Request for Additional Information [GCS Hackberry (R06-LA-0007)] [Request #A-2] Items 9 and 10

Collier Consulting/The *Hydrodynamics* Group independent cost estimate for groundwater remediation for the planned Hackberry CO_2 sequestration project is provided below. This independent cost estimate is specific to the U.S. EPA request for additional information (Items 9 & 10) for Underground Injection Control – Class VI Permit Application for Hackberry Carbon Sequestration Well No. 001 below.

9	40 CFR 146.85(a)(2)(iv), 40 CFR 146.94	**Background:** The applicant estimates costs for Emergency and Remedial response to be $1,400,000 while the EPA cost estimate tool allocates a range of $16,990,000 and $106,977,000. The applicant did not include an itemized list of costs, making this portion of the application difficult to analyze. **Comment:** Please provide an itemized third-party cost estimate for the activities associated with groundwater remediation that are described in the Emergency and Remedial Response Plan.	Applicant intends to contract with Collier Consulting to prepare an Emergency and Remedial Response Plan to address a potential unforeseen releases of stored fluid which may impact groundwater resources. This written plan will be completed and filed prior to Order to Inject issuance. A planned work scope is included in Appendix L.
10	40 CFR 146.94	**Background:** Scenario 1 of the Emergency and Remedial Response portion of the application includes potential migration of injected fluid outside of the proposed injection and confining zone. In response to this scenario, the applicant plans to amend the permit to include the zones into which the fluid has migrated. **Comment:** Although not specified by regulations, this plan may not be the appropriate response. 40 CFR 146.94(a) indicates that “the requirement to maintain and implement an approved plan is directly enforceable regardless of whether the requirement is a condition of the permit.” Please provide an itemized third-party cost estimate for the “Potential Response Actions” under “CO2 Migration” in the “Emergency and Remedial Response Plan” portion of the application that provides detailed actions in response to the migration of CO2 outside of the targeted injection zone.	Resolved. Added description in Section 8 for event: migration above UCL, but below USDW. In Section 10, increased costs for “Release into Outside Zone” from $150,000 to $900,000.

The Permit response to 40 CFR 146.85(a)(2)(iv) and 40 CFR 146.94 was presented in Appendix I, and **SECTION 8-EMERGENCY AND REMEIAL RESPONSE** in the Underground Injection Control-Class VI Permit Application for the Hackberry Carbon Sequestration Well No. 001.

Permit Appendix I is Sempra’s Emergency Operation Plan for the natural gas storage facility in a solution mined salt cavern. The plan provides an emergency response plan in Section **2.6 <u>Uncontrolled Flow from a Storage Well</u>** for the following storage system scenarios:

- Body Bleed Leak on Well Head Value
- Braden Head Leak
- Cavern Encroachment
- Cavern Subsidence
- Flange Leak on Inlet to Wing Valve
- Grease Fitting Leak on Well Head Value
- Leak in Cement
- Leaking Plug after Well Head Removal but before BOP Installation
- Leaking P-Seal on Well Head
- Salt Fracture
- Seismic Event: Sheared or Collapsed Casing

The Appendix I Sempra Emergency Operation Plan has limited application to the Hackberry CO_2 storage reservoir failure scenarios, and does not specifically address potential remediation of a CO_2 leak into a groundwater/Underground Source of Drinking Water (USDW).

Permit Section 8 provides response plans for the following events:

1. Well Blowout
2. Spill
3. CO_2 Migration
4. Loss of Mechanical Integrity

Event items 3 and 4 have the potential of releasing stored CO_2 into the relatively shallow Chicot aquifer that overlays the areal extent of the Hackberry CO_2 storage reservoir. The following bulleted list was presented for potential response actions for **Item 3-CO_2 Migration** from the storage reservoir and into the groundwater/USDW.

If groundwater/USDW is impacted:

- *Pump carbon dioxide-contaminated groundwater to the surface and aerate it to remove carbon dioxide.*
- *Apply "pump and treat" methods to remove trace elements.*
- *Drill wells that intersect the accumulation in groundwater and extract carbon dioxide.*
- *Provide an alternative water supply if ground water-based public water supplies are contaminated.*

The **Item 4-Loss of Mechanical Integrity** bulleted list of Potential Response Actions were specific to tasks to repair potential leaks in the CO_2 injection well. Potential leakage of CO_2 from the injection well into the groundwater/USDW were not addressed.

1.0 Approach to Analysis

Our independent groundwater remediation plan expands on the Hackberry Carbon Sequestration, LLC's EPA permit application Section 8-Potential Response Actions outlined in Item 3-CO_2 Migration. Response actions for groundwater/USDW impacted resulting from Item 4-Loss of Mechanical Integrity of CO_2 injection well will be essentially the same as Item 3 with the exception of repair/plugging of the well.

We need to understand the design and how the CO_2 storage system will be developed and operated to understand specific potential points of failure in the storage system that may result in CO_2 contamination of the shallow groundwater aquifers. Based on these system failure scenarios we developed a groundwater remediation program. We then prepared costs to implement the remediation program.

2.0 Hackberry CO_2 Sequestration Storage System Design

The design and operation of a porous media underground fluid storage system is based first on the concept of multiple barriers to fluid (natural gas/CO_2) migration, and second on reservoir engineering hydraulic principles. An additional principle is that stored fluid pressures must not compromise the stability or integrity of the storage reservoir by creating potential pathways (fractures) for fluid migration, and/or the loss of storage space due to chemical reactions.

The proposed storage system is designed to store up to 4.5 MM Metric Tons per year (MT/yr) of captured carbon in up to three CO_2 injection wells over a 20-year period. Figure 1 show the location of the planned three CO_2 storage injection wells, and the approximate areal extent of the stored CO_2 below Black Lake, Louisiana. The subject permit is for the injection of 2 MM MT/yr in the Hackberry Carbon Sequestration Well No. 001 over approximately a twenty-year period.

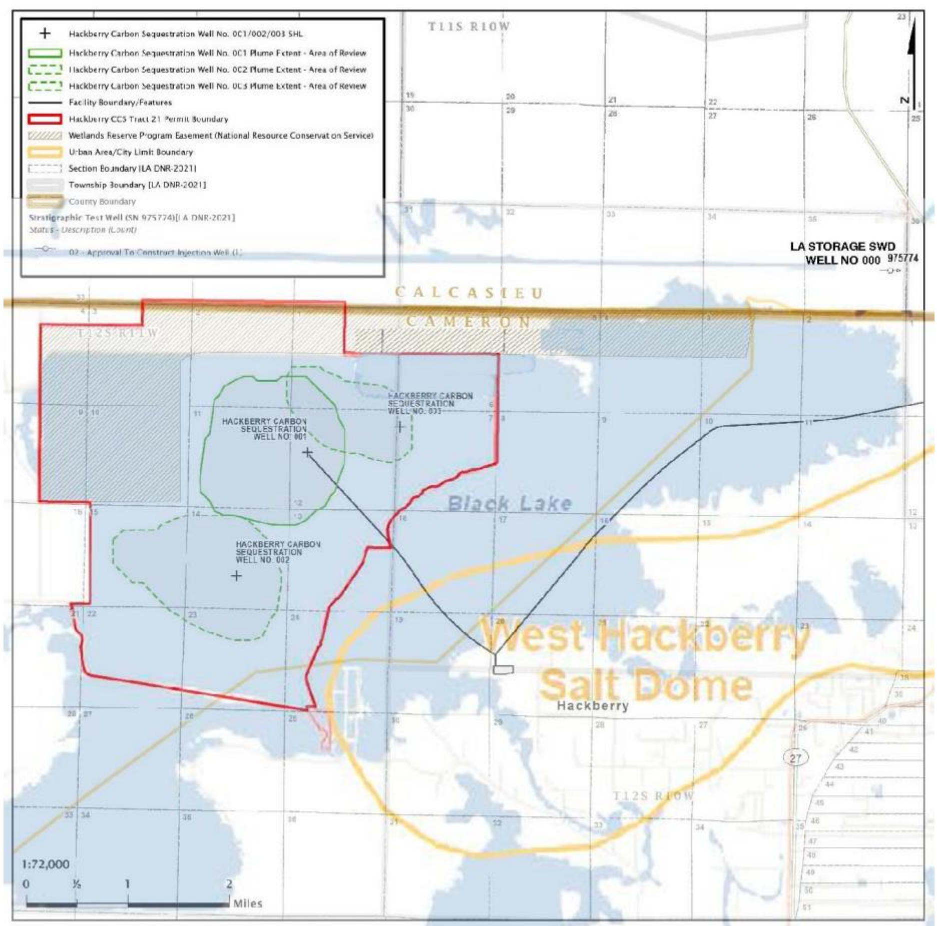


Figure 1. Location of the Hackberry CO2 Sequestration Storage System.

