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Marquis Carbon Injection LLC
Class VI Application MCI CCS#3
Permit No. IL-155-6A-0001, Putnam County, Hennepin
December 12, 2022

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Marquis Carbon Injection LLC (Marquis) is submitting a response to USEPA's technical questions concerning the above-listed pending Class VI permit application. Set out below are USEPA's questions in *italics* below, along with Marquis' response to the same.

For ease of reference, Marquis has included a General Table of Contents and a Quick Reference Index referencing any revised or additional figures, tables, logs, and reports submitted as part of our response.

GENERAL COMMENTS

This application appears to be based on data collection from regional sources and included drilling, logging, reservoir testing, and core sampling of a deep characterization well (MCI MW1) about a mile away from the planned injection well. In each response, please identify or confirm if the requested information will be obtained as part of the well construction or pre-operational testing activities.

Marquis understands there is a concern regarding the consistency of the geology across the project site due to the distance between the deep characterization well, MCI MW1, and the proposed injection well, MCI CCS3. In support of the geologic consistency across our project site, Marquis is providing additional support information as follows:

Additional Deep Well Information: Marquis is providing information concerning another deep regional well (J&L Well) that is located approximately 1.5 miles southwest of the MCI MW1 well. See **Figure R-1** that shows an aerial view of the location of the MCI MW1 well, J&L Well, and the proposed MCI CCS3 well. While the J&L well is outside of the area of review (AoR), it does provide geologic information that supports Marquis' project. The J&L well was drilled during the 1960's, and the basic characterization data collected during the installation of that well ties very closely to the MCI MW1 well log data and 2D and 3D seismic data collected on the Marquis' project site. See **Appendices A and B** which includes the well log information collected from the MCI MW1 well and J&L well.

Two-Dimensional (2D) Seismic Acquisition: A 2D seismic reflection survey was acquired prior to completing the 3D baseline seismic survey. See **Figure R-2** which outlines the boundaries of the area where 2D acquisition occurred. A summary of the 2D seismic reflection data acquired from the project site and the surrounding area is included in **Appendix C & L**.

Three-Dimensional (3D) Seismic Acquisition: Marquis conducted a 3D seismic acquisition of the project site and the surrounding area. See **Figures R-3 and R-4**. Results of the 3D seismic processing show that the deeper part of the subsurface was clearly imaged, and the application of high-resolution seismic techniques improved the subsurface image when compared to 2D. The 3D data was incorporated into the static earth model (SEM) to increase the accuracy of that model. See **Appendix D & L** for the 3D Processing Report and additional data.

The detailed information collected from the MCI MW1 well, J&L well, and 2D and 3D seismic surveys provides confidence that the formations are consistent in depth, thickness and porosity, and continuous across the project site.

USEPA SPECIFIC QUESTIONS REQUIRING RESPONSE/CLARIFICATION

1. *Regional Geology*

a. *What is the thickness of the Gunter Sandstone across the AoR?*

Figure 1-2 identifies the depth of the Gunter Sandstone. However, the thickness of the sandstone was determined based on the logs from the MCI MW 1 well and J&L well. Logs are included in **Appendices A and B**. The Gunter in the J&L well is 12-feet thick. The Gunter in the MCI MW 1 well is 14-feet thick. Similar thickness is expected in the MCI CCS 3 well due to the seismic data that reflects consistent general layering across the project site. The thickness of the Gunter Sandstone in the MCI CCS 3 well will be confirmed by the well logs that will be collected during construction. See **Pre-Operational Testing Program Rev 1, Section 5.3.3 and Table 5-11**.

b. *Regarding Pre-Operational Testing, establish how you will measure the depths, aerial extents, and thicknesses of the injection and confining zones at the location of CCS#3.*

Depths, aerial extents, and thickness will be measured using wireline logs for depths and thickness, and seismic data for aerial extent. For purposes of the Pre-Operational Testing Program, the existing well, seismic, and SEM data will be used as the basis for analysis and comparison of the MCI CCS 3 well key log data to the MCI MW 1 well and the SEM. The objective of the comparison of existing well data to the MCI CCS 3 well data is to confirm and add to the MCI MW 1 well as an accurate representation of the project site. See **Pre-Operational Testing Program Rev 1, Section 5.3, especially 5.3.4, and Table 5-12**.

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

a. *What was the extent of coverage for the 2D and 3D seismic surveys performed in 2021 and 2022?*

See **Figures R-2, R-3, and R-4** which depict the aerial extent of the 2D and 3D surveys. The surveys included the location of the MCI CCS 3, MCI MW 1, and J&L wells. The 2D survey covered 43-line miles around and across the project site and surrounding area. The 43-line miles consisted of 11 2D Seismic lines. The 3D Seismic

covered 3.7 square miles across the AOR and surrounding area. See **Appendices C, D and L** for 2D and 3D survey review.

