

# Panel Discussion Summary and Suggestions

Sally M. Benson, LBNL

Stefan Bachu, Alberta Energy and Utilities Board

John Tombari, Schlumberger

Lynn Orr, Stanford University

Robert Finley, Illinois Geological Survey

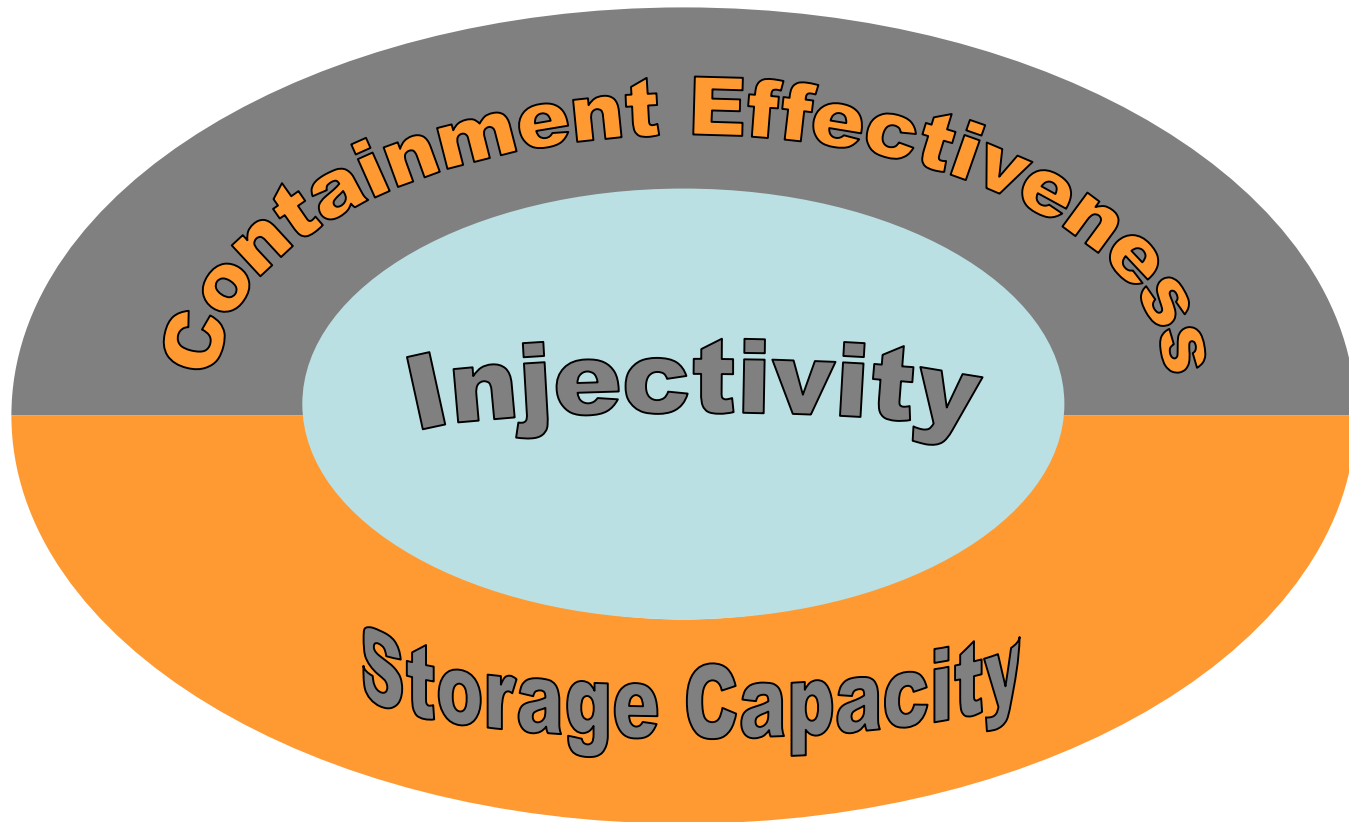
Fred Molz, Clemson University

# Site Characterization

*The collection, analysis and interpretation of data and the application of knowledge to judge, with a degree of confidence, if an identified site will store a specific quantity of CO<sub>2</sub> for a defined period of time and meet all health, safety, environmental requirements.”*

