

Fourth Annual Conference on Carbon Capture & Sequestration

*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

Geologic - Risk Assessment Issues

HSE Screening Risk Assessment (SRA) for Geologic CO₂ Sequestration

file#96

Curtis M. Oldenburg

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia



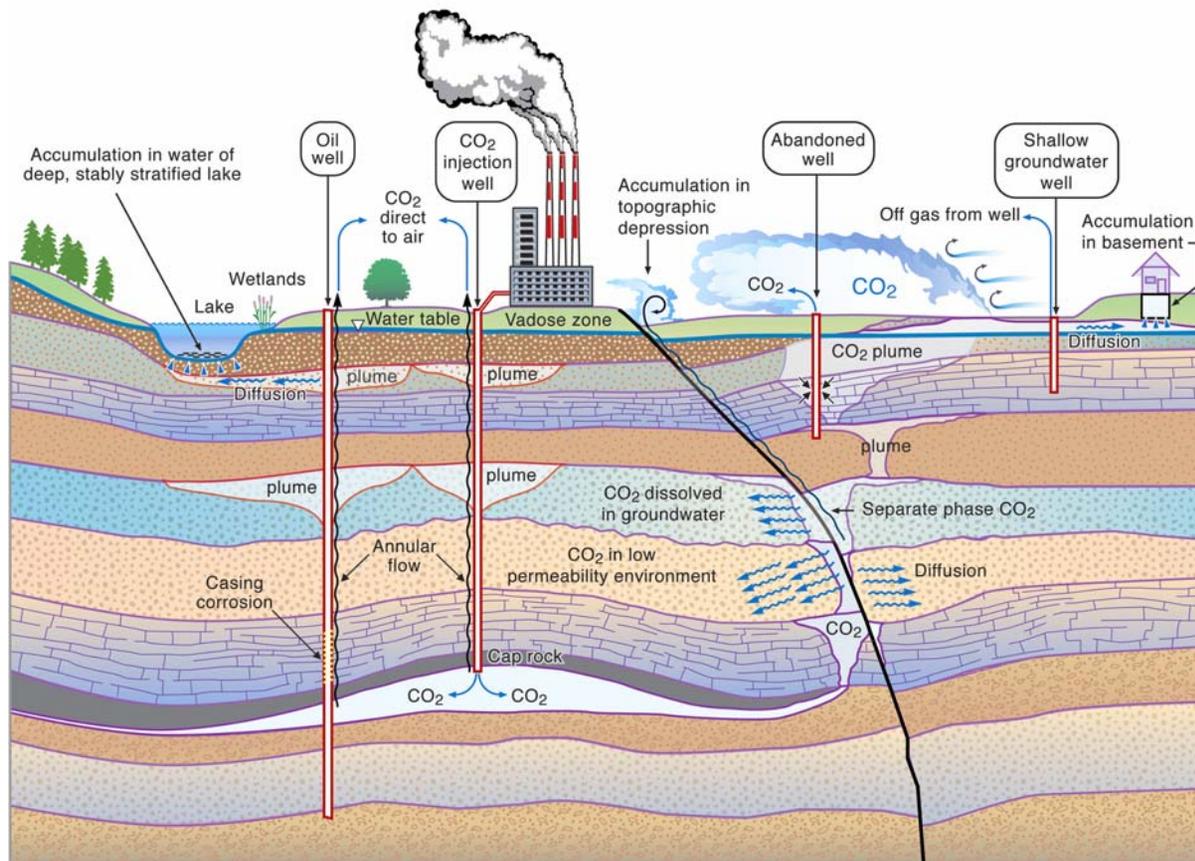
HSE Screening Risk Assessment (SRA) for Geologic CO₂ Sequestration

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CO₂ Leakage Risk Motivates SRA



Question to be addressed: From a choice of several potential sites, which site has the lowest Health, Safety, and Environmental (HSE) risk?

Introduction



We have developed a Screening Risk Assessment (SRA) tool for Health, Safety, and Environmental (HSE) risk assessment.

