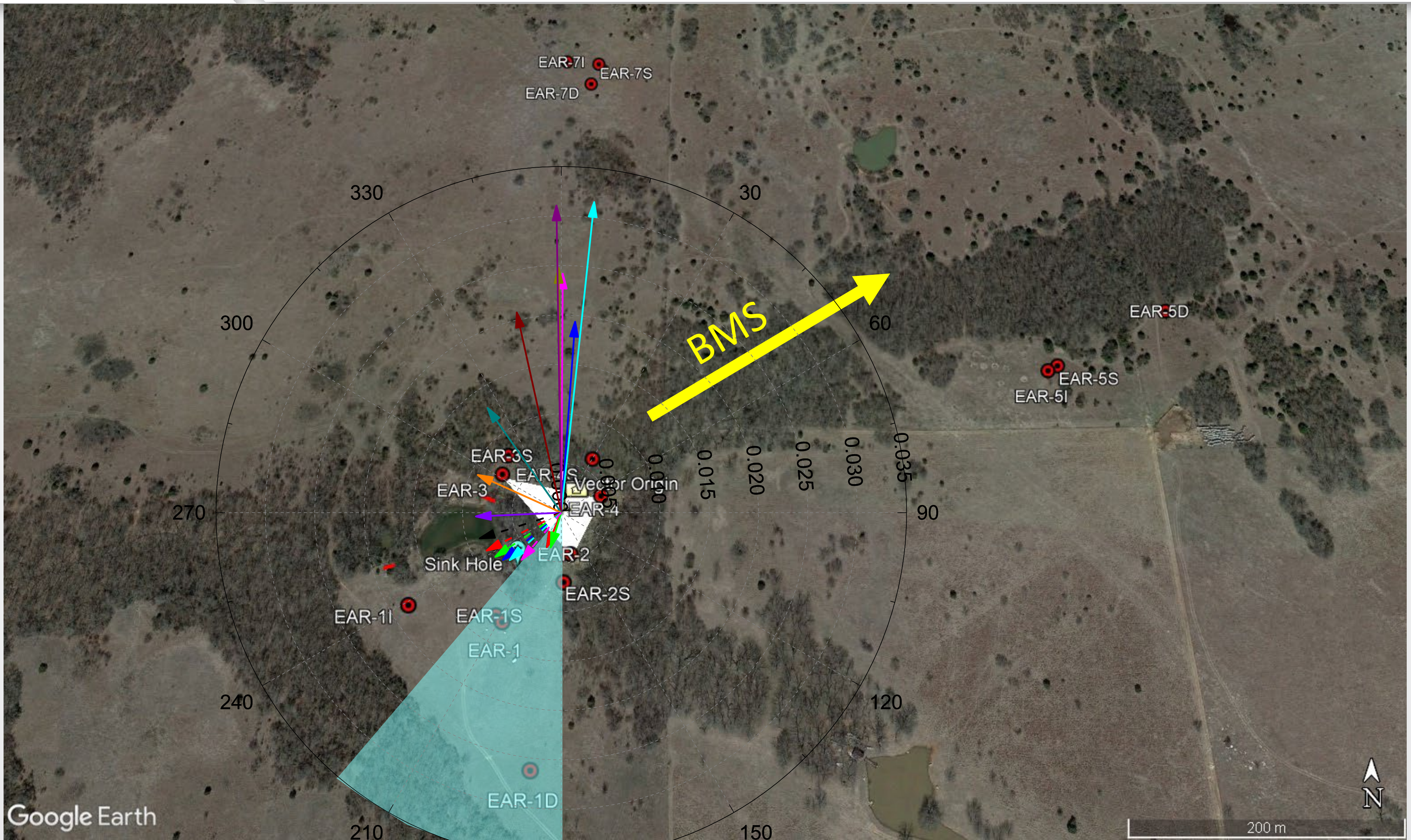

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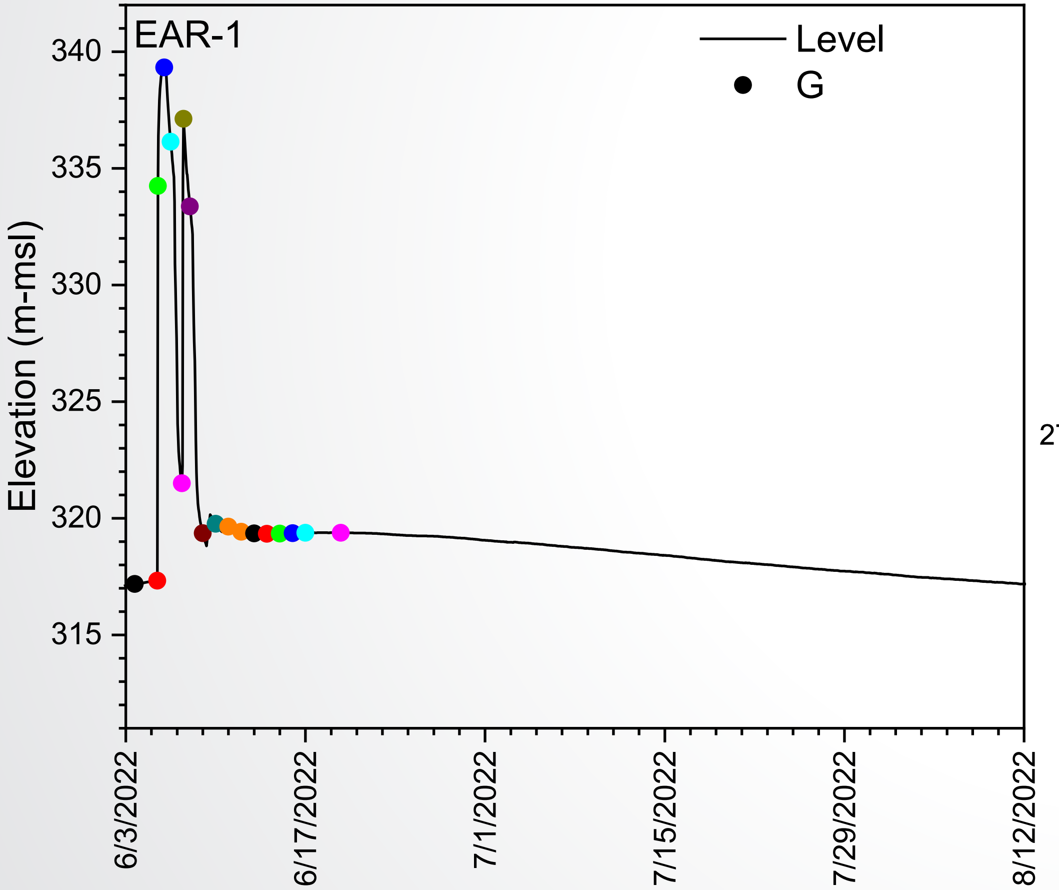
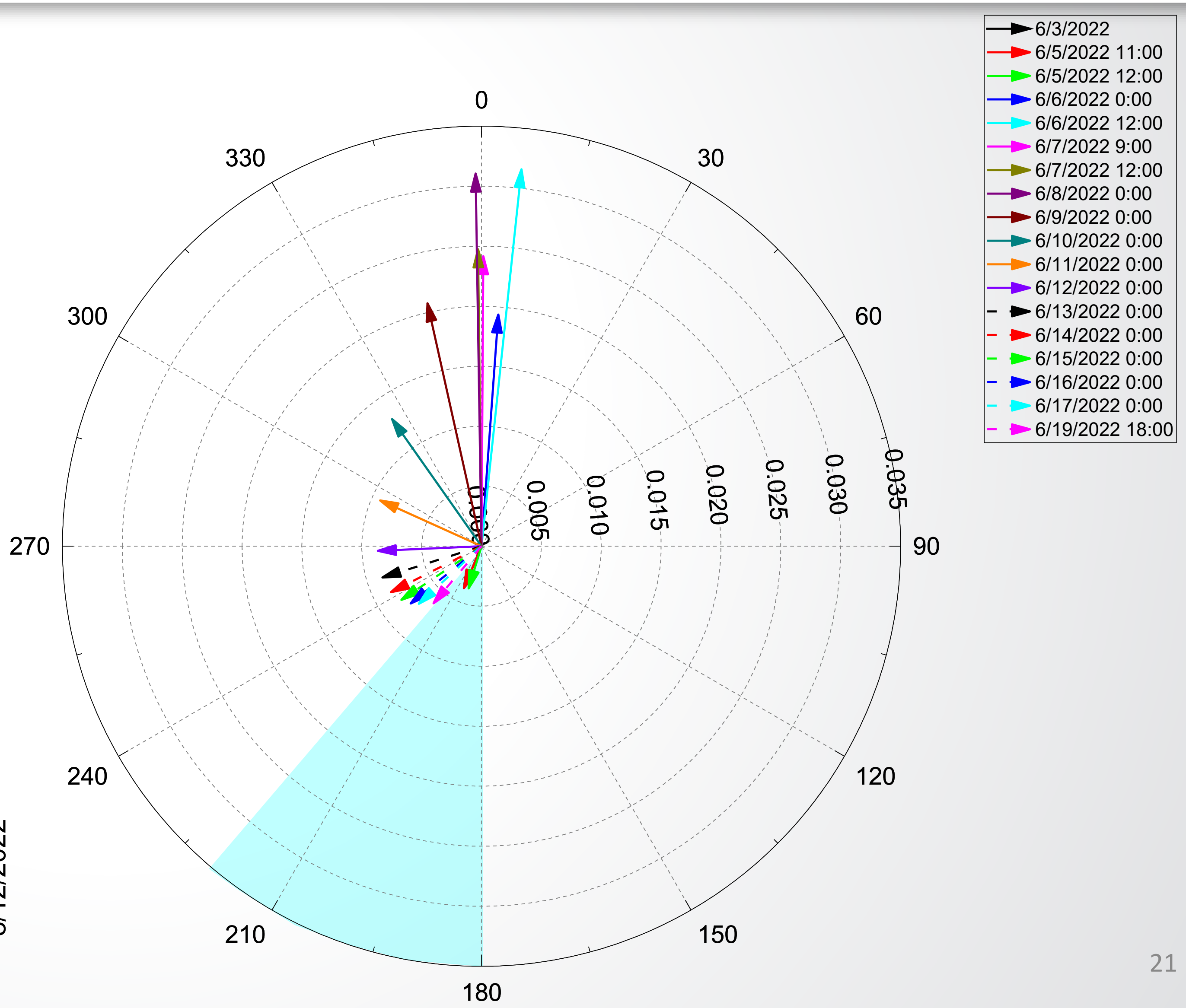
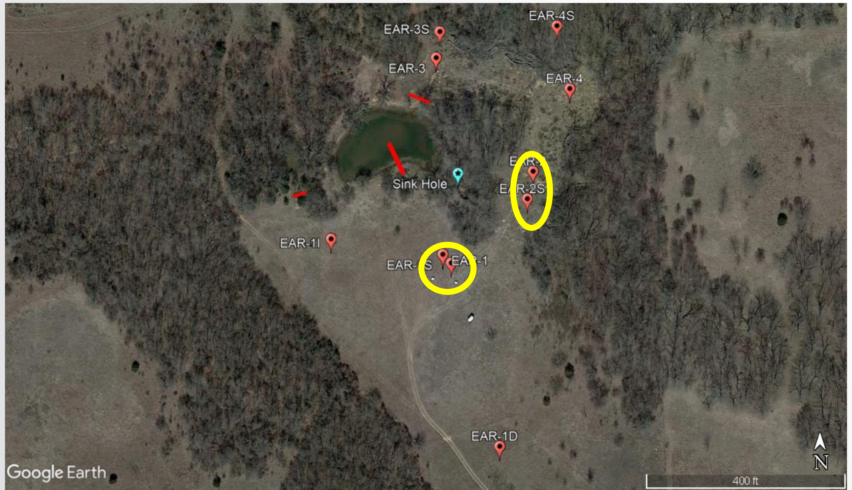
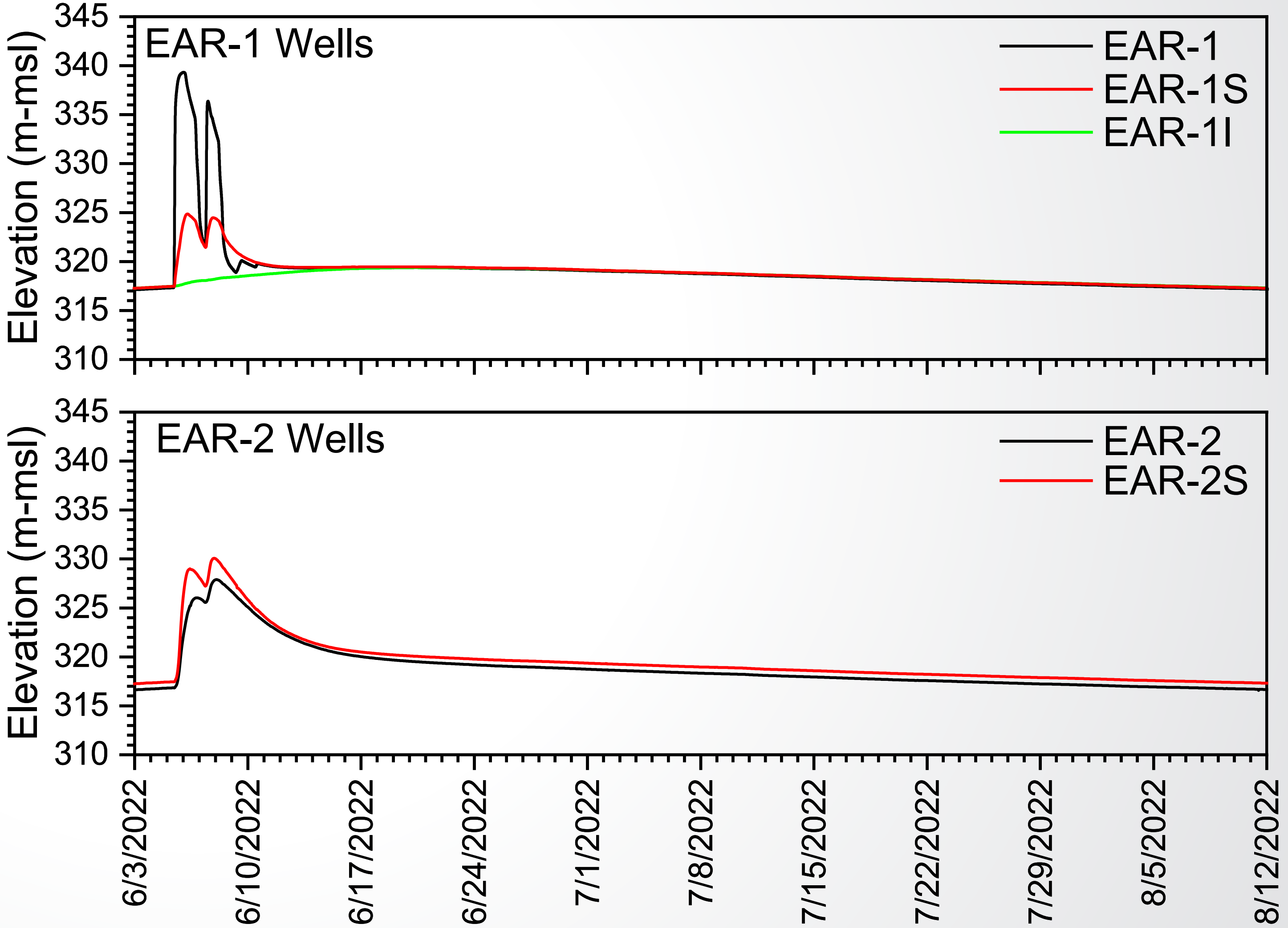




