DISCLAIMER

Project OASIS (DE-FE0032267)

Task 8.0 Deliverable - Commercialization Plan

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Introduction

The “Optimizing Alabama’s CO_2 Storage in Shelby County: Project OASIS” CarbonSAFE Phase II Project seeks to build on regional data sets that demonstrate that the subsurface within Shelby County, Alabama has the potential to store commercial volumes of CO_2 safely, permanently, and economically. This work builds on the initiatives of the Southeast Regional Carbon Utilization and Storage Acceleration Partnership (SECARB-USA, DE-FE0031830) that identified nearly 500 million metric tonnes of CO_2 emitted on an annual basis from industrial facilities that are not collocated with prospective storage geology (i.e., the Coastal Plain of the Southeastern U.S. in this context). This observation suggests costly investments in connective infrastructure (e.g., pipelines) or exploratory well drilling campaigns are required to identify CO_2 storage opportunities in under-developed areas. While not traditionally thought of for saline storage, these studies suggest that storage prospects in the Valley and Ridge Province of the Appalachian Fold and Thrust Belt occur in relatively flat lying structural panels between thrust faults. For the Project OASIS region, available geologic studies related to hydrocarbon exploration suggest that Cambro-Ordovician carbonates and Cambrian clastic units offer multiple potential storage intervals, and that regional confining systems are present, such as the tectonically thickened Floyd-Parkwood Shale.

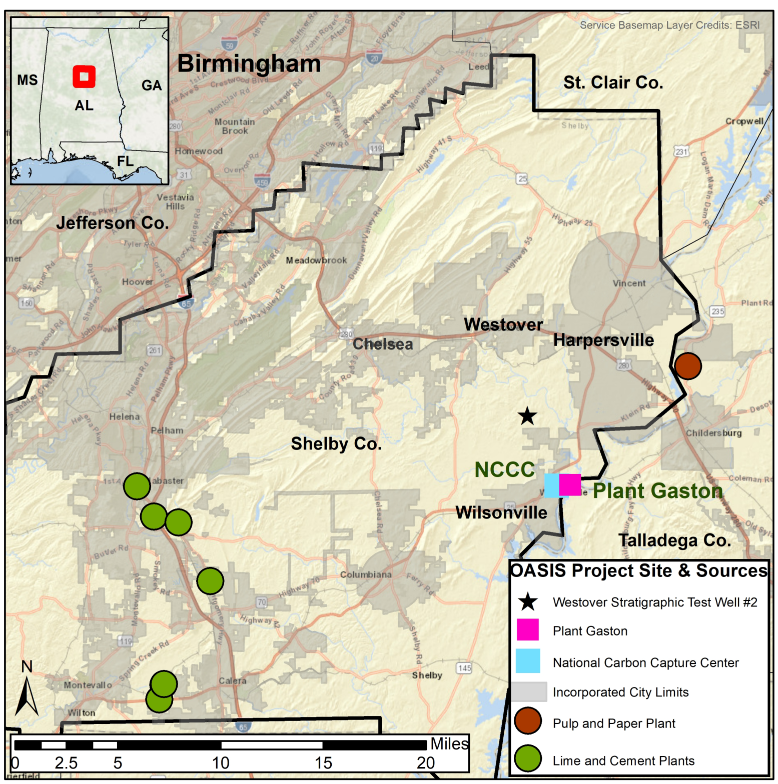

Figure 1. Location of Project OASIS in eastern Shelby County, Alabama. Also shown are regional emitters within relatively close proximity of the OASIS site.

While the project is focused on Plant Gaston as the anchor emitter, there are several additional emitters near the well site. In total, 7,223,779 million metric tons of CO_2 is emitted annually by eight separate facilities within 25 miles of the Project OASIS location (Table 1).

Table 1.CO_2 emitters within 25 miles of the OASIS site.

Industry/Facility Name	2023 CO_2 Emissions (MMT/Year)*	Distance to OASIS (Miles)
Cement and Limestone		
ARGOS Cement	1,054,894	22
Carmuse Lime & Stone Inc.	516,089	18
Cheney Lime and Cement Company	493,165	19
Mississippi Lime Co	462,637	22
Lhoist North America - O'Neal Plant	600,146	17
Lhoist North America - Montevallo Plant	974,682	23
Power Generation		
E C Gaston	2,978,599	4
Pulp and Paper		
Resolute Forest Product - Coosa Pines Operation	153,567	8
Total Emissions	7,233,779	

*Source: EPA FLIGHT 2023

The *Task 8.0 Commercialization Plan* is intended to serve as an overview of considerations relevant to the commercialization of the Project OASIS site, including subsurface characterization efforts and considerations for project economics. Indeed, this file endeavors to archive additional characterization needs for the storage complex to meet Class VI UIC permit requirements, well field design considerations (injection and monitoring wells), and infrastructure/transportation requirements from the region's industrial CO_2 sources. Also included are estimated costs to capture and store CO_2 at the Project OASIS site through the evaluation of separate scenarios. In summary, high capital costs associated with capture island construction and limited CO_2 injectivities observed at the OASIS site complicate project economics, and that achieving CarbonSAFE requirements of 50 million metric tons of CO_2 over a 30-year period is challenging based on current data. Improving on capture island capital expenditures through technology development or identifying a more promising storage solution (e.g., the Rome Formation) in the future may dramatically improve economics and make for a viable project.

Subsurface Analysis

As part of this project, the Project Team drilled a deep stratigraphic test well that penetrated a repeat section (fault bend fold and thrust ramp) of Cambro-Ordovician carbonates of the Alabama Valley and Ridge Geologic Province (Figure 2). This deep stratigraphic test well enabled the collection of sidewall core and geophysical data from several intervals of interest over multiple depths. The drilling program is detailed in the *Task 3.0 Milestone: Site Specific Drilling Report*. Collected sidewall core and whole core were sent for routine and special core analysis at a commercial laboratory. Purchased seismic data, licensed existing regional seismic data, downhole geophysical data, and core data were utilized to create a geologic model for the OASIS site. While summarized here, a detailed overview of these data and the methodologies employed to create the geologic model and dynamic model simulations can be found in the Project OASIS *Task 4.0 Deliverable: Geologic Analysis Report*.

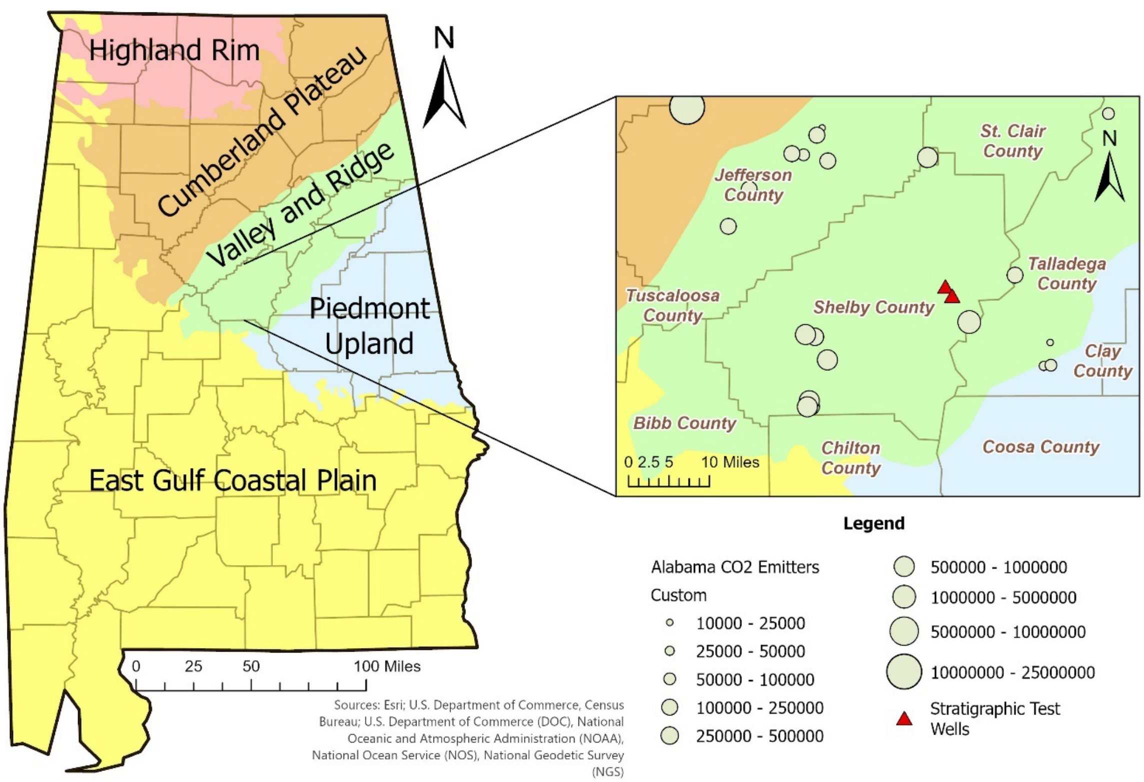

Figure 2. Valley and Ridge Province and regional emitters greater than 60,000 tons per year.

Structural Complexity and Subsurface Data

In support of Project OASIS, new 2D seismic data was collected as part of SECARB-USA (DE-FE0031830). The interpreted section shows a tectonically thickened section of Cambro-Ordovician formations. These data were utilized to relocate the Westover Strat #2 well pad to minimize the drilling challenges associated with drilling through the thick Vandiver shale duplex and provided the unique opportunity to sample a repeat section of the Cambro-Ordovician carbonates that make up the target for the Project OASIS characterization study (Figure 3).

