ATTACHMENT 1: CLASS VI PERMIT APPLICATION NARRATIVE 40 CFR 146.82(a)

HOOSIER #1 PROJECT

June 29, 2022

Several figures contained within this document contain Confidential Business Information (CBI) that is privileged and exempt from public disclosure – "Narrative without CBI". These images will be delivered to the United States (US) Environmental Protection Agency (EPA) in a separate document – "Narrative with CBI".

The figures listed below contain CBI and have been redacted from the publicly disclosed version of this document:

Figure 19: Confidential Business Information: 2D seismic lines two-way time (TWT) in a 3D view

Figure 20: Confidential Business Information: 2D surface seismic Line 1 EW

Figure 21: Confidential Business Information: 2D surface seismic Line 2 NS

Figure 22: Confidential Business Information: 2D surface seismic Line 3 short NS

Figure 31: Confidential Business Information: IN133540 input data and petrophysical analysis

Figure 32: Confidential Business Information: AK Steel input data and petrophysical analysis

Figure 33: Confidential Business Information: INEOS (BP Lima) Nitriles input data and petrophysical analysis

Figure 34: Confidential Business Information: IN144601 input data and petrophysical analysis

Figure 35: Confidential Business Information: Effective porosity and permeability cross plots with core plugs (grey)

Figure 52: Confidential Business Information: Feed Gas Composition Report From May 2021, Page 1.

Figure 53: Confidential Business Information: Feed Gas Composition Report From May 2021, Page 2.

Table 22. Confidential Business Information: Anticipated CO_2 Specifications

Table of Contents

List of Figures

List of Tables

Acronyms

2D	Two-dimensional
3D	Three-dimensional
ACZ	Above Confining Zone
ACZ1	Above Confining Zone Monitor Well
ALARP	As Low as Reasonably Possible
AoR	Area of Review
Avg	Average
CCS	Carbon Capture and Sequestration
CCS1	Proposed Injection Well
CI	Contour Interval
CO_2	Carbon Dioxide
CPO	Central Plains Orogenic Province
CWA	Clean Water Act
DGS	Division of Geological Survey
DOW	Division of Water
DST	Drill Stem Test
ECRB	East Continent Rift Basin
EGRP	Eastern Granite-Rhyolite Province
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response Plan
FEMA	Federal Emergency Management Agency
Fbsl	Feet Below Sea Level
Ft	Feet
GPM	Gallons Per Minute
GP	Grenville Province
GSDT	Geologic Sequestration Data Tool
h	Thickness
IDNR	Indiana Department of Natural Resources
IEc	Industrial Economics
IGWS	Indiana Geological and Water Survey
IGS	Indiana Geological Survey
JV	Joint Venture
k	Permeability
kt	metric kilotons
LAS	Log Ascii Standard
lbs	Pounds

LCZ	Lost Circulation Zone
LEPC	Local Emergency Planning Committee
mD	Millidarcy
MMT	Million Metric Tons
MMT/yr	Million Metric Tons per Year
MRS	Midcontinent Rift System
MSL	Mean Sea Level
NESHAPS	National Emission Standards for Hazardous Pollutants
NPDES	National Pollutant Discharge Elimination System
OBS1	Deep Observation Well
ODNR	Ohio Department of Natural Resources
OCP	One Carbon Partnership, LP
PISC	Post Injection Site Care and Site Closure
PSD	Prevention of Significant Deterioration
RA	Risk Assessment
RCRA	Resource Conservation and Recovery Act
RMP	Risk Management Plan
SDWA	Safe Drinking Water Act
SGRP/WGRP	Southern/Western Granite-Rhyolite Province
TBD	To Be Determined
TD	Total Depth
TDS	Total Dissolved Solids
TVD	True Vertical Depth
TWT	Two-way Time
UIC	Underground Injection Control
US	United States
USGS	United States Geological Survey
USDW	Underground Source of Drinking Water
USDW1	USDW monitoring well

Sensitive, Confidential, or Privileged Information

[redacted]

1 Project Background and Contact Information [40 CFR 146.82(a)(1)]

1.1 Project Contact Information

Project Name:	Hoosier #1
Facility Name:	Cardinal Ethanol
Facility Contact:	Jeremey Herlyn, Project Manager 866-559-6026 jeremeyherlyn@cardinalethanol.com
Well Location:	1554 N. 600 E. Union City, IN 47390 CCS1 Injection Well Location Latitude 40.186587° Longitude -84.864284°
Operator Name:	One Carbon Partnership, LP 1554 N. 600 E. Union City, IN 47390

1.2 Project Background

Vault 44.01 (Vault) and Cardinal Ethanol, LLC (Cardinal) have formed a joint venture (JV) to design, implement, and operate a successful commercial Class VI carbon dioxide (CO_2) sequestration project. The name of this JV is One Carbon Partnership, LP (OCP). The Cardinal plant is an ethanol production facility located in Randolph County, Indiana that began operations in 2008. Vault is a multi-national Carbon Capture and Sequestration (CCS) project development company.

Cardinal produces approximately 140 million gallons of ethanol per year. This ethanol is produced from the corn fermentation process. A natural byproduct of this process is CO_2. Cardinal produces approximately 420 metric kilotons (kt) of CO_2 per year, with an anticipated expanded volume of ethanol production that would equate to approximately 450 kt of CO_2 per year. The objective of this project is to sequester the full anticipated volume of up to 450 kt of CO_2 per year.

Cardinal will work with Vault to install a facility to capture the CO_2 generated by the corn fermentation process and sequester it deep underground via an injection well (CCS1). This well, the capture equipment, and all auxiliary equipment related to the project will be contained on property owned by Cardinal.

The capture portion of this project will use compressors, blowers, cooling units, and scrubbers to purify and condense the CO_2 into a supercritical state. This supercritical CO_2 will then be piped to CCS1 and injected deep into the Mt. Simon Sandstone. The Mt. Simon Sandstone is of sufficient depth and temperature at the site to maintain this supercritical state. The Mt. Simon Sandstone has served as a suitable injection interval for Class I and II wells in the region for multiple decades (INEOS (BP Lima) Nitriles, August 22, 2016; AK Steel Cleveland-Cliffs Steel Corporation, March 15, 2021). The confining zone is Eau Claire Shale with the Knox Dolomite as a secondary confining zone.

The Hoosier #1 Project intends to enable OCP to continue to provide jobs and economic opportunity while minimizing the amount of CO_2 emitted into the earth's atmosphere. OCP maintains that both economic and environmental stewardship can advance in unison with an asset such as the Hoosier #1 Project.

Thorough analysis has been performed using publicly available data, two-dimensional (2D) seismic lines, and other data sources to confirm the feasibility of this project.

Based on the maximum anticipated annual volume of 450 kt of CO_2 per year over a period of 12-years (5.4 MMT of CO_2) to 30-years (13.5 MMT of CO_2), the total mass of injected CO_2 is anticipated to range from 5.4-13.5 MMT, respectively.

Figure 1 shows the locations of the four primary wells associated with the project. Table 1 shows the coordinates, depth, and information for the four primary wells associated with the project. Features that are not located within the AOR include deep stratigraphic boreholes, State or EPA-approved subsurface clean-up sites, mines, quarries, and State, Tribal, or Territory boundaries. No major surface bodies of water are located within the AOR. Information on oil and gas wells and water wells within the AOR can be found in Section 4.1 of the AOR and Corrective Action Plan (Attachment 2: AoR and Corrective Action, 2022).

Figure 1: Project and Well Location Map

Table 1: Proposed Hoosier #1 Project wells

Well Name	X (ft) EPSG 2965	Y (ft) EPSG 2965	Elevation feet below sea level (fbsl)	Total Depth (TVD) (ft)	Purpose
CCS1	Sensitive, Confidential, or Privileged Information [redacted]	[redacted]	[redacted]	[redacted]	CO_2 injection well Designed to inject 450 metric kilotons of CO_2 per year.
OBS1	[redacted]	[redacted]	[redacted]	[redacted]	Injection reservoir observation well. Located [redacted] south of CCS1. Logging and pressure monitoring will be used to history match the CO_2 migration in the reservoir and ensure containment.
ACZ1	[redacted]	[redacted]	[redacted]	[redacted]	Above confining zone (ACZ) observation well. Targeting the most permeable formation above the confining zone, this well will be used as a detection point in the event CO_2 migration above the confining zones.
USDW1	[redacted]	[redacted]	[redacted]	[redacted]	Deepest underground source of drinking water (USDW) monitoring well. Completed in the deepest USDW, this well will be used to monitor the groundwater chemistry.

This document is one of the below 12 attachments that are being submitted to the United States US EPA for approval for a Class VI well for the Hoosier #1 Project. The other 11 attachments are listed below:

(Attachment 1: Narrative, 2022)

(Attachment 2: AoR and Corrective Action, 2022)

(Attachment 3: Financial Responsibility, 2022)

(Attachment 4: Well Construction, 2022)

(Attachment 5: Pre-Op Testing Program, 2022)

(Attachment 6: Well Operations, 2022)

(Attachment 7: Testing And Monitoring, 2022)

(Attachment 8: Well Plugging, 2022)

(Attachment 9: Post-Injection Site Care, 2022)

(Attachment 10: ERRP, 2022)

(Attachment 11: QASP, 2022)

(Attachment 12: Confidential Business Information: Risk Register, 2022)

1.3 Project Goals

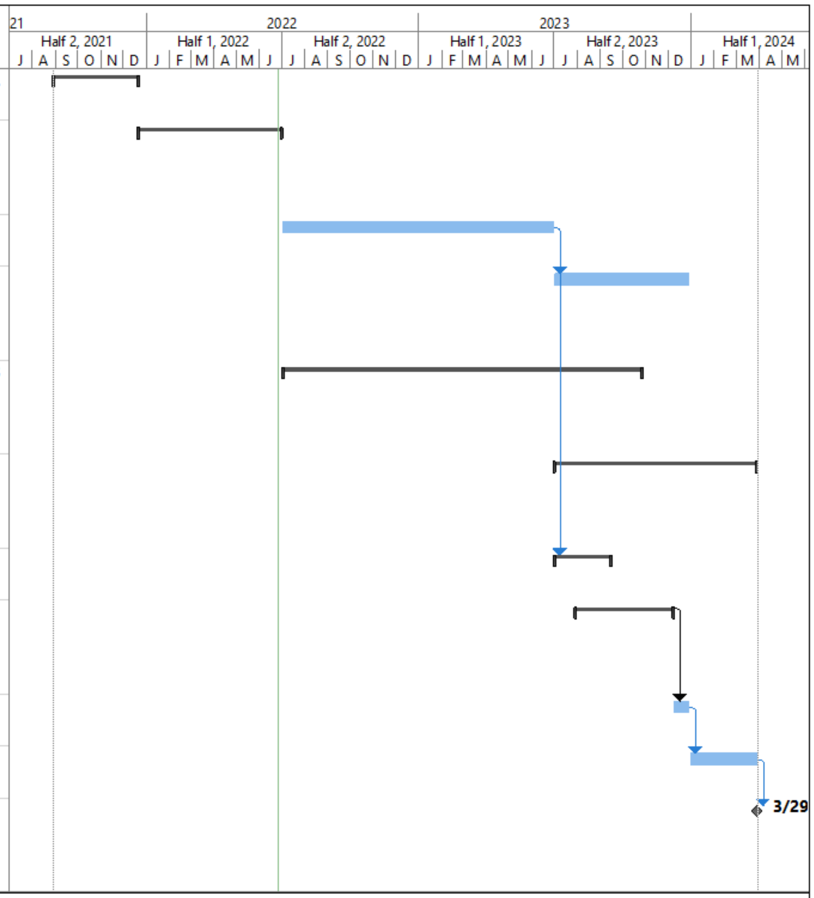
An objective of this project and Class VI application is to establish that CO_2 produced at the Cardinal corn processing facility can be effectively captured and permanently sequestered deep in the Mt. Simon Sandstone.

This application seeks approval to continue this effort. Upon approval, project execution will begin with the drilling and completion of several wells including the CO_2 injection well (Figure 1, Table 1). Real-time data will be collected as the wells are drilled and completed. The data gathered will be processed and analyzed to confirm or re-assess the project modeling efforts and current understanding. If necessary, additional data sets will be collected and analyzed.

1.4 Project Timeframe Overview

A projected pre-injection project schedule is shown in Figure 2.

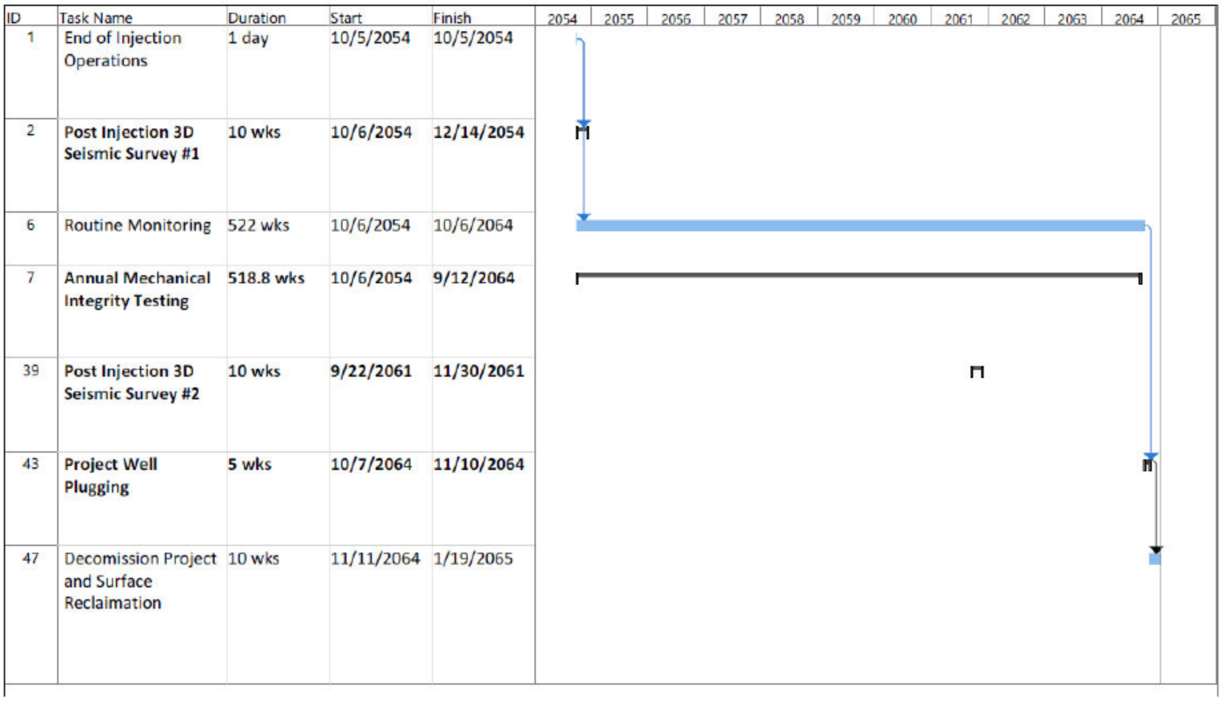
ID	Task Name	Start	Finish
1	**Phase I**	**8/30/2021**	**12/21/2021**
3	**Prepare Permit Application**	**12/22/2021**	**7/1/2022**
22	EPA Permit Review	7/4/2022	6/30/2023
23	Financial Assurance Demonstration	7/3/2023	12/29/2023
24	**Post Permit Technical Work**	**7/4/2022**	**10/27/2023**
27	**Baseline Data Collection**	**7/3/2023**	**3/29/2024**
33	**Well Installation**	**7/3/2023**	**9/15/2023**
38	**Post Installation Technical Work**	**7/31/2023**	**12/8/2023**
43	Permit Resubmital	12/11/2023	12/29/2023
44	Permit Received	1/1/2024	3/29/2024
45	Commence Injection Operations	3/29/2024	3/29/2024



Page 1

Figure 2: Pre-Injection Project Schedule.

