Institute for Energy Innovation

Assessing CO_2 Geologic Storage Impacts on Louisiana's Water Resources and Environment

Progress Update

Frank Tsai, PhD, PE, PG

Professor, Department of Civil and Environmental Engineering
Director, Louisiana Water Resources Research Institute
Louisiana State University

Institute for Energy Innovation

NSF EPSCoR
Established Program to Stimulate Competitive Research

USGS
science for a changing world

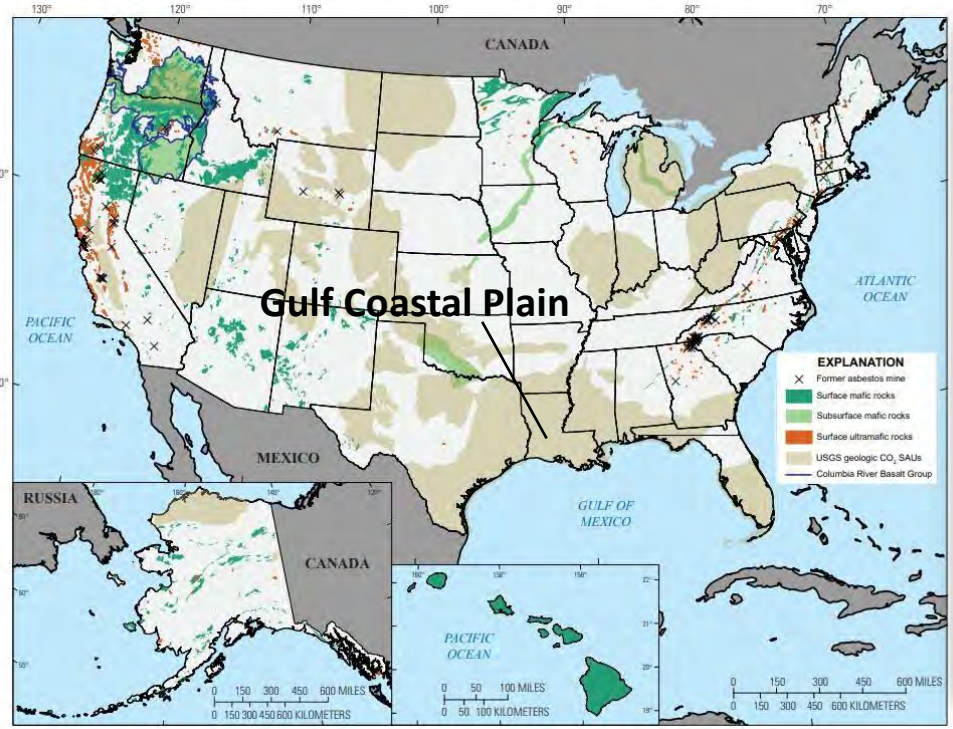
July 25, 2024

Outline

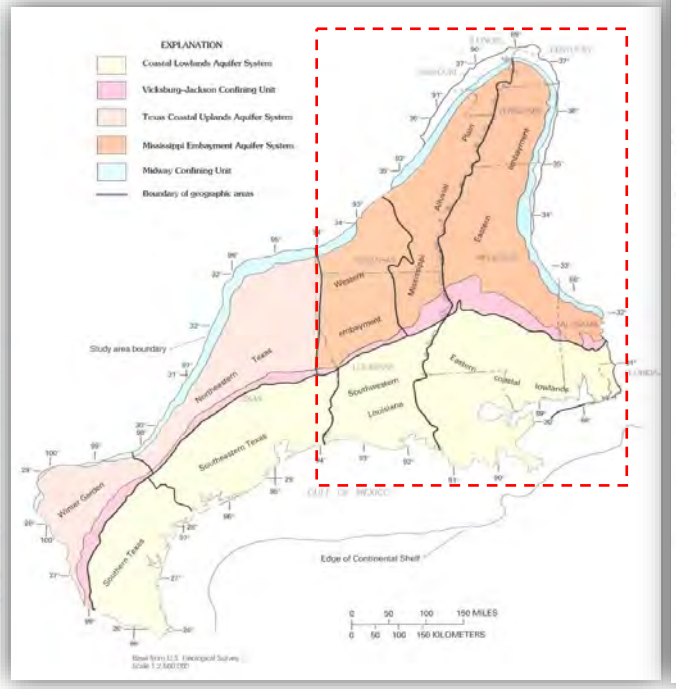
- Motivation
- Project overview
- Large-scale geological and groundwater model development
- CO_2 transport simulation and baseline information collection for understanding carbon budget and land-surface deformation
- Next steps

CO_2 Geologic Storage in the Gulf Coast Region

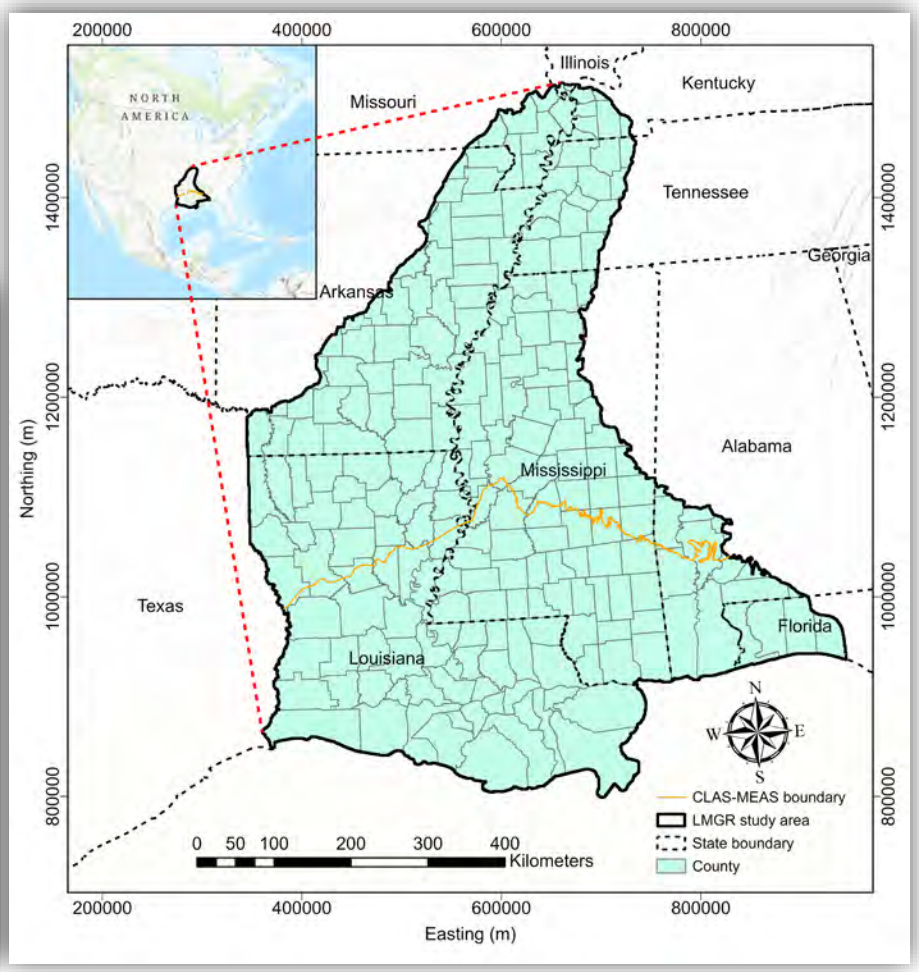
- The Coastal Plains region has the most storage potential for CO_2, accounting for 65% of the national total.
- The Gulf Coast region of the United States has a large storage capacity for carbon dioxide (CO_2) through geologic sequestration. It accounts for 59% of the national CO_2 storage capacity. (USGS Circular 1386, 2012).



Geologic Carbon Storage Potential in the United States (Blondes et al. 2019)

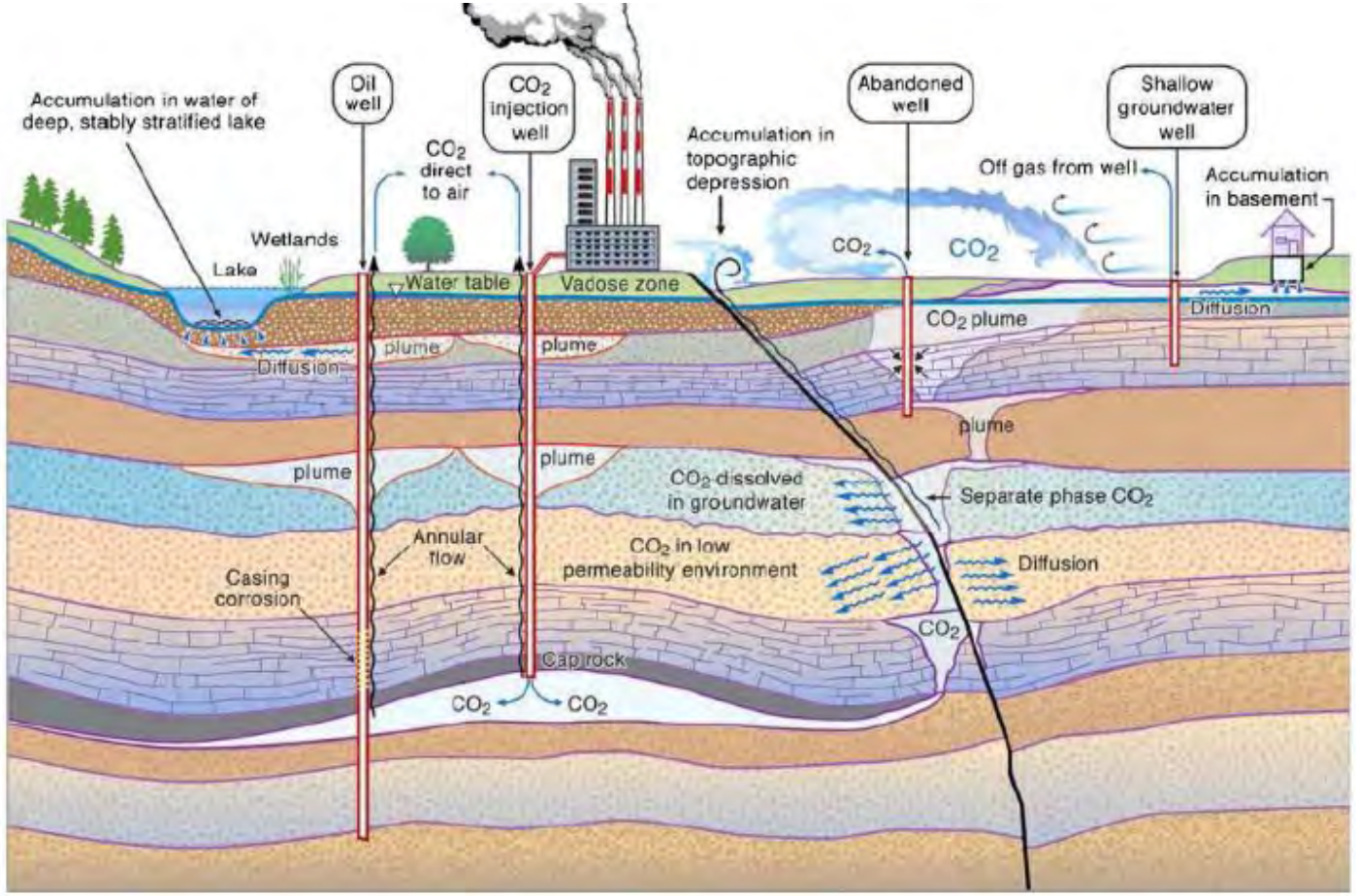


Gulf Coast Aquifer System (Grubb, 1998)

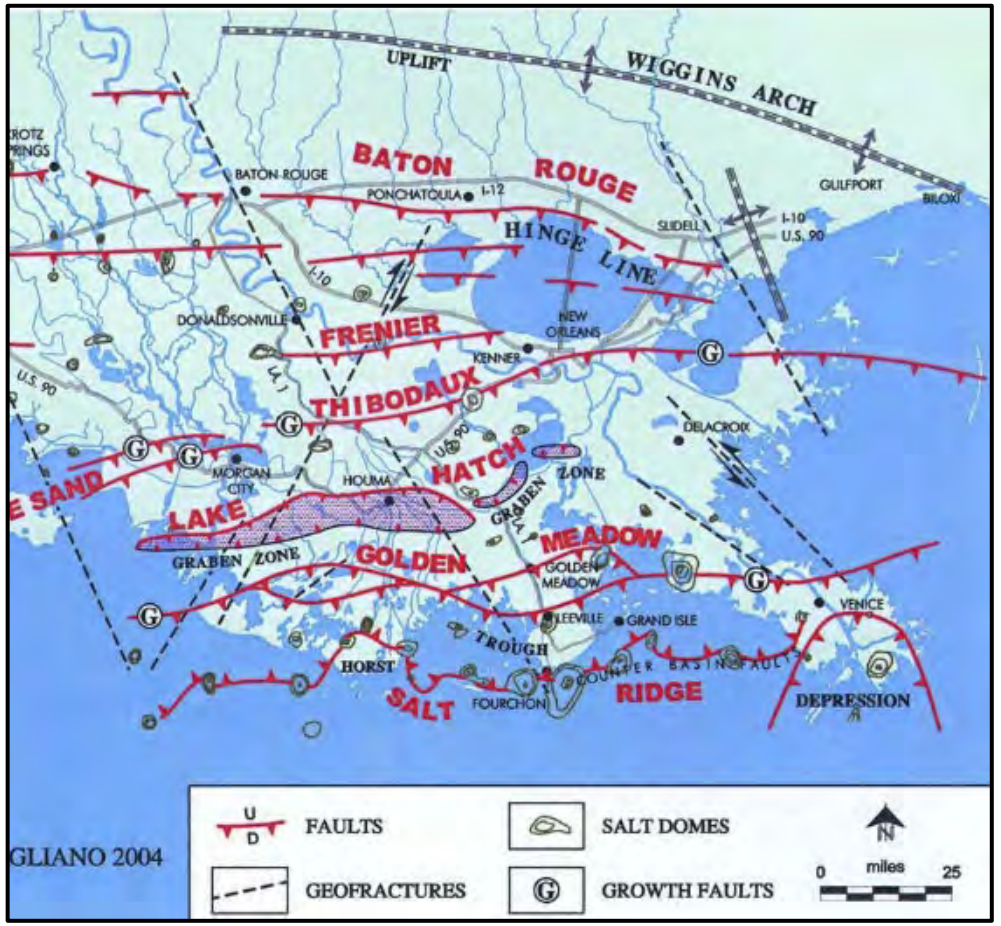


Lower Mississippi Gulf Region (LMGR)

Concerns of CO_2 Geologic Storage



Potential leakage pathways and consequences (Benson and Hepple 2005)



Major geological structural features in southeast Louisiana (Gagliano 2004)

5

Project Overview

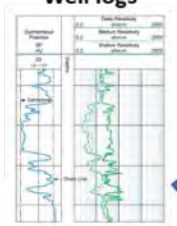
- Funding Source: LSU Institute for Energy Innovation
- Funding Program: Research for Energy Innovation 2023-I (Phase I)
- Project Title: Assessing CO_2 Geological Storage Impacts on Louisiana's Water Resources and Environment (Experimental)
- Project Period: 10/9/2023 – 10/8/2025 (2 years)
- Project Team:
  - Frank Tsai, Professor, Department of Civil and Environmental Engineering
  - Christopher Kees, Associate Professor, Department of Civil and Environmental Engineering
  - Yi-Jun Xu, Professor, School of Renewable Natural Resources
  - Ahmed Abdalla, Assistant Professor, Department of Civil and Environmental Engineering

Project Overview

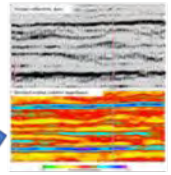
Project Goal: Develop baseline information on geology, groundwater, carbon budget, land-surface deformation, and scenario-based CO_2 transport simulation to assess potential impacts of CO_2 storage in Louisiana's porous rocks on drinking water, water supplies, and the environment.