The Hackberry carbon sequestration saline aquifer storage system is designed to store supercritical CO_2 into the extensive Lower Miocene-age sediments at depth (Figure 2). The Lower Miocene-age sediments consist of approximately 5,607 feet of alternating beds of sand and shale at depths between 5,774 feet to over 11,381 feet (Figure 2). The target CO_2 storage system is complicated by the estimated 52 individual sand lenses and 33 shale lenses (Figure 3). The individual sand lenses range in thickness from 8 feet to 185 feet thick. In addition, the individual sand and shale lenses have variable porosity and permeability properties. For purpose of storage system design, the individual lenses have been grouped into 13 CO_2 storage/ intervals. It is important to note that the lenticular extent of these sand and shale lenses from the exploration SWD No. 003 well and planned HCS Well No. 001 is unknown. The Lower Miocene-age sediments are vertically bounded by the Amphistegine-B Shale caprock from 5,477 feet to 5,774 feet (297 feet thickness). The storage system is also bounded by the basement Anahuac Shale at an approximate depth of 11,381 feet.

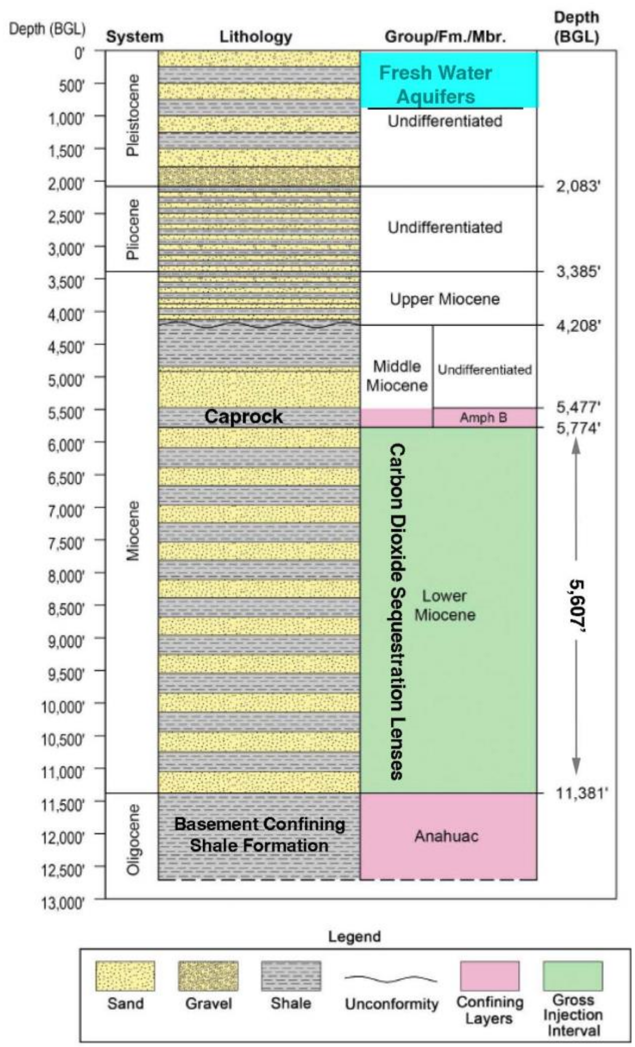


Figure 2. Stratigraphic Column for Hackberry CO2 Storage Reservoir. (Modified from Lonquist Sequestration LLC, 2021)

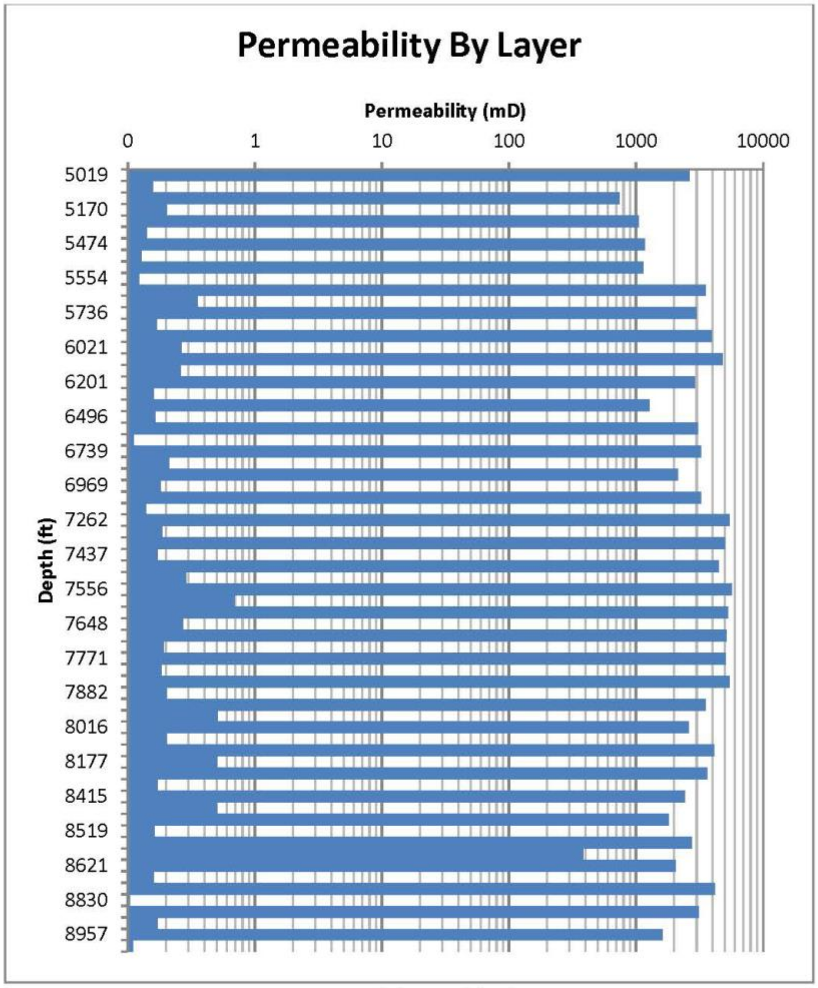


Figure 3. Vertical Distribution of Permeability for Individual Sand and Shale Lens.

In summary, the Hackberry carbon sequestration saline aquifer storage system is not a typical anticlinal structure with a single relatively massive sandstone storage reservoir with a shale caprock storage system. The CO_2 reservoir is essentially a flat lying storage reservoir composed of up to 52 alternating sand and shale lenses over a 7,000+ foot section with a shale caprock. Each sand lenses will basically act as an individual storage reservoir confined by the overlying shale lens. Vertical migration of CO_2 from this storage system will be extremely limited due to the numerous low permeability confining units stacked in the stratigraphic column.

3.0 Potential Storage System Failure Scenarios Evaluation

The key elements of the storage system were evaluated to determine storage system failure scenarios to determine potential 1) impact points in the shallow Chicot groundwater/USDW aquifer, 2) quantity of CO_2 potentially leaked into the aquifer, and 3) areal distribution of the impacts. The results of this analysis were used to develop a responsive groundwater remediation plan, and system costs. Specific storage system elements evaluated were the geological fluid containment structure, the storage system operating parameters, and CO_2 injection well potential leakage points.

3.1 CO_2 Migration Failure Scenario Evaluation

The integrity and operational constraints of the Hackberry Carbon geological fluid containment structure controls the potential migration of CO_2 in the potential storage system failure scenarios. Our understanding of the geological framework of Lower Miocene-age storage aquifer is based on an exploration core hole located approximately six miles northeast of the target CO_2 injection well location (Figure 1), and on an analysis of 2D seismic reflections surveys over the study area.

