1.0 PROJECT NARRATIVE
40 CFR 146.81

CAPIO MOUNTAINEER SEQUESTRATION PROJECT

Facility Information

Facility name:	MOUNTAINEER GIGASYSTEM
Facility contact:	Michael Neese Vice President, Operations and Project Development [redacted]
Well name:	MCCLINTIC SEQUESTRATION 001
Well location:	MASON COUNTY, WEST VIRGINIA
Latitude:	[redacted]
Longitude:	

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Description
°	Degree
µm	Micrometer
µS/cm	microsiemens per centimeter
13CR	Corrosion-resistant chrome
2D	Two-dimensional
3D	Three-dimensional
ACZ	Above confining zone
AEP	American Electric Power
AoR	Area of Review
API	American Petroleum Institute units
ASTM	American Society for Testing and Materials
bbls	Barrels
BOP	Blowout preventor
BOPE	Blow out prevention equipment
BTC	Buttress threaded and coupled
C	Celsius
CBL-VDL	Cement bond log – variable density log
CCS	Carbon capture and storage
CFR	Code of Federal Regulations
CO_2	Carbon dioxide
C_3S	Tricalcium Silicate
DAS	Distributed Acoustic Sensing
DOE	Department of Energy
DOT	Department of Transportation
DRM	Dynamic Reservoir Model
DTS	Distributed Temperature Sensing
EOD	Environment of deposition
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response Plan
F	Fahrenheit
FEMA AE	Federal Emergency Management Agency Adverse Effects
FMEA	Failure, Mode, Effect, Analysis
ft	Feet
FO	Fiber optic
gal	Gallon
GC	Gas chromatograph
GR	Gamma ray
H_2S	Hydrogen sulfide
ID	Identification
KCl	Potassium chloride
L	liter
lb	Pound

LCM	Lost circulation material
LTC	Long threaded and coupled
m	Meter
mb_lg	Seismic magnitude for regional earthquakes (USGS)
MD	Measured depth
mD	Millidarcy
md	Seismic magnitude based on duration of shaking (USGS)
mg	Milligram
MI	Move-in
mi	Mile
MIT	Mechanical integrity test
mL	Milliliter
MMscf	Million standard cubic feet
ms	Millisecond
MMmt	Million metric tonnes
MVA	Monitoring, Verification, and Accounting
MWD	Measurement while drilling
N_2	nitrogen
N/A	Not applicable
NACE	National Association of Corrosion Engineers
NaCl	Sodium chloride
NELAP	National Environmental Laboratory Accreditation Program
NETL	National Energy Technology Laboratory
NPT	national pipe thread
ORP	Oxidation-reduction potential
P&A	Plug and abandonment
PFO	Pressure fall-off
PGA	Peak ground acceleration
PISC	Post-injection site closure
PM	Project Manager
PNC	Pulsed neutron capture
Poz	Pozzolan
ppg	Pounds per gallon
ppm	Parts per million
psi	Pounds per square inch
psig	Pounds per square inch gauge
QA	Quality assurance
QC	Quality control
QASP	Quality Assurance and Surveillance Plan
QR	Quality Representative
RPD	Relative percent difference
RPN	Risk Priority Number
RU	Rig up
SCADA	Supervisory Control and Data Acquisition
SEM	Static Earth Model
SF	Safety factor

SGSim	Sequential Gaussian Simulation
sks	Sacks of Cement
SME	Subject matter expert
SOP	Standard operating procedure
SP	Spontaneous potential
SPCC	Spill Prevention, Control, and Countermeasure
SPF	Shots per foot
STC	Short threaded and coupled
STW	Stratigraphic Test Well
TD	Total depth
TDS	Total dissolved solids
TVD	true vertical depth
TVDss	True vertical depth sub-sea
TW	Test Well
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
USGS	United States Geological Survey
VSP	Vertical Seismic Profile
WMA	Wildlife management area
WVDEP	West Virginia Department of Environmental Protection

1.0 Project Narrative

1.1 Project Background and Contact Information

Fidelis, LLC's ("Fidelis") primary goal of the Capio Mountaineer Sequestration project is to sequester anthropogenic carbon dioxide (CO_2) near Point Pleasant, Mason County, West Virginia. Fidelis intends to build, own, and operate three Bioenergy with Carbon Capture and Storage (BECCS) plants at its 1,140-acre North Point Pleasant site in western West Virginia.

The sequestration of anthropogenic CO_2 will be sourced from the Mountaineer Gigasystem facility owned and operated by Fidelis. CO_2 will be captured onsite and transported via pipeline to the injection site for permanent sequestration [redacted] Operations of the capture facility and injection site will be conducted by Fidelis or a qualified designee.

The data used in the preparation of this permit application were acquired in a nearby CO_2 sequestration pilot project at American Electric Power's (AEP) Mountaineer Gigasystem, which consisted of numerous wells drilled less than 10 miles northeast from the Capio Mountaineer Sequestration Project location.

An extensive suite of wireline logs, whole core and sidewall cores were acquired at the AEP site and incorporated into the computational model. During injection well drilling, additional subsurface information will be collected to further reduce uncertainty in the characterization of the reservoir properties, geomechanical and hydrogeological subsurface at the Capio Mountaineer Sequestration Project site. Extensive wireline logging, coring, fluid sampling, and formation hydrogeologic testing will be performed. These data will be incorporated into the Static Earth Model (SEM) and Dynamic Reservoir Models (DRM) (Permit Section 2.0).

An overview of the project site is presented in **Figure 1-1** which shows the location of the proposed injection well (MCLINTIC SEQUESTRATION 001), local infrastructure, the Area of Review (AoR) and existing wells within and near to the AoR. **Figure 1-2** shows the relative location of the AEP site.

[redacted]

Figure 1-1: Map of Fidelis Capio Mountaineer Sequestration project showing proposed location of the injection well (MCCLINTIC SEQUESTRATION 001), AoR, documented wells within (and close to the AoR), and local infrastructure.

[redacted]

Figure 1-2: Map of Fidelis Capio Mountaineer Sequestration project showing proximity to AEP Mountaineer.

1.1.1 Project Goals

In this project, Fidelis plans to:

- Drill an injection well (MCCLINTIC SEQUESTRATION 001) to collect additional site-specific data to further support the data requirements of the Environmental Protection Agency (EPA) Class VI rule
- Drill required monitoring wells to monitor the subsurface for any potential impacts to the deepest underground source of drinking water (USDW)
- [redacted]
- Upon completion of the injection phase of the project, verify stability of the CO_2 plume and decline of storage formation pressure toward pre-injection levels, verify plume predictions made by the computational modelling, demonstrate non-endangerment of USDWs, safely plug all injection wells, and decommission associated infrastructure

1.1.2 Partners/Collaborators

Key partners and collaborators on this project are listed in **Table 1-1**.

Name	Role
Fidelis	Owner
Fidelis	Storage Operator
Fidelis	CO_2 Capture Operator

Table 1-1: Key project partners and collaborators.

1.1.3 Overview of the Project Timeframe

The overall timeframe of the project, including well drilling, CO_2 injection, monitoring, and closure, is anticipated to be approximately 64 years (**Table 1-2**). This includes:

[redacted]

[redacted]

Table 1-2: Project Gantt Chart

1.1.4 Proposed Injection Mass/Volume and CO_2 Source

[redacted] Prior to injection, the actual chemical physical characteristics of the injectant will be confirmed using appropriate analytical methods. The current planned composition of the injectant is shown in **Table 1-3**.

[redacted]

Table 1-3: Planned CO_2 stream composition for the Capio Mountaineer Sequestration project

1.1.5 Injection Depth Waiver or Aquifer Exemption Requested

No injection depth waiver or aquifer exemption is being sought as part of this permit application.

1.1.6 Other Administrative Information

Table 1-4 provides the administrative information for this Class VI injection well permit application as required by 40 CFR 144.31(e)(1 through 6).

[redacted]

Table 1-4: General Class VI CO_2 injection well permit application information.

1.2 Site Characterization

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

The Capio Mountaineer Sequestration project sits within the Appalachian Plateau of West Virginia, Pennsylvania, Virginia and Maryland (**Figure 1-3**). This region has favorable geology for carbon storage in porous and permeable deep saline formations interstratified with low porosity and low permeability confining zones. Rock formations present across the Appalachian Plateau are part of a thick succession of sedimentary rocks including clastics and carbonates. These rock formations were deposited in the Appalachian Basin during the opening of the Iapetus-Theric Ocean and its subsequent subsidence (Gao et al., 2000).

The main structural feature in the region is the Rome Trough, a northeast to southwest trending graben that formed during the Early and Middle Cambrian (Gao et al., 2000), and located southeast of the project area (Gao et al., 2000) (**Figure 1-3**). Additional structural features generally trend northeast-southwest, parallel to the Rome Trough. Structural features near the site area include literature documenting north-south trending faults (Patchen et al.; 2006; Hickman et al., 2006) (see Section 1.2.3 Faults and Fractures; **Figure 1-9**), extending northward into the eastern portion of the study area. Recent seismic interpretation supports the likely presence of deep basement faults east of the site area, however basement offset is not directly observed in the licensed two-dimensional (2D) seismic line south of the site (**Figure 1-10**). Dipping reflectors potentially indicative of faults are only observed within the Precambrian section, and do not extend into reservoir or confining formations. Further information regarding detailed discussion of nearby faults can be found in Section 1.2.3 Faults and Fractures and **Figures 1-7** and **1-8**.

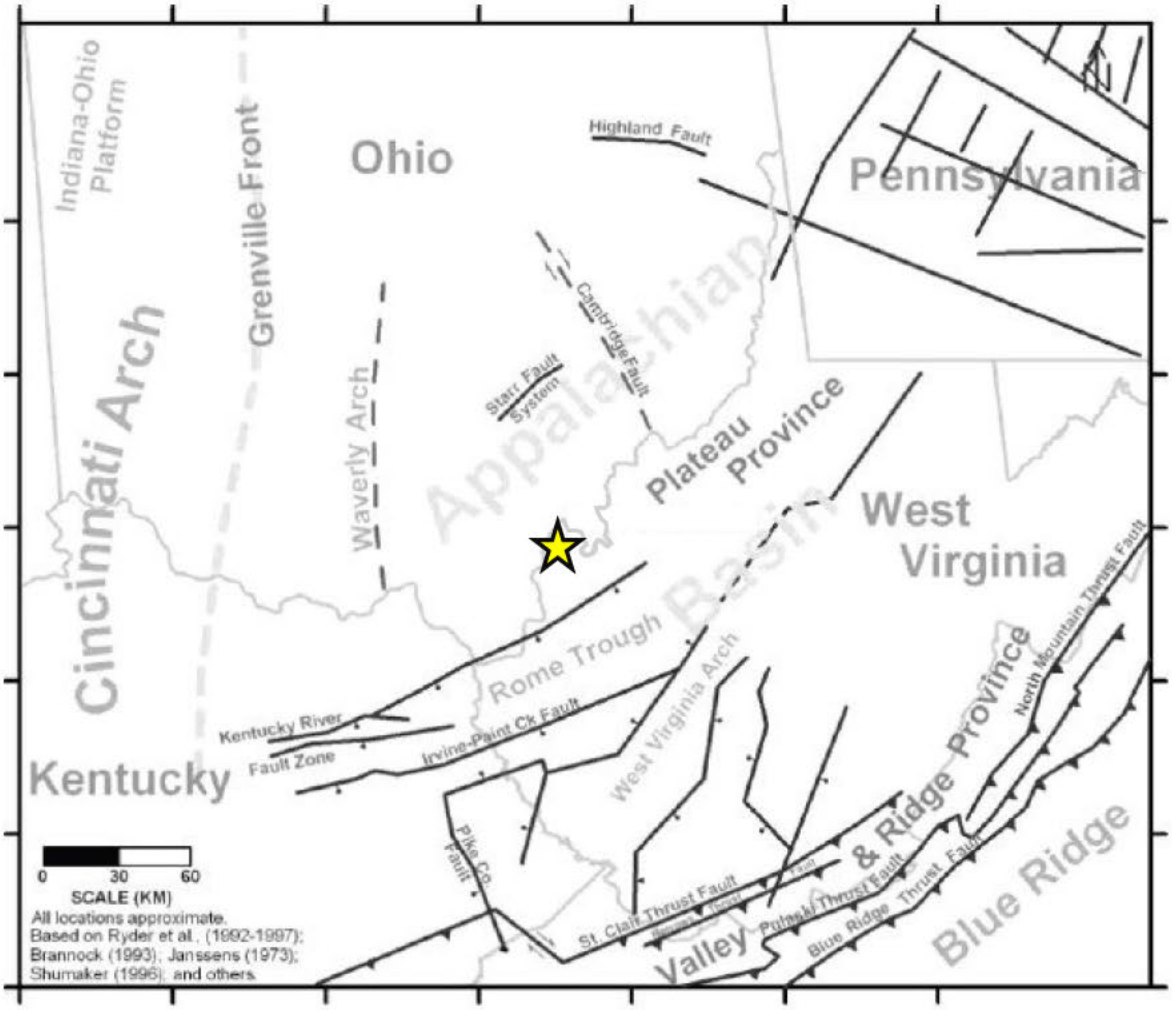

Figure 1-3: Structural Elements of the Appalachian Basin; McClintic site location denoted with yellow star (modified from Gupta, et.al., 2013).

