CO2 Storage, Monitoring, Verification and Accounting to document storage effectiveness and environmental protection

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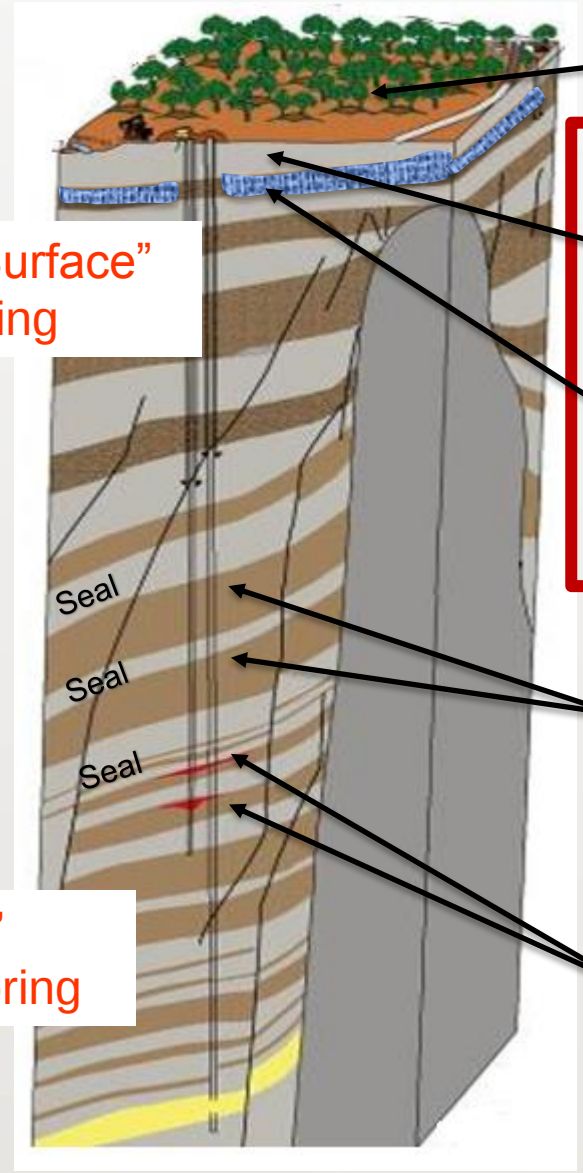
Talk outline

- Acknowledgments
- Experience monitoring CO_2 EOR
  - Commercial surveillance for optimization of the oil recovery
  - Regulatory oversight - environmental protection
  - Retention of CO_2 in isolation from atmosphere
- Issues and needs
- Recommendations for CO_2 EOR monitoring

Acknowledgements

- Observations based on:
  - Southwest Partnership (DOE RCSP) study at SACROC
  - SECARB (DOE RCSP) study at Cranfield
  - Monitoring program at Air Products DOE Industrial Capture Demonstration at Port Arthur TX with EOR + Storage at Hastings Field
  - Monitoring program at NRG- PetraNova DOE Clean Coal Program Capture demonstration at W. A. Parrish Plant itch EOR + Storage at West Ranch
  - Debate at International standards Organization (ISO 265) work group 6 on EOR

Overview of Monitoring Zones



"Near-Surface" Monitoring

"Deep" Monitoring

Biosphere

Vadose zone

Shallow groundwater

Above Zone Intervals

Reservoir

Strong variability, dynamic, many challenges, release to atmosphere, biosphere impacts

Moderate baseline variability, assurance of no damage to drinking water, easy access

Minimal variability, early detection, small signals

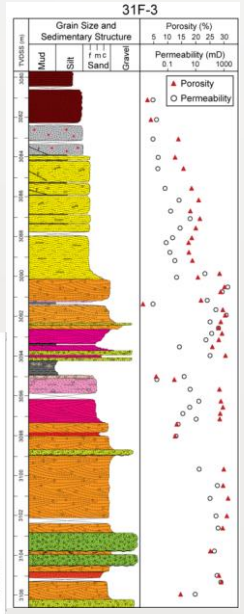
Static, quiet environment, variability is from CO_2 injection, CO_2/brine migration

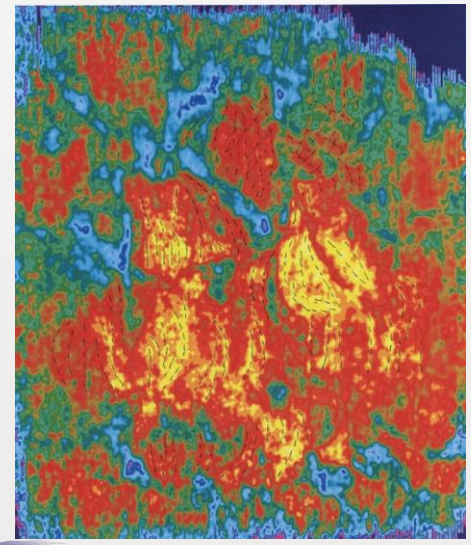
Figure courtesy of Sue Hovorka

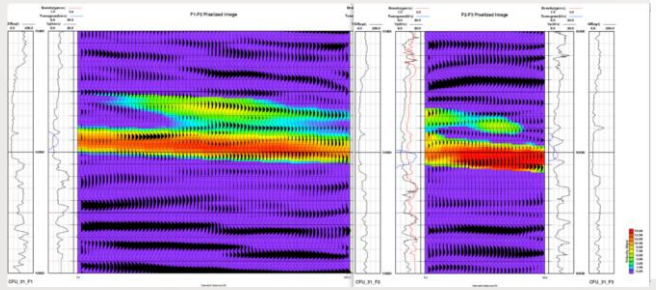
Experience Relevant to Monitoring CO_2 EOR – Optimizing the flood

- Characterization based on long production history
- Balanced flood
  - Fluid withdrawal (oil, water, gas CO_2) = Fluid injection (water, CO_2) during most of the operation
  - Area and magnitude of elevated pressure controlled by production
  - Area occupied by CO_2 controlled by production
- Controlled flood
  - Injection and production patterns
- Active surveillance
  - Production, pressure
  - Other techniques as needed
    - Wireline log, seismic, tracers,

Oil and gas trapped over geologic time







SECARB Time lapse seismic shows fluid change

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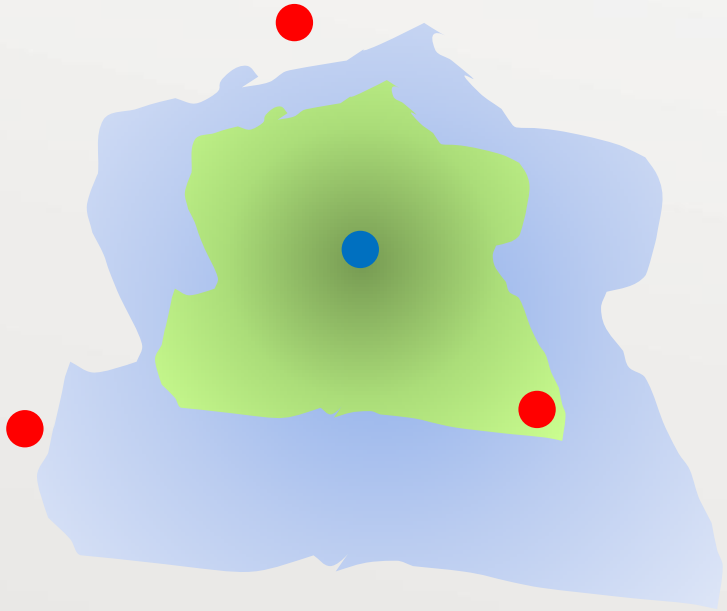
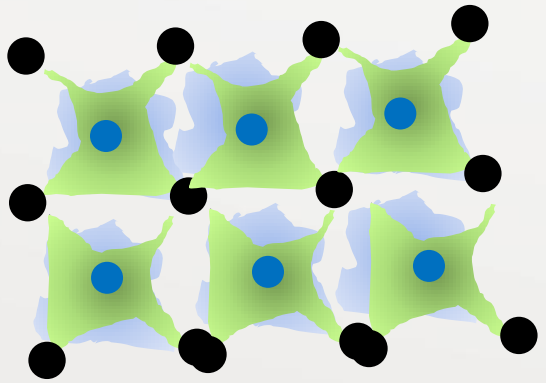
Comparing saline injection to CO_2 EOR pattern flood - value of active control

