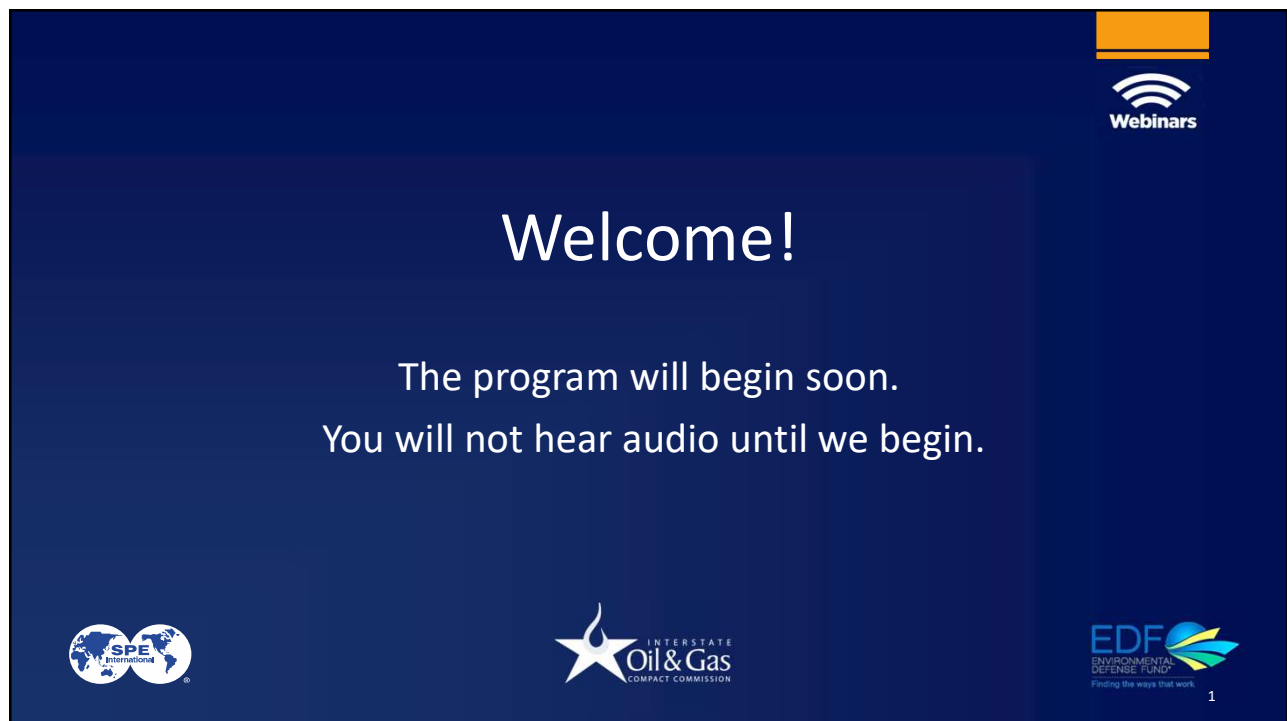




A dark blue rectangular slide with a white Wi-Fi symbol and the word "Webinars" in the top right corner. The center of the slide features the text "Welcome!" in a large white font, followed by "The program will begin soon." and "You will not hear audio until we begin." in a smaller white font. The bottom of the slide contains three logos: SPE International on the left, Interstate Oil & Gas Compact Commission in the center, and EDF Environmental Defense Fund on the right. A small white number "1" is located in the bottom right corner of the slide.

Webinars

Welcome!

The program will begin soon.
You will not hear audio until we begin.

1



Technical Challenges of CO2 Regulatory Approval Procedures

Speakers: Todd Bush & Jason Eleson
Moderator: PK Pande
October 4, 2023



2



Sponsored by:

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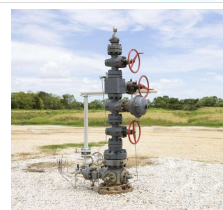
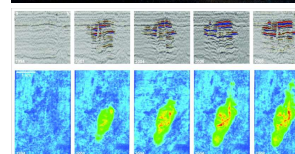