The Appalachian Plateau has favorable geology for carbon storage in various formations. The focus of this permit is the Copper Ridge Formation. This formation is composed of carbonate rocks with observed secondary vuggy porosity in nearby wells, and approximately 655 ft thick at the site. The depth to the top of the storage formation at the site location is approximately 7,061 ft true vertical depth (TVD), which exceeds the depth criteria required to sustain a supercritical phase of the injected CO_2 at the site.

The primary confining zones for the storage formation are composed of low permeability carbonates of the Black River Formation present in the Upper Ordovician section. This tight limestone, which is regionally continuous and over 500 ft thick at the site, has the reservoir characteristics to prevent supercritical CO_2 flow vertically into shallower formations. The stratigraphic column in **Figure 1-4** shows the study area's stratigraphic succession, highlighting the storage formation and confining zone.

[redacted]

Figure 1-4: Stratigraphic Column of Capio Mountaineer Sequestration project.

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

The formations found in the subsurface at the Capio Mountaineer Sequestration Project site are locally correlative and laterally extensive across the region, and none of the data reviewed suggests any formation pinch-outs within the area. This was evaluated and confirmed through regional reports, well correlations, and regional and local cross sections and maps throughout the immediate site location and surrounding area. In addition, one partial 2D seismic line was licensed to further evaluate lateral continuity and subsurface structure. Regional structure and thickness maps for these units and further detail on data types used can be found in Section 1.2.4. Major geologic units and their stratigraphic relationships are depicted in the local cross section shown in **Figure 1-6** and **Figure 1-7**.

A map of the AoR, including existing wells within the AoR and the proposed injection well, is shown in **Figure 1-1**. [redacted] More information on the wells within the AoR can be found in Section 2.4.1 of the AoR and Corrective Action Plan document.

The deepest documented federal USDW at the site location is the Upper Pennsylvanian Aquifer (Kozar, 1995) (**Figure 1-6** and **Figure 1-7**). This aquifer is composed primarily of fractured carbonates, with occasional sandstones and shales that typically do not contain primary porosity (Kozar and Mathes, 1991). In parts of Mason County, it is overlain by alluvium of the Ohio and Kanawa Rivers which act as the primary aquifer for drinking water in the area. Water wells in the area are typically less than 100 ft deep and utilize the alluvium as the source of fresh water, though none are present within the AoR (Kozar, 1995) (**Figure 1-5**).

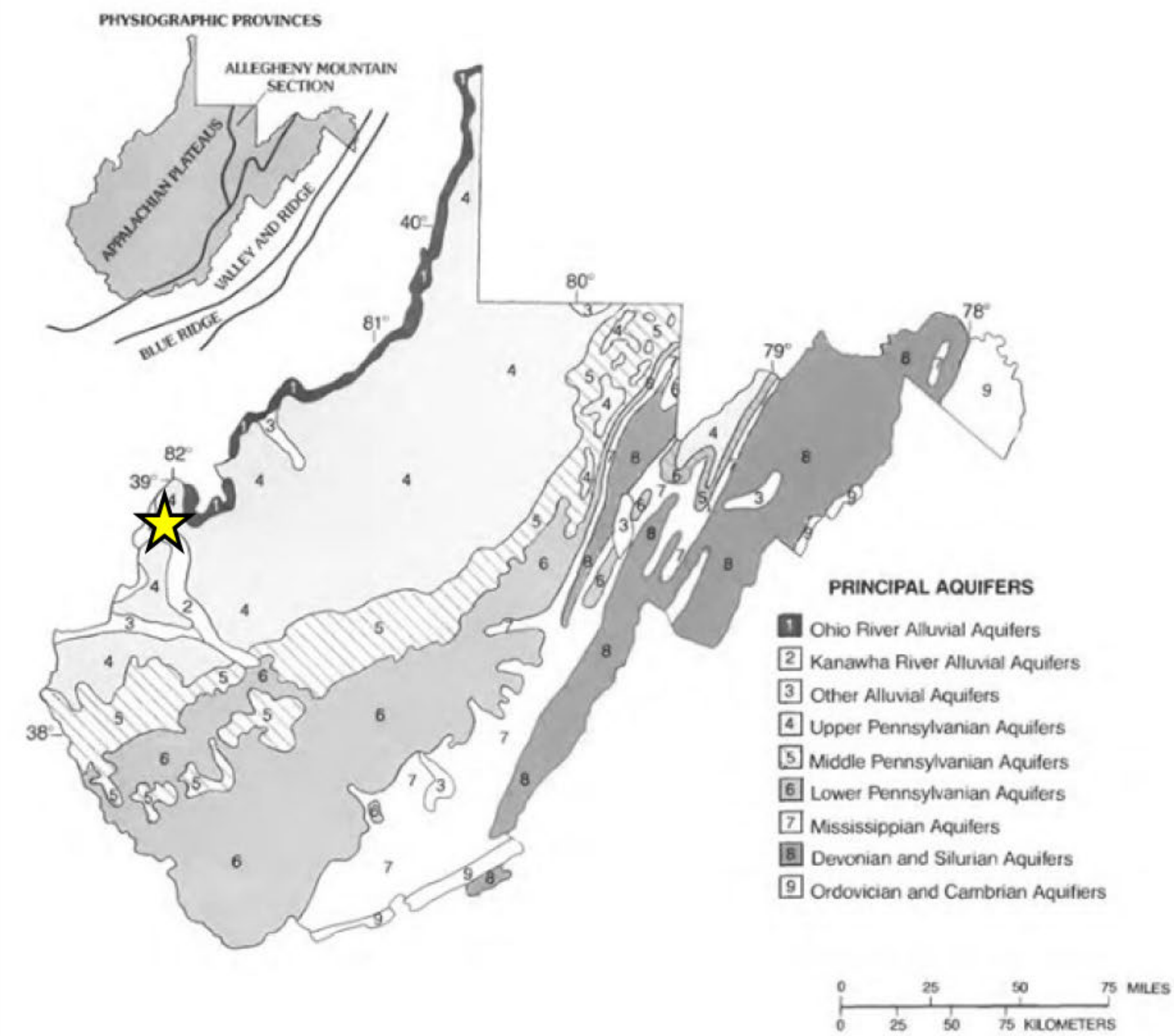

Figure 2. Principal aquifers and physiographic provinces in West Virginia. (Modified from Ferrell (1988, p. 524) and Puente (1985, p. 441).

Figure 1-5: Primary sources of drinking water in West Virginia (Kozar, 1995). Site location is denoted by the yellow star.

At the proposed well location, the top of the storage formation is expected to be at ~7,061 ft TVD. There are various secondary confining zones between the CO_2 storage formation and the base of the Upper Pennsylvanian Aquifer such as the Devonian Shale Group, Martinsburg Shale, Trenton Limestone and Black River Limestone (primary confining zone). At the project site, the base of the Upper Pennsylvanian Aquifer is at ~500 ft TVD. This provides over 6,000 ft of vertical separation between the lowest USDW and the storage formation. The exact spatial relationship between the lowest USDW and the injection and confining zones will be confirmed prior to start of injection.

[redacted]

Figure 1-6: Geologic cross section from Southwest to Northeast featuring the site’s shallow stratigraphy and USDWs. Well log track shows Gamma Ray (GR) on left and Measured Depth (MD) on right. Gamma Ray is color-filled from 0 to 200 API.

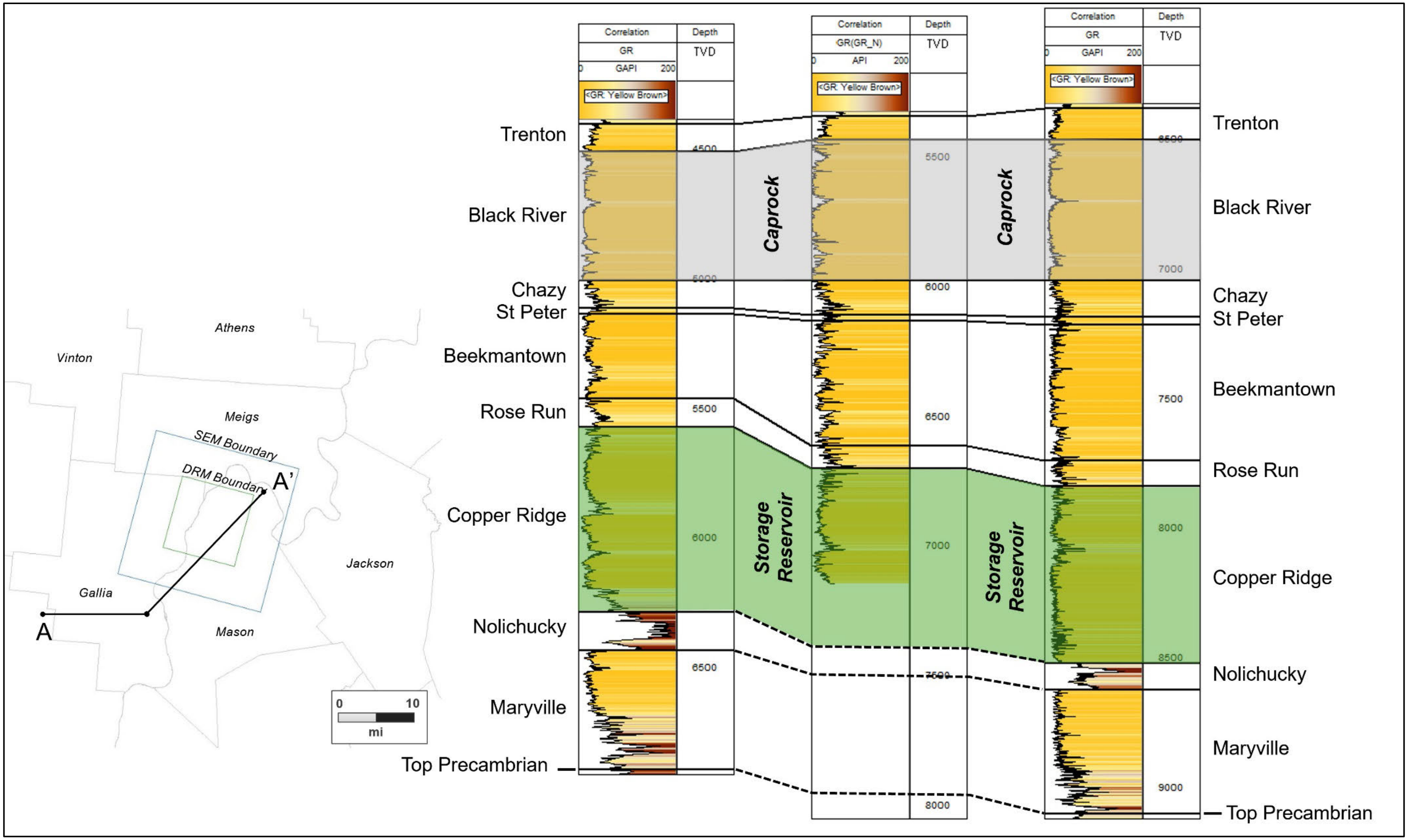

Figure 1-7: Geologic cross section from Southwest to Northeast featuring the site's deep stratigraphy including the storage formation and caprock. Well log track shows Gamma Ray (GR) on left and Measured Depth (MD) on right. Gamma Ray is color-filled from 0 to 200 API.