- b. Please provide detailed cross sections (e.g., based on available logs) that extend throughout the AoR in perpendicular directions to provide a more thorough depiction of formations within the AoR.*

The cross-section of the area shows consistent formation thicknesses and log characteristics between the J&L well and the MCI MW 1 well in **Figure R-5**. Thicknesses were extrapolated away from the wells, guided by 3D seismic interpretations, providing a data-constrained approximation of formation depths and thicknesses for the injection well, MCI CCS 3. The cross-sections as well as the static earth model show the flat consistent geology across the project site. There is a distinct absence of pinch-outs, basement highs, faults, and fracture networks across the project site.

- c. Please label the figure on page 18 as “Figure 1-4.”*

The label for **Figure 1-4** has been included on a single page.

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

- a. Please provide evidence, if available, from core samples from the characterization well that support the presence/absence of faulting or microfractures and their sealing capacity.*

The confining zone is defined by the top of the Eau Claire (2706 ft MD at the MCI MW 1 well) through a shale in the Elmhurst (3043–3110 ft MD). (Figure 1-2). The Fracture Core Descriptions for the cored intervals in this sealing zone can be found on pages 314–323 in **Appendix E** the Final Core Report (legend to this analysis is on pages 345–346).

There are three separate 20-foot whole core intervals throughout the Eau Claire. The deepest one, Core #3 (3045–3065 ft), was taken from the Elmhurst and covered the 11-foot-thick confining shale in the upper Elmhurst (3043–3054 ft). The Fracture Core Description for this zone in **Appendix E**, pages 320–323, shows no presence of open fractures in this shale-rich zone. The few fractures present are barite- and quartz-filled. Although a few short, open fractures were indicated in Core #2 (2880–2899 ft), open fractures were indicated in the relatively sand-rich zone of Core #2. There was an absence of open fractures in the shaley intervals in Core #2 and the entire cored interval in Core #1 (2800–2810 ft).

On the Formation Micro Imaging (FMI) log, the base of the confining zone, as defined above, is in **Appendix A.7** page 18. Throughout the confining zone, the FMI log does not show offset in bedding that would indicate the presence of faulting. A drilling induced fracture (drilling induced tensile fracture) shape and orientation are dependent upon a number of factors, including hoop stress distribution around the borehole, bore hole deviation/azimuth, present day stress orientation compared to depositional stress orientation, pressure overbalance, borehole cooling effect and drilling parameters (e.g., weight on bit, torque). Drilling induced fractures are localized to the wellbore and not indicative of a fracture network in the formation. Drilling induced fractures are common in the drilling process, mostly close after drilling is complete, and are filled with cement during well construction. They do not pose a threat to formation integrity as long as proper cement procedures are followed to ensure hydraulic isolation above, across, and below the formation. The Eau Claire shale zones fractures shown on the FMI log appear to be drilling induced.

- b. *Are additional results of the 2D seismic surveys (i.e., in lines parallel or perpendicular to Figure 1-6) available? If so, please provide these for additional evidence of the absence of faults in the area.*

Composite 2D lines taken from the MW1 location and running adjacent to the CCS3 location in the E-W and N-S directions demonstrate that no major faults or subsurface hazards were observed in the 2D seismic data.

Arbitrary lines taken from the Baseline 3D and extending from the MW1 location to the CCS3 location and the J&L Steel location to the CCS3 location, show the section to be structurally benign with very consistent bed thicknesses. Based on the 3D seismic response, the stratigraphic section at the MCI CCS 3 well is expected to be very similar to that observed at the MCI MW 1 and J&L Steel well locations.

Please see **Appendices C, D, J, and L** for report and data.

- c. *Regarding Pre-Operational Testing, describe how the absence of faults or fractures within the AoR will be confirmed to ensure consistency with findings from the characterization well.*

A comprehensive set of logs in the MCI CCS 3 well, which include more than those required by regulation, including a formation micro imager and dipole sonic log, will be acquired and analyzed. The Formation Micro-Imager (FMI) log will be used to visually verify the existence of faults and fractures at the MCI CCS3 well. Together with the core, dipole sonic log, and 3D seismic, the FMI will be able to increase confidence regarding the presence or absence of fractures and faults both in the well bore and throughout the surrounding area. If fractures or faults are discovered, similar

zones from the MCI MW 1 well will be compared to detect the extent of the faults/fractures in the AOR. The FMI comparison to the 3D seismic will also determine the impact on the seal and injection zones. See **Pre-Operational Testing Program Rev 1 Section 5.3.4**.

