Class VI Injection Well Application

Contains proprietary business information.

Attachment 08: Post-injection Site Care and Site Closure Plan

40 CFR 146.93(a)

Beargrass Project
Wabash County, Indiana

26 July 2024

Project Information

Project Name: Beargrass

Project Operator: Vault GSL CCS Holdings LP

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Beargrass Project Injection Well 1 (PNM INJ1) Location:
Wabash County, Indiana
Latitude: 40.94407° N
Longitude: -85.77952° W

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List of Acronyms

2D	two-dimensional
3D	three-dimensional
ACZ	above confining zone
AoR	Area of Review
BHFP	bottomhole flowing pressure
BHP	bottomhole pressure
CO_2	carbon dioxide
DIC	Dissolved Inorganic Carbon
EPA	Environmental Protection Agency
MD	measured depth
MIT	Mechanical Integrity Test
NRMS	Normalized Root Mean Square
OES	Optical Emission Spectrometry
P&A	plug and abandon
PBI	proprietary business information
PISC	Post Injection Site Care and Site Closure
PNL	Pulsed Neutron Logging
PNM ACZ1	Beargrass Project Above Confining Zone Monitoring Well 1
PNM INJ1	Beargrass Project Injection Well 1
PNM OBS1	Beargrass Project Deep Observation Well 1
PNM USDW1	Beargrass Project USDW Monitoring Well 1
psi	pounds per square inch
Q1	first quarter
QASP	Quality Assurance and Surveillance Plan
TBD	to be determined
TDS	Total Dissolved Solids
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water

This Post-injection Site Care and Site Closure (PISC) Plan describes the activities that Vault GSL CCS Holdings LP will perform at the project site to meet requirements of 40 CFR 146.93. Due to the current absence of site-specific data, Vault GSL CCS Holdings LP is not proposing an alternative PISC timeframe. The position of the subsurface carbon dioxide (CO_2) plume, pressure front, and aqueous geochemistry of the shallow groundwater will be monitored for portions of the 50-year PISC period. Vault GSL CCS Holdings LP may not cease post-injection monitoring until a demonstration of non-endangerment of USDWs has been approved by the Underground Injection Control (UIC) Program Director pursuant to 40 CFR 146.93(b)(3). Following approval to abandon the project wells, Vault GSL CCS Holdings LP will plug all monitoring wells, restore the site to its original condition, and submit the proper plugging and abandonment documentation. Following approval for site closure, Vault GSL Holdings LP will conclude all monitoring activities and submit a site closure report and associated documentation.

1. Pre- and Post-injection Pressure Differential [40 CFR 146.93(a)(2)(i)]

Claimed as PBI

[redacted]

2. Predicted Position of the CO_2 Plume and Associated Pressure Front at Site Closure [40 CFR 146.93(a)(2)(ii)]

Figure 1 shows the predicted pressure front at the end of 12 years and the extent of the CO_2 plume 50 years after injection has stopped. This figure represents the maximum extent of the pressure front and maximum extent of the CO_2 plume and is based on the AoR delineation modeling results submitted pursuant to 40 CFR 146.84.

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3. Post-injection Monitoring Plan [40 CFR 146.93(b)(1)]

The PISC monitoring plan for the Beargrass Project site includes shallow groundwater, above confining zone (ACZ), injection zone, and geophysical monitoring to meet the post-injection monitoring requirements of 40 CFR 146.93(b)(1). The results of PISC monitoring will be submitted annually, within thirty days of the conclusion of the activities or receipt of processed data, whichever is later, as described in Section 3.3 Schedule for Submitting Post-injection Monitoring Results [40 CFR 146.93(a)(2)(iv)].

