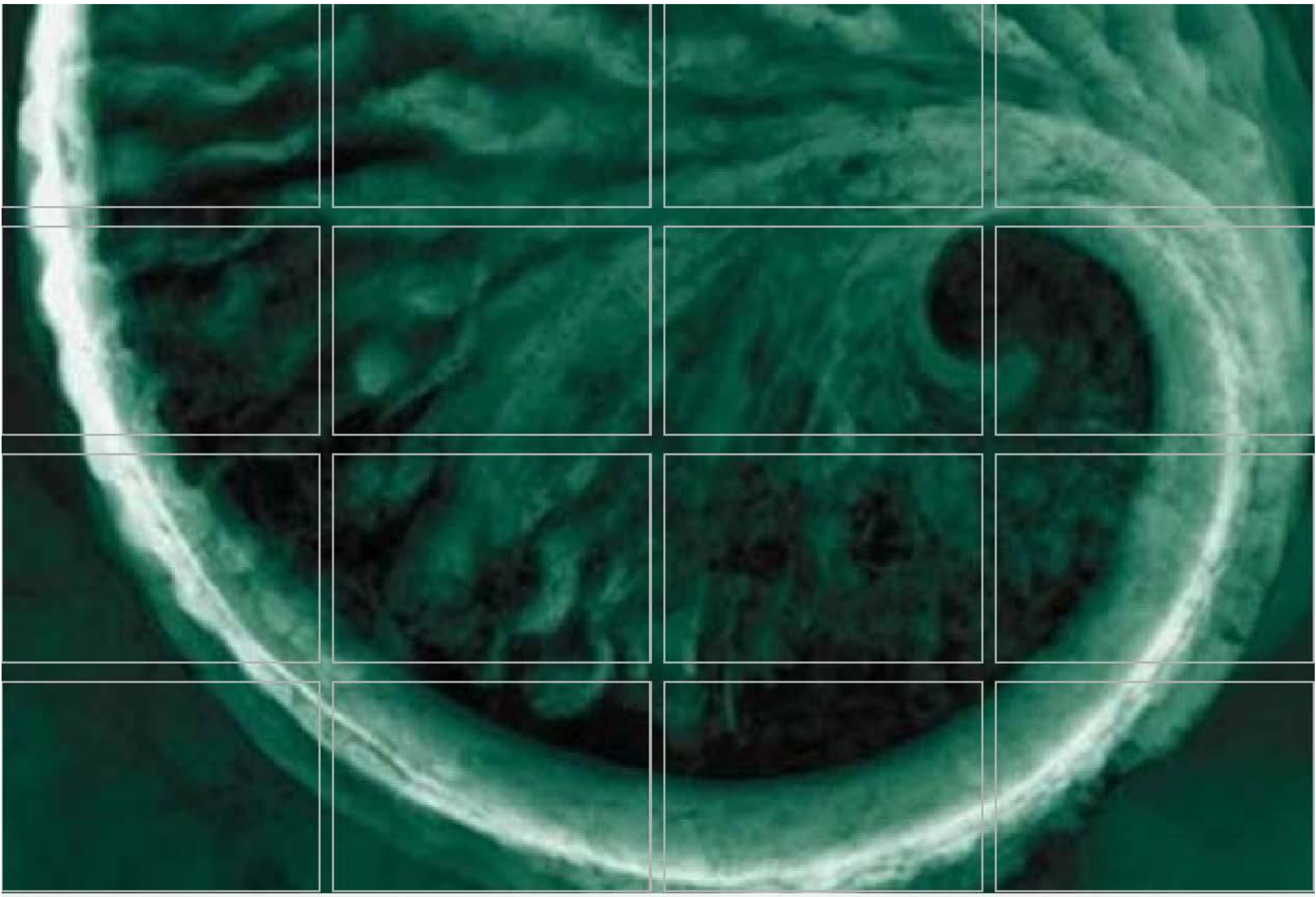

USDW Evaluation and Monitoring Well Installation Plan

Sulphur Mines Salt Dome
Calcasieu Parish, Louisiana

19 May 2023

Project No.: 0688077

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Sulphur Mines Salt Dome
Calcasieu Parish, Louisiana

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1. INTRODUCTION

Environmental Resources Management Southwest, Inc. (ERM), on behalf of Westlake US 2, LLC (Westlake), is pleased to provide this report in response to the April 18, 2023, Louisiana Department of Natural Resources (LDNR) Office of Conservation's Second Supplement to Compliance Order No. IMD 2022-027. Westlake was ordered to provide:

a. An Underground Source of Drinking Water ("USDW") report, which evaluates and better defines the depth to the top [*sic*] of the USDW over and around the salt dome and includes an assessment of hypothetical events that could affect groundwater quality.

b. A plan to install a minimum of three (3) monitoring wells in and around the area of investigation. The monitoring wells must be screened to monitor the deepest monitorable sand within the USDW.

This report contains both the USDW evaluation and the monitoring well installation plan. The USDW evaluation focused on determining the depth to the base of the USDW, and it is assumed that ground surface is the top of the USDW.

2. SITE SETTING

The Sulphur Mines Salt Dome (salt dome) is located approximately two miles northwest of the City of Sulphur in Calcasieu Parish, Louisiana (Figure 1). The salt dome is small and shallow relative to many similar domes along the Gulf Coast, approximately 2,500 feet in diameter with caprock encountered from approximately 400 feet to 1,000 feet below ground surface (bgs). Over the last century, underground sulfur, hydrocarbons and salt resources have been extensively mined and extracted from the salt dome and surrounding formations via the installation and operation of over 1,100 wells. In addition, produced water has been injected into the formations surrounding the dome for many decades.

3. SULFUR MINING AND E&P OPERATIONS

Commercial production of sulfur began in 1903 (Bauernschmidt, 1930). Sulfur was mined from the caprock of the salt dome using the Frasch method, wherein hot water is injected into the formation and the sulfur is melted and extracted using compressed air. Millions of tons of sulfur were removed, and the economic sulfur supply was exhausted by 1924 (Bauernschmidt, 1930). The locations of the historical sulfur mine injection wells are not known, but it has been reported that 735 sulfur extraction wells were installed (CH2M Hill, 1992).

Historical hydrocarbon seeps and mineralized water reports led to exploration for oil and gas beginning in the 1920s (Sandia National Labs, 1981). Oil shows have been reported as shallow as 357 feet below ground surface (Harris, 1910). Per the LDNR Strategic Online Natural Resources Information System (SONRIS) database, 467 oil and gas wells (36 wildcat and 431 listed within the Sulphur Mines field) have been drilled since the discovery of oil in the 1920s (Figure 2). The Sulphur Mines field was once one of the largest oil-producing fields on the Louisiana Gulf Coast (Bauernschmidt, 1930), though production has dramatically decreased over time. Based on information in the SONRIS database, 390 of the wells drilled have been plugged and abandoned (P&A'd) or are listed as temporarily inactive. Nineteen (19) wells are listed as shut-in or plugged back. Currently there are only eight (8) wells in the field listed as active producing wells.

There are currently 25 wells listed as active injection wells, with seven listed as saltwater disposal wells (SWDs), seven active solution brine mining wells, two inactive brine mining wells, five liquid petroleum gas (LPG) storage wells, and four observation wells. Several other brine wells have been P&A'd since solution brine mining began in the 1940s.

4. HYDROGEOLOGY

The Chicot aquifer is an important regional aquifer system underlying most of southwestern Louisiana and is the primary source of useable groundwater in Calcasieu Parish (USGS, 2017). The Chicot aquifer is a system of divided freshwater-bearing sands; in the Lake Charles area the sands are known as the "200-foot," "500-foot" and "700-foot" sands. In some areas in Southwestern Louisiana, the Chicot aquifer sands are not well defined and are undifferentiated. Regional cross sections constructed through Calcasieu Parish are provided as Figure 3 (Harder, 1960).

The Chicot surficial confining layer is comprised primarily of clays and fine-grained sediment. In the vicinity of the Sulphur Mines Salt Dome, the surficial confining unit is approximately 120-200 feet thick (Figure 4), and the top of the "200-foot" sand is encountered at approximately 120 feet bgs. The "200-foot" sand generally grades from fine- to medium-grained sand with gravel at the base (Harder, 1960). Below the "200-foot" sand is another clay confining layer of variable thickness. The "500-foot" sand is encountered at approximately 300 feet bgs in the vicinity of the salt dome. The "500-foot" sand also grades from fine- to medium-grained sand with gravel at the base (Harder, 1960). The industrial water-supply wells for solution brine mining at the dome, as well as the municipal water wells used by the City of Sulphur, are completed within the "500-foot" sand. Below the "500-foot" sand is another clay confining layer of variable thickness, which is underlain by the "700-foot" sand. The "700-foot" sand grades from fine-grained sand at the top to coarse-grained sand at the base (Harder, 1960). The base of the Chicot aquifer is usually identified as the base of the deepest gravel layer penetrated by wells (Harder, 1960).

Below the base of the "700-foot" sand is the upper confining unit of the Evangeline aquifer. The Evangeline aquifer consists of a series of fine-grained to medium-grained sand, silt and clay layers (Harder, 1960). There is considerable variability in the thickness of individual sand beds in the Evangeline aquifer (Harder, 1960). The base of the Evangeline aquifer was not evaluated for this report; however, Harder (1960) states that the Evangeline aquifer is about 2,000 feet thick in the industrial district of Lake Charles.

4.1 Groundwater Occurrence and Quality

The sands of the Chicot aquifer contain fresh groundwater (i.e., chloride concentrations less than 250 mg/L) in the vicinity of the salt dome and throughout Calcasieu Parish. A regional groundwater potentiometric surface map indicates that groundwater flow within the Chicot is generally toward the southeast near Sulphur (Figure 5). However, there are some data gaps in areas of heavy industrial pumping in the Sulphur and Lake Charles areas, and groundwater flow is likely influenced by heavy localized pumping.

Water levels have been periodically measured in the industrial water wells in the vicinity of the dome. Within the "500-foot" sand, the depth to groundwater is approximately 55 feet below ground surface. These depth measurements are consistent with others obtained by the United States Geological Survey (USGS) in observation wells throughout Calcasieu Parish. There are only minor differences in water levels in the "200-foot," "500-foot" and "700-foot" sands.

Chicot aquifer groundwater is commonly used for municipal supply throughout southwestern Louisiana. Under the Louisiana Department of Environmental Quality (LDEQ) Risk Evaluation/Corrective Action Program (RECAP), the Chicot aquifer is categorized as a Class 1A aquifer. Groundwater within the Chicot aquifer is generally sodium bicarbonate type, but moderately hard with elevated calcium, magnesium, and local iron variations. The chloride concentrations tend to increase with depth and the “700-foot” sand exhibits higher chloride concentrations than the “200-foot” or “500-foot” sands. Chloride concentrations above 250 mg/L have been reported in several areas in Calcasieu Parish due to incomplete flushing of the naturally saline water in the “700-foot” sand (Harder, 1960). Water quality in areas above salt domes has been documented to be of poorer quality due to natural interactions with the salt and cap rock (Harder, 1960).

The Evangeline aquifer contains fresh water in the northern quarter of the parish. In the southern three-fourths of the parish, the Evangeline aquifer contains salty water. There are two known water wells installed below the Chicot aquifer near the salt dome (Figure 6). A test well (019-666) was installed in 1956 to 990 feet deep, at a location approximately 7.8 miles northeast of the salt dome, and a monitoring well (019-1243) was installed in 1985 approximately 8.2 miles northeast of the salt dome. Harder (1960) states that the test well had a reported chloride concentration of about 14,000 mg/L, but no analytical data were publicly available. The chloride concentration in monitoring well 019-1243 was reported to be 4,050 mg/L in 1985. Two additional borings were drilled to approximately 1,000 feet deep: 019-1488, a well which was P&A’d in 2008, and 019-785, a boring drilled in 1964 and P&A’d without setting a well. Water quality data is not available from either of these locations. Two other wells (019-1490 and 019-1530) were installed as public supply wells in the northern portion of the parish where the Evangeline contains fresh water, at locations remote from the dome. Electric logs for oil and gas wells indicate that the Evangeline aquifer contains salt water in the vicinity of the salt dome.

5. USDW Evaluation

Under the Safe Drinking Water Act promulgated in 1974, the United States (US) Environmental Protection Agency (EPA) is required to provide safeguards so the underground injection of fluids will not endanger the Underground Source of Drinking Water (USDW). A USDW is defined as “an aquifer or a portion of an aquifer that: 1. Supplies any public water system, or 2. Contains a quantity of ground water sufficient to supply a public water system, and currently supplies drinking water for human consumption, or contains fewer than 10,000 mg/L total dissolved solids (TDS) and is not an exempted aquifer”.

LDNR has established guidance for defining the base of the USDW. Per LDNR, the base of the USDW can be determined as the bottom of the sand unit where the resistivity on the borehole electric logs is below 3 ohm-m for depths up to 1,000 feet, or below 2.5 ohm-m from depths of 1,000-2,000 feet, or below 2 ohm-m at depths greater than 2,000 feet. Following these basic guidelines, the USDW has been evaluated within 2-miles of the salt dome, with specific focus around Caverns 6 and 7.

Electric logs for wells surrounding the salt dome have been obtained and reviewed and a USDW value estimated, if possible. For this evaluation, it was assumed that the wellbores are vertical and the USDW value is below ground surface at the surface location of the well. The wellbore geometry and true vertical depth were not evaluated; such an evaluation could result in somewhat reduced depths to the base of the USDW and modified locations. Generally, the base of the USDW close to the salt dome occurs at approximately 1,100 feet below ground surface (Figure 7). The USDW is shallower over the salt dome and occasionally occurs below the top of the caprock. Local geologic cross sections through Cavern 7 (Figure 8) are provided as Figures 9 and 10. The base of the USDW determinations both by LDNR and ERM are summarized on Table 1.

