LDNR and CCUS – Carbon Sequestration in Louisiana

Office of Conservation

Injection & Mining Division

February 2023

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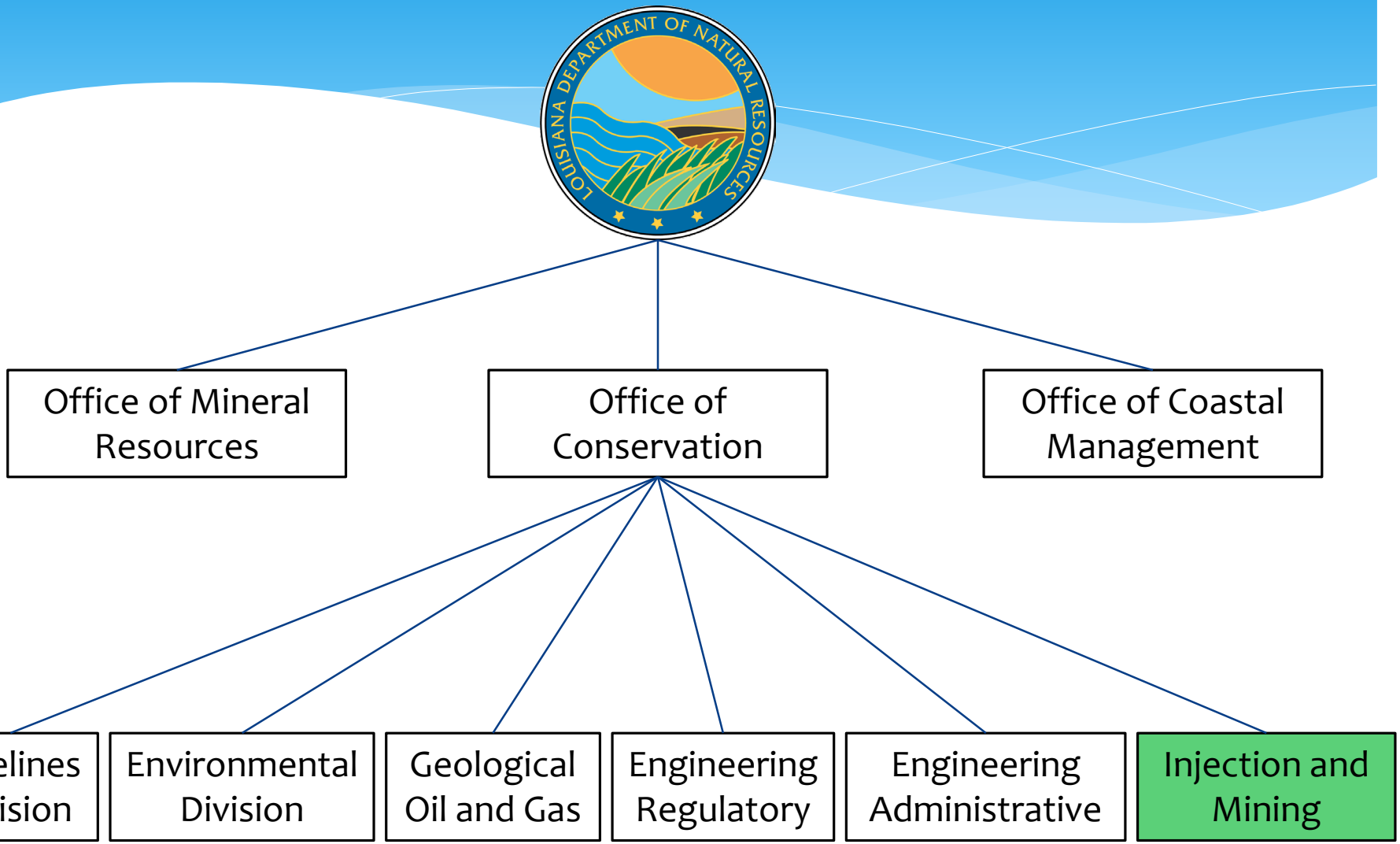
Louisiana Department of Natural Resources



Office of Conservation – IMD

* Office of Conservation- Injection & Mining Division 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 Primacy
  * Class VI injection wells - used for the geologic sequestration of anthropogenic CO_2
  * Conservation's application for Class VI primacy is currently under review by EPA

Injection Well Class Types

Class I	Industrial (Hazardous & Non-Hazardous) or Municipal Waste
Class II	Oil & Gas Related (*SWD*, *EOR*, *Storage*)
Class III	Solution Mining (Caverns)
Class IV	Hazardous Waste above or into USDW
Class V	Wells not covered under the remaining classifications
Class VI	Carbon Sequestration

