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Wellborne: A Platform for Standardized Legacy Well Integrity Screening and Class VI Well Permitting

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Abstract

Securing geological carbon storage requires a preemptive, standardized, and quantitative assessment of legacy wells within the Area of Review (AoR). To bridge the gap between complex regulatory frameworks and actionable field decisions, this work introduces the Wellborne platform, existing as a desktop application that operationalizes the first standardized quantitative risk framework designed to support “go/no-go” decisions for U.S. Environmental Protection Agency (EPA) Class VI permit applications. Wellborne transforms subjective judgment into objective, numerical intelligence by embedding global standards into an accessible, user-driven platform. The core of Wellborne is built on the philosophy of “practical accuracy over unnecessary precision”. It translates a strategic three-pillar methodology into a practical tool: (1) generating a definitive numerical risk score to unify communication across technical, corporate, and regulatory stakeholders; (2) being rooted in petroleum engineering first principles for practical adoption; and (3) ensuring compliance with NORSOK D-010, U.S. Code of Federal Regulations (CFR), and the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Risk Register. The platform quantifies risk across six diagnostic domains—Well Identity, Well Design, Freshwater Protection, Well Integrity, Primary Barrier, and Secondary Barrier—through a transparent hierarchical structure (attribute → domain → score-based prioritization). This design pinpoints not just *if* a well is high priority, but *why*. In a case study from a CarbonSAFE Phase II project in the Permian Basin, the Wellborne platform screened 38 legacy wells. The analysis identified that only 50% of these wells penetrated the primary confining zone. Of these, four were flagged as high priority without requiring immediate corrective actions. The platform successfully revealed specific wells with a high potential for interzonal CO_2 crossflow. The integrated, domain-based analysis proved that while well designs are often similar, their operational history and barrier integrity are the critical factors differentiating risk. This insight supports high-impact and data-driven decisions, including the justification for additional permit requests. The model maintained a conservative, acceptable false-

positive rate, a design feature that inherently prioritizes caution in its screening assessments. Wellborne transcends a mere framework; it is a new benchmark and the first industrial-strength tool to deliver a standardized quantitative risk score, enabling project teams to prioritize investment and investigation with confidence. It provides a reliable, minimalist-effort tool for efficacious risk management from the engineering level to executive strategy, derisking the path to Class VI well permitting.

Introduction

Geological carbon sequestration, encompassing both Carbon Capture and Storage (CCS) and Carbon Capture, Utilization, and Storage (CCUS), is a maturing technology with a history spanning over three decades. Depleted oil and gas reservoirs are prime candidates for CO_2 storage, offering proven geologic containment, extensive characterization data, predictive modeling expertise, and potential reuse of existing infrastructure. However, this advantage is counterbalanced by critical vulnerability: the existing or legacy wellbores that penetrate the storage complex (Benson et al., 2005). The integrity of these penetrations, therefore, must be definitively assessed, dealing with incomplete records and the challenge of locating old wells. As Torsæter et al. (2024) notes, permanently plugged and abandoned wells represent the most significant technical challenge, as remediation requires complex, high-cost interventions compared to accessible, open wells.

Despite the long history of risk assessment for such projects, the systematic assessment of legacy well integrity remains a profound and persistent challenge. A central limitation of existing risk methodologies, either quantitative or qualitative, is their lack of integration with the complete suite of regulatory and industry standards that govern modern carbon sequestration. For instance, while Nguyen et al. (2025) aligned their model with specific U.S. EPA Class VI rules, and Arbad et al. (2022) referenced the NORSOK D-010 well integrity fundamental, a holistic framework that unifies these pillars is absent.

This work addresses that gap by introducing a methodology built upon a tripartite vision for legacy well assessment, comprising of the absolute protection of Underground Source of Drinking Water (USDW), the safeguarding of low-CO_2 hydrocarbon-bearing zones, and the assurance of systemic integrity for the entire storage complex. To translate this vision into practice, the Wellborne desktop-based platform exists as a standardized, quantitative screening tool, transforming a meticulous historical issue into a manageable, data-driven process.

