
EERC
Critical Challenges. Practical Solutions.

CCS TECHNICAL DISCUSSION SERIES: SITE SELECTION

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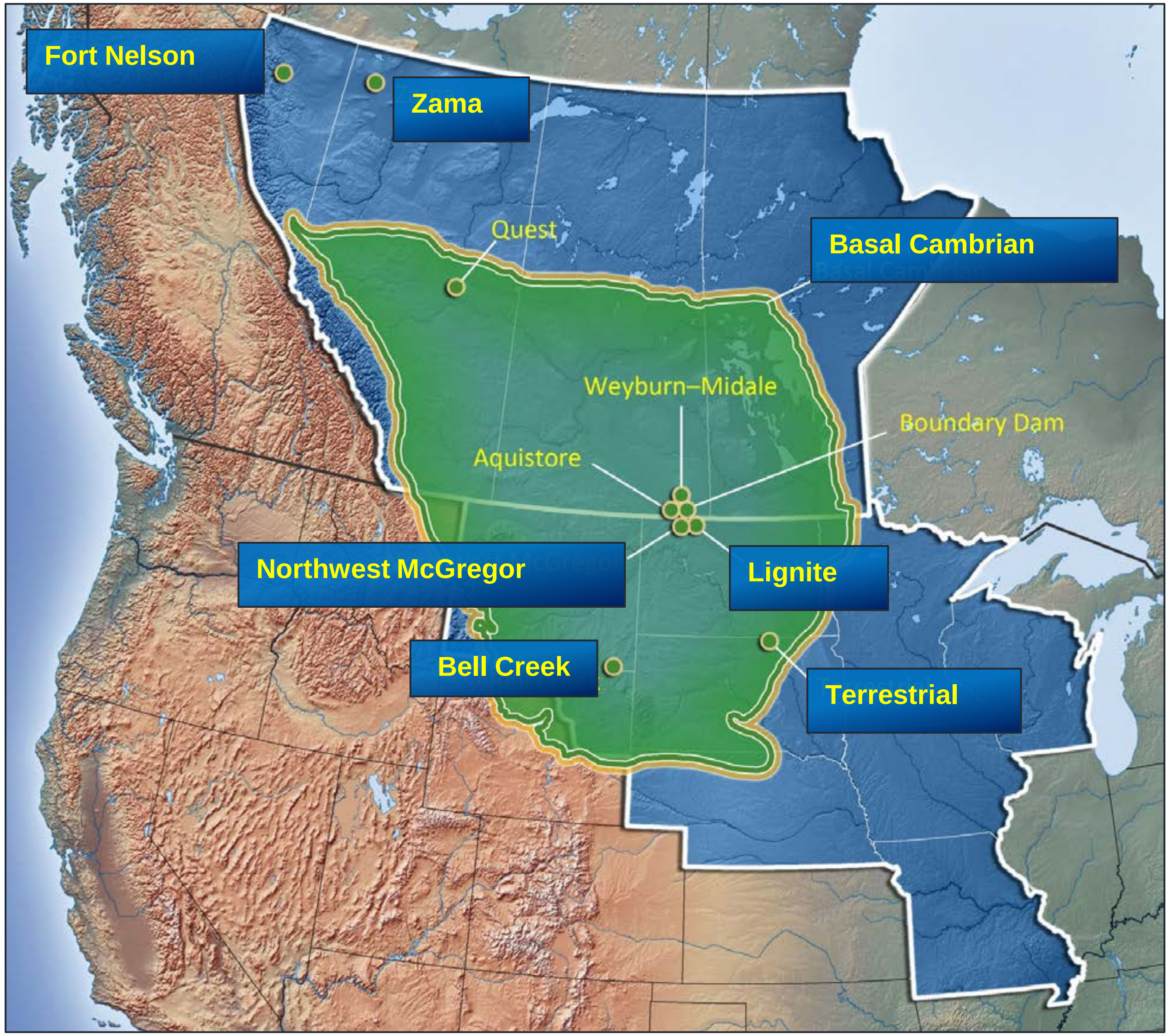
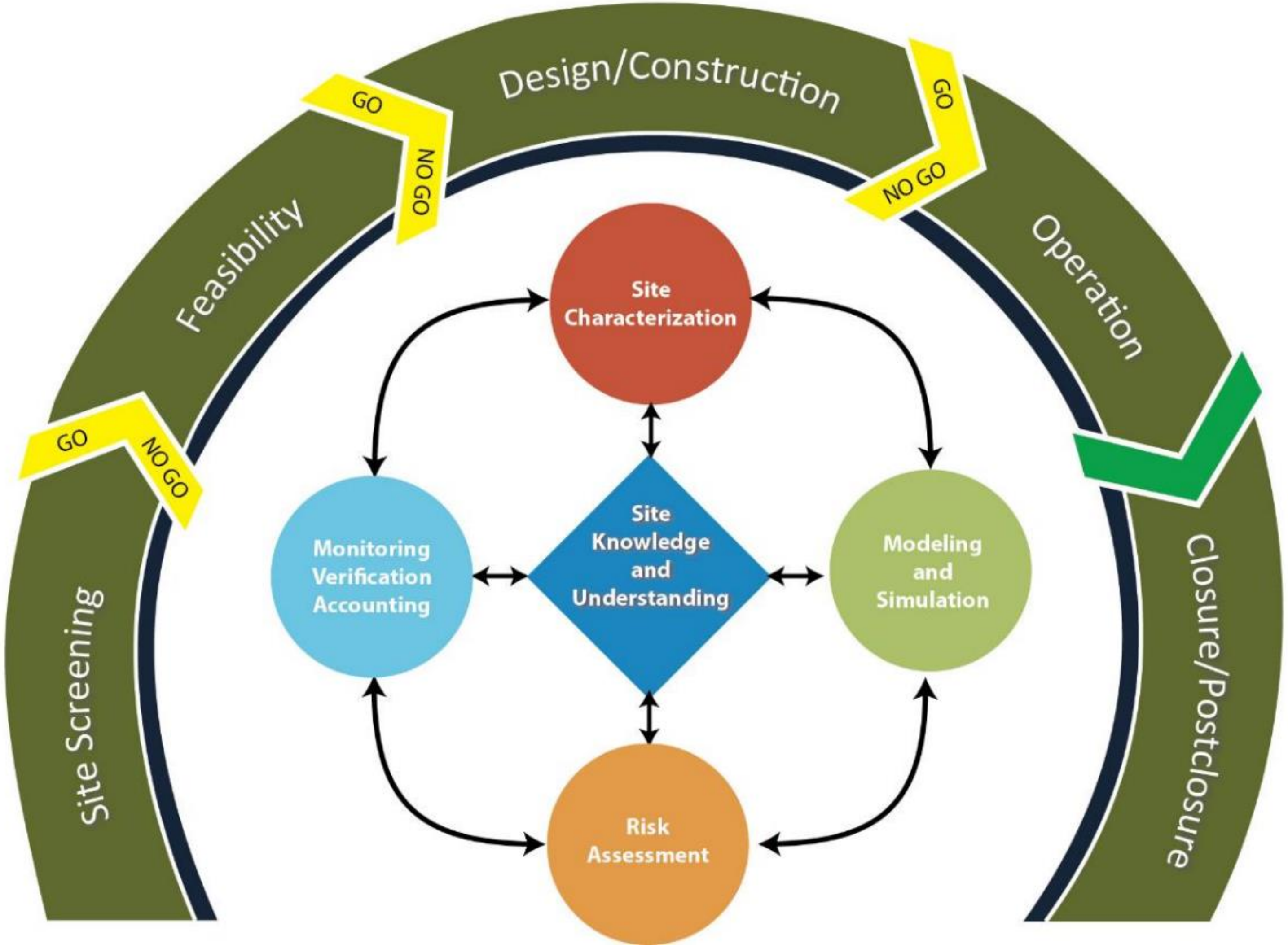
Critical Challenges. **Practical Solutions.**

