Managed aquifer recharge utilizing riverbank filtration and groundwater transfer and injection: A potential technology for sustainable groundwater-irrigated agroecosystems

by

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USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Groundwater Protection Council
ASR-MAR in Agriculture
3 October 2022

Partnerships

USDA ARS – Research lead, funding, and O&M

U.S. Army Corps of Engineers – Design, construction, and O&M

Extensive stakeholder support:

- Delta Council
- Delta Farmers Advocating Resource Management
- Mississippi Department of Environmental Quality
- Mississippi Farm Bureau Federation
- Mississippi Soil and Water Conservation Commission
- USDA Natural Resources Conservation Service
- U.S. Geological Survey
- Yazoo Mississippi Delta Joint Water Management District

Why Sustainable Aquifer Management?

- ➢ *Sustainable groundwater* is a <u>prerequisite</u> for *sustainable development*
- ➢ *Managed Aquifer Recharge (MAR)* technology can support sustainable management of aquifers

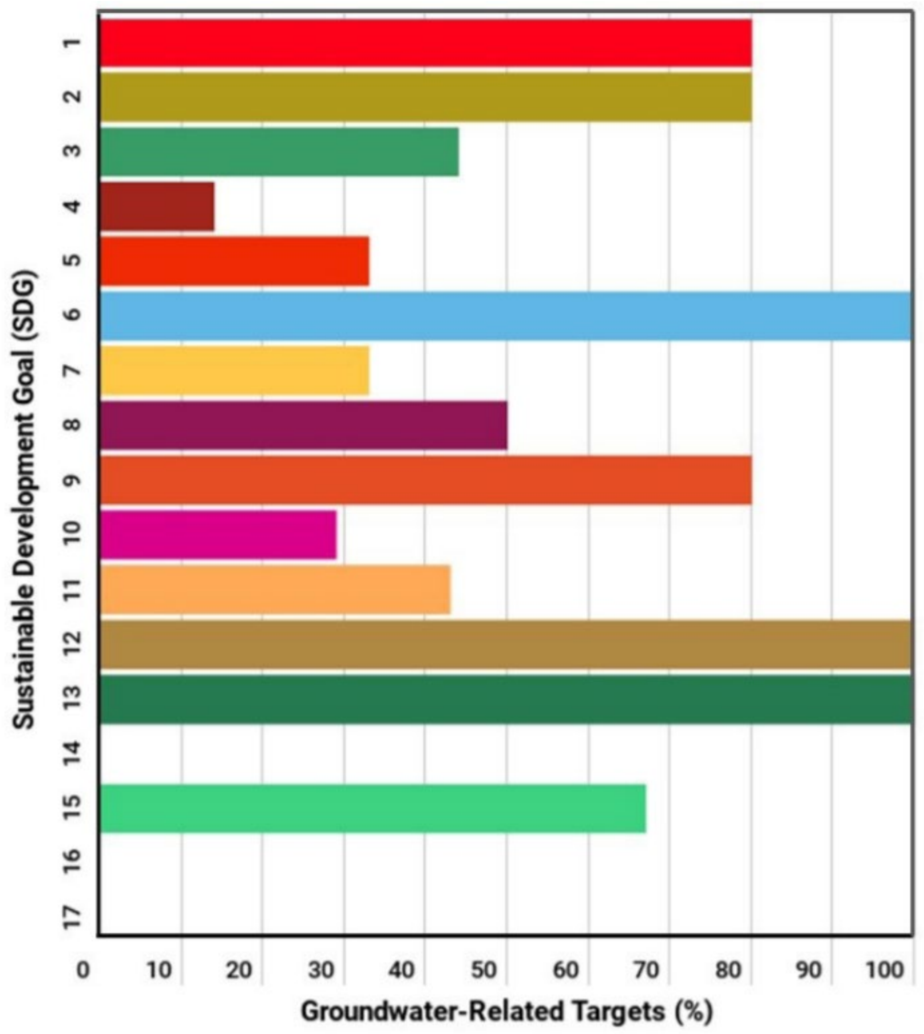

Figure 1. Percentage of groundwater-related targets per SDG

SOURCE: Guppy, L., Uyttendaele, P., Villholth, K. G., Smakhtin, V. 2018. *Groundwater and Sustainable Development Goals: Analysis Of Interlinkages*. UNU-INWEH Report Series, Issue 04. United Nations University Institute for Water, Environment and Health, Hamilton, Canada.

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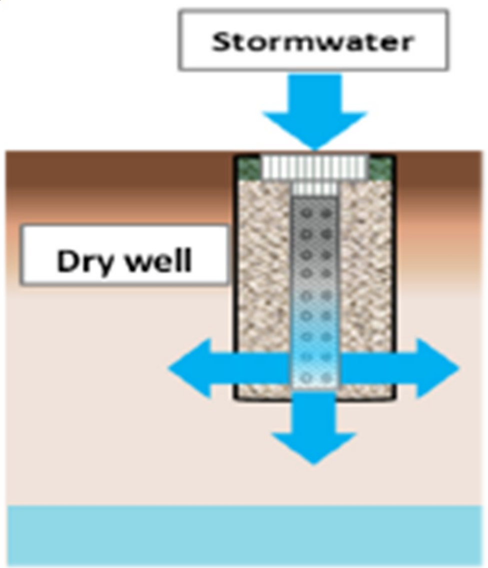
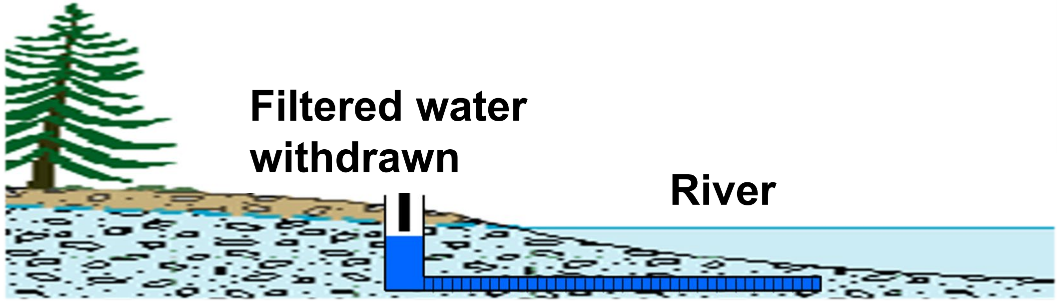
Managed aquifer recharge (MAR)