5.1 Underground Injection Operations

Currently there are seven active Class II SWDs (Figure 11) in the vicinity of the salt dome and surrounding area. Information on each of these wells is as follows:

1. **109963** – installed in 1965 along the western edge of the salt dome with the injection zone from 1,212-1,423 feet (open hole) in the caprock. The base of the USDW was determined to be 950 feet deep.
2. **110159** – installed in 1965 along the southwestern edge of the salt dome with the injection zone from 1,374-1,460 feet (open hole), within the caprock. The base of the USDW was determined to be 970 feet deep.
3. **195916** – installed in 1984 approximately 2,000 feet southwest of the salt dome with the current injection zone from 5,620-5,690 feet (perforated). The base of the USDW was determined to be 1,090 feet deep.
4. **972997** – installed in 2001, approximately 2 miles north of the salt dome with the injection zone from 2,056-2,086 feet. This well is not in close proximity to the salt dome.
5. **973458** – installed in 2007, approximately 1.5 miles south of the salt dome with the injection zone from 4,504-4,942 feet. This well is not in close proximity to the salt dome.
6. **973459** – installed in 2007, approximately 1.5 miles south of the salt dome with the injection zone from 4,560-4,920 feet. The base of the USDW was determined to be 1,140 feet deep. This well is not in close proximity to the salt dome.
7. **974838** – installed in 2001, approximately 2 miles north of the salt dome with the injection zone from 3,248-3,268 feet. The base of the USDW was determined to be 1,310 feet deep. This well is not in close proximity to the salt dome.

There are currently 14 active injection wells (see Figure 11) that utilize the salt either for solution brine mining or hydrocarbon storage. Information on each of these wells is as follows:

1. **32069** – installed in 1946, on the southern end of the salt dome. This well is a brine well with a current injection zone from 1,810-2,977 feet within the salt and a total install depth of 3,062 feet.
2. **33058** – installed in 1957 on the eastern side of the salt dome. This well is an LPG storage well with a current injection zone from 2,268-2,838 feet within the salt and a total install depth of 2,844 feet.
3. **37320** – installed in 1949, on the southern end of the salt dome. This well is a brine well with a current injection zone from 1,789-3,013 feet within the salt and a total install depth of 3,312 feet.
4. **57788** – installed in 1955 on the northwestern side of the salt dome. This well is a brine well with a current injection zone from 2,505-3,331 feet within the salt and a total install depth of 3,720 feet.
5. **67270** – installed in 1957 on the western side of the salt dome. This well is a brine well with a current injection zone from 2,501-3,137 feet within the salt and a total install depth of 3,420 feet.
6. **236863** – installed in 2008 on the northeastern side of the salt dome. This well is an LPG storage well with a current injection zone from 4,100-4,836 feet within the salt and a total install depth of 4,900 feet. The base of the USDW was determined to be 1,142 feet deep.
7. **971286** – installed in 1979, on the southern end of the salt dome. This well is a brine well with a current injection zone from 1,835-2,977 feet within the salt and a total install depth of 3,081 feet.
8. **973224** – installed in 2004 on the northern side of the salt dome. This well is a brine well with a current injection zone from 2,994-6,262 feet within the salt and a total install depth of 7,050 feet.
9. **973364** – installed in 2006 on the northeastern side of the salt dome. This well is a brine well with a current injection zone from 3,300-4,832 feet within the salt and a total install depth of 5,220 feet. The base of the USDW was determined to be 550 feet deep.

10. **973365** – installed in 2006 on the northern side of the salt dome. This well is a brine well with a current injection zone from 4,454-5,882 feet within the salt and a total install depth of 6,200 feet. The base of the USDW was determined to be 884 feet deep.
11. **973525** – installed in 2007 on the northeastern side of the salt dome. This well is an LPG storage well with a current injection zone from 3,791-4,354 feet within the salt and a total install depth of 4,647 feet. The base of the USDW was determined to be 560 feet deep.
12. **974245** – installed in 2013 on the western side of the salt dome. This well is a brine well with a current injection zone from 3,569-6,275 feet within the salt and a total install depth of 7,080 feet. The base of the USDW was determined to be 924 feet deep.
13. **974675** – installed in 2015 on the eastern side of the salt dome. This well is an LPG storage well with a current injection zone from 4,366-6,686 feet within the salt and a total install depth of 7,021 feet. The base of the USDW was determined to be 948 feet deep.
14. **974894** – installed in 2015 on the eastern side of the salt dome. This well is an LPG storage well with a current injection zone from 4,364-6,563 feet within the salt and a total install depth of 7,015 feet. The base of the USDW was determined to be 940 feet deep.

There are also 10 former injection wells utilized for solution brine mining that have been P&A'd (see Figure 11). Information on each of these wells is as follows.

1. **47444** – installed in 1953 on the southern end of the salt dome and plugged and abandoned in 2009. The well was cased to 1,734 feet and a total install depth of 3,745 feet.
2. **58711** – installed in 1955 on the northwestern side of the salt dome and plugged and abandoned in 2017. The well had an injection zone of 2,500-3,271 feet within the salt and a total install depth of 3,704 feet.
3. **67269** – installed in 1957 on the western side of the salt dome and plugged and abandoned in 2018. This well had an injection zone of 2,501-3,137 feet within the salt and a total install depth of 3,420 feet.
4. **148838** – installed in 1975 on the southwestern end of the salt dome and plugged and abandoned in 2011. The well had an injection zone of 2,302-3,240 within the salt and a total install depth of 3,700 feet.
5. **163676** – installed in 1979 on the southwestern end of the salt dome and plugged and abandoned in 2016. The well had an injection zone of 4,068-4,645 in the salt and a total install depth of 5,020 feet. The base of the USDW was determined to be 945 feet deep.
6. **163677** – installed in 1979 on the northwestern side of the salt dome and plugged and abandoned in 2012. The well had an injection zone of 1,998-4,020 feet within the salt and a total install depth of 4,020 feet.
7. **163678** – installed in 1979 in the central portion of the salt dome and plugged and abandoned in 2016. The well had an injection zone of 2,395-3,554 feet within the salt and a total install depth of 4,016 feet.
8. **971287** – installed in 1979 on the northwestern side of the salt dome and plugged and abandoned in 2017. The well had an injection zone of 2,578-3,271 feet within the salt and a total install depth of 3,410 feet.
9. **971288** – installed in 1979 on the western side of the salt dome and plugged and abandoned in 2018. The well had an injection zone of 2,419-3,143 feet within the salt and a total install depth of 2,855 feet.

10. **973478** – installed in 2007 in the central portion of the salt dome and plugged and abandoned in 2013. The well had an injection zone of 2,395-3,565 feet within the salt and a total install depth of 3,565 feet.

5.2 Hypothetical Migration Pathways

A hypothetical risk evaluation was performed for the USDW based on the most likely pathways for injected fluid migration into the USDW. The main pathways for migration of subsurface fluids into the USDW from underground injection activities include the following, per 40 CFR 144.12 (US EPA, 2012):

- Nearby Wells: Fluids from pressurized area in injection zone may escape through wells in injection area.
- Faults or Fractures in Confining Strata: Fluids may leak out of pressurized area through faults/ fractures in confining beds.
- Displacement: Fluid may be displaced from injection zone into hydraulically connected USDWs.
- Faulty Well Construction: Leaks in well casing or fluid escaping between well's outer casing and well bore.
- Direct Injection: Inject fluids into or above USDWs.

Direct injection into the USDW is not occurring at the site and was not considered a viable migration pathway. The injection zones for the permitted injection wells at the salt dome, both solution mining wells and SWDs, are at depths well below the defined base of the USDW. The potential for hypothetical impacts to the USDW under these various migration pathway scenarios is evaluated in the following sections.

5.2.1 Nearby Wells

Drilled wellbores installed through the USDW and into the injection zones can also hypothetically create potential pathways for fluid migration into the USDW. Wellbores terminated within the USDW, or wells completed in the USDW, pose the greatest risk. Improperly cemented casing, or improperly P&A'd wells can also pose a risk to fluid migration into the USDW.

Over 1,100 boreholes have been drilled into and around the salt dome. Many wells were installed, produced and P&A'd well before modern well installation and construction procedures and environmental regulations were established. The likelihood that old wells/wellbores may potentially serve as hypothetical migration pathways for fluid migration is moderate due to the age of the natural resources exploitation activities that have occurred in/on the salt dome.

There are three injection wells near the salt dome currently injecting fluid (produced water) for disposal. The majority of the injection wells are injecting into salt caverns either for immediate solution brine extraction or future extraction (storage). The two SWDs on the flank of the dome are currently injecting into the caprock at depths ranging from 1,212 to 1,460 feet bgs. Another SWD, located approximately 2,000 feet southwest of the salt dome, is injecting into a zone that is 5,620-5,690 feet deep. The majority of the wells installed on the dome are installed at least to the depth of the caprock or deeper. Several are perforated below the deepest injection zone of 5,620-5,690 feet. Casing leaks within old wells might not be easily identified in the groundwater unless there is a monitoring well installed at the same interval as the leak, and close enough to and downgradient of the leaky well, to identify in a sample.

Identifying hypothetical migration pathways would be difficult due to the extensive historical development of the dome, especially if there is more than one wellbore potentially contributing to the migration pathway. Stable isotopic evaluation of the water might provide some insight into mixing waters by comparing end-member data from the fluid being injected and the native formation water within the USDW.

Based on the number (>1,100) and age of the old wellbores, the shallow depths of injection, and the difficulty of identifying potential problematic wells/boreholes the potential exists for USDW impact from wellbore migration.

5.2.2 Faults and Fractures in Confining Strata

Regional faulting is difficult to fully evaluate in the near surface unconsolidated sediments of the Gulf Coast. However, faults have been mapped in the Lake Charles and DeQuincy areas within Calcasieu Parish (LGS, 2002; Heinrich, 2000). These faults are likely not located close enough to the salt dome to influence fluid migration into the USDW. Heltz (2005) suggested the presence of a NW-SW trending fault in the Sulphur area, terminating before reaching the salt dome. Localized faulting and fracturing are likely present but restricted to the vicinity of the dome (Harder, 1960), especially directly above the salt dome, within the salt and the more brittle overlying caprock. The unconsolidated sediments within the USDW are not expected to exhibit classic fault or fracture features due to the mobility and plasticity of the sediments, although some fracturing might to be preserved in the finer-grained clays. The potential for injected fluids to migrate through faults or fractures into the unconsolidated sediments of the USDW is possible, but unlikely and probably not discernible from the natural groundwater quality in the vicinity of the salt dome.

Fluid moving through natural fractures in the caprock, or salt is possible. Because the caprock is relatively shallow in relation to the USDW and likely relatively permeable due to natural conditions and past economic exploitation, fluid moving through the caprock poses a relatively high potential hypothetical risk to the USDW. Dense produced water and brine are not likely to travel up through faults or fractures unless there is a significant pressure differential driving the heavier fluids upward.

The piercement of the salt dome created a zone where the salt and caprock contact the adjacent strata. If fluid were hypothetically released from within a cavern through the salt wall, this contact zone between the salt and the native formations is the most likely path for fluid to potentially migrate. Again, a pressure differential would need to exist to drive the heavy brine upward into the USDW. Additionally, there are several factors that would need to be considered, such as the depth of the release below the base of the USDW, the pressure within the cavern, and the transmissivity of the salt-native strata contact zone. Were brine to hypothetically reach the USDW, the most likely place to detect it would be directly above the steep sidewall of the salt/caprock where the salt/caprock contacts the native strata.

Overall, the hypothetical risk for impact to the USDW from migration of fluids through faults and fractures is highest on and near the caprock. However outside of the salt dome, the hypothetical risk to the USDW is low.

Detecting fluid migration through faults into the USDW would be very difficult unless a monitoring well was installed in close proximity to a fault, or groundwater concentrations were detected that could not be explained by another migration pathway, probably unlikely.

5.2.3 Displacement

This hypothetical pathway implies that water being injected below the USDW can migrate vertically (or horizontally) from an underlying non-USDW zone into the USDW through direct hydraulic communication of the water-bearing units, without any secondary migration pathways (i.e., boreholes, faults, etc.).

As with faults and fractures, there must be a pressure gradient driving the fluid migration. Brine Caverns 6 and 7 are deep within the salt, with the roof of the caverns approximately 2,500 feet below ground surface. A leak from a cavern within the salt would likely be at least 1,000 feet below the base of the USDW. Heavier produced water and brine are not likely to travel upward into overlying hydrogeological units unless there is a significant pressure differential driving the heavier fluids upward. The heavier fluids would likely remain at the deepest elevations. Fluids less dense than water, such as gas, are more likely to find vertical upward migration pathways. The likelihood that diffusion and dispersion will lead to measurable impact to the USDW is unlikely.

Based on available electric logs (see Figures 9 and 10), the lithology below the USDW is interbedded with several thin sand and clay layers. Harder (1960) indicates that the interbedded layers within the Evangeline are discontinuous but are likely connected to other beds either above or below. Migration from below the USDW upward into the USDW is hindered by the lower permeability, finer-grained sediments of the Evangeline aquifer. The likelihood of injected fluids migrating into the USDW through a natural hydraulic connection from underlying formations is low. The hypothetical impact to the USDW would likely be low and wide-scale migration and transport is unlikely.

