

Cost of Selecting a Storage Site – Staged Investment to Decrease Risk

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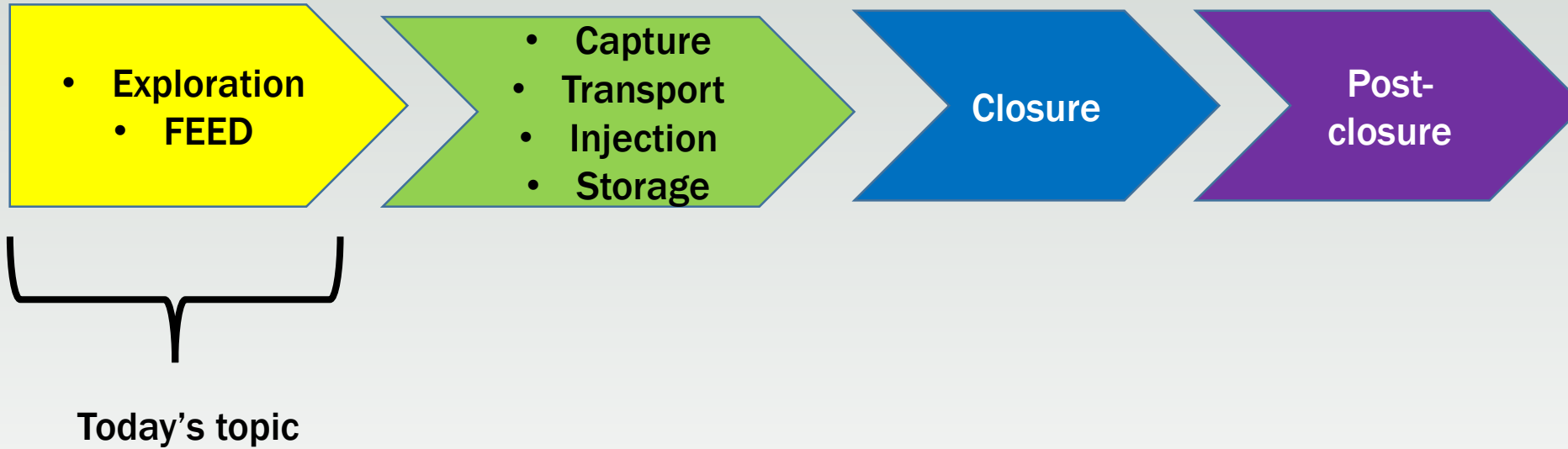
Groundwater Protection Council
Underground Injection Control Conference
Feb 18, 2020, San Antonio, TX



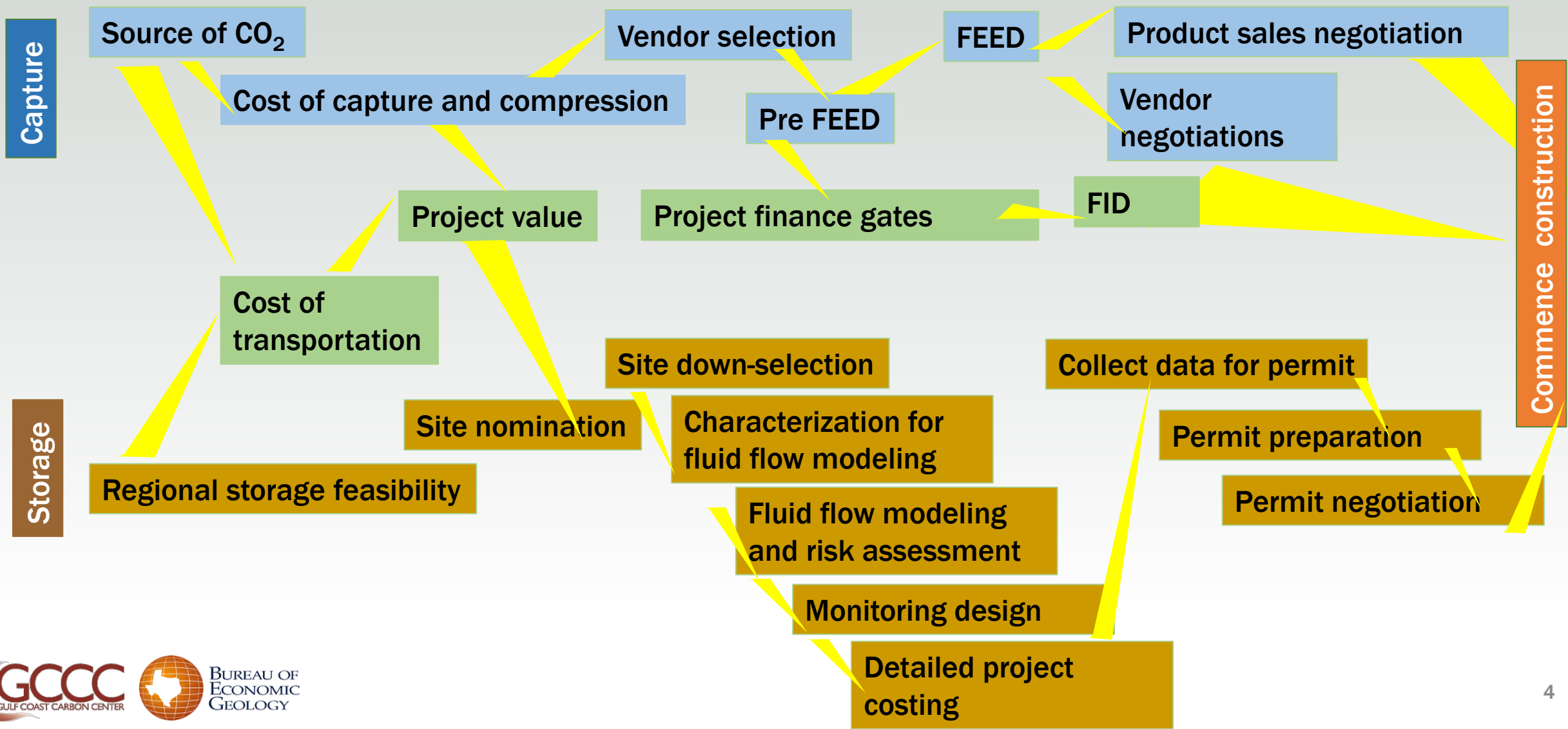
Statement of problem

- **As source industries consider storage, they need reliable information on cost & risk of developing suitable storage resource**
- **Cost and risk are not fixed; vary depending on geology, project characteristics & regulatory conditions**
- **Uncertain cost = deterrent to project development,**
 - **Especially early stages when total project risk is high**
 - **Site characterization = sunk cost whether or not project proceeds**

