LDNR and CCS - Overview of Class VI Injection Wells

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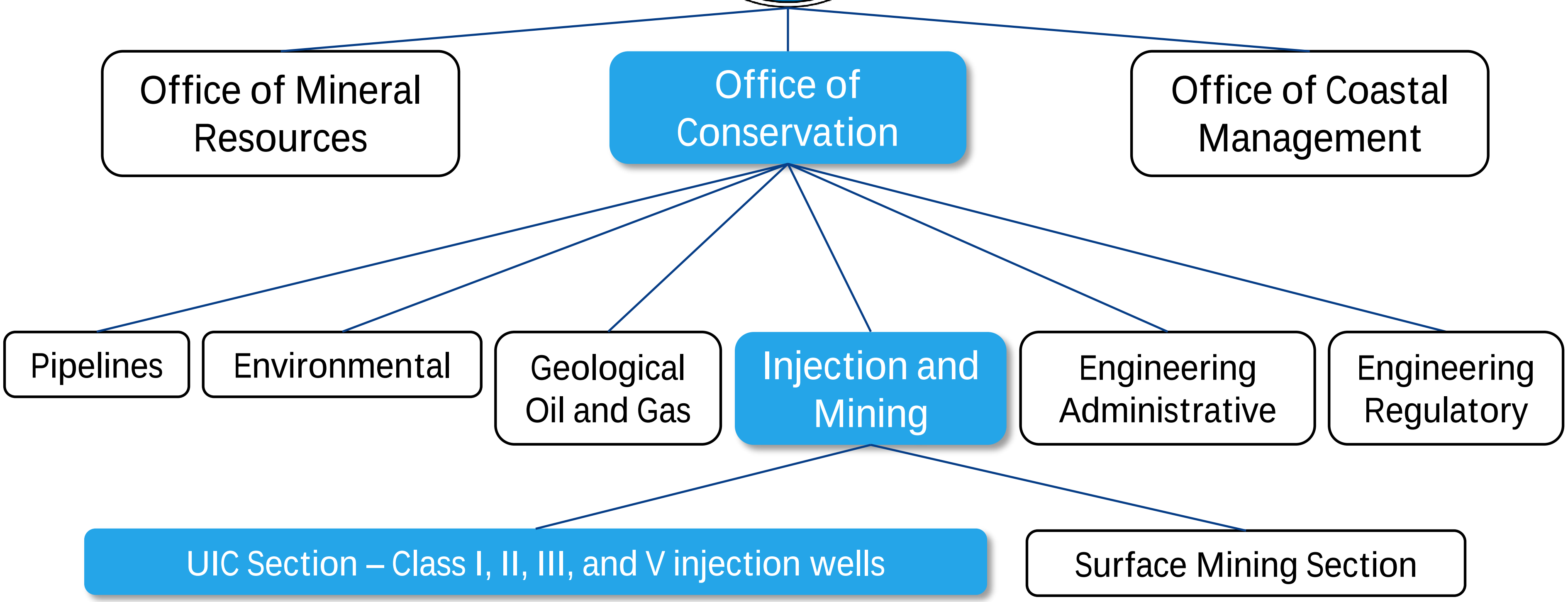
Louisiana AWMA Conference
October 25, 2023

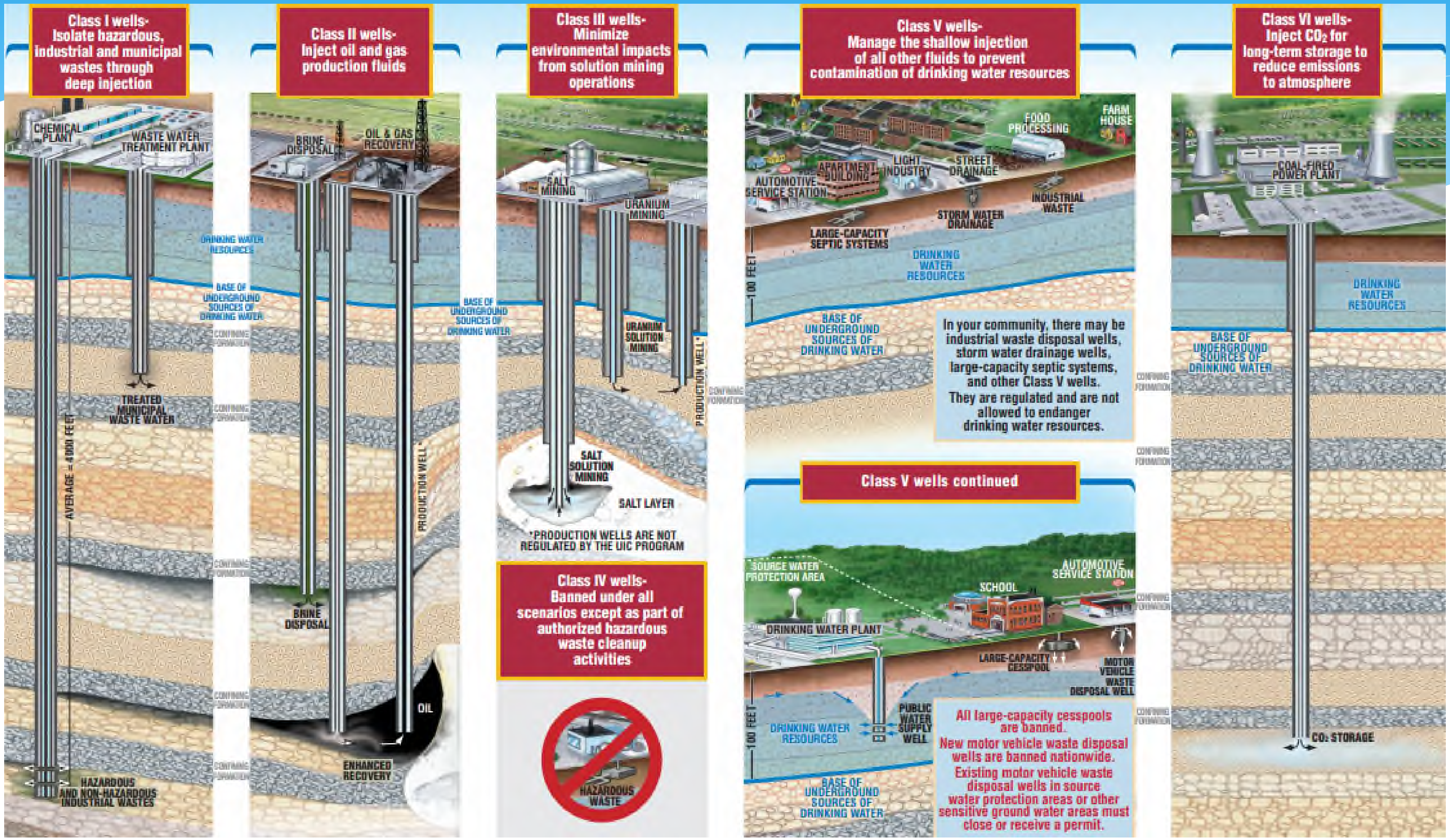
Louisiana Department of Natural Resources



