# Oklahoma Enhanced Aquifer Recharge (EAR) Project

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GWPC ASR-MAR Webinar

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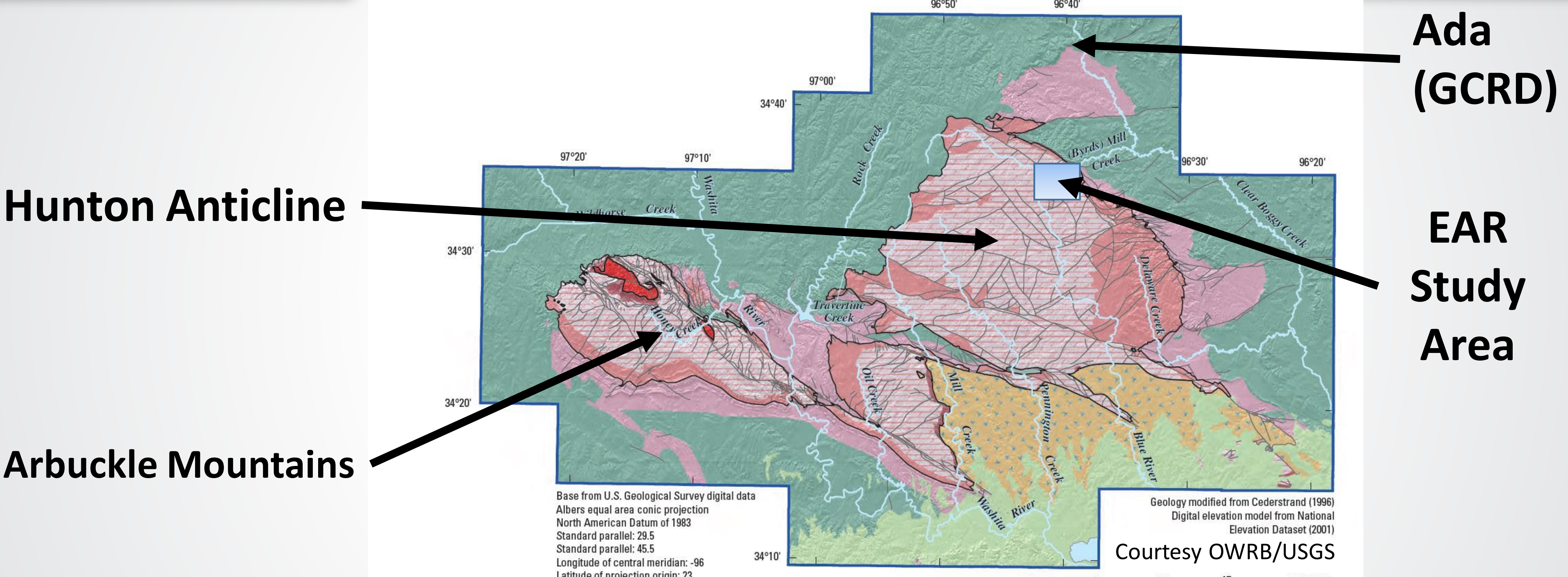
# External Partners

- Chickasaw Nation
- City of Ada, OK
- Oklahoma State University
- East Central University
- U.S. Geological Survey
- Oklahoma Water Resources Board
- Oklahoma Department of Environmental Quality
- EPA Region 6

# Arbuckle-Simpson Aquifer Geology




Base from U.S. Geological Survey digital data
Albers equal area conic projection
North American Datum of 1983
Standard parallel: 29.5
Standard parallel: 45.5
Longitude of central meridian: -96
Latitude of projection origin: 23

Geology modified from Cederstrand (1996)
Digital elevation model from National Elevation Dataset (2001)

Courtesy OWRB/USGS

**EXPLANATION**

**Rock-stratigraphic unit**

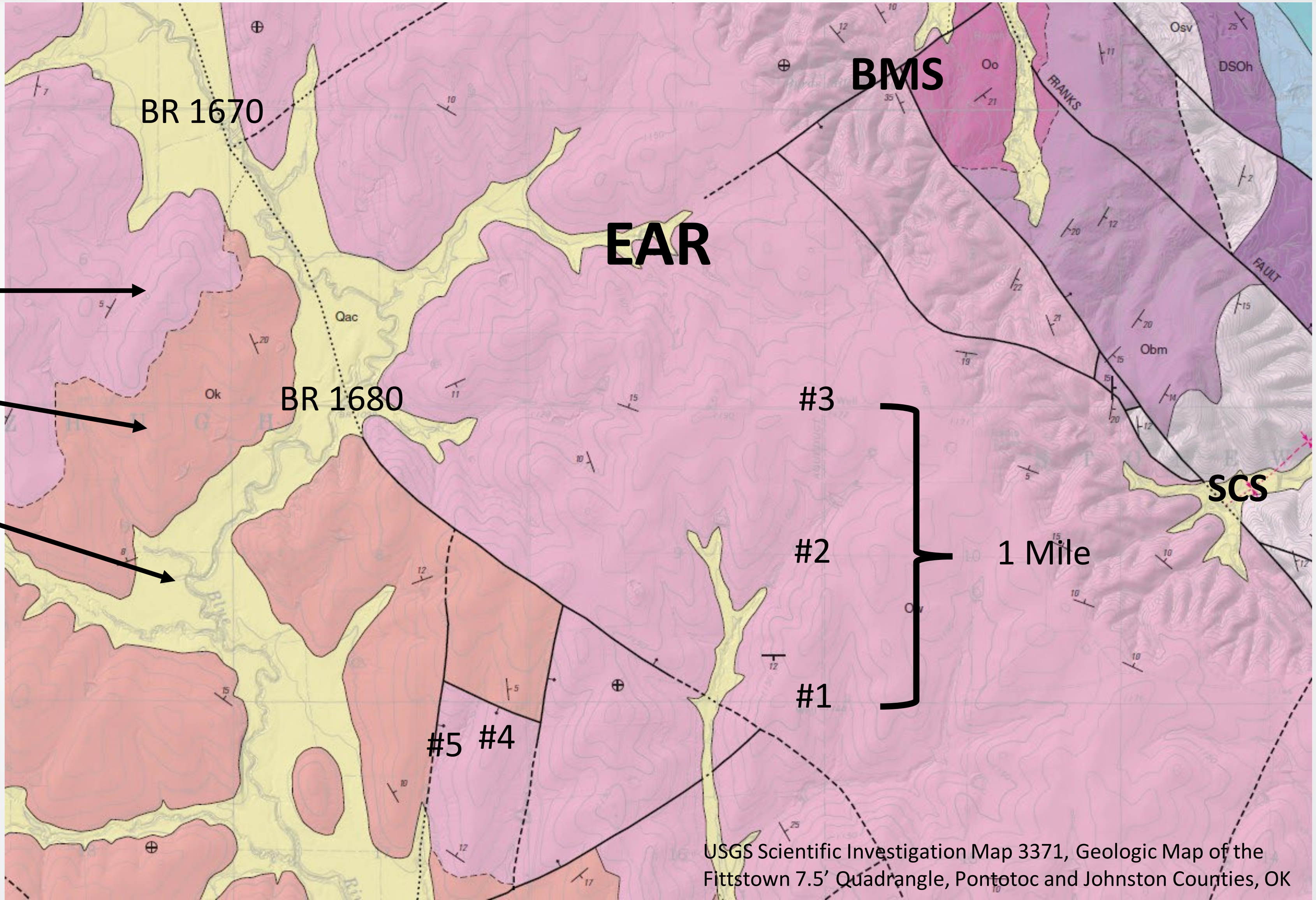
- Cretaceous formation
- Permian–Pennsylvanian formations
- Mississippian–Ordovician formations
- Ordovician Simpson Group
- Ordovician–Cambrian Arbuckle Group
- Cambrian Timbered Hills Group
- Cambrian Colbert Rhyolite
- Proterozoic igneous and metamorphic rocks
- **Water**
- **Fault**
- **Boundary of study area**
- **Arbuckle-Simpson aquifer boundary**

