Technical Support Document – CapturePoint Solutions, LLC, Proposed Permit Denial

The following technical support document (TSD) was composed to provide a more detailed explanation of factors related to the proposed denial of the permit applications submitted by CapturePoint Solutions, LLC. A summary of the reasons for denial is contained in the accompanying fact sheet available on https://www.regulations.gov under docket #EPA-R06-OW-2024-0583.

Model Summary

Technical reviews of the CapturePoint Solutions, LLC (CapturePoint) computational model have been performed by the EPA Region 6 Groundwater/Underground Injection Control (UIC) Section, and by Department of Energy (DOE) national laboratories as part of the DOE-EPA Federal Technical Assistance Program (FTAP). The FTAP program involves selected national laboratories providing technical assistance to EPA for reviewing Class VI permit applications including computational models for the secure geologic storage of carbon dioxide (CO_2).

The CapturePoint computational model is found in Section B, Area of Review (AOR) and Corrective Action (CA) Plan of the CapturePoint Class VI application. The EPA Region 6 Groundwater/UIC Section and DOE national laboratories also performed reviews of the Class VI Permit Application Narrative that includes descriptions of site characterization and geology. The complete AoR and Corrective Action Section and the complete Permit Application Narrative were reviewed in depth to develop requests for additional information (RAI). The DOE review of the computational model is found in Consensus Report-Evaluation of the AoR and Corrective Action Plan (undated report), and the DOE review of site characterization and geology is found in Supplement of Consensus Report, Project Narrative/Geology, (June 2024).

DOE national laboratory reviews follow checklists to ensure reviews are comprehensive and provide consistency among all Class VI reviews nationally. The Review Checklist for Area of Review Delineation Modeling, developed by EPA Headquarters, seeks to answer questions about computational models including whether applicants used an appropriate computer modeling program, whether computational models are adequately designed, checking input parameters and site-specific conditions, the accuracy of how model results are presented, whether model calibration and sensitivity analyses were performed, and additional questions.

As for reviewing site characterization and geology, DOE utilized the draft Geologic Characterization Narrative checklist. That checklist provides a comprehensive evaluation of the regional and local geologic, hydrogeologic, geochemical, storage capacity, confining zone integrity, and other geoscience related aspects that are needed to support a determination of site-suitability for the secure geologic storage of CO_2. Either following or concurrently with the DOE national laboratory reviews of modeling and site characterization/geology, the EPA Region 6 Groundwater/UIC Section develops RAIs that are then provided to applicants. However, in the case of Capture Pont, RAIs were not provided because early in the review process, it became clear from the information provided, that the site is unsuitable for the secure geologic storage of CO_2. This is mainly because of the lack of geologic conditions required to confine CO_2 in the injection zone.

The main concerns about the CapturePoint model, expressed in the Region 6 draft RAI table, consist of comments on the following topics: the applicant not performing model sensitivity analyses, not including faults and fractures in the model, failing to use site-specific data for model inputs, reservoir properties and reservoir capacity, lack of geochemical modeling, not considering influences of nearby wells, and concerns about the model grid design. The following paragraph summarizes the draft model RAIs that were developed and are mainly based on Section 2.0 (Review Summary) in the DOE Consensus Report.

On model sensitivities, reviewers suggest that CapturePoint perform sensitivity analyses to investigate parameters for the model domain area/size, storage zone porosity and permeability, and storage zone horizontal to vertical permeability ratio. A sensitivity analysis should reflect a conservative and reasonable modeling approach. Although sensitivity analyses are not mentioned in Class VI regulations, performing sensitivity analyses is a standard practice in modeling and should be done. The sensitivity analysis should evaluate the dynamic reservoir model domain area, storage zone permeability, storage zone porosity, and storage zone horizontal to vertical permeability ratio. The model did not include faults or fractures without providing sufficient supporting evidence, which is contrary to text in the AoR Corrective Action section that says there are faults in the Arbuckle Formation. It is not clear why the static model, and thus the computational model, rely on data from far away (10-55 mi) instead of site-specific data. There appears to be a wealth of site-specific data that are available but not used. The model uses a 20:1 vertical permeability ratio that would essentially block vertical migration in the model. Geochemical reactive transport simulation in the Arbuckle should be considered using site-specific (stratigraphic test well) data. CapturePoint needs to explain how the model evaluates the potential impacts of 8 active wells situated near the CO_2 injection wells. Finally, CapturePoint should provide references, methodology, and input parameters for a reported 90 million metric tonnes of expected storage capacity of the injection zone.