Office of Conservation – IMD

- Office of Conservation - Injection & Mining Division (IMD) regulates Class I, II, III, and V injection wells as an EPA Primacy Program
  - The 1974 Safe Drinking Water Act (SDWA) established national UIC Program
  - Office of Conservation was granted primacy in 1982
- Primary responsibility is to prevent endangerment of the Underground Source of Drinking Water (USDW) and for permitting, compliance, and enforcement for all injection wells in Louisiana
- Class VI Primary Enforcement Authority (Primacy)
  - Class VI injection wells - used for the geologic sequestration of anthropogenic CO_2
  - Louisiana's application for Class VI primacy is currently under review by EPA
    - Work on the application began in Fall 2019, the final application was submitted in September 2021, and potentially receiving primacy by Q1 2024

Office of Conservation – IMD



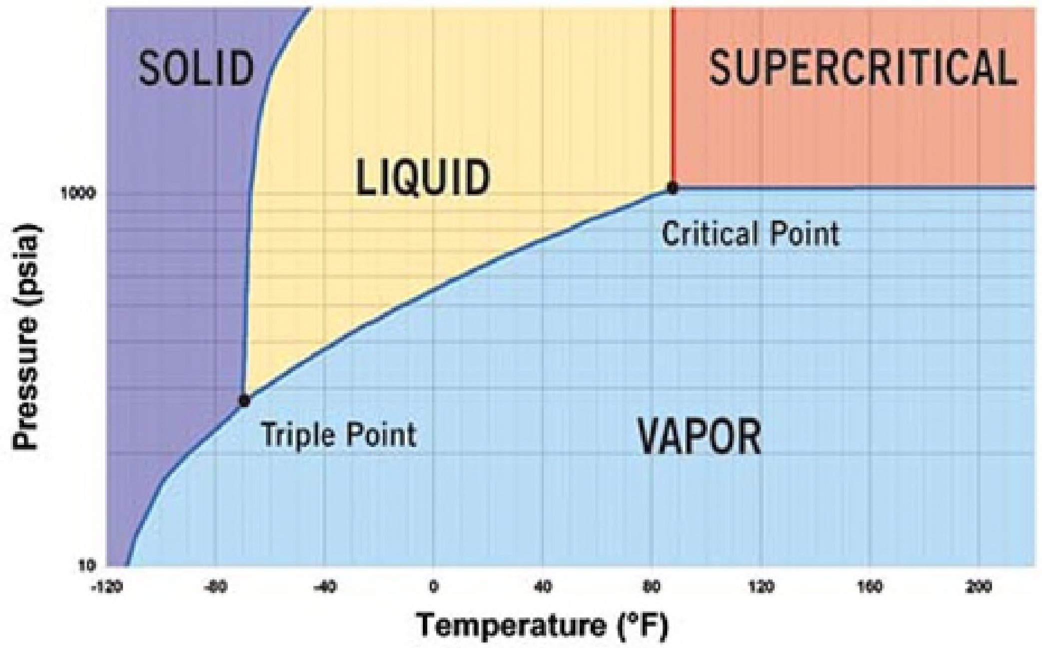
Source: US Environmental Protection Agency http://water.epa.gov/type/groundwater/uic/wells_drawings.cfm

Office of Conservation – IMD

Louisiana Administrative Code	Statewide Order	Subject or Regulation
LAC 43:XVII.103 Chapter 1	Statewide Order No. 29-N-1, Chapter 1	Class I Non-Hazardous Waste Injection
LAC 43:XVII Chapter 2	Statewide Order No. 29-N-2, Chapter 2	Class I Hazardous Waste Injection
LAC 43:XIX Chapter 4	Statewide Order No. 29-B, Chapter 4	Class II Injection/Disposal Well Regulations
LAC 43:XIX Chapter 3	Statewide Order No. 29-B, Chapter 3	Onsite storage, treatment and disposal of oilfield waste. Primarily oilfield pit regulations, but also has some general requirements for Class II disposal wells
LAC 43:XVII Chapter 3	Statewide Order No. 29-M, Chapter 3	Class II Hydrocarbon Storage in Salt Dome Cavities
LAC 43:XVII Chapter 33	Statewide Order No. 29-M-3, Chapter 33	Class III Solution-Mining Injection Wells
LAC 43:XVII Chapter 36	Statewide Order No. 29-N-6, Chapter 36	Class VI Geologic Sequestration of Carbon Dioxide
LAC 43:XVII.103 Chapter 1	Statewide Order No. 29-N-1, Chapter 1	Class V Injection Wells not included in Class I, II, III, IV or VI
LAC 43:XVII Chapter 37	Statewide Order No. 29-M-5, Chapter 37	Class V Storage Wells in Solution-Mined Salt Dome Cavities (Hydrogen, Helium, Ammonia, Compressed Air, etc.)