Saline injection map



EOR Pattern flood map



Injection well
Monitoring well
Production well
CO_2 plume
Elevated pressure

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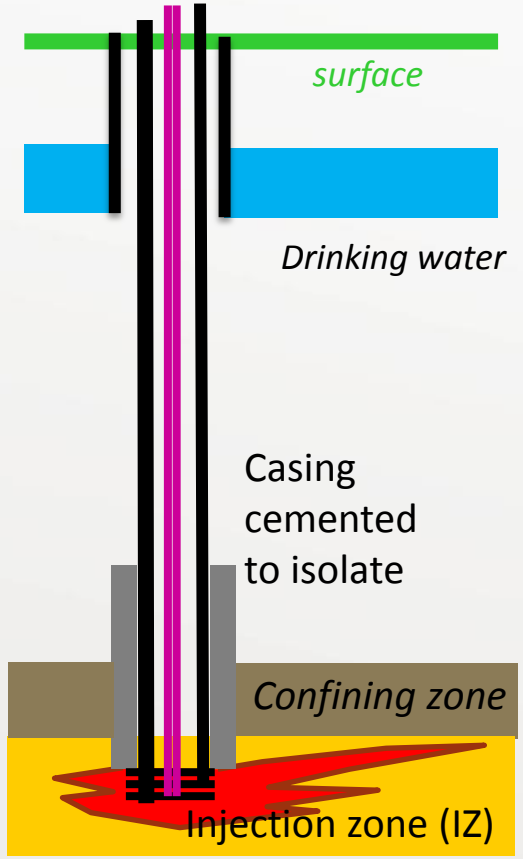
Experience Relevant to Monitoring CO_2 EOR – Environmental Protection

- Environmental protection is required in the US under Underground Injection Control (UIC) program
  - CO_2 EOR operations began at SACROC field in 1972
  - Environmental protection for **all injection** is required under the Safe Drinking Water act of 1974
  - Focuses on wells
    - Wells constructed to isolate injection zone from other intervals
    - Double barrier for injection wells – tubing, packer inside casing
    - Regular Mechanical Integrity Testing of well components
      - High frequency possible
    - Qualification of all wells in area of review (1/4 mile default)



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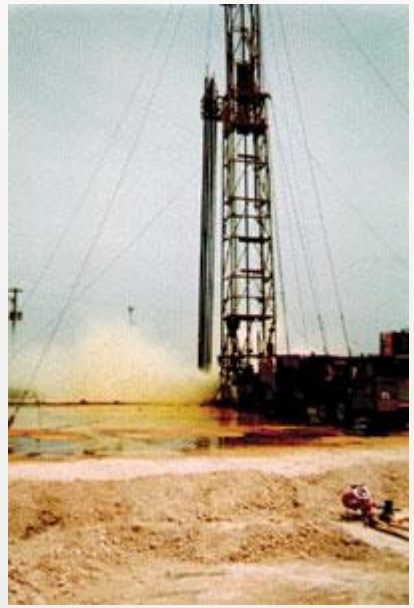
Experience relevant to monitoring CO_2 EOR – Environmental Protection (cont.)

- Program has operated with reasonable success.
  - Dozens of reports of non-compliance per year, few are serious
    - Lynch, 1985 JPT Sheep Mountain blowout
    - Skinner, 2003 World Oil, v.224, #1, p. 38-42
    - Kell, 2011, Groundwater Protection Council
    - Porse, Wade Hovorka, 2014, GHGT
    - http://www.rrc.state.tx.us/oil-gas/compliance-enforcement/blowouts-and-well-control-problems/blowouts-and-well-control-problems-11-15/
  - Risk does not appear to be elevated for wells handling CO_2 compared to other wells



Skinner 2003

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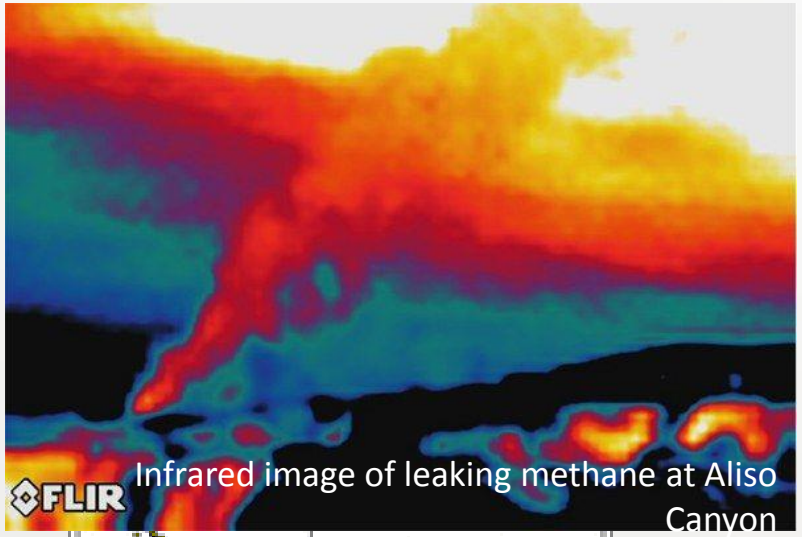
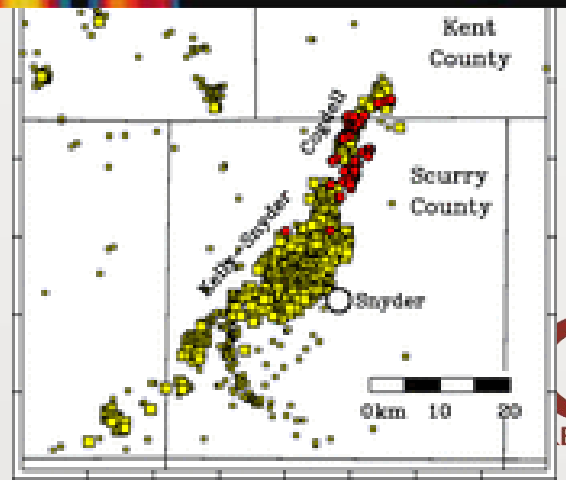
Experience relevant to monitoring CO_2 EOR – Environmental Protection (cont.)