The static geologic model and the computational model are interrelated. Reviews of both are reported here and are based, in part, on the information contained in the June 2024 Supplement of Consensus Report, Project Narrative/Geology. The following paragraph presents key points from the supplemental review and demonstrates, based on currently available data, that the intended CapturePoint injection zone is not acceptable for the secure geologic storage of CO_2.

CapturePoint proposes a primary and secondary confining unit for CO_2 storage. The primary overlying confining zone (Woodford Shale) is reported to average about 10 ft thick. Reviewers raised concerns about the thinness and the Woodford Shale and having an unknown lateral continuity. Further, the Woodford Shale was historically mapped as absent in the applicant's proposed area in northwestern Osage County (references cited in the DOE report, if needed). Studies have suggested the distribution and thickness of the Woodford Shale is irregular, and the shale being present throughout most of the reservation, it is thinning onto, and commonly being absent over, pre-late Devonian topographic highs (references cited). DOE reports that since the Woodford Shale is used as the primary confining unit, it is critical to characterize the shale and map its structure and thinness across the AoR with sufficient resolution using all available well data. CapturePoint proposes the lower Mississippian as the secondary confining unit. DOE reports that the lack of core evaluations for the Lower Mississippi lime in the AoR and possible fractures indicated by the type log undermines the effectiveness of this confining unit.

The Arbuckle Formation injection zone lies directly on basement rocks unless the Reagan Formation is present. DOE reported significant concerns about the likelihood for seismic activity in the project area from documented pre-existing basement faults that are critically stressed for strike-slip motion. The absence of the Reagan Formation would cause direct physical contact of the injection zone to basement rock with the potential for new seismic activity. Basement structural maps in the application do not provide detailed structural information needed to address these concerns due to sparse well penetrations.

Section 4.2 of the supplemental report discusses the need for modeling karst and the ability of STOMP-CO_2 to simulate karst is unclear. The supplemental report provides suggestions for deriving model input data and references for karst modeling. The report suggests that CapturePoint rebuild the model given the maturity of the field and abundant well data, using site-specific digital log data, as opposed to data derived from analogues and literature.

Overall, as reported by DOE, and as reflected in the draft RAI table prepared by the Groundwater/UIC Section, the CapturePoint application is insufficient and lacking key information necessary to make informed decisions to ensure safe operations (Supplemental Report, Section 2.2). The draft model RAIs are mainly based on DOE's two reports that clearly indicate major geological limitations of the overlying and underlying confining zones to safely store CO_2. Comments from DOE strongly suggest that it is likely technically infeasible to safely store CO_2 in the AoR. If the CapturePoint application is to be processed further, or is to be resubmitted later with additional studies, both the static and computational models will need substantial rework which must include major amounts of additional geological data.

Geology Summary

Injection Zone

The injection zone for this project is the Upper Cambrian to lower Ordovician-age Arbuckle Formation, as depicted in Figure 2-1 of the permit narrative (Osage County, Oklahoma Stratigraphic Chart). NBU CCS site is targeting the Arbuckle Formation for permanent CO_2 storage. The project involves injecting CO_2 at an approximate rate of 14.7 mmcf per day into the Arbuckle Formation, a karstic and fractured dolomite and limestone system. Key characteristics include:

- Approximately 1,100 feet thick in the Area of Review (AOR) and contains a triple-porosity system (interparticle, fracture, and vuggy pores), Appendix A-7, A-8
- Injection Zone parameters based on offset analog and regional core data are 5-20% porosity, 50-1,000 md permeability, and 100 million metric tonnes of expected CO_2 capacity, Table 2-8
- Injection depths are between 3,500 and 4300 feet, with the CO_2 plume expected to cover ~3,500 acres, while the AOR spans ~11,320 acres.

The majority of the data used to categorize the Arbuckle is from a test at the Wellington Field (55-mile northwest), though actual Arbuckle injection wasn't conducted due to permitting issues as stated in the permit application in Section 2.7.3.

