March 17, 2014

Blue Ribbon Commission on Bayou Corne and Grand Bayou Public Safety GAS SAFETY BENCHMARK FRAMEWORK AND GUIDANCE

BACKGROUND

The Blue Ribbon Commission (BRC) on Bayou Corne/Grand Bayou Public Safety is tasked with recommending the conditions necessary to lift the mandatory evacuation order for Bayou Corne, and to ensure that conditions in the area surrounding the sinkhole along the western edge of the Napoleonville Salt Dome in Assumption Parish, Louisiana remain safe for residents and visitors.

In the *Blue Ribbon Commission on Bayou Corne and Grand Bayou Public Safety Three-Day Working Session (Monday, April 29, 2013 – Wednesday, May 1, 2013) Key Outcomes Memorandum* dated June 3, 2013, the BRC recommended, among other things, that "in order to lift the evacuation order, gas pressure in the MRAA and overlying aquitard has to be maintained at or below hydrostatic pressure."

In response to this recommended safety benchmark, on November 8, 2013, Dr. Charlie Faust and Ted Borer of Tetra Tech submitted a *Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations* (Plan, see Appendix 1) to the Louisiana Department of Natural Resources (LDNR) on behalf of Texas Brine Company, LLC (TBC). This Plan suggests that the benchmark includes a "structured set of criteria for stages of observation relief well (ORW) operations and an alternative (or more detailed definition) to the BRC hydrostatic pressure objective for gas pressures in the Mississippi River Alluvial Aquifer (MRAA)." This Plan was forwarded to the Blue Ribbon Commission (BRC) Gas Subgroup on November 11, 2013 for their review and consideration.

On December 23, 2013, the BRC submitted a response to this Plan titled *Blue Ribbon Commission Comments to Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations* (see Appendix 2). Upon receipt of this response, TBC requested to present information regarding its Plan to the BRC. This meeting was held on January 20, 2014 and Dr. Charlie Faust presented *Criteria and Goals for Gas Venting Operations* (see Appendix 3). In addition, TBC, upon request of the BRC, has submitted an *Investigation Report for RRD-08B Extent of Gas* (see Appendix 4) and a *Current Conditions Report, Bayou Corne Sinkhole, Assumption Parish, Louisiana* (see Appendix 5).

All of this information has been reviewed and considered by the BRC Gas Subgroup, in coordination with the full commission, and the BRC offers the following response and guidance.

GAS SAFETY BENCHMARK GUIDANCE AND FRAMEWORK

The primary concern of the BRC is public safety. Explosive gas accumulations in or under buildings and other built structures is a hazard and a major concern for the safety of residents and visitors to the Bayou Corne community. In this guidance document, the gas of specific concern is methane and other petroleum gases. The BRC is also concerned about other gas risks (e.g., hydrogen sulfide) that are not the subject of this guidance document. Public safety can be improved by removing, or "mitigating," gas, with associated reductions in gas pressure, so that the risk is reduced to acceptable levels. It is the role of regulatory authorities to determine what level of gas reduction and pressure is acceptable. The BRC advises that there be no releases of gas from the ground or surface water into the environment in and around the community at present or in the future that would cause an unacceptable level of risk. The BRC points out that natural background levels of biogenic "swamp" gas are a traditionally accepted low-risk hazard to residents; however, the release of deep thermogenic gas and associated displacement of swamp gas by pressure buildup from thermogenic gas associated with the collapse of the Oxy 3 cavern are hazards that require removal or mitigation. In addition to eliminating current surface releases to a level typical of natural background biogenic "swamp" gas, the potential for releases emanating from the Mississippi River Alluvial Aquifer (MRAA) and the overlying aquitard must also be mitigated to reduce the risk of future releases to the surface to acceptable levels. In the considered opinion of the BRC, the elimination of these two hazards is an on-going and possibly long-term requirement for public safety.

The BRC has proposed a criterion for gas remediation of reduction of gas pressure to hydrostatic. TBC cites ambiguity in definition of gas pressure. So that there is no confusion, the BRC asserts without ambiguity that the suggested criterion is the difference between the well shut-in pressure as measured at the top of the screened interval and the water pressure measured in the same or adjacent well and referenced to the same depth calculated using the measured water density in the well. This is referred to as capillary pressure and is a practical measure of gas accumulation in the MRAA and overlying aquitard. This pressure difference can be determined using a properly completed and instrumented pressure monitoring well.

The BRC notes that any field investigation has elements of uncertainty and that the acquisition of some data may be difficult. Nonetheless, techniques are available that allow the reduction in gas pressure and thus the hazard at Bayou Corne to be evaluated. The use of multiple measurement approaches builds confidence in the ultimate determination of safety and such a multiple-criteria approach should be used.

While BRC believes that reduction of gas pressure to hydrostatic remains an appropriate criterion for gas hazard, it is also recognized that achievement of this criterion might be asymptotic. TBC proposed that reduction in gas flow-rates from ORWs be used as an alternate criterion. The BRC feels that ORW gas flow reduction alone cannot be used as a criterion and suggests additional criteria parameters that could be used to support the reduction in gas risk. These include the objectives and related criteria below. The Louisiana Department of Natural Resources (LDNR), with the support of other state agencies as appropriate, will be the regulatory agency responsible for defining the specific numerical or qualitative metrics to be met for each criterion.

First objective: Elimination of gas releases in and near community above those typical of that associated with natural background biogenic "swamp" gas:

- ***Reduction of gas bubbling rates at bubble sites.*** An appropriate reduction in the gas bubbling rate to that typical of natural background biogenic "swamp" gas should be achieved across the gas area. The type of gas (thermogenic, biogenic, mix), location relative to the community, and measurement and detection methods should be considered in defining the gas area and bubble rate reduction required or minimum rate allowed. In the interest of public safety, the gas monitoring systems in the homes in Bayou Corne should continue to be operated until the evacuation order is removed.

Second objective: Elimination of gas accumulations in MRAA and the overlying aquitard:

- ***Reduction in gas cap and aquitard pressures, as measured in pressure monitoring wells including shallow Geoprobe wells.*** The pressure monitoring wells ordered by LDNR under RRD-09 serve as the initial pressure monitoring network. For MRAA wells, gas pressure should be measured with downhole pressure sensors and compared to MRAA water pressure at the same elevation using deeper monitoring wells in the aquifer. Current low-pressure instrumentation and procedures are sufficient for the Geoprobe wells. Pressure monitoring wells should have confirmed hydraulic connectivity with aquifer such as demonstrated by gas flow drawdown and build-up tests (Horne, 1995) or slug tests if gas is not present. Gas in the pressure monitoring wells should be bled periodically to verify presence or absence of gas accumulation at each well. Pressure monitoring wells, including the shallow Geoprobe wells completed in the aquitard, should be monitored and maintained on a regular basis to provide data documenting continued reduction of gas pressure in the MRAA and overlying aquitard.

- ***Reduction in gas recovery rates associated with a corresponding reduction in gas cap pressure.*** Reduction in gas recovery rate from a vent well is an important confirming criterion, but gas recovery rate does not serve as an appropriate criterion for endpoint determination. Reduction in flow rate must be accompanied by corresponding vent well and pressure monitoring well demonstration of gas pressure reduction in the same strata.

- ***Reduction in gas pressure, as evaluated using new CPT penetrations.*** Measurements should be repeated on a regular basis to support continued reduction of gas pressure in the MRAA and overlying aquitard. Prior to use of CPTs to evaluate gas cap pressure, TBC should submit a report to LDNR documenting that CPT pressure data will consistently generate reproducible and accurate gas pressure data for use in monitoring gas pressure across the gas cap area.

- ***Reduction in gas cap thickness, as evaluated using new CPT and MiHPT borings.*** The CPTs and MiHPTs should penetrate the MRAA to an adequate depth to identify the base of the gas zone. In the event that the borings cannot reach the bottom of the gas zone, other methods such as PDK logs in new ORWs should be used to verify the bottom of the gas zone. Where the bottom of the gas zone is not defined, the depth measured using CPT/MiHPT data can only be used to establish a minimum gas thickness. Measurements should be repeated on a regular basis to support continued reduction of gas cap thickness.

Engineering design calculations and modeling for the gas mitigation system should demonstrate that the well spacing, locations, and construction are appropriate for mitigating gas across the MRAA gas cap area including the overlying aquitard and meet the above criteria. Site-specific empirical well spacing data from the current ORW and PWM wells should be used in this design. Areas of insufficient data on the map of gas cap thickness in *Investigation Report for RRD-08B Extent of Gas* (see Appendix 4; the areas shown in green shading) illustrate that data density is currently inadequate for full characterization of the gas cap. Furthermore, gas drawdown and buildup data and analysis including an assessment of the well "skin" (Earlougher Jr., 1977; Horne, 1995) should be obtained on each operating vent well to confirm that the well is in good hydraulic communication with the MRAA.

The BRC accepts that measurement variability is expected but points out that accepted practice (and many regulatory frameworks) require that the type, quantity, and quality of data are sufficient to support important decisions such as the lifting of the mandatory evacuation order at Bayou Corne (see, for example, the U.S. Environmental Protection Agency's Data Quality Objectives process). The BRC believes that confidence in decisions based upon analysis of field data can be much improved by the application of an approach such as the data quality objective process to gas cap thickness and pressure measurements.

TECHNICAL RESPONSE AND FEEDBACK TO THE *PLAN FOR OPERATING RELIEF WELLS AND CONCEPTUAL CRITERIA FOR ENDING OPERATIONS*

Further explanation of pertinent technical information/issues related to the above objectives and criteria is presented in the following section.

TBC has expressed concern that quantification and achieving the metric of reducing gas pressures to hydrostatic conditions is overly challenging as outlined in their submissions to the BRC. They have suggested reduction of gas flow-rates in the ORWs as an alternative metric for determining lifting of the evacuation order issued August 3, 2012 by Assumption Parish Office of Emergency Preparedness.

The BRC recognizes that reduction in gas flow-rates may be one indicator of reduction in gas volume and pressure and therefore be an indicator of reduced risk. However reduction in gas flow-rate from a given well may not be solely due to reduced gas pressure in the MRAA. Issues of concern to the BRC include the following:

1. Gas flow-rate reduction may be the result of removing sufficient gas from an area using sufficient well density that the BRC benchmark of reducing gas pressure to hydrostatic has been fundamentally met. This is the criterion proposed by TBC.

2. Gas flow-rate reduction may be the result of inadequate well completion, construction, and/or operational issues. It is important that any vent well be in good hydraulic communication with the MRAA gas cap for proper gas mitigation.
3. Gas pressure reduction in an ORW may be the result of the well "watering in" where the absence of water removal from the well causes the gas pressure at the well head at an ORW to diminish and the gas flow-rate to decrease significantly or cease.
4. Gas flow-rate and pressure reduction may be associated with low permeability in the vicinity of the well. As such, a depressurized ORW will have a small radius of influence in terms of gas removal. For any evaluation of safety and mitigation effectiveness regarding the evacuation order, when the gas pressure in a given ORW drops, it is important to assess the distance from the ORW that sufficient gas has been removed from the MRAA and overlying aquitard to reduce the gas pressure by the amount necessary to allow lifting of the evacuation order.

Examples of gas pressure reduction and tests to confirm gas pressure reduction

1. The installation and operation of the initial vent wells ORW-01 and 02 on the Dugas-Leblanc property provides an example of gas pressure reduction across an area where sufficient gas was removed to demonstrate that meeting the BRC Gas Benchmark is technically feasible. In this area, sufficient gas was removed by 10 ORWs resulting in wellhead pressures in many of the wells that were at or near zero (Figure 1 and Table 1). Additionally, the CPTs and MiHPT's installed in this area in the summer and fall of 2013 showed that little gas remained. Unfortunately, this area also experienced an inflow of additional gas in the fall-early winter of 2013 and the pressures in many of the ORWs have increased over the past several months (see example below under the "Increased Gas Pressure Over Time" heading),
2. Proper performance of a vent well is contingent on proper installation, construction, and operational procedures. As shown on Table 2, approximately half of the 50 ORWs with over 2 months of operation have flowed less than 300 thousand cubic feet (mcf) with about 30% having flowed less than 100 mcf. This performance can partially be attributed to variations in the lithology but part of the problem can also be attributed to the use of a drilling method (sonic) that used hydraulic pressure to force the borehole cuttings into the formation with no surface returns, creating formation damage adjacent to the well. The effect this formation damage has had on ORW performance has not been explicitly quantified but the recent pumping tests completed at ORW-38 and ORW-21 in the Bayou Corne Community showed marked differences between the sonic-driven well with no cleanout of cuttings (ORW-21) and the well installed with conventional screen and development methods (ORW-38). At ORW-21, the hydraulic conductivity measured during the pumping test was 1 foot/day (0.35 Darcys) and at ORW-38 the hydraulic conductivity was measured at 100 ft/d (35 Darcys). The wells are 800 feet apart and have similar sand lithology (CPT sand classification number 9) at the top of MRAA based on logs from CPT-10 and CPT-73 and the PDK log for ORW-21.
3. The best example of a well watering in (that is, formation water inflow suppressing gas flow) has been OGRW-01, in operation since November 2012 and produced over 5 million

cubic feet (mmcf) of gas (Figure 2). Over the last 15 months, the flow rate in OGRW-01 dropped to zero because of watering in of the well. As soon as water was removed from the well, the well would return to a high gas flow rate until it watered in again. Continuous dewatering since August 2013 has maintained a flow rate of approximately 5 mcf per day. Gas thickness was initially 8 feet and was still 8 feet thick after 2 months of flaring. No gas thickness data have been obtained at OGRW-01 since December 2012. Recent data from MiHPT-3A and PMW-16 well indicate that there is still a substantial gas cap in the vicinity of OGRW-01 even though 5 mmcf have been flared to date.

4. As stated in example 2 above, many of the ORWs produced very small quantities of gas even though the several feet of gas were measured at these locations. Part of the reason for this may have been initial installation methods (modified in mid-2013 so cuttings are no longer pushed into the formation) but some of the wells may be in areas of sufficiently low permeability that the radius of influence (ROI) of gas removal is less than 100 feet (Table 2). This means that it is important to evaluate the ROI of each individual vent well either with analytical or numerical modeling methods. The volumetric calculation in Table 2 is the simplest calculation method for ROI. This method is simple but may not generate the most accurate results. Therefore, it is necessary to confirm that gas pressure between ORWs has been sufficiently reduced to allow lifting of the evacuation order using CPT, MiHPT, and/or pressure monitoring well methods. For example, the ROI of OGRW-01 is calculated at approximately 450 feet. Based on the simple volumetric calculation, the gas in an area approximately 900 feet in diameter should have been removed by now. The continued flaring of ORW-14 (distance = 470 feet from OGRW-01), the elevated gas pressures at PMW-16S (distance = 300 feet from OGRW-01), and the gas "kick" at MRAA-06 (distance =300 feet from OGRW-01) indicate this is not the case. One possible explanation for this apparent lack of gas cap depletion is that gas is recharging into this area from deeper gas horizons through the disturbed rock zone caused by the cavern collapse.

Increases in Gas Pressure Over Time

There have been instances where gas pressure in ORWs and potentially other gas indicators (e.g., CPT or MiHPT investigations) have indicated reduced gas in some areas (e.g., Dugas-LeBlanc property discussed above) for persistent periods of time. Gas pressure has then increased to higher values over time. When the ORW gas pressure and flow-rate drops, one may erroneously cease gas extraction operations. Examples of pressure increasing with time are provided on the Table 1 and Figure 3. The pressure increases in some of the Dugas-Leblanc ORWs appear to correspond temporally to the increase in gas pressure in TBC-03 (Figure 4). This illustrates that gas recharge from deeper horizons and/or lateral migration of gas may still be occurring in the MRAA.

Accuracy and Reproducibility of CPT Formation Pressures

As part of the TBC alternative benchmark and in-lieu of pressure monitoring wells, TBC has proposed using repeat CPT data to confirm that the gas pressure in a given area has been reduced to an acceptable value. In the MRAA, the gas cap pressure appears to be approximately 5 pound per square inch (psi) greater than hydrostatic pressure at the top of the gas cap. This implies that the pressure data from repeat CPTs must be sufficiently accurate and reproducible to detect pressure changes over time of 1 or 2 psi or less. The calibration data provided to LDNR shows that the factory pore-pressure transducer calibration is linear in terms of millivolt response down to low pressures with a stated factory accuracy for the transducer of ±0.5% or 5 psi for the 1,000 psi cone being used at the site (Tetra Tech, 2013). Accordingly, the stated accuracy of the pore pressure transducer is about the same as the pressure difference that is to be monitored using repeat CPTs.

To date, no data have been submitted to LDNR on the field accuracy of the CPT pore-pressure transducer or the reproducibility of the CPT pore-pressure data. Data has been submitted to LDNR on a few repeat CPTs that allow for preliminary comparisons of the pore-pressure data log (Figure 5) and the stable pressure results from the dissipation tests. As shown on Figure 5, the pore-pressure data collected during the CPT push may not be repeatable within the above stated criteria for monitoring depletion of the gas cap. On the CPT dissipation tests where stable pressure data are available to LDNR for comparison (Table 3), some of the stable pressures agree within less than 1 psi, some agree within less than 2 psi, and some differ by more than 2 psi. The large stable pressure differences in the CPT-85 repeat data (Table 3) of over 5 psi are considered to be anomalous at this point in time but illustrates that absent other data, it may be possible to misinterpret equipment/procedure-related pressure differences as reduction in gas cap pressures.

References

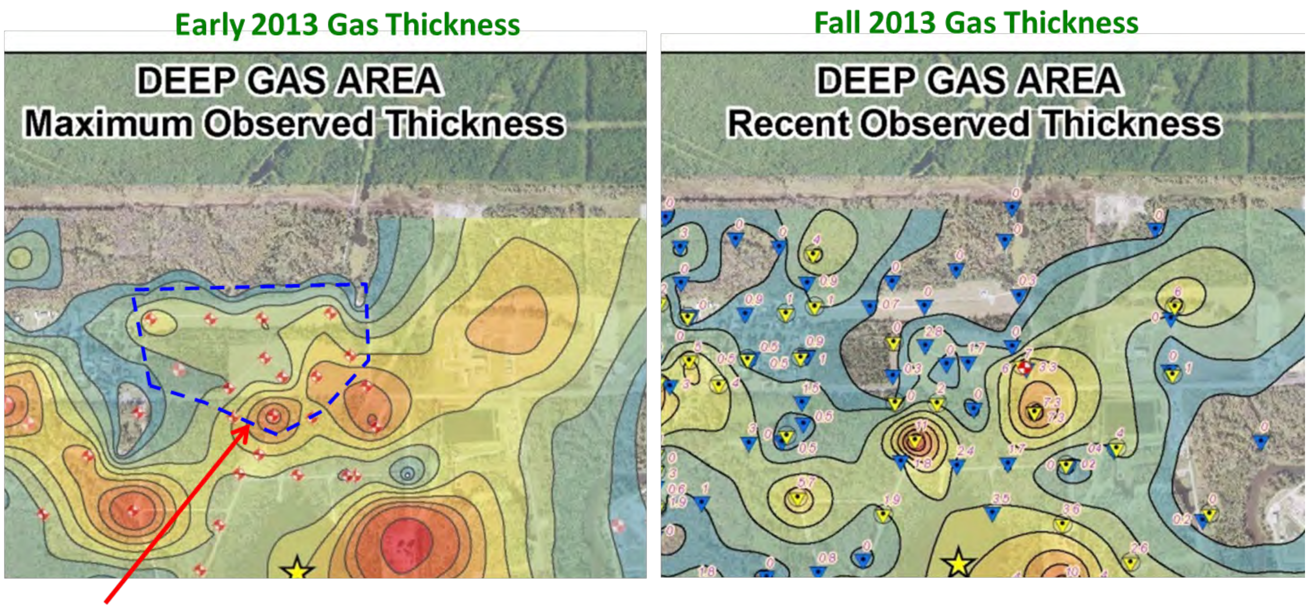
Earlougher Jr., R. C., 1977, Advances in Well Test Analysis, Society of Pertoleum Engineers, SPE Monograph Series, v. 5, 264 p.:

Horne, R. N., 1995, Modern Well Test Analysis, 2nd Ed., Palo Alto, CA, Petroway, Inc., 257 p.:

Tetra Tech, 2013, Response To LDNR's Eight Amendment Order Comprehensive Plan – CPT Program.

Table 1. Fall 2013 and January 2014 wellhead pressures in Dugas-Leblanc ORW wells. Data from TBC daily vent well reports.

Well	Jan. 24, 2014 Wellhead Pressure (psig)	Oct. 2013 Wellhead Pressure (psig)	Current Well Status	Flare Volume (mcf)
ORW-01	6	18	Shut in	1,100
ORW-02	0	0	Shut-in	1,700
ORW-15	36	46	Flaring @ 0.2 MCFD	1,500
ORW-22	31	5	Shut-in	1,100
ORW-23	0	0	Shut-in	110
ORW-24	25	15	Shut-in	300
ORW-26	45	5	Shut-in	170
ORW-28	30	0	Shut-in	30
ORW-29	10	0	Shut-in	60
ORW-30	12	12	Shut-in	40
ORW-31	30	15	Shut-in	13
ORW-32	0	8	Shut-in	90



Gas removed?

5.4 million cubic feet of gas were removed from this area over the past 12 months. ORW spacing in this area is approximately 300 to 400 feet (based on area & linear distance between wells).

Figure 1. Gas thickness reduction on Dugas-LeBlanc property.