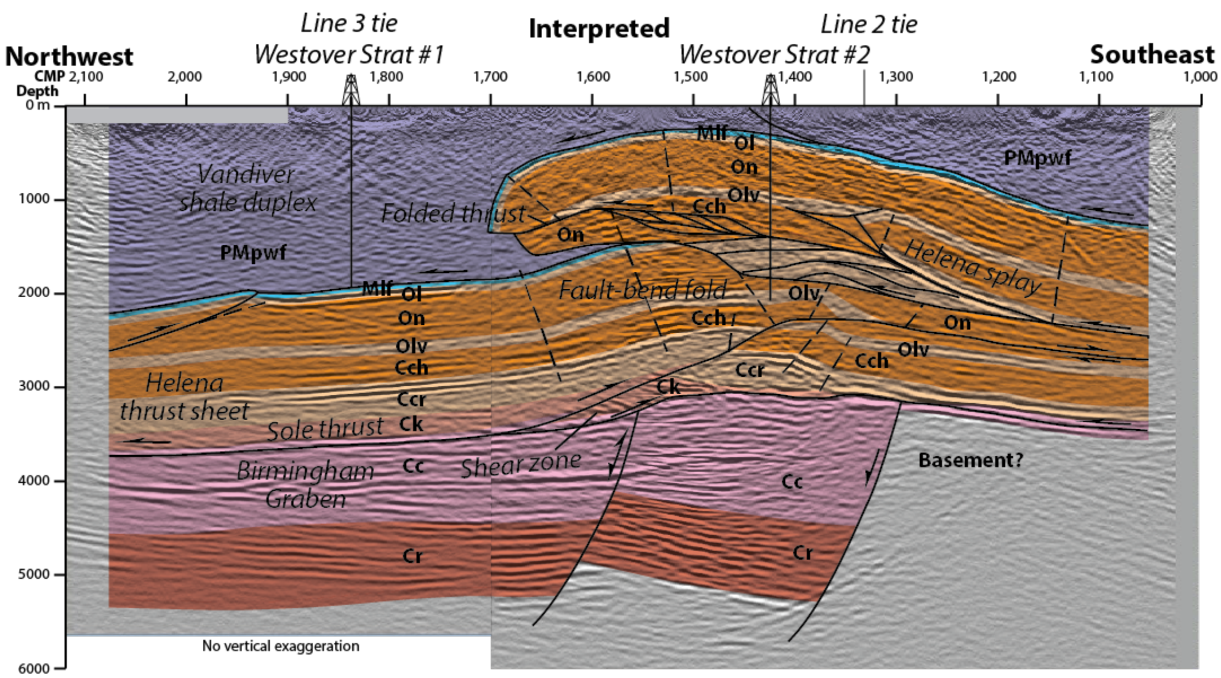

Figure 3. 2D seismic interpretation for the Project OASIS site illustrating the structural complexity of the Valley and Ridge Province in this area.

The Westover Strat #2 was spud on October 10, 2023, and a total depth (TD) of 6,725 ft was reached on November 2, 2023. After reaching total depth, a full suite of wireline logs was deployed, including Gamma Ray, Neutron-Density, Resistivity, Sonic, Magnetic Resonance, and Formation Micro-Imager (FMI) tools. These logs were run from total depth up to the surface casing shoe to evaluate formation properties and structural features. Following the logging operation, a rotary sidewall coring tool was deployed with 60 planned sampling points. However, due to issues related to rock hardness and borehole instability, only 49 coring attempts were executed, from which 39 sidewall cores were successfully recovered.

The logged interval consists of a stacked sequence of extremely tight carbonate rocks with very limited matrix porosity. The formation is heavily fractured, though the majority of these fractures are sealed with calcite, significantly restricting their contribution to effective permeability. Across the entire section, porosity remains consistently low, generally below 3%. Slightly elevated porosity values are observed in zones associated with fracturing, suggesting that the limited reservoir potential is largely fracture-dependent. Petrographic evaluations of whole core and sidewall core samples further enforce the observations of the open hole logging data. Here, thin sections of the Knox Group show poor primary porosity and limited permeability, with late fractures commonly filled with calcite cement.

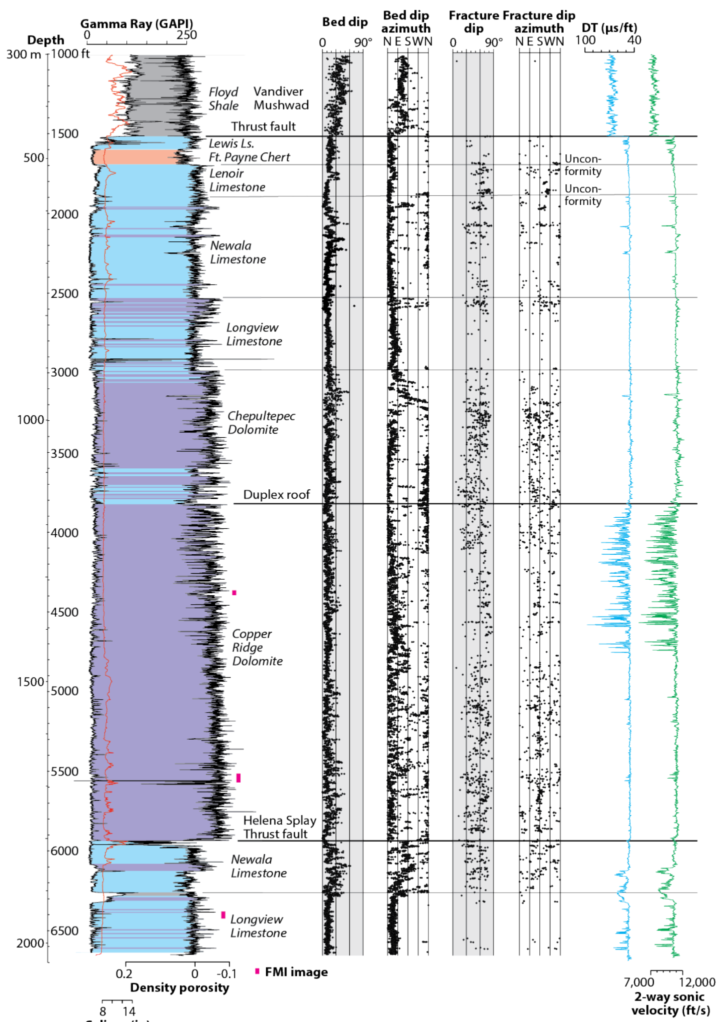

Figure 4. Summary of Westover #2 logging, including the gamma ray, density, sonic, and bedding dip information derived from FMI logs.

Geologic Model and Dynamic Simulations

Based on well log data from the Westover #2 well, the Copper Ridge Member of the Knox Group was assessed as a potential fractured reservoir for CO_2 storage. A new seismic interpretation allowed for the extrapolation of thrust ramp structures across a broader 182-square-mile area, which was subsequently incorporated into the regional geologic model. Key stratigraphic surfaces, including the top of the Knox Group, major formations, and the basement, were mapped by gridding seismic picks. A synthetic seismogram was created using well logs, providing a reliable time-to-depth conversion for these seismic surfaces. The final geologic model integrated seismic data, well logs, and regional mapping to produce structural surface maps and a preliminary reservoir framework. This framework served as input for dynamic reservoir simulation using *CMG GEM's* compositional equation-of-state simulator.

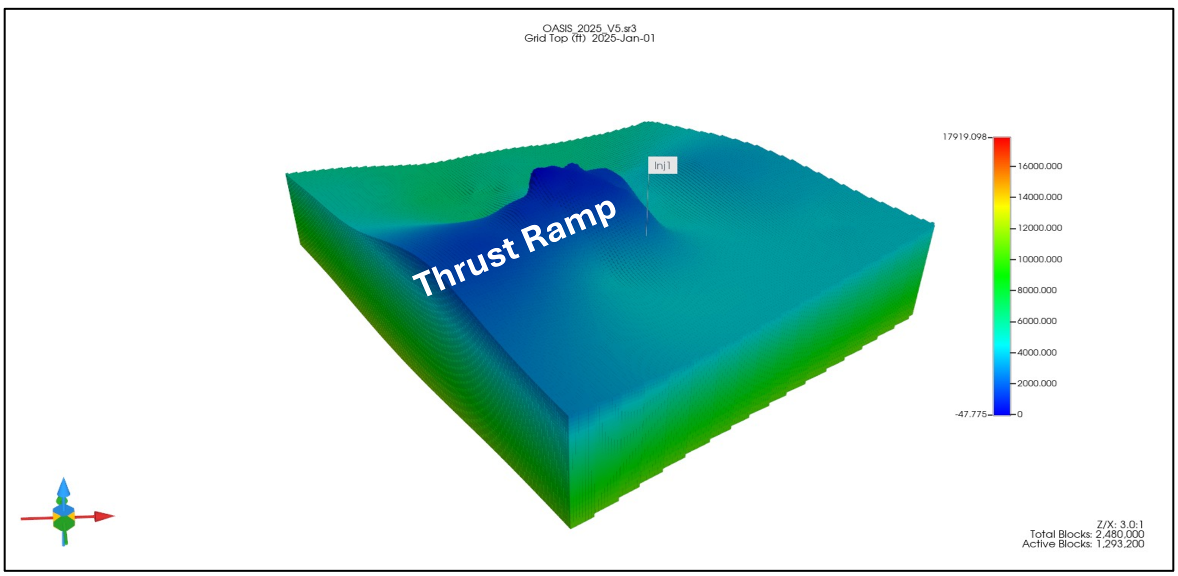

Figure 5. 3D model of the Project OASIS site utilized for reservoir modelling purposes.

Initial modeling focused on estimating potential CO_2 injection rates, total injected mass, and plume extent within a 25-square-mile area of the characterized thrust ramp near the Westover #2 well. The reservoir was initially treated as a closed system due to regional faulting. A series of sensitivity analyses were then conducted to assess the impact of varying boundary conditions, injection gradients, well configurations, and target zones. These scenarios helped define a range of possible injection capacities, addressing the uncertainties stemming from sparse regional data. Geological analysis drew from logs collected in the Westover #1 and #2 wells, as well as additional regional log and seismic data, maps, and published literature. This analysis informed the development of the reservoir layering scheme. Thin, higher-permeability and porosity "sweet spots" were identified and included in the model to reflect vertical heterogeneity indicated by available data. In the absence of site-specific measurements, relative permeability curves for carbonates were sourced from published studies and proprietary sandstone data libraries.

The model area was expanded utilizing collected and purchased regional seismic data to interpret the structure over the expanded 182 square mile study area as compared to the 25-square-mile area described in the preceding paragraph. Accordingly, new structure maps were created and incorporated into the dynamic reservoir model. The image above (Figure 5) demonstrates a 3D view of the finalized reservoir, highlighting the thrust ramp structure. The thrust ramp is interpreted to have a higher degree of fracturing, leading to enhanced permeability and porosity. As a result, the reservoir model has incorporated the Knox Fracture Zones into the model, which have higher permeability and porosity (2mD and 5% compared to the matrix values of 0.24mD and 0.54%), but are limited to the thrust ramp area.

Figure 6 shows an example profile view of a modeled CO_2 plume while Table 2 shows numerical modelling results for various development scenarios (Knox Fracture Zone, Knox Fracture Zone Perforated for the Entire Section, and the Deep Rome Formation). The stabilized injection rate per year for the scenarios presented in Table 2 provides the basis for the cashflow model presented in subsequent sections.