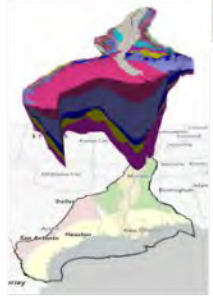
Dr. Frank Tsai

Well logs



Seismic data

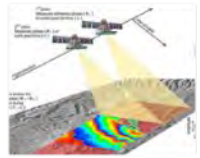




Hydrogeologic framework

Module-1
(Geology and Groundwater Characterization)
Method-1: Geologic modeling
Method-2: GW modeling

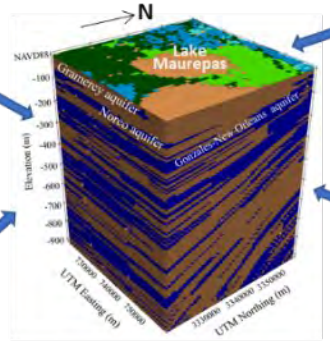
InSAR



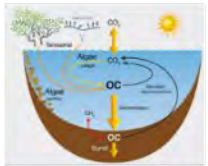
GNSS

Module-4
(Land-elevation change)
Method-1: InSAR
Method-2: GNSS

Dr. Ahmed Abdalla



Geological, GW, CO_2, land-elevation change models



Lake Carbon Cycle

CO_2 injection and distribution

CO_2 sampling

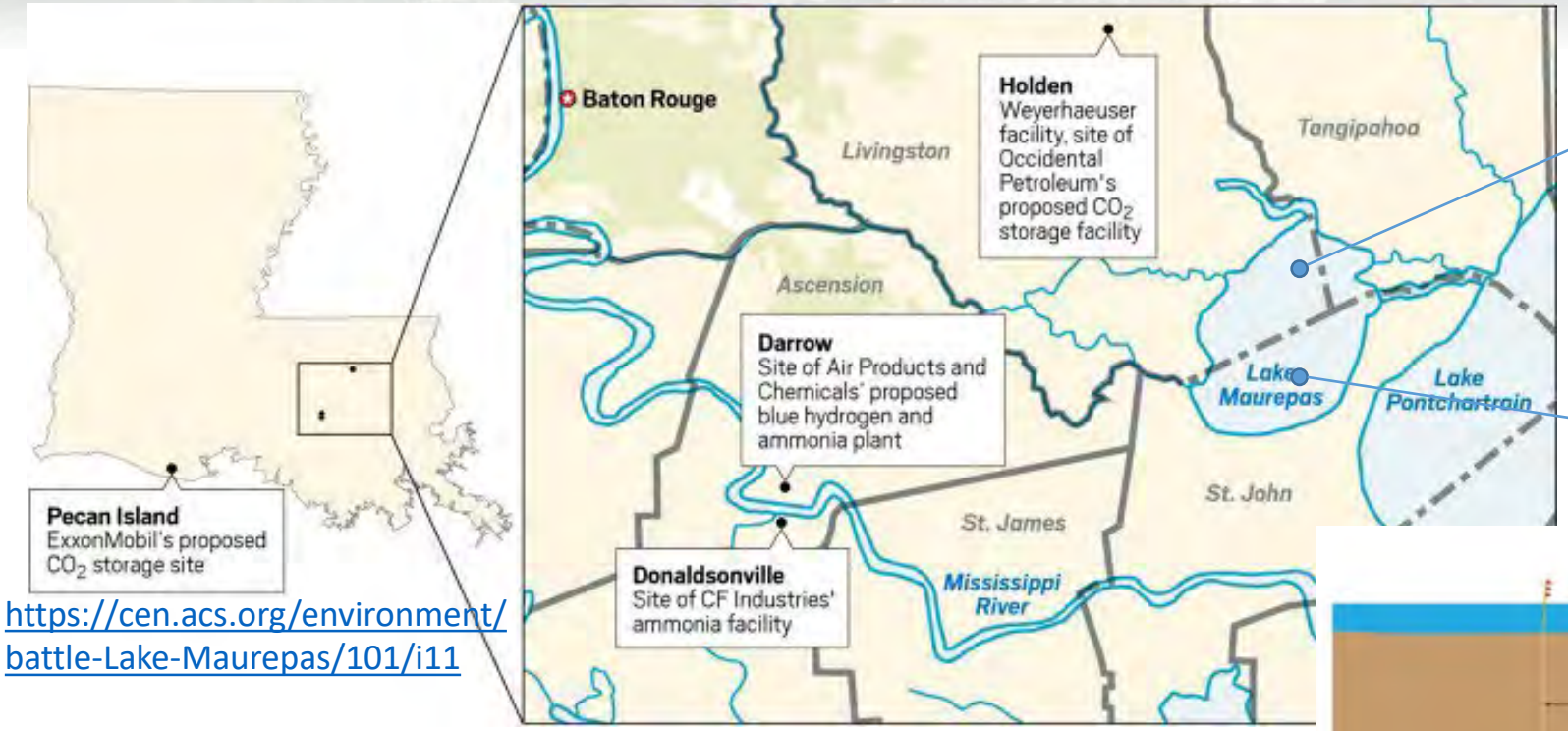
Dr. Yi-Jun Xu

Module-3
(CO_2 Monitoring)
Method-1: Field and lab work
Method-2: CO_2 outgassing

Module-2
(CO_2 modeling)
Method-1: Modeling validation
Method-2: Maurepas modeling

Dr. Christopher Kees

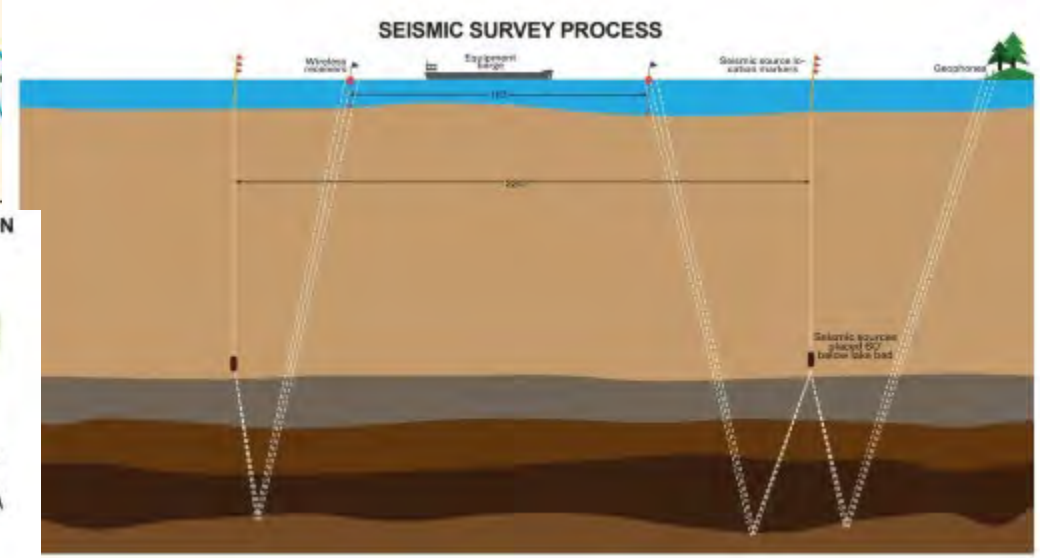
Project Overview



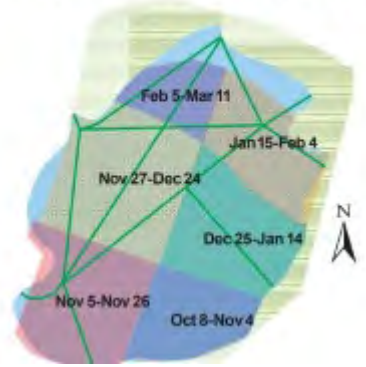
https://cen.acs.org/environment/battle-Lake-Maurepas/101/i11

Class V 976084: Depth=8213’

Class V 976031: Depth=9168’



LAKE MAUREPAS SURVEY LOCATION



- Seismic survey was finished.
- Two Class V test wells were approved for drilling
- Class VI well permit is under review
- Expected to have 12 to 16 CO_2 injection wells on the Lake
- Expected to start CO_2 injection in 2026

https://www.airproducts.com/louisiana-clean-energy/project-updates

Where Are Freshwater Zones and Potential CO_2 Injection Zones?

SN 196347

Chicot

Evangeline

Freshwater

1000’

Norco Aquifer

Gonzales-New Orleans Aquifer

Upper Ponchatoula Aquifer

Lower Ponchatoula Aquifer

Lower Ponchatoula Aquifer

Big Branch Aquifer

Abita Aquifer

2700’

Covington Aquifer

3100’

Slidell Aquifer

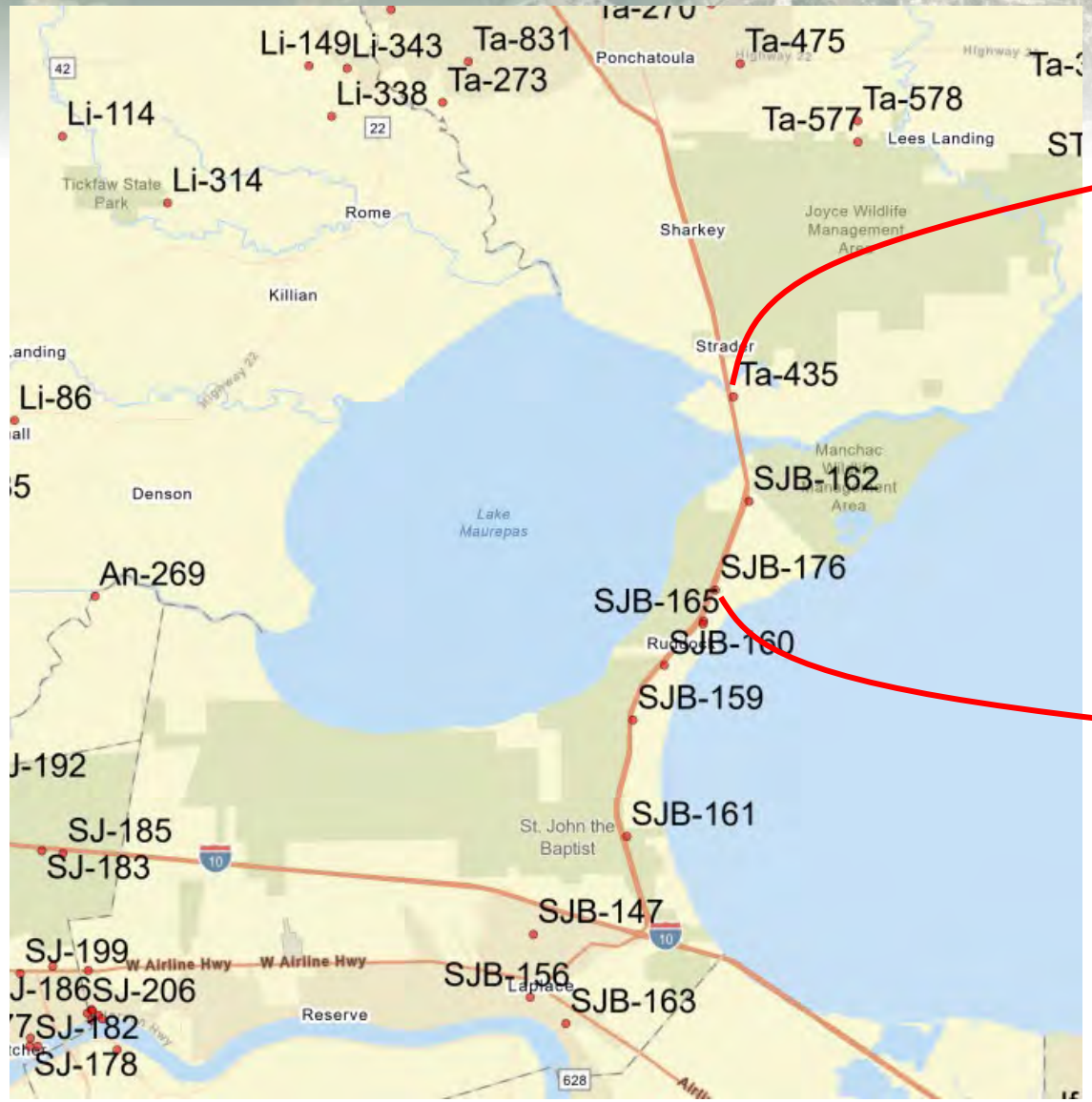
3650’