From Peter Cook, CO2SC 2006

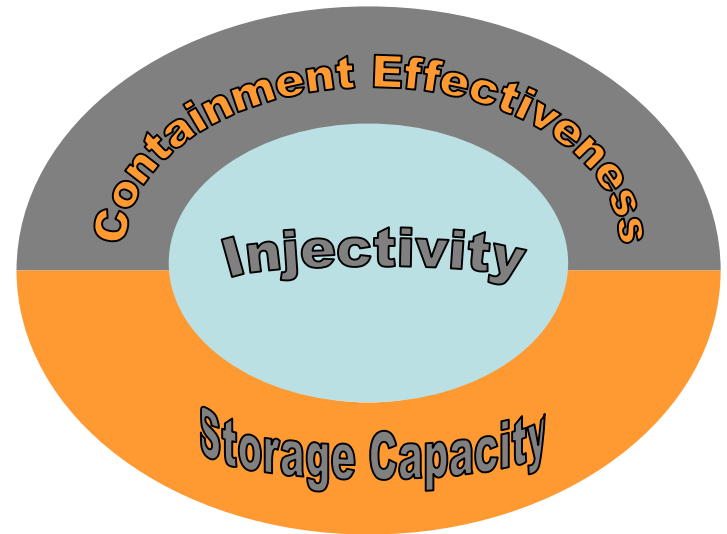
# Site Characterization Framework



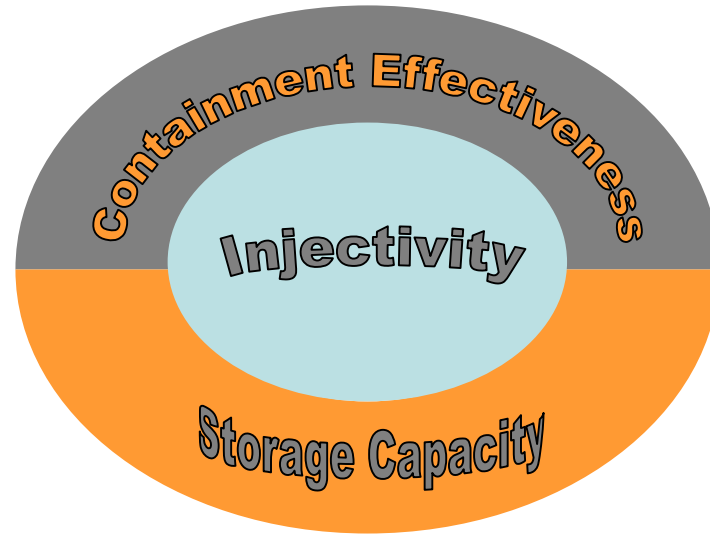
*What is the minimum set of information needed to obtain a permit to operate a storage facility?*

# Containment Effectiveness

- Seal Characteristics
  - Capillary barrier
  - Permeability barrier
  - Pressure barrier
- Continuous and thick
- Geographically extensive
  - More extensive than CO<sub>2</sub> plume
- Absence of conductive faults
- Stable during pressure buildup
  - Avoid hydrofracture, fault reactivation
- Not unmanageably compromised by leaking wells



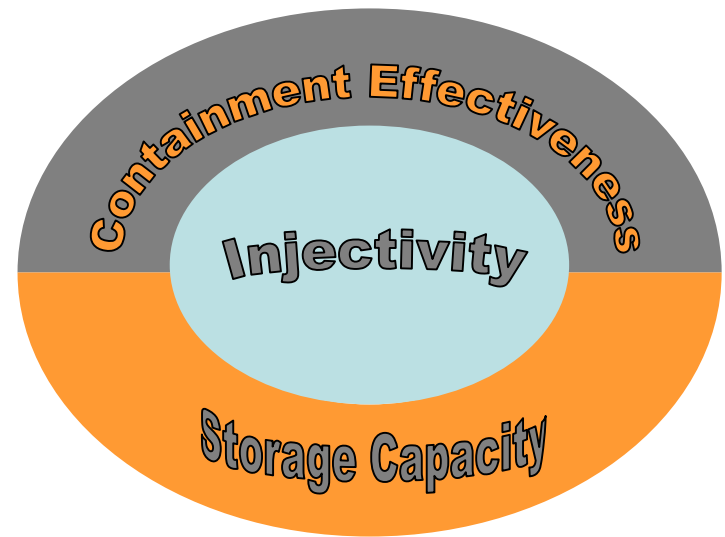
# Injectivity



- Adequate permeability x thickness
- Storage formation volume  $\gg$  injection volume