3

Agenda



- **Project Development and Implementation**
 - CCS screening and risk identification
 - Static & dynamic data collection considerations
 - Reservoir modelling best practices
- **Project Monitoring and Reservoir Management**
 - CO2 plume monitoring, observation wells
- **Injection and Well Operations**
 - Minimum and cost-effective data needs and practices
 - Well performance monitoring and analysis
- **Preparing for Potential Surprises**
 - Developing contingencies and optionality



Key Points for Today



Dynamic Performance

Upon injection, wells and reservoir “talk to us everyday”

Critical Measurements

Identify requirements to ensure sequestration performing as planned

Scale of Measurements

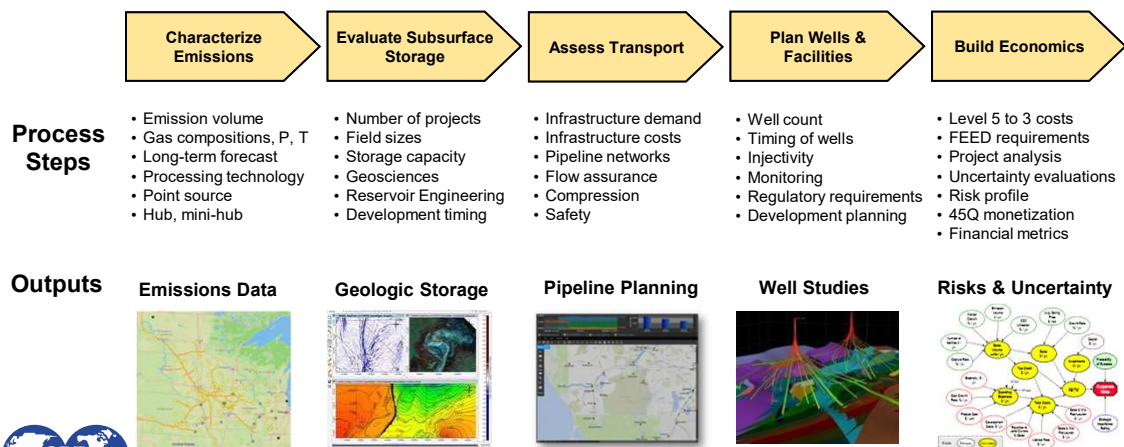
Regulatory process must address well and reservoir behavior