A preliminary Post Injection Site Care and Closure (PISC) schedule is shown in Figure 3.



ID	Task Name	Duration	Start	Finish
1	End of Injection Operations	1 day	10/5/2054	10/5/2054
2	**Post Injection 3D Seismic Survey #1**	**10 wks**	**10/6/2054**	**12/14/2054**
6	Routine Monitoring	522 wks	10/6/2054	10/6/2064
7	**Annual Mechanical Integrity Testing**	**518.8 wks**	**10/6/2054**	**9/12/2064**
39	**Post Injection 3D Seismic Survey #2**	**10 wks**	**9/22/2061**	**11/30/2061**
43	**Project Well Plugging**	**5 wks**	**10/7/2064**	**11/10/2064**
47	Decomission Project and Surface Reclaimation	10 wks	11/11/2064	1/19/2065

Figure 3: PISC Project Schedule

1.5 Partners

The Hoosier #1 Project and facilities will be jointly owned by Vault and Cardinal under the JV One Carbon Partnership, LP.

1.6 Proposed Injection Mass/Volume and CO_2 Source

It is anticipated that one injection well will be sufficient to handle the project's intended mass flow rate while maintaining maximized storage efficiency of the Mt. Simon Sandstone. The Hoosier #1 Project has been designed to operate for thirty years at a nameplate capacity per annum of 450,000 tons of CO_2.

1.7 Local, State, and Federal Emergency Contacts [40 CFR 146.82(a)(20)]

Table 2: Local, State, and Federal Emergency Contacts

Agency	Phone Number
Union City Police Department	765-964-5353
Union City Fire & EMS	765-964-4488 (Indiana) 937-968-5605 (Ohio)
Randolph County Sheriff	765-584-1721
Indiana State Police	765-778-2121

Agency	Phone Number
Indiana Emergency Management and Preparedness Division	765-584-1721 (Local)
Environmental services contractor	516-333-4526 (Environmental Consultant-RTP Environmental Associates) 260-489-7062 (Emergency Spill Response)
Underground Injection Control (UIC) Program Director (Region 5)	312-353-7648
EPA National Response Center (24 hours)	800-424-8802
Indiana Department of Natural Resources (IDNR)	317-232-4200

1.8 Summary of Other Permits Required

Table 3 provides a summary of permits required for the Hoosier #1 Project.

Table 3. Permits Required for the Hoosier #1 Project

Program	Permits	Status
a) Hazardous Waste Management program under the Resource Conservation and Recovery Act (RCRA)	Not required	Not Applicable
b) UIC program under the Safe Drinking Water Act (SDWA)	(UIC) Class VI Permit Randolph County Cardinal CCS1	Permit Submitted to EPA Region 5
c) NPDES program under the Clean Water Act (CWA)	Not planning to be used for Class VI UIC project	Not necessary, water from well installation will not be discharged into local bodies of water
d) Prevention of Significant Deterioration (PSD) program under the Clean Air Act	Not required	Not necessary, no additional air pollution will be introduced as part of the Class VI project
e) Nonattainment program under the Clean Air Act	Not required	Not applicable. Area is in attainment for all criteria pollutants
f) National Emission Standards for Hazardous Pollutants (NESHAPS) preconstruction approval under the Clean Air Act	Not required	Not Applicable
g) Dredge and fill permits under section 404 of the CWA	Not necessary for CO_2 plant and flowline(s); well pad(s) will not affect wetlands	Wetlands areas are being avoided at the power plant site and injection/monitoring well pad locations.

Program	Permits	Status
h) Other relevant environmental permits, including State permits		
Drilling Permit(s)	Required for injection/monitoring wells	Application(s) to permit the wells laid out in this permit application will be submitted at a later time, prior to well installation.
Well Permit(s)	Required for injection/monitoring wells	Application(s) to permit the wells laid out in this permit application will be submitted after they are installed. Regulatory path towards permitting these wells is currently being legislated at the state level in Indiana.

2 Site Characterization [40 CFR 146.82(a)(2), (3), (5), and (6)]

Unless otherwise stated, all depths are in reference to feet (ft) below ground surface.

2.1 Regional Geology, Hydrogeology, and Local Structural Geology [40 CFR 146.82(a)(3)(vi)]

The Hoosier #1 Project site is located on the Indiana-Ohio Platform/Arches Province that is a high region between the Illinois, Appalachian, and Michigan Basins (Figure 4). Structural relief on the Indiana-Ohio Platform is generally the result of differential subsidence of the surrounding basins as opposed to tectonic uplift (Drahovzal, et al, 1992).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 4. Regional Indiana-Ohio Platform/Arches Province

During the Precambrian (Keweenawan), a period of extension prevailed in North America's mid-continent that led to the formation of the Midcontinent Rift System (MRS) and associated East Continent Rift Basin (ECRB), with the peak of rifting, associated volcanic activity, and deposition of sedimentary rocks occurring at this time (Baranoski, 2002: Drahovzal, et al, 1992).

By the end of the Precambrian Era, Indiana/Ohio was the site of continental-continental convergent plate margin activity. This activity precipitated the Grenville Orogeny. The western structural boundary of these Precambrian mountains is known as the Grenville Front. Precambrian rocks to the west of this boundary consist of unmetamorphosed felsic igneous and metasedimentary rocks of the Granite-Rhyolite Province. Precambrian rocks of the Grenville Province (GP) lie to the east of this boundary and consist of metamorphic rock. The thrusting and metamorphism related to the Grenville Orogeny occurred approximately 1.06 to 1.03 billion years ago (Dickas et al., 1992). In Late Precambrian time, uplift and erosion occurred.

The Eastern Granite-Rhyolite Province (EGRP) is a Mesoproterozoic province of the North American Midcontinent basement region. The EGRP overlaps and overprints the older Central Plains Orogenic Province (CPO) to the west and is physically bound by the younger GP to the east. The EGRP is separated from the Southern/Western Granite-Rhyolite Province (SGRP/WGRP) to the south by a transitional change in the age of granitic magmatism of the two provinces (Green, 2015).

Erosion of the land mass continued in early Cambrian time, and the seas began a slow transgression from the east. Large quantities of clastics and some carbonates were deposited in the Paleozoic Appalachian Basin. As the sea continued to encroach upon the land, dolomite and limestone were being deposited in deeper waters while deposition of clastics was limited to near shore areas being fed by major drainage systems (Freeman, 1953). There was an uplifting of the Canadian shield near the end of Cambrian time that tilted the sediments of the area. Therefore, the Cambrian section represents an overall transgressive depositional sequence (Harris and Baranoski, 1996).

Much of the land mass was covered by the sea as the Cambrian Period ended and the Ordovician Period began. During the Ordovician Period, marine regression occurred exposing newly deposited sediments to erosion for the first time and resulted in the Middle Ordovician Knox unconformity. Another period of transgression began that resulted in a repeat of Cambrian history with one notable exception: Erosion of fresh sediments covering the land mass was occurring rather than erosion of igneous and metamorphic rocks of the Precambrian crust. Consequently, the lithology of these new deposits reflected the lithologies of the nearest source areas (Freeman, 1953). A series of transgressing and regressing shallow seas, associated with periods of broad, gentle uplifting of the uplands and continued subsidence in the basins dominated the remainder of Ordovician time.

By early to mid-Silurian time, eastern Indiana/western Ohio was close to wave-base while the basins to the west, north, and east received a large amount of sediments (Janssens, 1967). During early Devonian Period, the seas retreated, and uplift occurred, followed by extensive erosion. The seas returned and deposited Devonian-Mississippian shales across the region.

Subsidence and uplift continued well into the Pennsylvanian Period. Movement became slower and more episodic from Late Pennsylvanian until the close of the Paleozoic Era. Erosion or nondeposition prevailed throughout the Mesozoic Era and into the Cenozoic Era. During the Pleistocene Epoch, the region was exposed to Illinoisan and Wisconsin glaciation. Post-glacial streams have deposited up to 400 ft of valley fill along stretches of the major river systems.

2.1.1 Regional Stratigraphy

A stratigraphic chart (Figure 5) for southeastern Indiana, southwestern Ohio, and central Kentucky shows the pre-Knox unconformity correlations for the tri-state area (Drahovzal, et al, 1992). The stratigraphic nomenclature used in this report is shown on the generalized stratigraphic column (Figure 6). A regional cross-section is included to show regional continuity and characteristics of the Paleozoic formations [40 CFR 146.82(a)(3)(i)] (Figure 7). This cross-section includes two Ohio Class I wells critical in establishing the Mt. Simon Sandstone as a suitable injection horizon in eastern Indiana and western Ohio. The datum for this cross section is the Mt. Simon Sandstone and thickening and thinning of the individual geologic units can be seen up through the Trenton Limestone.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 5: Pre-Knox unconformity stratigraphic correlation chart for southeastern Indiana, southwestern Ohio, and central Kentucky. Post -Precambrian unconformity between the Mt. Simon Sandstone and the Middle Run Formation is indicated (Drahovzal, et al, 1992).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 6: Generalized stratigraphic column of Indiana bedrock including injection, primary confining, secondary confining, and lowest USDW horizons modified from (Indiana Geological Survey, 2016)

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 7: Regional North-South cross section demonstrating regional continuity of formations

2.1.1.1 *Precambrian Basement Complex*

The Precambrian basement of the Granite-Rhyolite Province/ EGRP consists of high grade metamorphic and igneous rocks (Figure 8). The Granite-Rhyolite Province has been mapped from western Ohio and Kentucky westward to Missouri, Kansas, and Oklahoma (Denison and others, 1984). The Grenville Front, which runs north-south through west-central Ohio ~100 miles east of the project, is the structural boundary that separates the Granite-Rhyolite Province from the GP.

Typical lithologies include granites, rhyolite, trachylite, and quartzite and fine- grained, micrographic to granophyric granite of extensional tectonic origin (Bickford and others, 1986). The GP consists of highly folded, intruded, medium to high grade metamorphic rock that include schist, amphibolite, and gneiss.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 8: Generalized map of the Eastern Granite-Rhyolite Province and surrounding basement provinces. (Modified by Michael Ray Green, 2015 from Bickford et al., 2015).

2.1.1.2 *Middle Run (Precambrian)*

The Middle Run Formation was first recognized as a new formation in the Ohio Department of Natural Resources (ODNR), Division of Geological Survey (DGS) DGS #2627 core located in Warren County approximately 58 miles southeast of the project. Based on core and thin section data, the Middle Run Formation is a tightly compacted, fine to medium-grained, subrounded to subangular, reddish lithic arenite (sandstone) with coarse, angular, weathered feldspar with red clay, quartz, and accessary biotite, magnetite and hornblende lithic clasts composed of (in the order of increasing abundance) volcanic, metamorphic, plutonic, and sedimentary fragments. The formation is well compacted and low porosity. An 80-foot siltstone was also identified in the upper most Middle Run (Dickas et al., 1992). The contact between the Middle Run Formation and the overlying Mt. Simon Sandstone was sharp where penetrated and cored in DGS 2627.

Both the sandstone and the siltstone elements of the Middle Run Formation at DGS #2627 were reported to have no identifiable porosity (Shrake et al., 1990). A thin section analysis of the Middle Run Formation indicated an intergranular porosity of about 0.5% (Shrake et al., 1991). The petrology of the Middle Run Formation has been described as "porosity is almost totally absent where cuttings have been observed it cores, and hence there is small likelihood that the Middle Run Formation could ever be a petroleum reservoir or a site for liquid waste disposal." (Wolfe et al., 1993).

The Middle Run Formation was deposited in a rift-associated sedimentary basin during Late Precambrian time (e.g., Shrake et al., 1991; Shrake, 1991; Drahovzal et al., 1992; Dickas et al., 1992; Lucius and von Frese, 1988). Lithologic similarities with other red clastic sequences associated with the Precambrian Midcontinent Rift System in Michigan and Wisconsin support the interpretation that the Middle Run Formation is related to a rift basin. In addition to lithologic similarities, seismic, magnetic, and gravity data suggest a genetic relationship between the Midcontinent Rift System and the rift basin containing the Middle Run. This relationship further supports the Late Precambrian age assigned to the Middle Run Formation. The Middle Run Formation was deposited in association with and following deposition of East Continent Rift System fill sequences and possibly with later foreland basin development (Baranoski et al., 2009). Geochronological analysis of detrital zircon from the Middle Run Formation supports the deposition of sediments at the end of the Grenville Orogeny (Baranoski et al., 2009). Recent work supports a complex history associated with pre-Mt. Simon Sandstone sedimentation that includes multiple sequences of sedimentary units culminating in the deposition of Middle Run-Foreland Basin sediment deposition followed by erosion prior to deposition of the Mt. Simon Sandstone.

The Middle Run Formation has been identified in seismic reflection surveys conducted in several locations in western Ohio. These surveys indicate the presence of a thick sequence of pre-Mt. Simon Sandstone stratified units consisting of clastic sedimentary layers and possibly layered volcanics (e.g., Richard and Wolfe, 1995; Shrake et al., 1990; Baranoski et al., 2009; Wolf et al., 1993; Dean et al., 2002a and 2002b). The topmost unit of this sequence in western Ohio is the Middle Run Formation (Figure 6).

Figure 9 and Table 4 summarize the wells within the basin that penetrate the Middle Run Formation.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 9: Map of the study area showing the location and lithology of the Middle Run formation and related intrabasinal volcanic rocks in the ECRB. Lithologic identifications are based on core or cutting samples from wells indicated.

Table 4: List of wells penetrating Middle Run Formation and associated mafic and felsic volcanics within the ECRB.

Map Number	*Well Name*	*County, State*	*Precambrian Top (Subsea)*	*Precambrian Thickness Penetrated*	*Rock Type*
1	ODNR DGS No. 2627	Sensitive, Confidential, or Privileged Information			lithic arenite
2	SOHIO No. 1 Vistron	[redacted]	[redacted]	[redacted]	lithic arenite
3	SOHIO No. 2 Vistron	[redacted]	[redacted]	[redacted]	lithic arenite
4	SOHIO No. 3 Vistron	[redacted]	[redacted]	[redacted]	lithic arenite
5	BP Chemicals No. 4 Fee	[redacted]	[redacted]	[redacted]	lithic arenite
6	Armco Steel No. 1 Fee	[redacted]	[redacted]	[redacted]	lithic arenite
7	Armco Steel No. 2 Fee	[redacted]	[redacted]	[redacted]	lithic arenite
8	Sun Oil No. 1 Levering	[redacted]	[redacted]	[redacted]	lithic arenite
9	Ohio Oil No. 1 Barlage	[redacted]	[redacted]	[redacted]	lithic arenite
10	Gulf Oil No. 1 Scott	[redacted]	[redacted]	[redacted]	lithic arenite
11	Ashland Oil No. 1 Collins	[redacted]	[redacted]	[redacted]	lithic arenite
12	Ashland Oil No. 1 Eichler	[redacted]	[redacted]	[redacted]	lithic arenite
13	Ford No. 1 Conner	[redacted]	[redacted]	[redacted]	lithic arenite
14	Ashland Oil No. 1 Wilson	[redacted]	[redacted]	[redacted]	lithic arenite, basalt
15	Texaco No. 1 Sherrer	[redacted]	[redacted]	[redacted]	lithic arenite, basalt
16	Farm Bureau No. 1 Brown	[redacted]	[redacted]	[redacted]	basalt
17	Farm Bureau No. 1 Binegar	[redacted]	[redacted]	[redacted]	basalt
18	Pet. Dev. No. 1 Binegar	[redacted]	[redacted]	[redacted]	basalt
19	Tecumseh No. 1 Gibson	[redacted]	[redacted]	[redacted]	basalt
20	NIPSCO No. 1 Leuenberger	[redacted]	[redacted]	[redacted]	basalt
21	Continental No. 1 Wykoff	[redacted]	[redacted]	[redacted]	basalt, andesite
22	Kewanee No. 1 Barnes	[redacted]	[redacted]	[redacted]	basalt, troctolite
23	Friend No. 1 Mattison	[redacted]	[redacted]	[redacted]	basalt, rhyolite
24	NAP No. 1 Walker	[redacted]	[redacted]	[redacted]	basalt, gabbro
25	Sun No. 1 Nelson	[redacted]	[redacted]	[redacted]	basalt, gabbro
26	Gump No. 1 Fogt	[redacted]	[redacted]	[redacted]	basalt
27	Harner No. 1 Yewey	[redacted]	[redacted]	[redacted]	rhyolite*
28	West Ohio No. 1 Hoelscher	[redacted]	[redacted]	[redacted]	rhyolite
29	Ohio Oil No. 1 Johns	[redacted]	[redacted]	[redacted]	rhyolite
30	California No. 1 Spears	[redacted]	[redacted]	[redacted]	rhyolite

* Data from Lucius and Von Frese, 1988.