3.1.1 Structural Geology Framework Evaluation: The structural framework of the Lower Miocene-age CO_2 storage sediments is provided in Figure 3. The sediments are within an east-west asymmetric syncline structure that is bounded by the West Hackberry salt dome on the east flank of the structure (Figure 4). Seismic reflection survey line JKB-489 (Figure 4) provides a geological profile that illustrates the vertical geometry of the carbon sequestration storage system. The CO_2 storage reservoir is laterally unbounded to the north, south, and west. The sediments have a relatively low dip of $\sim 4.5^{\circ}$ downward to the east. This is essentially a flat lying aquifer storage reservoir. The seismic reflection profile (Figure 5) illustrates the disturbance of the Lower Miocene-age deposition sequence with the intrusion of the West Hackberry Salt Dome. Sediments within the disturbance zone were reflected upward against the salt dome. Discontinuities are evident in this disturbance zone that extend into shallower sediments.

The seismic reflection profile (Figure 5) further indicates the lateral and vertical complexity of the multiple sand and shale CO_2 storage lenses. The structural framework of the CO_2 storage system provides multiple barriers to migration into the Chicot groundwater/USDW aquifers. The single source CO_2 injection well is situated between relatively thick and relatively low permeability caprock and basement shales. The injection well and projected radial extent of the CO_2 sequestration reservoir is over a mile from the storage sediment/salt dome disturbance zone. Furthermore, the CO_2 storage plume will migrate up dip from the salt dome disturbance zone over time. In addition, the vertical and areal distribution of the multiple sand and shale lenses, both within the CO_2 storage reservoir and in the Upper Miocene-age and Pliocene-age sediments (Figure 2), provides multiple barriers to fluid migration.

3.1.2 Hydraulic Reservoir Properties: Knowing the hydraulic CO_2 reservoir rock properties is necessary to understand the potential migration of CO_2 within the aquifer storage reservoir, and potential migration of CO_2 from the storage system. Key reservoir sediment and rock properties include mineralogy, porosity, and permeability. Key hydraulic reservoir conditions include the in-situ pressure regime, the rock fracture pressures, and hydraulic fluid gradients. Based on this pressure regime, the CO_2 maximum storage pressures and resulting pressure distribution, and migration pattern of the storage CO_2, can be determined to identify any potential leakage points. The salinity of the storage aquifer is a key factor in restricting CO_2 migration.

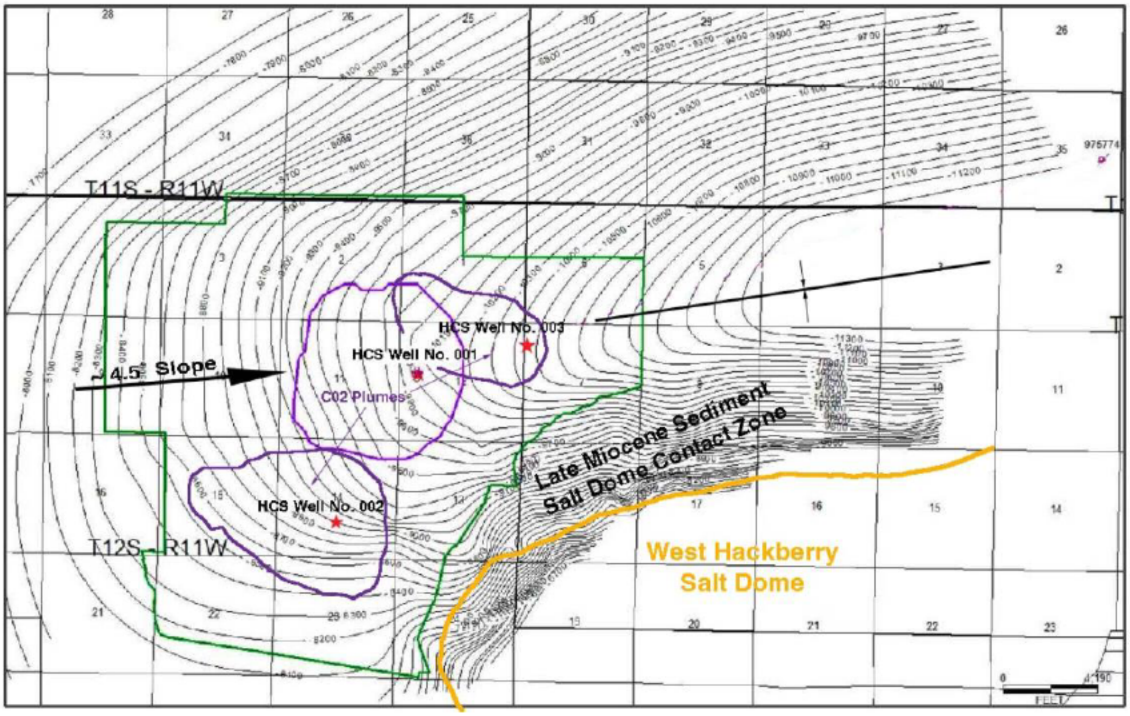


Figure 4. Top of the Lower-Miocene-age CO_2 Sequestration Storage Formation, Structural Geology Map (Contours MSL Elevations).

[redacted]

Figure 5. Seismic Survey Line JKB-489 that Illustrates the Vertical Geological Framework of the Lower Miocene-age CO_2 Storage System.

Reservoir Rock Properties: Reported storage aquifer rock properties are provided in Figure 6. The sand aquifer lenses are exceptionally permeable meaning the stored CO_2 will freely flow into the aquifer. The interbedded shale lenses have a relatively low permeability. Over time the CO_2 will migrate into the shale lenses over an extended period. The vertical distribution of sand and shale lens permeabilities at the LA Storage SWD No. 003 are shown on Figure 3. The lenticular nature of the CO_2 storage aquifer will result in multiple confined CO_2 storage zones. The result is multiple vertical barriers to CO_2 migration from the storage system.

		Porosity	Perm (mD)
Sand	Average	26.7%	3,201
	Min	17.7%	384
	Max	32.2%	5,706
Shale	Average	4.6%	0.2
	Min	0.7%	0.1
	Max	6.8%	0.7

Figure 6. Range of Porosity and Permeability Value for CO_2 Storage Reservoir Rocks.

Reported storage rock properties of the Amphistegine-B Shale and the Anahuac Shale confining shale formations are 0.0002 mD to 17.9 mD, respectively. The Amphistegine-B Shale is a smectite (swelling type clay), and is an effective caprock. The Anahuac Shale has about a 40% smectite concentration, and is an adequate lower confining boundary.

In-Situ Pressure Regime: The Lower Miocene-age CO_2 storage reservoir rock has an in-situ stress field of approximately 0.97 psi/ft calculated from a density data log. A typical overburden gradient is 1.0 psi/ft. This suggest the study region is under extensional forces verse compression. The rock fracture gradient was calculated from core analysis to be 0.66 psi/ft. The maximum allowable fluid storage pressure gradient selected for this storage system design is 0.6 psi/ft. This design gradient is conservative and are typical for most porous medium natural gas storage fields in the United States.

Storage Operating Pressure Conditions: Terminal carbon sequestration storage systems are designed to inject supercritical CO_2 into the porous aquifer storage sands at an adequate delta pressure to push the CO_2 into the highly saline (110,000 mg/L TDS) aquifer fluids. As planned, CO_2 will be injected into 13 perforation intervals starting at an approximate depth of 9,106 feet up to 5,019 feet. The expected injection period is twenty years for each interval. Individual injection intervals will be isolated in the CO_2 injection well.

Maximum reservoir storage pressures will range from 5,464 psi at the 9,106-foot interval down to 3,464 psi at the 5,774-foot interval based on the safe maximum injection pressure gradient of 0.6 psi/ft. Plume modeling indicated that the CO_2 plume will radiate from the injection well into the injection interval during the approximate five-year injection period. The super-critical CO_2 fluid will accumulate in the upper portions of each injection interval. The CO_2 plume pressure will equalize to the original storage aquifer hydrostatic pressure over an approximate 20-year period. Once equilibrium has been reached, the areal and vertical migration of the CO_2 plume will be limited to the natural long term up gradient migration of the storage aquifer.