- What is serious?
  - Surface releases of hydrocarbon and brine
    - Aliso Canyon well California
  - Induced seismicity concerns
    - Only one CO_2 injection at Cogdell field TX has reported seismicity
      - Gan and Frohlich, 2015 Nat Academy of Science



Infrared image of leaking methane at Aliso Canyon



injection volumes exceeded 16,000 m^3/mo during 2004–2011

2009–2011 earthquakes

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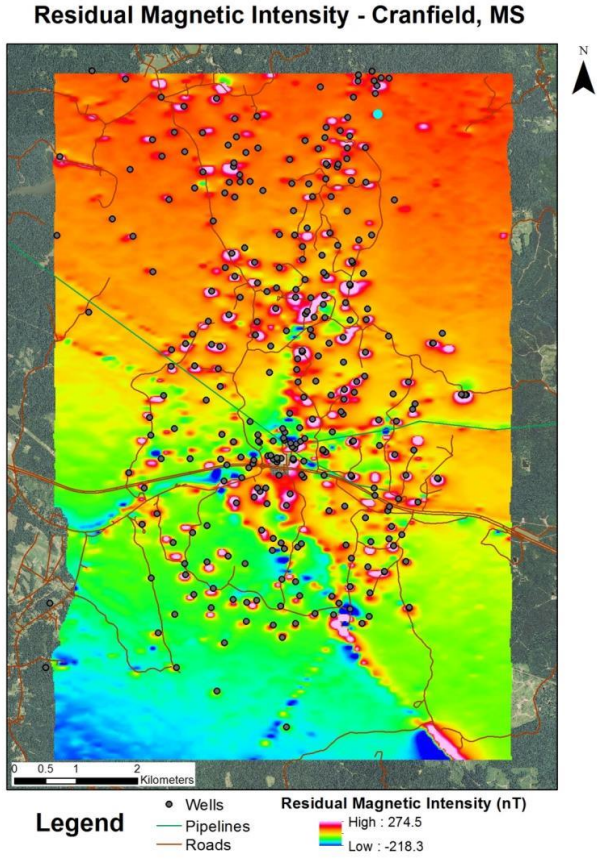
Detecting well leakage

- Classic field management techniques
  - Pre-flood preparation
  - During flood surveillance
    - Inspection, pressure measurements
- AZMI (above-zone monitoring interval) pressure and/or geochemical monitoring
  - Additional surveillance at depth for underground blowout
    - can be augmented by VSP, gravity, surface elevation
- Near surface surveillance
  - As needed – note limitations



Well density shown by SECARB airborne magnetic survey

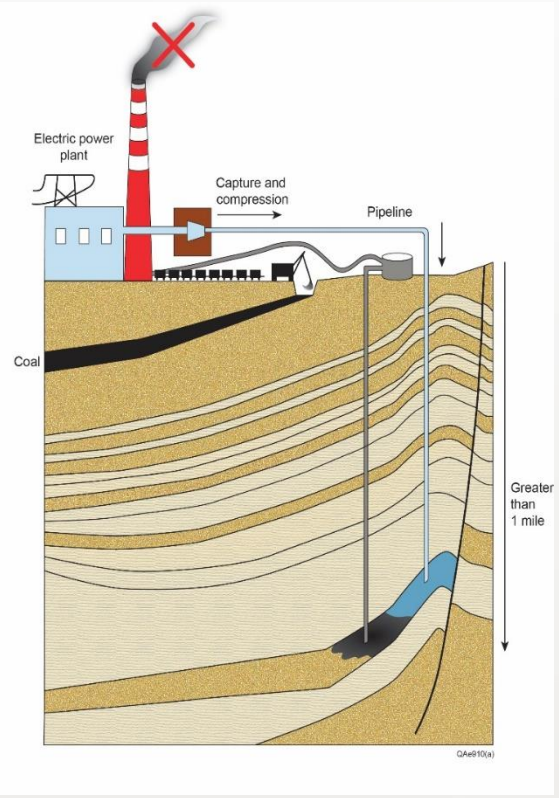
Current issues and limits of quality of CO_2 EOR as storage

- No widely accepted reporting protocol for qualifying storage at a CO_2 EOR project
- ISO WG6 standard
  - Needs international approval

http://www.iso.org/iso/iso_technical_committee?commid=648607

Retention of CO_2 in isolation from atmosphere

- New undertaking partly but not wholly related to environmental protection
- Need to document storage permanence **driven by motivation to capture**
- CO_2 available in new areas
- CO_2 available larger volumes
- Possible intermittent CO_2 supply (linked to power or other demand)



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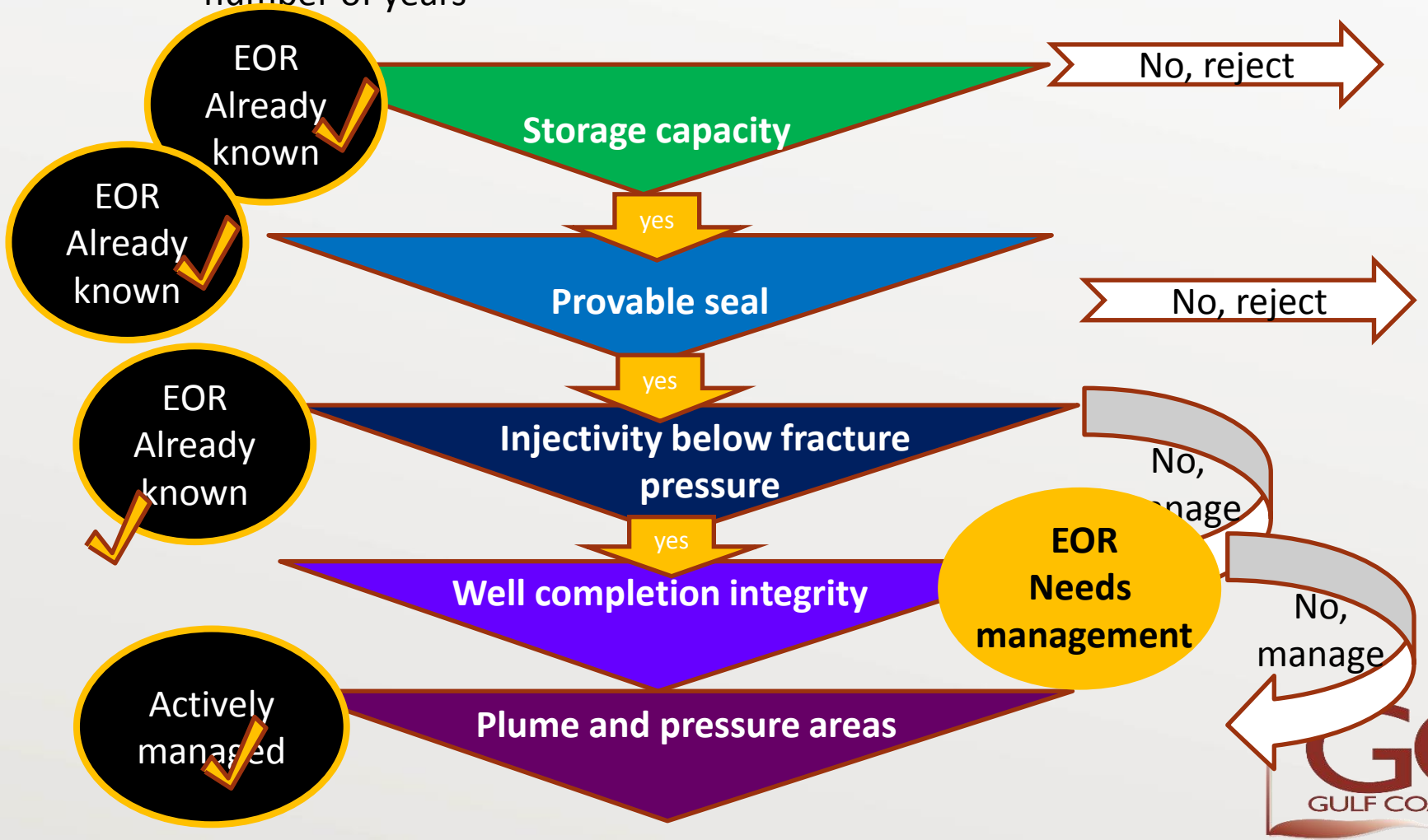
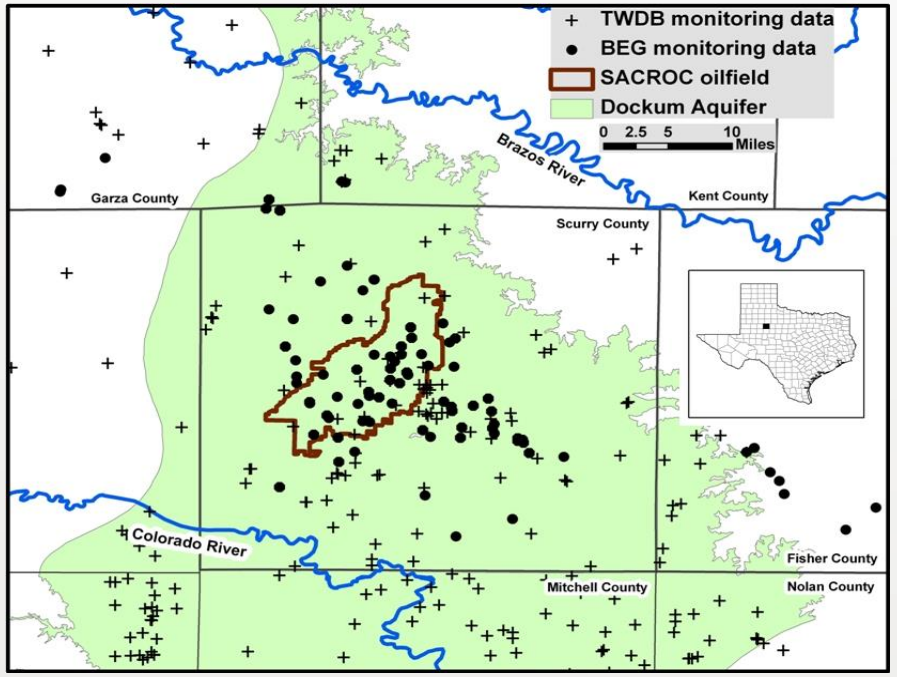
Characterization and monitoring geologic system for retention

