CLASS VI PERMIT APPLICATION NARRATIVE

40 CFR 146.82(a)

TRILLIUM CARBON STORAGE COMPLEX (TCSC)

Facility Information

Facility Name: Trillium Carbon Storage Complex (TCSC)
TCSC-1, TCSC-2, TCSC-3, TCSC-4, TCSC-5

Facility Contact: Claimed as PBI [redacted]

Facility Address: Claimed as PBI [redacted]

Well Locations: Claimed as PBI [redacted]

Well Name	Latitude	Longitude
TCSC-1	Claimed as PBI [redacted]	Claimed as PBI [redacted]
TCSC-2	Claimed as PBI [redacted]	Claimed as PBI [redacted]
TCSC-3	Claimed as PBI [redacted]	Claimed as PBI [redacted]
TCSC-4	Claimed as PBI [redacted]	Claimed as PBI [redacted]
TCSC-5	Claimed as PBI [redacted]	Claimed as PBI [redacted]

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Abbreviations and Acronyms

2D	Two dimensional
3D	Three dimensional
AoR	Area of Review
AP	Artificial Penetration
ASSF	Akron-Suffield-Smith Fault systems
AZM	Above-Zone Monitoring
CCS	Carbon Capture and Storage
CO_2	Carbon dioxide
CWA	Clean Water Act
DOE	Department of Energy
Dol	Dolomite
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response Plan
Fm	Formation
ftMSL	feet below Mean Sea Level
GCS	Geological Carbon Sequestration
Gp	Group
gpm	gallons per minute
HF	Highlandtown Fault system
IPaC	Information for Planning and Consultation
IPCFZ	Rockcastle River Fault Zone
IZM	In-Zone Monitoring
KGS	Kentucky Geological Survey
KRFZ	Kentucky River Fault Zone
LFZ	Lexington Fault Zone
Ls	Limestone
MMt	Million Metric tonnes

MMtpa	Million Metric tonnes per annum
MRCSP	Midwest Regional Carbon Sequestration Partnership
Mt.	Mount
n	Sample size
ND	Not Detected
NESHAPS	National Emission Standards for HAzardous PollutantS
NPDES	National Pollutant Discharge Elimination System
NR	Not Recorded
OCDO	Ohio Coal Development Office
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
OH	Ohio
PCN	Pre-Construction Notification
PHIT	Total porosity
Claimed as PBI [redacted]	[redacted]
PSD	Prevention of Significant Discharge
PWL	Pittsburgh-Washington Lineament
R^2	Coefficient of determination
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
Sh	Shale
SHPO	Ohio State Historic Preservation Office
SPCC	Spill Prevention and Control and Countermeasures
Ss	Sandstone
SWPPP	StormWater Pollution Prevention Plan
TBD	To Be Decided
TCSC	Trillium Carbon Storage Complex
TDS	Total Dissolved Solids
tH2Power	Trillium Hydrogen to Power
TML	Tyrone-Mount Union Lineament
Trillium	Trillium Piketon, LLC
UIC	Underground Injection Control
USACE	United States Army Corps of Engineers
USDW	Underground Source of Drinking Water
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VE	Vertical Exaggeration
WOTUS	Waters Of the United States

1. APPLICATION NARRATIVE

1.1. PROJECT BACKGROUND AND CONTACT INFORMATION

1.1.1. Project Background

The Trillium Carbon Storage Complex (TCSC, the Project) [redacted] is a carbon capture, transport, and sequestration (CCS) venture proposed by Trillium Piketon, LLC (Trillium) designed to geologically sequester [redacted] million metric tonnes (MMt) of carbon dioxide (CO_2) by injecting CO_2 into five injection wells over [redacted] years in the [redacted] subsurface Formations in [redacted].

No injection depth waiver and/or aquifer exemption will be sought for this permit application.

Table 1-1: TCSC partners and collaborators.

Contact	Role
Trillium Piketon, LLC	Project developer, facility operator
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

1.1.2. Project Timeframe

Trillium plans to inject CO_2 for [redacted] years, followed by a [redacted]-year post-injection monitoring period. The post-injection timeframe has been chosen after evaluating the results of computational modeling. Additional details on the post-injection timeframe can be found in the Area of Review (AoR) and Corrective Action Plan, as well as the *Post-Injection Site Care and Site Closure Plan*.

1.1.3. Proposed Injection Mass and CO_2 Source

Trillium plans to inject [redacted] of CO_2 at TCSC using five injection wells with an average injection rate of [redacted] tonnes per day per well. This equates to a total storage volume of [redacted] MMt for a [redacted]-year injection period at TCSC. CO_2 sequestered at TCSC is sourced from the [redacted] in [redacted] Ohio. [redacted] CO_2 produced by the project's [redacted] will be sequestered by the injection wells that are the subject of this UIC Class VI permit application. [redacted] (**Figure 1-1**).

Claimed as PBI [redacted]

Figure 1-1. Injection wells Claimed as PBI [redacted] **AZM = Above-Zone Monitoring.**

1.1.4. Injection Depth Waiver

No injection depth waiver is currently sought for this project.

1.1.5. Aquifer Exemption

No aquifer exemption is currently sought for this project.

1.1.6. Applicable Permit Information Under 40 CFR 144.31(e)(1) through (6)

Table 1-2 provides information on activities conducted by Trillium that require it to obtain permits under the Resource Conservation and Recovery Act (RCRA), Underground Injection Control (UIC), the National Pollution Discharge Elimination System (NPDES) program under the Clean Water Act (CWA), or the Prevention of Significant Deterioration (PSD) program under the Clean Air Act (CAA).

Table 1-2 Permit Information Required under 40 CFR144.31(e)(1).

CAA = Clean Air Act; CWA = Clean Water Act; EPA = U.S. Environmental Protection Agency; NPDES = National Pollution Discharge Elimination System; OEPA = Ohio Environmental Protection Agency; PSD = Prevention of Significant Deterioration; RCRA = Resource Conservation and Recovery Act; UIC = Underground Injection Control.

Regulation	Jurisdiction	Activity	Relevant Permits
RCRA	State	None	None anticipated
UIC	EPA – Region 05	CO_2 injection well drilling and operation	Class VI Injection Well Permits
NPDES – CWA	OEPA	Claimed as PBI [redacted]	Claimed as PBI [redacted]
PSD – CAA	OEPA	Claimed as PBI [redacted]	Claimed as PBI [redacted]

1.1.6.1. Contact Details for Trillium

Name: Claimed as PBI [redacted]
Mailing address: Claimed as PBI [redacted]
Tel.: Claimed as PBI [redacted]
E-mail: Claimed as PBI [redacted]
Project Location: Claimed as PBI [redacted]

1.1.6.2. Applicable SIC Codes

Per 40 CFR 144.31(e)(3), applicable SIC codes are listed below:

Claimed as PBI [redacted]

1.1.6.3. Operator Details

Name: Trillium Piketon, LLC
Contact: Claimed as PBI [redacted]
Mailing address: Claimed as PBI [redacted]
Tel.: Claimed as PBI [redacted]
E-mail: Claimed as PBI [redacted]

Claimed as PBI [redacted]

1.1.6.4. Other permit information required under 40 CFR 144.31(e)(6)

Table 1-3 Activities conducted by Trillium and applicable permits as noted in 40 CFR 144.31(e)(6).
ODOT = Ohio Department of Transport; ODNR = Ohio Department of Natural Resources.

Permit	Jurisdiction	Activity	Relevant Permits and Agreements
Drilling Permits	ODNR – Division of Oil and Gas	Drilling of characterization and monitoring wells	Stratigraphic test well permit
Valid Access Agreements	County, township/city, landowner	Construction of project wells, siting injection and monitoring infrastructure	Landowner leases to construct and operate
Encroachment Permits	County, township/city, landowner	Construction of project wells, siting injection and monitoring infrastructure	Special Use Permits from Claimed as PBI [redacted]
Restricted Lane Use Permits	State, county	Construction of project wells, siting injection and monitoring infrastructure	Road Use Permits with ODOT and any other applicable county/city offices

Table 1-4 Applicable permits and construction approvals, as noted in 40 CFR 144.31(e)(6).
NESHAPS = National Emission Standards for Hazardous PollutantS; NPDES = National Pollution Discharge Elimination System; SHPO = Ohio State Historic Preservation Office; SWPPP = StormWater Pollution Protection Plan; Claimed as PBI [redacted]; USACE = United Army Corps of Engineers.

Permit	Jurisdiction	Relevant Permits
Hazardous Waste Management Program under RCRA	Federal, state	None anticipated
EPA UIC Program under the Safe Drinking Water Act (SDWA)	Federal	Class VI Injection Well Permits from EPA Region 05
Stormwater General Permit for Construction Activities	State	Claimed as PBI [redacted]
NPDES under CWA	State	Claimed as PBI [redacted]
PSD under CAA	State	Claimed as PBI [redacted]
Nonattainment Program under CAA	State	Claimed as PBI [redacted]
NESHAPS under CAA	State	Claimed as PBI [redacted]
Section 401 Water Quality Certification or Director's Authorization	Claimed as PBI [redacted]	Claimed as PBI [redacted]

Permit	Jurisdiction	Relevant Permits
	Claimed as PBI [redacted]	Claimed as PBI [redacted]
Permit to Construct	Claimed as PBI [redacted]	Claimed as PBI [redacted]
Access Permits	ODOT	Driveway Access Permit – Construction and Operations, Utility Access Permit – Construction and Operations
SHPO	Claimed as PBI [redacted]	Claimed as PBI [redacted]

Table 1-5 Applicable permits and construction approvals, as noted in 40 CFR 144.31(e)(6).
IPaC = Information for Planning and Consultation; PCN = Pre-Construction Notification; Claimed as PBI [redacted] SPCC = Spill Prevention and Control and Countermeasures; USFWS = United States Fish and Wildlife Service; WOTUS = Waters Of The United States.