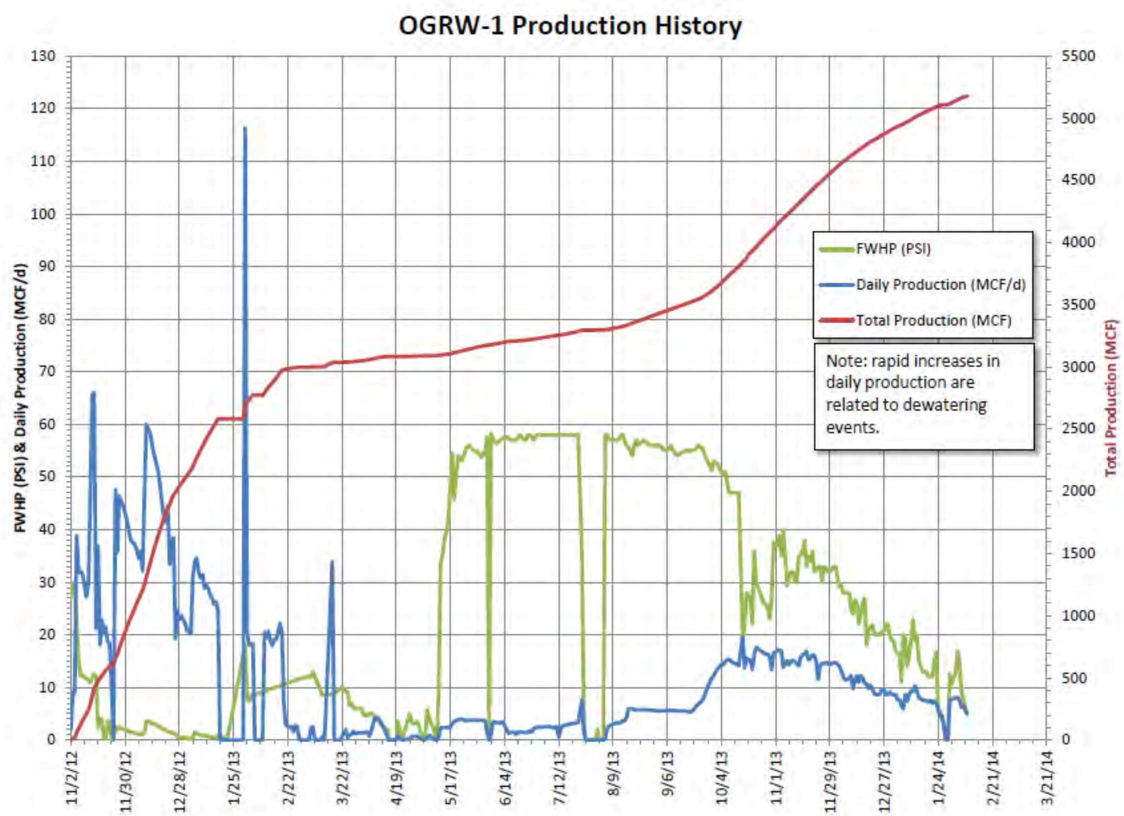


Figure 2. OGRW-01 flow pressure graph showing periods of high flow following well dewatering. Since August 2013, OGRW-01 has been continuously dewatered with a permanent pump.

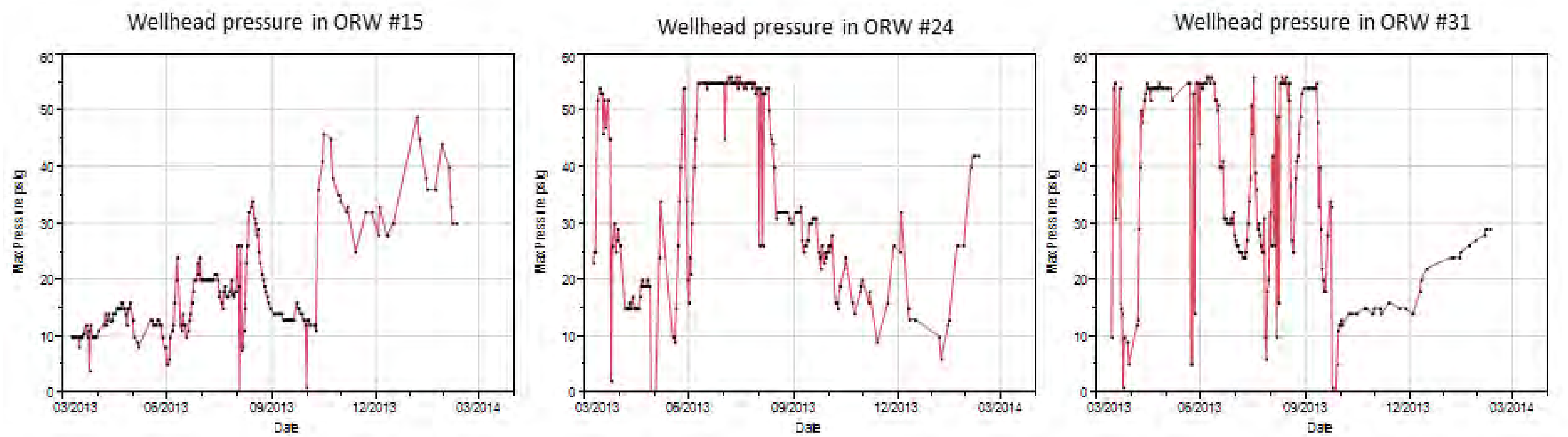


Figure 3. Wellhead pressures from selected wells on Dugas-LeBlanc property. Data from LDNR daily checklists.

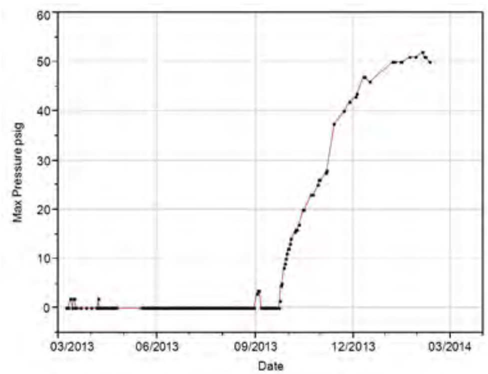


Figure 4. Time-series wellhead pressure data from pressure monitoring well TBC-03.

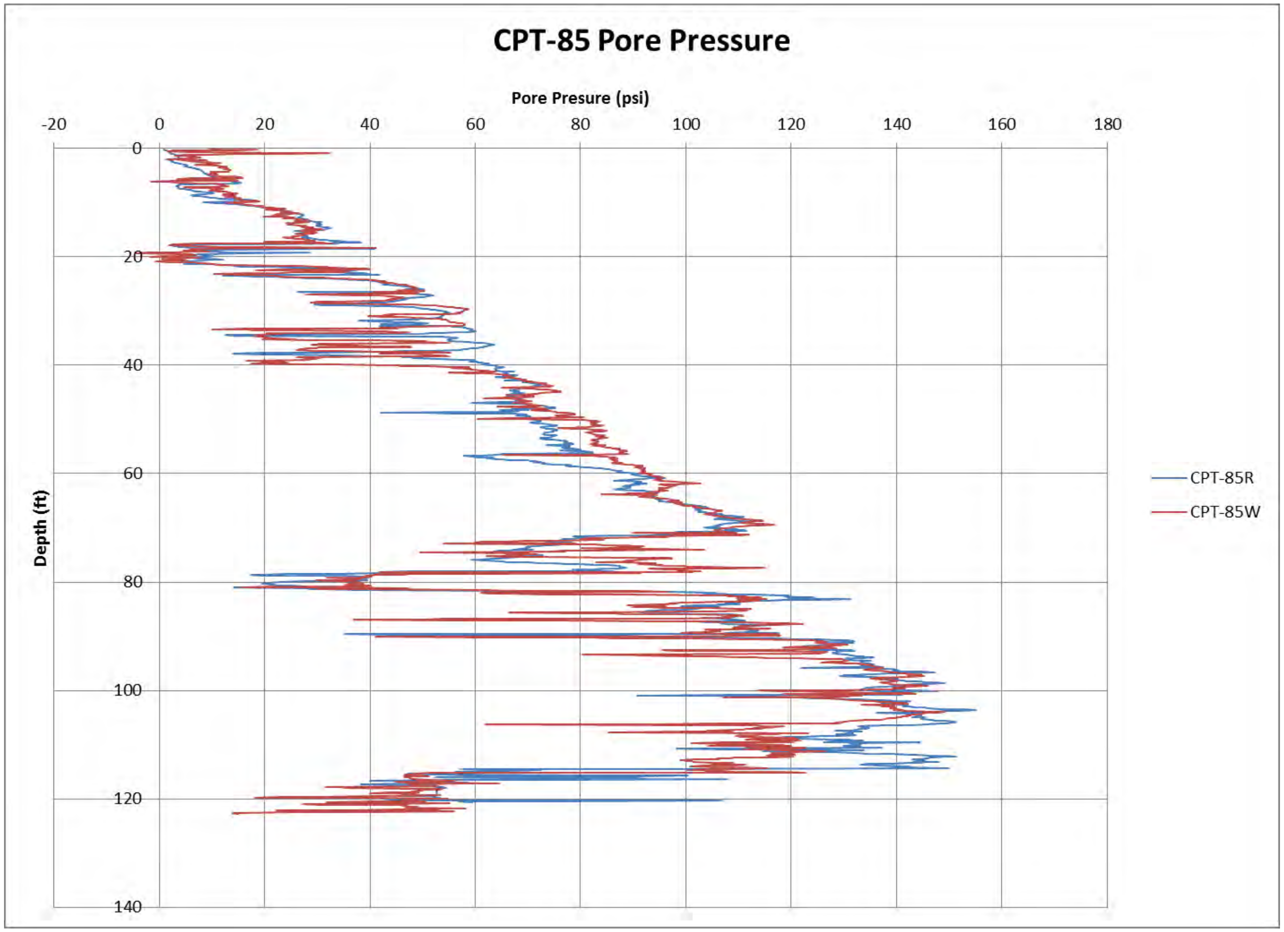


Figure 5. Repeat CPT pore pressure data curves.

Table 2. ORW vent well radius of influence calculations.

Well	Well Type	Original Gas Thickness (ft)	Volume Flared (mcf) as of 02/15/14	Volume Flared (scf) as of 02/15/14	Radius of Gas Removed (ROI, ft)	Diameter Gas Removed (ft)
ORW-01	Driven	6	1,099	1,100,000	240	480
ORW-02	Driven	2	1,682	1,700,000	520	1040
ORW-04	Driven	4	1,003	1,000,000	280	560
ORW-05	Sonic	5	1,026	1,000,000	250	500
ORW-06	Sonic	6	1,097	1,100,000	240	480
ORW-07	Sonic	2	58	58,000	96	192
ORW-08	Sonic	2	151	150,000	150	300
ORW-09	Sonic	10	1,036	1,000,000	180	360
ORW-10	Sonic	2	568	570,000	300	600
ORW-11	Sonic	3	112	110,000	110	220
ORW-12	Sonic	6	78	78,000	64	128
ORW-13	Sonic	1	3	2,800	30	60
ORW-14	Sonic	6	1,538	1,500,000	280	560
ORW-15	Sonic	2	1,526	1,500,000	490	980
ORW-16	Sonic	1	199	200,000	250	500
ORW-17	Sonic	2	62	62,000	99	198
ORW-18	Sonic	1	55	55,000	130	260
ORW-19	Sonic	2	199	200,000	180	360
ORW-22	Sonic	4	1,061	1,100,000	290	580
ORW-23	Sonic	3	110	110,000	110	220
ORW-24	Sonic	3	297	300,000	180	360
ORW-26	Sonic	8	173	170,000	82	164
ORW-28	Sonic	4	28	28,000	47	94
ORW-29	Sonic	4	59	59,000	68	136
ORW-30	Sonic	4	42	42,000	58	116
ORW-31	Sonic	4	13	13,000	32	64
ORW-32	Sonic	2	90	90,000	120	240
ORW-36	Sonic	7	2,166	2,200,000	310	620
ORW-37	Sonic	3	249	250,000	160	320
ORW-38	Screen	4	1	1,200	10	19
ORW-39	Screen	3	103	100,000	100	200
ORW-40	Screen	3	50	50,000	72	144
ORW-41	Screen	3	0.2	160	4	8
ORW-42	Screen	4	230	230,000	130	260
ORW-43	Screen	4	13	13,000	32	64
ORW-46	Screen	7.3	480	480,000	140	280
ORW-48	Screen	8	743	740,000	170	340
ORW-49	Screen	5	350	350,000	150	300
ORW-50	Screen	7	776	780,000	190	380
ORW-52	Screen	5	187	190,000	110	220
ORW-53	Screen	3	75	75,000	89	178
ORW-54	Screen	3	926	930,000	310	620
ORW-55	Screen	6	34	34,000	42	84
ORW-56	Screen	1	14	14,000	66	132
ORW-57	Screen		11	11,000		
ORW-58	Screen		1	580		
OGRW-1	Driven	8	5,207	5,200,000	450	900

Constant Calculation		Units
Porosity, n	0.3	Fraction
Residual Water, S_{wr}	0.15	Fraction
Recovery Factor, R_f	0.9	Fraction
Atm. Pressure, P_a	14.7	psia
Formation pressure, P_f	64.7	psia
Constant, C_1	0.56	Unitless

C_1=SQRT(1/(π*n*(1-S_{wr})*R_f*P_f/P_a))

ROI = C_1*SQRT(Vol_{flared}/$Thickness_{gas}$)

Table 3. Repeat CPT dissipation test stable pressures.

Zone of interest	Dissipation Test Final Pressure Data			
	CPT-85W		CPT-85R	
Depth Interval (feet)	Depth (feet)	Final Pressure (PSI)	Depth (feet)	Final Pressure (PSI)
17-22	17.82	6.80	17.87	7.27
17-22	18.70	7.28	18.90	7.69
17-22	20.93	7.96	20.88	8.52
33-40	34.29	14.08		
33-40	39.04	16.40	37.85	16.45
78-82	79.07	37.07	78.94	39.39
78-82	79.79	37.30	79.97	38.44
78-82	80.71	37.75	81.05	38.86
115-123.5	115.22	48.58	115.48	51.02
115-123.5	115.81	46.42		
115-123.5	116.47	47.41	116.68	52.74
115-123.5	117.62	47.28		
115-123.5	118.77	47.44	118.27	52.74
115-123.5	119.82	47.82	119.47	51.49
115-123.5	121.06	48.23	120.39	65.26
115-123.5	122.21	48.91	120.62	52.03
115-123.5	123.10	49.34		

Zone of interest	Dissipation Test Final Pressure Data			
	CPT-104W		CPT-104WR	
Depth Interval (feet)	Depth (feet)	Final Pressure (PSI)	Depth (feet)	Final Pressure (PSI)
8-13	8.30	5.95		
8-13	9.35	6.41		
8-13	12.14	7.53		
24-25	24.54	13.12		
27-32	28.15	14.52	28.54	13.46
27-32			29.30	13.83
27-32			30.68	14.33
71-74	72.34	36.45	79.95	38.24
80-83	80.22	39.65	80.94	38.89
80-83	82.09	40.44	82.19	39.14
95-97	95.70	46.93	95.64	45.45
95-97	96.36	47.17		
95-97	96.52	47.10		
95-97	96.79	47.06	96.85	45.90
107-110			107.94	51.02
107-110			108.50	49.56
122-126.5			123.26	54.63
122-126.5			124.51	55.65
122-126.5			125.89	55.60

Zone of Interest	Dissipation Test Final Pressure Data			
	CPT-122W		CPT-122WR	
Depth Interval (feet)	Depth (feet)	Final Pressure (PSI)	Depth (feet)	Final Pressure (PSI)
27-32	27.82	13.56		
27-32	27.81	13.16		
27-32	30.02	13.69		
27-32	31.59	14.31		
72-77.5	72.90	34.87		
72-77.5	74.38	35.45		
72-77.5	75.85	36.01		
82-84	83.17	39.74		
90-94	90.39	43.50	89.80	45.87
90-94	91.37	43.78	90.78	45.80
90-94	92.52	43.98	91.77	44.86
90-94	93.67	44.74	92.75	45.46
103-113	103.58	48.23	103.68	46.11
103-113	104.17	45.95		
103-113	104.99	47.67	104.99	45.47
103-113	105.64	47.71	105.97	47.71
103-113	106.53	45.66	106.96	47.29
103-113	107.45	47.73	107.94	47.34
103-113	108.43	47.01	108.99	47.66
103-113	109.42	46.92	109.97	47.47
103-113	110.47	47.29	110.96	47.47
103-113	111.45	47.81	111.94	47.49
103-113	112.60	48.06		

Appendix 1
Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations

MEMORANDUM

TO: Travis Williams, LDNR

FROM: Charles Faust and Ted Borer

SUBJECT: Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations

DATE: October 8, 2013

During the Gas Venting Technical Workgroup call held 1 NOV 13, TBC agreed to prepare a structured set of criteria for stages of observation relief well (ORW) operations and an alternative (or more detailed definition) to the BRC hydrostatic pressure objective for gas pressures in the MRAA. A plan for the various stages of ORW operation and monitoring is now needed and appropriate, because most of the ORWs are producing little or no gas. For the longer term, measurable and achievable criteria for ending active operations for groups of wells and, considering lifting the evacuation order should be developed. This need is in response to concerns with the practicality of applying the BRC objective given short and long term transient changes in gas and groundwater pressures that have been recorded in ORW and monitor wells. Attached to this memo, are three tables that summarize the approach that provide guidelines for operating ORWs and, ultimately, ending venting operations.

Table 1 provides a structure and criteria for various phases of ORW operations. After a well is installed, it typically can be vented (and flared) due to gas pressure in the well. Gas vent rates have declined to low values (<0.5 mcf/d) in many wells, after a periods of a few weeks to several months. For these wells, monitoring to assure no significant gas accumulations or dewatering to increase vent rates may be appropriate. After a well has moved into a monitoring phase, tests should be conducted on a scheduled basis to verify that gas has been depleted and not recharged in the vicinity of the well. Maintenance of the well would then be continued until the well can be plugged and abandoned. The phase descriptions and criteria for moving from one operational/monitoring phase to the next are provided in Table 1 and are based on our review of ORW performance and the dewatering tests done to date. The currently installed ORWs are evaluated on the basis of the criteria listed in Table 1, and are assigned to appropriate phases, which are presented in Table 2.

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The difficulty in reliably measuring the pressure difference and the theoretical impossibility of achieving gas pressures equal or less than groundwater hydrostatic pressures in a two-phase water wet system have been discussed in recent Gas Venting Technical Workgroup calls. TBC proposes alternative criteria that include evaluation of gas production data, repeat CPT soundings at ORW locations (and in the community, CPT soundings between depleted ORWs), and a statistically significant pressure difference between gas and hydrostatic or groundwater pressures. These criteria and measures reflect depletion and isolation of gas in the MRAA, which is implicit in the BRC objective. The application of these criteria for the assessment of when gas in a given area has been removed to the extent practicable is addressed in Table 3. A more detailed assessment is needed for areas in the community than in areas outside of the community. Also, included are proposed criteria to be considered when lifting of the evacuation order is appropriate.

The foregoing concepts and the attached tables are intended to provide background and TBC recommendations for LDNR review regarding operations, monitoring and end point objectives that may be presented to the BRC. As discussed during today's Gas Venting Technical Workgroup call, the presentation to BRC could be developed in a workshop that should be held as soon as possible.

Table 1. Phases and Criteria for Operation of MRAA Relief Wells.

Phase	Description	Criteria for Changing to Next Phase
1) Well Installation	Using available information and a well spacing of about 500' locate and install wells with perforations or screens open to the top of the gas zone at the upper portion of the MRAA. PDK logs initially used to identify gas intervals are now replaced by CPT soundings to locate MRAA gas zone intervals prior to well installation.	• Well is completed to specifications and developed; • Well head installed to specifications; and, • Piping and connections to flare completed.
2) Venting from gas pressurized conditions in well	Typically, a newly constructed relief well that is properly developed will build up gas pressures to values slightly less than, to a few PSI greater than, the hydrostatic pressure (computed from groundwater surface) at the screen (or perforation) depth. To avoid water encroachment into the well, the well is vented at flow rates such that gas pressure in the well is maintained at levels slightly below the initial buildup shut-in pressure. The well is operated such that the optimum balance between gas pressure and flow rate is achieved. Each well is different and a skilled operator uses his or her judgment and prior venting history to adjust the vent chokes and orifice plates through which gas must flow. As the gas flow rates and gas pressure decline, the operator may shut in the well to allow gas pressures to increase and gas flow rates to increase when the well is reopened.	If total gas flowed in a recent 10 day period is less than 5 mcf (or 0.5 mcf/day), **and** • Well has been online less than 6 months or • Total flared gas volume is greater than 50 mcf then Phase 3 dewatering; otherwise Phase 4 monitoring
3) Venting with dewatering	Gas flow rates can be increased by dewatering of wells undergoing two phase flow. Even with relatively low pumping rates, the water pressure next to the well can be reduced as much as 10 psi; because the well is open only to a very thin interval at the top of the MRAA where the permeability of the aquifer is lowest. Suitable pumps need to be installed to remove groundwater. Piping or some other means of transport must be constructed and/or available to move produced water from the well to the sink hole containment berm for discharge. Flow rates for water produced are anticipated to be from 0.5 to 5 gpm, based on the successful testing done at OGRW-1 and the ORW dewatering program.	• A total gas flow in a recent 10 day period is less than 5 mcf; and • Adjustments made to pumping rates and venting equipment do not increase gas flow above 0.5 mcf/d, then Phase 4 monitoring

Table 1. Phases and Criteria for Operation of MRAA Relief Wells (continued).