1.2.3 Faults and Fractures [40 CFR 146.82(a)(3)(ii)]

Regional tectonic faulting within the Appalachian basin has been previously studied by a variety of authors most recently by but not limited to Patchen et al. (2006), Gao et al. (2000), Wilson (2000), and Hickman et al. (2006). The Fidelis site is located northwest of the western margin of the Rome Trough, which is the primary structural feature in region (Wynn and Read, 2000) (**Figure 1-8**). The Rome Trough is a failed rift valley that runs southwest-northeast approximately 10 to 15 miles southeast of the study area. In this feature, a series of normal faults result in stepped-down blocks of rock leading into the Rome Trough, where Cambrian rock formations deepen and thicken substantially (Gao et al., 2000).

The West Virginia Geologic Survey, through the Trenton-Black River Project (Patchen et al., 2006), has identified regional faults from the interpretation of seismic data, gravity, and magnetic data. The Trenton-Black River Project documented a north/northeast-south/southwest basement fault on the eastern side of the AoR (**Figure 1-9**). A 2D seismic line was licensed south of the AoR extending across the literature-documented fault. The seismic data were tied to the AEP #1 well projected along depositional strike to the 2D line to ensure subsurface horizons were appropriately picked in time (**Figure 1-10**). The licensed seismic line has sufficient data quality, orthogonally crosses the literature-documented fault and does not show offset of time horizons above the Precambrian basement (**Figure 1-10**). The presence of dipping events was observed in the seismic line below the Precambrian basement surface close to the location of the literature-documented fault (**Figure 1-9**). Two basement faults were interpreted along the dipping events. No offset is observed in the seismic line at the storage formation interval (**Figure 1-10**). For this reason, breach of confinement due to faulting has been identified as low risk for saline storage at the primary site, as no through-going faults into the reservoir and confining units were observed in the orthogonally oriented 2D seismic line.

Additionally, the AEP #1 well collected image logs over the Lower Ordovician Beekmantown through the Upper Cambrian Copper Ridge intervals. Single and sporadic drilling induced fractures were interpreted, however no prolific fracture zones were observed in these intervals. Available image logs did not extend up through the confining zone. Additional data to be collected at McClintic Sequestration 001 well include additional image logs through the confining and reservoir zones as well as whole core samples to confirm the absence of fractures in the confining zone.

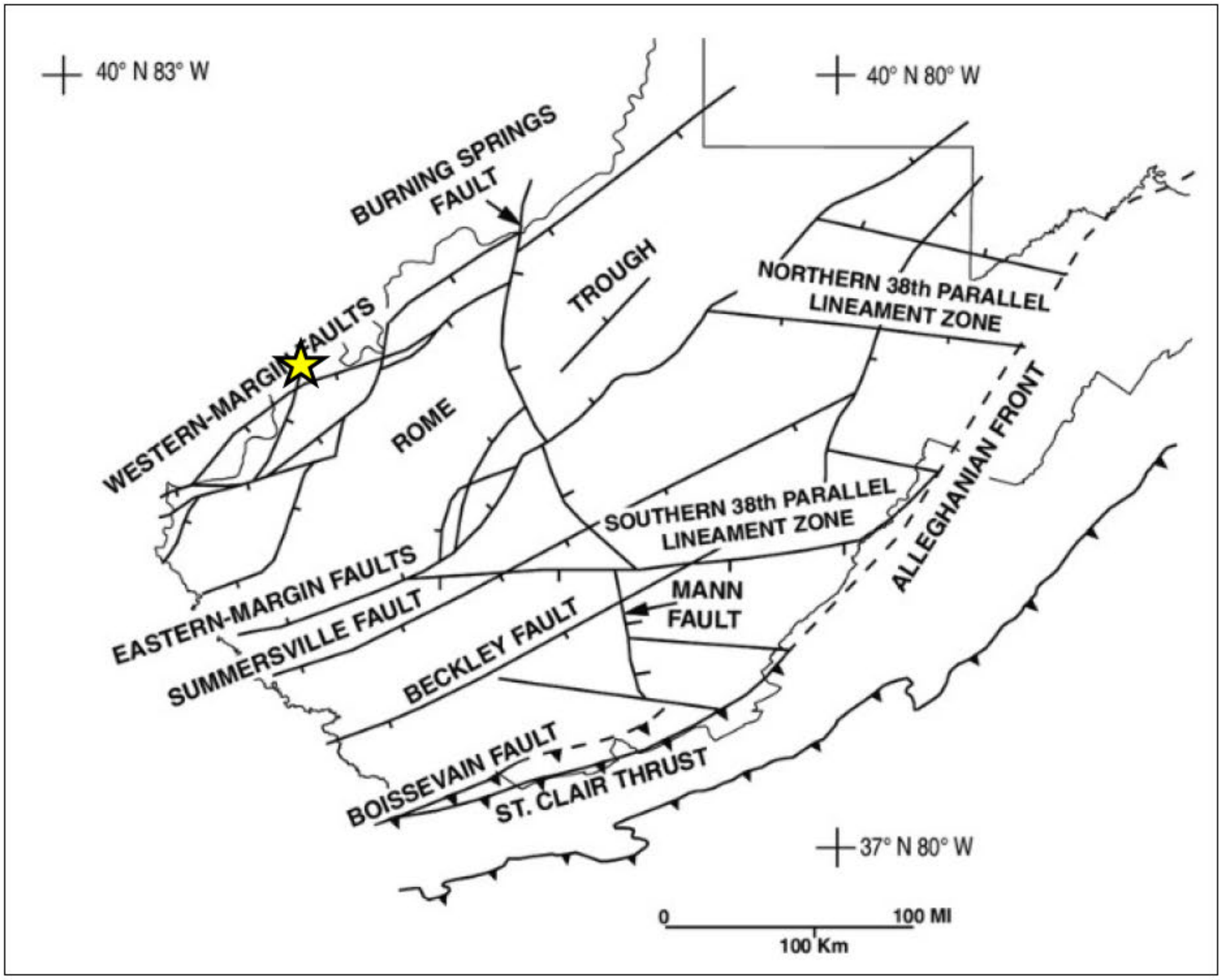

Figure 1-8: Basement features map of West Virginia. The site location is denoted with a yellow star (modified from Wynn and Read, 2000).

[redacted]

Figure 1-9: Trenton-Black River Project documented faults are shown in black. A portion of a regional 2D seismic line was licensed south of the study area crossing the literature-documented fault. No faults were observed in the licensed 2D seismic data. Seismic data owned or controlled by Seismic Exchange, Inc., interpretation by Fidelis.

[redacted]

Figure 1-10: 2D PSTM seismic Line 1-1 with injection well location projected (data courtesy of SEI). Seismic-to-well tie using Proxy AEP #1 well projected along depositional strike for horizon interpretation. The inset map shows the proposed injection well, licensed seismic data (blue line), and DRM boundary. Seismic data owned or controlled by Seismic Exchange, Inc., interpretation by Fidelis.

1.2.4 Storage Formation and Confining Zone Details [40 CFR 146.82(a)(3)(iii)]

Much of the subsurface data analyzed in this study are derived from regional wells where modern wireline log data exist, as well as historical log data from wells in proximity to the site (**Figure 1-11**). Well logs from 35 wells across the region were obtained, which provided multiple log types of interest and regional spatial and depth coverage. These were used to develop structural surfaces throughout the area. Of these wells, 11 had sufficient log data to provide regional and local measurements of in-situ physical rock properties, such as porosity, at depths that captured the entirety of the target storage formation and confining zone formations.

Additionally, the AEP #1 well was drilled less than 10 miles away from the site location in a pilot test to confirm the storage formation's presence and evaluate local storage formation quality. This well collected modern wireline log data as well as multiple sidewall cores that provided near-site storage formation information such as the expected formation depth and thickness, as well as porosity and permeability values. Further information regarding the data collected in this well is provided in Section 1.2.5 Geomechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]. These datasets enabled the project to interpret crucial subsurface information regarding the lithology and quality of the storage formation and confining zone and calculate rock properties.

In addition, one partial 2D seismic line measuring 12-line miles was licensed from Seismic Exchange, Inc. (SEI) to further evaluate the structure of the subsurface of the site location (**Figure 1-10, Table 1-5**). The licensed seismic line is of good seismic quality (**Table 1-5**) and was used to evaluate the presence of a literature documented fault located along the eastern side of the DRM boundary (Patchen et al., 2006) (**Figure 1-9**). A proxy AEP #1 well, projected along depositional strike, was used for a seismic-to-well tie to Line 1-1 (**Figure 1-10**). No check shot (time/depth) information was available in this well or any other nearby wells. Seismic interpretation was completed for key horizons and apparent basement faults. See Section 1.2.3 Faults and Fractures for additional information.

[redacted]

Figure 1-11: Map of the wells and 2D seismic data used for subsurface interpretation at the McClintic site location. The proposed injection well is denoted with a black dot. Seismic data owned or controlled by Seismic Exchange, Inc., interpretation by Fidelis.

Confidential Business Information

[redacted]

Table 1-5: Summary of licensed 2D seismic data from SEI south of the site location. Seismic data owned or controlled by Seismic Exchange, Inc., interpretation by Fidelis.

Confining Zone: Black River Limestone

The confining zone at the project location is the regional and laterally extensive Ordovician Black River Limestone, which sits atop the Chazy Limestone interval and below the Trenton and

Point Pleasant Limestone strata (**Figure 1-4**). [redacted] These were gridded using a minimum curvature algorithm from GeoGraphix® Discovery™ Suite and contoured in TVDss. Maps of the top structural surface and the thickness of the Black River Limestone are presented in **Figure 1-13**. Porosity ranges from 0 to 5% with permeability measuring less than 1.0 mD (Patchen et al., 2006). Sidewall core points taken at the Ohio River Valley Storage project, ~10 miles from the Fidelis site, measured porosities less than 1% and permeability between 0.003 and 0.001 mD (Gupta, 2008a). These results suggest the very low permeability of the Black River formation will make it an excellent confining layer and would inhibit vertical migration of injected CO_2.

The Black River formation is composed of light brown to gray, clean to slightly-argillaceous tight carbonate mudstone. Calcite is the primary mineral present, while minor amounts of dolomite, quartz and clay may also be present in lesser amounts, occupying less than 10% of the rock volume (Mudd, 2003). Sediments of the Black River Limestone consist of shallow subtidal to peritidal carbonates that were deposited across a very low-relief homoclinal carbonate ramp (Patchen et al., 2006). Literature, core and well log correlations show this formation is lithologically consistent across the region. Data and rock samples collected from the stratigraphic test well will be used to confirm that the mineral composition of the Cane River is conducive to confining CO_2 (**Figure 1-12**).