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

- a. *What is the source of the porosity and permeability data for the Eau Claire shale and Mt. Simon Sandstone formations as described in the application? What are the specific values in each formation?*

The moveable porosity curve used in the model was derived from the nuclear magnetic resonance (NMR) log, Rockview answer product log, and X-ray diffraction (XRD) core data, which took into account clay-bound water and capillary-bound water volumes.

The permeability curve was derived from NMR and corrected to core analysis data points. From there, a Flow Zone Indicator workflow was used to populate permeability in the model (see **Section 2.1.4**).

For specific values of each formation see Figures 2-16, 2-17, and 2-18, and **Appendix E** for the Final Core Report pages 91 and 94.

- b. *Are permeability and porosity values (as well as data on mineralogy) available at the core sampling locations within MCI MW 1 that are identified on Table 5-8 of the Pre-Operational Testing Plan? If so, please provide this, e.g., in a tabular format for each interval cored.*

Results are summarized in tabular format in **Appendix E** Final Core Report pages 91 and 94 for porosity and permeability data, and pages 372 and 373 for X-ray Diffraction (XRD) mineralogy data.

Core summary:

The laboratory core analyses were performed by Core Laboratories on conventional and rotary core samples from the MCI MW 1 well and include:

- Computed Tomography
- Slab Images - Visible Light
- Spectral Gamma
- Routine Analysis
- Shale Core Data (Gas Research Institute GRI)
Brine Permeability

- Threshold Entry Pressure
- Electrical Properties w/ Capillary Pressure
- Relative Permeability
- High Pressure Mercury Injection
- Rock Mechanics
- Core Fracture Description
- High-Resolution Thin Section Imaging
- X-ray Diffraction
- X-ray Fluorescence

Routine Core Analysis

Eight conventional cores totaling 141.85 feet and twenty-eight rotary sidewall cores were available from the MCI MW 1 well. Spectral gamma activity was measured on the core, which yielded API values ranging from 0.03 to 247.59. The conventional core was then scanned using high-resolution computed tomography. Dual-energy CT scans were also acquired to aid in creating a lithology of the cores.

Eighty-seven core plugs and thirteen bulk samples were acquired for routine core, special core, and geological analysis. Following sample acquisition, two (2) end trims were acquired from each core plug and archived for geological analysis. From the plug samples, sixty-two plugs and twenty-eight rotary sidewall cores were selected for routine core analysis, twenty-six for special core analysis, ten bulk samples for shale core analysis (GRI), and one hundred three end trims for mercury injection and geology. A review of the conventional core analysis at net confining stress (NCS) showed permeabilities to air from 0.002 to 1816.0 md, and porosities from 1.82 to 24.07 percent of bulk volume.

For GRI analysis, bulk volume measurements were made on the selected samples before preparing the samples for grain density and matrix permeability measurements. Porosity was calculated using the difference in bulk volume and grain volume, and the calculated total porosities ranged from 7.52 to 13.46 percent of bulk volume.

Special Core Analysis

Twenty-six core plugs and twenty-three end trims available for special core analysis. Twenty-two samples were CT scanned to evaluate internal condition prior to special core testing.

Permeability to brine was measured on eight plug samples, resulting in values ranging from 0.0026 to 2.40 mD. The two lowest permeability samples were selected for threshold entry testing. 950 and 1500 psi were recorded as minimum entry pressures.

Three of twenty-six core plugs were tested for electrical properties in conjunction with

porous plate capillary pressure. Electrical properties were at a frequency of 1000 Hz and net confining stress. At NCS, the measured apparent formation factors ranged from 35.2 to 131.37, individual cementation exponents (m) from 1.81 to 1.92. Gas-water capillary pressure measurements showed final inlet-face water saturations that ranged from 9.7 to 85.1 percent of pore volume at the final 200 psi capillary pressure. Relative permeability was measured on three core plugs using CO₂ and simulated formation brine. High pressure mercury injection measurements were made on twenty-three end trims. Triaxial compressive strength testing was conducted on ten core plugs to determine compressive strength, acoustic velocity, Young's Modulus, and Poisson's Ratio. Measured compressive strength ranged from 13,198 to 31,210.

Geological Services

Core slabs and CT images were used to describe fracture networks, lithology, grain size, and sedimentary structures for the "Fracture Core Description". Twenty-five end trims were used to make thin section slides for high-resolution imaging and detailed geological descriptions. Trims were also used for X-ray diffraction and Xray fluorescence testing. XRD measured total clay content resulted in values ranging from 1.8 to 65.7 percent of bulk volume.

