Wabash CarbonSAFE

Policy, Regulatory, Legal, and Permitting Evaluation
Task 6.0
Technical Report

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EXECUTIVE SUMMARY

This report revisits and updates work completed for the Phase I CarbonSAFE Illinois - East Sub Basin project, the precursor to the Phase II Wabash CarbonSAFE project; the current report summarizes the policy, regulatory, legal, and permitting considerations to-date as related to geologic CO_2 storage at the Wabash Valley Resources (WVR) gasification plant site in Vigo County, Indiana.

Indiana Senate Bill 442, signed into Public Law 291 in 2019, establishes that CCS operations at WVR would be a pilot project in need of Class VI Underground Injection Control (UIC) permit by the US EPA. The law provides for the use of eminent domain, if needed, for the pooling of subsurface pore space for CO_2 injection; and provides for the assumption of long-term ownership of the injected CO_2 by the State of Indiana.

Currently, the US Federal §45Q Tax credits are the greatest monetary incentive for CCS/CCUS projects. The current dollar amounts of the Section 45Q credits per tonne were established in the Bipartisan Budget Act of 2018, expanding the maximum dollar amounts in 2026 to $50 for sequestered carbon oxide and $35 for utilized CO_X. The credits were modified as recently as December 2020 when Congress passed The Consolidated Appropriations Act, 2021, which expanded the deadline for construction to begin, now required to commence by December 31, 2026. In addition, there is a general continued interest in scaling CCS technologies toward commercialization at the Federal level via funding through the bipartisan Infrastructure Investment and Jobs Act (IIJA), which was signed into law by President Biden on November 15, 2021.

The WVR facility is located above suitable geology for storage of the anticipated capturable CO_2 (ca 1.82 million tonnes per year) with minimal transportation distance providing WVR the opportunity to reduce costs with onsite injection. A high-level desktop study identified general pipeline routing parameters (e.g., line length, elevation, number of parcels and/or landowners crossed, and also road, utility, powerline, stream, and woodland crossings) to assess potential pipeline right-of-way (ROW) options. Detailed FEED study of route options and property ROW acquisitions would occur if a pipeline to any potential offsite injection location were to proceed. In Indiana, both the Eminent Domain for Transportation of Carbon Dioxide by Pipeline (IC 14-39) and Indiana Public Law 291 established carbon storage as a public good. As part of Law 291 the WVR project has access to the established eminent domain laws for the construction of CO_2 pipelines.

Public notice is a component of the US EPA UIC Class VI Permit application and review process. The project proponent must be prepared to respond to technical questions and comments from US EPA, and the permit applicant will respond to questions and comments from the public received during the public review period. The public notice requirements under the UIC program include that the EPA issue notice of the draft permit preparation to key stakeholders and open a public comment period of not less than 30 days. The EPA would also provide at least 30-days' advance notice and hold a public hearing regarding the permit application, if a hearing is specifically requested by the public. The permit application will be revised as needed and resubmitted to US EPA. Upon approval, the permit applicants will receive a "*Permit to Construct Class VI Underground Injection Well*".

Groundwater protection is addressed by the Safe Drinking Water Act and is regulated through the US EPA's Underground Injection Control (UIC) program. Protection of underground sources of drinking water (USDWs), in the context of CO_2 injection for geological storage, is achieved by geological characterization and validation of the storage complex site reservoir and seal integrity, and through successful UIC Class VI well permitting and proper injection well construction. Of primary importance to the development of a UIC Class VI permit application is the identification of the lowermost underground source of drinking water (LUSDW) to inform modeling and delineation of the Area of Review. Based on regional salinity data and sample analysis from the Wabash #1 well, a conservative determination of the LUSDW at the WVR site is the Silurian-Devonian Carbonate-Rock Aquifer.

There are several critical path elements that must be completed to develop the US EPA UIC Class VI permit application submittals. These include timely drilling and completion of a stratigraphic test well with testing and analysis to support site characterization, a site characterization report, and development of geologic and hydrogeologic models. Interim modeling results will be used to develop permit application components (preliminary Area of Review, monitoring planning, injection scenarios and conditions, injection well design, etc.) Other portions of the permit application can be completed using preliminary site modeling and with minimal technical input. These include the Emergency Response Plan, Post-Injection Site Care Plan, and Financial Responsibility sections.

A potential Class VI CO_2 injection well permit for the Wabash CarbonSAFE study site would be obtained through the US EPA Region 5, because the State of Indiana does not have UIC Class VI primacy. Meetings with regulators should be held as needed to review requirements for a Class VI permit as set forth in 40 CFR 146.82(a) and to review and concur on submittal requirements (e.g., electronic submittal formats).

In general, for development of Class VI permits under the US EPA Underground Injection Control (UIC) guidelines, the results of the reservoir modeling for the site can be used to estimate the Area of Review (AoR) and initiate development of the UIC permit application. AoR is considered as the region encompassing the CO_2 storage site where particular attention must be paid to USDW protection. Supporting documentation is required to accompany a UIC permit application to demonstrate that the injection zone is of sufficient capacity, and the confining zone is of sufficient thickness and integrity, for the site to permanently store the CO_2 in a manner that is protective of USDWs.

INTRODUCTION

This report presents an update of work completed for the Phase I CarbonSAFE Illinois - East Sub Basin project, the precursor to the Phase II Wabash CarbonSAFE project. This report also draws upon updated business environment information performed for Phase II as presented in Koenig, 2021 (Technical Report DOE-FE0031626-4).

A previous CarbonSAFE Phase I report (Topical Report DOE-FE0029445-4; Korose et al., 2018) outlined considerations relating to policy, regulatory, legal, and permitting requirements for the siting of a CO_2 injection and storage project in the East Sub-Basin pre-feasibility study area, and primarily focused on a site location in West Terre Haute, Indiana.

This Phase II report is focused on the Wabash Valley Resources (WVR) gasification plant in Vigo County, Indiana, under the Wabash CarbonSAFE project's objectives of establishing the feasibility of developing a commercial-scale geological storage complex for the storage of 50 million tonnes or more of CO_2. The WVR plant is expected to produce up to 2 million tons (1.82 million tonnes) of CO_2 annually as a byproduct of hydrogen production.

Included within this document is an update on key considerations related to geologic CO_2 storage at the WVR site, which include pore space ownership, the potential for long-term liability assumption, policies toward project economics, securing rights-of-way for pipelines, public notice and engagement, and groundwater protection. Also addressed is the determination of the lowermost underground source of drinking water (USDW) which underpins any further work toward obtaining a US Environmental Protection Agency (EPA) Class VI (Wells used for Geologic Sequestration of CO_2) Underground Injection Control (UIC) Program permit. A permitting plan is presented (see Appendix) which provides a general outline of tasks, timelines, and information needed to prepare a US EPA Class VI permit application for a storage site in the Wabash CarbonSAFE study area.

SUMMARY

Pore Space Ownership, Potential for Long-Term Liability Assumption

Considerations of pore space ownership and the potential for assumption of long-term liability at the WVR site are addressed at the level of the State of Indiana, which has shown support generally for Carbon Capture and Storage (CCS) and specifically for the WVR industrial project.

Indiana Senate Bill 442, signed into Public Law 291 in 2019, establishes that CCS operations at WVR would be a pilot project in need of Class VI Underground Injection Control (UIC) permit by the US EPA. The law provides for the use of eminent domain, if needed, for the pooling of subsurface pore space for CO_2 injection; and provides for the assumption of long-term ownership of the injected CO_2 by the State of Indiana (Korose et al., 2018).

