Resource Report No. 6 - Supplemental

Geological Resources

Leaf River Capacity Reallocation Project

March 2012

6.0 GEOLOGICAL RESOURCES

Leaf River Energy Center LLC (LREC) is seeking from the Federal Energy Regulatory Commission (FERC) an amendment to the certificate authorizations granted to it in the October 30, 2008 Order Issuing Certificates in Docket No. CP08-8-000 (Certificate). This amendment would authorize LREC to reallocate the aggregate certificated storage capacity of the Leaf River Energy Center among the previously authorized caverns. This will require increasing the capacities of certain individual caverns beyond the currently certificated levels (by slightly increasing the design diameter of the caverns from 300 to 350 feet), as explained herein. By reallocating capacity among its authorized caverns as it proposes here, Leaf River will be able to complete the development of its working gas storage capacity to the certificated 32 Bcf level expeditiously and efficiently. LREC refers to the project as described in this Resource Report and the accompanying amendment application as the “Capacity Reallocation Project” or the “Project”.

This Application seeks approval for the reallocation of the Leaf River Energy Center’s aggregate 32.0 Bcf certificated working gas capacity among its four certificated caverns as shown in the following table:

	Currently Certificated Capacity		Proposed Reallocation of Certificated Capacity		
	Working Gas (Bcf)	Base Gas (Bcf)	Working Gas (Bcf)	Base Gas (Bcf)	Total (Bcf)
Cavern No. 1	8.0	2.473	8.0	2.473	10.473
Cavern No. 2	8.0	2.473	10.0	3.091	13.091
Cavern No. 4	8.0	2.473	12.0	3.710	15.710
Cavern No. 3A	8.0	2.473	2.0	0.618	2.618
Totals	32.0	9.892	32.0	9.892	41.892

Cavern Nos. 1, 2, 3A and 4 each currently have a certificated working gas capacity of 8.0 Bcf. The proposed capacity reallocation requires increasing the certificated working gas capacities of Cavern Nos. 2 and 4 from 8.0 Bcf each to 10.0 Bcf and 12.0 Bcf, respectively, and would also result in a decrease in the certificated capacity of Cavern No. 3A. LREC’s refined and updated evaluation of the characteristics of the New Home Salt Dome, in which LREC has now developed three cavern wells, establishes that each of the four previously certificated caverns could be developed to 12.0 Bcf working gas capacity. Reallocating the aggregate certificated capacity among the four certificated caverns, and increasing the certificated capacities of two caverns, would allow Leaf River to achieve the certificated aggregate 32.0 Bcf working gas capacity earlier and more efficiently by allocating the majority of the capacity to the earlier drilled caverns. Ultimately, Leaf River would hope, in response to market and customer demand, and after receiving the required additional certificate authorization, to develop the Leaf River Energy Center to a total of at least 48.0 Bcf working gas storage capacity (i.e., four caverns each having working gas capacity of 12.0 Bcf).

This resource report addresses the geologic setting and mineral resources associated with the proposed Project. Potential geologic hazards that could exist in the Project area, or could be created by the Project’s construction and operation, are also addressed.

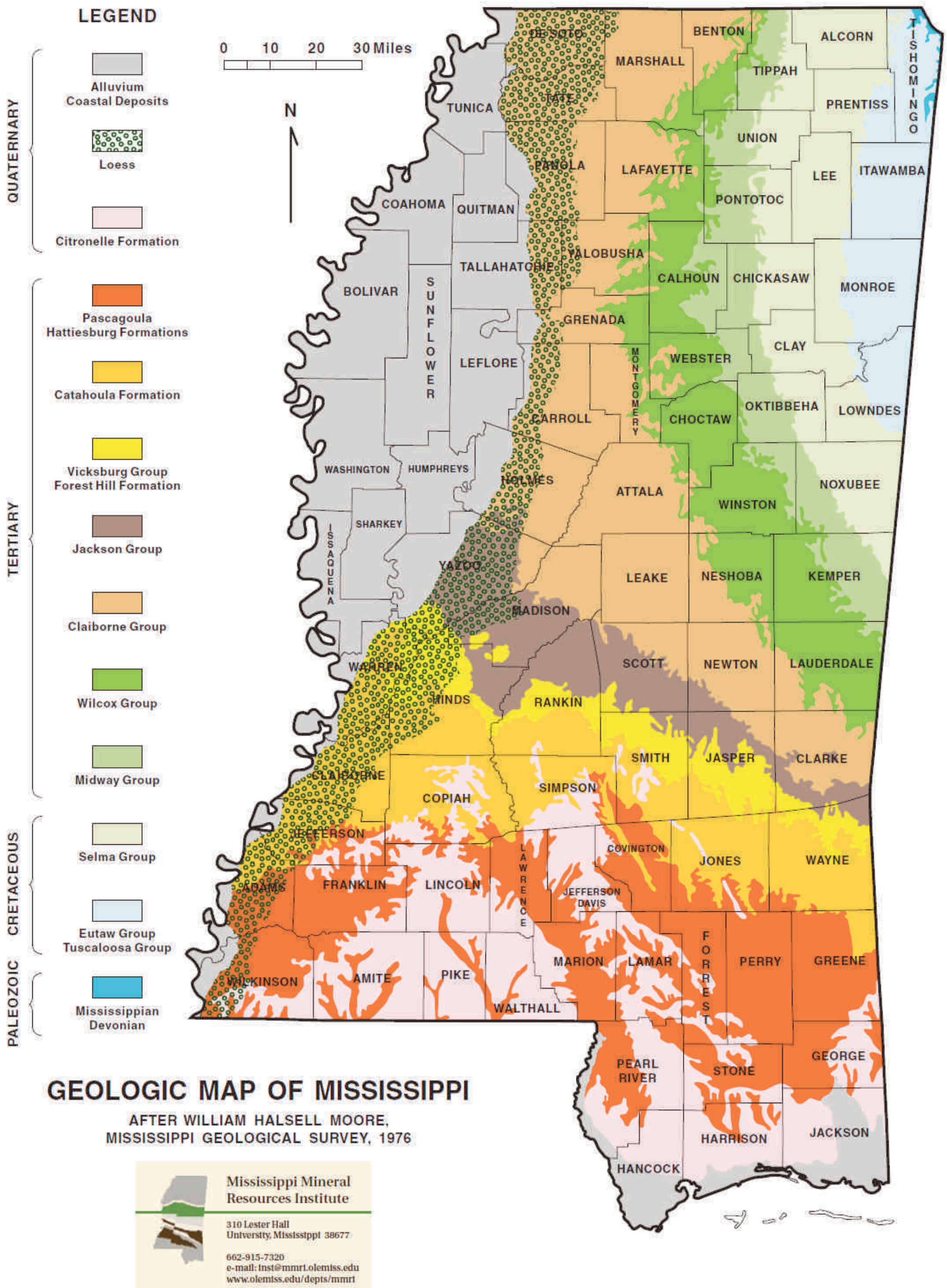
6.1 Geologic Setting

The New Home salt diapir and associated domal structure is primarily located under Section 5 and parts of the adjacent Sections of 6 and 9, T10N- R13W in Smith County and parts of Sections 4 and 9, T10N-R13W in Jasper County, Mississippi. LREC's investigation indicates that the salt diapir has a maximum diameter of somewhat over one mile at a subsea depth of -6000 feet. In its general aspects, the New Home Salt Dome is similar to many of the other salt domes in the Mississippi Salt Basin. Thieling and Moody (1997) provide the general characteristics of the dome and its drilling history.

Examination of the USGS map for this area shows elevations ranging from 350 feet to 450 feet. A rather circular area of higher elevations with outward, radial drainage patterns defines the outer limits of the domal area. The Buckhalter Branch drains the inner, lower area that overlies the main portion of the salt diapir.

The surface geology in the New Home area consists of the Miocene Catahoula Formation that contains various weakly consolidated sand, silts, and clays (Luper, 1972). The soils are classified as the Orangeburg sandy loams (Tharp and DeLong, 1923) (**Figure 6.1-1**).

Figure 6.1-1
Generalized Geologic Map of Mississippi



6.1.1 Subsurface Geologic Setting

6.1.1.1 Methods

A suite of geologic maps and cross-sections was constructed to characterize the geology of the New Home Salt Dome and adjacent strata. The scope of work included:

- Defining and updating the top of caprock/top of salt maps (**Figures 6.1-2** and **6.1-3** respectively) in greater detail than was provided by the published map in Thieling and Moody (1997) through the integration of six lines of commercially available seismic data, two VSP (Vertical Seismic Profile) surveys and well data collected from project related drilling activities to date.

- Providing appropriate subsurface structure maps that characterize the flanks of the dome and the proposed brine disposal area.

- Integrating the above information into geologic cross-sections.

- Review of a database consisting of 20 geophysical logs from wells in the area including six that were on the New Home Salt Dome or its flanks. This well control was integrated with six seismic lines that crossed the dome and extended for several miles in each direction and two VSP surveys and data collected from project related drilling activities. Mapping for the details associated with the dome was done at a scale of one inch equals 500 feet.

6.1.1.2 Caprock/Salt Map

Top of caprock and top of salt maps (**Figures 6.1-2** and **6.1-3** respectively) were constructed from the available geological information, including seismic lines and surrounding well data. Several of the wells on top of the New Home Salt Dome penetrated salt and the values mapped were the depth of the first penetration of either caprock or salt. The information on caprock and/or salt penetrations from Thieling and Moody (1997) was heavily relied upon and was checked against the actual geophysical logs where these were available. The total depths of wells on the flanks of the New Home Salt Dome that did not penetrate salt were used as indirect control in the mapping. The resulting data were integrated into the seismic lines and VSP surveys that provide additional information as to the geometry of the salt diapir and the overlying caprock.

Two of the wells on the southwest flank of the dome drilled through salt overhangs. All of the measured depth values from the well logs were converted to subsea values and the constructed top caprock/salt map is contoured in subsea values. The depth designations used on the map are (c) for top of caprock, (s) for top of salt, and (ns) for no salt having been penetrated at total depth of the well. The New Home salt diapir and overlying caprock was mapped to a subsea depth of -6000 feet. While the seismic data would allow for deeper mapping of the geometry of the diapir, such depths were below the depths of interest for the proposed gas storage caverns.

The resulting top of caprock/salt map shows a somewhat oval general outline with a northwest to southeast long axis of a little more than a mile. In detail, the geometry of the salt diapir shows numerous re-entrants and noses that most likely reflect salt movement history. Salt overhangs are present around much of the salt diapir. Two wells on the south flank of the dome verify the presence of the overhangs. These wells are the Gulf Refining Company - # 1 O.P. Foley and the Lone Star Producing Company - #1 H.E. Stone. The six seismic lines and two VSP surveys provide additional definition of these overhangs. The most severely overhung flank is on the south side of the diapir where the salt overhang commonly starts between -2000 feet and -3000 feet and extends to -6000 feet. The -6000 foot contour lies from just a few hundred feet to almost 1000 feet inward from the maximum shallower salt extent. A deeper overhang starting around -5000 feet is present on the north flank of the diapir. Here the -6000 foot contour is displaced inward by only a few hundred feet.