Geologic Carbon Sequestration Screening HSE Risk Assessment
Version 0.9

9/24/2004

C.M. Oldenburg (LBNL)

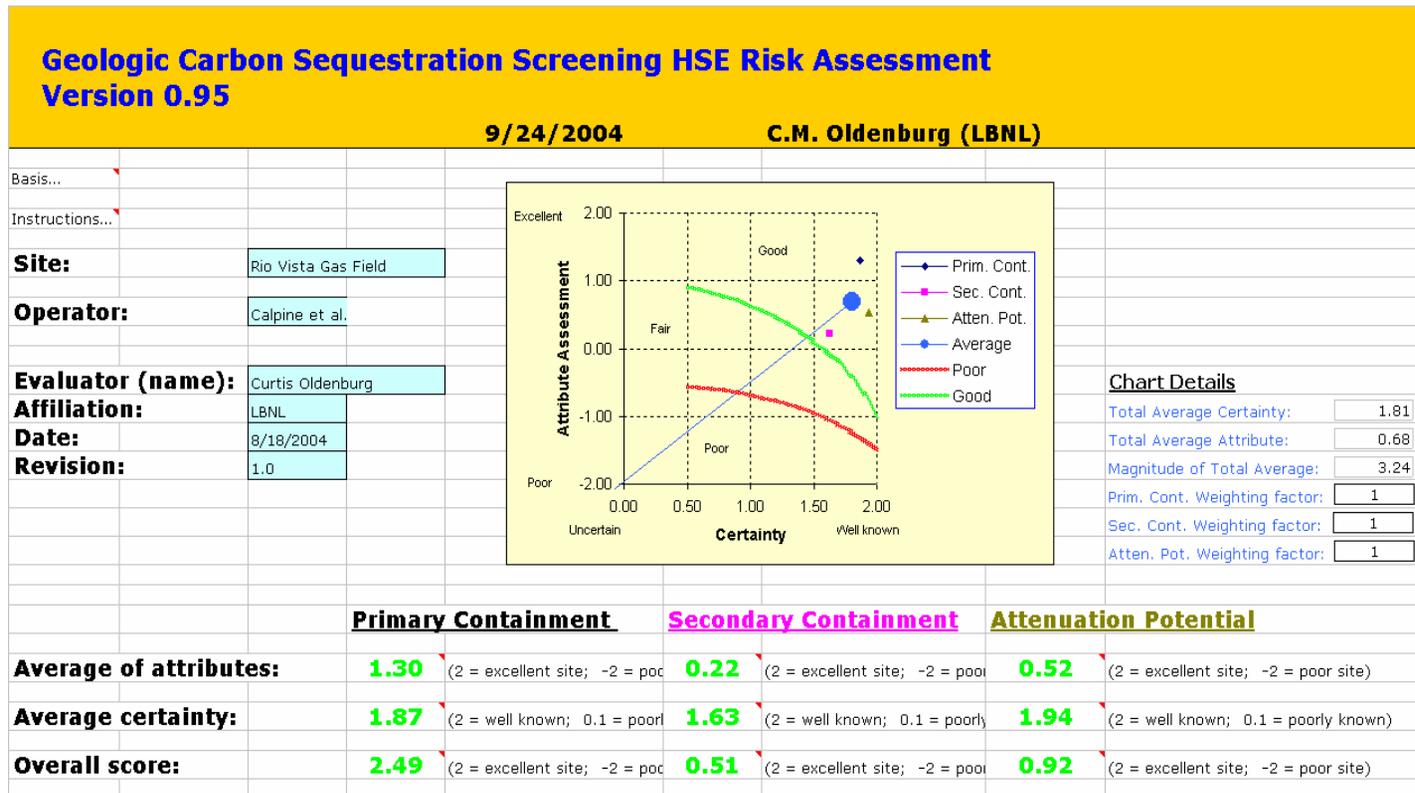
HSE risk is fundamentally related to three basic characteristics of a geologic carbon sequestration site:

- (1) Potential of the primary target formation for long-term containment of CO₂;
- (2) Potential for secondary containment if the primary target formation leaks;
- (3) Potential to attenuate and/or disperse leaking CO₂ if the primary formation leaks and secondary containment fails.

Introduction (Continued)



Design goal: Qualitative and independent assessment of the three characteristics through a numerical evaluation of the properties of various attributes.



The framework is implemented in Excel.