PCOR PARTNERSHIP

- Region includes:
  - Nine states.
  - Four Canadian provinces.
  - 1,382,089 mi^2.
- Several completed field projects.
- Bell Creek demonstration under way
- Participation in Aquistore
- More than 121 partners



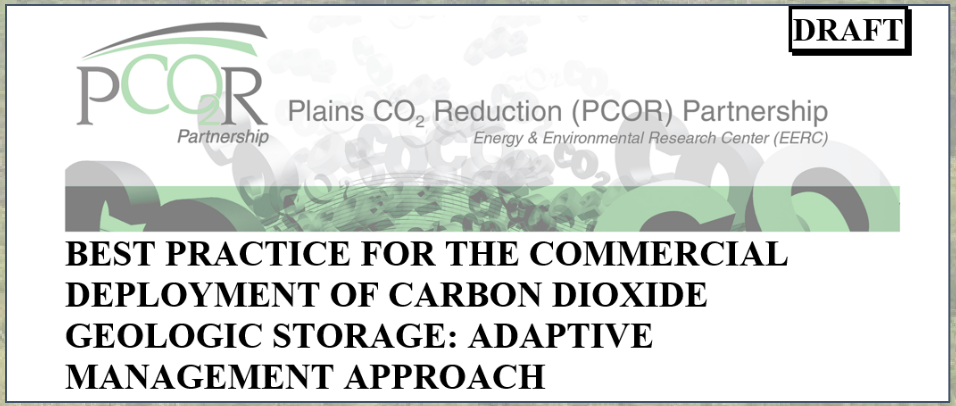
ADAPTIVE MANAGEMENT APPROACH



BEST PRACTICES MANUALS

- Participated in updating several DOE best practices manuals (BPMs)
  - Site characterization
  - Risk assessment/simulation
  - Monitoring, verification, and accounting (MVA)
  - Operations
  - Outreach

- PCOR Partnership BPMs (in development)
  - Adaptive management approach
  - Site characterization
  - Modeling and simulation
  - Risk assessment
  - MVA


DRAFT

PCOR Partnership

Plains CO_2 Reduction (PCOR) Partnership

Energy & Environmental Research Center (EERC)

BEST PRACTICE FOR THE COMMERCIAL DEPLOYMENT OF CARBON DIOXIDE GEOLOGIC STORAGE: ADAPTIVE MANAGEMENT APPROACH

SITE SELECTION

- Site selection: Process of assessing potential CO_2 storage reservoir based on geologic, hydrologic, geospatial, financial, or other parameters.

- ARB is seeking information and minimum requirements that should be considered when determining whether a proposed carbon capture and storage (CCS) injection site would be suitable for permanent geologic storage of CO_2.
- ARB is looking to identify specific requirements and analysis techniques for factors necessary to ensure permanent CO_2 containment.

- Site selection is not MVA, but potential future MVA activities should be considered during the site selection process.
- Difficult, if not impossible, to engineer your way out of a bad site.

SITE SELECTION

No shortage of opinions and guidelines

BASIC REQUIREMENTS FOR SITE SELECTION

- Big enough
  - To accept the rates and volumes commensurate with the source(s)
- Deep enough
  - To ensure high-density form of CO_2 (generally >800 m)

Practical

- Salty enough
  - To avoid USDWs (>10,000 ppm TDS)
- Secure enough
  - To ensure long-term containment of the CO_2

Regulatory

- Close enough
  - To the source(s) to reduce pipeline costs

Economic

SITE SELECTION REQUIREMENTS

- Site-specific criteria matched with CO_2 storage needs.
- One-size does not fill all.
- If targeting a lowest common denominator, sites suitable for smaller sources/injection rates of CO_2 may be unnecessarily eliminated.
- Overly prescribed requirements can impede implementation.

DETERMINING INITIAL STORAGE RESOURCE

- Proper use of the DOE volumetric methodology for saline formations.
- Be aware of how much you know about the target formation.
- Don't use the default E-factors if you have the knowledge to use a more informed E-factor.
- Dynamic storage resource will be less than the static estimate.
- Dynamic storage will eventually match the static estimate, but at very long time frames.

- $G_{CO2} = A_t h_g \varphi_{tot} \rho E_{saline}$
  - A_t= Area
  - h_g= Thickness
  - φ_{tot} = Porosity
  - ρ = Density of CO_2
  - E_{saline} = Efficiency factor