Phase	Description	Criteria for Changing to Next Phase
4) Monitoring	Gas pressures and vent tests will be performed to determine if gas in the vicinity is producible due to localized gas accumulation near the well or migration from a continuing gas source. Gas pressure measured by transducers at the well head, will record at hourly intervals and will be downloaded monthly. Analog or digital gas pressure gauge will be installed for visual inspection. Vent test at 6 weeks and quarterly thereafter will be conducted. Tests will be run for 2 days with venting relying on the gas pressure in the well to yield gas. If no gas pressure had developed in well, one well volume of water will be removed to evidence gas flow.	• 3 consecutive tests with gas flow rates less than 0.5 mcf/d – Phase 5 maintenance • Vent test with initial gas flow >1 mcf will be extended for 10 days and if total >10 mcf return to prior Phase 2 or 3 • If extended test total flow is less than 10 mcf, continue monitoring
5) Maintenance	The wells will be maintained and secured. Gas pressure gauges for visual inspection will not be removed. Other well head equipment may be removed.	• Overall venting program completed – Phase 6 plug and abandon • Well needs to be plugged and abandoned for some other reason
6) Plug and Abandon	The well will be plugged and abandoned in compliance with state requirements.	

Table 2. Assignment of Currently Installed Relief Well to Operational Phases.

Well ID	Well Type	Installation Date	Phase Number	Comments
OGRW-1	A		3	
ORW-1	A	10/6/12	3	
ORW-2	A	10/7/12	3	
ORW-3	A	10/8/12	4	
ORW-4	A	10/25/12	3	
ORW-5	B	2/25/13	6	
ORW-6	B	2/22/13	3	
ORW-7	B	2/14/13	6	
ORW-8	B	2/12/13	6	
ORW-9	B	2/20/13	3	
ORW-10	B	3/10/13	3	
ORW-11	B	2/6/13	3	
ORW-12	B	1/10/13	6	
ORW-13	B	1/22/13	4	
ORW-14	B	1/23/13	2	
ORW-15	B	1/29/13	2	
ORW-16	B	2/12/13	3	
ORW-17	B	2/13/13	3	
ORW-18	B	2/24/13	4	
ORW-19	B	3/14/13	3	
ORW-21	B	5/24/13	4	
ORW-22	B	2/5/13	3	
ORW-23	B	2/10/13	3	
ORW-24	B	2/10/13	2	
ORW-26	B	1/31/13	3	
ORW-27	B	2/27/13	4	
ORW-28	B	3/6/13	4	
ORW-29	B	3/7/13	3	
ORW-30	B	3/12/13	4	
ORW-31	B	3/11/13	4	
ORW-32	B	3/9/13	3	
ORW-33	B	4/30/13	4	
ORW-36	B	4/29/13	2	
ORW-37	B	4/29/13	3	
ORW-38	**C**	6/21/13	4	
ORW-39	**C**	6/30/13	3	
ORW-40	**C**	6/28/13	4	
ORW-41	**C**	8/6/13	4	
ORW-42	**D**	8/21/13	3	
ORW-43	**C**	8/25/13	4	
ORW-46	**D**	8/29/13	2	
ORW-48	**C**	8/29/13	2	
ORW-52	**C**	10/27/13	2	
ORW-53	**C**	10/25/13	2	
PMW-12S	**C**	8/15/13	2	

Type A: Pile driven casing, perforated across PDK log gas zone(s)
Type B: Sonic drilled permanent casing, perforated across PDK log gas zone(s)
Type D: Sonic drilled permanent casing (excavation of MRAA soil), perforated across PDK log gas zone(s)
Type C: Sonic drilled temporary casing (excavation of MRAA soil), 4" well with screen across CPT determine gas zone(s)

Table 3. Criteria for Ending Venting Operations in the Community and Other Areas and Lifting the Evacuation Order.

Area Impacted	Criteria
Community	• Venting operations will be considered complete when all vent wells in area of concern have entered monitoring phase. The area of concern are North and South of Highway 70; • CPT soundings adjacent to and in between relief wells show no evidence of producible gas; and • Gas pressures in shut-in relief wells and pressure monitoring well are within a statistically verifiable difference (>) of less than 1 psi relative to hydrostatic groundwater pressure
Areas Outside of Community	• Venting operations will be considered complete when all vent wells within a definable area have moved into monitoring phase
Evacuation Order in Community	• Consideration for lifting the evacuation order can be given when venting operations in both areas of the community are completed, or; • Gas pressure in shut-in relief wells and pressure monitoring wells are within a statistically verifiable difference (>) of less than 1 psi relative to hydrostatic or groundwater pressure; • Other criteria based on residential and sub slab methane monitoring; and • Other

Appendix 2
Blue Ribbon Commission Comments to Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations

December 23, 2013

BLUE RIBBON COMMISSION COMMENTS

MEMORANDUM
PLAN FOR OPERATING RELIEF WELLS AND CONCEPTUAL CRITERIA FOR ENDING OPERATIONS
TEXAS BRINE COMPANY, L.L.C.

Provided By:
Tetra Tech, Inc.
Submitted: November 8, 2013

On November 8, 2013, Charlie Faust and Ted Borer of Tetra Tech submitted *Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations* to the Louisiana Department of Natural Resources (DNR). This memo suggests that it includes a "structured set of criteria for stages of observation relief well (ORW) operations and an alternative (or more detailed definition) to the BRC hydrostatic pressure objective for gas pressures in the Mississippi River Alluvial Aquifer (MRAA)."

This memo was forwarded to the Blue Ribbon Commission (BRC) Gas Subgroup on November 11, 2013 for their review and consideration and was originally discussed during their November 14, 2013 BRC Gas Subgroup Meeting. In addition, this topic was discussed during the December 5, 2013 and December 12, 2013 BRC Gas Subgroup Meetings, as well as the December 10, 2013 BRC Stability Subgroup Meeting and the December 16, 2013 Full Commission Meeting.

It is the consensus of the Blue Ribbon Commission on Bayou Corne and Grand Bayou Public Safety that the focus of this plan should be on how to demonstrate that gas pressures have been suitably reduced to satisfy the BRC recommendation related to the gas presence benchmark, as specified in the *Blue Ribbon Commission on Bayou Corne and Grand Bayou Public Safety Three-Day Working Session (Monday, April 29, 2013 – Wednesday, May 1, 2013) Key Outcomes Memorandum* dated June 3, 2013. The BRC recommended, among other things, that "in order to lift the evacuation order, gas pressure in the MRAA and overlying aquitard has to be maintained at or below hydrostatic pressure."

In the *Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations*, it is proposed that well operational measures be used to determine depletion of gas to suitable levels. The BRC rejects this approach because it is an indirect measure that has not been shown to correlate to direct measures and it tends to reward the improper installation and operation of vent wells. The BRC views vent well operations as a mitigation effort, a means to achieve an established objective, not a compliance measure.

In addition, any direct measure proposed for the determination of the presence and pressure of gas should be shown to be reliable by comparison with other methods in a statistically significant comparison. The suggestion that gas pressure be measured by cone pentrometer test (CPT) only near vent wells is inadequate. The benchmark is for gas reduction across the entire gas area, not just at vent wells.

Based upon current information, the BRC feels there is little evidence that the current mitigation efforts will be successful in achieving the stated BRC safety benchmark for gas pressure in the MRAA. As such, the BRC recommends that TBC develop a gas mitigation and management plan to address all potential sources of gas (deep and shallow), not just in the community, but in the entire affected area and measure gas presence and pressure in the MRAA at a suitable number of locations over a suitable amount of time to demonstrate compliance with the BRC benchmark, given a specified level of uncertainty.

While the BRC recommends that this plan be developed, the BRC will not endorse or recommend proposed mitigation steps. Those efforts, as well as consideration for potential risks and uncertainties, need to be discussed and determined through the regulatory process. However, the BRC will review and comment on any recommendations to measure gas presence and pressure in the MRAA in order to determine if such measurements could be used to verify whether or not the safety benchmark has been achieved.

Appendix 3
Criteria and Goals for Gas Venting Operations

Criteria and Goals for Gas Venting Operations
Bayou Corne, LA

Conference call

20 JAN 2014

Call Agenda

- Purpose of call
- Review concept of hydrostatic pressure and its relationship to groundwater and methane gas pressures in and above MRAA
- Review current understanding of gas distribution, thickness and pressures
- Discuss application of hydrostatic pressure goal
- Assess need for additional pressure monitor wells (PMWs)
- Present alternative to BRC goal

Purpose of Call

- Present concepts and data that are relevant to the development of achievable, measureable, and practical criteria and goals for venting operations
- Assess application of hydrostatic pressure goal, if practicable and useful and assess need for additional pressure monitoring wells
- Reference for additional review
  - CCR Section III.G
  - Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations, 8 NOV 2013

The Blue Ribbon Commission Gas Group has agreed to recommend that reducing and maintaining methane gas formation pressures in the Mississippi River Alluvial Aquifer (MRAA) to equal to hydrostatic pressure across the Bayou Corne gas area is necessary in order to lift the mandatory evacuation order

- The hydrostatic pressure benchmark (BRC) was set during early part of venting program.
- Since then, ongoing operations, CPT soundings, laboratory tests of multi phase soil properties, and data from relief wells and monitoring wells have provided a more complete characterization of subsurface conditions .
- This more complete understanding shows that the MRAA gas cap is thinner, more variable spatially, and under less pressure than believed earlier.
- The additional data and information suggest that the hydrostatic pressure goal, while appropriate for conditions believed to exist when the goal was set, is not now easily applied or useful.

Concept of Hydrostatic Pressure

- Hydrostatic pressure in groundwater is a theoretically calculated pressure at an elevation or depth different from a reference point of known (or assumed) pressure and elevation. The calculation is based on the weight of water expressed as the hydraulic gradient (0.433 psi/ foot of elevation change, for pure water at standard conditions).

Relationship of hydrostatic pressure to groundwater and gas pressures

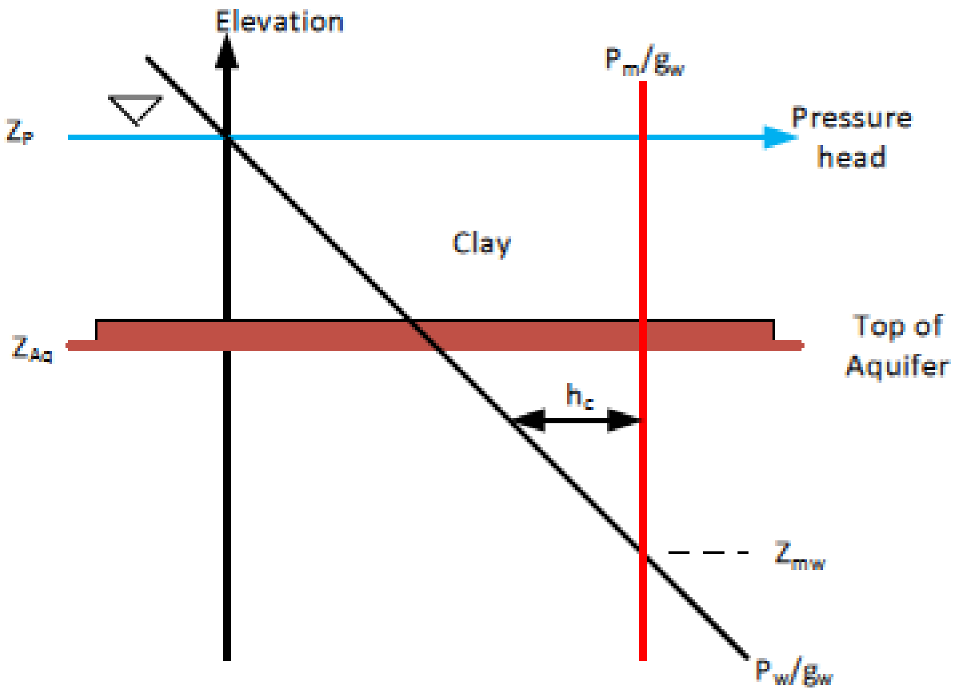


Figure 1: Pressure distribution for water (P_w) and methane (P_m) at the gas cap located adjacent to the top of aquifer

Charbeneau, R. C., 2013, Model Analysis of Methane Gas Behavior at Bayou Corne: report to Blue Ribbon Commission May 2, 2013.

CPT Soundings at Bayou Corne Confirm Theoretical Pressure Profile

- CPT records pore pressure measurements as probe is pushed though to MRAA
- To get accurate pore pressures measurements it is necessary to pause CPT push at selected depths and allow pore pressures next to cone to equilibrate.
- Equipment and analysis approach for gas cap identification was developed by Dr. John Garlanger of Tetra Tech for the Bayou Corne site.
- CPT 69 at Sportsman's Drive illustrates application

Napoleonville Salt Dome

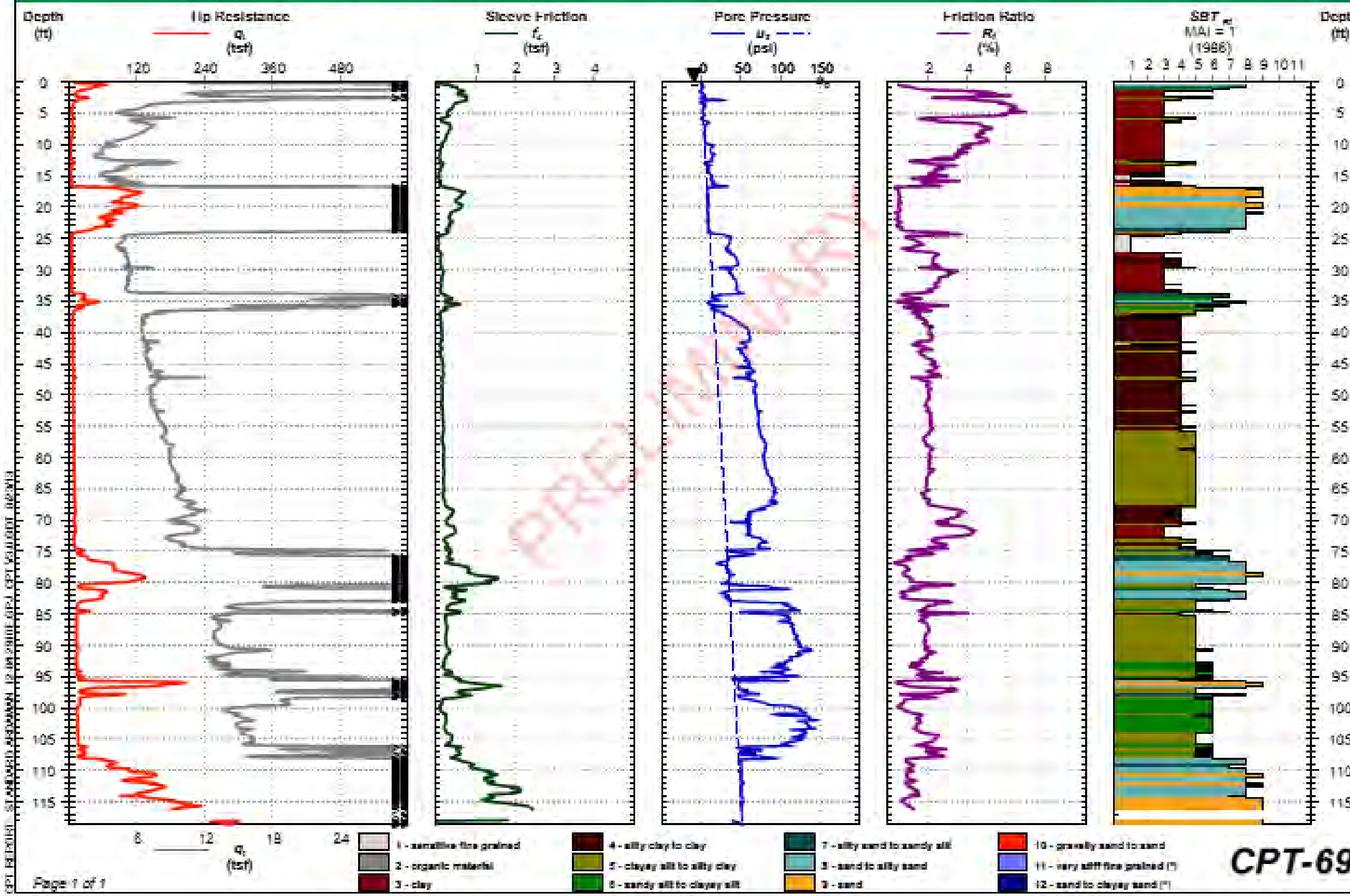
Cone Penetration Test

CPT-69

Project #: 12-84-2910E
Date: Aug. 22, 2013

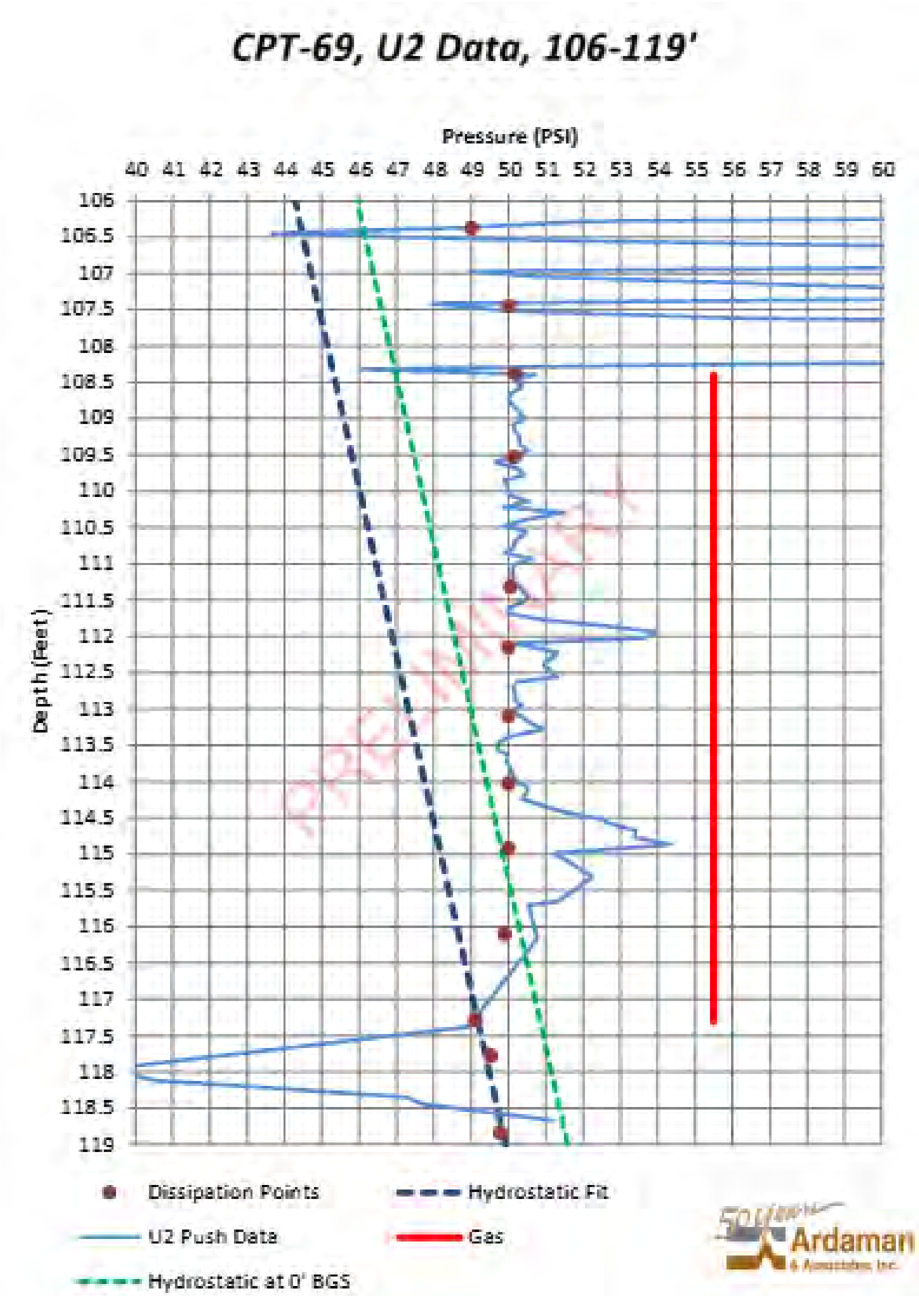
Northing:
Easting:

Elevation:
Total Depth: 118.7 ft



CPT-69

Page 1 of 1



Gas cap pressure profile with hydrostatic pressure gradient below gas cap

Capillary pressure is the difference between gas and water pressure in porous media. For water wet systems the gas pressure is greater than the water pressure.