Theory and/or Methods

The Wellborne framework synthesizes three authoritative pillars: NORSOK D-010 (general well barrier guideline), U.S. CFR (operational compliance), and the U.S. DOE NETL Risk Register (actionable classification). This integration yields a quantitative assessment across 17 attributes in six diagnostic domains: Well Identity (Age, Type, Status); Well Design (Trajectory, Casing Strings, Completion, Stimulation); Freshwater Protection (Surface Casing Coverage, Surface Casing Cementing); Well Integrity (Probable CO_2 Leakage Rate, Squeeze Cementing); Primary Barrier (Annular Cement, Plug and Primary Seal, Plug and Annular Cement); Secondary Barrier (Annular Cement, Plug and Secondary Seal, Plug and Annular Cement).

Each domain's attributes are evaluated through a severity score (1-3) and a weighting factor (1-3), derived from regulatory scenarios and industry practice. The Wellborne desktop-based platform then automates the assessment workflow (Figure 1), transforming complex model into a handy screening tool.

Results

The Wellborne platform was deployed in a pilot application for a U.S. DOE CarbonSAFE Phase II project within the Permian Basin. As illustrated in Figure 2, a specific injection location (labeled I) had been designated through prior project studies. The objective of this Phase II initiative is to execute a comprehensive feasibility study and risk assessment, forming the critical technical foundation for a subsequent Underground Injection Control (UIC) Class VI well permit application to the U.S. EPA. Securing a Class VI permit is a mandatory regulatory milestone for authorizing the geologic sequestration of CO_2, with its regulations centrally focused on the protection of USDW.

The visualization in Figure 2 provides typical actionable insights by categorizing wells within the project's preliminary AoR of 3 miles: high-priority wells (red) and low-priority wells (green). Wells located outside the AoR boundary are marked in black for contextual reference. The total of 37 wells assessed reflects an adjustment from an initial data pull of 38 wells as per the 5-mile search area; one well was removed as its drilling permit was canceled. For the sake of a thorough and conservative assessment, Well 19 was intentionally included despite its location falling just outside the preliminary 3-mile AoR.

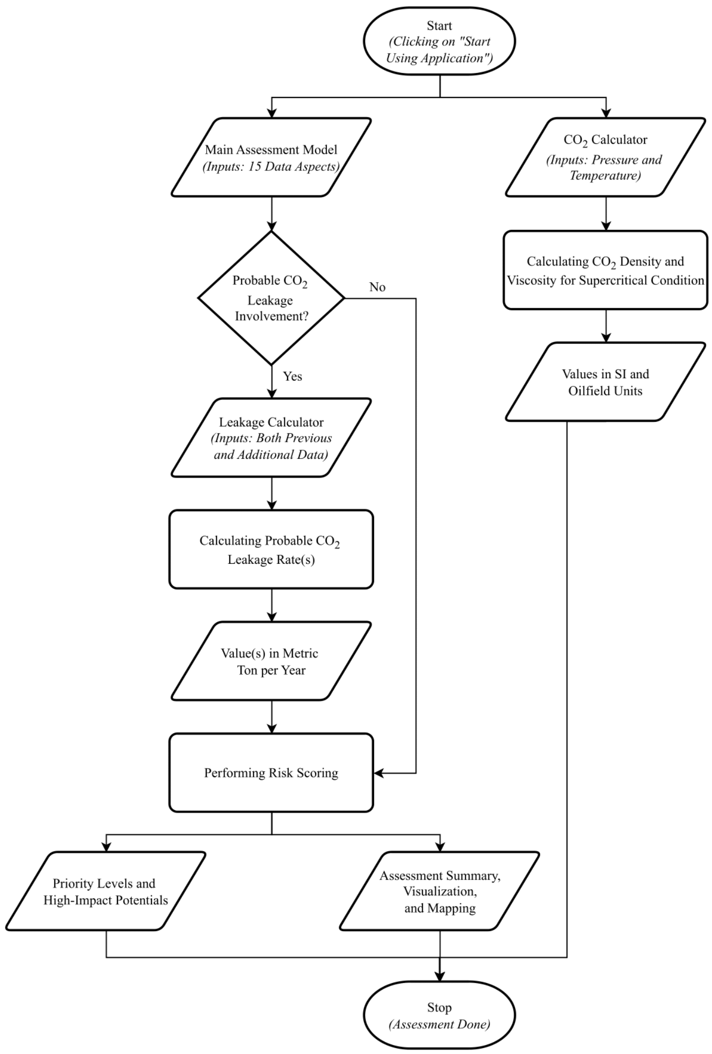

Figure 1. Processing and execution workflow of the Wellborne platform.