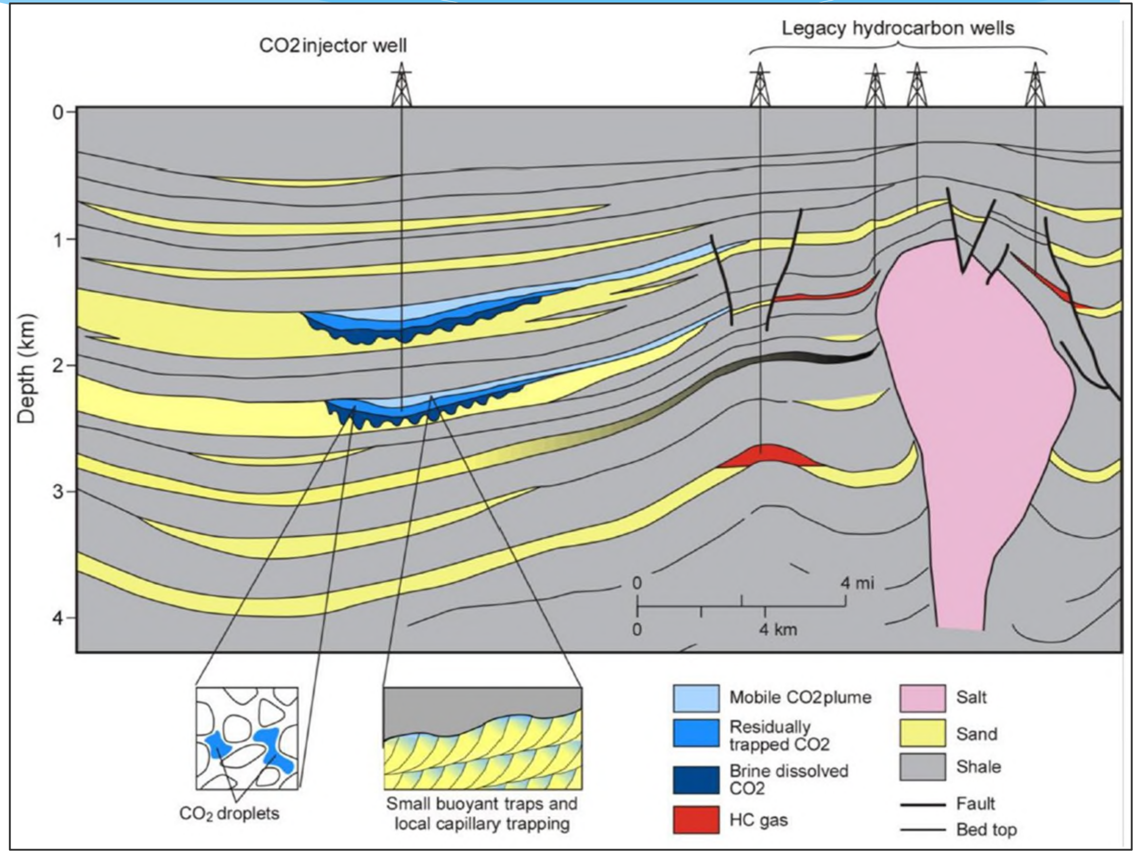
CO_2 Injection

- Supercritical CO_2 remains in supercritical phase when injected at sufficient depth and formation pressure
- Supercritical CO_2 ~3.5 – 6 ppg
- Typical saline reservoir brine ~ 8.65 ppg
- Complex interactions between supercritical CO_2, reservoir brines, and the reservoir rock itself that will impact evolution of CO_2 plume