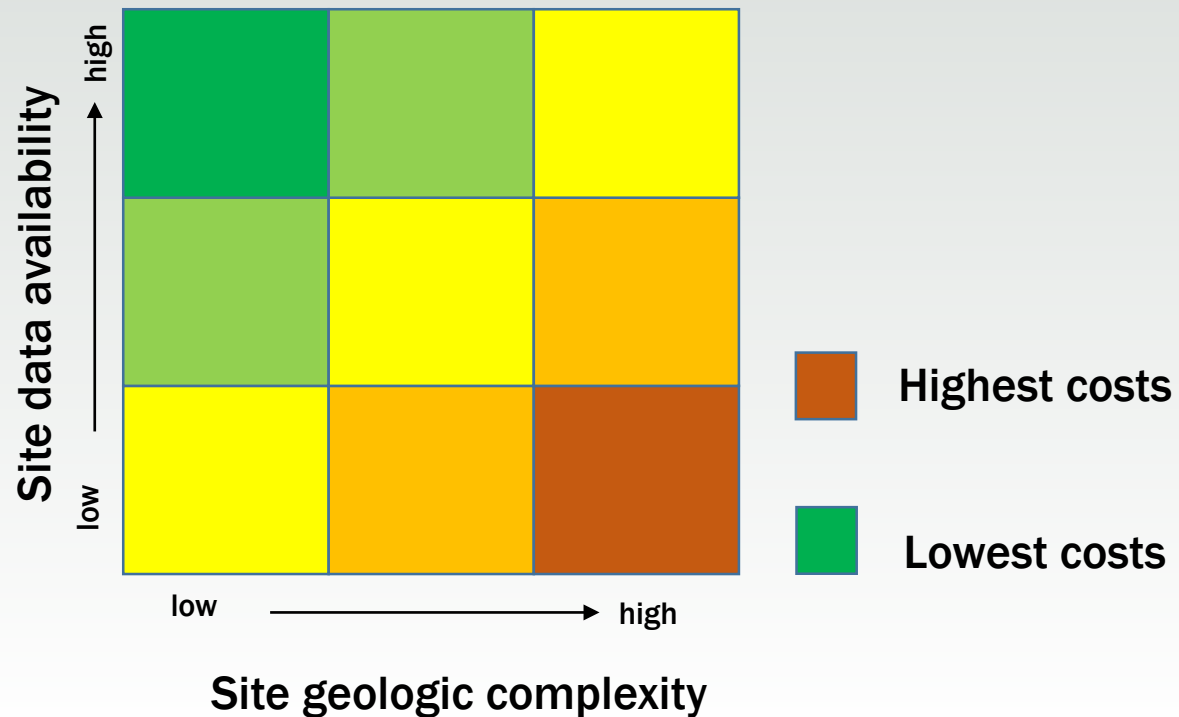
Phases of a CCS project



Cost elements in first phase of CCS project

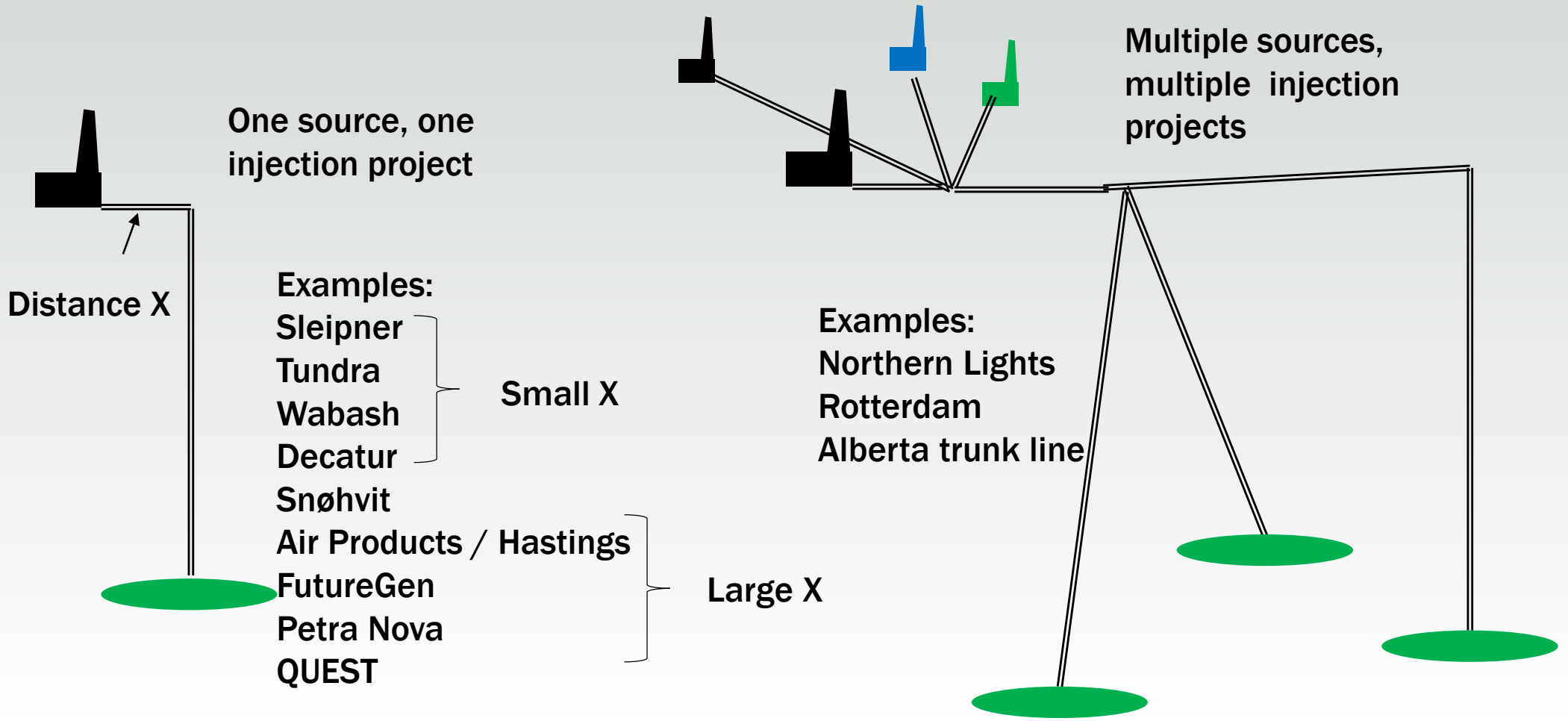


Total Cost Variables



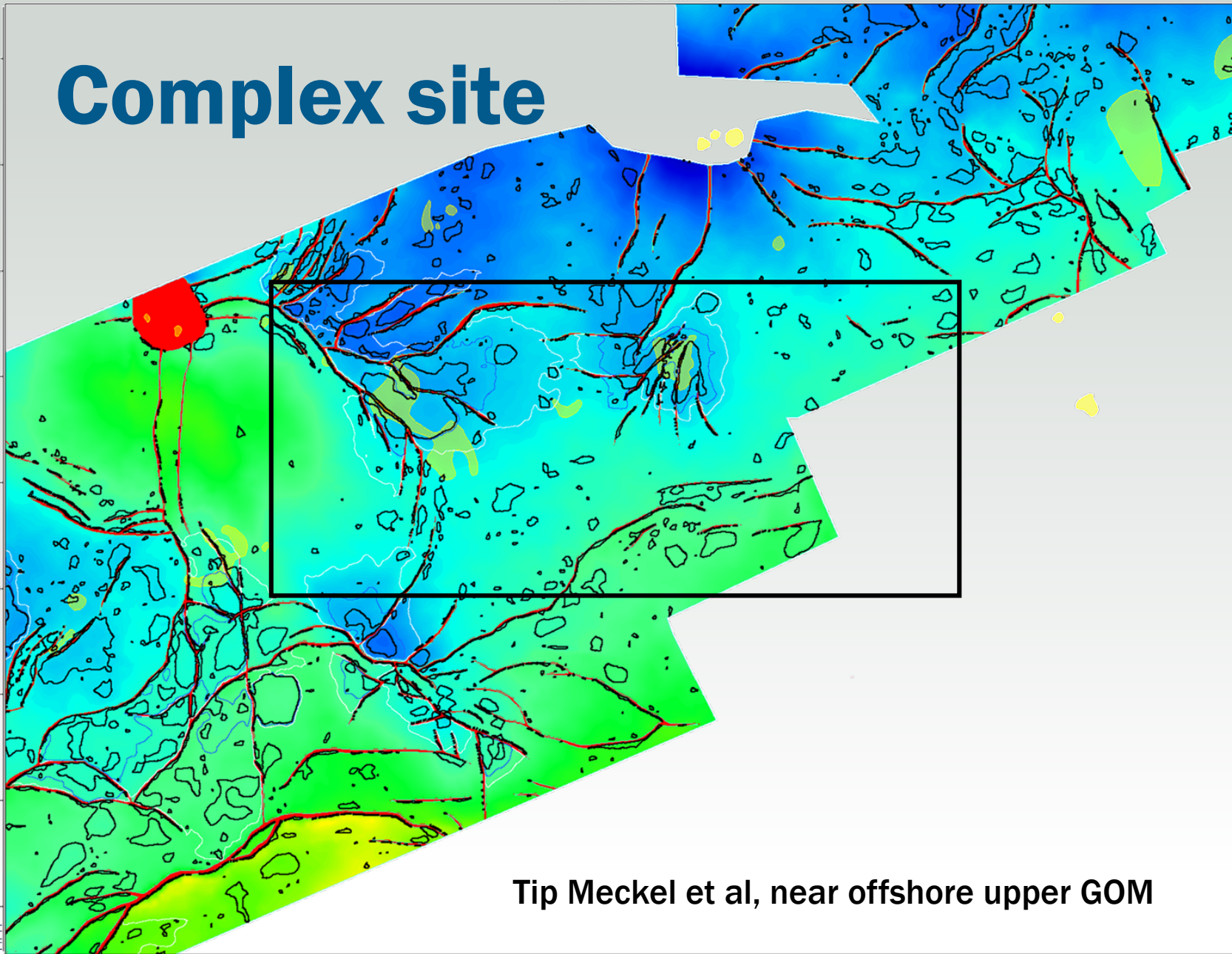
- Top costs variables
 1. site geologic complexity
 2. data availability
- Other factors
 1. risk tolerance
 2. permitting demands
 3. existing wells