June 2022 “Impacted Wells”

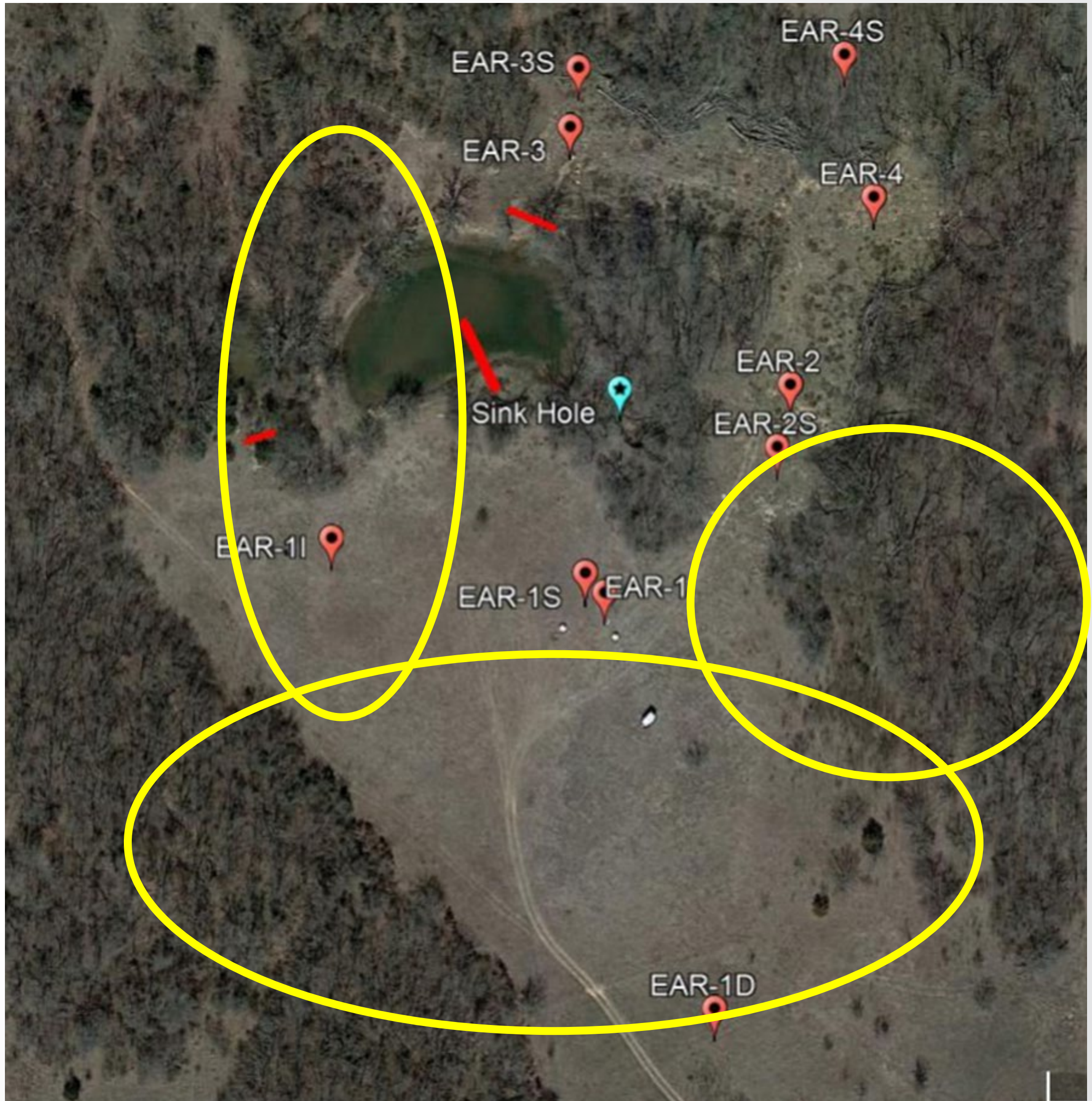
- Water Levels
  - EAR-1, -1S, -2, and 2S show nearly immediate response to sinkhole
  - EAR-1, -1S, -2, and 2S drain until meet overall aquifer rise in water
- Suggests mounding





Monitoring Scheme Deficiencies