Information on the Arbuckle Formation can be found in Section 2.3.4 Injection Zone in the permit application narrative. The technical team reviewed the application narrative and the AOR to evaluate the geology of the site, along with the consensus report, including the geology assessment provided by the DOE. All pages and figures referenced are from the permit application narrative.

The Arbuckle Formation is confirmed to exhibit extensive karsting and solution-collapse brecciation in multiple areas. This is attested in the permit narrative (pgs. 11, 12, 26, 33, 34, 54 and 83) and illustrated in Figures A-17 and A-18 from Fritz (2012). Additionally, lithological studies conducted by Milad et al., (2018) (pg. 34) using core samples and photoelectric log interpretations further confirm the present of karst features within the Arbuckle Formation. The Arbuckle being karstic and fractured makes it a complex reservoir system which leads to significant modeling uncertainties, especially in predicting CO_2 migration, containment, and pressure dynamics. As mentioned in the permit application, core analysis from wells in the Wellington field demonstrated the Arbuckle Formation to have a triple-porosity system. The karst system's complex structure (vuggy, interparticle, and fractures pores) creates irregular flow pathways, complicating containment predictions and increasing uncertainty in the AOR. The fractured and vuggy nature raises concerns about its ability to confine CO_2 without upward leakage or lateral migration.

The permit application indicates that the Reagan Formation may be present beneath the Arbuckle Formation, pending further evaluation, but otherwise the Arbuckle will sit directly on the basement rock (pgs. 12 and 26). Injection into the Arbuckle near the crystalline basement could perturb faults, increasing the risk of induced seismicity. Even if present, the Reagan Formation would not serve as a confining zone due to its high porosity and permeability, which would instead make it a dissipation interval (pg. 32). The DOE reports that approximately 10 miles northeast of the proposed injection sites, pre-existing basement faults have been documented as critically stressed for strike-slip motion and could be reactivated by even minor stress or pore pressure perturbations of 2 MPa or less (Kolawole et al., 2019). The DOE review of fault data identified faults as close as 5.2 miles to the proposed site (Holloway, Holland, and Keller, 2016; Luza and Lawson, 1983). Additionally, the Antelope and Pearsonia 3-D seismic surveys, released by the Osage Tribe, have identified basement faults cutting through the Arbuckle Formation and extending to shallower formations (Elbiju et al., 2011; Firkins, 2021; Kolawole et al., 2019). These observations provide direct evidence of physical connectivity between the reservoir and the basement, raising concerns about fault activation and associated seismic risks. The applicant acknowledges the potential for induced seismicity associated with injecting fluid into the Arbuckle Formation, particularly given its proximity of the underlying basement rock. The permit narrative further recognizes that wastewater injection into the Arbuckle Formation perturbs stresses on basement faults, potentially causing them to slip and contribute to seismic events (pgs. 55 and 64).

Data from the Wellington Field may not fully apply to the NBU site due to the difference in geology being 55-miles away and the fact that the Arbuckle injection was not performed there due to unspecified permitting reasons (pg. 81). The applicant lacks site-specific data on CO_2 brine interactions and geomechanically properties, instead relying on regional studies/literature, DOE data, and generalized assumptions. This approach fails to meet the requirements under CFR 146.82 (a)(3)(iii) which demands detailed site-specific characterization, including mineralogy, geochemistry, and fluid dynamics. There are also limitations in characterizing the entire injection zone. The cross sections developed for this permit are based on data from 149 wells, none which penetrate the lower portion of the Arbuckle Formation, as noted in Section 2.2.1 (Data Sets, pg. 24)