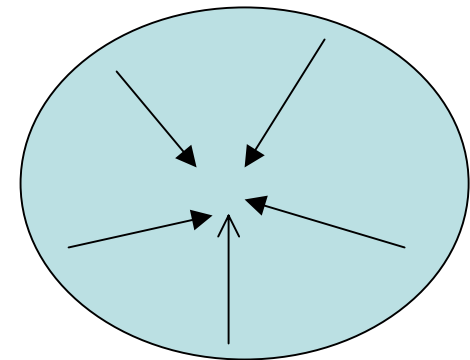
# Capacity

- Adequate accessible pore volume
  - Short term focus on separate phase CO<sub>2</sub>
  - Pore volume occupancy over extent of the plume
    - 5%, 10%, 40%, 80%?
- Footprint of the CO<sub>2</sub> plume
- Longer term, dissolved, capillary trapped, mineralized CO<sub>2</sub>

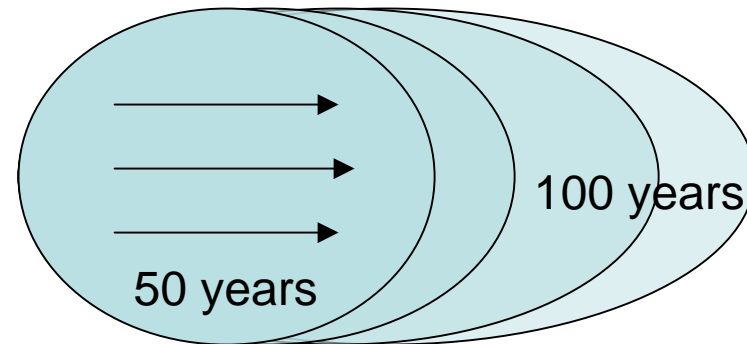


# Key Site Characterization Needs Are Different

- Oil and gas
  - Current and future abandoned wells
  - Geomechanical impact to seal integrity
- Saline formations
  - Seal adequacy over  $\sim 100 \text{ km}^2$ 
    - Closed trap vs. open trap
  - Pore volume occupancy
    - Plume size
- Coal beds
  - Injectivity
  - Containment
    - Adsorption
    - Seals
    - Hydraulic fractures



Closed Trap

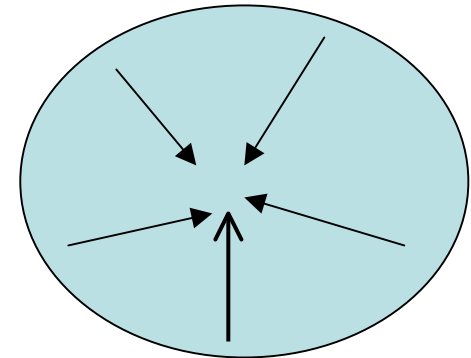


Open Trap

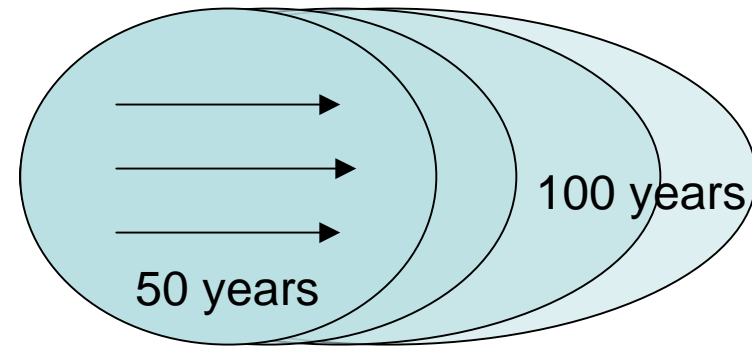
*Fit for purpose characterization is needed.*

# Characterization to Support Storage Strategy

- Closed trap
  - Seal properties
  - Geological closure
  - Injectivity and geomechanics
  - End-member of relative permeability curves
- Open trap
  - Seal properties
  - Multiphase flow dynamics
  - Solubility trapping
  - Capillary trapping
  - Mineral trapping