2.1.1.3 *Mt. Simon Sandstone/Injection Zone (Cambrian)*

At the Hoosier #1 site, the Cambrian-Ordovician Sauk sequence unconformably overlies the Middle Run Formation (Figure 6). This includes the Mt. Simon Sandstone, the Eau Claire, and the Knox formations.

The basal sandstone unit, named the Mt. Simon Sandstone, is a quartz-rich, occasionally arkosic, fine to coarse-grained sandstone deposited unconformably upon the Precambrian (Janssens, 1973). It is interpreted to be a barrier bar sequence which migrated across a basal lagoonal estuarine sequence (Saeed, 2002). The Mt. Simon Sandstone is a thick sandstone present in several states including Indiana, Illinois, Michigan, western/northern Kentucky, and western Ohio (Baranoski, 2007). The Mt. Simon Sandstone is a clear, very bright red to yellowish orange, or white, fine to coarse grained, poorly sorted, friable, hematinic, feldspathic quartzose sandstone (generally equal portions of quartz and feldspar). Isolated sandstone beds within the formation can be well-sorted and extremely permeable. Over the past decade, the Mt. Simon

Sandstone has been the target of numerous studies to evaluate its potential for CO_2 sequestration over a wide range of target areas (e.g., Medina et al., 2010, Wickstrom et al., 2005, Barnes, et al., 2009, MRCSP 2005, 2011). These studies verify the presence of the Mt. Simon Sandstone throughout eastern Indiana and western Ohio at much shallower depths than in other locations in the Michigan and Illinois basins.

The Mt. Simon Sandstone was deposited in an area limited to western Ohio and the adjacent proto-Michigan-Illinois Basin. The eastern limit of the Mt. Simon Sandstone is redefined along a north–northwest-trending, broad, Precambrian paleotopographic arch (exposed Laurentian craton), which extends in the subsurface from an area north of present-day western Lake Erie, southward to the Ohio River, and corresponds to the northwestern Rome Trough boundary fault system. The Mt. Simon Sandstone subcrops along the northern portion of this north–northwest-trending arch. Along the southern portion of this trend, the Mt. Simon Sandstone thickness thins to the east, grading laterally with mixed clastic-carbonate Conasauga Group facies (Baranoski, 2007).

Regionally, it has been noted that the lower Mt. Simon Sandstone is conglomeritic and arkosic (Kemron/AK Steel). It grades upwards into a sandstone or sandy dolomite. Thin green and red shale streaks parallel very porous and permeable red sands just above the base. The middle/upper Mt. Simon Sandstone contains medium to coarse-grained, poorly sorted, round to angular, frosted, poorly consolidated sandstone. Minor amounts of silica or carbonate cement with possible feldspar growth have been reported. Dolomite and hematite may act as additional cement. It becomes increasingly calcareous towards the top and contains a few marine fossils. Some siltstone layers and thin shales are present in the upper zone. Glauconite is only present where the Eau Claire overlies the Mt. Simon Sandstone in western Ohio (Janssens, 1973).

2.1.1.4 *Eau Claire/Primary Confining Zone (Cambrian)*

The Eau Claire Formation (Figure 6) overlies the Mt. Simon Sandstone at the Hoosier #1 site. This formation consists of interbedded glauconitic sandstones, siltstones, shales, and dolomite. Siltstones and sandstones are light to medium greenish-gray, brown, or very light orange. Interbedded green and reddish-brown glauconitic shales are more prevalent near the top of the formation. Limestone may occur in trace amounts (Janssens, 1973). The contact of the Eau Claire Formation with the Mt. Simon Sandstone is transitional with the base of the Eau Claire Formation being a glauconitic siltstone and very fine-grained sandstone. Increasing carbonates towards the top of the section indicates increasingly marine conditions during deposition of the Eau Claire Formation. The Eau Claire Formation undergoes facies change to the east where it becomes the Rome Formation and the Conasauga Shale. This facies change runs north-south near the top of the Findlay and Cincinnati Arch Axes, which is east of the Hoosier #1 site and significantly outside the Area of Review (AoR). Sensitive, Confidential, or Privileged Information [redacted]

2.1.1.5 *Davis (Cambrian)*

The Eau Claire Formation is overlain by the Davis Formation which is conformable with both the Eau Claire Formation and overlying Knox Dolomite (Figure 6). The following rock types have been identified in the Davis Formation:

1. Dolomite that is brownish gray, fine to medium crystalline, glauconitic, slightly silty, sandy, and pseudo-oolitic,
2. Siltstone that is yellowish gray, dolomitic, glauconitic, and slightly feldspathic,
3. Shale that is dark gray, hard, brittle, and calcareous,
4. Limestone that is gray to brownish gray, dense, shaly in many places, somewhat pseudo-oolitic, and interbedded with glauconitic siltstone and fine-grained sandstone (Becker; et al, 1978).

2.1.1.6 *Knox/Potential Secondary Confining Zone (Cambrian-Ordovician)*

The Davis Formation is overlain by the Cambrian-Ordovician Knox Dolomite (Figure 6). When sea floor spreading slowed during tectonically quiescent periods, carbonate deposits of the Knox Group occurred on the shelf (Hansen, 1997 and Milici, 1996). In southeastern and eastern Indiana, this depositional time is referred to as the Knox Supergroup (Prairie Du Chien Group and Potosi Dolomite). The transition from deposition on a passive margin to deposition on a convergent margin caused the Knox Dolomite to be truncated by a major regional unconformity (Drahovzal, et al, 1992, Read 1980). The continent was uplifted, and karst topography and associated drainage patterns probably formed on the exposed surface (Dolly and Bush, 1972; Mussman and Read, 1986: from Drahovzal, et al, 1992). This formation consists of dolomite, shale, sandstone, and stratigraphically restricted limestone. Stromatolitic structures and fossils have been recognized in cores from the Knox (Botoman, 1975).

The lower and middle Knox formations are Cambrian in age. The Knox Formation is micro crystalline to coarse crystalline dolomite with interbedded pyritic shale and clear sandstone at its base. The middle Knox Formation is micro crystalline to medium crystalline, partly sandy dolomite and silty dolomite with sand and occasional chert, shale, silicified oolite and pebbles. The upper Knox Formation is Ordovician in age. This part of the formation is porous to occasionally dense, fine crystalline dolomite. It may occasionally have associated shale, glauconite and chert. [redacted] Variation in thickness across Indiana and Ohio can be attributed either to depositional thinning, erosion before the Middle Ordovician, or a regional truncation of individual units.

2.1.1.7 *Ancell – Indiana/Wells Creek – Ohio (Ordovician)*

After the Knox Formation surface erosion, subsidence created a shallow sea that covered the area, resulting in a brief period of intercalated clastic and carbonate sediments, represented by the Ancell/Wells Creek Formation (Figure 6) (Drahovzal, et al, 1992). A sharp contact is easily seen on gamma ray - neutron logs and in samples, between the clean Knox Dolomite and the clastic, sandy dolomite of the Wells Creek Formation. The Wells Creek Formation consists of sandstone, siltstone, gray, green, and brown shale, and argillaceous and sandy dolomite. Sandstone interbedded with dolomite is generally fine-grained but may be fine to coarse-grained. Internally this unit is called the Glenwood Formation, which is overlain by the Gull River Formation, both nomenclatures are commonly used in Ohio.

2.1.1.8 *Black River (Ordovician) Group*

Subsequent encroachment from the east to west caused deposition of the Ordovician Black River Group (Figure 6) (micritic to finely crystalline limestone) in environments ranging from subtidal to intertidal (Drahovzal, et al, 1992). This formation consists of lithographic limestone with sandstone, chert, and brown shales. Thin interbedded limestone is present in the upper section of the Black River Group, while the lower section contains lenses of fine-grained brown dolomite. The Black River Limestone terminates with a volcanic metabentonite zone (Botoman,1975). After Black River Group deposition, the epeiric sea deepened and became more normal marine in composition. Bentonites at the top of the Black River Group are evidence that the Taconic Orogeny was increasing in intensity to the east (Drahovzal, et al, 1992). Deepening of the sea resulted in the deposition of the basal, subtidal, and open-shelf facies of the Ordovician Trenton Limestone. As a result of the subsidence of the proto-Appalachian Basin and the early stages of the Taconic Orogeny, the deposition of the basal Trenton facies ended which is marked by a change in depositional strike. This caused shallowing of the sea to the northwest and the deposition of the thick carbonates of the platform facies of the Trenton Limestone.

2.1.1.9 *Trenton Limestone (Ordovician)*

Overlying the Black River Group is the Ordovician Trenton Limestone (Figure 6). The Trenton Limestone consists of limestone that becomes increasingly dolomitic in northern Indiana, and in places it is completely dolomitized. The Trenton Limestone is tan to light tannish gray to medium tannish gray. The color variation in the limestone is due to the variation in the content of skeletal grains versus micrite where the darker color correlates with the higher micrite content. In the dolomite the size of the crystals appears to be the controlling factor the more coarsely crystalline phases are lighter colored. The Trenton Limestone is everywhere in the subsurface of Indiana except for far southeastern Indiana as noted below. Sensitive, Confidential, or Privileged Information [redacted] This narrow area of dual facies change extends northeastward from Spencer and Perry Counties to eastern Fayette County (Keith, 1985).

2.1.1.10 *Cincinnatian/Maquoketa Group (Ordovician)*

The Trenton Limestone is overlain by the Upper Ordovician Cincinnatian Series (Figure 6), a succession of fossiliferous limestone and gray calcareous shale or siltstones. For the purposes of this project the Cincinnatian Series is subdivided into the Kope (dark brown to nearly black shale and minor interbedded limestone), and Maquoketa formations. Sensitive, Confidential, or Privileged Information [redacted] Limestone, which constitutes about 20 percent of the group, is most abundant in the upper part. The Maquoketa is a clastic wedge that spread across Indiana from east to west and is the first of the Paleozoic sediments to have had an evident eastern source. The Maquoketa Shale has been identified as the lowest USDW in the project area (Figure 6).

2.1.2 Regional Structure

This section discusses the regional Precambrian structural element and the relation to the overlying sediments where the Mt. Simon Sandstone is the injection zone, and the Eau Claire Formation and lower portion of the Knox Formation act as confining units.

Major features of Indiana consist of parts of the Cincinnati and Kankakee Arches and segments of the Illinois and Michigan basins (Figure 4). The structural axis of the Cincinnati and Kankakee Arches extends from southeastern to northwestern Indiana. The crestal area of the arch is broad and flat and is as much as 75 miles wide. The Illinois Basin is the large structural depression southwest of the arch, and the Appalachian Basin is the structural depression to the east of the arch. [redacted] Detailed mapping of the Trenton Limestone indicates that the lower Paleozoic sequence is disturbed by minor faulting (Dawson, 1971). Although there is a lack of deep well control along the trace of the faults, it is presumed that the Precambrian basement was also disturbed with displacement. Generally, less than 100 ft of displacement is observed on the Trenton Limestone (Becker, et al, 1978).

Sparse well data, magnetic gradient models, and scattered surface seismic data has been used to map the crystalline basement. In Figure 10, crystalline basement is defined as pre-rift igneous rock. Shaded areas indicate the Grenville (metamorphic) and Granite-Rhyolite (igneous) Provinces adjacent to the ECRB, which were mapped using basement well control. The fault boundaries of the ERCB are shown by bold lines. Areas within the ECRB were mapped using a combination of magnetic anomaly trends and seismic data. Circles within the basin indicate the location of estimated depths to magnetic basement derived from magnetic anomaly data. Volcanic rocks interpreted to be part of the rift-fill sequence are not considered part of the crystalline basement. No wells have penetrated the pre-rift crystalline basement beneath the basin fill sequence; therefore, the mapping of this surface is highly speculative (Drahovzal, et al, 1992).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 10: Structure contour map of the Precambrian crystalline basement surface. (Drahovzal, et al, 1992).

West of the Grenville frontal thrust, the top of the crystalline basement changes lithologically, and abruptly deepens to depths as great as 27,500 fbsl. The overall structure varies from a deep basin immediately adjacent to the Grenville Front Sensitive, Confidential, or Privileged Information [redacted] A broad, south-east plunging arch extends from an upthrown block of Granite-Rhyolite Province rock in eastern Indiana into southwestern Ohio, dividing the basin into deeper portions both to the north and south. The Fort Wayne Rift trend (Figure 11), located approximately ten miles north, defines another northwest-oriented high area in eastern Indiana and western Ohio that also separates deeper portions of the basin

(Drahovzal, et al, 1992). Located approximately six miles northeast of the project, the questionable Auglaize fault/structural trend ends in Ohio and is not mapped into Indiana.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 11: Ohio fault lines map showing Fort Wayne rift and Auglaize Fault (ODNR Division of Geological Survey, 2022)

While the Auglaize Fault is considered questionable by ODNR, its potential proximity to the project site warranted further investigation. Historically, much of the seismicity in Ohio has been centered near the town of Anna in Shelby County. In the 1970s, the Nuclear Regulatory Commission contracted with researchers affiliated with the University of Michigan to investigate the possible causes of the seismicity. Several engineering firms, including Stone & Webster and Dames & Moore, were also commissioned to investigate the area.

It is from these studies that the Auglaize fault was first mapped (Figure 12). The mapped Auglaize Fault terminates to the southwest at the Anna-Champagne fault and does not extend to the state line, as it does on later maps. The authors noted that none of the faults mapped were exposed at the surface or had been described in the literature at the time (Jackson, 1982). Of the three potential faults that were identified, the Auglaize Fault had the least evidence for its existence. Its presence was inferred from well log data alone; unfortunately, none of the data used for the interpretation was published with the map (Jackson, 1982).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 12: One of the early published maps detailing potential faults in the area of Anna, Ohio (reference)

In the early 1990s, Wickstrom and others expanded on the idea of the three postulated faults and extended the Auglaize Fault southwest all the way to the Indiana border as can be observed in current ODNR maps (Figure 11) (Wickstrom, 1993). The only data available at the time were the previous maps from the earlier report and their mapped depositional trends of the lower Paleozoic strata which the authors believed were controlled by faults. While these depositional trends could be caused by existing faults, there could be other possible explanations.