Regulatory Agency	Permit/Clearance	When Required	Potential Studies & Application Requirements
Federal Permits			
[redacted]	[redacted]	Claimed as PBI [redacted]	[redacted]
USACE	[redacted]	Claimed as PBI [redacted]	[redacted]

Regulatory Agency	Permit/Clearance	When Required	Potential Studies & Application Requirements
		Claimed as PBI [redacted]	
USACE	[redacted]	Claimed as PBI [redacted]	[redacted]
USFWS	[redacted]	Claimed as PBI [redacted]	[redacted]
EPA - Region 05	[redacted]	Claimed as PBI [redacted]	[redacted]
EPA – Region 05	[redacted]	Claimed as PBI [redacted]	[redacted]
EPA – Region 05	Class VI UIC Permit	Geologic sequestration of carbon dioxide	Detailed reservoir studies and site background studies
Ohio Environmental Permits			
OEPA	[redacted]	Claimed as PBI [redacted]	[redacted]
OEPA	Claimed as PBI [redacted]	[redacted]	[redacted]

Regulatory Agency	Permit/Clearance	When Required	Potential Studies & Application Requirements
	Claimed as PBI [redacted]	[redacted]	
OEPA	Claimed as PBI [redacted]	[redacted]	[redacted]
OEPA	Claimed as PBI [redacted]	[redacted]	[redacted]
OEPA	[redacted]	[redacted]	Claimed as PBI [redacted]
OEPA	[redacted]	Claimed as PBI [redacted]	[redacted]
ODNR - Division of Wildlife	[redacted]	Claimed as PBI [redacted]	[redacted]
Ohio Fish and Wildlife	[redacted]	Claimed as PBI [redacted]	[redacted]
SHPO	[redacted]	Claimed as PBI [redacted]	[redacted]
Local, Claimed as PBI [redacted] Permits/Registrations			
	Claimed as PBI [redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

Regulatory Agency	Permit/Clearance	When Required	Potential Studies & Application Requirements
	[redacted]	Claimed as PBI [redacted]	[redacted]
		Other Permits	
ODOT	Claimed as PBI [redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	Claimed as PBI [redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

Regulatory Agency	Permit/Clearance	When Required	Potential Studies & Application Requirements
	[redacted]	[redacted]	Claimed as PBI [redacted]
[redacted]	[redacted]	Claimed as PBI [redacted]	[redacted]

1.2. Site Characterization

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

TCSC is located in the Appalachian Basin (**Figure 1-2**). The local geology was evaluated using geologic maps, reports, and databases from the Geological Survey Division of the Ohio Department of Natural Resources (ODNR) and the Midwest Regional Carbon Sequestration Partnership (MRCSP)[1] to characterize the geologic properties at TCSC, determine containment feasibility, and estimate CO_2 storage resources.

Two primary injection zones have been identified at TCSC: The Claimed as PBI [redacted] (**Figure 1-3** and **Figure 1-4**). The Claimed as PBI [redacted]. Several secondary reservoirs and confining zones are present.

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[1] The MRCSP is a public/private consortium established in 2003 as part of the U.S. Department of Energy's (DOE) Regional Carbon Sequestration Partnership Program to assess its region's technical potential, economic viability, and public acceptability of carbon sequestration. The MRCSP region consists of seven contiguous states: Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia. It is one of seven such partnerships across the U.S.

Claimed as PBI

[redacted]

Figure 1-2: Regional geological setting of the project area [4].
OCDO = Ohio Coal Development Office, one of the MRCSP partners.

Claimed as PBI [redacted]

Figure 1-3: GCS system at TCSC.

*Claimed as PBI [redacted] Dol = Dolomite; Fm = Formation; Gp = Group; Ls = Limestone; Ss = Sandstone; Sh = Shale; USDW = Underground Source of Drinking Water.

Claimed as PBI [redacted]

Figure 1-4: Stratigraphic column at TCSC.

Claimed as PBI [redacted] Dol = Dolomite; Fm = Formation; Gp = Group; Ls = Limestone; Mt. = Mount; Sh = Shale; Ss = Sandstone; USDW = Underground Source of Drinking Water.

1.2.1.1. Geologic History

The following outline of the area's geological history is from the Precambrian (basement) to the Late Devonian, which is the age of the lowermost Underground Source of Drinking Water (USDW) in the area of interest. This overview is based on [4] with maps from [5].

The Precambrian basement complex of Ohio consists of portions of the Grenville Province, the East Continent Rift Basin System, and the Eastern Granite-Rhyolite Province (**Figure 1-2**) that were part of the Laurentia crustal plate, which straddled the equator [5]. The basement in the area of interest lies within the Grenville Province, which formed during the Grenville Orogeny, a late Precambrian mountain-building event.

The Appalachian Basin began to take on its present configuration after the Middle Cambrian time following major movement of the Rome Trough to the east. The Rome Trough is thought to have controlled the formation and orientation of the northern Appalachian Basin [4].

The earliest record of sedimentation within the region is found within the Rome Trough. Deposition of this sequence began with the lowermost Paleozoic Basal Sandstone in the Middle Cambrian. Rifting of the eastern Laurentian continent resulted in the opening of the Iapetus Ocean [4]. The pre-Knox section of the Rome Trough is older and greatly thickened compared to the same intervals of the stable cratonic sequence of the Appalachian Basin.

From the Late Precambrian through most of the Middle Cambrian, eastern Ohio was a stable emergent cratonic platform. Erosion of exposed Grenville Basement supplied clastic sediments to the Rome Trough. Near the end of the Middle Cambrian, seas completely transgressed the exposed Precambrian basement complex in Ohio, resulting in near-shore to marginal marine deposition of the Basal Sandstone.

Open-marine conditions continued with the deposition of the Knox Group (Gp), which is subdivided into the Copper Ridge Dolomite, the Rose Run Sandstone, and the Beekmantown Dolomite.

A major regression occurred during the Middle Ordovician, giving rise to the regional Knox Unconformity on the emergent Knox Carbonate Platform [4].

Tropical seas returned to the Ohio region during the Middle Ordovician and inundated the subsiding Knox Platform. The Wells Creek Fm represents a major marine transgression over the Knox Unconformity.

Shallow-marine sedimentation continued through the Middle and Late Ordovician with deposition of the Black River Group, Trenton Limestone, and the Cincinnati group of shales and limestones.

Marine sedimentation in the region temporarily ceased during the Late Ordovician-Early Silurian as another major regression began and a regional unconformity developed on top of the Cincinnati Group. Repeated sea level fluctuations flooded and retreated from the coastal lowlands on the western flank of the Appalachian Basin. The Clinton Group was deposited in near-shore to marginal marine environments at the onset of another marine transgression. A mixture of clastics and carbonates was followed by the deposition of the Lockport Dolomite, Salina Group, Bass Islands Dolomite, and Helderberg Limestone.

An unconformity within Lower Devonian strata marks another period of regression. This was followed by a period of transgression and deposition of the Oriskany Sandstone, the overlying Onondaga Limestone, and shales of the Hamilton Group, including the Marcellus Shale, which marks the onset of the Acadian Orogeny.

During the Late Devonian Acadian Orogeny, tropical seas again inundated the region, depositing the West Falls Formation and the Ohio Shale in a partially restricted marine basin. The overlying Bedford Shale and Berea Sandstone represent the progression of gray shales and sandstones over this restricted basin.

1.2.1.2. Regional Reservoirs and Seals

The formations underneath Knox Unconformity comprising the two GCS systems are referred to collectively as the Sauk Megasequence [6]. The Sauk Megasequence is capped by Ordovician shales and limestones of the Wells Creek Fm, Chazy Limestone, Black River Gp, and Cincinnati Gp [6].

Reference [5] provides detailed information on the formations of interest for carbon sequestration in Ohio. The information presented below on the regional reservoirs and seals has been taken from that publication.

1.2.1.2.1 Cambrian and Ordovician Stratigraphic Nomenclature

Because of the low number of wells penetrating the section and the great distances between wells, Cambrian stratigraphic nomenclature is problematic in the Appalachian Basin and Rome Trough [5], [6]. The Basal Sandstone in the Rome Trough is older than the Basal Sandstone on the Appalachian craton, which is not the same as the Mt. Simon Sandstone that overlies the Precambrian Basement in the west of Ohio (**Figure 1-5**).

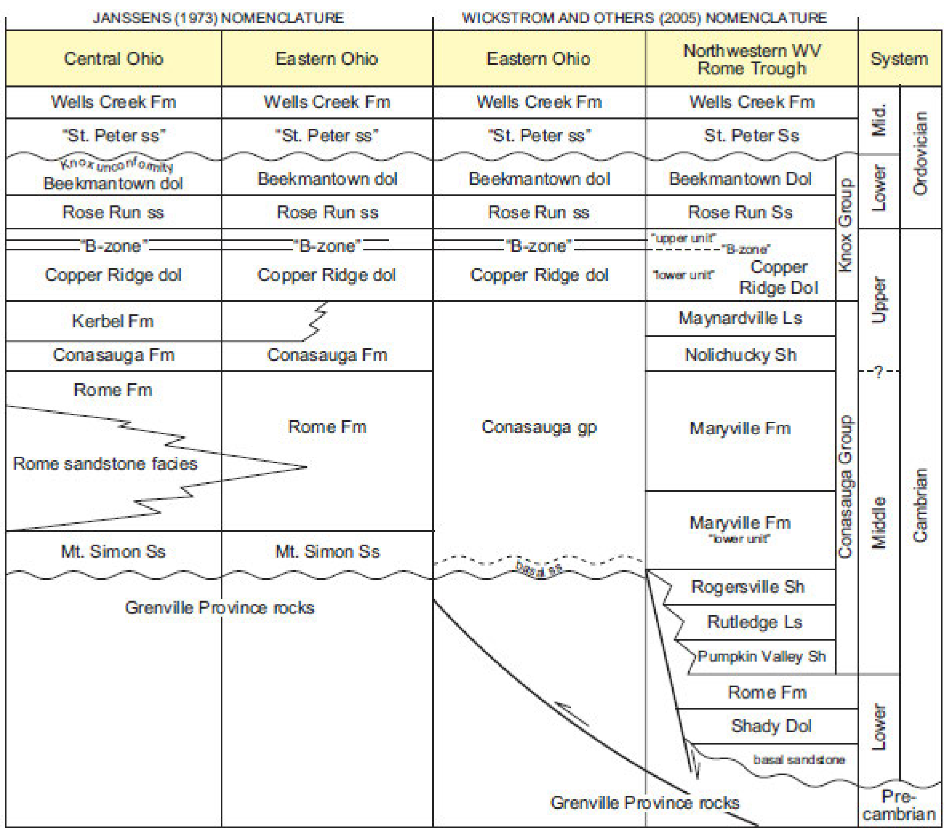

Figure 1-5: Correlation chart for stratigraphic nomenclature in eastern Ohio and the Rome Trough [4].
Dol = Dolomite; Fm = Formation; Sh = Shale; Ss = Sandstone.