- Three general types of recharge systems:
  - Surface infiltration, e.g. basins
  - Vadose-zone infiltration, e.g., wells, trenches, galleries
  - Direct injection with wells

- Alternative water sources (AWS) – use *non-groundwater* sources
  - Stormwater harvesting
  - Surface water (riverbank filtration)
  - Reclaimed water (treated wastewater)



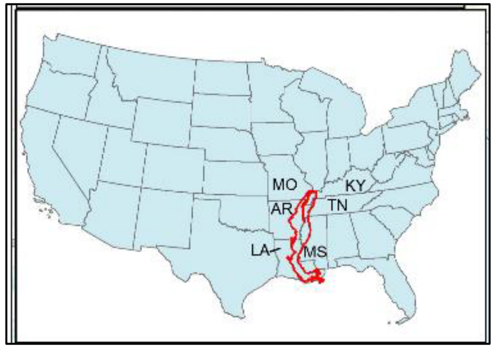
SOURCE: California Environmental Protection Agency



SOURCE: Water Conserv II facility, Orlando, Florida

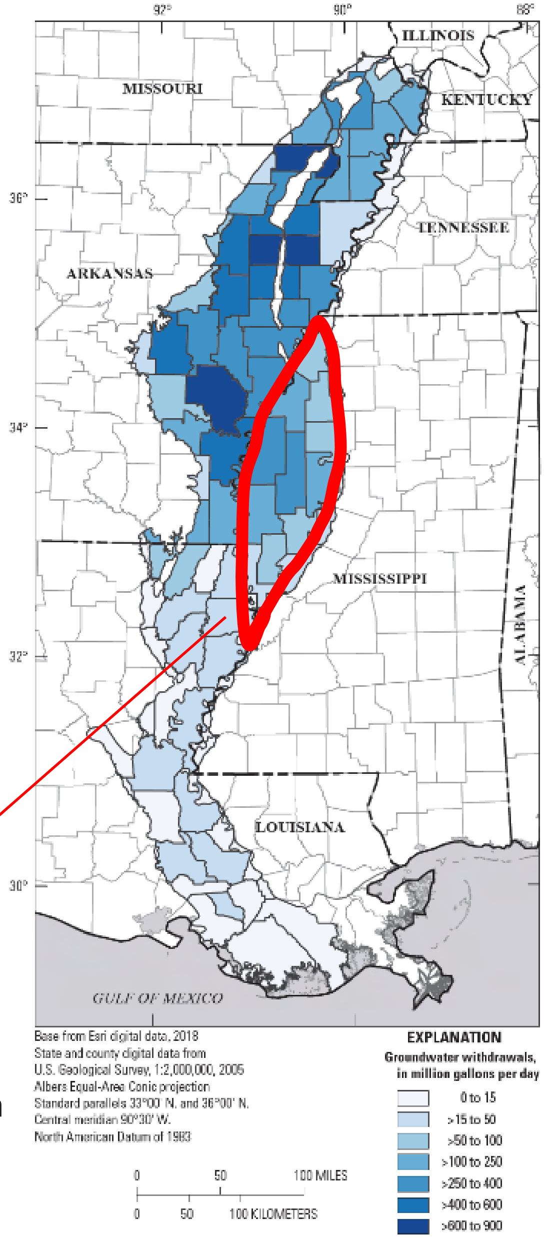
Second highest GW withdrawals in the United States

- The *Mississippi River Valley alluvial aquifer (MRVAA)* had the second highest groundwater withdrawals of any principal aquifer in the U.S. of *12.1 Bgal/day*
- In the humid southeastern U.S, we get a lot of rain – still can have *imbalances* between aquifer inflows (recharge) and natural outflows and pumpage



Groundwater withdrawals for the year 2015

Mississippi Delta



SOURCE: Lovelace, J.K., Nielsen, M.G., Read, A.L., Murphy, C.J., and Maupin, M.A., 2020, Estimated groundwater withdrawals from principal aquifers in the United States, 2015 (ver. 1.2, October 2020): U.S. Geological Survey Circular 1464

THE MISSISSIPPI DELTA…

Source: https://www.bbking.com/gallery/

Source: http://www.mississippibluestravellers.com/mississippi-freedom-trail/

- Birthplace of the blues and other uniquely American musical genres
- Extreme hardship due to the history and enduring legacy of slavery, sharecropping, segregation, and racism and the unpredictability of the Mississippi River itself
- Major producer of food, fuel, and fiber products, yet many communities are suffering from pervasive and long-term economic depression
- Increased water security thorough sustainable management of the MRVAA would support a sustainable agroecosystem and economic opportunity in the Delta