- c. *In the injectivity section on page 27, the application narrative states that mini-frac testing was conducted on the Eau Claire shale and the Mt. Simon Sandstone; however, data are only provided for the Mt. Simon. Please provide any formation properties for the Eau Claire as determined by the testing.*

The Eau Claire fracture gradient results are available in **Appendix F** Reservoir Testing Results Pages 38-43 and analysis summary on page 48-49.

- d. *Is any porosity or permeability data available for the Elmhurst Formation, particularly the portions that are hydraulically connected to the injection and confining zones?*

See answer to **3.a** above. Additionally, porosity and permeability log data are available over this interval in **Appendix A**, and the following core data:

- One sidewall core from the sandy shale in the Lower Elmhurst for RCA: 3073ft
- One 20-foot whole core from the Middle Elmhurst (3045–3065 ft), which covered the 11-foot-thick confining shale in the upper Elmhurst (3043–3054 ft) from which:
 - Three plugs were taken for RCA: 3056.00, 3059.75, 3060.80
 - Two plugs were taken for MICP: 3054.25, 3060.8

Sands below the 11-foot-thick shale within the Elmhurst are separated from the injection zone by an 8 ft shale unit at the base of the formation. It is unclear if the

units are hydraulically connected. For this reason, they were not included in the sealing unit description, but also injection into this unit is not being requested as part of this permit application. See **Section 1.2.4** and revised **Figure 1-2**. Results are shown in **Appendix E** Final Core Report. See pages 91 and 94 for routine core analysis data and pages 134 and 247–260 for MICP data.

- e. Given the variety of intervals documented within the Mt. Simon, please provide evidence that there are no heterogeneities that may affect injectivity or other aspects of injection operations.*

Vertical heterogeneities are present and expected, and they will be used to the advantage of the project to help distribute the CO₂ vertically and avoid large-scale coning effects. Horizontal heterogeneities that would cause restrictions to flow were not found based on the longer-term reservoir testing. Please see **Appendix F** Reservoir Testing Pages 9-14 for pumping test results.

- f. Please upload a higher-resolution version of Figure 3.10-1.*

See the new resolution Figure 2.2-10 from the Computational modeling section.

- g. Regarding Pre-Operational Testing, identify the porosity, permeability, mineralogy, and lithologies of the injection and confining zones at the project site, e.g., via core samples and open-hole logs during drilling of the injection well. Verify that they are consistent with observations at the characterization well.*

- *Confirm thicknesses and depths of the injection and confining zones at the project site through information gained during drilling of the injection well and deep monitoring well.*

In order to make a comprehensive comparison between the two wells, a full suite of wireline logs will be run in the MCI CCS 3 well. This would include neutron porosity, density, gamma ray, spontaneous potential, resistivity, micro imager/fracture finder, dipole sonic, NMR, elemental spectroscopy, and gamma-ray spectroscopy as is shown in Table 5-12. These logs will be compared to the same logs run in the MCI MW 1 well. Core will also be taken at certain intervals and fluid samples and reservoir tests performed at the injection site. Each of these data points either through direct field-acquired data or through analytical results will be compared to similar data points or answer products in the MCI MW 1 well. See Pre-Operational Testing Program Rev 1 **Sections 5.3-5.7** for a full explanation of the characterization to be done in the MCI CCS 3 well and how the new data will verify data from the MCI MW 1 well. See **Section 5.9** for a summary of characterization to be done in the deep

monitoring well.

5. *Geo-mechanical and Petrophysical Information [40 CFR 146.82(a)(3)(iv)]*

- a. *Please provide the geo-mechanical and petrophysical testing results from the minifrac testing for the confining and injection formations as referenced in Section 1.2.5.*

Please see **Appendix F** Reservoir Testing Results Pages 37-49 for the minifrac testing for the confining and injecting formations.

- b. *Please provide a tabulation of the data from the MCI MW 1 well described in the pre-operational testing plan at each interval tested.*

A tabular summary of the data collected in the MCI MW 1 well by zone and formation can be found in **Appendix K**. The results from the data acquisition are available in **Appendices A, E, F, G, H, and I**.

- c. *Regarding Pre-Operational Testing, confirm the fracture pressure within the Mt. Simon injection zone at the location of the injection well, e.g., via a step-rate test.*
i. *Confirm confining zone integrity via site-specific measurements during drilling of the injection well MCI CCS 3 well (including capillary pressure; information on fractures, stress, ductility, rock strength, elastic properties; and in situ fluid pressures) and compare and correlate with measurements collected from characterization well MCI MW 1.*

A wireline-conveyed reservoir testing tool will be employed in the MCI CCS 3 well to obtain several mini-frac measurements and confirm a fracture gradient. After open hole logging is complete a dual packer reservoir testing tool will be lowered in the hole and set at each depth. The packer elements will be inflated, and fluid pumped in between the inflated packers. A fracture pressure, closing pressure, reopening and propagation pressure will be acquired during the test. The logging, coring, and testing program planned for the MCI CCS 3 well will provide the critical information required to evaluate the integrity of the confining zone at the injection well location. For example, logs and core-test data will provide the following parameters: formation thickness, lithology, porosity, permeability, capillary pressure, density, pore-size distribution, elastic properties (Young's modulus, shear modulus, bulk modulus, and Poisson's ratio), Inelastic properties (fracture pressure, formation tensile strength). Fracture pressure of the confining zone can be determined by conducting a mini-frac test in the open borehole section.