# EAR Area Geology

West Spring Creek Fm.

Kindblade Fm.

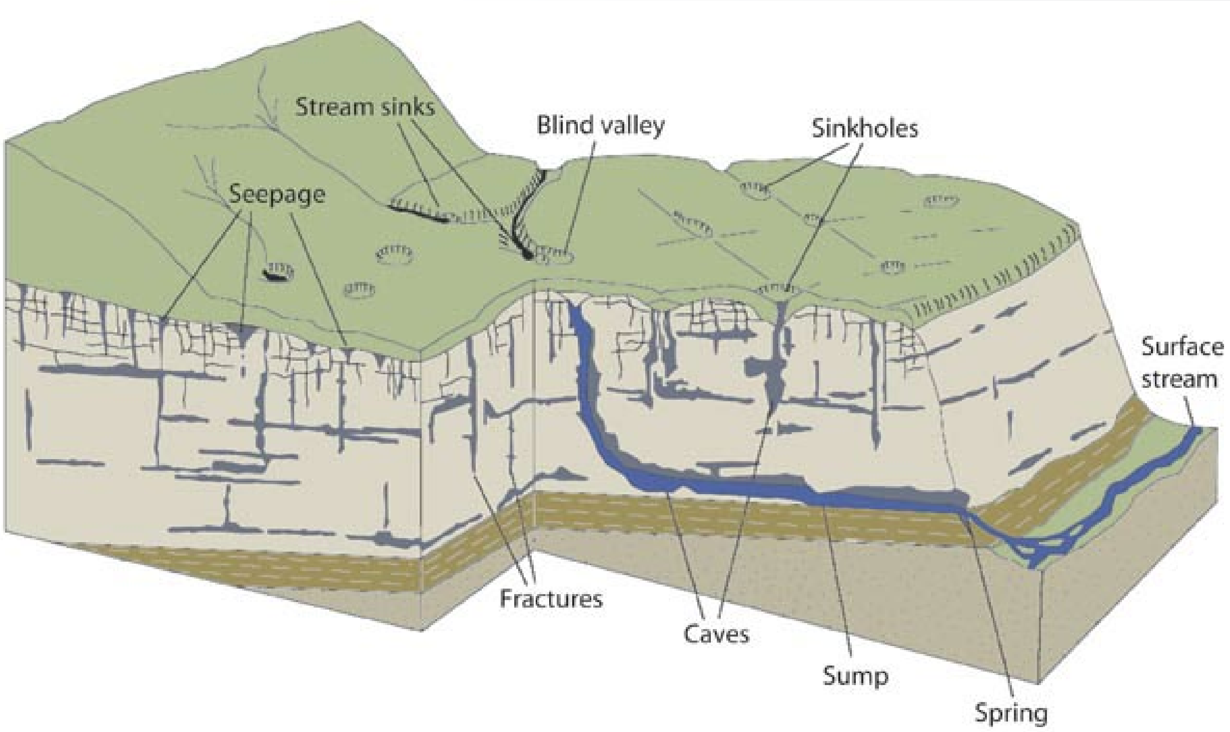
Quaternary Alluvium



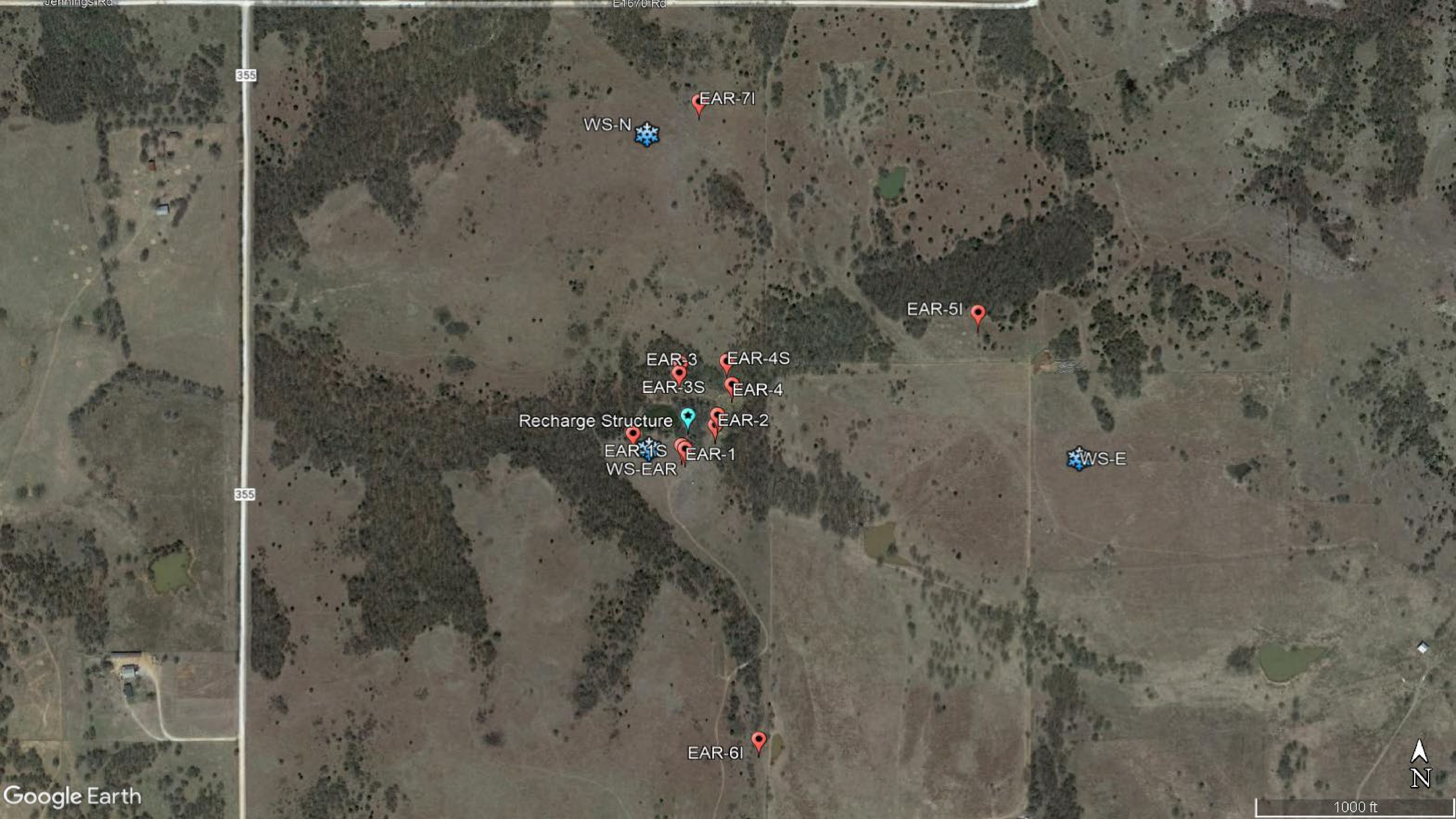

USGS Scientific Investigation Map 3371, Geologic Map of the Fittstown 7.5' Quadrangle, Pontotoc and Johnston Counties, OK

# Karst Hydrogeology

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




Source: Wisconsin Geological and Natural History Survey, 2021

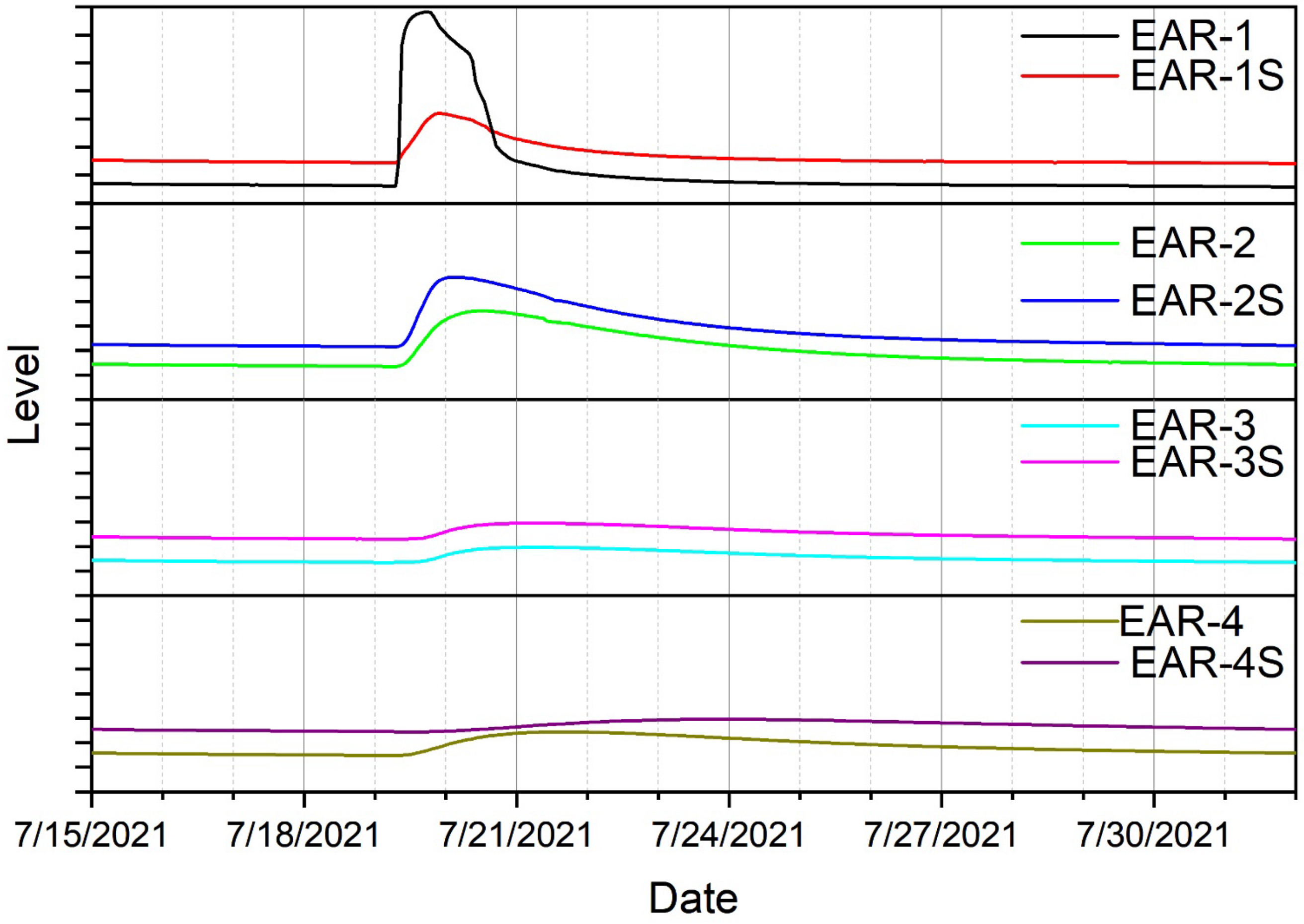

Jennings Rd
E1670 Rd
355
EAR-7I
WS-N
EAR-5I
EAR-3
EAR-4S
EAR-3S
EAR-4
Recharge Structure
EAR-2
EAR-1S
EAR-1
WS-EAR
WS-E
355
EAR-6I
Google Earth
N
1000 ft

EAR-4S
EAR-3S
EAR-3
EAR-4
EAR-2
Recharge Structure
EAR-2S
EAR-1I
EAR-1S
EAR-1
WS-EAR
Google Earth
N
300 ft

- Sinkhole estimated recharge rate ~1400 gpm based on volumetric calculations and water level declines (e.g., pressure transducer data).
- Local water levels rapidly increase after flooding of sinkhole