This pressure difference needs to be considered when comparing groundwater and gas pressures

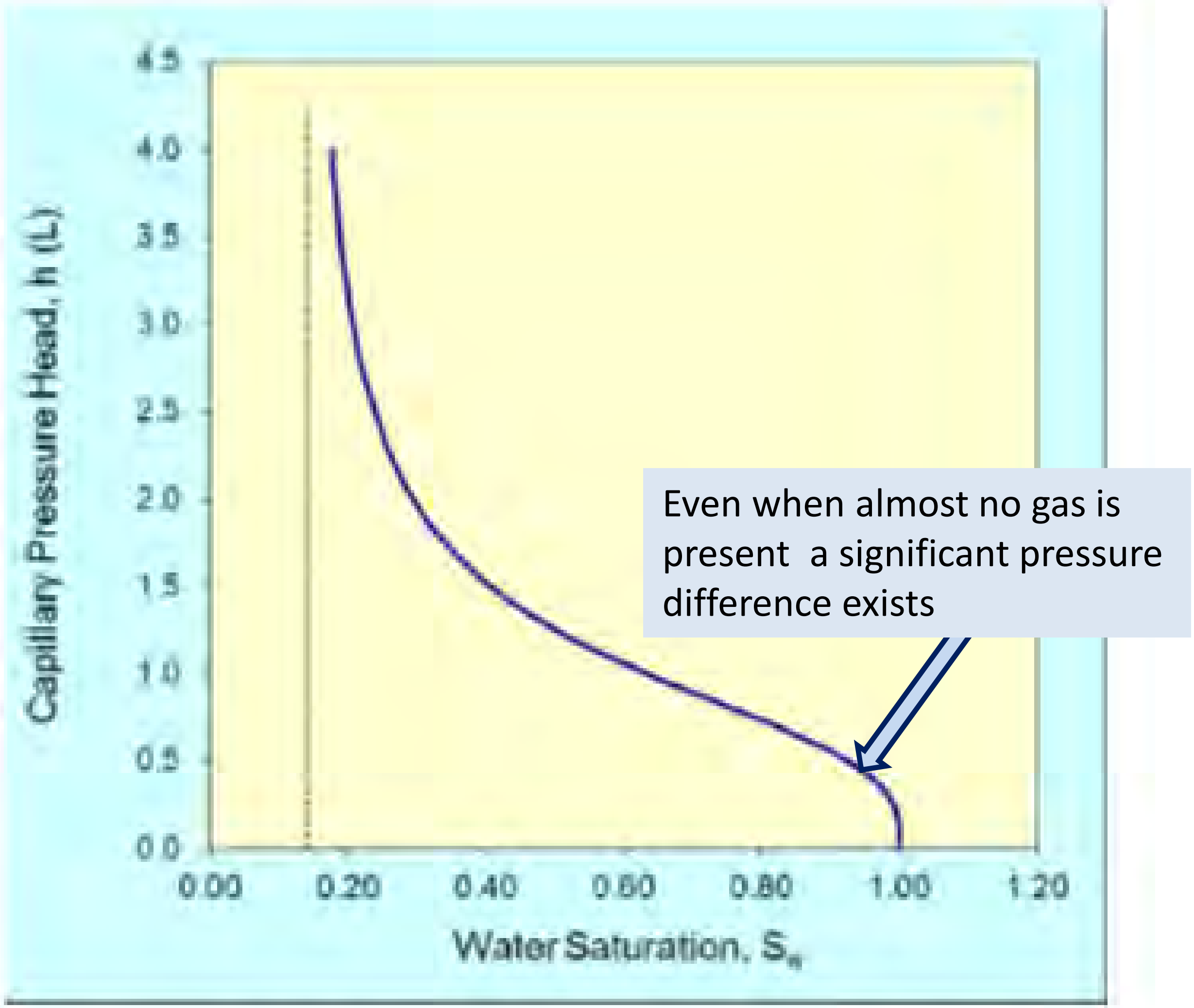


Figure 2. Representative soil characteristic curve for sand texture soil

Charbeneau, R. C., 2013, Model Analysis of Methane Gas Behavior at Bayou Corne: report to Blue Ribbon Commission May 2, 2013.

Example One: Assume that $Z_P - Z_{Aq} = 110$ ft and that $P_m = 50$ psig ($P_m/\gamma_w = 115.4$ ft gage). This corresponds to $Z_{Aq} - Z_{mw} = 5.4$ ft, that is, the gas cap has thickness 5.4 ft. With $n = 0.375$, $P_m = 9320$ psfa, and $P_{atm} = 2120$ psfa, Eq. (3) gives

$$D_M = \frac{0.375 \times (1 - 0.14) \times 9320}{2120} \times (5.4 - 1.42) = 5.64 \text{ ft}$$

Thus within a circle of radius 200 feet, the gas cap would contain $\pi * 200^2 * 5.64 =$ 710,000 standard cubic feet of methane. Not all of this would be recoverable; roughly 1/3 would be trapped at residual saturation. The methane gas saturation within the gas cap is shown in Fig. 3, where the elevation datum represents the base of the clay confining bed. The red-dashed curve corresponds to residual methane saturation, where an f-factor = 0.3 is assumed for the sand-texture soil. The volume represented by the region between the saturation and residual curves corresponds to the methane volume that can be removed by venting.

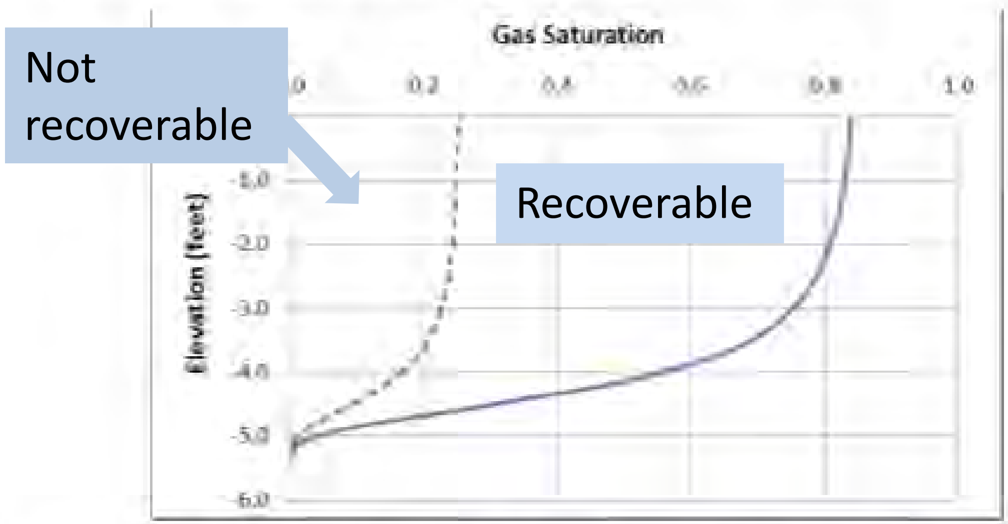
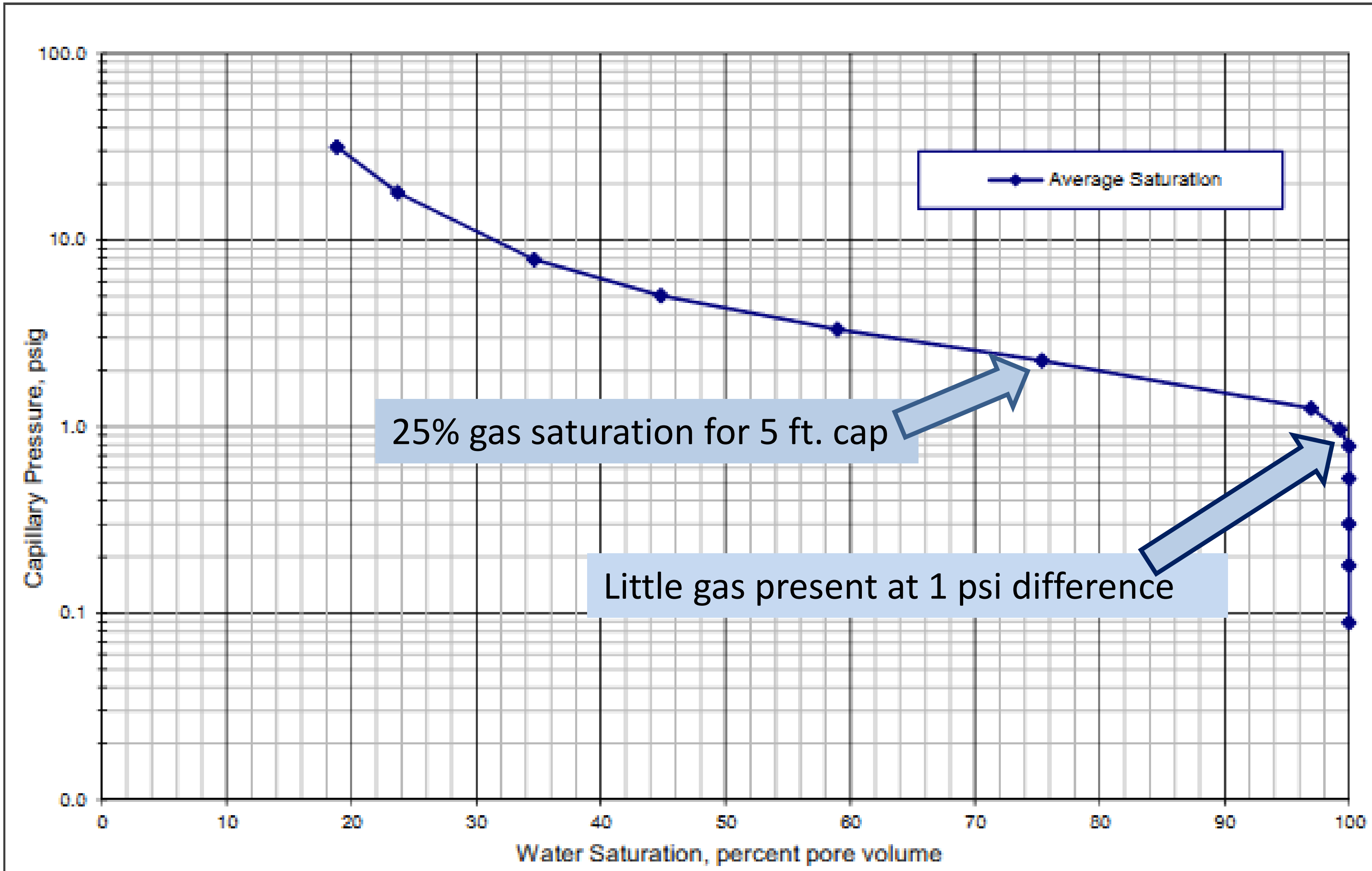


Figure 3. Calculated gas cap saturation distribution based on a gas pressure = 50 psig

Charbeneau, R. C., 2013, Model Analysis of Methane Gas Behavior at Bayou Corne: report to Blue Ribbon Commission May 2, 2013.

MRAA sample from PMW 8 shows greater capillary pressure than above example.



PTS Laboratories

Sample PMW-1-130-135-B , Depth 133.5 ft, horizontal hydraulic conductivity 1.52E-03 cm/s

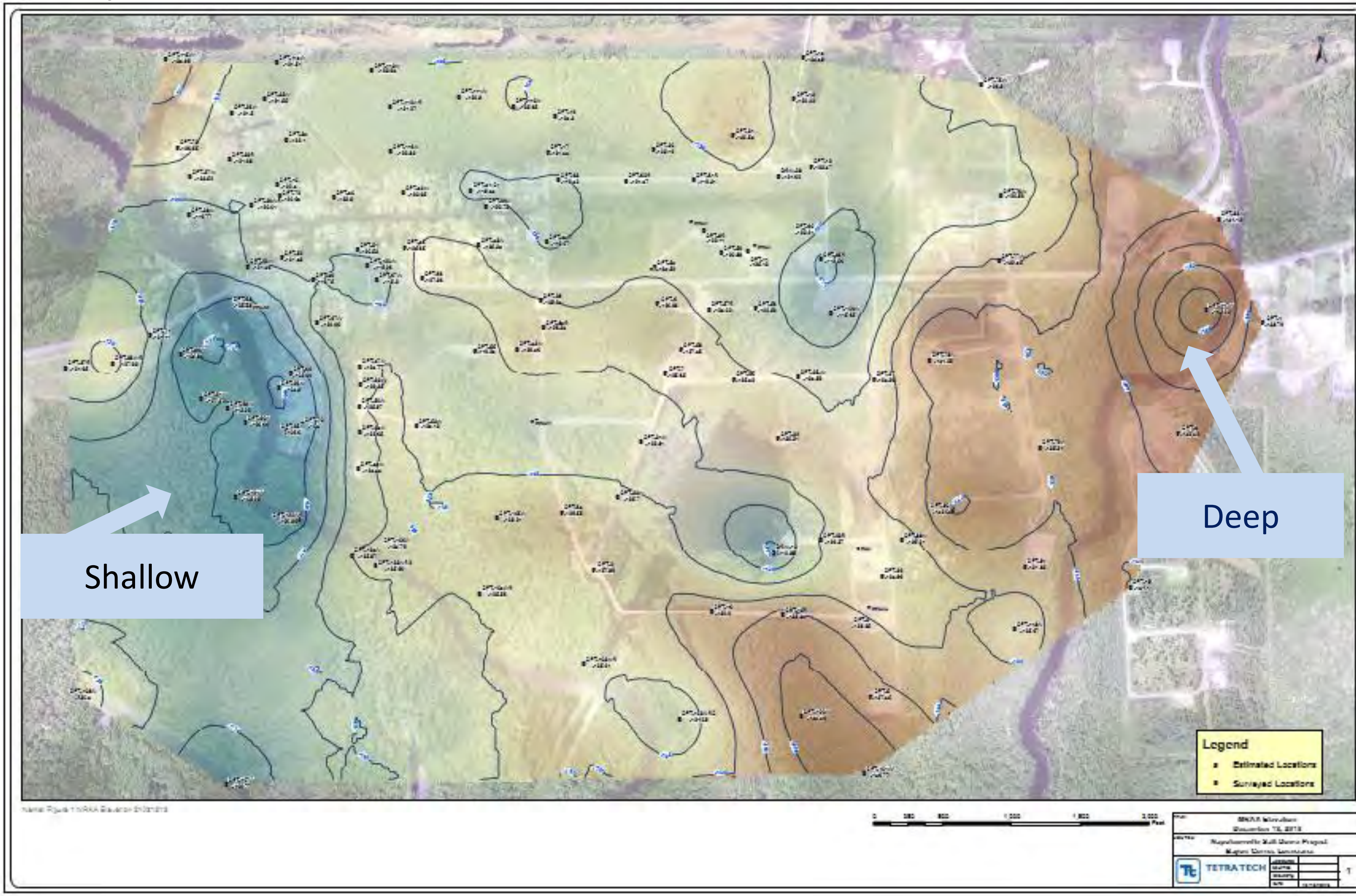
Significance of Capillarity to Assessment of Gas Recoverability

- Theoretically, any remaining non recoverable or trapped gas after venting is completed will have gas pressures greater than groundwater pressures.
- PTS lab analysis of MRAA sample indicates the non recoverable gas would have an excess pressure greater than 1 psi at the sample location.
- Criteria or goals tied to gas pressures must account for capillarity.

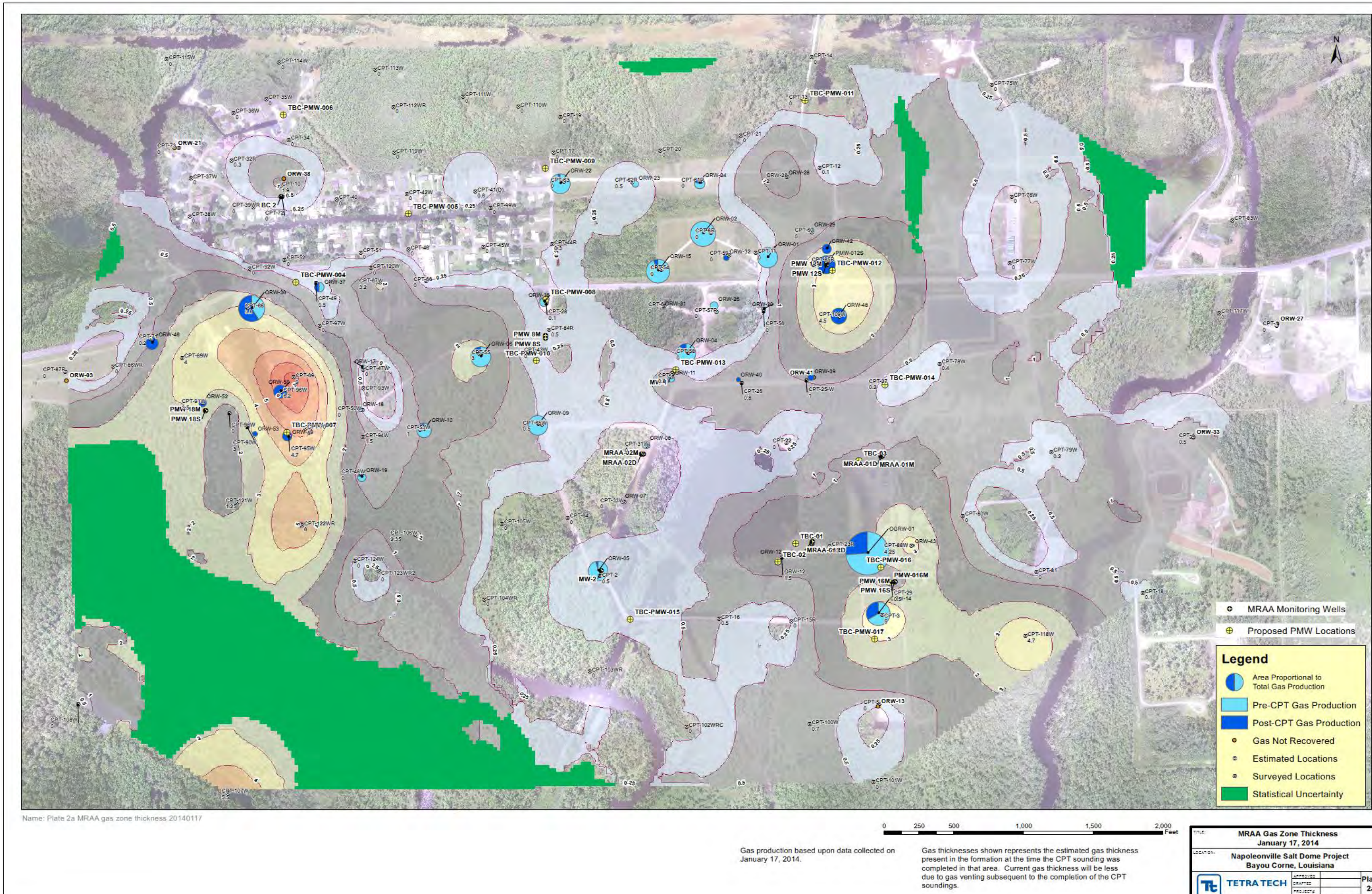
Current Conditions and Understanding

- Top of MRAA/gas cap
- Extent and thickness of gas
- Volumes of recoverable gas
- Gas production
- Gas pressures
- Aquitard