Figure 1-12: M[redacted]tone core from Woods County, WV. Described as lime mudstone with occasional quartz silt (Qtz), showing no visible porosity or features (Patchen, 2006).

Storage formation: Copper Ridge

The primary storage formation at the project location is the Copper Ridge Dolomite. [redacted] At these depths, pressure and temperature conditions are high enough to sustain a supercritical phase of the injected CO_2 at the site. Maps of the top structural surface and the thickness of the Copper Ridge are presented in **Figure 1-13**. Formation tops have been interpreted from well logs associated with a CO_2 injection pilot program, a stratigraphic test well, and deep oil and gas exploration test wells in the area that are now plugged and abandoned. Depth and thickness across the AoR were determined by picking formation tops from digital well log data proximal to the site. These were gridded using a minimum curvature algorithm from GeoGraphix® Discovery™ Suite and contoured in TVDss. The modest variation in thickness demonstrates there is no evidence of local formation pinch out or faulting that would affect CO_2 storage.

Much of the subsurface data analyzed in this study are derived from regional wells with modern wireline log data, as well as historical log data from wells proximal to the site. Additionally, the Ohio River Valley CO_2 Storage Project, located ~10 miles from the primary site (**Figure 1-11**), was also analyzed as the project successfully demonstrated CO_2 injection into the Copper Ridge. This pilot test was completed as a collaboration between AEP and Battelle to determine if carbon sequestration was a possibility in the Appalachian Basin. The program consisted of drilling a total of six wells, all penetrating the storage reservoir, including two injection wells, three monitoring wells, and one post injection stratigraphic test well off site. Well logs were run on all wells, 290 ft of whole core and 24 sidewall core plugs were collected covering multiple formations, including the Black River and Copper Ridge. Multiple injection tests were also conducted in these three formations after drilling, coring, and logging the well (Gupta, 2008b; Sminchak, 2006). The CO_2 pilot injection site provided core data and dynamic injection data used to calibrate the reservoir models. The program confirmed commercial volumes of CO_2 can be injected into the Copper Ridge and demonstrated no vertical movement of CO_2 post-injection (Gupta, 2013).

A total of 35 wells from across the region were acquired that provided: 1) multiple log types of interest, 2) adequate spatial and depth coverage, 3) core analysis data, and 4) velocity survey data. Eleven wells supplied regional and local measurements of in-situ physical rock properties, such as porosity, at depths that captured the target reservoir and caprock formations. Two wells with routine core analysis data provided data points in the Copper Ridge and Black River formations. The wireline log and core data are consistent with observations pertaining to depth, thickness, lateral extent, and lithology from the 2D seismic line shown in **Figure 1-10** and described further in Section 1.2.3. These datasets enabled the project to interpret crucial subsurface information regarding the lithology and quality of the reservoir and caprock and calculate rock properties.

[redacted]

Figure 1-13: Structural map depicting True Vertical Depth Sub-Sea (ft) of the Black River top (left) and Black River formation thickness map (right) at the Capio Mountaineer Sequestration Project location. Contour intervals are 100 ft and 10 ft, respectively. The black box indicates the Static Earth Model area, the white line indicates the Dynamic Reservoir Model boundary, and county lines are posted in light grey.

[redacted]

Figure 1-14: Structural map depicting True Vertical Depth Sub-Sea (ft) of the Copper Ridge top (left) and total Copper Ridge formation thickness map (right) at the Capio Mountaineer Sequestration Project location. Contour intervals are 100 ft and 10 ft, respectively. The black box indicates the Static Earth Model area, the white line indicates the Dynamic Reservoir Model boundary, county lines are posted in light grey, state line in thick black.

The Copper Ridge formation is a homogeneous carbonate formation composed primarily of fine to coarse-grained dolomite with occasional shale interbeds. As such the most common mineral found in the formation is dolomite, with lesser amounts of quartz, potassium feldspar, and clay (illite), anhydrite, and calcite (Gupta, 2008c; Mudd, 2003). Results from Schlumberger's Elemental Analysis tool in the AEP #1 well indicate the Copper Ridge consists of 80% dolomite, 16% quartz, 2% calcite, and 2% anhydrite by volume. The mineral proportions are shown in **Figure 1-15**, and **Table 1-6** summarizes the mineralogical make-up. The dolomite of the Copper Ridge was deposited as primary dolomite on a large carbonate platform in supratidal to shallow subtidal water depths (Gupta, 2008a). Battelle has evaluated the potential for CO_2 storage in the Copper Ridge at sites across West Virginia, Kentucky, and Ohio, and found that these formations are regionally continuous with consistent mineralogy.

[redacted]

Figure 1-15: Mineral proportions of the Copper Ridge based on Schlumberger's Elemental Analysis wireline logging tool (from Gupta, 2008c).

Copper Ridge Mineralogy	
Major Mineral	Dolomite
	Quartz
Minor Minerals	Potassium Feldspar
	Clay
	Calcite
	Plagioclase Feldspar
	Anhydrite

Table 1-6: Summary of the mineralogical make-up of the Copper Ridge (Mudd, 2003).

Within the region, the Copper Ridge has demonstrated excellent injectivity when secondary porosity and permeability networks are present, particularly in the form of vugs and karst surfaces (Gupta, 2008b). An example of the vuggy nature of the Copper Ridge can be seen in a computed tomography scan or CT scan of whole core taken from the AEP BA-02 well, located approximately 10 miles from the Fidelis site (**Figure 1-16**). Large, high permeability vugs have clear permeability indicators on image logs, while smaller, more isolated vugs are also present. Wireline log porosity within the vuggy zones of the AEP #1 well averaged over 15%, and wireline permeabilities averaged 50 to 200 millidarcy (mD) and reached up to 5,000 mD (Gupta, 2008a).

[redacted]

Figure 1-16: CT scan of Copper Ridge core from the AEP #1 CO_2 injection well showing extensive vugs (Gupta, 2013). Dark spots within core are vugs, light area is rock matrix. The vugs create a highly permeable, connected secondary porosity network.

Based on the Department of Energy (DOE)-National Energy Technology Laboratory (NETL) methods for static volumetric calculations (Peck et al., 2014), the estimated storage capacity for the Copper Ridge within the AoR is approximately 2.2 MMmt of CO_2 per square mile. Inputs for thickness and porosity were determined by calculating the average net thickness and effective porosity values based on history matched injection data and injection test data from the Ohio River Valley CO_2 Storage Project for the Copper Ridge section (274 ft and 7%, respectively). This methodology was used to incorporate the dynamic data available and due to standard well logs not being able to measure the Copper Ridge secondary porosity and permeability network. The methodology is further explained in Section 2.1.4. The input for the density of CO_2 was calculated using the same temperature and pressure gradients as the reservoir model, which were applied to the midpoint depth for the Copper Ridge in the center of the AoR (approximately 7,600 ft below ground surface). Finally, a storage efficiency factor of 20% was applied based on the formation's depositional environment (Haeri, 2022).

Current interpretations of the injection and confining zones at the Fidelis site will be confirmed by routine and advanced datasets acquired from the stratigraphic test well as detailed in the Pre-operational Testing Plan. Site-specific geologic core and special core analysis will confirm porosity and permeability, mineralogy, capillary pressure, and relative permeability as specified by EPA (2012) [40 CFR 146.82(a)(3)(iii)]. Additionally, geomechanical data in the storage zone will confirm the maximum injection pressure, rock strength, and in-situ fluid pressure as specified by EPA (2012) [40 CFR 146.82(a)(3)(iv)].

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

Strength of confining zones was measured though laboratory testing of rock samples acquired from the Black River formation and Wells Creek in a nearby well (AEP BA-02 well). To determine rock compressive strength, triaxial compressive tests were performed. This test is a commonly used test to provide information regarding elastic parameters, uniaxial compressive strength, and peak compressive strength. **Table 1-7** shows the elastic parameters, uniaxial compressive strength, and peak strength of rock samples.

[redacted]

Table 1-7: Summary of elastic properties and rock strength of confining zone using core samples from adjacent well.

Table 1-7 shows the Black River (primary confining zone) has an average confined compressive strength of 35,925 pounds per square inch (psi) and uniaxial compressive strength of 16,872 psi. This is significantly beyond compressive strength of weak rocks with uniaxial compressive strength of ~1500 psi (10 megapascal (MPa)) or lower (ISRM Commission, 1981; Sajid & Arif, M., 2015). High strength of the confining zone indicates that rock is capable of bearing compressive stresses to keep its integrity during CO_2 injection.

Average fracture pressure of [redacted] psi/ft was estimated for the Copper Ridge formation using multiple data (drilling induced, breakout, rock strength, stress polygon method) of regional wells in the Appalachian basin (Raziperchikolaee et al., 2018; Lucier et al., 2006). Fracture pressure has also been measured for Copper Ridge formation in a nearby well (AEP #1 well). Although the test quality was not as good as other formations/intervals, average fracture pressure of 0.72 psi/ft was estimated for the Copper Ridge formation (Lucier et al., 2006). Note that the measured fracture pressure for Black River formation (as primary caprock) was [redacted] psi/ft through the test in AEP #1 which is higher than the Copper Ridge formation (Lucier et al., 2006).

Additional geomechanical properties (e.g., in-situ stresses, fracture pressure, pore pressure, rock strength, and ductility) will be evaluated and confirmed through well tests, wireline logs, and rock mechanics laboratory analyses of core samples from the proposed injection well. Collected core samples will be analyzed to determine the strength and ductility of confining zone properties. Advanced well log data including dipole sonic, density log, and image log will be collected, and used in combination with the well tests (minifrac test, pressure measurements) to help further characterize in-situ stress, fracture pressure, pore pressure, and characteristics of natural fractures(if existed) of the injection and confining zones.

Petrophysical analysis was conducted to integrate available log data in the study area, generate the porosity log curves used to populate the SEM, and determine the storage reservoir properties. The logs compiled as part of the data collection effort, detailed in Section 1.2.4, were first edited, and normalized as part of the quality control procedure to eliminate erroneous data points, correct for varying signal intensities, and establish consistent readings between wells. A lithologic log representing the fraction of clay with depth, Vclay, was generated and integrated with core data and routine porosity logs to calculate refined porosity curves, and subsequently, permeability curves. The permeability log was further refined by rock type after modeling hydraulic facies, or zones of rock that have comparable properties controlling fluid flow.

Reservoir properties were provided for the Knox Group from petrophysical and reservoir engineering analysis based on the AEP #1 well logs and injection tests, with the analysis tied to core data collected from the AEP #1 and AEP #2 pilot injection wells (Gupta, 2008b). Petrophysical analysis has also been completed on six nearby wells that penetrate the entire rock column down to basement. From these logs, the porosity, thickness, and net/gross have been calculated. Thickness of intervals expected to be encountered at the site were determined by creating isochore maps from offset wells. Formation tops were correlated based on similar log signatures seen in offset wells and correlated to core. The footage between the tops was calculated and used as the gross interval.

Additional geomechanical and petrophysical properties will be evaluated and confirmed through well tests, wireline logs, and laboratory analyses of core samples from the injection well. Geomechanical properties of the target and confining zone will be confirmed from minifrac test analysis and dipole sonic logs. The geomechanical integrity of the confining zone is confirmed if its fracture pressure exceeds the target zone's. Data will be collected in the injection well using wireline logging tools such as the dipole sonic to determine elastic rock properties such as Young's modulus, stresses and Poisson's ratio which will be used as an accuracy check for the minifrac data in case of any operational issues during testing.