Site selection end members

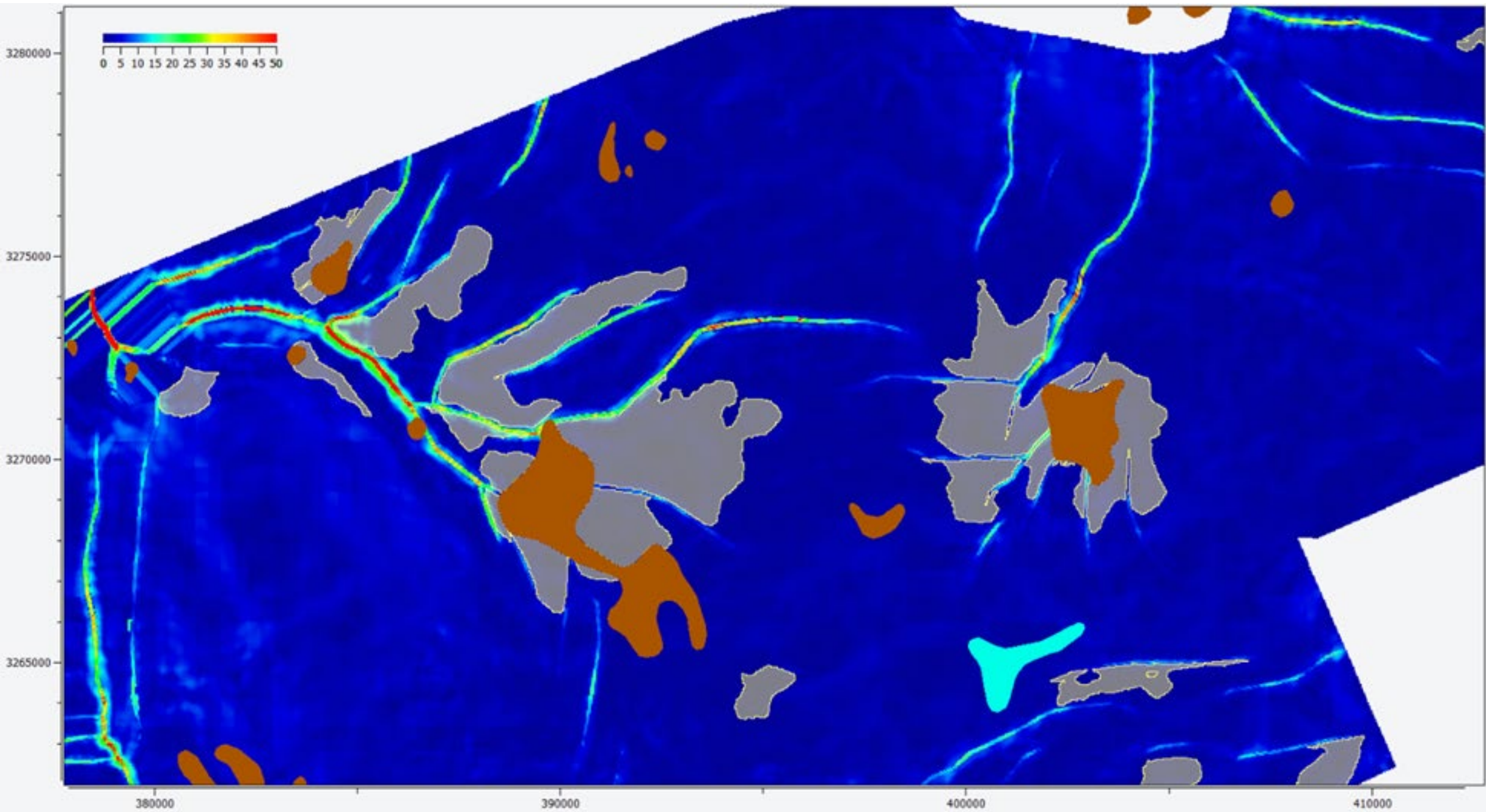


Complex site

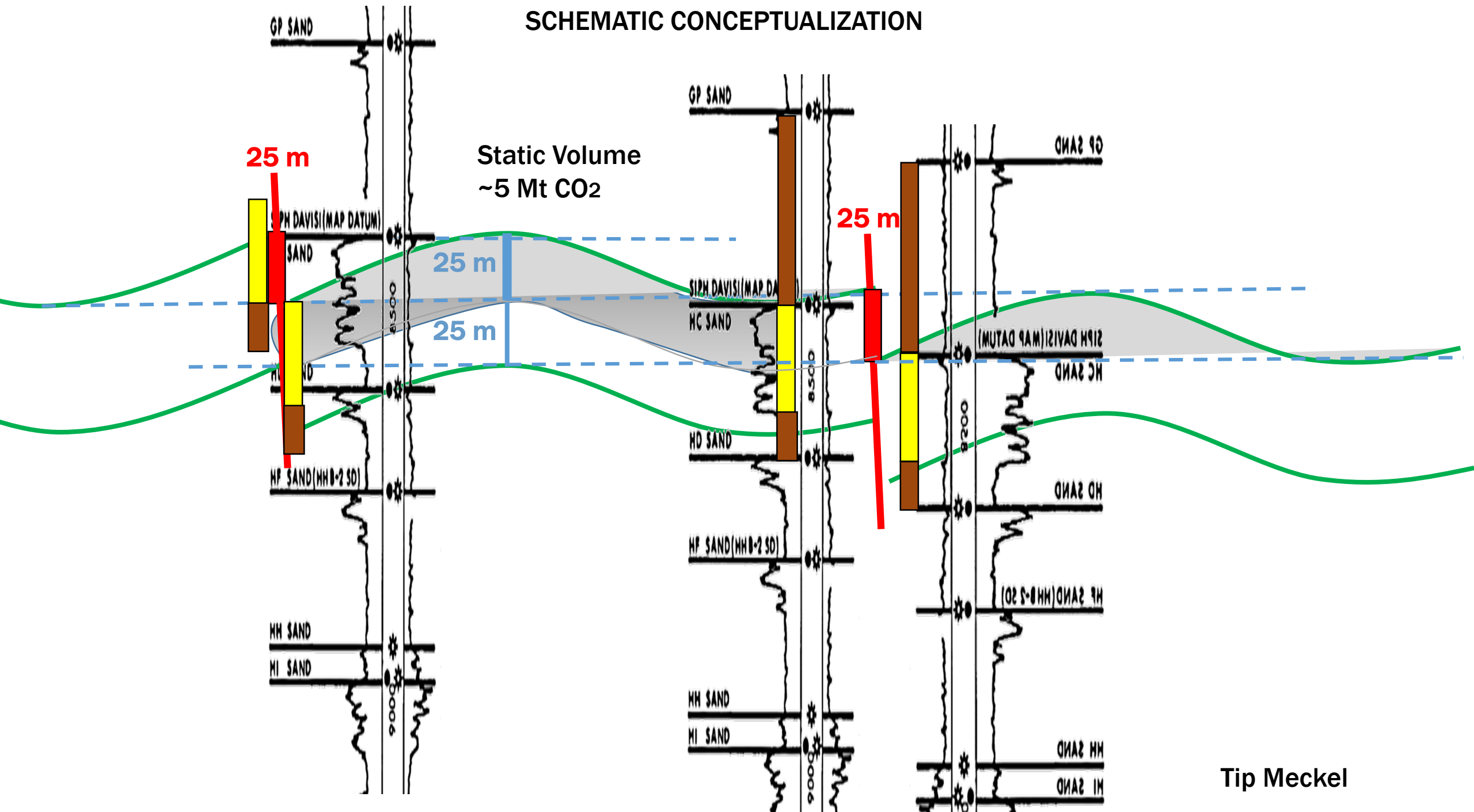
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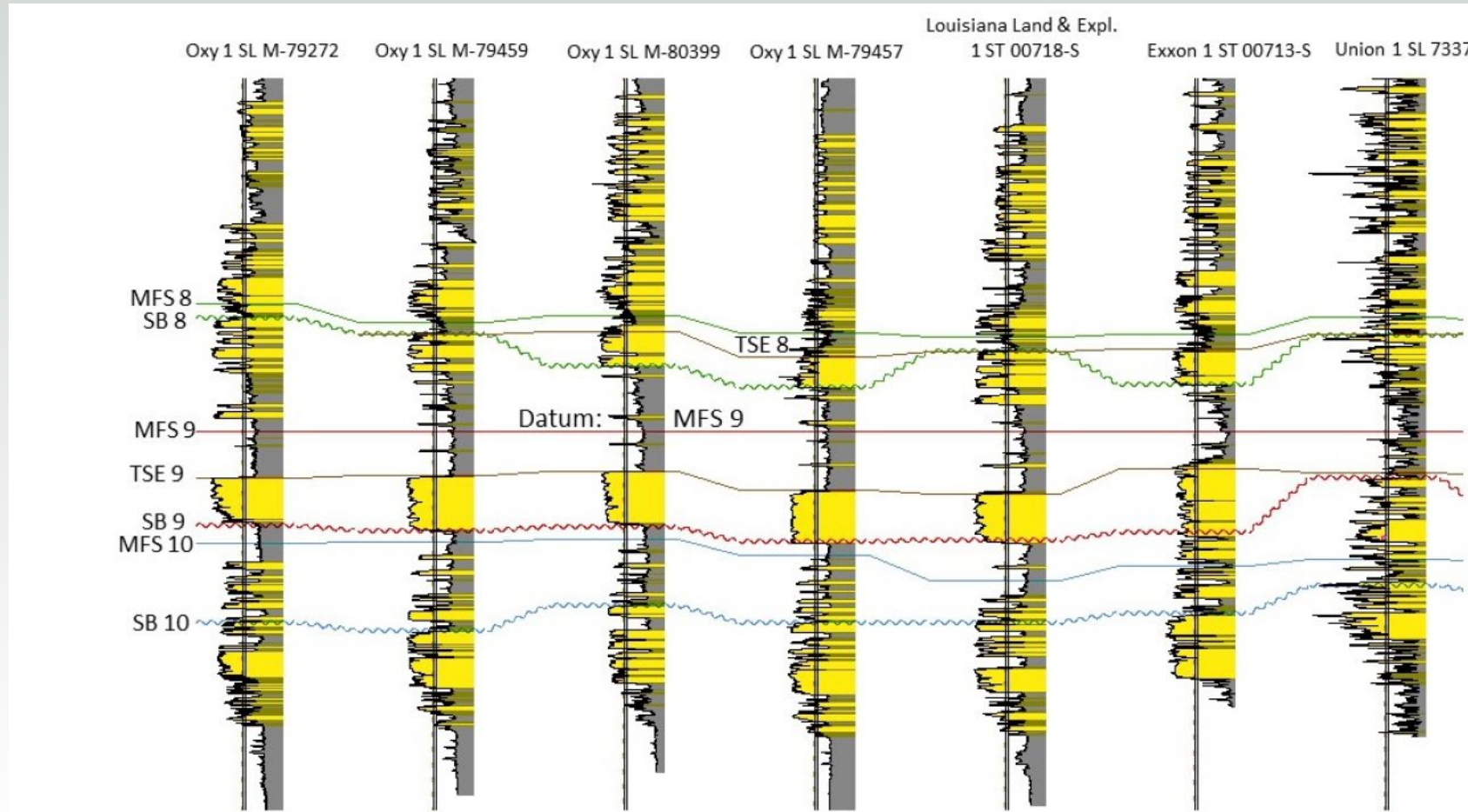