A. Goodman and others, 2011, International Journal of Greenhouse Gas Control, v. 5, p. 952–965.

GEOLOGIC AND CONTAINMENT FACTORS

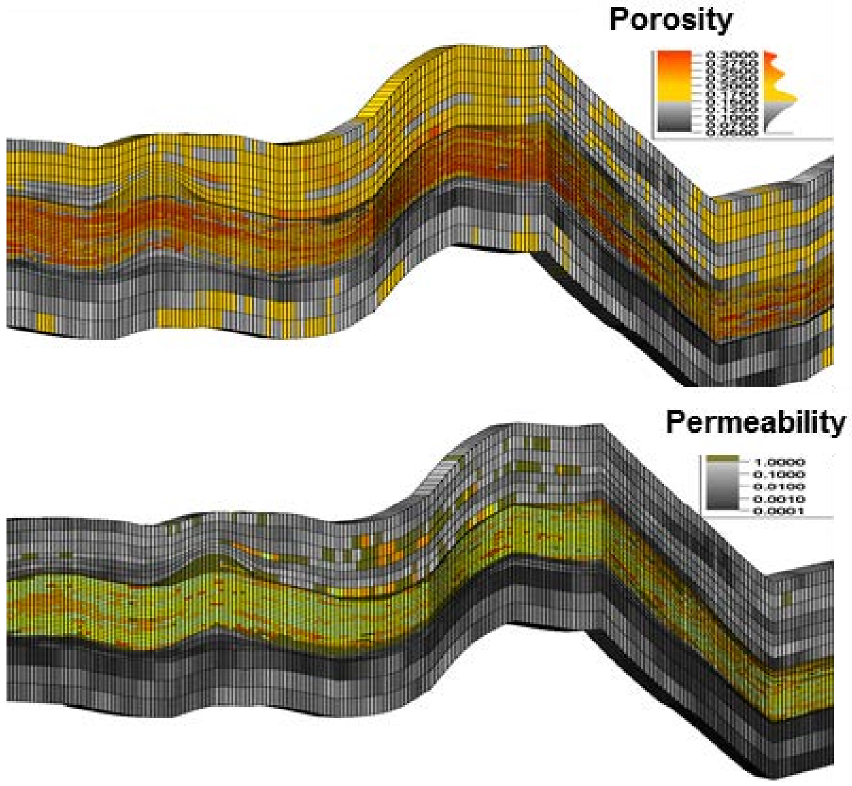
- Knowledge of injection formation characteristics.
- Knowledge of confining formation characteristics.
- 1 Identify preinjection background for characteristics such as groundwater chemistry, seismic levels, pressure/temperature conditions, etc.
- 2 Identify trapping mechanisms.
- Identify potential leakage pathways.
  - Identify the amount and need for corrective action for the site.
- 3 Determine potential injectivity: planned injection rate and total injection volume.
- Identify and define pressure limitations for the site.
- Evaluate geomechanical response to anticipated pressures.
- Evaluate hydrological response and communication in reservoir.
- Perform geochemical interaction analysis.
- Evaluate existing and anticipated seismic concerns.

MODELING FACTORS AND PLUME SIZE

- Define minimum modeling parameters required.
  - Will depend on the complexity of the model.
- Define acceptable limitations/uncertainties in the model used.
  - Will depend on the model and the input (GIGO).
- Model should determine how reservoir boundaries will affect the plume.
  - Important to understand the nature of the model boundaries (closed vs. open).
- Model should determine anticipated plume extent, pressure front extent, and help set AOR boundaries.
  - A requirement for Class VI well permits.
- Model should identify any areas of seismic concern.
  - Identify or incorporate?
  - NRAP's Short-Term Seismic Forecasting (STSF)