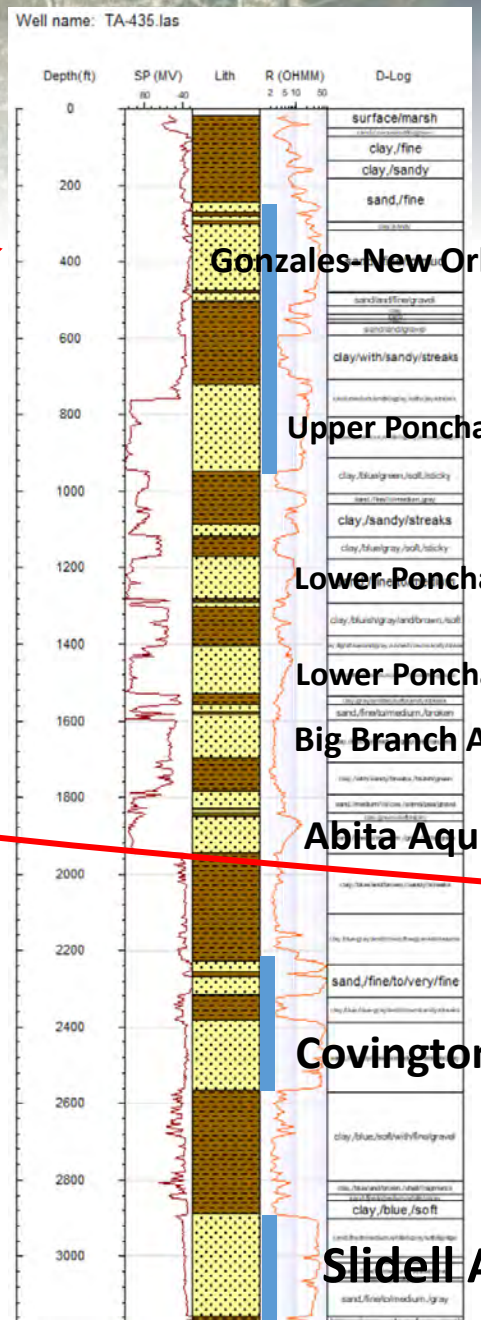
saltwater

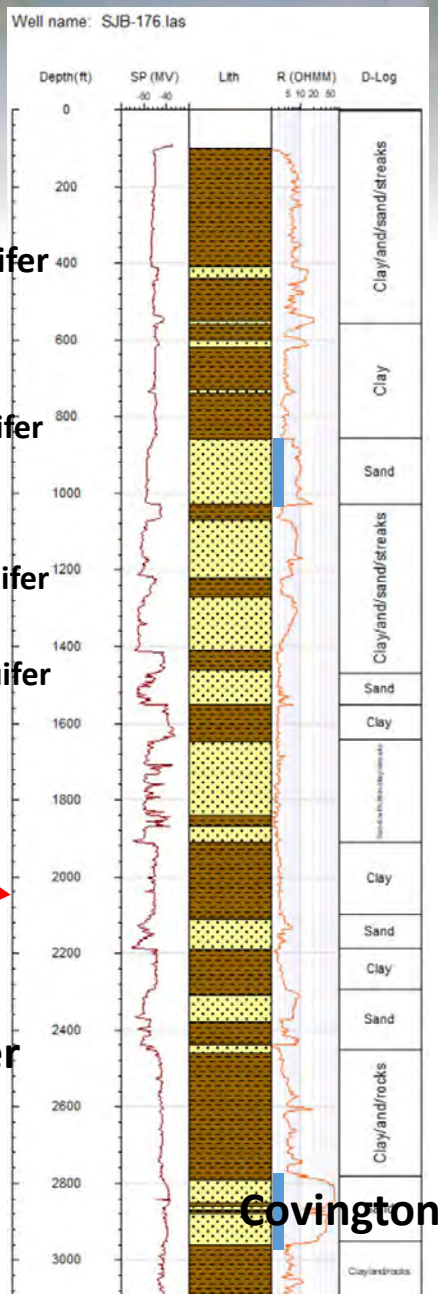
Jasper Formation

8050’

Water Well E-log







Gonzales-New Orleans Aquifer

Upper Ponchatoula Aquifer

Lower Ponchatoula Aquifer

Lower Ponchatoula Aquifer

Big Branch Aquifer

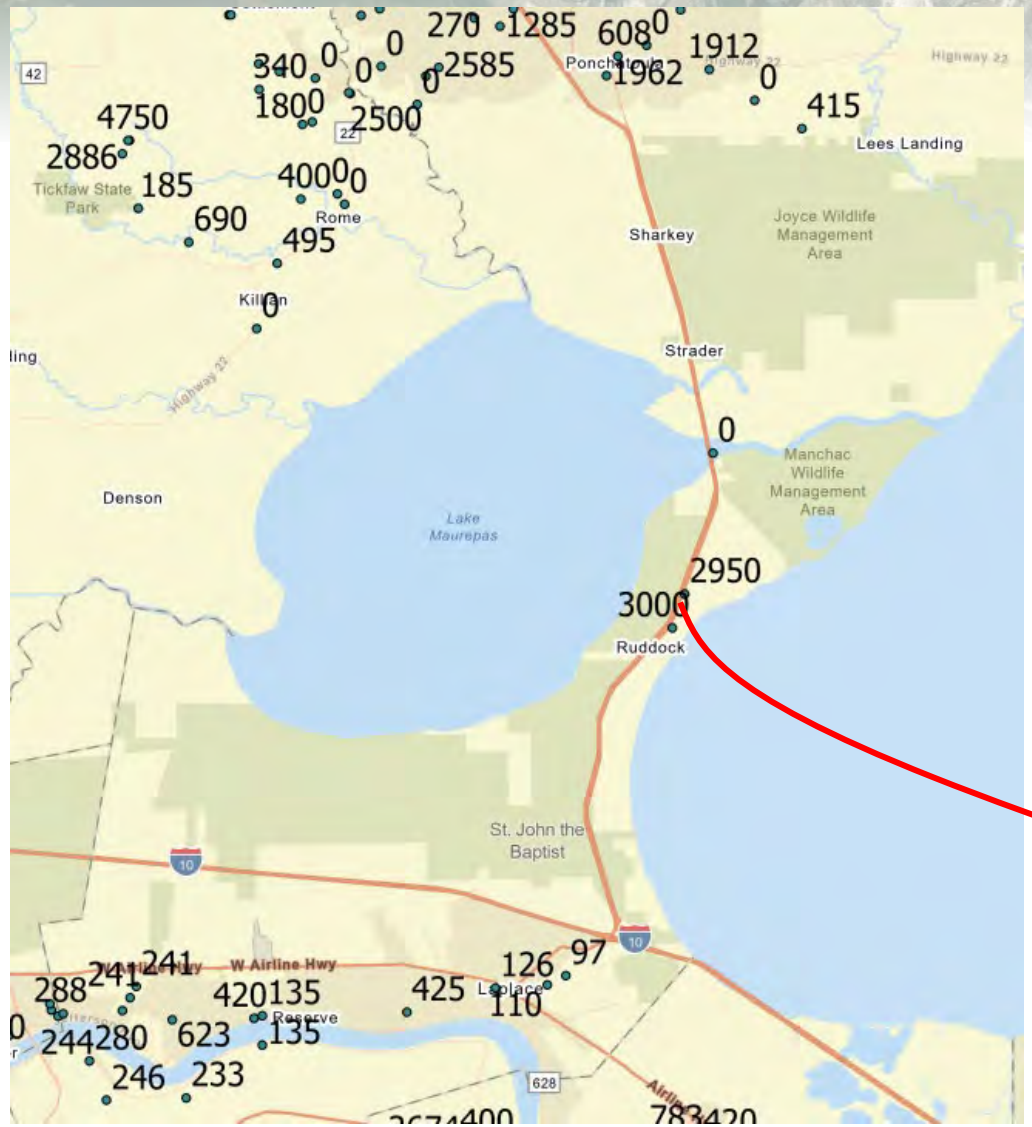
Abita Aquifer

Covington Aquifer

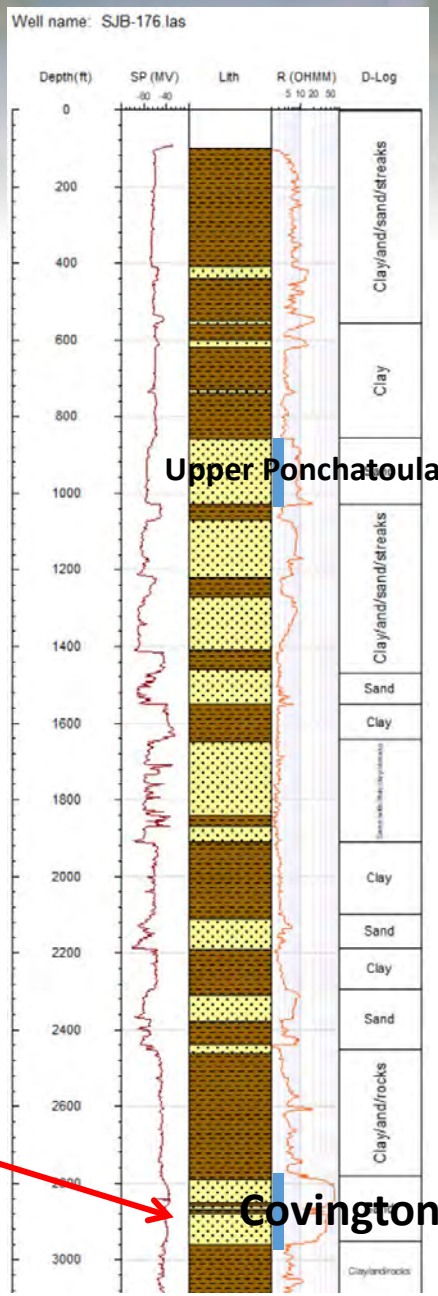
Slidell Aquifer

Covington Aquifer

Groundwater Pumping Wells – Depth (ft)



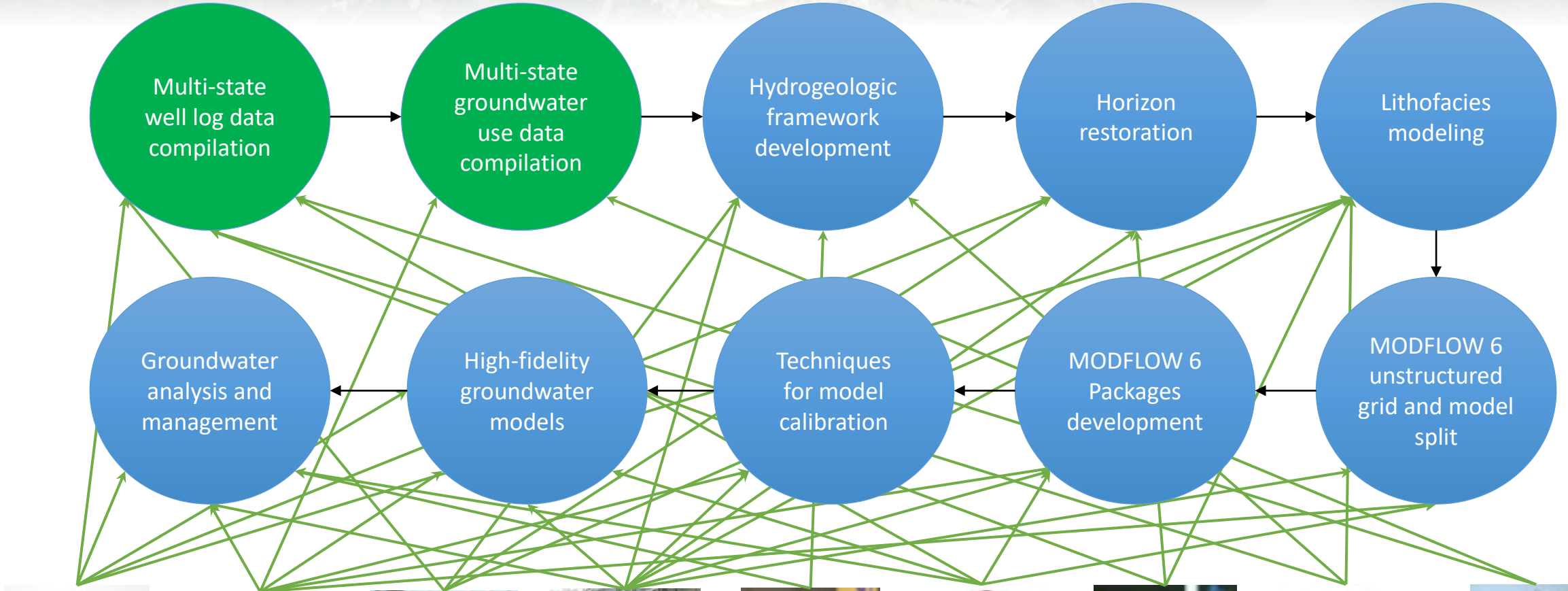
Public Supply Well

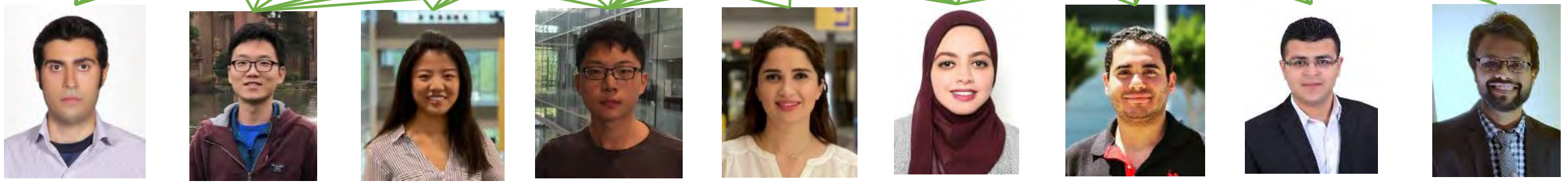


Upper Ponchatoula Aquifer

Covington Aquifer

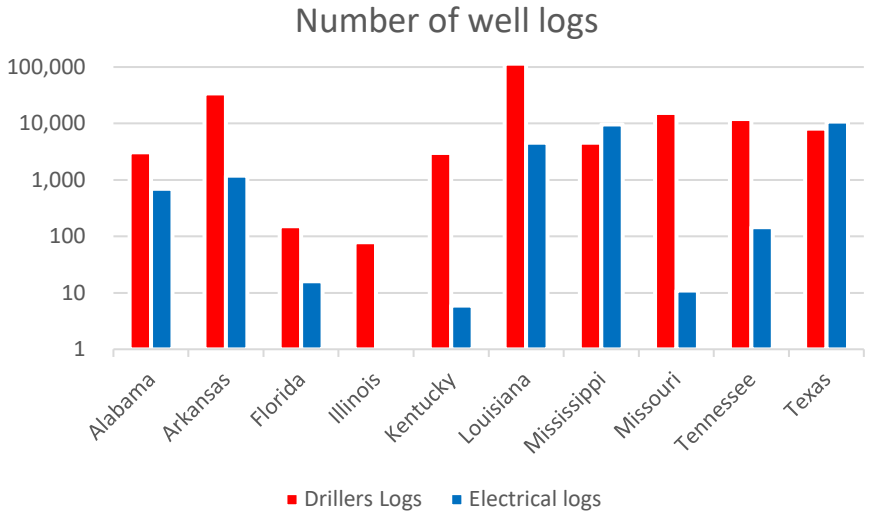
Module 1:
Workflow for Large-Scale High-Resolution Groundwater Model Development