The distribution of the CO_2 plume will be marginally impacted by a portion of the CO_2 fluid being dissolved into the aquifer fluids, and by reduction in the effective permeability of the storage sands due it's relatively high salinity. The magnitude of the impact on the reduction in the effective permeability in a highly saline aquifer was documented in the publication:

> *Moridis, et. al, 2023, Practical Aspects and Implications of Long-Term CO2 Sequestration in Saline Aquifers Using Vertical Wells, SPE-213168-MS.*

The maximum areal extent of the CO_2 plume for the Hackberry Carbon Sequestration Well No. 001 is shown on Figure 1.

3.2. Loss of Mechanical Integrity Failure Scenarios

Natural gas has been reported to have leaked from natural gas storage injection/withdrawal wells at several sites. Recent gas well leaks have been reported at the Rager Mountain Storage Field in Pennsylvania, and in the Manlove Storage Field in Illinois. In both cases, potable shallow groundwater was impacted by the leaked natural gas.

A possible loss of mechanical integrity failure is possible from the CO_2 injection well(s). Typical types of mechanical failure are with the tubing packer equipment, fluid migration through casing annular grouting materials, and/or from corrosive failure of well casings and tubing strings. A potential also exists for CO_2 migration through the well abandonment materials. The planned CO_2 injection well completion and well abandonment designs were reviewed to identify potential conditions that may result in CO_2 leakage into the shallow Chicot groundwater/USDW aquifer. The following potential leakage scenarios were identified:

Current Well Design

- Review centralizer design to evaluate feasibility of cementing of long string casing (20 centralizers);
- Cement channeling –If cement channeling occurs, the carbon steel portion of the production casing may be exposed to CO_2 and lead to corrosion allowing CO_2 plume migration up to USDWs;
- Formation cap above the Miocene sands can fail due to acidization of the formation water and the CO_2 plume can migrate up to USDWs;

These potential leakage conditions for the injection well and abandonment designs are considered minor conditions that can be addressed during final well system designs. However, well construction materials are known to deteriorate over time for saline aquifer storage systems. Minor modifications to the well design, as suggested, may make the well more intrinsically safe.

3.3 Summary of Potential Storage System Failure Scenarios

The two potential storage system failure scenarios that may require remediation of the shallow Chicot groundwater/USDW aquifers are the 1) CO_2 storage system migration, and 2) injection well failure scenarios. The potential risk of these failure scenarios impacting the Chicot groundwater/USDW aquifers was determined. Each of the failure scenario was evaluated to determine the mechanism of failure to determine the point of failure and level of impact on the shallow Chicot groundwater/USDW aquifers as is necessary to prepare a groundwater remediation program.

3.3.1 CO_2 Storage System Migration Failure Scenarios: The potential risk for CO_2 storage system migrations failure scenario is considered "Low". The Hackberry Carbon Sequestration system design provides both multiple barriers to fluid migration from the storage reservoir, and will be operated at safe operating fluid injection pressures.

The Late Miocene-age carbon sequestration reservoir is located in a tectonically stable region. As previously stated, the CO_2 storage reservoir is laterally unbounded to the north, south, and west. The sediments have a relatively low dip of ~ 4.5˚ to the east. This is essentially a nearly flat lying aquifer storage reservoir. The only disturbance in the storage reservoir rock was the intrusion of the West Hackberry Salt Dome to the southeast. The storage reservoir rock is truncated at the salt dome with a disturbance zone immediately adjacent to the salt dome. Seismic reflection survey data indicate the possibility of discontinuities in the disturbance zone. The selected CO_2 injection storage zone is located up gradient of the disturbance zone. The CO_2 plume would need to migrate down structure to reach potential fractures in the disturbance zone which is physically unlikely.

The stratigraphy from the CO_2 storage zone up to the Chicot groundwater/USDW aquifers consists of multiple sand and shale lenses. Each of the shale lenses provide a hydraulic barrier to vertical CO_2 migration. Our experience with natural gas leakage through the caprock of an aquifer storage reservoir is that the leaked gas will accumulate in an upper porous medium before migration to a shallow aquifer. The gas will remain in this upper porous reservoir until it reaches saturation before migration up to a shallow aquifer. The observed leaked natural gas migration time from the Manlove St. Peter Formation storage reservoir was approximately 50 years. The concentration of leaked natural gas detected in the shallow aquifers was in the non-detect range.

The reservoir pressure of the stored CO_2 will only be above the storage aquifer hydrostatic pressure for approximately five years. Within approximately a 20-year period, the reservoir will approach equilibrium near the original reservoir pressure. At this point, there will be essentially no driving force for CO_2 to migrate from the storage reservoir.

In the unlikely event the storage system fails and CO_2 migrates vertically into the shallow groundwater/USDW aquifers, the leaked CO_2 would most likely enter evenly into the shallow groundwater somewhere within the areal extent of the stored fluid plume, as shown on Figure 1.

3.3.2 Injection Well Failure Scenario: The potential risk for an injection well failure scenario is considered "Moderate". The failure of the mechanical injection equipment (i.e. tubing/packer equipment) will typically be identified in a short time period after CO_2 injection begins because of the planned injection well monitoring program. Thus, leakage would most likely be into the tubing/casing annulus spaces and not into the groundwater/USDW aquifer. Deterioration of the well construction and plugging materials may occur after considerable time (20+ years).

Stored fluid leaks are typically confined to the immediate area around the injection well. The leaked stored fluids are typically at an elevated pressure that can be as high as reservoir storage pressures. Basically, in the case of a failure, the injection well could be a point source for injection of CO_2 into the Chicot groundwater/USDW aquifer. Leaked fluids will radially spread out into the lower aquifer unit. The volume and areal distribution of leaked fluids will be dependent on the time elapsed between detection and remediation.

4.0 System Remediation Plan

The general outline of groundwater/USDW remediation actions presented in the permit application, listed below, are applicable to the two potential storage system failure scenarios of 1) CO_2 storage system migration, and 2) injection well failure. A groundwater remediation program was prepared that is specific to the geological framework and storage operating parameters for the Hackberry Carbon Sequestration Storage system, as illustrated in Figure 7.

Taken From Permit Section 8-Emergency and Remedial Response Plan

If groundwater/USDW is impacted:

- *Pump carbon dioxide-contaminated groundwater to the surface and aerate it to remove carbon dioxide.*
- *Apply "pump and treat" methods to remove trace elements.*
- *Drill wells that intersect the accumulation in groundwater and extract carbon dioxide.*
- *Provide an alternative water supply if ground water-based public water supplies are contaminated.*

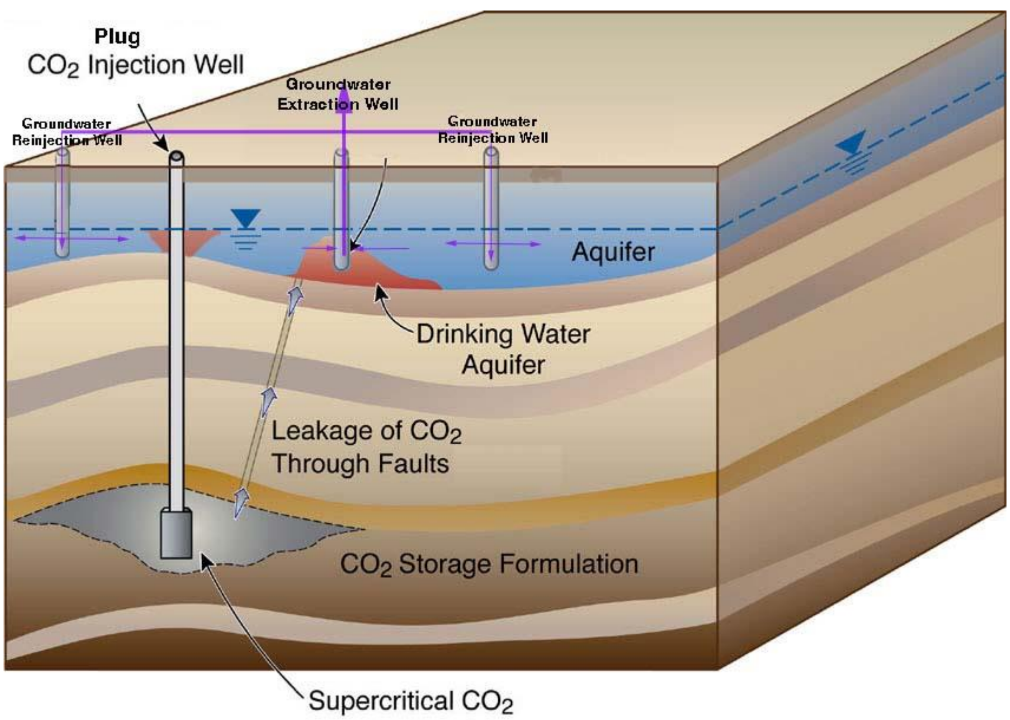


Figure 7. Illustration Showing the Key Elements of the Groundwater/USDW Program.