Tip Meckel et al, near offshore upper GOM



SCHEMATIC CONCEPTUALIZATION

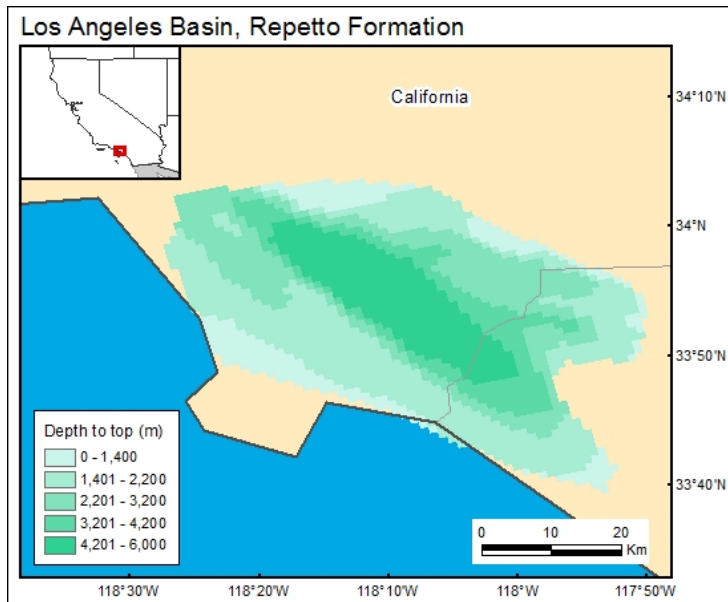


Stratigraphic Complexity

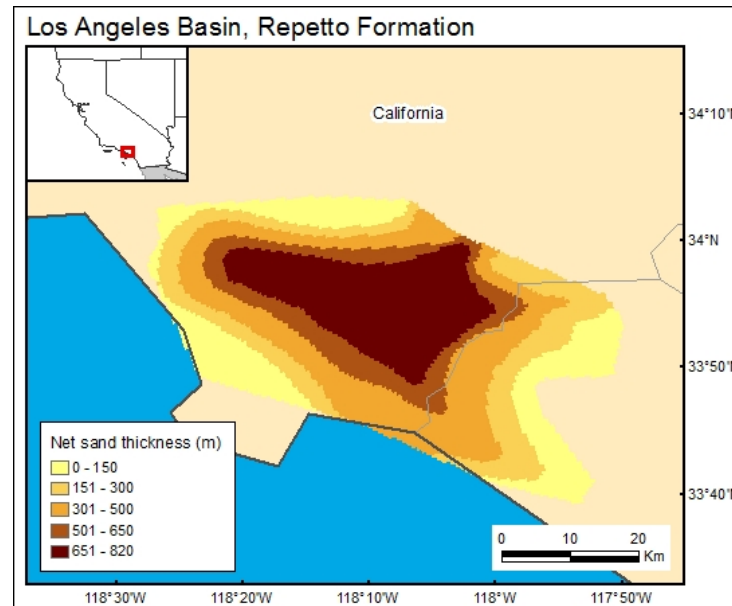


Another complex case (Repetto Formation, CA)