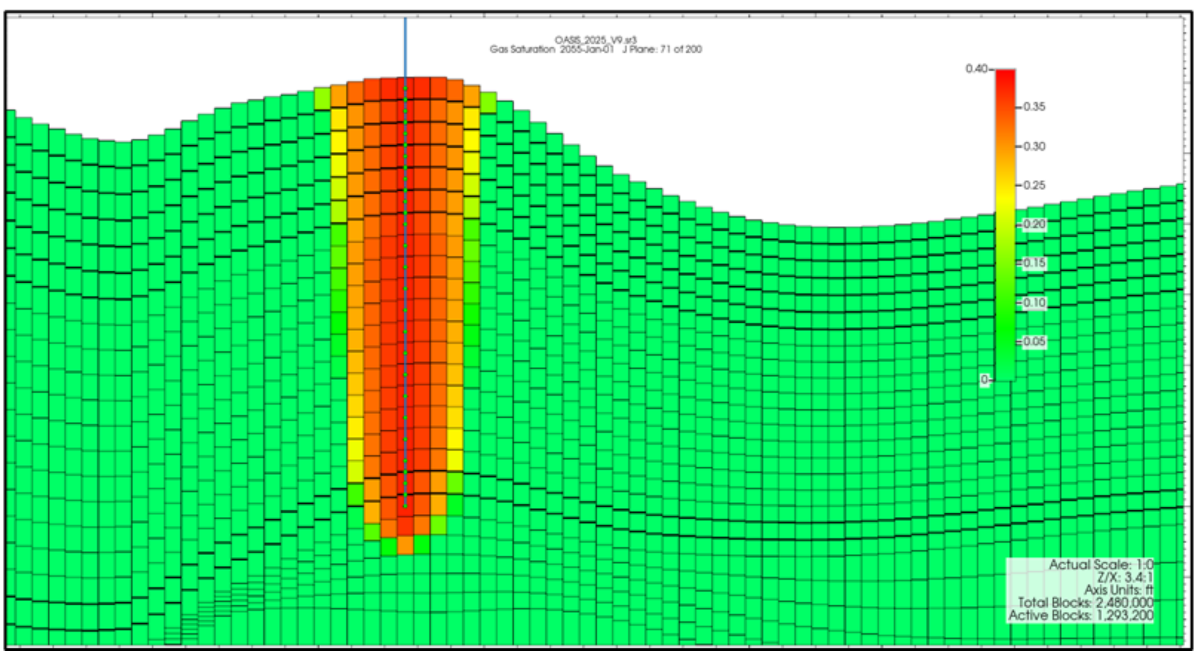

Figure 6. Cross-Sectional View of CO_2 Plume at the End of Injection - Gas Saturation.

Table 2. Summary of the dynamic modelling sensitivity analysis, showing injectivity for three different modelling scenarios.

Numerical Modeling Results		
Injection Scenario	**Stabilized CO_2 Injection Rate per Year (million tonnes/year)**	**Wells to Reach 50 million tonnes of CO_2 over 30 Years***
Knox Fracture Zone	0.02	84
Knox Fracture Zone – Perforate Entire Knox Section	0.06	28
Rome Injection-(Theoretical)	1.33	2

Storage Cost Considerations

As described in the preceding section, both static and dynamic modeling suggest that the known storage resource at the Project OASIS site (excluding the Rome Formation) is limited. Table 2 above shows the modeled dynamic capacity for the OASIS site for several injection scenarios. To determine costs associated with developing the OASIS site, estimated Authorization for Expenditure (AFE) costs for injection wells and monitoring wells were developed (see Table 3). The well cost encompasses all major components, including site preparation, drilling, and well completion, along with the installation of monitoring equipment and the use of corrosion-resistant alloys designed to ensure long-term integrity and full compliance with Class VI regulatory requirements. Well bore schematics for the Knox Group and Rome Formation are included in this document as Appendix A and B, respectively, while the detailed AFEs are included as Appendix C and D.

Table 3. Well cost estimates developed for various OASIS injection scenarios.

Injection Scenario	Cost for each Injection Well*	Cost for Each in-Zone Monitoring Well*	Cost for Each Above-Zone Monitoring Well*
Knox Fracture Zone – Perforate Entire Knox Section	$8,201,200	$7,902,505	$4,378,800
Rome Injection – (Theoretical)	$17,684,075	$13,109,530	$7,012,970

*AFE details included as Appendix A and B.

Capital costs for constructing numerous injection wells and the associated monitoring program may prove to be cost prohibitive for emitters in the region. For example, assuming the scenario where the entire Knox section is perforated, 27 separate injection wells with a total capital cost of over $221 million USD will be required to achieve CarbonSAFE objectives of injecting 1.6 million metric tons of CO_2 per annum. It is important to note that this figure does not include monitoring wells, which would likely sum to 14 separate wells with a capital cost of an additional $110 million USD. It is possible that more favorable storage geology is observed in the deep Rome Formation, however, this formation was not sampled directly as part of the OASIS project and the figures included in Table 2 are inferred from other regional data. Future studies to support storage in the Rome Formation may provide a pathway to commercial scale storage as the necessary capital costs associated with injection and monitoring wells would be greatly reduced.

Transportation Cost Considerations

As part of a broader evaluation of cost considerations, the Project OASIS team evaluated the capital investment and operating costs associated with transporting regional CO_2 emissions via pipeline to the OASIS site (see Table 1) and compared these estimates to CO_2 transportation cost curves developed for 0.5, 1.0, and 2.0 million metric tons of CO_2 over distances of 25, 100, and 400 km. For these calculations, a fixed pipeline cost of $280,000 USD per inch-mile was used, which represents a combination of existing cost models available through DOE-NETL and existing studies, such as the Project ECO_2S CarbonSAFE Phase III pipeline front-end engineering and design study (Dombrowski et al., 2023). In all cases except for the Resolute Pulp and Paper facility, transportation via CO_2 pipeline is cost effective (Figure 7). For the Resolute Pulp and Paper facility, the transport cost per ton of CO_2 is high ($42.55/ton), owing to the

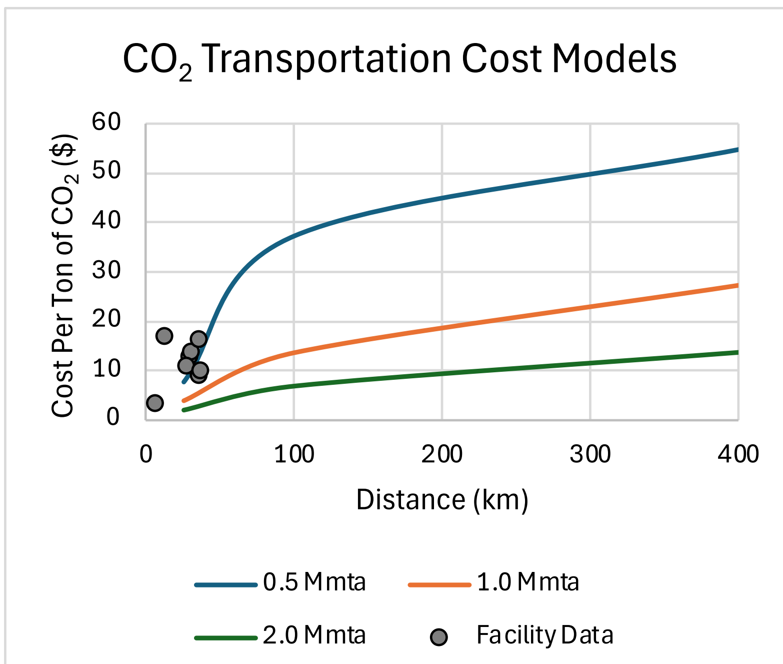

Figure 7. CO_2 pipeline transportation cost curves and calculated cost associated with transporting CO_2 for each of the eight regional emitters.

relatively low volume of emissions. Due to its higher volume of emissions and proximity to the OASIS site, Plant Gaston represents the lowest cost to transport CO_2 of the facilities included in the dataset ($10.11/ton).

CarbonSAFE Eligible Project

Figure 8. Satellite image illustrating cashflow model scenario. Alabama Power Company's Plant Gaston is shown (green dot, bottom right), along with existing transmission rights-of-way (white lines), and the Project OASIS site (white diamond).

The construction of a CarbonSAFE project could advance based on revised geological work to allow a minimum of 50 million tons of CO_2 to be stored in 30 years. While technically feasible, it appears that development based on our current understanding of the OASIS site is cost prohibitive. To develop a detailed understanding of cashflow, the Project OASIS Team evaluated a hypothetical scenario wherein CO_2 is captured at Alabama Power Company's Plant Gaston, transported 4-miles via an 8-inch diameter pipeline (Figure 8), and injected into the Knox Group (entire section perforated) utilizing 27 separate injection wells. Two scenarios are explored, driven by difference in capital cost estimates for post combustion capture on a natural gas combined cycle power plant. OPEX estimates are fixed and equivalent to 20% of the total capital requirements. The input parameters for the cashflow model for each scenario are shown in Table 4. It should be noted that the two capture islands (650 MW and 557 MW) capturing equivalent amounts of CO_2 would imply different capture efficiencies. However, for the purposes of these calculations, this is disregarded as a minor consideration.

Table 4. Assumptions used to support cashflow model development for OASIS.

Parameter	Scenario 1	Scenario 2	Assumption
Capture Island CAPEX, $M	845.00	1,322.00	Scenario 1 is a 650 MW NGCC retrofit[1]; Scenario 2 is a 557 MW NGCC retrofit[2]
Pipeline CAPEX, $M	7.50	7.50	4-mile, 8-inch diameter[3]
Injection Wells CAPEX, $M	221.40	221.40	27 total wells at 0.06 Mmta[4]
Monitoring Wells CAPEX, $M	110.60	110.60	14 total wells[4]
Total CAPEX, $M	1,184.50	1,661.50	
Total O&M (over 30 yrs), $M	236.90	332.30	20% of total capital
Annual CO_2 injection	1.6 Mmta	1.6 Mmta	Held constant for simplification
45Q Credit	$85/t	$85/t	IRS Section 45Q Tax Credit for saline storage, 12-year window
Project Life	30 yrs	30 yrs	

[1]OCED Portfolio Insights: Carbon Capture in the Power Sector: https://www.energy.gov/sites/default/files/2024-04/OCED_Portfolio_Insights_CC_part_i_FINAL.pdf; used for the low-end capture island capital estimate

[2]Stoles, J., 2024, Retrofittable Advanced Combined Cycle Integration for Flexible Decarbonized Generation (557 MW NCCC retrofit); used for the high-end capture island capital estimate

[3]National Energy Technology Laboratory, FECM/NETL CO_2 Transport Cost Model (2023)

[4]OASIS AFEs developed by ARI

Note that in-field pipe is not included in this scenario

For the cashflow model, 100% debt financing was assumed for all capital associated with project development, which includes capital associated with (1) capture island construction, (2) pipeline construction, and (3) storage field construction (injection and monitoring wells). All debt is repaid within the first 12 years of operation which coincides with the timeframe that the IRS Section 45Q tax credit can be realized. Annual net cashflows for years 1 through 12 are equivalent to revenues generated through the IRS Section 45Q tax credit with debt service and operating expenses subtracted. For years 13 through 30, annual net cashflows represent only the operating expenses associated with the project as the IRS Section 45Q tax credit can no longer be realized and all debt has been repaid. Over 30 years, the total net cashflow for Scenario 1 (lower capture island capital requirement) and Scenario 2 (high capture island capital requirement) are **negative** $211 million USD and **negative** $951.5 million USD, respectively, indicating a deeply uneconomic project based on current information. Detailed cost estimates and cashflows are included in Table 5 below.