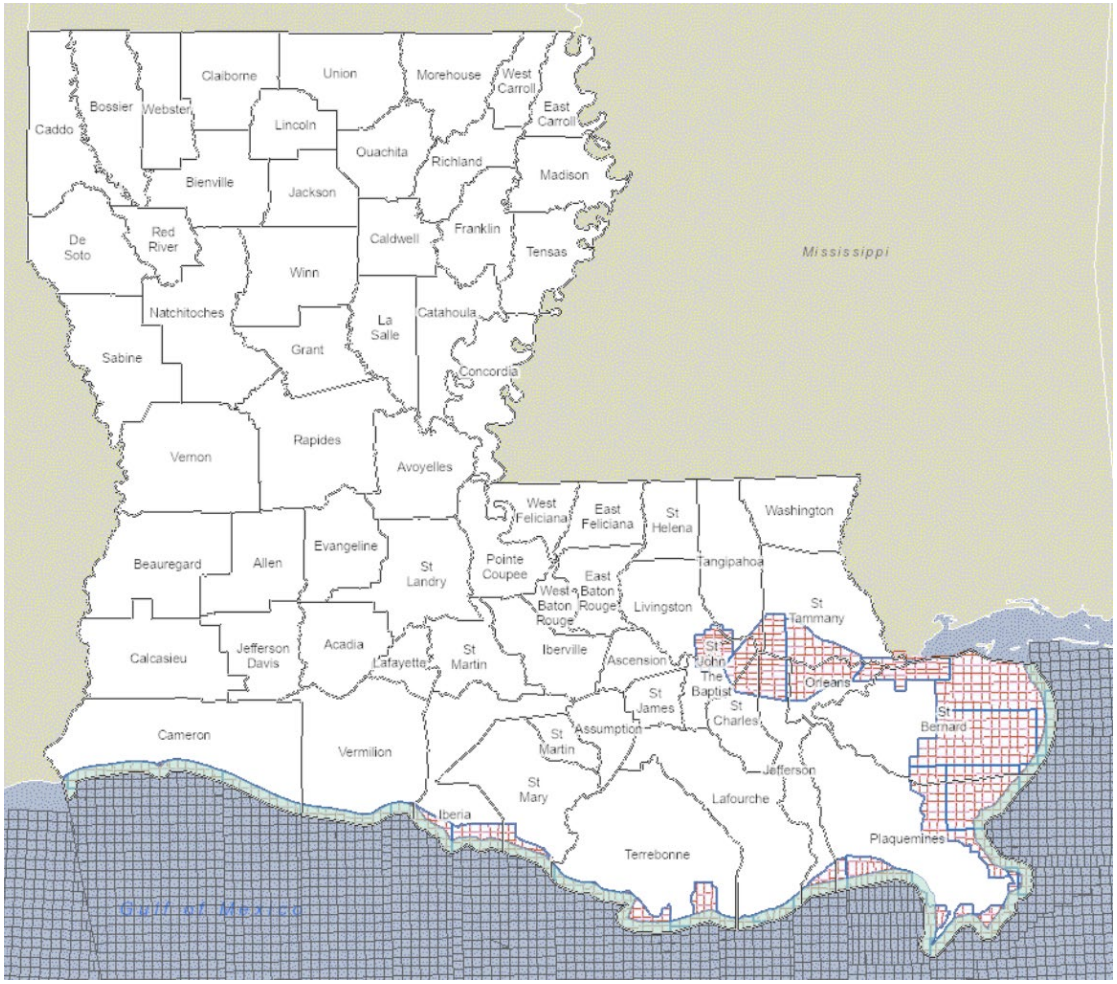
Injection wells in Louisiana

As of February 15, 2023

Total Wells	4625
Class I	35
Class II	3361
Class III	85
Class IV	0
Class V	1144
Class VI	0… yet

CCS in Louisiana

Louisiana Department of Natural Resources



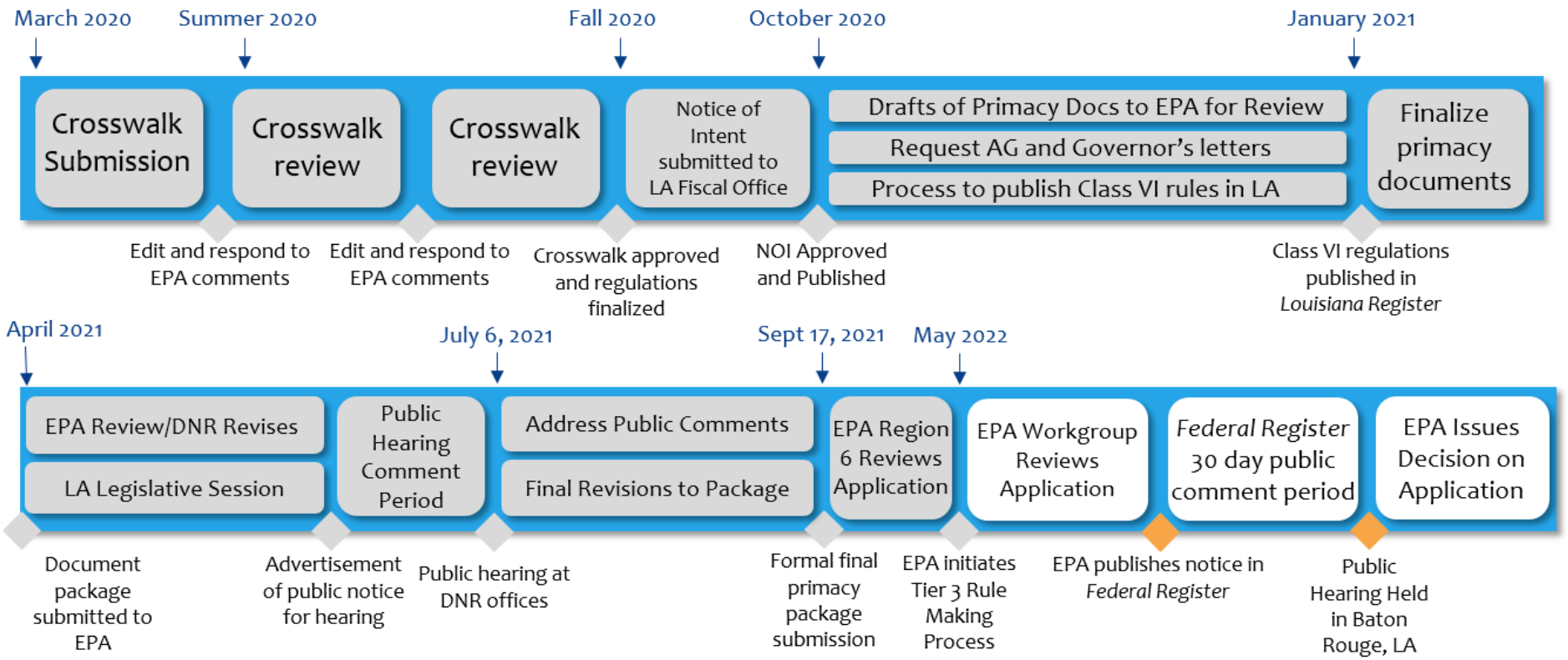
- **Interest in Louisiana**
  - South LA focus
  - Saline aquifers most popular
  - No CO_2 sequestration in salt caverns
  - Fifteen (15) administratively complete applications under review/pending review in Louisiana[1] (as of February 16, 2023)
- **Louisiana Class VI regulations promulgated January 2021[2]**
- **Primacy Application from LDNR to USEPA in progress (app is under review at EPA HQ)**