See Pre-Operational Testing Program Rev 1 **Section 5.6 (and 5.3-5.4)** for more details.

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

- a. *Are there any additional details related to the 1985 earthquake (e.g., depth or any observations near the project site)?*

The correct year and magnitude are 1881 and 4.6, respectively. Given the age of the earthquake, the available information is limited. See USGS link below.

Source information:

<https://earthquake.usgs.gov/earthquakes/eventpage/ushis222/executive>

Below is a tabulated summary of seismic events within a 100-mile radius of Hennepin, IL since 1900.

Location	Year	Modified Mercalli Intensity (MMI)	Depth	Location
M 4.0 - 1 km ESE of Moline, Illinois	1934	VI	NA	41.500°N 90.500°W
M 3.5 - 8 km W of Amboy, Illinois	1999	NA	5 km	41.721°N 89.433°W
M 4.0 - 8 km SSW of Amboy, Illinois	1972	VI	11 km	41.645°N 89.369°W
M 4.2 - 12 km NW of Dayton, Illinois	2004	V	10.0 km	41.460°N 88.900°W
M 4.5 - 2 km NW of Lisbon, Illinois	1912	VI	NA	41.500°N 88.500°W
M 5.1 - 3 km WNW of Lockport, Illinois	1909	VII	NA	41.600°N 88.100°W
M 3.2 - 1 km SSW of Lyons, Illinois	2013	IV	1.0 km	41.800°N 87.825°W
M 3.0 - 3 km S of Lombard, Illinois	1985	V	5.0 km	41.848°N 88.014°W
M 3.8 - 2 km NW of Lily Lake, Illinois	2010	IV	10 km	41.969°N 88.498°W
M 2.6 - 4 km NNE of Virgil, Illinois	2013	III	5.0 km	41.990°N 88.509°W
M 2.9 - 3 km WNW of Lake in the Hills, Illinois	2015	III	6.0 km	42.188°N 88.366°W
M 2.3 - 1 km SW of Lakemoor, Illinois	2012	IV	5.0 km	42.319°N 88.213°W
M 3.2 - 1 km SSW of Lyons, Illinois	2013	IV	1.0 km	41.800°N 87.825°W

See **Figure R-7** identifying the location of the seismic events within a 100-mile radius. Hennepin, IL is denoted with star. (Hennepin location: 41.252°N 89.343°W). Please note that only two of the earthquakes are above the Precambrian and those closest to the project site are 35 miles away along the known LaSalle anticline.

- b. *Is any information available, e.g., based on the AoR modeling, that induced seismicity related to injection within the formations will not occur at magnitudes that could affect local resources or infrastructure, including at the project site?*

While the Class VI regulations do not specifically address the specific magnitude of a seismic event that would affect local resources and infrastructure, a seismic event with an MMI intensity over VIII is shown to affect local resources and infrastructure. Please see table below:

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

In addition, Decatur, IL has a Class VI well permit and has been injecting CO₂ from a similar fermentation process since 2012. There are four denoted events surrounding Decatur all before injection commenced occurring in the years 1977, 1978, 1983, and 2020. No MMI results were recorded.

A magnitude 2.7 seismic event is quoted in other regulations (CARB CCS Protocol) to affect local resources and infrastructure. The reservoir testing Marquis performed over several days of injection showed a formation that is very accepting of fluid and that dissipates pressure very quickly. This combined with the fact that the same formation has been used for gas storage for decades in other parts of the Illinois basin, give us confidence that seismic events at magnitudes larger than 2.0 will not occur.

Moreover, once the injection well is constructed, Marquis will be conducting microseismic monitoring across the site at all times. See **Section 7.8.3** of the Monitoring Plan for more information. The ongoing monitoring will provide initial notice prior to an event that would be felt at the surface or affect local resources and infrastructure, and allow time for corrective action measures.