Table 5. Cashflows for the OASIS site for the two development scenarios.

Metric	Scenario 1	Scenario 2
CAPEX, $M	1,184.50	1,661.50
OPEX (30 yrs total), $M	236.90	332.30
Annual OPEX, $M	7.90	11.08
Annual Debt Payment (5%, 12 yrs)[1], $M	133.80	187.60
Total Debt Repayment (12 yrs), $M	1,606.00	2,251.10
Annual Net Cashflow (Years 1 – 12)[2], $M	–5.73	–62.67
Annual Net Cashflow (Years 13 – 30)[3], $M	–7.90	–11.08
Total Net Cashflow (30 yrs), $M	–211.00	–951.50

[1]Assumes 100% debt financing of CAPEX at 5% APR

[2]Annual net cashflow = IRS Section 45Q revenue - OPEX - debt service; debt is fully paid in 12 years

[3]Annual net cashflow for Years 13 through 30 represents OPEX only

Note that discount rates and PISC are not included in these calculations

The cashflow models above show the constraints of this hypothetical project primarily reside in capital expenditures associated with capture island construction and injection field development. Further, preliminary results indicate that 27 injectors targeting the Knox Group would require a minimum of nearly 32,000 acres of pore space rights (see Figure 9).

While currently not a viable option, future work may prove that CO_2 can be stored safely and securely in the Rome Formation. Given the improved storage potential in the Rome Formation, the number of injection and monitoring wells is reduced greatly to achieve CarbonSAFE requirements (two injection wells, two monitoring wells). This reduction in storage field development costs improves the commercial outlook for CO_2 capture in the

Vally and Ridge and results in a project that is cashflow positive over a 30 year period (~ $200 million USD for Scenario 1), but will likely still necessitate reductions in capture island costs associated with Nth-of-a-kind deployment as opposed to the costs of current early-stage captures system. Although the Valley and Ridge may not currently appear commercially viable for CO_2 storage projects, the insights gained from completing Project OASIS will serve as a valuable guide for other emitters in the region considering smaller-scale injection projects or for other projects considering similar terrain throughout the Appalachian fold and thrust belt.

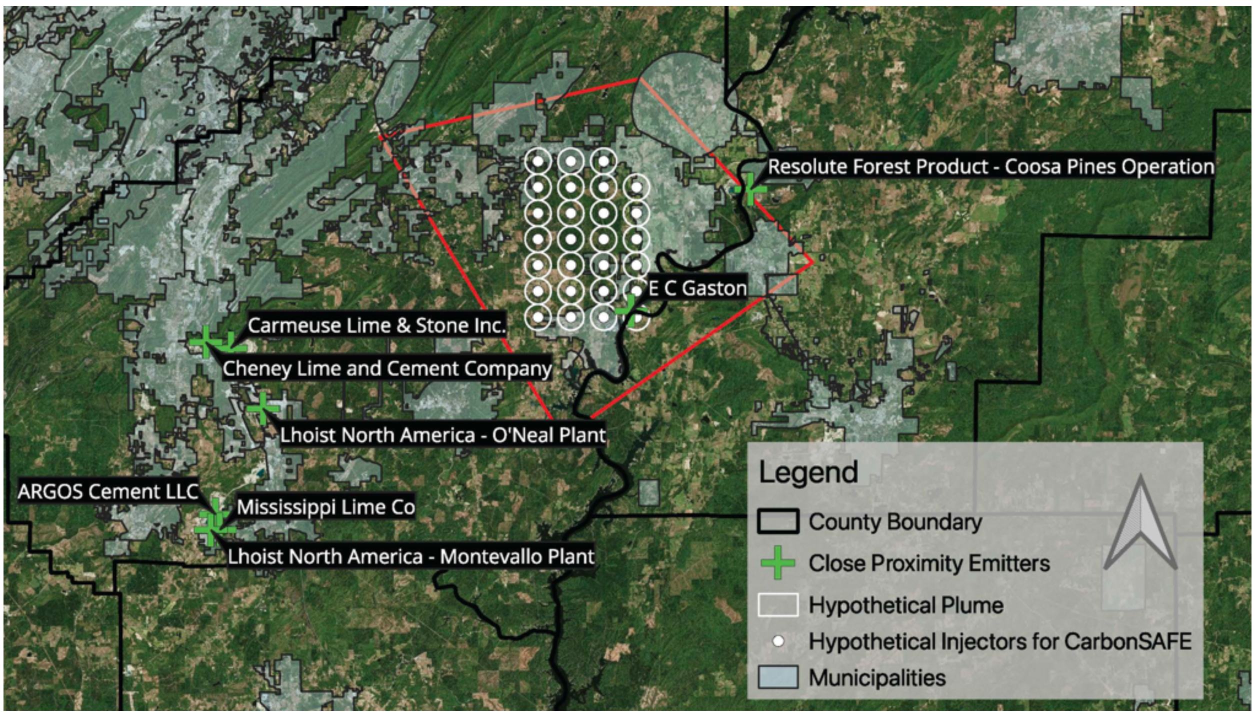

Figure 9. Satellite image illustrating the 27 injection-well scenario included in the cashflow model. The 27 injection wells and their modelled CO_2 plume account for approximately 32,000 acres. The red polygon represents the 182 square-mile domain included in the regional geologic model.

Regional Project Considerations

As illustrated in Figure 1 and Table 1, eight emitters within 25 miles of the OASIS site release more than 7 million metric tons of CO_2 per year. Excluding Plant Gaston from consideration highlights a group of smaller local emitters that could potentially support the development of a smaller-scale storage project near the study area. Table 6 provides estimated CO_2 volumes at a 90% capture rate based on 2023 emissions data, along with the number of injection wells required to store the captured CO_2 from each facility (assuming the whole Knox Group is perforated).

Table 6. Low-volume emitters within proximity of the Project OASIS location and number of wells needed to inject the facilities emissions into the Knox Group (assuming entire section is perforated).

Industry/Facility Name	90% capture of 2023 CO_2 Emissions (MMT/Year)	Total Wells needed at 60,000 Tons Per Year
Cement and Limestone		
ARGOS Cement	949,404	16
Carmeuse Lime & Stone Inc.	464,480	8
Cheney Lime and Cement Company	443,848	8
Mississippi Lime Co	416,373	7
Lhoist North America - O'Neal Plant	600,146	9
Lhoist North America - Montevallo Plant	877,213	15
Pulp and Paper		
Resolute Forest Product - Coosa Pines Operation	153,567	3

Among these emitters, Mississippi Lime and Resolute Forest Products are the smallest and would require comparatively modest storage fields, with 7 and 3 injection wells, respectively. Mississippi Lime could potentially target low-population areas within the modelled domain (red box, Figure 9). Resolute Forest Products could similarly pursue storage in lower-population areas within the modelled domain. This scenario would require nearly 20 and 7 miles of CO_2 pipeline for Mississippi Lime and Resolute, respectively. Notably, it is possible that there are proximal storage solutions for these lower volume emitters in low population areas such as the Cahaba Wildlife Management area, however, there is currently not sufficient data in these areas to evaluate prospectivity.

Lessons from the Westover 1 and Westover 2 drilling campaigns emphasized the importance of seismic acquisition to confirm accessibility of target formations in the Valley and Ridge. Figure 10 shows additional seismic lines available for purchase, which may support targeting alternative storage locations in the region. Several lines are available for purchase near the I-65 cement and lime facilities, suggesting opportunities to explore for prospectivity in this region. Finally, the Project OASIS *Task 3.0 Milestone – Site-Specific Drilling Report*, may serve as a tool to regional emitters by providing critical guidance for subsurface exploration in similar terrain and offering a comprehensive evaluation of Knox Group data, potentially reducing the cost of future exploration.

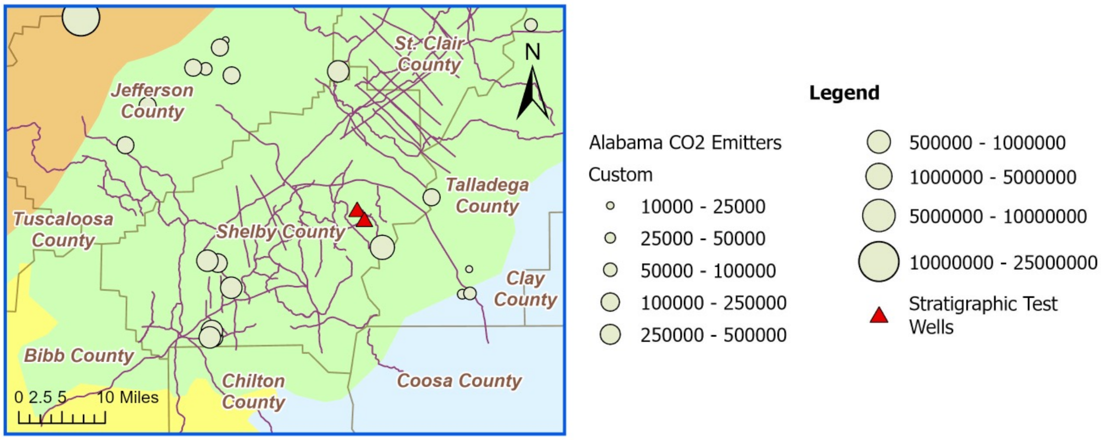

Figure 10. Existing seismic data available for purchase and regional emitters near Project OASIS.

Alternative Options

Emitters in the Shelby County, Alabama area that are considering near-term CO_2 capture but prefer to avoid the uncertainties of evaluating the Rome Formation for storage may need to explore alternative CO_2 storage or utilization pathways. The OASIS project site lies roughly 40 miles east of the Black Warrior Basin and about 90 miles north-northeast of the Coastal Plain (Figure 11).