Figure 6.1-2

Structure Map of Top of Caprock Above 6,000 Feet

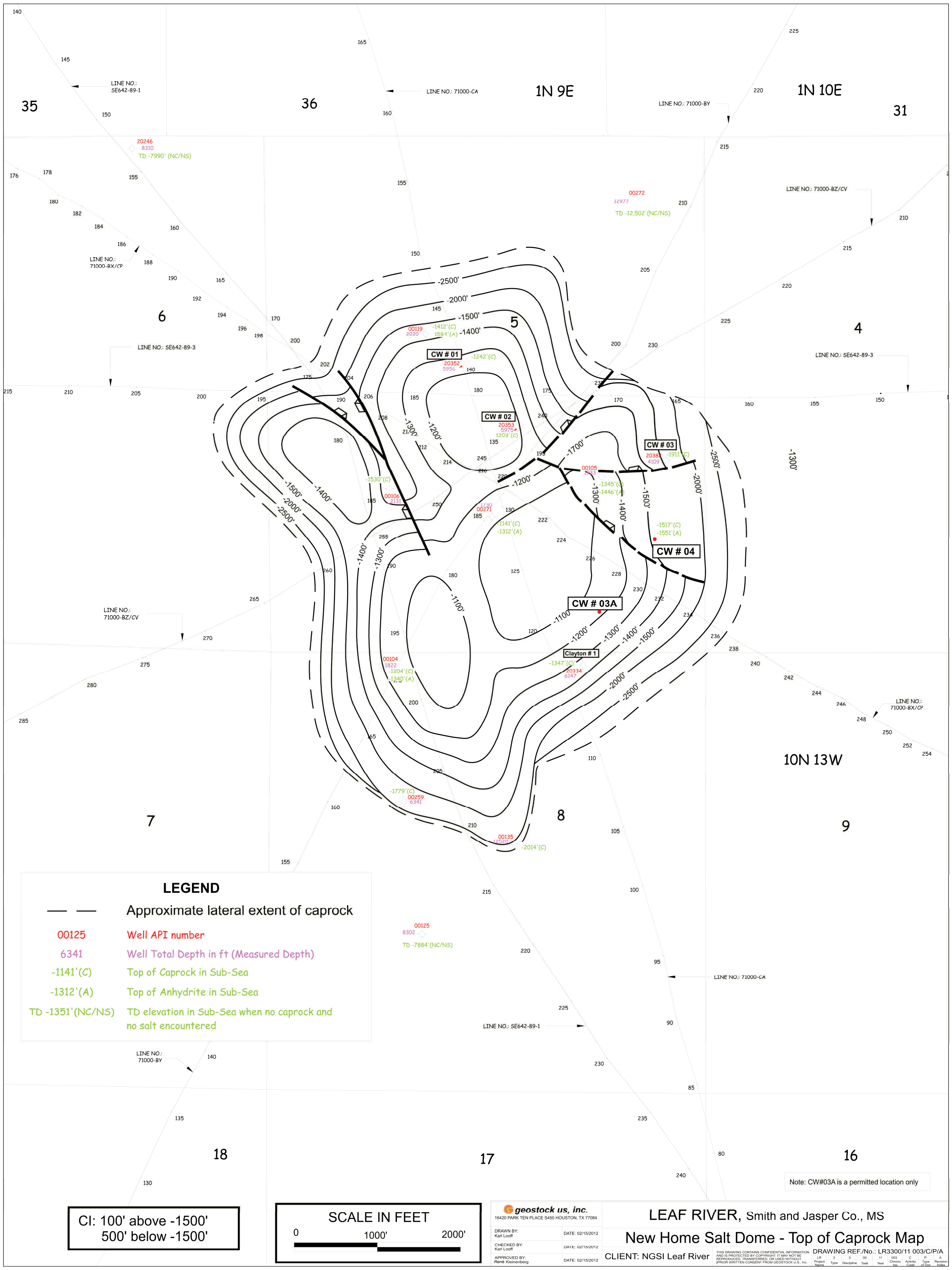
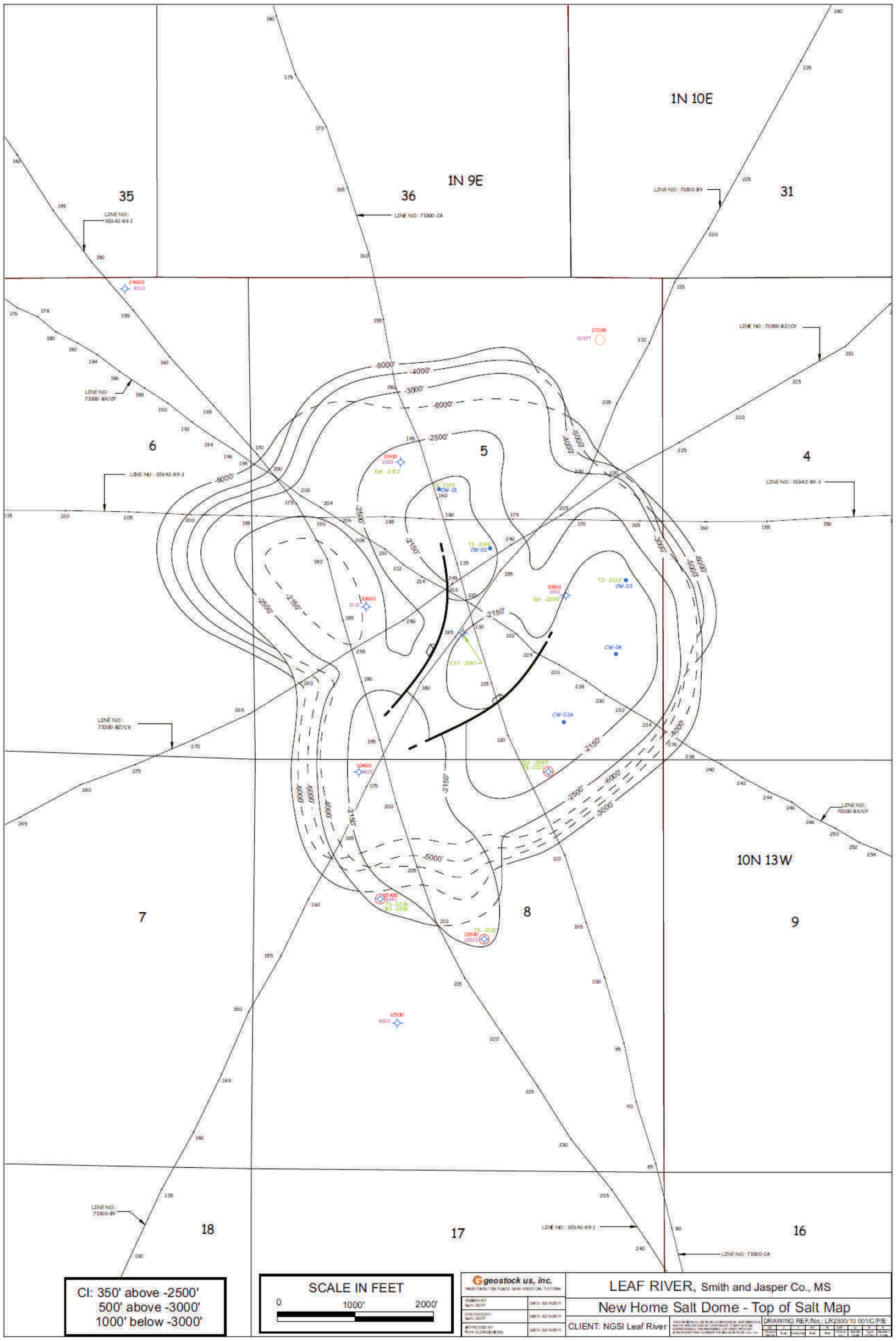


Figure 6.1-3
Structure Map of Top of Salt Above 6,000 Feet



The only noticeable anomalous feature displayed on the top of caprock/salt map is a northwest to southeast trending linear feature located on the northwest quadrant of the dome that is defined by four seismic lines and two of the shallow wells. The seismic data show that shallow faulting in the caprock occurs in proximity to this feature. Based on the available data, the northwest part of the New Home salt diapir appears to be more complex than the rest of the dome.

Figures 6.1-2 and **6.1-3** show the location of the gas storage caverns and their relation to the edge of the salt diapir. **Figure 6.1-4** shows the locations of Cross Sections AA', BB', CC', DD' and EE' within the salt diapir. **Figure 6.1-5** shows Geological Profile AA' through Cavern Wells 3A and 4. **Figure 6.1-6** shows Geological Profile BB' through Cavern Wells 1, 2, and 3A. **Figure 6.1-7** shows Geological Profile CC' through Cavern Well 1. **Figure 6.1-8** shows Geological Profile DD' through Cavern Well 2. **Figure 6.1-9** shows Geological Profile EE' through Cavern Wells 1, 2 and 4. In each profile the caverns are shown with a maximum diameter of 350 feet, which is an increase of 50 feet from the diameter described in prior LREC filings, which depicted each cavern as being 300 feet in diameter. The well to well spacing of 1,000-1,100 feet is on the high end for recent salt cavern storage projects in the Gulf Coast, as is the minimum 650-750 feet of salt between caverns assuming all caverns are expanded to 12.0 Bcf working gas capacity (15.71 Bcf total gas capacity). From the standpoint of the geometry of the salt diapir at the depths to be utilized for the caverns, there appears to be ample room to expand each of the caverns up to 350 feet in diameter while maintaining adequate salt pillars between caverns. A 350 foot diameter cavern will readily accommodate 12 Bcf of working gas capacity.

6.1.1.3 Structure Maps of the Strata Adjacent to the Dome

The flanking strata and surrounding area were defined by mapping four stratigraphic horizons from shallowest to deepest: top of the Wilcox formation, top of the Midway formation, top of the Eutaw formation, and the top of the Lower Tuscaloosa interval. All mapping integrated the well control with the seismic data and is presented as subsea values. Because of the differences in the map scales, the outline position of the salt on the structure maps is approximate. These maps were presented in previous filings.

Top of Wilcox Formation Map

The top of the Wilcox formation was chosen as being the top of the interval selected as a water source for leaching of the caverns. The Wilcox formation is a sand and shale interval that approaches 3,000 feet in thickness across the area mapped. The upper and lower portions of the formation are sand dominant while the middle portion is more shale dominant. Generally, the sands included in the upper interval are brackish although there may be some fresher water sands locally. The sands in the lower interval appear to contain brackish to saline formation waters. Both the upper and lower intervals contain sands with ample thickness and lateral extent to serve as adequate sources of water for leaching.

The top of the Wilcox maps shows that the New Home Salt Dome is elongated to the northwest and has steep dips on the other flanks. The domal structure interrupts the otherwise generally southwest regional dip. The dome is separated from the regional dip by weak synclines produced by the up-hinging of the strata by the salt. About three miles to the south of the New Home Salt Dome the map shows the shallow northern portion of the Soso field structure.

Top of Midway Formation Map

The Midway formation consists of a thick shale section and combined with the underlying chalk section forms a thick regional aquiclude. This interval separates the shallow units that contain saline, brackish, and fresh water sands from the deeper Eutaw/Tuscaloosa section that is proposed for brine disposal. The

Midway structure map is very similar to the Wilcox structure map. Shallow faulting was not defined by the seismic data or contour patterns from the well control in either case.

Top of the Eutaw Formation

The Eutaw formation is a relatively thin sand-dominated interval that overlies the thick Tuscaloosa formation. The Eutaw formation includes sands that have sufficient thickness and lateral extent to be considered for brine disposal; therefore, the top of this formation was mapped as being the top of the proposed brine disposal interval although the main sands for disposal consideration are in the Tuscaloosa formation and in particular the lower part. The Eutaw structure is very similar to the structure of the shallower formations, and the flanks around New Home Salt Dome are steeper, but show little or no radial faulting with the present data. Significant faulting is present towards the southwest of New Home Salt Dome in eastern and southern parts of T10N, R14W. The existing and certificated brine disposal area is far removed from this faulting and would not be affected by the interpreted faults based on the regional structure.

Lower Tuscaloosa Map

The lower Tuscaloosa interval consists of a massive sand section about 400 to 500 feet thick that is present across the entire area. This interval is being used as the primary brine disposal interval. Underlying this massive sand interval is the top of the Lower Cretaceous. The structure of the Lower Tuscaloosa is very similar to that the shallower mapped units. The extent of the dome is somewhat broader and a pronounced radial fault is present on the south flank of the dome.