Claimed as PBI

[redacted]

Deep fluid samples will be taken from PNM ACZ1for geochemical analysis as a contingent action to verify CO_2 containment should other monitoring parameters indicate potential CO_2 leakage may have occurred above the confining zone. Note that no fluid samples can or will be collected after the ACZ well is plugged and abandoned. Shallow groundwater samples for geochemical analysis will be obtained from the shallow groundwater wells annually until the project wells (PNM INJ1, PNM OBS1, PNM ACZ1, and PNM USDW1) are plugged at which point they will be sampled every 5 years until the end of the PISC phase. Surface access to the shallow groundwater wells for testing will be negotiated as part of the landowner leases for the project.

Passive seismic monitoring will continue during the initial months of the PISC and will be phased out as pressure and the frequency of detectable events decreases. These criteria will be evaluated during the initial months of the PISC phase. The Underground Injection Control (UIC) Program Director will be consulted prior to ending any monitoring activities during the PISC phase of the project.

Claimed as PBI

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- Verification of CO_2 containment in the injection zone,
- Demonstration of increasing post-injection CO_2 plume stability,
- Input for calibration and verification of computational modeling.

The Quality Assurance and Surveillance Plan (QASP) for all testing and monitoring activities during the injection and post injection phases is provided in Attachment 10: Quality Assurance and Surveillance Plan, (2024). Table 1 summarizes the monitoring activities of the PISC phase of the Beargrass Project.

Claimed as PBI

[redacted]

3.1 Monitoring Above the Confining Zone

The monitoring plan for the PISC is designed to be adaptive and respond to evolving project risks over time. No changes will be made to the PISC without informing the UIC Program Director (40 CFR 146.93 (a)(3)).

Table 2 presents the proposed groundwater monitoring methods, locations, and frequencies. The ACZ monitoring zone will be in the Ironton-Galesville Sandstones at a depth to be determined through the Pre-operational Testing Program (Attachment 05: Pre-operational Testing Program, 2024). Formation fluid samples will be collected using a bailer system that maintains the formation pressure for analysis of dissolved inorganic carbon, alkalinity, and pH. Samples for all other analytes will be collected with an open-ended bailer. Prior to sample collection, stagnant water will be removed from the well and ensure representative water is collected from the formation. The fluid removed from the well will be monitored for field parameters, such as pH, specific conductance, and temperature, using a calibrated water quality meter. Once these parameters stabilize, it will be an indication that representative formation fluid is in the well at the time the sample is collected.

Further detail on specifications, sample collection methods, analytical techniques, detection limits, and means of storing and transporting fluid samples is provided in Attachment 10: Quality Assurance and Surveillance Plan, (2024).

Claimed as PBI

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Table 3 identifies the initial groundwater parameters to be monitored and the analytical methods that will be used for the samples in the baseline analysis of the data.

Table 3: Summary of analytical and field parameters for ground water samples

Parameters	Analytical Methods [1]
Cations: Ca, Fe, K, Mg, Na, Si	EPA 6010B
Cations: Al, Sb, As, Ba, Cd, Cr, Cu, Pb, Mn, Hg, Se, Tl	EPA 200.8, EPA 245.1
Anions: Br, Cl, F, NO_3, and SO_4	EPA 300.0
Alkalinity	SM 2320B
Total Dissolved Solids (TDS)	SM 2540C
Total Organic Carbon	SM 5310C
Dissolved Inorganic Carbon	SM 5310C
Total and Dissolved CO_2	ASTM D513-06B
Stable Isotopes of δ13C [2]	Isotope Ratio Mass Spectrometry [3]
pH	Field with multi-probe system
Conductivity/Resistivity	Field with multi-probe system
Temperature	Field with multi-probe system

[1] An equivalent method may be employed with the prior approval of the UIC Program Director.
[2] Isotope analysis is contingent.
[3] Gas evolution technique by Atekwana and Krishnamurthy, 1998 with modifications made by (Hackley et al., 2007)

All sampling and analytical measurements will be performed in accordance with project quality assurance requirements. A qualified laboratory will be selected for the fluid sampling and analysis. All samples will be tracked using appropriately formatted chain-of-custody forms as per Attachment 10: Quality Assurance and Surveillance Plan, (2024).