In summary, it appears that the closest documented Precambrian faulting with Paleozoic reactivation is in the Fort Wayne Rift zone. The highly speculative Auglaize Fault (Figure 11) has questionable Precambrian displacement and highly unlikely Paleozoic movement (Baranoski, 2002). The Auglaize Fault is not expected to present a hazard to the project. Further discussions on local structure and interpretation of seismic lines acquired for the project can be found in Section 2.3.

2.2 Maps and Cross Sections of the AoR [40 CFR 146.82(a)(2), 146.82(a)(3)(i)]

Table 5 is the site-specific stratigraphic column for the project. As discussed in Section 2.1.2, the closest regional structural features to the project are the Fort Wayne Rift Zone and the questionable Auglaize Fault at ten and six miles to the north and northeast, respectively.

Sensitive, Confidential, or Privileged Information [redacted]

Table 5: Site specific stratigraphic column and formations of use

Sensitive, Confidential, or Privileged Information [redacted]

Sensitive, Confidential, or Privileged Information

[redacted]

To develop the best understanding of the site-specific geology for the project a comprehensive database was compiled of publicly available geophysical well logs from Indiana and Ohio. Interpretation of these well logs were used to develop the static model for the region. [redacted]

[redacted]

Figure 13 displays the well logs from nine offsetting wells that penetrate the Trenton Limestone and deeper formations. Six of the wells are within eight miles of the site which penetrate the Trenton Limestone through to the Potosi Formation (Table 5). Sensitive, Confidential, or Privileged Information [redacted] The cross section shows:

- The Maquoketa Shale to Trenton Limestone formations thicken to the east
- Slight thinning to the east
    - Trenton Limestone to Knox Unconformity
    - Knox Group to Eau Claire Formation
    - Eau Claire Formation to Mt. Simon Sandstone

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 13: Cross section - thickening of Maquoketa to Trenton to the east and slight thinning to the east.

Structure and thickness maps were generated for the Precambrian, Mt. Simon Sandstone, Eau Claire Formation, and Trenton Limestone using existing publicly available well log data (Figure 14 to Figure 17). The proposed CCS1 well location is shown on each map along with the broad Indiana-Ohio platform and the associated arches. The maps demonstrate the continuous nature of these formations throughout the region, and do not show evidence for regional pinch-outs or structural traps in these formations.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 14: Regional Precambrian lower confining zone elevation

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 15: Regional Mt Simon Sandstone injection zone a) elevation and b) thickness

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 16: Regional Eau Claire Formation upper confining zone a) elevation and b) thickness

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 17: Regional Trenton Limestone elevation

The Knox Dolomite has been identified as a secondary confining zone should injection zone fluids migrate past the Eau Claire Shale (Section 2.2.1.3). Low porosity and permeability values have been measured in part of the Knox Dolomite that corresponded to siltstones, shales, and dense dolomites at the INEOS (BP Lima) Nitriles disposal site (INEOS USA, LLC, 2015)

2.3 Faults and Fractures [40 CFR 146.82(A)(3)(ii)]

Based on Class I well research, it is anticipated that fracture occurrence will likely be a localized phenomenon with a few short and open natural fractures (AK Steel Cleveland-Cliffs Steel Corporation, March 15, 2021; INEOS (BP Lima) Nitriles, August 22, 2016). The Pre-Operational Testing Program details the geophysical log and core data that will be acquired and evaluated to characterize potential fractures that could impact the long-term integrity of the confining zone (Attachment 5: Pre-Op Testing Program, 2022).

Three 2D seismic lines (Line 1 EW, Line 2 NS, Line 3 Short NS) were acquired and interpreted to provide information on the subsurface structure around at the project (Figure 18). Approximately 19 miles of seismic data were acquired in early 2021 by Integrity Geophysical Services, Inc. The data were acquired with a vibrator truck using a one (1) millisecond sample rate, a broad band and long duration sweep, with multiple sweeps and diversity stacking. A stack fold of 144 was achieved for the acquisition on the surveys. The seismic lines were reprocessed by Earth Signal (Calgary, Alberta, Canada).

Interpretation of the Precambrian structure have identified features that could be interpreted as minor or fracture planes (Figure 19 to Figure 22). Seventeen potential minor faults were identified; however, it should be noted that some of these features may also be related to Precambrian topography rather than actual faulting.

The interpreted faults were depth converted and an attempt was made to interpret them in a three-dimensional (3D) space; however, given the nature and geometry of 2D surface seismic data, the 3D fault interpretation was highly uncertain and inconclusive. The future 3D seismic survey will provide more detail on 3D geometry (length, displacement etc.) of these minor faults. The layout of the 3D seismic survey is currently being designed to obtain full fold data over the predicted extent of the CO_2 plume after 30 years of injection and a 10-year PISC period (Attachment 7: Testing And Monitoring, 2022).

Some of the interpreted features appear to extend into the Mt. Simon Sandstone and have a maximum throw of approximately 42 ft. Uncertainties associated with these features include:

- Whether the features are minor faults or related to Precambrian topography
- Locations of these fault planes in 3D space

The Trenton Limestone and Eau Claire Formation reflectors are a constant throughout the area with no evidence of faulting (Figure 19 to Figure 22). Based on interpretations of this data the minor faults identified are not expected to act as conduits through the confining zone and USDWs will not be endangered.

At this time, no studies have been completed into the sealing capacity of these faults as they do not transect the confining zone. After the project acquires a baseline 3D surface seismic survey, if it becomes apparent that the minor faults do transect the confining zone the sealing capacity of the faults will be assessed at that time.

The project also plans to acquire a baseline 3D surface seismic survey that will be used to:

- Evaluate the properties of the injection zone and confining zone away from the project wells,
- Further characterize the potential faults in the Precambrian basement within the AoR, and
- Characterize Precambrian basement topography.

The data gathered during the pre-operational phase of the project will be used for geomechanical modeling. The geomechanical modeling will help determine if the minor faults identified in the surface seismic data are stable or whether they are critically stressed.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 18 Seismic program location

Figure 19: Confidential Business Information: 2D seismic lines two-way time (TWT) in a 3D view

Figure 20: Confidential Business Information: 2D surface seismic Line 1 EW

Figure 21: Confidential Business Information: 2D surface seismic Line 2 NS

Figure 22: Confidential Business Information: 2D surface seismic Line 3 short NS

2.4 Injection and Confining Zone Details [40 CFR 146.82 (a)(3)(iii)]

2.4.1 Formation Tops and Mapping

The 2D seismic lines acquired for the project provide valuable site-specific information about the structural character of the Mt Simon Sandstone and Eau Claire Formation. The Trenton, Knox, Eau Claire, Mt Simon Sandstone and Precambrian horizon tops were first interpreted in the TWT domain and then depth converted so they could be incorporated into the geological structural model (Figure 19 to Figure 22).

Seismic well tie analysis (Figure 23) was completed to calculate the relationship between the TWT horizon interpretations and the interpreted structural surfaces in the depth domain. Ideally, the seismic data should be tied to a nearby well with good well log data; however, given the lack of well penetrations of the Mt. Simon Sandstone in the region, the closest well with reliable sonic and density data was 53 miles to the southeast ([redacted]). The well log data from this well was transposed into a synthetic well at the intersection of Line 1 EW and Line 2 NS and used to generate a synthetic seismogram. The synthetic seismogram was used to tie the well log data in depth and the 2D surface seismic data in TWT. Once this relationship was established, the interpretations of the horizons in TWT were converted to the depth domain and integrated into the structural framework model of the local area.

[redacted]

Figure 23: Seismic well tie

The convergent interpolation method was able to interpolate the details of the seismic interpretation between the seismic lines with the well tops. Horizons between the seismic interpretable horizons were generated using convergent interpolation and were matched to seismic interpretable horizons.

There is some uncertainty in the precision in the depth conversion due to the offset of the well data; however, the character of the seismic lines shows a relative consistency in the thickness of the Mt Simon Sandstone injection zone and Eau Claire confining zone. When the project acquires a 3D surface seismic survey and drills the first well at the site, this relationship will be re-assessed, and the current uncertainties will be reduced substantially.

The well logs and the depth converted seismic horizons were used to generate structural surfaces for the Eau Claire, Mt Simon Sandstone, and Precambrian horizons (Figure 24 to Figure 27). Thickness maps for the Eau Claire Formation and Mt Simon Sandstone are presented in (Figure 28).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 24: Seismic based local elevation maps. A) Eau Claire, b) Mt Simon Sandstone, c) Precambrian

Sensitive, Confidential, or Privileged Information

[redacted]

The elevation variations interpreted in the horizons are minor and do not show any significant thinning of the injection or confining zones. CO_2 plume development is expected to be controlled in part by heterogeneities in the injection zone as opposed to any structural features or stratigraphic thinning. The confining zone will provide a thick, consistent barrier to upward migration of injection zone fluids over time.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 25: AoR Eau Claire upper confining zone surface a) elevation and b) TVD

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 26: AoR Mt Simon Sandstone injection zone surface a) elevation and b) TVD

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 27: AoR Precambrian lower confining zone surface a) elevation and b) TVD

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 28: AoR Thickness Maps a) Eau Claire confining zone and b) Mt Simon Sandstone injection zone

2.4.2 Porosity and Permeability

Three wells have provided significant data to assist in the characterization of the injection and confining zones: Sensitive, Confidential, or Privileged Information. These wells have well logs, core, and fluid injection data covering the complete Mt. Simon Sandstone section. The data from these wells represent the nearest analog for how the injection and confining zones may perform and are believed to be reasonably representative of the injection zone at the project site. The data from these wells were used as a calibration point for the petrophysical analysis of eight wells in the region (Figure 29).

Sensitive, Confidential, or Privileged Information

Figure 29: Wells used for injection zone, confining zone and petrophysical analysis

2.4.2.1 *Mt. Simon Sandstone*

The Mt. Simon Sandstone lies unconformably upon the Middle Run Formation. There is an abrupt change from the poorly sorted, heterogenous, angular, well cemented rocks of the Middle Run Formation and the lighter, homogenous, less cemented partially friable basal Mt. Simon Sandstone (Saeed, 2002). The Mt. Simon Sandstone can be sub-divided into two lithologic packages related to depositional environment. The lower portion likely represents a fluvial-deltaic environment with increasing marine influence towards the top of the sequence. The upper portion represents a transitional marine sequence characterized by the presence of glauconite.

Section 2.1.1.1 discusses the regional mineralogy and petrology of the Mt. Simon Sandstone in detail. The Mt. Simon Sandstone contains feldspar, potentially carbon cement, and clay minerals. Some of these minerals are reactive with CO_2. And it is expected that there will be changes to the aqueous geochemistry of the Mt. Simon Sandstone fluids once CO_2 injection commences. Site specific information about the injection zone will be acquired when the project wells are drilled through the pre-operational testing program that will include well logging, fluid sampling, and core acquisition and analysis (Attachment 5: Pre-Op Testing Program, 2022). This data can be used for geochemical modeling that will predict the geochemical reactions likely to occur in the injection zone with the introduction of CO_2 to the formation.

Table 6 summarizes the porosity and permeability values for the Mt. Simon Sandstone that were derived from the AK Steel, INEOS (BP Lima) Nitrile, and 133540 wells (AK Steel Cleveland-Cliffs Steel Corporation, March 15, 2021; INEOS (BP Lima) Nitriles, August 22, 2016). The values in the table were derived from a combination of core and reservoir testing. These values were incorporated in the static model developed for the project (Attachment 2: AoR and Corrective Action, 2022).

Table 6: Summary of porosity and permeability values for the Mt. Simon Sandstone from three wells in the region

Well	Porosity Range (%)	Permeability Range Millidarcy (mD)
AK Steel	Sensitive, Confidential, or Privileged Information [redacted]	[redacted]
INEOS (BP Lima) Nitrile	[redacted]	[redacted]
133540	[redacted]	[redacted]

Well logs and core analyses completed as part of the pre-operational testing program will be used to further characterize the porosity and permeability of the injection zone (Attachment 5: Pre-Op Testing Program, 2022). The baseline 3D surface seismic data will be calibrated to the well data and used for inversion analysis. This will allow the project to characterize variations in porosity and lithology away from the project wells for the entire injection zone over the imaging area of the 3D surface seismic data volume.

Computational modeling has confirmed that the injection zone will have the capacity to store 450 kt/ yr and a total of 13.5 million tons of CO_2 over a 30-year injection period (Attachment 2: AoR and Corrective Action, 2022).

2.4.2.2 *Eau Claire Formation*

Section 2.1.1.4 discusses the regional mineralogy and petrology of the Eau Claire Formation in detail. The Eau Shale includes interbedded green and reddish-brown glauconitic shales. The Eau Claire Silt is composed of glauconitic siltstone and very fine-grained sandstone. The Mt. Simon Sandstone is transitional with the base of the Eau Claire Formation, and CO_2 is expected to migrate into this part of the Eau Claire Formation over time.

The minerals in the Eau Claire formation are not expected to be reactive with CO_2 over time. However, the site specific information about the confining zone that is acquired when the project wells are drilled through the pre-operational testing program will be used for geochemical modeling to establish whether or not prolonged contact with CO_2 will impact the integrity of the confining zone (Attachment 5: Pre-Op Testing Program, 2022).

In 1988, the ODNR drilled a stratigraphic test in Warren County to investigate the presence of Precambrian rifting. The well substantiated the theory with the discovery of Precambrian aged sedimentary rocks. During detailed geologic analysis of this well, three facies were identified from thin section within the Eau Claire Formation (Table 7).

Table 7: Eau Claire Formation facies identified in the Warren County stratigraphic test well

Facies	Depth (ft)	Effective Porosity (%)	Permeability Range (mD)
Bioclastic Oolitic Packstone/Grainstone	Sensitive, Confidential, or Privileged Information [redacted]		
Silty Dolomite/Dolomitic Siltstone	[redacted]		
Glauconitic Fine-Grained Sandstone	[redacted]		

The sample in the Glauconitic Fine-Grained Sandstone facies Sensitive, Confidential, or Privileged Information [redacted] showed different vertical and horizontal air permeabilities showing that the Eau Claire Formation is anisotropic at this interval (Table 7). An interval with a relatively high horizontal permeability provides a valuable buffer to attenuate possible fluid pressure buildup. According to the report on thin section examination of the test hole core, porosity in the sample Sensitive, Confidential, or Privileged Information [redacted] has developed due to dissolution of dolomite. Secondary fracture porosity was not noted (Kemron Environmental Services, Inc, 2018).

Porosity and permeability measurements taken from INEOS (BP Lima) Nitriles facility provide site-specific information about the regional permeability of the Eau Claire Formation and are considered correlative to the project site. Sensitive, Confidential, or Privileged Information [redacted]

Table 8: INEOS (BP Lima) facility Eau Claire porosity and permeability (INEOS USA, LLC, 2015)

POROSITY AND PERMEABILITY OF THE ARRESTMENT INTERVAL
(2430 Feet – 2640 Feet)

FORMATION	MODELING LAYER DEPTH	POROSITY (%)	PERMEABILITY (md)
Eau Claire	EC_6 2430' 2490'	3 – 5.4	0.0012 – 0.0040
	EC_5 2548'	0.1 – 0.2	0.000017 – 0.00033
	EC_4 2617'	0.2 – 2.7	0.000227 – 0.00131
	EC_3 2640' 2676'	4.0 – 10.1	0.00047 – 0.25

Eau Claire Formation core permeability measurements taken from AK Steel disposal well also provide site-specific information about the regional permeability of the confining zone and are considered representative of the project site (Table 9). [redacted] Eight of the ten samples tested had no measurable fluid permeability.