More specifically (in Koenig, 2021):

> The law, written specifically for the WVR facility project, grants the power of eminent domain to the pilot operator to obtain ownership of land that may be needed for construction of the injection site, transportation pipeline, or required for monitoring facilities under Class VI guidelines. Eminent domain may also be applied to subsurface strata in which the carbon dioxide is stored. The power of eminent domain may only be applied if no purchase agreement is made with the effected landowners.

Additionally, Indiana Public Law 291 (in Korose et al., 2018):

> Provides that the pilot project operator's [WVR] acquisitions by eminent domain must be made through the law on eminent domain for gas storage, which provides that a condemnor, before condemning any underground stratum or formation, must have acquired the right to store gas in at least 60% of the stratum or formation by a means other than condemnation. [Indiana Public Law 291 also] amends the law on eminent domain for gas storage to make it applicable to the pilot project operator's acquisitions by eminent domain.

At the time of this report, there are no publicly announced contractual agreements between WVR and the surrounding landowners of the project, concerning either land access or pore space (Koenig, 2021). At the WVR plant site, the current owner of the subsurface rights has extensive holdings and is known, but confidential at this time. In the broader region, pore space owners may need to be identified (Korose et al., 2018).

Policies Toward Project Economics

Prior research (Korose et al., 2018 and Koenig, 2021) suggests that no meaningful Indiana State-level tax credits or R&D incentives for CCS exist that would be relevant to the WVR case study site's business scenario and that any revenue-positive business case likely will need to be supported by Federal tax credits. Currently, the US Federal §45Q Tax credits are the greatest monetary incentive for CCS/CCUS projects; for the WVR case, non-electric-generating facilities that capture at least 100,000 tonnes of qualified carbon oxide, that would otherwise be emitted each taxable year, are eligible for the amended 45Q tax credits, discussed below.

As stated in Koenig, 2021:

> Carbon capture and sequestration is primarily incentivized via the Section 45Q tax credits offered on a dollar amount-per-tonne basis through the IRS. The tax credits are non-refundable, meaning the §45Q credits can only reduce taxes owed (i.e., cannot be added to a tax refund). The tax credits are non-transferrable but can be recognized by other project investors. The current dollar amounts of the Section

45Q credits per tonne were established in the Bipartisan Budget Act of 2018, expanding the maximum dollar amounts in 2026 to $50 for sequestered carbon oxide and $35 for utilized CO_X (BBA, 2018). The credits per-tonne amount grows each year to the 2026 amounts, illustrated below in Table 1. After 2026, the tax credit amounts are the 2026-dollar amount multiplied by an inflation adjustment factor, which is expected to increase the dollar-per-tonne amount above $60/tonne over the life of the project. An injecting entity may claim the tax credits for a 12-year service period. The credits were modified as recently as December 2020 when Congress passed The Consolidated Appropriations Act, 2021, which expanded the deadline for construction to begin, now required to commence by December 31, 2026 (CAA, 2020).

Table 1: Dollar-Per-Tonne §45Q Amounts for Storage and Utilization (from Koenig, 2021)

Taxable Calendar Year	Deep Saline Storage $/Metric Ton of CO_2
2021	34.81
2022	37.85
2023	40.89
2024	43.92
2025	46.96
2026	50.00

In February 2020, the IRS released two parts of the full guidance needed for companies to implement the 45Q tax credits: guidance documents relating to the beginning of construction (IRS, 2020a) and the revenue procedure (IRS, 2020b; in Global CCS Institute, 2020.)

Wabash Valley Resources has further backing by the U.S. Department of Energy. In 2021, WVR has applied for and received grant DE-FE0031994; the grant will continue the Front-End Engineering Design (FEED) and development of the project with the focus on achieving a net-zero carbon intensity gasification-based hydrogen production (Koenig, 2021).

There is a general continued interest in scaling CCS technologies toward commercialization at the Federal level. On November 5th, 2021 the US House of Representatives passed H.R. 3684, the bipartisan Infrastructure Investment and Jobs Act (IIJA), which was signed into law by President Biden on November 15, 2021. As summarized by the Carbon Utilization Research Council (2021):

> The IIJA includes $12.1 billion for carbon capture, utilization, and storage (CCUS) technology activities… In particular, the bill includes legislation … to fund CCUS large-scale pilot and demonstration projects, large-scale carbon storage projects, and CCUS transportation infrastructure. Each of these activities … are a critical component of scaling CCUS technologies towards commercialization. The bill also includes significant funding [$8 billion] for hydrogen-related RD&D activities and allows for hydrogen produced via fossil fuels with CCUS to qualify for that funding.

Generally funded across Fiscal Years 2022-2026, the IIJA also provides increased funding to the US EPA to improve Class VI permitting (Underground Injection Control Class VI Wells used for Geologic Sequestration of CO_2; EPA, 2021), as well as $50 million in grants for States to establish their own Class VI permitting program. Note that at present, only Wyoming and North Dakota have primacy over Class VI permits as delegated by the US EPA (JD Supra, 2021).

Securing Rights-of-Way for Pipelines

The WVR facility is located above suitable geology for injection of the full amount of CO_2 expected to be captured (ca 1.82 million tonnes per year) with minimal transportation distance providing WVR the opportunity to save on transportation costs with onsite injection (Koenig, 2021).

A high-level desktop study was performed for a potential offsite sequestration field location to assess potential pipeline right-of-way (ROW) options (Hux Management Services, 2020). General pipeline routing parameters were considered in the desktop study, and are discussed below:

- The **length** of a pipeline is one of the most significant pipeline parameters in respect to cost. In general, the longer the line the more expensive it is to develop, construct, and operate. Therefore, the length of the route from origin to destination should be minimized, so long as doing so does not add considerable construction cost due to terrain.
- The number of **parcels** along a pipeline route has only a small amount of impact on the development cost of a project. Title work needs on be performed on each parcel to determine the rightful owner prior to ROW acquisition. Impacted parcels are also drawn as part of the mapping process to create accurate exhibits (Permanent ROW Acreage, Temporary Workspace Acreage, Line Length, Access Road Length, etc.) to support ROW acquisition.
- The number of **landowners** on a pipeline project primarily impacts the ROW acquisition process. The more landowners impacted by the project the more likely it is to encounter project opposition. Difficult negotiations may result in the project delays and increased cost for the ROW itself and/or legal fees. Landowners that are opposed to the project from the start are often rerouted if practical. This tactic however often lengthens the route and impacts additional landowners. It is therefore a best practice to keep the number of impacted landowners as small as reasonable possible.
- **Elevation** as a single point has no impact on pipeline construction or operation. However, steep terrain can make construction more difficult, and significant elevation change can impact on pipeline hydraulics. During design it will be important to verify the pressure at the low point does not exceed the designed maximum operating pressure, and the pressure at the high point is sufficient to keep the CO_2 a liquid.
- **Road crossings** have varying impact on pipeline construction costs based upon the crossing method utilized, some of which can be significant. There are three primary crossing methods, in order from least expensive to most expensive, open cut, bore, and horizontal directional drill (HDD). The crossing method is dictated by constructability and the crossing permit.
- **Pipeline and other buried utility crossings** increase pipeline construction costs, as they require specialized tie-in crews to complete the work. Specifically, for pipelines the crossing details must be agreed to by the pipeline operator. It is typical for the new line to cross as near 90 degrees as possible and be placed below the existing line. Other buried utilities will need to be identified via field survey, though most will be crossed in conjunction with road crossings.
- **Powerline crossings** have little impact on pipeline construction provided they do not need to be relocated. Crossing details also must be agreed to by the powerline owner, with crossing

performed near 90 degrees and sufficient separation maintained between the poles and the pipeline. High voltage lines can require AC mitigation be installed to prevent induced current on the pipeline from causing corrosion. This is generally the case when pipeline run parallel to high voltage lines.