Figure 6.1-4
Cavern Well Top of Salt Cross Sections

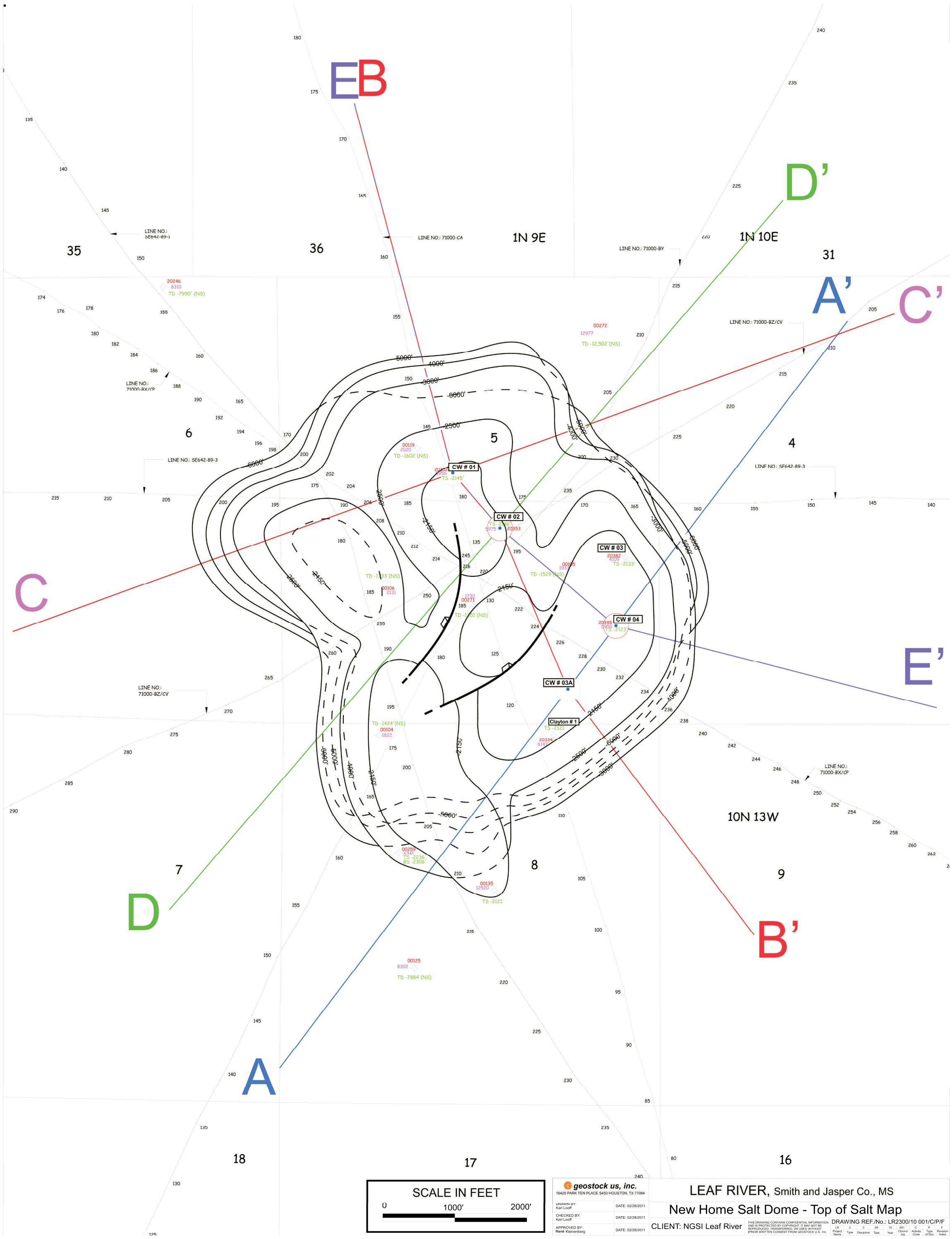


Figure 6.1-5
Geological Profile AA' Through Cavern Wells 3A and 4

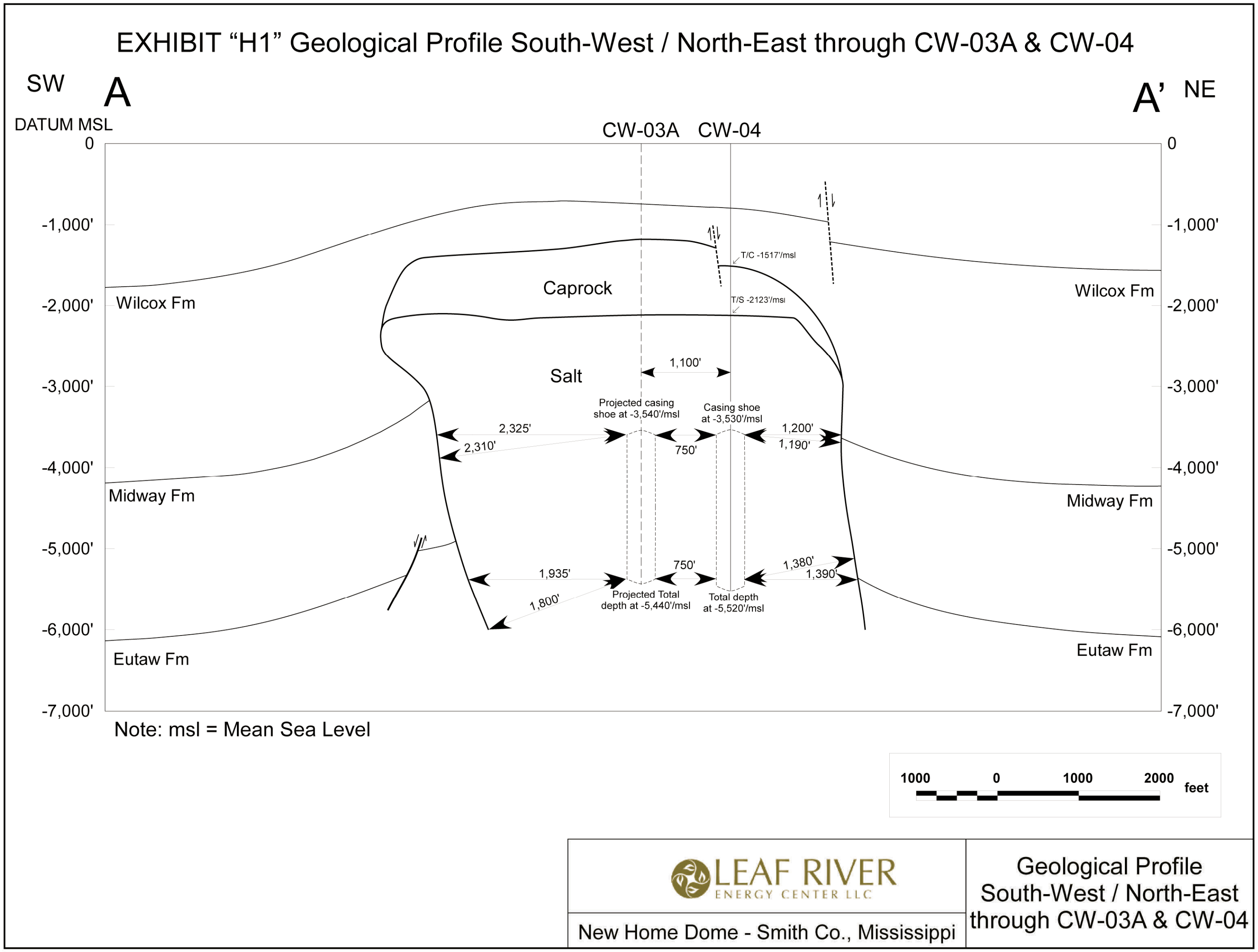


Figure 6.1-6
Geological Profile BB' Through Cavern Wells 1, 2 and 3A

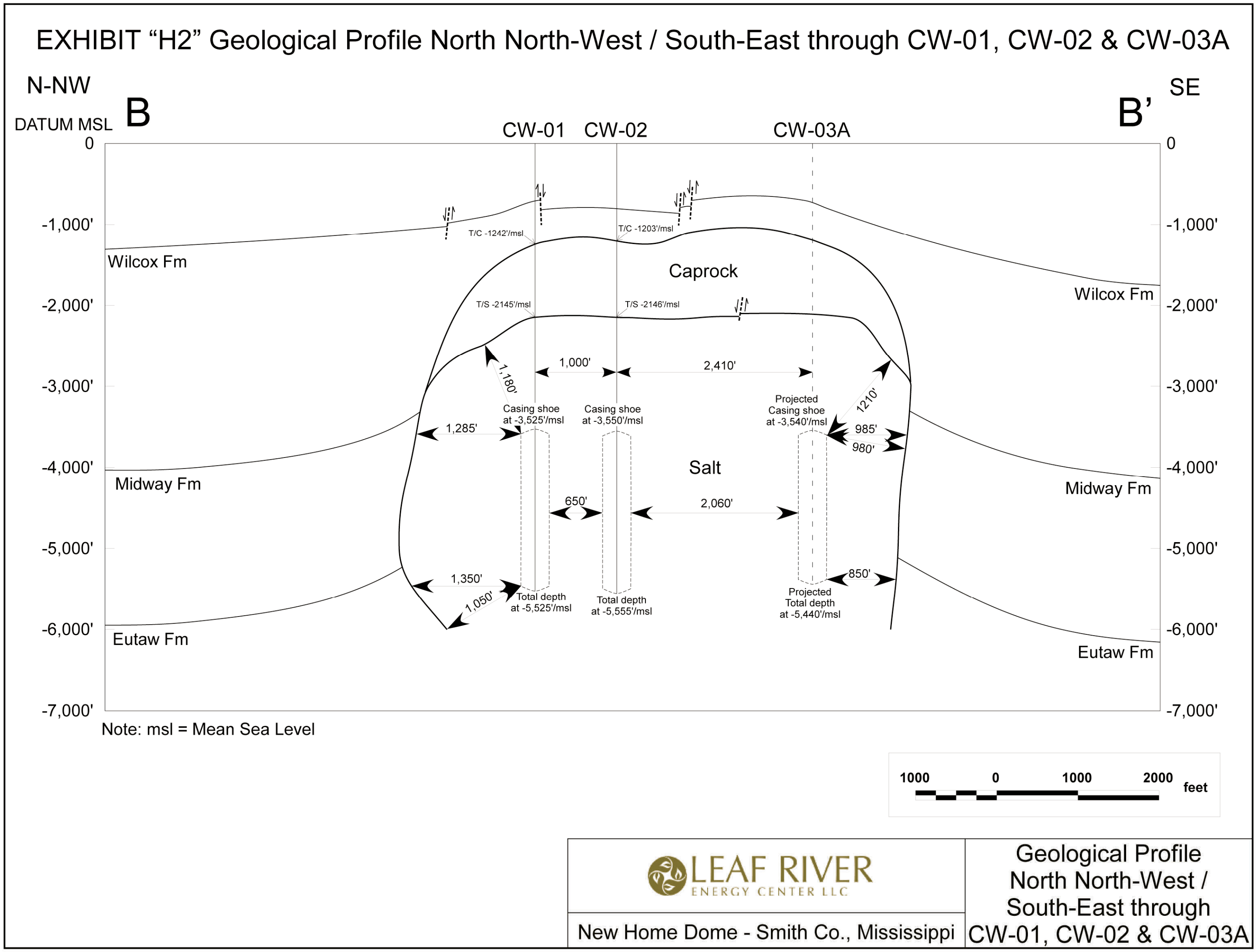


Figure 6.1-7
Geological Profile CC' Through Cavern Well 1

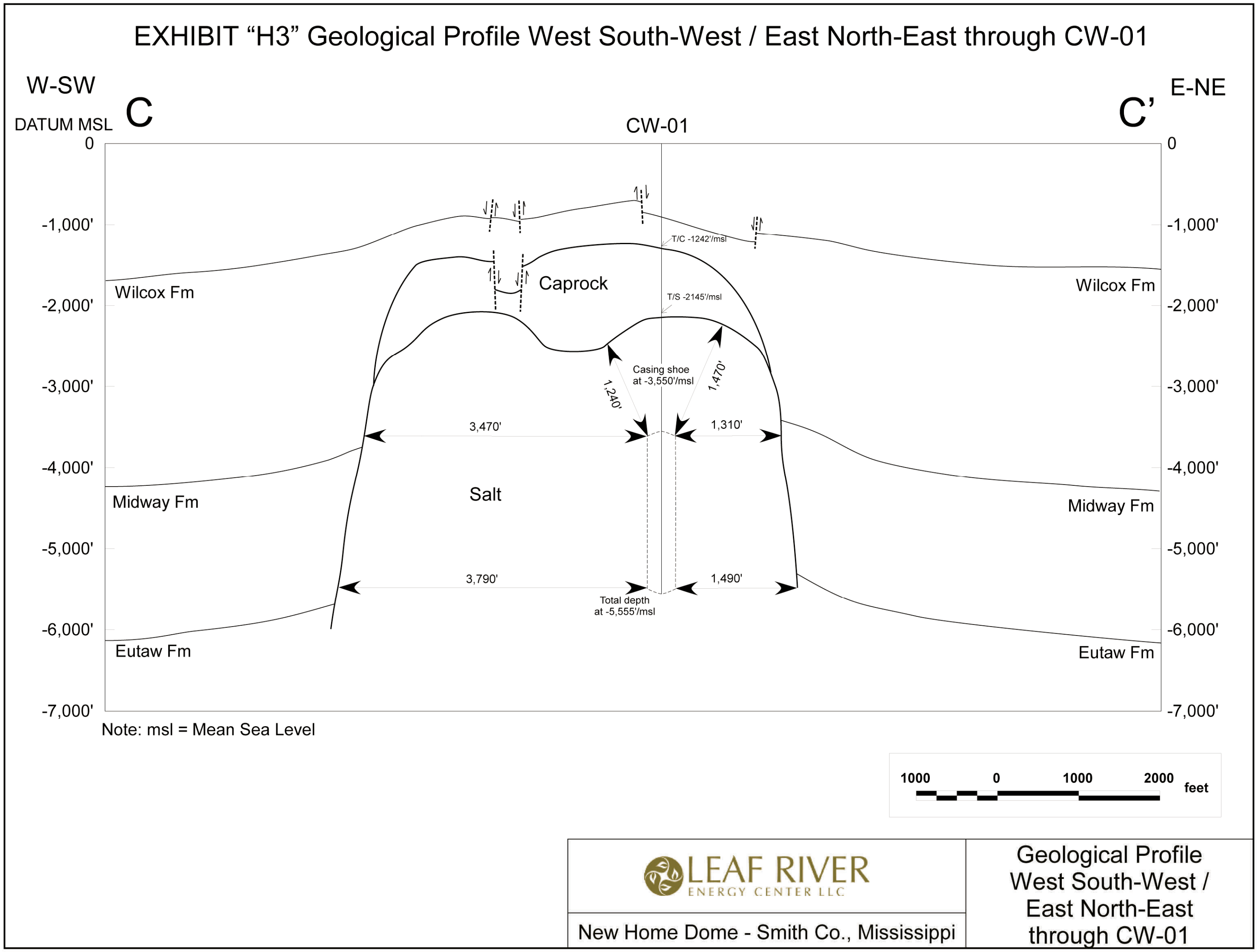


Figure 6.1-8
Geological Profile DD' Through Cavern Well 2

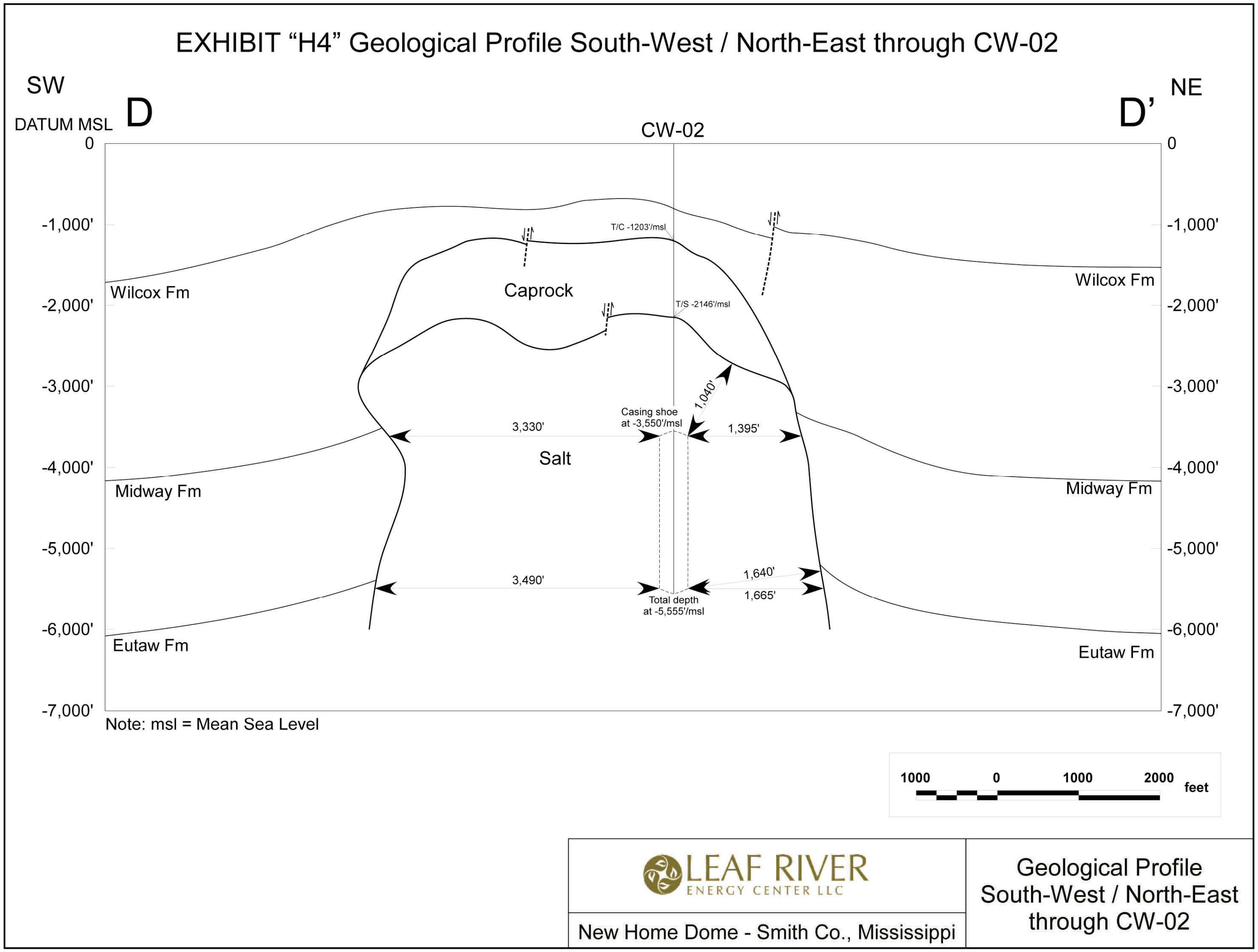
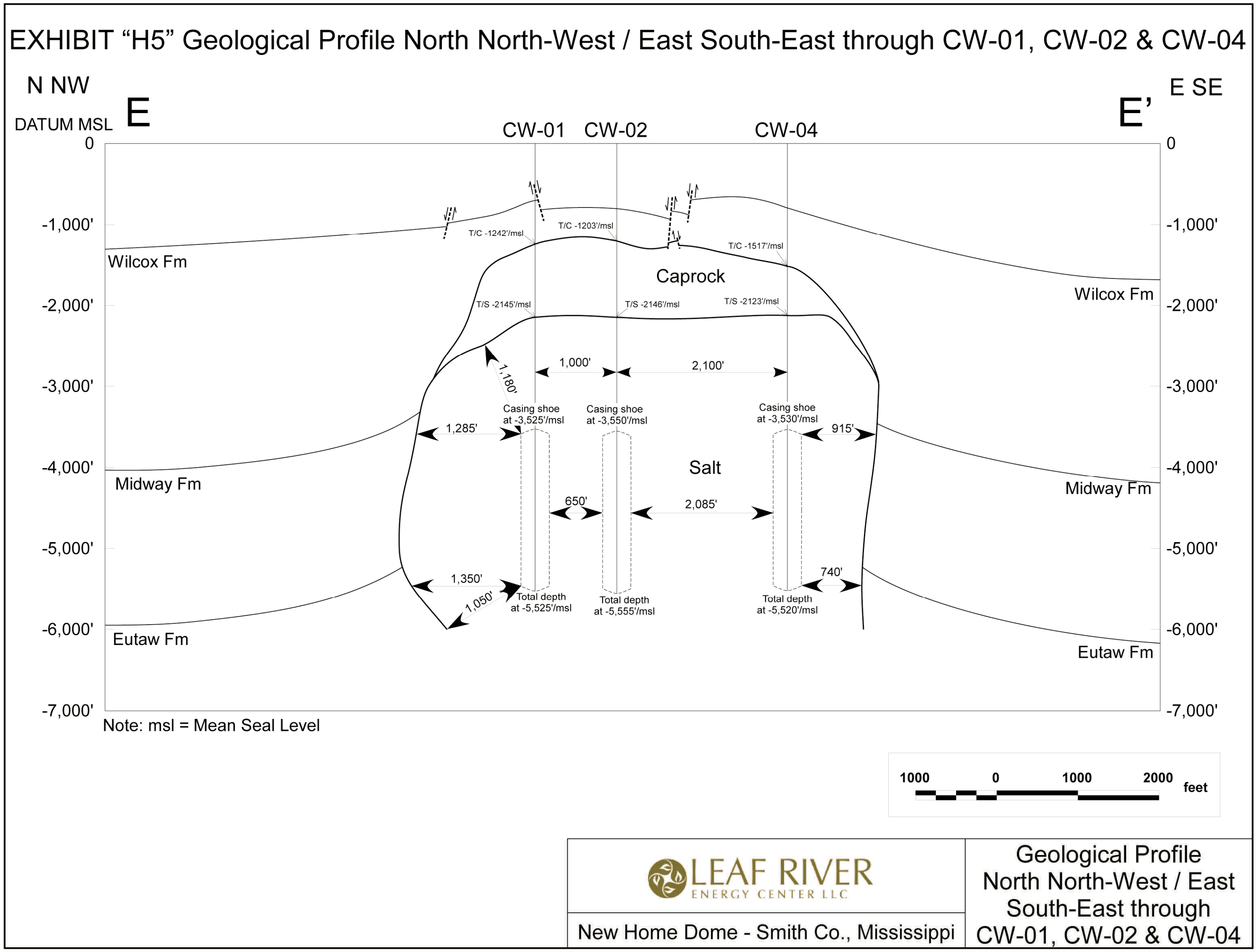


Figure 6.1-9
Geological Profile EE' Through Cavern Wells 1, 2 and 4



6.2 Blasting

LREC has not had to conduct any blasting to date in connection with its construction activities, and it does not anticipate that any blasting will be required at the proposed Project areas. LREC has determined that there are no identified soil associations that have the potential for bedrock at depths of less than 60 inches below ground surface (Docket No. CP11-107-000, **Addendum to Resource Report 7 - Attachment 7B** - *Map Unit Descriptions*, submitted Feb 25, 2011). If rock were encountered at the planned depth, it would likely be a sandstone or shale that could be removed with standard earthmoving or rock-picking equipment. If blasting is required, it would be performed in accordance with all local, state, and federal guidance and advance notice would be given to the necessary agencies and landowners in the surrounding areas, including the FERC.

6.3 Mineral Resources

6.3.1 Oil & Gas Exploration

To date, five exploration wells for oil and gas have been drilled along the flanks of the New Home Salt Dome. None of these wells has encountered commercial oil or gas accumulations. Since these wells have tested the flanking strata to depths approaching 13,000 feet and have penetrated the formations from the shallow Wilcox Formation to the deep Hosston Formation, it is unlikely that significant undiscovered oil or gas accumulations are present. This seems particularly clear in the case of the shallow strata above 6,000 feet. Project construction will not impact any producing oil and gas wells.

6.3.2 Sulfur Exploration

Five shallow wells on the top of the dome were drilled to test for sulfur deposits. According to Thieling and Moody (1997), these wells drilled what is presumed to be the carbonate facies of the caprock and stopped when the anhydrite facies of the caprock were encountered. No commercial sulfur deposits were found.

6.3.3 Mineral Deposits

The principal mineral resources for Mississippi include clay, lime, gravel and lignite. Typically, lignite deposits occur at depths greater than 250 feet. There are no underground or lignite surface mines in the Project area. Surface mining for sand, gravel, crushed stone, and common clay takes place within Smith County. There are no active surface mines that are expected to be affected by the Project.