Consolidating stratigraphic nomenclature is beyond the scope of this permit application. In a similar manner to MRCSP, TCSC combines, in terminology, sands occurring on top of the Precambrian Claimed as PBI [redacted] (**Figure 1-6** and **Figure 1-7**).

Claimed as PBI [redacted]

Figure 1-6: Locations of TCSC Claimed as PBI [redacted] **7].**

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Figure 1-7: Generalized stratigraphy and lithology of strata Claimed as PBI [redacted] **[7].**

Claimed as PBI [redacted]

[redacted]

[redacted]

[redacted]

Claimed as PBI [redacted]

Figure 1-8: Structure contour map of the Claimed as PBI [redacted] **[5].**
The yellow star indicates the TCSC site.

Claimed as PBI [redacted]

Figure 1-9: Thickness contour map of the Claimed as PBI [redacted] **[5].**

The yellow star indicates the TCSC site.

Claimed as PBI [redacted]

Claimed as PBI [redacted]

[redacted] [5].

Claimed as PBI [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Claimed as PBI [redacted]

Figure 1-10: Near top Claimed as PBI [redacted] structure contour map [5].

Note that this map is at the top of the Claimed as PBI [redacted] The yellow star indicates the TCSC site.

[redacted]

Figure 1-11: [redacted] **thickness contour map [5].**

Please note that this [redacted]

Claimed as PBI [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted] The yellow star indicates the TCSC site.

Claimed as PBI [redacted]

Claimed as PBI [redacted] The blue star indicates the TCSC site.

Claimed as PBI [redacted]

[redacted] [redacted]

[redacted]

[redacted]

Claimed as PBI [redacted]

Figure 1-14: Claimed as PBI [redacted]
The blue star indicates the TCSC site.

1.2.1.3. Regional Hydrogeology

Claimed as PBI [redacted] (**Figure 1-15**).

Claimed as PBI [redacted]

Figure 1-15: Geographic regions of Ohio.
The yellow star indicates the TCSC site.

Claimed as PBI [redacted]

[redacted]

Claimed as PBI [redacted]

[redacted]

Claimed as PBI

Figure 1-16: Sand and gravel aquifers in Claimed as PBI

The yellow star indicates the TCSC site.

Claimed as PBI [redacted]

Figure 1-17: Water wells and aquifers in the vicinity of TCSC [15].

Claimed as PBI [redacted] The yellow star indicates the TCSC site.

Claimed as PBI

[redacted]

Figure 1-18: Depth to water (ft) [15].

The blue star indicates the TCSC site.

[redacted] **Figure 1-19**):

- 6Da – Regolith over bedded sedimentary rock (unglaciated)
  - Widespread, encompassing most slopes and ridge tops in central and eastern [redacted] and ridge tops in the county's western portion. The area is characterized by high relief with broad, steep slopes and narrow, somewhat flatter ridge tops. The vadose zone and aquifers consist of slightly dipping, fractured, alternating sequences of dirty sandstones, shales, and siltstones of the Mississippian age. Multiple aquifers are typically present. Depth to water is typically shallow. Shallower perched zones commonly overlie low permeability shales and siltstones. Soils are highly variable and reflect the surficial bedrock parent material on gentler slopes. Soils are evaluated as being thin to absent on steeper slopes. Groundwater supplies are typically poor, with yields averaging less than 5 gpm. Recharge is limited due to steep slopes, low permeability soils, vadose zones, and aquifers [12].
- 6E – Limestone
  - Limited to steep valley walls in [redacted]. The limestone usually crops out just above the stream base. The aquifer consists of relatively dense, low-porosity limestone with a relatively low percentage of solution features. The vadose zone consists of limestone or dense, overlying Devonian shale. Depth to water is typically shallow due to the close proximity of streams. Soils are highly variable and are dependent upon the underlying parent material. Slopes are commonly steep. Groundwater supplies are typically poor, with yields averaging less than 5 gpm. Recharge is moderately low due to steep slopes and low permeability vadose zone media and soils [12]
- 6F - Alluvium over bedded sedimentary rock (unglaciated)
  - Widespread and includes most of the tributary valleys throughout the county. Depth to water is usually shallow, averaging less than 30 feet. Thin alluvium, composed primarily of fine-grained overbank sediments, overlies bedrock. Soils are generally silty loams or clay loams derived from the fine-grained alluvium. The alluvial deposits are typically saturated and may be in hydraulic connection with the underlying bedrock. The bedrock aquifers are variable and include limestone, shale, and interbedded shale and sandstone. Groundwater yields an average of less than 5 gpm. Recharge is moderate due to the relatively shallow depth to water, flatter topography, the alluvium's relatively high permeability, and the bedrock's contrasting lower permeability. Recharge is much higher than the surrounding uplands [12].
- 6L - Shale (unglaciated)
  - Limited to steep valley walls in [redacted] The shale occupies the majority of the valley wall. Limestone may crop out at the bottom of the shale or be encountered deeper in the subsurface. A thin, hard layer of Berea Sandstone commonly caps the shale. The aquifer and vadose consist of relatively dense, low-permeability shale. Depth to water is typically shallow. Soils are usually silt loams. Slopes are commonly steep. Groundwater supplies are typically poor, with yields averaging less than 5 gpm. Wells usually obtain water from the uppermost few feet of weathered, broken shale. The remainder of the well depth is available for extra borehole storage. Recharge is low due to steep slopes and low permeability of the shale vadose zone and aquifer media [12]

- 6M - Sandstone (unglaciated)
  - Limited to steep uplands in [redacted]. The sandstone is primarily of the Pennsylvanian Sharon Conglomerate (Sandstone). The area is characterized by high relief with steep slopes and broad, relatively flat ridge tops. The aquifer and vadose consist of relatively dense, massive sandstone. Although the sandstone is moderately coarse-grained, the porosity is somewhat low due to the nature of the cementation. Permeability depends upon fractures, joints, and bedding planes. Depth to water is variable and depends upon the topography at any given area. Soils are variable, with silt loams being the most common. Slopes are commonly steep. Groundwater supplies are typically poor, with yields averaging less than 10 gpm. The sandstone ridges usually are well above drainage and have limited recharge areas. The water levels in these aquifers tend to decline during the summer months. Recharge is low due to steep slopes and greater depth to water [12].
- 6N – Preglacial valley
  - Limited to the [redacted] and is characterized by relatively broad, short valleys. [redacted] The preglacial valleys typically lack modern streams. Depths to water are moderately shallow. Topography is flat to gently sloping. Soils are clay loams. The aquifer consists of thin sand and gravel lenses interbedded with thicker sequences of clayey to silty lacustrine and alluvial deposits. Wells that do not obtain water from these sand and gravel lenses can be drilled deeper and completed in the underlying interbedded sandstone and shale bedrock. Yields are typically less than 5 gpm for bedrock wells and less than 10 gpm for wells completed in the sand and gravel lenses. Recharge is moderately high due to the shallow depth to water, flat topography and the moderate permeability of the sand and gravel lenses [12].
- 7Ae - Glacial till over shale
  - This setting is limited to a small area of [redacted] The setting is characterized by rolling uplands that are less steep than the adjacent unglaciated uplands. The aquifer consists of massive Devonian-age black shale. Groundwater supplies are typically poor, with yields averaging less than 5 gpm. Wells usually obtain water from the uppermost few feet of weathered, broken shale. The remainder of the well depth is available for extra borehole storage. The vadose zone media is comprised of silty Illinoian-age till. The till may be fractured, especially where it is thin and weathered. Soils are derived from the weathering of till and vary from clay loam to silt loam. Recharge is low due to the low permeability of the soils, vadose zone, and aquifer materials [12]
- 7Ba – Outwash
  - This area is limited to a [redacted]. A steep, gravelly terrace characterizes this setting. This terrace is found at the toe of a steeper upland area. The depth of water is relatively shallow. Groundwater is obtained from sand and gravel lenses interbedded with

finer-grained silt and clay. Yields are in the 5 to 25 gpm range. Soils are loams, and slopes are quite steep. Recharge is moderately high due to the relatively permeable soils, vadose zone media, aquifer, and the shallow depth to water [12],

- 7Bc - Outwash over limestone
  - This area is limited to a [redacted] This setting is similar to the [redacted] setting except that the outwash is somewhat thinner and overlies solution limestone instead of interbedded shale and sandstone. The depth to water is shallow. Groundwater is obtained from the limestone that underlies the outwash. Yields are in the 5 to 25 gpm range. The sand and gravel outwash may be in direct hydraulic connection with the underlying limestone. Soils are silt loams, and the topography is flat. Recharge is high due to the flat topography, relatively permeable soils, vadose zone media and aquifer, and the shallow depth to water [12].
- 7Be - Outwash over shale
  - This area is limited to a [redacted] This setting is similar to the [redacted] over Solution Limestone setting, except that the outwash overlies massive shale instead of solution limestone. The depth to water is shallow. Groundwater is obtained from fractured, massive shale that underlies the outwash. Yields are usually less than 10 gpm. The sand and gravel may be in direct hydraulic connection with the underlying shale. Soils are sandy loams, and the topography is flat. Recharge is high due to the flat topography, the relatively permeable soils and vadose zone media, and the shallow depth to water [12].
- 7D - Buried valley
  - This setting was used for the [redacted] This setting is characterized by broad, flat-lying valleys that may or may not contain a modern river. [redacted] Yields from these deposits can range up to 1000 gpm, depending upon whether the deposits are in hydraulic connection with the river. [redacted] is obtained from sand and gravel lenses interbedded with thick sequences of fine-grained alluvial and lacustrine deposits. Wells completed in these lenses have yields ranging up to 50 gpm, with most yields being in the 5 to 25 gpm range. [redacted] These areas have yields usually less than 5 gpm. Soils are highly variable. Depths to water are commonly shallow. Recharge is high in the [redacted] due to the highly permeable vadose and aquifer and proximity of the modern river. Recharge in the [redacted] due to the finer-grained nature of the vadose zone media and aquifer and the [redacted] [12].
- 7F - Glacial lake deposits

- This setting was used for a [redacted] setting for the buried valley immediately to the [redacted], except that the drift is thinner and contains fewer sand lenses. The fine-grained sediments are associated with [redacted] Wells not completed in the thin sand lenses are finished in the underlying bedrock. Yields are commonly less than 10 gpm. Depths vary and tend to become shallower to the south. Soils are variable, and the topography is flat-lying. Recharge is moderate due to the flat topography and moderately permeable vadose zone media and aquifer [12].