- **Stream crossings** impact pipeline projects both in the permitting process and in the cost of construction. Regarding the permitting process the fewer impact to waterways, floodplains, and wetlands the better. The U.S. Army Corps of Engineers (USACE) is responsible for issuing Section 404 Permits as governed by Section 404 of the Clean Water Act. This permit will dictate the approved methods for constructing within streams and wetlands.
- **The portion of a pipeline route that is wooded** has impact on both the permitting of the project and the construction cost. Some landowners also will object to clearing trees on their property, typically resulting in higher ROW acquisition costs. Generally, the fewer trees impacted the better. Wooded areas carry a higher environmental impact than areas that are devoid of trees, specifically if the wooded areas are classified as forested wetlands or are habitat to protected species, such as the Indiana Bat. Construction costs increase because of the amount of time and specialized equipment required to clear large areas of timbered land. Unless surveys are performed to prove the Indiana Bat is not present in the project area, all trees within the construction workspace will need to be dropped between November 1 and March 31.
- **Colocation** refers to the portion of the route that is parallel and immediately adjacent to another utility, typically another pipeline or a powerline. Colocation can positively impact permitting due to the reduced impact of following an existing corridor as compared to a greenfield route.
- Note that the desktop study did not include any **archeological research**. Specifically, along the agricultural portions of the routes there is potential that archeological survey may result in minor re-routes or modified installation techniques, such as boring, to avoid impacts.

If a pipeline to any offsite injection location were to proceed, it is expected that a more detailed FEED study of route options and property ROW acquisitions would occur before final pipeline route permitting, design, and construction.

As stated in Korose et al., 2018:

> The Indiana DNR oversees the application process for issuance of a certificate of authority to construct, operate, and maintain a pipeline and the explicit use of eminent domain to the owner or operator of the pipeline. In 2011, the of Indiana state passed the Eminent Domain for Transportation of Carbon Dioxide by Pipeline (IC 14-39) which declares pipeline transportation of CO_2 exclusively to a carbon management application, including sequestration, enhanced oil recovery, and deep saline injection as a benefit to the welfare of Indiana and the people (Indiana State, 2011).

Building on this effort, Indiana Public Law 291 (Senate Bill 442) was passed in 2019 that established carbon storage as a public good. As part of Law 291 the WVR project has access to the established eminent domain laws for the construction of CO_2 pipelines and access to subsurface storage formations (Koenig, 2021).

Public Notice and Engagement

The following section was excerpted and updated from the CarbonSAFE Illinois East Sub-Basin Topical Report DOE-FE0029445-4 (Korose et al., 2018, *Policy, Regulatory, Legal, and Permitting Case Study);* see DOE-FE0029445-4 for additional details.

Public notice is a component of the US EPA Class VI Permit application and review process. As noted in this document's UIC Class VI Permit Plan (see Appendix), the project proponent must be prepared to respond to technical questions and comments from US EPA, and the permit applicant will respond to questions and comments from the public received during the public review period. The permit application will be revised as needed and resubmitted to US EPA. Upon approval, the permit applicants will receive a "*Permit to Construct Class VI Underground Injection Well"*.

In their Quick Reference Guide for Public Participation (2011), the US EPA state that:

> While owners or operators submitting a Class VI permit application do not have specific requirements for public involvement, they may choose to work with the UIC Program Director during the development and execution of a public participation plan for their Class VI permit application (especially in providing background information on the proposed Class VI injection well(s)). The owner or operator may choose to inform the public about the proposed Class VI injection well(s) to solicit community input and to help facilitate increased community acceptance of the proposed Class VI injection well(s).

Strategies and frameworks for public and stakeholder engagement are presented in Wabash CarbonSAFE Technical Report DOE-FE0031626-2 (Brumbaugh and Rupp, 2020). However, formal public notice components pertaining to Class VI well permitting are highlighted herein.

For the case of a Class VI CO_2 injection well (or a Class I waste injection well) permit, the public notice requirements under the UIC program include that the EPA issue notice of the draft permit preparation to key stakeholders and open a public comment period of not less than 30 days. The EPA would also provide at least 30-days' advance notice and hold a public hearing regarding the permit application, if a hearing is specifically requested by the public.

The EPA compiles and responds to all public comments on the permit application. Following a public hearing, there would then be another comment period and subsequent responses from the EPA. Pending no major permit modifications or appeals (which would necessitate other comments/responses), the permit requestor should generally plan for 3-4 months to be dedicated solely to the public notice and comment periods, including a potential public hearing.

The US EPA's permit application review timeline and public notice schedule from the FutureGen Alliance 2.0 permit application (EPA, 2016) shows a general example covering one-and-a-half years (assuming there are no appeals to the permit). However, each potential geological storage project and/or Class VI injection permit application will have its own unique circumstances. For example, the Midwest Geological Sequestration Consortium's project experience observed a more extended timeline to receive permits for CO_2 injection wells CCS1 (Illinois Basin—Decatur Project) and CCS2 (Illinois Industrial Carbon Capture and Storage project) in Illinois. The overall permitting process to-date has a high degree of variability.

Groundwater Protection, Determination of Lowermost USDW

Groundwater protection is addressed by the Safe Drinking Water Act and is regulated through the US EPA's Underground Injection Control (UIC) program. Protection of underground sources of drinking water (USDWs), in the context of CO_2 injection for geological storage, is achieved by geological characterization and validation of the storage complex site reservoir and seal integrity, and through successful UIC Class VI well permitting and proper injection well construction (Korose et al., 2018). Of primary importance to the development of a UIC Class VI permit application is the identification of the lowermost underground source of drinking water (LUSDW) to inform modeling and delineation of the Area of Review (AoR).

Per the US EPA, a USDW is an aquifer in whole or part that supplies (or may supply) a public water system or contains fewer than 10,000 milligrams/liter of Total Dissolved Solids (TDS; EPA, 2021). Based on regional salinity data and calculations from the Wabash #1 well, a conservative determination of the LUSDW in the vicinity of the WVR site is the Silurian-Devonian Carbonate-Rock Aquifer. A summary of the LUSDW assessment for the area surrounding the WVR site is presented below:

Regional Silurian-Devonian salinity data

Schnoebelen et al. (1998) examined the 10,000 mg/L total dissolved solids boundary in the Silurian and Devonian Carbonate-Rock Aquifer in western and southwestern Indiana using: 1) analysis of available water quality data, and 2) calculation of dissolved-solid concentration from available borehole geophysical log data. Silurian-Devonian salinity data compiled from a joint regional USGS/IGWS analysis are presented in Schnoebelen et al. (1998 – Table 1 p. 8-12) and displayed in map view in Figure 1. The 10,000 mg/L dissolved solids boundary line has been mapped for the Silurian-Devonian aquifer through an area including Vigo, Vermilion, and Parke Counties (Figure 1). The Silurian-Devonian carbonate bedrock aquifer is expected to be the lowermost USDW through the area and overlies the Maquoketa Group confining unit.

Regional St. Peter Sandstone salinity data

Below the Maquoketa Group, the St. Peter Sandstone is not expected to be a USDW in southwestern Vermilion and northwestern Vigo Counties. The nearest brine samples from wells that penetrated the St. Peter are in an adjacent county to the west (Clark County, Illinois) and were measured for ion concentrations (Meents, 1952). Converting chloride concentration into salinity, the resulting salinities for the two samples were 20,800 and 125,000 mg/L TDS.