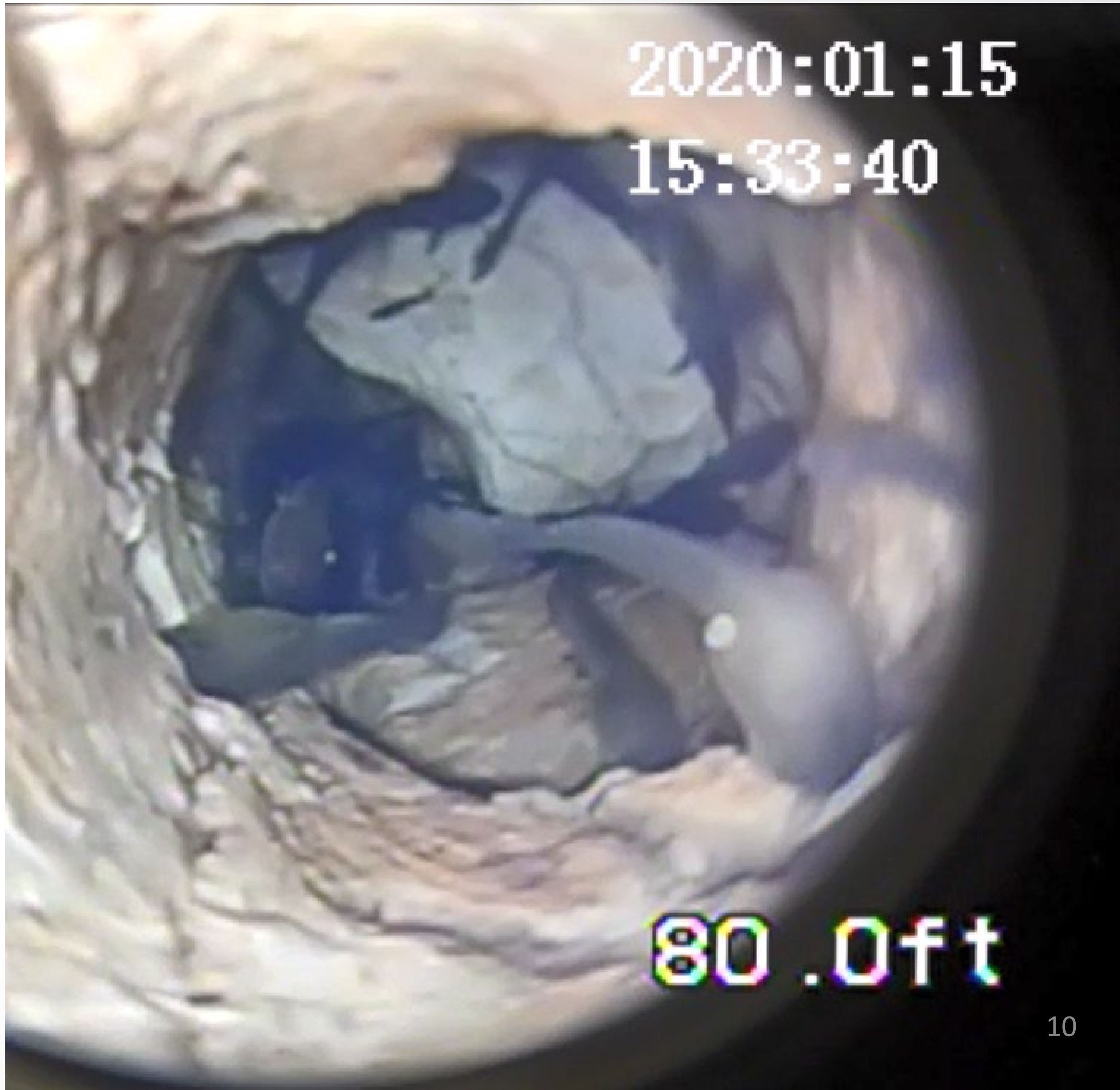
# Time To Peak Water levels (July 2021)

| Well | Elapsed Time (hr) |
|---|---|
| EAR-1 | 11 |
| EAR-1S | 14 |
| EAR-2 | 35 |
| EAR-2S | 21 |
| EAR-3 | 42 |
| EAR-3S | 42 |
| EAR-4 | 59 |
| EAR-4S | 123 |

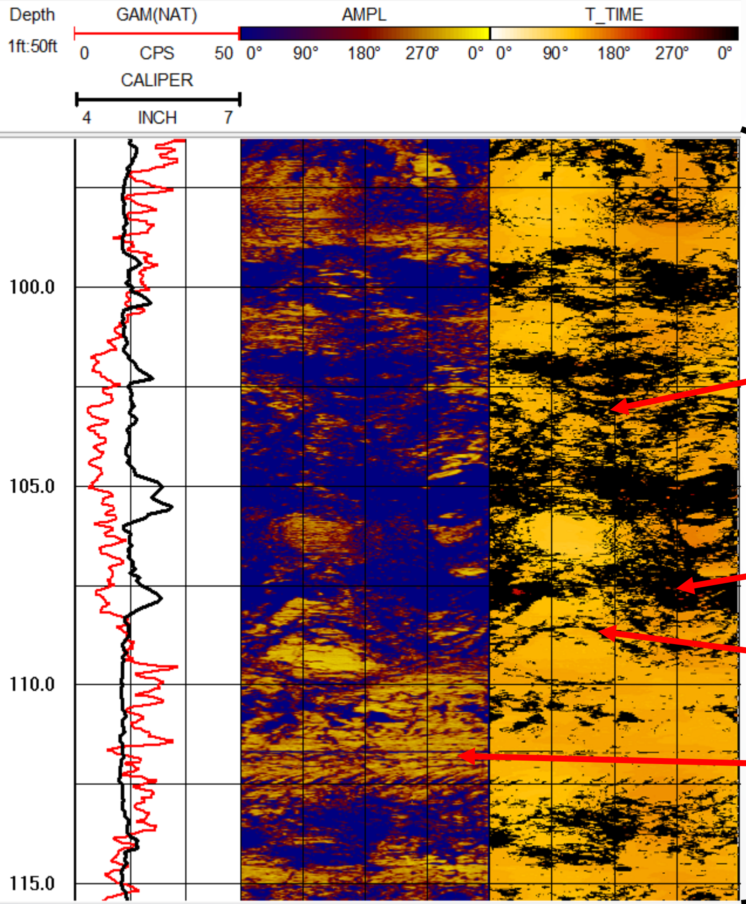


# Sink Hole Well Connectivity EAR-1

- **Rapid water level response to overland flow events.**
- **Direct connection between sinkhole (i.e., fish & tadpoles).**