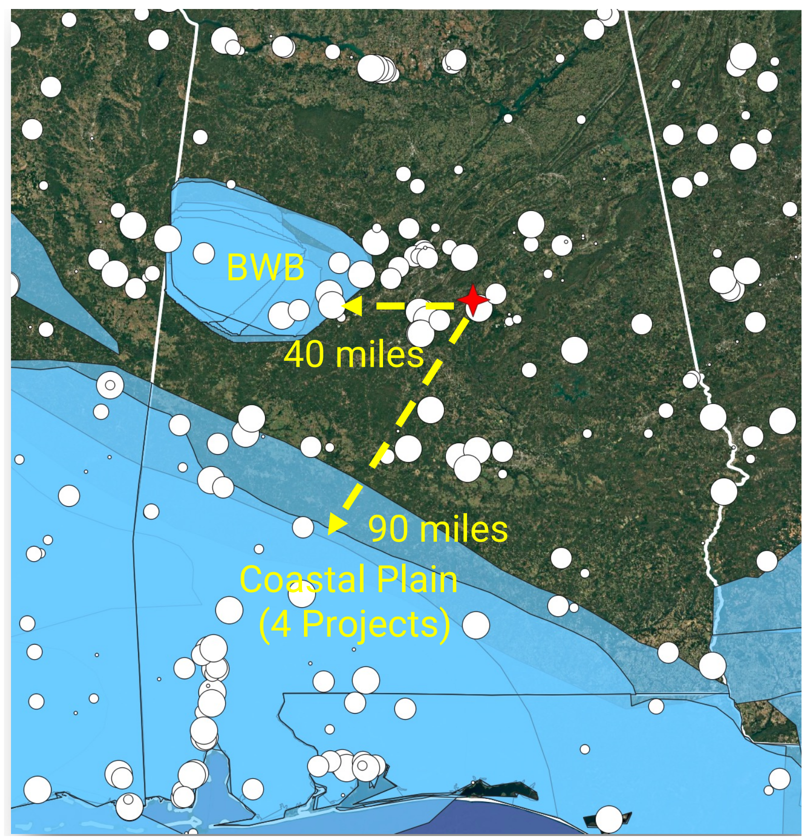

Figure 11. Map illustrating the location of OASIS (red star), regional emitters (white), and distance to known saline storage opportunities of the Black Warrior Basin (BWB) and the Coastal Plain.

The Black Warrior Basin, spanning western Alabama and eastern Mississippi, has an extensive history of oil and natural gas production and could become a significant consumer of CO_2 if operators pursue enhanced oil recovery (EOR) or enhanced gas recovery (EGR). In 2010, a pilot test was conducted in a mature coalbed methane well in the Blue Creek Degasification Field, Alabama. The test involved injecting 3,250 barrels of water and 252 tons of CO_2 in a series of slugs over two months to assess whether CO_2 injection could improve gas recovery. Results indicated that post-test production performance improved substantially relative to the four years preceding injection. During the first year, gas production was limited by the return of injected water, but as water rates declined, gas output increased by more than 50% compared to pre-injection levels. Long-term performance gains appeared linked to several mechanisms, including removal of wellbore scale, dissolution of cleat-filling calcite, and methane displacement as CO_2 was adsorbed into the reservoir matrix (Pashin, 2015). While small in scale, the test demonstrated the potential of CO_2 injection to enhance gas recovery in the Black Warrior Basin, suggesting that larger-scale trials could further validate its effectiveness. At present, Advanced Resources International (ARI) is assessing opportunities for EOR and EGR in the Black Warrior Basin through the SECARB-USA project. Results from this work may provide operators with valuable insights into future CO_2 utilization potential in the region.

Companies located in the Valley and Ridge region may also look to the south for potential storage options in one of the four known projects located in the Coastal Plain region of Alabama. Here, storage costs are expected to be dramatically improved due to the high injectivities observed in the Cretaceous sandstones that are commonly targeted as CO_2 reservoirs. The Cretaceous section of the Alabama Coastal Plain consists primarily of a thick succession of sandstones, siltstones, and shales that dip gently toward the Gulf of Mexico. The section includes regionally extensive sand dominated formations, such as the Tuscaloosa Group, which are known to possess high porosity and permeability. The regional continuity of these formations, combined with their depth provide sufficient pressure and temperature conditions for CO_2 to remain in a supercritical state, maximizing storage efficiency. Overall, the Cretaceous section offers favorable geologic characteristics for long-term carbon storage if transport is financially viable. The tradeoff here would be the expected higher transportation costs associated with moving CO_2 over distances as high as 150 miles.

Challenges to Commercialization

Any integrated Carbon Capture, Utilization, and Storage (CCUS) project must overcome a series of challenges during development, construction, and operations. In the Valley and Ridge region, one of the most immediate hurdles is the limited suitability of the Knox Group for CO_2 storage. Projects considering the Knox will likely require very large storage fields with a high number of wells. This, in turn, leads to expansive Areas of Review (AOR), making landowner engagement and pore space acquisition a substantial undertaking. The large number of injection and monitoring wells needed to develop the Knox also puts considerable pressure on project economics. These economic pressures are compounded by the structure of the federal 45Q tax credit, which is only guaranteed for 12 years. For many projects, this timeframe may not be long enough to recover the significant upfront capital required for capture, transportation, and storage infrastructure before the tax credit expires.

In addition, the land footprint required for a CarbonSAFE-scale project is substantial (~ 32,000 acres or more). Public concerns over CO_2 storage at this scale, along with related pipeline construction, could pose a major barrier to project progress. While Alabama law does provide for unitization of CO_2 storage, projects must still reach the required threshold of landowner consent to trigger unitization. If public perception issues create resistance, permitting delays could occur at the capture site, along the pipeline route, or within the storage field.

Finally, large, integrated CCUS projects are particularly sensitive to cost escalation. Inflation and permitting delays can both increase costs significantly, making timely development and public acceptance critical to the success of these efforts.

Conclusions

At present, large-scale commercial CCUS development in the Valley and Ridge region of Alabama have limited viability. This project highlighted several key challenges: difficult drilling conditions, constrained storage capacity, and large AOR that necessitate numerous wells to accommodate CarbonSAFE-scale volumes. These geologic limitations make development of a regional storage facility particularly challenging.

Given these constraints, emitters in the region may find smaller, single-emitter projects more practical than pursuing a large, integrated CarbonSAFE project. They may also need to consider alternatives to local storage, such as CO_2 utilization or transportation of CO_2 by truck or pipeline to other regional storage facilities in Alabama.

Looking ahead, opportunities could improve with advances in capture technology, cost reductions in Nth-of-a-kind systems, and successful demonstration of safe, permanent CO_2 storage in the Rome Formation. In the interim, smaller projects may consider transporting CO_2 by truck or pipeline to storage or utilization sites in the Coastal Plain (e.g., the existing Longleaf CarbonSAFE Class VI project) or for future EOR/EGR applications in the Black Warrior Basin.

References

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Appendix A – Knox Group Well Bore Schematics

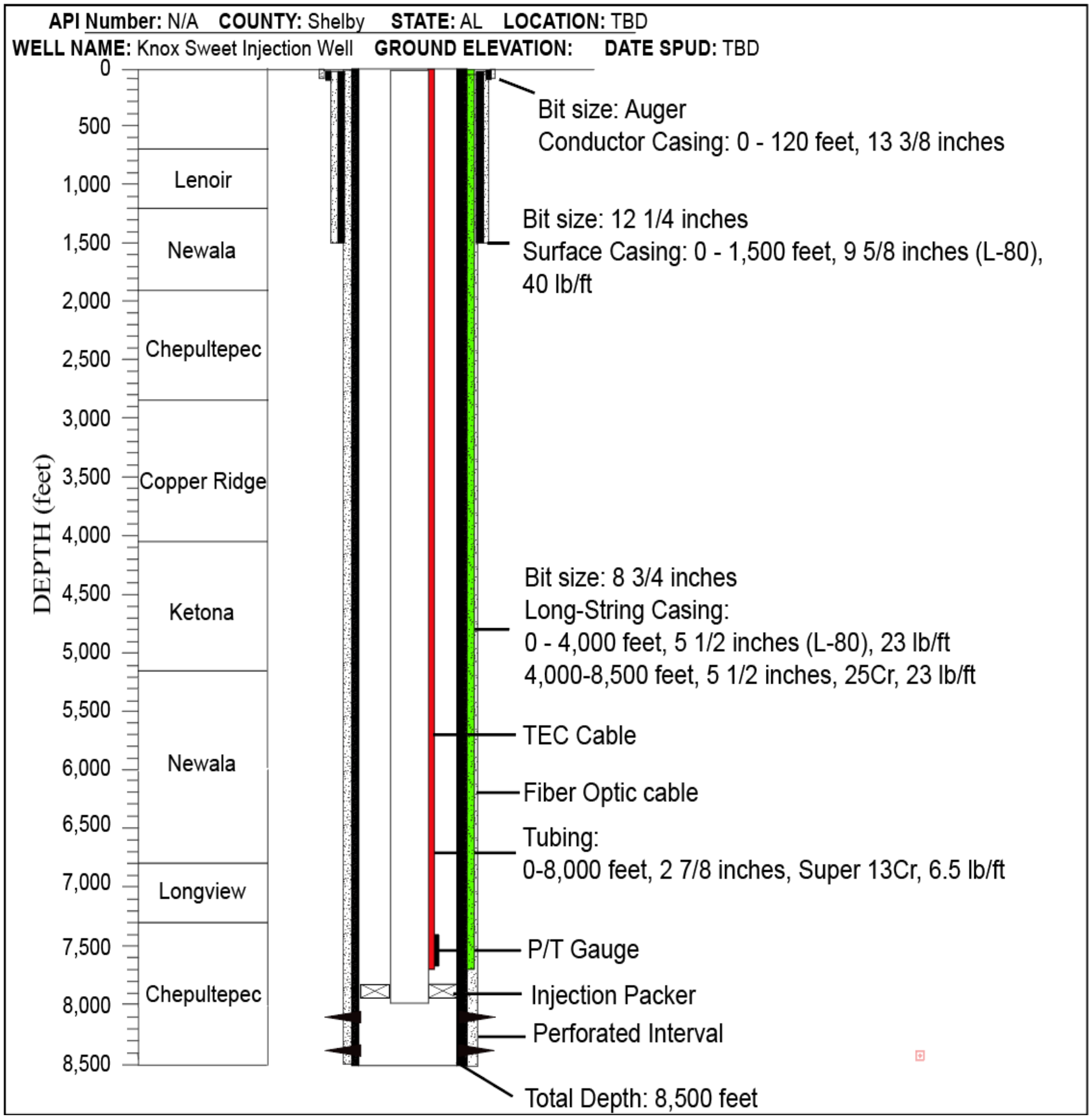

Figure 12. Knox Group injection well schematic.