Confining Zones

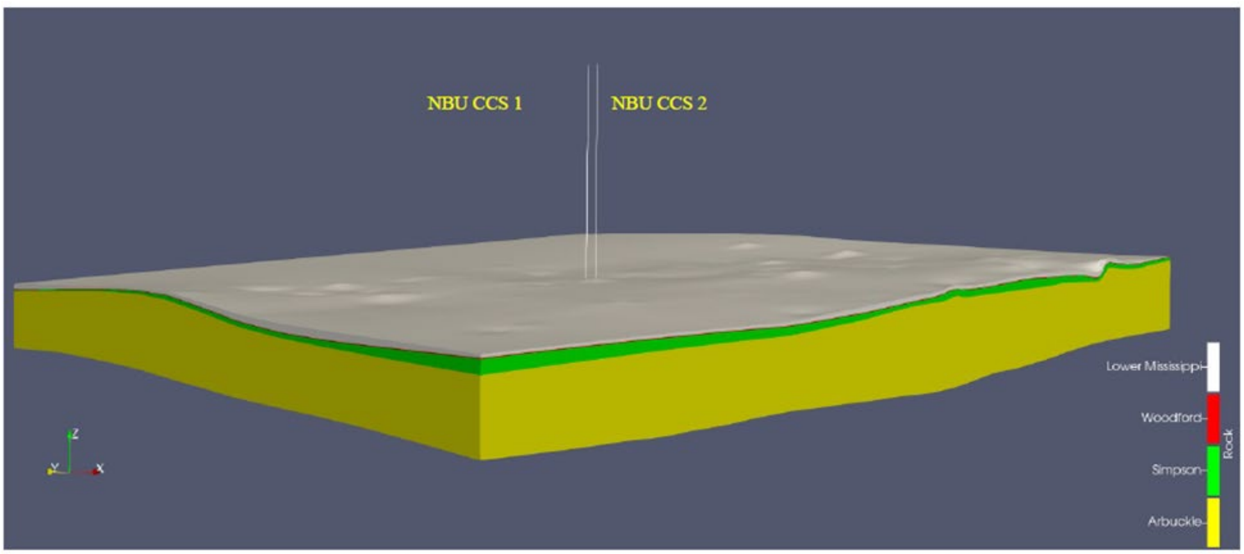
Sections 2.1.2.4 and 2.1.2.5 (pg. 14) of the project narrative discuss the regional geology that make up the formations selected for confinement, the Woodford Shale and Lower Mississippi. The Woodford Shale, designated as the primary confinement, formed in the late Devonian and early Mississippi Period, and is described as a "fissile and carbonaceous shale" with an average thickness that is less than 50 feet as shown in the isopach map Figure A-13 and cited from literature (Thorman and Hibpshman, 1979). The Mississippi Limestone, also referred to as the Mississippi Lime, overlays the Woodford and is comprised of a group of geologic units. The Mississippi Lime formed during the Mississippian Period from the deposition of carbonate sediments and predominately consists of silica and dolomite. The Lower Mississippi, a formation within the Mississippi Lime, is designated to serve as a secondary confining zone. It is a tight limestone and characterized in the narrative as having "little to no permeability".

Section 2.3 and subsequent sub-sections 2.3.1 – 2.3.3 (pgs. 27 – 31) provides descriptions of the confining zones at the proposed NBU CCS site. The Woodford Shale, designated as the primary upper confining zone, is approximately 75 feet above the injection zone. As indicated in narrative (pg. 29) the degree of thickness of the Woodford Shale is regionally varied across Oklahoma. In northern Oklahoma, the thickness ranges between 50 -100 feet and 200 – 900 feet in southern Oklahoma (Johnson and Cardott, 1992). However, the thickness of the Woodford Shale at the proposed injection site is approximately 10 feet. The Woodford's thickness is depicted in an isopach map and 3D model of the stratigraphy in Appendix B, Figure B-11 and Appendix 2, Figure 10, respectively. Additionally, in the northern region of Osage county and areas that are in close proximity to the proposed site, the Woodford Shale is either absent or become increasingly thinner. This deficiency is shown evident on a structure map found in Appendix A, Figure A-12.

Designated as a secondary confining zone, the Lower Mississippi is indicated to range between 55-65 feet across the area of review and 60 feet at the injection site (narrative section 2.3.2). Composite type log data derived from three offset wells were used to determine formation properties. As shown in Figure 2-2, a high divergence in the induction responses occurring in the log depth interval of the Lower Mississippi signifies the formation is potentially fractured, thus a probable conduit for vertical fluid migration. The Reagan Sandstone is identified as a lower confining zone; however, as indicated in the narrative, it is unknown if the formation is present at the injection site (narrative section 2.3.3, pg. 31). Consequently, without this layer of protection, there is no barrier to dissipate the pressure of the injected fluid from hitting the basement rock.