Table 9: AK Steel UIC Well1 Core Flow Study results for the Eau Claire Formation permeability (Kemron Environmental Services, Inc, 2018)

[redacted]

[redacted]

Well logs and core analyses completed as part of the pre-operational testing program will be used to further characterize the porosity and permeability of the confining zone (Attachment 5: Pre-Op Testing Program, 2022). The baseline 3D surface seismic data will be calibrated to the well data and used for inversion analysis. This will allow the project to characterize variations in porosity and lithology away from the project wells for the entire confining zone over the imaging area of the 3D surface seismic data volume.

The capillary pressure of the confining zone is not known, but it is not considered to be a significant factor in confining zone integrity. The permeability of the confining zone is very low and is not likely to allow any migration of CO_2 vertically. The capillary pressure and permeability of the Eau Claire Shale will be measured as part of the core analysis completed as part of the pre-operational testing program (Attachment 5: Pre-Op Testing Program, 2022).

Geomechanical modeling of the confining zone integrity was completed using step-rate test results from the INEOS (BP Lima) Nitriles disposal site (INEOS (BP Lima) Nitriles, August 22, 2016). This modeling demonstrated that the increase in effective stress on the confining zone associated with injection rates of 400 kt/yr would not be large enough to open any existing fractures in the confining zone. Even if the project were to increase the injection rate to 1.9

Million Metric Tons per Year (MMT/yr) the increases in effective stress would not be enough to open existing fractures.

2.4.2.3 *Knox Formation*

The Knox Dolomite is a potential secondary confining zone for the project and has been identified as a potential above confining zone (ACZ) monitoring interval. It is primarily a dolomite that is composed of white to brown, very fine to coarse-grained, crystalline to sugary dolomite, containing pyrite, white and light blue oolitic chert, and dolomite rhombs with fossil fragments. Portions of the Knox Dolomite are vuggy and thus the unit contains some intervals capable of acting as buffering units. Occasional frosted subangular quartz grains cemented with calcium carbonate are noted, as are glauconitic siltstones and dark gray to black shale (Kemron Environmental Services, Inc, 2018).

At the INEOS (BP Lima) Nitriles disposal site, the Knox Dolomite has been identified as the confining zone. Core-derived porosity and permeability in the lower one third of the Knox Dolomite indicate that porosity ranges from less than 0.1 to 14.5 percent and permeability from 0.00005 md to 24.1 md (Table 10). The lower values correspond to the siltstones, shales, and dense dolomites while the upper values correspond to the vugular and sandy dolomites.

Table 10: Knox Dolomite porosity and permeability from the INEOS (BP Lima) Nitriles disposal site (INEOS USA, LLC, 2015)

FORMATION	MODELING LAYER DEPTH	POROSITY (%)	PERMEABILITY (md)
Knox Dolomite	2100 KD_2 2310	Ave 0.8	Ave. 0.00029
	KD_1 2430	5.1 – 14.5 Ave 7.8	Ave 6.3 0.01 – 24.1

Calculations made using AK Steel #1 well log show the Knox Dolomite porosity ranges from 0% to 4%. A few thin beds that are approximately 3 to 5 ft thick with porosities of approximately 9% are scattered throughout the formation (Kemron Environmental Services, Inc, 2018).

Well logs acquired as part of the pre-operational testing program will be used to further characterize the porosity and permeability of the Knox Group formations and verify that some of the formations will provide an effective secondary confining interval (Attachment 5: Pre-Op Testing Program, 2022). The well logs are expected to identify a porous, permeable interval under the Knox Unconformity that can be used as a ACZ monitoring zone. The baseline 3D surface seismic data will be calibrated to the well data and used for inversion analysis. This will allow the project to characterize variations in porosity and lithology away from the project wells for the Knox Group formations over the imaging area of the 3D surface seismic data volume.

2.5 Geomechanical and Petrophysical Information [40 CFR 146.82 (a)(3)(iv)]

2.5.1 Geomechanics

Simple geomechanical modeling was completed to test the integrity of the confining zone. The computation modeling results were used as input to for the geomechanical modeling (Attachment 2: AoR and Corrective Action, 2022). Geomechanical information for the Eau Claire and Mt. Simon formations was found in the INEOS (BP Lima) Class I permit (Table 11). The average values were used to model the Eau Claire confining zone integrity given the anticipated injection rate of 400 kt/Y. In addition, step-rate test data and information on the breakdown, propagation, and closure gradients were obtained from this permit to support the modeling of the confining zone integrity (Figure 30 and Table 12).

Table 11: Summary of Young's Modulus, Poisson's Ratio, and Bulk Compressibility values from the INEOS (BP Lima) Nitriles UIC permit (INEOS USA, LLC, 2015).

Horizon	Young's Modulus (psi)	Poisson's Ratio	Bulk Compressibility (1/psi)
Cincinnati Group	2.17E+06	0.14	5.35E-07
Trenton	6.51E+06	0.06	3.19E-07
Black River	6.88E+06	0.09	3.48E-07
Knox (KD2)	1.06E+07	0.10	2.67E-07
Knox (KD1)	5.39E+06	0.19	3.59E-07
Knox Average	7.67E+06	0.14	3.06E-07
Eau Claire (EC4)	1.78E+06	0.01	1.41E-07
Eau Claire (EC3)	4.19E+06	0.11	5.40E-07
Eau Claire (EC2)	3.61E+06	0.25	5.17E-07
Eau Claire (EC1)	2.65E+06	0.11	4.25E-07
Eau Claire Average	5.65E+06	0.12	5.60E-07
Mt. Simon (MS3)	2.62E+06	0.11	1.06E-06
Mt. Simon (MS2)	2.50E+06	0.17	6.95E-07
Mt. Simon (MS1)	2.39E+06	0.13	1.06E-06
Mt. Simon Average	2.46E+06	0.14	1.07E-06
Middle Run	5.26E+06	0.11	7.85E-07

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 30: Geomechanical data from the INEOS (BP Lima) Nitriles disposal site. A. step rate test results b. breakdown, propagation, and closure gradients (INEOS (BP Lima) Nitriles, August 22, 2016)

Table 12: Summary of breakdown, propagation, and closure gradients and pressures for the top of the Mt. Simon Sandstone at 3,100 ft based on the INEOS (BP Lima) Nitriles permit (INEOS (BP Lima) Nitriles, August 22, 2016)

	Gradient (psi/ ft)	Pressure (psia)
Breakdown	0.842	2,610
Propagation	0.776	2,406
Closure	0.690	2,139

Sensitive, Confidential, or Privileged Information

[redacted] It also showed no evidence of CO_2 migration into the Eau Claire Shale after 30 years of injection. Even at injection rates of 1.9 MMT/yr, the decrease in effective stress on the confining zone was not enough to open existing fractures.

During the pre-operational phase of the project, a variety of site-specific data from the confining and injection zones will be acquired in the project wells to support further geomechanical modeling. Information on the core testing that will provide ductility information for the injection and confining zones are provided in Table 5 of the Pre-Operational Testing Program (Table 5, page 16, Attachment 5: Pre-Operational Testing Program). These data include:

- Caliper and image logs,
- Triaxial testing to establish geomechanical parameters such as rock strength, Young's Modulus, Poisson's Ratio, and fracture gradient,
- Step-rate testing.

2.5.2 Petrophysics

Petrophysical analysis of the Eau Claire, Mt Simon, and Precambrian formation was completed on eight wells in the region (Figure 29). Log ascii standard (LAS) files and routine core data was acquired from the Indiana Geological & Water Survey and Ohio Division of Oil & Gas public data sources. These wells were the only wells within the Mt Simon Sandstone that had reliable data. The vintages of the data from these wells range from 1966 -1985, as a result data quality is variable. The log data associated with these wells is shown in Table 13.

Aptian Technical Ltd. and CORE Petrophysical Consulting Inc completed the petrophysical analysis using PowerLog and Geology respectively.

Table 13: Available well logs used for petrophysical analysis

Sensitive, Confidential, or Privileged Information

[redacted]

Core and log data were calibrated to Class I water disposal wells at AK Steel and INEOS (BP Lima) and used as a primary input to the geomodel (Figure 7). These Class I wells have years of injection volumes and significant geologic and reservoir data sets, all of which were used to model the injection and confining intervals. Using the Class I wells as analogs petrophysical analysis was completed on these and other well logs. Histograms and cross plots were made using this data which enabled better analysis of wells which did not have core data and improved the geologic model.

The petrophysical analysis was completed to estimate the facies, porosity, and permeability of the confining and injection zones. Core data was available in four of these wells and was used to guide the petrophysical calculations. Preprocessing work was required to get the raw log data ready for the petrophysical calculations. This included a depth shift of curves, unit correction for consistency, and creation of synthetic curve data to remedy intervals of bad data and missing logs.

While deriving porosity and permeability curves for these wells, the core (porosity and permeability) plug measurements were used as a calibration point. Core measured porosity and permeability values were very erratic with high and low values that occurred at specific depth ranges. This may indicate the presence of natural fractures. A relationship with the gamma, neutron porosity, sonic, and density logs was used to derive the petrophysical properties for the eight wells which included:

- Volume Clay (VCLAY),
- Facies
  - Sandstone 1 (Mt Simon Sandstone)
  - Sandstone 2 (Mt Simon Sandstone)
  - Silty sandstone (Eau Claire and Davis)
  - Shale (Eau Claire)
  - Limestone (Davis and small amounts in Eau Claire)
  - Dolomite (Davis)
  - Precambrian (Precambrian)
- Mineralogy (where the data quality was reliable)
  - Volume Shale
  - Volume Quartz
  - Volume Limestone
  - Volume Dolomite
  - Volume Sphalerite
- Effective Porosity
- Permeability

Figure 31 to Figure 34 show the results of the petrophysical analysis for IN 133540, the AK Steel, INEOS (BP Lima) Nitrile, and IN144601 wells. The porosity and permeability relationships were calculated for each facies type (Figure 35). The petrophysical results in the Precambrian basement were not considered reliable. The petrophysical log results were calibrated to core by adjusting the petrophysical model to align with the core data. The expected heterogeneities were resolved by establishing a best fit between input logs and output petrophysical logs (Table 13). The input core data showed the vertical anisotropy (kv/kh) to be about 5. The porosity and permeability relationships presented in Figure 35 were used to develop the static model (Attachment 2: AoR and Corrective Action, 2022).

The petrophysical calculations within the Eau Claire Formation and Mt Simon Sandstone show a reasonable estimate of porosity and permeability despite the vintage of the log data. The petrophysical analysis will be re-visited once the project acquires site-specific well logs and core data in the project wells (Attachment 5: Pre-Op Testing Program, 2022).

Figure 31: Confidential Business Information: IN133540 input data and petrophysical analysis

Figure 32: Confidential Business Information: AK Steel input data and petrophysical analysis

Figure 33: Confidential Business Information: INEOS (BP Lima) Nitriles input data and petrophysical analysis

Figure 34: Confidential Business Information: IN144601 input data and petrophysical analysis

Figure 35: Confidential Business Information: Effective porosity and permeability cross plots with core plugs (grey)

2.6 Seismic History [40 CFR 146.82(a)(3)(v)]

The project site is located in an area of the United States which is classified by the Federal Emergency Management Agency (FEMA) as earthquake hazard category A/White where there is a very small probability of experiencing damaging earthquake effects (Figure 36 and Table 14). The United States Geological Survey (USGS) keeps an up-to-date online library of earthquakes and seismic events that have occurred in the United States from 1800 to the present day (USGS, 2022). Figure 37 and Table 15 display the epicenter of each of the 2.5 or greater magnitude earthquakes (or seismic events) recorded within a 100-mile radius of the project site from 1800 to February 2022 (USGS, 2022). In addition, Figure 38 is a merged map of earthquake epicenters and bedrock structural features from the Indiana Geological and Water Survey (IGWS) and the ODNR Division of Geological Survey.

All the earthquakes since 2004 have had a magnitude of less than four. The nearest epicenter to the project was approximately 20 miles north. The event occurred in 1990 and was 3.0 magnitude. The most recent earthquake occurred on June 12, 2015, approximately 53 miles from the project site and had a magnitude of 2.6. The largest recorded earthquake (5.4 magnitude) within 100 miles occurred on March 9, 1937 and had a magnitude of 5.4; it was approximately 36 miles from the project site. No earthquakes have been identified that have an epicenter within the project AoR.

The Hoosier #1 Project is located is in an area with minimal earthquake activity, which suggests that there are no major structural faults in proximity to the project site. Section 2.1.2 discusses the status of the questionable Auglaize Fault; this fault is not expected to present a hazard to the project.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 36: FEMA Earthquake Hazard Map (FEMA, 2022)

Table 14: FEMA Earthquake Hazard Level (FEMA, 2022).

SDC/Map Color	Earthquake Hazard	Potential Effects of Shaking
A/White	Very small probability of experiencing damaging earthquake effects.	
B/Gray	Could experience shaking of moderate intensity.	Moderate shaking—Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
C/Yellow	Could experience strong shaking.	Strong shaking—Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built structures.
D/Light Brown D1/Darker Brown D2/Darkest Brown	Could experience very strong shaking (the darker the color, the stronger the shaking).	Very strong shaking—Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures.
E/Red	Near major active faults capable of producing the most intense shaking.	Strongest shaking—Damage considerable in specially designed structures; frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Shaking intense enough to completely destroy buildings.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 37: 2.5 or greater magnitude epicenters within 100 miles from 1800 to February 2022 (USGS, 2022)

Table 15: 2.5 or greater magnitude epicenters within 100 miles from 1800 to February 2022 (USGS, 2022).

#	Date	Latitude	Longitude	depth	Magnitude
1	**6/12/2015**	**40.955**	**-84.762**	**5**	**2.6**
2	12/30/2010	40.43	-85.914	5	3.8
3	9/30/2008	40.41	-84.31	5	2.8
4	8/15/2006	40.71	-84.11	5	2.5
5	5/12/2006	40.74	-84.08	5	2.8
6	9/12/2004	39.604	-85.662	2.4	3.8
7	1/30/2004	40.67	-84.65	5	2.5
8	4/4/1994	40.4	-84.4	5	2.9
9	6/4/1990	41.098	-83.638	5	2.5
10	**4/17/1990**	**40.46**	**-84.852**	**5**	**3**
11	7/12/1986	40.537	-84.371	10	4.5
12	6/17/1977	40.707	-84.582	5	3.2
13	**3/9/1937**	**40.47**	**-84.28**	**3**	**5.4**
14	3/2/1937	40.488	-84.273	2	5
15	9/20/1931	40.429	-84.27	5	4.7
16	9/30/1930	40.3	-84.3		4.2
17	9/19/1884	40.7	-84.1		4.8
18	6/18/1875	40.2	-84		4.7
19	2/8/1812	39.4	-84.1		4.4
20	1/27/1812	39.6	-85		4.2

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 38: Earthquake epicenters and bedrock structural features

2.7 Hydrologic and Hydrogeologic Information [40 CFR 146.82(a)(3)(vi), 146.82(a)(5)]

The following sections provide information regarding available drinking water resources and delineation of the lowermost USDW within the AoR. The AoR and Corrective Action Plan includes a discussion of the number and locations of the groundwater wells within the AoR (Attachment 2: AoR and Corrective Action, 2022).