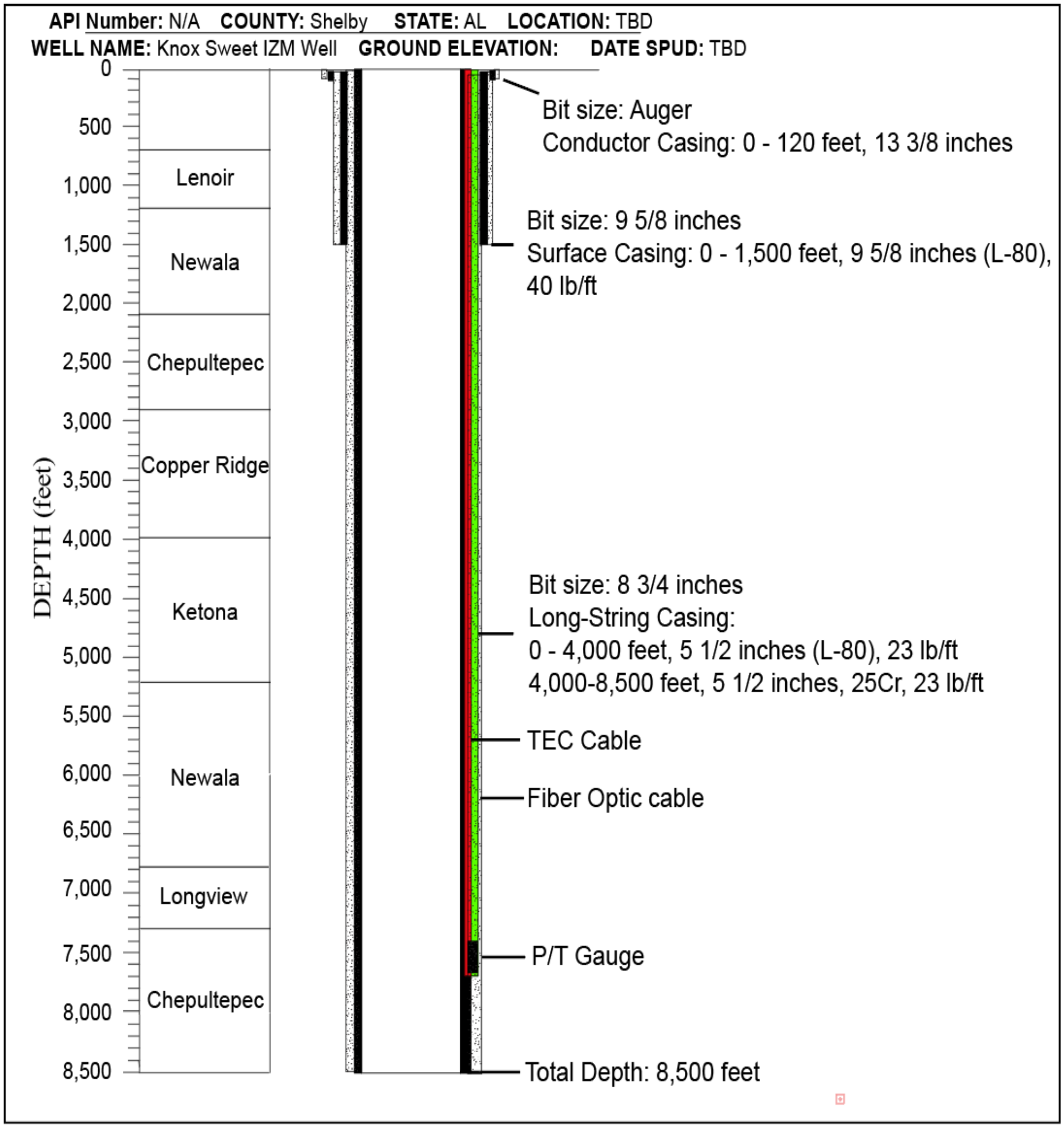

Figure 13. Knox Group in-zone monitoring well bore schematic.

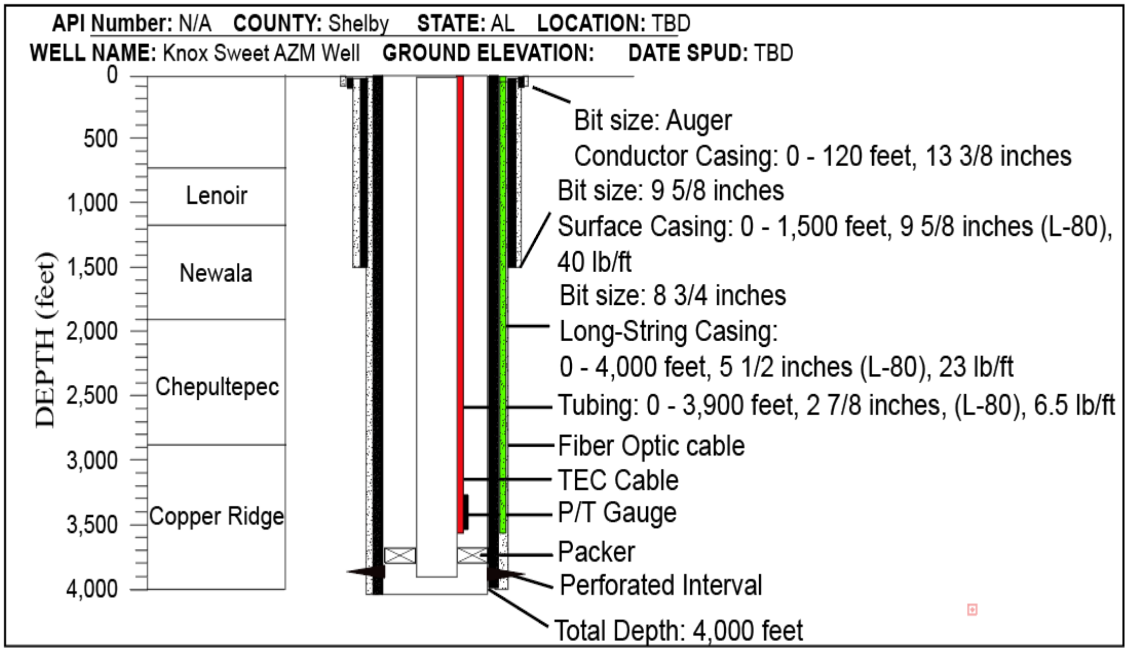

Figure 14. Knox Group above-zone monitoring well bore schematic.

Appendix B – Rome Formation Well Bore Schematics

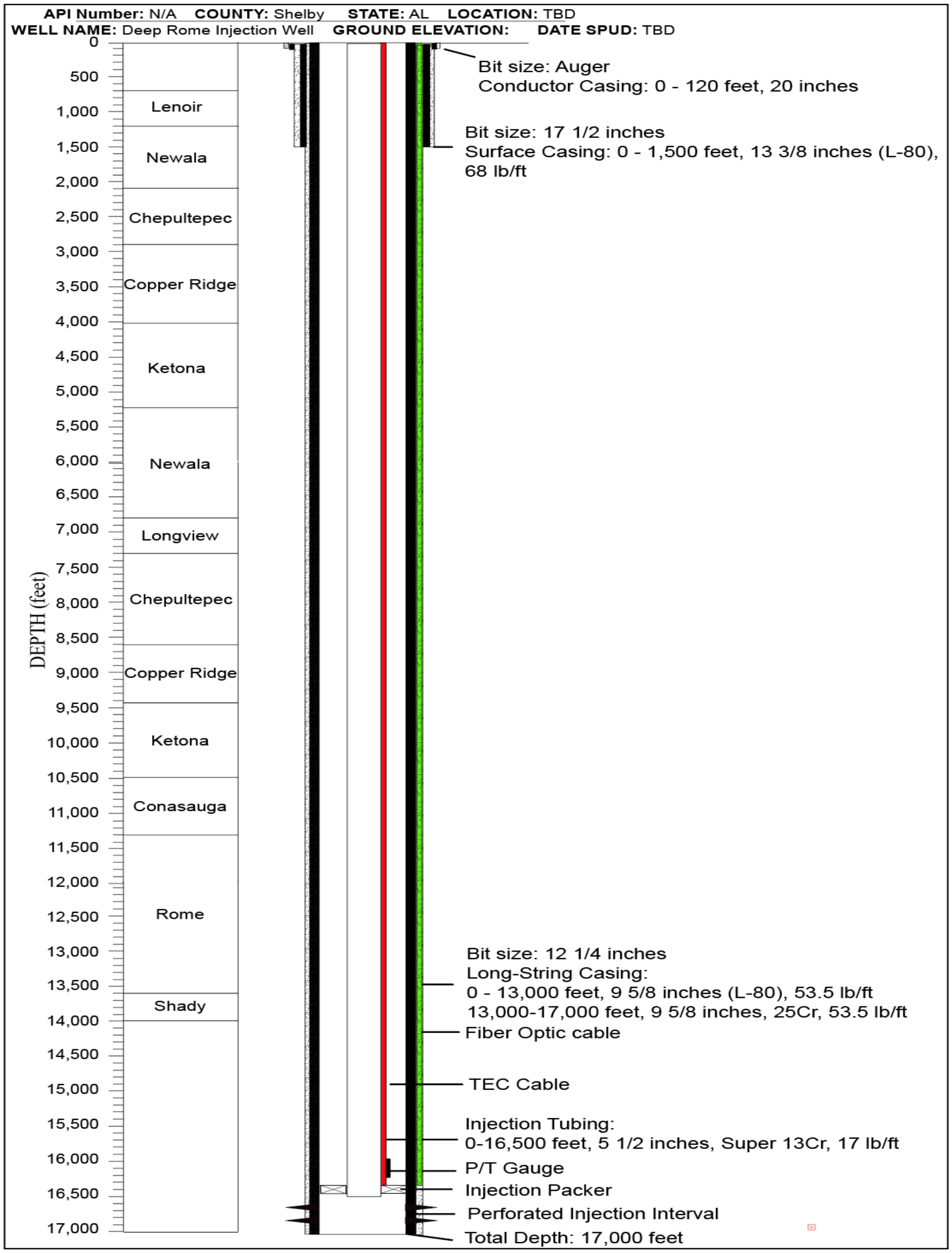

Figure 15. Rome Formation injection well bore schematic.