[redacted] at TCSC (**Figure 1-21**).

Claimed as PBI

Figure 1-19: Hydrogeologic setting.

Only prominent hydrogeologic settings that occur in Claimed as PBI are indicated in the legend, which would otherwise contain 40 entries. Base map from [15]. Inset figures labeled “a” from [12]. The inset figure labeled “b” from [3]. The yellow star indicates the TCSC site.

Claimed as PBI

[redacted]

Figure 1-20: Deepest USDWs in Ohio [16].

Claimed as PBI [redacted]. The yellow star indicates the TCSC site.

Claimed as PBI [redacted]

Figure 1-21: Elevation contours (in ftMSL) on the base of the deepest USDW [16].
Claimed as PBI [redacted]. The yellow star indicates the TCSC site.

1.2.1.4. Regional Structural Geology

Ohio is a tectonically uneventful state. Unfaulted Paleozoic strata are overlying the Precambrian basement, which is dipping gently towards the southeast (**Figure 1-22**).

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Figure 1-22: Geologic cross-section through Claimed as PBI [redacted]

Claimed as PBI

[redacted]

Figure 1-23: Geologic structures in southern Ohio.

Claimed as PBI [redacted]

Figure 1-24: Lineaments evident on the Claimed as PBI [redacted] **[4].**
The yellow star indicates the TCSC site.

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

Claimed as PBI [redacted]

Figure 1-25. TCSC area of review relative to project elements.

TCSC_AZM = Above-Zone Monitoring wells; TCSC_IZM = In-Zone Monitoring wells. 50YPIP = 50 years post-injection period.

Five injection wells will be located on the injection well pad. The yellow polyline north of the injection well pad in **Figure 1-25** represents the well laterals for TCSC-1 and TCSC-3, which will be completed within the Claimed as P [redacted], respectively. The yellow polyline to the south of the injection well pad represents the well laterals for TCSC-2 and TCSC-4, which will be completed within the Claimed as PBI and Claimed as PBI, respectively. The yellow polyline to the east of the injection well pad represents the well lateral for TCSC-5, which will be completed within the Claimed as PBI.

Figure 1-25 shows the injection wells for which a permit is sought, the applicable AoR and features of interest inside the AoR.

A Top Claimed as PBI depth map is shown in **Figure 1-26**, and geological cross-sections through TCSC are shown in **Figure 1-27** and **Figure 1-28**. The map and cross-sections reveal the following:

- The structure dips gently to the southeast. (Please note that the vertical exaggeration (VE) in the cross-sections is 35 times).
- Apart from the [redacted], all formations have a constant thickness throughout the area of interest.
- There are no faults in the area.

Claimed as PBI

Figure 1-26: Depth map (ftMSL) of the Claimed as PBI **from the TCSC SEM.**

Contour interval is 20 ft. Cross-sections are shown in **Figure 1-27**, **Figure 1-28**, **Figure 1-38** and **Figure 1-39**.

Claimed as PBI

[redacted]

Figure 1-27: W-E cross-section through the TCSC site.

Vertical exaggeration x35. Well projection distance = 5,000 ft. Line of section is shown in **Figure 1-26**.

N

Claimed as PBI

[redacted]

Figure 1-28: N-S cross-section through the TCSC site.

Vertical exaggeration x35. Well projection distance = 5,000 ft. Line of section is shown in **Figure 1-26**.

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

As stated in section **1.2.1.4. Regional Structural Geology** and shown in **Figure 1-23**, TCSC is not affected by known or inferred faults. Claimed as PBI [redacted] of the TCSC site (**Figure 1-24**).

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Figure 1-29: Seismic data availability in south central Ohio.

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

A 50-square-mile Static Earth Model was built from available well logs across the study area. Modeled depths and thickness of the formations making up the GCS complex are shown in **Table 1-6**. Claimed as PBI [redacted] Based on publicly available data, there are no known faults that penetrate the TCSC storage systems within the AoR **(Figure 1-26** through **Figure 1-28)**. Seismic Claimed as PBI [redacted]

Table 1-6: Stratigraphic Table.

Claimed as PBI [redacted]

Estimations of the petrophysical profiles of reservoir and caprock units were derived from well log and core data collected from eight wells across the project area **Figure 1-30**. Well log data was first quality checked and corrected (i.e., unit conversion, borehole effects, matrix) and conditioned (normalization, baseline shifting according to available core data) as needed. A shale (clay) volume model was created for wells using linear gamma ray and neutron-density clay models, with the selected clay volume value being the minimum value.

Claimed as PBI [redacted]

Figure 1-30: Map of structural, petrophysical and cored wells used in geologic modeling.

Claimed as PBI [redacted]. Multimineral models yield estimates of volumetric mineral fractions (%quartz, %calcite and %dolomite) per given depth, which are then used to calculate a depth-specific grain density for subsequent porosity calculations [20].

TCSC reservoir and caprock apparent mineralogy and clay volumes are summarized in **Table 1-7**. The mineral volumes are based on a three-mineral model, and therefore, has uncertainties and limitation. The volume of clay added to the volumetric mineral fractions gives the volumes explained by the multimineral model. The remaining volumes specified within **Table 1-7** are interpreted to be related to unmodelled mineral content and pore volume. The mineral model will be updated upon the collection of additional mineralogy and petrology data, such as X-ray diffraction, thin-sections and elemental spectroscopy logs, after drilling of the next well.

Porosities were calculated using the density porosity model with variable grain density sourced from the mineral model. Average porosities for each given unit are summarized in **Table 1-8**. The spatial distribution of average porosity of the [redacted] are shown in **Figure 1-34**, **Figure 1-35** and **Figure 1-38**.

Table 1-7: Average mineral volumes (%)

[redacted]

To model reservoir and caprock permeability, routine core analysis data was collected and cross-plotted across all geologic units, and porosity-to-permeability trends were identified using various regression methods (**Figure 1-32**, **Figure 1-31**, **Figure 1-33**). Data analysis revealed that permeability and porosity varied as a function of:

1. Depth
2. Lithology, either dolomite or sandstone
3. Shale volume

Therefore, permeability was modeled according to lithology and depth using the equations depicted in **Table 1-9**. The resulting permeabilities are given in **Table 1-8**. A cross-section through the three-dimensional (3D) permeability model is shown in **Figure 1-39**. **Figure 1-36** and **Figure 1-37** show the permeability-height maps of the [redacted], respectively.

[redacted]

Data gaps for the TCSC project will be addressed upon collecting advanced subsurface datasets, as detailed in the **Pre-Operational Testing Program**. Additionally, [redacted]

Table 1-8: Average porosities and permeabilities of reservoirs and confining zones.

Claimed as PBI

[redacted]

Table 1-9: Models used to calculate TCSC permeabilities.

PHIT = total porosity; R^2 = coefficient of determination; n = sample size.

Claimed as PBI

[redacted]

Claimed as PBI [redacted]

Figure 1-31: Poro-perm regressions Claimed as PBI [redacted]

Claimed as PBI [redacted]

Figure 1-32: Poro-permeability for Claimed as PBI [redacted]

Claimed as PBI

[redacted]

Figure 1-33: Poro-perm regressions Claimed as PBI [redacted]

Claimed as PBI

Figure 1-34: Average porosity (ft^3/ft^3) map of the Claimed as PBI **.**

Claimed as PBI [redacted]

Figure 1-35: Average porosity (ft^3/ft^3) map of the Claimed as PBI [redacted]**.**

Claimed as PBI

Figure 1-36: Permeability-height map (mD×ft) of the Claimed as PBI **.**

Claimed as PBI

Figure 1-37: Permeability-height map (mD×ft) of the Claimed as PBI**.**

Claimed as PBI

[redacted]

Figure 1-38: Cross-section through the 3D porosity (ft^3/ft^3) model.

Vertical exaggeration x35. Well projection distance = 5,000 ft. Line of section is shown in **Figure 1-26**.

Claimed as PBI

[redacted]

Figure 1-39: Cross-section through the 3D permeability (mD) model.

Vertical exaggeration x35. Well projection distance = 5,000 ft. Line of section is shown in **Figure 1-26**.

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

Claimed as PBI [redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

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

Sources of data characterizing the seismic history are the Ohio Seismic Network, OhioSeis[2], which went online in 1999, and the historical records of the USGS[3].

Southern Ohio has a low (5-25%) chance of slight damaging natural earthquake shaking [21] (**Figure 1-40**). Claimed as PBI [redacted] have not experienced damaging seismic activity. There is no induced seismic activity in Ohio. There has been one recorded seismic event within the AoR (**Figure 1-41, Table 1-10**). The magnitude two event occurred in 2014 at a depth of five kilometers. There have been no further signs of seismic activity in the AoR.

Interestingly, the seismicity in the area cannot be related to any known fault systems (**Figure 1-41**). Seismic data will be acquired over the AoR to better define the subsurface structure.