2.7.1 Regional Hydrology

The project is located in the Central Till Plain section of the New Castle Till Plains and Drainageways physiographic province (IGWS). During the Pleistocene Epoch, the region was exposed to Illinoisan and Wisconsin glaciation. Post-glacial streams have deposited up to 400 ft of valley fill along stretches of the major river systems. The glacially derived cover is generally less than 50 ft to over 300 ft thick in Randolph County (Figure 39).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 39: IGWS/ IndianaMAP unconsolidated thickness (Contour Interval (CI) = 50 ft) (State of Indiana, 2022).

2.7.2 Local Hydrology

In Randolph County, a relatively thin veneer of glacially derived sediments covers the bedrock surface. The project site is in the Upper Wabash River Basin and sits between the Price and Shelley Ditches, which are tributaries to the Little Mississinewa River to the northeast. Elevation of the ground level at the project site averages approximately 1,100 ft above mean sea level (MSL). Groundwater flow direction in the glacial aquifer at the project site follows the bedrock surface contours and is generally towards the north as can be seen in Figure 40.

[redacted]

Figure 40: IGWS/ IndianaMAP bedrock surface contours (CI = 50 ft) (State of Indiana, 2022).

2.7.3 Near Surface Aquifers

Cardinal Ethanol completed a groundwater resource assessment in 2007 and was used for some of the content in this section (Leggette, Brashears, and Graham, Inc., 2007).

The project is in the Little Mississinewa River watershed. The main source of groundwater is the unconsolidated glacial aquifers. [redacted] The Cincinnatian Series is a succession of fossiliferous limestone and gray calcareous shale or siltstones that can be subdivided into the Kope and Maquoketa formations.

The main aquifer systems in the area are the New Castle Till and Bluffton Till Aquifer Systems (Figure 42). In Randolph County, these aquifer systems are mapped as one system because the aquifer characteristics are similar. They are composed primarily of glacial tills that are separated by intratill sand and gravel aquifers of limited thickness and extent. [redacted]. Potential aquifer materials include sands and gravels that are commonly 5 ft thick. In places, the New Castle Till Aquifer System and Bluffton Till Aquifer System overlie deep bedrock valleys. However, in Randolph County, there is little known unconsolidated aquifer potential in the valleys below these systems.

The New Castle Till Aquifer System and Bluffton Till Aquifer System generally have a low susceptibility to surface contamination because intratill sand and gravel units are commonly overlain by thick glacial till.

Table 16 summarizes the significant water withdrawal facilities using sand & gravel aquifers (Leggette, Brashears, and Graham, Inc., 2007). IGWS has records for the offsetting groundwater wells shown in Figure 43.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 41: IGWS/ IndianaMAP unconsolidated thickness (CI = 50 ft) (State of Indiana, 2022)

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 42: IDNR unconsolidated aquifer system map. The red hatching indicates till over a buried valley. (Unterreiner, Unconsolidated Aquifers Systems of Randolph County, Indiana, 2006)

Table 16: Significant water withdrawal facilities using sand & gravel aquifer (Leggette, Brashears, and Graham, Inc., 2007).

Sensitive, Confidential, or Privileged Information

[redacted]

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 43: Offsetting freshwater well data (State of Indiana, 2022).
The depths and flow rates for each well are indicated on the map.

The Cardinal Ground Water Resource Assessment 2007 also details shallow geology and hydrogeology in the area. Figure 44 shows the location of two cross sections (Figure 45, Figure 46). Figure 47 shows offsetting sand and gravel deposits.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 44: Locations of the geologic cross sections presented in the preceding figures (Leggette, Brashears, and Graham, Inc., 2007)

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 45: North-south geologic cross section A - A' of near surface aquifers (Leggette, Brashears, and Graham, Inc., 2007)

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 46: East-west cross section B - B' of near surface aquifers (Leggette, Brashears, and Graham, Inc., 2007)

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 47: Offsetting sand and gravel deposits cross section frp, the Terracon borings in the area around the project (Leggette, Brashears, and Graham, Inc., 2007)

2.7.4 Determination of Lowermost USDW

A USDW is defined by the EPA as an aquifer that (40 CFR 146.3):

- Supplies any public water system
- Contains a sufficient quantity of groundwater to supply a public water system; and
    - Currently supplies drinking water for human consumption, or
    - Contains fewer than 10,000 mg/l total dissolved solids (TDS),
- Which is not an exempted aquifer.

For the purposes of this project, the lowest USDW depth is identified by Permit Number 30922 (IGS Well ID/PDMS 144860) located 1.5 miles SW of Cardinal CCS1 (Attachment 2: AoR and Corrective Action, 2022). The Well Plugging Plan for this well identifies the lowest USDW at 622 ft as shown in Figure 48. Figure 49 shows the appended geophysical log indicating Maquoketa Shale top at 240 ft and lowest USDW (622 ft).

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 48: Permit Number 30922 (IGS Well ID/PDMS 144860) well plugging plan. USDW is identified at 622 ft by IDNR.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 49: Permit Number 30922 (IGS Well ID/ PDMS 144860). IDNR has identified the lowermost USDW at 622 ft

2.7.4.1 *Silurian and Devonian Carbonates*

In Randolph County, the younger Devonian aged carbonates are not present, and this aquifer system consists only of Silurian age carbonates. The Silurian and Devonian Carbonates Aquifer System outcrops/subcrops throughout much of Randolph County. [redacted]

[redacted]

Wells using the Silurian and Devonian Carbonates Aquifer System are generally capable of meeting the needs of domestic users and some high-capacity users in this county. [redacted] A few flowing wells have been reported for this bedrock aquifer system in the county. High-capacity well depths range from approximately 40 to 400 ft below the land surface. Several of the high-capacity wells have contributions from both the Silurian and Devonian Carbonates Aquifer System and the underlying Maquoketa Group Aquifer System (Table 17).

This aquifer system is generally not very susceptible to surface contamination due to the thick clay deposits over most of the county. However, solution features (caves) are described in a few well records suggesting minor karst development. However, there are localized areas, especially near the White and the Mississinewa Rivers, where the bedrock surface is shallow or exposed. Therefore, these areas are at moderate to high risk for contamination (Unterreiner, Bedrock Aquifer Systems of Randolph Country, Indiana, 2006).

[redacted]

* Facilities which also operate wells in the unconsolidated glacial material and therefore do not meet all demand from bedrock wells

Table 17: Significant water withdrawal facilities using limestone aquifer (Leggette, Brashears, and Graham, Inc., 2007)

2.7.4.2 *Ordovician Maquoketa Group*

The outcrop/subcrop area of this aquifer system is limited to the three main bedrock valleys in this county. The Maquoketa Group consists mostly of shales with interbedded limestone units. [redacted]

In Randolph County, some wells completed in the Maquoketa Group Aquifer System are open to and receive some water from the Silurian and Devonian Carbonates Aquifer System. However, wells completed solely in the Maquoketa Group Aquifer System are generally capable of meeting the needs of domestic users in this county. [redacted]

The Maquoketa Group Aquifer System is generally not very susceptible to contamination from the land surface because thick layers of clay-rich material overlie the bedrock (Unterreiner, 2006).

The Maquoketa Group is present at the bedrock surface in small areas in Randolph, Delaware, Henry, and Madison counties. It is the least extensive bedrock aquifer system in the West Fork White River basin. The rocks in this group are the oldest at the bedrock surface in the basin, exposed only in pre-glacial valleys that have since been filled with glacial drift.

The thickness of the Maquoketa Group is highly variable because the top of the group is an erosional disconformity and has local relief of more than 100 ft due to pre-glacial erosion of the bedrock surface.

[redacted] Well depth depends upon bedrock elevation and unconsolidated material thickness. The bedrock surface elevation for a specific area can be estimated using Figure 40. The thickness of unconsolidated material for an area can be estimated using Figure 39. The penetration of wells into bedrock in this aquifer system is also highly variable and ranges from about 10 to more than 290 ft. Data are not sufficient to correlate yields with the depth of penetration. [redacted]

In general, because of the high shale content, the Maquoketa Group is considered to be an aquitard having poor yield potential. However, in the West Fork White River Basin higher yields are reported than in other parts of the state because there is higher limestone content in the upper part of the group. The moderate yield potential in the basin is related to joints and solution cavities that formed in the limestone units.

Well yields from the Maquoketa Group, as indicated by drillers' tests, range from 0 to 200 GPM. Yields of 5 to 15 GPM are typical and yields above 15 GPM are not common. Dry holes have also been reported to IDNR (Unterreiner, Bedrock Aquifer Systems of Randolph Country, Indiana, 2006).

Generally, the Maquoketa Group is not highly productive, and it is typically used only when the overlying drift does not contain an adequate sand and gravel aquifer. It is bounded by the younger, overlying Silurian and Devonian Carbonate Aquifer System.

2.7.5 Topographic Description

The Hoosier #1 Project is located in Section 17, Wayne Township, Randolph County, Indiana near Union City at an elevation of approximately 1,100 ft. This is an area of minimal flood hazard as established by the FEMA (Figure 50). The Quaternary surface geology is the result of Wisconsinan (Huron-Erie Lobe) glaciation and filled with loam till (Figure 51). At the project site, glacial deposits are approximately 120 ft thick.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 50: National Flood Hazard Layer FIRMette (FEMA, 2022)

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 51: Quaternary geology related to the Wisconsinan (Huron-Erie Lobe) Glaciation (State of Indiana, 2022).

2.8 Geochemistry [40 CFR 146.82(a)(6)]

There are a limited number of wells that penetrate the Mt. Simon Sandstone and, currently, little data to support detailed aqueous or solid phase geochemical modeling for the project. The Mt. Simon Sandstone does contain feldspar, potentially carbon cement, and clay minerals. These minerals are reactive with CO_2. and it is expected that changes to the aqueous geochemistry of the Mt. Simon Sandstone fluids will occur once CO_2 injection commences.

The computational modeling investigated the effect of mineralization on long-term trapping of CO_2 based on the potential reactions with calcite, anorthite, and kaolinite as part of the PISC Alternative Timeframe using the information currently available (Attachment 9: Post-Injection Site Care, 2022). This modeling demonstrated that mineralization is not expected to play a significant role in trapping for thousands of years. No other geochemical or reactive transport modeling has been completed for the injection zone or the confining zone at this time give the scarcity of data.

The Pre-Operational Testing Program details the data that will be acquired in CCS1 and from the Deep Observation Well (OBS1) that may be used to support future geochemical modeling (Attachment 5: Pre-Op Testing Program, 2022). The mineralogy of the injection zone and confining zone will be determined through a combination of core analysis and well logging. Well log data will also be acquired through the lowermost USDW and ACZ monitoring zone to assist in establishing the mineralogy of these formations.

Fluid samples will be acquired from the lowermost USDW, the ACZ monitoring interval, and the injection zone when the project wells are drilled. The Testing and Monitoring Plan details the parameters and analytes that will be used to establish baseline conditions for these formations as well as during the injection phase of the project (Attachment 7: Testing And Monitoring, 2022). The aqueous geochemistry data gathered during the pre-operational phase of the project will also be used to support future geochemical modeling work. Geochemical modeling will likely focus on reactions in the injection zone and any reactions in the confining zone that may impact long-term containment and endangerment of USDWs.

2.9 Other Information (Including Surface Air and/or Soil Gas Data, if Applicable)

The Pre-Operational Testing Program presents the data that will be collected in order to determine and verify the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the injection zone, confining zone, and other relevant geologic formations via petrophysical logging and analysis, and core acquisition and testing (Attachment 5: Pre-Op Testing Program, 2022). In addition, baseline 3D surface seismic data will be acquired during the pre-injection phase of the project to assist in characterizing injection zone and confining zone rock properties away from CCS1 and OBS1.

At this time, the project does not plan to acquire baseline atmospheric or soil gas data nor are there plans to pursue atmospheric or soil gas monitoring during the injection phase of the project.

2.10 Site Suitability [40 CFR 146.83]

The AK Steel and INEOS (BP Lima) disposal wells provided useful data on the Eau Claire Formation and Mt. Simon Sandstone and were used as analogs for this project. In addition, study of other regional well data and computational modeling indicate that the geologic setting of the proposed injection zone has the capacity to store 13.5 million metric tons of CO_2 over 30 years of injection based on:

Sensitive, Confidential, or Privileged Information

[redacted]

Given the lateral continuity, open nature of the injection zone, and computational modeling, the injection zone is expected to have more than adequate capacity for the injection volumes proposed. CO_2 plume development is expected to be controlled by heterogeneities within the injection zone. These heterogeneities will be characterized using a combination of well log, core, and 3D surface seismic data acquired during the pre-operational phase of the project (Attachment 5: Pre-Op Testing Program, 2022). The AoR and Corrective Action Plan includes discussion of the capacity estimates for the injection zone (Attachment 2: AoR and Corrective Action, 2022).

The Eau Claire Shale is expected to be an excellent confining zone for the project. It is estimated to be 487 ft thick at the project site and has excellent lateral continuity across the basin. Based on the petrophysical analysis of sixteen wells in the region, it has very low permeabilities that average 2.7 mD. Computational modeling indicates that the Eau Claire Shale will be an effective barrier to upward migration of CO_2 and injection zone fluids (Attachment 2: AoR and Corrective Action, 2022). Data gathered during the pre-operational phase of the project is expected to verify that the Eau Claire Shale is a suitable confining zone (Attachment 5: Pre-Op Testing Program, 2022).

While the Eau Claire Shale is expected to be a highly competent confining zone, additional formations within the Knox Group afford additional containment including the Knox Dolomite, which has permeabilities from 0.00005 – 24.1 mD at the INEOS (BP Lima) Nitriles disposal site. If injection zone fluids were to migrate past the primary confining zone, multiple formations within the Knox Group will prevent the fluids from migrating up to the lowermost USDW. Other similar projects indicate the Middle Run and Precambrian basement rock will act as an impermeable lower confining zone for the Mt. Simon Sandstone injection zone.

No deep wells penetrate the confining zone within the AoR. The closest well (Sensitive, Confidential, or Privileged Information [redacted]) penetrating the Eau Claire Formation is 13 miles to the southwest, which is a significant distance outside of the AoR. No natural conduits, such as fault or fractures, for injection zone fluid migration beyond the confining zone have been identified on the existing 2D surface seismic data. It is anticipated there will be a lack of large-aperture tension fractures in Cardinal CCS1, as determined from the image and sonic logs, indicating that the well is not proximal to normal (tensional) faults that might be close to failure.

The well casing, tubing, and cement used through the confining zone and injection zone will be CO_2 resistant (Attachment 4: Well Construction, 2022). It is expected that the CO_2 will interact with mineral components of the Mt. Simon Sandstone over time. As discussed in Section 2.9, once the project acquires more site-specific data during the pre-injection phase of the project, it will be used to model the potential geochemical reactions that will occur in the injection zone. These reactions will be monitored using fluid samples that will be taken from the injection zone in OBS1 during the first three years of the injection phase of the project (Attachment 7: Testing And Monitoring, 2022). Geochemical interactions between the CO_2 and the confining zone are not expected to impact long-term containment of the CO_2 based on the thickness and lack of fractures the project expects to encounter in the confining zone.

3 AoR and Corrective Action

Through the computational modeling, a 2.26-mile AoR has been determined for this project (Attachment 2: AoR and Corrective Action, 2022). After a thorough review of all identified wells in the region, it has been determined that there are no wells within the AoR that penetrate the confining zone, and there is no requirement for corrective action.