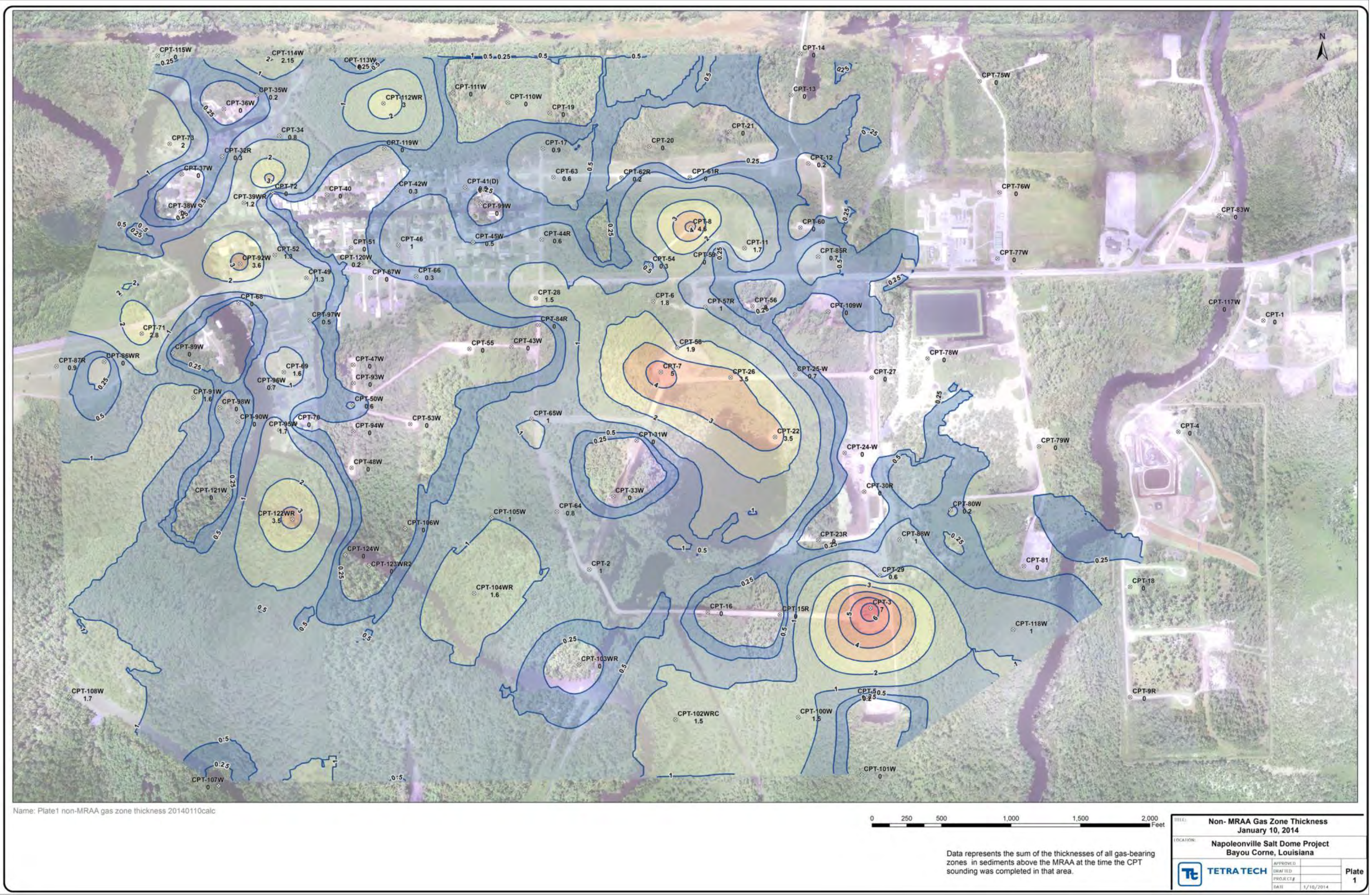
Top of MRAA/GAS



Gas Thickness in MRAA



Net Gas Thickness in Aquitard



Recoverable Gas Volumes

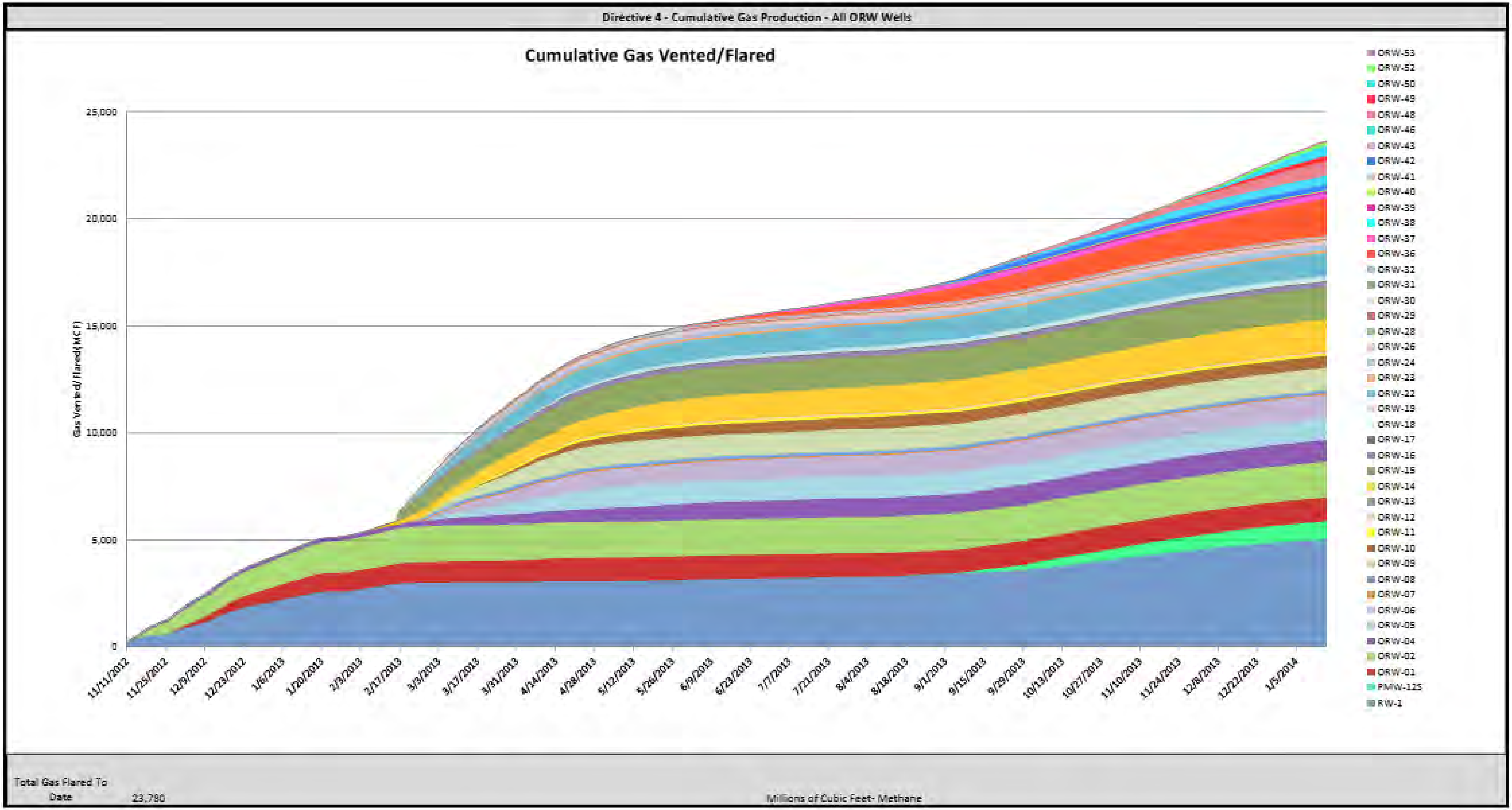
Area of Interest	Gas Zone Thickness (ft)	Recoverable Gas Volume* Millions of Cubic Feet
Entire Site Including Statistical Uncertainty Zone	> 0.25	20.4
	> 0.50	18.9
	> 1.00	15.4
Entire Site Excluding Statistical Uncertainty Zone	> 0.25	16.7
	> 0.50	15.2
	> 1.00	11.8
Entire Site Excluding Area South of Sportsman's Landing	> 0.25	15.2
	> 0.50	13.7
	> 1.00	10.3
Volume Based Upon *porosity - 25%* *recoverable gas - 50%*		

MRAA

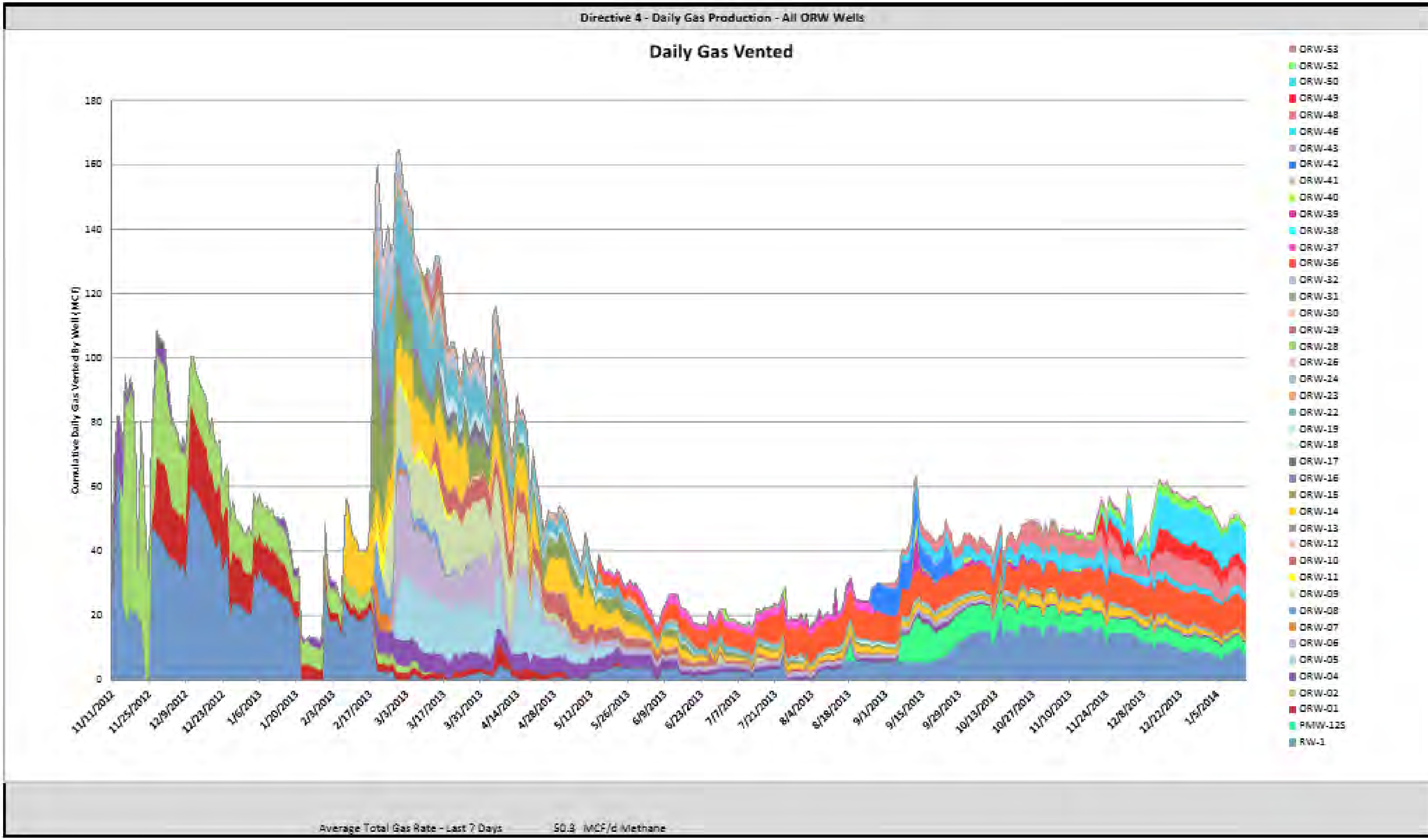
Total Thickness of all Aquitard Gas-Bearing Zones (ft)	Volume of Gas (ft^3)
>0	12,106,318.0
>=0.25	11,612,892.3
>=1	6,772,183.3
>=2	2,717,534.0

Aquitard

Total Gas Vented as of 17 JAN 2014 was 23,780 mscf



Combined Gas Vent Rate as of 17 JAN 2014 was 48.2 mscf/d



15 out of 47 wells venting and 6 wells account for 86.5% of gas vented (as of 17 JAN 2014)

Gas Pressures

- All ORW wells currently flaring have pressures less than hydrostatic pressures calculated based on ground surface reference elevation.
- All shut-in ORW wells where gauge pressures are available have gauge pressures less than hydrostatic pressures calculated based on ground surface reference elevation.
- All shut-in ORW wells with transducers indicate that pressures in gas interval (if gas is still present) have pressures less than hydrostatic pressures calculated based on ground surface reference elevation.
- All pressures for PMW wells completed in gas intervals based on trackit and pressure transducers data have pressures less than hydrostatic pressures calculated based on ground surface reference elevation.
- Groundwater pressures are below hydrostatic pressures calculated based on ground surface reference elevation.

Aquitard Understanding Based on CPT Data

- Thin silt/sand seams or lenses are interbedded with thicker silt/clay layers.
- Very few sand/silt seams occur between depths of 40 to 80 feet.
- Gas and water pressures below 80 feet are typically greater than below hydrostatic pressures calculated based on ground surface reference elevation.
- Gas and water pressures above 40 feet are typically lower than below hydrostatic pressures calculated based on ground surface reference elevation.

Ardaman

Napoleonville Salt Dome

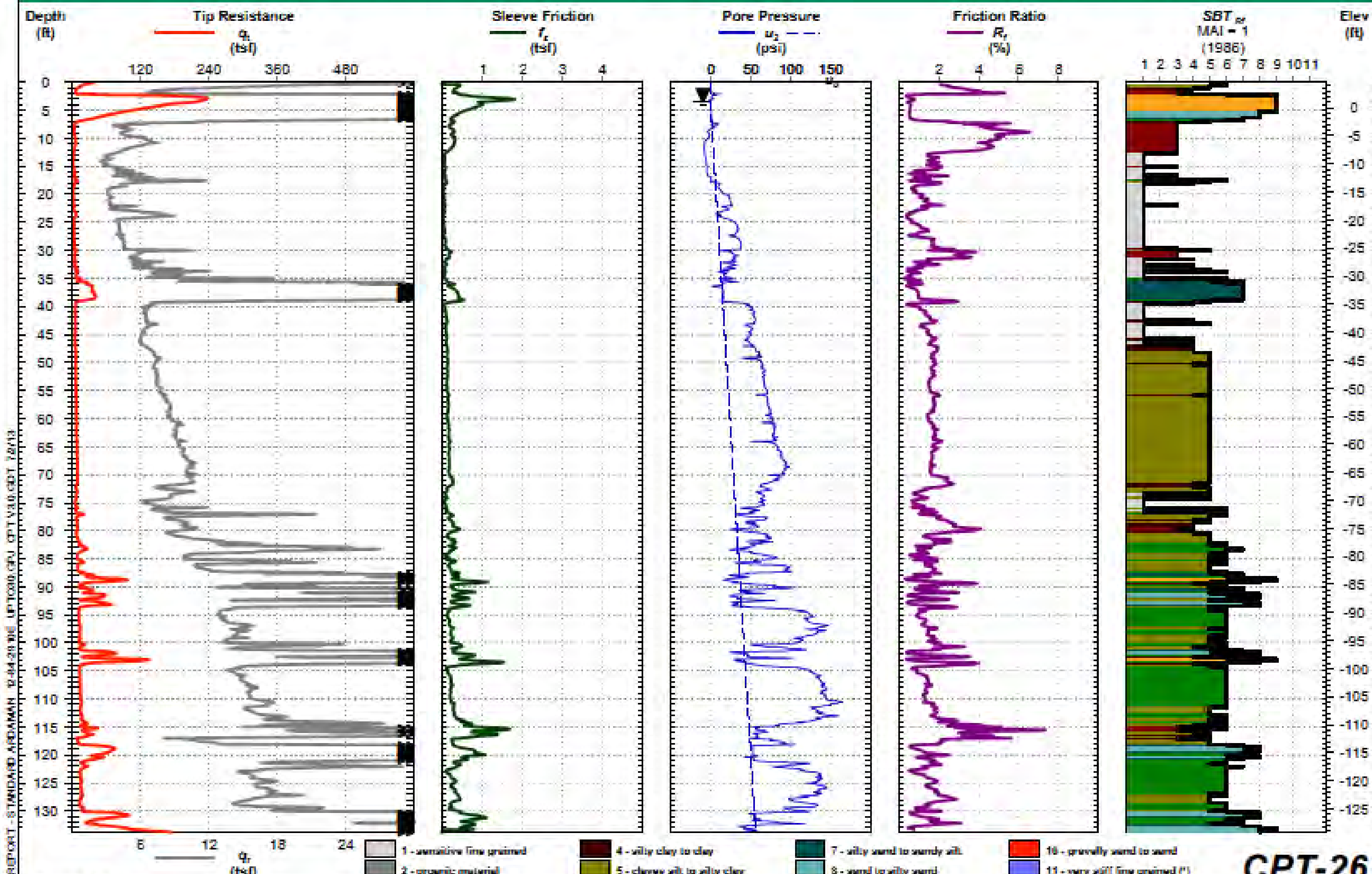
Cone Penetration Test

CPT-26

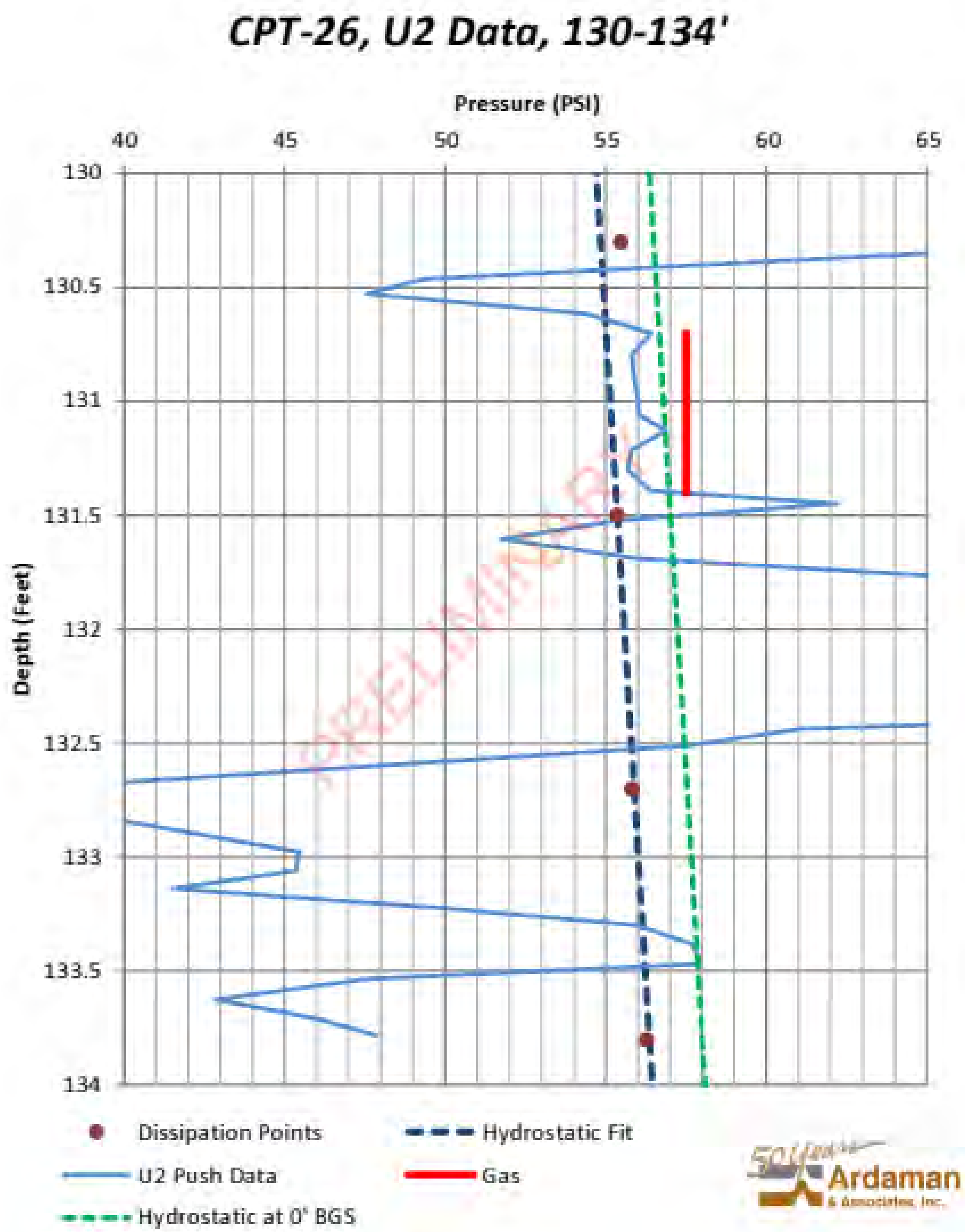
Project #: 12-84-2910E
Date: Jun. 20, 2013