[1]https://www.epa.gov/uic/class-vi-wells-permitted-epa

[2]http://www.dnr.louisiana.gov/assets/OC/im_div/uic_sec/43v17_2021.pdf#page=149

Steps to Class VI Primacy

Louisiana Department of Natural Resources



CONTACT INFORMATION
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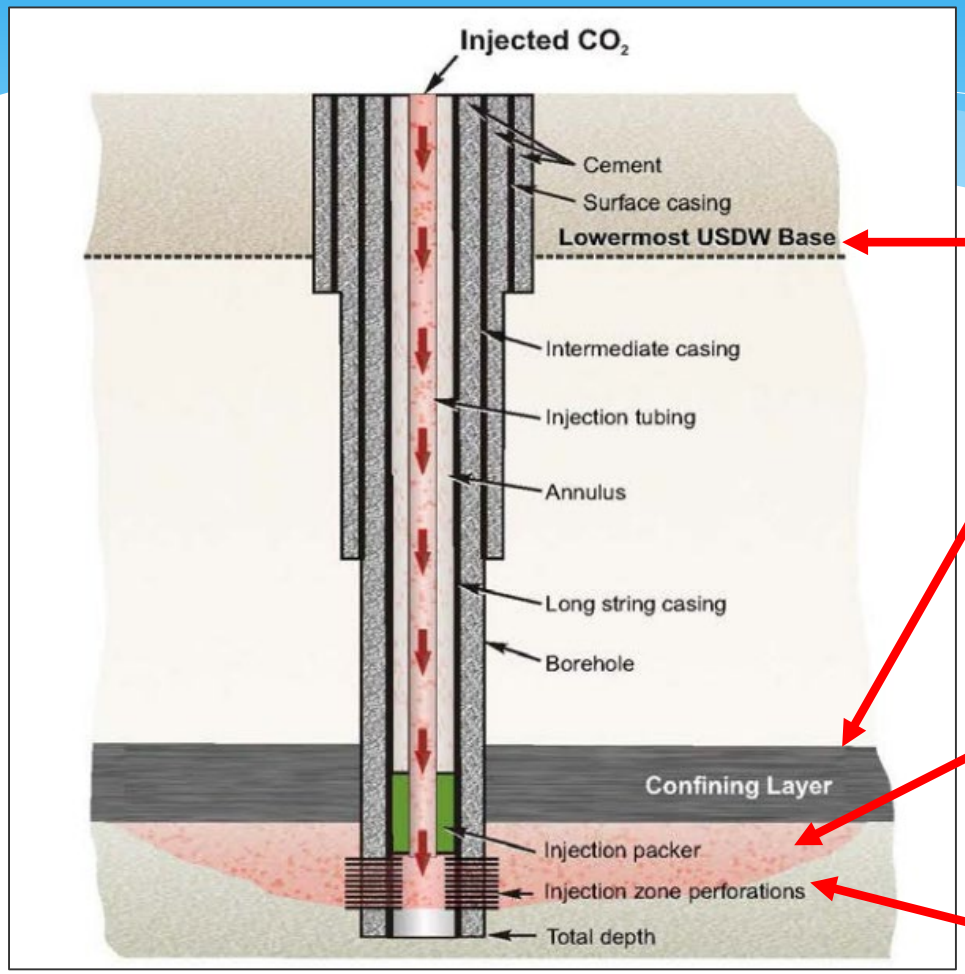
Basics of Underground Injection



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

Base of the USDW – base of the lowermost aquifer with less than 10,000 mg/l TDS

Confining Zone – formation overlying the injection zone that acts as a barrier to fluid movement

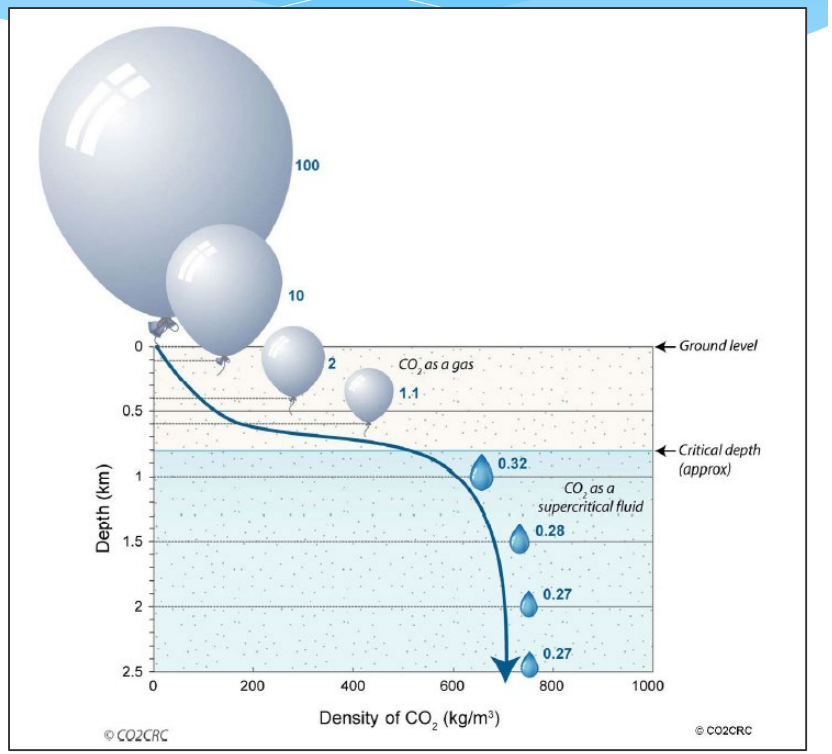
Injection Zone – formation receiving fluids through a well; must be of sufficient areal extent, thickness, porosity, and permeability

Injection Interval – part of the injection zone that is screened or perforated

CO_2 Injection

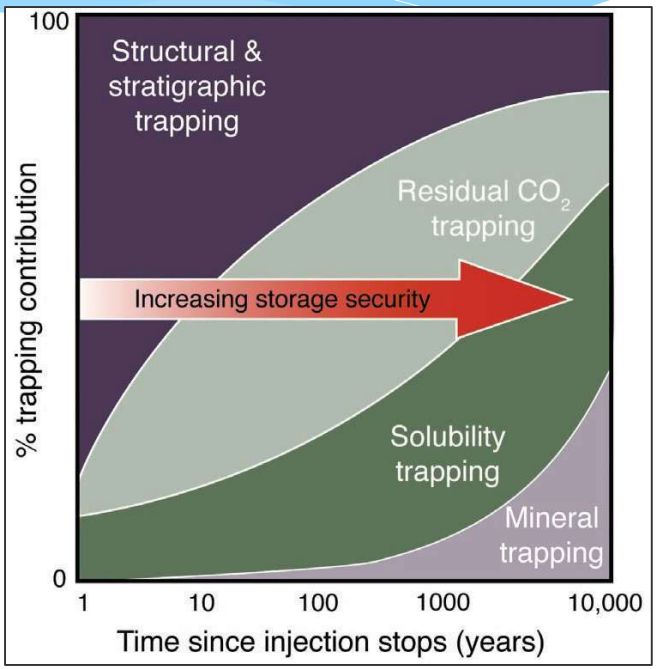
How does injected CO_2 stay underground?

- Captured CO_2 gas is compressed to supercritical phase
- Supercritical phase – point above 87.7 degrees F and 1,070 psi where CO2 begins to share physical properties of liquid and gas
- Supercritical CO_2 can be injected underground and will remain in supercritical phase due to naturally high reservoir pressures of deep geologic formations



CO_2 Injection

- CO_2 sequestration happens in the permeable pore space between grains of sediment that make up the rock. Not in underground caverns or cave-like structures.
- Ways that CO_2 becomes trapped during sequestration
  - **Structural Trapping** – primary trapping mechanism where a low permeability shale overlies the permeable injection zone and is a barrier to upward migration
  - **Capillary Trapping** – also called residual phase trapping or hysteresis, CO_2 that invades the pore space is trapped by brine in the smaller pores, pore throats, and pore edges
  - **Solubility Trapping** – the CO_2 and other injection stream constituents go into solution within the brine resulting in decreased amount of CO_2 subject to buoyant forces
  - **Mineral Trapping** – dissolved CO_2 reacts with minerals in the formation and precipitate out as carbonate minerals



Modified from Benson and Cole, 2008.