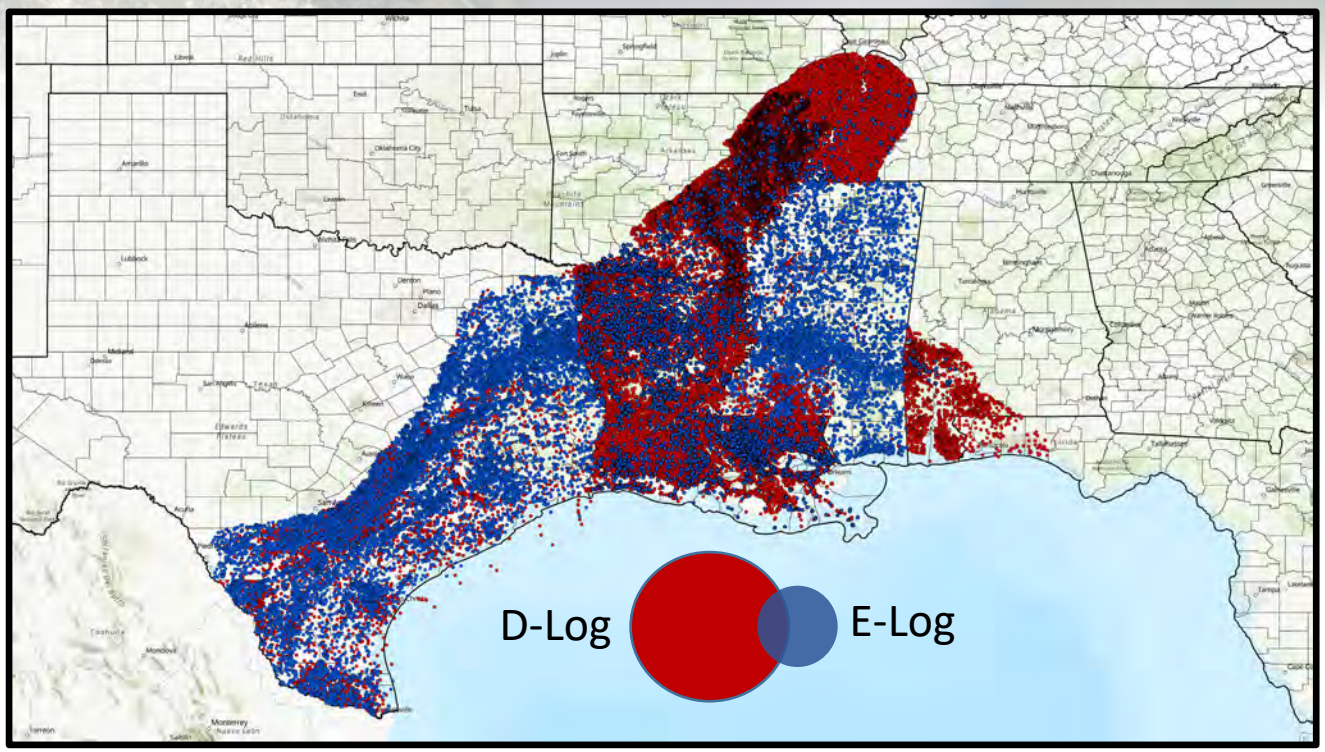




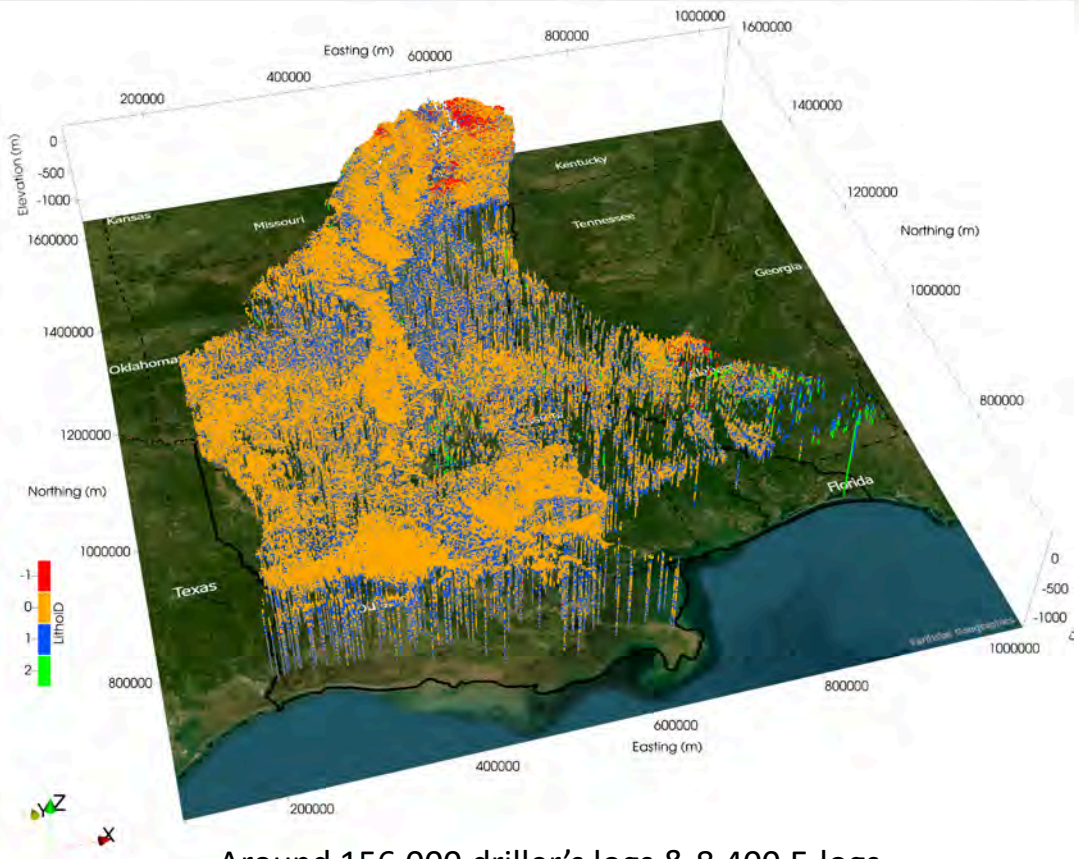
Compilation of Driller's Logs and Electrical Logs

State	Driller's Logs	Electrical logs	Total
Alabama	3,106	702	3,808
Arkansas	34,278	1,191	35,469
Florida	152	16	168
Illinois	79	1	80
Kentucky	3,028	6	3,034
Louisiana	114,472	4,556	119,028
Mississippi	4,561	9,584	14,145
Missouri	15,368	11	15,379
Tennessee	11,933	145	12,078
Texas	8,071	10,804	18,875
Total	**195,048**	**27,016**	**222,064**





Lower Mississippi-Gulf Hydrogeologic Framework



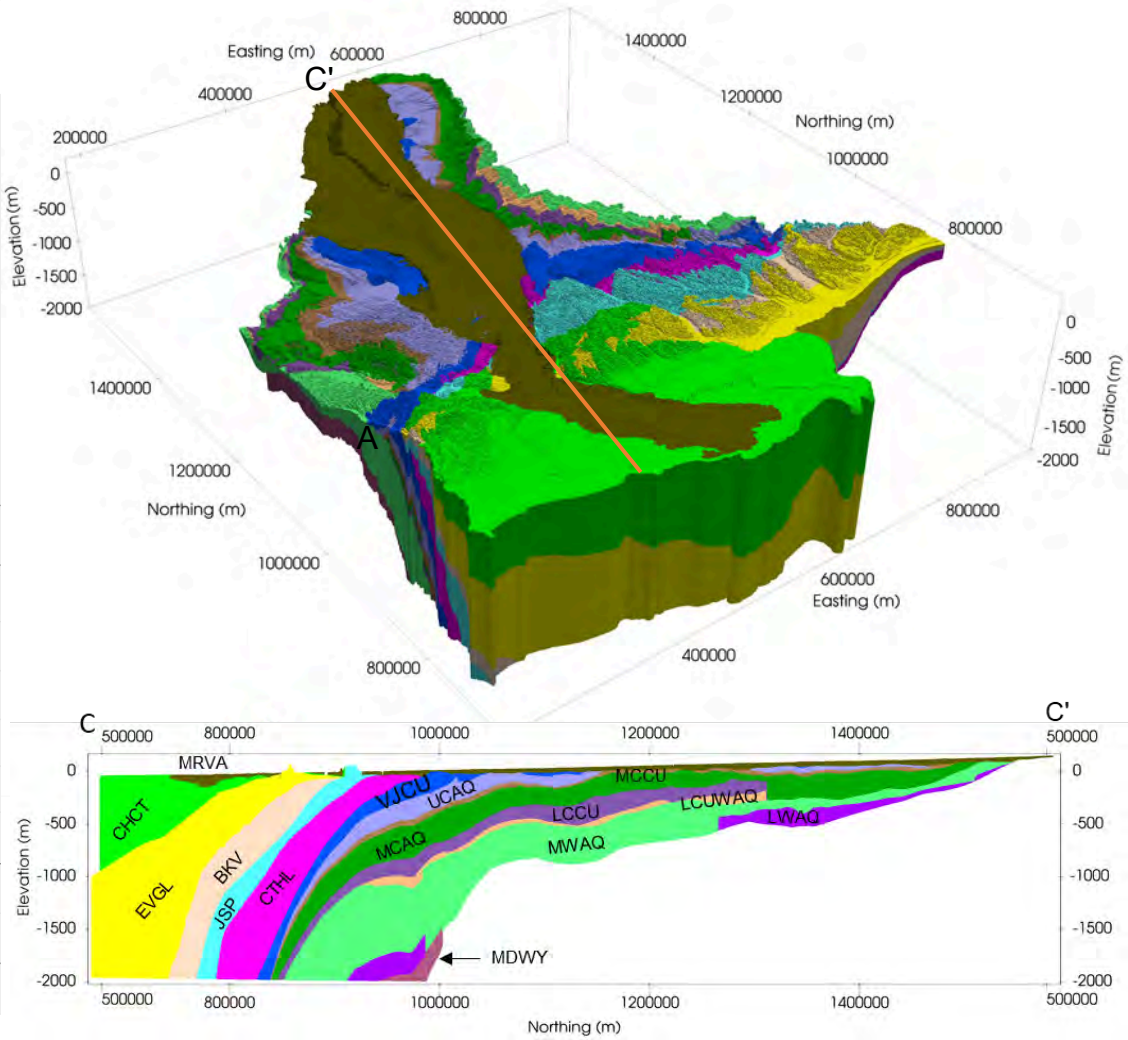
Around 156,000 driller's logs & 8,400 E-logs

-1 : Unknow Lithofacies
0 : Clay Lithofacies
1: Sand Lithofacies
2: Limestone Lithofacies

System	Series	Hydrogeologic units
Quaternary	Holocene	Mississippi River Valley Alluvium (MRVA)
Quaternary	Pleistocene	Chicot (CHCT)
Tertiary	Pliocene	Evangeline (EVGL)
Tertiary	Miocene	Burkeville (BKV)
Tertiary	Miocene	Jasper (JSP)
Tertiary	Miocene	Catahoula (CTHL)
Tertiary	Oligocene	Vicksburg-Jackson Confining Unit (VJCU)
Tertiary	Eocene	Upper Claiborne Aquifer (UCAQ)
Tertiary	Eocene	Middle Claiborne Confining Unit (MCCU)
Tertiary	Eocene	Middle Claiborne Aquifer (MCAQ)
Tertiary	Eocene	Lower Claiborne Confining Unit (LCCU)
Tertiary	Eocene	Lower Claiborne - Upper Wilcox Aquifer (LCUWAQ)
Tertiary	Paleocene	Middle Wilcox Aquifer (MWAQ)
Tertiary	Paleocene	Lower Wilcox Aquifer (LWAQ)
Tertiary	Paleocene	Midway Confining Unit (MDWY)

