Groundbreaking Time-Based Model Sets New Standard for Class VI Permits

SCS Engineers, in collaboration with the U.S. Environmental Protection Agency, stands on the verge of a groundbreaking Class VI well permit approval—driven by an innovative computational modeling approach that redefines how critical pressures are calculated. By integrating both spatial and temporal dimensions, the model delivers site-specific results and produces a realistic project Area of Review (AoR), typically at a fraction of the size generated by standard equilibrium methods. This makes on-site CO2 storage viable, reduces reliance on costly pipelines and long-distance transport, and mitigates public opposition tied to safety and land use concerns.

A Step Change in Modeling for Carbon Capture and Sequestration

The Class VI well permit requires defining the AoR by determining the critical pressure threshold where CO2 saturated brine can migrate upward and endanger an underground source of drinking water (USDW). Standard EPA guidance is based on reaching hydrostatic equilibrium and uses a potential energy comparison of the two boreholes: one filled with brine, and another assumed to be improperly sealed with cement from prior oil and gas production. In theory, this comparison establishes a balance point between pressure differentials, at which brine will not migrate into the USDW.

The standard approach has limitations: it does not capture how pressures rise or fall over time, or how long equilibrium takes to establish. As a result, the standard method can significantly underestimate critical pressure and overestimate AoR size. That distortion magnifies project complexity and directly drives up costs for CO2 transport, long-term monitoring, and corrective action planning. In many cases, a proposed project becomes infeasible after defining the AoR using the standard guidance.

To address this, SCS Engineers developed a Computational Pressure Model that calculates brine migration as a function of time and overpressure in the injection zone.

Brine Migration: Time Tells a New Story

In 2023, SCS Engineers partnered with the EPA to create a customized CP Model for a deep well injection site along a tectonically active continental margin. Unlike standard pressure comparisons, the CP Model accounts for how temperature, pressure and salinity gradients influence hydrostatic pressure and brine migration over time.

Built to include site-specific subsurface geologic and salinity data, the CP Model uses discrete cells to represent the USDW, an unplugged legacy borehole, and the CO2 injection zone. This model generates project-specific timelines of pressure by including:

- **Time-stamped data** at 1- and 5-year intervals to track brine migration as pressures rise and fall.
- **A 70-year model horizon**—50 years beyond the proposed injection period to provide added safety.

One of the important discoveries is that the duration of overpressurization in the injection zone is limited, and this in turn limits the potential for upward brine migration. AoR dynamic models show that pressure in the injection zone typically decreases quickly after the end of injection. Consideration of the limited duration of overpressure is important to understanding the potential risk improperly plugged wells may pose to underground sources of drinking water.

The models also show that it takes long durations of overpressure to reach hydrostatic equilibrium, contrary to the standard guidance assumption that balance is reached immediately upon the start of injection. The model demonstrates that the rate of brine flow in an improperly plugged well is a complex function of time, and that the dynamics of the system must be considered to accurately assess potential risk.

A First-of-a-Kind Map for Brine Migration Potential

During the two-year collaboration, SCS Engineers and EPA refined the CP Model and introduced the Endangerment Potential Map—a spatial visualization of migration risk across the site. Instead of relying on a single evaluation point, the EPA suggested a spatially distributed map using thousands of data points. Using advanced mathematics and statistical evaluation, SCS Engineers generated a sitewide contour map that spatially depicts potential brine migration, integrating modeled pressure increases, salinity and subsurface geologic conditions.

The map reveals zones of higher and lower endangerment potential, ultimately showing that the risk from any single borehole is about one in 10 million, providing the EPA with a significant margin of safety.

As required in the permit, subsurface conditions are monitored regularly during and after injection. If conditions change significantly over time, SCS Engineers will evaluate whether the CP Model requires revision. Both the model and map can be updated with real-world monitoring data to fine-tune ongoing site management.

CCS Unlocked Across Industries

The time-based CP Model represents a paradigm shift in critical pressure calculations and the power of collaboration. Time-based critical pressure calculations define an authentic AoR, enabling more cost-effective CCS projects and strengthened accountability to regulators and stakeholders.

This model doesn't just redefine pressure calculations—it makes CCS a viable emissions reduction stopgap as industries pursue operational decarbonization. For sectors like ethanol processing, where CO2 is inherent to production, CCS isn't merely transitional—it can be a cornerstone of their CO2 management strategy. With SCS Engineers' CP Model, that foundation starts here. Large-scale carbon storage is happening today. SCS Engineers can help you make it happen.