6.4 Geologic Hazards

6.4.1 Seismicity and Faulting

Table 6.4-1 presents a summary of what is felt at the ground surface during earthquakes and the relative correlation of the Richter and Modified Mercalli (MM) Intensity Scale. The proposed Project areas are located in an area of little to no seismic activity. Based on a review of the USGS Earthquake Hazards Program, Quaternary Fault and Fold Database, no faults underlie or are observed near the Project areas (USGS 2007c). **Table 6.4-2** presents a historical record of reported earthquakes in the vicinity of the Project locations.

The USGS Hazard Map for the United States presents earthquake ground accelerations (horizontal) having a 10 percent probability of being exceeded in the next 50 years for a firm rock site (**Figure 6.4-3**). This map is based on seismicity and fault-slip rates and takes into account the frequency of occurrence of earthquakes of various magnitudes. The scale runs from 0-2 %g (lowest hazard) to 32+ %g (highest hazard). The factor “g” is equal to the force on an object at the surface relative to gravity. Analysis of the USGS Earthquake Hazard Map of the United States indicates that the Mississippi County of Smith is located in an area of low seismic hazard 2-3 %g (USGS 2007b and 2007c). Hence, it is unlikely that the Project would be affected by earthquakes. Superficial faulting could occur in the area, but it has not been observed in the Project area.

Table 6.4-1
Earthquake Intensity Scales

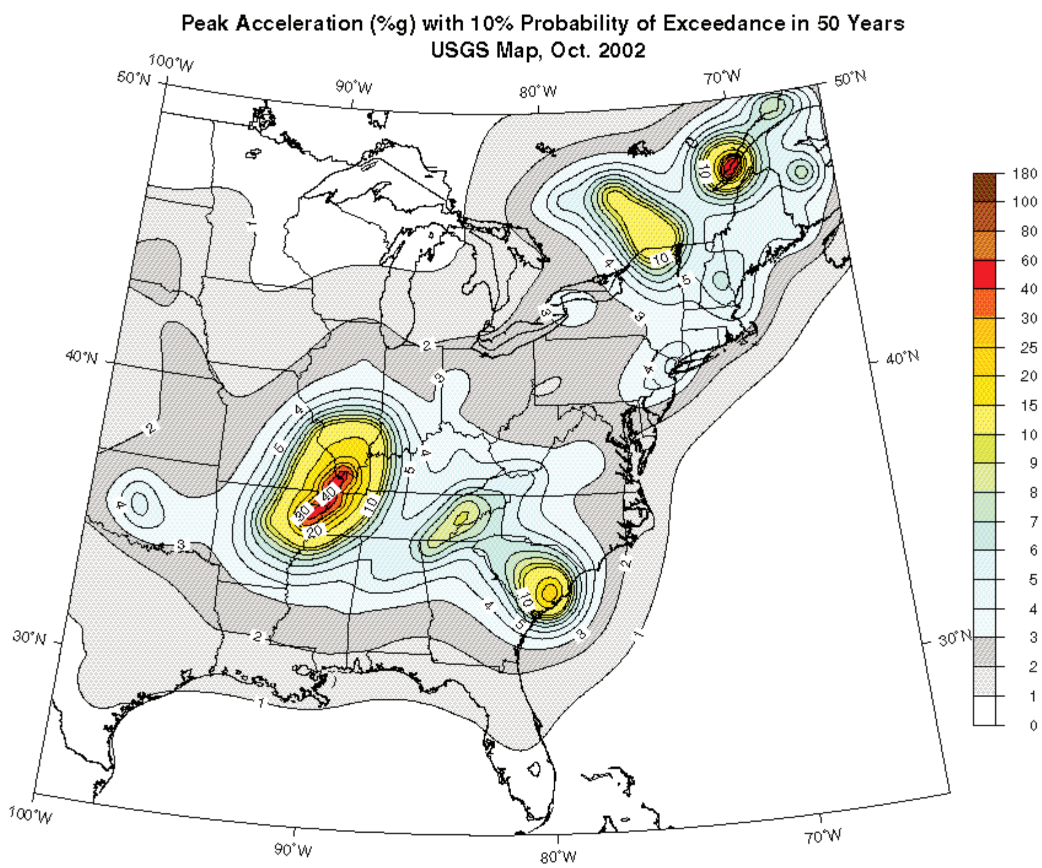
Magnitude (Richter Scale)	Intensity (MM Intensity Scale)	Descriptions
1.0 - 3.0	I	I. Not felt except by very few under especially favorable conditions.
3.0 - 3.9	II – III	II. Felt only by a few persons at rest, especially on upper floors of buildings.
		III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing vehicles may rock slightly. Vibrations are similar to the passing of a truck. Duration estimated.
4.0 - 4.9	IV – V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make a cracking sound. Sensation like a heavy truck striking building. Standing vehicles rocked noticeably.
		V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0 - 5.9	VI - VII	VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
		VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0 - 6.9	VIII – IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
		IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	X or higher	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
		XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
		XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Table 6.4-2
Earthquakes in the Vicinity of the Project Location