Northing: 550343.9
Easting: 3341124.0

Elevation: 4.58
Total Depth: 133.8 ft

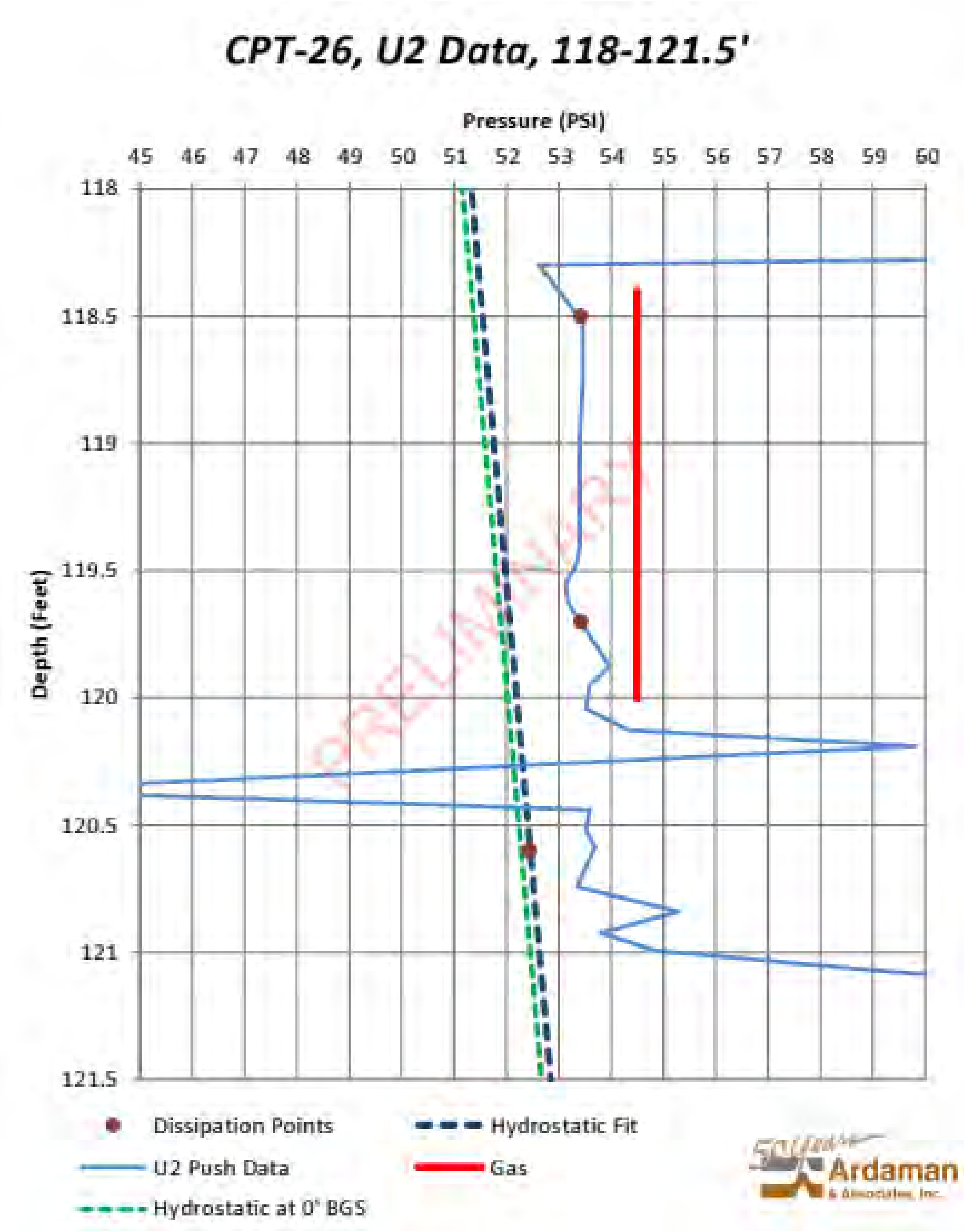


CPT-26



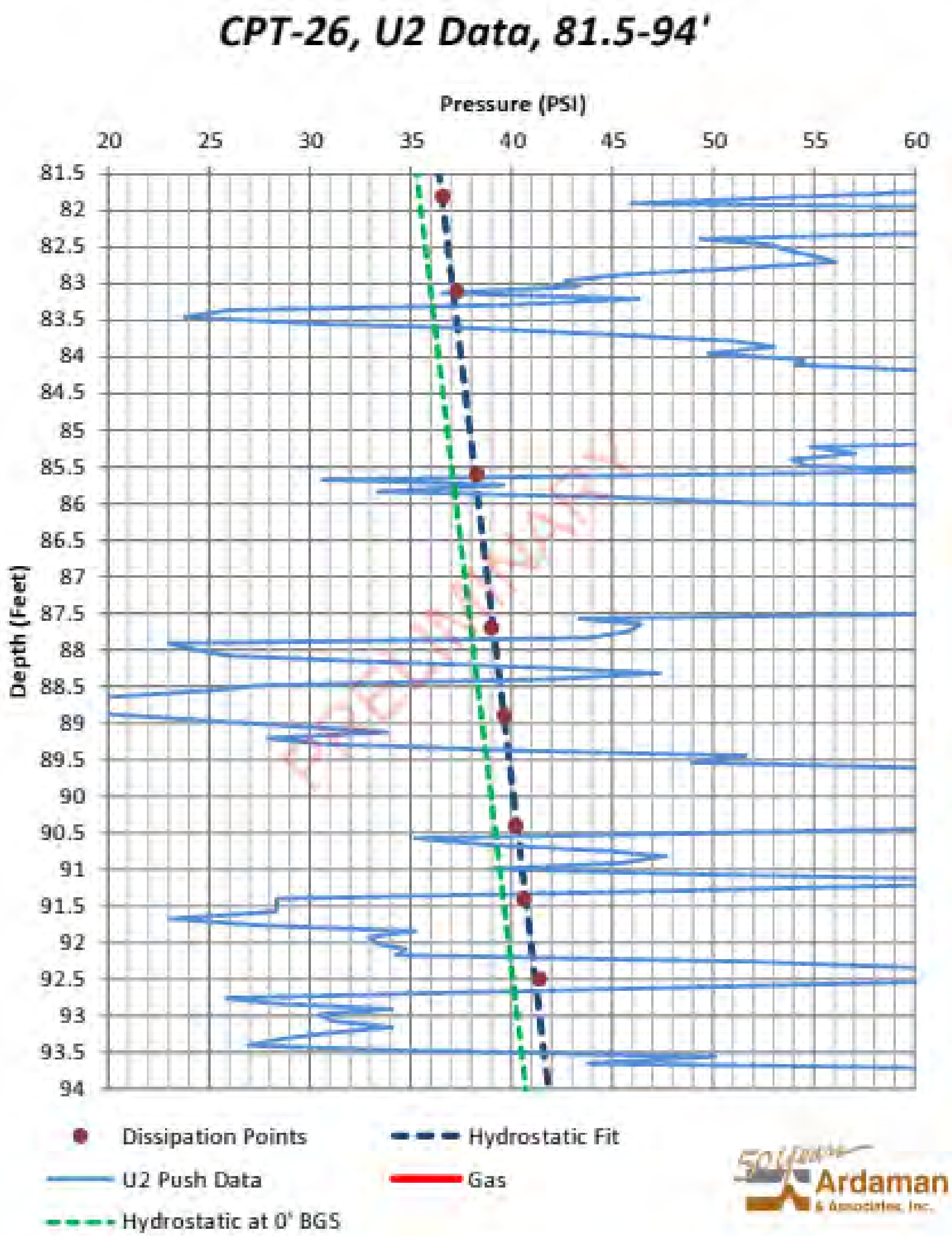
Gas and groundwater pressures less than ground surface based hydrostatic pressures

MRAA



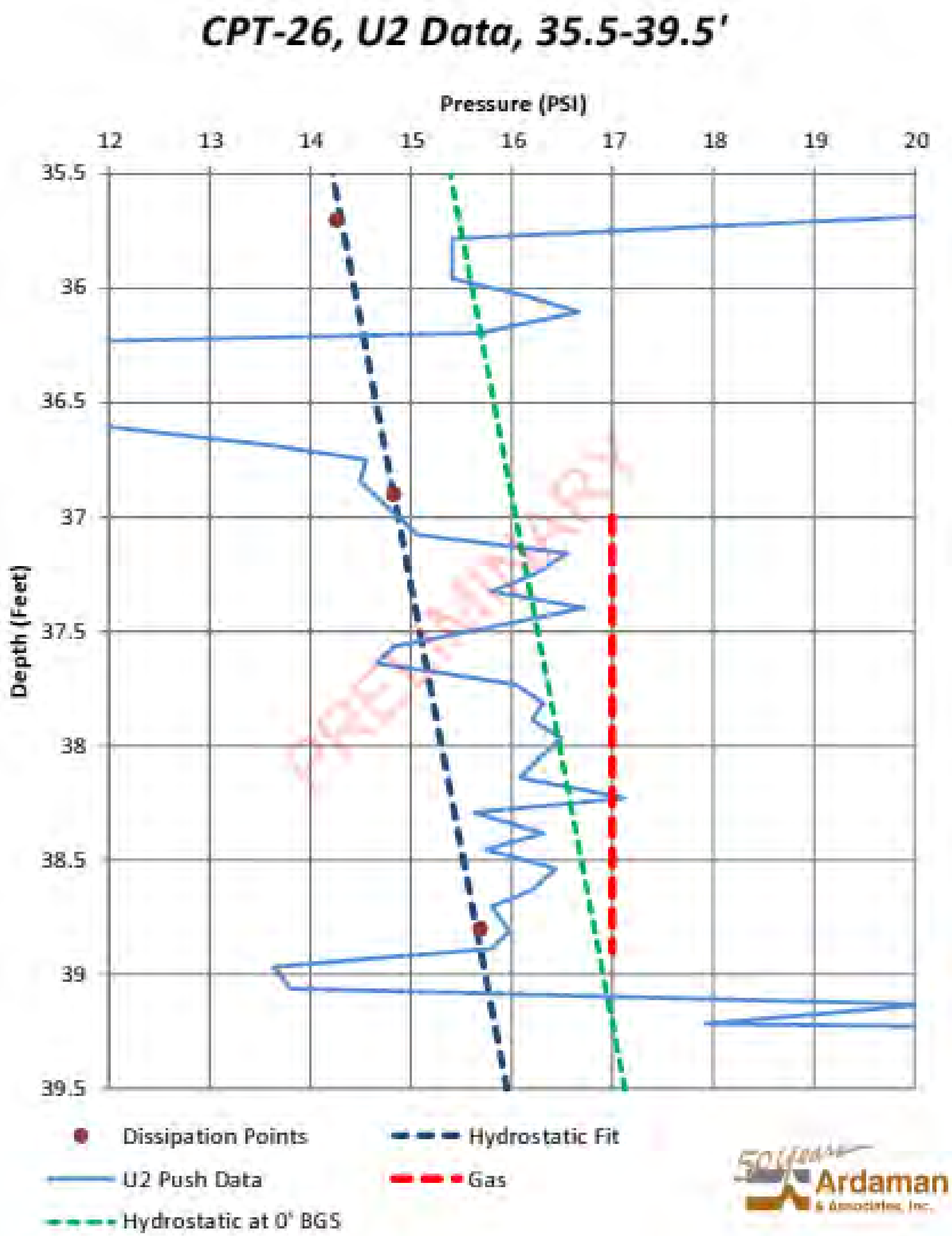
Gas and groundwater pressures greater than ground surface based hydrostatic pressures

Deep sand/silt seams



Groundwater pressures less than ground surface based hydrostatic pressures

Deep sand/silt seams



Gas and groundwater pressures less than ground surface based hydrostatic pressures

Shallow sand/silt seams

Application of Hydrostatic Pressure Goal

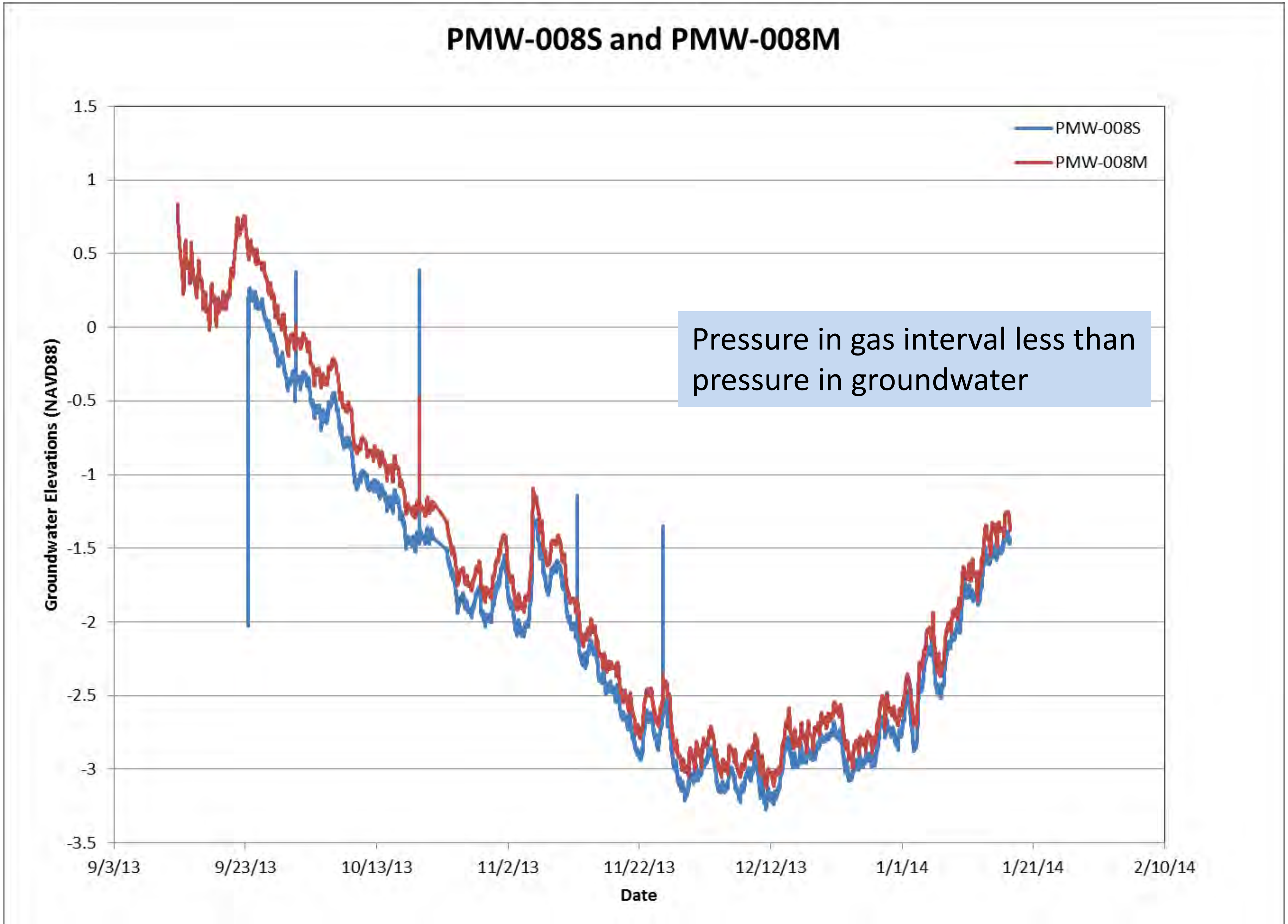
- Not useful for guiding relief well operations
- Needs clear definition
  - Based on fixed reference elevation such as ground surface or
  - Based on comparison between gas pressures and nearby groundwater pressures
- Fixed reference
  - Simple comparison
  - Does not account for pressure changes due to seasonal recharge and groundwater production
- Gas/groundwater pressure comparisons
  - Subject to double uncertainty because of two measurements per comparison
  - Does account for seasonal effects
- Both methods subject to measurement error
- Both methods need to consider capillary pressure differences

Comparison Based on Fixed Reference Elevation Such as Ground Surface

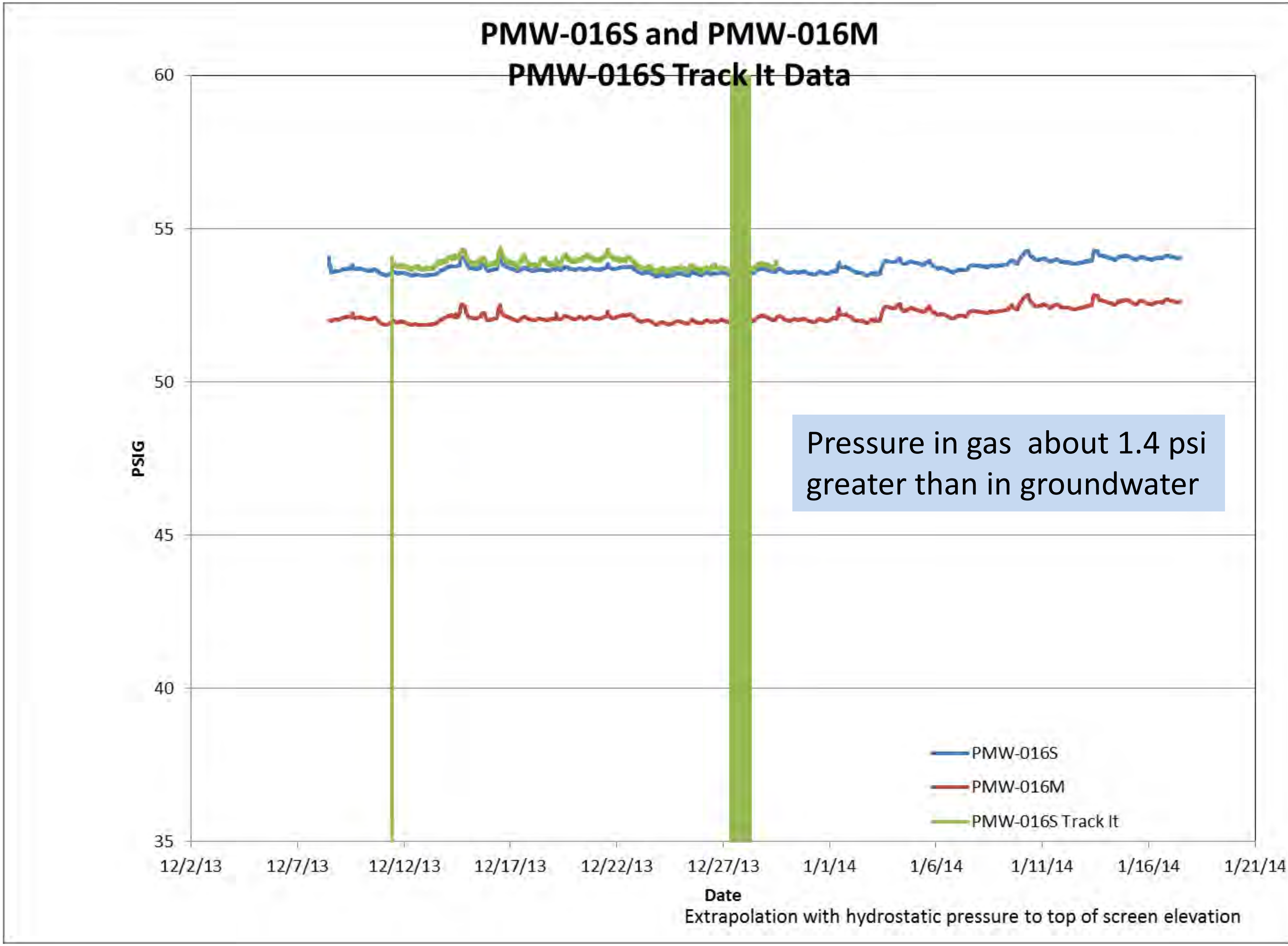
- Using this criteria alone would lead to conclusion that venting operations are no longer needed.
  - All measured gas pressures are below hydrostatic
- Relief wells are currently producing significant amounts of gas from the MRAA

Comparison Between Gas Pressures and Nearby Groundwater Pressures

- Pressure differences are small as measured in test well pairs (< 1.5 psi) in areas of significant gas production
- Maximum pressure difference observed is about same as capillary pressure difference measured at very low gas saturations on samples from site.
- Pressure differences are reversed (gas pressure less than groundwater pressure) at some times at two well pairs.
- Confidence in this criteria is limited to vicinity of wells with significant production, even in these areas small differences in pressures and inconsistencies with theory are evident.



PMW-008S and PMW-008M
PMW-008S
PMW-008M
Pressure in gas interval less than pressure in groundwater
Groundwater Elevations (NAVD88)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
9/3/13
9/23/13
10/13/13
11/2/13
11/22/13
12/12/13
1/1/14
1/21/14
2/10/14
Date


PMW-016S and PMW-016M
PMW-016S Track It Data
60
55
50
45
40
35
PSIG
Pressure in gas about 1.4 psi
greater than in groundwater
PMW-016S
PMW-016M
PMW-016S Track It
12/2/13
12/7/13
12/12/13
12/17/13
12/22/13
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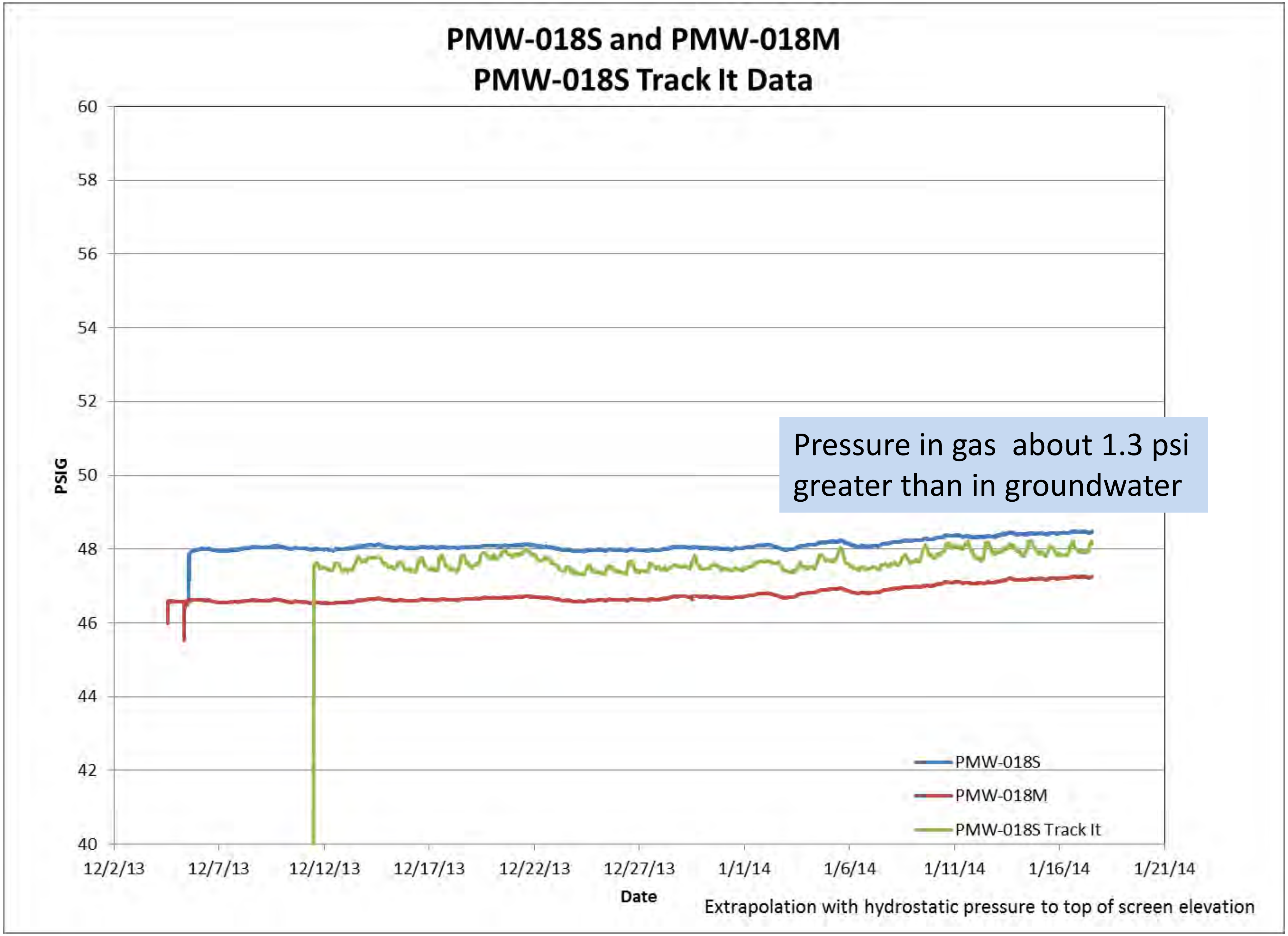
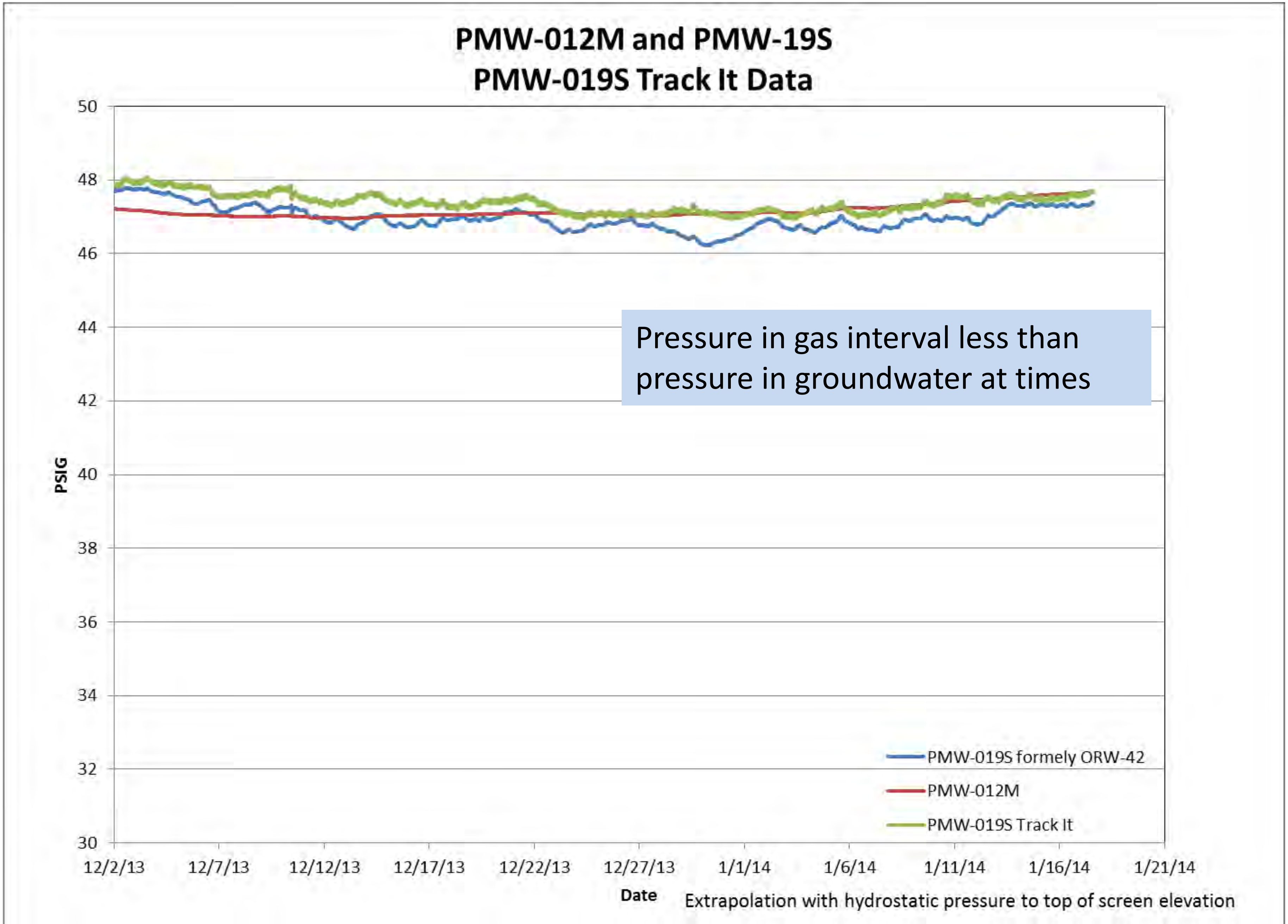
1/1/14
1/6/14
1/11/14
1/16/14
1/21/14
Date
Extrapolation with hydrostatic pressure to top of screen elevation