5.2.4 Faulty Well Construction

Injection wells injecting fluids through cased well bores into naturally saline formations below the base of the USDW must be drilled and installed through the USDW, placing the USDW at potential risk from fluid leaks through the well casing entering the USDW. Operators have the responsibility to ensure the wells are properly installed, constructed, and maintained.

The potential for impact to a USDW from a leaky well casing depends on a variety of factors. For example, if a well has multiple strings of telescoping well casings, fluids potentially leaking from an inner casing would be contained within outer casings and therefore not be a threat to the USDW. Hypothetically, if a leak in a casing was directly in connection with the USDW, the volume of fluids entering the USDW would only be a fraction of the total injection volume, as most of the fluids would enter the target injection zone (i.e., travel the path of least resistance). The hypothetical impact to groundwater quality within the USDW would depend upon the rate and volume of fluid being injected. Leaks from casings are typically identified by conducting well integrity testing. The solution mining salt cavern wells have been tested and passed mechanical integrity testing (MIT). The salt cavern wells that have not been P&A'd have to undergo MIT's every 5 years to remain in compliance. The hypothetical risk to the USDW from a leaky well casing is low. In the hypothetical event that injection fluids were to enter the USDW, it is anticipated that the impact would be localized and that the source would be quickly addressed and eliminated.

6. MONITORING WELL INSTALLATION PLAN

The April 18, 2023, LDNR Compliance Order requires the installation of a minimum of three monitoring wells into the deepest monitorable sand within the USDW.

6.1 Installation Procedures for Base USDW Monitoring Wells

The installation of three monitoring wells is proposed around Caverns 6 and 7. Based on the USDW evaluation presented above, and the available electric logs, it is estimated that these wells will be up to approximately 1,000 feet deep. The proposed approximate locations (dependent upon access and underground utilities) are shown on Figure 12. The wells will be installed utilizing a truck mounted, mud-rotary drilling rig operated by a Louisiana-licensed water well driller and constructed in accordance with LDNR's *Guidance Manual for Environmental Boreholes and Monitoring Systems* (2021). The total depth of each well will be dependent on the depth at which the base of USDW is identified using the appropriate geophysical logging tools. A generalized schematic of the proposed well construction is provided as Figure 13.

To minimize the potential for a blow-out due to subsurface gas pressure, a minimum 8-inch outside diameter (OD), carbon steel surface casing will be installed to a minimum depth of 20-feet bgs at each location and cemented using a Portland cement/bentonite grout mixture. Additional grout will also be placed around the outside of the casing at the ground surface. The grout will be allowed to set overnight prior to re-entering the borehole. A blow-out preventor (BOP) will be affixed to the surface casing prior to further advancement of the borehole.

A minimum approximately 6-inch diameter drill bit will be utilized to drill through the grout and advance the borehole to total depth. The drill pipe will be advanced using water obtained from one of Westlake's industrial water wells. Core samples will not be collected during the drilling process. However, soil cuttings will be logged by Louisiana registered professional geologist. The borings will extend below the base of the USDW by as much as 30 feet. The USDW in the area of Caverns 6 and 7 is estimated to range from between 920 and 1,050 feet below ground surface. If caprock is encountered prior to the target total depth, the boring will be terminated at the caprock.

Upon reaching the proposed target depth, the drilling mud-filled borehole will be kept open to run geophysical logging tools. An open hole log will be run for the entire length of the borehole to evaluate the depth of the base of the USDW. At a minimum, gamma and resistivity logs will be run. Notification will be made to LDNR at least 24 hours prior to the logging so a representative can be available to discuss the logging results either in person or via telephone to determine to most appropriate screened interval.

Once the screened interval is selected, a minimum two-inch inside diameter, carbon steel casing and a minimum 2-inch inside diameter 10-foot long stainless-steel screen [No. 10 slot – 0.01-inch] will be installed inside the borehole.

A filter pack consisting of 20-40 grade silica sand will be placed on top of the native sand pack and will extend approximately 2-feet above the top of the well screen. A minimum five-foot thick bentonite pellet/and or Volclay seal will be placed on top of the sand pack and allowed to hydrate per the manufacturer's recommended time or overnight. The remaining annulus will be tremie-grouted from the bottom up using a Portland cement/bentonite grout mixture.

The monitoring wells will be capped with a locking well cap and completed at the ground surface with a protective steel or aluminum casing installed in an approximate 5-foot by 5-foot four-inch thick concrete pad equipped with four guard posts. The protective casing and guard posts will be painted safety yellow. An ERM geologist will document the installation and construction of each monitoring well in a field logbook and/or field log sheets.

The drilling residuals will be containerized and managed by Westlake.

Following the installation and surface completion of the wells, each well will be surveyed by a Louisiana licensed professional surveyor. The survey will include the well's horizontal position as well as the top-of-casing [TOC (i.e., top of well cap)], top of well pad, and ground surface elevations of each monitoring well.

6.2 Well Development Procedures

The monitoring wells may be developed by a combination of flushing, swabbing, surging, air-lifting, and/or overpumping utilizing a drilling rig and associated equipment to remove water/drilling mud residuals. Additives may be used to assist in the breakdown and removal of the drilling residuals. Initial well development will be done by surging within the well screen using a surge block to loosen drilling mud or skin remaining in the well. Air-lifting or overpumping will be used to further remove residuals. If air-lifting is used the air injection point will not be closer than 100 feet from the top of the well screen. Field parameters, including specific conductance (SC), pH, temperature, and turbidity, will be recorded with a water quality meter (YSI or equivalent) during the well development process. Development of the well will continue until the field parameters stabilize and/or the water shows no further improvement in clarity and a minimum of three borehole volumes of water have been removed from each well. The well development water will be containerized during the well development process and managed by Westlake. ERM's field observations and field parameters will be recorded in a bound field logbook.

6.3 Monitoring Well Sampling Procedures

The newly-installed monitoring wells will be allowed to recover for a minimum of 48 hours following installation and development before groundwater samples are collected.

Groundwater samples will be collected using low-flow purging and sampling techniques. The intake will be installed at the approximate mid-point of the well screen interval. A closed flow-through cell and recording field instrument (YSI or equivalent) will be utilized to measure field parameters including SC, pH, temperature, oxidation-reduction potential (ORP), and dissolved oxygen during well purging/sampling. Turbidity will be measured with a field turbidity meter. A minimum of one well casing volume will be purged prior to sampling.

Based on the results of the brine samples collected from Cavern 7 and the water quality data from 019-1243, the water quality within the Evangeline aquifer has a similar signature to the brine (Figure 14). It will likely be difficult to distinguish the native Evangeline aquifer water from the brine using typical water quality parameters. The brine is comprised of Chicot aquifer water, with high levels of dissolved salt and some low-level hydrocarbons. It is reasonable to assume that the Evangeline aquifer groundwater is naturally salty with the possibility of natural hydrocarbons present along the flank of the salt dome or on top of the salt dome. Detections of low-level hydrocarbons including benzene, total petroleum hydrocarbons, or other organic compounds cannot definitively point to a brine cavern as a source. However, the brine is a concentrated salt solution, so the concentrations of chloride and TDS are expected to be much higher than the Evangeline groundwater. Also, the stable isotopes of the brine are expected to be the same as the Chicot, which should differ from the Evangeline.

The constituents that are typically used to identify/distinguish brine/produced water are chloride, strontium, sulfate, TDS, benzene and light-end hydrocarbons. However, due to the naturally poor water quality below the Chicot aquifer, and the possible presence of naturally occurring hydrocarbons, ERM proposes to sample for the following constituents:

- Calcium, magnesium potassium, and sodium by SW-846 Method 6020
- Chloride, bromide, and sulfate by SW-846 Method 9056A
- pH by method SW-846 9040B or EPA 150.2
- Total dissolved solids (TDS) by Method SM 2540C
- Carbonate and bicarbonate alkalinity by Method SM2320B
- Dissolved gases (methane, ethane, ethane, propane and butane)
- Stable carbon ($\delta^{13}C$) and hydrogen (δD) isotopes of dissolved hydrocarbon gases (Isotech)
- Stable oxygen ($\delta^{18}O$) and hydrogen (δD) isotopes of the water (Isotech).

Each groundwater sample will be collected in new, clean laboratory supplied containers. The sample containers will be placed on ice following their collection and delivered or shipped with proper Chain-of-Custody documentation to ALS in Houston, Texas or Isotech Laboratories, Inc. (Isotech) in Champaign, Illinois for analysis.

6.4 Water Level Monitoring

Upon installation of the new monitoring wells, a full round of water level measurements will be recorded utilizing an electronic tape graduated to the nearest hundredth of a foot to manually measure the depth to water from the TOC. Water levels will be recorded prior to sampling the wells.

6.5 Schedule

Installation and geophysical logging of the monitoring wells is expected to take approximately one month from mobilization of the drilling crew to final completion of the three wells. There is no scheduled start date at this time, but two water well drilling contractors are currently developing cost and scheduling estimates. Weather, equipment malfunctions, access, etc. may impact the schedule.

6.6 Reporting

The monitoring wells will be registered with LDNR within 30 days of installation. A summary of the well installation, along with any relevant findings, will be provided to LDNR Injection and Mining Division (IMD) within 30 days of receipt of the final laboratory reports from the first sampling event. Additional data collected from these wells will be included in regular data transmittals to IMD.

FIGURES

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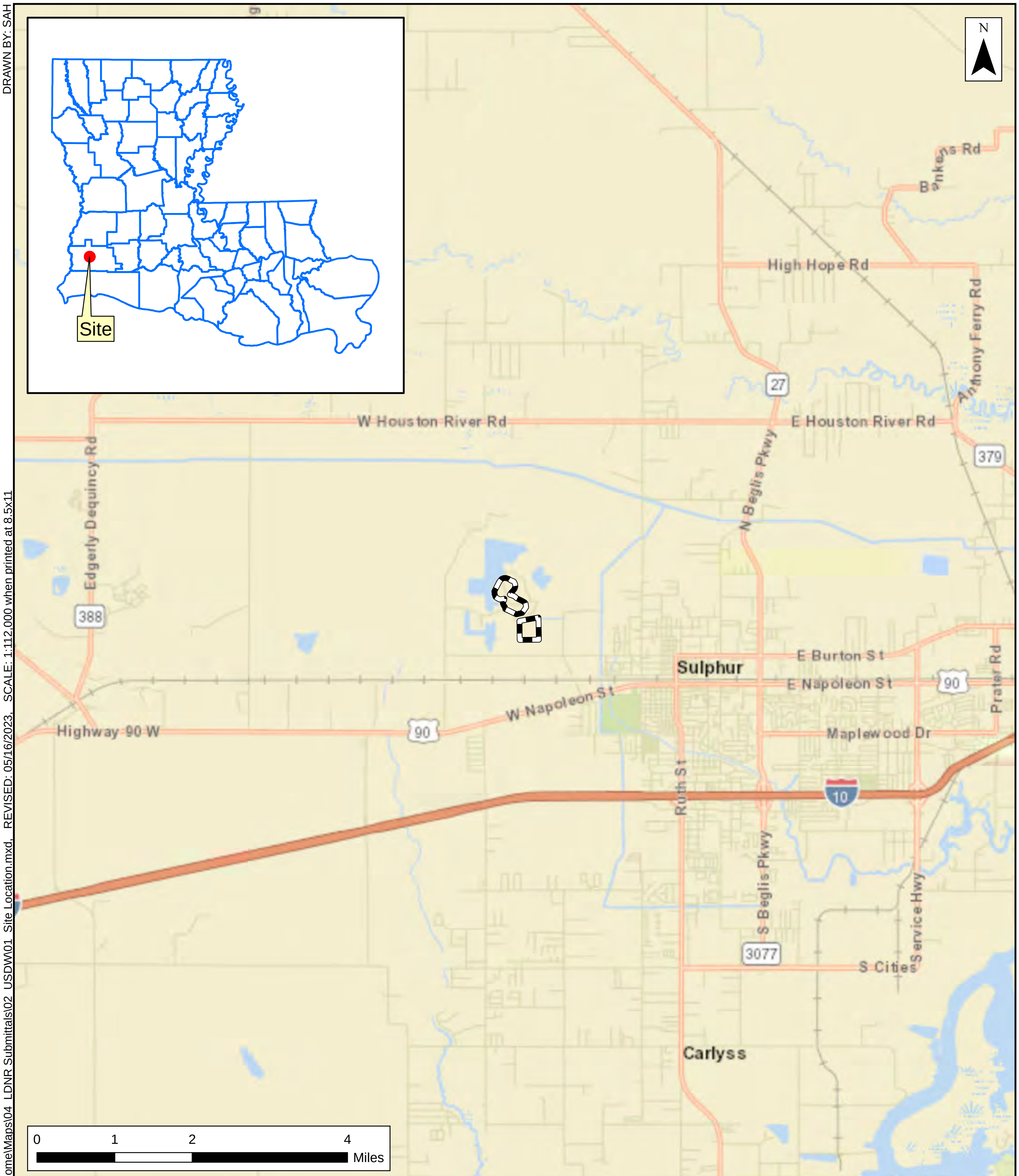

Legend

Westlake Property

Figure 1
Site Location
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

Notes:
World Street Map via ArcGIS online.