Panno et al. (2018) developed an IL Basin-wide contour map of chloride concentration for the St Peter Sandstone based on available brine data (Figure 2). The authors developed Equations 9 and 10 (as numbered in Panno et al. 2018) to convert TDS concentrations to Cl^- concentrations for samples with TDS concentrations less than and greater than or equal to 5000 mg/L, respectively:

$$< 5000\ mg/L:\ Cl^- = 0.0022 \times TDS^{1.5328} \qquad (R^2 = 0.895) \qquad \text{Eq. 9}$$

$$\geq 5000\ mg/L:\ Cl^- = 0.637 \times TDS \qquad (R^2 = 0.989) \qquad \text{Eq. 10}$$

Based on the chloride concentration mapping contours (Figure 2) and accompanying cross section (Figure 3), the St. Peter Sandstone salinity trend for the area in southwestern Vermilion and northwestern Vigo Counties is expected to be greater than the 10,000 mg/L TDS USDW threshold, and increase with depth through the underlying Cambrian-Ordovician rock units.

Salinity sample and calculations from the Wabash #1 well

The most reliable determination of formation salinity is through chemical analysis of fluid samples; however, no samples exist from the Wabash #1 well for the shallower Silurian-Devonian formations and for the St. Peter Sandstone (Ordovician).

A swab sample from the Cambrian Potosi Dolomite, which underlies the St. Peter Sandstone, in the Wabash #1 well was analyzed to be 34,250 mg/L TDS (Khosravi et al., 2022).

Based on estimates using resistivity logs from the Wabash #1 well (Damico et al., 2021), the salinity for the Devonian ranges from 6,400 to 6,450 ppm and salinity for the Silurian ranges from 46,800 to 50,700 ppm.

For the St. Peter Sandstone, using a spontaneous potential (SP) log-based calculation method indicated a salinity of 16,800 to 17,800 ppm; however, when using resistivity calculations, the estimated salinity in the St. Peter Sandstone was significantly greater. Although resistivity tools are generally considered more reliable, the low porosity of the St. Peter Sandstone in the Wabash #1 well may affect the accuracy of the resistivity-based calculations (Crain and Ganz, 1986), resulting in the increased salinity values.

There is a large variation in the results depending on the log-based calculation method employed (using resistivity or SP logs), which underscores the need for direct sampling. Yet, the log-based estimates help support the regional trends that project a salinity of greater than 10,000 ppm TDS through the area for the St. Peter Sandstone which lies below the lowermost USDW determination in the Silurian-Devonian carbonate aquifer.

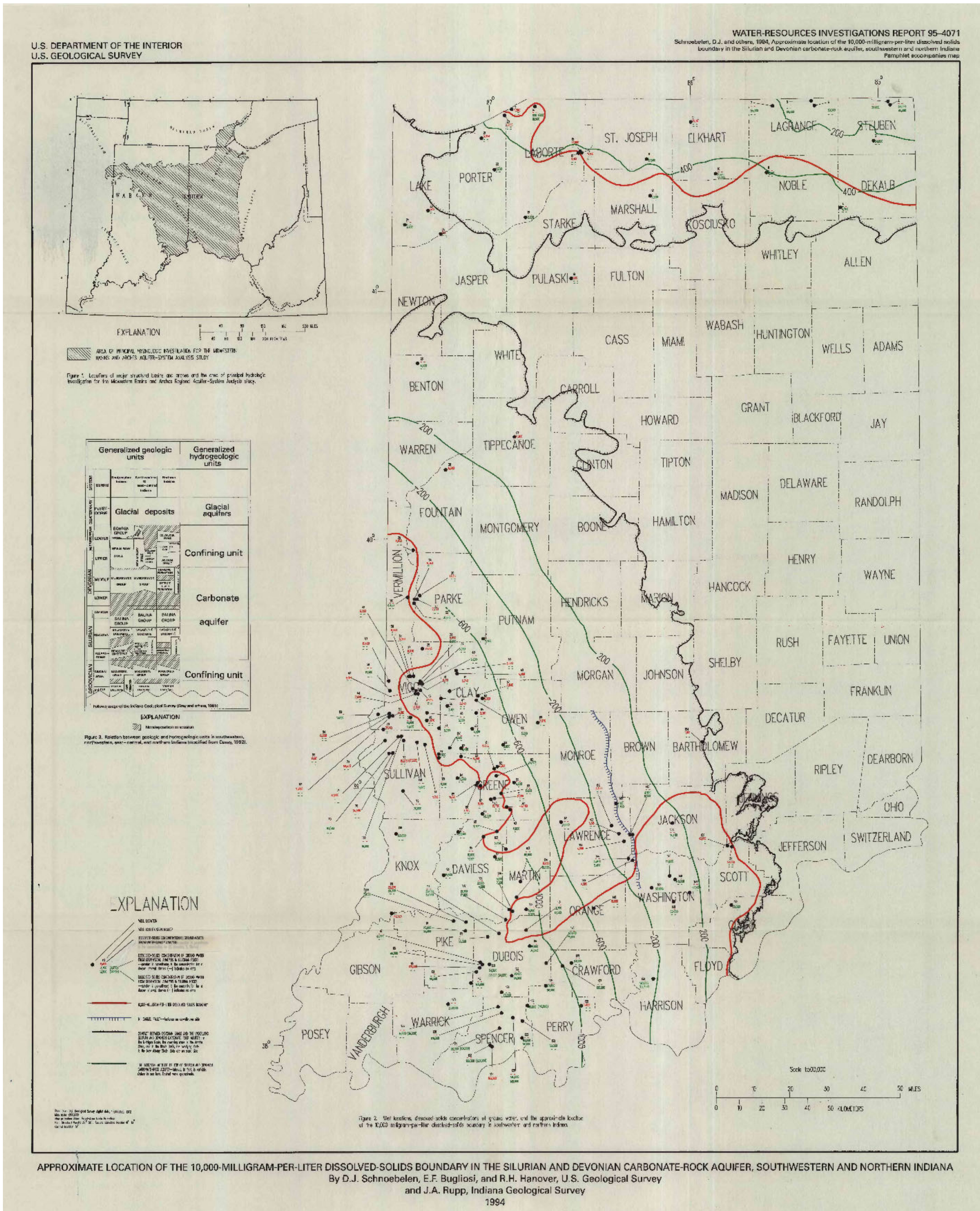

Figure 1. *Location of the 10,000 mg/L dissolved solids boundary in the Silurian and Devonian carbonate aquifer systems (Schnoebelen et al. 1998).*