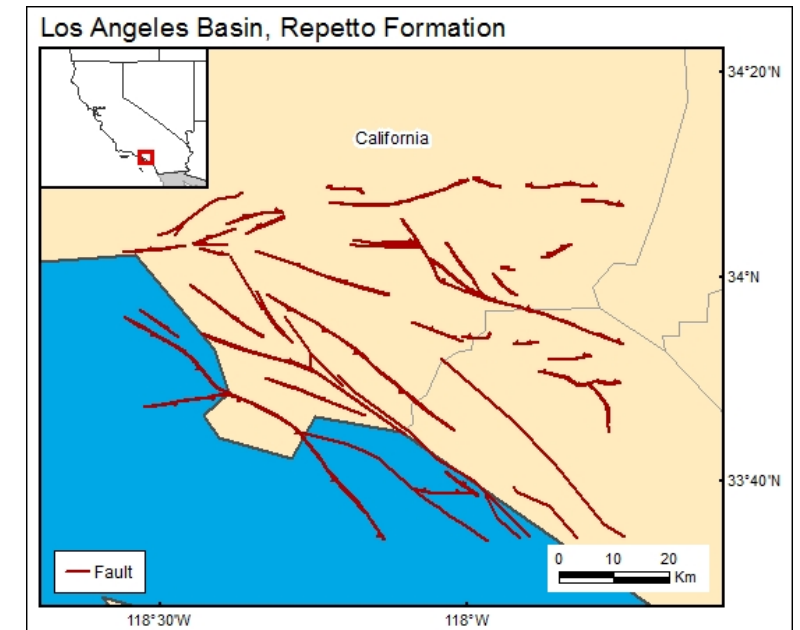
Depth



Net Sand



Mapped Faults

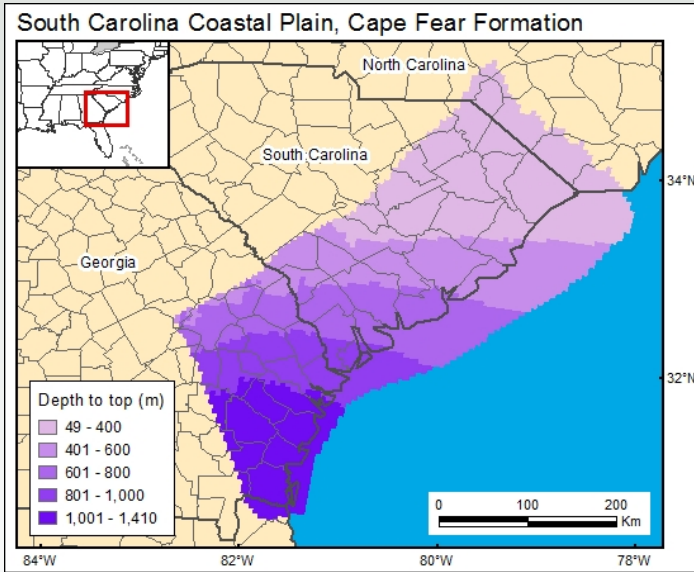


Simpl(er) site

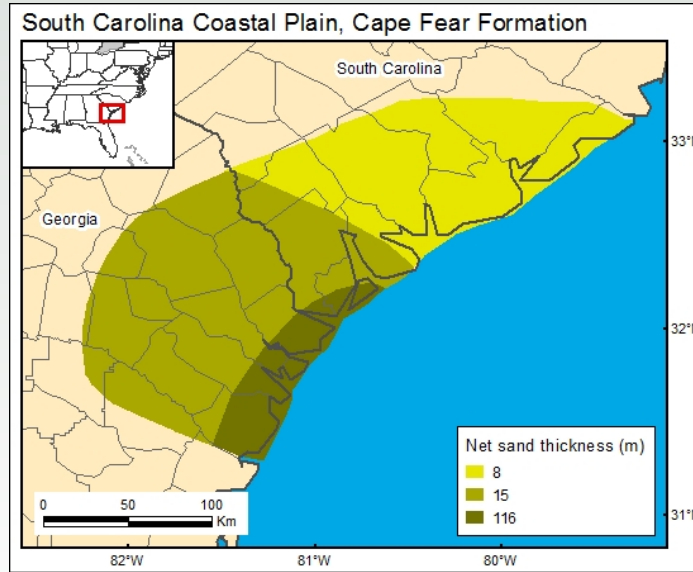
- Little to no structure
- Little to no reservoir heterogeneity
- Confining system thick and laterally extensive