# EAR Site Geophysical Logs




Fracture Trace

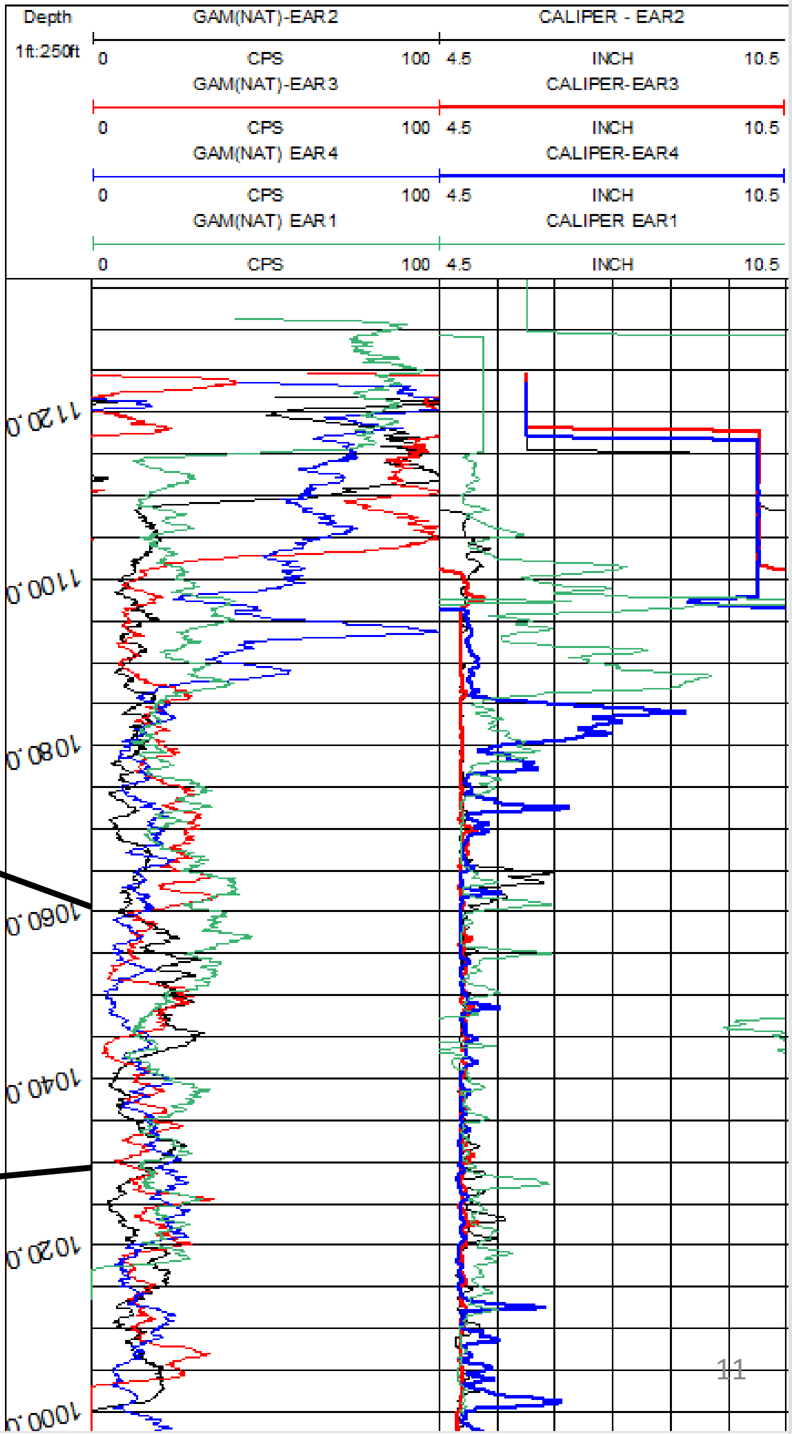
Dissolution Feature

Fracture Trace

Drill Bit Grooves
(Competent Rock)