The results of the geochemical analysis will be delivered in the form of lab reports. If anomalous changes in the aqueous geochemistry are observed in lowermost USDW or shallow groundwater monitoring zones, new samples will be obtained from the affected zone to verify the changes. The frequency with which fluid samples are obtained for analysis from that zone will also be increased.

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Table 4: Sampling and recording frequencies for continuous monitoring in PNM ACZ1

Parameter	Device(s)	Location	Minimum Sampling [1] Frequency	Minimum Recording [2] Frequency
Pressure	Wellhead Pressure Gauge	PNM ACZ1	Continuous (every hour)	Continuous (every hour)
Pressure	Downhole Pressure Gauge	PNM ACZ1	Continuous (every hour)	Continuous (every hour)

[1] Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.

[2] Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

3.2 CO_2 Plume and Pressure Front Tracking [40 CFR 146.93(a)(2)(iii)]

The project will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure throughout the PISC phase. Table 5 presents the direct and indirect methods that will be used to monitor the CO_2 plume including the activities, locations, and frequency of sampling.

The quality assurance procedures for seismic monitoring methods will be performed as described in Attachment 10: Quality Assurance and Surveillance Plan, (2024).

Claimed as PBI

[redacted]

PNL will be received as LAS files and its interpreted products can be imported into the static model. PNL will be used to monitor the distribution and saturation of CO_2 adjacent to the wellbore in PNM INJ1 and PNM OBS1. The PNL will be run through the ACZ monitoring zone to verify that there are no accumulations of CO_2 adjacent to the wellbore above the confining zone in PNM INJ1 and PNM OBS1. Note that the intervals the PNL will be run in PNM INJ1 are the same as those listed in Attachment 06: Testing and Monitoring (2024). Technical details on PNL tools can be found in Attachment 10: Quality Assurance and Surveillance Plan, (2024).

Surface seismic data is delivered in a variety of formats including acquisition and processing reports and SEG-Y data files. In the context of time-lapse analysis, an assessment will be provided on the differences between the baseline and time-lapse surveys as well as data files that can be incorporated into the static model. The injection of CO_2 and expansion of the plume is expected to change the acoustic impedance of intervals within the Mt. Simon Sandstone and increase the time it takes seismic waves to travel through the CO_2 plume over time. Both the acoustic impedance and travel time changes will be used to track CO_2 plume during the PISC phase of the project. In addition, time-lapse analysis metrics such as normalized root mean square and predictability can be used to track the plume. The time-lapse surface seismic data will also be monitored for changes that may suggest that CO_2 has migrated past the confining layer and into the ACZ monitoring zone.

No direct fluid sampling is planned for the injection zone for the PISC phase of the project.

Table 6 presents the direct and indirect methods that will be used to monitor the pressure front.

Claimed as PBI

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Claimed as PBI

[redacted]

The final monitoring interval within the Mt. Simon Sandstone in PNM OBS1 will be determined after the well has been drilled and the well logs have been analyzed (Attachment 05: Pre-operational Testing Program, 2024).

The results of the aqueous geochemistry, PNL, and time-lapse surface seismic data will all be integrated to develop a comprehensive understanding of the CO_2 plume behavior during the PISC phase. PNL and time-lapse surface seismic data can be incorporated into the static model for comparison to the computational modeling predictions at different points in time. The data can be used to constrain the computational modeling results and produce better plume predictions over the course of the project.

The PNL data will be used to calibrate the computational modeling and provide information on the vertical and horizontal CO_2 plume behavior as well as supply more detailed and direct measurement of CO_2 saturations than indirect seismic methods. The time-lapse surface seismic data will be used to update the models after the data has been analyzed. If the CO_2 plume monitoring data diverges significantly from the modeled plume predictions, it may result in a reassessment of the AoR as per Attachment 02: AoR and Corrective Action Plan, (2024).