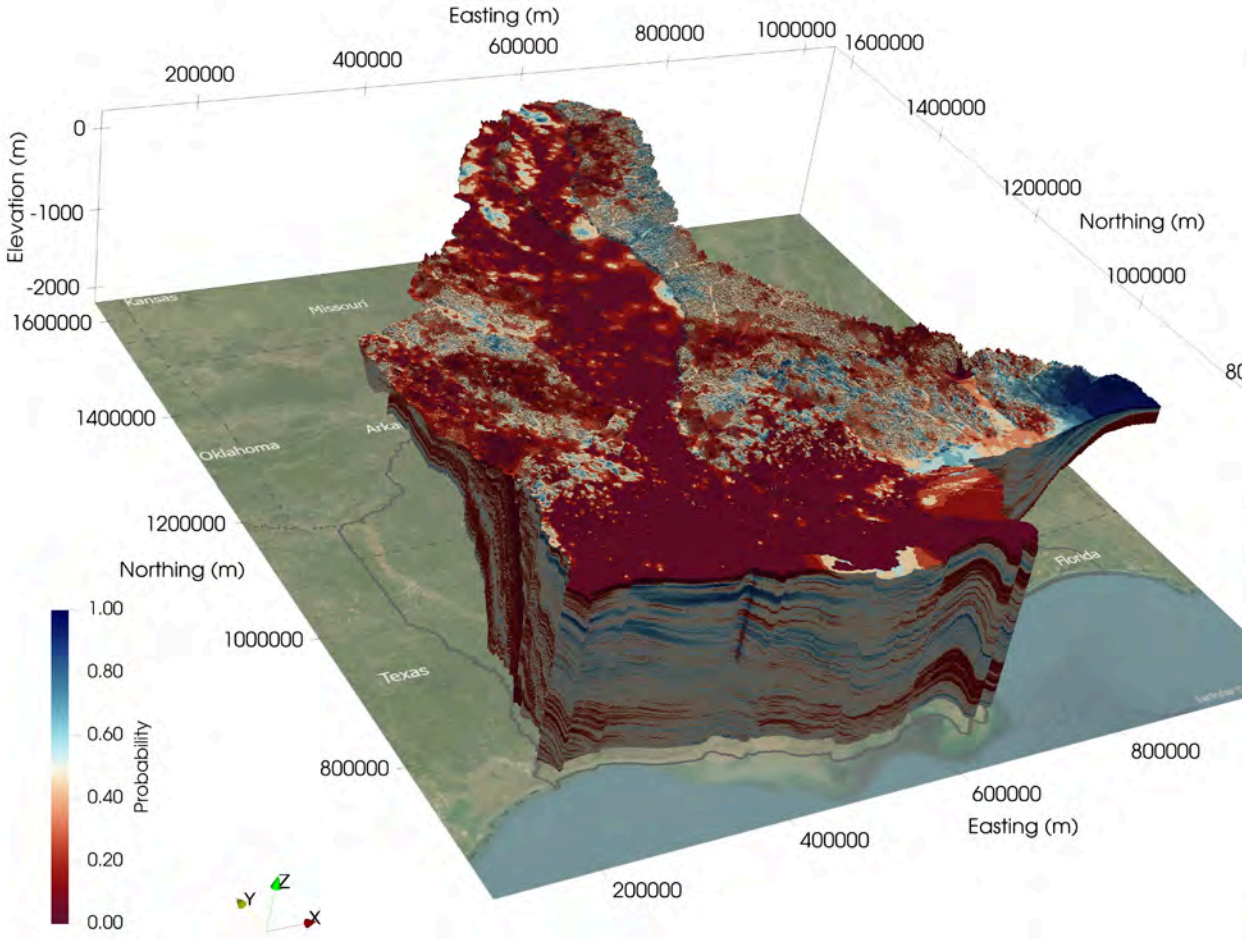
Coastal Lowlands Aquifer System

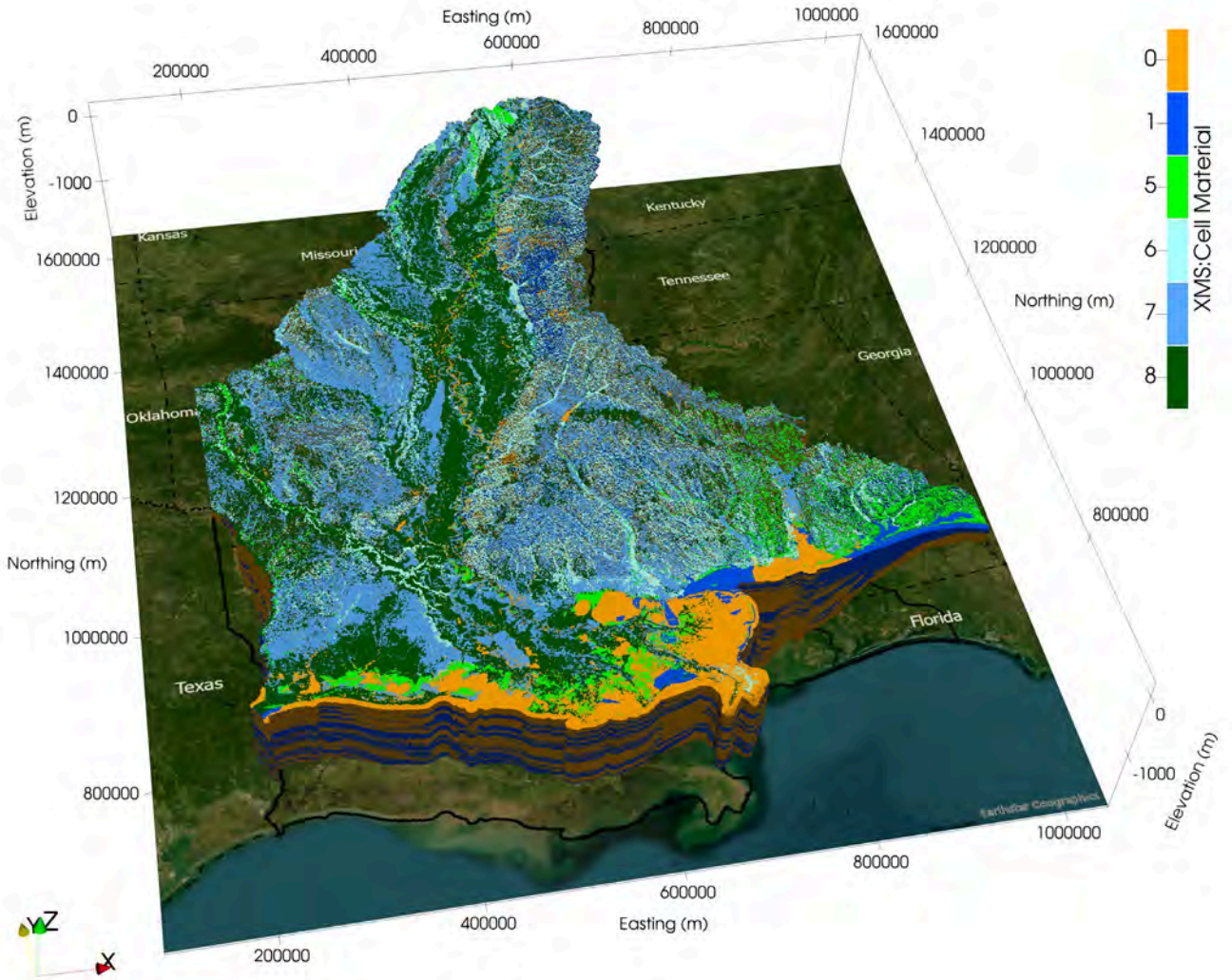
Mssissippi Embayment Aquifer System



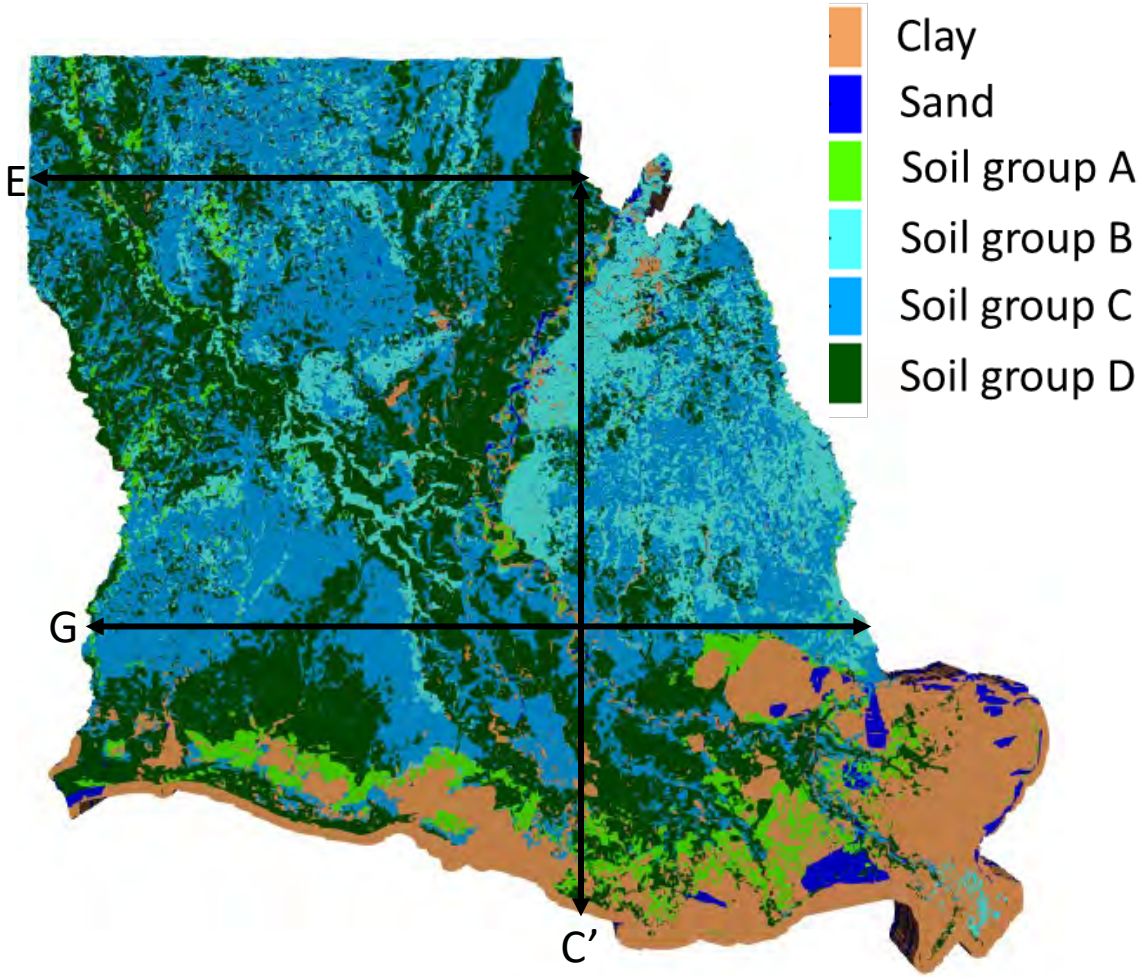
Lower Mississippi-Gulf Lithologic Model

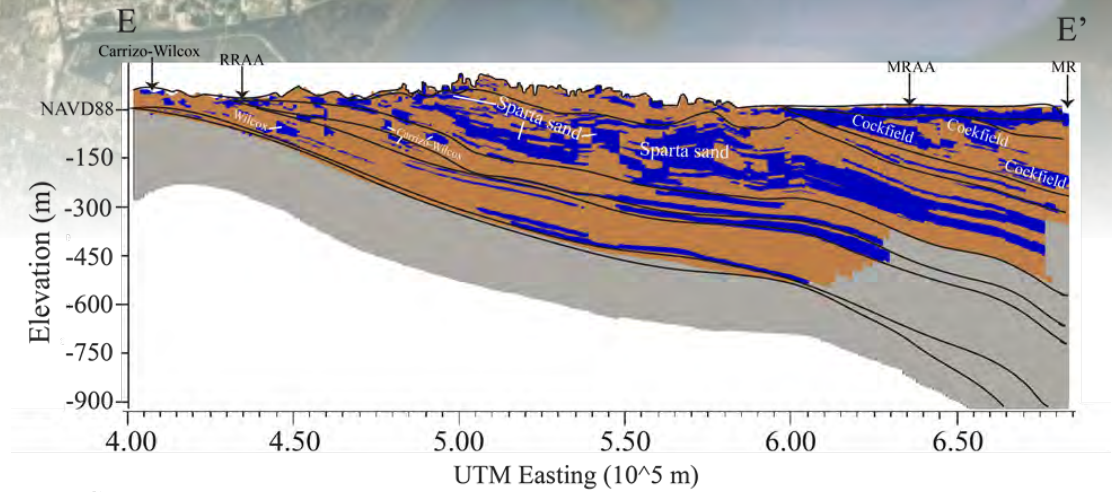
Sand probability model

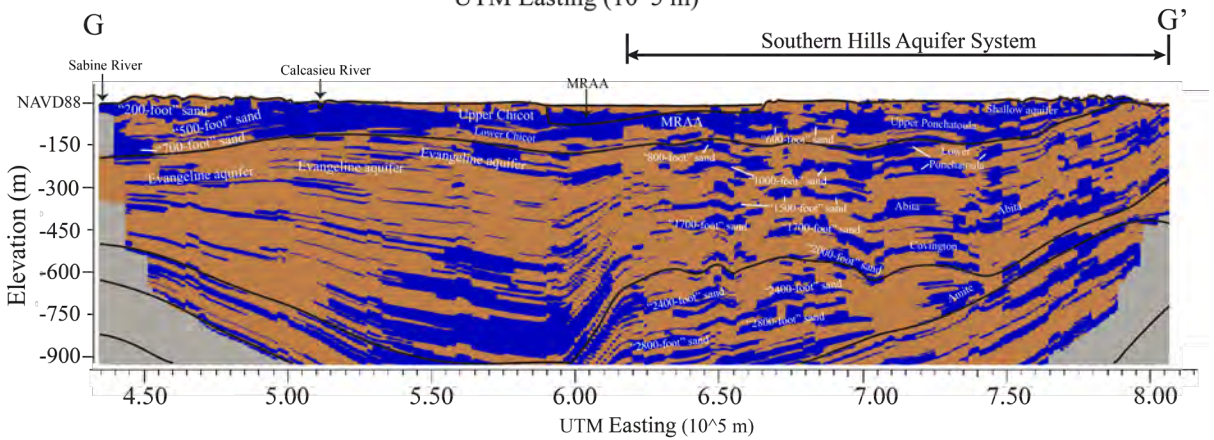


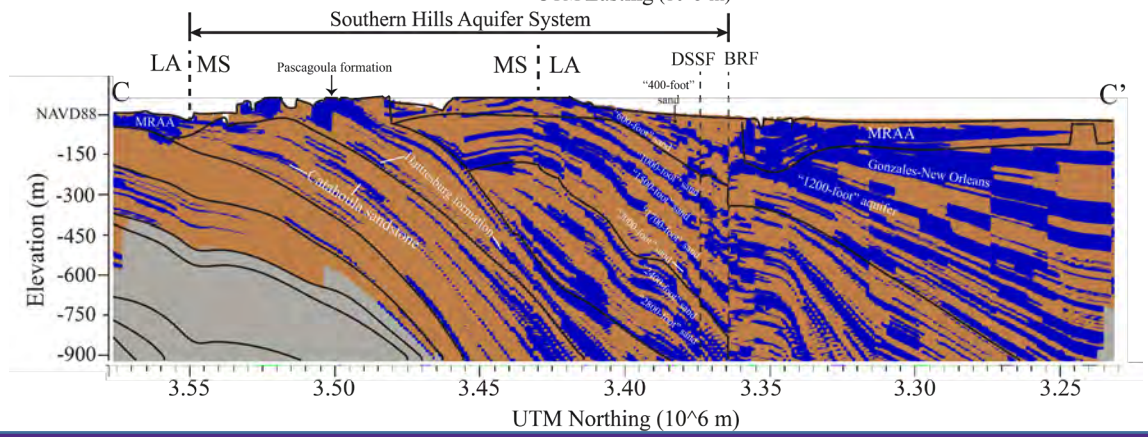


Louisiana Lithologic Model
(Provisional Result)