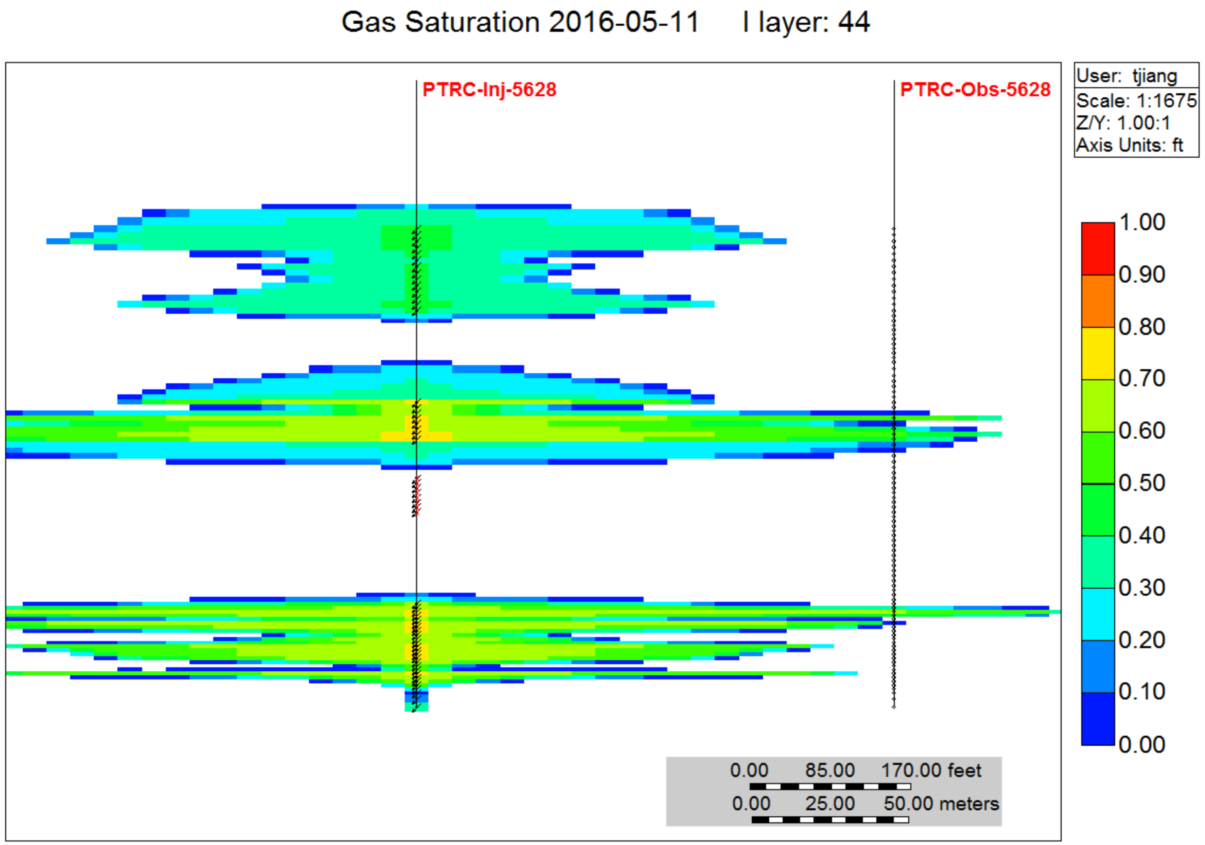
GEOCELLULAR MODELING FACTORS

- Core analysis data (porosity and permeability)
- Well logs and formation tops (depth and thickness)
- Geologic interpretation of structural, depositional, diagenetic history of the target formation
- Seismic data (2-D and 3-D)
- Heterogeneity
- Temperature and pressure
- Footprint (geographic size vs. cell size)



DYNAMIC MODELING FACTORS

- Fluid properties (in situ and injectate)
  - Salinity
  - Viscosity
  - Density
- Relative permeability
- Boundary conditions (i.e., open, closed, semiclosed)
- Initial reservoir pressure and temperature
- Fracture pressure and regulatory relationship
- Footprint of model (grid sizes and overall model size)
- Operating objectives (rate and volume)