Based on the current computational modeling results, the CO_2 plume is expected to stabilize during the PISC phase of the project (Figure 2). Time-lapse surface seismic surveys acquired during the first quarter in Year 0 and Year 8 of the PISC phase of the project will demonstrate the stabilization of the CO_2 plume and be used to verify the computational modeling results.

3.3 Schedule for Submitting Post-injection Monitoring Results [40 CFR 146.93(a)(2)(iv)]

All PISC monitoring data and results obtained using the methods described above will be submitted to the Environmental Protection Agency (EPA) in annual reports. These reports will contain information and data generated during the reporting period (i.e., well-based monitoring data, sample analysis, and results from updated site models).

4. Alternative PISC Timeframe [40 CFR 146.93(c)]

Due to the absence of applicable site-specific data, Vault GSL CCS Holdings LP will not be requesting an alternative PISC timeframe.

5. Non-endangerment Demonstration Criteria

Prior to approval of the end of the post-injection phase, Vault GSL CCS Holdings LP will submit a demonstration of non-endangerment of USDWs to the UIC Program Director, per 40 CFR 146.93(b)(2) and (3).

Vault GSL CCS Holdings LP will issue a report to the UIC Program Director. This report will make a demonstration of USDW non-endangerment based on the evaluation of the site monitoring data used in conjunction with the project's computational model. The report will detail how the non-endangerment demonstration evaluation uses site-specific conditions to confirm and demonstrate non-endangerment. The report will include all relevant monitoring data and interpretations upon which the non-endangerment demonstration is based, model documentation and all supporting data, and any other information necessary for the UIC Program Director to review the analysis. The report will include the following sections.

5.1 Introduction and Overview

A summary of relevant background information will be provided, including the operational history of the injection project, the date of the non-endangerment demonstration relative to the post-injection period outlined in this PISC and Site Closure Plan, and a general overview of how monitoring and modeling results will be used together to support a demonstration of USDW non-endangerment.

5.2 Summary of Existing Monitoring Data

A summary of all previous monitoring data collected at the site, pursuant to Attachment 06: Testing and Monitoring (2024) and this document, including data collected during the injection and post-injection phases of the project, will be submitted to help demonstrate non-endangerment. Data submittals will be in a format acceptable to the UIC Program Director [40 CFR 146.91(e)] and will include a narrative explanation of monitoring activities, including the dates of all monitoring events, changes to the monitoring program over time, and an explanation of all monitoring infrastructure that has existed at the site. Data will be compared with baseline data collected during site characterization [40 CFR 146.82(a)(6) and 146.87(d)(3)].

5.3 Summary of Computational Modeling History

The computational modeling demonstrates non-endangerment of USDWs in several ways:

- Computational modeling indicates that the CO_2 plume expansion slows considerably once injection operations cease (Figure 2 and Figure 3)
- Injection zone pressures decline rapidly once injection operations cease and will fall below the delta pressure of [redacted] psi within approximately [redacted] years (Figure 4, Figure 5, and Figure 6),
- Residual gas, gas solubility, aqueous ions, and mineralization trapping of the CO_2 will increase with time and contribute to trapping the CO_2 more effectively than structural trapping alone (Attachment 02: AoR and Corrective Action Plan, 2024),
- Geomechanical modeling shows that integrity of the confining layer will not be impacted by planned injection rates and would be maintained at much higher annual injection rates (Attachment 01: Narrative, 2024).

Table 7 summarizes the monitoring data that will be used to verify and calibrate the computational modeling and support the demonstration of non-endangerment of USDWs.

[redacted]

The monitoring data will be compared predicted properties from the computational model such as vertical and horizontal CO_2 plume location, rate of movements, and pressure decline. These data will verify that the computational model predictions accurately represent CO_2 plume and pressure front behavior and can be used as a proxy for future behavior. The monitoring and modeling results will be compared using maps and graphs of the CO_2 and pressure front development over time. If there is major disagreement between monitoring and modeling results at the time of the demonstration, the models will be updated to reflect the monitoring results.