Discussion

The Wellborne analysis provides diagnostic clarity for both high- and low-priority well classifications. For the four high-priority wells, a critical determination is whether they mandate immediate corrective action under 40 CFR 146.84(d). The model is programmed to trigger a mandatory corrective action alert upon detecting any of three specific integrity failure conditions: (1) high-risk "freshwater protection" domain, (2) high-risk "primary barrier" domain concurrent with a high-risk probable CO_2 leakage rate, or (3) the co-occurrence of conditions (1) and (2). In this pilot assessment, none of the four wells met these definitive failure criteria. Consequently, while flagged for heightened scrutiny, no immediate corrective action is currently required.

For the low-priority wells, Wellborne's guiding philosophy of "practical accuracy over unnecessary precision" translates into a nuanced assessment: everything is important, but something is always more important. The analysis identified five low-priority wells with indications of potential interzonal CO_2 crossflow, primarily due to deficiencies in either the primary or secondary barrier domains. This finding carries significant strategic implications. It demonstrates that resolving the high-priority flags does not fully derisk the storage complex. The potential conduit risk presented by these five wells persists, creating a concern that spans both legal and operational corridors. This insight directly informs next steps, indicating that further pressure-based simulation modeling or the strategic submission of an additional CO_2 injection permit request may be necessary to robustly support the primary UIC Class VI well application and ensure long-term project integrity.

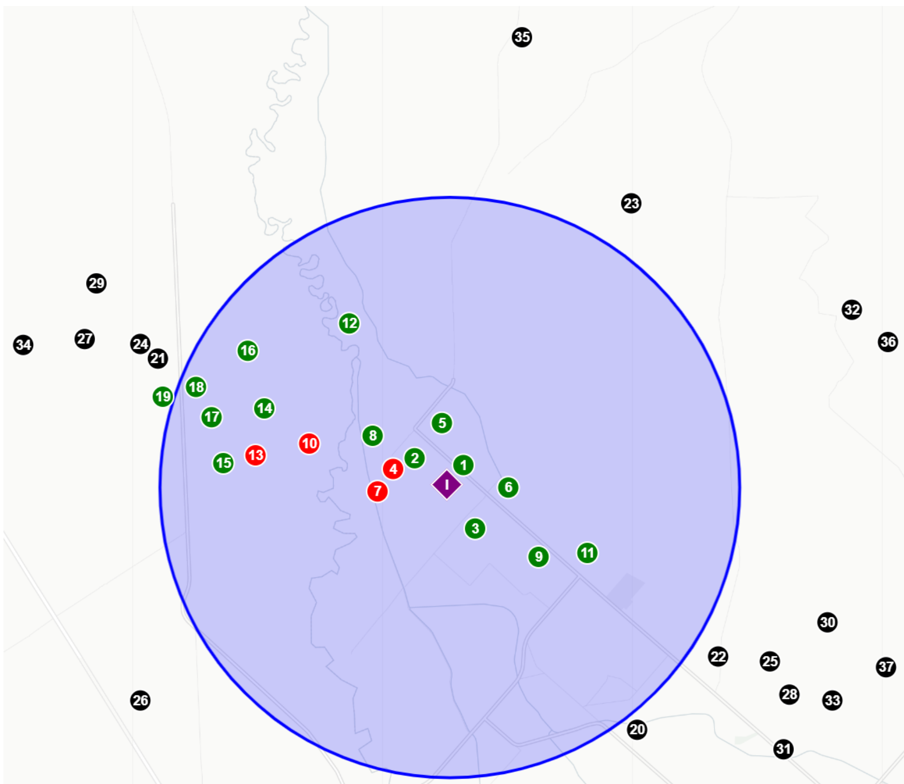

Figure 2. Typical screening result yielded by the Wellborne platform, specifically for the Permian Basin CarbonSAFE Phase II project.

Conclusions

The pilot implementation of Wellborne highlights its essence in streamlining the U.S. EPA Class VI well permitting and derisking geological carbon sequestration projects, concluding the work as follows:

1. Wellborne standardizes risk communication among stakeholders and provides a common, quantitative language for risk profiles, aligning operators, regulators, and institutions on a transparent basis for "go/no-go" decisions.
2. The software platform actualizes complex methodology into practical screening. This focuses resources on the highest-priority wells, ensuring strategic allocation of effort and public funds for necessary corrective actions.

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