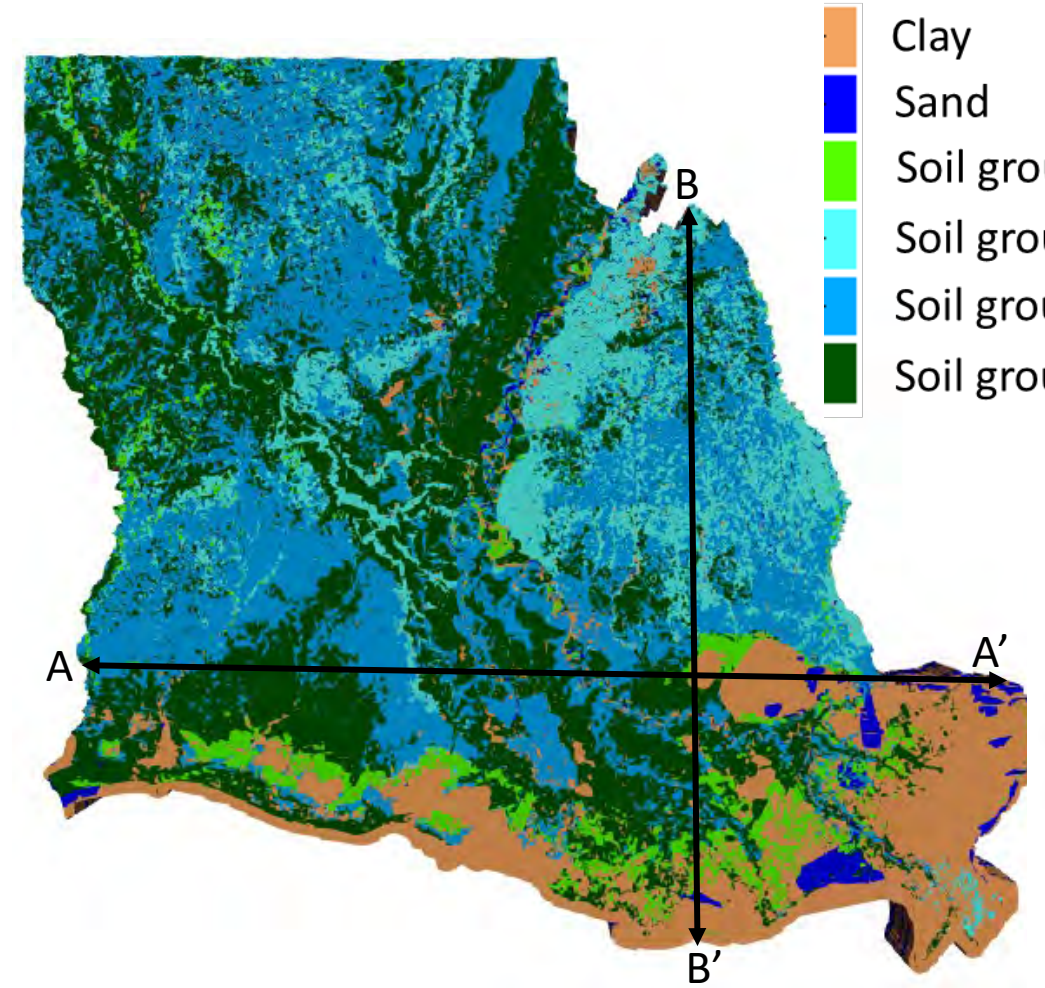


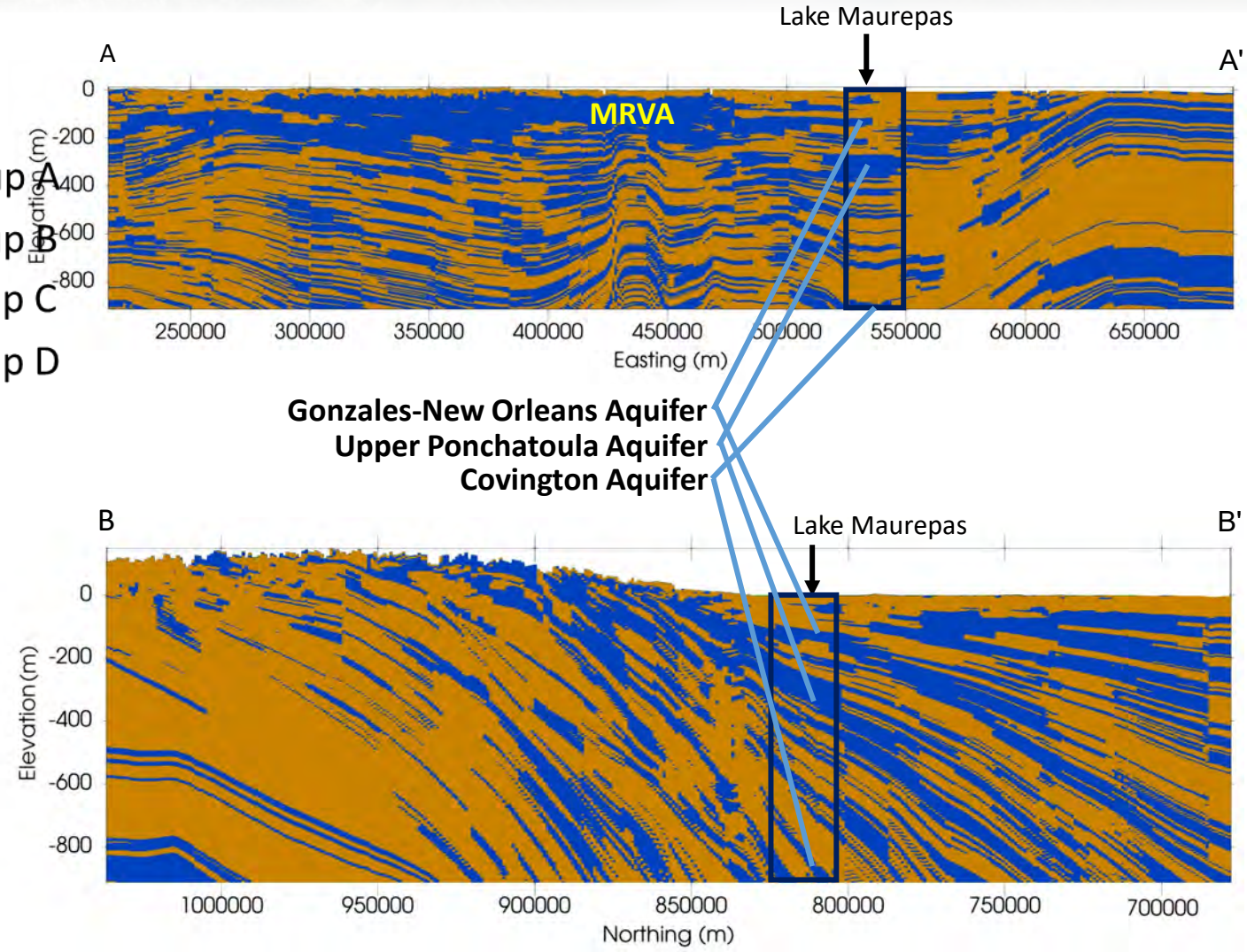




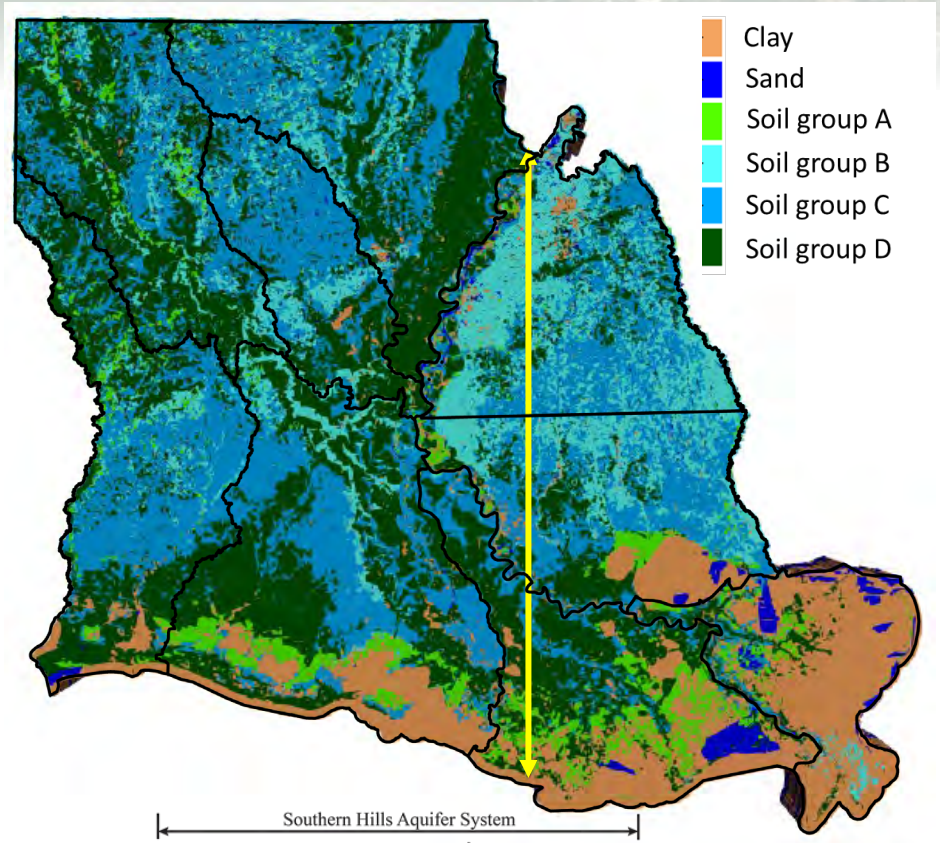


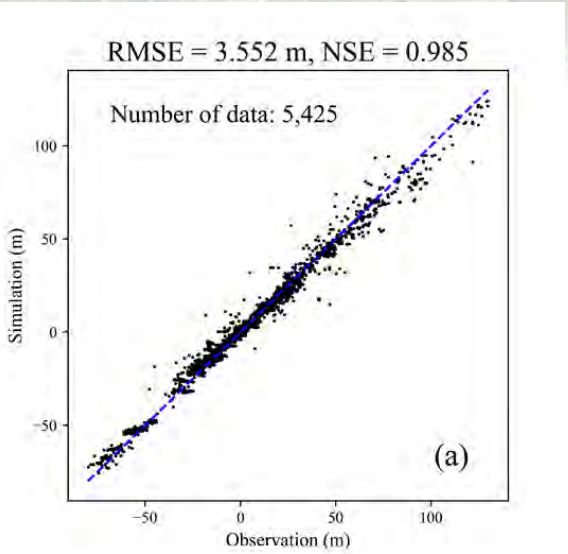
Louisiana Lithologic Model (Provisional Result)