5.4 Evaluation of Reservoir Pressure

Claimed as PBI

[redacted]

If CO_2 injection operations result in induced seismicity, it is expected that the rate of the events generated will decrease as injection zone pressure decreases. The rates of induced seismicity will provide further qualitative information about the decrease in pressure throughout the injection zone during the PISC phase.

Increased pressure in the injection zone is one of the main drivers for fluid migration through the confining layer through conduits such as well penetrations. As the injection zone pressure decreases during the PISC phase so to will the risk of fluid migration out of the injection zone and the potential risk to USDWs.

5.5 Evaluation of CO_2 Plume

Claimed as PBI

[redacted]

5.6 Evaluation of Emergencies or Other Events

Table 8 provides a summary of the monitoring data that will be used to demonstrate that injection zone fluids have not migrated above the confining layer. Data acquired through the injection and PISC phases of the project will be compared to the baseline data gathered for the project to ensure that there are no indications that injection zone fluids have migrated into the

ACZ monitoring interval. If the PISC monitoring data shows no significant changes from the baseline data, it will demonstrate the integrity of the confining layer and that injection zone fluids are not an endangerment to USDWs.

Claimed as PBI [redacted]

The closest artificial penetration to the project wells in the injection and confining zones is the Hudson Well (API: 13-169-29024, IN29024) which penetrates the Eau Claire Shale and Mt. Simon Sandstone and is located approximately 1.5-miles to the west-southwest of the injection well (Attachment 02: AoR and Corrective Action Plan, 2024). The well was a dry hole that was drilled and abandoned in 1965. Claimed as PBI [redacted]

The well integrity of PNM INJ1 will be thoroughly assessed during the Pre-Operational Testing Program using Cement Bond Logs as well as ultrasonic cement evaluation tools that will be run specifically over the injection zone, confining layer, and ACZ monitoring interval (Attachment 05: Pre-operational Testing Program, 2024).

During the injection phase, the well integrity of PNM INJ1 will be continuously monitored using wellhead pressure gauges, and annular pressure, and annulus fluid volume levels for any indications of any problems (Attachment 06: Testing and Monitoring, 2024). Wellhead and downhole pressures will continue be monitored in PNM INJ1 during the PISC phase until the well is abandoned. The project will continue to run static temperature logs at a maximum of every five years and PNL logs every second year starting in Year 1 to ensure that PNM INJ1 and PNM OBS1 are not providing a conduit for injection zone fluids to migrate above the confining layer until the project wells are abandoned.

The Emergency and Remedial Response Plan includes further discussion of how emergencies or other events will be addressed by the project (Attachment 09: Emergency and Remedial Response Plan, 2024).

6. Site Closure Plan

Vault GSL CCS Holdings LP will conduct site closure activities to meet the requirements of 40 CFR 146.93(e) as described below. Vault GSL CCS Holdings LP will submit a final Site Closure Plan and notify the permitting agency at least 120 days prior to its intent to close the site. Once the permitting agency has approved closure of the site, Vault GSL CCS Holdings LP will plug the monitoring wells and submit a site closure report to EPA. The activities, as described below, represent the planned activities based on information provided to EPA. The actual site closure plan may employ different methods and procedures. A final Site Closure Plan will be submitted to the UIC Program Director for approval with the notification of the intent to close the site.

6.1 Plugging Monitoring Wells

As discussed in the Testing and Monitoring section of the application, the project will have dedicated monitoring wells (Attachment 06: Testing and Monitoring, 2024). The PNM OBS1 and PNM ACZ1 wells will be plugged as part of the site closure process.

This subsection serves to provide the methods and procedures that will be utilized to plug each of the wells. In addition to discussion of the proposed methodology and procedures, the schematics displaying the anticipated layout of the well following completion of operations to plug and abandon (P&A) have been provided. The cost estimates developed for these activities are provided in the Financial Assurance section of this application (Attachment 03: Financial Assurance Plan, 2024).