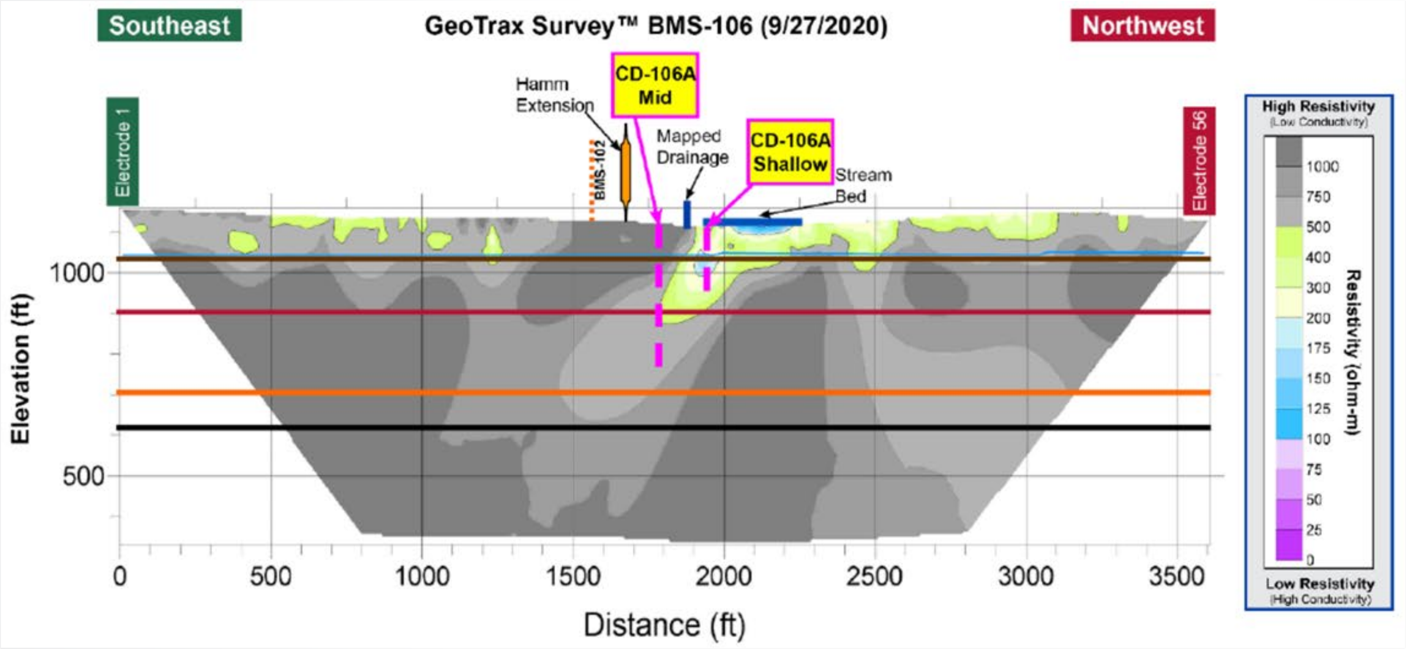
High Water Level

Low Water Level



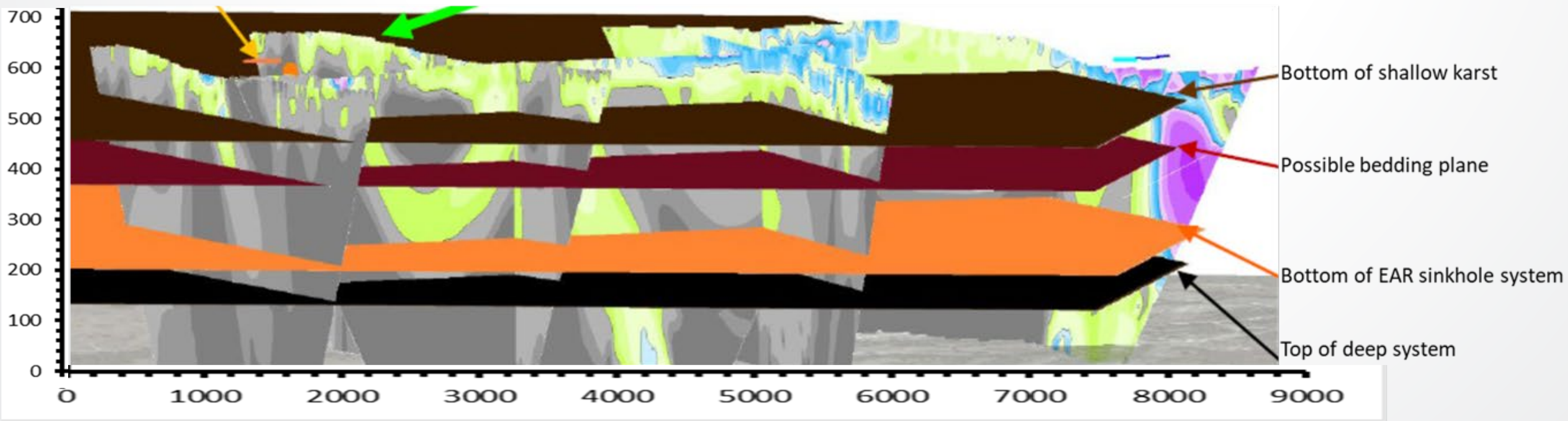

EAR-2 Acoustic Televiewer (ATV), Caliper & Natural Gamma Logs

# ERI Investigations - Deep Hydrology ("Plumbing")



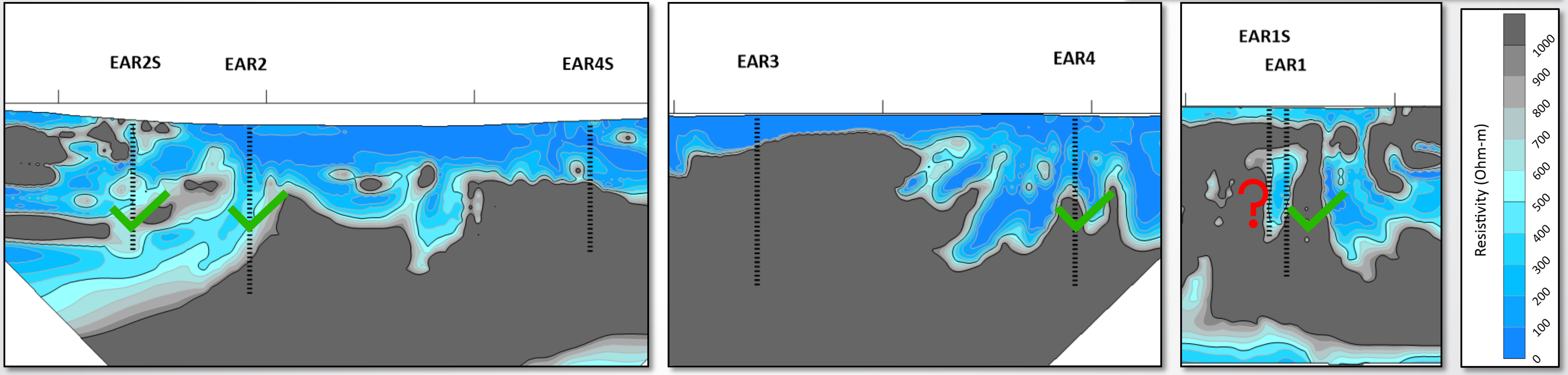

Figures from Aestus, Inc., 2020

EAR sink hole and pond



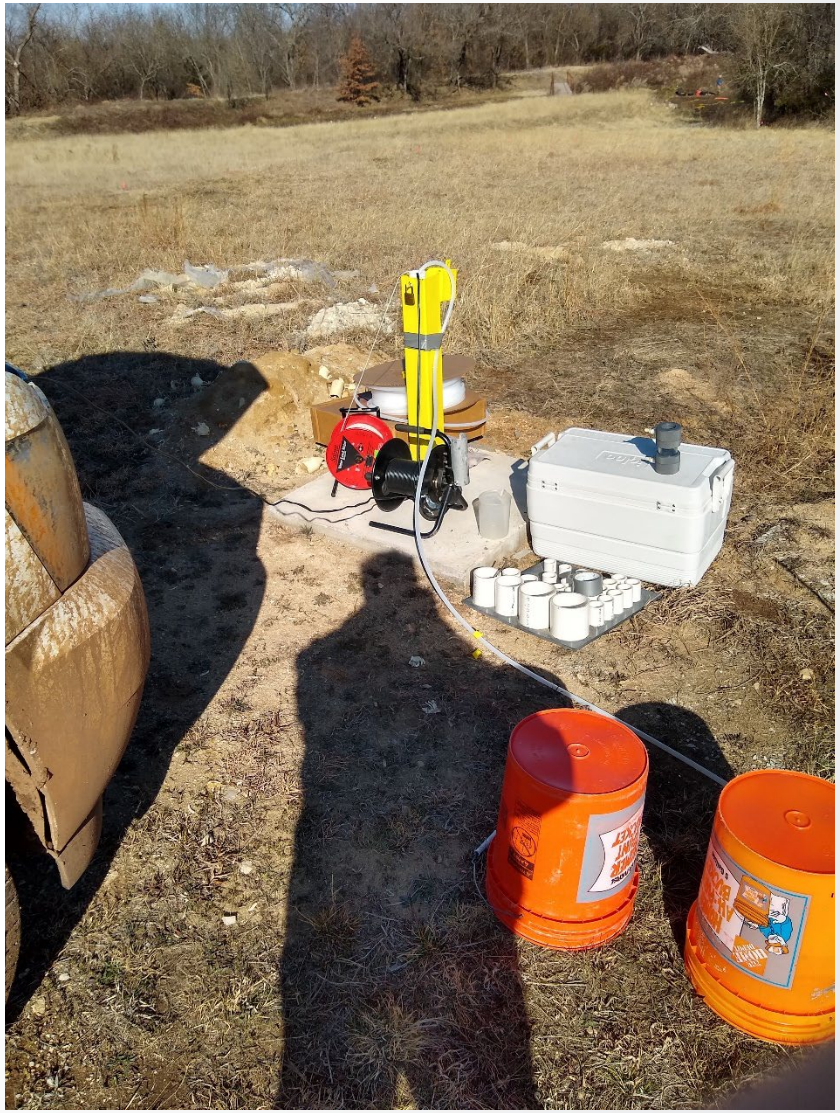
# ERI - Well siting

- 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

# Sample Types

- Groundwater
  - Wells
  - Springs
- Surface water
  - Blue River
  - Pond
- Precipitation
- Soil porewater (vadose zone)
- Climate data
- Soil/ sediment/ rock cores
- Soil moisture



# Parameters Analyzed

- Field parameters
  - T, SPC, TDS, DO, pH, ORP, turbidity, alkalinity
- Major anions and cations
  - $Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$, $Cl^{-}$, $SO_4^{2-}$, $HCO_3^{-}$, $CO_3^{2-}$
- Nutrients
  - $NO_3^{-}$, $NH_3$, $PO_4^{3-}$, TN, TP, DOC, TOC
- Trace elements
  - $F^{-}$, $I^{-}$, Trace metals
- Isotopes
  - Water isotopes ($\delta^{18}O$ & $\delta^{2}H$)
  - Strontium Isotopes ($^{87}Sr/^{86}Sr$, $^{88}Sr/^{86}Sr$)
- Volatile organic compounds
- Dissolved gases
  - $CO_2$, $CH_4$, $N_2O$