The Chicot groundwater/USWD remediation plan is essentially the same for both the CO_2 migration and CO_2 injection failure scenarios. The primary difference is the location of the point source for CO_2 entering into the groundwater/USWD aquifers. The potential point source for the CO_2 migration scenario could be anywhere in and/or around the areal footprint of the carbon sequestration reservoir boundaries (Figure 8). The CO_2 injection well failure scenario will likely be at the injection well. A general layout of the remediation plan for the CO_2 injection well failure scenario is illustrated in Figure 8. The only difference to this plan is that the groundwater extraction well will be located at the point of highest concentration of CO_2 in the groundwater/USWD aquifer. The location of the groundwater reinjection will be adjusted accordingly. A system monitoring program is provided that will allow the detection of CO_2 storage system and well leakage, and will allow the development of the required remediation plan. A description of the Chicot groundwater/USDW aquifer is provide below. Descriptions of the key elements of the remediation used to estimate remediation costs are also provided below.

4.1 System Monitoring Program

The Class VI Permit Application for Hackberry Carbon Sequestration Well No. 001 provides for testing and monitoring of CO_2 sequestration operations and post-operating conditions in Sections 5 and 7. The system monitoring program presented in these permit application sections is adequate to detect leaks into the groundwater/USWD aquifers for both CO_2 storage system migrations and injection well failure scenarios. Section 5 Figure 5-1 indicated a single groundwater/USWD aquifers monitoring well. This remediation plan provides for three groundwater/USWD aquifers monitoring wells, as shown on Figure 8.

4.2 Chicot Groundwater/USDW Aquifers

Our potential storage system failure scenarios evaluation determined that the Chicot aquifer is the primary fresh water aquifer that would be impacted from CO_2 leakage from the carbon sequestration storage reservoir and/or leakage from the CO_2 injection well. Our understanding of the hydrogeology of the Chicot aquifer was presented in the follow report:

> *LBG-Guyton Associates, 2009, Analysis of Groundwater Withdrawal Impacts on the Chicot Aquifer Liberty Gas Storage Expansion Project Cameron Parish, Louisiana; Consultant Report to Liberty Gas Storage, LLC.*

This study evaluated potential impacts on the Chicot aquifer from groundwater withdrawals to support the expansion of the Liberty Gas Storage Project in the West Hackberry Salt Dome. The project study area is approximately 1.5 miles southwest of the planned Hackberry Carbon Sequestration Well No. 001. The Chicot aquifer is composed of three sand units identified as the 200-foot, 500-foot, and 700-foot sands. A geological profile of the Chicot aquifers is provided in Figure 9. The three Chicot aquifers are confined units. The 200- and 500-foot aquifers are fresh water aquifers. The 700-foot aquifer is saline with a TDS of approximately 10,000 mg/L.

Figure 8. General Layout of Chicot Groundwater/USDW Aquifers Remediation Wells for the CO_2 Injection Well Failure Scenario.

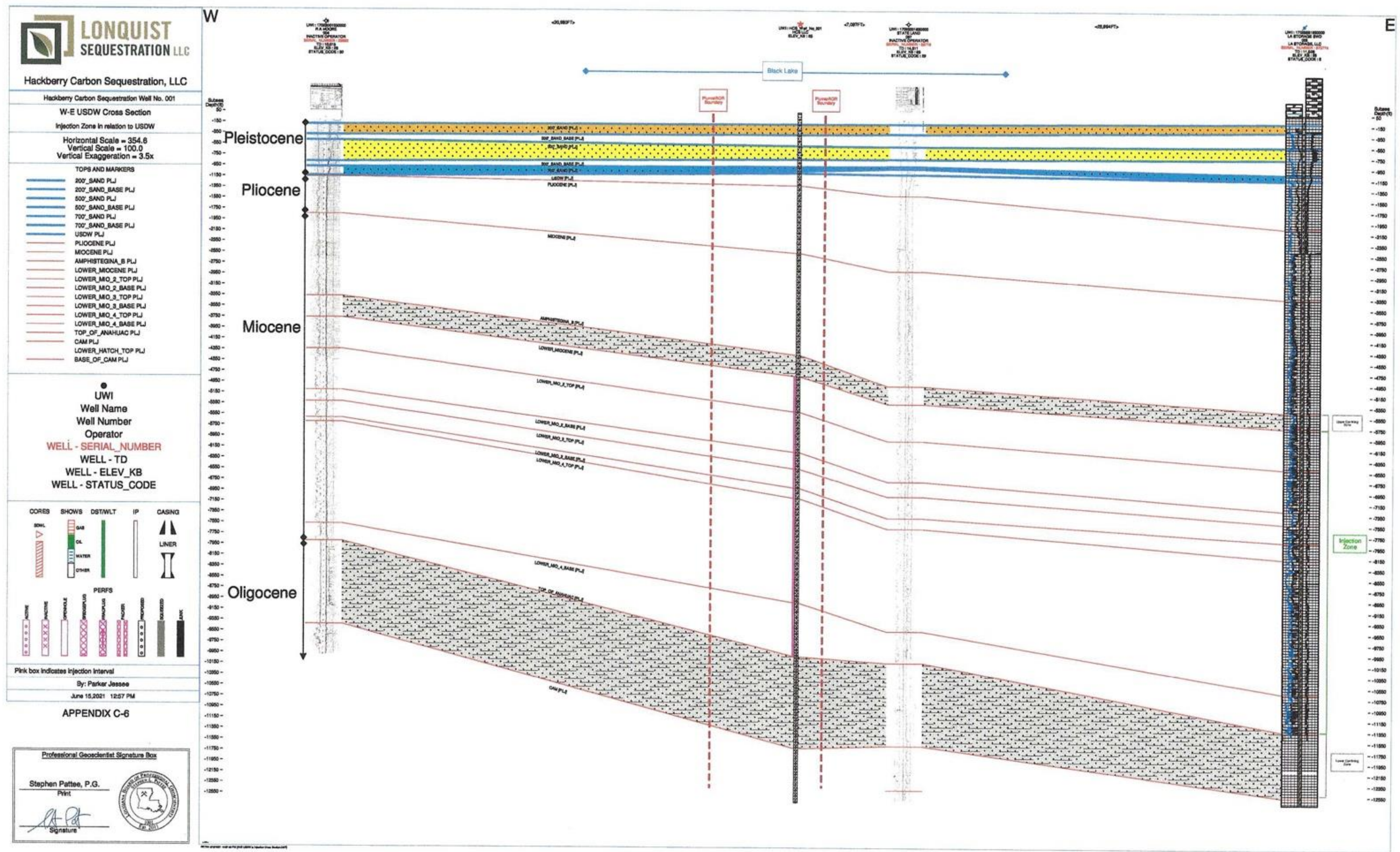
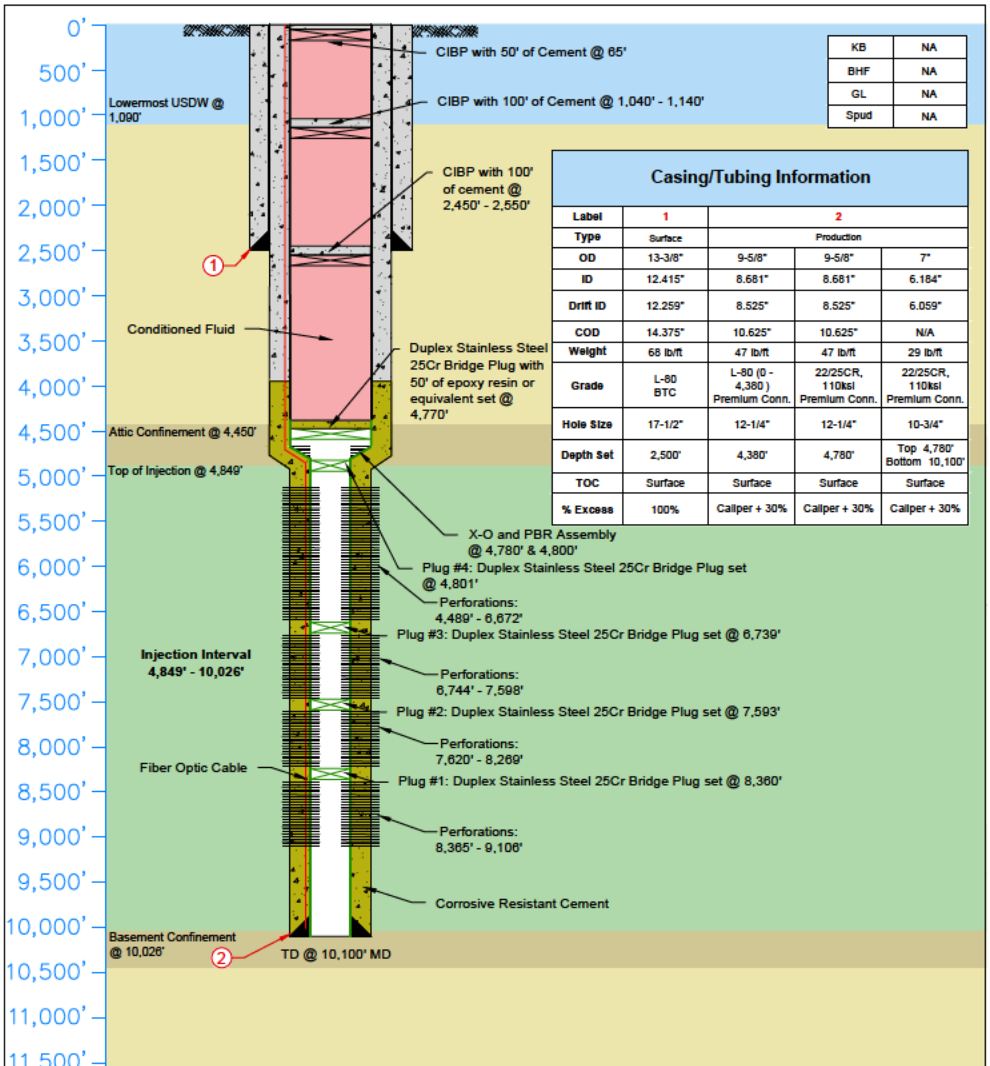