The ADM injection site in Decatur, Illinois is permitted for similar injection rates and has been injecting into the same geologic formation and has not had issues with induced seismicity at high enough magnitudes to be felt at surface or affect local infrastructure. The Marquis Biocarbon Project site targets the same injection interval and confining zone as the ADM site but is located approximately 100 miles north (up-dip) and several thousand feet shallower. Due to its closer proximity to the original sediment source during deposition relative to ADM, and its up-dip location within the present-day Illinois Basin, the Marquis Biocarbon Project site has a larger storage capacity (thicker deposits of higher reservoir quality sands) which it will use to

distribute the CO₂ and pressure across and is shallower (i.e., under less overburden pressure equating to more permeability). The injection pressure at Marquis site is significantly less as well, reducing the risk for induced seismic activity at the Marquis site.

- c. Regarding Pre-Operational Testing, establish baseline seismicity. Incorporate geomechanical information and micro-seismic monitoring data into the analysis of seismic risk to inform setting of operating conditions and emergency response planning.*

A baseline measure of the local seismicity for the Marquis Biocarbon Project site will be established prior to the start of injection via a 6-12 month seismicity monitoring program. Any observed seismicity at the site, prior to injection, will be assessed in conjunction with the geomechanical data to inform models of potential future seismic risk associated with the injection of CO₂. See **Section 5.6 of the Pre-Operational Testing Program Rev 1.**

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

- a. Do any of the data sources identified in Section 1.2.7 include water quality data, e.g., TDS, for the USDW or shallow drinking water layers? If so, please provide this.*

See pages 3-11 of the Analysis of Various Water Samples for Various Sites in **Appendix G** and page 4-5 of **Appendix H** for water quality data that includes TDS in addition to cations and anions, from MCI-MW1 for the USDW or shallow drinking water layers.

- b. The application narrative states (on pg. 17) that 7 shallow groundwater wells are present within the AoR; however, 8 wells are shown on Table 2-6 of the AoR and Corrective Action Plan. Please clarify the discrepancy.*

This is a procedural nomenclature error. There are only 7 well bores, but one was deepened at a later date which put a second data point on the state water wells map. We adjusted to a common value for consistency. See corrected Table 2-6 below.

API Number	Latitude	Longitude	Date Drilled	Total Depth (ft)	Total Depth Lithology	Bedrock top depth (ft)	Aquifer Top Depth (ft)	Aquifer Bottom Depth (ft)	Aquifer Description	Static Water Level (ft)
121552046800	41.263135	-89.30066	3/25/1996	216	SH/CL	216	206	216	S	169
121552076400	41.277758	-89.31269	9/8/2006	210	SH	188	133	187	S	99
121552082100	41.278067	-89.30605	11/18/2007	190	SH	166	138	165	S	80
121552084100	41.27699	-89.30599	2/13/2011	177	SH	175	141	175	SG	86
121552084200	41.277739	-89.3055	4/19/2011	194	SH	192	136	193	SG	78
121552084300	41.27549	-89.3121	5/4/2011	181	SH	180	150	179	SG	74
121552085800	41.271028	-89.29614	7/24/2014	179	S		150	179	S	130

Lithology Key: SH = shale, CL = clay, S = sand, SG = sand & gravel.

- c. *Please provide a map of aquifers across the Illinois Basin, including the elevation of the lowermost USDW and other groundwater resources.*

Please see **Appendix G** Geochemistry Lab Results and **Appendix H** Geochemistry Analysis (particularly page 5) which details elevations and geochemical data, including Total Dissolved Solids (TDS) and chloride concentrations, that were sampled from the MCI MW1 well. This report summarizes which formations qualify as USDWs.

Figure R-6 is a map of the aquifers across the State of Illinois extracted from the Ground Water Atlas of the United States data, published as part of the National Atlas in 1998, revised 2003.

To further define the aquifer in Putnam County in the location of the area of review, the “Public Groundwater Supplies in Putnam County” (ISWS/BUL-60(18)/76) denotes “below the Maquoketa Group occurs a thick sequence of hydrologically connected aquifers of Ordovician age. They consist in downward order of the Galena-Platteville Dolomite Groups, Glenwood-St. Peter Sandstone, Shakopee Dolomite, New Richmond Sandstone, and Oneota Dolomite. Water supply wells in Putnam County have not penetrated below the Glenwood-St. Peter Sandstone.”

The **Appendix H**, the Geochemistry Report page 5, details elevations and geochemical data, including TDS and chloride concentrations, that were sampled from the MCI MW1 well. This report summarizes which formations qualify as USDWs and which do not.

d. Are there any notable springs within the project site location?

While naturally occurring springs and upwellings of Cambrian brines can occur within the Illinois basin, the conditions under which they occur require factors which are not present in the formations of the AoR of MCI-CCS 1 well. Below are three specific features known to be associated with these springs and the evidence supporting they are not present.