CO2 mass emitted/year x number of years



Experience relevant to monitoring CO_2 EOR – Environmental Protection (cont.)

- Multi-year 100 water well monitoring program at SACROC oilfield as a task of the South West partnership Phase II Program of RCSP
- 80 MMT CO_2 purchased and injected over >35 years
- 100's of CO_2 injectors and producers managed under normal UIC rules
- No detection of CO_2 signal in groundwater in BEG study



Rebecca Smyth

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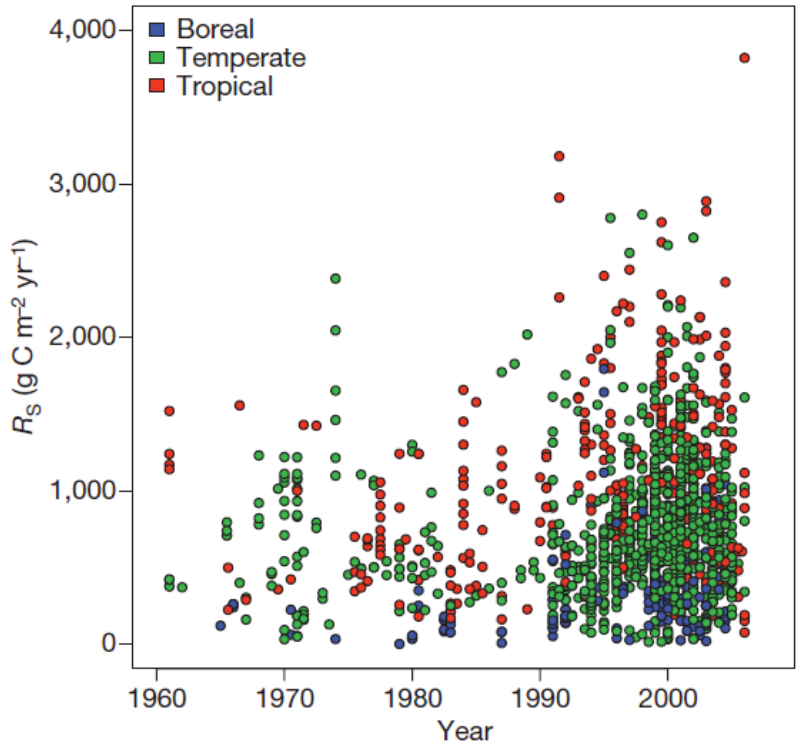
Limits of near surface monitoring

- Environment (ground water, soil and atmosphere) are highly variable
  - High risk of change not related to project
    - Climate change
    - Development and land uses
- High risk on failing to detect leakage from reservoir
  - Long travel time – delayed arrival
  - Localized leakage may not be detected

"Baselines" are Shifting!

nature
Vol 464|25 March 2010|doi:10.1038/nature08930

Temperature-associated increases in the global soil respiration record



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Geochimica et Cosmochimica Acta 72 (2008) 5581–5599
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Increasing shallow groundwater CO_2 and limestone weathering, Konza Prairie, USA

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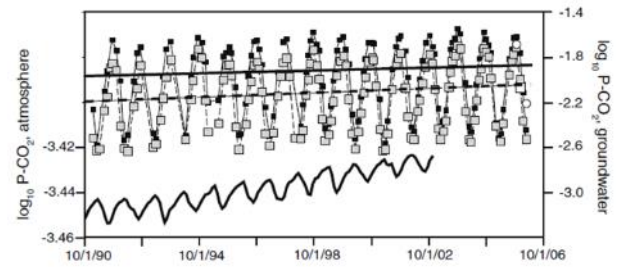