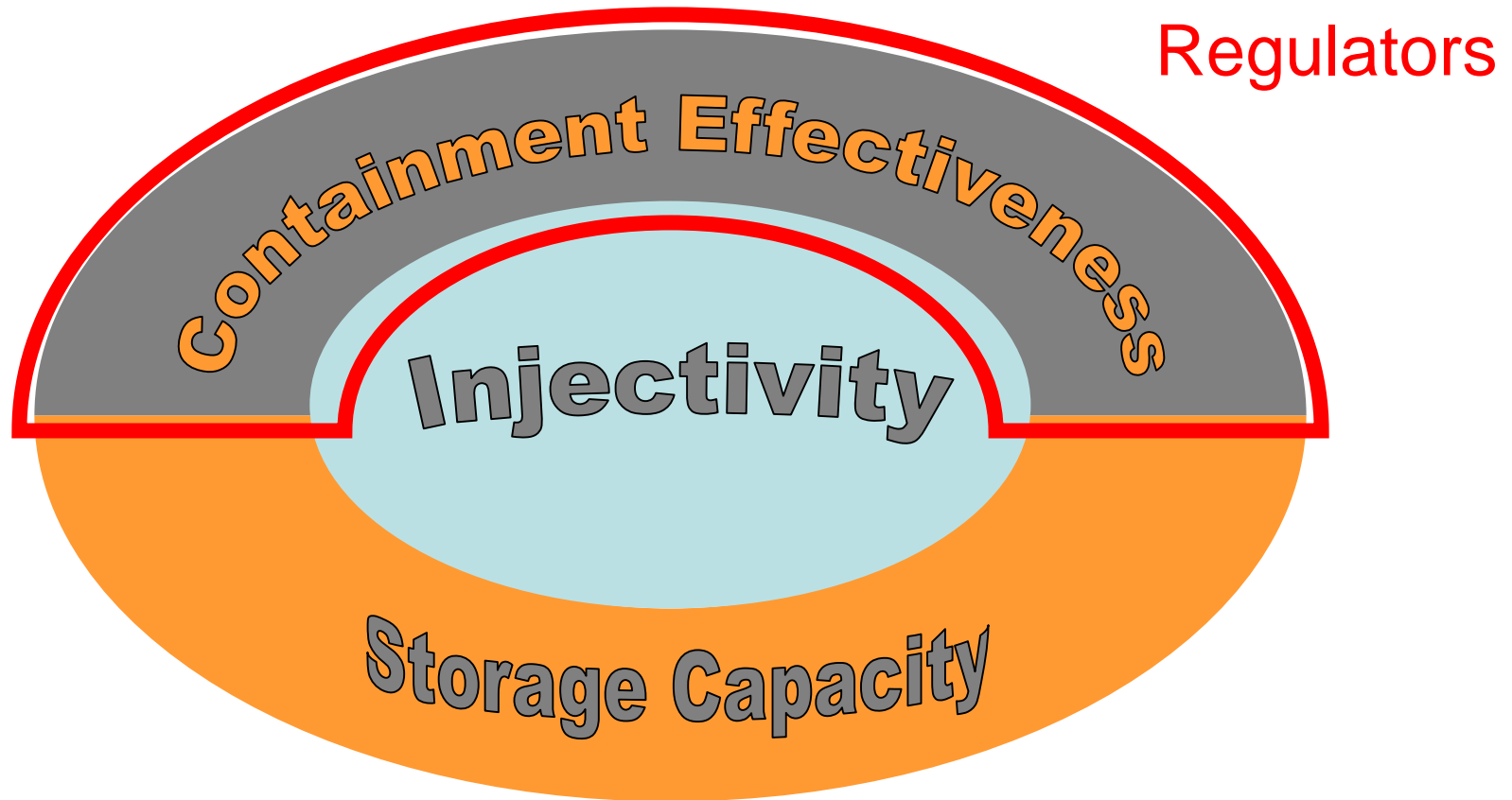


Closed Trap



Open Trap

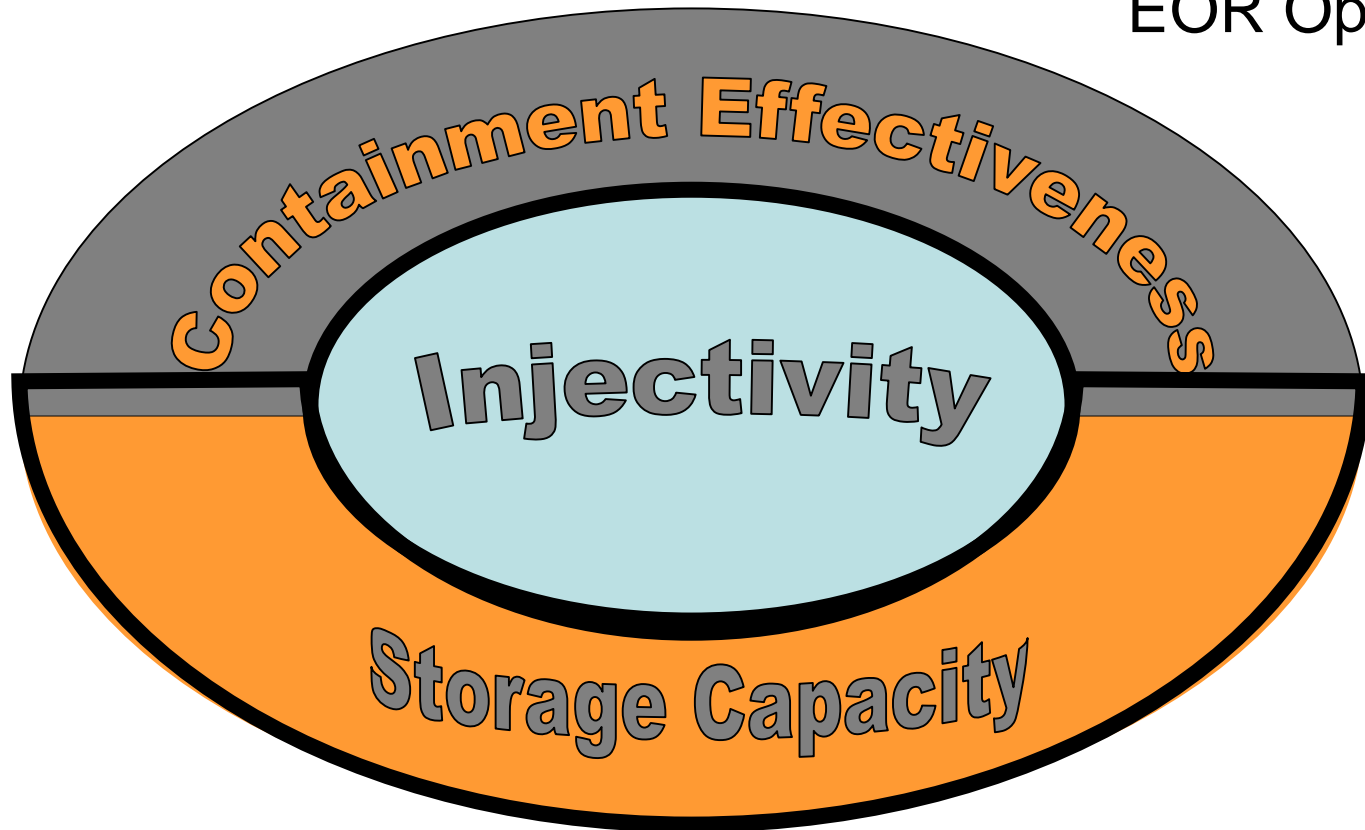
# Site Characterization Framework



*Not everyone thinks the same things are most important.*

# Site Characterization Framework

EOR Operators



*Not all characterization data is needed for a storage permit.*

# Characterization Methods and Technology

- Geology, geology, geology!
- Lots of characterization technology available, more in the pipeline
- Pilot-scale CO<sub>2</sub> injection performed as part of site characterization in some cases
- Regional scale geochemistry is missing from saline formation characterization
  - Age of water
  - Connectivity and compartmentalization assessment
- Avoid specifying particular technologies
  - Different needs
  - Varying effectiveness
  - Stifle innovation

# Regional and Project Case Studies

- Very important base of experience
- Learn from surprises
- Develop best practices
- Site Characterization Network
  - Information sharing
  - Repository of case studies