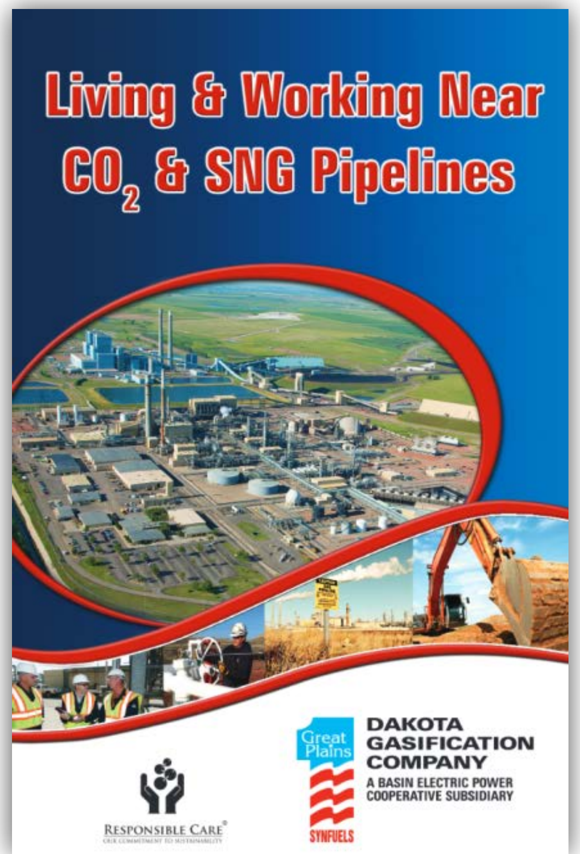
SITE DEVELOPMENT/LOCAL FACTORS

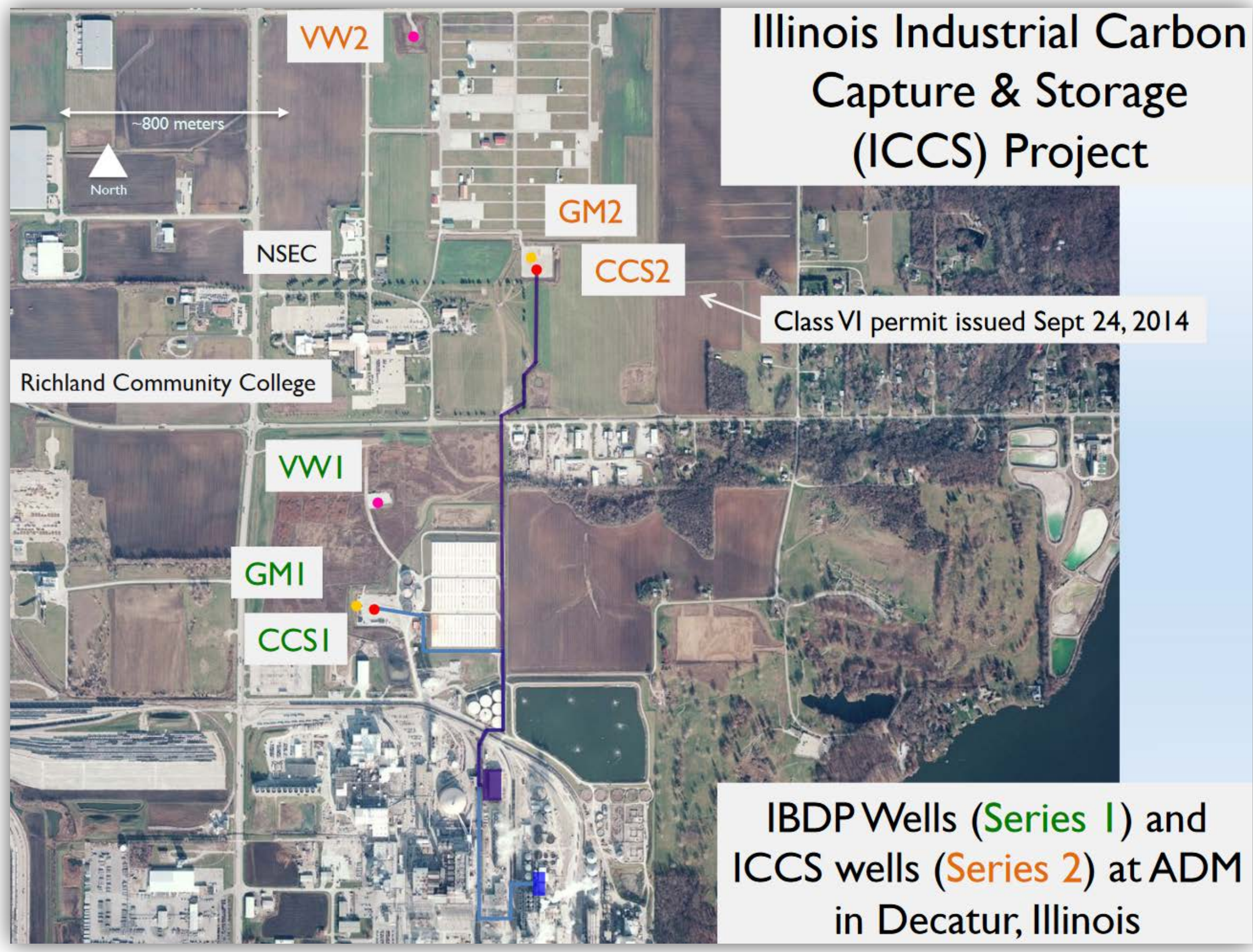
- Determine proximity to sources of CO_2
- Determine proximity to protected environmental areas and environmental justice communities
- Determine proximity to population centers
- Required consideration of existing resource development (impact on local aquifers, oil/gas fields, mineral resources, etc.)

Injection well/facility or plume extent?

LOCATION, LOCATION, LOCATION

- In an area of suitable geology
- Close to the source to minimize pipeline costs