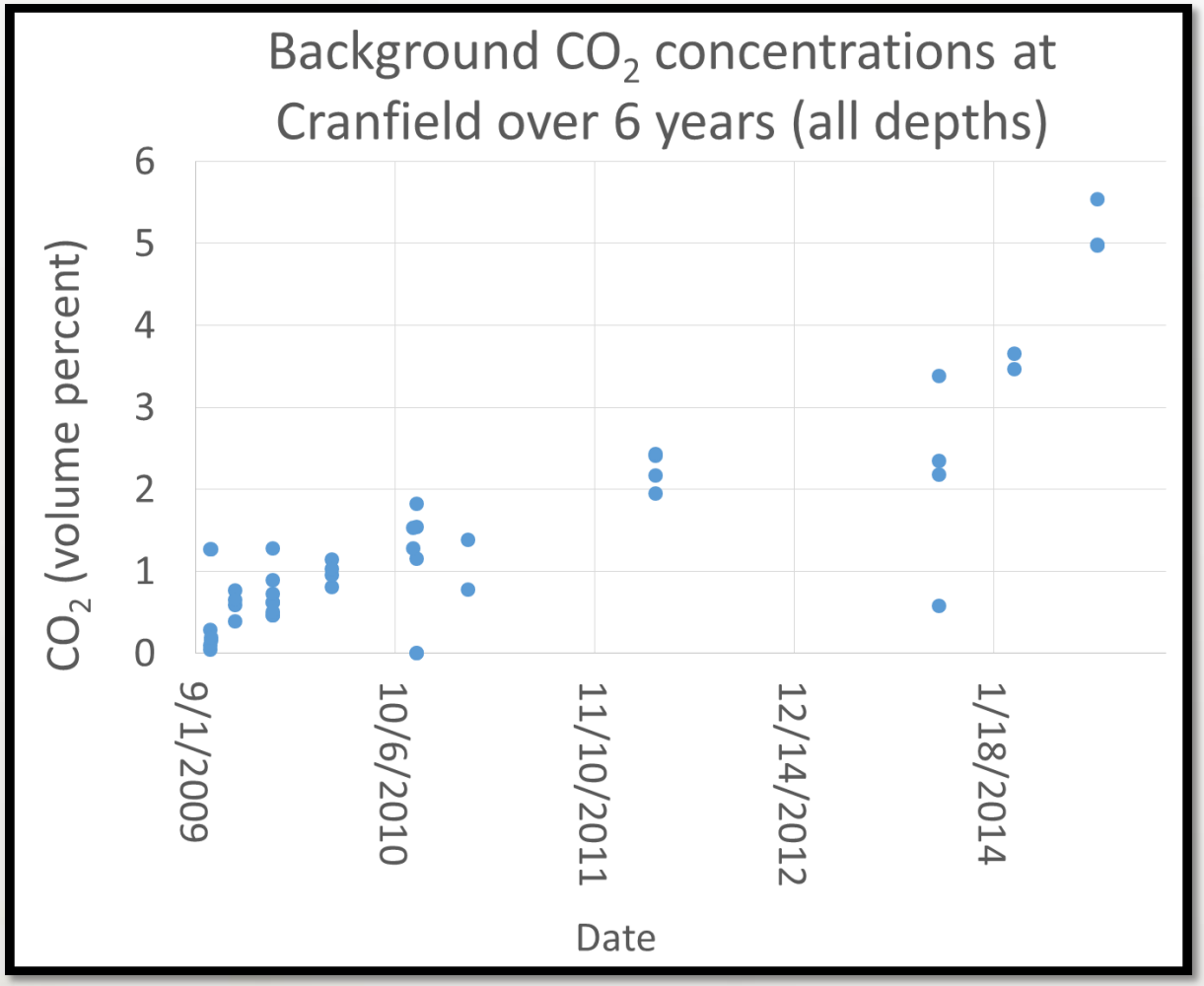
Fig. 7. P-CO_2 cycles annually and has been rising in Konza Prairie groundwater. Speciation modeling of groundwater from two wells, 3–5 Mor, 6.3 m deep (shaded squares) and 4–6 Mor, 12.6 m deep (filled squares), shows that log P-CO_2 cycles annually; points are connected with lines, without smoothing. Kendal Theil lines (see text) are shown for time series for both wells (dashed line, well 3–5 Mor; solid line, well 4–6 Mor). The increase is highly probable ($p \ll 0.1$) and tau values are positive for both trends (see Table 2). In any year, highest P-CO_2 occurs in September to November and lowest P-CO_2 occurs in February to April. Large white symbols in 2005 are measured dissolved CO_2 in the two wells (circles, 3–5 Mor; squares, 4–6 Mor); the measured values correspond well with model-predicted results. Atmospheric P-CO_2 (mixing ratio) from Niwot Ridge is shown as a heavy line.

RS = the flux of microbially and plant-respired CO_2 from the soil surface to the atmosphere,

Increased dissolution of CO_2 in groundwater and associated mineral dissolution

Katherine Romanak GCCC

…and at our Monitoring Sites



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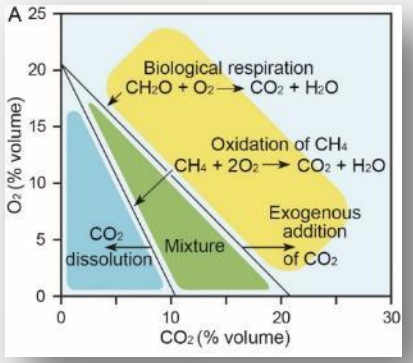
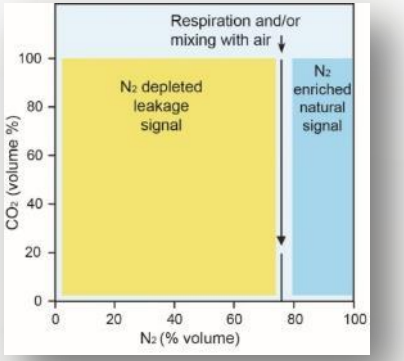
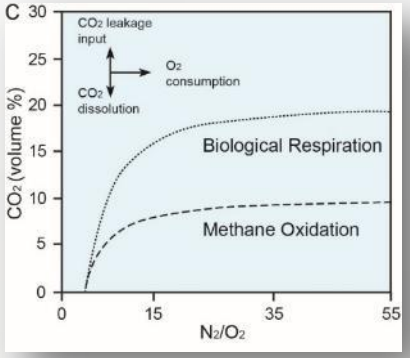
Process-Based Soil Gas Ratios



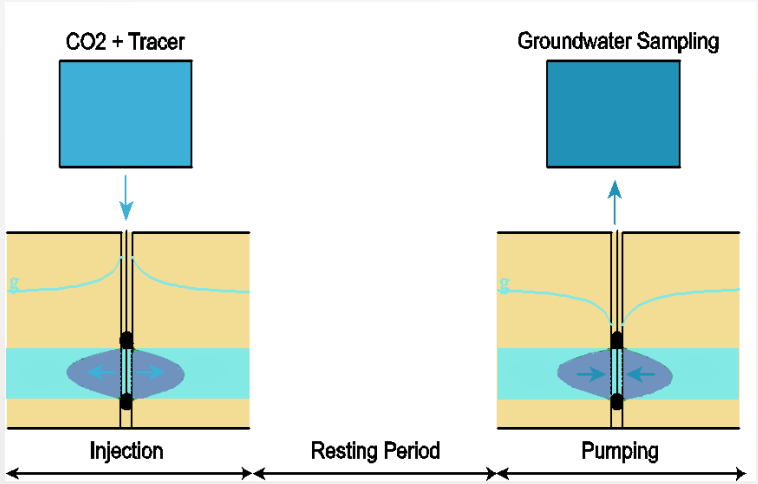




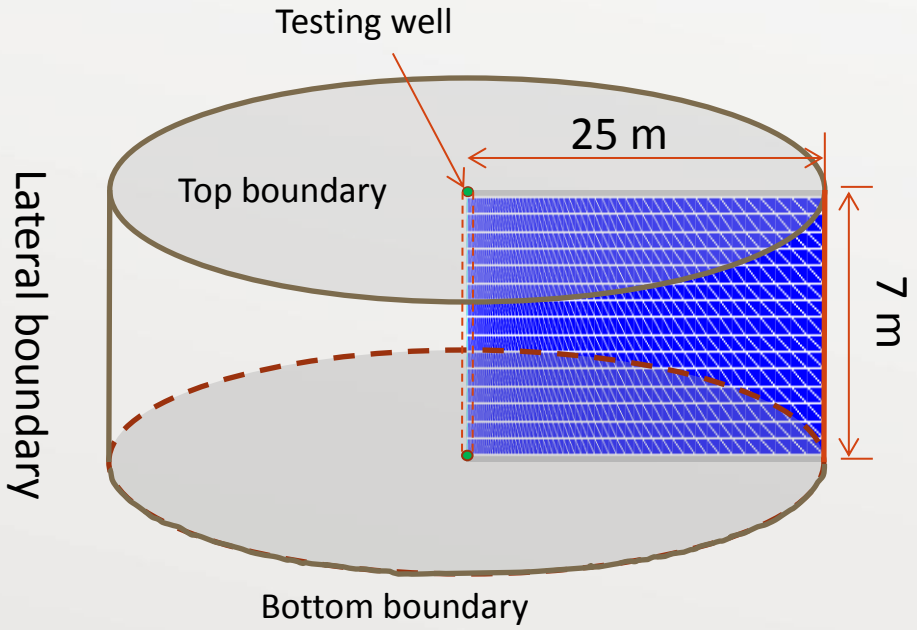
- Uses simple gas ratios to identify **processes.**
  - Biologic respiration
  - Methane oxidation
  - Dissolution
  - Leakage
- No need for years of background.
- Method can be applied in any environment regardless of variability

Romanak et al., 2014, International Journal of Greenhouse Gas Control, 30, 42-57
Romanak et al., 2012, Geophysical Research Letters, *39* (15).