Simpler region- Cape Fear SC

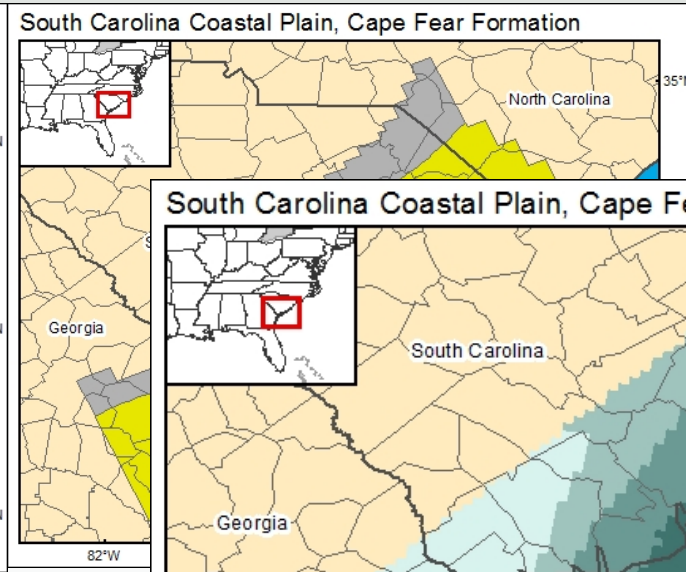
Depth



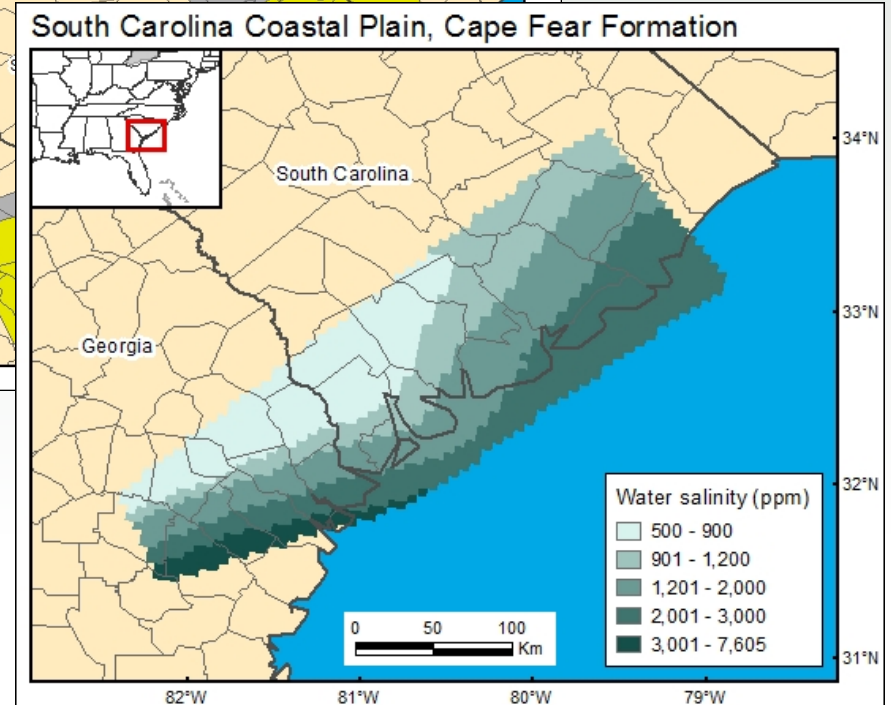
Sand thickness



Seal continuity



Salinity

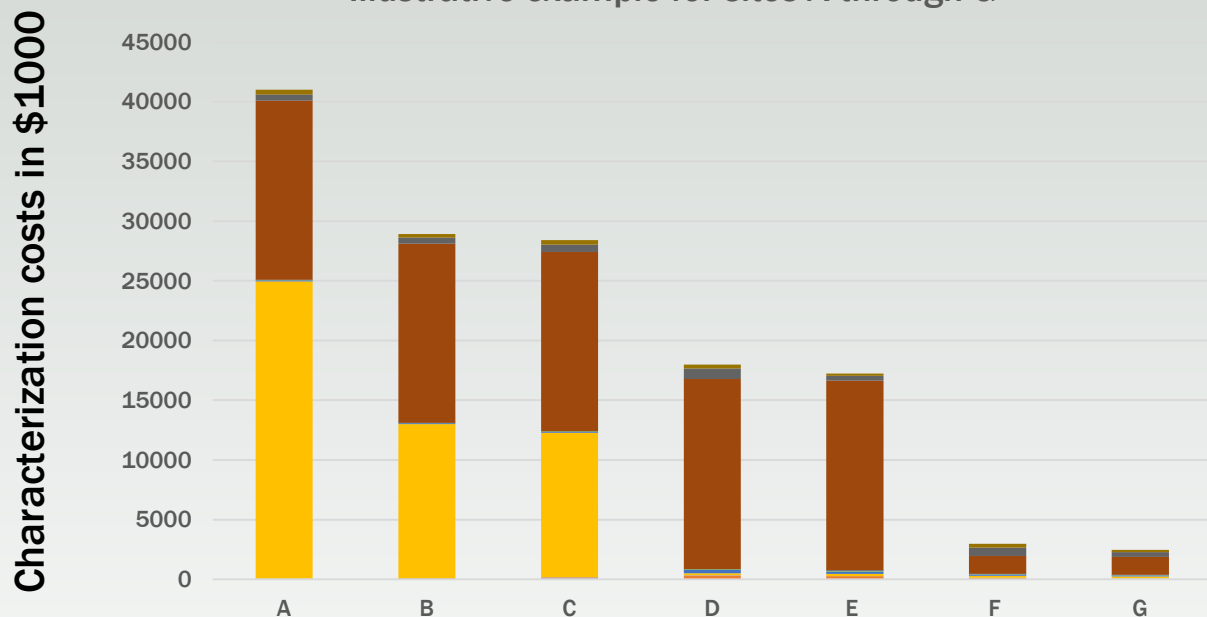


Project Status

- **Conducted about a dozen studies (onshore and offshore) - mined for input data**
 - What was done
 - Motivation
 - Method
 - Cost
- **Use other sites characterized by others (data challenge)**

Project Goal

Illustrative example for sites A through G



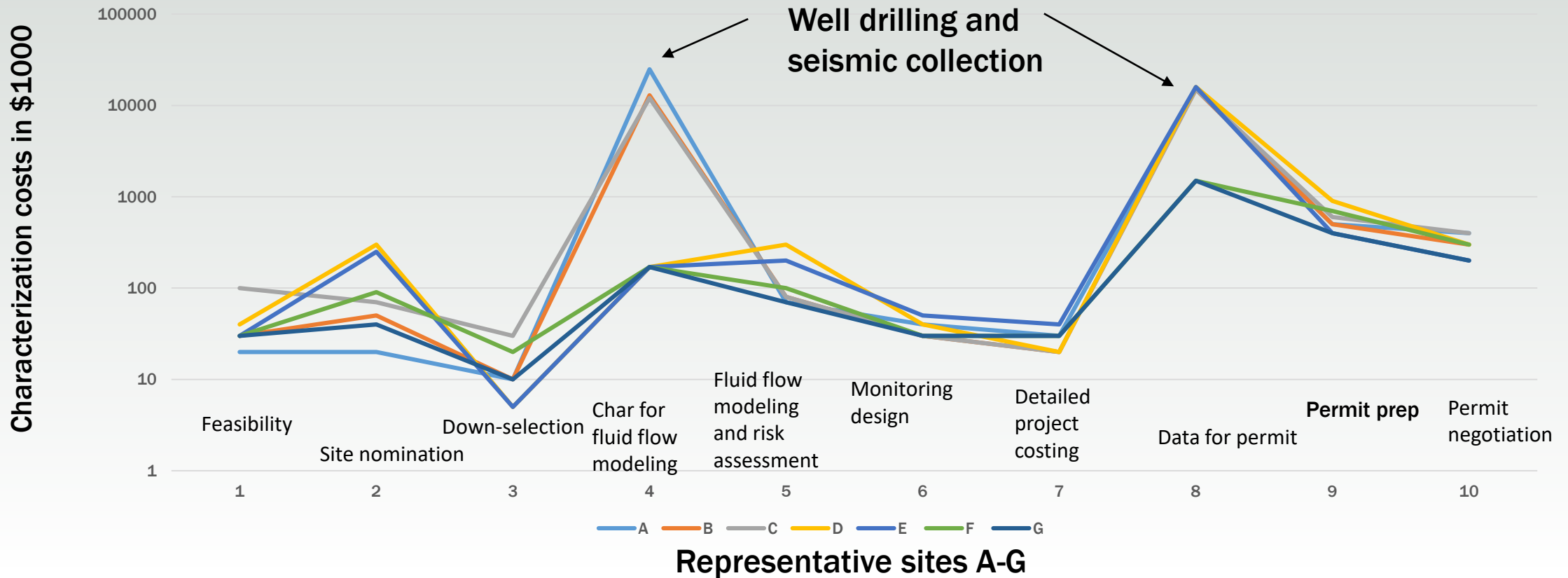
Example sites

Project stages

- Permit negotiation
- Permit preparation
- Site-specific data collection
- Detailed project costing
- Monitoring design
- fluid flow modeling and Risk assessment
- Characterization for initial model
- Downslection

- **Develop geologic characterization :**
 1. **Constrained cost curve**
 2. **Cost-predictive matrix**

Spending per Project Stage



Site-specific data collection Permit preparation Permit negotiation

Data Types

- **Comprehensive list of data needs (e.g. reservoir thickness and porosity)**
- **Types of input**
 - core, thin sections, SCAL, logs, log calibration
- **Risk based driver**
 - thickness and porosity limit project?
 - need large investment?
- **Data availability at sites**
- **Order-of-magnitude cost for acquiring data**
 - analyze existing vs. collect new core

Capacity Estimation

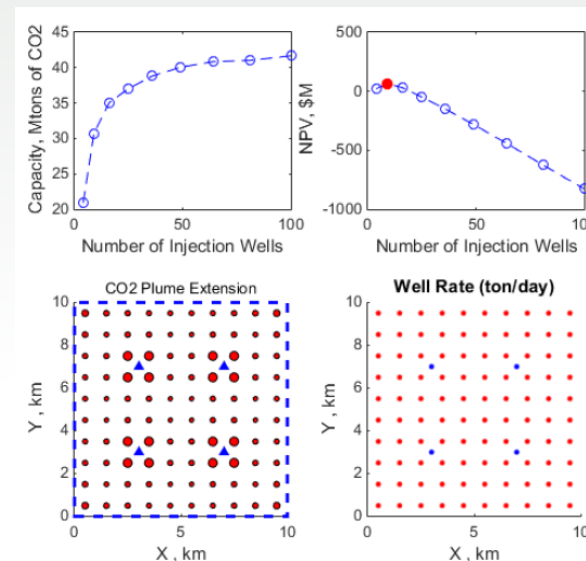
- Rate based because it must match project economics
mass per year x planned project duration < total capacity