Contingencies

Adjust plan to actual well and reservoir performance

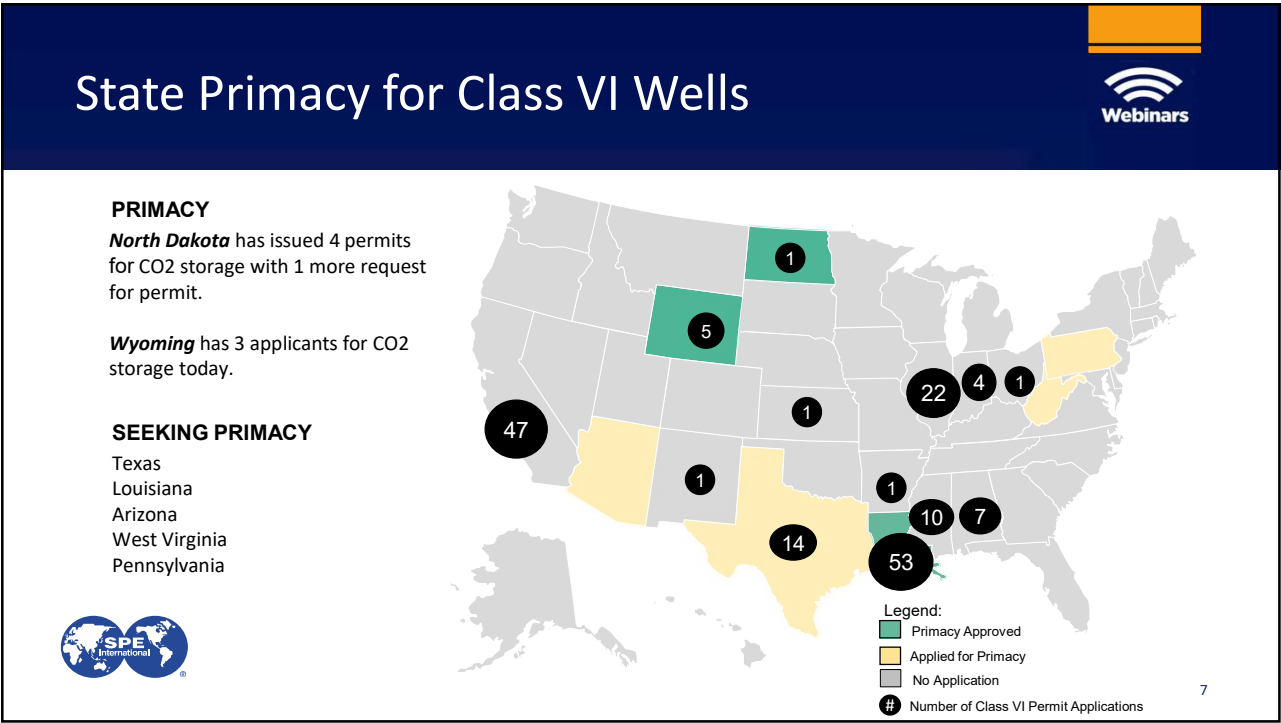


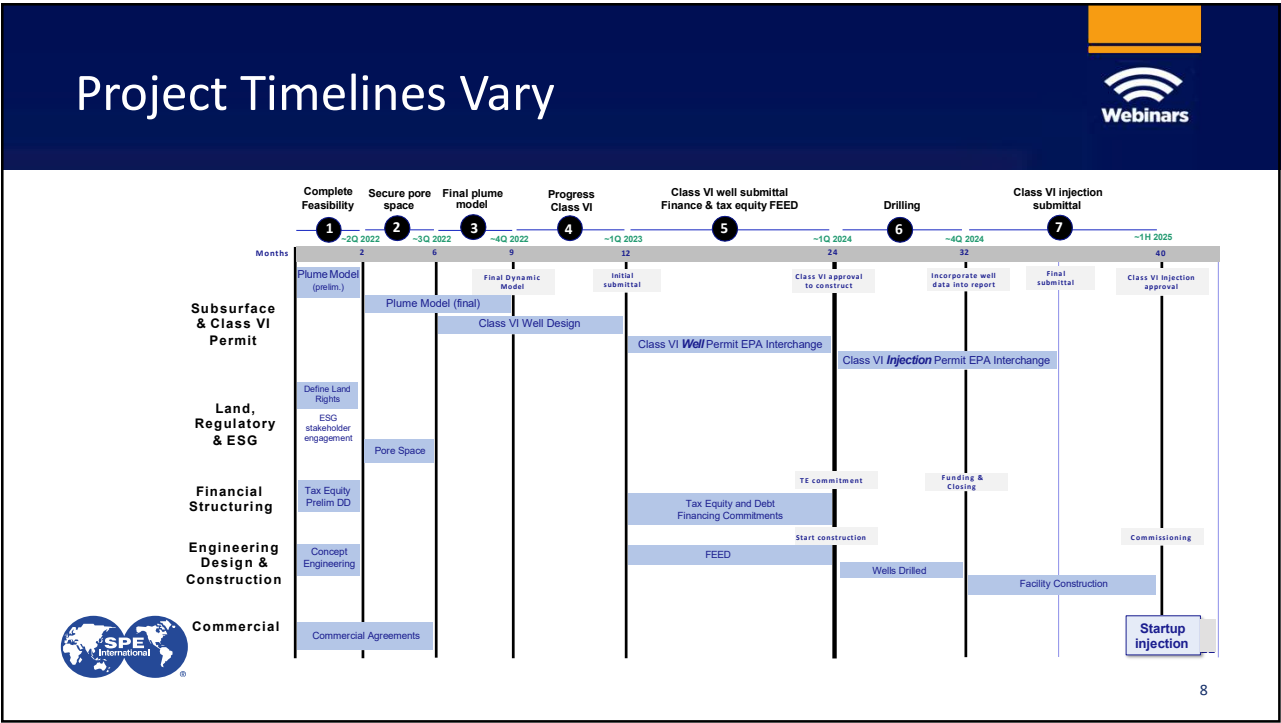
Workflow for CCUS Market Participation

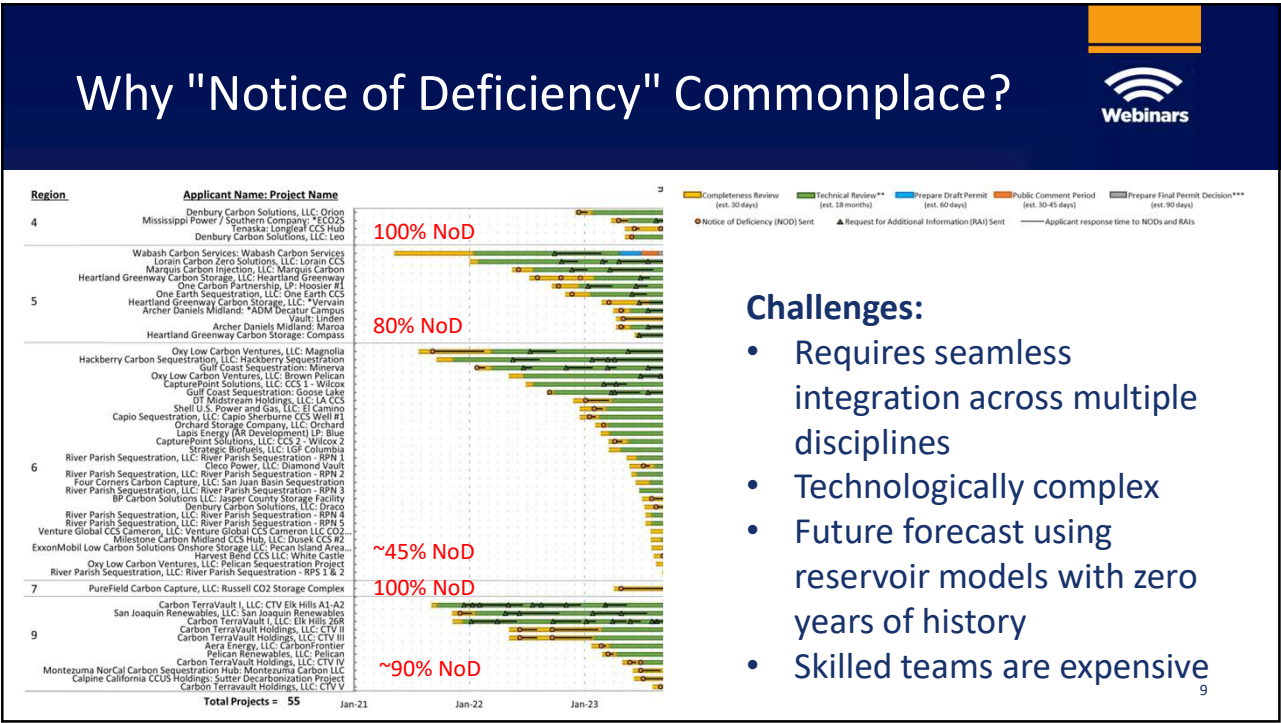


Emissions & Petroleum Systems Based Commercial Approach

6







What Data is Required for Permit?



Site Characterization Data

- Regional geologic structure
- Maps, Cross-sections AoR
- Faults, fractures
- Injection zone data
- Confining zone data
- Geomechanical data
- Seismic history
- Geologic / hydrology topography
- Baseline geochemical data
- Site suitability demonstration



Testing and Monitoring

- Testing, monitoring plan
- CO2 stream analysis
- Operational parameters continuous recording
- Corrosion monitoring
- Above confining zone monitoring
- External mechanical integrity tests
- Pressure fall-off tests
- Direct CO2 plume and pressure front tracking
- Indirect CO2 plume and pressure front tracking
- Surveillance plan
- Interference and tracer tests

Well Operations

- Average, maximum daily injection rates
- Maximum injection pressure
- CO2 source

AoR Review

- AoR delineation methodology
- AoR reevaluation schedule
- Corrective action planning
- Wells in AoR

10

CCS Technical Screening Criteria

Ensure requirements met to progress projects



Reservoir Characteristics

- Reservoir Properties
- Seal Integrity
- Overburden Characterization
- Faulting, Fractures, Seismicity
- Thermodynamics (P, T)
- Legacy Wells
- Drilling and Testing