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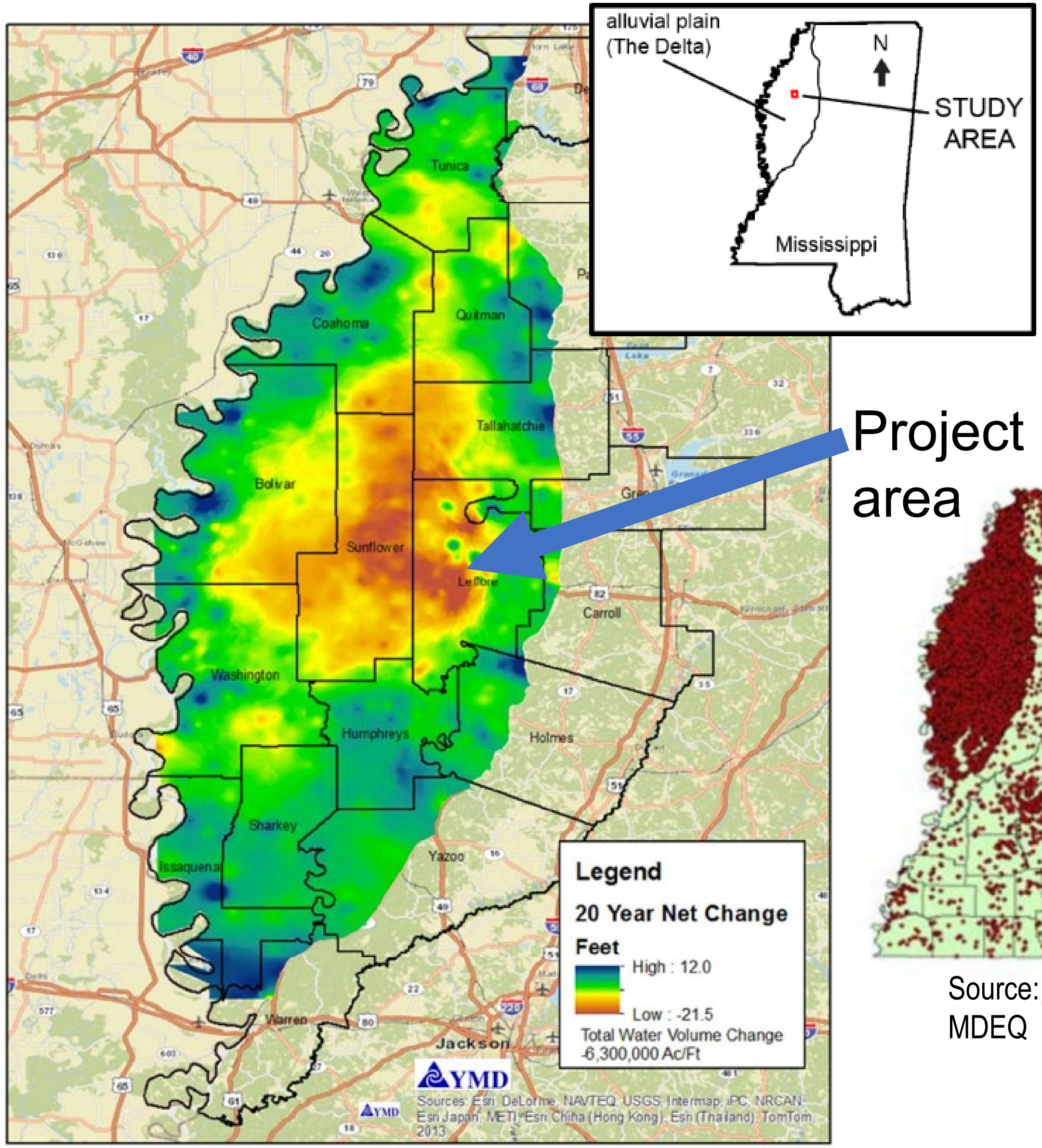
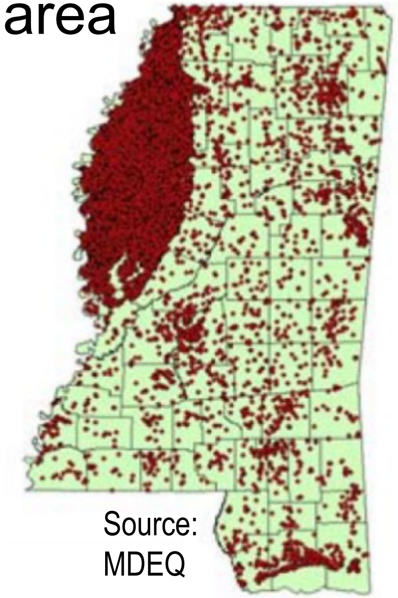
Mississippi Delta –
A groundwater-irrigated agroecosystem under stress



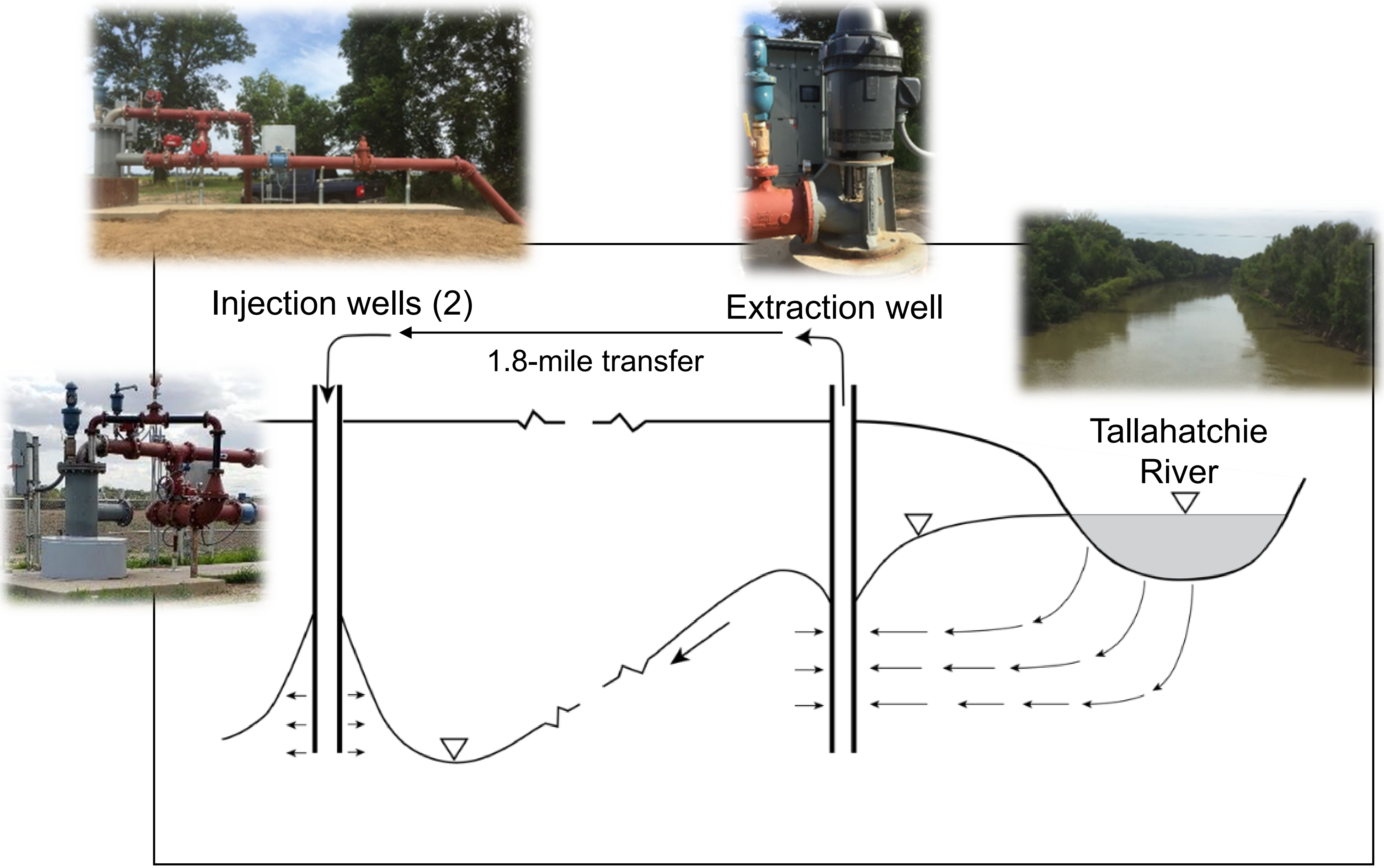
Source: YMD Joint Water Management District, 2014 Water Level Survey