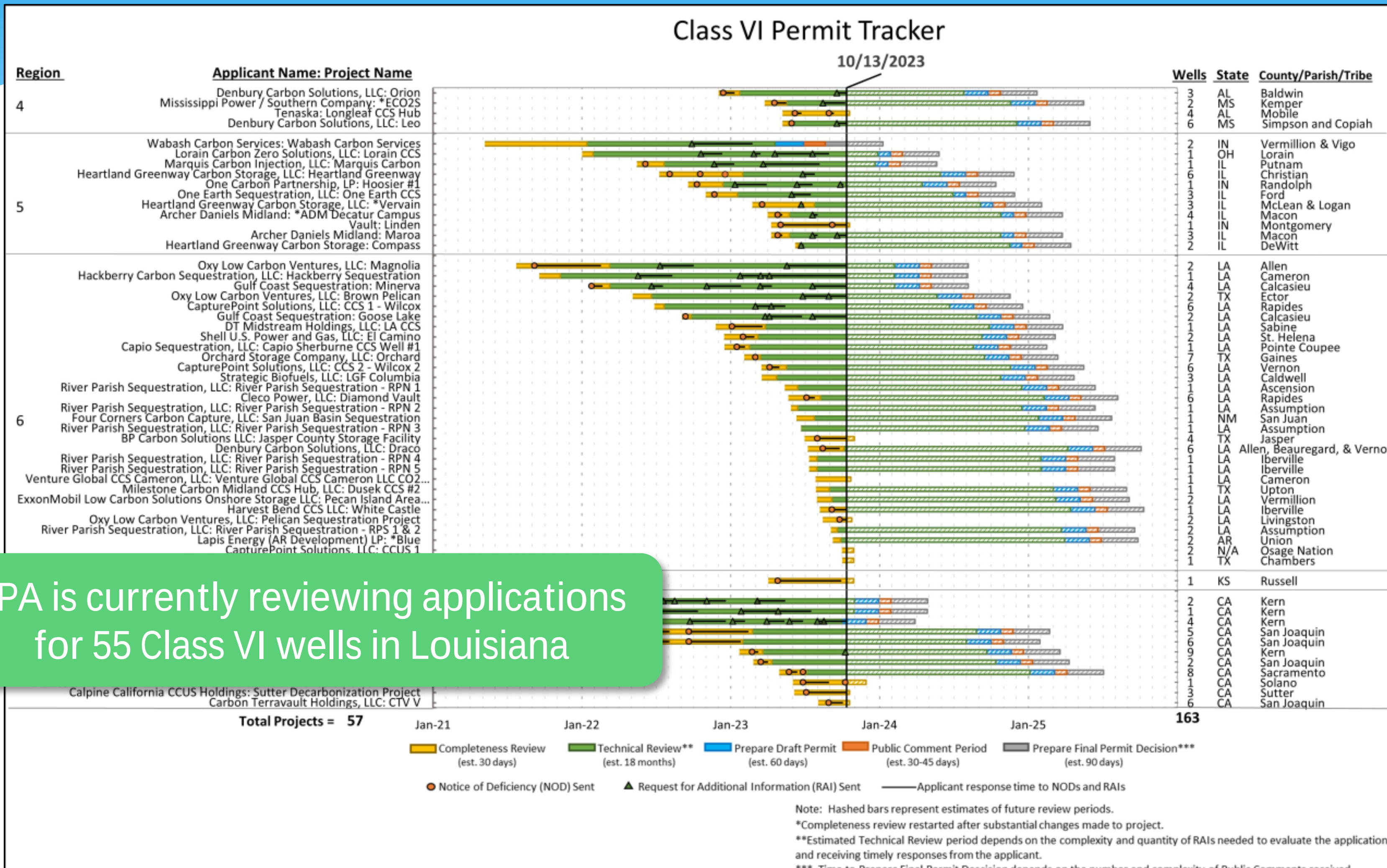
CO_2 Injection

- Generalized cross-section of typical Gulf Coast geology
- Saline reservoirs vs. depleted oil reservoirs
- Relative contributions of various trapping mechanisms
  - Structural
  - Capillary
  - Solubility
  - Mineral
- Containment Risks



Modified from Bump and Hovorka, 2023.

EPA Applications Under Review



EPA is currently reviewing applications for 55 Class VI wells in Louisiana

Regulatory Process

Pre-construction

- Site characterization
- AOR modeling
- Financial responsibility
- Well construction
- Proposed operating data and pre-injection testing
- Proposed project plans

Permit To Construct

Pre-injection

- Review revisions to plans (site characterization, corrective action, etc)
- Confirm background data is collected
- Verify adherence to Permit to Construct

Permit To Inject

Injection

- Review operating, monitoring, and testing data
- AOR updates at least every five years
- Annual financial responsibility updates
- Enforcement and compliance
- Permit modification

Injection Ceases

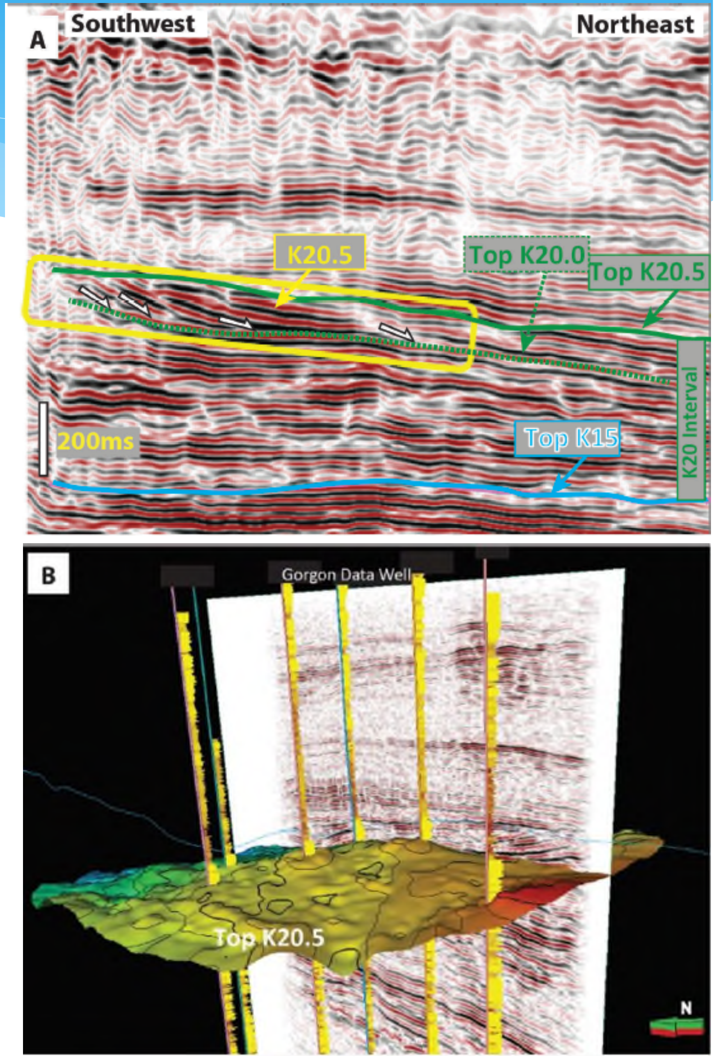
Post-injection

- Well P&A
- Post-injection site monitoring
- Emergency and remedial response
- Project and financial responsibility updates
- Non-endangerment demonstrations
- Site closure

The technical characterization required for a Class VI injection well, both during permitting and throughout the lifespan of the project, is an iterative process by design.