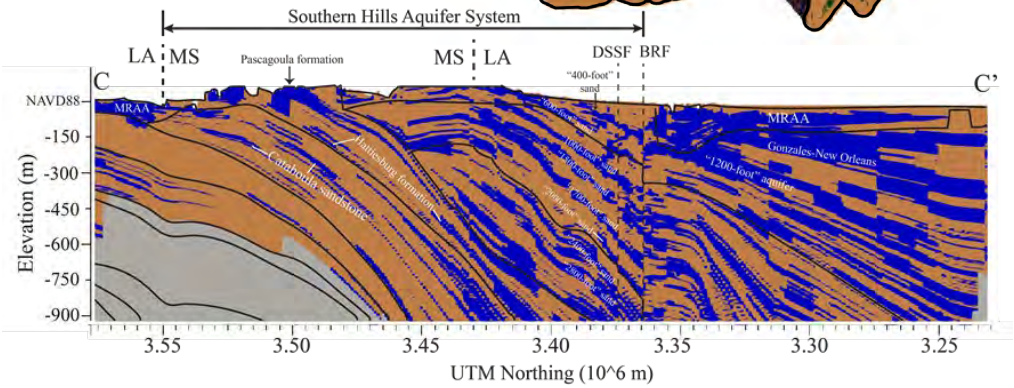




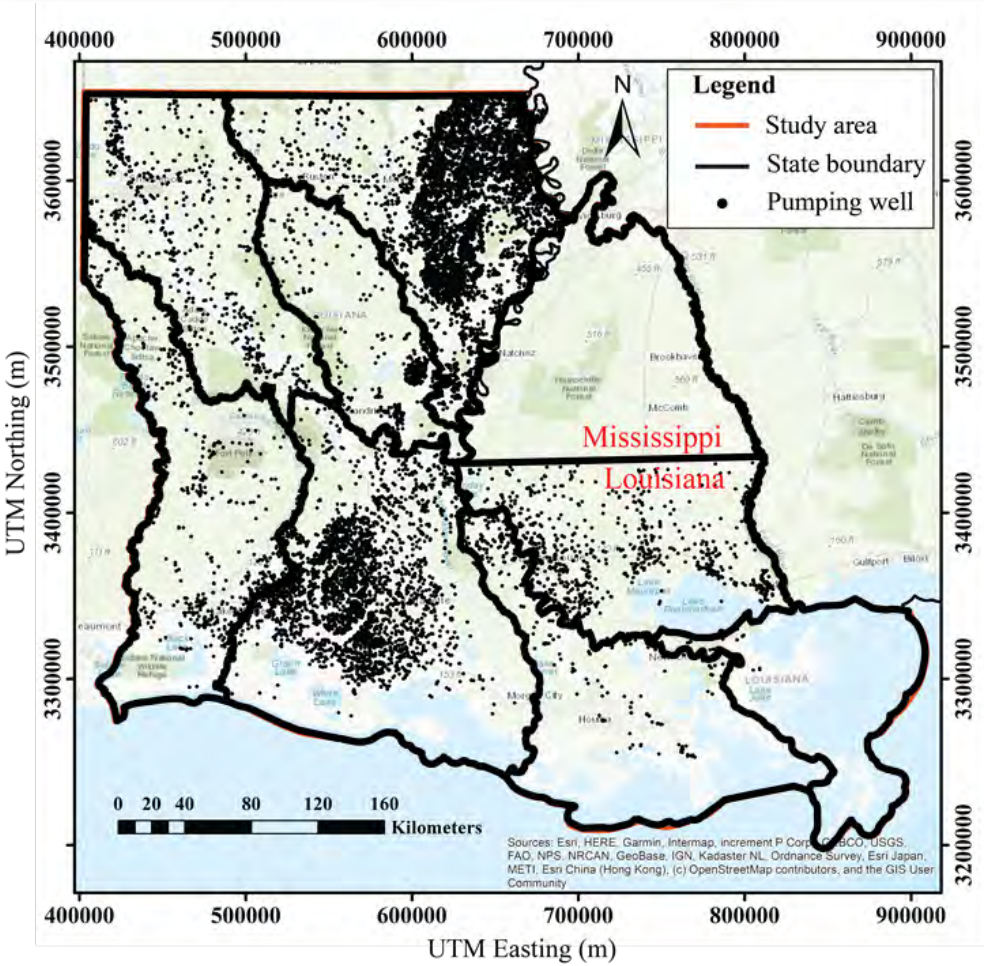
Louisiana Groundwater Model





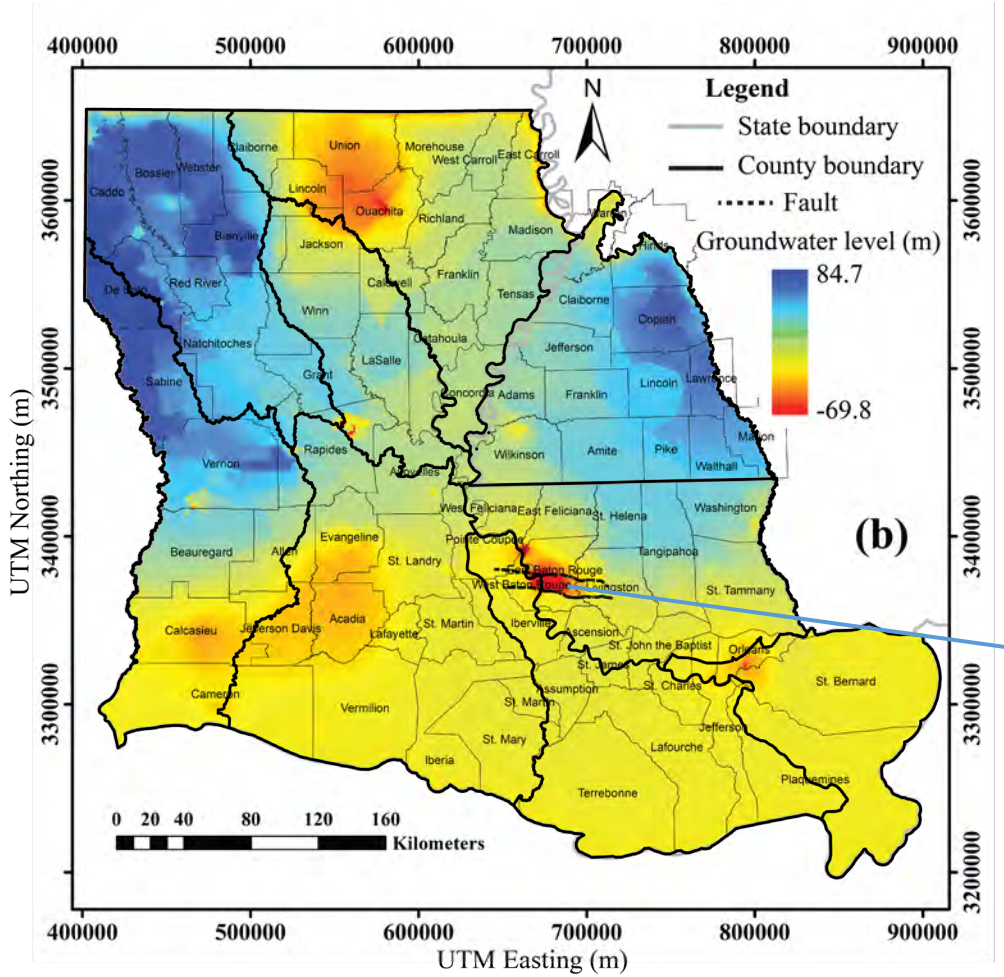


- Parallel MODFLOW 6 – Unstructured Grid
- Nearly 4.4 million 3D cells
- 2004-2021
- 9 sub-models
- 16 EXG files
- Single core: 15 hr 44 min
- 9 cores: 1 hr 50 min
- Speedup: 8.6

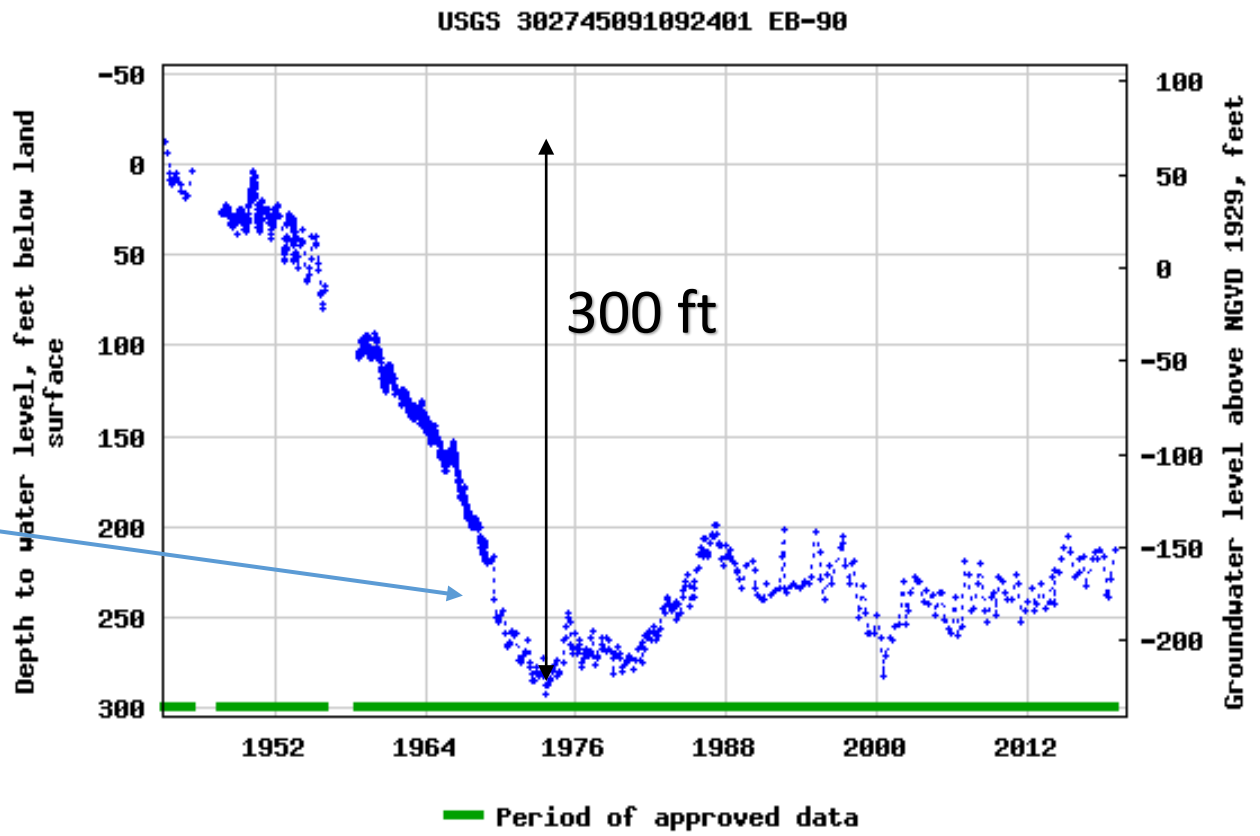


Pumping wells > 24,500

Simulated Groundwater Level



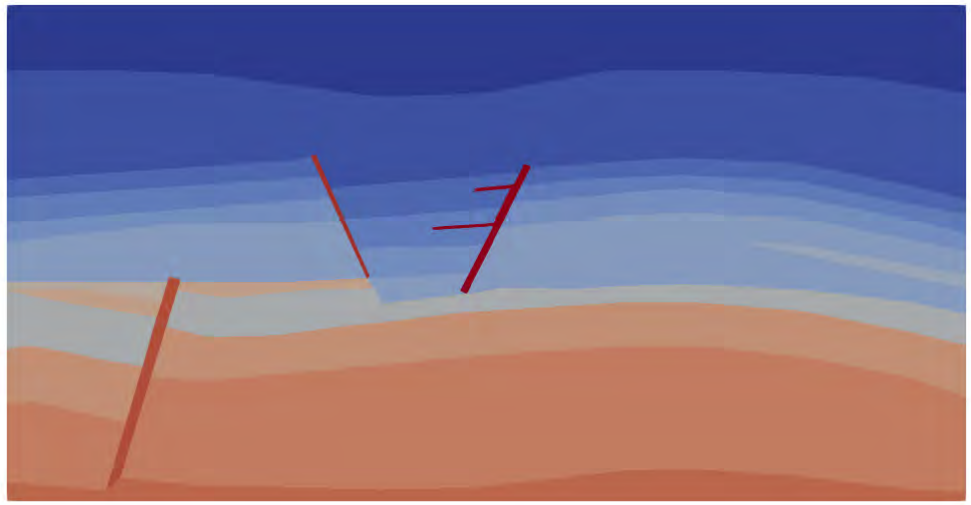
Simulated groundwater level on 12/2021



Module 2 (Kees) – CO_2 Transport (Computational Modeling)

- Developing model verification and validation on the laboratory experiment and international benchmark of Nordbotten, J. M., Fernø, M., Flemisch, B., Juanes, R., & Jørgensen, M. (2022). Final Benchmark Description: FluidFlower International Benchmark Study.
- Building on existing multiphase flow models and numerics for unstructured mesh representations of subsurface geology
- Extending recently developed high-resolution Finite Element Methods based on Flux Corrected Transport (FCT)

Module 2 (Kees) – CO_2 Transport (Computational Modeling)
(provisional result)



Unstructured FEM mesh extracted from benchmark data (above) under soil/rock properties, and water flood

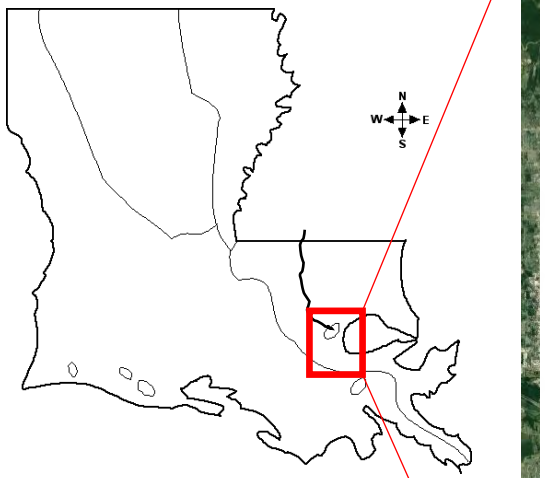
21

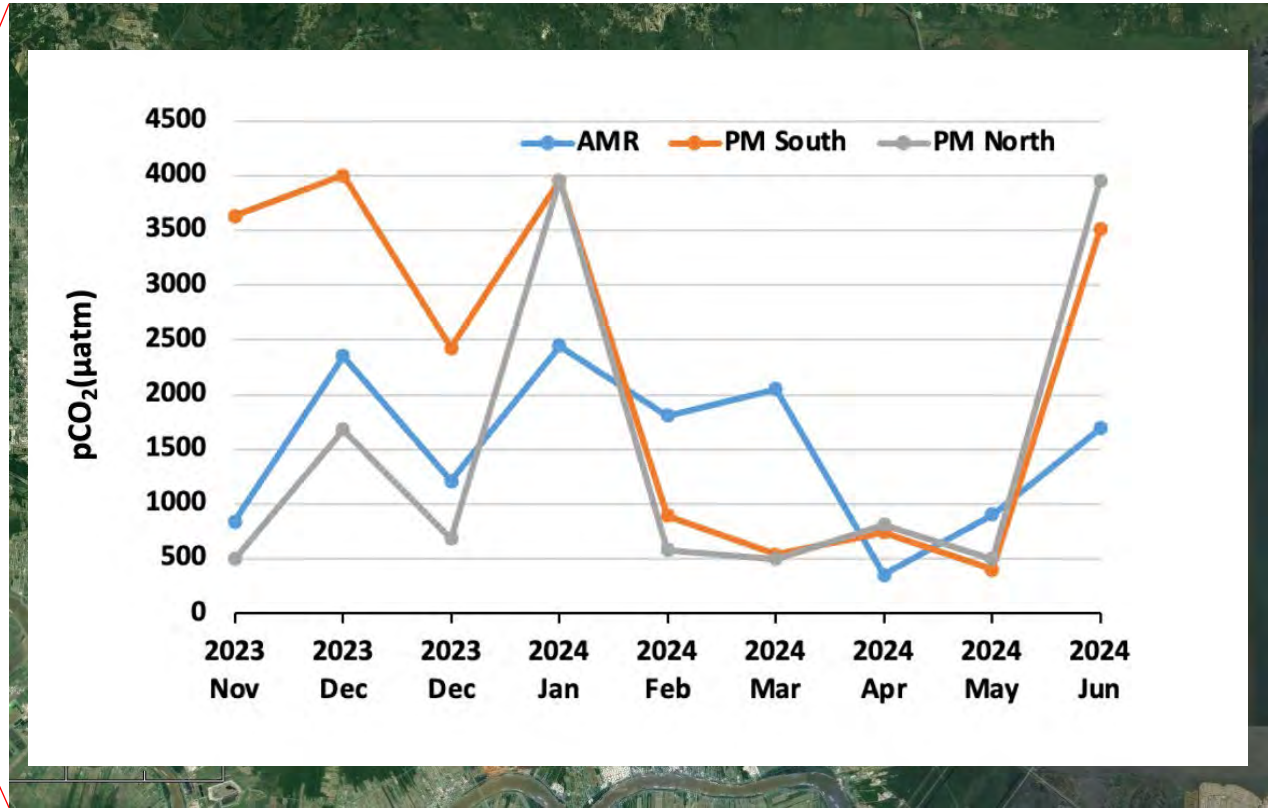
Module 3 (Xu) – Understand the Carbon Budget of Lake Maurepas