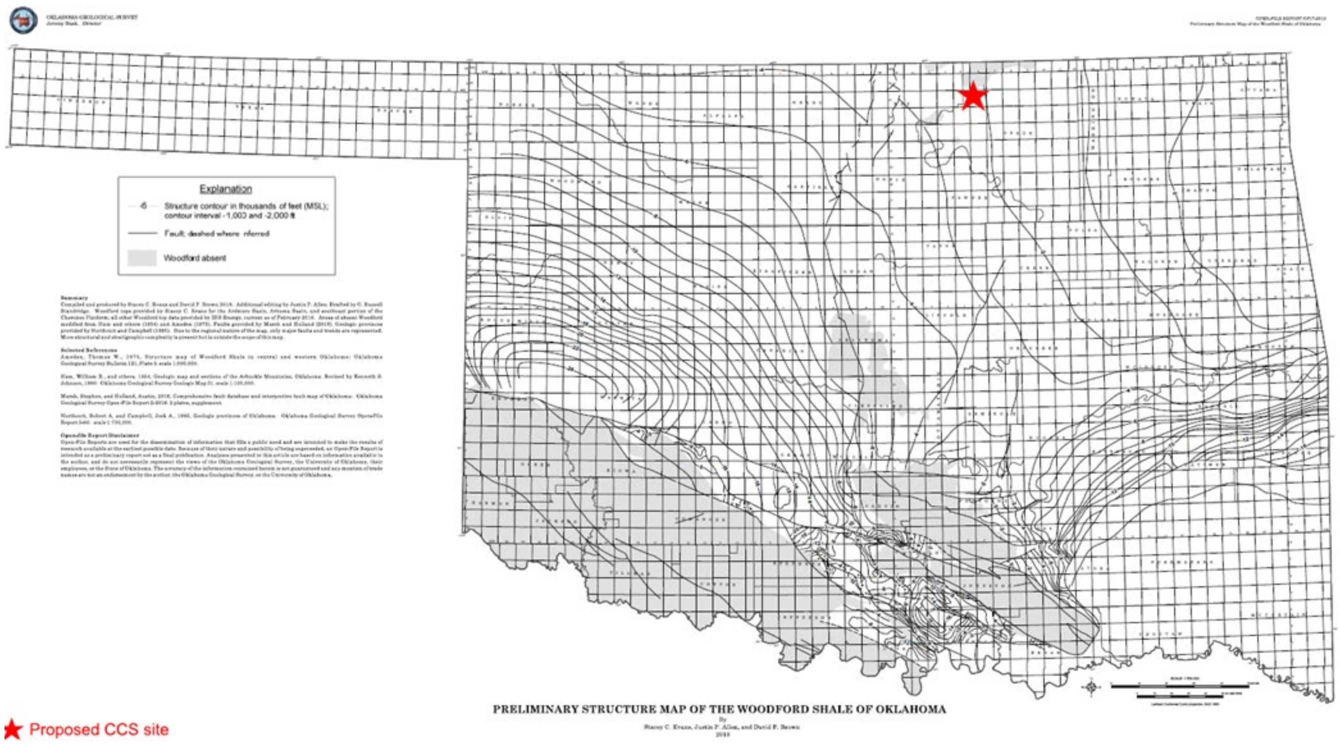
CPS stated in the project information narrative (Section 1.0, p. 5) that "The AoR was calculated using the base of the Vanoss freshwater zone…," but stated in the same paragraph that there are no USDWs at the project site due to freshwater zones having limited deliverability. In the same narrative in Section 2.4.2 (p. 45) as well as in Figures 2-2 and 2-17, CPS indicates that the deliverability of the Oscar and Vanoss freshwater zones "is extremely low and average 2 to 3 gallons per hour" and that, "Although these are not considered to be USDWs due to the low volume of water deliverability, the monitoring strategy proposed for this permit application will monitor them as such since some of their TDS values are below 10,000 mg/L." Based on the regulatory definition of a USDW (40 CFR 144.3) – which CPS directly quotes in Section 2.4.2 – as well as EPA guidance issued in 1993 (see Elder 1993), the declaration in Section 1.0 that there are no USDWs at the project site is not supported. A TDS of less than 10,000 mg/L and a flow rate of 1 gallon per minute or greater indicates that the Vanoss should indeed be considered a USDW.