Three Fundamental Characteristics



(1) Primary Containment

Primary Seal
Depth
Reservoir

(2) Secondary Containment

Secondary Seal
Shallower Seal(s)
Reservoir

(3) Attenuation Potential

Surface characteristics
Hydrology
Existing wells
Faults

Attributes

Attributes of Primary Containment



Primary Seal

- Thickness
- Lithology
- Demonstrated sealing
- Lateral continuity

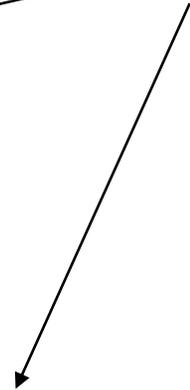
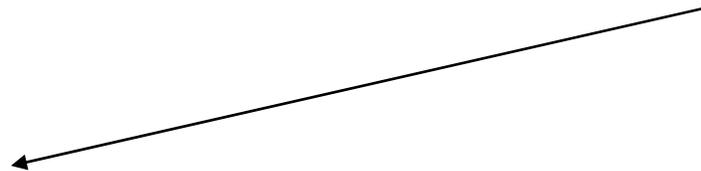
Depth

- Distance below ground

Reservoir

- Lithology
- Perm., poros.
- Thickness
- Fracture or primary poros.
- Pores filled with...
- Pressure
- Tectonics
- Hydrology
- Faults
- Deep wells

Properties



Secondary Seal

Thickness
Lithology
Demonstrated sealing
Lateral continuity
Depth

Properties

Shallower Seals

Thickness
Lithology
Lateral continuity
Evidence of seepage

Attributes of Attenuation Potential



Surface Characteristics

Topography
Wind
Climate
Land use
Population
Surface water

Existing wells

Deep wells
Shallow wells
Abandoned wells
Disposal wells

← Properties →

Groundwater Hydrology

Regional flow
Pressure
Geochemistry
Salinity

Faults

Tectonic faults
Normal faults
Strike-slip faults
Permeability

← Properties →

Evaluation



User:

- Weights the importance of each property.
- Assigns values based on given options.
- Assigns a certainty factor.

Spreadsheet:

- Averages the weighted property assessments.
- Averages the certainty factors.
- Generates graphical display.
- Presents both assessments and certainties.

Evaluation of Primary Containment



| Primary Containment | | | Overall score for this sheet | Average of the weighted assessments of attributes | Average certainty | |
|----------------------------|--|-------------------|------------------------------------|---|----------------------------------|---|
| | | | 2.49 | 1.30 | 1.87 | |
| Attribute | Weight 10 = most important 1 = least | Normalized Weight | Property/Value | Assessment of Attribute Property Relative to HSE Risk 2 = excellent (positive attribute) 0 = neutral (fair attribute) -2 = poor (negative attribute) | Weighted Assessment of Attribute | Certainty Factor 2.0 = Very well known 1.0 = Generally accepted 0.1 = Poorly known |
| Primary Seal | | | Description | | | |
| Thickness | 10 | 0.48 | 100 m | 0 | 0.00 | 2 |
| Lithology | 5 | 0.24 | Shale | 2 | 0.48 | 2 |
| Demonstrated sealing | 5 | 0.24 | Good seal | 2 | 0.48 | 2 |
| Lateral continuity | 1 | 0.05 | Large areal extent of gas | 2 | 0.10 | 2 |
| | 21 | 1.00 | Average: | 1.50 | 1.05 | 2.00 |
| Depth | | | Description | | | |
| Distance below ground | 10 | 1.00 | some v. shallow, but most 1000 m - | 2 | 2.00 | 2 |
| | 10 | 1.00 | Average: | 2.00 | 2.00 | 2.00 |
| Reservoir | | | Description | | | |
| Lithology | 1 | 0.07 | Sandstone | 2 | 0.13 | 2 |
| Perm., poros. | 2 | 0.13 | 5-1800 mD, 20-34% | 2 | 0.27 | 2 |
| Thickness | 1 | 0.07 | 150 m | 2 | 0.13 | 2 |
| Fracture or primary poros. | 1 | 0.07 | Primary | 2 | 0.13 | 2 |
| Pores filled with... | 1 | 0.07 | atural gas and low-TDS water | 2 | 0.13 | 1 |
| Pressure | 1 | 0.07 | Hydrostatic to depleted | 1 | 0.07 | 1 |
| Tectonics | 2 | 0.13 | with faults, but not v. active | 0 | 0.00 | 2 |
| Hydrology | 2 | 0.13 | Water drive | 0 | 0.00 | 1 |
| Deep wells | 2 | 0.13 | Many deep wells | -2 | -0.27 | 2 |
| Fault permeability | 2 | 0.13 | Trapping faults (low k) | 2 | 0.27 | 1 |
| | 15 | 1.00 | Average: | 1.10 | 0.87 | 1.60 |