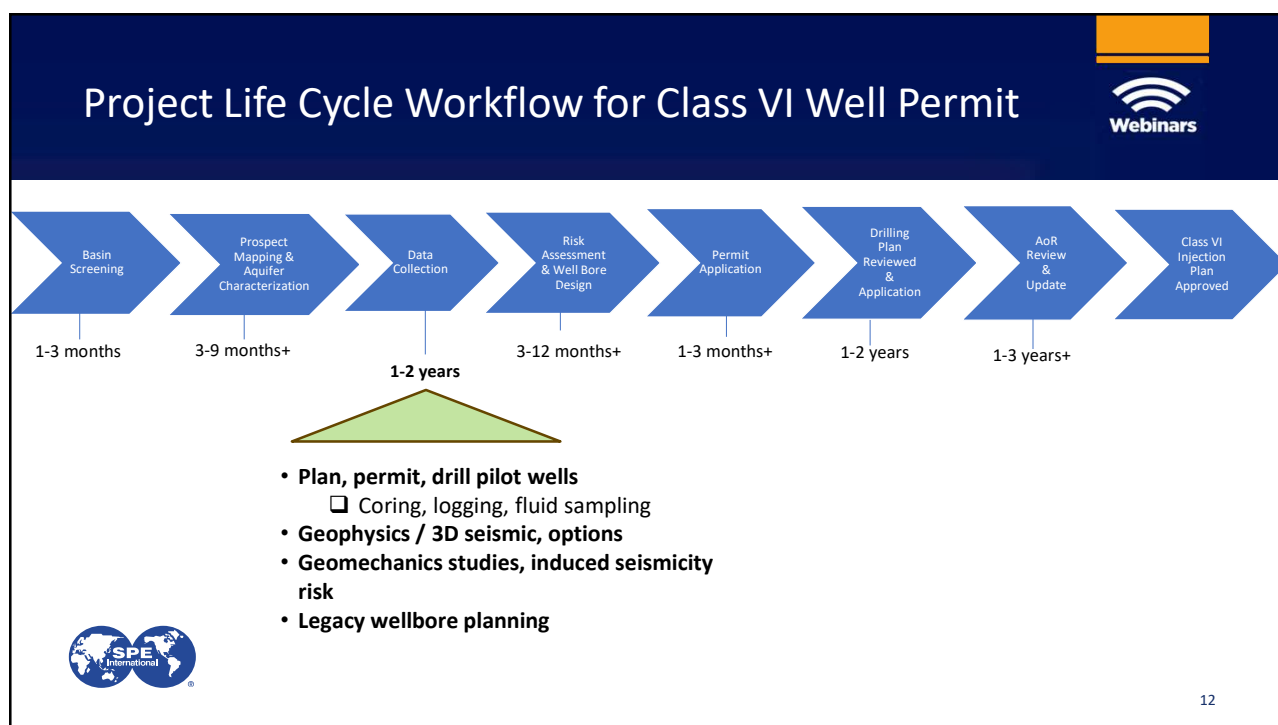




Key Insights

- Site Screening**
 - Evaluate geology, reservoir, existing operations
- Understand unsuitable geology**
 - Highly fractured or faulted reservoir
- Groundwater and Hydrology**
 - Understand freshwater aquifers and potential interactions with storage
- Operational, Legacy Wells**
 - Integrate into overall project
- Monitoring and Land Use**
 - Understand key surveillance requirements
 - Ensure land use considerations met for needed surface monitoring techniques

11



Critical AoR Data for Permit Application

Improves chances for Class VI permit acceptance AND is crucial for sound business planning



- **Well Data:**
 - Dynamic well tests (DST, MDT, Fall-off, interference, tracer tests)
 - Log data
 - “Triple combo” is minimum requirement
 - Gamma Ray, Resistivity, Neutron Porosity, Bulk Density, Photoelectric
 - Core and core analysis
 - Conventional core
 - Routine and special core analysis are possible
 - Rotary sidewall cores
 - Routine analysis only
 - Bond logs
 - Ensure wellbore integrity for groundwater protections
- **Geomechanics**
 - Core based testing
 - Mechanical integrity tests
 - Dipole sonic
 - Borehole image logs
 - Leak-off tests
- **Geophysics:**
 - Baseline 3D seismic survey
- **Fluids, Geochemistry**
 - Reservoir fluid characterization
 - Water quality (saline aquifers and USDW)
 - Geochemical assays, including surficial water reservoirs
 - Stable isotopes
 - Microbial activity
 - Trace elements and metals