6.1.1 PNM OBS1 Plugging and Abandonment

The techniques used to P&A PNM OBS1 will be similar to those applied to the PNM INJ1 well as discussed in the Injection Well Plugging Plan (Attachment 07: Injection Well Plugging Plan, 2024). Similar to the injection well, CO_2 resistant cement will be placed from the bottom of the well to above the confining zone, and then normal cement will be placed above that.

Cement volumes are anticipated to be similar to those used for PNM INJ1, as PNM OBS1 will use similar sized tubulars. The cement volumes to be used to P&A the PNM OBS1 well will be finalized following the installation of the well. Figure 7 displays the proposed P&A schematic for PNM OBS1.

Claimed as PBI

[redacted]

6.1.2 PNM ACZ1 Plugging and Abandonment

The techniques used to P&A PNM ACZ1 will be similar to those applied to PNM OBS1 and PNM INJ1 (Attachment 07: Injection Well Plugging Plan, 2024). Normal cement will be placed from well bottom to surface.

Cement volumes are anticipated to be lower than those used for the injection well as PNM ACZ1 is a shallower well that uses smaller sized tubulars. The cement volumes to be used to P&A the PNM ACZ1 well will be finalized following the installation of the well. Figure 8 displays the P&A schematic for PNM ACZ1.

Claimed as PBI

[redacted]

6.2 Site Closure Report

In accordance with 40 CFR 146.93(f), a site closure report will be prepared and submitted within 90 days following site closure, documenting the information required by 40 CFR 146.93(f), as applicable, including but not limited to the following:

- Plugging of the monitoring wells as well as PNM INJ1 if it has not previously been plugged,
- Location of sealed PNM INJ1 on a plat of survey that has been submitted to the local zoning authority,
- Notifications to state and local authorities as required at 40 CFR 146.93(f)(2),
- Records regarding the nature, composition, and volume of the injected CO_2, and
- Post-injection monitoring records.

In accordance with 40 CFR 146.93(g), Vault GSL CCS Holdings LP will record in the real property records of the county where the project is located, notice of the property tracts integrated for the storage facility and proper notice of the PNM INJ1 well that will include the following:

- That the property was used for CO_2 sequestration,
- The name of the local, state, federal, etc. agencies to which a plat of survey with PNM INJ1 location was submitted,
- The volume of fluid injected,
- The formation into which the fluid was injected, and
- The period over which the injection occurred.

In accordance with 40 CFR 146.93(h), the site closure report will be submitted to the permitting agency (EPA) and maintained by the owner or operator for a period of ten years following site closure. Additionally, the owner or operator will maintain the records collected during the post-injection period for a period of ten years after which these records will be delivered to the UIC Program Director.

6.3 Quality Assurance and Surveillance Plan

The Quality Assurance and Surveillance Plan is presented in the QASP (Attachment 10: Quality Assurance and Surveillance Plan, 2024).

References

Atekwana, E. A., and R. V. Krishnamurthy, 1998, Seasonal variations of dissolved inorganic carbon and δ13C of surface waters: application of a modified gas evolution technique: Journal of Hydrology, v. 205, no. 3, p. 265–278, doi:10.1016/S0022-1694(98)00080-8.

Attachment 01: Narrative, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 02: AoR and Corrective Action Plan, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 03: Financial Assurance Plan, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 05: Pre-operational Testing Program, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 06: Testing and Monitoring, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 07: Injection Well Plugging Plan, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 09: Emergency and Remedial Response Plan, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Attachment 10: Quality Assurance and Surveillance Plan, 2024, Underground Injection Control Class VI Permit Application: Beargrass Project.

Hackley, K., S. Panno, H.-H. Hwang, and W. Kelly, 2007, Groundwater Quality of Springs and Wells of the Sinkhole plain in Southwestern Illinois: Determination of Dominant Sources of Nitrate: ISGS Circular, v. 570.