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[2] https://ohiodnr.gov/discover-and-learn/safety-conservation/about-odnr/geologic-survey/division-of-geologic-survey/ohio-seis

[3] https://www.usgs.gov/programs/earthquake-hazards/earthquakes

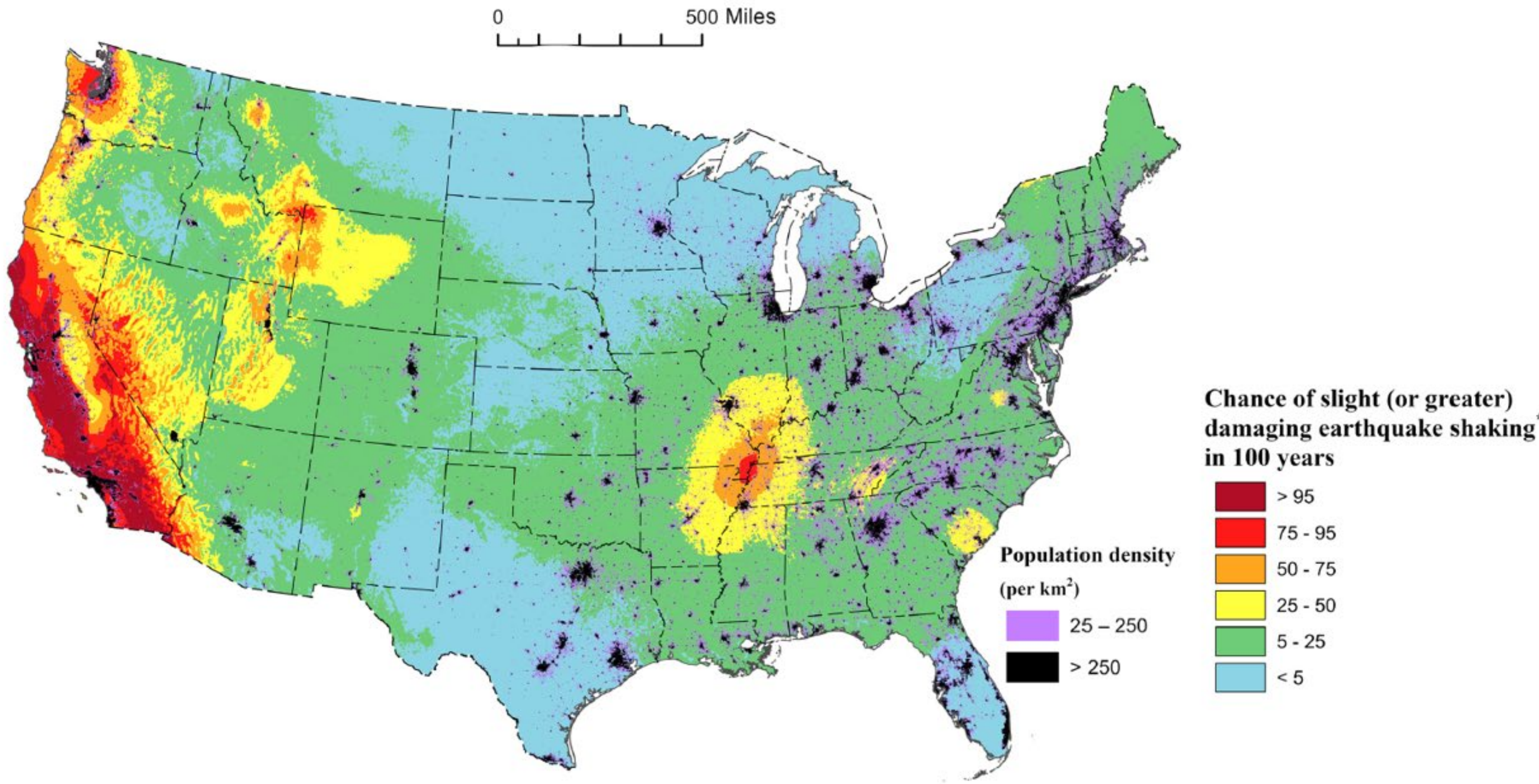

Figure 1-40: Map showing the chance of any level of damaging earthquake shaking in 100 years [21].

* Equivalent to Modified Mercali Intensity VI, identified as: "Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight."

Claimed as PBI

[redacted]

Figure 1-41. Year, depth, and magnitude of past seismic events in southern Ohio.

Table 1-10: Seismic events in southern Ohio, as shown in Figure 1-41.
The bolded text event was within the AoR.

Year	Magnitude	Depth (km)	County	Latitude	Longitude
Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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

Regional hydrogeologic maps (**Figure 1-16** through **Figure 1-21**) are provided in section **1.2.1.3. Regional Hydrogeology**. A more detailed description of the hydrology of the TCSC is given here.

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

[redacted]

Claimed as PBI [redacted]

Figure 1-43: Stratigraphic profile of the unconsolidated and consolidated geologic u Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI

[redacted]

Figure 1-44: Claimed as PBI [redacted]

Claimed as PBI [redacted]

Figure 1-45: Claimed as PBI [redacted]

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

1.2.8.1. Fluid Phase Geochemistry

The USGS Produced Waters Database was queried for available pore-fluid data throughout the Claimed as PBI [redacted] to determine the baseline fluid-phase geochemistry in the AoR [25]. There are two wells within the AoR with available geochemical data for the prospective storage reservoirs **(Table 1-12, Figure 1-46)**.

Claimed as PBI [redacted] Previous studies and historical data provide regional geochemical trends for fluid-phase data. Deep formation fluids are brines with high Total Dissolved Solids (TDS) values; values increase with depth to TDS values above 300,000 ppm [23]. These brines contain chloride, calcium, sodium, magnesium, and potassium at concentrations above 1,000 mg/l and aluminum, barium, bromide, iron, and sulfate at below 1000 mg/l. Fluid density typically vary between 1.010 to 1.250 g/cm^3 [23].

Claimed as PBI [redacted]

Additional fluid-phase geochemical data will be collected as a part of the **Pre-Operational Testing Program** to bridge the gap in site-specific data**.** Fluid samples will be collected from the storage zone reservoirs and hydrogeologic units. The fluid-phase geochemical data indicates that the storage reservoirs are saturated with saline brines and that all reservoirs are likely elevated above 140,000 ppm Total Dissolved Solids (TDS). The fluid-phase geochemical data does not suggest any adverse reactions will occur and that the storage reservoir pore fluids are compatible with the CO_2 injectate.

Claimed as PBI

[redacted]

Figure 1-46: Wells with geochemical data.

Table 1-11. Claimed as PBI [redacted]

TDS = Total Dissolved Solids. ND = Not Detected. All units are in mg/l unless otherwise specified. NR = Not Recorded.

Formation	Depth (ft)	Well API	Date	Density	Alkalinity	Ca	Mg	Na	Ba	Sulfate	Chloride	Silica	Total Iron	Al	K	Br	CO2	TDS

Claimed as PBI [redacted]

Table 1-12. USGS data within TCSC's AoR [26].

Temperature in deg F; SG = Specific Gravity; All other units mg/l. NR = Not Recorded.

API	FORMATION	TDS	SG	PH	TEMP	Br	Ca	Cl	I	K	Mg	Na

Claimed as PBI [redacted]

1.2.8.2. Solid Phase Geochemistry

The mineralogy of TCSC formations has been discussed earlier and is shown in **Table 1-7**. Claimed as PBI [redacted]

Additional mineralogical and geochemical data for the storage zone reservoirs will be acquired through wireline logging, coring, and fluid sampling as discussed in the **Pre-Operational Testing Program**.

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

TCSC does not plan to collect surface air and/or soil gas data at the proposed storage site.

1.3. SITE SUITABILITY [40 CFR 146.83]

There are two primary injection zones at TCSC, the Claimed as PBI [redacted] and the Claimed as PBI [redacted]. Each injection zone has its own primary seal, the Claimed as PBI [redacted] and the Claimed as PBI [redacted], respectively, and are ultimately capped by the Claimed as PBI [redacted] (**Figure 1-3** and **Figure 1-4**). All formations are present across the project area and are unfaulted.

1.4. AOR AND CORRECTIVE ACTION [ENTER CFR]

The information and files submitted in the **AoR and Corrective Action Plan** satisfy the requirements of 40 CFR 146.84(b). This plan addresses the details of computational modeling to delineate AoR, corrective action in the AoR, and triggers for AoR re-evaluation. The AoR is created to encompass the entire region surrounding TCSC where USDWs may be endangered by injection activity. The AoR is delineated by the lateral and vertical migration extent of the CO_2 plume, formation fluids and pressure front in the subsurface. A computational model was built to predict the lateral and vertical movement of CO_2 injected into the Claimed as PBI [redacted] formations at TCSC. The computational model incorporates physical flow and trapping processes associated with CO_2 injection into subsurface reservoirs. Computer Modeling Group's General Equation of State Model, widely known as GEM, was used as the simulator. A multi-component and multi-phase fluid flow process was employed to assess the development of the CO_2 plume, the pressure front, and the long-term fate of the injection.

The delineated AoR is shown in. This is usually the largest of either the CO_2 plume at 50 years post-injection period or the elevated pressure front during the injection phase. The threshold pressure calculations methods recommended by U.S. EPA was used for both formations. The Claimed as PBI [redacted] had the largest lateral extent of the threshold pressure size and thus defines TCSC AoR. The geologic model is calibrated to the petrophysical data obtained from eight wells within the TCSC SEM extent, **Figure 1-30**. The reservoir architecture and petrophysical properties will be updated as necessary upon importing geophysical logs from drilled project wells. Details of the computational modelling, assumptions that are made, and the site characterization data that the model is based on satisfies the requirements of 40 CFR 146.84(c).

Claimed as PBI

[redacted]

Figure 1-47. Area of Review for TCSC and CO_2 plume extent 50 years after injection are shown. (YPIP = years post-injection phase)

1.5. FINANCIAL RESPONSIBILITY

Pursuant to 40 CFR 146.85, TCSC has prepared this **Financial Responsibility** (FR) document which describes the cost of covering corrective action, emergency response, post-injection monitoring, injection well conversion, and site closure activities that will be conducted as part of TCSC. Injection well plugging and costs are estimated according to the *Injection Well Plugging Plan* and PISC and site closure costs are presented to reflect a Claimed as PBI [redacted] PISC period. The Emergency and Remedial Response costs cover one (1) unmitigated leakage event throughout the project life.

The Financial Responsibility document also describes TCSC's approach to securing the adequate and appropriate financial instruments required to cover the expenses. The approach to financial responsibility is broken into two phases – each phase detailing the associated FR costs and timing for pre-injection (Phase I) and injection/post-injection (Phase II).