Model calibration with field tests



Single well push-pull test



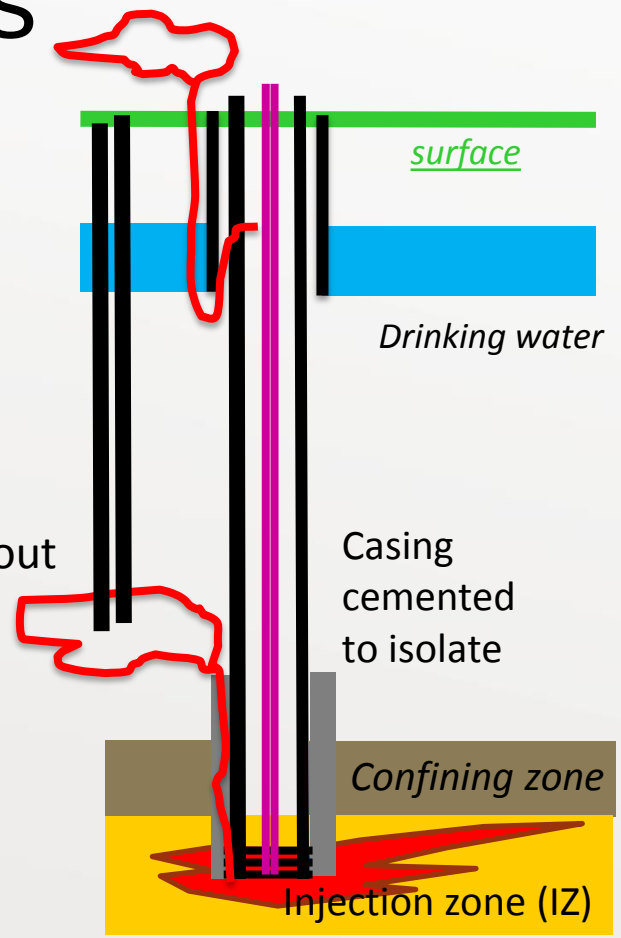
Changbing Yang, GCCC

Recommendation

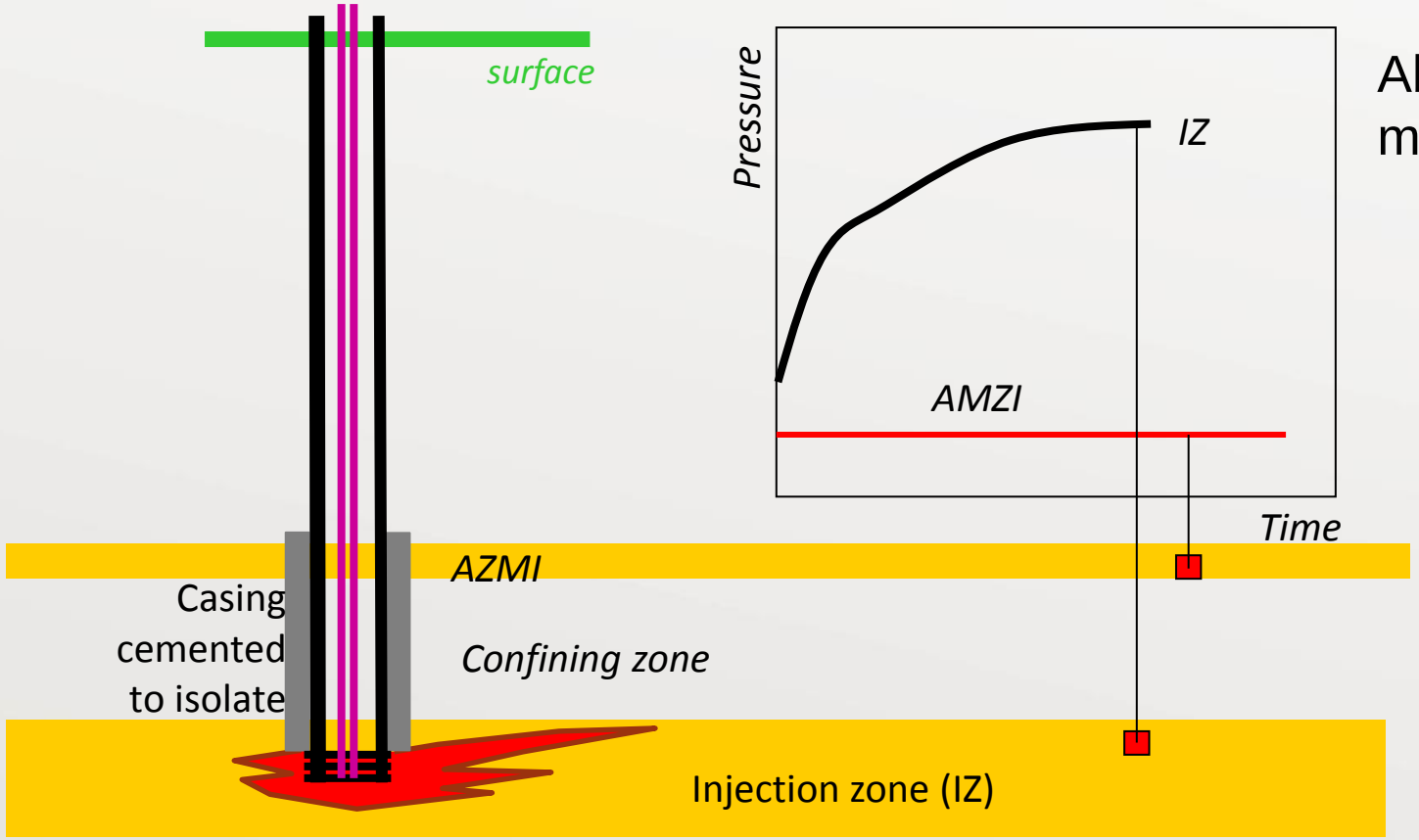
- Characterize groundwater and possibly soil gas
- Model in lab or via experiments the response of groundwater system to fluid leakage
- Prepare response to allegation or event
  - Allegation – stakeholder claim of damage
  - Event – occurrence of leakage
- No long term routine monitoring

Surface blowout is probably not the major risk in storage effectiveness

- Surface blowout is:
  - Usually obvious
  - Can be repaired relatively promptly
- Subsurface blowout
  - Not detected quickly
  - Large volumes of CO_2 lost before detection
  - May or may not reach atmosphere
  - Likely will not harm water