Evaluation of Secondary Containment



| | | | Overall score for this sheet | Average of weighted assessments of attributes | | Average certainty |
|------------------------------|--------------------------------|-------------------|-------------------------------|--|----------------------------------|---|
| Secondary Containment | | | 0.51 | 0.22 | | 1.63 |
| Attribute | Weight | Normalized Weight | Property/Value | Assessment of Attribute Property Relative to HSE Risk | Weighted Assessment of Attribute | Certainty Factor |
| | 10 = most import. 1 = least | | | 2 = excellent (positive attribute) 0 = neutral (fair attribute) -2 = poor (negative attribute) | | 2.0 = Very well known 1.0 = Generally accepted 0.1 = Poorly known |
| Secondary Seal | | | Description | | | |
| Thickness | 10 | 0.38 | 150 m (Sidney Flat shale) | 0 | 0.00 | 2 |
| Lithology | 5 | 0.19 | Shale | 2 | 0.38 | 2 |
| Demonstrated sealing | 1 | 0.04 | as prod. from multiple horiz. | 1 | 0.04 | 2 |
| Lateral continuity | 5 | 0.19 | Laterally continuous | 1 | 0.19 | 2 |
| Depth | 5 | 0.19 | Sidney Flat shale ~800 m | 0 | 0.00 | 2 |
| | 26 | 1.00 | Average: | 0.80 | 0.62 | 2 |
| Shallower Seals | | | Description | | | |
| Thickness | 10 | 0.33 | Thin mudstone | -1 | -0.33 | 1 |
| Lithology | 5 | 0.17 | Shale | 0 | 0.00 | 1 |
| Lateral continuity | 5 | 0.17 | Extensive | 1 | 0.17 | 1 |
| Evidence of seepage | 10 | 0.33 | Historic gas seeps | 0 | 0.00 | 2 |
| | 30 | 1.00 | Average: | 0.00 | -0.17 | 1.25 |

Evaluation of Attenuation Potential



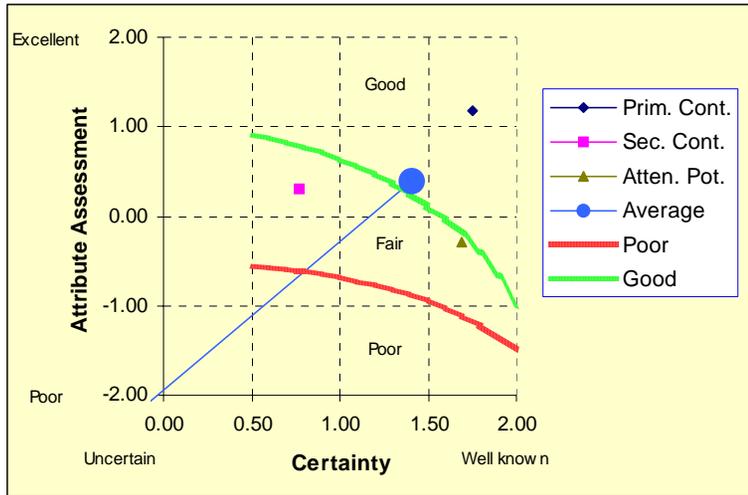
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| | | | Overall score for this sheet | Average of weighted assessments attributes | Average certainty | |
|--------------------------------|--|-------------------|---------------------------------|--|----------------------------------|---|
| Attenuation Potential | | | 0.92 | 0.52 | 1.94 | |
| Attribute | Weight 10 = most important 1 = least | Normalized Weight | Property/Value | Assessment of Attribute Property Relative to HSE Risk 2 = excellent (positive attribute) 0 = neutral (fair attribute) -2 = poor (negative attribute) | Weighted Assessment of Attribute | Certainty Factor 2.0 = Very well known 1.0 = Generally accepted 0.1 = Poorly known |
| Surface Characteristics | | | Description | | | |
| Topography | 5 | 0.15 | Flat | 2 | 0.30 | 2 |
| Wind | 10 | 0.30 | Windy | 2 | 0.61 | 2 |
| Climate | 2 | 0.06 | Sub-humid | -1 | -0.06 | 2 |
| Land use | 4 | 0.12 | Farmland/wetlands | 1 | 0.12 | 2 |
| Population | 10 | 0.30 | Rural | 1 | 0.30 | 2 |
| Surface water | 2 | 0.06 | Perennial wetlands exist | -2 | -0.12 | 2 |
| | 33 | 1.00 | Average: | 0.50 | 1.15 | 2.00 |
| Groundwater Hydrology | | | Description | | | |
| Regional flow | 6 | 0.32 | Variable, away from Mont. Hills | 1 | 0.32 | 2 |
| Pressure | 7 | 0.37 | Hydrostatic | 0 | 0.00 | 2 |
| Geochemistry | 2 | 0.11 | Fresh, slightly alk. | 2 | 0.21 | 2 |
| Salinity | 4 | 0.21 | Very low TDS | 2 | 0.42 | 2 |
| | 19 | 1.00 | Average: | 1.25 | 0.95 | 2.00 |
| Existing Wells | | | Description | | | |
| Deep wells | 5 | 0.25 | Many deep wells | -2 | -0.50 | 2 |
| Shallow wells | 4 | 0.20 | Numerous shallow gw wells | -2 | -0.40 | 2 |
| Abandoned wells | 10 | 0.50 | Many abandoned wells. | -2 | -1.00 | 2 |
| Disposal wells | 1 | 0.05 | Water is re-injected. | -2 | -0.10 | 2 |
| | 20 | 1.00 | Average: | -2.00 | -2.00 | 2.00 |
| Faults | | | Description | | | |
| Tectonic faults | 10 | 0.59 | Impermeable tectonic faults | 2 | 1.18 | 2 |
| Normal faults | 1 | 0.06 | Normal faults form traps | 2 | 0.12 | 2 |
| Strike-slip faults | 1 | 0.06 | Few strike-slip faults | 2 | 0.12 | 1 |
| Fault permeability | 5 | 0.29 | 6% of gas plays are fault traps | 2 | 0.59 | 2 |
| | 17 | 1.00 | Average: | 2.00 | 2.00 | 1.75 |