Date	Location	Magnitude (Richter)
December 16, 1811	New Madrid, MO Region	8.1 (including fatalities)
January 23, 1812	New Madrid, MO Region	8.0
February 7, 1812	New Madrid, MO Region	6.6
October 9, 1872	Sioux City, IA	4.9
April 13, 1905	Blytheville, Arkansas	4.9
October 20, 1965	Eastern Missouri	4.9
November 9, 1968	Illinois	4.9

Source: http://earthquake.usgs.gov/regional/states/iowa/history.php

Figure 6.4-3
USGS Hazard Map



Source: http://earthquake.usgs.gov/research/hazmaps/products_data/2002/2002October/CEUS/CEUSpga500v3.pdf

Although earthquakes occur in the state, Mississippi is not considered to be very seismically active. Low intensity earthquakes have occurred in Mississippi but rarely cause damage to structures. During a period from 1853 – 2003, 42 low magnitude earthquake epicenters have been located mostly in the northwestern portion of the State and Clarke County along the east-central border of the state (Bograd, 2005, 2006). Many of these earthquakes were detected by instruments but not felt at the surface (Bograd, 2005).

The greatest seismic risk to Mississippi is from strong earthquakes in the New Madrid Seismic zone, the southern end of which about 40 miles from the NW corner of Mississippi (Bograd, 2005). The largest recorded events being near New Madrid, Missouri in 1811 and 1812 when 4 to 5 quakes of an estimated magnitude of 8 or higher occurred (USGS).

The largest earthquake epicenter recorded in Mississippi was an intensity VI – VII quake that occurred in 1931 at Charleston in Tallahatchie County located approximately 150 miles NNW of the Leaf River site (Hake, 1974). Damage in Charleston was limited to a cracked foundation at the local high school and some fallen chimneys. The shock was perceptible over the northern 2/3 of Mississippi as well as adjacent portions of Alabama, Arkansas, and Tennessee.

6.4.2 Slope Stability

The map of Landslide Areas in the Contiguous United States map (Radbruch-Hall et al., 1983) and USGS Open File Report 97-289 (Godt) showing the geographic distribution of major hazards indicate that this portion of Mississippi has a low susceptibility for landslides. Landsliding involves the downward and outward movement of earth material under the force of gravity due to natural or artificial causes. Landslide susceptibility is associated predominantly with greater relief and more varied and rugged terrains than those found in the Project area.

All Project components are located within areas of level or gently sloping or rolling terrain (i.e. less than 8 percent slopes in the Mississippi County of Smith) (**Addendum to Resource Report 7 - Attachment 7B** - *Map Unit Descriptions*). For this reason, slope stability should not be an issue of concern for the Project areas.

6.4.3 Subsidence and Karst Terrain

Subsidence is defined as the local downward movement of surface material with little or no horizontal movement. In the Project areas, the main causes of subsidence are sediment compaction and human activities. The accumulation and compaction of several hundred feet of sediment since the last ice age has pushed the southern edge of North America downward, thus creating a potential for subsidence. In addition to natural subsidence, man-made causes of subsidence may include the extraction of oil and water from shallow wells. The proposed facilities will be designed and constructed to meet or exceed the federal safety standards set forth in *Minimum Federal Safety Standards for the Transportation of Natural and Other Gas by Pipeline* (49 CFR, Part 192), which will help ensure the integrity of the Project facilities and minimize the potential for failures in the facilities due to subsidence. LREC will conduct visual inspections of the facilities during operation to identify hazardous conditions, such as ground subsidence. The Project design and operational inspections will help to minimize the potential risks associated with subsidence.

Areas that have been identified for possible subsidence may be surveyed to determine the nature and severity of potential subsidence, if necessary. Depending upon the severity of the subsidence hazard, appropriate measures can be instituted, such as using heavier walled pipe and locating surface facilities outside of susceptible areas. However, since LREC has not experienced any problems relative to subsidence and karst terrain on its system in this region, no surveys or mitigation are proposed at this time.

Karst topography refers to geologic, hydrologic, and landscape features that are associated with the dissolution of soluble rocks, such as carbonates and evaporates (IDNR, 2007). A common feature of karst landscapes are sinkholes, which form when the land surface collapses into subsurface voids formed in the slowly dissolving rock. There is no indication that karstic conditions exist in the Project area.

6.4.4 Volcanism

Active volcanism is not present in the Project area (USGS 2007d). During the past several hundred years, more than 50 volcanoes have erupted one or more times in Alaska, Hawaii, Washington, Oregon, and California. All of these locations are associated with the Pacific Rim "ring of fire".

6.4.5 Paleontology

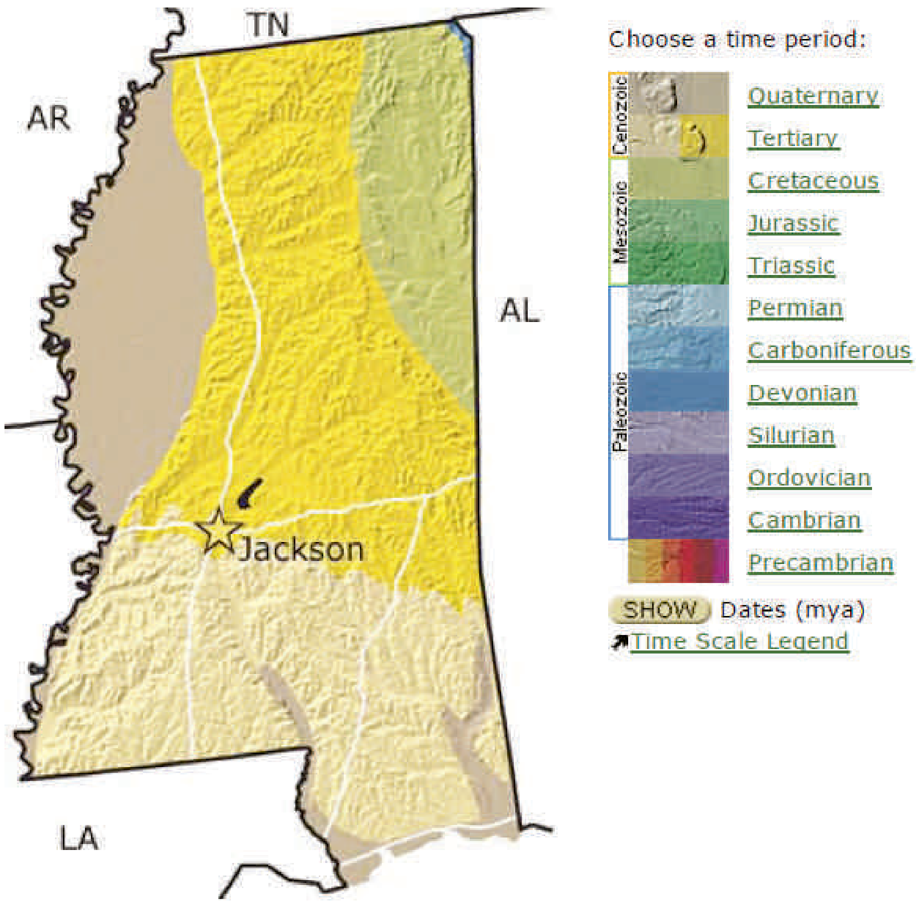
There are no Precambrian rocks that are known to occur in Mississippi (**Figure 6.4-4**). The State of Mississippi, as such, did not exist during this time. The youngest rocks found in Mississippi are marine in origin, formed during the Late Devonian. A sea with pockets of deep, oxygen-poor water covered the northeastern part of the state at this time. The fossils in these dark-colored rocks are primarily plant fragments and the remains of animals that could swim above the oxygen-starved depths. The sea continued to cover portions of the state into the later part of the Paleozoic and provided a home to mollusks, crinoids, brachiopods, and trilobites. During the Late Carboniferous, the water retreated as vast amounts of sediments were poured into the sea from the erosion of newly formed mountains. Forests of primitive trees and fern-like plants grew on the resulting broad coastal plains. By the end of the Paleozoic, the entire state was above sea level and exposed to erosion.

Mississippi remained above sea level for much of the Mesozoic. However, during the latter part of this era, a shallow sea flooded the region as North and South America moved farther apart during the breakup of the supercontinent of Pangea. The rocks originally deposited as sediment on the floor of this sea contain abundant fossils of both invertebrates and vertebrates. Also, pieces of petrified wood are common.

Warm, tropical seas periodically flooded southern Mississippi during the early part of the Cenozoic, while the northern part of the state remained above sea level. Marine fossils include whales, sharks, and bony fish, as well as numerous mollusks and other invertebrates. Fossilized wood found in northern Mississippi provides evidence of the forests and swamps that existed there at this time. In the Late Cenozoic, most of the state was covered by coastal plain and shallow sea. Glaciers far to the north of the state affected the climate and caused fluctuations in sea level. Blankets of wind-blown silt (loess) eroded from the Mississippi River floodplain cover large areas in the northwestern part of the state. Fossil shells of various terrestrial and freshwater mollusks, as well as the fossil bones of a number of terrestrial mammals, have been recovered from the loess deposits.

Since the proposed Project components involve limited vertical disturbance over substantial areas, it is highly unlikely that sensitive paleontological resources will be disturbed. However, in the event paleontological resources are discovered during the construction process, all work will be halted immediately until such time as the area can be assessed by qualified personnel.

Figure 6.4-4
Paleontology Map of Mississippi



Source: http://www.paleoportal.org/index.php?globalnav=time_space&sectionnav=state&name=Mississippi

6.4.6 Unique Geologic Features

Unique geologic features are not present in the areas of the proposed Project segments; therefore, impacts to unique geologic features are not anticipated.

6.4.7 Soil Liquefaction

Soil liquefaction is a process whereby the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. The result is a transformation of the material from a solid to a liquid state. Liquefaction occurs in saturated soils where the space between individual particles is filled with water. This water exerts a pressure on the soil particles that influences how tightly the particles themselves are pressed together. Because soil liquefaction occurs in saturated soils, it is most commonly observed near bodies of water such as rivers, lakes, bays, and oceans and associated wetlands.

Earthquakes are the common trigger for liquefaction. Prior to an earthquake, the water pressure is relatively low. However, earthquake shaking can cause the water pressure to increase to the point where the soil particles can readily move with respect to each other. Soil liquefaction is not anticipated to be a concern in the Project areas. However, in areas of high water table, limited dewatering will be performed in accordance with the conditions of water appropriation and dewatering discharge permits which will be obtained prior to the commencement of construction (if required). In general, depth to groundwater ranges from 18 to 30 inches for the mapped soil associations that are included in the Project areas (**Addendum to Resource Report 7 - Attachment 7B** - *Map Unit Descriptions*). In combination with the low potential of encountering seismic activity (Section 6.4.1), it has been determined that soil liquefaction is not a concern for the Project areas.

6.4.8 Surface and Subsurface Mines

There is no surface or subsurface mining known to be planned or active in the Project area. Therefore, the Project is not likely to hinder mine reclamation or expansion efforts, nor induce contamination from surface mines or induce ground failure associated with surface and subsurface (underground) mining.

6.4.9 Active Faults

Mississippi lies within the geologic province known as the Gulf Coast Basin where thick sedimentary rocks overlie basement rock structures. Despite that faults parallel to the coast are common throughout the Gulf Coast, including Mississippi, they consist of subsurface faulting with no evidence of surface expression. These faults are inactive and surface topography does not indicate any upward movement of active faults in the Project area.