PMW-018S and PMW-018M
PMW-018S Track It Data
PSIG
60
58
56
54
52
50
48
46
44
42
40
12/2/13
12/7/13
12/12/13
12/17/13
12/22/13
12/27/13
1/1/14
1/6/14
1/11/14
1/16/14
1/21/14
Date
Pressure in gas about 1.3 psi greater than in groundwater
PMW-018S
PMW-018M
PMW-018S Track It
Extrapolation with hydrostatic pressure to top of screen elevation


PMW-012M and PMW-19S
PMW-019S Track It Data
50
48
46
44
42
40
38
36
34
32
30
PSIG
Pressure in gas interval less than pressure in groundwater at times
PMW-019S formely ORW-42
PMW-012M
PMW-019S Track It
12/2/13
12/7/13
12/12/13
12/17/13
12/22/13
12/27/13
1/1/14
1/6/14
1/11/14
1/16/14
1/21/14
Date
Extrapolation with hydrostatic pressure to top of screen elevation

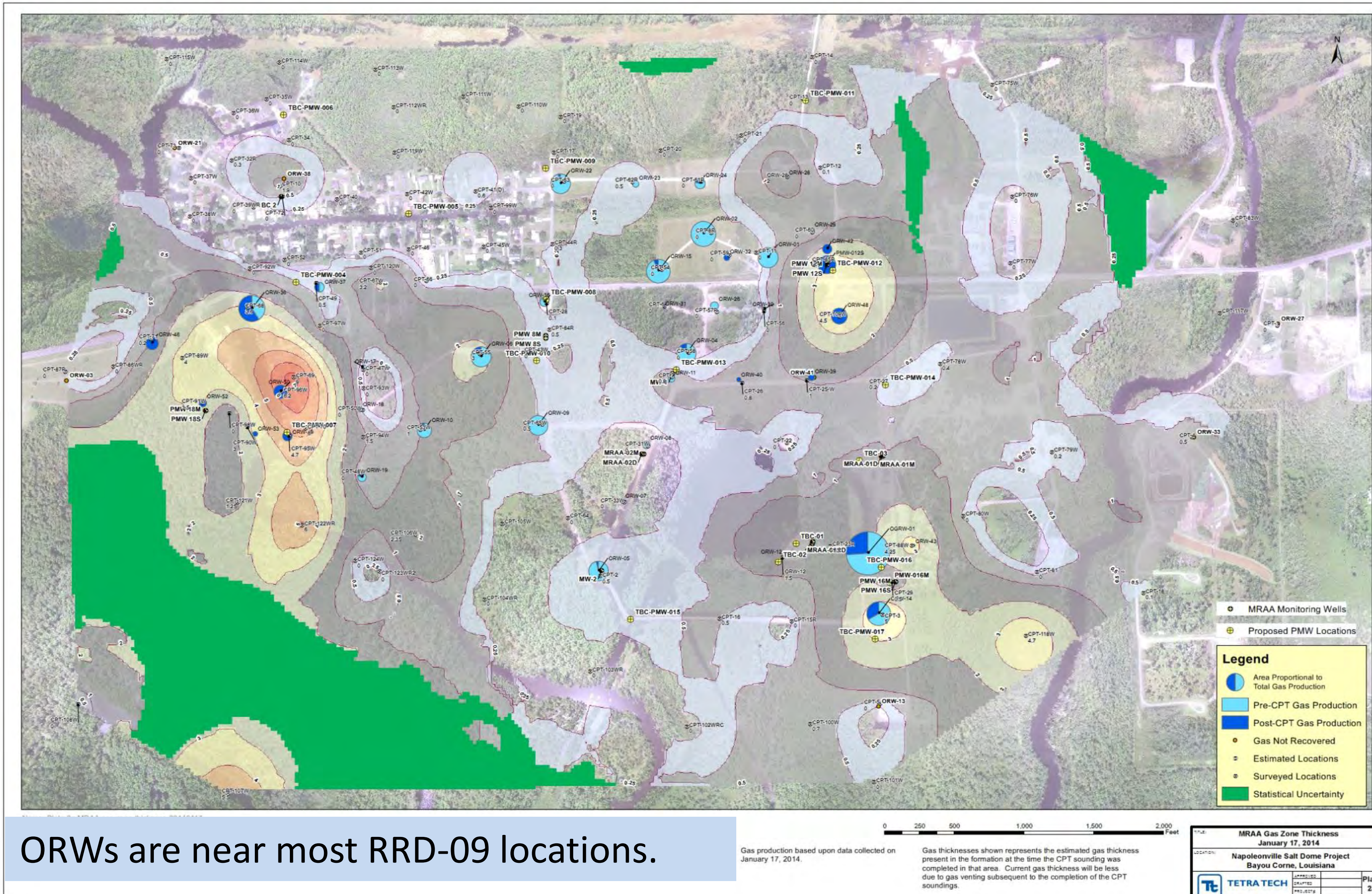
Application of Hydrostatic Pressure Goal

- Ambiguous results adding little information to that which can be obtained from relief wells and CPT soundings
- Needs to be augmented with other meaningful criteria

Need for additional PMWs

- Ambiguity of hydrostatic pressure comparisons renders any extensive network of pressure monitoring wells unnecessary.
- Depleted ORWs can be used to characterize pressures where gas is present in the MRAA
  - Screened or perforated in gas interval
  - Instrumented
  - Located over all areas of MRAA gas in vicinity of Bayou Corne

Gas Thickness in MRAA



ORWs are near most RRD-09 locations.

Proposed Alternative to BRC goal

- TBC submitted the *Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations* on November 8, 2013. This plan proposes establishing measureable and achievable criteria for ending operations for groups of ORWs with the goal of depleting the MRAA of gas to the extent practicable.
- In Current Conditions report just submitted section III. G. (Proposed Alternative Remediation Metric, If Any, As To When Gas Mitigation May Be Terminated) updated tables from the November plan were included.
- Plan covers all phases of relief well status
  - Installation
  - Venting gas only
  - Venting gas with pumping of water
  - Monitoring
  - Maintenance
  - P&A

Appendix 4
Investigation Report for RRD-08B Extent of Gas

INVESTIGATIVE REPORT FOR RRD-08B EXTENT OF GAS

Prepared for:

Texas Brine Company

Prepared by:

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Tetra Tech Project No. 114-010647

December 19, 2013

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1.0 INTRODUCTION

This report has been prepared by Tetra Tech, Inc. (Tetra Tech) on behalf of Texas Brine Company, LLC. (TBC) in response to the request from the Blue Ribbon Commission on Bayou Corne and Grand Bayou Safety (BRC). The BRC requested on 11 NOV 2013 a series of reports documenting ongoing TBC technical activities. It provides the documentation requested for Recommend Requirements Document (RRD) for Extent of Gas (RRD-0O8B). This report follows the general outline suggested by the BRC.

This report presents the results of investigations undertaken to determine the extent of subsurface gas in the vicinity of the Oxy 3 cavern collapse. It is important to note that the source of subsurface gas identified in these investigations is uncertain. Free gas is common in the subsurface in the vicinity of salt domes and areas of oil and gas exploration and production. Gas that is distant from the Oxy 3 cavern or isolated by low permeability barriers such as clay layers is most likely background gas. The tests conducted to find gas and the relief wells installed to vent gas were required by DNR directives and not based upon findings that any gas found must be attributable to formation of the sinkhole.

2.0 OBJECTIVES OF GAS EXTENT INVESTIGATION

The objectives of RRD-08B are to determine the extent of gas at the top of the Mississippi River Alluvial Aquifer (MRAA) and to monitor changes in the amount of gas in the MRAA. More specifically, the BRC notes in regard to the extent of gas: "The extent of gas determination is intended to address the full extent of thermogenic gas related to the Oxy 3 cavern collapse in the MRAA and overlying aquitard at gas saturations greater than background." Discrimination between background and gas that may be related to cavern collapse is complicated in those areas where both are potentially present and has been a secondary focus of the investigation. Determination of gas extent present in the subsurface has been necessary to define the location and indicated gas zone thickness in order to design, install, and operate the network of observation relief wells (ORWs) for removal of producible gas potentially . In particular, gas that is present below habitable structures and roads in Bayou Corne and Grand Bayou, is the highest priority. The investigation has thus focused on locations most likely to provide a pathway for gas migration from the cavern collapse area to locations below habitable structures and roads. These investigations have led to the installation of 47 relief wells that have vented 22 million standard cubic feet (scf) of gas and currently vent approximately 60,000 scf/day.

The second objective of RRD-08B is to monitor changes in the amount of gas present in the subsurface. Operation of the relief wells is removing gas from the MRAA at a rate that is generally decreasing even as new relief wells are brought online. These declining rates indicate that depletion of the MRAA gas present in the subsurface has occurred as a result of a year of relief well operations. Concern for gas recharge from below the MRAA has been expressed by the community and the BRC. Gas depletion by venting and any significant amount of gas recharge will be monitored by evaluating relief well performance and testing, and by using some of the methods used to initially identify producible gas extent and thickness in the MRAA. The use of pressure monitoring wells (PMWs) to measure excess gas pressures has been required by the BRC and may be practicable where the gas cap is thick. However, it is unlikely to be practicable for areas where the gas cap is thin (less than 3 feet), because pressure differences would be small and subject to background variability requiring any interpretation and conclusions to be drawn from this data to be highly qualified.

Although not explicitly stated as an objective for RRD-08B, it has also been necessary to characterize the stratigraphy (the relationships between clay, silt, and sand layering and lenses present) in and above the MRAA. The same tools used to identify producible (recoverable) gas also provide stratigraphic data. Other information from drilling and soil sampling (coring) provide additional indirect and direct observations.

3.0 METHODS USED TO IDENTIFY AND MONITOR PRODUCIBLE GAS

Three different methods have been used to identify gas at the top of the MRAA. These methods are Pulsed Neutron Decay (PDK) logging, Cone Penetrometer Testing (CPT), and Membrane Interface Probe and Hydraulic Profile Testing (MiHPT). During the initial installation of relief wells, gas zone identification was based on PDK logging inside casings installed by driving or sonic drilling. Based on PDK logs that provided an indication of gas presence and together with another geophysical log (Natural Gamma) and observations recorded during drilling that identified the depth of the MRAA, the casing was perforated at the depth of the top of the MRAA gas (gas cap). Because this method required the very lengthy process of installation of the casing and other infrastructure construction before determining whether gas was present, TBC investigated CPT and MiHPT screening methods to evaluate gas presence and likely producibility in a time-efficient manner. The CPT method proved to provide the better characterization of subsurface geology, fluid (gas and water) pressures, and producible gas. The MiHPT methods provided less specific information on geology, but could identify the presence of small amounts of gas (thickness) that was not necessarily producible. Because the CPT method could also penetrate deeper into the MRAA, it has been used as the primary method for defining the horizontal and vertical extent, (including depth) and thickness of producible gas.

The three investigative methods (PDK, CPT, and MiHPT) used to identify potential producible gas bearing intervals are either confirmed or not by the amount and rates of gas that can be vented by relief wells. The TBC approach to monitor changes in subsurface gas volumes (as the program moves from emergency response to operation and monitoring) is based on:

1) repeat CPT boring installation at prior locations near relief wells;

2) CPT soundings in between select relief wells; and,

3) venting rates and relief well testing.

The approach for monitoring is described in Section 6 of this report.

A review of PDK, CPT, and MiHPT methods are presented in the remainder of this section.

3.1 PDK Logging

An established protocol for identifying gas bearing intervals at the top of and above the MRAA involves interpretation of geophysical logs, including PDK-100 and natural gamma, taken inside well casings completed about 25 feet into the MRAA. PDK logs have been used to identify gas zones in petroleum exploration and characterization for more than 20 years. These logs have also been applied reliably to identify the MRAA gas cap in the vicinity of the Bayou Corne sinkhole.

The PDK-100 is a pulsed neutron borehole logging system designed primarily to measure Sigma (Σ), the macroscopic thermal neutron capture (adsorption) cross section of the bulk formation. The name PDK-100 denotes the 100 channels per detector used to describe the neutron pulse and decay spectra. Raw data from both the Short Space (SS) and Long Space

(LS) detectors are continuously collected both during and after the neutron burst from the pulsed neutron source which spreads into the borehole and formation. After this initial pulsed neutron bombardment, the thermal decay time log is created to record the rate of capture of thermal neutrons in the formation The capture cross section Sigma is defined as the relative ability of a material to "capture" or absorb resultant free thermal neutrons. A spectrum that exhibits rapid decay is produced by a high Σ formation, such as a shale or high-porosity zone. Conversely, a low Σ formation, such as low porosity materials and gas zones, is represented by a slowly decaying spectrum.

In addition, the borehole geophysical system provides logging curves which furnish information concerning borehole conditions. The natural gamma log measures natural radiation that tends to be higher in clay and lower in sand. This profile is helpful in determining the approximate top of the MRAA, where the gamma response shifts from higher to lower values with depth, as well as clean sand layers/lenses in the clay aquitard.

Identification of the gas interval is largely based on low relative values of the RIN and Sigma curves of the PDK log. The Sigma response is a measure of the amount of gas in the zone. The associated midpoint of the RIN response inflections defines the upper and lower elevations of the gas cap. The minimum value point on the Sigma curve gives a relative measure on how much gas is in the interval. As the gas quantities becomes less and less from venting operations, the Sigma response in subsequent logs should shift higher.

A typical PDK geophysical log is provided in Figure 1. The natural gamma log (GR) curve is presented in blue on the left. The GR inflection lower starting at 116 ft bgs represents a decrease in natural gamma radiation, which coincides with less clay in formation and is interpreted (and confirmed with drilling penetration logs) as the top of the MRAA. The Sigma curve is shown in black. The maximum negative deflection to 17.5 units at 121 ft bgs indicates the presence of gas. TBC and the PDK vendor, Baker Hughes, established a relative gas scale based on the Site Sigma Value with a value of 23 or higher indicating no free gas available; and a value of 14 or lower indicating free gas readily available, with gradations in between. The associated dramatic drop in the RIN response curve (shown in red) can be interpreted to show gas cap thickness, determined by RIN midpoint responses. In this example, the RIN-identified gas cap would be located approximately 116-124 ft bgs.

3.2 CPT

The piezocone is a probe used in the geotechnical engineering field for subsurface exploration. In modern cone penetration testing (CPT), an electronic steel probe is hydraulically pushed into the subsurface to collect continuous readings of point load, sleeve friction, and pore-water pressure. Penetration depths of over 150 feet were reached at the Site. Data are logged directly to a field computer and generate soil type, pore (water or gas) pressures;, and the strength, compressibility, and permeability of the different soil layers that are penetrated. The CPT rigs were used terrestrially on constructed roads and pads, and amphibiously with the machine placed on a barge and towed through the swamp to designated sounding locations where it pushed through the water column into the sediment below.

The concept for identifying gas in and above the MRAA using CPT pore pressure data relies upon the fact that gas in continuous accumulation areas has a near constant pressure with depth. Since the pressure in the hydraulically conductive pore water above and below the gas varies linearly with depth, the presence of gas is manifested by a sharp break in the slope of the water pressure-depth curve. Because the piezocone can collect static water pressure readings on very close intervals, e.g. 0.5 feet, CPT operators were able to evaluate data in real time and tailor the soundings to screen for the presence and thickness of gas zones.

All CPT testing was performed in accordance with ASTM D-5778 using a cone rig with a weight of at least 35,000 pounds. When the piezocone is pushed into a layer of soil, the pore water pressure will increase or decrease relative to the static water pressure. Soft clays and loose sands generate positive pore pressure during penetration whereas stiff clays and dense sands sometimes generate negative pressures during penetration. To obtain accurate readings of the static water pressure, the probe must remain at the tested depth until the pore pressures resulting from the dynamic action of advancing the cone have dissipated. The dissipation rate in sandy soils is relatively quick and equilibrium with the static water pressure will occur in a few minutes. Equilibrium in clay soils will take much longer. Dissipation of excess pore pressures near the top of the MRAA was monitored until equilibrium with the static water (or gas) pressure was achieved.

A typical CPT log is provided in Figure 2. This standard CPT log provides geotechnical information and an interpretation of the penetrated stratigraphy. The leftmost section of the output provides piezocone tip resistance in two scales for readability. The red line is associated with the uppermost 0 to 500 tons per square foot (TSF) scale. The same curve is expanded to show tip resistance in the 0 to 0-30 TSF range in the gray line and lower scale. Sleeve friction at sensors along the side of the piezocone is shown in the next box. The ratio of the sleeve friction to tip resistance is shown in the friction ratio box and compared to standard CPT values to provide soil stratigraphy with up to 12 different soil types displayed on the right side of the output. One interpretation of this log is that the MRAA begins at 115 ft bgs, based on the inflection of the tip pressure curve and associated stratigraphy.

A typical CPT piezocone log is provided in Figure 3. Dynamic pore pressure readings are shown by the blue lines over the penetration depth. The static pore pressure dissipation test equilibrium results are plotted at the depth taken by the brown indicator circles. The dashed blue line is the best fit linear hydrostatic pressure line through dissipation points above and below the suspected gas zones. Dissipation points with pressures higher than the best-fit hydrostatic line at the same depth are indicators of a near constant pressure gas zone. These zones are flagged with a red vertical line for clarity. In addition, the dashed green line shows the linear hydrostatic depth curve if the water surface corresponded to ground surface. This log in Figure 3 shows a producible gas pocket from 115.2 to 117.5 ft bgs.

3.3 MiHPT

The Membrane Interface Probe (MIP) and Hydraulic Profiling Tool (HPT) was used at the Site as a direct push percussion tool to provide real-time logs of relative methane concentrations and soil electrical conductivity (EC) with depth (MIP) while simultaneously measuring HPT injection pressure during the same push. The logs of water injection pressure over depth correlate to estimates of hydraulic conductivity. The tool was also used to collect discrete interval pore pressure dissipation test data and has the capability of collecting in-situ methane molecules from depth.

A typical MiHPT log is provided in Figure 4. The first column features a log with black and green lines. The black curve represents the dynamic soil and pore water electrical conductivity with depth log using the uppermost horizontal scale. The green curve provides the HPT average line pressure using the lowermost horizontal scale. The maximum HPT line pressure curve is shown in the second box with a hydrostatic pressure linear line. The flame ionization detector (FID) response to the carrier gas exposed on the tool side of the semi-permeable membrane in direct contact with formation is shown in the third box. This curve indicates the presence or absence of methane in formation from either the liquid or gas phase. The final column on the right indicates the HPT water flow rate, which is associated with hydraulic conductivity (K) of the formation penetrated.