Figure 9. Geological Profile of the Hackberry Carbon Sequestration Reservoir Showing the Chicot Aquifers.

4.3 Plugging and Abandonment of CO_2 Injection Well

The CO_2 injection well will need to be plugged and abandoned at the time of storage site closure, and/or if and when the integrity of the well fails. Thus, the plugging and abandonment of the CO_2 injection is included in our groundwater/USWD program. The CO_2 injection well abandonment design provided in the permit application (Figure 10) was utilized for our cost analysis. Previously suggested modification to the well abandonment plans were applied to the design.



KB	NA
BHF	NA
GL	NA
Spud	NA

Casing/Tubing Information

Label	1	2		
Type	Surface	Production		
OD	13-3/8"	9-5/8"	9-5/8"	7"
ID	12.415"	8.681"	8.681"	6.184"
Drift ID	12.259"	8.525"	8.525"	6.059"
COD	14.375"	10.625"	10.625"	N/A
Weight	68 lb/ft	47 lb/ft	47 lb/ft	29 lb/ft
Grade	L-80 BTC	L-80 (0 - 4,380) Premium Conn.	22/25CR, 110ksi Premium Conn.	22/25CR, 110ksi Premium Conn.
Hole Size	17-1/2"	12-1/4"	12-1/4"	10-3/4"
Depth Set	2,500'	4,380'	4,780'	Top 4,780' Bottom 10,100'
TOC	Surface	Surface	Surface	Surface
% Excess	100%	Caliper + 30%	Caliper + 30%	Caliper + 30%

LONQUIST SEQUESTRATION LLC	LA Storage/Sempra	Hackberry Carbon Sequestration Well No. 001	
	Country: USA	**State/Province:** Louisiana	**County/Parish:** Cameron
	API No: TBD	**Field:**	**Well Type/Status:** Class VI CCS
Louisiana License EF-7423	**RRC District No:**	**Project No:** 2393.4	**Date:** 7/7/2023
12912 Hill Country Blvd. Ste F-200 Austin, Texas 78738 Tel 512.732.9812 Fax 512.732.9816	**Drawn:** JML	**Reviewed:**	**Approved:**
	Rev No: 1	**Notes:**	

Figure 10. CO2 Injection Well Plug Design.

4.4 Drill & Complete CO_2 Capture Well

The purpose of the CO_2 groundwater capture well is to remove CO_2 from the potentially impacted 700-foot aquifer(s). The capture well will 1) remediate the impacted aquifer(s), and 2) provide a capture zone to limit the areal migration of CO_2.

A groundwater/USWD CO_2 capture well is to be drilled either in close proximity to the CO_2 injection well (Figure 8), or at the point of observed maximum CO_2 concentrations in the Chicot aquifers. A CO_2 capture well design in the 700-foot aquifer is provided in Figure 11. The well is design to pump approximately 2,000 gallons per minute of CO_2 contaminated groundwater to a wellhead separator system to allow the venting of CO_2 to the atmosphere, and allow the treated water to be pumped into up to three groundwater reinjection wells.

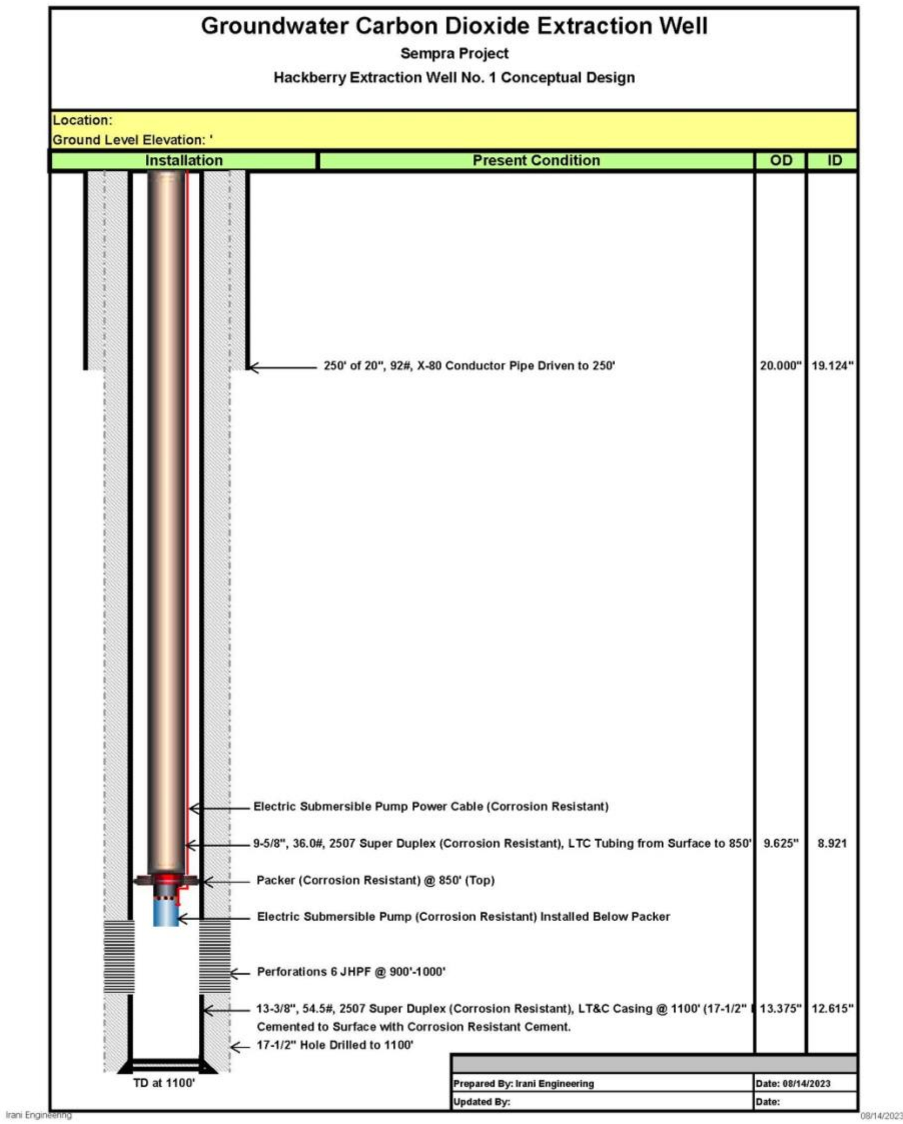


Figure 11. CO_2 Capture Well Design.