- Microbial
  - Coliforms, *E. coli*, Enterococci
  - DNA

# MAR-EAR Implementation Needs

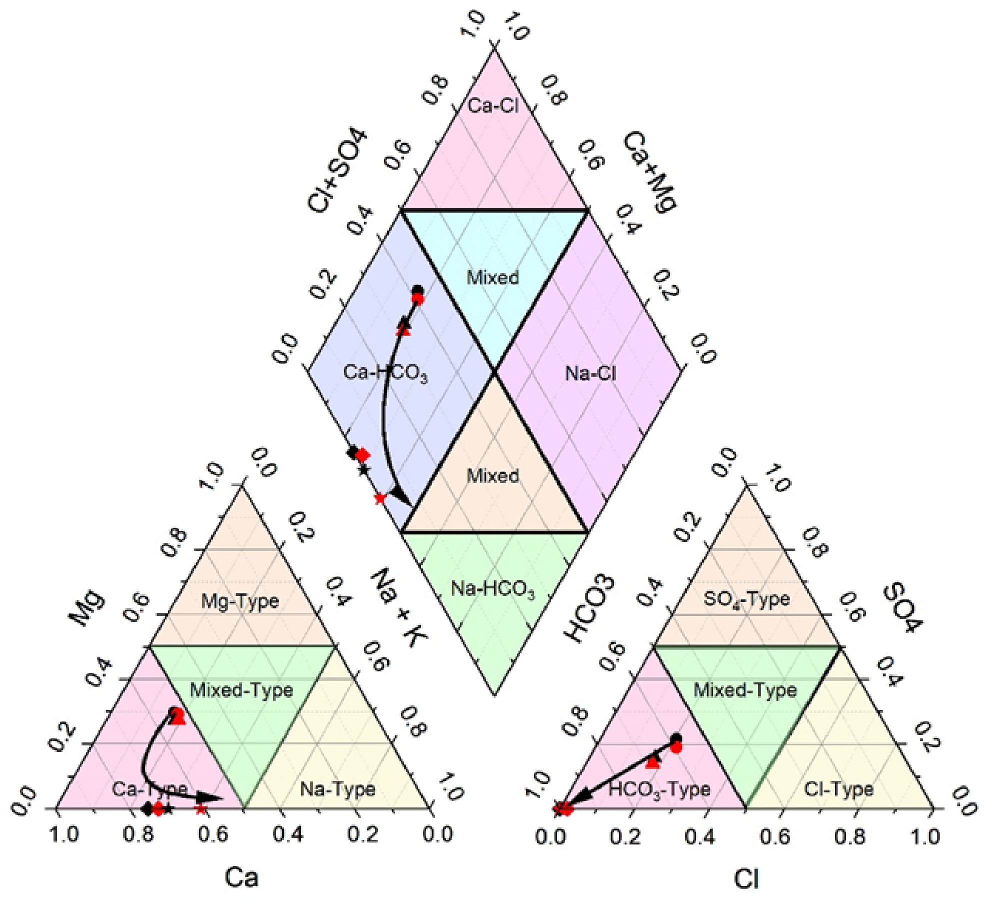
- Site Characterization
  - More than just hydrological considerations
  - Assess ambient groundwater
  - Assess the “chemical geology”
    - What are the minerals that make up the aquifers and vadose zone (likely heterogenous distribution)
    - What are the potential natural contaminants present in system
    - What are the potential biogeochemical processes
    - What conditions would cause the release of naturally contaminants

# MAR-EAR Implementation Needs Continued

- Characterization of source water
  - How will the source water “interact” with native water
  - Does the source water contain contaminants of concern?
  - Will source water potentially mobilize naturally occurring contaminants present?
  - Will source water chemically react with native water and produce contaminants of concern?
  - Will the mixing of the source water with the ambient groundwater produce potential drinking water treatment impacts?
  - Assess potential source water treatment/ mitigation strategies
- Long term monitoring
  - Assess water quality
  - Assess performance