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Source: ESRI - ArcGIS Online; NAD 1983 UTM Zone 15N

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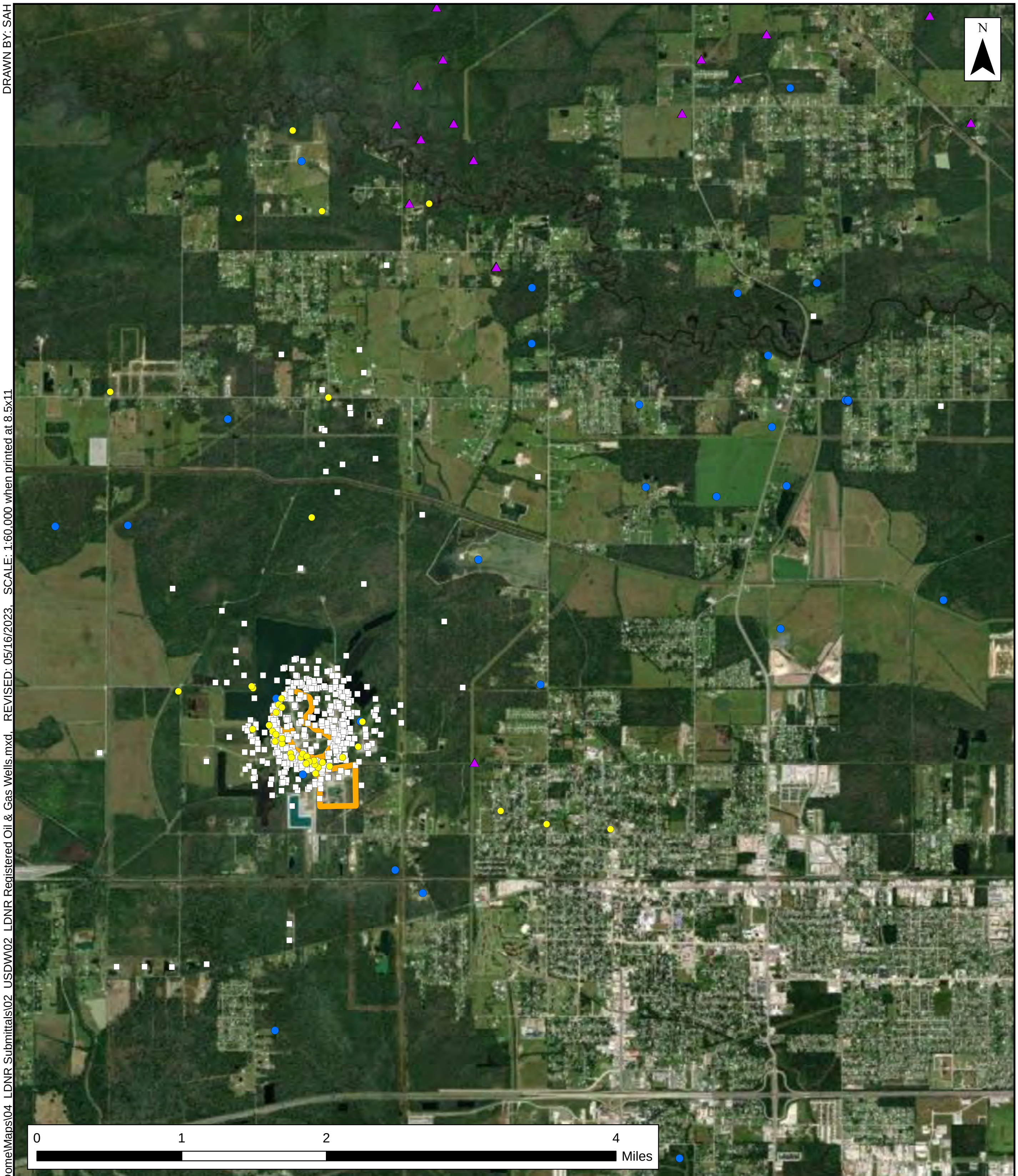

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Legend

- Sulphur Mines Field Well
- Wildcat Well (Pre 1930)
- Wildcat Well (Post 1930)
- Other Oil & Gas Well
- Westlake Property

Notes:
Well locations via SONRIS database.
World Imagery via ArcGIS online.

Figure 2
LDNR Registered Oil & Gas Wells
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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Source: ESRI - ArcGIS Online; NAD 1983 UTM Zone 15N

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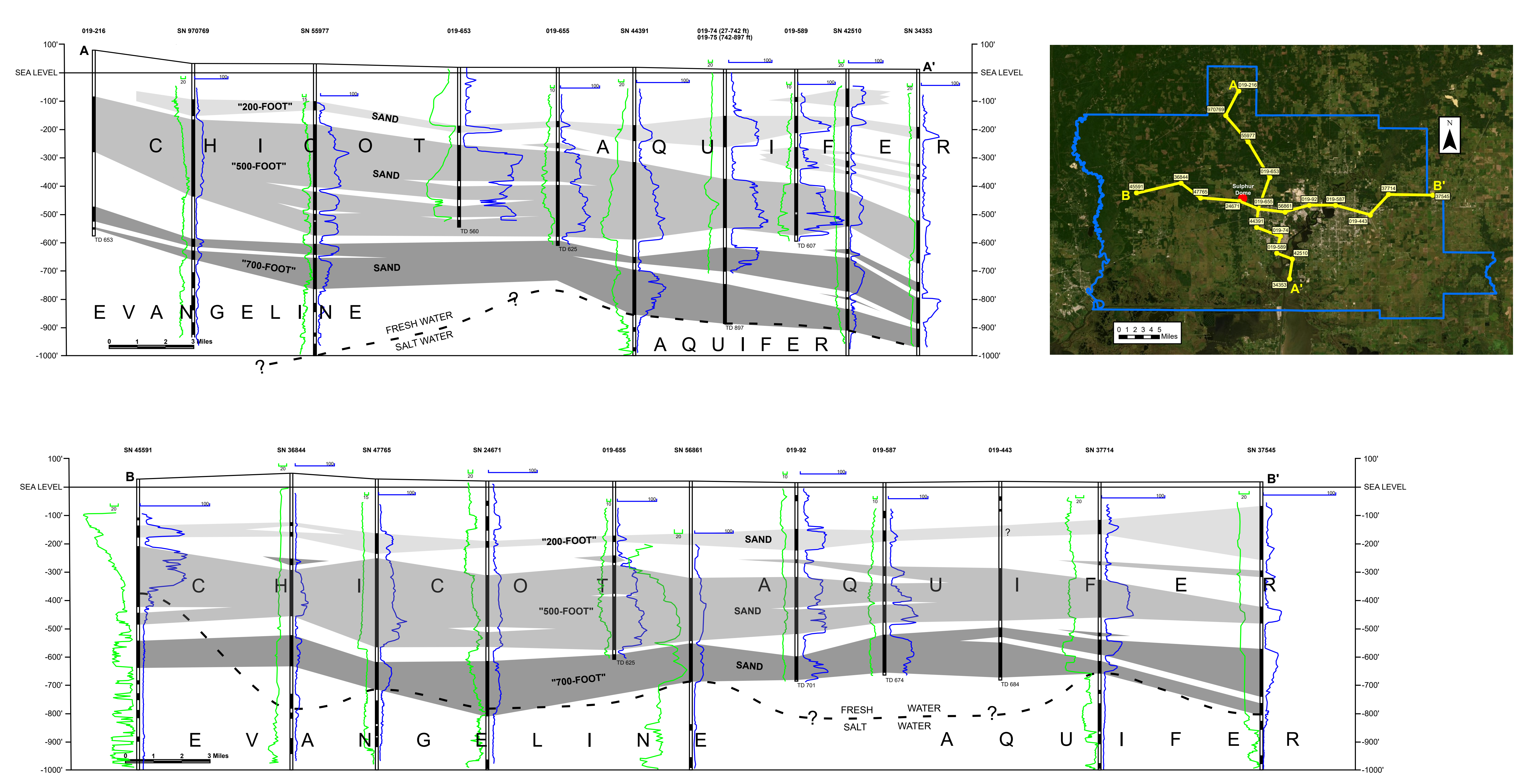

Figure 3
Regional Geologic Cross Section

Sulphur Dome

Westlake US 2, LLC

Calcasieu Parish, Louisiana

Notes:
Modified from Harder, 1960.

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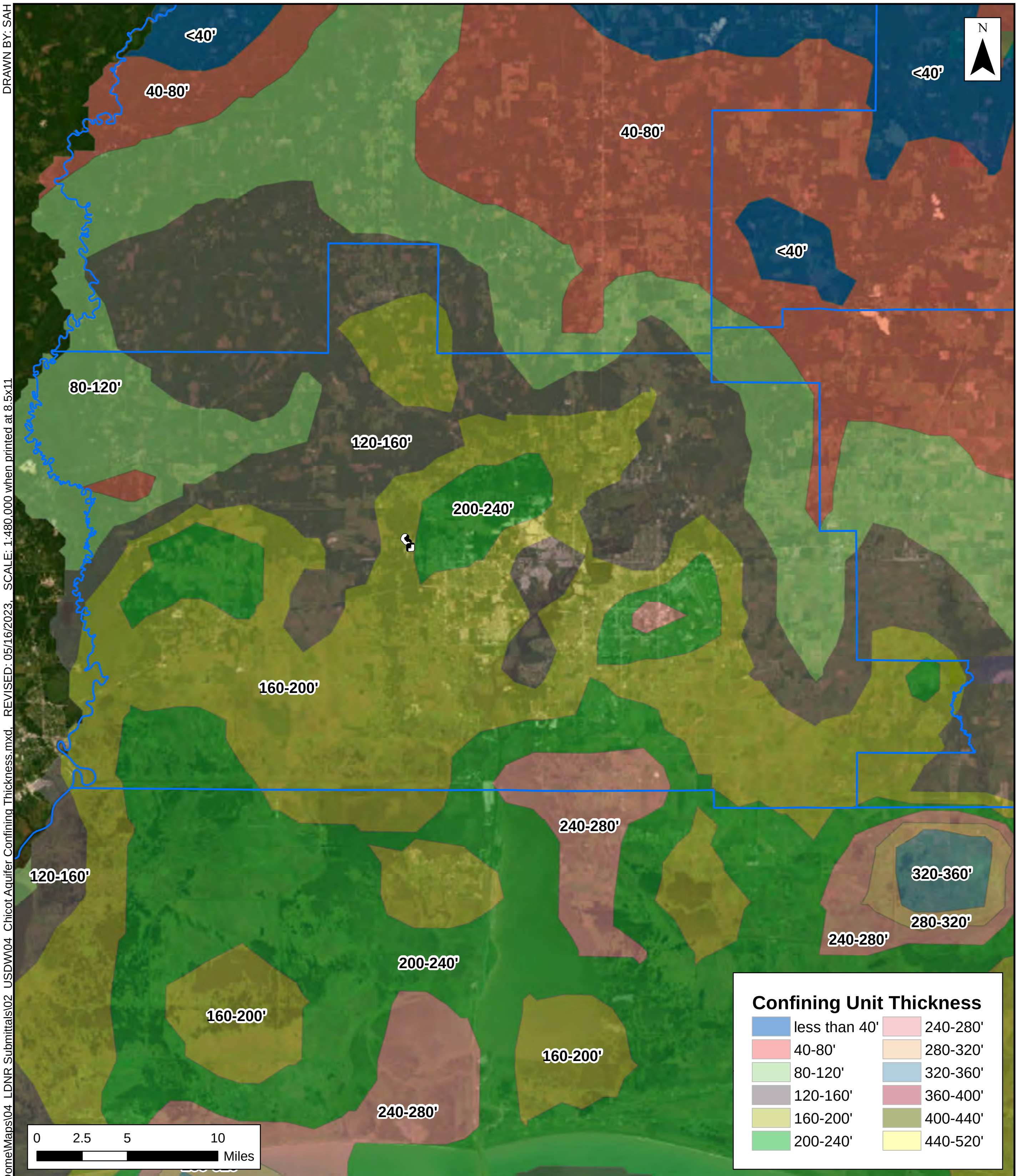

Legend

Westlake Property

Figure 4

Chicot Aquifer Confining Thickness

Sulphur Dome

Westlake US 2, LLC

Calcasieu Parish, Louisiana

Notes:
Modified from Sargent, 2004
World Imagery via ArcGIS online.

