Introduction

Carbon storage in geological formations is widely regarded as a critical technology for carbon abatement. In depleted hydrocarbon fields, with their extensive and well-documented subsurface data, offer a more predictable and straightforward approach to CO2 sequestration; however, the situation is far more complex when it comes to saline aquifers. These saline aquifer formations are often characterized by a stark lack of high-quality subsurface data, making it exceptionally difficult to evaluate their CO2 storage potential with any degree of certainty. The challenge is compounded by the geological variability of aquifers, which can vary significantly over short distances, further obscuring accurate resource estimation. This data paucity, coupled with substantial geological uncertainty, presents one of the most formidable hurdles in saline aquifer storage maturation.

This abstract presents a methodology designed to address the challenges associated with storage assessment for saline aquifer projects, particularly in situations where there is limited data available. The approach maximizes the utility of sparse subsurface data, multiple realizations, analysis from geosciences to be integrated to enable wide ranges of uncertainty in CO2 storage capacity estimation at lead or prospect level. Additionally, the sensitivity results will help identify key risks that require data to be acquired from the appraisal wells.

Method

Typical issue in resource maturation for saline aquifer is lack of well penetration and even reliance on limited 2D seismic data lead to significant challenges in reservoir characterization, modelling and simulation, risk assessment, and development planning. These challenges and uncertainty need an integrated approach that not only utilize current limited dataset available but combines geoscience and reservoir engineering expertise. This should incorporate regional geological data, available subsurface data to multiple static-dynamic model scenarios for uncertainty and sensitivity (Figure 1).

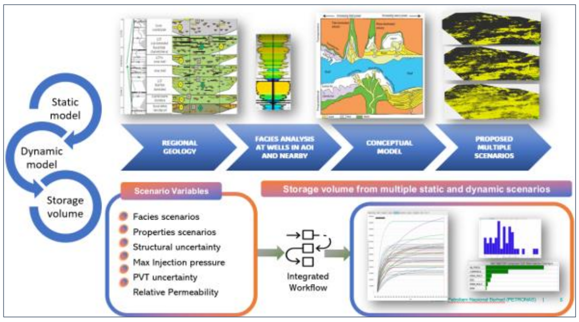

Figure 1 *General workflow of storage volume assessment for saline aquifers by integrated regional geology, static and dynamic modelling.*

As normal, the first step is to conduct containment risk assessment to at least eliminate high risk areas where are highly faulted, overpressure or incompetent top seal, prior to assessing sweet spots and storage injectivity efficiency. Other common limitations in database of saline aquifers is no core and 3D seismic data, there is significant uncertainty in understanding how facies (rock types, grain sizes, porosity, permeability, etc.) are distributed laterally within the reservoir. Since depositional environments influence rock properties, this uncertainty extends to the overall quality of the reservoir, which directly affects fluid flow characteristics. The uncertainty in rock properties and facies distribution translates to potential variability in injectivity, as different facies may exhibit very different behaviors in terms of fluid flow and storage capacity. To help to establish a range of potential reservoir behaviors, allowing for more robust decision-making, multiple scenarios of depositional concepts, is a way of capturing a broad range of possible outcomes for the reservoir's capacity and injectivity. Some examples below of saline aquifer projects which have their own key challenges and proposed different facies scenarios used for dynamic modelling and storage volume assessment (Figure 2). In situations of limited well control and lack of 3D seismic coverage, it also leads to other uncertainty to capture structural dipping and its impact on CO_2 plume size requires multiple structural scenarios that capture the potential variability in dip angles and geometries.

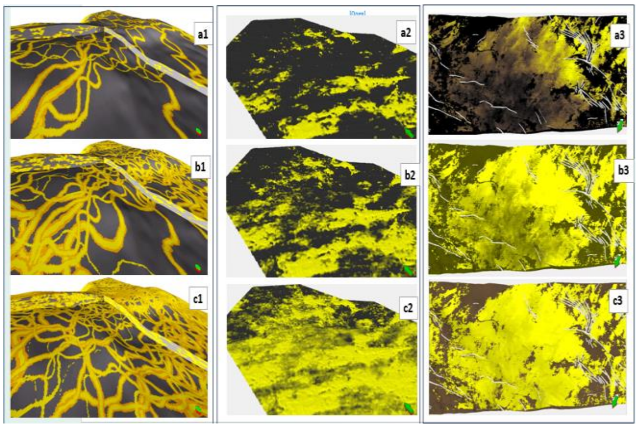

Figure 2: *Left (a1, b1, c1) are proposed low, base, high scenarios of saline aquifer X in lower coastal plain; only a few wells and some 2D seismic lines available in the area. Middle (a2, b2, c2) are proposed low, base, high scenarios of saline aquifer Y in shoreface, a project with 3D seismic available but no well penetration. Right (a3, b3, c3) are proposed low, base, high scenarios of saline aquifer Z in deltaic setting, a project with 3D seismic available and only one well penetration.*

Dynamic modelling is a powerful tool used to integrate multiple static models with different dynamic parameters to simulate and predict the behavior of systems over time. In the context of storage estimation, dynamic modelling allows for the incorporation of various dynamic variables, such as maximum pressure, injection strategies, injection rate and the effects of water withdrawal, to account for different operating conditions. The results from this static and dynamic integration provide a comprehensive analysis of storage volumes, capturing the effects of a broad spectrum of static and dynamic parameters. These parameters are influenced by varying injection strategies, including those applied in closed and open systems, as well as scenarios with and without water take-off. This enables the exploration of storage volume ranges, effectively addressing potential uncertainties and a wide array of operational possibilities. Below is shown one of the examples of storage assessment from static and dynamic integration (Figure 3).

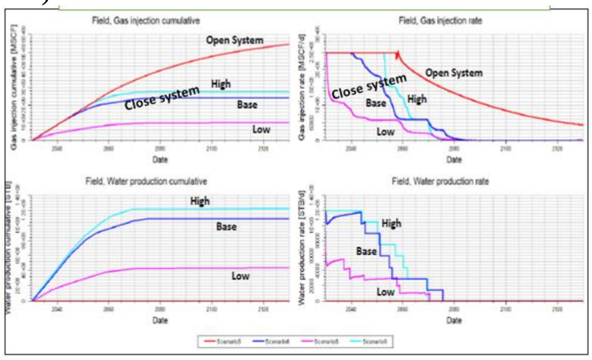

Figure 3*: An example of storage volume assessment resulted from different injection strategies using static model scenarios.*

Conclusion

Assessing the storage volume of saline aquifers presents a complex challenge, largely due to the significant uncertainties stemming from limited data and the necessity of making numerous assumptions. The applied workflow, utilized in some saline aquifer projects, helpfully captures this uncertainty through sensitivity and uncertainty analysis, covering a wide range of possible scenarios. However, to enhance the accuracy and reliability of these estimates, it is clear that further data acquisition is imperative, such as 3D seismic surveys and appraisal well drilling. By integrating economic evaluations with these technical assessments, the results offer insights into the potential risks and opportunities, guiding decisions for further investment in data acquisition to mature projects for storage development plans.

Acknowledgements

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References

Stefan Bachu, (2015). Review *of CO2 storage efficiency in deep saline aquifers*. International Journal of Greenhouse Gas Control 40 188–202.