- *Spring and upwellings factors: extensive vertical faulting which creates fluid pathways along which brines can migrate*

The presence of structural features, such as faults, which create fluid pathways along which the brines can migrate are **not observed** through multiple data sources, including wireline logs, image logs, core, 2D and 3D seismic. See **Appendix L, Appendix E, and Appendix A Image log**

- *Spring and upwellings factors: interconnected fracture networks through which the briny fluids can move*

An abundance of interconnected effective (open) fractures through which briny fluids can move are **not observed** in either core or image logs. See **Appendix E pages 314-343 and Appendix A Image log**

- *Spring and upwellings factors: Coincidence of structural features with rivers or streams at the intersection of the basin edge.*

The AoR of MCI-CCS 1 well is not situated in an area where a water feature, such as a stream or river, intersects the basin edge. A basin edge is an area where older formations trend toward the surface and outcrops occur allowing communication with fluids in those formations. While the site does sit next to the Illinois river, is located 20+ miles from the basin edge, in a structurally quiet area with flat-lying strata.

In addition to the above data-supported conditions at Marquis, the MCI MW 1 well, located approximately 1.2 miles from the injection site, acquired subsurface water samples that did not show any signs of seepage of brine waters into fresh waters. The deepest measured USDW occurred in the Gunter Sandstone and had a salinity of 665 ppm, while samples taken from the Cambrian Mt. Simon formation measured at 44,413 ppm.

- e. Regarding Pre-Operational Testing, provide sample formation water collected during drilling of the injection well and the above confining zone monitoring well to confirm the base of the lowermost USDW at the well site and confirm reported information in the permit application.*

In the **Pre-operational Testing Program Rev 1 Section 5.5** the MCI CCS 3 well formation water will be sampled past the lowest USDW to confirm geochemical data from the MCI MW 1 well.

The lowest USDW location will be further supported through analysis of the MCI MW 2 well, located 1,650 ft away, as stated in **Section 5.9 of the Pre-Operational Testing Program Rev 1.**

8. *Injection Zone Geochemistry [40 CFR 146.82(a)(6)]*

- a. *Is there any data available or studies (e.g., geochemical modeling) that characterizes potential reactions between the CO₂ and the formation rock and fluids within the Mt. Simon?*

Marquis obtained fluid samples from above the caprock and within the Mt. Simon representative of the entire formation during the pumping test on the MCI MW 1 well and conducted a geochemical assessment. See **Appendices G & H** for site-specific geochemical data.

Other studies have been conducted to assess the geochemical changes from injection of CO₂ into the Mount Simon Formation. Two examples are listed below:

Harbert, William, Goodman, Angela, Spaulding, Richard, Haljasmaa, Igor, Crandall, Dustin, Sanguinito, Sean, Kutchko, Barbara, Tkach, Mary, Fuchs, Samantha, Werth, Charles J., Tsotsis, Theodore, Dalton, Laura, Jessen, Kristian, Shi, Zhuofan, and Frailey, Scott. CO₂ induced changes in Mount Simon sandstone: Understanding links to post CO₂ injection monitoring, seismicity, and reservoir integrity. United States: N. p., 2020. Web. doi:10.1016/j.ijggc.2020.103109.

Peter M. Berger, Edward Mehnert, and William R. Roy; GEOCHEMICAL MODELING OF CARBON SEQUESTRATION IN THE MT. SIMON SANDSTONE (Presentation); Illinois State Geological Survey Prairie Research Institute University of Illinois at Urbana-Champaign; April 2009

- b. *Are data/results of analysis for other major cations and anions, trace metals, pH, and alkalinity in MCI MW 1 available?*

Chemical analyses were performed on water samples collected from above the confining zone and the Mt. Simon from the MCI MW 1 well. Numerous parameters were measured including major and minor cations and anions, metals, pH, conductivity, hardness, salinity, TDS, density, resistivity, alkalinity, and dissolved organic carbon. The data is presented in tabular form in **Appendices G & I.**

- c. *Please describe the methodology and results of the modeling or analyses performed to determine geochemical equilibrium conditions and geochemical reactions that may occur*

from the injection of CO₂ as described on page 35 of the permit application.

The Geochemical modeling methodology and results can be found in **Appendix M**.

- d. *Regarding Pre-Operational Testing, establish baseline geochemical and hydrogeological data and fluid characteristics (including TDS) at the location of the injection well, including for all permeable water-bearing formations, including USDWs. Compare and correlate to measurements in MCI MW 1.*

Starting at the St. Peter and continuing downhole, the lowest USDW's will be tested until the two highest non-USDW have been evaluated. From these sampled points a correlation between the logs (including porosity, resistivity, and elemental spectroscopy) and the samples will be used to confirm the presence of USDWs. See the revision of **Pre-operational Testing Program Rev 1 Section 5.5** for details on the approach.