A review of the material submitted (narrative discussion, isopach maps, structure maps, etc.) has concluded CPS did not provide adequate supporting evidence from localized site-specific data to corroborate the assertions that the Woodford Shale and Lower Mississippi has the appropriate sealing properties to be viable confining zones or that the cumulative approximate thickness of 70 feet would be effective confinement to contain any vertical migration of CO_2 to prevent endangerment to underground sources of drinking water. The applicant relied mainly on literature resources and test trial data obtained from a small-scale $CO_{2.}$ sequestration test field located in Kansas (Wellington Field) to characterize the geologic conditions of the Mississippian. Because of this, the sealing characteristics of the selected confining zones at the injection site cannot be considered regionally equivalent or acceptable to satisfactorily meet the requirements at 40 CFR 146.82(a)(3)(iii) when compared to data obtained from the Wellington Field. Additionally, low shale volume and lack of lateral continuity indicate the Woodford Shale is unsuitable for primary confinement for geologic sequestration.



3D view of the stratigraphic model and injection wells, viewed from southwest to northeast with 10x vertical exaggeration.

Appendix 2, Figure 10



Appendix A, Figure A-12

Induced Seismicity

Overlying the basement rocks in some areas of Oklahoma is the Reagan Formation as shown in the Osage County Oklahoma Stratigraphic Chart in Project Information Figure 2-1. The Reagan Formation is regionally described as a fine-grained, well-sorted sandstone with an average thickness of 30 feet and a maximum thickness of around 60 feet (Section 2.1.2.1; pg. 12; Thorman and Hibpshman, 1979). Figure 2-1 correlates three geologic formations, the Reagan Formation, Arbuckle Formation and Simpson Formation, as Ordovician and Cambrian in age. Figures A-2 and A-3 are regional cross sections that display a thin layer of Ordovician and Cambrian aged sedimentary rocks at the proposed site location. The cross section in Figure A-10 shows the granitic basement rock in direct contact with the Arbuckle Formation at the proposed project site.

Project Information Section 2.2 Local Geology contains maps and cross sections that are focused on the AoR. All figures pertaining to the local geology are contained in Appendix B, and Table 2-3 contains a list of the cross sections and maps used in the local evaluation. Section 2.2 pg. 23 states that four cross sections, Figures B-1 through B-4, at eight wells per cross section, were created to document the stratigraphy of northeastern Kay County and northwestern Osage County. The regional maps provide structural and thickness information for units within the modeled area of the project. Table 2-4 provides a list of wells used in cross sections B-1 through B-4, and Table 2-5 lists the wells with log and LAS files. The narrative states that the limitation on this information is that many of the wells were not drilled into the lower portion of the Arbuckle Formation. Figures B-1 through B-4 note that the full section of the Arbuckle was not drilled. The structural cross section in Figure B-1 estimates the Reagan and basement at depths greater than 3,420 feet (subsea depth); however, these estimates are based on one well in the cross section (Well Map #1396 Conklin #9-3 API 35071228360000) that is located in Kay County, outside of the modeled AoR. Figures B-3 and B-4 are cross sections oriented north to south; however, the wells used in these cross sections do not penetrate the full section of the Arbuckle and estimates for the depth of the Reagan Sandstone and the basement were not provided.

It is unknown whether the Reagan is present at the proposed site location. Section 2.2.2 describes the local stratigraphy and states that in certain locations where the basement rocks are at paleotopographic highs, the Reagan Sandstone is not present and is sporadic and very thin in Osage County (pg. 31, Reeves et al., 1999). Therefore, at these locations, the Arbuckle Formation rests directly on top of the basement and Figure 2-2 is a type log that combines logs from three wells (NBU No. 15-42, NBU No. 15-41, and MW #3C) located 3,675 feet west of the proposed northern sequestration well. Figure 2-2 estimates the Reagan Sandstone at a depth of 4,515 feet; however, the compiled well log only extends to a depth of 4,262 feet as indicated from well NBU #15-42 API #35113441250000. The narrative states that there are three basement penetrations in close proximity to the proposed NBU site. All three have approximately 70 feet of very low porosity rock on top of the Reagan Formation or Precambrian basement, and this interval will be logged to confirm lateral extent and represents a possible secondary lower seal above basement (pg. 26). The narrative states that type wells for the Arbuckle member are Conklin 9-3, Graham Ranch 28-1, and the Riley #1-A; however, well log information was not provided for Riley #1-A in the application materials. There is concern that when injection occurs on or near granitic basement rock, the potential for seismic events is greater.