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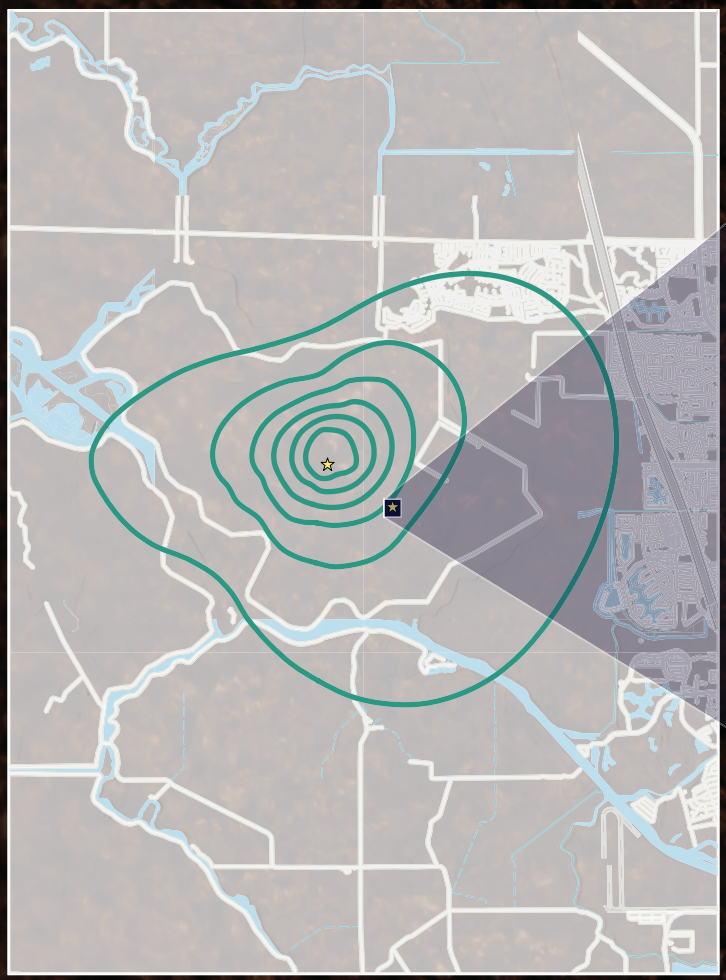
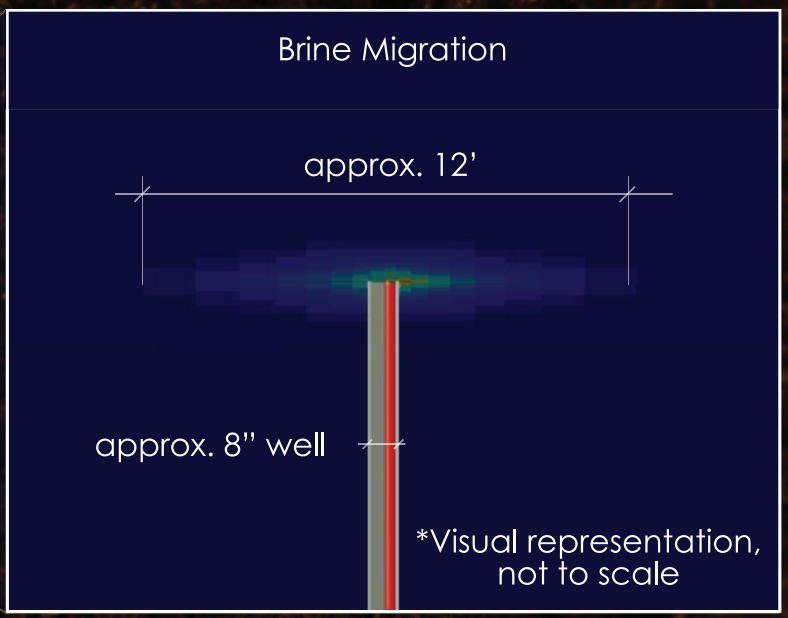
SCS has collaborated with the EPA to develop a new pressure modeling approach that demonstrates the AoR for most projects is smaller than originally predicted, increasing the viability of many CCUS projects.





Restricted seepage rates of deep brine lead to low risk of salinization of drinking water.

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