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Minimizing exposure to legacy wells and avoiding conflict between storage projects: Exploring area of review as a screening tool

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ABSTRACT

Elevated pressure from large-volume injection is a key driver of risk and project cost. If transmissive features (e.g., non-isolating wells or fracture systems) are present, increased injection-zone pressure can drive fluids from depth toward protected freshwater resources. In US Carbon Capture and Storage (CCS) law, the area at risk is known as the Area of Review (AoR). The size and number of potentially transmissive features to be evaluated and possibly remediated or managed is a function of the size and location of the AoR. The size of the AoR depends on several variables, including properties of the injection zone, properties of protected resources, and injection rate and duration. Evaluation of the intersection of these variables across a portfolio of sites highlights the injection zone depth and boundary conditions as top-level controls. Deep injection, use of multiple stacked injection zones, reduced injection rate and choice of injection well location can all be used to minimize AoR and the number of potentially transmissive features within it. We introduce the concept of pressure space (defined as connected pore volume times pressure) as the key subsurface commodity for CO_2 storage and we suggest that it forms a more robust basis for leasing and regulation than pore space alone.

1. Introduction

Among regulators, operators and even the general public, considerable attention is focused on the spread of injected CO_2 in the subsurface. To some degree, this concern is understandable. CO_2 is, after all, an introduced substance and the success of geologic carbon sequestration rests on the assurance of permanent sequestration. Indeed, monitoring of the injected plume is a common regulatory requirement (Directive 2009/31/EC, 2009; UIC Class VI, 2010; ISO/TC 265, 2017). However, CO_2 injection also elevates pressure, which often spreads much farther than the CO_2 itself and may be far more consequential. Elevated pressure can drive displacement of existing formation brines which may be much more hazardous than the CO_2 itself if released to the environment (Kreitler and Richter, 1986; Jiang et al., 2022). At a minimum, these brines are highly saline and they may also contain trace heavy metals, naturally-occurring radioactivity, and/or hydrocarbons, any of which could be damaging to fresh-water resources. In the presence of critically-stressed fractures, pressure build-up may also trigger induced seismicity (e.g., Weingarten et al., 2015; Hennings et al., 2019). Last, pressure build-up may cause loss of injectivity, possibly impacting neighboring storage projects as well (e.g., Frei-Pearson and Bryant, 2014; Grude et al., 2014).

At least in part because of its roots in the Safe Drinking Water Act (Safe Drinking Water Act, 1974), the US Underground Injection Control (UIC) program places strong emphasis on pressure elevation and the associated risks to fresh water aquifers,[1] within an Area of Review (AoR; UIC Class VI, 2010; US EPA, 2013). For CO_2 injection wells (UIC Class VI) this AoR is defined as the map-view extent of pressure elevation sufficient to lift injection zone brines to the lowest freshwater aquifer through a (hypothetical) open wellbore (Fig. 1). Put another way, the AoR "is the area around an injection well where, during injection, the [hydraulic] head of the formation fluid in the injection zone is equal to or greater than the [hydraulic] head of USDWs" (Thornhill et al., 1982 as quoted by US EPA, 2013). Prior to receiving an injection permit, a project developer must define the AoR with computational modeling, review all legacy penetrations and perform any corrective action needed to ensure their integrity under elevated pressure. During injection operations, the AoR delineation must be periodically reviewed and

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[1] Formally known as "Underground Source of Drinking Water" or USDW and defined by the EPA as an aquifer with less than 10,000ppm total dissolved solids (TDS; https://www.epa.gov/uic).

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