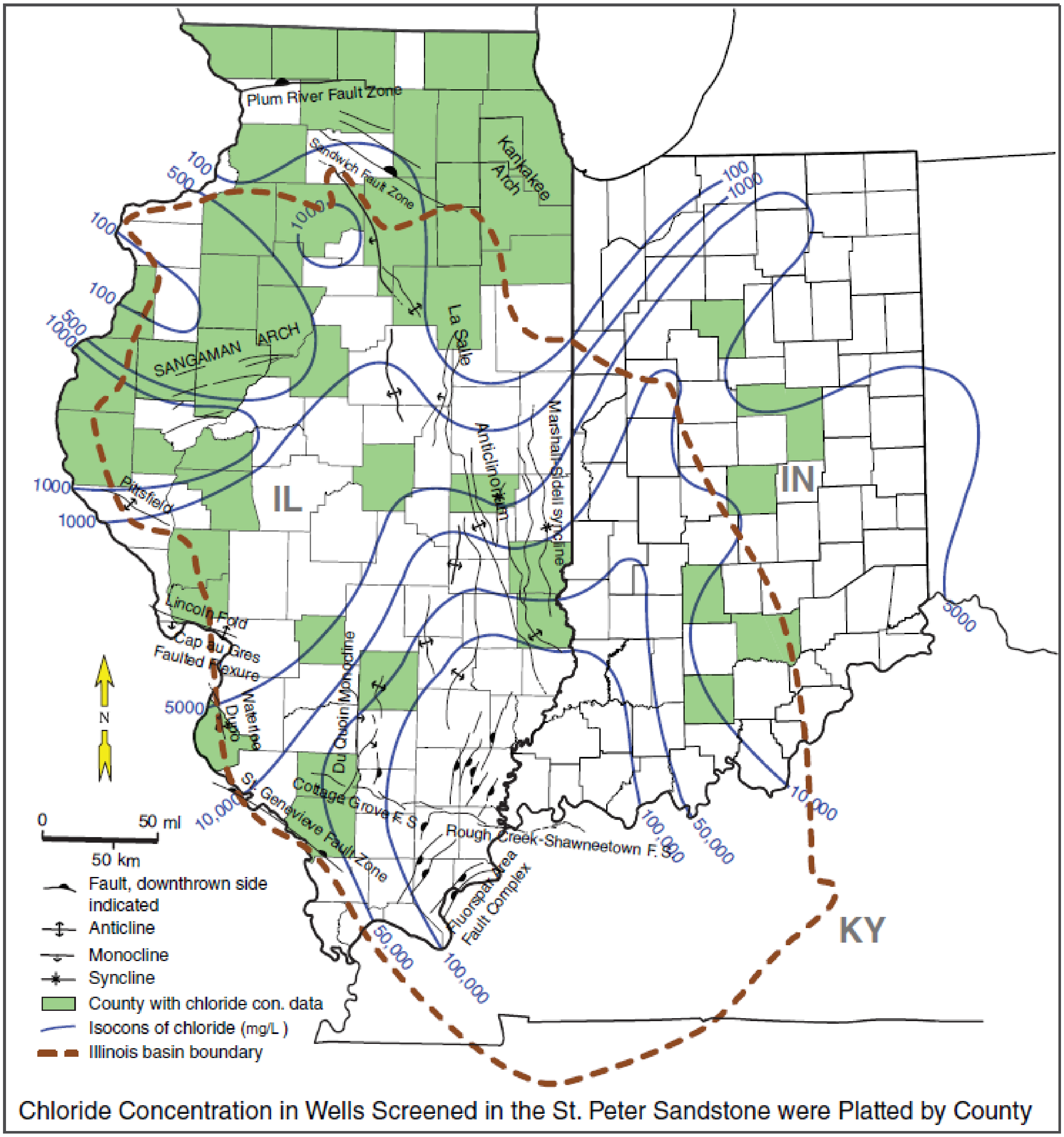

***Figure 2**. Chloride isocons in groundwater for the St. Peter Sandstone. Water quality data are from groundwater samples from wells screened in the St. Peter Sandstone. All concentrations are from published data and were plotted by county (Panno et al. 2018). (The relationship for chloride concentration to TDS concentration is presented above in Equations 9 and 10; for example: the 10,000 mg/L chloride isocon in the map equates to 15,699 mg/L total dissolved solids).*

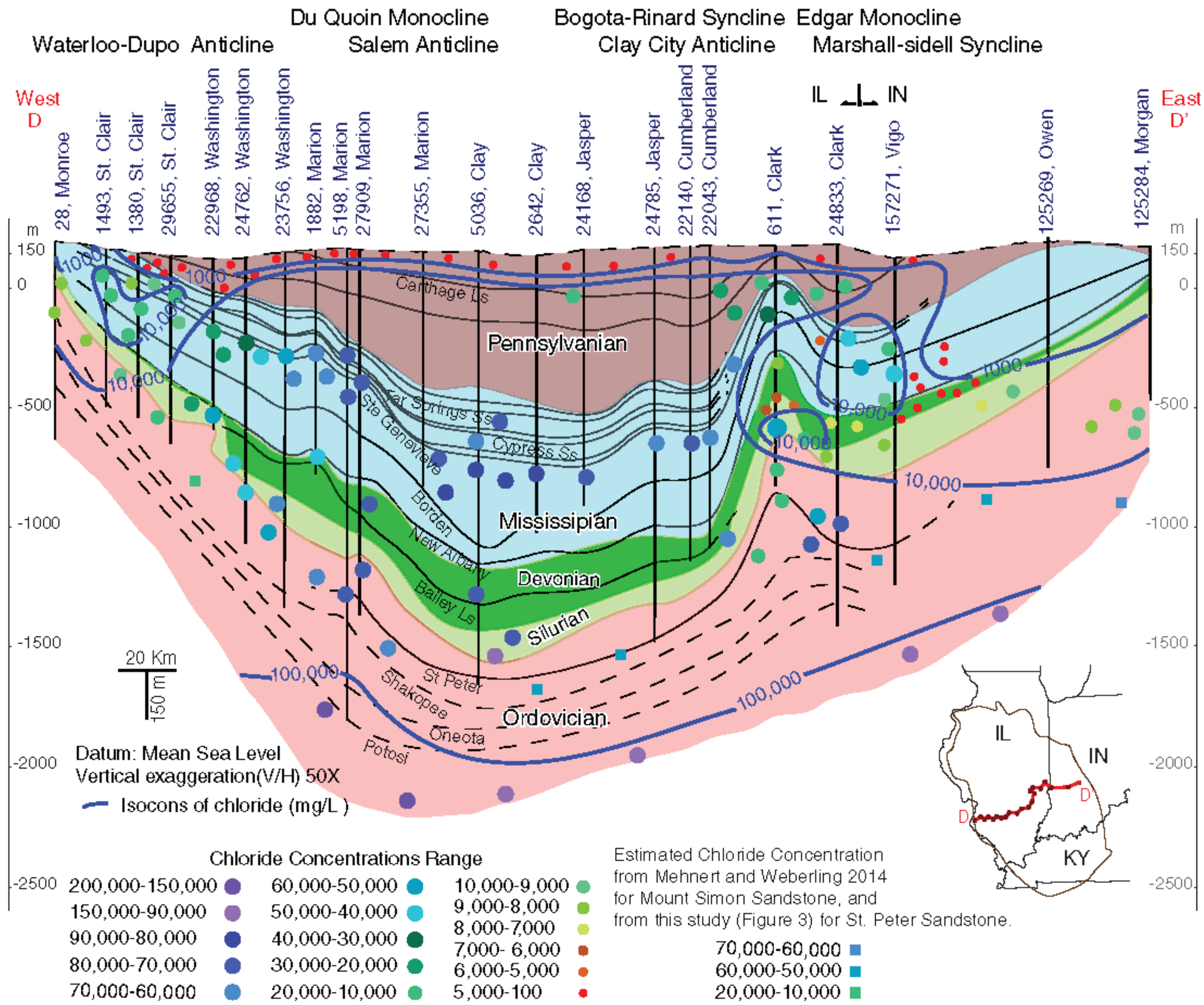

Figure 3. *Cross section D-D' extending east-west across southern Illinois and southern Indiana, showing general chloride (Cl−) concentration in Illinois Basin aquifers (Panno et al. 2018).*

US EPA Class VI UIC Permitting Timelines and Requirements

A UIC permitting plan has been developed (see Appendix) which provides a general outline of tasks, timelines, and information needed to prepare a US EPA Class VI permit application for a storage site in the Wabash CarbonSAFE study area.