Faults in central Mississippi are classified as Class B by Wheeler (1998) because of their low seismicity and because they may be decoupled from underlying crust, making it unclear if they can generate significant seismic ruptures that could cause damaging ground motion.

6.5 Project Design and Location

This section describes how the Project has been located or designed to avoid or minimize adverse effects to the resources or risk to itself, including geomechanical investigations and monitoring.

6.5.1 General Storage Cavern Design Parameters

6.5.1.1 Suitability of the New Home Salt Dome for Storage Construction

Underground salt cavern gas storage facilities must he created in impermeable salt formations and operated to prevent waste or uncontrolled escape of the stored gases, pollution of fresh water, and danger to life or property.

From a geologic standpoint, LREC's review of the New Home Salt Dome shows, and its experience to date confirms, that there is sufficient opportunity for cavern development, brine disposal, and raw water sources. The geological information was augmented during the initial construction phase of the Project by coring the salt to determine the nature of the salt, salt dissolution activity, and the internal structure and mineralogy of the salt. Each of these items of information will be used to refine the design of the caverns during leaching and future gas operations. All cores have been, or will be, described in detail and photographed. The logging of all wells is important; therefore, the initial drilling of these wells was done in a manner that allowed a quality log to be obtained.

6.5.1.2 Applicable Standards and Codes

The Project has been designed and will be operated in strict accordance with all federal and state standards and codes regulating the construction, operation, and safety of underground natural gas storage facilities including:

- U.S. Department of Transportation (DOT) Pipeline Safety Regulations 49 CFR Part 192 - Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards;
- FERC Regulations 18 CFR Part 380;
- Mississippi State Oil and Gas Board - Rule 64;
- Mississippi State Oil and Gas Board - Rule 63; and
- All the most recent applicable federal, state and local codes and regulations.

LREC is in the process of obtaining all required state and local permits for the project, including the MSOGB permit authorizing the increase in the cavern size of Cavern Nos. 2 and 4.

6.5.1.3 Geotechnical Investigation

This section addresses the geomechanical issues related to enlarging the caverns from 8 Bcf to 12 Bcf of working gas capacity (15.71 Bcf total capacity). The additional working gas capacity will be achieved by increasing the cavern diameter. An 8 Bcf working gas capacity cavern has an approximate maximum diameter of 250 feet. LREC's prior filings indicated that the LREC caverns would be constructed within a 300 foot diameter design envelope. A 12 Bcf working gas capacity cavern will require an approximate maximum diameter of 300 feet, within a 350 foot diameter design envelope. The design envelope allows for some degree of nonconcentric cavern development.

Gulf Coast salt domes provide a stable geologic medium for gas storage caverns. The 326 known Gulf Coast salt domes are located in four states: Texas, Louisiana, Mississippi, and Alabama (Halbouty, 1979). The vast majority of the shallow salt domes have been extensively explored and studied since the early 1900s for various applications, including U.S. Strategic Petroleum Reserve Storage, nuclear waste repository sites, salt mining, LPG storage, brine production, and natural gas storage.

Over several decades, salt cavern engineering and design methodologies have been developed and tested successfully based on experience with similar caverns. As a result, guidelines, regulations and compliance requirements from state agencies and other commissions integrating historical trial and error experiences have been established.

The homogeneity of the Gulf Coast salt domes, the purity of the salt (reportedly ranging as high as 99.2%), the consistent strength characteristics of the salt (Louann Salt), as well as the extent of the salt mass (typically 1 to 2 miles in diameter and 12,000 feet deep) have made it possible to use conventional leaching techniques to create the caverns. The quasi- perfect cavern shape (vertical ellipsoid) resulting from specifically engineered natural gas storage caverns using conventional leaching techniques provides geomechanical stability of the system, reducing greatly the risk of excessive subsidence, excessive shrinkage (creep) and the risks of catastrophic failure of the cavern.

Specific information on the mechanical behavior of various salt strata is well documented in the literature. In particular, the American nuclear waste management literature from the period 1970-1995, when salt was a major subject of study as a potential repository rock, provided large amounts of data.

LREC has taken core samples from Monitor Well 1, Cavern Well 2 and from Cavern Well 4 and will take core samples in Cavern Well 3A. Generally, geomechanical salt parameters can be expected to be similar over the entire heights of caverns constructed in Gulf Coast domes because of the homogeneity of salt present; however, core samples have been and will be taken at various relevant depths within the salt formation. The cores from Monitor Well 1 have been tested to assess the elastic constants (e.g., Young's modulus and Poisson's ratio) of the salt cores. Additional tests were performed to assess the time-dependent behavior of the salt cores (triaxial creep tests). To ensure the accuracy and validity of the test results, these experiments were carried out over a period of several months. These tests showed the salt to have properties consistent with other Gulf Coast salt domes.

The LREC caverns and proposed caverns are very similar to those employed at the Egan Storage Facility (ESF). The ESF caverns were analyzed in detail and discussed in Sandia National Laboratory (SNL) Report 99-0421, Feb. 1999 (attached to the original certificate application submitted by Leaf River Energy Center LLC in Docket No. CP08-8-000, Dec. 11, 2008). The SNL Report examined the effects of enlarging the ESF caverns using both slow creeping and relatively fast creeping salt properties over a 50 year period. The creep properties for the New Home Salt Dome measured from core samples taken from Monitor Well 1 fall within this range. The study evaluated the potential for damage to or around the caverns based on two different criteria: tensile failure and dilation damage. The tensile strength and dilation properties for New Home salt are typical of other Gulf Coast salt domes and consistent with those used in the SNL Report. The salt thickness separating individual caverns relative the cavern diameter will be the same or greater between the proposed Project caverns than those assumed in the SNL Report. The SNL Report finding of geomechanical suitability of the ESF caverns for gas storage can safely be transferred to the proposed Project caverns and supports increasing the capacity of the caverns up to 12.0 Bcf working gas (15.71 Bcf total gas storage capacity).

The LREC Cavern design and solution mining process will be continually reviewed throughout the construction phase to take into account pertinent additional information. LREC will inform the Mississippi State Oil and Gas Board (MSOGB) about any tests or surveys conducted during the construction phase and provide copies to MSOGB and FERC as soon as practical.

6.5.1.4 Storage Cavern Location and Geometry

Per MSOGB Rule 64, the walls of the proposed caverns will be at least 100 feet from the property lines and more than 300 feet from the edge of the salt mass. Additionally, Rule 64 states that at maximum cavern development, cavern walls will be more than 200 feet apart. The current LREC plan and design has cavern wellhead to wellhead separation of 1,000-1,100 feet at a minimum. With a maximum design envelope diameter of 350 feet, the minimum pillar spacing (i.e., the amount of salt remaining in place between adjacent caverns) will be 650-750 feet. The minimum distance from the caverns' walls and the edge of the salt mass is estimated at 740 feet. These spacing intervals all exceed by a substantial margin the minimum spacing values prescribed by MSOGB Rule 64.

The base of salt extends below 7,000 feet, thus providing an ample buffer below the bottom of each completed Cavern, which is estimated at approximately 5,950 feet. **Figures 6.1-5** through **6.1-9** depict five cross sections through the New Home Salt Dome and show the location of all the Caverns, the separation between Caverns and between Caverns and the edge of the salt dome.

6.5.1.5 Well Completion, Casing and Cementing

The cavern wells will be drilled and completed in accordance with applicable statewide rules and regulations of the Commissioner of MSOGB. The casing program includes a 36-inch surface casing, a 30-inch intermediate contingency string) and a 26-inch intermediate string that will be cemented to the surface. The 36-inch surface casing string will be set approximately 50 feet into the caprock (in the range of approximately 1,600 feet to 1,850 feet below ground surface). The 30-inch intermediate contingency string (if needed) will be set between the 36-inch surface casing and top of salt. The 26-inch intermediate casing string will be set approximately 150 feet below the salt top (approximately 2,700 feet below ground surface). A 20-inch production casing will be set in the range of approximately 3,900 feet to 3,950 feet below ground surface. The salt interval between the top of salt and the production casing seat will range from approximately 1,300 feet to 1,500 feet. The caverns will be at an approximate common depth of -3,500 feet below mean sea level.

All casings have been designed in accordance with applicable regulations and good engineering practice. In particular, the production casing will be welded to maintain gas tightness and will be cemented back to surface. All casing strings will be centralized throughout the interval to be cemented.

Cement slurries will be compatible with the salt formation and cement will be placed by the plug and displacement method. The casing cement job will be documented by an affidavit from the cementing company showing the amount and type of cementing materials and the method of placement. All cementing and service reports will be filed with MSOGB within 30 days. As the production casing string will be installed by welding, it will be of a weldable grade such as API 5L Grade B or an ASTM weldable grade.

Casing string welders will be qualified under either Section 3 of API 1104 specification or Section IX of the ASTM Boiler and Pressure Vessel Code for the thickness to be welded. In addition to a visual inspection of the completed weld, an x-ray or ultrasonic inspection will be run on at least 100% of the string. Defective welds will be ground, re-welded and re-inspected.

The production casing will be pressure tested in accordance with the requirements of MSOGB Rule 64.12. The hydraulic tests will be performed before drilling out the plug. The test pressure calculated at the casing seat will equal the maximum operating pressure at that point. The test pressure will be maintained for a minimum of one hour to verify casing integrity and absence of thread leaks.

The casing seat and cement of the final cemented casing string will be hydrostatically tested after drilling out the plug. At least 10 feet of salt below the casing will be penetrated prior to this test. The test pressure will be maintained for a minimum of one hour. The test pressure calculated at the casing seat will equal the maximum operating pressure at that point. However, the test pressure will not exceed 0.9 psi per foot of depth.

The test will be prepared and supervised by a qualified engineer and a report of these test results attested to and filed with MSOGB within 30 days.

6.5.1.6 Cavern Operating Pressure

The anticipated storage minimum and maximum operating pressures are based on the geological investigation on the New Home Salt Dome and typical geomechanical properties of Gulf Coast salt domes. As previously stated, these values will be revised after the above described site-specific core tests are completed. The maximum allowable operating pressure at the 20-inch production casing seat of the cavern will not exceed 0.9 psi per foot of overburden. For a 20-inch production casing shoe of 3,950 feet, the corresponding maximum operating pressure at the production casing shoe is 3,555 psig. The corresponding maximum surface pressure will vary depending on the average gas specific gravity and the bottomhole and surface gas temperatures. For a bottomhole temperature of 140° F and a surface temperature of 100° F and a natural gas specific gravity of 0.6, the maximum surface pressure will be approximately 3,252 psig.

The minimum operating pressure at the 20-inch production casing seat of the cavern will not be below a 0.175 psig per foot of overburden corresponding to 692 psig at 3,950 feet (20-inch production casing depth). The wellheads will be fitted with pressure control equipment in order to ascertain that the storage cavern will not be subjected to pressures in excess of the maximum operating pressure regardless of the time period involved.

6.5.2 Gas Storage Cavern Development

Cavern wells will be solution-mined at an average flow rate of approximately 5,500 gallons per minute (gpm) in 16-inch- and 10-3/4-inch-diameter leaching tubulars (hanging strings). Direct and reverse circulation will be used and a diesel oil blanket fluid will be utilized to prevent uncontrolled leaching of the cavern roof and to protect the production casing seat. The hanging strings will consist of 16-inch- and 10-3/4-inch-diameter concentric strings. Initial cavern development work will be performed utilizing direct circulation leaching, with the outer string located between approximately 4,900 feet to 5,100 feet bgs and the injection string between approximately 5,900 feet to 5,950 bgs. Initially, the protective diesel blanket will be located at approximately 4,300 feet (i.e., 350 feet below the 20-inch production casing). The blanket depth will be monitored and repositioned as necessary to protect the casing seat and create a cavern roof that displays the desired dome shape.

Insoluble material will build up on the bottom of the cavern throughout the cavern development process. The insoluble depth will be verified periodically and the inner-most hanging string will be cut or perforated as necessary to prevent plugging of the string. The direct circulation phase of leaching will be completed after approximately 0.6 to 1.0 million barrels of cavern space have been created (between 2 - 4 months). At this point, the cavern shape and capacity will be confirmed by performing a sonar survey (through tubing technique). If the shape and volume are acceptable, the main cavern leaching phase will start.

The remainder of the cavern development process will be accomplished primarily using reverse circulation (i.e., raw water will be injected down the annulus of the outside hanging string and the inside hanging string) with the resulting brine being produced through the innermost (long) hanging string. Blanket fluid depth will be raised at several intervals throughout the development to a final depth of 4,050 feet, leaving approximately 150 feet between the cavern well production casing shoe (3,950 feet) and top of cavern roof (4,100 feet). The protected zone from the cavern roof to the casing shoe is known as the cavern neck. This process shapes the roof for structural integrity and will be confirmed during cavern development by employing additional sonar surveys. In all cases the blanket material will be maintained at a level to protect the production casing seat.