9. *Site Suitability [40 CFR 146.83]*

- a. *Is any estimate available (e.g., based on modeling) of the storage capacity of the Mt. Simon formation within the AoR (i.e., that sufficient pore volume exists at the proposed storage conditions)?*

A volumetric calculation, using the equation below, was performed to estimate CO₂ storage capacity of the Mt Simon within the AOR. Input parameters used in the equation are from various data sources. An AOR aerial extent of 1.4 miles² was determined using the Petrel area measuring tool. The net pay thickness was calculated based on a 95% net to gross of a 1756 ft Mt Simon thickness. The porosity used in the equation is the average porosity of Mt Simon zones 1-7 within the AOR in the static earth model (SEM). The initial water saturation S_{wi} of 0.29 was determined from the relative permeability core tests from the MCI MW1 well. Density of CO₂ was based on initial reservoir pressure and temperature at the Mt Simon midpoint depth at injection well location. The efficiency factor of 14% was estimated following the methodology explained by Goodman et al, 2016 for calculation of P50 efficiency factors. Results are summarized in table below. The calculated storage capacity of 12 MM tonnes of CO₂ capacity exceeds injection targets.

$$GCO_{2n} = Ah\phi(1 - S_{wi})\rho_{CO_2}E_n \left(\frac{1 \text{ tonne}}{2,205 \text{ lb}}\right)$$

Where:

GCO_{2n} = Storage Capacity (tonnes) of P-value (n)

A = Area of reviewed area (ft²)

h = Net pay (ft)

φ = Average porosity in Mt Simon formation (dec.)

S_{wi} = Initial Water Saturation (dec.)

E = Efficiency factor (dec.)

ρ_{CO2} = density of CO₂ at reservoir temperature and pressure (lbs/ft³).

Temperature assumed is 88 °F (average in Mt Simon based on MCI MW 1 temperature well logs) and pressure is 1,760 psi (based on a gradient of 0.44 psi/ft at Mt Simon midpoint depth OF 4002 ft at the injection well location). The corresponding CO₂ density at this pressure and temperature is 49 lb/ft³.

	Area (mi ²)	Net Pay (h) (ft)	Net Porosity (φ) (dec.)	Initial Water Sat. (dec.)	ρCO ₂ (lb/ft ³)	Efficiency Factor (dec.)	Storage Capacity (GCO ₂) (MMt)
Mt Simon	1.4	1668	0.083	0.29	49	0.14	12

- b. *Given the seismic history within the region, what evidence is there that any induced seismic events would not affect the integrity of the confining zone?*

Historic seismic events in the region have been located along the La Salle Anticline belt, see **Response 6.a. and 6.b. above**. Only two events are above the Precambrian formations. The Marquis Biocarbon Project site is further west from this structure, and no evidence of faulting in the seal was found through the 2D and 3D seismic data interpretation.

At the Decatur CCS site micro seismic events occurred in the Pre-Cambrian and lower Mt. Simon section and did not affect the integrity of the caprock nor the surface. They were identified and remedies, as published in “*Post-Injection Site Care and Site closure Plan for ADM CCS#2 – Modified September 2021 Attachment E*” page E22-E23. See **Appendix N**. As part of induced seismic risk mitigation, the MCI CCS 3 well will not be perforated in or injecting into the lowest 100 ft of the Mt. Simon. During injection, continuous microseismic monitoring will alert the project team if any induced micro-seismic events are occurring so corrective action measures can be undertaken. See the microseismic monitoring plan in **Section 7.8.3** in the Monitoring Plan.

- c. *Regarding Pre-Operational Testing, confirm mineral compatibility between the injectate and minerals in the injection and confining zones (per § 146.84(a)(7)(iv)) based on evaluation of cores (and using benchtop geochemical tests if needed).*

We will confirm similar geochemical makeup in the MCI CCS 3 well by use of logs, cores, and fluid samples, especially elemental capture spectroscopy and Gamma-ray spectroscopy. We expect that due to the very low geologic flow and connectivity of the formations between the wells, the formation waters will be very similar. See attached **Appendices G & H** and the Pre-Operational Testing Program Rev 1 **Section 5.5**

- *Confirm and correlate injection zone formation capacity characteristics that could affect the suitability of the Mt. Simon for injection, including facies changes that could facilitate preferential flow.*

The 3D seismic data has been integrated into the SEM and the injection well correlation looks very good. We will confirm characteristics through a comprehensive suite of logs, core, and tests, and incorporate that data in the updated facies model. See the Pre-Operational Testing Program Rev 1 **Section 5.3-5.7.**