Development of Criteria to Identify the Leakage Potential of Wells in Depleted Oil and Gas Fields for CO_2 Geological Sequestration

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Background

A fundamental step in selection of a storage site for CO_2 sequestration is to make sure that the selected site not only meets the project economics but also has good storage and long term retention features. The selection of depleted oil and gas fields as a potential CO_2 geological storage site has both positive and negative aspects that need to be considered.

Positive aspects: (1)The storage capacity or pore volume can be reliably estimated from field's production history, (2) reservoir characterization can be performed with more readily available well, log or seismic data without additional expenses

Negative aspects: Presence of wells in the field, as each well may provide a leakage pathway for injected CO_2

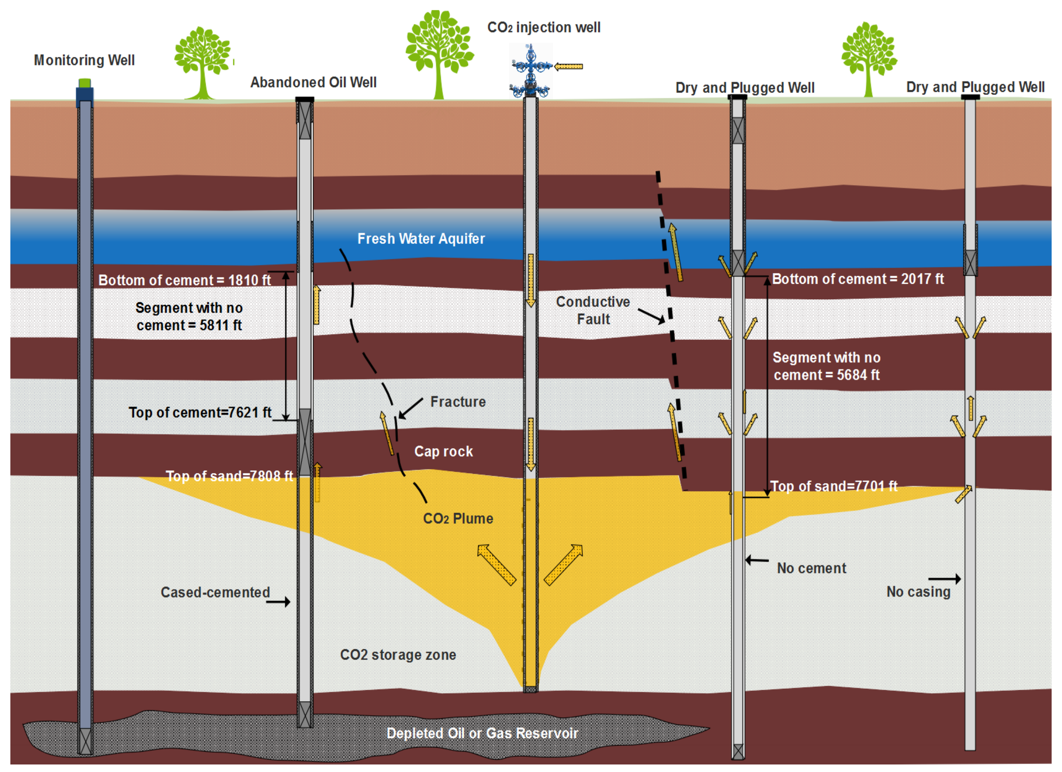
Study Objectives: To present a simplified approach to quantitatively categorize a wellbore's relative leakage risk

Leakage Pathways From Storage Zone

CO_2 from storage zone can leak either through

- Fractures in caprock
- Faults
- Wellbores

Leakage through existing wellbores is the focus of this study



Wellbore Leakage: Important Parameters

Four parameters play an important role in determining the leakage potential of a well passing through the storage zone

- Wellbore type (CI)
- Injector-Leaky well distance (DI)
- Storage zone boundaries (BI)
- Buffer layers (segments) (LI)