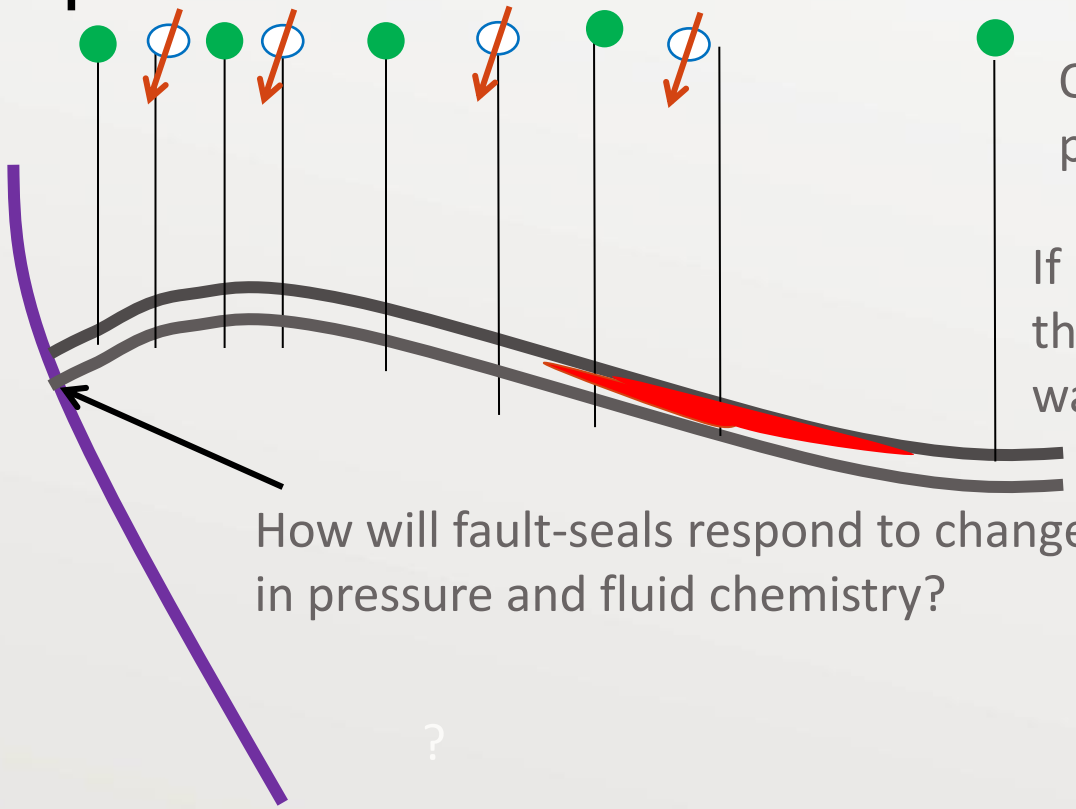
Recommendation: Document proper isolation performance of many wells: Above-Zone pressure monitoring detect subsurface blowouts



Above-Zone pressure monitoring

Need to monitor performance of the seal and trap?

Traps and seals that held oil will hold CO_2 ?



Out of pattern loss of CO_2 to adjacent production

If injection occurs much more rapidly than charge, will it fill the trap the same way?

How will fault-seals respond to changes in pressure and fluid chemistry?

?

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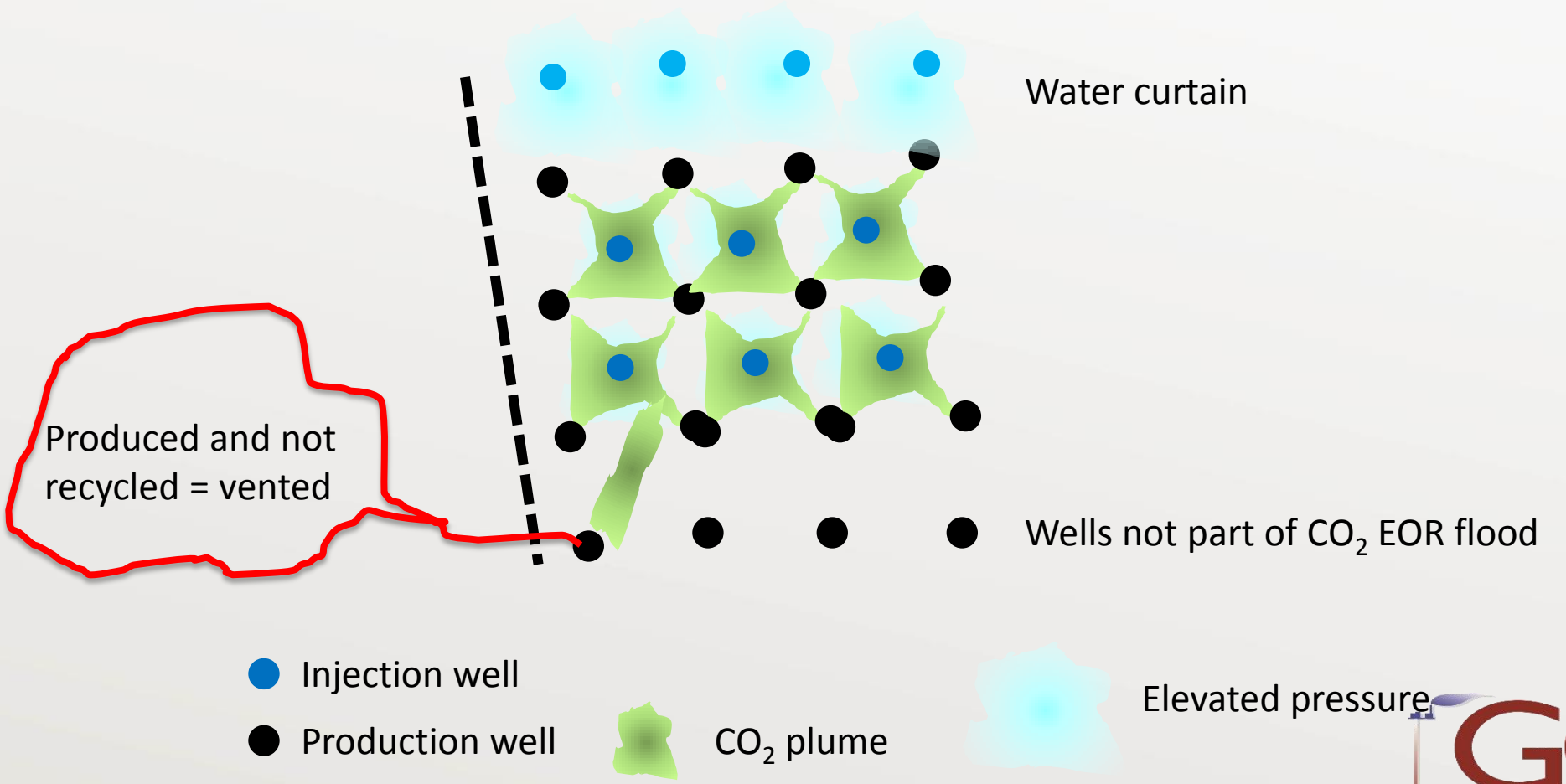
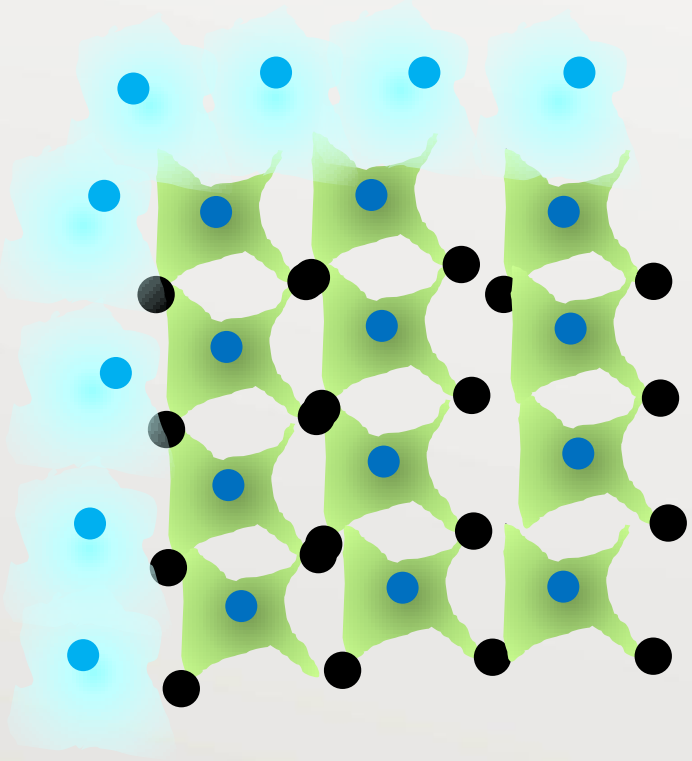
Out-of-pattern migration to production