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APPENDIX: UIC CLASSS VI PERMIT PLAN

Wabash CarbonSAFE

UIC Class VI Permit Plan

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Report Issued: January 31, 2022

Work Performed Under
U.S. DOE Cooperative Agreement Number: DE-FE0031626

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Disclaimer

INTRODUCTION

The Wabash CarbonSAFE project has established the feasibility of developing a commercial-scale geological storage complex at the Wabash Valley Resources (WVR) hydrogen production facility near Terre Haute, Vigo County, Indiana, (Figure 1) for storage of 50 million tonnes or more of carbon dioxide (CO_2).

The primary source of CO_2 for this project, the WVR Integrated Gasification Combined Cycle (IGCC) facility, and former power plant, is now being retrofitted and converted into a hydrogen production facility that will capture, compress, and inject up to 2 million tons of CO_2 annually. This is the first hydrogen production facility in the United States to implement carbon capture and storage (CCS) technology. With the goal of net-zero carbon emissions, WVR is focused on producing a clean hydrogen fuel, generating up to 300MW of electricity using a hydrogen power block, and sequestering the greenhouse gas emissions in geologic formations (Koenig, 2021).

The Wabash CarbonSAFE project drilled the Wabash #1 stratigraphic test well (ID# 168045) at the WVR facility location to evaluate the feasibility of commercial-scale CO_2 storage near the site. After the Mt. Simon Sandstone (initial target) was found to have generally poor reservoir qualities, the Potosi Dolomite and confining units were evaluated using lithologic and geophysical data, geomechanical analysis of core samples collected from confining units, and well testing and fluid sampling within the Potosi Dolomite reservoir interval.

Regionally, deep wells drilled throughout the Illinois Basin have demonstrated the Potosi's lost circulation zone and excellent reservoir properties; the Potosi Dolomite, along with other formations within the Knox Group, has been used for liquid chemical waste disposal wells at Tuscola, IL since the 1970s (Leetaru et al., 2014). Local 2D seismic reflection data indicate that there are no faults penetrating the Potosi Dolomite reservoir or confining zones within the study area. More regionally, approximately 35 miles of 2D seismic information has been acquired to aid in evaluating reservoir and caprock continuity.

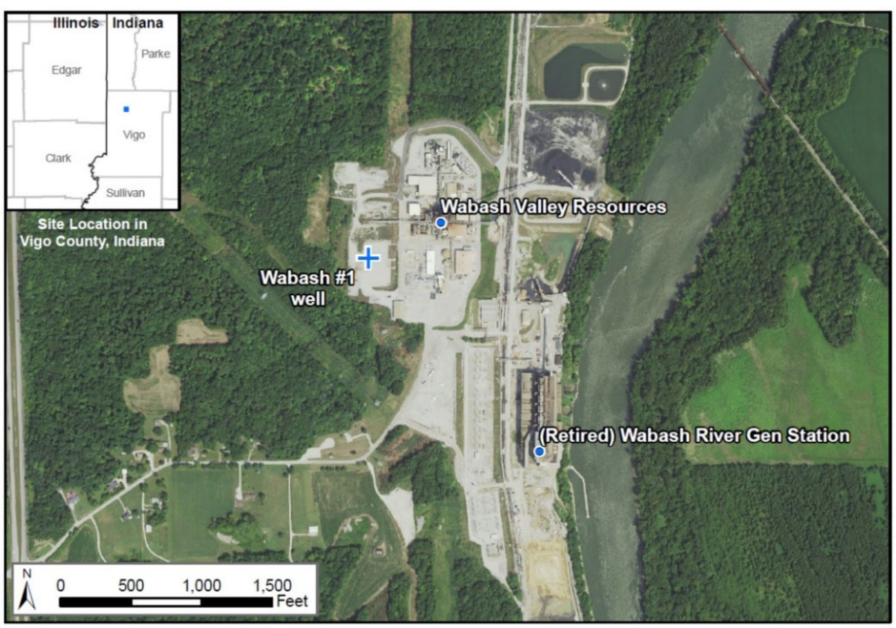

Figure 4. Wabash Valley Resources plant site and location of the Wabash #1 stratigraphic test well.

The Wabash #1 characterization well, now plugged and abandoned, serves as a basis for the development of models to evaluate the commercial potential of storage using the Potosi Dolomite – Maquoketa Group as a storage complex. The Silurian-Devonian carbonate bedrock aquifer is expected to be the lowermost underground source of drinking water (USDW) and overlies the Maquoketa Group confining unit near the WVR site.

Reservoir simulations were performed to assess CO_2 injectivity, plume radius and pressure distribution as a function of time for a single injection well scenario using the Wabash #1 static Potosi Dolomite reservoir model. For the scenario of injecting 50 million tonnes (Mt) over 30 years (1.67 million tonnes annually [Mta]), the predicted maximum CO_2 plume radius was 3.8 miles at the end of injection (Figure 2). A 50-year post-injection period showed no further lateral migration of CO_2, while upward movement of CO_2 was restricted to the lower Oneota Dolomite.

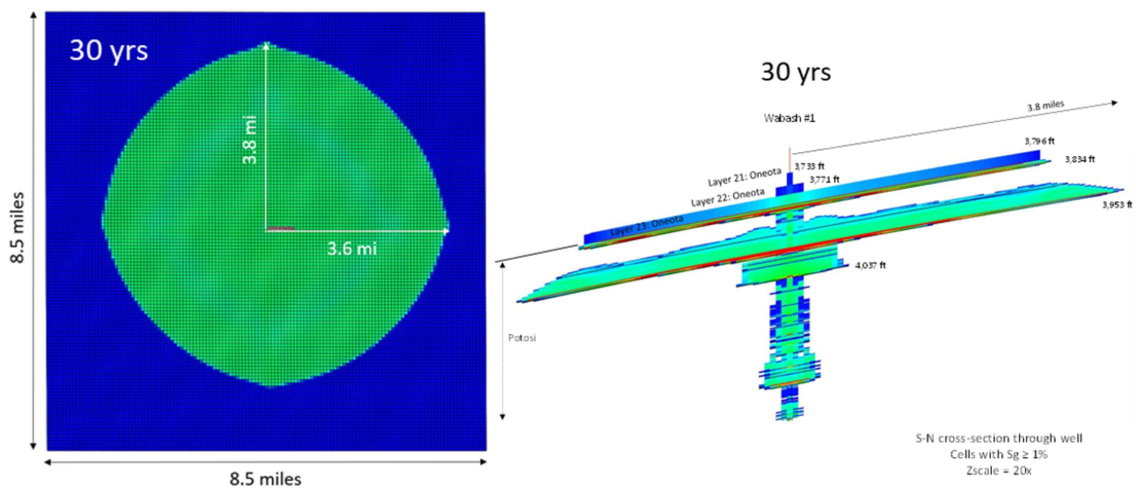

Figure 2. Map view (left) and cross-sectional view (right) of CO_2 plume after 30 years of injection (1.67 million tonnes annually). The predicted areal extent of CO_2 at the end of the injection period is indicated by green pixels (left) and colored pixels (right).

In general, for development of Class VI permits under the US EPA Underground Injection Control (UIC) guidelines, the results of the reservoir modeling for the site can be used to estimate the Area of Review (AoR) and initiate development of the UIC permit application. AoR is considered as the region encompassing the CO_2 storage site where particular attention must be paid to USDW protection. Supporting documentation is required to accompany a UIC permit application to demonstrate that the injection zone is of sufficient capacity, and the confining zone is of sufficient thickness and integrity, for the site to permanently store the CO_2 in a manner that is protective of USDWs.