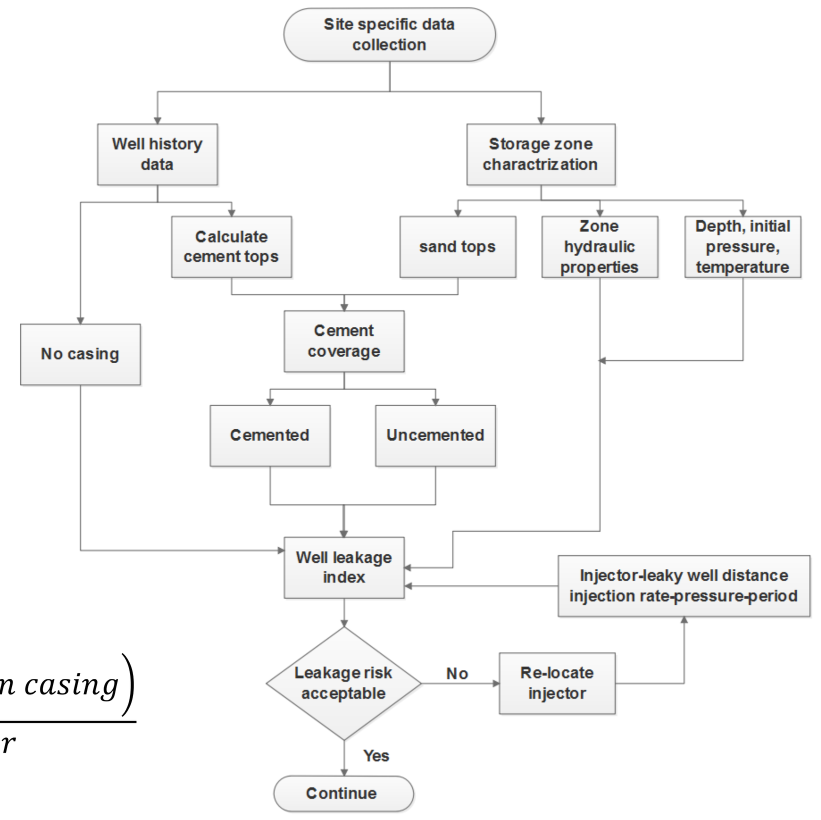
		Assumed ranges	
Variable category	Symbols	Min	Max
Wellbore type (cased-cemented, cased-uncemented, uncased)	cement index (CI)	0	1
Injector-leaky well distance	distance index (DI)	0	1
Buffer layers	Layer index (LI)	0	1
Boundary type (open, semi-closed, closed)	Boundary index (BI)	0	1

Well Tiers	WLI range (fraction of field's maximum WLI)	Remarks
1	WLI <= 0.25	Wells with minor leakage risk
2	0.25 <= WLI <=0.50	Wells with moderate leakage risk
3	0.50< WLI <=0.75	Wells with high leakage risk
4	0.75 < WLI	Wells with severe leakage risk

Process Flow Diagram

- Steps involved in estimation of leakage risk of a well are described in this flow diagram
- Cement and sand tops can be calculated from well history files and well log data
- The following formulation is used to calculate cement tops

$$L = \frac{\left(Sacks \times \frac{cement\ volume}{sack} - cement\ volume\ left\ in\ casing\right)}{annular\ capacity \times cement\ access\ factor}$$