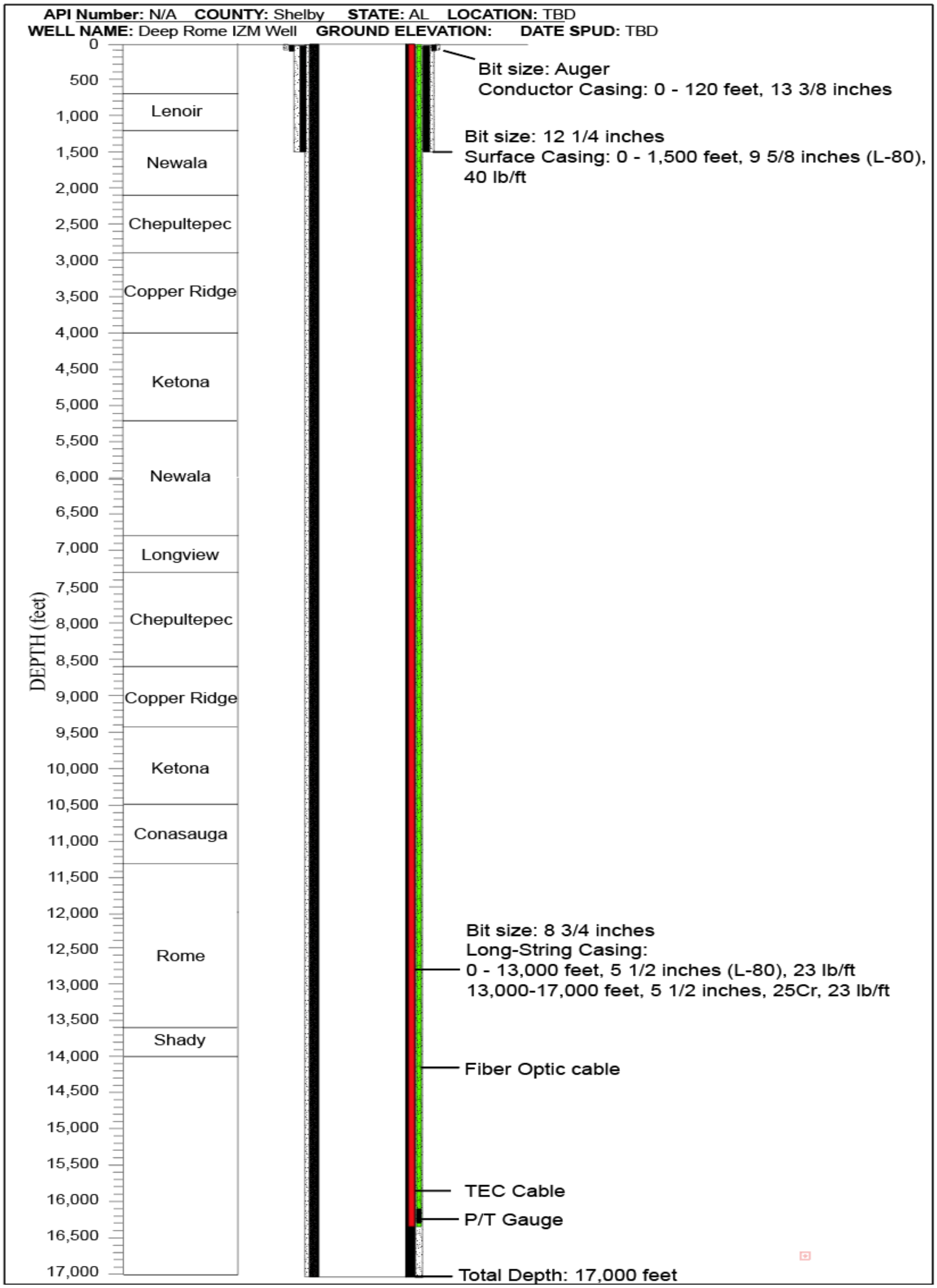

Figure 16. Rome Formation in-zone monitoring well bore schematic.

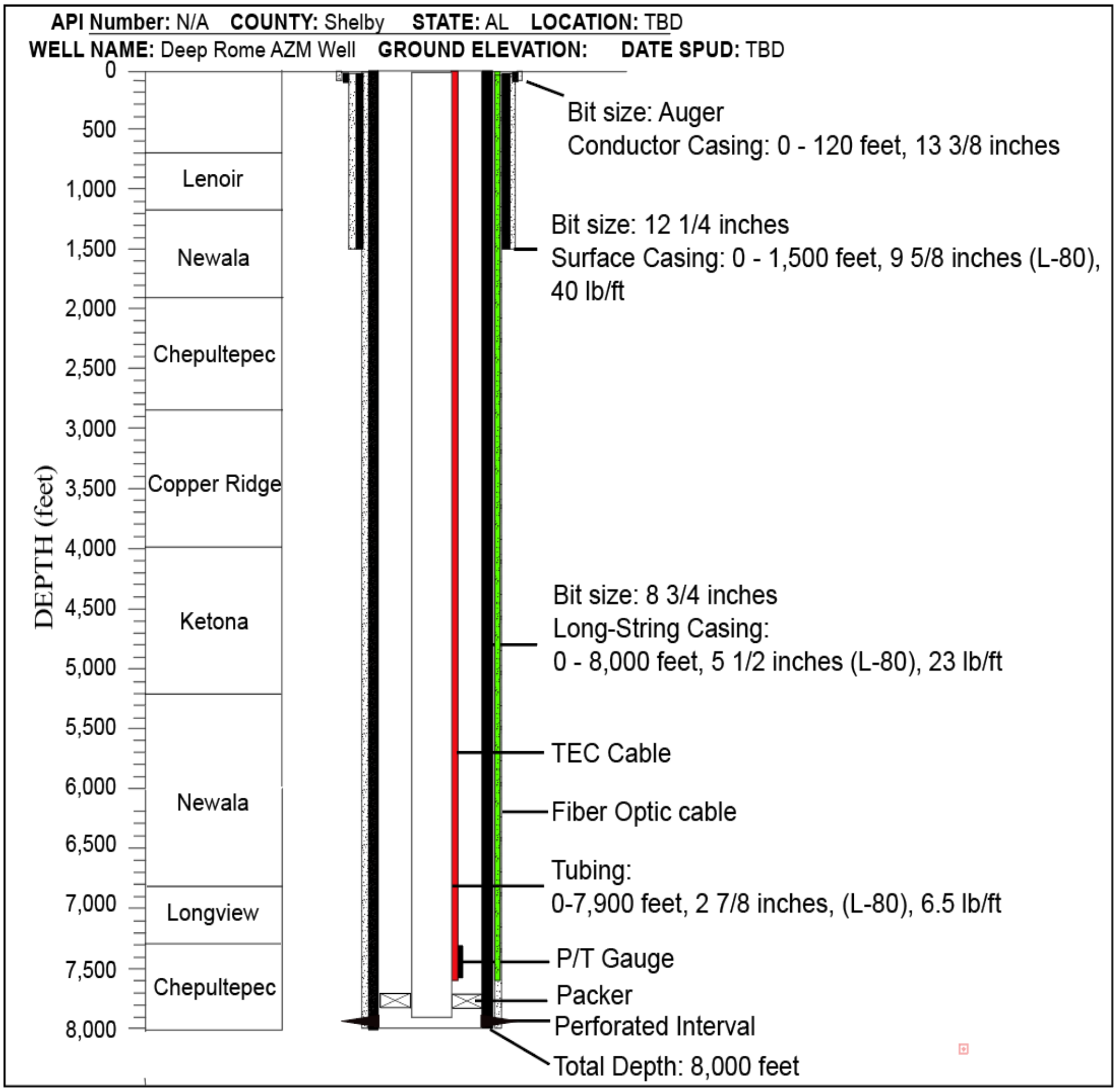

Figure 17. Rome Formation above-zone monitoring well bore schematic.

