geoconvention
Calgary • Canada • May 11-13 2026

Identification of Key Parameters Controlling CO_2 Storage Performance in Canadian Unconventional Formations

Le Viet Nguyen, Wanju Yuan, Xiaolong Peng, Zhuoheng Chen
Natural Resources Canada, Geological Survey of Canada, Calgary Division

Summary

This study presents a preliminary assessment of the reservoir, hydraulic fracturing, and operational parameters that control CO_2 storage performance in major unconventional formations in Canada, focusing on the Bakken, Duvernay, Horn River, and Montney. Using a systematic parameter investigation framework, we evaluate the sensitivity of storage capacity to variations in geological characteristics, fracture and completion design, and operating strategies. The results provide an initial basis for identifying dominant controls on CO_2 storage capacity and support future optimization of injection design and development of predictive models across a range of geological settings and operating conditions.

Method

We investigate impact of key parameters on CO_2 storage performance using a numerical simulation workflow. The input parameters include reservoir properties, hydraulic fracturing and completion design variables, and operational conditions. Parameter ranges were compiled from published literature to represent real field conditions (Nguyen et al., 2025).

The workflow begins with a base-case reservoir model in which parameter values are set to formation-representative averages. The base case includes a horizontal well producing hydrocarbons for the first 25 years, after which the same well is repurposed to CO_2 injection for long-term storage. The total simulated life cycle is 50 years.

The impact of individual parameters is evaluated using a one-variable-at-a-time (OVAT) approach, where one parameter is varied across its range while all others are held constant. Storage performance is quantified using the cumulative CO_2 injected and stored in the reservoir.

Results

Base-case simulations indicate that the Duvernay formation provides the highest storage capacity, followed by Montney and Horn River, while Bakken has the lowest storage capacity.

Overall, the most influential controls on CO_2 storage performance are formation thickness, reservoir pressure, and matrix permeability; lateral well length; and hydraulic fracturing design variables such as stage spacing, fracture half-length, and fracture conductivity. In contrast, parameters including matrix porosity, gas adsorption capacity, initial water saturation, injection start time, and safety factor generally have moderate to low influence.

Parameter effects also vary by formation. Several parameters show consistent trends across all formations (e.g., reservoir pressure, matrix permeability, adsorption capacity, completion and fracture design properties, and safety factor). In contrast, initial water saturation and injection start time increase storage capacity in Bakken but decrease storage capacity in Duvernay, Horn River, and Montney, likely reflecting differences in rock-fluid behavior among formations.

On the other hand, while most parameters exhibit a monotonic relationship with storage capacity, formation thickness and matrix porosity show non-monotonic responses: storage capacity increases from the lower bound to the base value, then decreases from the base value to the upper bound. This trend reflects fracture-height limitations. When fracture height is capped, the increased formation thickness is not effectively stimulated, therefore pressure drawdown during depletion is smaller and the available pressure margin for CO_2 injection (and thus cumulative stored CO_2) decreases at the upper bound.

Conclusions

Numerical simulation with an OVAT design reveals clear correlations between individual parameters and CO_2 storage performance, and it highlights that dominant controls and trends can be formation-specific. To better represent field complexity and quantify overall parameter influence, future work should incorporate simultaneous variation of all parameters (e.g., global sensitivity analysis). The non-monotonic behavior observed for some parameters indicates that optimization is required to identify best-performing design points rather than assuming “more is better.”

Future studies will apply machine learning/AI methods to efficiently analyze parameter effects and develop formation-specific proxy models to support rapid prediction and optimization of CO_2 storage performance.

Acknowledgements

Authors would like to acknowledge the project funding support from NRCan OERD CCUS stream. This project is part of the GSC GeoEnergy program.

References

Nguyen, L.V., Yuan, W., Chen, Z., Mort, A., 2025. Geological Characteristics of Major Unconventional Formations in Canada. Presented at the GeoConvention 2025, Calgary, Alberta, pp. 1–3.