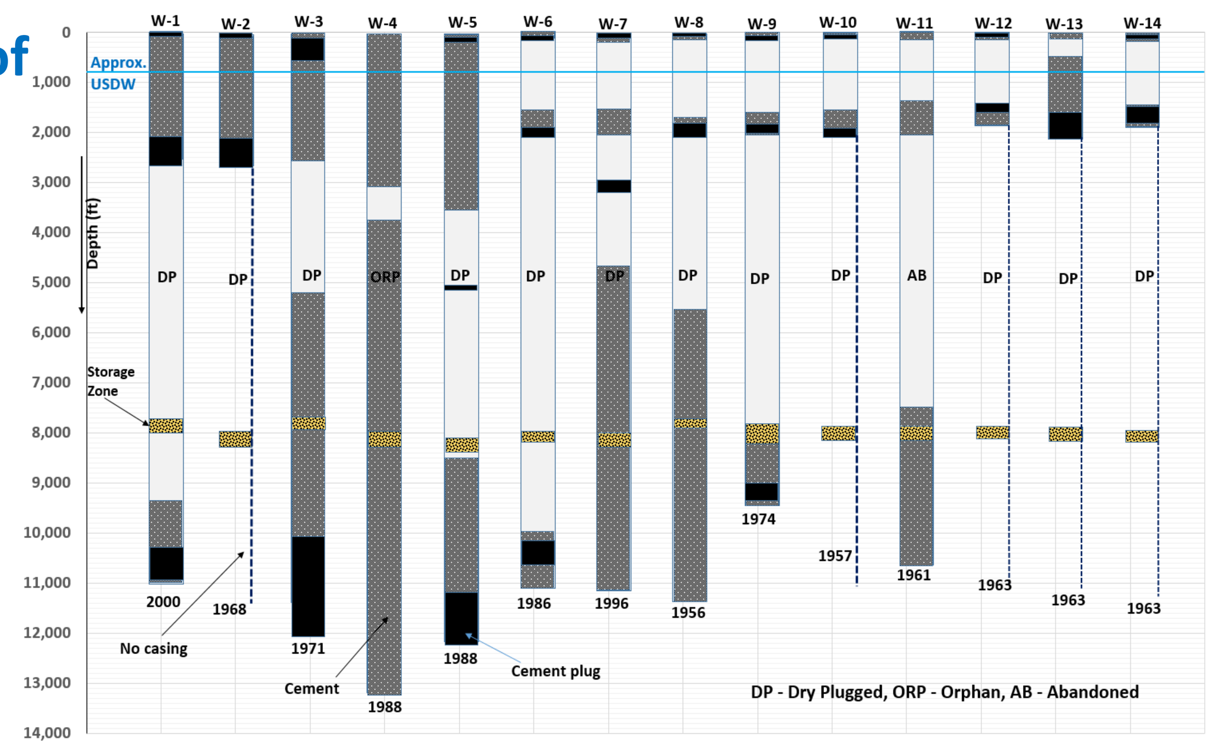


Cement data of 14 Selected wells

- Storage zone
- Cased/Uncased
- Cement tops
- Cement Plugs
- USDW

Average wellbore permeability

$$k_{avg} = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} \left(\frac{L}{k}\right)_i}$$



Cemented wellbore model (CWM)[1,2]

- This model is based on the results of 3-D numerical simulations of injection into a storage zone with abandoned wellbore (Jordan et al., 2015). Leakage is treated as a flow through porous media by using Darcy's law, (Huerta and Vasylkivska, 2016)
- Used for storage zone boundary sensitivity analysis

Multi-segment wellbore model (MWM)[3]

- This model can calculate leakage to multiple overlying aquifers or thief zones and was developed by (Nordbotten et al., 2009). This model focuses on modeling flow across large distances and does not take into account the flow in cement fractures and cracks
- Used for wellbore type, injector-leaky well distance and buffer layer sensitivity analysis

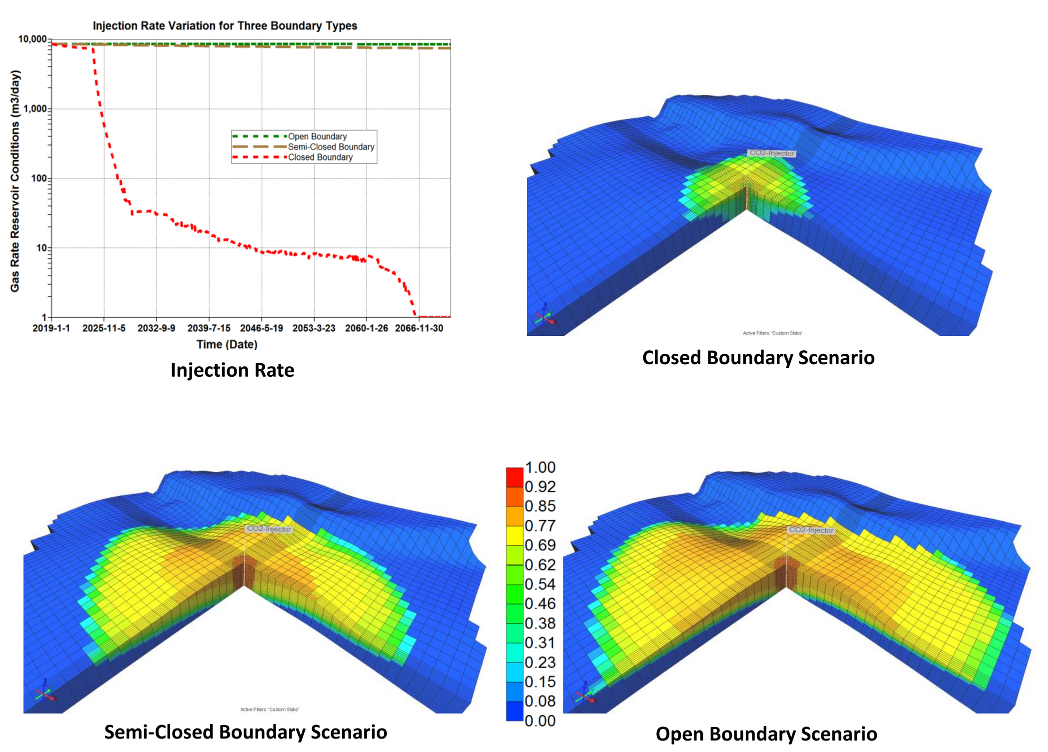
$$Q = k_{eff} A \frac{\psi_L - \psi_T}{L}$$