Appendix C – Injection and Monitoring Well AFEs for the Knox Group

Cost Type	Description	5.5" Injection Well	5.5" In-Zone Monitoring Well	5.5" Above-Zone Monitoring Well
	FIXED COST			
Fixed	Casing(Surface)	$71,430	$71,430	$71,430
Fixed	Casing (Long String)	$1,196,270	$1,339,325	$109,520
Fixed	Tubing	$208,000	$0	$31,200
Fixed	Wellhead	$55,000	$55,000	$50,000
Fixed	Rig Prepayment	$0	$0	$0
Fixed	Mob/Demob Prepayment	$0	$0	$0
Fixed	Living Quarters Prepayment	$0	$0	$0
Fixed	Location Lease	$10,000	$10,000	$10,000
Fixed	Insurance	$10,000	$10,000	$10,000
Fixed	Permits & Fees	$5,000	$5,000	$5,000
Fixed	Civil Engineering Fees and Inspections	$25,000	$25,000	$25,000
Fixed	ARI-Allocated Overhead	$0	$0	$0
Fixed	Miscelaneous Fixed Costs	$0	$0	$0
	Total Fixed Costs	$1,580,700	$1,515,755	$312,150
	WELL LOCATION PREPARATION			
Lump Sum	Survey	$5,000	$5,000	$5,000
Lump Sum	Location Staking & Positioning	$10,000	$10,000	$10,000
Lump Sum	Wellsite Clearing, Road Preparation, Civil Engr.	$150,000	$150,000	$150,000
Lump Sum	Matting	$170,000	$170,000	$100,000
Lump Sum	Mob/Demob	$300,000	$300,000	$300,000
Lump Sum	Wellsite Reclamation	$50,000	$50,000	$50,000
Lump Sum	Water Well Digging/Water System	$25,000	$25,000	$25,000
Lump Sum	Conductor Casing(Casing, Driving, and Cement)	$65,000	$65,000	$65,000
Lump Sum	Miscelaneous Wellsite Preperation Cost	$0	$0	$0
	Total Preparations/MOB	$775,000	$775,000	$705,000
	DRILLING & W/O OPERATIONS			
Variable	Drilling Rig	$1,560,000	$1,440,000	$840,000
Variable	Workover Rig/Drilling Rig Crew and Catering	$0	$0	$0
Variable	Drilling Mud	$260,000	$240,000	$140,000
Variable	Mud Engineer	$0	$0	$0
Variable	Solids Control/Mud Equipment	$210,000	$210,000	$122,500
Variable	Mud Logging Services	$75,000	$75,000	$37,500
Variable	Non Potable Water	$14,000	$14,000	$7,500
Variable	Drill Bits	$250,000	$250,000	$125,000
Variable	PVT and Monitoring	$90,000	$90,000	$52,500
Variable	Directional Driller/Tools	$500,000	$500,000	$250,000
Variable	Rig Fuel	$245,000	$245,000	$150,000
Variable	Frac Tanks	$14,000	$14,000	$10,000
Variable	Rig Standby Charges	$0	$0	$0
Variable	Mud/Cuttings Disposal Cost	$250,000	$250,000	$150,000
Variable	Drill Pipe/Collar Inspection	$30,000	$30,000	$20,000
Variable	Miscelaneous Drilling Cost	$0	$0	$0
	Total Drilling Operations	$3,498,000	$3,358,000	$1,905,000
	WELL MONITORING			
Variable	Fiber Optic Cable	$80,000	$85,000	$39,000
Fixed	Fiber Optic Interrogator(DTS)	$75,000	$75,000	$75,000
Fixed	Electronic Pressure Gauges	$50,000	$50,000	$50,000
Variable	Electronic Gauge Cable(TEC)	$28,000	$29,750	$14,000
Fixed	Electronic Gauge Accessories(Carriers/SDA/Splices)	$25,000	$25,000	$10,000
Variable	Well Moitoring Accessories(Clamps/Centralizers)	$8,000	$8,000	$3,900
Variable	External Casing Perforating Guns	$0	$35,000	$0
Lump Sum	Installation Services	$125,000	$125,000	$75,000
Lump Sum		$0	$0	$0
Lump Sum		$0	$0	$0
Lump Sum		$0	$0	$0
Lump Sum		$0	$0	$0
	Well Monitoring and Completion Tools	$391,000	$432,750	$266,900
	COMPLETION			
Lump Sum	Casing Running Services	$175,000	$175,000	$85,000
Lump Sum	Casing Cement	$500,000	$500,000	$350,000
Lump Sum	Cased Hole WL Logging Services	$50,000	$50,000	$40,000
Lump Sum	WL Perforating	$15,000	$0	$15,000
Lump Sum	Packers and Flow Control	$75,000	$0	$25,000
	Total Completion Costs	$815,000	$725,000	$515,000
	PLUG AND ABANDONMENT			
Lump Sum	Well Abandonment Cement	$375,000	$375,000	$175,000
Lump Sum	Bridge Plugs and Cement Retainers	$0	$0	$0
Lump Sum	Abandonment Wireline Services	$0	$0	$0
Lump Sum	Miscelaneous Abandonment Cost	$0	$0	$0
	Total Completion Costs	$375,000	$375,000	$175,000
	General			
Variable	Supervision	$162,500	$150,000	$87,500
Variable	Wellsite Rentals(Fork Lift,Trash, Generators, Lights, Telehandlers)	$97,500	$90,000	$52,500
Variable	Safety	$52,000	$48,000	$28,000
Variable	Transportation/Trucking	$65,000	$60,000	$35,000
Variable	Fuels-Non Rig/Drilling	$16,250	$15,000	$15,000
Variable	Communications(Phone, Satellite, Internet)	$58,500	$54,000	$31,500
Variable	Fresh/Drinking Water	$9,750	$9,000	$5,250
Variable	Security/Gate Guard	$0	$0	$0
Fixed	Living/Sleeping Quarters	$305,000	$295,000	$245,000
	Total General Costs	$766,500	$721,000	$499,750
	No Contingency	$8,201,200	$7,902,505	$4,378,800

Appendix D – Injection and Monitoring Well AFEs for the Rome Formation

Cost Type	Description	9.625x 5.5 " Injection Well	5.5" In-Zone Monitoring Well	5.5" Above-Zone Monitoring Well
	FIXED COST			
Fixed	Casing(Surface)	**$121,425**	**$71,430**	**$71,430**
Fixed	Casing (Long String)	**$3,380,030**	**$1,449,100**	**$219,040**
Fixed	Tubing	**$1,897,500**	**$0**	**$63,200**
Fixed	Wellhead	**$65,000**	**$50,000**	**$50,000**
Fixed	Rig Prepayment	**$0**	**$0**	**$0**
Fixed	Mob/Demob Prepayment	**$0**	**$0**	**$0**
Fixed	Living Quarters Prepayment	**$0**	**$0**	**$0**
Fixed	Location Lease	**$10,000**	**$10,000**	**$10,000**
Fixed	Insurance	**$10,000**	**$10,000**	**$10,000**
Fixed	Permits & Fees	**$5,000**	**$5,000**	**$5,000**
Fixed	Civil Engineering Fees and Inspections	**$25,000**	**$25,000**	**$25,000**
Fixed	ARI-Allocated Overhead	**$0**	**$0**	**$0**
Fixed	Miscelaneous Fixed Costs	**$0**	**$0**	**$0**
	Total Fixed Costs	**$5,513,955**	**$1,620,530**	**$453,670**
	WELL LOCATION PREPARATION			
Lump Sum	Survey	**$5,000**	**$5,000**	**$5,000**
Lump Sum	Location Staking & Positioning	**$10,000**	**$10,000**	**$10,000**
Lump Sum	Wellsite Clearing, Road Preparation, Civil Engr.	**$150,000**	**$150,000**	**$150,000**
Lump Sum	Matting	**$500,000**	**$500,000**	**$250,000**
Lump Sum	Mob/Demob	**$300,000**	**$300,000**	**$300,000**
Lump Sum	Wellsite Reclamation	**$50,000**	**$50,000**	**$50,000**
Lump Sum	Water Well Digging/Water System	**$25,000**	**$25,000**	**$25,000**
Lump Sum	Conductor Casing(Casing, Driving, and Cement)	**$120**	**$65,000**	**$65,000**
Lump Sum	Miscelaneous Wellsite Preperation Cost	**$0**	**$0**	**$0**
	Total Preparations/MOB	**$1,040,120**	**$1,105,000**	**$855,000**
	DRILLING & W/O OPERATIONS			
Variable	Drilling Rig	**$3,000,000**	**$2,760,000**	**$1,440,000**
Variable	Workover Rig/Drilling Rig Crew and Catering	**$0**	**$0**	**$0**
Variable	Drilling Mud	**$500,000**	**$460,000**	**$240,000**
Variable	Mud Engineer	**$0**	**$0**	**$0**
Variable	Solids Control/Mud Equipment	**$437,500**	**$402,500**	**$210,000**
Variable	Mud Logging Services	**$172,500**	**$157,500**	**$75,000**
Variable	Non Potable Water	**$25,000**	**$24,000**	**$15,000**
Variable	Drill Bits	**$750,000**	**$750,000**	**$300,000**
Variable	PVT and Monitoring	**$187,500**	**$172,500**	**$90,000**
Variable	Directional Driller/Tools	**$1,150,000**	**$1,050,000**	**$500,000**
Variable	Rig Fuel	**$450,000**	**$440,000**	**$275,000**
Variable	Frac Tanks	**$25,000**	**$24,000**	**$15,000**
Variable	Rig Standby Charges	**$0**	**$0**	**$0**
Variable	Mud/Cuttings Disposal Cost	**$500,000**	**$500,000**	**$300,000**
Variable	Drill Pipe/Collar Inspection	**$75,000**	**$75,000**	**$35,000**
Variable	Miscelaneous Drilling Cost	**$0**	**$0**	**$0**
	Total Drilling Operations	**$7,272,500**	**$6,815,500**	**$3,495,000**
	WELL MONITORING			
Variable	Fiber Optic Cable	**$0**	**$170,000**	**$79,000**
Fixed	Fiber Optic Interrogator(DTS)	**$75,000**	**$75,000**	**$75,000**
Fixed	Electronic Pressure Gauges	**$50,000**	**$50,000**	**$50,000**
Variable	Electronic Gauge Cable(TEC)	**$0**	**$0**	**$27,650**
Fixed	Electronic Gauge Accessories(Carriers/SDA/Splices)	**$45,000**	**$25,000**	**$10,000**
Variable	Well Moitoring Accessories(Clamps/Centralizers)	**$0**	**$17,000**	**$7,900**
Variable	External Casing Perforating Guns	**$0**	**$35,000**	**$0**
Lump Sum	Installation Services	**$150,000**	**$150,000**	**$100,000**
Lump Sum		**$0**	**$0**	**$0**
Lump Sum		**$0**	**$0**	**$0**
Lump Sum		**$0**	**$0**	**$0**
Lump Sum		**$0**	**$0**	**$0**
	Well Monitoring and Completion Tools	**$320,000**	**$522,000**	**$349,550**
	COMPLETION			
Lump Sum	Casing Running Services	**$375,000**	**$350,000**	**$150,000**
Lump Sum	Casing Cement	**$900,000**	**$750,000**	**$450,000**
Lump Sum	Cased Hole WL Logging Services	**$150,000**	**$125,000**	**$75,000**
Lump Sum	WL Perforating	**$25,000**	**$0**	**$25,000**
Lump Sum	Packers and Flow Control	**$125,000**	**$0**	**$25,000**
	Total Completion Costs	**$1,575,000**	**$1,225,000**	**$725,000**
	PLUG AND ABANDONMENT			
Lump Sum	Well Abandonment Cement	**$600,000**	**$550,000**	**$350,000**
Lump Sum	Bridge Plugs and Cement Retainers	**$0**	**$0**	**$0**
Lump Sum	Abandonment Wireline Services	**$0**	**$0**	**$0**
Lump Sum	Miscelaneous Abandonment Cost	**$0**	**$0**	**$0**
	Total Completion Costs	**$600,000**	**$550,000**	**$350,000**
	General			
Variable	Supervision	**$312,500**	**$287,500**	**$150,000**
Variable	Wellsite Rentals(Fork Lift,Trash, Generators, Lights, Telehandlers)	**$187,500**	**$172,500**	**$90,000**
Variable	Safety	**$100,000**	**$92,000**	**$48,000**
Variable	Transportation/Trucking	**$125,000**	**$115,000**	**$60,000**
Variable	Fuels-Non Rig/Drilling	**$31,250**	**$28,750**	**$28,750**
Variable	Communications(Phone, Satellite, Internet)	**$112,500**	**$103,500**	**$54,000**
Variable	Fresh/Drinking Water	**$18,750**	**$17,250**	**$9,000**
Variable	Security/Gate Guard	**$0**	**$0**	**$0**
Fixed	Living/Sleeping Quarters	**$475,000**	**$455,000**	**$345,000**
	Total General Costs	**$1,362,500**	**$1,271,500**	**$784,750**
	No Contingency	$17,684,075	$13,109,530	$7,012,970