Permit Technical Content

- **Site characterization** – Forms the basis of the design and calibration of models used to predict CO_2 plume extent
- Geologic maps - structure, cross-sections, isopachs, fault plane, etc.
  - Must account for regional geology, local geology with AOR, and hydrology
  - Must characterize all structure, stratigraphy, lithology, and faulting within confining and injection zones
- Reservoir characteristics - mineralogy, porosity, permeability, capillary pressure, formation fluid, etc.
  - Must be verified using site specific log and core data.



Modified from Barranco et al, 2013.

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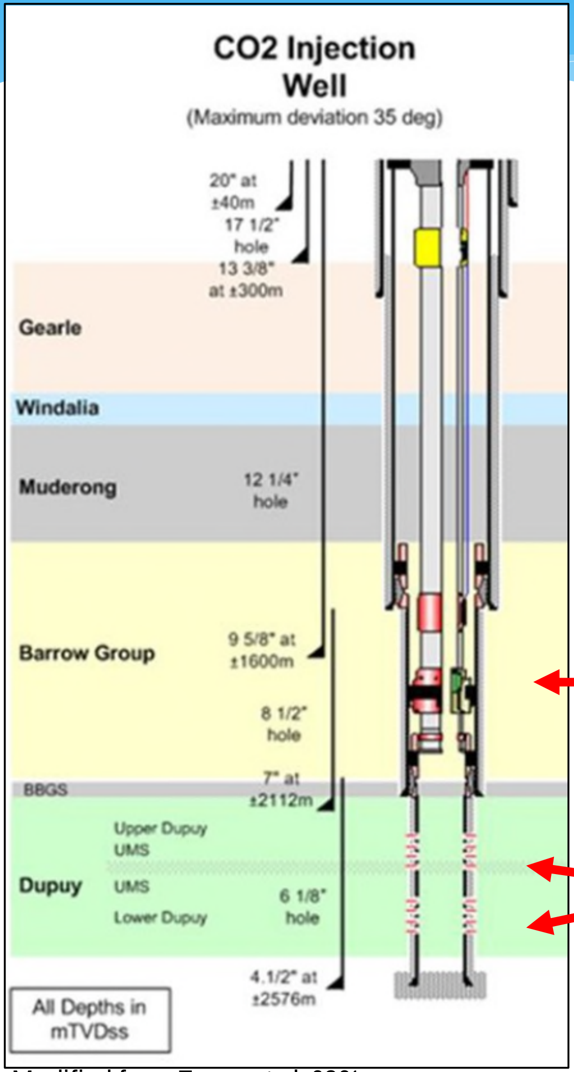


Modified from Trupp et al, 2021.

- Example of CO_2 injection well schematic from an ongoing CCUS project in Australia
  - CO_2 injected into the permeable sands of the injection zone is prevented from migrating upwards due to low permeability shales of the confining zone
  - Upward buoyancy of supercritical CO_2 must be accounted for in geologic assessment

Confining Zone – regional extensive deltaic shale

Injection Zone – multiple sandstone targets that include channelized slope deposits with massive sandstones and turbidites

Investigation of	Seismic						Gravity		Electrical/Electromagnetic			Magnetic
	2D	3D	VSP	3D-VSP	Cross-well	Borehole microseismic	Aerial & surface gravity	Borehole gravity	Natural source	Controlled source	ERT	Aerial & surface magnetic
Near borehole and shallow subsurface			W	W	W	W		W		W		
Field-wide subsurface studies	W	W		W		P	W		W	W		W
Stratigraphy	W	W	W	W	W		W	W	P	P	W	P
Thickness	W	W	W	W	W			W			W	
Structure 0 - 100 m				P		P	P		P	P	P	P
Structure 100 m - 1 km	W	W		W	W	W	P	P	P	P	W	P
Structure > 1km	W	W		W	P	W	W	P	W	W	P	W
Fault/fracture	W	W		W	W	W	P		W	W	P	
Porosity							P	W	W	W	W	
Pore pressure	P	W	P		P							
Abandoned wells											W	W

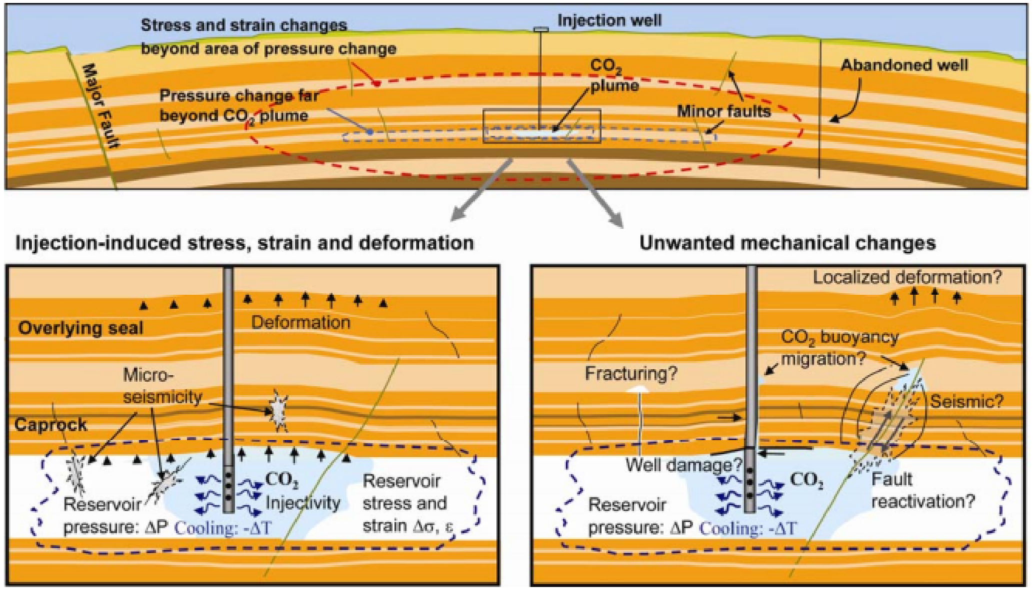
Modified from EPA , "Underground Injection Control (UIC) Program Class VI Well Site Characterization Guidance"