4.5 Wellhead CO_2 Separator

The purpose of the CO_2 separator system is to treat contaminated groundwater and to provide a clean source of water for reinjection into the impacted aquifer(s).

4.6 Groundwater Barrier Injection Wells

The purpose of the groundwater barrier injection wells is to limit the areal extent of contaminated groundwater by creating a hydraulic barrier to CO_2 movement. The injected groundwater will push contaminated groundwater back toward the CO_2 capture well for extraction and treatment. Over time the concentration of the CO_2 will be reduced to permitted levels. A CO_2 reinjection well design for the 700-foot aquifer is provided in Figure 12. The 700-foot aquifer exceeds the 10,000 ppm TDS injection limit requirement. The three injection wells will be connected to the CO_2 extraction well through a manifolded 6-inch diameter pipeline system.

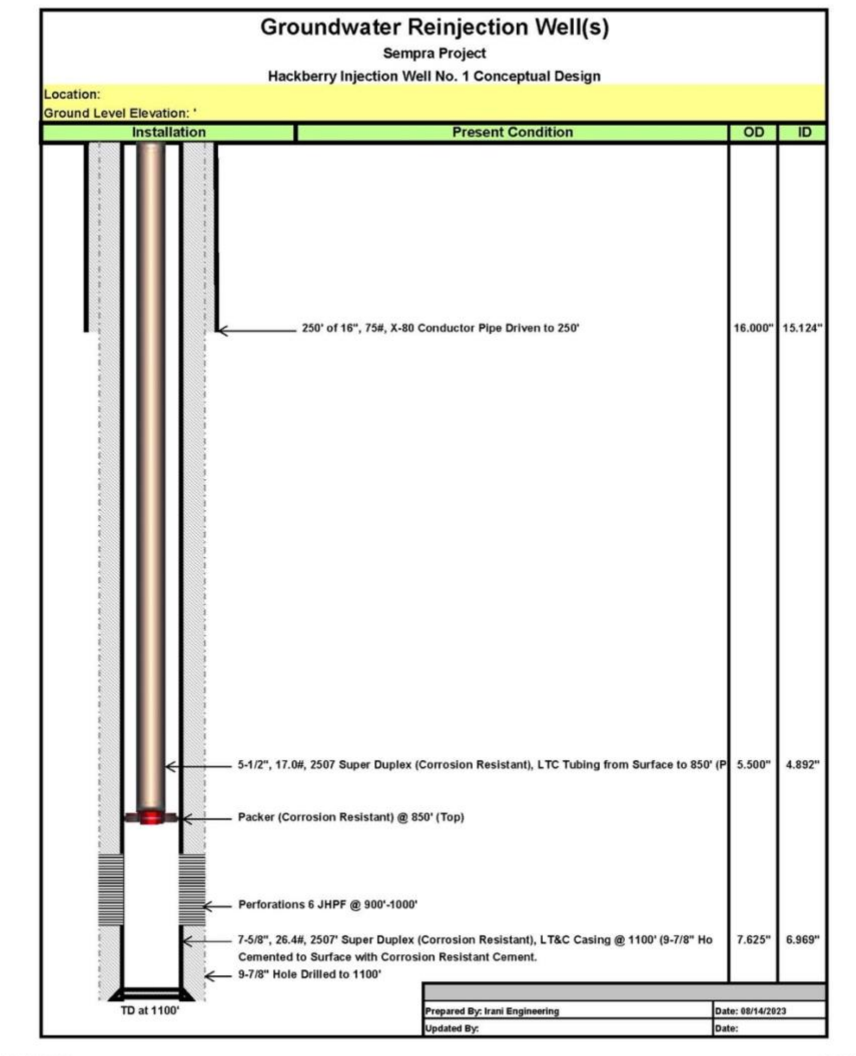


Figure 12. Groundwater Reinjection Well Design.

5.0 Cost Analysis of Remediation Plan

Our groundwater/USWD plan cost analysis consist of cost to:

1. Abandon the CO_2 Injection Well
2. Drill and construct the CO_2 Groundwater Extraction Well
3. Install the CO_2 Wellhead Separator
4. Drill and Construct Three Groundwater Reinjection Wells
5. Install the Manifolded Pipeline System

Our cost analysis assumes that a drilling platform and method to mobilize the equipment will exist at the time of the implementation of the remediation plan. All costs are in 2023 dollars. Detailed abandonment and new well drill costs were provided in Authorization for Expenditures (AFE's) provided in Figures 13, 14, and 15, below. Cost estimated are based on cost quotes from drilling companies, oil field service companies, and equipment manufactures. The required permits for installation of remediation plan facilities are dependent on the specific failure scenario, and are not included in cost analysis. The cost of the groundwater remediation plan is listed below:

1. Plug CO_2 Injection Well	$ 982,000
2. Install of CO_2 Extraction Well	$ 1,830,000
3. Groundwater Extraction Well Pump	$ 400,000
4. Install Groundwater Reinjection Well-1	$ 1,365,000
5. Install Groundwater Reinjection Well-2	$ 1,365,000
6. Install Groundwater Reinjection Well-3	$ 1,365,000
7. CO_2 Wellhead Separator	$ 200,000
8. Groundwater Injection Well Pipelines	$ 3,300,000
Total Estimated Costs	$10,807,000

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Brad Cross, P.G.
Principal Hydrogeologist

COST ESTIMATE & AUTHORITY FOR EXPENDITURE		
DATE: August 29, 2023		
OPERATOR: Hackberry Carbon Sequestration, LLC		
LEASE & WELL NO.: Hackberry CO2 Sequestration Well No. 1 FIELD: Hackberry, Louisiana		
LOCATION:		
County: Cameron STATE: Louisiana PROJECTED TD:		
PORPOSE: Run Casing inspection logs, plug and abandon well per Sempra's abandonment schematic which is attached.		
Classification: Re-completion ( ) Development ( ) Oil ( ) CO_2 Seq. (X) Abandonment (X)		
THIS IS AN ESTIMATE ONLY AND THERE IS NO GUARANTEE, EITHER EXPRESS OR IMPLIED, THAT THE ACTUAL COSTS WILL BE EQUAL TO, LESS OR GREATER THAN THOSE ESTIMATED.		
	Completion	REMARKS
TANGIBLE LEASE & WELL EQUIP.		
1. Surface Csg. & Cond.		
2. 13-3/8" Casing		
3. 9-5/8" Casing		
4. Tubing		
5. Work String		
6. Wellhead & Tree (5M), Crown and Swab Valve		
7. Process & Storage Equip.		
8. Packers, Mill out Extension, Seal Assembly Misc.		
Total Lease & Well Equip.	**$0**	
Intangibles		
1. a. Footage ft. @ $		
b. Workover Rig Mobilization & Demobilization	$10,000	Workover Rig, not icluding barge cost
c. Daywork, 15 Days @ $6,500 per day	$98,000	5 Man Crew, Incl Pump
d. Water	$2,000	
e. Kill Fluid	$10,000	
2. a. Operator's Overhead		
b. Engineering & Site Supervision	$60,000	
d. Wireline: Casing inspection logs	$30,000	Including Pressure Control Equipment
3. a. Torque Control & Test Unit		
b. Casing Tongs Services, Lay Down Machine & Handling Tools	$20,000	
c. BOP, Adapter Flanges & Accumulator Rentals	$45,000	
d. Production Casings External Pressure test		
e. Casing Prep, Inspection & Tally		
f. Spears		
4. a. Bridge Plugs	$200,000	Stainless Steel bridge plugs
b. Cementing	$200,000	
5. a. Locations Restoration		
b. Rig Anchor	$2,000	
c. Transportation, Freight, Vac Truck & Crane	$30,000	Including Crane & Excavator Rentals & Operators
d. Roustabout Labor	$20,000	
e. Lodging & Meals		
f. Welder (Misc.)	$20,000	
6. a. Bits		
b. Rentals	$60,000	
c. Repairs & BOP Consumables	$15,000	
d. Contingencies (~20%)	$160,000	
Total Intangibles	**$982,000**	
Total	**$982,000**	
$982,000 to Plug & Abandon Well		**Approval Date**

Figure 13. Hackberry CO_2 Sequestration Well No. 1 AFE Costs.