Solution mining software called SANSMIC (developed by Sandia National Laboratory) was employed to simulate the leaching process described above and predict cavern shape. Throughout the cavern creation process, the cavern capacity will be verified utilizing sonar surveying technology (acoustical wave reflection technology). The sonar surveys will determine the size, shape and overall extent of the caverns. At completion of the cavern development process, a final sonar survey in brine (and without the leach tubings) will be performed and submitted to the MSOGB. This last survey in brine will be measured with the leaching strings pulled out of the well. Hanging strings will be reinserted into the well for dewatering and future Solution Mining Under Gas (SMUG) operations. At this time the hanging strings may be reduced in size to 13-3/8-inch and either 9-5/8-inch or 8-5/8-inch to provide better gas hydraulics during SMUG. Prior to conversion, the cavern will be shut-in for stabilization for about one month and a nitrogen/brine interface Cavern Mechanical Integrity Test will be performed as required by MSOGB Rule 64. This test will be completed by pressuring the entire cavern, well, and wellhead system, while monitoring any associated movement of the interface nitrogen. A mass balance will be calculated for the nitrogen over the whole test. The surface test pressure will be calculated in order to pressurize the cavern to a pressure equivalent of 0.90 pounds per square inch (psi) per foot of depth at the production casing seat.

Following confirmation and approval by the MSOGB of the pre-operation requirements, as provided in MSOGB Rule 64.14, the proposed caverns will be converted to natural gas storage service. The caverns will be dewatered by injection of natural gas in the annulus of the 20-inch-diameter production casing and the outer hanging string. Brine will be displaced from the cavern via the hanging strings for ultimate disposal in saltwater disposal wells. Natural gas will be injected by multistage compressors. Once the cavern has been debrined (brine removed to within 5 feet of the bottom of the tubing), the brine outlets will be blocked in. The duration of the gas first-fill operation is approximately 2-4 months. Gas injection will continue and the cavern will reach operating pressure. The cavern pressure will not be allowed to exceed a 0.9 psi/foot gradient at the casing shoe (approximately 3,950 feet) or decrease below a 0.175 psi/foot gradient at the casing shoe (approximately 3,950 feet). Natural gas will be injected under pressure and withdrawn from the caverns through expansion and pressure reduction. Gas will be withdrawn and injected as needed.

Cavern volumes will be increased to the final permitted volume by use of the SMUG technique. The flow rate will range to approximately 4,200 gpm during this operation. Only the bottom part of the cavern will be increased in size during this phase.

6.5.3 Raw Water for Solution Mining

LREC consulted local experts and the MDEQ to discuss potential water supply zones. The Sparta Aquifer and Lower Catahoula were rejected because they are being used as an underground source of drinking water (USDW). It was determined that the Wilcox formation, particularly the Upper and Middle Wilcox zones, showed the best potential as a suitable water source. Based on correlations from deep geophysical logs in the area it is estimated that the top of the Wilcox Formation is approximately 1800 to 1900 feet bgs and its base between 4,400 and 4,500 feet bgs. The Middle and Upper Wilcox is expected to have total dissolved solids (TDS) of less than 1,000mg/L. The bottom of the Wilcox will likely have TDS levels greater than 1,000 mg/L. There are no known water quantity limitations or quality issues in the area of the Project.

LREC will use its existing and certificated water supply wells as the sources for raw water during the cavern development process. LREC does not foresee the need to drill additional water supply wells at this time. A total of about 80 million bbls of water supply will be necessary to create one gas storage cavern. There are no other industrial facilities in the area of the LREC facility to compete with the Project for the water quantities required and therefore the water production for the Project is not anticipated to have a substantial effect on the existing water table. Moreover, the Wilcox aquifer is used typically for brine disposal in Mississippi and was chosen in consultation with the MDEQ.

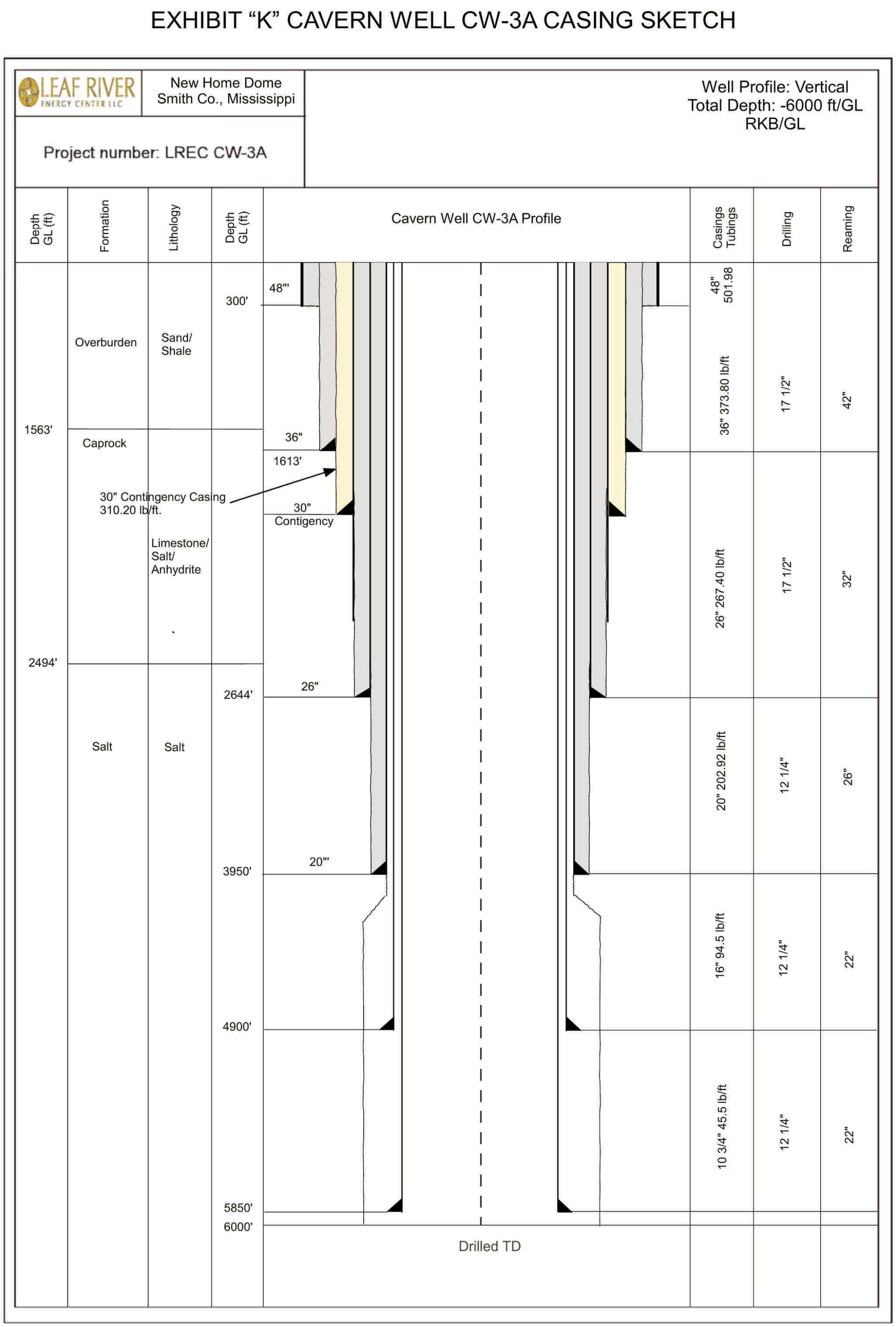
6.5.4 Brine Disposal Wells

Brine from the solution mining of the Gas Storage Caverns will be disposed of in the existing and certificated SWD wells that have been drilled and completed in accordance with MSOGB Rule 63. The wells are located on a company-owned 260-acre property. The wells were completed in the highly-permeable Eutaw and Tuscaloosa sand. There are no known disposal wells using the Eutaw or Tuscaloosa formation in this area and so it not anticipated that there will be interference.

6.5.4.1 Well Design and Construction Specifications

The existing cavern wells (LREC CW-01, CW-02 and CW-04) have been drilled and completed in accordance with applicable statewide rules and regulations of the MSOGB. Cavern Well 3A will be drilled and completed in accordance with the same requirements. The casing program includes two cemented casings from the surface into the salt dome (**Figure 6.5-1**). At the proposed Cavern Well 3A a 26-inch-diameter intermediate casing is planned to be set at approximately 2,640 feet BGL and a 20-inch-diameter production casing is planned to be set at approximately 3,950 feet BGL. The salt interval between the top of salt and the production casing seat is approximately 1,450 feet.

Figure 6.5-1
Cavern Well 3A Casing Sketch



6.5.4.2 Wellheads and Flowline Equipment

All wellhead components (casing head, tubing head, etc.), valves and fittings will be made of steel. The water side of the wellhead will have the same pressure rating as the products side. Each flowline connected to the wellhead will be equipped with a remotely operated shut-off valve as well as a manually operated positive shut-off valve located on the wellhead. The wellhead, flowlines, valves, and all related connections will have a test pressure rating at least equivalent to 125 percent of the maximum pressure which could be exerted at the surface. All valves will be inspected periodically and maintained in good working order.

The wellhead and storage cavern will be protected with safety devices to prevent pressures in excess of maximum operating pressure from being exerted on the storage cavern, and to prevent backflow of stored products in event of flowline rupture. The brine flow line will be equipped with a safety shut-off valve to prevent the escape of gas. Competent personnel will be present at the control room during injection or withdrawal of gas. The wellheads will be protected from mechanical damage by trespassers and/or accidental physical damage.

6.6 Gas Storage Caverns Operation Monitoring and Safety

This section of Resource Report 6 describes how LREC would monitor potential effects of the proposed underground storage operation on adjacent operations and vice versa; describes the measures that would be taken to determine the condition and location of old wells; and finally, identifies and discusses safety and environmental safeguards required by state and federal drilling regulations.

6.6.1 Monitoring of Old Wells

Limited oil and gas activity has occurred in the vicinity of the New Home Salt Dome. Only four wells have been drilled in the search for oil and gas since the first well was drilled in 1945. All five of these wells failed to encounter oil or gas accumulations and were plugged and abandoned. Based on the Tobin listing and Theiling and Moody (1997), these wells are:

1. Gulf Refining Co. - E.G. King #1 (API #2312900125); sec.8, T10N-R13W; TD 8302; D& A; 4/1945.

2. Gulf Refining Co. – O.P. Foley #1 (API #2312900259); sec.8, T10N-R13W; TD 6341; D & A; 12/1945.

3. Lone Star Producing Co. (James Harris) –H.E. Stone #1 (API 2312900135); sec 8, T10N-R13W; TD 12520; D & A; 6/1958. Tobin lists Harris as the operator and a D & A date of 4/1964.

4. Mossbacher Energy Co. – B. L. Parker #1 (API 2312920246); sec.6, T10N-R13W; TD 8310; D & A; 11/1991.

5. Bean Resources (Century Exploration) – J.B. Ishee #1 (API 2312920272); sec. 5,T10N-R13W; TD 12977; 12/2002.

None of the above wells appears within the proposed Project area.

6.6.2 Monitoring Drilling Activities of Others Within the Field

In the event that there are any drilling activities in the vicinity of the storage field, special field rules will be implemented by MSOGB. Should any drilling activity occur within the field, the operator would have to comply with these special field rules.

6.6.3 Monitoring Potential Effects of the Operation of/on Adjacent Storage or Production Facility

Currently, there are no storage fields in the vicinity of the LREC Project.

6.6.4 Monitoring and Inspections During Gas Operation

6.6.4.1 Safety Inspections

LREC will perform semi-annual inspections of each Cavern Storage Well and file a written report with the MSOGB within 30 days of the inspection, as required by MSOGB Rule 64. LREC will notify the MSOGB at least five days prior to such inspections so that its representative may be present to witness the inspections.

These inspections will include, as a minimum, the following:

- Operation of all manual valves;
- Operation of all automatic shut-in safety valves, including sounding of alarm devices;
- Flare system installation, or hydrocarbon filters;
- Earthen brine pits, tanks, firewalls and related equipment;
- Flowlines, manifolds, and related equipment;
- Warning signs, safety fences, etc.

6.6.4.2 Cavern Capacity Determination

The storage cavern capacity will be verified at least once every five years in accordance with the requirements of MSOGB Rule 64. These capacity verification data will be submitted to the MSOGB within 30 days of the measure.