W = well suited (already in use for site characterization with good results)
P = potential (could be used, but better alternatives available or results lack desired resolution)

- **Geophysical characterization** – uses indirect geophysical methods to provide information about the subsurface. Specific methods may vary in spatial scale and resolution but generally provide more information over a larger area that direct sampling of the formations may provide.
  - Four main types of methods: seismic, gravity, electrical/electromagnetic, and magnetic
  - Applicants must demonstrate that selected method(s) are will provide the needed levels of resolution at the depth that's being characterized

Permit Technical Content

- **Geomechanical studies** – important for evaluating integrity of confining zones as well as safe operational parameters for the well
- Important for determining maximum surface injection pressure (MASIP)
- Risks to be avoided
  - Fracturing that might lead to loss of containment
  - Activation of existing faults
  - Induced seismicity that can be felt at the surface
  - Localized deformation
  - Mechanical damage to injector



Modified from Rutqvist, 2012.

Permit Technical Content

- **Computational Modeling**
  - *Static/geologic model* – model of the physical framework of the earth using geologic structure, lithology, stratigraphy, facies distribution, porosity and intrinsic permeability distribution, reservoir characteristics, etc.
  - *Simulation/reservoir model* – models the flow of the multiphase CO_2 plume through the pore space. Accounts for any CO_2 phase transition (supercritical/liquid/gas), dissolution of CO_2 into reservoir fluids, density and thermal effects, chemical and physical changes over time, etc.
    - *Reactive transport modeling* – component of reservoir model that evaluates mineral dissolution and precipitation, potential effects of trace constituents in the CO_2 stream (e.g., H_2S, So_x), mineralization as a trapping mechanism, etc
    - Note regarding constituents in CO_2 stream – acid gas injection wells **will not** be permitted in Louisiana. The addition of any waste chemicals to the CO_2 injection stream is strictly prohibited.
  - All models and model inputs will be reviewed and verified by technical staff.
  - Must be updated **at least every five years** or as warranted by operating and monitoring conditions

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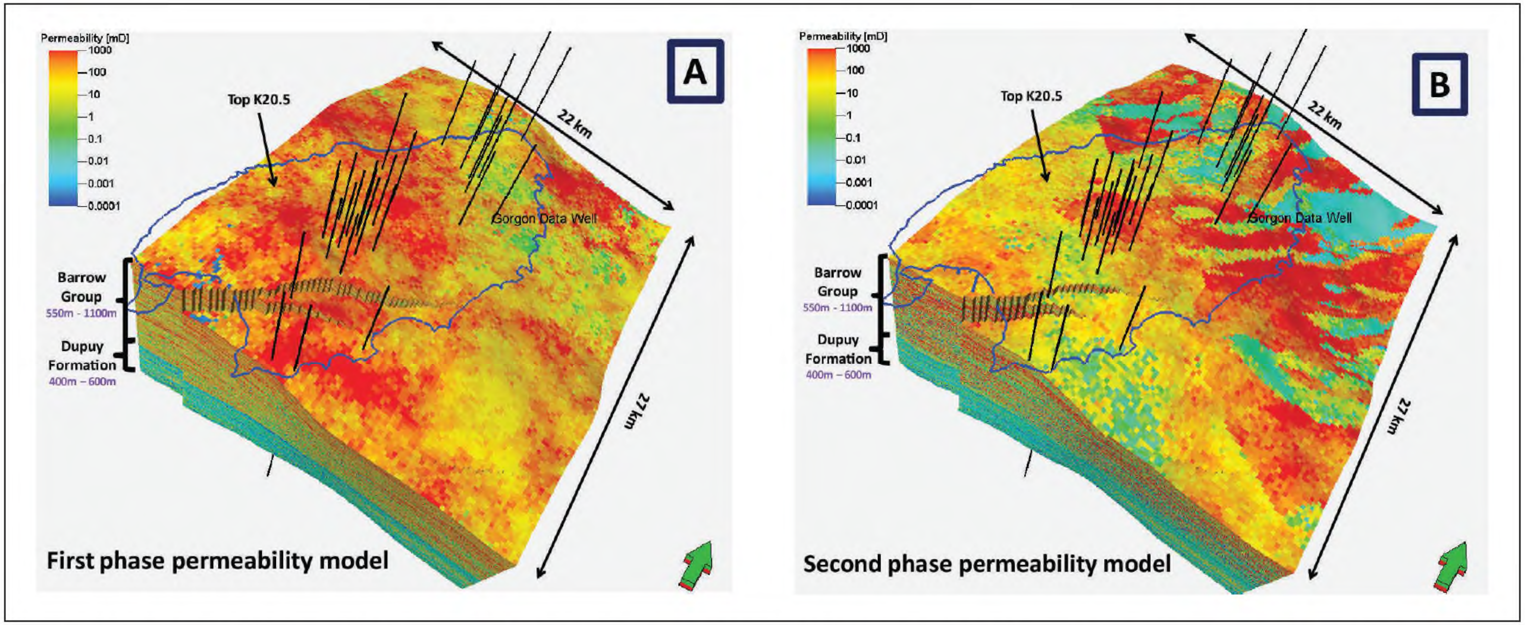

Figure 16. a) First phase permeability model. This model was conditioned to a simple facies model created using Sequential Indicator Simulation (SIS). b) Second phase permeability model conditioned to a facies model populated using Multipoint Statistic Simulation (MPS) which gives a more geological representation of the Barrow Group.

Modified from Barranco et al, 2013.