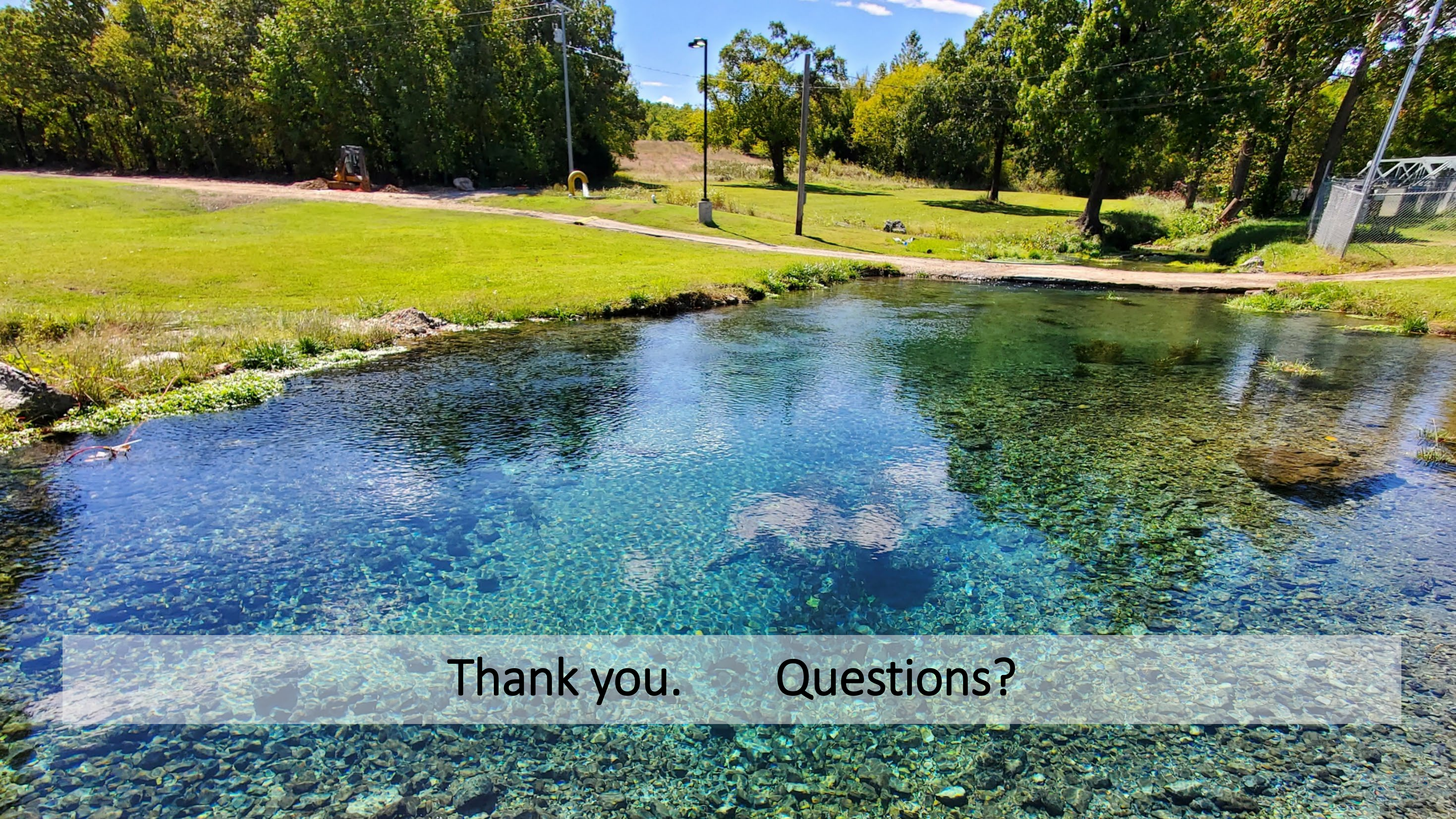
- Full discussion beyond scope of this presentation
- Understand subsurface geology, hydrogeology, and geochemistry
  - i.e., in situ conditions, expected flow rate, potential geochemical reactions, and potential contaminants of concern
  - Consider scale (i.e. regional or local data) of background data collected
  - Groundwater flow and transport models
- Adequate spatial coverage; temporal coverage
- Monitor potential leakage from zone/formation recharged
- Knowledge of potentially impacted public and private wells



Summary

- Need a better understanding of hydrogeology and site characterization to adequately protect groundwater.
- Flexibility in adapting monitoring needs will be important in fractured/karst aquifers.

- Questions
  - Is the monitoring well network sufficient to identify potential changes to water quality?
  - Can we trace chemical changes over distance/time?
  - Are water quality changes local and short lived or larger scale and long duration?
  - Role of diffuse recharge to aquifer?



Thank you. Questions?