13

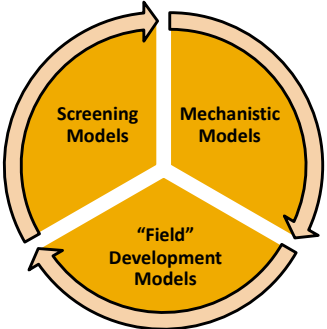
Reservoir Modeling Results

Field Development Stage & Objectives Drive Modelling Approach



Screening Insights

- Technical screening (geology, fluids)
- Injection rates
- First order economic screen



Mechanistic Studies

- Understand key geological & reservoir performance drivers
- Identify additional data needs
- Select key injection intervals
- Explore performance improvement strategy and opportunities

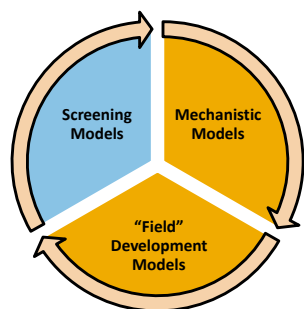
Field Development Planning and Studies

- Field development planning
- Well requirements and timing
- Staged development
- Well and facility requirements
- Compression requirements
- Economics to FEED


14

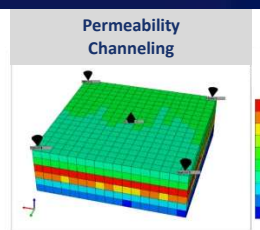
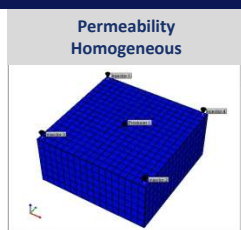
Reservoir Modeling – Screening Studies

Use publicly available information and regional data

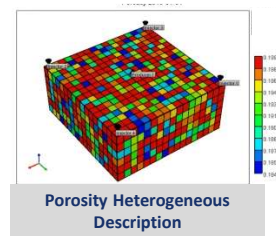
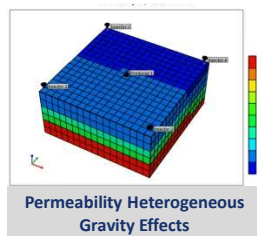


Screening Insights

- Technical screening (geology, fluids)
- Injection rates
- First order economic screen



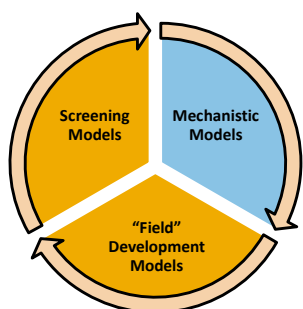
Adegbite & Al-Shalabi, 2020



15

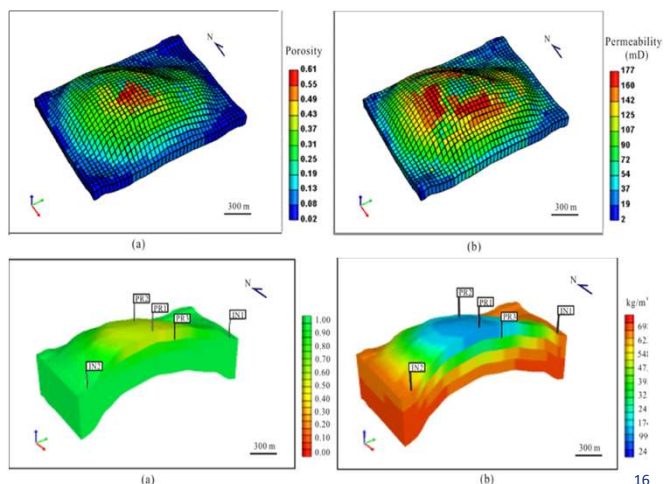
Reservoir Modeling – Mechanistic Studies