[redacted]

TCSC will work with the provider to ensure that U.S. EPA Region 05 has authority to notify the trustee of the need for payments from the fund to cover costs of activities covered under the agreement in accordance with 40 CFR 146.85(a)(6)(iii). Information on third-party carrier financial strength and commitment to covering the cost of each phase will be provided prior each phases instrument review by the EPA. For more details, refer directly to the *Financial Responsibility* document where the financial instrument(s) are outlined, and costs are presented in more detail.

1.6. INJECTION WELL CONSTRUCTION

Trillium plans to drill and construct five new Class VI carbon dioxide (CO_2) injection wells as a part of the Trillium Carbon Storage Complex (TCSC), pursuant to 40 CFR 146.86. The CO_2 injection wells (TCSC-[1-5]) will be designed pursuant to 40 CFR 146.86(a) to (1) prevent the movement of fluids into or between underground sources of drinking water (USDW) or into any unauthorized zones, (2) permit the use of appropriate testing devices and workover tools, and (3) permit continuous monitoring of the annulus space between the injection tubing and long string casing. Additionally, pursuant to 40 CFR 146.86(b) and (c), materials used for well construction (e.g., wellhead, casing, cement, tubing, packers) will have sufficient structural strength for CO_2 injection operations and be compatible with the fluids they are expected to encounter.

1.6.1. Proposed [redacted] Program [40 CFR 146.82(a)(9)]

[redacted]

1.6.2. Construction Procedures [40 CFR 146.82(a)(12)]

The five injection wells are designed to accommodate the maximum instantaneous mass rate that is expected from the capture facility while considering critical characteristics of the CO_2 storage reservoir. This mass rate is approximately [redacted] MMtpa of CO_2. This section highlights the key components of the injection well design at the TCSC. Please see the **Injection Well Construction Plans** included with this application for further details on the design and construction of the injection wells.

Well design principles and materials detailed in subsequent sections were selected and vetted to ensure construction materials have sufficient structural strength to provide sustained mechanical integrity throughout the life of the CCS project in addition to permitting the use of appropriate testing devices, workover tools and continuous monitoring of the annulus space between the injection tubing and long string casing. All well construction materials were selected to be compatible with fluids of which they may be expected to come into contact (e.g., corrosion-resistant cement) and meet or exceed API and ASTM International standards. This summary and the Injection Well Construction Plan illustrates the comprehensive analysis performed to comply with and exceed the standards detailed in 40 CFR §146.86 and other related sections (§146.87, 146.88, 146.89, 146.90, 146.94 (a), 146.91), in pursuant to 40 CFR § 146.82 regarding the design of the injection well casing, cement, and wellhead and their relation to subsequent testing, monitoring, and reporting activities.

The construction of the TCSC injection wells will be performed using best practices and will conform to all requirements of Class VI Rule VI at 40 CFR 146.86(b). [redacted]. The surface casing for all wells will be set to approximately [redacted] ft from surface and will be cemented to surface to protect drinking water. The intermediate sections will be set at various depths (**Table 1-13)** to protect the lowermost USDW. The long string [redacted] will be set at various depths with the [redacted]. See **Figure 1-48** to **Figure 1-52** for schematics of TCSC-1 to TCSC-5, respectively.

The targeted injection formations will be tested prior to final completion using step-rate testing and pressure fall-off testing. These tests will confirm that the proposed injection zone will be able to receive the required volume of CO_2 while injection pressures will stay below 90% of the fracturing pressure per 40 CFR 146.88(a). The injection tubing will be of [redacted] material based on modeling) and will be sized to accommodate the expected injection rate. The size of the wellbore will allow monitoring equipment to be placed in the wellbore so that injection and annular pressure can be monitored. The tubing will also be sized such that surveillance logging can be accommodated. More details of the well construction methods and materials will be found in the following sections.

1.6.2.1. Casing and Cementing

The TCSC injection wells will be constructed with casing and cement that will be compatible with the injected CO_2 and formation brine chemistry. A [redacted] or similar casing will be used across the injection zones and caprocks. Cement across these sections will be CO_2 resistant. The overall well design was developed to accommodate [redacted] outer diameter (OD) tubing string, based on nodal analysis results. Please see section 4.6 of the **Well Construction Plan** for the details on the nodal analysis results. The design implemented concentric casing sizes required to isolate the injection reservoir from USDWs and prevent fluid flow into any unauthorized zones. In accordance with 40 CFR §146.87, prior to running each casing string, all open-hole logging and testing operations (deviation surveys, open hole logging, and formation testing) will be completed. Please see section 5.2 of the **Pre-Operational Testing Program** of the permit for a detailed breakdown of which specific methods and tools will be utilized for these wells.

The wells will consist of a [redacted]-diameter conductor casing string set at a depth of approximately [redacted] below ground surface (BGS) inside a [redacted] borehole; a 1[redacted] inch diameter surface casing string set at a depth of approximately [redacted] feet BGS inside a [redacted]-inch borehole; a [redacted] inch diameter intermediate casing string set at various depths (**Table 1-13**) to protect the lowermost USDW; a [redacted]) casing set at various depths inside a [redacted]; and a [redacted] diameter (injection) tubing string set at approximately [redacted] feet but no more than [redacted] feet above the target perforation interval.

Material	Setting Depth Interval (ft MD)	Tensile Strength (ksi)	Burst Strength (psi)	Collapse Strength (psi)	Material (e.g., weight/grade/ connection)
	1) TCSC-1 2) TCSC-2	*3) TCSC-3*	*4) TCSC-4*	*5) TCSC-5*	
Tubing	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Casing loadings and stress were modeled using SLB's Tubing Design and Analysis (TDAS) software to ensure sufficient structural strength and mechanical integrity throughout the life of the TCSC project. Stresses were analyzed and calculated according to the worst-case scenarios and tubular specifications were selected accordingly. Further information on the analysis of the selected casing is available in Section 4.5 of the **Well Construction Plans**. All casing strings will be cemented to the surface using staged cement jobs as needed. The borehole diameters are considered conventional sizes for the sizes of casing that will be used and should allow ample clearance between the outside of the casing and the borehole wall to ensure that a continuous cement seal can be emplaced along the entire length of the casing string.

The conductor, surface casing, intermediate, and long-string casing will be cemented to surface in accordance with requirements at 40 CFR 146.86(b)(3). The proposed cement types and quantities for each casing string are summarized in section 4.7 of the **Well Construction Plan**. The final blends and quantities will be determined through discussions with cement vendors. The final volumes will be determined through caliper logs. These will be provided to the U.S. EPA Region 05 UIC Program Director prior to injection well construction. Casing centralizers will be used on all casing strings to centralize the casing in the hole and ensure that cement completely surrounds the casing along the entire length of pipe. The long-string casing will be cemented to the surface using a two-stage cement job. The transition from stage one to stage two will be targeted at an approximate depth of [redacted] feet above the caprock. Cement-bond logs will be run and analyzed for each casing string.

Table 1-13. Casing details.

Casing String	Casing Depth Interval (ft MD)	Borehole Diameter (in)	Wall Thickness (in)	External Diameter (in)	Casing Material (e.g., weight/grade[A]/ connection)
	1) TCSC-1 2) TCSC-2 3) TCSC-3 4) TCSC-4 5) TCSC-5				
Conductor	[redacted]	[redacted]	[redacted]	[redacted]	Claimed as PBI [redacted]
Surface	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Intermediate	1) 0-2,790 Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Long String Claimed as PBI [redacted]	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Long String Claimed as PBI [redacted]	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted] Claimed as PBI [redacted]

1.6.2.2. Tubing and Packer

The tubing connects the injection zone to the wellhead, providing a pathway for safely injecting and storing CO_2. In accordance with 40 CFR § 146.86 (c), the tubing and packer material used for the construction of Trillium's injection wells will be compatible with the fluids with which the material may be expected to come into contact with. The packer and tubing were selected to be a minimum of Claimed as PBI [redacted] similar material. The packer will be set to a depth opposite a cemented interval. Any change to the tubing and packer specifics detailed below will be communicated to the Region 05 UIC Program Director.

The TCSC injection wells will utilize Claimed as PBI [redacted] tubing, which will resist corrosion from the injectate. The packer system will be equivalent to a Claimed as PBI [redacted] (or equivalent). The packer will be connected to a Claimed as PBI [redacted] or equivalent to allow for easy workover operations. Both the packer and locator seal assembly will feature Claimed as PBI [redacted] to be compatible with expected reservoir fluids. The annulus between the tubing and long-string casing will be filled with noncorrosive fluid in accordance with 40 CFR 146.88(c). **Table 1-14**

Material	Setting Depth Interval (ft MD)	Tensile Strength (ksi)	Burst Strength (psi)	Collapse Strength (psi)	Material (e.g., weight/grade/ connection)
	1) TCSC-1 2) TCSC-2 3) TCSC-3 4) TCSC-4 5) TCSC-5				

Tubing	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Claimed as PBI [redacted]	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]

provides tubing and packer details for all injection wells. See section 4.8 of the **Well Construction Plan** for details on the annular fluid program.

Table 1-14. Tubing and Packer details

Material	Setting Depth Interval (ft MD)	Tensile Strength (ksi)	Burst Strength (psi)	Collapse Strength (psi)	Material (e.g., weight/grade/ connection)
1) TCSC-1 2) TCSC-2 3) TCSC-3 4) TCSC-4 5) TCSC-5					
Tubing	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Claimed as PBI [redacted]	Claimed as PBI [redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted] Claimed as PBI [redacted]

Claimed as PBI

[redacted]

Figure 1-48. Design schematic of the TCSC-1 injection well.

Claimed as PBI

[redacted]

Figure 1-49. Design schematic of the TCSC-2 injection well.

Claimed as PBI

[redacted]

Figure 1-50. Design schematic of the TCSC-3 injection well.

Claimed as PBI

[redacted]

Figure 1-51. Design schematic of the TCSC-4 injection well.

Claimed as PBI

[redacted]

Figure 1-52. Design schematic of the TCSC-5 injection well.