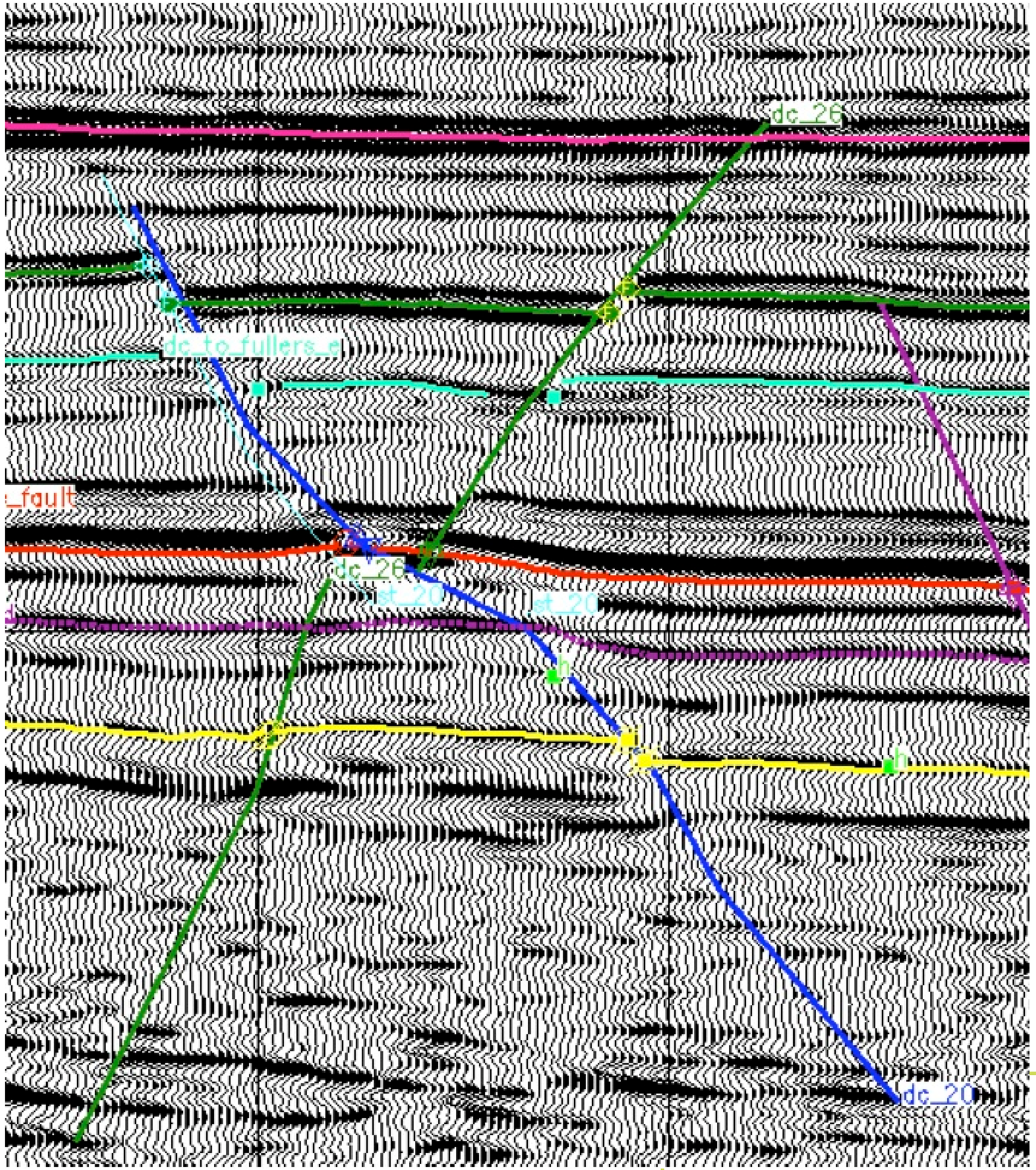
Source: http://conference.co2geonet.com/media/1051/open-forum-day-2-5_greenberg.pdf

MINIMUM REQUIREMENTS

- Injection formation
  - Site/project specific but sufficient to meet the rates/volumes needed. If properties will not accommodate the desired rate/volume then site is unsuitable.
- Cap rock
  - Thick enough to be resolved on seismic. Often cited as >10 m.
  - Depends on lithology.
  - Extensive areal coverage.

MINIMUM REQUIREMENTS

- Existence or proximity to faults
  – Avoid if at all possible. Collect 3-D seismic data to determine degree of faulting. No extensive (long, large throw) faults in the AOR as defined by Class VI well requirements.
- How should risk factors on geologic characteristics impact monitoring requirements?
  – Should monitoring requirements impact site selection?
  – Higher risk = high-priority monitoring (type, density, frequency of monitoring).
  – Risks may be acceptable and site may be quite suitable, but higher costs for monitoring become a consideration.



CAP ROCK

- Thick enough to be resolved seismically.
- Often cited as >10 m.
- Minimum thickness dependent on lithology (salt and anhydrite vs. carbonate and shale).
- Not faulted.
- Extensive areal coverage.
- Redundant layers are a bonus.

Very Good	Seal thickness significantly greater than any fault throws observed in top seal.
Good	Faults in top seal offset the top seal (fault throw ~ 25 and 75% of top seal thickness)
Bad	Fault throws significantly offset top seal (fault throw >75% of seal thickness)
Very Bad	Fault throw is greater than seal thickness.

Source: http://ieaghg.org/docs/General_Docs/Reports/2011-01.pdf

DETERMINING SUITABILITY OF SITES BASED ON MODELING OR OTHER TECHNIQUES

- Should baseline measurements of the storage site (e.g., seismic, groundwater, soil gas, etc.) be required for judgment of site suitability?
  - No. Functionally, this is not a site selection activity.
- Should determination of CO_2 isolated by various trapping mechanisms be required?
  - No. The suitability of site should not be based on how much CO_2 may get dissolved in water or eventually mineralized.
- EPA Class VI limits injection pressure ≤90% fracture pressure. Is this good enough?
  - Yes. The Class VI pressure limitation is based on rigorous investigation and is in line with regulations in many oil/gas producing states.
- Should the ARB require more stringent AOR requirements than EPA Class VI?
  - Not sure why this would be needed.