where Q is the volumetric flow rate, k_{eff} is the effective permeability, A is the cross sectional area of flow, ψ_L and ψ_T are leakage potential at leakage source and sink respectively and L is the leak path length.

Reservoir Simulation Results

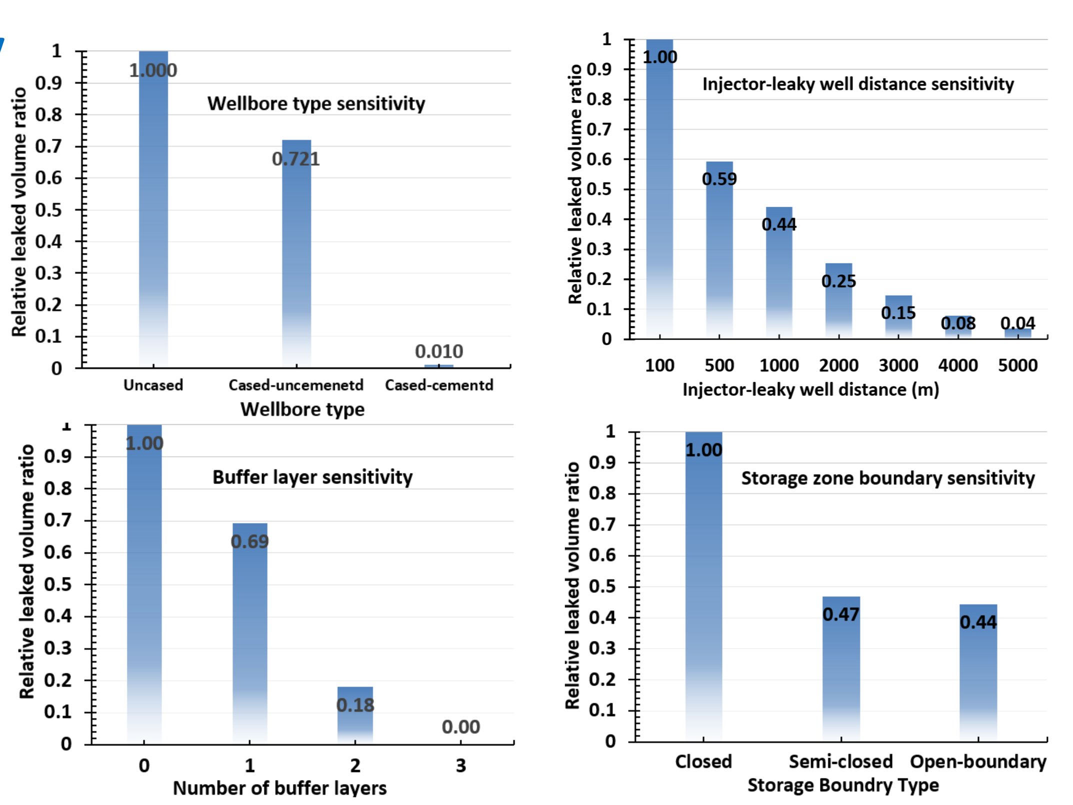
Storage zone boundary sensitivity analysis