1.7. PRE-OPERATIONAL LOGGING AND TESTING

The **Pre-Operational Testing Program** has been designed to obtain the physical and chemical characteristics of the TCSC confining and storage reservoir zones prior to CO_2 injection pursuant to 40 CFR 146.87. Pre-operational testing will demonstrate compliance with the injection well construction requirements under 40 CFR 146.86 and inform subsequent injection and post-injection phase testing and monitoring activities. The testing plan includes a combination of well logging and geophysical surveying, mechanical integrity testing, geologic coring, fluid sampling, formation testing, and hydrogeological testing. These methods will generate datasets to aid in determining and/or verifying the depth, thickness, porosity, permeability, mineralogy, and geochemical profiles of the caprocks (i.e., Claimed as PBI [redacted]) and storage reservoirs (i.e., Claimed as PBI [redacted]). Data will also be collected from the first permeable zone above the caprock (i.e., Claimed as PBI [redacted]) to establish a baseline description of the geology, geochemistry, and groundwater quality of the above confining zone, pursuant to 40 CFR 146.82(a)(6), to inform injection and post-injection phase above-zone monitoring required by 40 CFR 146.90(d); testing and monitoring of the first permeable zone is a preventative measure in place to protect USDWs as it will allow for early detection of any out of zone CO_2 and/or reservoir fluids prior to them reaching shallow groundwater sources in the unlikely event there is loss of containment from the storage complex. For detailed information on the pre-injection testing activities, please refer to the **Pre-Operational Testing Program**.

Trillium will provide the EPA Region 05 UIC Program Director with the opportunity to witness all logging and testing along with a schedule of the injection well logging and testing activities 30 days prior to their commencement. The UIC Program Director will be promptly notified of any updates to the testing and logging schedule upon finalization. Results of proposed testing activities discussed throughout the **Pre-Operational Testing Program** will be summarized in a report and submitted to the UIC Program Director.

1.8. WELL OPERATIONS

1.8.1. Operational Procedures [40 CFR 146.82(a)(10)]

The injection wells will be constructed as shown in the **Injection Well Construction Plans**. Injection in TCSC-1 and TCSC-2 will be facilitated through tubing set in the long-string casing in a packer before the perforations in the Claimed as PBI [redacted] formation. Injection in TCSC-3, TCSC-4, and TCSC-5 will be facilitated through tubing set in the long-string casing in a packer before the perforations in the Claimed as PBI [redacted] formation. Operational values for each injection well detailed in **Tables 6-[1-5]** in the **Well Operations Program** were obtained by using PipeSIM to conduct the nodal analysis presented in the Injection Well Construction Plan. The nodal analysis was used to determine the range of possible injection rates. Using the analysis an average injection rate of Claimed as PBI [redacted] TCSC-1, TCSC-2, TCSC-3, TCSC-4, and TCSC-5, respectively. Also, a Claimed as PBI [redacted] of CO_2 for TCSC-1, TCSC-2, TCSC-3, TCSC-4, and TCSC-5, respectively, to meet project requirements. The total annual injection rate for the project will be [redacted] MMtpa of CO_2. The expected wellhead pressures during injection operations will likely be between [redacted] TCSC-1, TCSC-2, TCSC-3, TCSC-4, and TCSC-5, respectively. Operational parameters are expected to remain constant throughout the duration of the injection period.

Each injection well will be monitored to ensure safe operations. Safety monitoring includes monitoring the injection pressure at the wellhead and bottomhole, monitoring the pressurized annulus, continuous fiberoptic temperature monitoring along the well or equivalent, and corrosion coupon monitoring to identify corrosion. Each system is fully described in the ***Testing and Monitoring Plan Section 7.2.2***.

Each injection well will have a wellhead pressure gauge and data logger, both tied into the injection control system and set to trigger an alarm at the project control room and shut down injection in the well if the MASP is reached. Injection parameters including pressure, rate, volume and/or mass, and temperature of the CO_2 stream will be continuously measured and recorded. The pressure and fluid volume of the annulus between the tubing and long-string casing will also be continuously measured. All automatic shutdowns will be investigated prior to bringing injection activities back online in the well to ensure that that no integrity issues were the cause of the shutdown. If an un-remedied shutdown is triggered or a loss of mechanical integrity is discovered, Trillium will immediately investigate and identify as expeditiously as possible the cause of the shutdown. If, upon such investigation, the well appears to be lacking mechanical integrity, or if monitoring indicates that the well may be lacking mechanical integrity, Trillium will:

(1) Immediately cease injection in the affected well and in any other wells that may exacerbate the leakage risk of the affected well

(2) Take all steps reasonably necessary to determine whether there may have been a release of the injected CO_2 stream or formation fluids into any unauthorized zone

(3) Notify the Director in writing within 24 hours

(4) Restore and demonstrate mechanical integrity prior to resuming injection

(5) Notify the Director when injection can be expected to resume

The annular space between the tubing and long string casing of each injection well will be pressurized with a non-corrosive fluid. The annulus will be monitored continuously to ensure integrity of the well. The annulus will be filled with a [redacted] and [redacted] pounds per gallon (ppg) sodium chloride brine with a corrosion inhibitor and oxygen scavenger additives. The minimum pressure held on the annulus at the wellhead will be [redacted] psia, including times of shut-in. Additional pressure may be required on the annulus; if this is the case, the value will be set in conjunction with US EPA Region 05.

The fiberoptic line cemented into the annulus on the outside of the long-string casing will be used to continuously monitor temperature along the length of the casing. Rapid temperature changes or other excursions from a normal operating temperature profile will be investigated to ensure that there has been no breach of wellbore integrity.

Additional injection well operations information can be found in the **Well Operations Program**.

1.8.2. Proposed Carbon Dioxide Stream [40 CFR 146.82(a)(7)(iii) and (iv)]

Claimed as PBI [redacted]

The CO_2 will come into the site meeting the specifications presented in the **Testing and Monitoring Plan**. The CO_2 will enter a header and be piped to each injection well. Each well will inject continuously. The wells will be connected to the source that has a maximum pressure of [redacted] psi, so no pumps will be needed to maintain injection pressure. Claimed as PBI [redacted]

Table 1-15 below displays the anticipated chemical composition of the CO_2 stream. Claimed as PBI [redacted]

Table 1-15 below displays the physical and chemical composition of the two anticipated CO_2 streams.

Table 1-15. Summary of the expected physical and chemical characteristics of the CO_2 injectate stream at TCSC.

Parameter[A]	Expected Value	Unit
Physical Characteristics		
Pressure[B]	[redacted]	psi
Temperature[C]	[redacted]	°F
Chemical Characteristics		
Claimed as PBI [redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[A]This list is subject to change based on source injectate stream composition results.

[B]Represents pressure at the CO_2 outlet. Injectate pressure will be adjusted accordingly to meet desired injection rate.

[C]Represents the temperature the injectate stream will be Claimed as PBI [redacted].

1.9. TESTING AND MONITORING PLAN

The **Testing and Monitoring Plan** describes how Trillium will monitor the TCSC site, pursuant to 40 CFR 146.90, for the duration of the project's injection phase of [redacted]. The **Testing and Monitoring Plan** has been designed to ensure that TCSC is operating as permitted and to ensure the injected CO_2 and/or storage reservoir fluids do not become a contamination risk to USDWs. The plan includes:

- CO_2 stream analysis (40 CFR 146.90(a)).
- Continuous recording of operational parameters (40 CFR 146.90(b)).
- Corrosion monitoring (40 CFR 146.90(c)).
- Groundwater quality and geochemical monitoring above the confining zone (40 CFR 146.90(d)).
- Mechanical integrity testing (40 CFR 146.90(e)).
- Pressure fall-off testing (40 CFR 146.90(f)).
- CO_2 plume and pressure front tracking (40 CFR 146.90(g)).

13 wells are proposed to be drilled across the TCSC site including five CO_2 injection wells (TCSC-1, TCSC-2, TCSC-3, TCSC-4, TCSC-5), three in-zone monitoring wells (TCSC_IZM-1, TCSC_IZM-2, TCSC_IZM-3), and five above-zone monitoring wells (TCSC_AZM-1, TCSC_AZM-2, TCSC_AZM-3, TCSC_AZM-4, TCSC_AZM-5). All five injection wells are proposed to be located on one well pad. Injection wells TCSC-1 and TCSC-2 will be completed within the [redacted] (i.e., storage reservoir) whereas injection wells TCSC-3, TCSC-4, and TCSC-5 will be completed within the [redacted] (i.e., storage reservoir). Testing and monitoring activities including mechanical integrity testing, corrosion monitoring, pressure fall-off testing, and continuous recording of operational parameters (i.e., injection rate, volume, temperature, and pressure) will be performed in each CO_2 injection well or on their shared well pad. The three in-zone monitoring wells are proposed to be located along the modeled maximum extent of the CO_2 plume and within the AoR to allow for direct pressure front tracking and CO_2 plume verification. In-zone monitoring wells are proposed to be dual-zone completed and will be capable of monitoring both the [redacted] and [redacted] storage reservoirs. In addition to CO_2 plume and pressure front tracking via in-zone wells, repeat surface seismic or equivalent will be utilized to indirectly image the CO_2 plume across the TCSC site throughout time. The five above-zone monitoring wells are proposed to be completed within the [redacted] (i.e., first permeable zone above the caprock) and will be located in [redacted]. Monitoring the first permeable zone above the caprock is a preventative measure in place that is best suited to detect any out of zone CO_2 and/or reservoir fluids prior to them reaching overlying USDWs in the unlikely event there is loss of containment from the storage complex.

The **Testing and Monitoring Plan** will be reviewed at a minimum of once every five years pursuant to 40 CFR 146.90(j). The plan will be adjusted accordingly to meet any changes to the facility or site conditions over time. All amended plans will be sent to the Region 05 UIC Program Director for approval as outlined in the permit modification requirements under 40 CFR 144.39 and 144.41. Results of activities described throughout this **Testing and Monitoring Plan** may trigger action according to the **Emergency and Remedial Response Plan** (**ERRP**).

For detailed information on the TCSC testing and monitoring activities, please refer to the **Testing and Monitoring Plan**.

1.10. INJECTION WELL PLUGGING

Prior to plugging the injection wells, mechanical integrity will be demonstrated to ensure no pathway has been established between the injection zone and the USDWs or ground surface according to 40 CFR 146.82(a)(16) and 40 CFR 146.92(b).