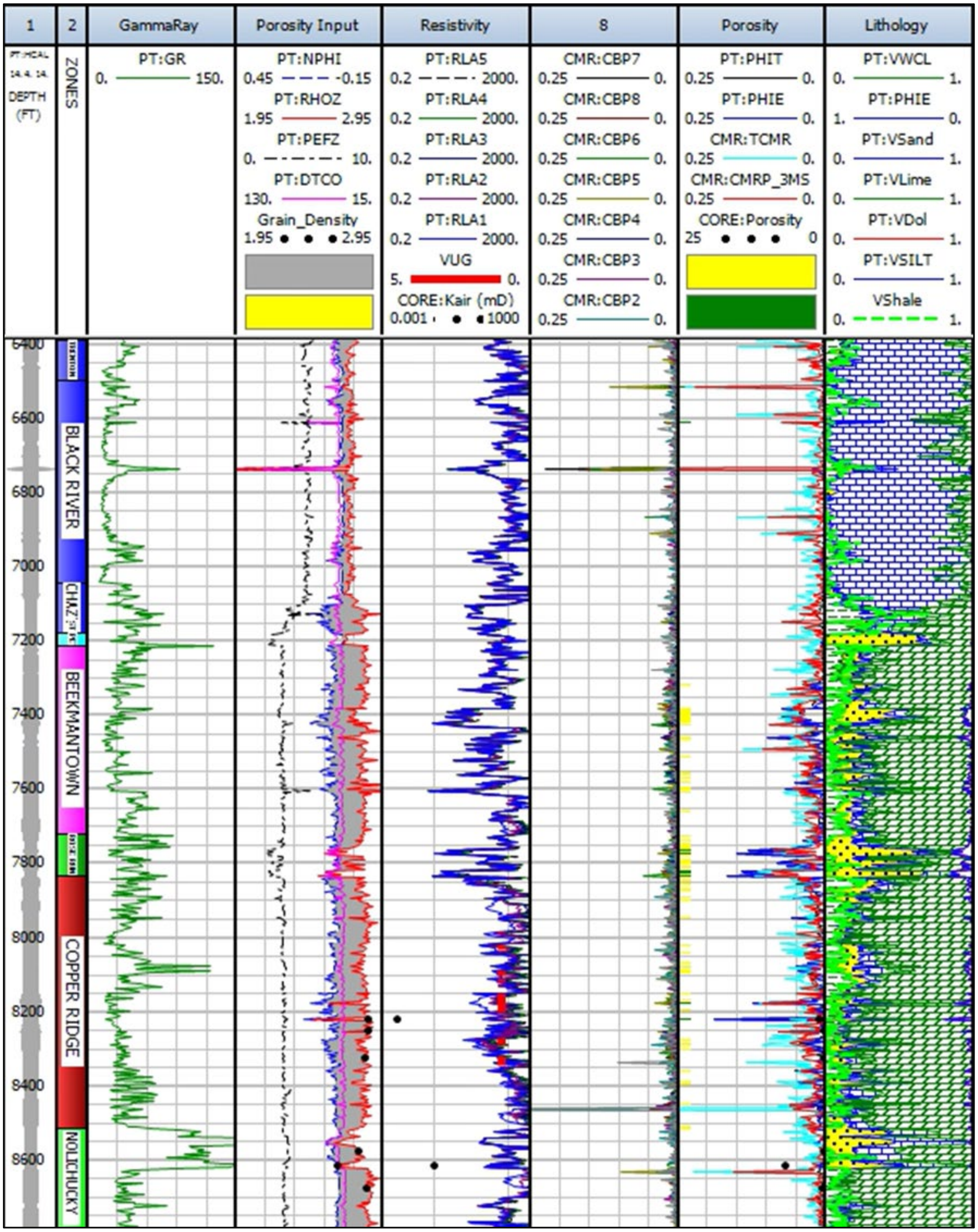

Figure 1-17: Plot of AEP #1 well showing (left to right) caliper, stratigraphic zone, gamma ray, porosity inputs, resistivity, CMR permeability, calculated log porosity and calculated lithology.

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

The seismic history for the area was characterized using publicly available data from the United States Geological Survey (USGS). West Virginia is a largely inactive state for natural seismicity and earthquakes have historically occurred with low frequency and magnitude. The western region of West Virginia has relatively low faulting. The faults in this area are primarily deep faults associated with basement structural features of the Rome Trough. For more information on local structures and faults refer to Section 1.2.3.

The low frequency of recorded naturally occurring earthquakes near the project site is consistent with the regional seismic hazard map published by the USGS (2014), which designates the area as a relatively low-risk area for seismic activity. There is a [redacted] chance of a naturally occurring seismic event happening over the next 50 years near the project site location (**Figure 1-18**). According to the USGS, low magnitude recent seismic events (Jan. 1950 - June 2024) have been attributed to non-tectonically driven sources such as explosions and naturally occurring earthquakes. These seismic events can be seen in **Figure 1-19** and are recorded in **Table 1-8**.

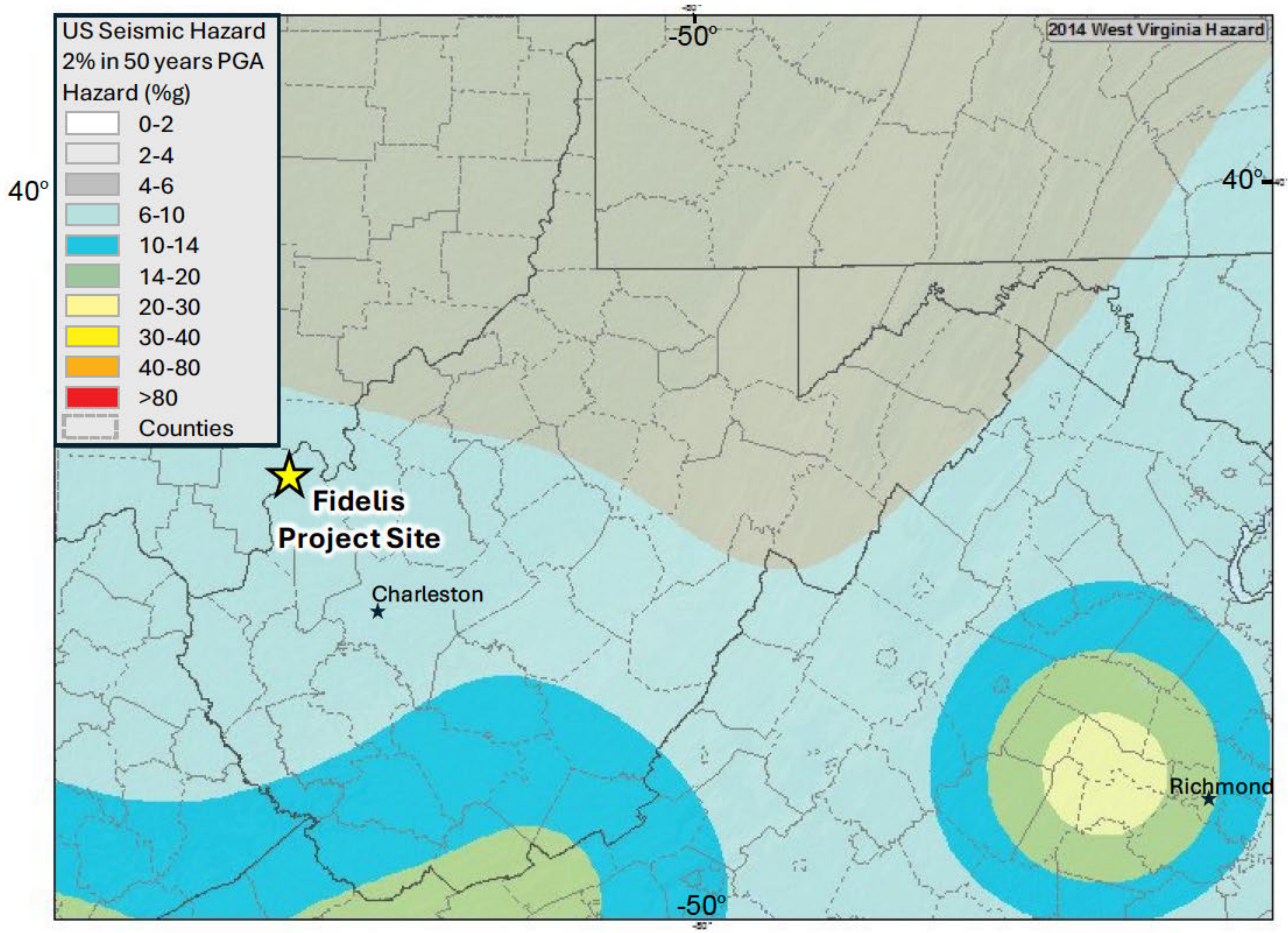

Figure 1-18: 2014 regional seismic hazard map for West Virginia showing peak ground accelerations (PGA) having a 6-10% probability of being exceeded in 50 years, for a firm rock site; %g denotes percent of acceleration due to gravity (USGS, 2014).

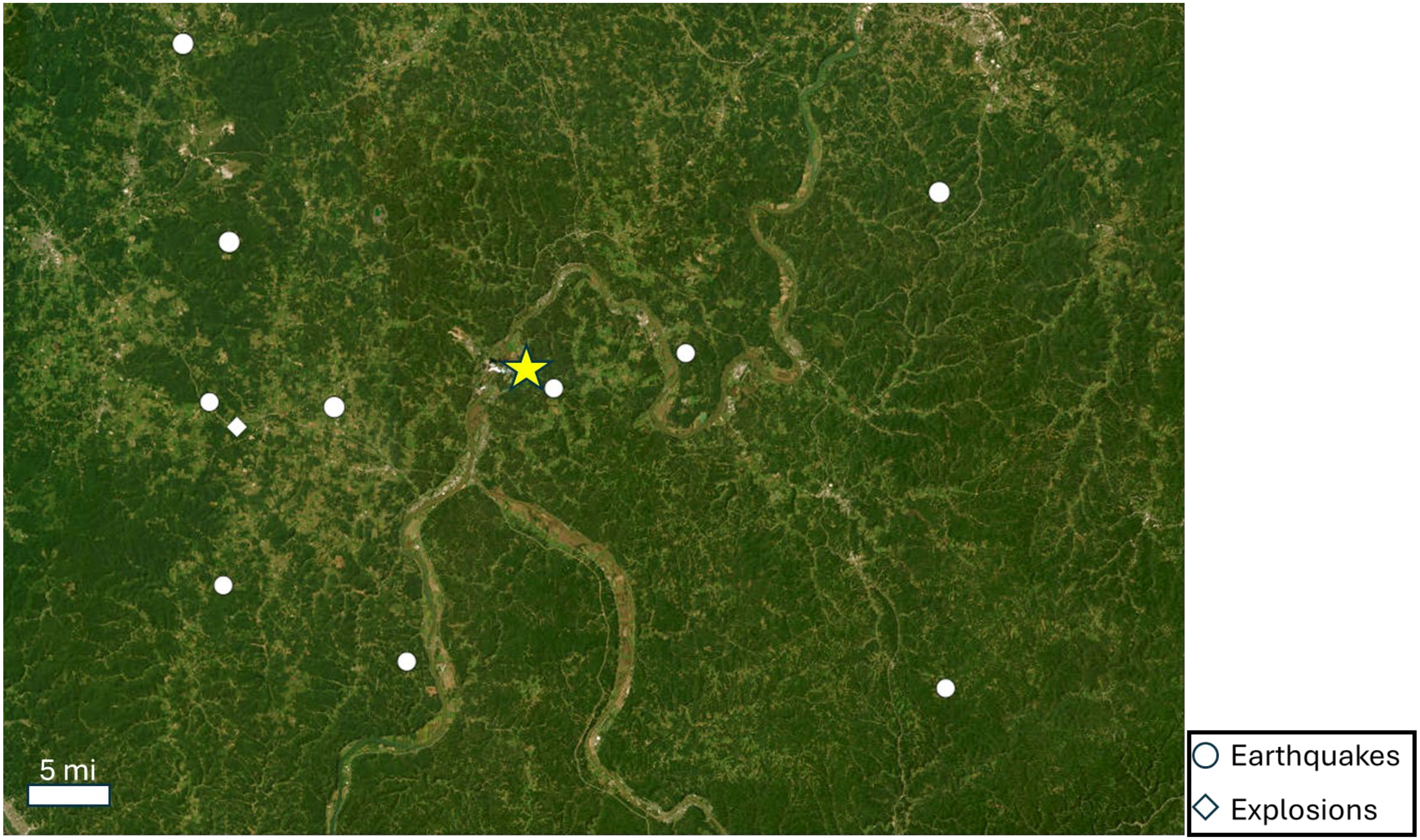

Figure 1-19: Map of recent seismic events (Jan. 1950 – June 2024) in the McClintic Site location and surrounding area (data from USGS). The McClintic site location is denoted with a yellow star.