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

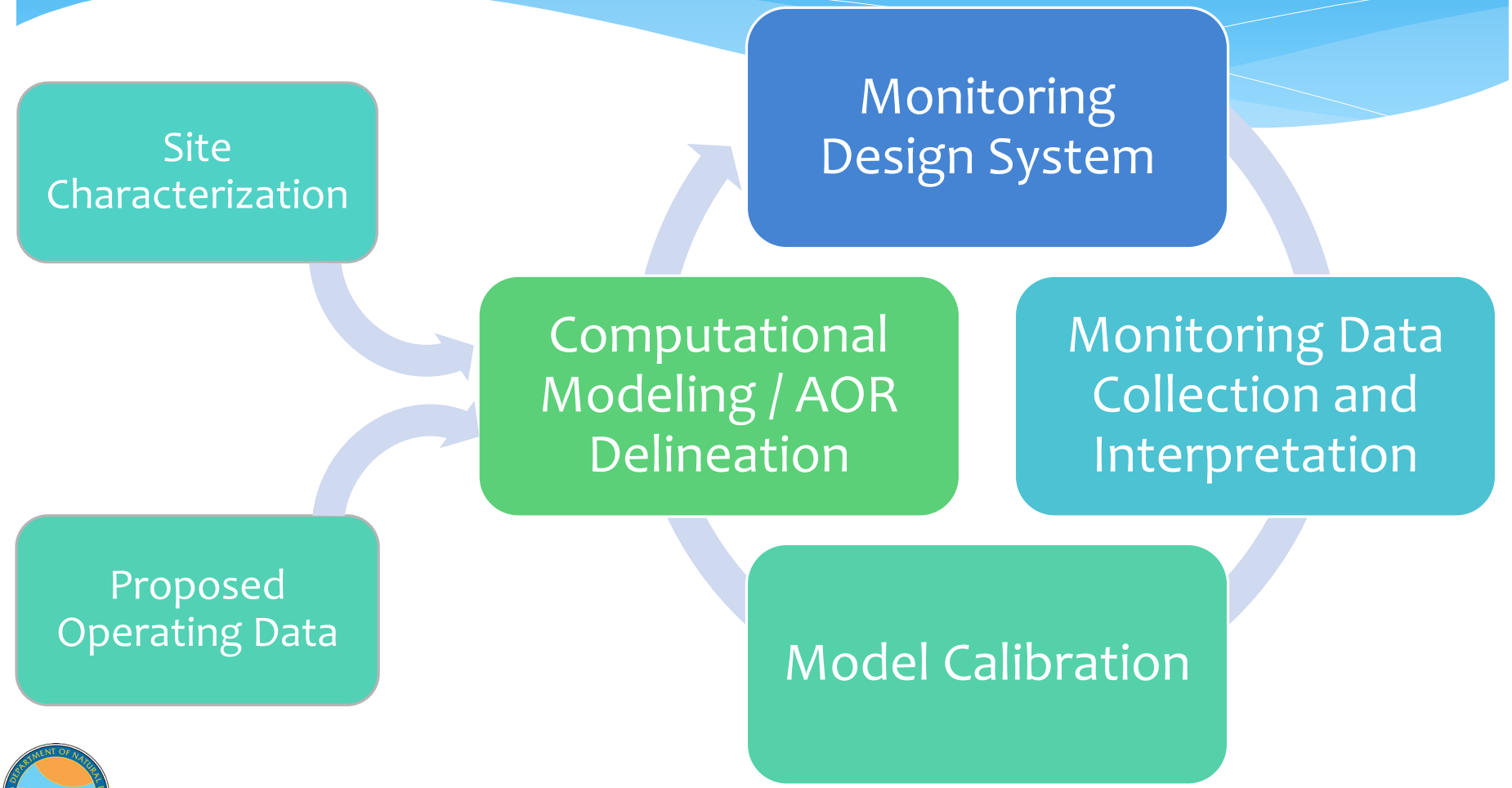
Injection Ceases

Post-injection

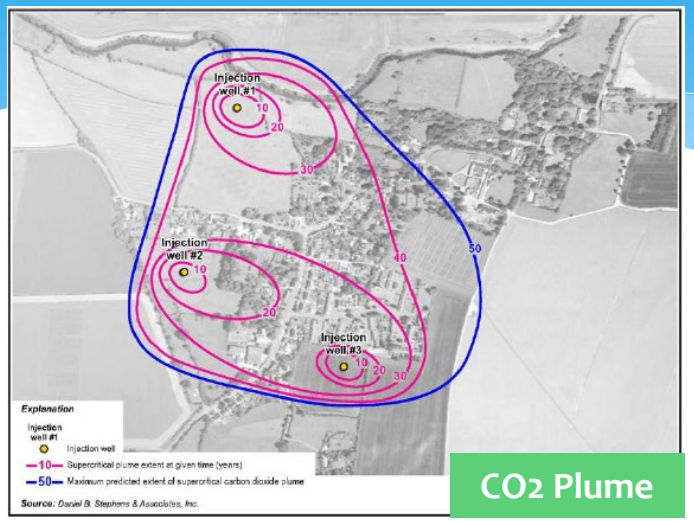
- Well P&A
- Post-injection site monitoring
- Emergency and remedial response
- Project and financial responsibility updates
- Non-endangerment demonstrations
- Site closure

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



Permit Technical Content – Area of Review



CO2 Plume

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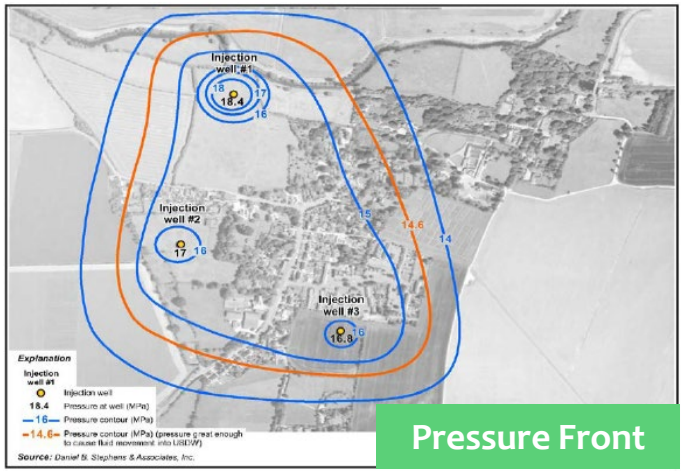

