

Monitoring, Mitigation, and Verification (MMV) in Geological Sequestration Scenarios, Technical Advances and Economic Constraints

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Where MMV is Needed

Power Plants



- Separate CO₂- S, NO_x, Metal
Scrubbers, Membranes
- Leak Testing – Pipes
Monitors (CO₂, S, N, T)

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Pipelines



- Leak Testing Monitors (gas, biology)
- Pipe Integrity Sensors inside pipe (nanotechnology, acoustics)

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Reservoirs



- Leak Testing Monitors (gas, H₂O, biology)
- Reservoir Integrity CO₂ movement Faulting, cementing

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Purpose of Monitoring in Geological Reservoirs



- Determine effectiveness of CO₂ storage
 - safety (public, environment)
 - economics (carbon credits, infrastructure)
- Determine impacts on reservoir
 - chemical/physical changes
 - CO₂ movements, calibrate models
 - remediation
- Settle legal disputes
 - storage/seepage scenarios
 - impacts to other reservoirs

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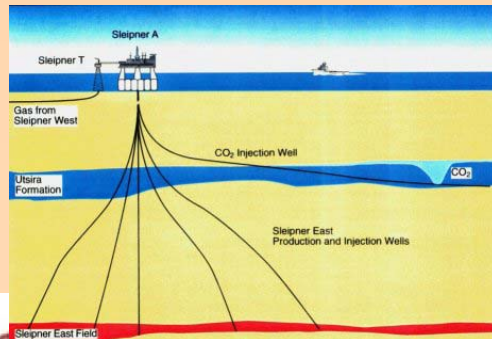
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Reservoirs – EOR, coal beds, aquifers



- Spatial set-up of MMV- subsurface, surface, local, satellite
- Timeline of measurements -Baseline, operation, closure
- Safety/regulations set-up – workers/public, environment, mitigation
- Economic constraints – tech costs and sampling designs

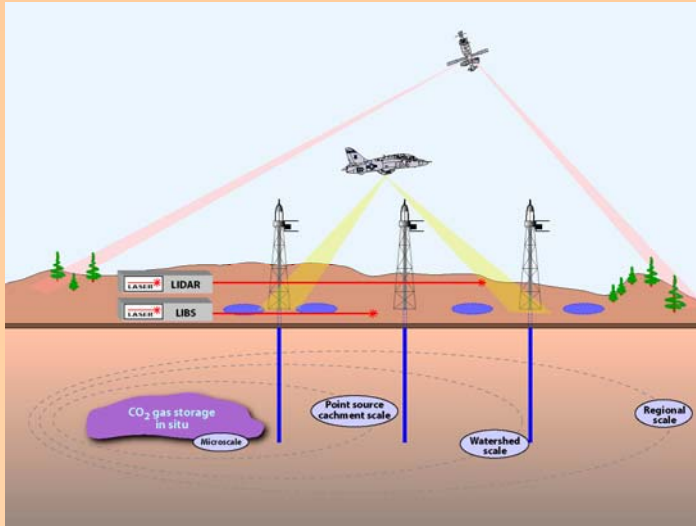


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Spatial Analyses and Technologies



- Satellite = Vegetation (NDVI), [CO₂], geology
- Regional = [CO₂], H₂S, Rn, EM
- Local = Eddy Flux, LIDAR, Tracers
- Surface = Chamber, Tracers, LIBS, Vegetation, microbes, soil gas/water composition
- Wells = injection/production rate, temperature, pressure (wellhead, formation, casing, annulus) wire line (gamma, neutron, resistivity)
- Subsurface = Groundwater, Ground Deformation, Seismics (Passive, 4D, X-well, Micro), gravity, Tracers, tilt, EM

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Temporal Scales Needed to be Monitored

Daily



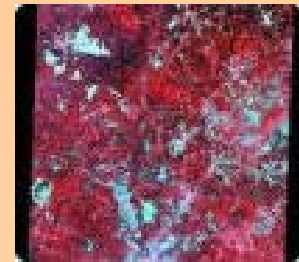
Injection well monitor
(T, P, CO₂, flow)

Weekly

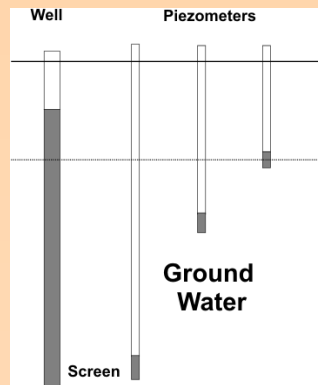


Eddy Covariance
(T, flow, CO₂)