- For closed boundary scenario, plume size is of limited size, but pressure buildup is greatest
- Injection rate 2.64 Mt/y
- For semi-closed and open boundary scenario, the behavior is opposite



Parametric sensitivity

- Parametric variation in terms of normalized cumulative leaked volume of CO_2 to a shallow aquifer
- Injection rate 2.64 Mt/y for 30 years
- Each parameter is normalized by the highest leaked volume for that particular category



Well Leakage Risk

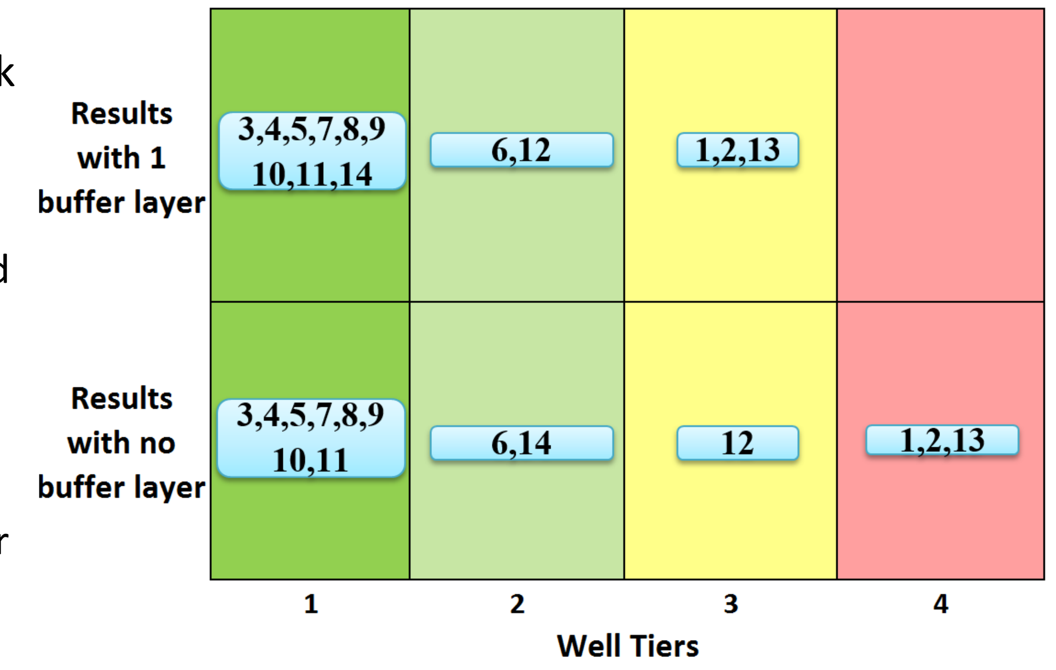
- This table presents the values extracted from wellbore leakage modeling results
- They can be used to find relative wellbore leakage risk

Variables	Category-1	Category-2	Category-3
Wellbore Type	Cased-cemented	Cased-uncemented	Uncased
Cement Index (CI)	0.01	0.72	1
Injector-leaky well distance (m)	5000	1000	100
Distance index (DI)	0.04	0.44	1
Boundary Type	Open boundary	Semi-closed	Closed
Boundary Index	0.44	0.47	1
No. of Buffer Layers	2	1	0
Layer Index (LI)	0.18	0.69	1

Risk Matrix

Results in the form of a risk matrix provides a better feel for sensitivity analysis

- The results of 14 selected well are displayed
- Sensitivity of buffer layer is highlighted
- Resultant shift in well tier category can be seen for some the wells



Conclusions

- A risk based approach is developed to find a well's CO_2 leakage potential
- The approach uses the wellbore leakage index as the primary variable to identify the leakage potential
- Wellbore leakage index is based on a well's cement coverage of the storage zone, proximity to injection well, storage zone boundary type and number of buffer zone with low permeability values
- Quantitative measure of these four parameters is obtained by using the well leakage models
- The criteria is applied to a representative set of 14 wells from a depleted oil and gas field in South of Louisiana to show an example application
- The criteria is presented in a tabular form for easy applications

Acknowledgements

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References

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