Increased data and analysis core, petrophysics, and injection offset well data



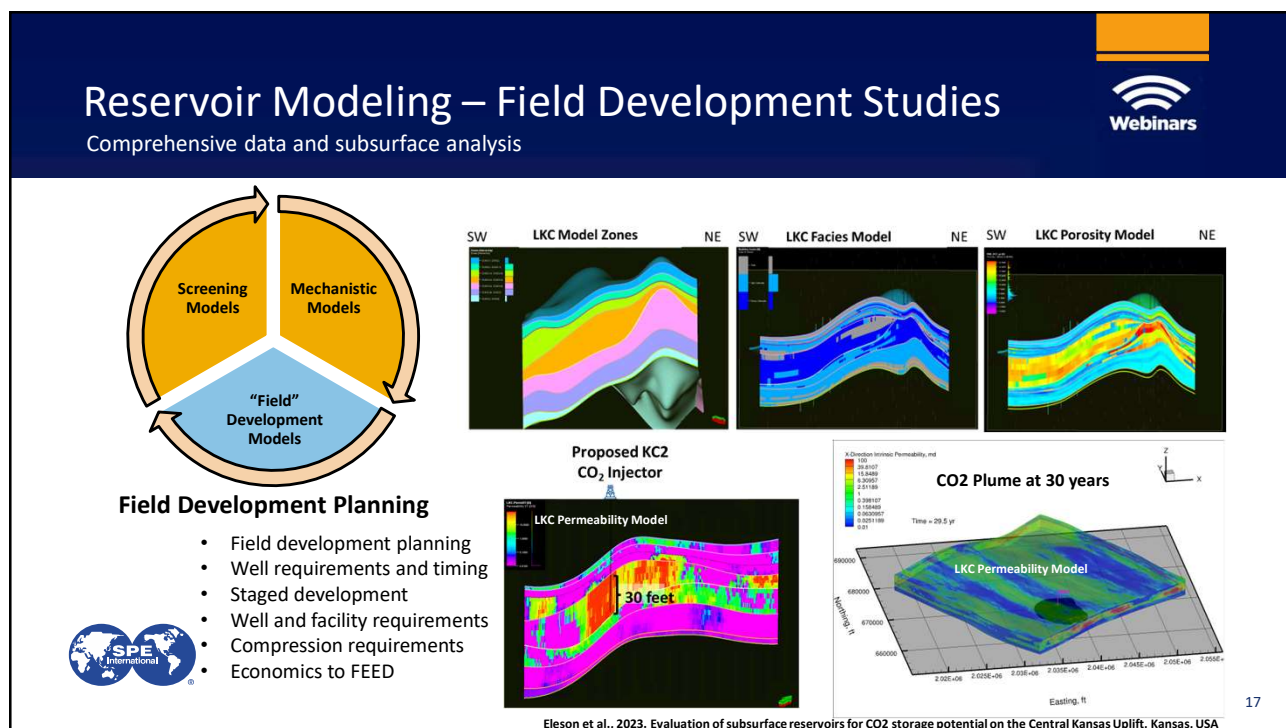
Mechanistic Studies

- Understand key geological & reservoir performance drivers
- Select key injection intervals
- Explore performance improvement strategies



ACS Omega 2021, 6, 50, 34832–34841

16



Existing Wellbores in Storage Complex

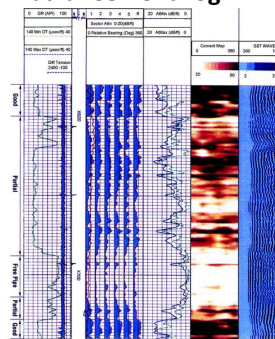
Legacy Wells and Conditions Must Be Integrated Into Storage Project



- Bond logs & radial cement logs
- Casing inspection
 - Caliper logging, casing thickness, magnetic flux leakage, etc.
- Pressure tests
- Casing metallurgy, potential interactions with CO2 brine
- Wellbore geometry and completion review
- P&A protocols

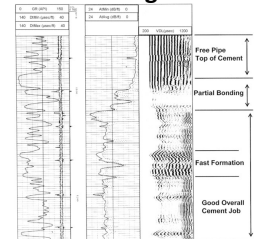


Radial Cement Log

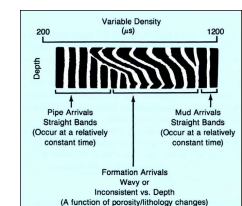


https://petrowiki.spe.org/File:Vo5_Page_0192_image_0001.png
Courtesy of Baker Atlas