Source:
MDEQ

- 3,000 → 21,000 irrigation wells from 1980's to today
- Pumpage 1.61 Bgal/day in 2015
- 3.3 Million ac-ft of GW loss within the cone of depression from 1987 to 2009
- *Aquifer injection and storage* identified as a MAR technology to potentially reverse groundwater depletion

Groundwater Transfer and Injection Pilot Project



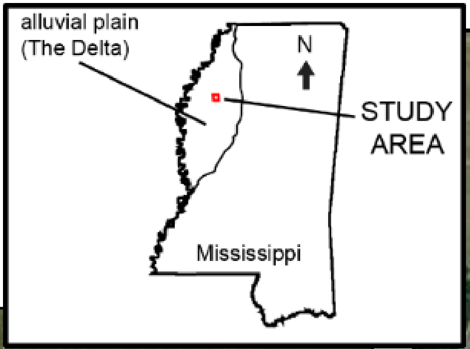
1) ***Extract*** groundwater of improved quality via riverbank filtration
2) ***Transfer*** water to area of greater groundwater depletion
3) ***Inject*** water into aquifer storage
4) Withdraw groundwater as needed using ***existing infrastructure***

Project objectives

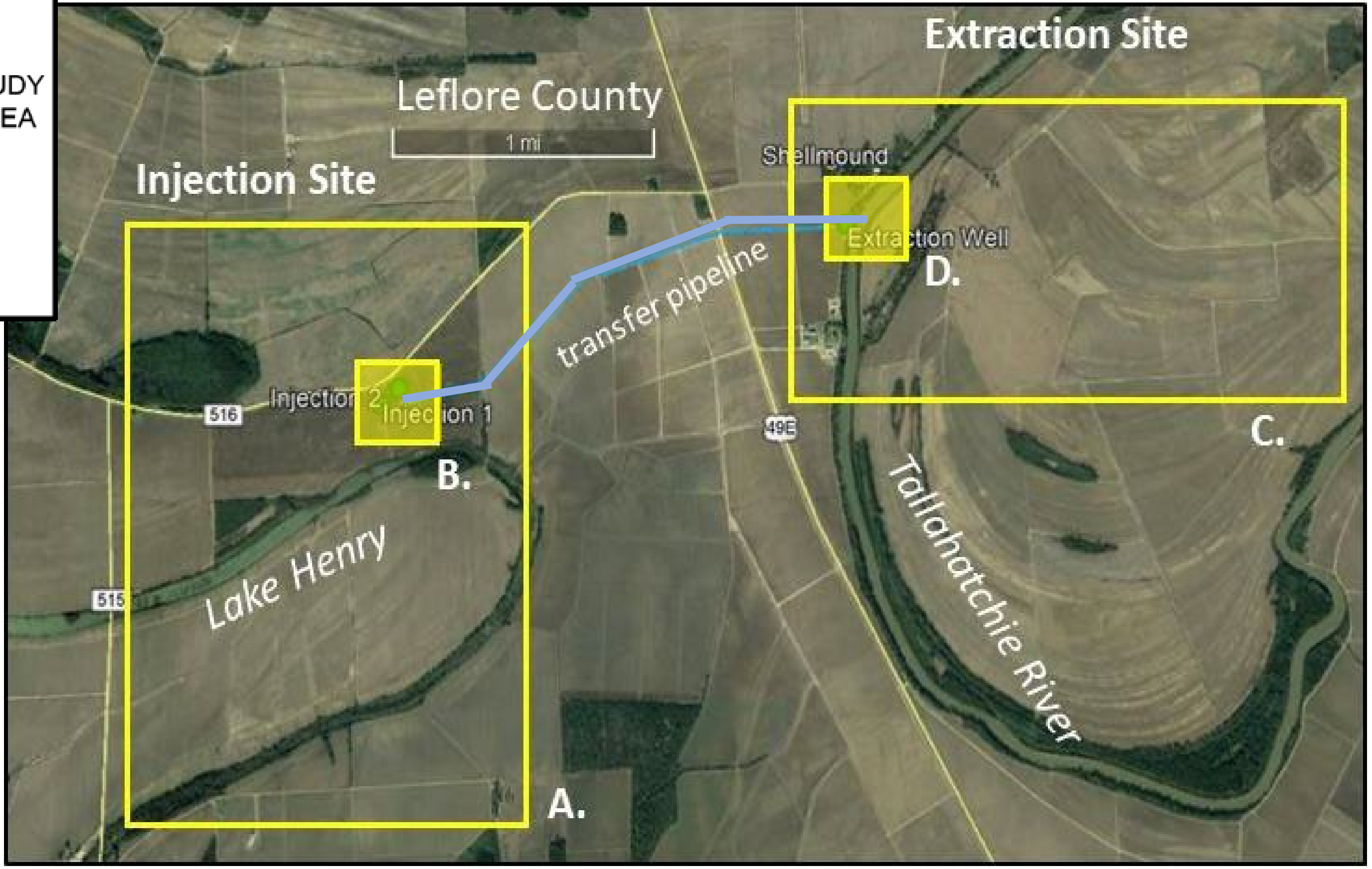
- Pilot facility to *assess feasibility*
- Identify *sustainable injection* rate and *O&M requirements*
- Is this a viable path toward *sustainability* in the region?