Section 2.1.2.1 pg. 12 states the composition of the crystalline basement varies throughout northeastern Oklahoma (Figure 2-4). The proposed CCS site is located within the area of the Washington Volcanic Group (WVG) of basement rocks composed of rhyolite, meta rhyolite, and andesite with an isotopic age of 1.4 to 1.2 billion years old (Section 2.1, pg. 9, Figure 2-6, Section 2.3.3, pgs. 31-32.) Section 1.0 of the narrative states that the expected depth to the basement is approximately 4,500 feet. Figure A-4 is a regional structure map that illustrates the top elevation of the basement at 3,500-4,000 feet at the proposed site location, although the site symbol in the map obstructs the contour intervals. Note the reference for Figure A-4 was also not provided in the Module A References folder. The narrative explains that in the southeast and northeast areas of Osage County, the basement shallows to less than 2,200 feet, and along the western margin of the county the basement is at depths greater than 3,700 feet (Bass, 1942). The structural variations are a result of paleotopographic highs of Precambrian strata. The shallower areas of the basement result in thinner overlying sections.

The depth to the top of the basement at the NBU CCS site is unknown. Section 2.1 pg. 10 states that basement tests are primarily located in northeast Oklahoma on the Arbuckle and Wichita uplifts (Figures 2-5 and 2-9); Figure 2-9 shows the location of wells that are drilled into the basement. There are a few wells drilled to basement within close proximity to the proposed site location as shown in Figure 2-9; however, well data and the reference were not provided. Section 2.3.3.2 pg. 32 of the narrative states that there is no core material available for the basement rocks within the AoR. The narrative states core is available from one well, the Marland No. 1 Joynson approximately 12 miles northwest of the site in Kay County. The mineral and petrophysical properties of the basement were described from this well. The narrative states that the well, Wha Zha Zhi API 35-116-44568 was drilled approximately 6.7 miles east of the NBU CCS site, but "[a]dditional information has been held confidential." The narrative states that 41 out of 124 digitized wells have complete stratigraphic thickness of Arbuckle rocks with some depths into the Precambrian basement (pg. 34); however, additional information was not provided to characterize the Reagan Sandstone and the basement. Section 2.2.2 pg. 25 states that an injection profile on the well Williams 7-D 22 API 35113418360000 approximately 20 miles from the site stated the top of the Granite was 4,497 feet and the total depth to be 4,800 feet (Table 2-5). Figure 2-2 estimates the basement at a depth of 4,531 feet; however, the type log in Figure 2-2 does not extend greater than 4,262 feet (NBU No. 15-42).

Local structure and isopach maps were developed from subsurface correlation of available well logs using Petra software. Figure B-5 is a structure map that shows the top of the basement at 3,450-3,400 feet at the proposed injection well locations. Note the elevation in Figure B-5 is not specified as TVD or SSL. Section 1.0 pg. 4 of the narrative, the applicant states that the injection interval is set to be 200 feet above the top of the underlying basement rocks to avoid significant pore pressure changes within the basement rocks in order to minimize induced seismicity risk; however, the application lacked site-specific data regarding the stratigraphic formations below the injection zone.

