The Role of Existing Wells as Pathways for CO_2 Leakage

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Injection of CO_2 into deep formations leads to a multi-phase flow problem that may involve important mass exchange between phases, non-isothermal effects, and complex geochemical reactions. In addition, because enormous quantities of CO_2 must be injected to have any significant impact on the atmospheric carbon problem, the spatial scale of the subsurface problem becomes very large. Broad questions involving the fate of the injected CO_2, including possible leakage of CO_2 out of the formation, as well as the fate of displaced fluids like resident brines, lead to very challenging modeling and analysis problems. Because important leakage pathways such as existing wells can be highly localized, and their properties can be highly uncertain, an overall analysis of the system requires resolution of multiple length scales in the context of a probabilistic approach. These requirements render standard numerical simulators ineffective due to excessive computational demands. A series of simplifying assumptions may be proposed, in the context of multi-scale modeling, to provide more efficient numerical calculations, even to the point of allowing for analytical or semi-analytical solutions. Such simplifications, while somewhat restrictive in their assumptions, allow for large-scale analysis of leakage in a probabilistic framework while capturing much of the essential physics of the problem. Example calculations illustrate the utility of these methods, and show the current state of leakage estimation. Specific applications to the Wabamun Lake area of Alberta, Canada show how large numbers of existing oil and gas wells can lead to complex leakage patters across multiple formations. Simulations involving multiple realizations allow various well parameters to be correlated to estimated leakage levels. Numerical results also provide guidance on options for monitoring by providing estimates of sizes of leakage plumes and pressure perturbations across multiple layers in the sedimentary sequence.