EASi Tool as a first step:

<https://www.beg.utexas.edu/gccc/research/easitool>

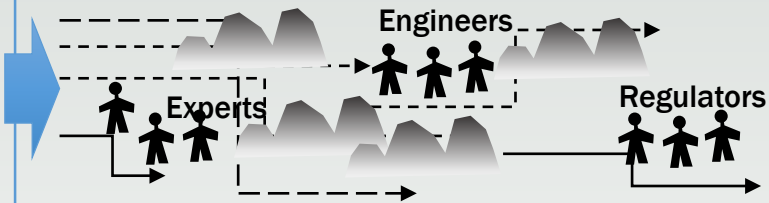
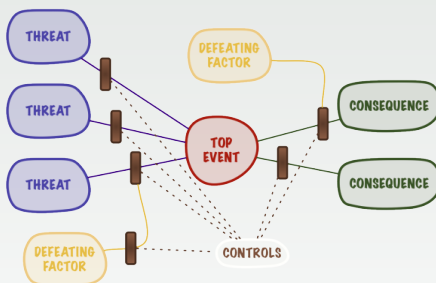
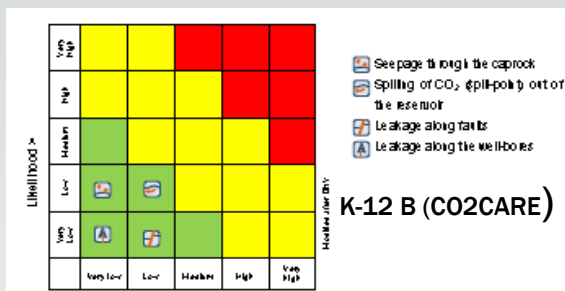
The screenshot shows the EASi Tool interface with the following sections:

- 1-RESERVOIR PARAMETERS:** General Geometry/Pattern, Input File Name, Pressure (MPa) 20, Temperature (C) 65, Thickness (m) 100, Salinity (mol/Kg) 2, Porosity () 0.2, Permeability (mD) 100, Rock Compressibility [1/Pa] 5e-10, Max Injection Pressure (MPa) 30, Reservoir Area (km²) 100, Basin Area (km²) 100, Boundary Condition Closed.
- 2-RELATIVE PERMEABILITY (Brooks-Corey):** Residual Water Saturation 0.5, Residual Gas Saturation 0.1, m 3, n 3, k_{ra0} 1, k_{rg0} 0.3.
- 3-SIMULATION PARAMETERS:** Uniform Injection/Extraction Rate, Sensitivity Analysis (Slow), Simulation Time (year) 20, Injection Well Radius (m) 0.1, Min Extraction Pressure (MPa) 29, Injection Rate (ton/day/well), Extraction Rate (m³/day/well), Max Number of Injectors 400, Number of Extractors 0.
- 4-NPV:** Injector Drilling Cost (\$M/well) 1, Extractor Drilling Cost (\$M/well) 1, Injector Operating Cost (\$K/well/yr) 500, Extractor Operating Cost (\$K/well/yr) 500, Monitoring Cost (\$K/yr/km²) 50, Tax Credit (\$/ton) 10.
- 5-RESULT CONTROLS:** Number of Injection Wells, Estimated Max Inj Pressure (MPa), Total Injected CO₂ (Mton), Total Extracted Brine (Mm³), Highest Bottomhole Pres. (MPa), Lowest Bottomhole Pres. (MPa), Number of Failed Wells.



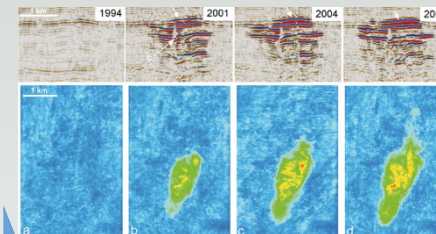
Linking risk assessment with monitoring

Risk Assessment method

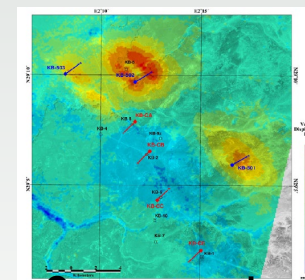


Process of designing and selecting monitoring can be complex, conducted without documented process, non-linear and therefore difficult to duplicate or justify

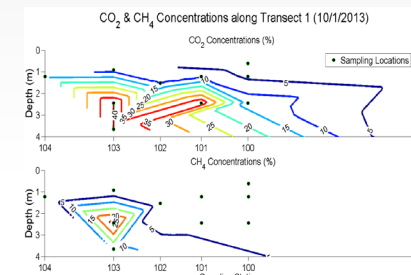
Select monitoring systems



Chadwick BGS



Onuma and Ohkawa, 2009



Proposed Method for Linking

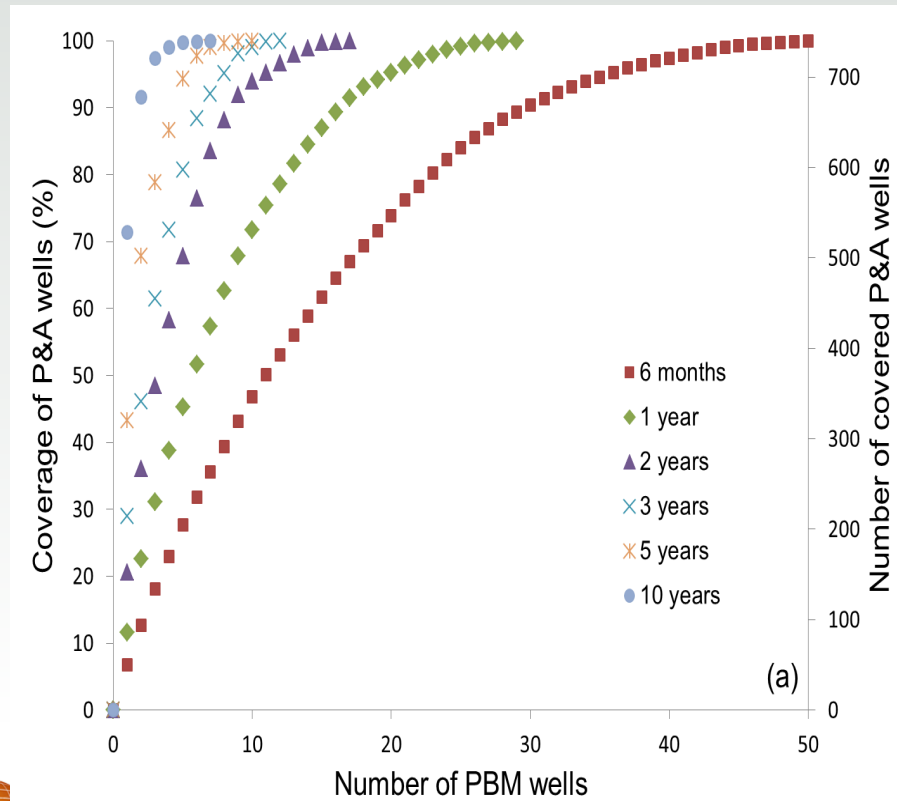
- Matching monitoring to risk via forward modeling -variant using an ALPMI* process

Assessment of **L**ow **P**robability **M**aterial **I**mpact (ALPMI)