Pressure Front

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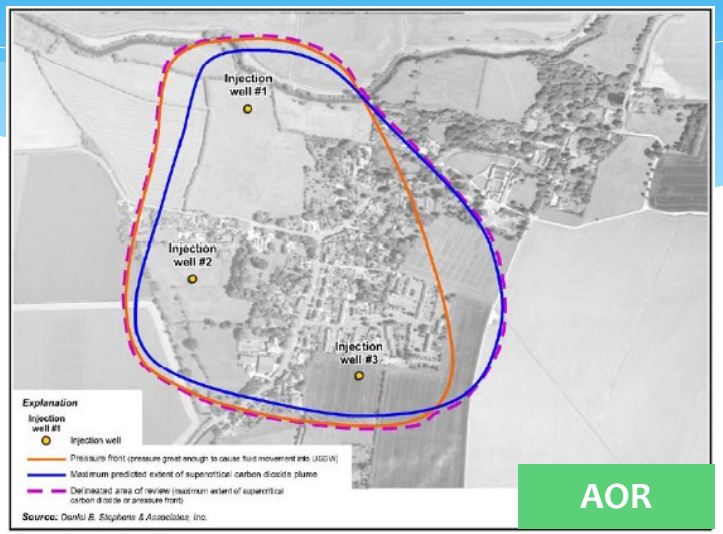
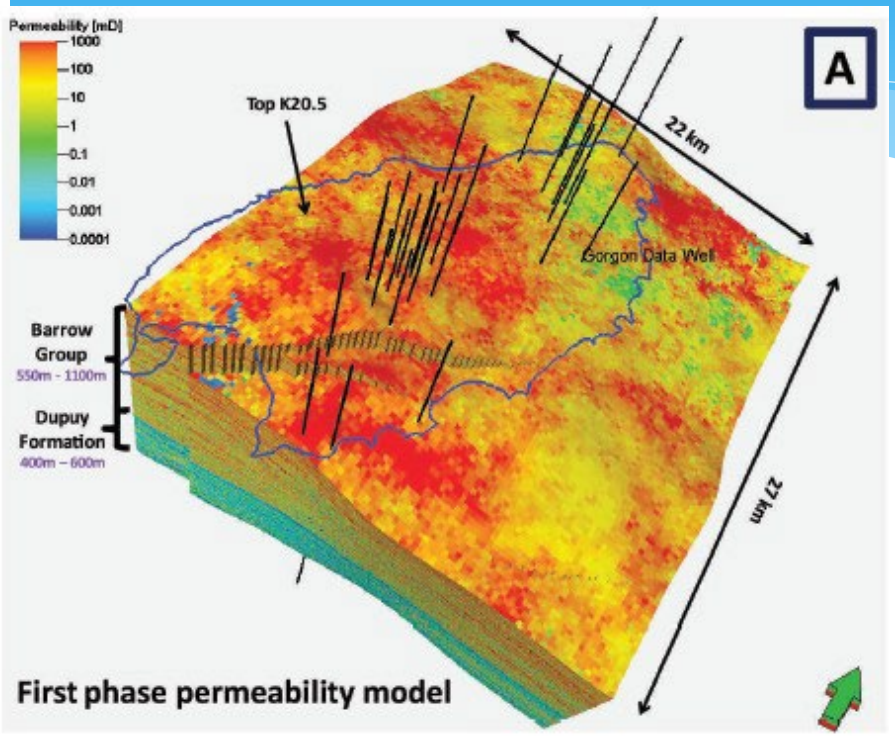


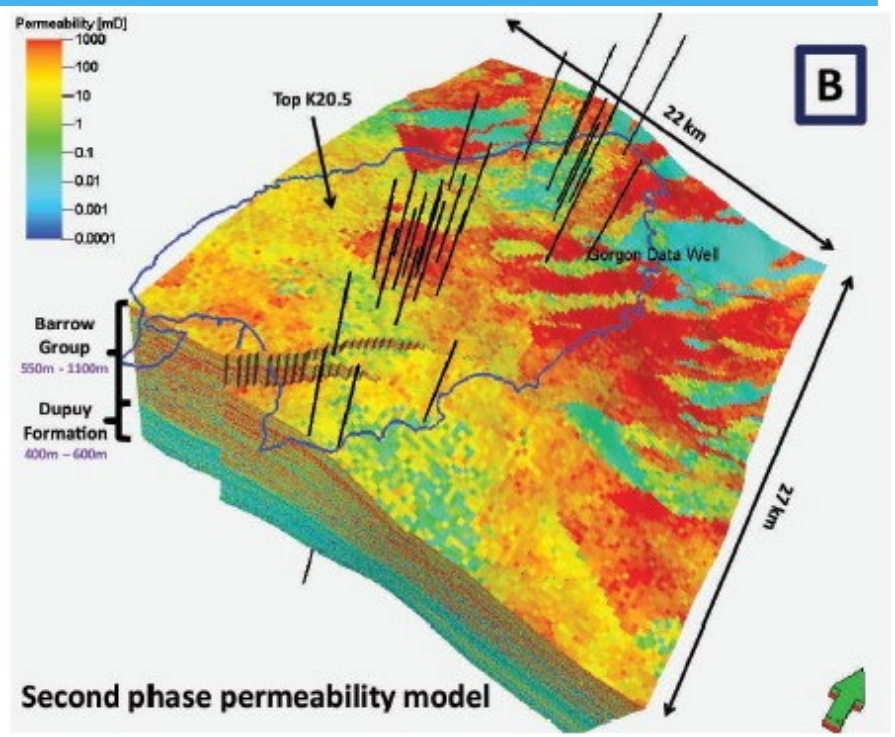
AOR

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 (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

Permit Technical Content – Site Characterization



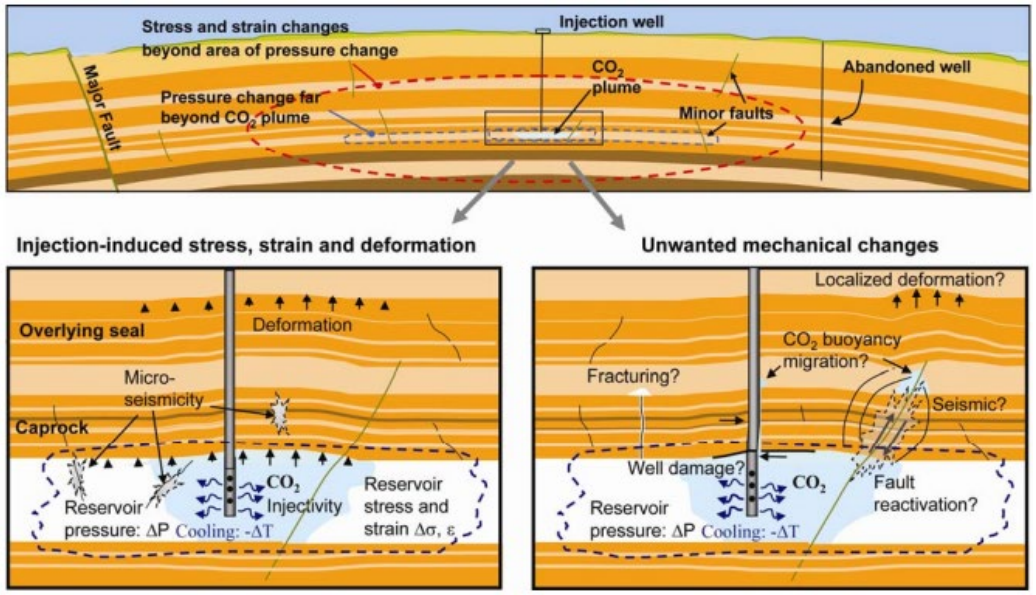


Modified from Barranco et al, 2013.

* 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.
  * Reservoir characteristics - mineralogy, porosity, permeability, capillary pressure, formation fluid, etc.