Example of Graphical Result

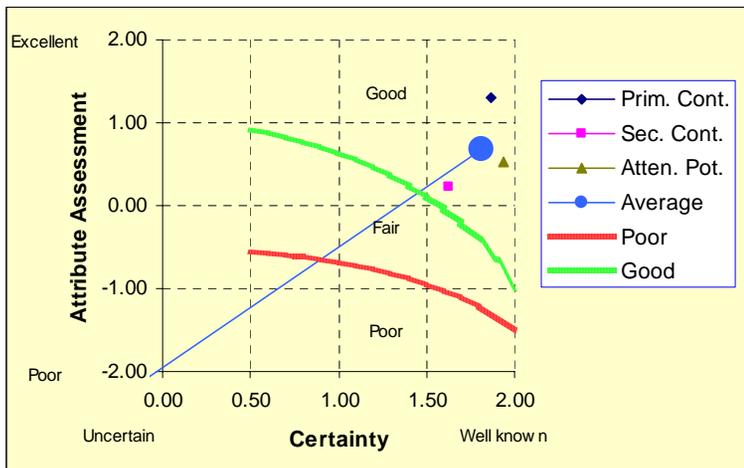


Ventura Oil Field



| <u>Chart Details</u> | |
|-------------------------------|------|
| Total Average Certainty: | 1.41 |
| Total Average Attribute: | 0.40 |
| Magnitude of Total Average: | 2.78 |
| Prim. Cont. Weighting factor: | 1 |
| Sec. Cont. Weighting factor: | 1 |
| Atten. Pot. Weighting factor: | 1 |

Rio Vista Gas Field



| <u>Chart Details</u> | |
|-------------------------------|------|
| Total Average Certainty: | 1.81 |
| Total Average Attribute: | 0.68 |
| Magnitude of Total Average: | 3.24 |
| Prim. Cont. Weighting factor: | 1 |
| Sec. Cont. Weighting factor: | 1 |
| Atten. Pot. Weighting factor: | 1 |

Summary



- A HSE screening risk assessment framework has been developed based on three fundamental characteristics of a CO₂ sequestration site:
 - 1) Primary containment potential
 - 2) Secondary containment potential
 - 3) Attenuation potential
- This is a *screening* risk assessment (SRA) tool.
- HSE SRA is just one component of site selection.
- Testing and further development are underway.

Acknowledgments



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