Year-Multiyear



Satellite-15 m resolution
(CO₂, vegetation index)



Groundwater (DIC)



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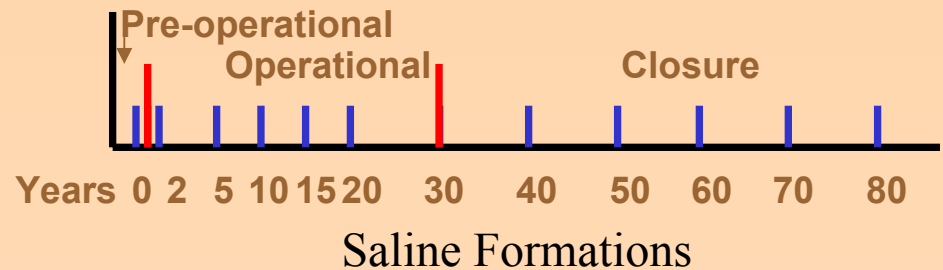
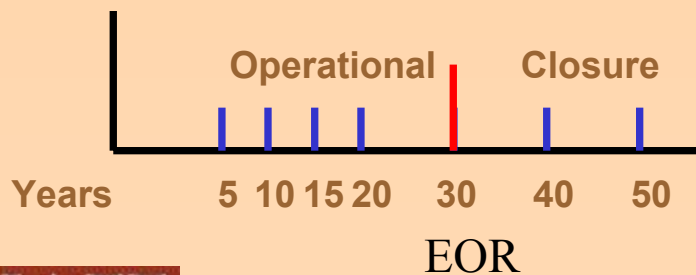
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Rock/cement weathering
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Timeline for Monitoring at Varying Sites

- Baseline Measurements = seismic, groundwater, atmospheric CO₂, tracers, vegetation type, microbes, soil gas/water composition
- Operation = well logs, seismics (4D-frequency below), groundwater (comp., pH), [CO₂] and isotopes (regional, local, surface), vegetation
- Closure = periodic checks of seismics, groundwater, [CO₂], pressure

Proposed frequency of geophysical measurement (Larry Myer LBNL)



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Safety and Regulations in Place

- Worker/public: EPA standards, controls, safety locks, emergency response
- Risk assessment/mitigation: Potential hazards (geologic, public), emergency response
- Outreach efforts: townships, company, local/state governments

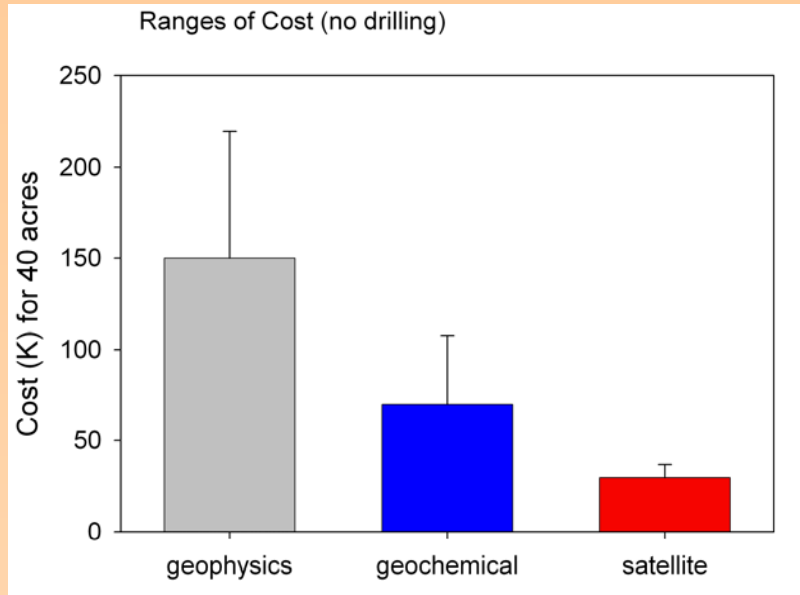


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Economic Issues in Geological MMV



- Technological costs
 - geophysics, geochemical, satellite
- Sampling designs (network arrays)
 - temporal and spatial
 - regulatory constraints