Permit Technical Content

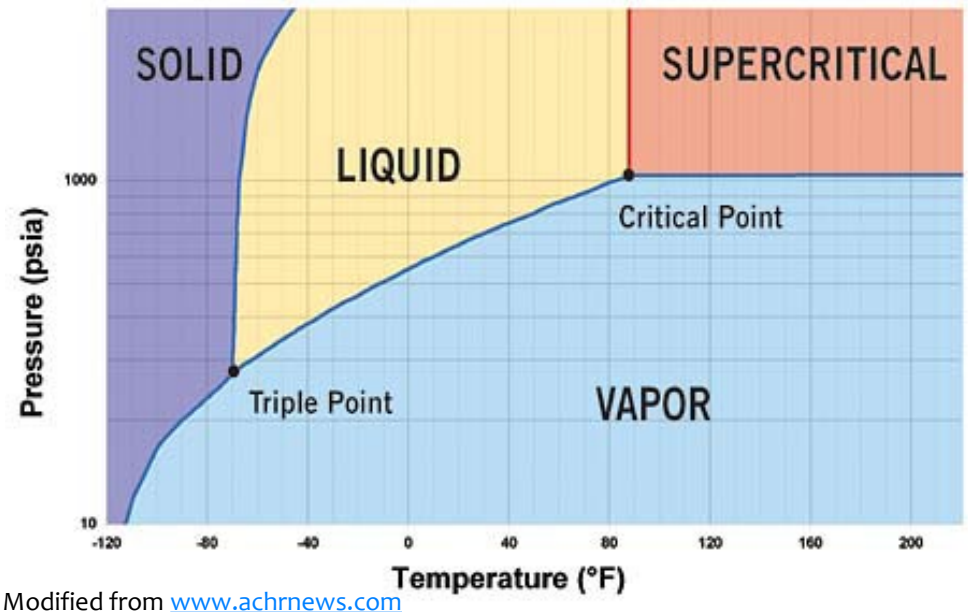
- **Geomechanical studies –** important for evaluating integrity of confining zones as well as safe operational parameters for the well
  - Important for determining maximum surface injection pressure (MASIP)
- Risks to be avoided
  - Fracturing leading that might lead to loss of containment
  - Activation of existing faults
  - Induced seismicity that can be felt at the surface
  - Localized deformation
  - Mechanical damage to injector
  - "Thou shalt not frack."



Modified from Rutqvist, 2012.

Types of geomechanical info	Potential tools to evaluate
Presence of existing fractures	Detection in wellbores using logs like microseismic, caliper, acoustic, or video logs.
Ductility – capacity of a rock to undergo plastic strain/deformation without fracturing	Triaxial load test on core samples
Rock strength – the ability of a rock to undergo differential stress	Triaxial load test on core samples
In situ stress field – the orientation and magnitude of stress in formation before being disturbed by outside influences	Evaluating density of the surrounding formations and performing formation stress tests