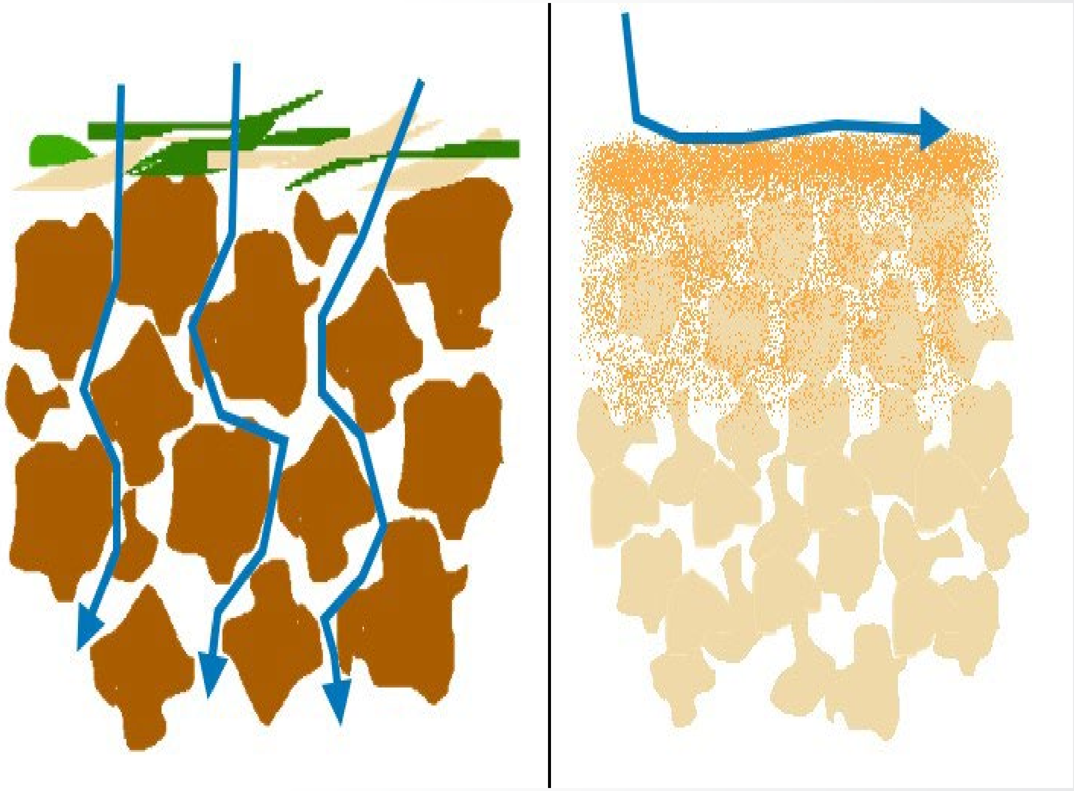
# Lessons Learned – De-icing Agents

- Mixing and dilution of infiltrated stormwater with GW caused changes to GW quality
- Concentrations of major anions and cations in stormwater <<< GW
  - Except when de-icing agents applied
- If GW is used for drinking water:
  - Dilution and increasing sodium can cause water type changes
  - Impacts to drinking water treatment are possible



# Lessons Learned – De-icing Agents

- De-icing can impact water quality and quantity
- Data suggested reverse ion exchange was occurring in vadose zone
  - Loads sodium onto particle surface (e.g., clays)
  - Dispersion of particles
  - Reverse ion exchange can lead to:
    - Clogging
    - Diminished infiltration and water movement
- Enhanced mobility of some metals could be problematic when chloride salts are applied as de-icing agents and stormwater is infiltrated

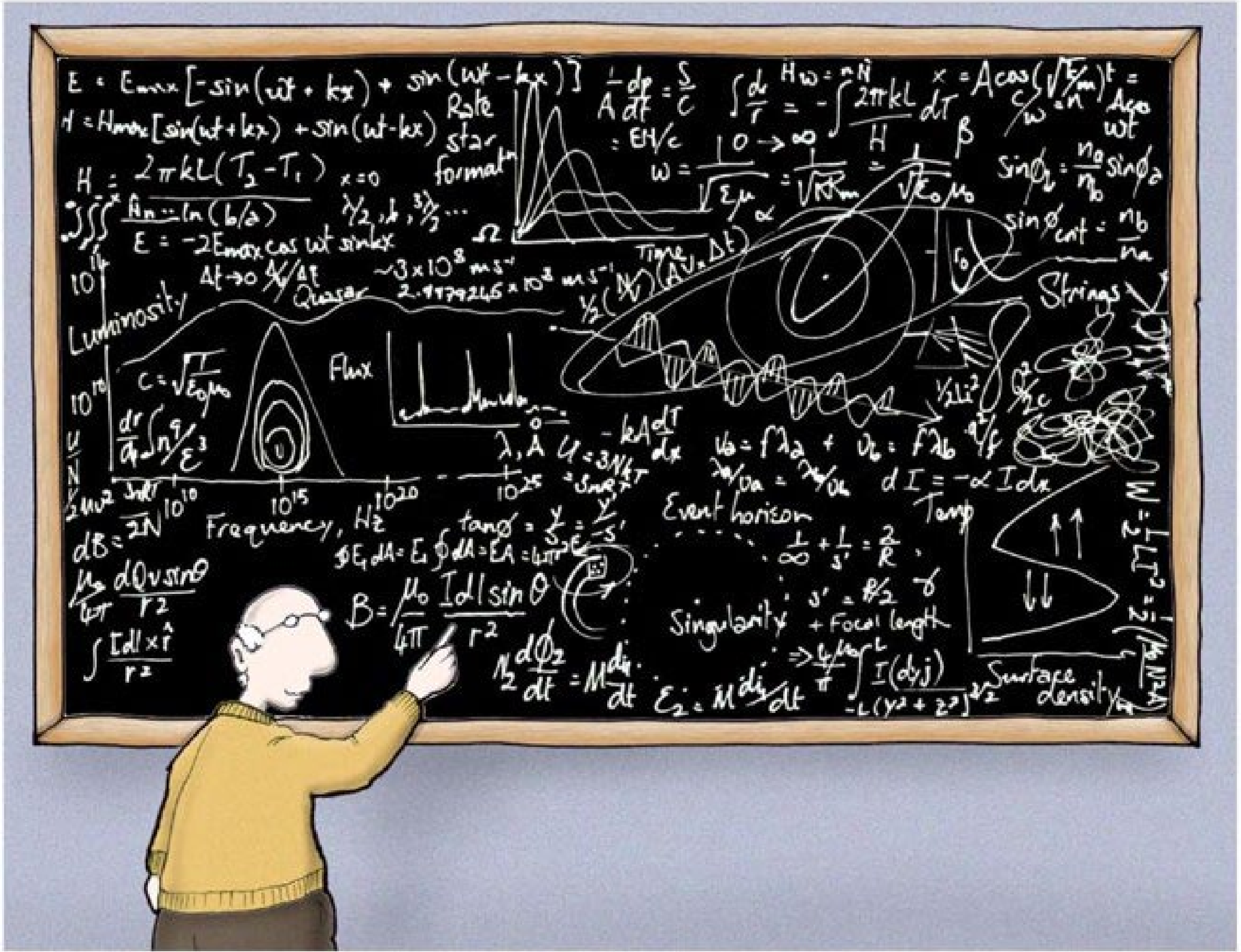


Healthy Soil

Dispersed Soil

Source: Linnburn Station, 2020

# Question?



Luminosity
Flux
Frequency, Hz
Quasar
Event horizon
Singularity
Focal length
Strings
Temp
Surface density