# Characterization of Leakage Pathways

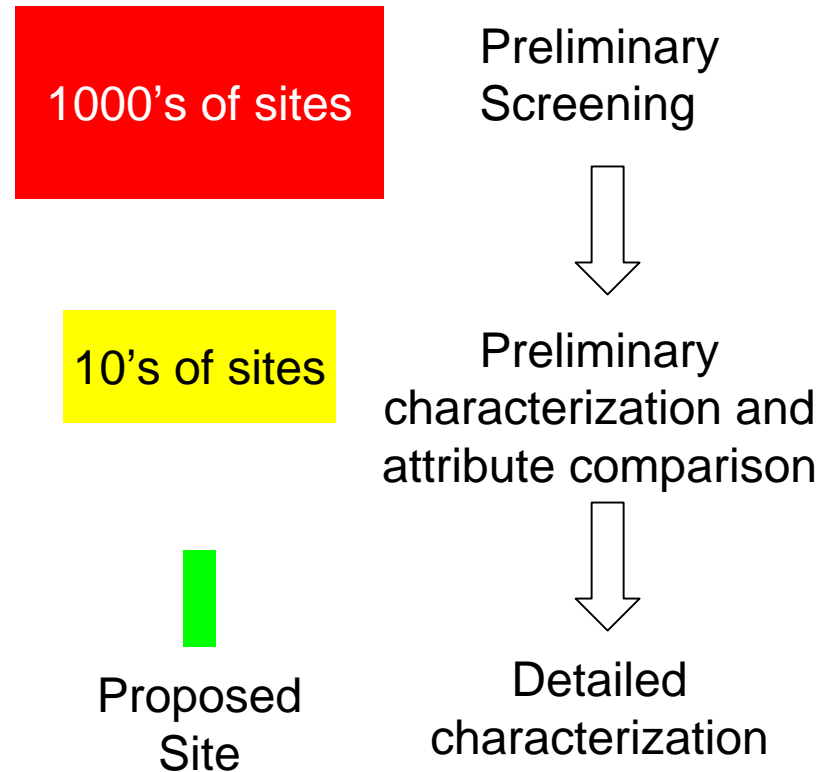
- Need for fundamental understanding and quantitative assessment of self-enhancing and self limiting processes controlling leakage up faults and wells
  - Coupled multi-phase flow and heat dynamics
  - Geochemical interactions, dissolution and precipitation
  - Geomechanical changes to seals
- Need for data on fault and well leakage properties – geometry and permeability of flow paths

# Fundamental Processes

- Multi-phase flow and transport from oil and gas, non-aqueous phase pollutants, vadose zone studies, etc....
  - Analytical and numerical approaches predict future behavior
  - Some challenges for existing numerical models
  - Data on CO<sub>2</sub>-brine systems are becoming available
  - Some surprises, high residual liquid saturations
  - More data and assessments needed
- Geochemical interactions
  - Leading to dissolution or mineralization – positive or negative impacts on containment
  - Core and fluid samples needed for analysis
  - Laboratory experiments and numerical simulation
  - Some field experience e.g. Weyburn and Frio
  - To date, difficulty obtaining data to carry out reliable studies
- Geomechanical effects
  - Important for assessing the dynamic competence of the seal
  - Models available, but more needs to be done to validate them, data availability limited
  - Use as guide for maximum injection pressures

# Screening Tool and Processes

- Quick and reliable methods for down selecting storage options
- Comparative assessment of attributes
- Focus detailed characterization on most promising options
- Several models under development with different perspectives
  - EOR/EGR
  - Risk Assessment
  - Economic
  - Geologic
- Could these have a role to play in permitting?
  - e.g. standard and accepted criteria