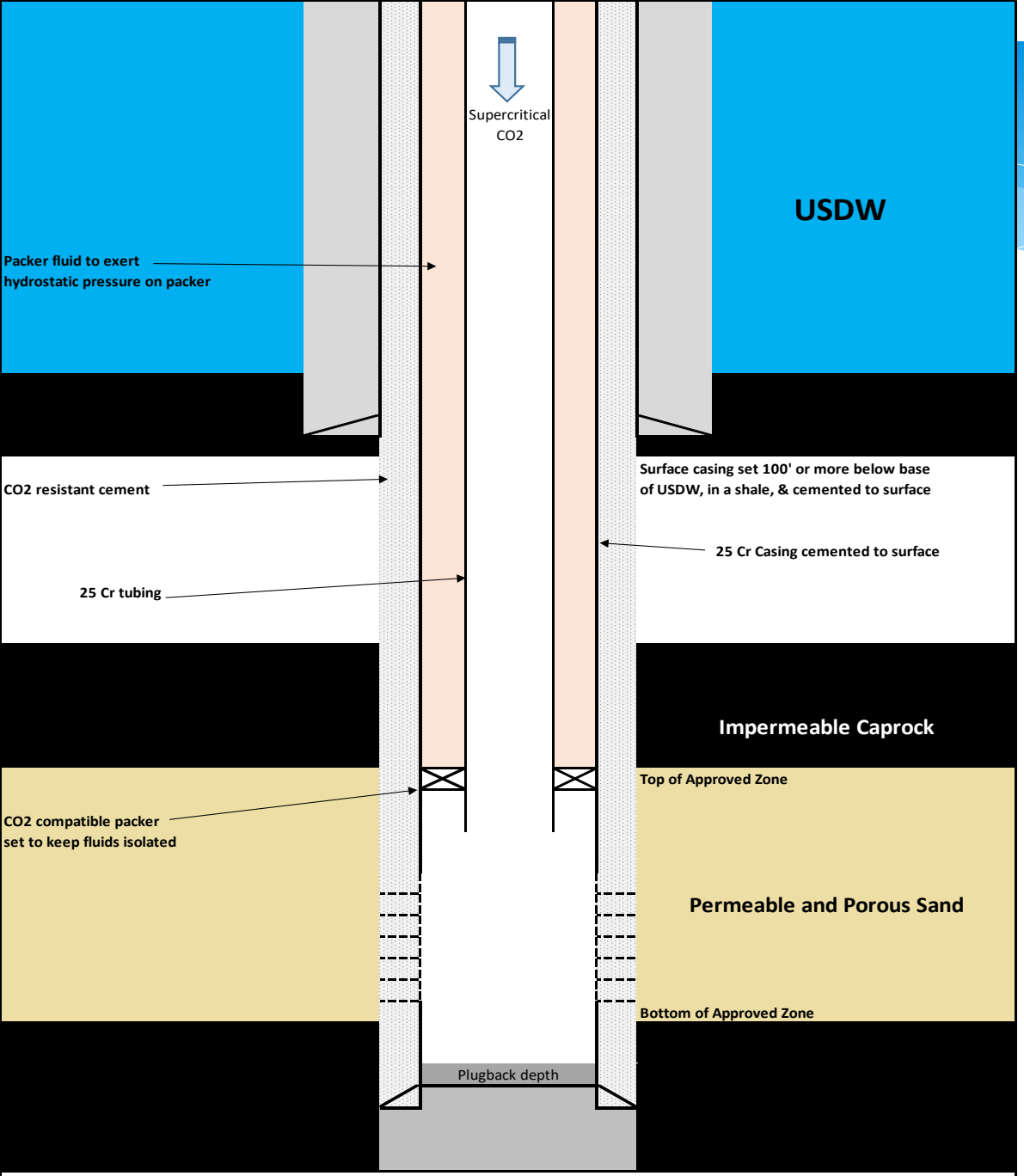
Engineering Considerations - Buoyancy



Modified from www.achrnews.com

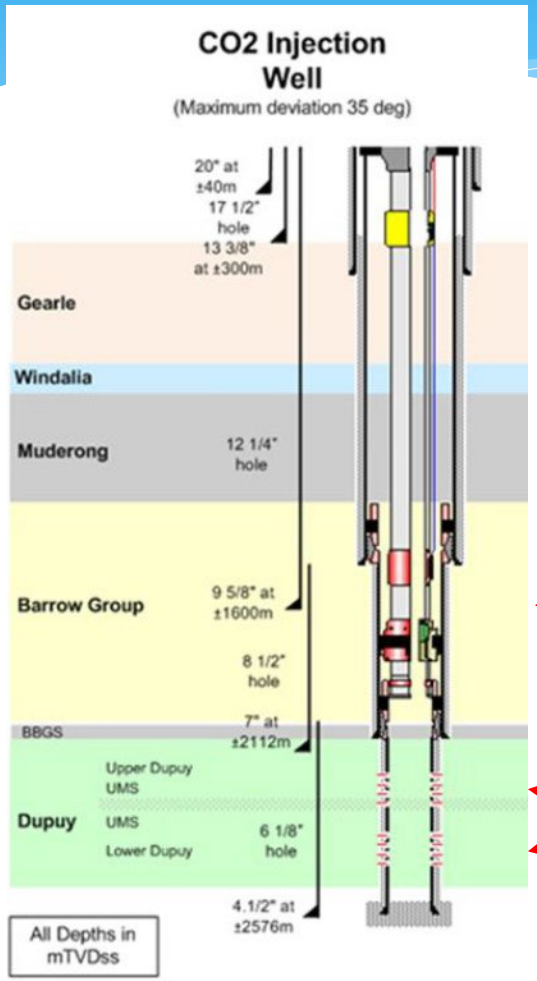
* Relative buoyancy and mobility of supercritical CO_2
* Supercritical CO_2 ~3.5 – 6 ppg
* Typical saline reservoir brine ~ 8.65 ppg

Example Wellbore Schematic



Schematic created by Cody Todd on 10/20/2022 for example purposes only

Engineering Considerations - Buoyancy

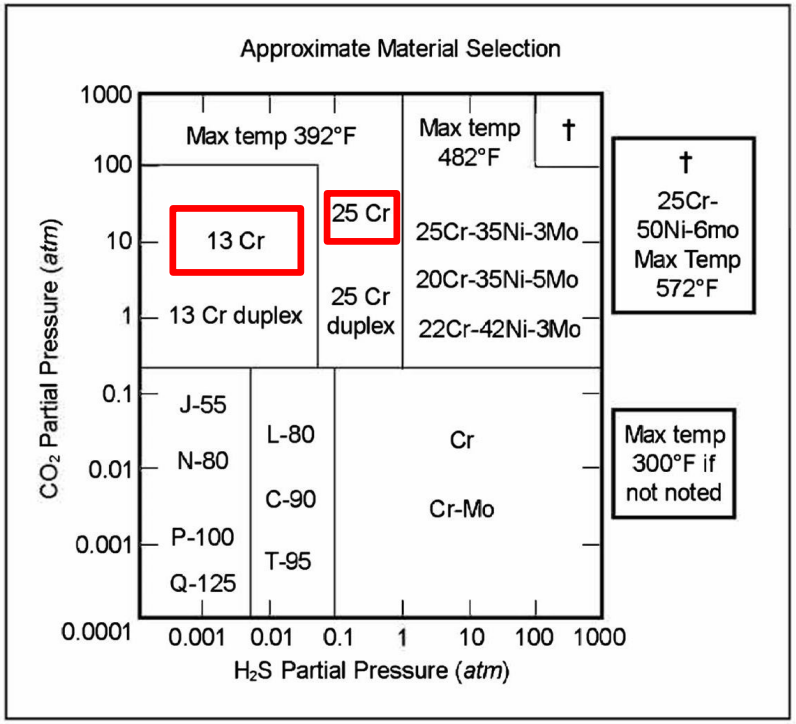


Modified from Trupp et al, 2021.

Confining Zone – regional extensive deltaic shale

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

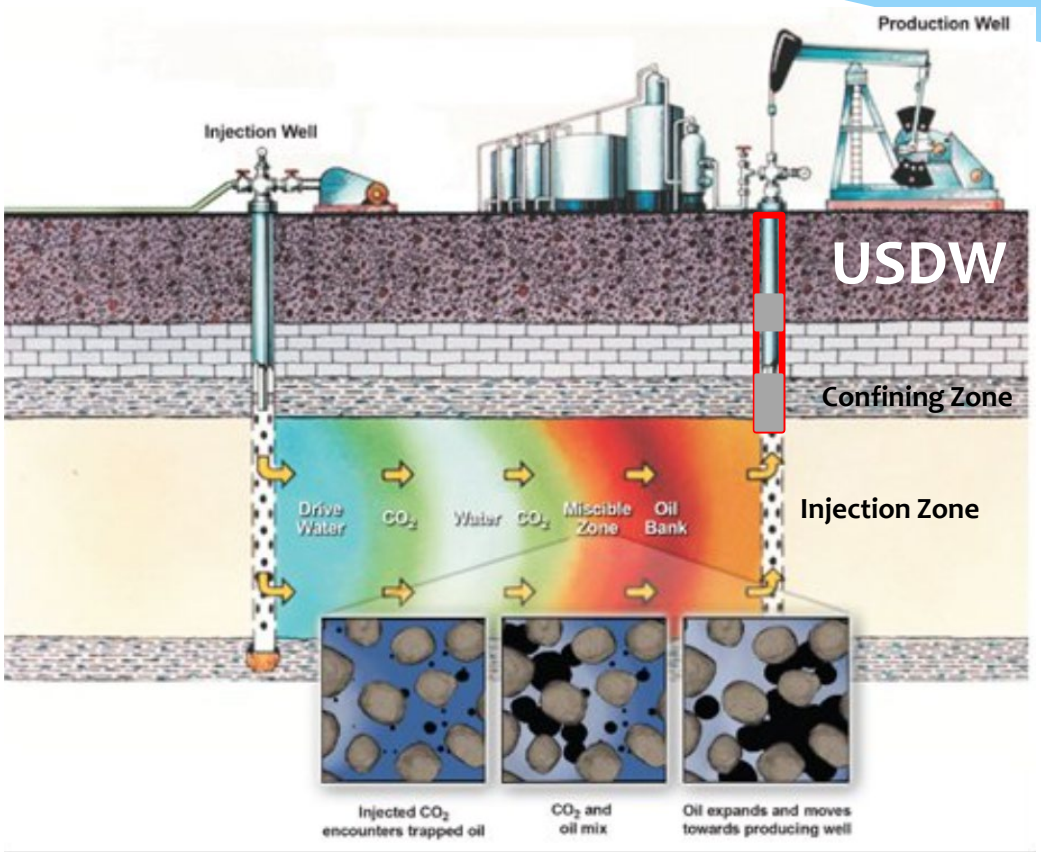
Engineering Considerations - Corrosivity



PE License Exam Reference Guide – Ali Ghalambor

* $H_2O + CO_2 \longrightarrow H_2CO_3$ (Carbonic Acid)
* Selections for wellbore materials through material compatibility studies must account for characterization of CO_2 injection stream
* Compatible materials will be required in any wellbore that may interact with the CO_2 plume