COST ESTIMATE & AUTHORITY FOR EXPENDITURE				
DATE: August 26, 2023				
OPERATOR: Hackberry Carbon Sequestration, LLC				
LEASE & WELL NO.: Extraction Well No. 1				FIELD OR AREA:
LOCATION: Section 12, T 12S, R 11W				
COUNTY: Cameron		STATE: Louisiana		PROJECTED TD: 1100'
Vertical Well				
Classification: Extraction Well				
THIS IS AN ESTIMATE ONLY AND THERE IS NO GUARANTEE, EITHER EXPRESS OR IMPLIED, THAT THE ACTUAL COSTS WILL BE EQUAL TO, LESS OR GREATER THAN THOSE ESTIMATED.				
TANGIBLE LEASE & WELL EQUIP.	DRILLING	COMPLETION	TOTAL	REMARKS
1. Conductor	$28,000		$28,000	250' of 20", 92#, X-80
2. Inter. Csg. & Lnr.			$0	
3. Production Csg. & Lnr.		$250,000	$250,000	300' of SS and 800' of 13-3/8", 54.5#, LT&C
4. Tubing		$380,000	$380,000	850' of 9-5/8", 36#, LT&C, Stainless steel
5. Wellhead		$130,000	$130,000	3000# WP
6. Seal Bore Pkr, Seal Assembly & BHA		$50,000	$50,000	Stainless Steel Packer
Total Lease & Well Equip.	$28,000	$810,000	$838,000	
Intangibles				
1. a. Footage ft. @ $			$0	
b. Mobilization/Demobilization	$120,000		$120,000	4 well project
c. Daywork 4 Days @ $15,000	$60,000	$30,000	$90,000	Incl. Per Diem, Tandem Pumping
d. Service Rig - Compl.			$0	
e. Water	$3,000	$1,000	$4,000	
f. Mud & Mud Supervision	$25,000	$10,000	$35,000	
g. Mud Conditioning	$6,000		$6,000	
2. a. Operator's Overhead			$0	
b. Engineering Supervision	$20,000	$6,000	$26,000	24 hrs/day incl. office engineering
c. Mud Log	$6,000		$6,000	
d. Wireline Surveys Open Hole	$30,000		$30,000	Triple Combo
e. Wireline Cased Hole		$8,000	$8,000	RCBL
g. Perforations		$73,000	$73,000	
g. Pressure-Temp Measurements			$0	
3. a. Cement & Service		$210,000	$210,000	Corrosion resistance cement
b. Floating/Casing Equipment		$10,000	$10,000	
c. Welding	$4,000	$4,000	$8,000	
d. Handling Csg. & D. P.		$10,000	$10,000	
e. Packer Operator & Setting Tools		$8,000	$8,000	
f. BOP Pressure Test		$3,000	$3,000	
g. Tree Installation & Pressure Test		$8,000	$8,000	
h. Casing & Packer Pressure Test		$3,000	$3,000	
i. Water Sampling & Analysis (TDS)			$0	
4. a. Location not Incl. Road & Comp. Pad			$0	Platform, Sempra will provide
b. Transp. & Freight	$20,000	$5,000	$25,000	Not including barge transportation
C. Vacuum Trucks & Disposal	$30,000	$2,000	$32,000	Including mud disposal
c. Roustabout Labor	$10,000	$5,000	$15,000	
d. Fuel	$20,000	$5,000	$25,000	
5. a. Bits, hole opener, reamers	$15,000	$4,000	$19,000	
b. Rental Tools	$40,000	$20,000	$60,000	Including HW's repair
c. Driving Conductor	$25,000		$25,000	
d. Contingencies	$70,000	$65,000	$135,000	
Total Intangibles	$504,000	$490,000	$994,000	
Total	$532,000	$1,300,000	$1,832,000	
Grand Total = 1,832,000 to complete the well not including downhole submersible pump				

Figure 14. Groundwater CO_2 Extraction Well AFE Costs.

COST ESTIMATE & AUTHORITY FOR EXPENDITURE				
DATE: August 25, 2023				
OPERATOR: Hackberry Carbon Sequestration, LLC				
LEASE & WELL NO.: Injection Well No. 1 of 3				FIELD OR AREA:
LOCATION: Section 12, T 12S, R 11W				
COUNTY: Cameron		STATE: Louisiana		PROJECTED TD: 1100'
Vertical Well				
Classification: Extraction Well				
THIS IS AN ESTIMATE ONLY AND THERE IS NO GUARANTEE, EITHER EXPRESS OR IMPLIED, THAT THE ACTUAL COSTS WILL BE EQUAL TO, LESS OR GREATER THAN THOSE ESTIMATED.				
TANGIBLE LEASE & WELL EQUIP.	DRILLING	COMPLETION	TOTAL	REMARKS
1. Conductor	$24,000		$24,000	250' of 16", 75#, X-80
2. Inter. Csg. & Lnr.			$0	
3. Production Csg. & Lnr.		$130,000	$130,000	300' of SS and 800' of 7-5/8", 26.4#, LT&C
4. Tubing		$180,000	$180,000	850' of 5-1/2", 17#, LT&C, Stainless steel
5. Wellhead		$120,000	$120,000	3000# WP
6. Seal Bore Pkr, Seal Assembly & BHA		$40,000	$40,000	Stainless Steel Packer
Total Lease & Well Equip.	$24,000	$470,000	$494,000	
Intangibles				
1. a. Footage ft. @ $			$0	
b. Mobilization/Demobilization	$120,000		$120,000	4 well project
c. Daywork 4 Days @ $15,000	$60,000	$30,000	$90,000	Incl. Per Diem, Tandem Pumping
d. Service Rig - Compl.			$0	
e. Water	$3,000	$1,000	$4,000	
f. Mud & Mud Supervision	$15,000	$2,000	$17,000	
g. Mud Conditioning	$6,000		$6,000	
2. a. Operator's Overhead			$0	
b. Engineering Supervision	$20,000	$6,000	$26,000	24 hrs/day incl. office engineering
c. Mud Log	$6,000		$6,000	
d. Wireline Surveys Open Hole	$30,000		$30,000	Triple Combo
e. Wireline Cased Hole		$8,000	$8,000	RCBL
g. Perforations		$73,000	$73,000	
g. Pressure-Temp Measurements			$0	
3. a. Cement & Service		$150,000	$150,000	
b. Floating/Casing Equipment		$10,000	$10,000	
c. Welding	$4,000	$4,000	$8,000	
d. Handling Csg. & D. P.		$10,000	$10,000	
e. Packer Operator & Setting Tools		$8,000	$8,000	
f. BOP Pressure Test		$3,000	$3,000	
g. Tree Installation & Pressure Test		$8,000	$8,000	
h. Casing & Packer Pressure Test		$3,000	$3,000	
i. Water Sampling & Analysis (TDS)			$0	
4. a. Location not Incl. Road & Comp. Pad			$0	Platform, Sempra will provide
b. Transp. & Freight	$20,000	$5,000	$25,000	
C. Vacuum Trucks & Disposal	$20,000	$2,000	$22,000	Including mud disposal
c. Roustabout Labor	$10,000	$5,000	$15,000	
d. Fuel	$20,000	$5,000	$25,000	
5. a. Bits, hole opener, reamers	$10,000	$4,000	$14,000	
b. Rental Tools	$35,000	$15,000	$50,000	Including HW's repair
c. Driving Conductor	$25,000		$25,000	
d. Contingencies	$60,000	$55,000	$115,000	
Total Intangibles	$464,000	$407,000	$871,000	
Total	$488,000	$877,000	$1,365,000	
Grand Total = 1,365,000 to complete the well.				

Figure 15. Groundwater Injection Well AFE Costs.