A UIC application should be based on regional and site-specific data typically derived from a stratigraphic well drilled specifically in support of the UIC application. The well data will be used as input to numerical models which will serve to delineate the projected AoR and to optimize the storage site design. The DOE (Department of Energy) NETL (National Energy Technology Laboratory) Best Practices Manual for CO_2 storage provides significant guidance and reference information for permit preparation (https://netl.doe.gov/sites/default/files/2019-02/BPM_Operations_GeologicStorageClassification.pdf)

PERMITTING TASKS, MILESTONES, AND TIMELINE

Pre-Permitting Activities

This UIC permitting plan provides a general outline of tasks, timelines, and information needed to prepare a US EPA Class VI permit application for a storage site in the Wabash CarbonSAFE study area. A potential Class VI CO_2 injection well permit for the Wabash CarbonSAFE study site would be obtained through the US EPA Region 5, because the State of Indiana does not have UIC Class VI primacy. Meetings with regulators should be held as needed to review requirements for a Class VI permit as set forth in 40 CFR 146.82(a) and to review and concur on submittal requirements (e.g., electronic submittal formats). These meetings should provide information to the regulatory agency on site characterization, methods to establish AoR, modeling, well construction, financial requirements, risks, communication and outreach, and permit schedule.

UIC Class VI Permit Application

The permit applications must be prepared in accordance with Class VI guidance (described more fully in the following sections). Adhering to the regulatory guidance assures that required technical and administrative aspects of the project are addressed, and that documentation is complete. Key sections of the permits include: Site Characterization, AoR and Corrective Action, Financial Responsibility, Injection Well Construction, Pre-Operational Testing, Proposed Operating Conditions, Testing and Monitoring Plans, Injection Well Plugging, Post-Injection Site Care (PISC) and Site Closure, Emergency and Remedial Response, Demonstration of Containment, Public Participation, CO_2 source and chemical makeup of CO_2 Stream.

Permit Application Revisions

The project proponent must also be prepared to respond to technical questions and comments from US EPA. The permit applicant will also respond to questions and comments from the public received during the public review period. The permit application will be revised as needed and resubmitted to US EPA. Upon approval, the permit applicants will receive a "*Permit to Construct Class VI Underground Injection Well*".

General Timeline

There are several critical path elements that must be completed to develop the UIC permit application submittals (Figure 3). These include timely drilling and completion of a stratigraphic test well along with other testing and analysis to support site characterization, a site characterization report, and development of geologic and hydrogeologic models. Interim modeling results will be used to develop permit application components (preliminary AoR, monitoring planning, injection scenarios and conditions, injection well design, etc.).

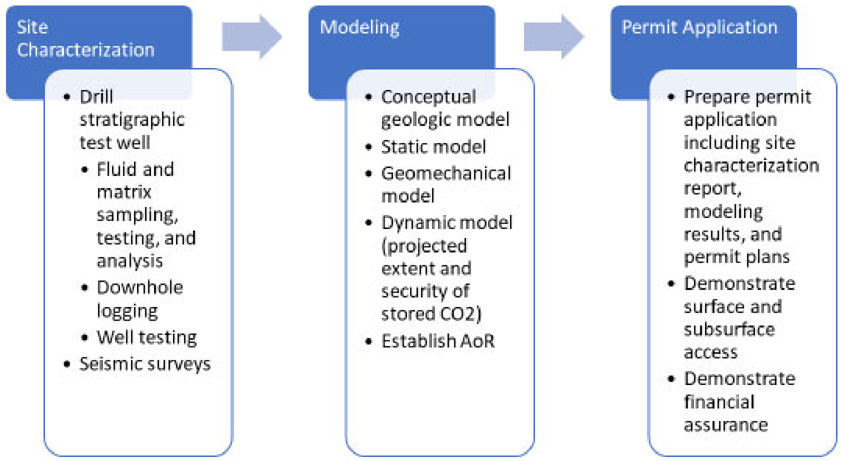

Figure 3. Site characterization and modeling needs in support of Class VI UIC permit application.

Portions of the permit application can be completed using preliminary site modeling as described above and with minimal technical input. These include the Emergency Response Plan, Post-Injection Site Care Plan, and Financial Responsibility sections.

COMPONENTS OF PERMIT APPLICATIONS

The Class VI Permit Applications will include six key components:

1. General administrative project and contact information— Facility name, location, mailing address, etc.; operators' contact information; a brief summary of the proposed permitted activities, CO_2 source, quantity, etc.; and list of contacts for states, tribes and territories within the AoR.

2. Site Characterization Data—Fluid chemistry, geologic, and depth data on both the injection and confining zones and information on all USDWs in the area (https://www.epa.gov/sites/production/files/2015-07/documents/epa816r13004.pdf).

3. Map(s)—showing the planned injection well location and preliminary AoR; location of the AoR boundary and all known artificial penetrations (wells, boreholes) that breach the injection or confining zones; known or suspected faults and fractures in the AoR; and other surface features such as waste site locations (landfills, cleanup sites), surface water features, springs, drinking water wells, mines, quarries, roads, buildings, property and political boundaries like townships, counties and state lines. Non-public site-specific data, such as information from the stratigraphic test wells and seismic surveys, will be included in the permit records and noted on the AoR map.

4. Tabulations—Wells in the AoR that penetrate the confining zone and/or the injection zone; location of wells on the AoR map including well record ID numbers; location (latitude/longitude); well type (oil gas, test); depth; deepest formation penetrated; completion date; current status (active, inactive, plugged or unknown); and information about whether the well is in need of corrective action.
5. Project Plans that will eventually become a part of the permit to drill and operate the well (see following section).
6. Provision for financial responsibility—Requirements established in 40 CFR 146.85 and in US EPA guidance. (https://www.epa.gov/sites/production/files/2015-07/documents/uicclass6reasearchandanalysisupdatedpg84.pdf)

Additional discussion and details in the permit applications include well construction (https://www.epa.gov/sites/production/files/2015-07/documents/epa816r11020.pdf), proposed operating conditions, proposed well stimulation, and steps for conducting the injection operations. A summary of the formation testing program will also be provided.

PROJECT PLANS

Each permit application will include five project plans as described in US EPA general project plan development guidance (https://www.epa.gov/sites/production/files/2015-07/documents/epa816r11017.pdf). These plans include:

- **AoR and Corrective Action Plan**—Describes how the owner or operator intends to delineate the AoR for the Class VI injection well and ensure that all identified deficient artificial penetrations (wells that are improperly plugged or completed) will be addressed by corrective action techniques so that they will not become conduits for fluid movement into USDWs (https://www.epa.gov/sites/production/files/2015-07/documents/epa816r13005.pdf).
- **Testing and Monitoring Plan**—Describes how the owner or operator intends to perform all necessary testing and monitoring associated with the storage project, including injectate monitoring, performance of mechanical integrity tests (MITs), corrosion monitoring, tracking of CO_2 plume and area of elevated pressure, monitoring of geochemical changes above the confining zone, and--at the discretion of the UIC Program Director--surface, air, and/or soil gas monitoring for CO_2 fluctuations and any additional tests necessary to ensure USDW protection from endangerment (https://www.epa.gov/sites/production/files/2015-07/documents/epa816r13001.pdf).
- **Injection Well Plugging Plan**—Describes how, following cessation of injection, the owner or operator intends to plug the Class VI injection well using the appropriate materials and methods to ensure that the well will not become a conduit for fluid movement into USDWs in the future. Information on plugging monitoring wells is provided in the UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance and the EPA Region V's "Guidance on Plugging and Abandoning

Injection Wells,": (https://www.epa.gov/sites/production/files/2016-12/documents/uic_program_class_vi_well_plugging_post-injection_site_care_and_site_closure_guidance.pdf).