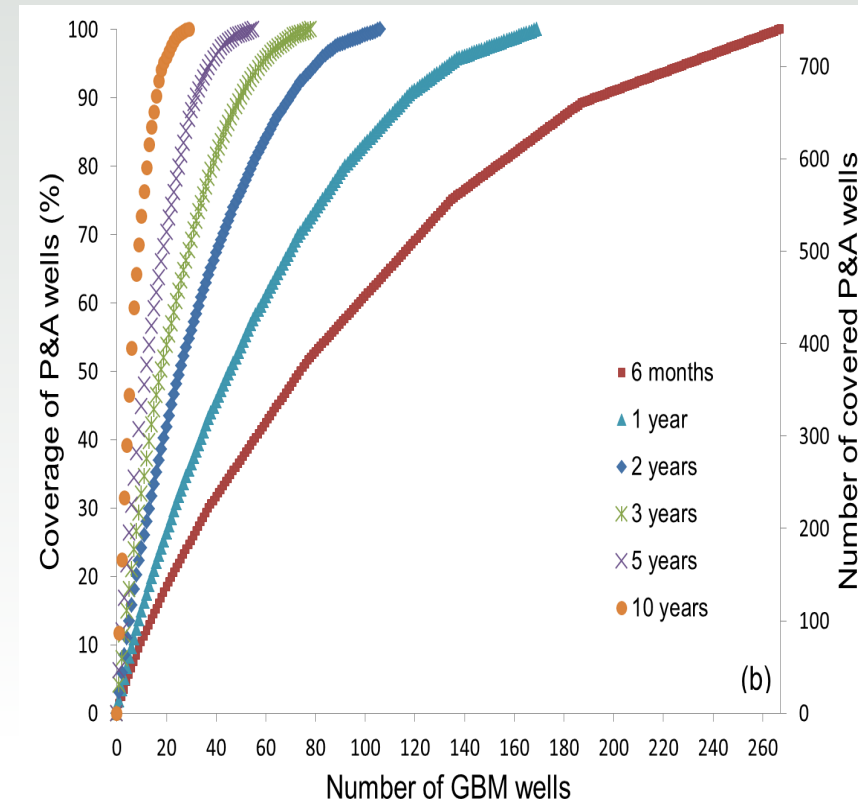
- Part 1: Describing *material impact** quantitatively
- Part 2: Sensitivity of monitoring strategy to *material impact**
- Attaining confidence in retention prior to closure

Sensitivity analysis for leakage detection time in models

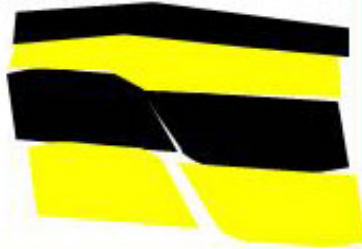
Detecting pressure signal



Detecting geochemical signal



**Characterization
Uncertainty: Fault-seal?**



ALPMI



Monitoring options

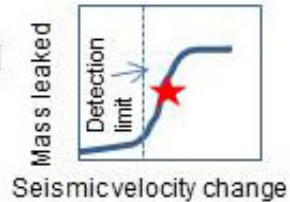


Image free-phase with surface 4-D
Measure change in pressure AZMI
Microseismic
Temperature change along fault
Microseismic

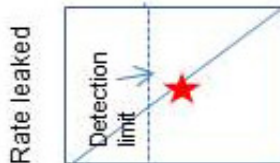
Mass/pressure balance in reservoir

Test Sensitivity of Monitoring Options

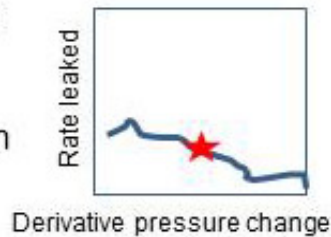
Image free-phase leaked CO₂ with surface 4-D



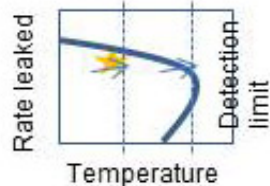
Measure change in pressure AZMI



Change in rate pressure increase in reservoir



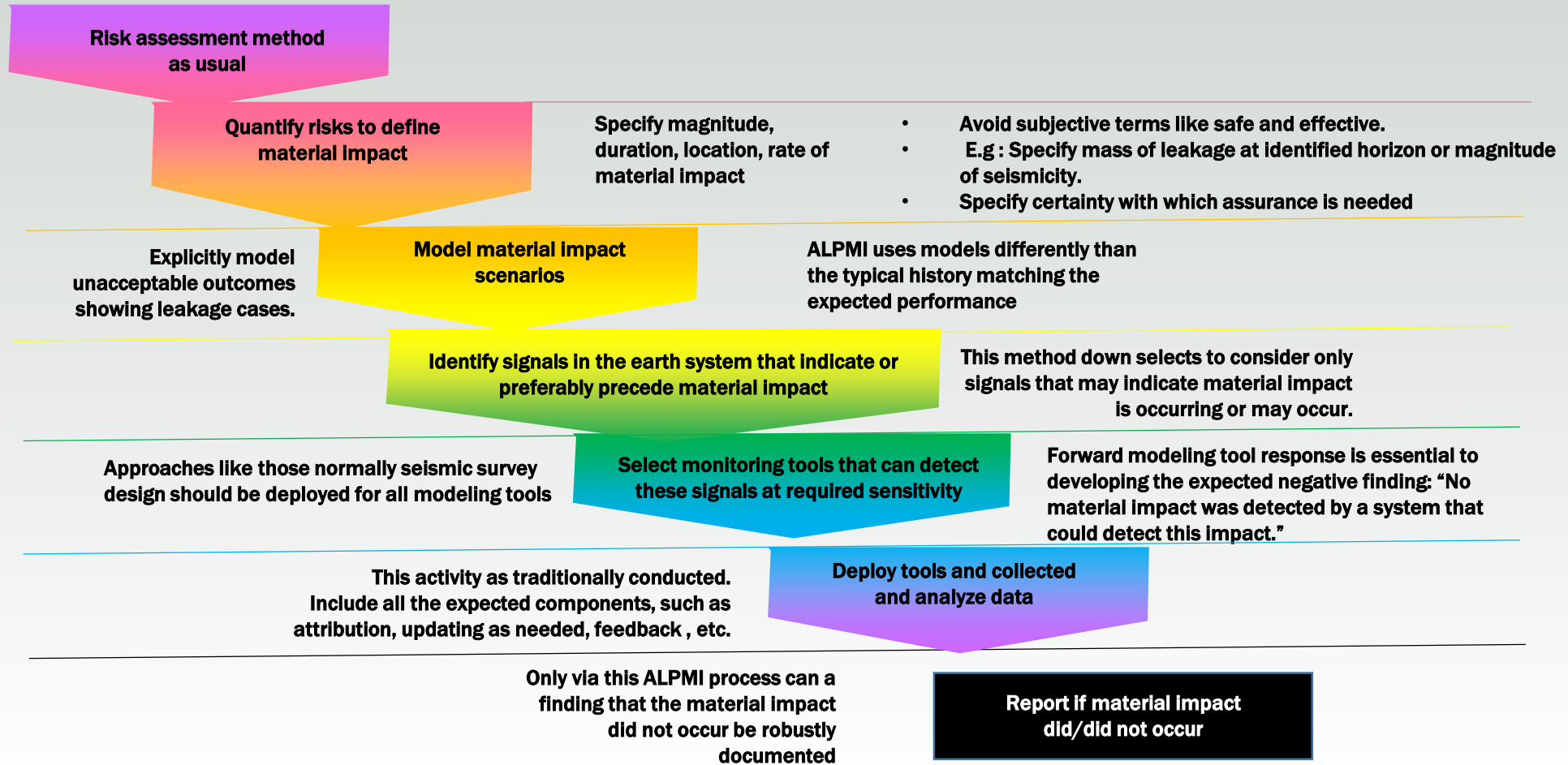
Pressure change
Temperature change along fault



Set triggers, stage monitoring options

- Select microseismic as pre-failure trigger
- AZMI pressure as most sensitive trigger
- Select Image with surface 4-D and change in rate of pressure change in reservoir as post-trigger follow up.
- Decrease analysis of microseismic after pressure peaks and plateaus

ALPMI method overview



Suggestions?

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www.gulfcoastcarbon.org