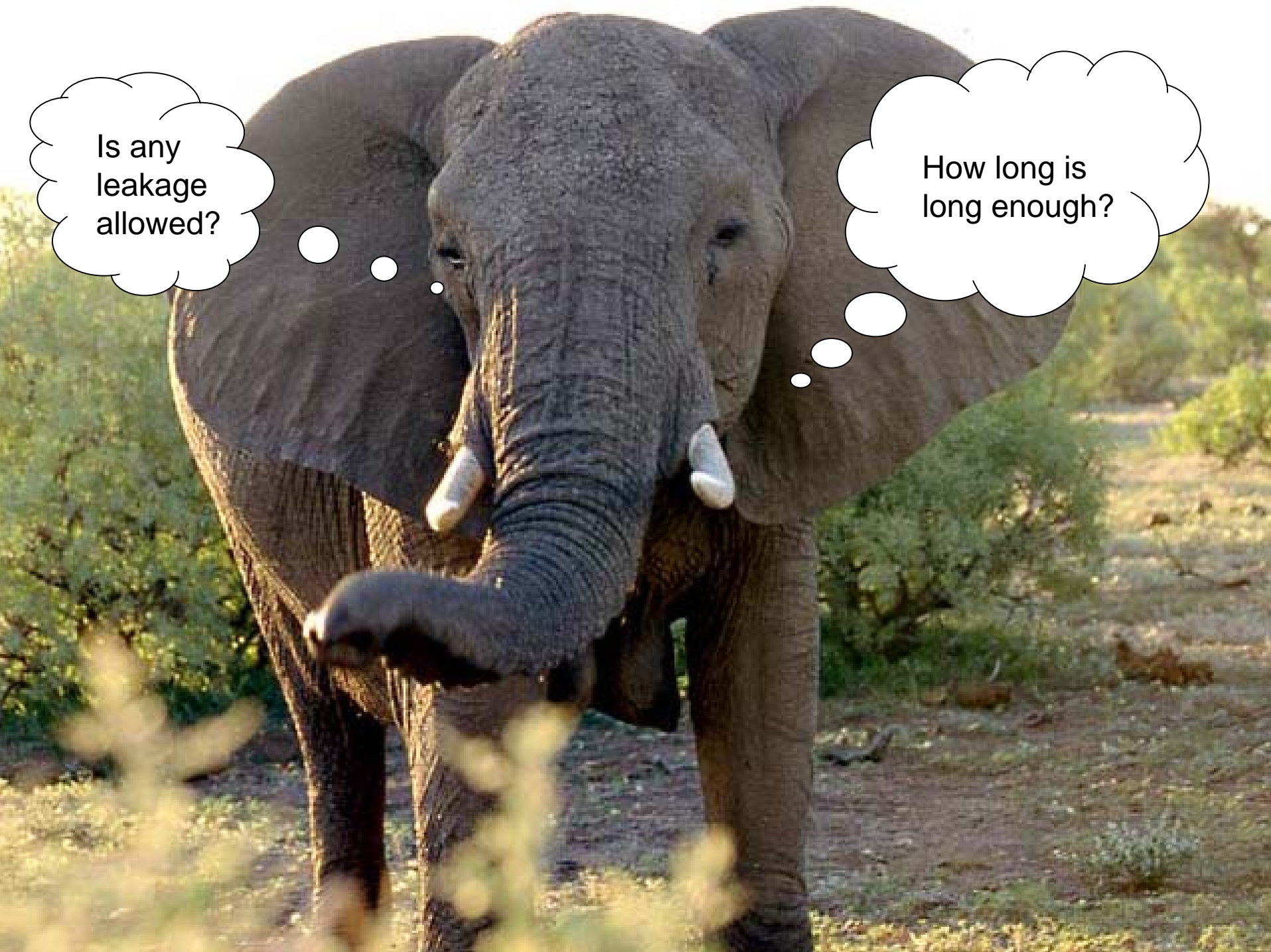


# Regulatory and Social Issues

- Build on existing regulatory framework and experience
  - Lots of experience with injection well siting and regulatory oversight (30 years with UIC program)
  - Some similarities, some differences
  - Class V for DOE Regional Partnerships... facilitate gaining early experience
  - Need framework for large scale implementation
  - Need to build public confidence by robust and effective regulation
- Need cost-effective regulatory oversight
  - Regulatory burden commensurate with the benefit
- Deployed in a complex political, social and regulatory framework
  - Local, regional, national and global
- Long term liability, monitoring, remediation needs to be resolved

# Key Knowledge Gaps and Research Opportunities

- Large scale  $\sim 100 \text{ km}^2$  characterization of seals for saline formations
  - Thickness, continuity, uniformity, properties
  - Transmissivity of faults, static and dynamic conditions
- Effective procedures/protocols for characterization of abandoned well conditions and leakage potential
- Characterization and permitting approaches for multiple reservoir storage or storage without closed traps
  - stacked reservoir, reserve reservoir, secondary containment
- Predicting plume extent and storage capacity considering multi-phase flow with heterogeneity and dissolution
  - Upscaling strategies for multiphase flow
  - Challenge to simultaneously predict pressure, displacement and dissolution
- For very large scale storage,  $\text{CO}_2$  volume  $> 10\%$  storage formation volume - where does the water go?



Is any  
leakage  
allowed?

How long is  
long enough?

# Key Questions

- What is the minimum set of information needed to obtain a permit to operate a storage facility?
  - Containment effectiveness
  - Capacity
  - Injectivity
- How can we facilitate early large-scale projects?
  - Can we learn by doing... Or, do we have to have all the answers first?
- Are we missing something important?

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