Modeling is an iterative process where applicants are required to update and refine their geologic and reservoir models with site specific data. A model is only as good as the data that's fed into it, so these revisions with up-to-date information are vital to ensure effective characterization over the lifespan of the project.

Permit Technical Content

Area of Review (AOR)

* "the region surrounding the *geologic sequestration project* where USDWs may be endangered by the injection activity, and is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected *carbon dioxide stream* and displaced fluids, and is based on available site characterization, monitoring, and operational data as set forth in §§3615.B. and 3615.C." - LAC 46.XVII.3601.A
* <u>AOR = Plume Extent + Pressure Front</u>
* Pressure front is extent of sufficient pressure to force injection zone fluid into the USDW
* Must be reevaluated at least every five years, or when monitoring and operational conditions warrant
* Updates must incorporate monitoring data and any changes in operating conditions
* <u>**Importance of a fully characterized AOR cannot be overstated**</u>

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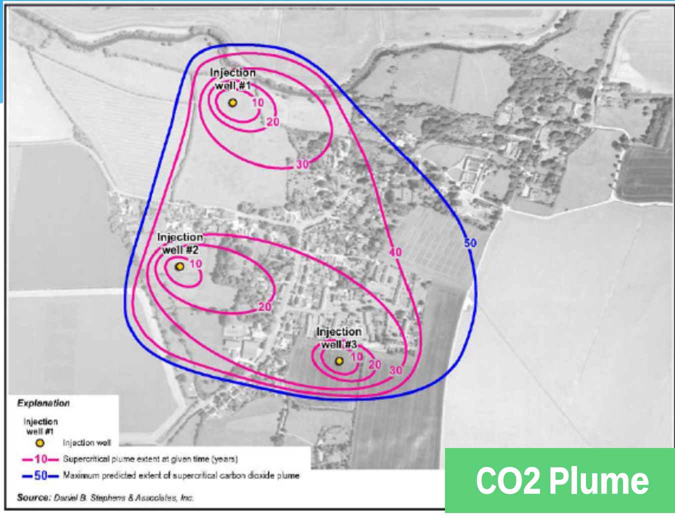

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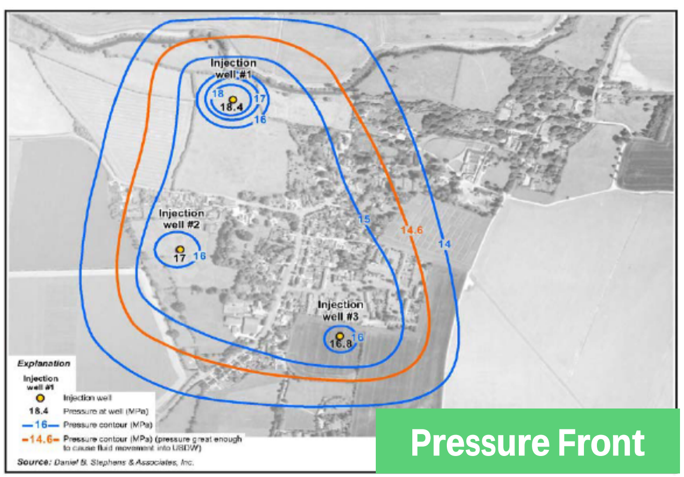

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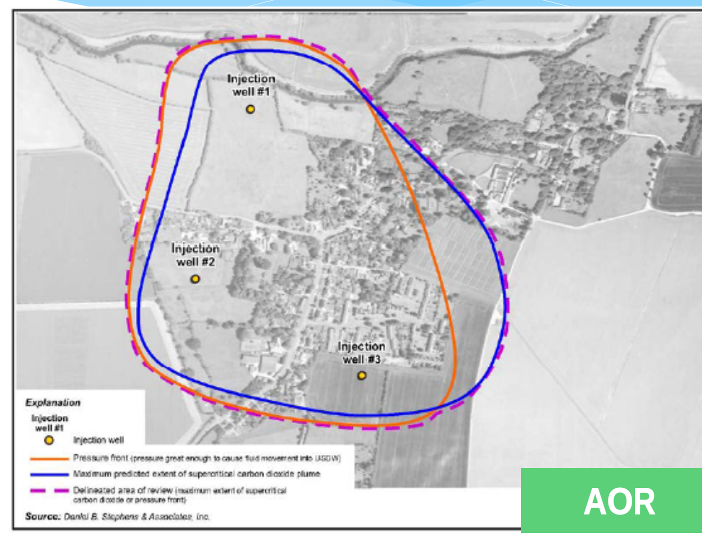

Modified from EPA , "Underground Injection Control (UIC) Program Class VI Well Area of Review Evaluation and Corrective Action Guidance"

* Theoretical AOR based on max extent of multiphase CO_2 plume **AND** maximum extent of pressure effects