Objectives:

- To determine levels and fluctuations of dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), and partial pressure of dissolved carbon dioxide (pCO_2) in Lake Maurepas, the Amite River, and water wells near the lake;
- To quantify total mass inputs and/or exchange of DIC and DOC from the river and groundwater into Lake Maurepas, and investigate seasonality of the inputs;
- To estimate hourly, daily, and monthly outgassing rates of CO_2 from the lake and river water surface; and
- To assess the factors affecting dissolved carbon mass transport and CO_2 outgassing in the Amite-River-Lake-Maurepas continuum.

Module 3 (Xu) - Monitoring CO_2 Concentrations (provisional result)





Field measurements

- Air and water temperature
- pH
- pCO_2
- Turbidity
- Dissolved oxygen
- Chlorophyll
- cDOM
- Wind speed

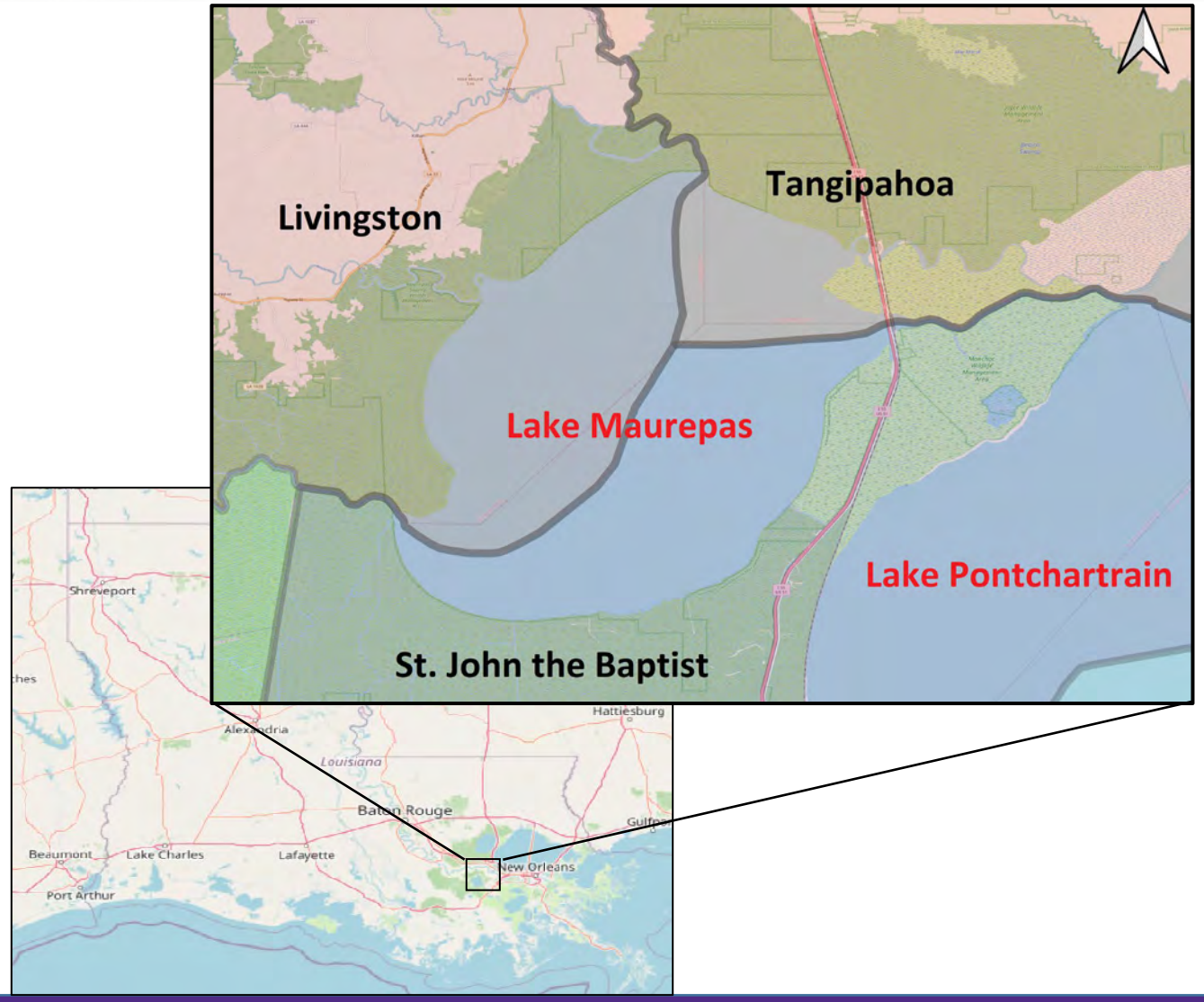
Lab analysis

- DIC
- DOC

Field measurements and sampling conducted in the Amite River at Port Vincent and Lake Maurepas at Pass Manchac north and south

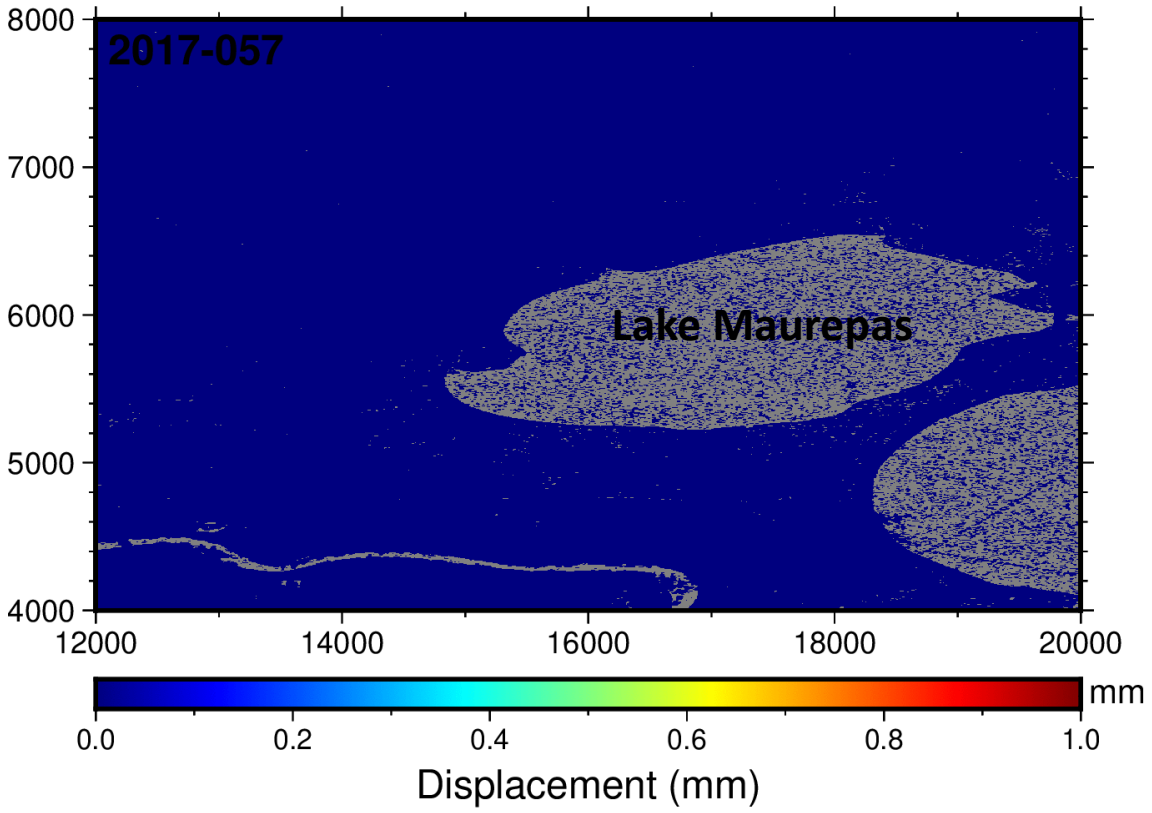
Module 4 (Abdalla) - Monitoring Land Surface Displacement around Lake Maurepas

- Preliminary survey over Lake Maurepas assessed 25 InSAR images in 2017
- Sentinel-1 Satellite images produced every 12 days
- Good SAR coverage exists at the boundary of Livingston and St. John the Baptist Parish Parishes.
- Low SAR signal is shown in the vegetation area.

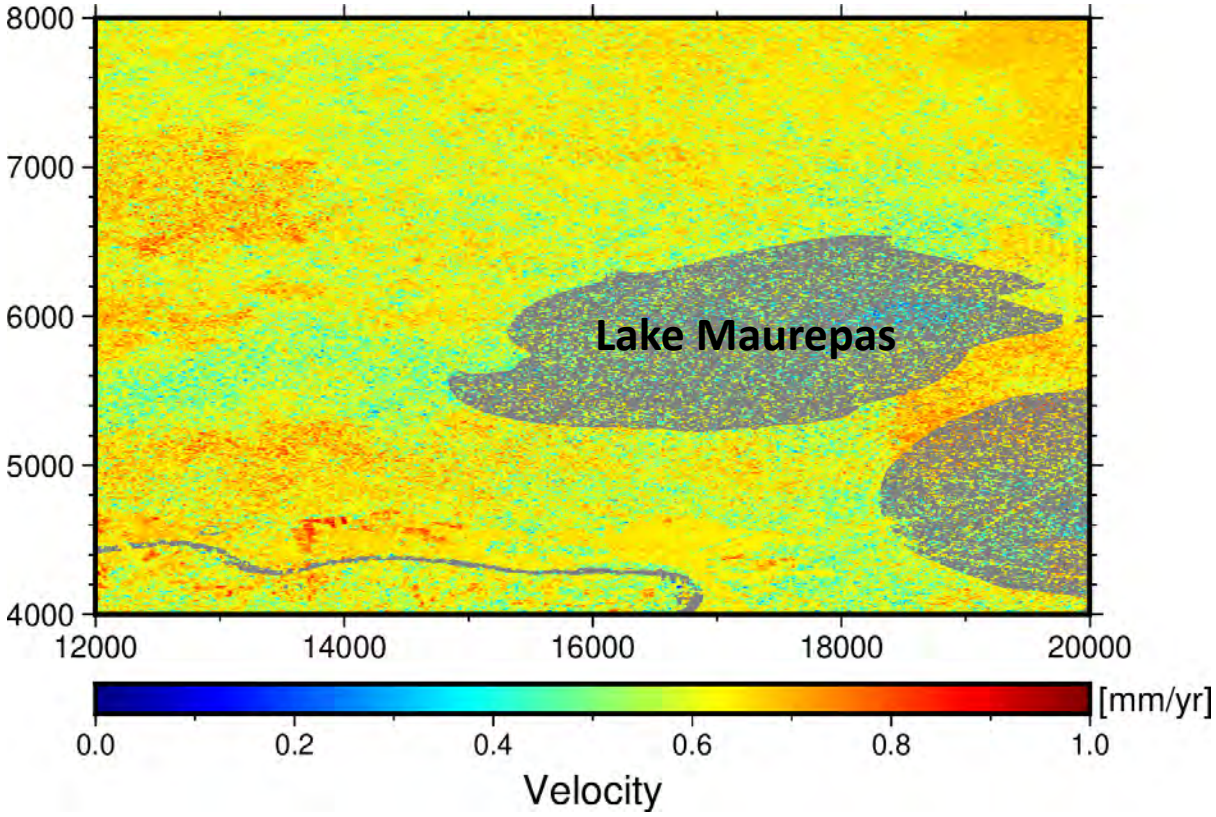


Module 4 (Abdalla) - Monitoring Land Surface Displacement around Lake Maurepas (provisional result)

Displacement per image
2/27/2017 to 12/24/2017



Average velocity of 2017
Uplift 0.5 to 0.8 mm



Next steps

- Analyze geological structure and groundwater flow for the Lake Maurepas area
- Post-process the MODFLOW 6 mesh and model results for high-resolution Finite Element Methods for CO_2 simulation
- Continue CO_2 concentration monitoring and analysis
- Continue land surface displacement analysis with satellite data

Thanks for your attention!

Questions?