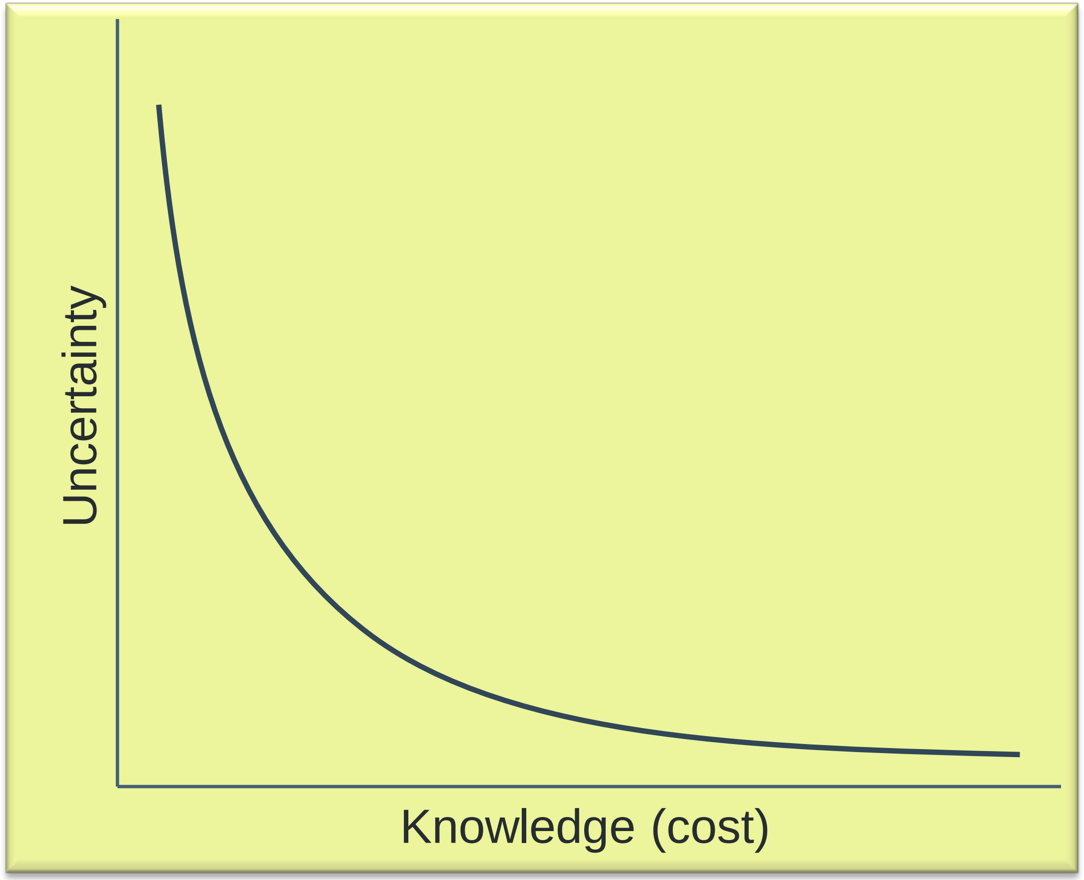
DETERMINING SUITABILITY OF SITES BASED ON MODELING OR OTHER TECHNIQUES

- What types of models exist to help evaluate a potential CCS injection site on a geochemical, hydrological, and/or geomechanical basis? Pros/cons of each?
- How much uncertainty is common in these types of models?
  - Can be very high with geochemical models.
- How should the modeling results influence monitoring techniques?
  - Yes, but this is not a site selection metric.

SELECTION OF APPROPRIATE GEOLOGICAL STORAGE SITES

- Screening–assessing–selection
- Initial estimation of storage resource and level of uncertainty
- Awareness of subsurface competition (natural resources, pore space, etc.)
- Faulted/fractured areas not automatically out of contention
- Assessment of data gaps after screening effort
- Data availability vs. cost of new data acquisition
- Strat test well
- Geomodeling and dynamic simulation
- 2-D (good) and 3-D (really good) seismic
- Potential out-of-zone migration pathways (faults and wells)
- Legal/regulatory framework
  - Pore space ownership, AOR

THE TRADE-OFF



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