Costs taken from contractors, universities, labs, web

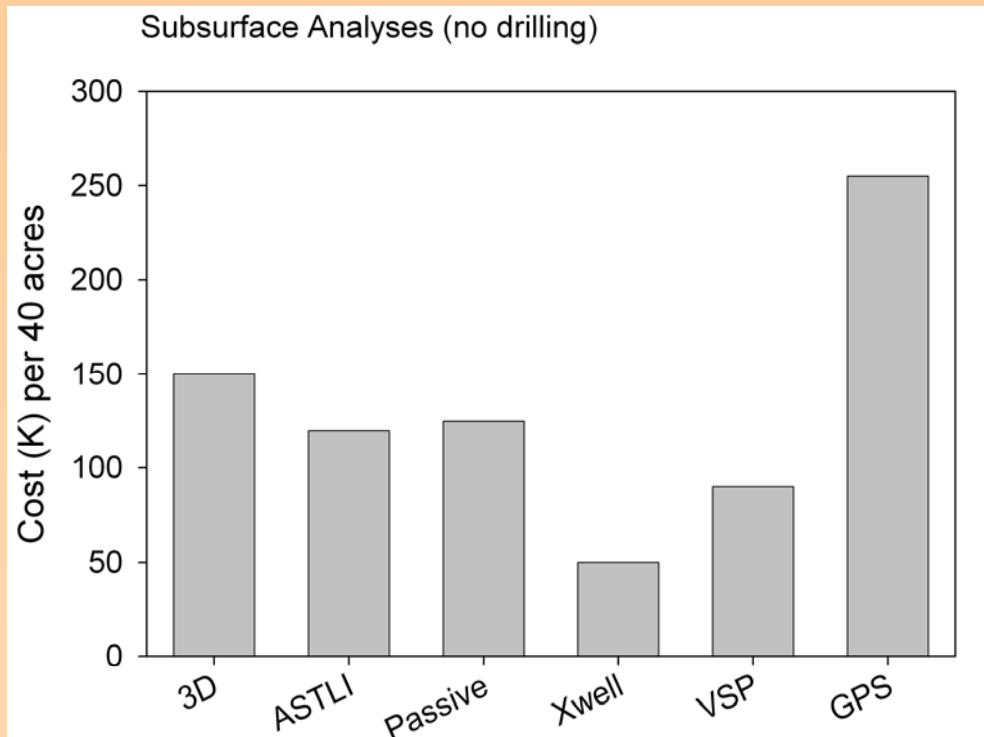


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Geophysical Costs - Technologies

- Costs = equipment, collection, analyses
1 time costs for 40 acres
No drilling of new wells