Extensive soybean and corn fields surrounding injection well site (looking south)

System configuration



Backflush discharge into Lake Henry



Extraction and Injection sites at Shellmound, Mississippi

System characteristics

- $1.9 million construction costs
- One extraction well with variable frequency drive (up to 1,500 gpm)
- Two injection wells, each with permitted capacity 750 gpm
- 16-inch diameter wells
  - Extraction well: 63–113 ft depth of withdrawal
  - Injection wells: 80–120 ft depth of injection
- Submersible pumps in both injection wells for backwash (1,200 gpm)

Operational tests

➢ <u>Injection Period #1, 3-month test</u> :

- April 14 – July 12, 2021
- Injected total of 550 ac-ft
- Average injection rate 730 gpm/well (total 2.1 MGD; minimum daily mean river flow is 378 MGD)
- Well clogging, leaks, and rehabilitation

➢ <u>Injection Period #2, 6-month test</u> :

- February 8 – August 31, 2022
- Injected total of 575 ac-ft
- Two wells (570 gpm/well); alternating wells (600 gpm/well) began May 13
- Backflushed twice per week
- Successfully minimized well clogging

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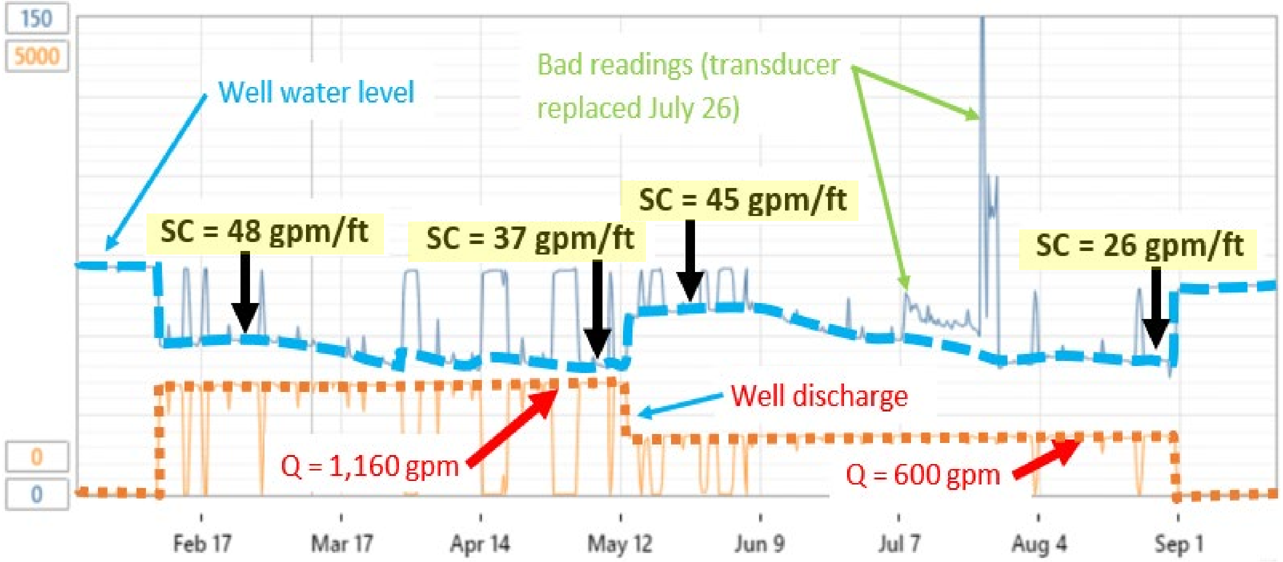
Some challenges…

- Natural *high iron concentrations*
  - Biofouling of injection wells
  - Discharge of backflush water to Lake Henry exceeds 1 mg/L total iron limit in NPDES permit



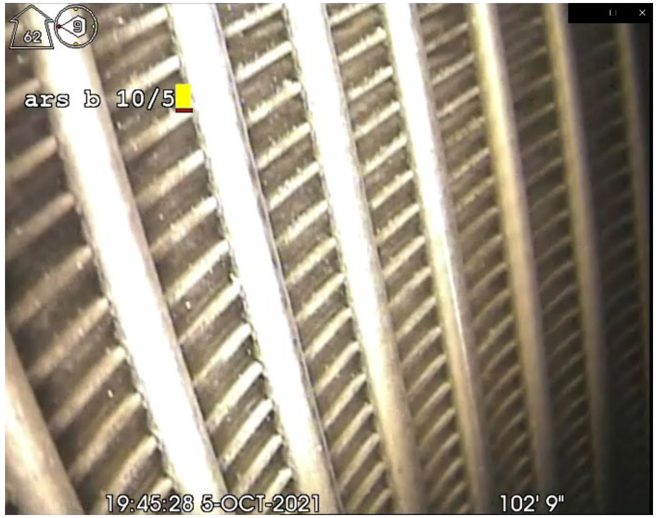
- *Sand boils and leakage* of water at land surface at injection wells
- *Sinkhole* at extraction well

- *Decreasing specific capacity* of extraction well possibly due to sinkhole and reduced recharge from river during low stage

Sand boils and well rehabilitation

- Most-permeable injection zones *clogged* with iron bacteria causing *increased pore-water pressure*
- Exceeded buoyant weight of overburden
- USACE conducted *oxalic acid rehabilitation* of both injection wells Sept. 22–28, 2021
- Specific capacity returned to *~95%* initial value (~35–45 gpm/ft, May 2021); now (Aug 2022) *~130%* initial value