The seismicity of the area is discussed in Section 2.5. This section discusses general knowledge related to seismicity and how earthquakes can be expressed by intensity or magnitude. It discusses the importance of instrumental seismology and how the entire country is not adequately covered by seismographs, therefore many small events are felt but may not be recorded or detected. Section 2.5.1 pg. 53 discusses seismicity in the region and includes Table 2-9 that is data compiled from the USGS Earthquake catalogue and includes seismic events that occurred between 1981 and 2023 with a magnitude of 2.5 or greater. Figure 2-22 are the reported earthquakes between 2000-2023 with a magnitude of 2.5 and greater surrounding the project area. The figure does not identify any earthquakes within the project area. The application states that a magnitude 1.4 earthquake occurred near the southern edge of the AoR (pg. 53); however, details related to the earthquake were not provided and, additionally, data for earthquakes that occurred with a magnitude of less than 2.5 were not provided. The application states that the USGS does not purport to record every earthquake but rather gives a magnitude threshold of approximately 2.4 and a moment magnitude of 2.7 for catalog completeness. The narrative states that the catalog contains no seismic events meeting these thresholds within the AoR, and pg. 54 states the AoR in Osage County, Oklahoma, is seismically quiescent, devoid of both natural and human-induced earthquakes (Figure 2-22).

Section 2.5.1 of the narrative discusses seismicity in the region and states that substantial increases in seismicity across northcentral Oklahoma in the last decade have been generally attributed to human activity. The application states that wastewater injection into the Arbuckle, which directly overlies crystalline basement, has been proposed to hydraulically or elastically perturb the stresses on basement faults, causing them to slip (pg. 55). The narrative states that the area of Osage experienced less than a dozen earthquakes in the decades-long history of the Oklahoma seismic network; however, additional information regarding those earthquakes was not provide. Crain et al. 2017 is referenced in the narrative (pg. 55) to present a possible geologic explanation for the quiescent Osage County; however, this reference was not provided. The narrative acknowledges that the injection of fluid increases the pore fluid pressure in the Arbuckle and, more importantly, in the immediate underlying crystalline basement rock (pg. 55). The narrative further states that all seismic events in southwestern Osage County are spatially and temporally associated with saltwater disposal near the associated faults of the Nemaha Uplift. This section also summarizes the multiple orogenic events that have caused extensive faulting in the crystalline basement in Oklahoma (Thomas, 2014). Section 2.5.2 pg. 57 discusses the seismic risk of the site. The narrative states that a preliminary seismic risk evaluation is conducted for the project area and that the proposed site is in an area of no known faulting. It states that seismic risk is very low based on:

- Low frequency of natural earthquake events near the CCS area
- Low intensity of natural earthquakes felt in the CCS area, with maximum ground motion on the surface being less than or equal to an intensity range of Modified Mercalli Intensity Scale (MMI)=IV
- Low population density near the CCS site limits exposures and impacts
- Lack of injection-induced seismicity in Class I or Class II wells in the area
- There are no known faults in the AoR

Page 58 states that based upon the low seismic risk evaluation for the site, a plan specific to earthquakes should not be required. The application states that a review of “The National Earthquake Information Center” (http://earthquake.usgs.gov/contactus/golden/neic.php) indicates that Osage County site area has a low potential for seismic activity. The narrative states vertical separation between the injection point and basement faults is known to be important for reducing seismicity risk (pg. 61). Fault depth matters because the depth below ground surface controls the total weight of overburden and confining pressure at the fault. Section 2.5.4.1 Induced Seismicity Analysis and Injection Site pg. 63 states a hydraulic conduit from the injection zone to a fault may induce earthquakes (Ellsworth, 2013; this reference was not provided). The narrative further states that the largest injection-induced events are associated with faulting that is deeper than the injection interval, suggesting that the increased pressure into the basement increases the potential for inducting earthquakes (Ellsworth, 2013). In all cases, faults have been reactivated at or in close proximity to Class II injection sites. In some cases, previously unknown faults have been discovered (pg. 63).

Based on a review of the application materials, there is concern that the Reagan Sandstone, which lies between the proposed injection zone and the basement rock may be thin or absent at the project site. Site-specific data was not provided to identify or characterize the Reagan Sandstone or the basement rock at the proposed site. DOE reported significant concerns about the likelihood for seismic activity in the project area from documented pre-existing basement faults that are critically stressed for strike-slip motion. There is concern that the absence of the Reagan Formation would cause direct physical contact of the injection zone to basement rock with the potential for new seismic activity. The DOE report stated that basement structural maps in the application do not provide detailed structural information needed to address these concerns due to sparse well penetrations. The technical review concluded that the application did not contain enough site-specific data regarding the Reagan Sandstone and the basement, and the lack of vertical separation between the injection zone and the basement at the proposed site indicates an unacceptable potential for injection-induced seismicity.

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