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Source: ESRI - ArcGIS Online; NAD 1983 UTM Zone 15N

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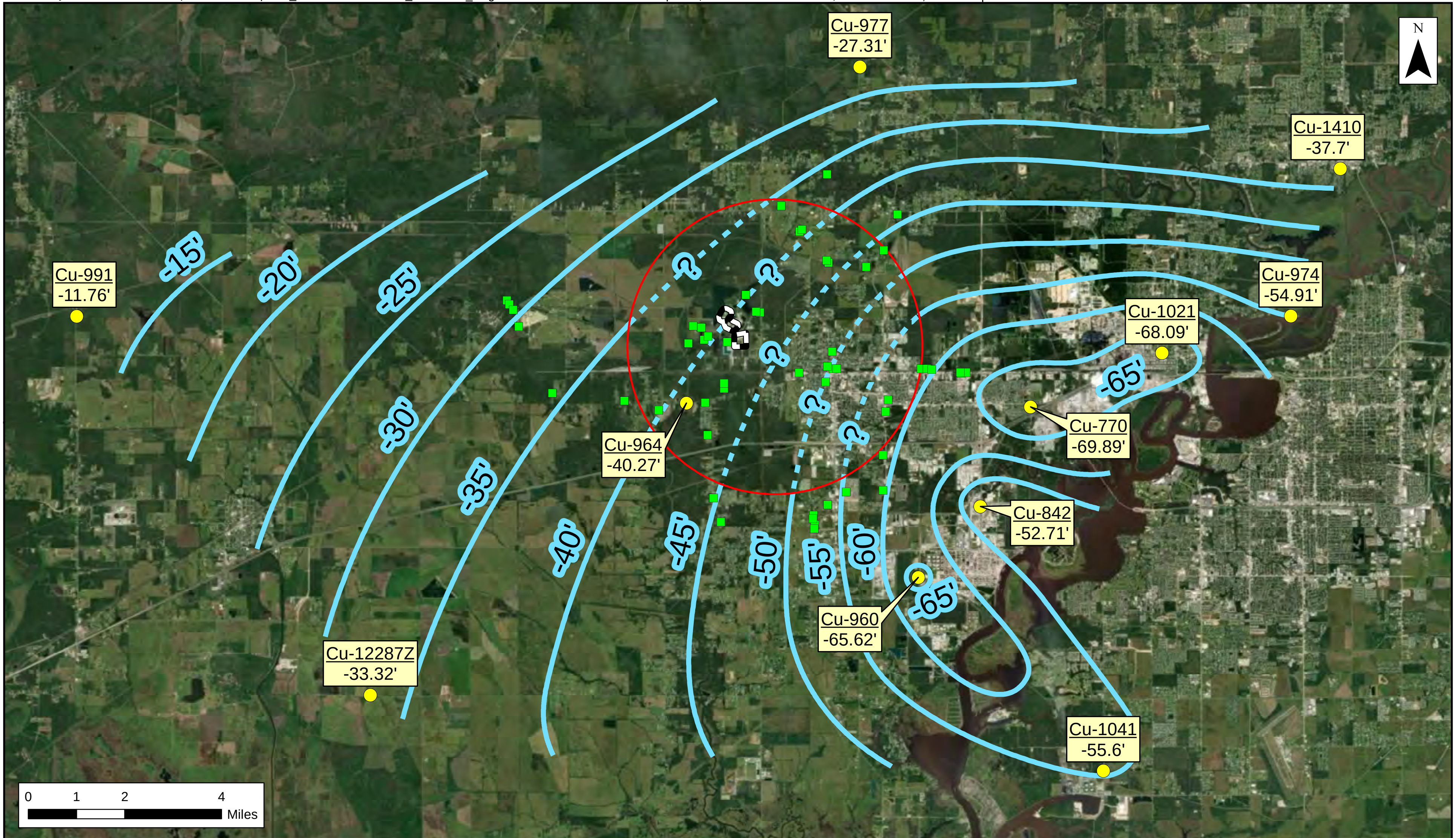

Legend

- Active Industrial, Municipal Supply, or Irrigation Well
- Area of Uncertainty due to pumping
- Westlake Property
- USGS Water Well (500-ft Sand)
- Potentiometric Surface Contour (dashed where inferred)

Notes:
Water Levels via USGS.
World Street Map via ArcGIS online.

Figure 5
Regional Potentiometric Surface Map (February 2023)
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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Source: Esri - ArcGIS Online; NAD 1983 UTM Zone 15N

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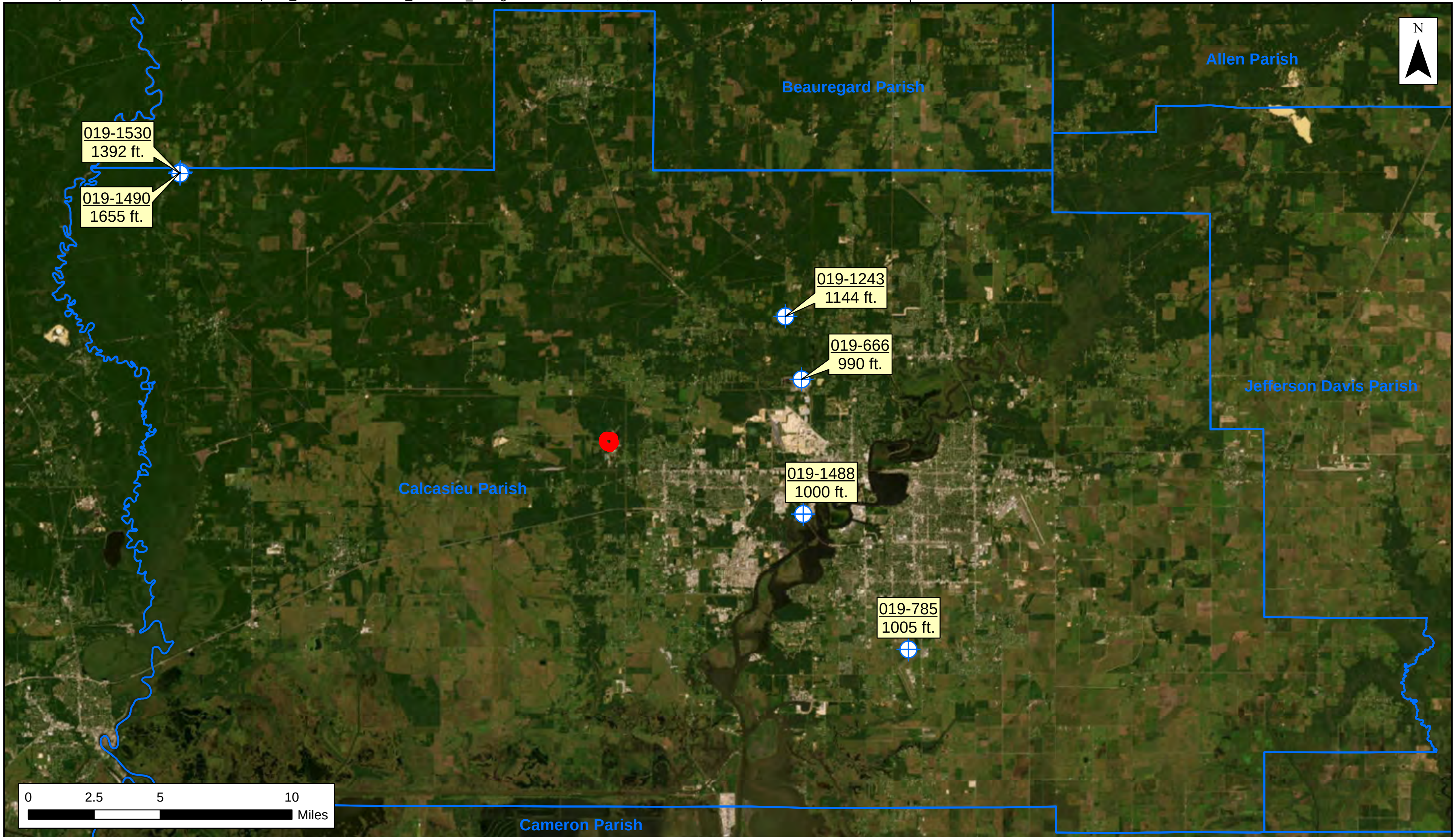

Legend

- Water Well
- Sulphur Dome
- Parish Boundary

Notes:
Well data via SONRIS database.
World Imagery via ArcGIS online.

Figure 6
Evangeline Aquifer Water Wells
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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Source: Esri - ArcGIS Online; NAD 1983 UTM Zone 15N

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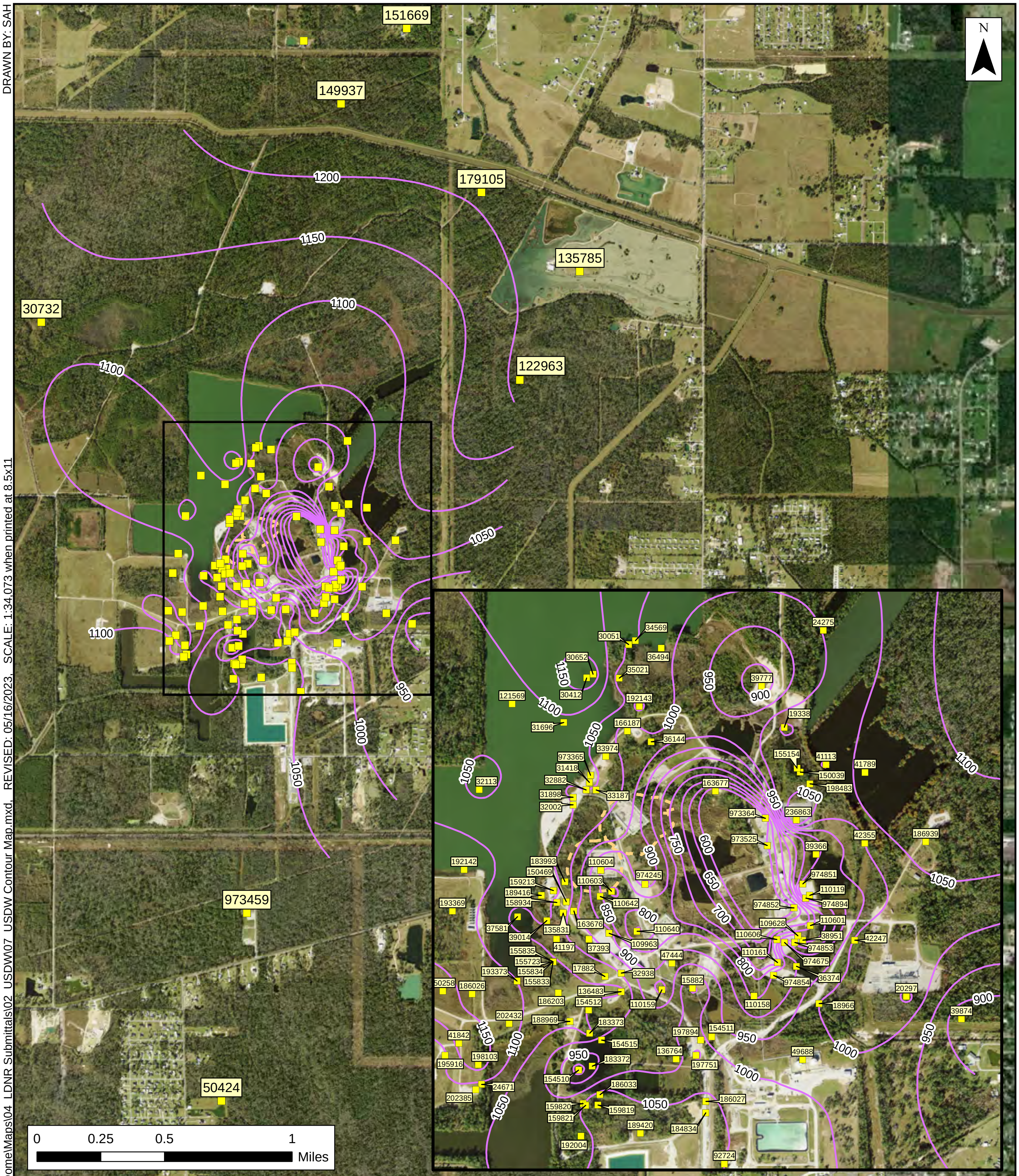

Legend

- USDW Contour (50 ft)
- USDW Value Location
- Cavern 6 & 7 Footprint

Notes:
Well locations via SONRIS database.
Cavern footprint via Lonquist.
Nov 22, 2021 aerial imagery via USGS.

Figure 7
USDW Contour Map
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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Source: ESRI - ArcGIS Online; NAD 1983 UTM Zone 15N

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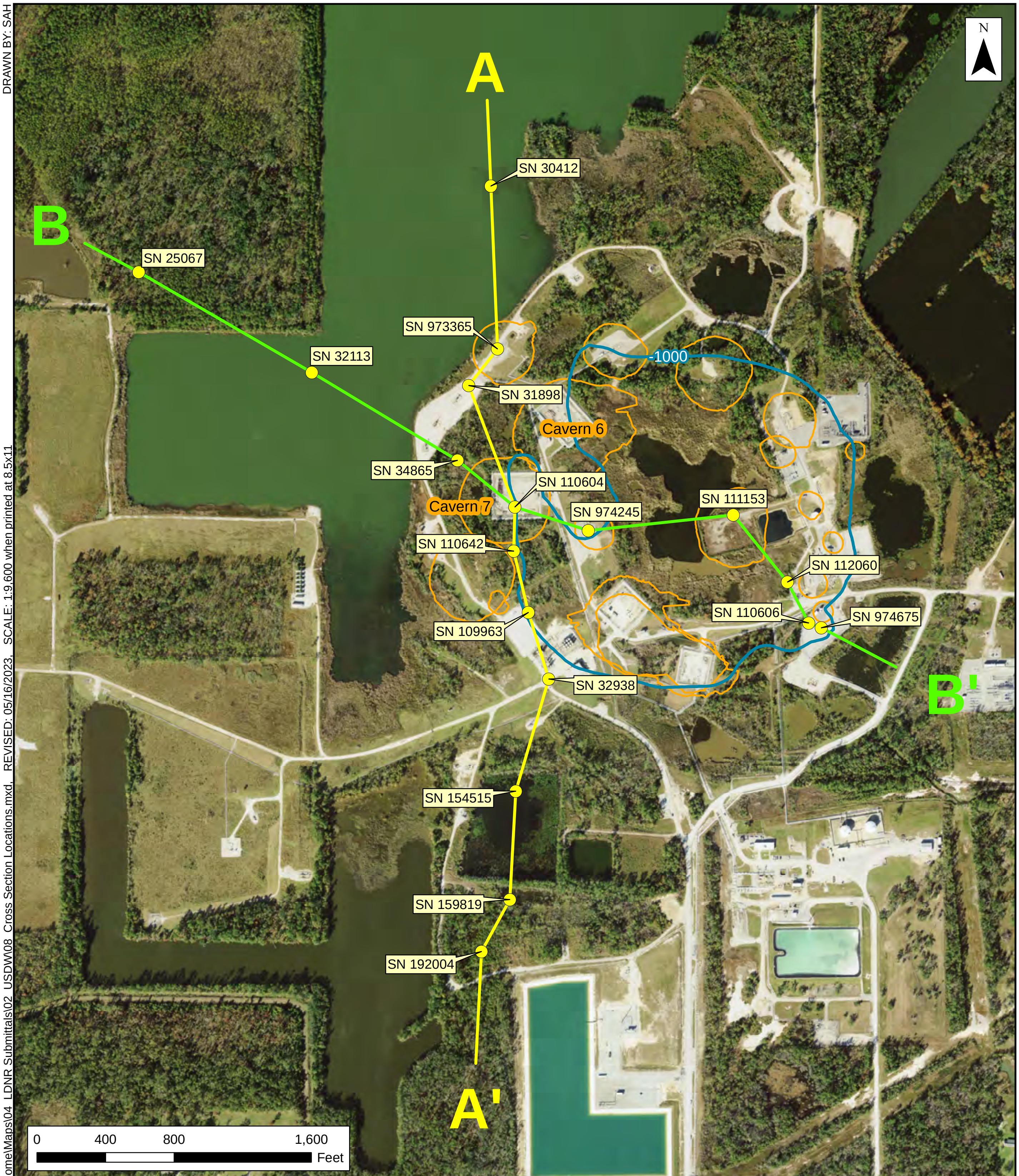

Legend

- Oil & Gas Well
- -1,000 ft Caprock Contour
- Cavern Footprint

Figure 8
Cross Section Locations
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

Notes:
Well locations via SONRIS database.
Salt and caprock contours, and cavern footprint via Lonquist.
Nov 22, 2021 aerial imagery via USGS.