AoR and Corrective Action GSDT Submissions
GSDT Module: AoR and Corrective Action ***Tab(s):*** All applicable tabs Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Tabulation of all wells within AoR that penetrate confining zone ***[40 CFR 146.82(a)(4)]*** ☒ AoR and Corrective Action Plan *[40 CFR 146.82(a)(13) and 146.84(b)]* ☒ Computational modeling details ***[40 CFR 146.84(c)]***

Sensitive, Confidential, or Privileged Information

[redacted]

Sensitive, Confidential, or Privileged Information [redacted]

5 Injection Well Construction

Vault intends to use materials of construction (casing, cement, etc.) that are verified by independent third-party sources as suitable for the worst-case corrosive load expected to occur during the life of the project. Verification of the suitability is provided as part of the supporting documents for (Attachment 4: Well Construction, 2022).

Sensitive, Confidential, or Privileged Information [redacted]

Should a substantial lost circulation zone (LCZ) be encountered during the drilling of the long string section, well control and loss prevention measures will be implemented, and the hole will be reamed up to run a contingent intermediate string. The potential anticipated LCZ is the Potosi. The end of this section is to be determined (TBD) and is dependent on drilling conditions experienced in the field. It is, however, anticipated that this section total depth (TD) will occur above the top of the Eau Claire Formation.

Wellheads will be used with appropriately sized components and materials of construction based on the build of the wellbore. The wellhead will vary depending on whether the intermediate contingency section is needed or not.

Following installation of the long string casing and cement, perforations will be made into the casing to access the Mt. Simon Sandstone for injection.

Schematics for the wellbore and wellhead (planned and contingency) are provided in the well construction plan attachment of the permit application.

Sensitive, Confidential, or Privileged Information [redacted] The downhole pressure gauge will be used to help ensure that the maximum allowable bottomhole pressure (BHP) does not exceed 90% of the fracture pressure (40 CFR 146.88 [a]). The downhole temperature gauge will used to calculate the bottomhole density and volume of the injected fluid. The BHP gauges will be programed to take data at the intervals outlined in the testing and monitoring program section of this application (Attachment 7: Testing And Monitoring, 2022). The data collected from these measurement systems will be collected continuously and sent to a surface SCADA system. More information about these sensors is provided in the Well Operations and Testing and Monitoring Plans (Attachment 6: Well Operations, 2022; Attachment 7: Testing And Monitoring, 2022).

Further details on the proposed stimulation program, construction plan, and materials of construction are provided in this section as well as in the well construction attachment.

5.1 Proposed Stimulation Program [40 CFR 146.82(a)(9)]

It is not currently anticipated that any additional stimulation will need to be performed on the well after initial completion, other than to clean out the perforations made in the long-string casing.

Vault reserves the right to perform intermediate stimulation on this well, should the need arise. A list of some of the common remediation techniques that may be deployed in the future is listed below. Note that this is not an exhaustive list and additional technologies or treatments may be used. Further detail on methods, materials, and chemicals to be used during treatments is provided in (Attachment 4: Well Construction, 2022).

- Matrix acid stimulation,
- Coil tubing chemical stimulation,
- Coil tubing mechanical stimulation,
- Perforations.

Stimulations will occur as necessitated by well conditions. These will be identified by evaluating well performance over time. The necessary notification will be provided to the Agency prior to any field mobilization. Within this notification, detail on the proposed procedure, equipment, and chemicals to be used will be provided.

5.2 Construction Procedures [40 CFR 146.82(a)(12)]

The injection well will be drilled as a new well. Multiple strings of carbon steel and 13-Chrome casing will be installed and cemented in place to protect the USDWs and other strata overlying the injection formation. Fluids will be injected into the Mt. Simon Sandstone using internally coated carbon steel casing landed in in a nickel coated packer. The Mt. Simon Sandstone will be accessed through perforations in the long string casing.

A high-level procedure is provided below. A more detailed schedule and procedure is provided in Attachment 4.

1. Conductor casing will be drilled then cemented in place.
2. Surface hole will be drilled. This hole will be drilled to a sufficient depth below the base of the USDW such that the entire USDW can be logged during open and cased hole logs.
3. Open hole logs will be run.
4. Casing will then be run and cemented in place.
5. After allowing sufficient time for the cement to harden, cased hole logs will be run, and the casing will be pressure tested.
6. Long string hole will be drilled. This hole will be drilled into basement (if OBS1 does not penetrate it) or above basement (if OBS1 does penetrate it).
    a. Should a substantial LCZ occur during drilling the long string section, an intermediate contingent string of casing will be run.
    b. Prior to operations, well control and loss prevention measures will be implemented until the well is stable.
    c. The hole will be reamed up to size and open hole logs will be run.
    d. Casing will then be run and cemented in place.
    e. After allowing sufficient time for the cement to harden, cased hole logs will be run, and the casing will be pressure tested.
7. Open hole logs will be run.
8. Casing will then be run and cemented in place.
9. After allowing sufficient time for the cement to harden, cased hole logs will be run, and the casing will be pressure tested.
10. Perforations will be made in the long string casing into the Mt. Simon Sandstone.
11. The tubing, packer, and wellhead will then be installed.

Specifications on the tools, equipment, casing, cement, and other things are provided in more detail in Attachment 4. All materials of construction are designed to API standards.

5.2.1 Casing and Cementing

Table 18 and Table 19 display the safety factors and safety factor loads based on the proposed well design. It is noted that an 80% derating factor is applied prior to any analyses. This implies an additional 1.20 safety factor on top of those displayed in the table. Additionally, material and specification derating based on tensile loading is also considered. Finally, worst-case analyses (i.e., evacuated casing while pumping cement while also pulling up at the max tensile rating) were considered in casing evaluation. Anticipated loads are displayed first, followed by worst case loads. Additional details on these analyses that were performed on: external pressure (collapse), internal pressure (burst), and axial loading (Tensile and Von Mises) are provided in the Section 1.2.5 and 1.3 of the Injection Well Construction Plan (Sections 1.2.5 and 1.3, pages 14-18, Attachment 4: Injection Well Construction Plan).

In addition to these analyses, cyclic and temperature loading analysis was performed. The results of this analysis are presented in (Attachment 4: Well Construction, 2022).

Table 20 displays the setting depths and specifications of the casing to be used for the well. All casing conforms with API specifications. Table 23 shows the design parameters of the casing, tubing, and packer to be used for the well.

Details on the cement program are provided in (Attachment 4: Well Construction, 2022). All cement used conforms with API standards. Corrosion resistant cement will be used from the bottom of the well to above the top of the Eau Claire Formation.

Mechanical integrity will be demonstrated as part of the initial completion, and routinely as discussed in (Attachment 5: Pre-Op Testing Program, 2022) and (Attachment 7: Testing And Monitoring, 2022), respectively.

All materials of construction are suitable for the anticipated loading and are not anticipated to decrease in suitability over time.

Table 22 displays the anticipated target, maximum, minimum, and worst-case specification for post compression CO_2 that will be injected into the well. Figure 52 and Figure 53 display a sample of the CO_2 purity prior to any compression occurs.

Table 18. Casing Safety Factors for Design.

Sensitive, Confidential, or Privileged Information

[redacted]

Table 19. Casing Safety Factor Loads for Design.

Sensitive, Confidential, or Privileged Information

[redacted]

Table 20. Casing and Tubing details.

Casing String	Casing Depth	Borehole Diameter	Wall Thickness	External Diameter	Casing Material	String Weight
Surface	Sensitive, Confidential, or Privileged Information [redacted]					
Long String (Metal)						
Long String (Chrome)						
Injection Tubing						
Intermediate (contingency)						

*Internal diameter of long string casing

Table 21. Casing, Tubing, and Packer Details

Material	Setting Depth (ft)	Tensile Strength	80% of Tensile Strength	Burst Strength	80% of Burst Strength	Collapse Strength	80% of Collapse Strength	Material of Construction
Surface Casing	Sensitive, Confidential, or Privileged Information [redacted]							
Long Strong Casing								
Injection Tubing								
Intermediate (contingency)								
Baker Signature F								

Table 22. Confidential Business Information: Anticipated CO_2 Specifications

Figure 52: Confidential Business Information: Feed Gas Composition Report From May, 2021, Page 1.

Figure 53: Confidential Business Information: Feed Gas Composition Report From May, 2021, Page 2.

5.2.2 Tubing and Packer

The tubing, [redacted], is anticipated to withstand the corrosive loading experienced during normal operations. The internal coating to be used has been routinely used in waste disposal and Enhanced Oil Recovery (EOR) projects. This internal coating has proved to be suitable for use in more corrosive environments than are anticipated to be experienced in this application. Further detail on the suitability is provided in (Attachment 4: Well Construction, 2022).

The packer to be used for the project is Baker Signature F style retrievable packer. This packer will also be nickel coated to prevent any corrosion. This packer and coated mechanism are typical for disposal purposes and designed to prevent corrosion or leakage. Further details on the packer are provided in (Attachment 4: Well Construction, 2022).

6 Pre-Operational Logging and Testing

Details on the pre-operation testing plan are provided in the relevant section of this permit application (Attachment 5: Pre-Op Testing Program, 2022).

Pre-Operational Logging and Testing GSDT Submissions
GSDT Module: Pre-Operational Testing ***Tab(s):*** Welcome tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Proposed pre-operational testing program ***[40 CFR 146.82(a)(8) and 146.87]***

7 Well Operation

This section is meant to provide a brief overview of the well operation conditions. Further details on the well operation program are provided in (Attachment 6: Well Operations, 2022).

7.1 Operational Procedures [40 CFR 146.82(a)(10)]

Table 23 displays the operational parameters that will be used during injection operations. Details on the methods of calculations and inputs for these values are provided in (Attachment 6: Well Operations, 2022). Values provided in this table are designed to stay below the critical fracture pressure, while also managing the pressure loading experienced during operations to protect equipment. It is not anticipated that significant deviation from these values will occur during the life of the project.

Table 23. Proposed operational procedures.

Sensitive, Confidential, or Privileged Information

[redacted]

7.2 Proposed CO_2 Stream [40 CFR 146.82(a)(7)(iii) and (iv)]

Cardinal Ethanol will analyze the CO_2 stream during the injection phase of the project to provide data representative of its chemical characteristics and to meet the requirements of 40 CFR 146.90 (a). Details on the testing and monitoring of the CO_2 stream are provided in the testing and monitoring section of this permit. Additional details on technical standards, QA/QC policy, sample collection and storage policies, and analytical methods are provided in the QASP (Attachment 11: QASP, 2022).

Based on the nature of the ethanol fermentation process, the CO_2 stream produced is anticipated to be of high purity. Even so, after fermentation, the CO_2 stream will pass through two scrubbers prior to entering the compressor and the pipeline.

It is currently anticipated that quarterly sampling of the CO_2 injection stream will be sufficient to accurately track the composition of the stream. The regular samples will be taken on quarterly intervals, at the end of each quarter (March, June, September, and December).

8 Testing and Monitoring

Testing and Monitoring GSDT Submissions
GSDT Module: Project Plan Submissions **Tab(s):** Testing and Monitoring tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Testing and Monitoring Plan [40 CFR 146.82(a)(15) and 146.90]

This section is meant to provide a brief overview of the Testing and Monitoring Plan. Further details on the well operation program are provided in (Attachment 7: Testing And Monitoring, 2022).

9 Injection Well Plugging

Following the conclusion of injection operations, the injection well will be permanently plugged and abandoned. Details on the methods of these operations are provided in (Attachment 8: Well Plugging, 2022). The methods and procedures presented in the attachment are consistent with industry standards and the requirements detailed in 40 CFR 146.92. All materials to be used for the plugging and abandonment are suitable for the anticipated corrosive loading below the top of the Eau Claire. Above the top of the Eau Claire Formation, the materials are standard construction materials, conforming the API specifications.

Injection Well Plugging GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** Injection Well Plugging tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Injection Well Plugging Plan [40 CFR 146.82(a)(16) and 146.92(b)]

10 Post-Injection Site Care and Site Closure

The requested documents listed below have been included in the file submission (Attachment 9: Post-Injection Site Care, 2022). These documents address the rule requirements for the above EPA citations. The Hoosier #1 Project is requesting an alternative PISC timeframe.

PISC and Site Closure GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** PISC and Site Closure tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ PISC and Site Closure Plan [40 CFR 146.82(a)(17) and 146.93(a)]
GSDT Module: Alternative PISC Timeframe Demonstration ***Tab(s):*** All tabs (only if an alternative PISC timeframe is requested) Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Alternative PISC timeframe demonstration ***[40 CFR 146.82(a)(18) and 146.93(c)]***

11 Emergency and Remedial Response

The below requested documents have been included in the file submission (Attachment 10: ERRP, 2022). These documents address the rule requirements for the above EPA citations.

Emergency and Remedial Response GSDT Submissions
GSDT Module: Project Plan Submissions ***Tab(s):*** Emergency and Remedial Response tab Please use the checkbox(es) to verify the following information was submitted to the GSDT: ☒ Emergency and Remedial Response Plan *[40 CFR 146.82(a)(19) and 146.94(a)]*

12 Injection Depth Waiver and Aquifer Exemption Expansion

Cardinal and Vault do not intent to apply for a Depth Waiver or Aquifer Exemption. As such, no supplemental documents have been filed.

Injection Depth Waiver and Aquifer Exemption Expansion GSDT Submissions
GSDT Module: Injection Depth Waivers and Aquifer Exemption Expansions ***Tab(s):*** All applicable tabs

Please use the checkbox(es) to verify the following information was submitted to the GSDT:

☐ Injection Depth Waiver supplemental report ***[40 CFR 146.82(d) and 146.95(a)]***

☐ Aquifer exemption expansion request and data ***[40 CFR 146.4(d) and 144.7(d)]***

13 Risk Assessment

Development of both a Project Risk Assessment (RA) and a Risk Management Plan (RMP) are critical to advancement of a carbon sequestration project. These plans will be dynamic and evolve over time through the pre-injection, operational, and PISC phases of a project as new data are acquired and assessed. One primary goal of conducting an RA early in the feasibility and characterization phase of a project is to identify potential risk scenarios that can be managed through site characterization along with testing and monitoring activities. As such, the RMP will be closely linked to the Pre-Operational and Testing and Monitoring Plans throughout all phases of the project's life cycle (Figure 54). Initially, the RMP will identify areas of subsurface uncertainty, which will help determine the site characterization and development activities, as well as to identify any potential long-term risk scenarios that can be managed and mitigated through testing and monitoring activities.

The geologic characterization studies, static modeling, and computational modeling work were used to inform the risk assessment and scenario ranking for the Hoosier #1 Project (Figure 54). A high-level list of sixty risk scenarios was compiled based on Vault's experience working on RAs for over a dozen carbon sequestration projects in North America. The risk scenarios were ranked individually on severity and likelihood scale that each ranged from one to five. All the risk scenarios ranked between two and eight out of a possible 25.

Table 24 provides a description of the risk rank categories, associated color code, and description. Thirty-seven of the risk scenarios can be managed and mitigated through site characterization and testing and monitoring activities.

Sensitive, Confidential, or Privileged Information

[redacted]

Figure 54: Workflow from initial site characterization for a project through to testing and monitoring plan design.

Table 24: Risk rank categories, associated color coding, and description

Risk Rank	Color Code	Description
20 – 25	Black	Non-Operable: Evacuate the zone or area
10 – 16	Red	Intolerable: Do not take this risk
5 – 9	Yellow	Undesirable: Demonstrate as low as reasonably possible (ALARP) before proceeding
2 – 4	Green	Acceptable: Proceed carefully with continuous improvement
1	Blue	Negligible: Safe to Proceed

Table 25 summarizes the risk rankings, high-level risk scenario categories, and the number of scenarios that fit into each category. The risk scenario categories cover subsurface elements such as geology, containment, injectivity, geochemical effects, and potential for induced seismicity events. Table 1 in Risk Register contains a full list of the 60 risk scenarios and rankings (Attachment 12: Confidential Business Information: Risk Register, 2022).