Bond Log



https://petrowiki.spe.org/File:Vo5_Page_0185_image_0001.png
Courtesy of Baker Atlas



https://petrowiki.spe.org/File:Vo5_Page_0186_image_0001.png
Courtesy of Baker Atlas

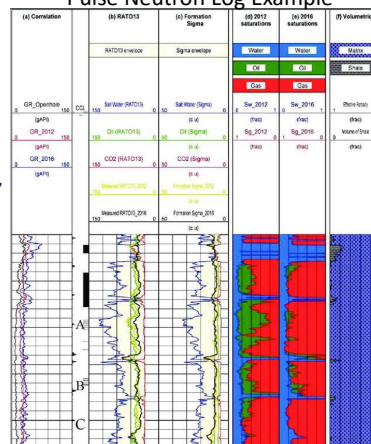
Reservoir & Plume Management



- **Pressure management**
 - Downhole measurements (SIBHP, fiber, etc.)
 - Shut-ins, fall-off tests, workovers, recompletions, pressure management wells
- **Plume (Saturation) monitoring activities**
 - Direct measurements (Lower Cost)
 - Saturations, pressures, temperatures, pulsed neutron, density and dipole sonic logs, geochemical monitoring
 - Additional and Indirect measurements (Highest cost)
 - 4D seismic, microseismic
 - Interpretative activities
 - Reservoir model updates when additional direct measurements available
- **Workovers for reservoir formation issues**
 - MEG chemical treatments for salt precipitation
 - Solvents for asphaltene plugging
 - Cement squeeze for high perm zones



Pulse Neutron Log Example



19

Contingencies and Potential Surprises



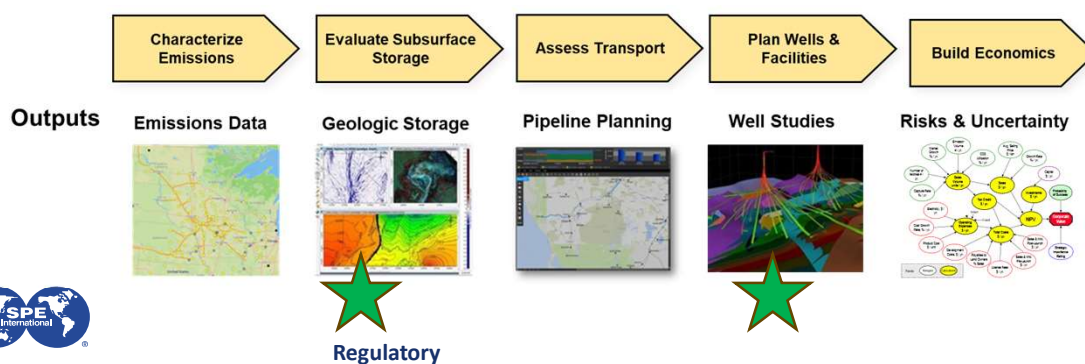
- **Leakage & Induced Seismicity**
 - Vertical and lateral CO₂ migration
 - Legacy boreholes
 - Induced seismicity
 - Wellbore integrity
- **Reservoir heterogeneity or compartmentalization results increase in formation pressure**
 - High permeability streaks
 - Greater reservoir variation than anticipated
 - Reservoir compartmentalization requiring pressure management
- **Formation damage**
 - Wellbore skin
 - Salt deposition
 - Asphaltene dropout
 - Permeability decrease from mineralization
- **Plume MRV**
 - Plume extends beyond planned AoR and/or licensed acreage
 - Projects with inadequate reservoir surveillance plan to manage sequestered CO₂

20

Regulatory Permitting is Project Value Driver



- Communicate and collaborate early
- Integrate within and across all disciplines
- Thorough and comprehensive analysis

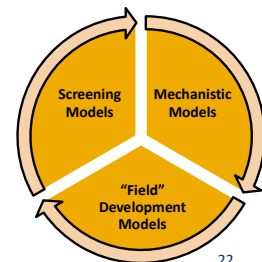


21

Regulatory Challenges



- Resourced to handle the volume of permits?
- Own independent work or rely on operator guidance?
- Skills expertise to collaborate with developers?
- Needs to make the process efficient and effective?
- Diminishing high notice of deficiency occurrence?
- Handle CCS in operational phase?



22

Backup Slides





23