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Source: ESRI - ArcGIS Online; NAD 1983 UTM Zone 15N

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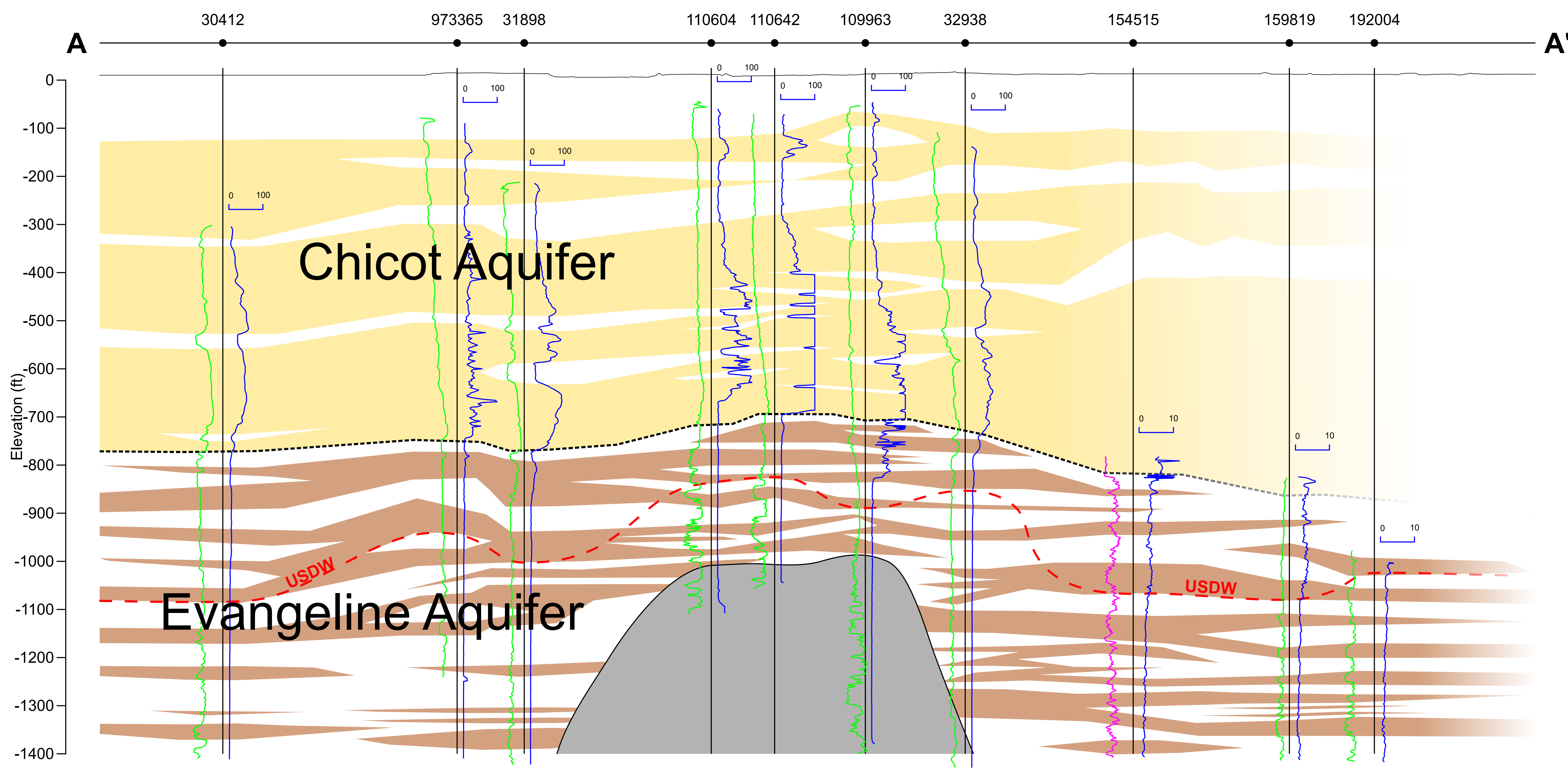
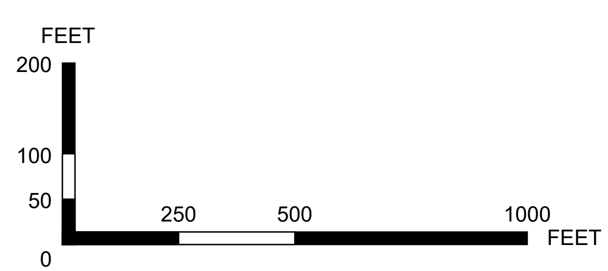


Legend

- Resistivity Log
- SP Log
- Gamma Log
- Chicot Aquifer Sands
- Clays and Silts (not colored)
- Evangeline Aquifer Sands
- Cap rock



Notes:
Well logs and locations obtained from SONRIS database.
Lithology and USDW values estimated from historic well files.
Cap rock contours via Lonquist.

Figure 9
North-South Cross Section
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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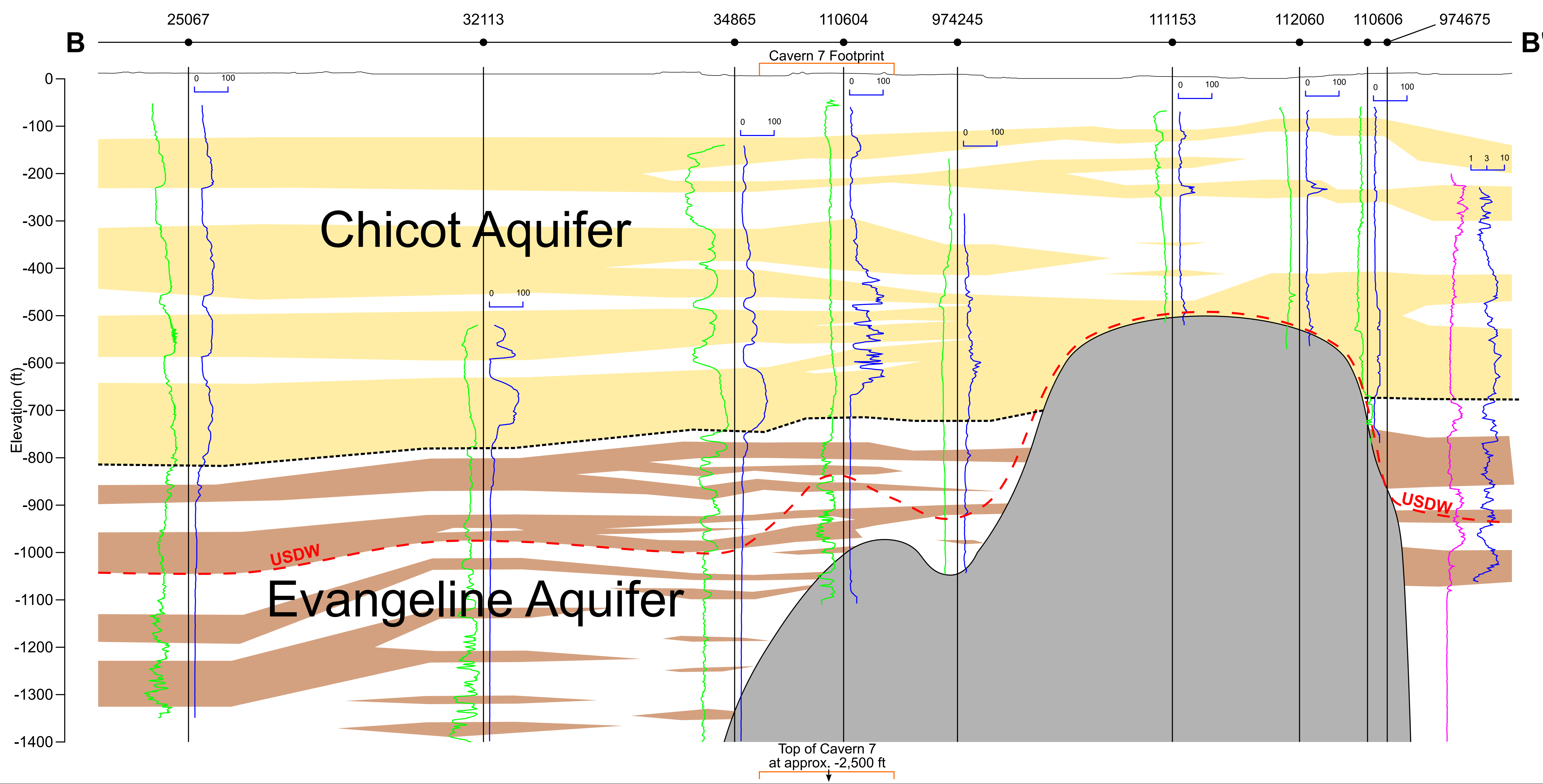

Legend

- Resistivity Log
- SP Log
- Gamma Log
- Chicot Aquifer Sands
- Clays and Silts (not colored)
- Evangeline Aquifer Sands
- Cap rock

FEET 200 100 50 0

250 500 1000 FEET

Notes:
Well logs and locations obtained from SONRIS database.
Lithology and USDW values estimated from historic well files.
Cap rock contours via Lonquist.

Figure 10
West-East Cross Section
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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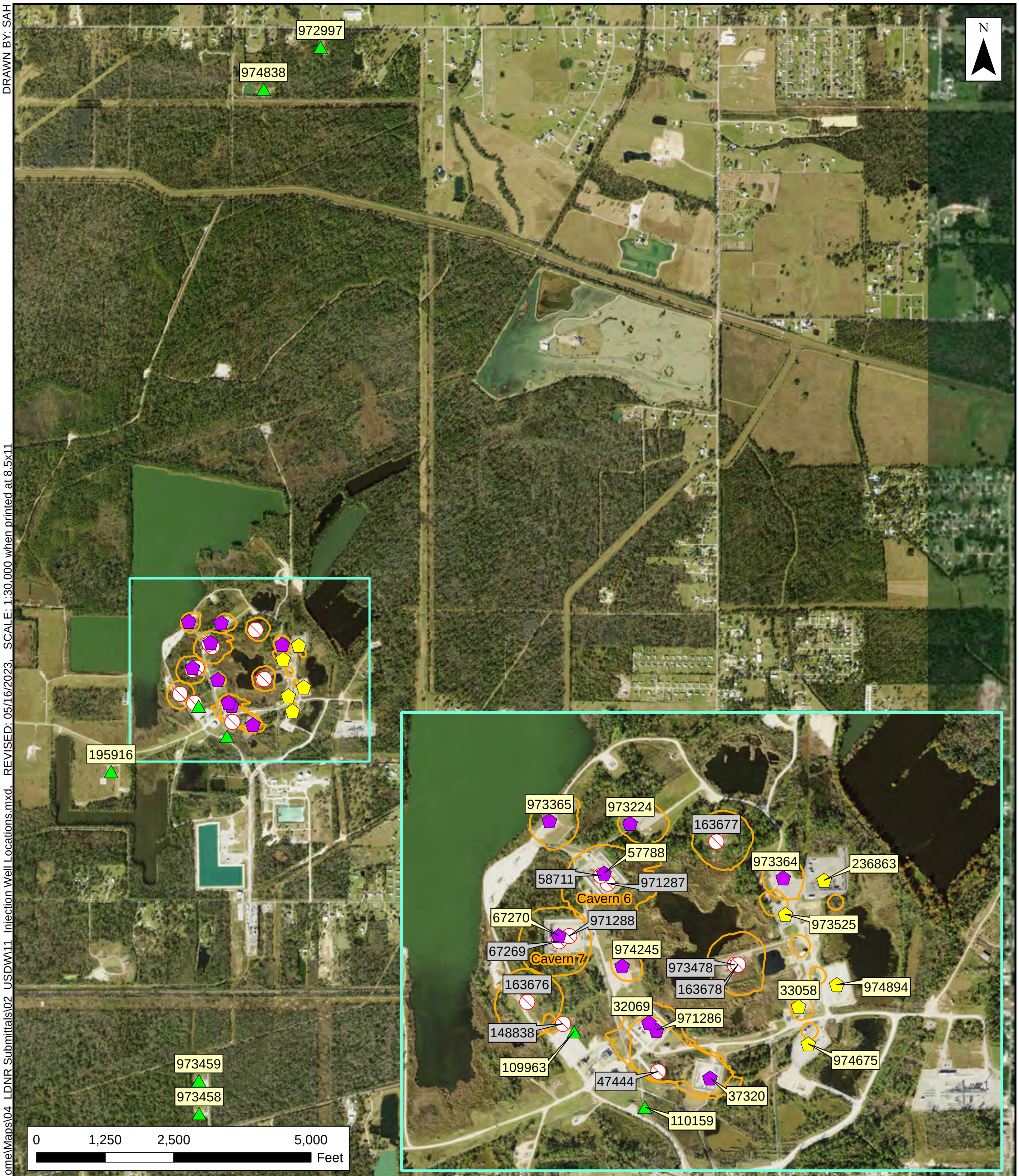

Legend

- Active Class II SWD Well
- Active Brine Well
- Active LNG Storage Well
- Plugged and Abandoned Well
- Cavern Footprint

Notes:
Well locations via SONRIS database.
Cavern footprint via Lonquist.
Nov 22, 2021 aerial imagery via USGS.