After the [redacted] injection period, the TCSC-2 and TCSC-3 will be converted to monitoring wells to ensure containment of the CO_2 in each injection zone. Prior to plugging the injection wells, bottom hole measurements will be taken from downhole gauges to determine bottomhole reservoir pressure and necessary fluid density to kill the well. Subsequently, the well will then be flushed with a brine fluid with sufficient kill weight [40 CFR §146.92]. The mechanical integrity of the wells will be determined to ensure no communication has been established between the injection zone and the USDWs or ground surface (per 40 CFR § 146.92). All casing in the wells will be cemented to the surface during construction [40 CFR §146.86] and will not be retrievable at abandonment.

Upon permanent cessation of well operations, including completion of post-injection monitoring, the tubing and packer will be removed. After removal of the tubing and packer, the balanced-plug placement method will be used to plug the well. If, after flushing, the tubing and packer cannot be released, an electric line with tubing cutter will be used to cut off the tubing above the packer and the packer will be left in the well, and the cement retainer method will be used for plugging the injection formation below the abandoned packer. After removal of the tubing and packer, the balanced-plug placement method will be used to plug the well. If, after flushing, the tubing and packer cannot be released, an electric line with tubing cutter will be used to cut off the tubing above the packer and the packer will be left in the well, and the cement retainer method will be used for plugging the injection formation below the abandoned packer. All the casing strings will be cut off at least 3 feet below the surface, below the plow line. A blanking plate with the required permit information will be welded to the top of the cutoff casing. All surface features associated with the plugged well and well-pad will be removed. A plugging report will be submitted within 60 days after plugging operations are completed to the U.S EPA Region 05 UIC Director [40 CFR §146.92].

For more specific information on well plugging procedures, please refer to the **Injection Well Plugging Plan.**

1.11. POST-INJECTION SITE CARE (PISC) AND SITE CLOSURE

The **Post-Injection Site Care (PISC) and Site Closure Plan** describes the activities to be performed to meet the requirements of 40 CFR 146.93. The purpose of this plan is to demonstrate there is no USDW endangerment throughout the post-injection phase up to site closure (PISC begins upon injection cessation and ends with site closure) of the TCSC. Additionally, this plan provides an overview of the activities to be performed in order to properly close the Class VI geologic storage site. The **Post-Injection Site Care and Site Closure Plan** covers:

1. Pre- and post-injection pressure differential (40 CFR 146.93(a)(2)(i)).
2. Predicted position of the free-phase carbon dioxide (CO_2) plume and associated pressure front (40 CFR 146.93(a)(2)(ii)).
3. Post-injection monitoring plan (40 CFR 146.93(a)(2)(iii) and (iv), 146.93(b)).
4. Alternative PISC timeframe (40 CFR 146.93(a)(2)(iv) and (v), 40 CFR 146.93(c)).
5. Non-endangerment demonstration criteria (40 CFR 146.93(b)).
6. Site closure plan (40 CFR 146.93(d) through (h)).

A computational model was built to predict the lateral and vertical movement of CO_2 injected into the [redacted] storage reservoirs at TCSC. The computational model incorporates physical flow and trapping processes associated with CO_2 injection into subsurface reservoirs. Computer Modeling Group's General Equation of State Model, widely known as GEM, was used as the simulator. A multi-component and multi-phase fluid flow process was employed to assess the development of the CO_2 plume, the pressure front, and the long-term fate of the injectate. Based on the current post-injection phase modeling results, which are discussed in detail throughout the **Post-Injection Site Care and Site Closure Plan**, a [redacted] timeframe is proposed.

In addition to modeling exercises, various post-injection monitoring activities will be performed to demonstrate the position of the CO_2 plume and pressure front are not endangering USDWs. Post-injection phase monitoring includes (1) external mechanical integrity testing, (2) groundwater quality and geochemical monitoring, and (3) CO_2 plume and pressure front tracking. External mechanical integrity testing in each CO_2 injection well prior to their plugging and abandonment will verify the absence of fluid leakage through channels adjacent to the wellbore or long-string casing. Monitoring the groundwater quality and geochemistry of the first permeable zone (i.e., Claimed as PBI) is a preventative measure best suited to detect out of zone CO_2 and/or reservoir fluids prior to them reaching overlying USDWs in the unlikely event there is loss of containment from the storage complex. Lastly, CO_2 plume and pressure front monitoring will verify the injectate and associated pressure front are migrating throughout the storage complex as anticipated.

Once CO_2 plume and pressure front stabilization and USDW non-endangerment are demonstrated, the EPA Region 05 UIC Program Director will be provided with a notice of intent for site closure pursuant to 40 CFR 146.93(d). Upon the approval of site closure by the UIC Program Director, all remaining project wells used for monitoring (i.e., TCSC-2, TCSC-3, TCSC_IZM-(1-3)), and TCSC_AZM-(1-5)) will be plugged pursuant to 40 CFR 146.92, 146.93(e), and/or state regulations, the project site will be restored to a condition agreed upon with the Program Director, and a site closure report, pursuant to 40 CFR 146.93(f), will be submitted along with any other required documentation.

Please refer to the **Post-Injection Site Care and Site Closure Plan** for detailed information on the post-injection phase modeling, monitoring activities, and site closure procedures.

1.12. EMERGENCY AND REMEDIAL RESPONSE

The **Emergency and Remedial Response Plan (ERRP)** details actions that Trillium shall take to address the movement of the injection fluid or formation fluid in a manner that may endanger a USDW during the construction, operation, or post-injection site care periods, pursuant to 40 CFR 146.82(a)(19) and 146.94(a).

Claimed as PBI [redacted]

[redacted]

In the case of an emergency, site personnel, project personnel, and local authorities will be relied upon to implement this ERRP.

Trillium will communicate to the public about any event that requires an emergency response to ensure that the public understands what happened and whether there are any environmental or safety implications. This will include a detailed description of the event, any impacts to the environment or other local resources, how the event was investigated, what actions were taken, and the status of the remediation. The ERRP will be reviewed at least once every five years following its approval, within one year of an AoR reevaluation, within the timeframe indicated by the Region 05 UIC Program Director following any significant changes to the injection process or the injection facility, or an emergency event, or as required by the permitting agency. Periodic training will be provided to well operators, plant safety and environmental personnel, the plant manager, the plant superintendent, and corporate communications to ensure that the responsible personnel have been trained and possess the required skills to perform their relevant emergency response activities described in the ERRP.

1.13. INJECTION DEPTH WAIVER AND AQUIFER EXEMPTION EXPANSION

None requested.

1.14. OTHER INFORMATION

None.

1.15. REFERENCES

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

[4] C.J. Perry, M.S. Erenpreiss, T.E. Leftwich, R.A. Riley, G.A. Schumacher, M.P. Solis and M.E. Wolfe. Conducting research to better define the sequestration Options in Eastern Ohio and the Appalachian Basin. Ohio Department of Natural Resources, Division of Geological Survey, Open File Report 2013-2, 2022.

[5] L.H. Wickstrom, E.R. Venteris, J.A. Harper, J. McDonald, E.R. Slucher, K.M. Carter, S.F. Greb, J.G. Wells, W.B. Harrison III, B.C. Nuttall and others. Characterization of geologic sequestration opportunities in the MRCSP region. Ohio Department of Natural Resources, Division of Geological Survey, OFR 2005-1, 2010.

[6] Battelle. CO2 storage resources and containment assessment in Cambrian and Ordovician Formations eastern Ohio – Final summary report. Battelle project # 100034452, 2018.

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

[redacted]

[redacted]

Claimed as PBI [redacted]

Claimed as PBI [redacted]

[redacted]

[15] Ohio Department of Natural Resources, Division of Geological Survey. Ohio Geology Interactive Map. https://gis.ohiodnr.gov/website/dgs/geologyviewer/.

[16] R.A. Riley. Elevation contours on the base of the deepest underground sources of drinking water in Ohio. Ohio Department of Natural Resources, Division of Geological Survey, Map EG-6, scale 1:500,000, 2012.

[17] H.P. Woodward, H.P. Preliminary subsurface study of southeastern Appalachian Interior Plateau. Bulletin of the American Association of Petroleum Geologists, v. 45, no. 10, pp. 1634–1655, 1961.

Claimed as PBI [redacted]

[19] R.T. Ryder, R.D. Crangle Jr., M.H. Trippi, C.S. Swezey, E.E. Lentz, E.L. Rowan, and R.S. Hope. Geologic cross-section D-D' through the Appalachian Basin from the Findlay Arch, Sandusky County, Ohio, to the Valley and Ridge Province, Hardy County, West Virginia. U.S. Geological Survey. Scientific Investigations Map 3067, 2009.

[20] M. Kennedy. Practical Petrophysics. Amsterdam: Elsevier, Amsterdam, 2015

[21] M.D. Petersen, A.M. Shumway, P.M. Powers, E.H. Field, M.P. Moschetti, K.S. Jaiswal, K.R. Milner, S. Rezaeian, A.D. Frankel, A.L. Llenos and others. The 2023 US 50-State National Seismic Hazard Model: Overview and implications. Earthquake Spectro, Vol. 40, No. 1, pp. 5-88, 2024.

Claimed as PBI [redacted]

[23] Battelle. Background Geologic Assessment for CO2 Storage In Deep Saline Reservoirs and Coal Seams. National Energy Laboratory Project DE-AC26-98FT40418, 2003.

[24] Ohio Department of Natural Resources, Division of Oil & Gas. Ohio Oil & Gas Wells. https://gis.ohiodnr.gov/mapviewer/?config=oilgaswells.

[25] United States Geological Survey, U.S. Geological Survey National Produced Waters Geochemical Database (ver. 3.0, December 2023) Viewer. https://www.usgs.gov/tools/us-geological-survey-national-produced-waters-geochemical-database-ver-30-december-2023.

[26] Rochelle, C., Czernichowski-Lauriol, I., and Milodowski, A., 2004, The impact of chemical reactions on CO2 storage in geological formations: A brief review. Geological Society, London, Special Publications. 233. 87-106. 10.1144/GSL.SP.2004.233.01.07.

[27] Battelle. CO2 storage resources and containment assessment in Cambrian and Ordovician formations of eastern Ohio – Final summary report. 2018.