Engineering Considerations - USDW protection



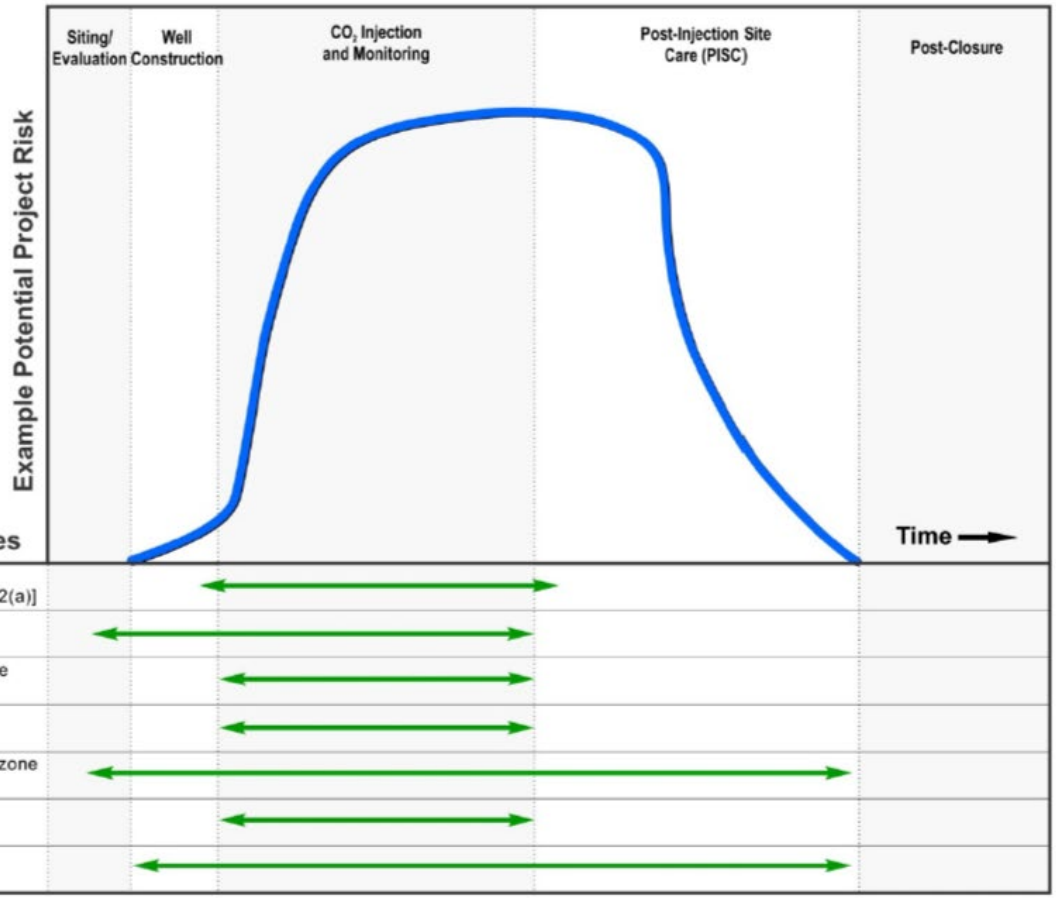
Modified from www.energy.gov

* Casing through the confining zone
* Plug across confining zone
* Plug across USDW

* **CO_2 compatible materials will be required**

Monitoring After a Project Begins

"The Class VI Rule requires various testing and monitoring activities to identify any risks to, and endangerment of, USDWs during the various phases of a [geologic sequestration] project (i.e., pre-injection, injection, and post-injection)… Figure 1-1 presents an example 'risk diagram' for the stages of a GS project and the accompanying Class VI Rule testing and monitoring requirements that address this risk. Note that the relative risks to USDWs during different stages of a GS project are site- and project-specific; Figure 1-1 presents a simplified example for explanatory purposes."



Corresponding LAC 46.XVII Chapter 36 Regulations
§3617.B.1.d, §3627.A, §3627.A.5, §3631.A.2
§3625.A.1
§3625.A.2
§3625.A.3
§3625.A.4,
§3625.A.6
§3625.A.7, §3633.A.2

Table and text modified from EPA , "Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance". Note – regulatory citations in chart refer to Title 40 Code of Federal Regulations (CFR) Part 146. See side table for equivalent Louisiana regulations.

Permit Technical Content

* **Class V Stratigraphic Test Well**
  * Permitted through IMD (3-6 month permitting process)
  * Useful tool for site characterization
  * Can be utilized for logging, core collection, injectivity tests, etc.
    * CO_2 cannot be injected as test fluid
  * Possible future utilization as a monitor well or an injector
  * May need to include CO_2 compatible materials depending on operational plans
  * **Not required by regulations but is being strongly encouraged to ensure site specific information is included in the Class VI application.**

Environmental Justice

* Class VI applicants will be required to conduct an EJ review and submit that report with their application. IMD has proposed in our primacy application to the EPA that we will conduct a preliminary screening to help identify the presence of an EJ community within the AOR for the injection project. If a community is identified, we will send the application to a qualified third-party contractor with expertise in EJ to conduct a full evaluation.
* An enhanced public comment period may extend the public comment period for the application, may require a more inclusive public participation process, including targeted public outreach and creation of better visual tools and approachable language, or may be supplemented in other ways recommended by the reviewer
* LDNR currently lacks statutory authority to make the results of an EJ review part of the actual permit decision.
* A weighing of siting, environmental effects, and a cost benefit analysis is required in the application as a result of Save Ourselves, Inc., et al vs. the Louisiana Environmental Control Commission, et al1 . The five required question responses, colloquially known as the "Louisiana Constitutional Considerations," the "IT Question Responses," or the "Save Ourselves Questions," are hereafter the "SOS Decision Questions", and are presented in Appendix II. Answers to these questions must provide adequate detail with sufficient justification and supporting data to enable LOC to conduct a balanced review of environmental, social, economic and other factors as required by the Louisiana Constitution.

Key Louisiana Takeaways

Additional things to know
While IMD doesn't have primacy yet, we've had preliminary meetings with many potential applicants and have begun reviewing technical information.
Existing wells within AOR (artificial penetrations) will have to be addressed.
Sequestration in salt caverns will not be permitted.
"Thou shalt not frack."
Due to concerns around some formations in NW Louisiana, we've encourage potential applicants in this area to speak with IMD sooner rather than later.
Any AOR that crosses or approached boundaries of other jurisdictions (e.g., neighboring states and federally recognized Tribes) may trigger additional review. IMD is currently working with Texas, Arkansas, and Mississippi on this process.
Some applicants plan to drill Class V stratigraphic test wells to gather reservoir data.
Environmental justice reviews will be required for all Class VI wells.

Questions?

Useful Links
Louisiana Regulations for Injection and Mining
Office of Conservation - Injection & Mining
LDNR Class VI Primacy Application
EPA Class VI Wells
Gulf Coast Carbon Center
Groundwater Protection Council

Thank you!

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