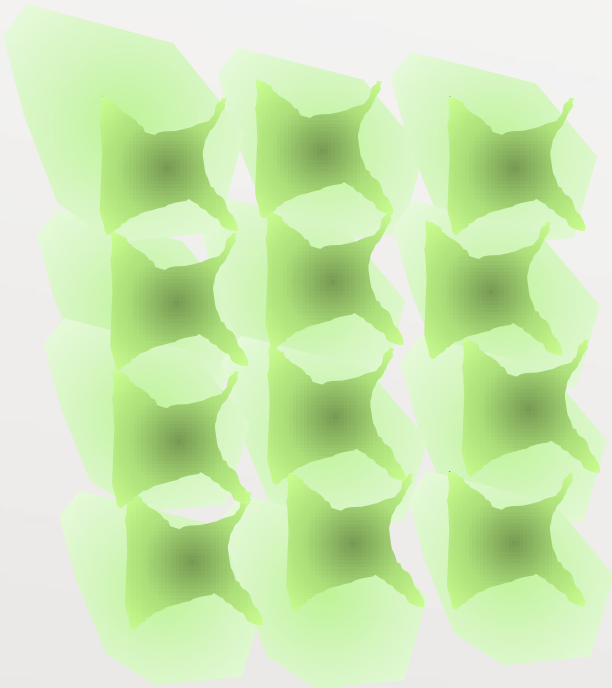


Post closure out-of-pattern migration

During operation CO2 is managed by engineering – production, water curtain etc.

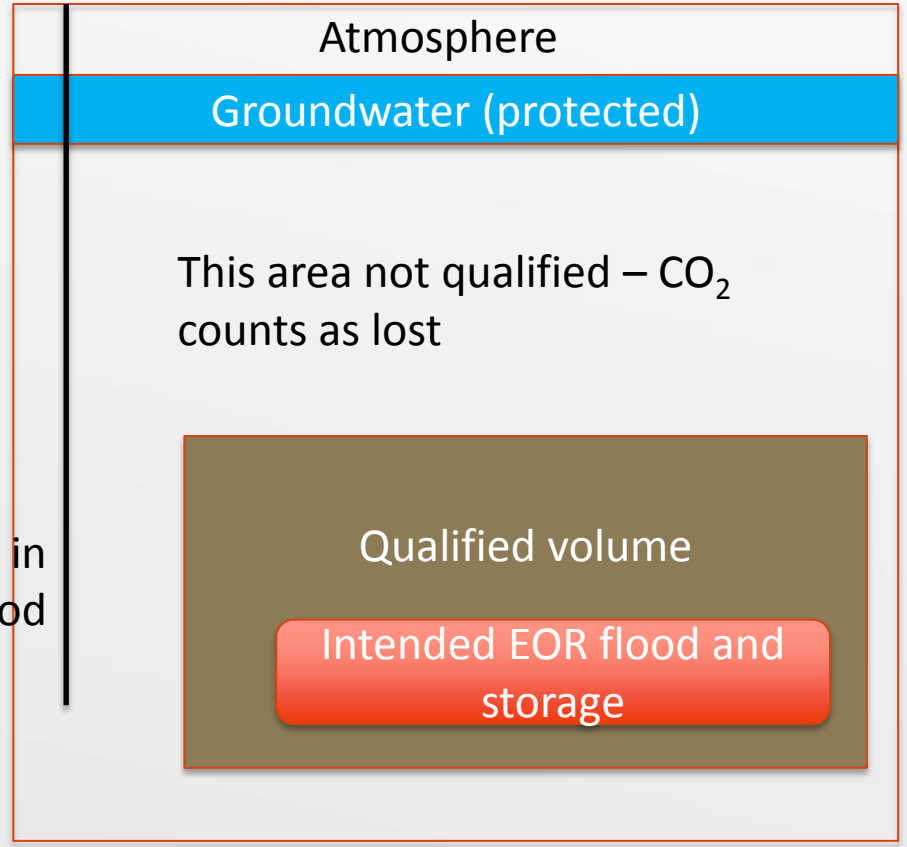


At the end of operation production, water curtain etc. cease. CO_2 will migrate to stable configuration



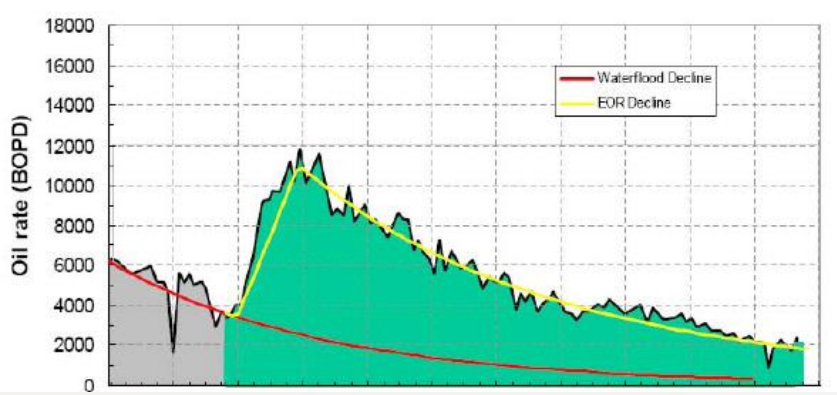
What data are needed to document storage

- Define 3-D volume that is qualified to retain CO_2
  - Document mechanisms by which conformance of CO_2 to intended volume is assured
    - Injection-withdrawal ratio, pattern flood
    - Surveil success and document
- Inventory possible mechanisms of loss out of that volume
  - Flawed well completions (especially subsurface blowouts)
    - Qualify and surveil all wells that penetrate qualified volume
    - AZMI pressure may be useful, document success
  - Out of pattern migration to adjacent production
    - Identify risk and design management
    - Surveil success and document
  - Evaluate any geomechanical risks
    - If significant risk design management
    - Surveil success
  - Long term stabilization – any risk of loss?
    - If significant risk design management
    - Surveil success



Value of documenting storage during CO_2 EOR

- EOR needs additional CO_2
- CO_2 sequestration needs EOR offtake
- High quality, dependable offtake
  - $ + engineered management+ mature regulatory and public acceptance
- Is in fact highly qualified storage



Conclusions

- Do not rely on surface monitoring
  - High risk of poor outcome
- CO_2 EOR operators have much of the information needed to document storage
  - Characterization: reservoir and seal
  - Well integrity
  - Detailed reservoir surveillance
  - Some specific to EOR questions need to be addressed

More Information: www.gulfcoastcarbon.org

Thank you!

谢谢

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