[redacted]

Table 1-8: Recent seismic events (Jan. 1950 - Sept. 2023) in the McClintic location and surrounding area (data from USGS).

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

To further understand the subsurface underlying the Capio Mountaineer Sequestration Project location, an assessment of the local hydraulic and hydrogeologic conditions was completed. This included a review of the stratigraphy, hydrogeology, and salinity of shallow and deep aquifers underlying the project site.

Fresh water aquifers in the surrounding areas include shallow alluvium aquifers along the Ohio and Kanawha Rivers and bedrock aquifers within Upper Pennsylvanian formations (**Figure 1-20**). Shallow groundwater moves to nearby valleys from upland intake areas and is released into stream beds or discharged into springs and seeps (Wilmoth, 1966). Unconsolidated clastics ranging from clay, silt, sand, gravel and boulders comprise alluvial aquifers. Alluvium aquifers along the Kanawha River are found to contain higher proportions of clay and silt (Kozar and Mathes, 1991). A generalized cross section of the alluvial aquifers just south of the site is shown in **Figure 1-21**. There are no active springs within the AoR (USGS, 2020).

The deepest documented USDW within the region is the Upper Pennsylvanian which is an undivided group of formations. Bedrock aquifers of the Pennsylvanian are primarily comprised of carbonate rocks, specifically dolomite and limestone, though shales and sandstones may also be present. These aquifers have little primary porosity and capacity is largely dependent on fracture number, extent and aperture (Kozar and Mathes, 1991). Groundwater capacity is low in bedrock aquifers and salinity rapidly increases with depth. The base of the Upper Pennsylvanian formation has been mapped by the West Virginia Geological Survey and is expected to be encountered at ~500 ft TVD at the proposed well location (**Figure 1-22**; WVDEP, 2022). Thorough review of logs from water wells from the Ohio River Valley Storage Project helped identify an unnamed sandstone within the Upper Pennsylvanian section that represents the deepest identifiable USDW at the proposed well location. The depth to the base of this unnamed sandstone is ~250 ft TVD, which coincides with the deepest depth any water wells in Mason County, West Virginia, were drilled to (Mudd, 2003). The top of the Black River is expected to be present at a depth of ~5,870 ft MD at the project site. There would be over 6,000 ft of rock and multiple confining layers separating the potential storage reservoirs and the deepest USDW. No sole source aquifers are present in Mason County nor any other county in West Virigina (EPA, 1989).

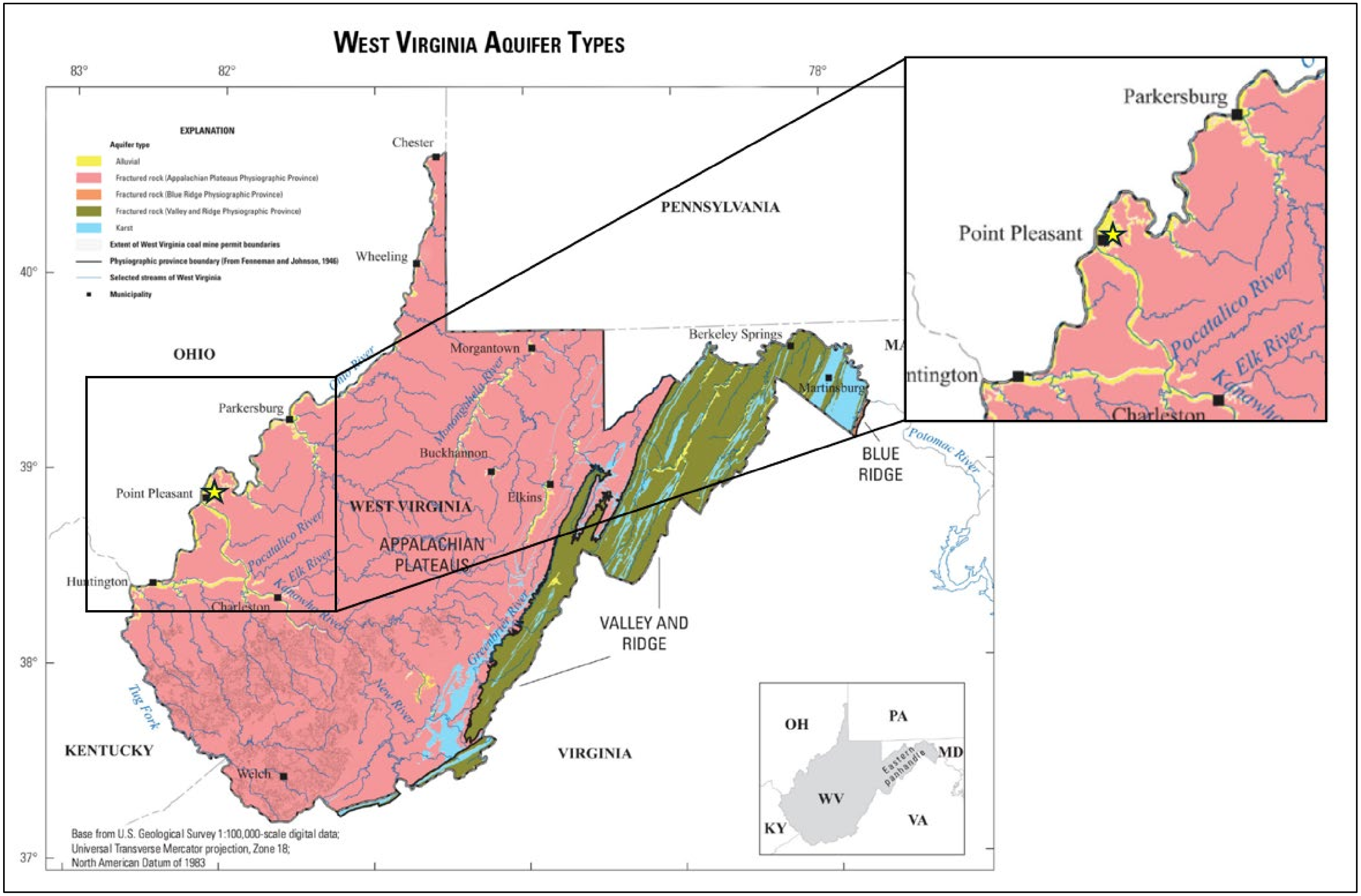

Figure 1-20: West Virginia aquifer types, physiographic provinces, and select rivers. The McClintic site location is denoted with the yellow star (modified from USGS, Viginia and West Virginia Water Science Center 2002).

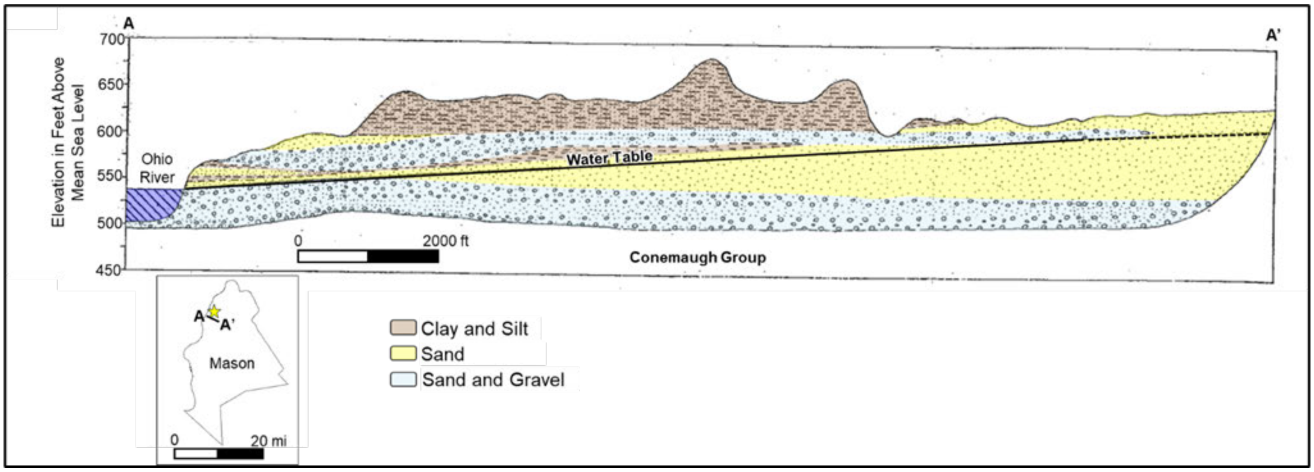

Figure 1-21: Generalized geologic cross section showing the alluvial aquifers and lithologies overlying the deeper Pennsylvanian bedrock aquifers. The geologic section extends south of the McClintic site, which is denoted with a yellow star. Modified from Wilmoth (1966).

[redacted]

Figure 1-22 Depth to base of Upper Pennsylvanian Group in Mason County. Site denoted by the yellow star (modified from WVDEP, 2022).

In addition to reviewing shallow subsurface freshwater aquifers, it was also necessary to review the salinity levels of the potential saline storage formation. Pickett plots are a graphical solution to Archie's water saturation equation and are a cross-plot of deep resistivity versus porosity on a log-log scale (**Figure 1-23**). Formation water resistivity is a function of salinity and temperature. Where the formation is fully saturated, the Pickett plot, also known as the resistivity-porosity method, can be used to determine formation salinity (U.S. EPA, 1988; Pickett, 1973). The red and blue lines represent lines of equal water saturation, with the red line drawn through the fully water-saturated reservoir log derived data. The red line is extrapolated to Total Porosity = 1 and the intercept indicates a resistivity of the water in the formation (Rw) at in-situ formation temperature. The Rw is converted to salinity in parts per million (ppm) using an industry standard chart within the petrophysical software (U.S. EPA, 1988). The slope of these lines is the m-exponent. The n-exponent and a-factor are standard inputs into the Archie equation. These Pickett-plot-derived salinity values should be considered a minimum salinity. [redacted]

The Pickett Plot calculated salinity is significantly lower than the measured salinity of the Copper Ridge from water samples collected in the same well, which were over [redacted] ppm in the Copper Ridge and overlying formations. This is likely due to the low porosity of the matrix rock that makes up the Copper Ridge. Lower porosity creates a higher resistivity response, which can lead to an artificially lower calculated salinity than what is actually present. Salinity will be directly measured in the Copper Ridge, and additional formations, from fluid samples collected from the proposed MCCLINTIC SEQUESTRATION 001 well.

[redacted]

Figure 1-23: Calculated log salinity of the Copper Ridge interval for the AEP #1. The Copper Ridge salinity is calculated to be 49,400 ppm.