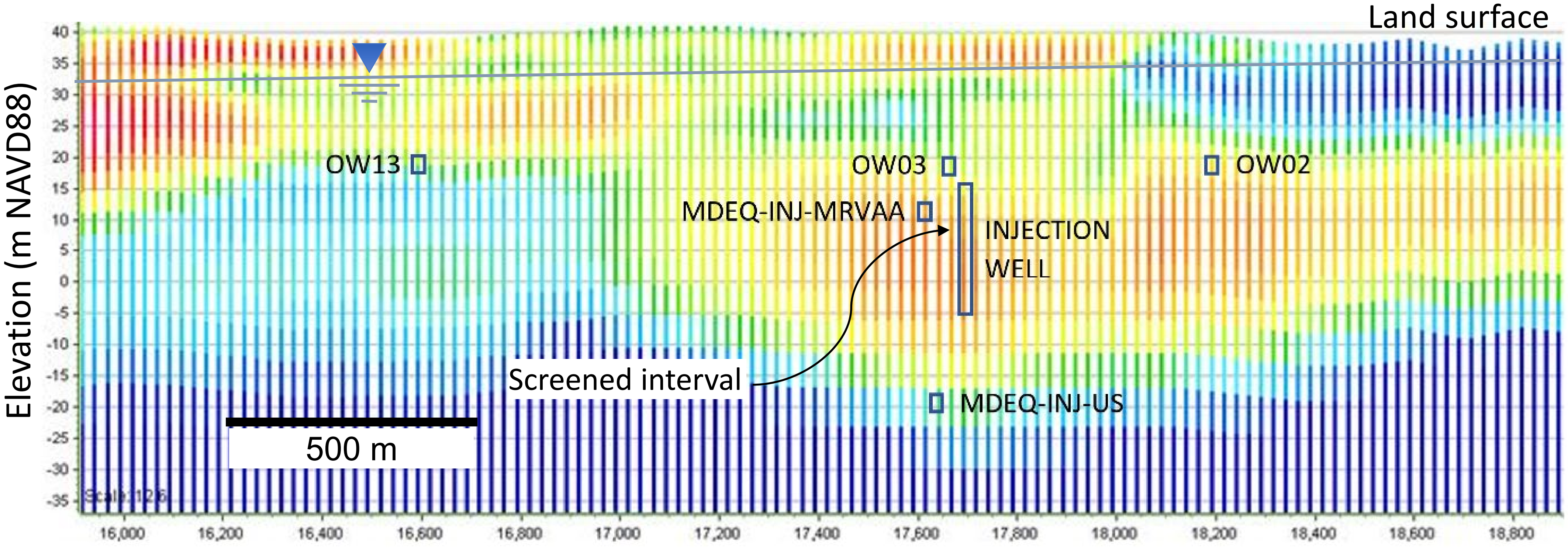
Injection Well B before rehab



Injection Well B after rehab

Airborne electromagnetic geophysical survey by USGS shows complex geological heterogeneity

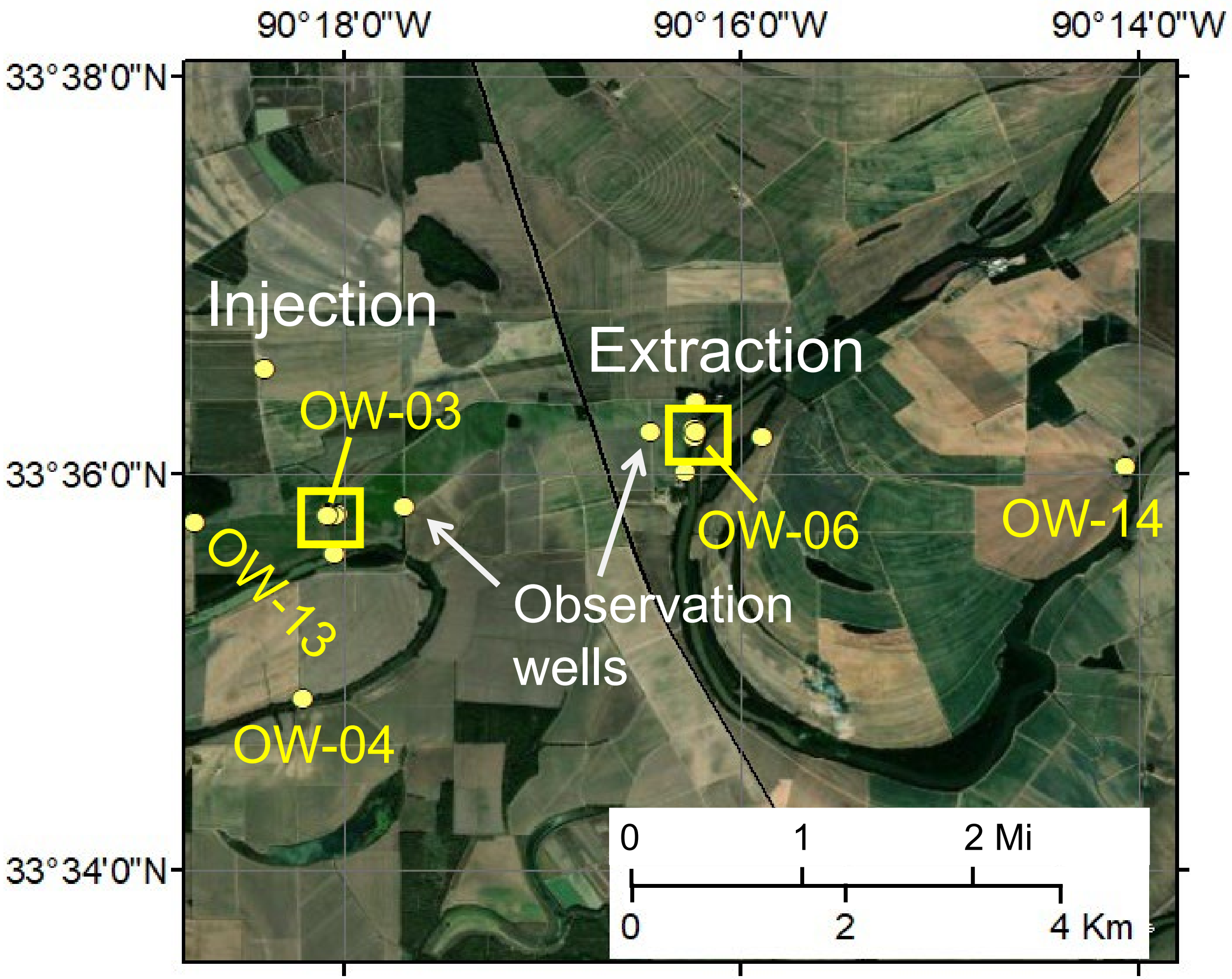
- Variations in lithology likely contributed to soil piping at injection wells (& extraction well)
- Higher resistivity (yellow and warmer colors) are more sandy texture sediments
- Heterogeneity a key control on groundwater flow and quality