Table 25: Breakdown of the risk rankings, categories, and number of scenarios identified.

Ranking	Risk Category	Scenarios Identified
Undesirable (5 – 9)	Schedule	3
	Regulatory	1
	Geology	5
	Geology: Containment	2
	Opposition: Public	8
	Economic	1
	Project Wells: Drilling	1
	Reservoir Performance	1
	Monitoring: General	2
Acceptable (2 – 4)	Geology	5
	Geology: Containment	1
	Reservoir Performance	2
	Project Management	3
	CO_2 Injectate	1
	Project Wells: Drilling	2
	Project Wells: Operations	1
	Project Wells: Integrity	3
	Project Wells: Completions	1
	Existing Wells	3
	Monitoring: General	6
	Weather	1

Ranking	Risk Category	Scenarios Identified
	Liability	1
	Regulatory	1
Negligible (1)	Project Wells: Operations	4
	Geology	1
Total		**60**

Thirty-two of the risk scenarios identified can be managed and mitigated through the pre-operational testing program that will be executed when the project wells are drilled. The data collected over this phase will be used to manage and mitigate uncertainties and risks related to capacity, containment, injectivity, injection pressures and fracture gradient, as well as potential seismic events (Attachment 12: Confidential Business Information: Risk Register, 2022).

Thirty-two of the risk scenarios identified can be managed and mitigated through testing and monitoring activities that will be implemented through the injection and PISC phases of the project. The project Risk Register summarizes the risk scenarios with their associated testing and monitoring mitigations (Attachment 12: Confidential Business Information: Risk Register, 2022).

14 Approval

Wade Zaluski P.Geo.

May 31, 2022

APEGA Permit to Practice Number Vault4401

P15447

15 References

AK Steel Cleveland-Cliffs Steel Corporation. (March 15, 2021). *Ohio Environmental Protection Agency Division of Drinking and Ground Waters Underground Injection Control Permit to Operate Class I Hazardous Well; Ohio Permit UIC 05-09-001-THO-I.*

(2022). *Attachment 1: Narrative.* Class VI Permit Application Narrative; Project Hoosier#1, Vault 4401.

(2022). *Attachment 10: ERRP.* Emergency And Remedial Response Plan; Hoosier#1 Project, Vault 4401.

(2022). *Attachment 11: QASP.* Project Hoosier#1, Vault 4401.

(2022). *Attachment 12: Confidential Business Information: Risk Register.* Rick Register; Project Hoosier#1, Vault 4401.

(2022). *Attachment 2: AoR and Corrective Action.* Area Of Review And Corrective Action Plan; Project Hoosier#1, Vault 4401.

(2022). *Attachment 2: AOR and Corrective Action.* Area Of Review And Corrective Action Plan; Project Hoosier#1, Vault 4401.

(2022). *Attachment 3: Financial Responsibility.* Financial Responsibility; Project Hoosier#1, Vault 4401.

(2022). *Attachment 4: Well Construction.* Injection Well Construction Plan; Project Hoosier#1, Vault 4401.

(2022). *Attachment 5: Pre-Op Testing Program.* Pre-Operational Formation Testing Program; Project Hoosier#1, Vault 4401.

(2022). *Attachment 6: Well Operations.* Well Operation Plan; Project Hoosier#1, Vault 4401.

(2022). *Attachment 7: Testing And Monitoring.* Testing And Monitoring Plan; Project Hoosier#1, Vault 4401.

(2022). *Attachment 8: Well Plugging.* Project Hoosier#1, Vault 4401.

(2022). *Attachment 9: Post-Injection Site Care.* Post-Injection Site Care And Site Closure Plan; Project Hoosier#1, Vault 4401.

Degterev, A. Y. (2020). Multivariate Spatial Temporal Model of Gas Dynamic in Underground Gas Storage Based on Saturation Parameter from Well Logging Data. *SPE Russian Petroleum Technology Conference, Virtual, October 2020.*

FEMA. (2022, June). *Earthquake Hazard Maps*. Retrieved from https://www.fema.gov/emergency-managers/risk-management/earthquake/hazard-maps

FEMA. (2022, June). *National Flood Hazard Layer*. Retrieved from https://www.fema.gov/flood-maps/national-flood-hazard-layer

Indiana Geological Survey. (2016). *Generalized Stratigraphic Column of Indiana Bedrock.* Retrieved from https://igws.indiana.edu/ignis/GeneralizedStratigraphicColumn.pdf

INEOS (BP Lima) Nitriles. (August 22, 2016). *Ohio Environmental Protection Agency Division of Drinking and Ground Waters Underground Injection Control Permit to Operate Class I Hazardous Well; Ohio Permit UIC 03-02-005-PTO-I .*

INEOS USA, LLC. (2015). *Class I Underground Injection Control Permit to Operate Renewal Applications.*

Jackson, P. D. (1982). *Geophysical investigation of western Ohio-Indiana region, final report Nov. 1975-Sept 1981.* Nuclear Regulatory Commission Report CR-2484.

Kemron Environmental Services, Inc. (2018). *UIC Permit Renewal Application Class I Wells.*

Leggette, Brashears, and Graham, Inc. (2007). *Caridnal Ethanol Plant Ground-Water Resource Assessment.*

ODNR Division of Geological Survey. (2022). *Ohio Geology Interactive Map*. Retrieved from https://gis.ohiodnr.gov/website/dgs/geologyviewer/#

State of Indiana. (2022, June). *Indiana Map*. Retrieved from https://www.indianamap.org/

Unterreiner, G. A. (2006). *Bedrock Aquifer Systems of Randolph Country, Indiana.* Indiana Department of Natural Resources, Division of Water and Resource Assessment.

Unterreiner, G. A. (2006, December). *Unconsolidated Aquifers Systems of Randolph County, Indiana.* Retrieved from https://www.in.gov/dnr/water/files/randolph_unconsolidated.pdf

USGS. (2022, June). *USGS Latest Earthquakes*. Retrieved from https://earthquake.usgs.gov/earthquakes/map/?extent=10.74697,-134.73633&extent=58.49369,-55.2832)

Wickstrom, L. J. (1993). *Stratigraphy, structure, and production history of the Trenton Limestone (Ordovician) and adjacent strata in northwestern Ohio.* Ohio Geological Survey Report of Investigation 14.

Baranoski, Mark, 2002, Structure Contour Map on Precambrian Unconformity Surface, Ohio Division of Geological Survey, Map PG-23

Baranoski, Mark T., 2007, Thickness and Extent of Saline Cambrian Reservoirs in the Ohio Region Is Controlled, in Part, by the Underpinning Precambrian Complex and Paleotopography, Eastern Section AAPG

Baranoski, Mark T., Dean, Stuart L., Wicks, John L., Brown, Vernon M., Unconformity-bounded seismic reflection sequences define Grenville-age rift system and foreland basins beneath the Phanerozoic in Ohio, Geosphere (2009) 5 (2): 140–151.

Barnes, D. A., Bacon, D. H., and Kelley, S. R., 2009, Geological sequestration of carbon dioxide in the Cambrian Mount Simon Sandstone: Regional storage capacity site characterization, and large-scale injection feasibility, Michigan Basin: Environmental Geosciences, v. 16 no. 3

Becker, Leroy E., Hreha, Andrew J., Dawson, T. A., 1978, Pre-Knox (Cambrian) Stratigraphy in Indiana, pg. 36, 13

Bickford, M. E., Van Schmus, W. R., and Zietz, Isidore, 1986, Proterozoic history of the Midcontinent region of North America: Geology, v. 14, p. 492-496.

Botoman, George, Precambrian and Paleozoic Stratigraphy and Potential Mineral Deposits Along the Cincinnati Arch of Ohio; Ohio State University, 1975, pg. 14, 19

Colton, George W., 1961, Geologic Summary of the Appalachian Basin, With Reference to the Subsurface Disposal of Radioactive Waste Solutions, PG 6, 36

Dawson, T. A., 1971, Map of Indiana showing structure on top of Trenton Limestone: Indiana Geological Survey Miscellaneous Map 17

Dean, S.L., and Baranoski, M.T., 2002a, Ohio Precambrian 1: A look at western Ohio's Precambrian tectonic setting: Oil and Gas Journal, v. 100, no. 29, p. 34-37.

Dean, S.L., and Baranoski, M.T., 2002b, Ohio Precambrian 2: Deeper study of Precambrian warranted in western Ohio: Oil and Gas Journal, v. 100, no. 30, p. 37-40.

Denison, R. E., Lidiak, E. G., Bickford, M. E., and Kisvarsanyi, E.G., 1984, Geology and geochronology of Precambrian rocks in the Central Interior Region of the United States: U.S. Geological Survey Professional Paper 1241-C, 20 p

Dickas, Albert B., M.G. Mudrey, Jr., Richard W. Ojakangas, and Douglas L. Shrake 1992 A • Possible Southeastern Extension of the Midcontinent Rift System located in Ohio Tectonics, Vol. 11, No. 6, p. 1406- 1414, December 1992.

Dolly, E. D., and Busch, D. A., 1971, Stratigraphic, structural, and geomorphic factors controlling oil accumulation in Upper Cambrian strata of central Ohio: AAPG Bulletin, v 56 no 12, 2335-2369

Drahovzal, James C., Harris, David C., Wickstrom, Lawrence H., Walker, Dan, Baranoski, Mark T., Keith, Brian, Furer, Lloyd C., 1992, The East Continent Rift Basin—A New Discovery: Indiana Geological Survey Special Report, v. 52, p. 7, 25

Droste, J. B., and R. H. Shaver, 1983, Atlas of early and middle Paleozoic paleogeography of the southern Great Lakes area: Indiana

FEMA Earthquake Hazard Map/Table https://www.fema.gov/emergency-managers/risk-management/earthquake/hazard-maps

Geological Survey Special Report 32

Freeman, Louise. B., Regional subsurface stratigraphy of the Cambrian and Ordovician in Kentucky and Vicinity, 1953 Kentucky Geol. Survey, ser.9, Bull.4, p.14, 22

Gray, HENRY H. 1972, Lithostratigraphy of the Maquoketa Group (Ordovician) in Indiana, DEPARTMENT OF NATURAL RESOURCES GEOLOGICAL SURVEY SPECIAL REPORT 7

Gray, H. H., 2000, Physiographic Divisions of Indiana, Indiana Geological Survey Special Report 61,

Green, Michael Ray, 2015 Geophysical Exploration of The Upper Crust Underlying North-Central Indiana: New Insight into the Eastern Granite-Rhyolite Province, pg. 1,

Hansen, Michael C., 1997, The Geology of Ohio - the Cambrian: Ohio Geology, Ohio Division of Geological Survey, Columbus, Ohio, Winter 1997.

Harris, D.C., and M.T. Baranoski, 1996, Play Cpk: Cambrian Pre-Knox Group Play, in J.B. Roen, and B.J. Walker, editors, The Atlas of Major Appalachian Gas Plays, West Virginia Geological and Economic Survey Publication v. 25, p. 188-192.

INEOS USA LLC, 2015, Class I Underground Injection Control Permit to Operate Renewal Applications

Janssens, Adrian, Analysis of the Paleozoic Movements of the Cincinnati Arch; Ohio State University, 1967

Janssens, Adrian, Stratigraphy of the Cambrian and lower Ordovician in Ohio,1973 Ohio Div. Geol. Survey Bull. 64, pg. 11, 9, 9

Keith, B. D., 1985, Map of Indiana showing thickness, extent, and oil and gas fields of Trenton and Lexington Limestones: Indiana Geol. Survey Misc. Map 45.

Leggette, Brashears and Graham, Inc., 2007, Cardinal Ethanol Plant Ground-Water Resource Assessment

Medina, Cristian R., Rupp, John A., Reservoir characterization and lithostratigraphic division of the Mount Simon Sandstone (Cambrian): Implications for estimations of geologic sequestration storage capacity, Environmental Geosciences, v. 19, no. 1 (March 2010)

Midwestern Regional Carbon Sequestration Partnership (MRCSP), A Regional Characterization and Assessment of Geologic Carbon Sequestration Opportunities in the Upper Cambrian Mount Simon Sandstone in the Midwest Region, 2010

Midwestern Regional Carbon Sequestration Partnership (MRCSP), Regional Geologic Cross Sections for Potential Storage and Containment Zones in the MRCSP Region, 2020, p. 11

Milici, Robert C., 1996, Stratigraphic History of the Appalachian Basin in Roen, John B., and Brian J. Walkers, editors, The Atlas of Major Appalachian Gas Plays: West Virginia Geological and Economic Survey Publication V-25, Morgantown, West Virginia

Mussman, W. J., and Read, J. F., 1986, Sedimentology and development of a passive to convergent margin unconformity: Middle Ordovician Knox Unconformity, Virginia Appalachians, Geological Society of America Bulletin, v. 97, no. 3, p. 282-295

Read, J.F., 1980, Carbonate ramp-to-basin transitions and foreland basin evolution, Middle Ordovician, Virginia Appalachians, Am. Assoc. Petrol. Geol. Bull., v. 64, p. 1575-1612

Richard, B. H., and Wolfe, P. J., 1995, An Early Cambrian(?) Basin in Southwestern Ohio

Saeed, A., 2002, Subsurface Facies Analysis of the Cambrian Mt. Simon Sandstone in Western Ohio, M.Sc. Thesis, Bowling Green, 167 p.

Santos, J.O., Hartman, L.A., McNaughton, Easton, RM., Rea, RG. and Potter, P.E, 2002, Sensitive High Resolution Ion Microprobe (HRIMP) Detrital Zircon Geochronology Provides New Evidence for a Hidden Neoproterozoic Foreland Basin in the Eastern Midwest, USA: Canadian Journal of Earth Sciences, v. 39, p. 1505-1515.

Schrader, Greg, Spaeth, Ralph, Herring, Bill, Grove, Glenn, and Meier, Randy, 2002, Ground-Water Resources in The White and West Fork White River Basin, Indiana, State Of Indiana Department Of Natural Resources Division Of Water

Shrake, D.L., Wolfe, P.J., Richard, B.H., Swinford, E.M., Wickstrom, L.H., Potter, P.E., and Sitler, G.W., 1990, Lithologic and geophysical description of a continuously cored hole in Warren County, Ohio, including description of the Middle Run Formation (Precambrian?) and a seismic profile across core site: Ohio Geological Survey Information Circular 56, pg. 10.

Shrake, D.L., 1991, The Middle Run Formation: A new stratigraphic unit in the subsurface of southwestern Ohio: Ohio Journal of Science, v. 91, p. 55.

Shrake, D.L., Carlton, R.W., Wickstrom, L.H., Potter, P.E., Richard, B.H., Wolfe, P.J., and Sitler, G.W., 1991, Pre-Mount Simon Basin under the Cincinnati Arch: Geology, v. 19, p. 139-142.

Thompson, Todd A., Sowder, Kimberly H., and Johnson, Matthew R., 2016, Generalized Stratigraphic Column of Indiana Bedrock, Indiana Geological Survey,

USGS Earthquake Map/Table, USGS Map

Wickstrom, Lawrence H., 2005, Characterization of Geologic Sequestration Opportunities in the MRCSP Region Phase I

Wolfe, P.J., Richard, B.H., and Potter, P.E., 1993, Potential seen in Middle Run basins of western Ohio: Oil and Gas Journal, v. 91, no. 14, p. 68-73