- **Post-Injection Site Care (PISC) and Site Closure Plan**— Describes how the owner or operator intends to monitor the site after injection has ceased, to ensure that the CO_2 plume and pressure front are moving as predicted and USDWs are not endangered. PISC monitoring must continue until it can be demonstrated that the site poses no further endangerment to USDWs. (The default duration for PISC, as stated in the 40 CFR 146.91(c) is 50 years). (https://www.epa.gov/sites/production/files/2016-12/documents/uic_program_class_vi_well_plugging_post-injection_site_care_and_site_closure_guidance.pdf).
- **Emergency and Remedial Response Plan**—Describes the actions that the owner or operator intends to take in the event of movement of the injectate or formation fluids in a manner that may cause danger to a USDW, including the appropriate people to contact.

The Geologic Sequestration Data Tool (GSDT) can assist the UIC Program in organizing and retaining the large volume of material related to permit application reviews and subsequent project oversight activities. The EPA developed the GSDT to:

- Facilitate compliance with the electronic reporting requirement of the Class VI Rule at 40 CFR 146.91(e), providing reporting modules by which permit applicants/owners or operators can submit required information in an approved electronic format, and
- Support permitting authorities in tracking and managing submissions associated with Class VI reporting, including support for evaluation and oversight activities over the duration of a Class VI project.

US EPA (permitting authority), and other team members (as needed), will have access to the GSDT, which allows them access to submitted materials. US EPA will have full access and will use the GSDT to support technical evaluations (including AoR delineation modeling), manage communications with owners or operators, and store all information related to the projects. The GSDT allows permitting authorities to review and manipulate information while preserving the integrity of the original submitted data. Permitting authority users are limited to read-only access unless they are assigned to a particular project; however, no users can modify the original, time-stamped files submitted by owners or operators.

Data management for the project and compliance with the GSDT is described in "Underground Injection Control (UIC) Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance for Owners and Operators" (https://www.epa.gov/sites/production/files/2016-09/documents/rrdm_guidance_for_operators_final_2016.pdf).

PERMIT APPLICATION OUTLINE

Permit applications at each site will follow a similar organization and format. Based on the program guidance, supporting material for the permit application submittal is outlined as follows:

- 1.0 Introduction
  - 1.1 Project Overview
  - 1.2 Required Administrative Information
- 2.0 Geology
  - 2.1 Geology
  - 2.2 Regional Geology
  - 2.3 Major Stratigraphic Units
  - 2.4 Site Geology
  - 2.5 Injection Zone Water Chemistry
  - 2.6 Geologic Structure
    - 2.6.1 Site Geologic Structure
    - 2.6.2 Geomechanical Information
    - 2.6.3 Karst
    - 2.6.4 Local Crustal Stress Conditions
    - 2.6.5 Elastic Moduli and Fracture Gradient
    - 2.6.6 Seismic History of Region
  - 2.7 Regional Topography and Geomorphology
  - 2.8 Site Surface Topography
- 3.0 Hydrogeology
  - 3.1 Groundwater
  - 3.2 USDWs
  - 3.3 Deep Groundwater zones (e.g., injection formation, non-USDWs above injection zone)
  - 3.4 Wells Within the Survey Area
- 4.0 Area of Review and Corrective Action Plan
  - 4.1 Area of Review
    - 4.1.1 Description of Simulator
    - 4.1.2 Conceptual Model of AoR
    - 4.1.3 Numerical Model Implementation
    - 4.1.4 Representative Case Scenario Description
    - 4.1.5 Computational Model Results
    - 4.1.6 Method for Delineating the AoR from Model Results
    - 4.1.7 Delineation of the AoR
    - 4.1.8 Periodic Reevaluation of AoR
    - 4.1.9 Parameter Sensitivity and Uncertainty
  - 4.2 Corrective Action
    - 4.2.1 Identification of Primary Confining Zone Penetrations
    - 4.2.2 Corrective Actions
- 5.0 Construction and Operations Plan
  - 5.1 Operating Data
    - 5.1.1 Source of CO_2

        - 5.1.2 Chemical and Physical Characteristics of the CO_2 Stream
        - 5.1.3 Daily Rate and Volume and/or Mass and Total Anticipated Volume and/or Mass of the CO_2 Stream
        - 5.1.4 Pressure and Temperature of CO_2 Delivered to the Storage Site
    - 5.2 Well Design
        - 5.2.1 Average and Maximum Wellhead Injection Pressure
        - 5.2.2 Casing and Tubing Program
        - 5.2.3 Cementing Program
        - 5.2.4 Packer
        - 5.2.5 Annular Fluid
        - 5.2.6 Wellhead
        - 5.2.7 Perforation Plan
        - 5.2.8 Schematic of the Subsurface Construction Details of the Well
- 6.0 Financial Responsibility
    - 6.1 Financial Requirements Compliance Approach
    - 6.2 Injection construction, Maintenance, and Operations Cost Estimate
    - 6.3 Identification and Discussion of Financial Instrument(s)

Other plans will follow the project templates provided in the GSDT. Each plan will include information such as:

- Testing and Monitoring Plan
    - Pre-Operational Formation Testing
        - Wireline Logging
        - Coring and Testing
        - Mechanical Integrity Testing
        - Stimulation Program
    - Proposed Groundwater Monitoring Well Network
        - Monitoring Activities and Program Summary
        - Groundwater Quality and Geochemistry Monitoring
        - Injection Zone Monitoring
    - CO_2 Injection Process Monitoring
    - Injection Well Testing and Monitoring
        - Pressure Fall-Off Testing
        - Mechanical Integrity Testing During Service Life of Well
        - Well Annulus Pressure Maintenance and Monitoring System
        - Injection Well Control and Alarm System
        - Monitoring, Verification, and Accounting
    - Testing and Monitoring Schedule
    - Monitoring Data Management
    - Testing and Monitoring Plan Maintenance
    - Quality Assurance and Surveillance Plan
- Injection Well Plugging Plan
    - Injection Well Tests
    - Tests or Measures for Determining Bottom-Hole Reservoir Pressure
    - Injection Well Testing to Ensure External Mechanical Integrity

        - Plugging Plan
- Post-Injection Site Care and Site Closure Plan
    - Computational Modeling for the Post-Injection Period
        - Pressure Differential
        - Predictions of CO_2 Migration During the Post-Injection Site Care Period
        - Predicted Extent of the CO_2 Plume at Site Closure
    - Post-Injection Monitoring Plan
        - Groundwater-Quality Monitoring
        - Carbon Dioxide Storage Zone and Pressure Monitoring
        - Seismic Methods for CO_2 Plume Tracking
        - Post-Injection Monitoring Locations, Methods, and Reporting Schedule
        - Monitoring Plan Review and Maintenance
    - Site Closure Plan
        - Surface Equipment Decommissioning
        - Monitoring Well Plugging
        - Site Restoration/Remedial Activities
        - Site Closure Reporting
- Class VI Emergency and Remedial Response Plan
    - Identification of Potential Adverse Events
    - Resources or Infrastructure Potentially Affected
    - Emergency and Remedial Response Actions to Protect USDWs
    - Amending the Emergency and Remedial Response Plan
    - Staff Training and Exercise Procedures
    - Emergency Contacts
    - Communications with Adjacent Landowners and Emergency Response Personnel
    - Communications Plan and Emergency Notification Procedures

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