Additionally, the USGS provides a database of formation water salinity tests from various sources, including the West Virginia Geological Survey, published literature, and private companies (USGS, 2024). Samples from Mason County and bordering counties in West Virginia and Ohio show that salinity is high even at shallow depths. [redacted]

A map of the AoR, known wells within the AoR, and proposed injection wells is shown in **Figure 1-1**. There are no documented shallow groundwater wells within the AoR.

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

Regional geochemical data and well log analysis provide insights into the storage formation water salinity (total dissolved solids [TDS]) of the Copper Ridge Formation. However, site-specific geochemistry data are not currently available due to a lack of subsurface water samples. The acquisition of these data will be completed either during the drilling of the proposed injection wells, the MCLINTIC SEQUESTRATION 001 injector, or in an independent deep groundwater well that may be drilled if it provides a more efficient sampling procedure. Water samples will be collected for aqueous and solid-phase geochemical data through analysis of major cations and anions, trace metals, and general geochemical properties (i.e., pH, TDS, alkalinity, etc.). These analyses will be used to determine:

- The deepest USDW at the project site
- Baseline geochemical data for the project site to evaluate any migration of CO_2 and brine waters at the site
- Baseline geochemical equilibrium conditions to evaluate the saturation relationship between the dissolved and solid-phase minerals at the site
- Geochemical reactions that may occur from the injection of CO_2

The analysis of onsite geochemical properties in the subsurface reservoirs above and within the storage formation will confirm the intervals identified for CO_2 storage meet the criteria outlined for Class VI permit approval.

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

No surface air and/or soil gas data were collected at the McClintic site location.

1.2.10 Site Suitability [40 CFR 146.83]

An extensive set of subsurface data has been analyzed at the Fidelis Site location to support the evaluation of site suitability. The integration of well logs, 2D seismic, and regional maps and cross sections confirm the lateral extent of the storage formation and confining zones, as well as the absence of faulting at the site location and surrounding area that would impact the integrity of the storage formation and confining zones. Therefore, the containment risk is low, and although multiple secondary confinements zones are present, none are necessary for USDW protection. There are no deep wellbore penetrations into the confining zone above the storage formation within the AOR (refer to section 2.4.2 Wells Penetrating the Confining Zone). Additional well and rock data to be collected from the injection well will provide further geomechanical data to support the integrity of the storage formation and confining zones.

The Fidelis site location is suitable for CO_2 sequestration due to the favorable lithologies of the storage and confining formations. The storage formation, the Copper Ridge, is mostly composed of dolomite ranging from finely crystalline to sucrosic in texture. The most common mineral in the formation is dolomite followed by very minor amounts of quartz and clay. Baseline primary porosities typically range from [redacted] although zones with secondary porosity networks have measured porosities [redacted] and permeabilities range from [redacted] (Gupta, 2008b). Furthermore, although neither the CO_2 stream nor formation waters are expected to be highly corrosive, the injection well materials that come in contact with the CO_2 stream and/or reservoir brines will be constructed of corrosion-resistant materials, such as 13CR steel, or similar. For example, the casing string across the Copper Ridge formation, the packer, and deep portions of the tubing with be constructed with corrosion-resistant materials or coatings. The thickness, porosity and permeability of the Copper Ridge storage formation make this site location optimal for CO_2 sequestration with a large CO_2 storage capacity. [redacted]

The Ordovician aged Copper Ridge was deposited on a broad carbonate shelf covering the entire Appalachian Basin and much of the midwestern United States. The resulting geometries are influenced by the orientation of the carbonate shelf and basin structure during deposition, and a slight thickening of the formation to the southeast into the Appalachian Basin is the result (see **Figure 1-24**). These geometries were integrated into the SEM to provide depositionally informed anisotropy. This does not have a major influence on the direction of plume migration for the injected CO_2. Present day structure shows the greatest effect on the plume geometry.

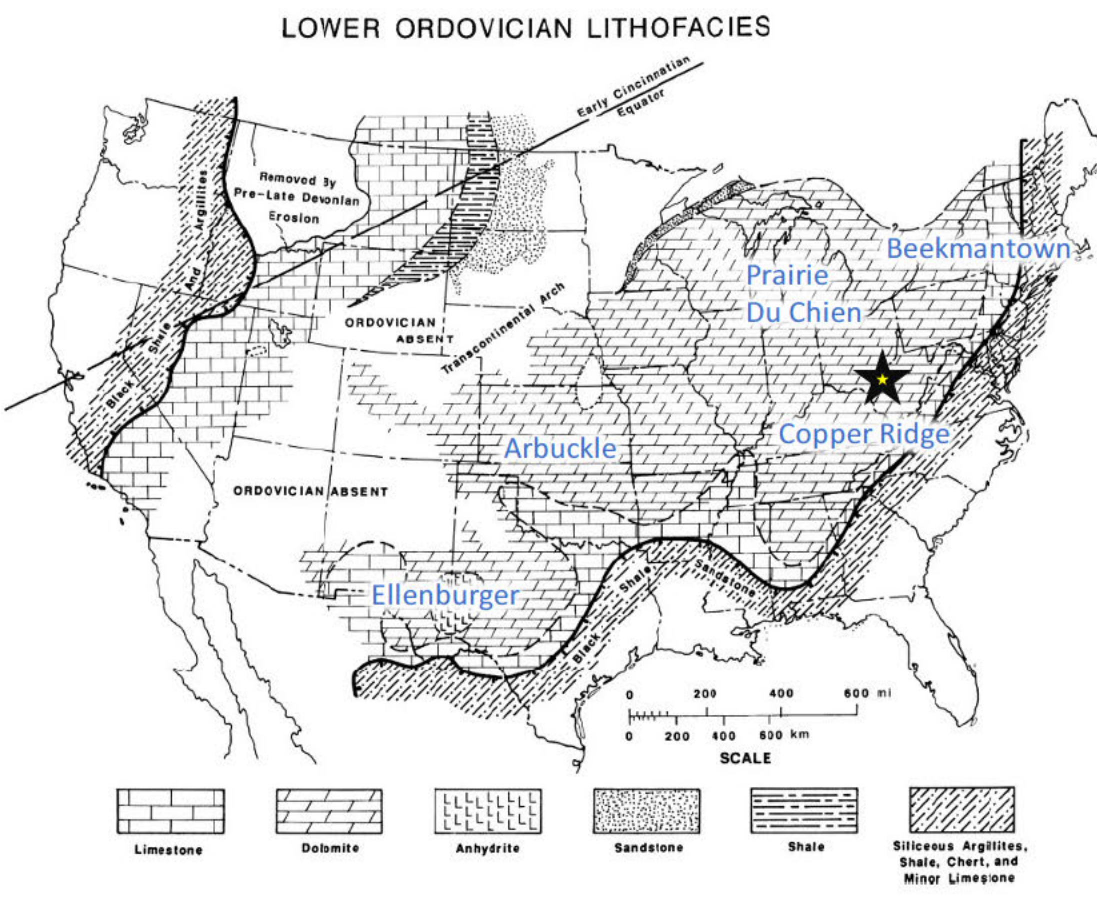

Figure 1-24: Depositional trend, extent and lithologies of the Copper Ridge and its stratigraphic equivalents across the Eastern and Midwest United States. Site is denoted by the yellow star (modified from Fritz et al, 2012).

1.3 Permit Section 2.0: AoR and Corrective Action

The Area of Review (AoR) and Corrective Action Plan describes the computational modeling performed by Fidelis to derive the AoR and the corrective actions to be taken in response to changes in the AoR, in compliance with 40 CFR 146.84.

The data used in the computational modeling were acquired in a nearby carbon dioxide (CO_2) sequestration pilot project at American Electric Power's (AEP's) Mountaineer Gigasystem, which consisted of numerous wells drilled less than 10 miles northeast from the Capio Mountaineer Sequestration Project location.

Thirty-five (35) wells provided depth control on horizon surfaces, two key wells (AEP 01, 8.9 miles northeast, and AEP BA-02, 7.5 miles east/northeast), provided the well logs and history data to condition model properties. An extensive suite of wireline logs, sidewall cores, whole core and injectivity data were acquired and incorporated into the computational model.

The plan describes the computational modeling approach and results. The objective of the computational modeling is to track the CO_2 plume size and shape, area of pressure buildup, and determine an AoR for CO_2 injection at the Fidelis project site. The SEM is a three-dimensional (3D) geocellular model that represents the porosity and permeability of different stratigraphic formations, most notably, the intended CO_2 storage formation and overlying confining zone. This type of model was selected as it offers the best options for quantifying, representing, and visualizing the subsurface geologic interpretations for the site. The purpose of this model is to represent available pore volume and enable the estimation of CO_2 storage capacity. Primarily, this geologic model serves as the framework (in terms of delineating zones, surfaces, permeability, and porosity) for dynamic computational modeling of CO_2 injection within the SEM.

Computational modeling to simulate CO_2 injection into the saline aquifer was performed using a 3D multiphase flow simulator CMG-GEM (Computer Modelling Group, 2022). In addition to the geological framework imported from the SEM, additional parameters, such as relative permeability data, initial conditions, phase behavior model, and well/perforation parameters, were added to the computational model to complete the dynamic modeling. An extensive suite of wireline logs, sidewall and whole core data, and injection test results were acquired and incorporated into the computational model.

CMG-GEM is an equation-of-state based compositional simulator that models the phase behavior of brine and CO_2 saturations (at high concentrations defined as a plume) during the injection and post-injection phases of a project. Multiple phases were accounted for in the computational model including aqueous, gas, and supercritical phases.

Modeling multiphase flow processes in porous media, with all components as described above, enables:

- Estimation of pressure buildup in the storage formation – confining layer system
- Characterization of CO_2 phase behavior at storage reservoir conditions
- Estimation of CO_2 saturation (plume extent) in the storage formation (Early-Stage Granite Wash)
- Understanding of confining layer parameters to ensure seal integrity over the project life

The processes bulleted above are modeled throughout the entire project life (injection and post-injection).

The estimated CO_2 saturation map and pressure buildup from modeling multiphase flow processes predicts CO_2 movement during the injection and post injection periods and helps define the AoR. **Figure 1-25** shows the CO_2 saturation map at the end of the 10-year injection period and the AoR.

[redacted]

Figure 1-25: CO2 Saturation after 10-years of injection (summation plan view left, cross section right).

1.4 Permit Section 3.0: Financial Responsibility

The Financial Responsibility Plan is submitted as Section 3.0 to meet the requirements of 40 CFR 146.82(a)(14) and 146.85.

1.5 Permit Section 4.0: Injection Well Construction

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

No completion stimulation is planned at this time because the reservoir quality is expected to be adequate for the planned injection volumes. A typical acid wash will be used to clean any drilling mud and debris in the near-wellbore region that may be generated during drilling operations.

1.5.2 Construction Procedures [40 CFR 146.2(a)(12)]

A newly drilled injection well (MCCLINTIC SEQUESTRATION 001) will be constructed at the Fidelis site, to meet the requirements of 40 CFR 146.86.

1.5.3 Casing and Cementing

The injection well will deviate from vertical between the surface to total depth (TD) locations. The injection well construction plan is designed to prevent the movement of fluids into or between underground sources of drinking water (USDWs) or into any unauthorized zones and to permit the use of appropriate testing devices and workover tools. The design also accommodates continuous monitoring of the annulus space between the injection tubing and long string casing ((146.86 (a)(1,2,3)). The proposed injection well diagram is shown in **Figure 1-4**. The well will deviate below the surface casing, building a tangent interval and then dropping back to vertical before cutting into the top of the caprock formation.

A comprehensive suite of wireline logs, core, fluid samples and reservoir testing will be acquired during the drilling of the well.

Table 1-9 summarizes the casing program for the injection well. All casing strings will be cemented to the surface and any changes to the final well design will be discussed with the UIC Director or representative. **Table 1-10** details the cement types and corresponding casing strings. The design is robust, meeting industry accepted minimum safety factors with significant margin. American Petroleum Institute (API) minimum safety factors are based on 1.125 for collapse, 1.1 for burst and 1.6 for axial loading.