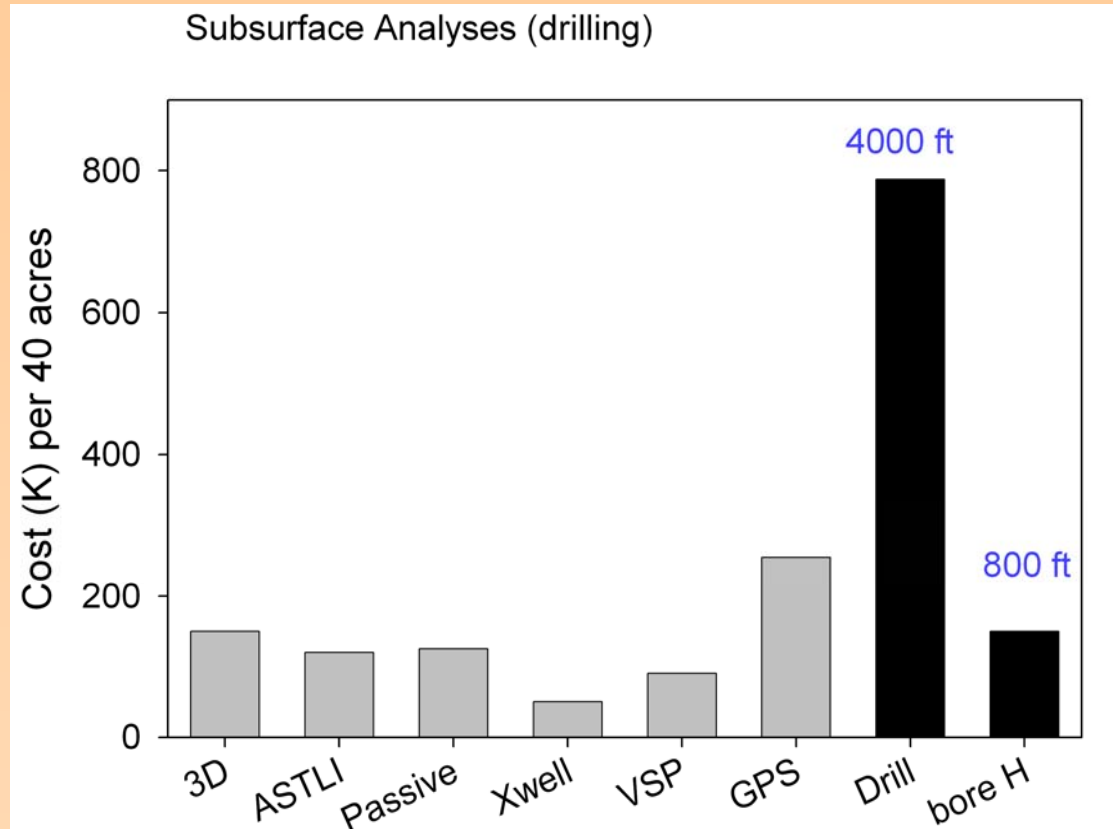
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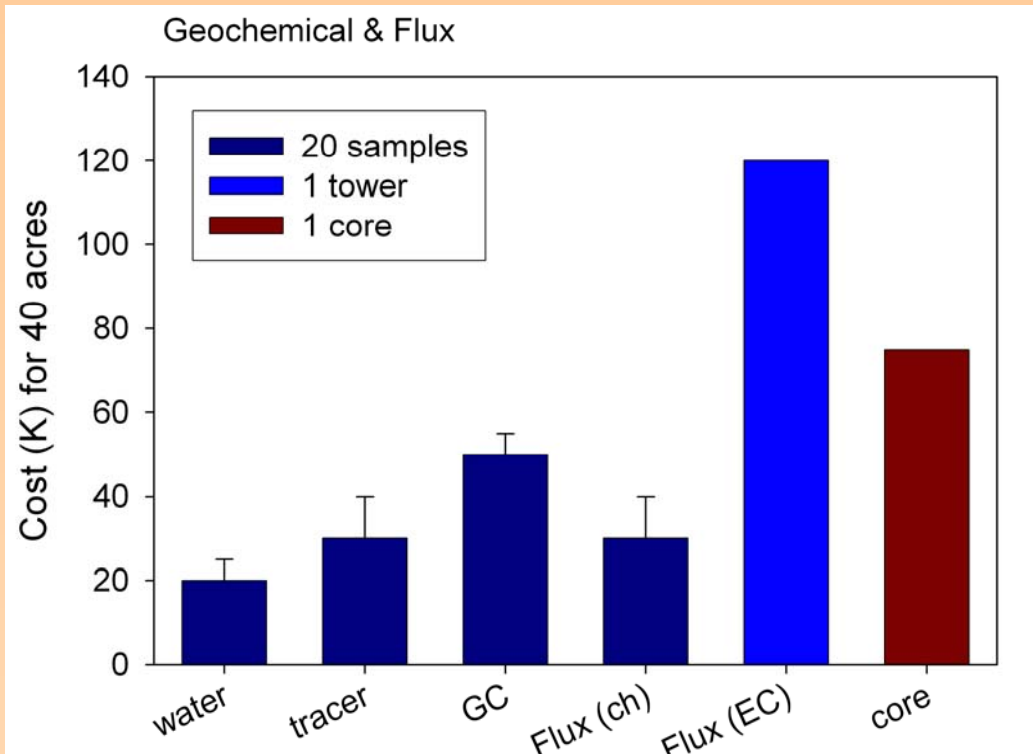
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Geophysical Costs - Technologies



- Cost = Drilling (1 hole)

Geochemical Costs - Technologies



- Costs = analyses (lab)
analyses + equipment (field)

Costs taken from contractors, universities, labs, web

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Tailored Approach to Monitoring Site

- Reservoir type and history – Geology, well location, data archives,
Land ownership (permitting)
Infrastructure, risks/safety
- Economics – Dictate MMV technologies, sampling strategies
- Technology Overlap – Geophysics, couple tests with similar equipment



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Conclusions & Future Directions

Conclusions:

- MMV – Power plants, pipelines, reservoirs
- MMV – Spatial and temporal scales
- Economics – Dictate technology & sampling
- Tailored approach used per reservoir

Future Directions

- Economic modeling: Needed for MMV
 - Help with sampling designs
 - Help with risk/safety evaluations

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