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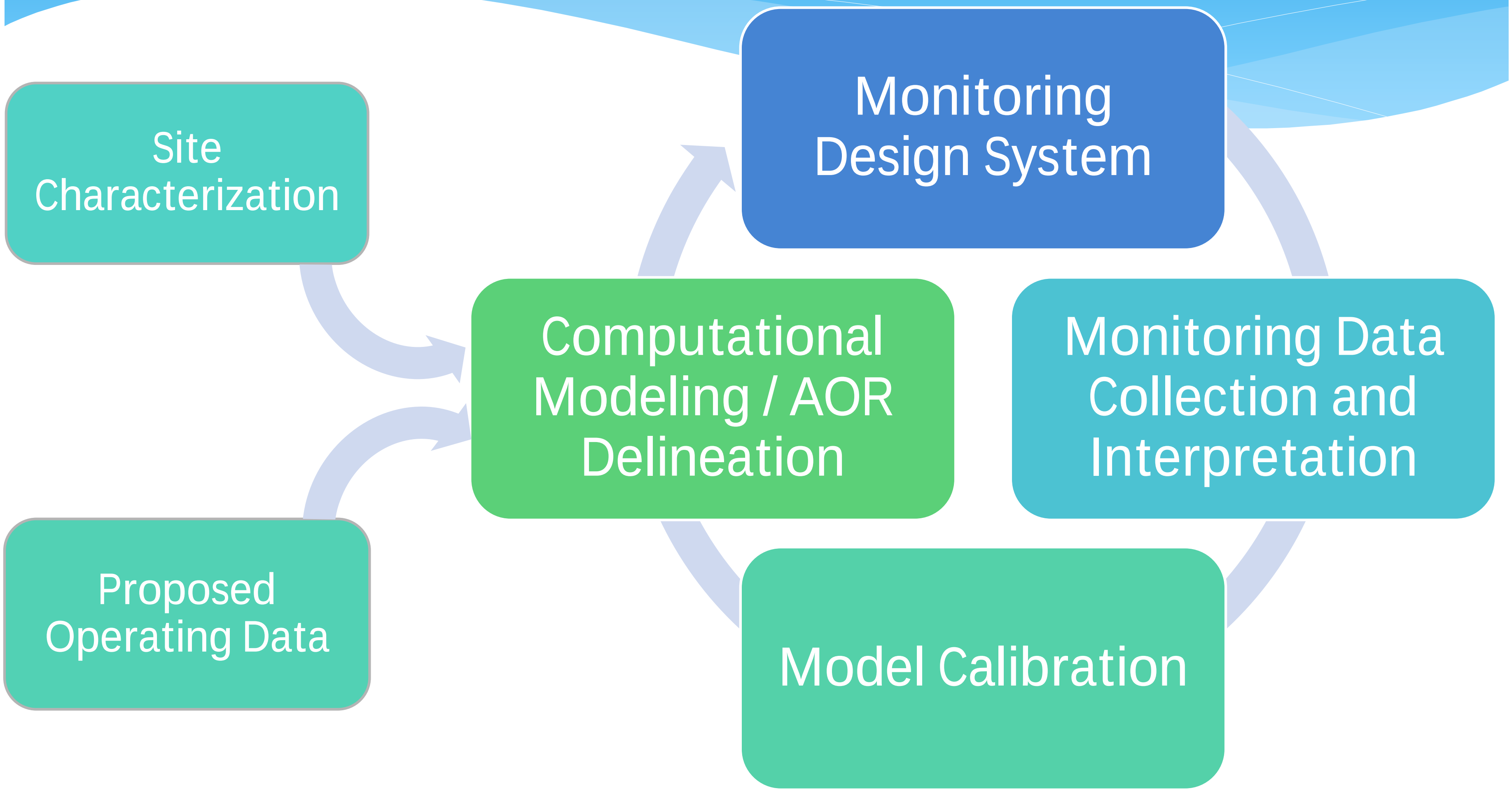

Monitoring After a Project Begins

- LDNR's monitoring requirements largely match federal requirements
- "How do you get representative monitoring data and what do you do with it?"
- Testing and Monitoring Plan will need to provide specificity on methods, equipment, site-specific technical justification, sensitivities, operator responses to any deviations, etc.
- **Area of Review (AOR) of plume and pressure extent must reevaluated at least every five years, or as warranted by monitoring and operational conditions**

Monitoring After a Project Begins

- Groundwater Quality Above the Confining Zone
  - Testing to detect changes in groundwater chemistry that may indicate loss of containment; compare to baseline data collected during site characterization
- Plume and Pressure Front Tracking
  - Results necessary for model comparison and verification
  - *In situ fluid pressure monitoring* – e.g., pressure transducers in monitoring wells
  - *Indirect geophysical monitoring* – seismic, gravity, electromagnetic, electrical
  - *Groundwater geochemical monitoring* – detection of CO_2 plume in monitoring wells; adjusted sampling procedures for high temp/pressure conditions
  - *Computational modeling* – part of required AOR updates
- Surface Air/Soil Gas Monitoring
  - May be required to detect movement of CO_2 outside of the permitted injection zones
- Additional takeaways – just like the AOR updates, monitoring is a dynamic process that requires includes updates and revisions throughout life of project. Each monitoring plan is site specific where up-to-date information on CO_2 plume movement and CO_2 stream composition will be repeatedly updated in the reservoir model and AOR characterization.

Monitoring After a Project Begins

Testing and Monitoring Activities required by state and federal regulations	Siting/Evaluation	Well Construction	CO_2 Injection and Monitoring	Post-Injection Site Care (PISC)	Post-Closure
Mechanical integrity testing		↔	↔		
Analysis of CO_2 stream	↔	↔	↔		
Monitor injection pressure, rate, and volume			↔		
Corrosion monitoring			↔		
Monitor groundwater in zones above confining zone	↔	↔	↔	↔	
Monitor USDW	↔	↔	↔	↔	
Pressure falloff testing			↔		
Plume and pressure front tracking	↔	↔	↔	↔	

Modified from EPA , “Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance”

Post Injection Site Care Period and Site Closure

* Monitoring, as specified in approved PISC plan, is required for at least 50 years unless an alternative timeline is approved by LDNR's Commissioner of Conservation, in consultation with the EPA
* Demonstration of Alternative PISC Timeframe
  * Must be based on significant, site-specific data and information
  * Must contain substantial evidence that the geologic sequestration project will no longer pose a risk of endangerment to USDWs at the end of the alternative post-injection site care timeframe
  * Full requirements for consideration and documentation detailed at LAC 46.XVII.3633.A.3
* Under any scenario, an operator **<u>must</u>** submit a demonstration that no additional monitoring is necessary to demonstrate no threat to the USDW before receiving authorization for site closure

Questions?

CONTACT INFORMATION

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