[redacted]

Table 1-9: Injection well casing details.

[redacted]

Table 1-10: Summary of cement types and corresponding casing strings.

The injection tubing-casing annular fluid will be a dilute salt solution such as potassium chloride (KCl), sodium chloride (NaCl), or similar. The fluid will be mixed on site from dry salt and good quality (clean) fresh water, or it will be acquired pre-mixed. The fluid will also be filtered to ensure that solids do not interfere with the packer or other components of the annular protection system. The likely density of the annular fluid will be approximately [redacted] ppg. The final choice of fluid will depend on availability and wellbore conditions.

1.6 Permit Section 5.0: Pre-Operational Testing Program

The Pre-Operational Logging and Testing Plan is submitted to meet the requirements of 40 CFR 146.82(a)(8) and 40 CFR 146.87.

The pre-operational formation testing program will supplement the local subsurface characterization data used in the preparation of this permit application which was acquired in the carbon dioxide (CO_2) sequestration pilot project at American Electric Power's (AEP's) Mountaineer plant, less than 10 miles northeast from the Capio Mountaineer Sequestration project location. The AEP project included numerous wells in which extensive suites of wireline logs, whole core and sidewall cores were acquired.

The pre-operational testing program provides and verifies the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the storage formation, the overlying confining layer, and other relevant geologic formations. In addition, pre-operational testing data are used to provide baseline information for the site that will be used for comparative purposes throughout the project. For example, fluid samples collected during the pre-operation testing will be used as a reference to identify geochemical changes in samples collected during injection operation that may result from the injection of CO_2.

1.7 Permit Section 6.0: Well Operations

This section describes the source of the CO_2 that will be delivered to the storage site, its chemical and physical properties, flow rate, and the anticipated pressure and temperature of the CO_2 at the pipeline outlet. In addition, this section provides the monitoring that will be performed on the injection well to confirm that it does not provide a conduit for CO_2 and/or brine from the storage formation up past the confining zone and into USDWs or the surface.

Monitoring of the injection well parameters will be performed to ensure proper operation and compliance with 40 CFR 146.90(b). The wellhead injection pressure will be used to confirm that storage formation pressures remain below the regulated limit while the storage formation pressure will be measured with downhole pressure sensors. The mass injection rate will be continuously monitored to ensure the rate remains below the regulated limit. The annular pressure and temperature will be measured continuously to maintain compliance with the EPA Class VI permit and to monitor the internal mechanical integrity of the well. The operational monitoring data will be connected to the main facility (CO_2 emission source's control room) through a supervisory control and data acquisition (SCADA) system.

In addition to the annular monitoring system that will evaluate the internal mechanical integrity of the well, a mechanical integrity test will be performed on the well after the tubing has been placed in the well and the packer has been set. External mechanical integrity will be monitored on an annual basis via external temperature measurements over the entire depth of the well in an attempt to identify any vertical fluid movement above the storage reservoir.

The injection stream will be monitored during the baseline and operational phases of the project. Prior to the start of the injection phase, the CO_2 stream will be sampled for analysis during regular plant operations to obtain representative CO_2 samples that will serve as a baseline dataset.

1.8 Permit Section 7.0: Testing and Monitoring

The Testing and Monitoring Plan describes how Fidelis will monitor the site pursuant to 40 CFR 146.82(a)(15) and 146.90.

The Testing and Monitoring Plan has been developed in conjunction with the project risk assessment to reduce the risks associated with carbon dioxide (CO_2) injection into the subsurface at this site. Goals of the monitoring strategy include:

- Meeting the regulatory requirements of 40 CFR 146.90
- Protecting underground sources of drinking water (USDWs)
- Ensuring that the injection well is operating as planned.
- Providing data to validate and calibrate the geological and dynamic models used to predict the distribution of CO_2 within the injection zone
- Support Area of Review (AoR) re-evaluations over the course of the project

The Testing and Monitoring Plan will be adaptive over time; the plan can be adjusted to respond:

- As project risks evolve over the course of the project
- If significant differences between the monitoring data and predicted dynamic modeling results are identified
- If key monitoring techniques indicate anomalous results related to well integrity or the loss of containment

Figure 7-1 of the Testing and Monitoring Plan (Permit Section 7.0) illustrates the AoR at the end of the Post Injection Site Closure (PISC) period, the proposed location of the deep monitor well, the conceptual location of the above confining zone (ACZ) well, and the conceptual distribution of seismicity stations.

The Testing and Monitoring Plan will outline several proposed direct and indirect technologies used throughout the injection and PISC phases of the project selected to appropriately monitor:

- Daily activities of the injection operations
- Development of the CO_2 and pressure plumes in the storage formation over time
- Well integrity

- CO_2 or brine containment within the injection reservoir
- Groundwater quality in multiple aquifers, including the USDWs and the deepest water-bearing formation above the caprock

Monitoring injection operations will be through a range of continuous, daily, and quarterly techniques as detailed in the Well Operations Plan (Permit Section 6.0). **Table 1-11** summarizes the proposed testing and monitoring plan for the project. Plume monitoring and USDW sampling will include pre injection baseline monitoring for comparison with injection and post injection results.

Monitoring Activity	Baseline Data Frequency	Injection Phase Frequency	Location	Formation top / Depth Range (ft, MD)
Assurance Monitoring:				
USDW Sampling	Quarterly	Quarterly	AoR Groundwater well network[1]	Producing zone
USDW Isotope Analysis	Biannually	Annually	AoR Groundwater well network[1]	0 – TD
Operational Monitoring:				
CO_2 Stream Analysis	NA	Quarterly	CO_2 Delivery Pipeline	NA
Corrosion Coupon Analysis	NA	Quarterly	CO_2 Delivery Pipeline	NA
Injection Pressure	NA	Continuous	Injection Wellhead	Surface
Mass Injection Rate	NA	Continuous	Injection Wellhead	Surface
Injection Volume (Calculated)	NA	Continuous	Storage Formation	Surface
Annular Pressure	NA	Continuous	Injection Well	Surface
Annular Fluid Volume	NA	Continuous	Injection Well	Surface
Temperature Measurement	Once	Annually	Injection Well	0 – TD
PFO Tests	Once	Every 5 years	Injection Well	Surface

Monitoring Activity	**Baseline Data Frequency**	**Injection Phase Frequency***	**Location**	**Formation top / Depth Range (ft, MD)**
Verification Monitoring:				
Fluid Sampling				
Deepest USDW	Twice	Annually	ACZ well or independent groundwater well	TBD
Top confining zone	Twice	Annually	ACZ well	TBD
Injection zone	Twice	Annually	Deep monitor well[2]	TBD
Isotope Analysis	Twice	Annually	ACZ Well	All samples
Pressure Sensors	Prior to injection			
Deepest USDW	Continuous	Continuous	ACZ Well or independent groundwater well	TBD
Top confining zone	Continuous	Continuous	ACZ Well	TBD
Injection zone	Continuous	Continuous	Deep monitor well	TBD
			Injection Well	TBD
Temperature Sensors (DTS)	Prior to injection			
Deepest USDW	Continuous	Continuous	ACZ Well	TBD
Top confining zone	Continuous	Continuous	ACZ Well	TBD
Injection zone	Continuous	Continuous	Deep monitor well	TBD
PNC Logging				
Deepest USDW	Once	Annually	ACZ Well	TBD
Top confining zone	Once	Annually	ACZ Well	TBD
Injection zone	Once	Annually	Deep Monitor well	TBD
Microseismic Monitoring	Prior to injection	Continuous	Surface stations	TBD
Time-lapse Borehole Seismic VSP Data	Once	Every 5 years and as required	Surface Sources, downhole DAS	

[2] In-zone fluid sampling will be discontinued once CO_2 breakthrough occurs at the well

Table 1-11: General schedule and spatial extent for the testing and monitoring activities for CCS project.

1.9 Permit Section 8.0: Injection Well Plugging

The Injection Well Plugging Plan describes how Fidelis will plug the injection well pursuant to 40 CFR 146.82(a)(16) and 146.92.

A Notice of Intent to plug the well will be submitted to the Environmental Protection Agency (EPA) at least 60 days prior to the plugging operations (40 CFR 146.92 (c)). After the project has verified that there are no external well integrity issues, the well will be flushed with a buffer fluid to remove any fluids or particulates that may be present in the well (Section 8.6). The weight of the buffer fluid will be determined from the final reservoir pressure measurement and will be chemically compatible with the formation fluids and solids to reduce the potential of corrosion of the well materials. A minimum of three casing volumes will be circulated without exceeding the fracture pressure of the storage formation.

The injection well casing will be plugged with cement to ensure that it does not provide a conduit outside the storage formation. **Table 1-12** presents the intervals that will be plugged as well as the materials and methods that will be used to plug the intervals. The cement volume required for each plug was calculated using the inside diameter of the deep casing string, the length of the zone to be plugged, and the yield of the cement slurry ([redacted]/sack for Class L or G or H and [redacted] ft^3/sack for the CO_2 resistant cement). The storage formation will be plugged using CO_2 resistant cement with a retainer/squeeze method or other method approved by the Underground Injection Control (UIC) Director. A cement retainer will be set in the injection casing a minimum of 100 ft above the top perforation. These depths will be re-evaluated after the injection well has been drilled and precise formation depths have been established. CO_2 resistant cement will be used to plug the storage formation; this will include a 20% excess volume to be squeezed into the storage formation. It requires approximately 0.2 sack of cement to seal 1 ft of hole, and this value may be used to estimate the amount of cement needed for different perforation scenarios.

[redacted]

Table 1-12: Intervals to be plugged and materials/methods used (40 CFR 146.92 (b)(2 – 4)).

1.10 Permit Section 9.0: Post-Injection Site Care (PISC) and Site Closure

The PISC and Site Closure Plan describes the activities that Fidelis will perform to meet the requirements of 40 CFR 146.82(a)(18) and 146.93(c).

Fidelis will monitor groundwater quality and track the position of the CO_2 plume and pressure front for 50 years after the cessation of injection. Additional information on the projected post-injection pressure decline and differentials is presented in the Post-Injection Site Care and Site Closure Plan (Permit Section 9.0).

1.11 Permit Section 10.0: Emergency and Remedial Response

The Emergency and Remedial Response Plan (ERRP) is submitted to meet the requirements of Plan 40 CFR 146.82(a)(19) and 146.94(a).

The ERRP provides actions that Fidelis will take in the event of an emergency and to address movement of CO_2 or formation fluid that may endanger a USDW during the construction, operation, or PISC periods.

If evidence indicates that the injected CO_2 stream, formation fluids, and/or associated pressure front may cause an endangerment to a USDW, the following actions must be performed:

1. Initiate shutdown plan for the injection well
2. Take all steps reasonably necessary to identify and characterize any release
3. Notify the permitting agency/UIC Program Director (UIC Director) of the emergency event within 24 hours
4. Implement applicable portions of the ERRP

If an emergency shutdown should occur, CO_2 injection will only resume with the consent of the UIC Director. If Fidelis can demonstrate that the injection operation will not endanger USDWs, the UIC Director may allow the resumption of injection prior to remediation.

If a non-emergency shutdown of the CO_2 injection system is required, the operator will complete the shutdown in a stepwise approach to prevent over-pressure situations and/or damage to the equipment. Efforts will also be made to maintain the CO_2 in the injection stream in a supercritical phase to prevent special operations during the restart of the system.

1.12 Injection Depth Waiver and Aquifer Exemption Expansion

Fidelis is not applying for a depth waiver or an aquifer exemption.

Appendix A – Environmental Justice Baseline Analysis

The baseline Environmental Justice report can be found in a separate accompanying document.

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