Figure 11
Injection Well Locations
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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Source: ESRI - ArcGIS Online; NAD 1983 UTM Zone 15N

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Legend

- Proposed Monitoring Well
- Active Brine Well
- Active LNG Storage Well
- Cavern Footprint
- Westlake Property

Notes:
Well locations via SONRIS database.
Cavern footprint via Lonquist.
Nov 22, 2021 aerial imagery via USGS.

Figure 12
Proposed Monitoring Well Locations
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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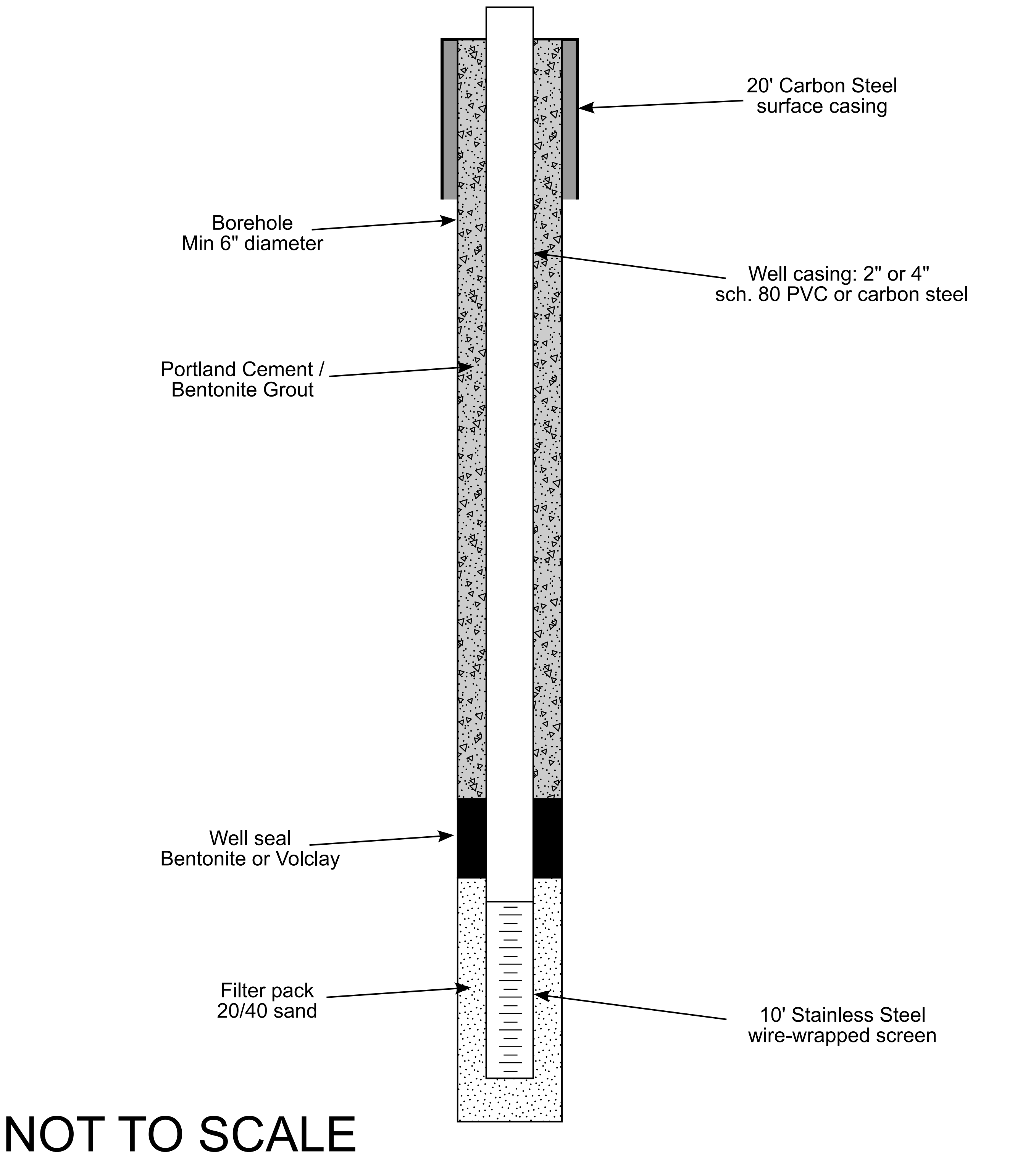

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Figure 13
Proposed Monitoring Well Schematic
Sulphur Dome
Westlake US 2, LLC
Calcasieu Parish, Louisiana

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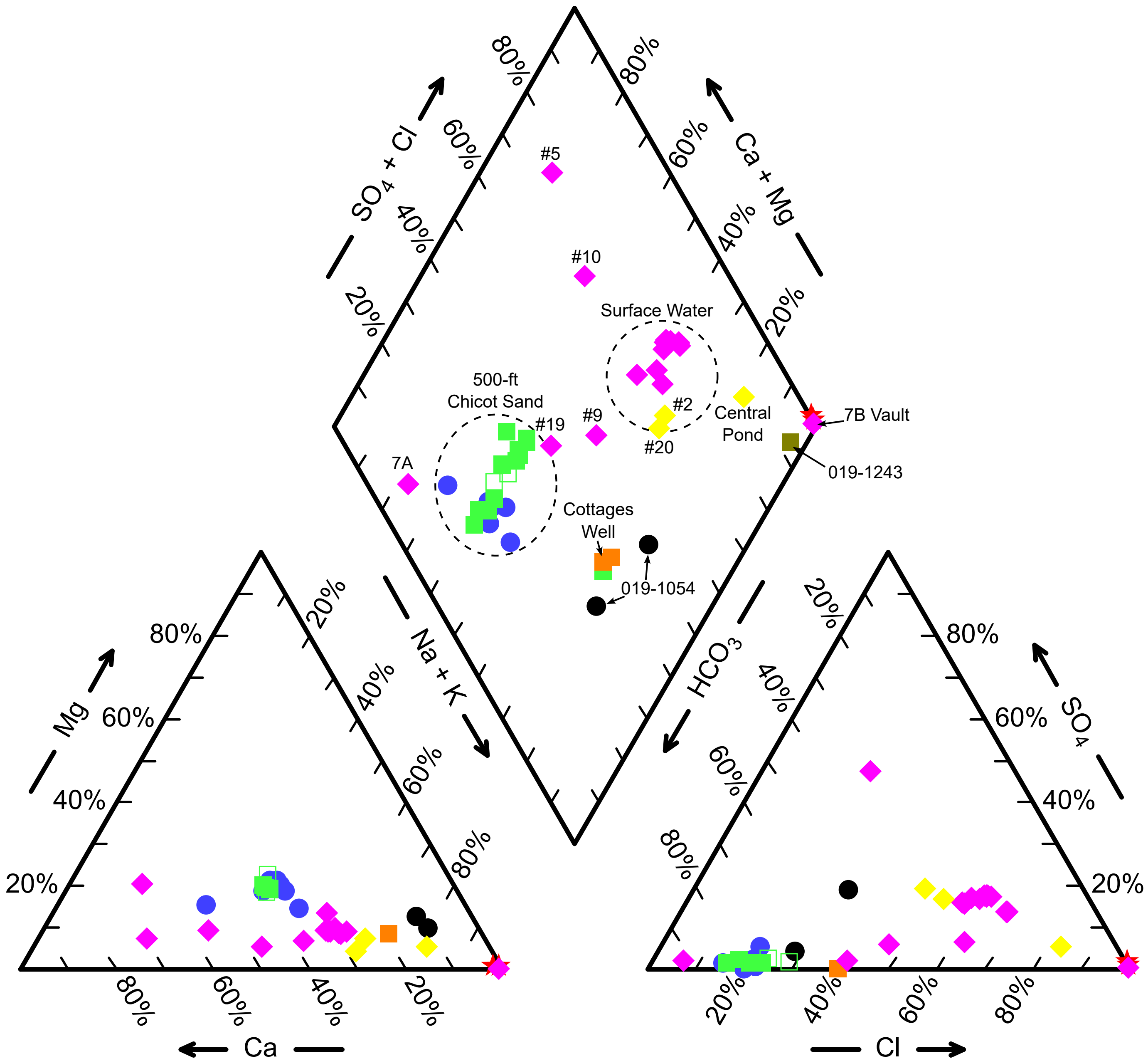

Legend

- Bubble Site & Surface Water
- Other Surface Water
- Industrial Water Well (Current)
- Industrial Water Well (Historic)
- Cottages Well
- Other Water Well
- 019-1054 (Historic)
- Evangeline Aquifer Water Well (Historic)
- Brine

Figure 14
Piper Diagram
Sulphur Dome
Westlake US 2, LLC
Calcacieu Parish, Louisiana