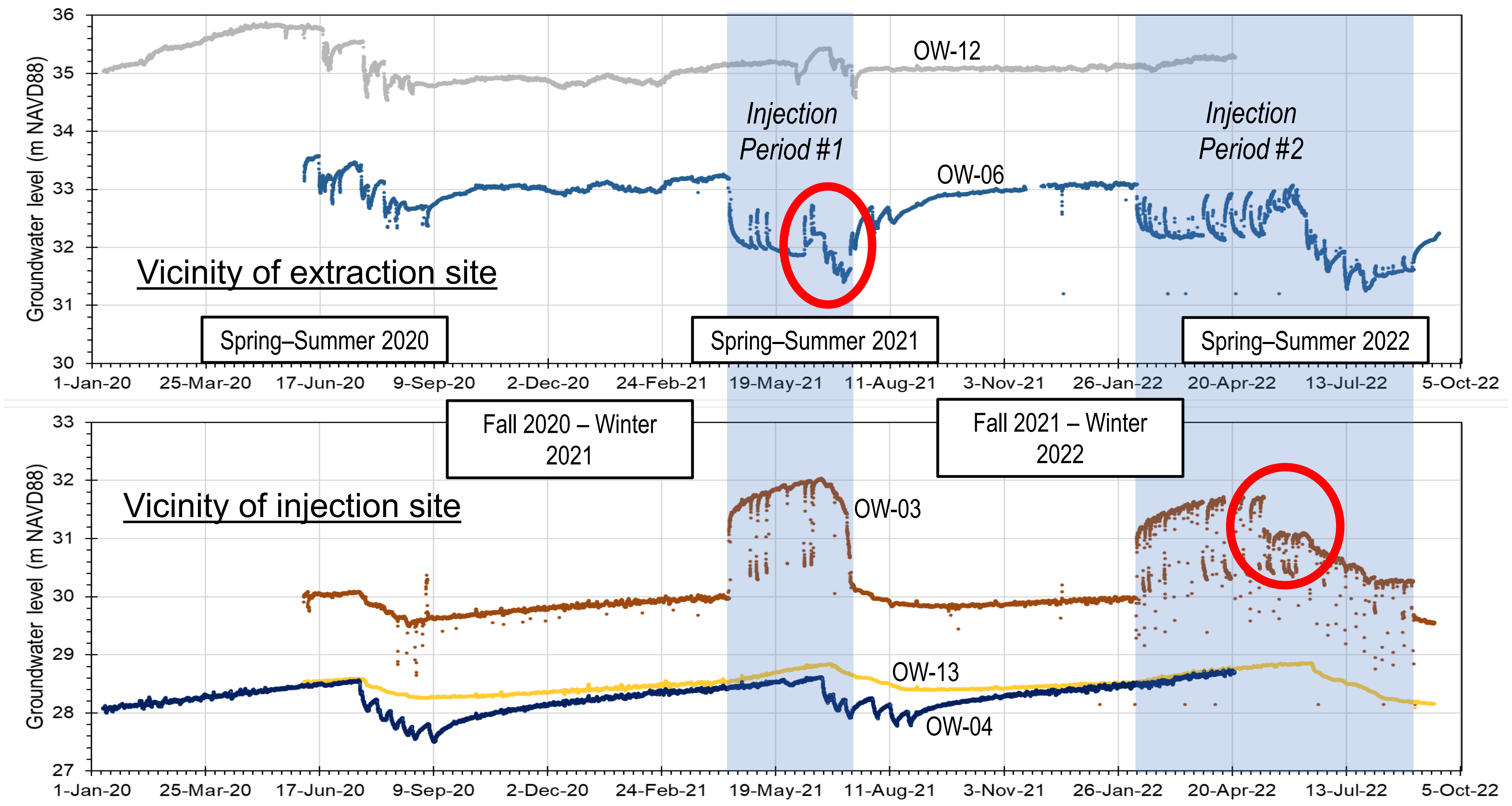
Source: Burton, B.L., Minsley, B.J., Bloss, B.R., Rigby, J.R., Kress, W.H., and Smith, B.D., 2019, Airborne electromagnetic, magnetic, and radiometric survey, Shellmound, Mississippi, March 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P9D4EA9W

Groundwater impacted by system operation

- 17 Observation wells
- Monitor *hourly groundwater level* since January 2020
- Collect samples for *monthly lab groundwater quality* during injection since March 2021