6.6.4.3 Cavern Mechanical Integrity Test

Prior to storing natural gas, each cavern will be subjected to a Mechanical Integrity Test conducted in accordance with the requirements of MSOGB Rule 64. A detailed testing procedure will be submitted to the MSOGB for review and approval prior to conducting the Mechanical Integrity Test as required by MSOGB Rule 64. The outline of the test procedure will be as follows:

- After the end of the leaching phase, the cavern brine temperature and salt saturation will be allowed to approach stability;
- For test purposes, the cavern will be considered stable and the test will commence when the shut-in brine pressure changes less than 10 psig in 24 hours;
- Calibrated temperature and pressure gauges will be used to monitor both wellhead and ambient temperatures throughout the test;

- A conventional nitrogen-brine interface test will be conducted, in which sufficient nitrogen will be injected to lower the nitrogen-brine interface in the outer annulus to below the final production casing, but above the cavern roof;

- Temperature and interface surveys will be employed at the beginning and at the end of the test. These data will be combined with surface pressure and temperature data to determine the mechanical integrity of the well.

6.6.4.4 Christmas Tree (Wellhead) and Cemented Casing Inspection

Once the cavern is in service, the Christmas tree (wellhead) and the casing will be inspected periodically as required by MSOGB Rule 64.

6.6.4.5 Cavern Inventory Monitoring

The volume of gas injected into and withdrawn from each storage well will be determined by gas movement data from the master meter and records of pressure and temperature change (or by an alternate method approved by MSOGB).

6.6.4.6 Cavern Pressure Monitoring

The pressure of the storage caverns will be monitored continuously. Cavern wellheads will be instrumented with a high and low level pressure recorder and alarms/shutdowns. This system will prohibit any violation of maximum and minimum operating pressure limits even for a short period of time. All gas injection and withdrawal activities will be continuously monitored by an individual who is experienced and trained in such activities.

6.6.4.7 Subsidence Monitoring

A subsidence monitoring program will be implemented and maintained throughout the life of the Project. Permanent monuments will be installed around each storage cavern and a regular monitoring program to check the elevation changes at each monument will be undertaken. The monuments will be anchored into the bedrock below the ground to avoid near surface effects (or at 30 feet below the surface). The cavern wellheads will form part of the subsidence monitoring program. Elevation surveys (cavern wellheads and monuments) will be performed every six months during the dewatering period and once a year thereafter. The surveys will take place in the same season of the year to minimize the effect of ambient temperature.

6.6.5 Planned Safety and Emergency Response Plans

MSOGB has jurisdiction over safety precautions regarding the storage and transmission of the gas while it is stored underground and in the associated wellhead facilities. LREC must have all required safety measures and equipment in place before the facility may begin operation as required by MSOGB Rule 64.

6.6.5.1 Risk Identification

<u>Geomechanical Accident</u>

The risk of a geomechanical accident that could lead to gas loss, explosion and/or subsidence will be minimized by using conventional salt cavern technology that has been employed successfully for decades in the United States. This technology was used in the development of the cavern design at the Moss Bluff and Egan Hub Gas Storage Facilities, which have experienced no measurable volume loss due to creep, cavern instability or surface subsidence. If a geomechanical accident were to occur, it would be unique in nature and would require a case-specific analysis to determine the appropriate response. In any event, LREC would take appropriate action to ensure the safety of its employees and the public, and would take appropriate action to minimize damage and/or negative impact to the facilities and surrounding areas.

Gas Leak

In the case of a gas leak, the action taken would depend on the location of the leak. If the leak is aboveground (e.g., on the wellhead, or piping leaving the wellhead), the wellhead and/or piping would be shut-in and isolated, and repairs made to stop the leak. These repairs could range from tightening flange bolts to removing and replacing components such as valves, fittings, etc.

If the leak is determined to be downhole (e.g. cavern well) the operator will immediately notify the MSOGB in accordance with Rule 64. Under the supervision of the MSOGB, a workover would likely be conducted to resolve the situation. However, each downhole situation is unique in nature, and a thorough analysis would be conducted at the time of the incident in order to develop an appropriate solution to remedy the situation, on a case-by-case basis. If a solution to stop gas migration is not deemed feasible, the cavern causing gas migration would be plugged and abandoned in accordance with MSOGB Rule 64.

6.6.5.2 Safety Warnings

Appropriate safety precaution signs will be displayed and unauthorized personnel kept out of the storage area. Each storage wellhead will be visibly marked with an appropriate identifying sign.

6.6.5.3 Emergency Shutdown

Emergency shutdown valves will be installed on the gas injection/withdrawal piping of each storage well and on any brine or fresh water piping that is connected at the wellhead.

For salt cavern storage activities, automatic surface shut-in safety valves are used in lieu of downhole shut-in safety valves. The gas-operated automatic surface shut-in safety valves configured for Fail-Safe Closed operation (i.e., valve will close automatically if there is a loss of control signal, loss of valve operator supply pressure, thermal (fire) activation, signal from a safety control sensing device, or manual activation of emergency shutdown system), will be installed within 10 feet of a positive shut-off manual wellhead valve on the fresh water, brine and gas piping.

Safety control sensing devices will include hydrocarbon sensors, overpressure sensors and excess flow sensors on the fresh water piping entering and brine piping that exits the cavern wellhead. These safety control sensors will be tied into the cavern emergency shutdown controls to shut in the appropriate gas operated automatic shut-in safety valves automatically in the event that gas enters the water or brine piping during cavern expansion operations. These valves can be actuated either by an automatic shutdown triggered by a safely sensing device, manually from the control room computer, or manually at the cavern. Closing these valves during an emergency situation would effectively isolate the caverns from the rest of the facility.

6.6.5.4 Fire Prevention and Control

All equipment will be designed with the appropriate fail-safe emergency shutdown systems and alarms. Emergency shutdown valves, which will be capable of remote and local operation, will be activated automatically by over- or under-pressuring in the natural gas system, and detection of natural gas heat or flame.

Manual isolation valves will be installed on each wellhead and ignition sources will not be located within *75* feet of a well or unprotected source of flammable gas. Any building containing a source of flammable gas will be constructed in accordance with all state and federal building codes and regulations applicable to hazardous locations. All piping and valves will be protected against the thermal expansion of hydrocarbons.

6.6.5.5 Emergency Planning

An emergency response plan will be developed in accordance with all applicable local, state and federal regulations. The plan will include procedures for the safe control or shutdown of the storage facility in the event of a failure or other emergency. The emergency response plan will be documented and include roles and responsibilities; emergency response procedures; and training, testing, and implementation requirements so that the safety of personnel is ensured, the protection of the environment is maximized, and damage to property and the environment is minimized.

Emergency response equipment will be positioned strategically to ensure a rapid, efficient, and effective response to "most likely" events. Also, LREC will develop plans intended to minimize the possibility of emergencies. These plans will address methods for safe handling, storage, and disposal of hazardous and non-hazardous materials, procedures for performing routine inspections of equipment and systems, storage tanks and drums, containment structures, and storm water management devices, procedures for repairing equipment leaks or drips, and applicable pollution prevention laws, rules, and regulations.

6.6.5.6 Site Security

Security measures, including the installation of barricades, 6-foot-high small-mesh industrial-type steel fence, locking gates, security lighting and/or alarm systems, will be provided to prevent unauthorized access and protect the public, and alert the facility operator and other personnel of any abnormal operating conditions, so that they can react quickly in evaluating the situation. Heavy-duty barriers will be constructed to protect the wellhead and aboveground piping in the wellhead area from vehicular and equipment damage. The facilities will be manned 24 hours per day. Operators will make rounds at scheduled intervals to ensure all equipment is operating as designed.

6.6.6 Records Retention

All records pertaining to the Project design, construction and gas operation will be retained for the life of the storage caverns. These records will include well drilling logs, electrical logs, directional surveys, completion and cementing data, pressure test records, geophysical records, solution mining records, surveys, photographs, inspection, maintenance, reports, permits, certified location plot, storage well pressures, volumes of gases injected and withdrawn, and the inventory of gas in storage.

6.6.7 Noise Control

The drilling of the cavern wells will be conducted on a 24 hours per day basis and may require site-specific noise control equipment for such 24-hour operations. Once a specific drill rig has been selected, LREC will file with the FERC and the appropriate state and local authorities a description of the rig and its noise emitting characteristics, including a specification of noise control measures. The drilling operations will require 120 to 150 days per cavern well. Plans relating to well drilling activity noise mitigation are discussed in Resource Report 9 – Addendum.

6.6.8 Abandonment Procedure

Prior to starting the plugging operations on any Project well or the abandonment of the Project storage caverns, an application describing the method to be used will be filed with and approved by the MSOGB (under Rule 64.35) and FERC. Unless the MSOGB specifies to the contrary, the wells will be plugged in accordance with MSOGB Rule 64.35.

6.7 References

API Recommended Practice 1114 (June 94), Design of solution mined underground storage facilities

API Recommended Practice 1115 (Sept 94), Operation of solution mined underground storage facilities

Barton, D.C., 1926, Leaf River Salt Dome; in Geology of Salt Dome Oil Fields; R.C. Moore (ed.), The American Assoc. of Petroleum Geologists, p. 419-436.

Bograd, M.B.E. (2005) Earthquake in Mississippi, Fact Sheet 1, Mississippi Dept. of Environmental Quality, Office of Geology, revised June 2005.

Bograd, M.B.E. (2006) Earthquake in Mississippi, Open File Report 115, Mississippi Dept. of Environmental Quality, Office of Geology, revised July 2006.

Bryant, W.R., J. Lugo, C. Cordova, & A. Salvador, 1991, Physiography and bathymetry; in The Geology of North America, Vol. J., The Gulf of Mexico Basin; A. Salvador (ed.), The Geological Society of America, Boulder, CO, p. 13-30.

Fisk, N.H., 1944, Geological investigations of the alluvial valley of the Lower Mississippi River: U.S. Army Corps of Engineers Mississippi River Commission, 78 p.

Frankel, A.D;M.D. Peterson; C.S. Mueller; K.M. Haller; R.L. Wheeler; E.V. Leyendecker; R.L. Wesson; S.C. Harmsen; C.H. Cramer; D.M. Perkins; K.S. Rukstales (2002), 2002 National Seismic Hazard Maps, Open-file report 02-420, US Department of the Interior, US Geological Survey (http://earthquakes.usgs.gov).

Gas Research Institute, 1992, Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs; D.G. Bebout, W.A. White, C.M. Garret Jr., & T.F. Hintz (editors); Austin, TX, 88 pp.

Godt, J.W., Digital Compilation of "Landslide Overview Map" published as US Geol. Survey Open-File Report 97-289; http://landslides.usgs.gov/html~files/landslides/nationalmap/national.

Halbouty, M.T., 1979, Salt Domes, Gulf Region, United States and Mexico, 2nd Ed., Gulf Publishing Co., Houston, 425 pp.

Halke, C.A. (1974), Earthquake Information Bulletin, Vol.6, Number 1, March-April 1974; abridged on USGS Hazards Program, Mississippi Earthquake History (http://earthquakes.usgs.gov/regional/states/mississippi/history.php).

Iowa Department of Natural Resources (IDNR). 1997. Iowa Geology. Jean Cutler Prior. Editor.

Iowa Department of Natural Resources (IDNR). 2007. Geologic Hazards. http://www.igsb.uiowa.edu/service/hazards.htm

Luper, E.E., (1972), *Smith County Geology and Mineral Resources:* Mississippi Geological, Economic and Topographic Survey, Bulletin 116, Jackson, MS.

Paleoportal. 2007. http://www.paleoportal.org. Reviewed February 8, 2011.

Radbruch-Hall, D.H., R.B. Colton, W.E. Davies, I. Lucchitta, B.A. Skipp and D.J. Varnes (1983) Landslide Overview Map of the Conterminous United States; Geological Survey Professional Paper 11 83, United States Geol. Survey, Washington.

Tharp, W.E. and DeLong, W., (1923), *Soil Survey of Smith County, Mississippi:* U.S. Department of Agriculture, Bureau of Soils, Government Printing Office, Washington.

Thieling, S.C. and Moody, J.S., (1997), *Atlas of Shallow Mississippi Salt Domes:* Mississippi Department of Environmental Quality, Office of Geology, Jackson, MS.

U.S. Geological Survey (USGS). _2007a. A Tapestry of Time and Terrain: The Union of Two Maps - Geology and Topography. http://tapestry.usgs.gov/physiogr/physio.html. Reviewed February 8, 2011.

____ . 2007b. Earthquake Hazards Program. http://earthquake.usgs.gov/research/ hazmaps/products_data/ index.php. Reviewed February 8, 2011.

U.S. Geological Survey (USGS). 2007c. Earthquake Hazards Program, Quaternary Fault and Fold Database. http://gldims.cr.usgs.gov/qfault/viewer.htm. Reviewed February 8, 2011.

_____. 2007d. USGS Volcano Hazards Program. http://volcanoes.usgs.gov. February 8, 2011.

_____. 2007e. Sand and Gravel Operations in the United States. http://nationalatlas.gov/atlasftp.html. Reviewed February 8, 2011.

Veni, G. 2002. Revising the karst map of the United States. Journal of Cave and Karst Studies 64(1): 45-50.

Wheeler, R.L., compiler, 1998, Fault number 2655, Gulf-margin normal faults, Mississippi, in Quaternary fault and fold database of the United States: U.S. Geological Survey