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TABLES

Table 1
USDW Evaluation
Sulphur Mines Salt Dome
Calcasieu Parish, Louisiana

				Surface Location			USDW Value Estimate (ft)	
Well Serial Number	**Well Name**	**Well Number**	**Status Code**	**Latitude**	**Longitude**	**Description**	**LDNR**	**ERM**
15882	FEE	782	30	30.2502088	-93.41216488	Plugged And Abandoned Oil	1090	1090
17882	FEE	812	30	30.25051003	-93.41486372	Plugged And Abandoned Oil	1045	1040
18966	FEE	831	30	30.24980817	-93.40826345	Plugged And Abandoned Oil	1080	1005
19338	FEE	836	30	30.25720802	-93.40936522	Plugged And Abandoned Oil	1075	1075
20297	FEE	848	30	30.25001006	-93.40556564	Plugged And Abandoned Oil	NI	1060
24275	FEE	865	29	30.25980929	-93.40816507	Dry And Plugged No Product Specified	1180	1005
24671	FEE	871	35	30.24760913	-93.41866432	Plugged Back - No Perforations - No LUW Oil	1110	1075
30051	FEE	885	30	30.25940955	-93.41416636	Plugged And Abandoned Oil	1175	1040
30412	FEE	888	30	30.25850902	-93.41546537	Plugged And Abandoned Oil	1190	1190
30652	FEE	889	30	30.25860844	-93.4152647	Plugged And Abandoned Oil	1190	1190
30732	B ULRICH	1	30	30.26650748	-93.42826469	Plugged And Abandoned Oil	1120	1120
31418	FEE	890	30	30.25570818	-93.41536547	Plugged And Abandoned Oil	NI	1095
31696	FEE	891	30	30.2573099	-93.41616568	Plugged And Abandoned Oil	NI	1090
31898	FEE	892	30	30.25530979	-93.41586398	Plugged And Abandoned Oil	950	1000
32002	FEE	893	30	30.25510899	-93.4158661	Plugged And Abandoned Oil	NI	1140
32113	FEE	894	30	30.25550877	-93.41876356	Plugged And Abandoned Oil	NI	1035
32882	FEE	895	30	30.25550858	-93.41546583	Plugged And Abandoned Oil	NI	1050
32938	FEE	896	30	30.25060864	-93.4143653	Plugged And Abandoned Oil	1090	1000
33187	SM MIO B 898 VU FEE	898	30	30.25550783	-93.41516487	Plugged And Abandoned Oil	NI	1030
33974	FEE	899	30	30.25640913	-93.4148638	Plugged And Abandoned Oil	NI	1020
34569	FEE	897	30	30.25950897	-93.4139657	Plugged And Abandoned Oil	1175	1055
35021	FEE	902	30	30.2585083	-93.41446428	Plugged And Abandoned Oil	1180	1015
36144	FEE	901	30	30.25680795	-93.41346561	Plugged And Abandoned Oil	NI	1000
36374	FEE	882	30	30.25080918	-93.4089654	Plugged And Abandoned Oil	895	900
36494	FEE	903	30	30.25930981	-93.41316636	Plugged And Abandoned Oil	1190	1015
37393	FEE	904	30	30.25150867	-93.41536615	Plugged And Abandoned Oil	960	960
37581	S M MIO 905 VU;FEE	905	30	30.25210926	-93.41756448	Plugged And Abandoned Oil	NI	1025
38951	FEE	906	30	30.25150813	-93.4087646	Plugged And Abandoned Gas	750	750
39014	FEE	907	30	30.25200794	-93.41666588	Plugged And Abandoned Oil	1060	1060
39366	FEE	908	29	30.25380804	-93.408366	Dry And Plugged No Product Specified	590	590
39777	FEE	910	30	30.25830806	-93.41006615	Plugged And Abandoned Oil	NI	850
39874	FEE	909	29	30.24940972	-93.40386478	Dry And Plugged No Product Specified	NI	850
41113	FEE	911	30	30.25620817	-93.4080645	Plugged And Abandoned Oil	1115	985
41197	FEE	912	30	30.25150942	-93.41636399	Plugged And Abandoned Oil	1005	1005
41789	FEE	913	30	30.25600974	-93.40686607	Plugged And Abandoned Oil	1230	1075
41842	FEE	914	33	30.24870911	-93.41936525	Shut-In Productive - Future Utility Oil	NI	1170
42247	FEE	915	29	30.25150853	-93.40716491	Dry And Plugged No Product Specified	NI	1010
42355	FEE	916	29	30.2541094	-93.40686442	Dry And Plugged No Product Specified	NI	1000
47444	BRINE	5	29	30.25087529	-93.41280287	Dry And Plugged No Product Specified	NI	930
49688	FEE NO 917	917	29	30.24830971	-93.40876436	Dry And Plugged No Product Specified	1090	975
50258	FEE	918	29	30.25010931	-93.41986343	Dry And Plugged No Product Specified	1240	1170
50424	AMERICAN OIL & SULPHUR CO	2	29	30.22221085	-93.41626367	Dry And Plugged No Product Specified	1090	1090
92724	FEE	919	29	30.24550806	-93.41116391	Dry And Plugged No Product Specified	NI	1050
109628	FEE S	1	29	30.25162126	-93.40891585	Dry And Plugged No Product Specified	800	800
109963	FEE SWD	S-4	9	30.25167246	-93.41474554	Active - Injection Produced Salt Water	950	930
110119	FEE S	5	30	30.2527076	-93.40856475	Plugged And Abandoned No Product Specified	725	580
110158	FEE S	6	29	30.25000772	-93.41026325	Dry And Plugged No Product Specified	870	860
110159	FEE SWD	S-7	9	30.25016649	-93.4131048	Active - Injection Produced Salt Water	970	860
110161	FEE S	9	30	30.25090464	-93.40954075	Plugged And Abandoned No Product Specified	760	750
110601	FEE S	13	29	30.25189676	-93.40853514	Dry And Plugged No Product Specified	950	760
110603	FEE S	15	29	30.25279576	-93.41466771	Dry And Plugged No Product Specified	770	770
110604	FEE S	16	29	30.25336251	-93.41500269	Dry And Plugged No Product Specified	840	840
110606	FEE S	12	29	30.25152308	-93.40956318	Dry And Plugged No Product Specified	670	730
110640	FEE S	19	29	30.25172733	-93.4138819	Dry And Plugged No Product Specified	NI	710
110642	FEE S	21	29	30.25265545	-93.41501955	Dry And Plugged No Product Specified	830	870
121569	FEE	921	29	30.25780996	-93.4177633	Dry And Plugged No Product Specified	1125	1055
122963	UNION TEXAS FEE	1	29	30.26330862	-93.39686471	Dry And Plugged No Product Specified	1255	1220
135785	ALLIED CHEMICAL CORP	1	29	30.26950788	-93.39296345	Dry And Plugged No Product Specified	1300	1235
135831	SM 2800 RA SU;FEE	922	30	30.25220838	-93.41616324	Plugged And Abandoned Gas	NI	1040
136483	FEE	923	30	30.25010813	-93.41436432	Plugged And Abandoned No Product Specified	1060	1060
136764	FEE	924	30	30.24830884	-93.41266368	Plugged And Abandoned Oil	960	960
149937	ALLIED CHEMICAL CORP	1	29	30.2790085	-93.40866443	Dry And Plugged No Product Specified	1240	1240
150039	FEE	927	30	30.25600857	-93.40886497	Plugged And Abandoned Oil	NI	1010
150469	SM 3400 RA SU;FEE	928	30	30.2525097	-93.41606503	Plugged And Abandoned Oil	NI	1045
151669	L. HACK RB SUA;SL 6544	2	30	30.28330848	-93.40436559	Plugged And Abandoned Oil	1230	1230
154510	SM MARG 1 RA SU;FEE	930	30	30.24800853	-93.41566346	Plugged And Abandoned Oil	850	850
154511	SM 3550 RA SU;FEE	929	30	30.24890918	-93.41156438	Plugged And Abandoned Oil	935	935
154512	SM BM 1 RA SU;FEE	932	30	30.24960833	-93.41536435	Plugged And Abandoned Oil	1045	1045
154515	SM MARG 1 RB SU;FEE	931	20	30.24880885	-93.41496433	PA-35 Temporary Inactive	1070	950
155154	SM 3000 RA SU;FEE	938	30	30.25610875	-93.40896527	Plugged And Abandoned Oil	NI	1010
155723	SM 4800 RA SU;FEE	939	30	30.25090828	-93.41646543	Plugged And Abandoned Oil	990	1050
155833	SM 3500 RA SU;FEE	934	30	30.25090828	-93.41646543	Plugged And Abandoned Oil	1070	1070
155834	SM 3600 RA SU;FEE	935	30	30.25090828	-93.41646543	Plugged And Abandoned Oil	1065	1065
155835	FEE	937	30	30.25090828	-93.41646543	Plugged And Abandoned Oil	985	1075
158934	SM 3100 RB SU;FEE	940	30	30.25249411	-93.41635613	Plugged And Abandoned Oil	NI	1030
159213	SM 2850 RA SU;FEE	942	20	30.25280867	-93.4164641	PA-35 Temporary Inactive	NI	1065
159819	FEE	943	33	30.24706913	-93.4150673	Shut-In Productive - Future Utility Oil	1080	1080
159820	SM CH RA SU;FEE	944	20	30.24710781	-93.41552301	PA-35 Temporary Inactive	1045	1045
159821	SM MARG 5 RA SU;FEE	945	20	30.24706594	-93.41544418	PA-35 Temporary Inactive	1070	1070
163676	LIBERTY GAS STORAGE	1	29	30.25226591	-93.41582867	Dry And Plugged No Product Specified	945	945
163677	PPG BRINE	16	29	30.25548894	-93.41147709	Dry And Plugged No Product Specified	550	NI
166187	SM 4000 RA SU;FEE	946	30	30.25709064	-93.41420015	Plugged And Abandoned Oil	NI	960
179105	ALLIED CHEMICAL CORP	3	29	30.27399405	-93.39943137	Dry And Plugged No Product Specified	NI	1240
183372	SM MARG 1 RC SU;FEE	948	20	30.24811135	-93.41524749	PA-35 Temporary Inactive	935	935
183373	SM MARG 1 RD SU;FEE	949	30	30.2489901	-93.41532923	Plugged And Abandoned Oil	1070	1070
183993	SM BASAL MIOCENE RB SU;FEE	950	30	30.253048	-93.41611116	Plugged And Abandoned Oil	NI	1040
184834	SM BSL MIO RC SU;FEE	954	30	30.2468741	-93.41173727	Plugged And Abandoned Oil	1060	1060
186026	FEE	959	29	30.2500328	-93.41896221	Dry And Plugged No Product Specified	NI	1130
186027	SM 5200 RA SU;FEE	963	30	30.24717652	-93.41174358	Plugged And Abandoned Oil	1060	1060
186033	SM CH RC SU;FEE	961	33	30.24734506	-93.41500972	Shut-In Productive - Future Utility Oil	1080	1080
186203	SM BSL MIO1 STRINGER RA SU;FEE	960	30	30.25007481	-93.41630224	Plugged And Abandoned Oil	1060	1060

Table 1
USDW Evaluation
Sulphur Mines Salt Dome
Calcasieu Parish, Louisiana

Well Serial Number	Well Name	Well Number	Status Code	Surface Location		Description	USDW Value Estimate (ft)	
				Latitude	Longitude		LDNR	ERM
186939	FEE	962	29	30.25415818	-93.40498376	Dry And Plugged No Product Specified	NI	1090
188969	SM BSL MIO RA SU;FEE	966	30	30.24931052	-93.41593779	Plugged And Abandoned Oil	1065	1065
189416	SM 2850 RA SU;FEE	969	33	30.25267911	-93.41683201	Shut-In Productive - Future Utility Oil	NI	1070
189420	SM MARG 2 RE SU;FEE	973	20	30.24631982	-93.41375292	PA-35 Temporary Inactive	1080	1080
192004	FEE	977	33	30.24623587	-93.41558835	Shut-In Productive - Future Utility Oil	1030	1030
192142	SM 3100 RC SU;FEE	979	30	30.2533564	-93.41922205	Plugged And Abandoned Oil	NI	1140
192143	FEE	980	29	30.25775365	-93.41383706	Dry And Plugged No Product Specified	1070	1070
193369	SM MARG 1 RB SU;FEE	982	30	30.25225069	-93.41957896	Plugged And Abandoned Oil	NI	1120
193373	SM 2000 RE SU;FEE	986	30	30.25038472	-93.41757581	Plugged And Abandoned Oil	NI	1100
195916	FEE SWD	987	9	30.24838339	-93.41978922	Active - Injection Produced Salt Water	1090	1090
197751	SM MARG 1 RJ SU;FEE	989	20	30.24841754	-93.41204826	PA-35 Temporary Inactive	1070	1070
197894	SM 3550 RA SU;FEE	990	20	30.24882407	-93.41190471	PA-35 Temporary Inactive	1080	1055
198103	SM MARG 1 RB SU;FEE	996	30	30.24813833	-93.41876411	Plugged And Abandoned Oil	NI	1190
198483	FEE	995	29	30.25569704	-93.40856385	Dry And Plugged No Product Specified	NI	1040
202385	SM CH RC SU;FEE	997	33	30.24747441	-93.41883572	Shut-In Productive - Future Utility Oil	NI	1080
202432	SM MARG 5 RC SU;FEE	998	30	30.24924239	-93.41781478	Plugged And Abandoned Oil	1095	1120
236863	SULPHUR STORAGE	3	9	30.25472518	-93.40898071	Active - Injection LPG Storage Salt Dome	1142	1160
973364	PPG	20	9	30.25476802	-93.40992878	Active - Injection Brine Solution Mining	550	NI
973365	PPG	21	9	30.25589848	-93.41533145	Active - Injection Brine Solution Mining	884	NI
973459	SULPHUR SWD	2	9	30.23291247	-93.41464759	Active - Injection Swd For Salt Cavern	1140	1070
973525	SULPHUR STORAGE	1	9	30.25404011	-93.40987238	Active - Injection LPG Storage Salt Dome	560	600
974245	PPG BRINE	22	9	30.25299069	-93.41364226	Active - Injection Brine Solution Mining	924	924
974675	SULPHUR STORAGE	4	9	30.25144418	-93.40933346	Active - Injection LPG Storage Salt Dome	948	950
974838	D R ANCELET SWD	1	9	30.28258364	-93.41111568	Active - Injection Produced Salt Water	1310	NI
974851	SULPHUR MINES OBSERVATION	1	9	30.25301513	-93.40877075	Active - Injection Injection Monitor Well	950	950
974852	SULPHUR MINES OBSERVATION	2	9	30.25237012	-93.4090392	Active - Injection Injection Monitor Well	600	600
974853	SULPHUR MINES OBSERVATION	3	9	30.25144097	-93.40901345	Active - Injection Injection Monitor Well	968	840
974854	SULPHUR MINES OBSERVATION	4	9	30.25056169	-93.40966346	Active - Injection Injection Monitor Well	NI	905
974894	SULPHUR STORAGE	5	9	30.25263427	-93.40868043	Active - Injection LPG Storage Salt Dome	940	NI

Notes:
USDW values reported in feet below ground surface assuming vertical boreholes.
LDNR USDW values obtained from SONRIS database.
NI - Not identified

Table 2
List of References
Sulphur Mines Salt Dome
Calcasieu Parish, Louisiana

Bauernschmidt, A. J., Jr., 1930, Sulphur Dome, Calcasieu Parish, Louisiana: AAPG Bulletin, vol. 14, iss. 8, pp. 1079-1086.

CH2M Hill, 1992, Environmental Remedial Evaluation Report, Sulphur Mines Field, Sulphur, Louisiana, prepared for Meridian Oil, Inc.

Harder, A.H., Kilburn, C., Whitman, H.M. and Rogers, S.M., 1960. The Geology and Ground-Water Resources of Calcasieu Parish Louisiana: U.S. Geological Survey, Water-Supply Paper 1488, 102 p. and plates.

Harris, G.D., 1910. Oil and Gas in Louisiana, with a brief summary of their occurrence in adjacent states, U.S. Geological Survey, Bulletin 429, 192 p.

Heinrich, P.V., 2000. De Quincy Fault-Line Scarp, Beauregard and Calcasieu Parishes, Louisiana: Louisiana Geological Survey, Basin Research Institute Bulletin, vol. 9, pp. 38-50.

Heltz, J.O., 2005. Evidence of neotectonic activity in southwest Louisiana; Louisiana State University Master's Thesis, 89 p.

Louisiana Geological Survey, 2002, Lake Charles 30x60 Minute Geologic Quadrangle, 1 sheet.

Sandia National Labs, 1981. Strategic Petroleum Reserve (SPR) Geological Site Characterization Report Sulphur Mines Salt Dome Sandia 80-7141, 428 p.

Sargent, B.P., Frederick, C.P., Roberts, F.C., 2004. Thickness data for the Chicot aquifer system surficial confining unit: Louisiana Department of Transportation and Development Water Resources, Basic Records Report no. 22, 91 p.

US EPA, 2012, Protecting Drinking Water Through Underground Injection Control: Office of Water, EPA 816-K-10-004, 46 p.

USGS, 2017, Water Resources of Calcasieu Parish, Louisiana. U.S. Geological Survey, Fact Sheet 2016-3066, 6 p.

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