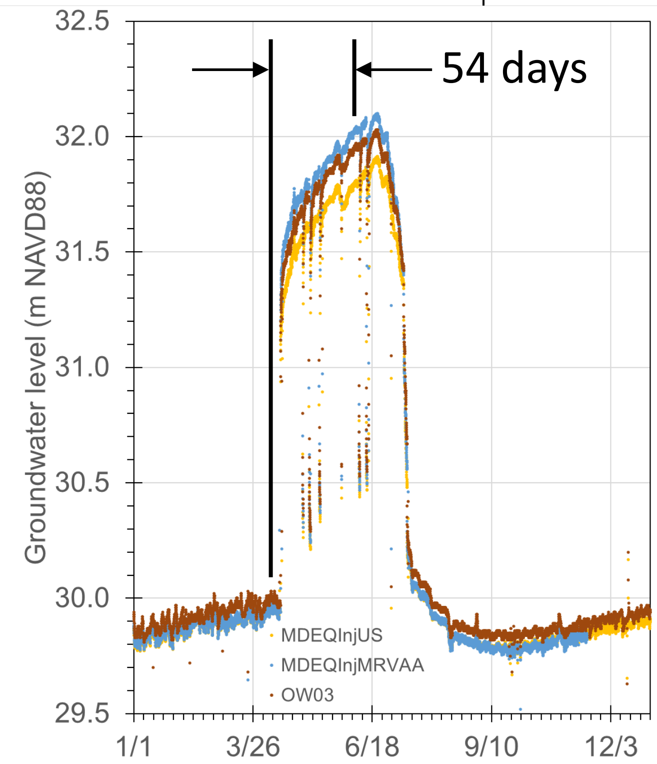


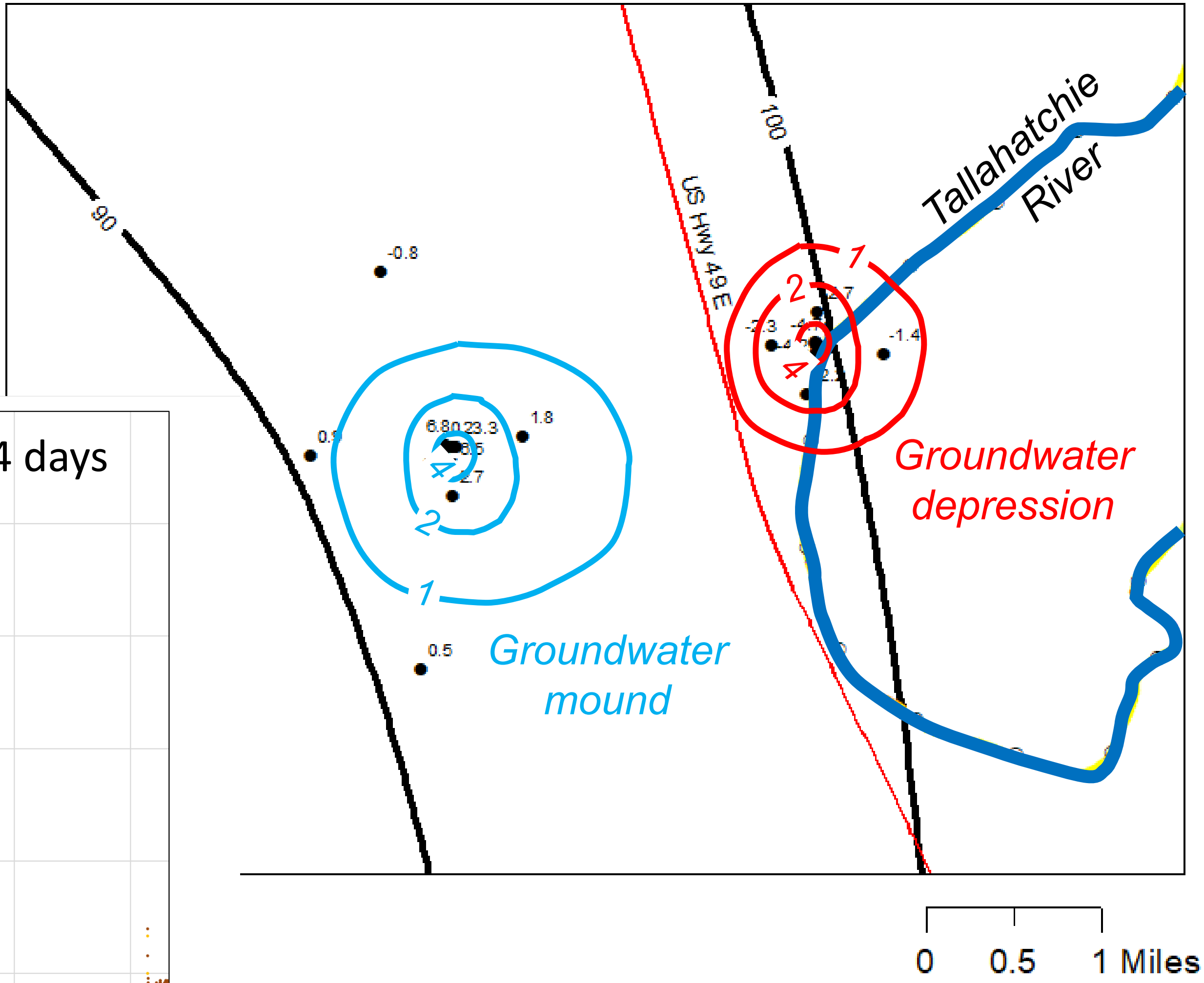
Groundwater levels vary by season, withdrawals, and injection



Water level impacts larger from injection than extraction

- Water level change 54 days into Injection Period 1 (June 7)
- Groundwater mound up to 7 ft high
- Groundwater depression up to 5 ft deep
- Depression smaller than mound likely due in part to recharge by river water



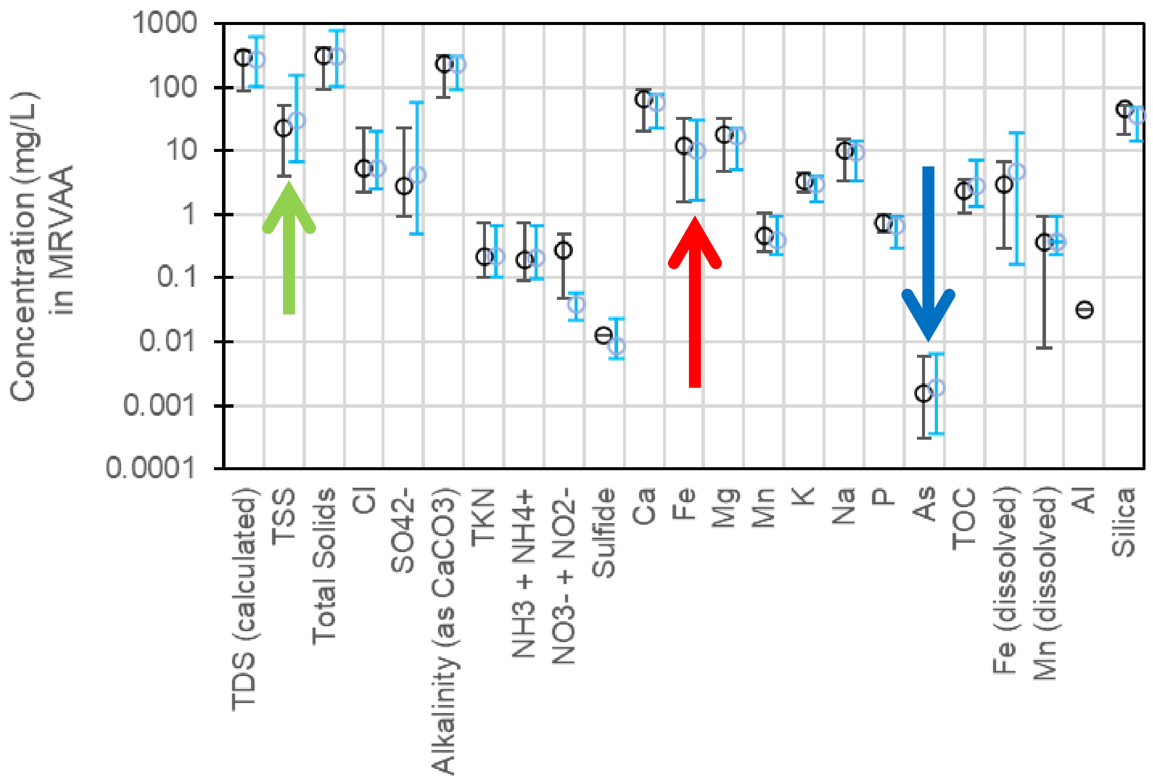


Large water quality changes during riverbank filtration, Small GW quality changes during injection

- River oxic, high TSS
  GW suboxic/anoxic, low TSS
  - River: Diss. O_2 6+ mg/L
  - Wells: Diss. O_2 <0.3 mg/L
  - River → GW: **TSS** ~10x decrease
- High **Iron** concentration
- Low **Arsenic** concentration. USEPA drinking water limit 0.01 mg/L
- Overall, small changes in MRVAA water quality
- Larger changes during second injection period?

March and **November** 2021 sampling events

Observation wells: Median & Minimum-Maximum range



Current Status and Future Work

- ➢ Pull pumps in all wells, video log, assess condition, and perform maintenance
- ➢ Determine best O&M practices for safe ***injection rate*** and ***backflush frequency***
- ➢ Assess environmental and hydrological sustainability of the technology
  - Regional modeling – USGS
  - Local-scale modeling, Hydrogeology, and Geochemistry – USDA-ARS and Univ. of Mississippi
- ➢ Assess technical and economic feasibility of a larger scale implementation

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Thank You

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