3.4 COMPARISON OF PDK, CPT AND MIHPT INVESTIGATION METHODS

Numerous PDK, CPT and MiHPT investigations have been completed at the Site. Many were collocated to compare methodologies and results. A critical analysis summary of these methodologies is provided in Table 1. All CPT, MiHPT, and PDK logs obtained to date have been provided to LDNR.

4.0 DATA ANALYSIS METHODS

An evaluation of the extent and thickness of recoverable gas at the top of the MRAA was prepared based on the PDK geophysical logs and CPT data that has been compiled into an electronic data base. At each location, the thickness of producible gas and the elevation of the top of the MRAA have been estimated. These estimates have then been used to prepare maps of the top of the MRAA and the horizontal extent and thickness of gas.

CPT soundings have been conducted adjacent to all ORWs and over a wide area surrounding the sinkhole (Plate 1). Additionally, MiHPT soundings have been conducted at most of the CPT locations. Information from PDK logs of the relief wells and MiHPT soundings have been compared and found to be generally consistent with the CPT interpretations (in terms of subsurface geology and gas intervals). Because the CPT data set is the most extensive and because the PDK, CPT, and MiHPT measures of gas presence can only be compared qualitatively, the CPT data is used for the evaluation of the extent of gas while CPT and PDK geophysical data are used for definition of the top of the MRAA.

4.1 GIS Data base

Geologic data collected during relief well installation and CPT data are stored in an ArcGIS™ geodatabase. The relational nature of the geodatabase allows for the concurrent storage of observation data and geospatial information. The Bayou Corne geodatabase includes CPT sounding observation data such as: the depth to the top of the MRAA; the total depth of each sounding; the depth and dimension of each gas bearing zone; and, raw lithologic classification data. Other data include as-built dimensions of the wells and associated surveys. Tables generated from the geodatabase summarize the location of each recovery well, the depths and dimensions of screened intervals and the total depth of the wells. To maintain consistency and the relational nature of the geodatabase, all geospatial data (northing and easting locations) is stored in the Louisiana State Plane (NAD 1983) South horizontal coordinate system and the North American Vertical Datum of 1988 [NAVD88 (Mean Sea Level)].

Data contained in the geodatabase are used in many of the maps and calculations made throughout the site investigation. One example of this is the frequently updated maps of the elevation of the top of the MRAA. Data maintained in the geodatabase are updated as soon as information is available from the field. In this way each successively newer map includes contoured surface data based upon the most up to date information available enabling better and more timely decisions to be made throughout the ongoing investigation.

4.2 Preparation of Maps

Throughout the investigation the geostatistical estimation method called Kriging has been used to evaluate the site wide elevation of the top of the MRAA, and more recently the distribution of gas producing zones in the MRAA. In a two-step process, Kriging uses discrete observation data to estimate elevations (or thicknesses) across the entire site.

Geostatisical analysis is first used to determine the predictability of values of elevation or thickness across the site. Then, using the relationship developed during the first step, estimated values are calculated at regularly spaced intervals over the entire study area. The benefits of this approach include contoured surfaces that honor data collected in the field and the ability to develop an understanding of uncertainty (potential variances between estimated and actual values) throughout the area under study.

In the case of the Bayou Corne site, kriging has been used to estimate the elevation of the top of the MRAA and the thickness of gas bearing zones across the site. Because not all of the CPT soundings encountered the top of the MRAA and not all of the CPT soundings that did reach the MRAA encountered gas at that depth (or encountered at the bottom of the gas zone), the spacial variability of these data sets is quite different, requiring different evaluation criteria during the kriging process. In the case of the MRAA surface evaluation, many of the CPT soundings successfully penetrated to the top of the stratigraphic unit, and as a result, the potential variance between estimated and actual values of elevation is much smaller than potential variances associated with MRAA gas zone thickness estimates.

Table 2 provides the basic kriging parameters applied to each of the surface estimations described above:

1. Range – Statistical analysis of the data indicates that for the MRAA elevation estimation (Plate 1) there is little or no correlation between data points that are separated by more than 1,000 ft. For the estimation of gas bearing zone thickness (Plate 2) there appears to be little correlation between points that are more than 800 ft apart.
2. Points – For both MRAA elevation and gas zone thickness evaluations, data from the twelve (12) closest CPT soundings where the MRAA was encountered were used to complete the surface estimation.
3. Grid Distribution – Kriging was completed on a regularly spaced grid of locations with each grid cell measuring 25 X 25 ft. In all the study area was represented by approximately 61,700 grid cells.

5.0 FINDINGS

The findings of site investigations to date are presented in maps of the top of the MRAA and the thickness of producible gas in the area where CPT soundings have been conducted. Also, gas thickness data has been used to estimate the volume of producible gas.

5.1 Compilation of Data

All CPT, MiHPT, and PDK logs have already been provided to LDNR. A summary of gas bearing intervals identified from CPT soundings is presented in Table 3.

5.2 Top of the MRAA

Plate 1 is a map of the site showing the estimated (kriged) elevation of the top of the MRAA. The elevation of the MRAA ranges from approximately -103 ft mean sea level (MSL) in the western part of the site to -163 ft MSL in the eastern part of the site. Data is reasonably well distributed throughout the study area because most of the soundings were installed at sufficient depth to penetrate the MRAA.

5.3 Gas Thickness and Extent

Plate 2 is a map of the site showing the distribution of gas bearing zones at the top of the MRAA. The contoured data highlight areas where gas-bearing sediments are present at thicknesses that range from 0.25 ft up to the thickest zones (near CPT-69) where 9 ft of gas bearing sediments were encountered. Because not all of the CPT soundings encountered gas-bearing sediments at the top of the MRAA the gas-bearings zones appear to be distributed in a more discrete manner. Plate 2 also includes areas (dark green) where the potential difference between the estimated thicknesses (shown on the plate) and actual values is too high. On Plate 2, if the statistical variance was more than 2.6 ft the contours and shaded areas representing gas bearing sediments have been covered over to indicate statistical uncertainty.

Table 3 summarizes gas production from each of the recovery wells. This information is also displayed on Plate 2 as a pie diagram for each ORW location. For the ORW pie diagrams, the size of the pie circle is proportional to the total volume of gas produced at the recovery well. Wells that have produced more gas than others have larger pie circles.

Table 3 includes the volume of gas produced prior to the completion of a nearby CPT sounding and after the completion of the sounding. This information is also shown on the ORW pie circles on Plate 2. The gas thickness shown on Plate 2 represents the thickness encountered by the CPT; thus the dark blue portion of each ORW pie represents the amount of gas produced after the CPT sounding, suggesting that currently, the gas thickness in that area is actually less than what is shown on Plate 2.

Table 4 lists the name of paired/co-located CPT sounding and the current recovery well (12/11/2013) gas production rate.

5.4 Post-CPT Recoverable Gas Volumes

Once the distribution of gas bearing sediments was estimated, a series of recoverable gas volumes was calculated using the data shown on Plate 2. As described above, the entire site was represented by approximately 61,700 grid cells measuring 25 X 25 ft. Recoverable gas volume calculations also took into account estimates of porosity of 25% and a recoverable gas fraction of 50%. Recoverable gas volume calculations took into account both the entire site and the statistical uncertainty area shown on Plate 2.

Tabulated results of the analyses are presented in Table 5.

Three gas thickness range interpretations were completed for three distribution scenarios:

- Volume associated with gas zone thicknesses greater than (>) 0.25 ft.
- Volume associated with gas zone thicknesses greater than (>) 0.50 ft
- Volume associated with gas zone thicknesses greater than (>) 1.00 ft

When the entire site was considered, including estimated thicknesses in the statistical uncertainty zone, the volume of recoverable gas ranged from 20 million standard cubic feet (SCF) (>0.25 ft) to 15 million SCF(>1.00 ft).

When the statistical uncertainty zone was not considered the volume of recoverable gas ranged from 17 million SCF (>0.25 ft) to 12 million SCF (>1.00 ft) across the entire site.

The final recoverable gas volume estimation was completed without taking into account the estimated gas zones in the southwest corner of the site, to the south of Sportsman's Drive. With this area excluded from the study area, the volume of recoverable gas ranged from 15 million SCF (>0.25 ft) to 10 million SCF (>1.00 ft) across the remainder of the site.

The volumes listed above represent the estimated recoverable gas that was present in the formation at the time the CPT sounding was completed in that area. They do not include gas that was vented prior to the CPT sounding, but does include the gas that has been vented since the CPT sounding was completed.

Based on Table 4 approximately 5 million scf of gas has been vented subsequent to completing the CPT investigation. This represents approximately 1/3 to ½ of the recoverable gas volume estimated to be in-place post CPT installation (Table 5, Scenario 3). At a typical venting rate of 0.5 million SCFD this represents 100 to 200 days of additional gas venting. Actual venting time is expected to be slightly longer since production rates will decline as gas depletion progresses.

5.5 Data Coverage

CPT soundings have been completed over most of the surface area below which gas that could be associated with the Oxy 3 cavern collapse may have potentially migrated. Two general areas are shown in green shading on Plate 2 where gas thickness estimates are not inferred due to wider spacing of CPT soundings One is located directly south of the Bayou Corne Community. The second is located northeast of the TBC facility.

There are two areas where gas has been identified in the MRAA, but is not potentially associated with migration from the cavern collapse zone. One area is located south of the green shaded uncertainty area south of the Bayou Corne community. Two soundings in this area, CPT 107 and CPT 108 indicated gas in the MRAA. These two locations are at prior oil and gas drill sites. Because the elevation of the gas at these two sites is deeper than gas found in the community of Bayou Corne, the gas is likely related to the prior oil and gas exploration activities. No additional CPT soundings are needed in this area, because this gas is not potentially related to the cavern collapse and because no habitable structures or roads are located in this area. The second area is east of Grand Bayou near CPT-4 and CPT-18. This small amount of gas cannot be potentially attributed to the cavern release, because the MRAA is much deeper in this area.

A third area of subsurface gas is present in the MRAA northeast of the TBC facility on CrossTex property. This minor amount of gas is below industrial property and the thickness of gas is indicated to be 0.5 feet or less. No further CPT investigations are proposed for this area.

5.6 Background Gas

Free gas is common in the subsurface in the vicinity of salt domes and areas of oil and gas exploration and production. Discrimination between background and gas potentially related to cavern collapse is complicated in those areas where both could potentially be present. MRAA gas identified in Plate 2 over most of the area shown could be related to the cavern collapse or could be related to prior oil and gas exploration and production or could be present from natural seepage over thousands of years. No pathways for gas shown south of the Bayou Corne community and east of Grand Bayou are evident due to distance from the sinkhole and depth of the MRAA; any gas in this area is considered unrelated to the cavern collapse.

No natural pathway related to the Oxy 3 cavern collapse can explain gas found in the aquitard above the MRAA in less than a year. Clay and silty/sandy clay strata separate the gas bearing sand layers within the aquitard from the thin gas cap at the top of the MRAA. The continuity of the low permeability strata separating sand layers and lenses in the aquitard are illustrated in Plate 3. Geologic interpretations of CPT soundings are shown for a north – south cross section though the Bayou Corne community in Plate 3. Modeling analysis presented to LDNR (*Preliminary Modeling Results at the Napoleonville Salt Dome in Bayou Corne, LA to Assess Gas Cap Evolution and Migration*, Tetra Tech, July 12. 2013 indicated very long transit times for gas migrating upward through a thin clay layer. Further, a pump test conducted at ORW-41 showed no response across the ten foot clay layer separating ORW-39 from ORW-41 (Tetra Tech Technical Memorandum, *ORW Enhanced Methane Recovery Pilot Test Program Report* November 26, 2013). Based on the continuity and extent of clay and silty/sandy clay strata overlying the MRAA and the low permeability of these strata, gas found in the aquitard is background gas.

6.0 REPORTING SCHEDULE FOR NEW DATA

CPT soundings will be conducted as part of the operation and monitoring phase for gas venting. A plan for this program is under development and will be submitted to LDNR by January 13, 2014. The plan will provide for repeat soundings at relief well locations as they progress from venting to monitoring phase status, and on a six month schedule for any wells that are venting. The first series of repeat soundings will be conducted during the month of March 2014. CPT data will be submitted to LDNR after each sounding is completed in accordance with current procedure.

PLATES

Name: Plate 1 MRAA Elevation 21031213

0 250 500 1,000 1,500 2,000 Feet

Contour interval (5 ft) represents elevation with respect to Mean Sea Level [North American Vertical Datum,1988 (NAVD88)].

TITLE: Elevation of the MRAA
December 13, 2013

LOCATION: Napoleonville Salt Dome Project
Bayou Corne, Louisiana

TETRA TECH

APPROVED
DRAFTED
PROJECT#
DATE 12/13/2013

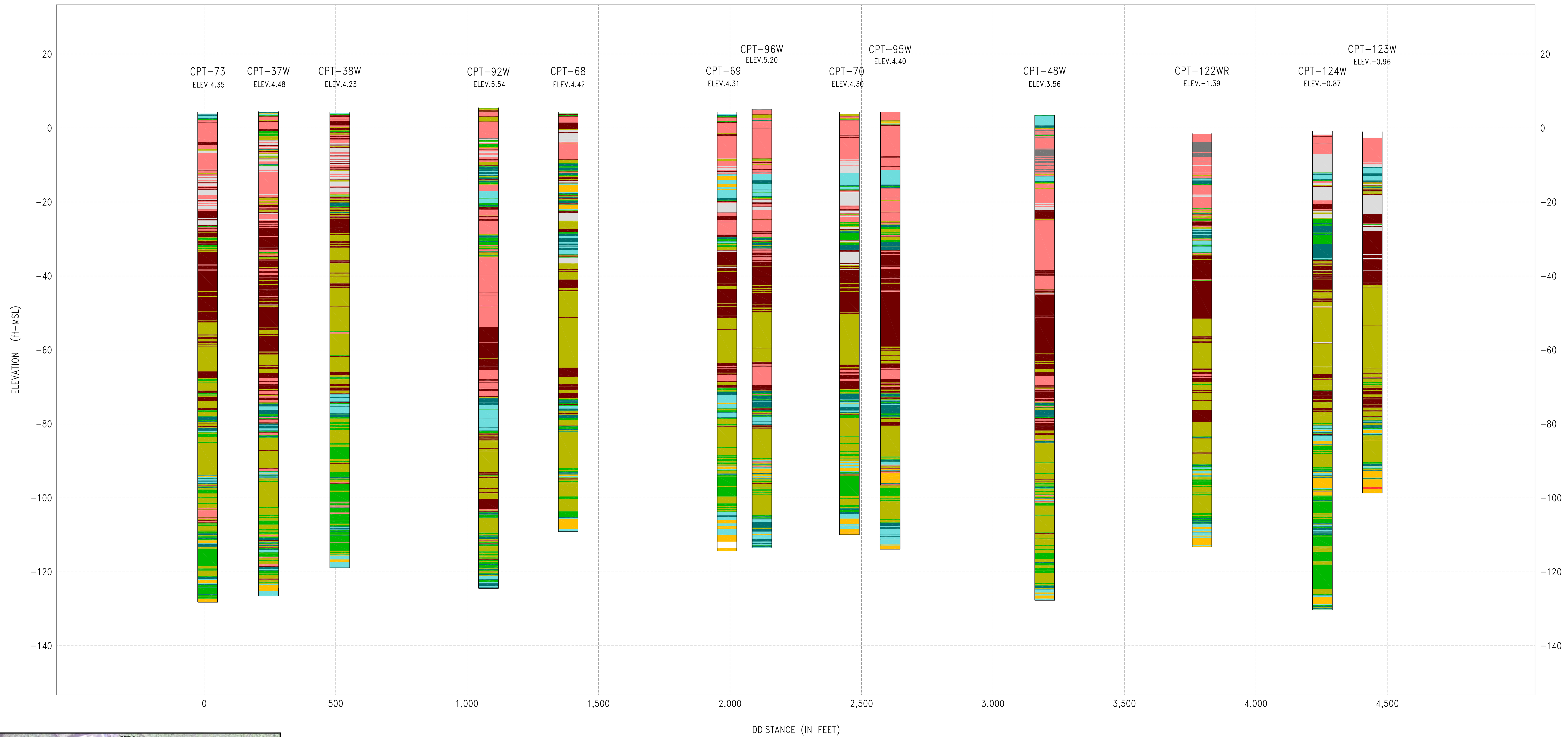
1

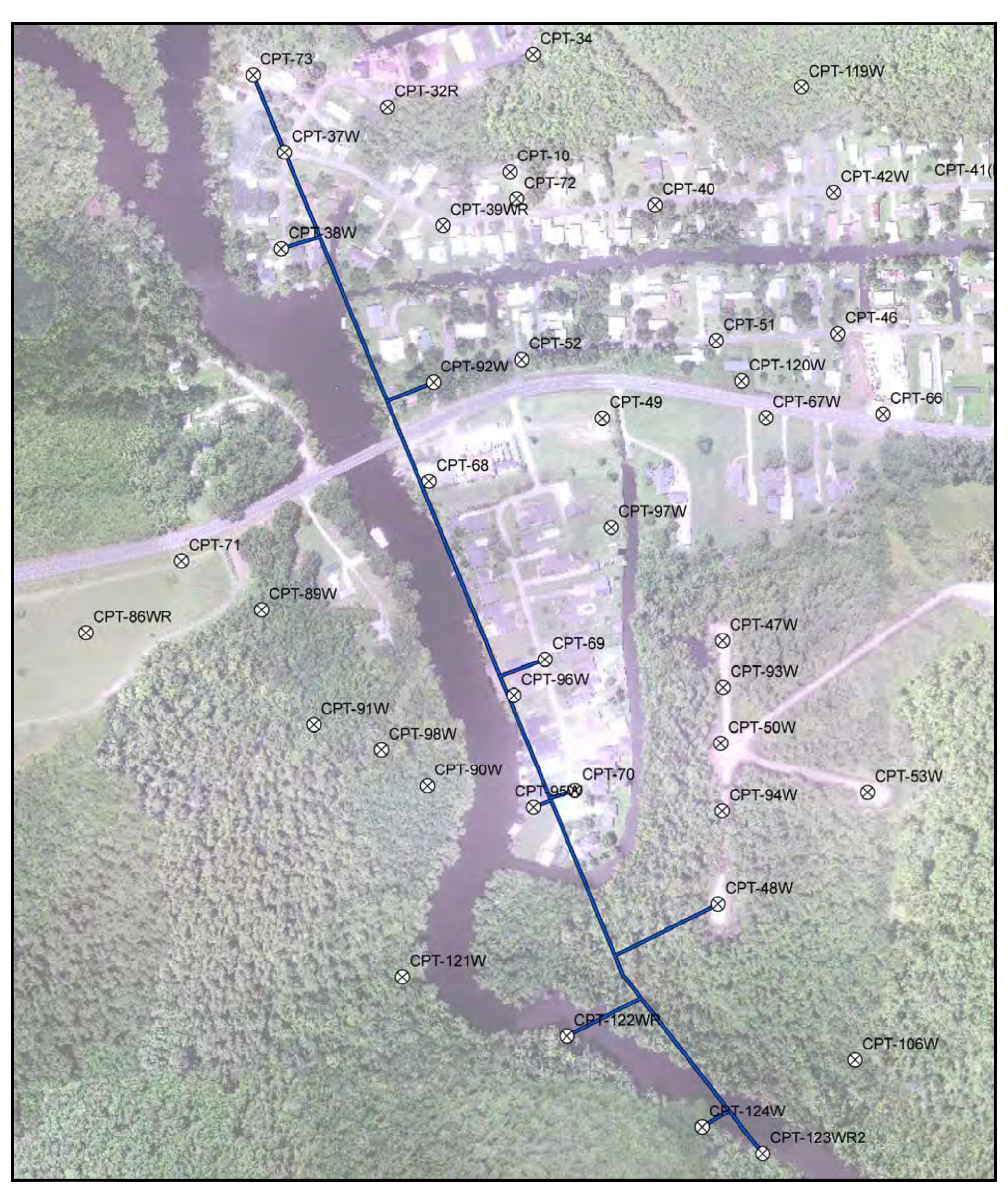
Name: Plate 2 MRAA gas zone thickness 21031213

0 250 500 1,000 1,500 2,000 Feet

Gas thicknesses shown represents the estimated gas thickness present in the formation at the time the CPT sounding was completed in that area. Current gas thickness will be less due to gas venting subsequent to the completion of the CPT soundings.

TITLE:	MRAA Gas Zone Thickness December 13, 2013
LOCATION:	Napoleonville Salt Dome Project Bayou Corne, Louisiana
TETRA TECH	APPROVED DRAFTED PROJECT# DATE 12/13/2013
	2





CROSS SECTION LOCATION MAP

CPT MATERIAL GRAPHICS

- sensitive fine grained
- organic material
- clay
- silty clay to clay
- clayey silt to silty clay
- sandy silt to clayey silt
- silty sand to sandy silt
- sand to silty sand
- sand
- gravelly sand to sand
- very stiff fine grained (*)
- sand to clayey sand (*)

Robertson et al (1986) qt vs Rf - MAI = 1

TITLE:	CPT CROSS SECTION THROUGH THE COMMUNITY (NW-SE)		
LOCATION:	Napoleonville Salt Dome Project Bayou Corne, Louisiana		
TETRA TECH	APPROVED	CF	PLATE
	DRAFTED	HP/CP	3
	PROJECT#	117-0504124	
	DATE	12-18-13	

FIGURES

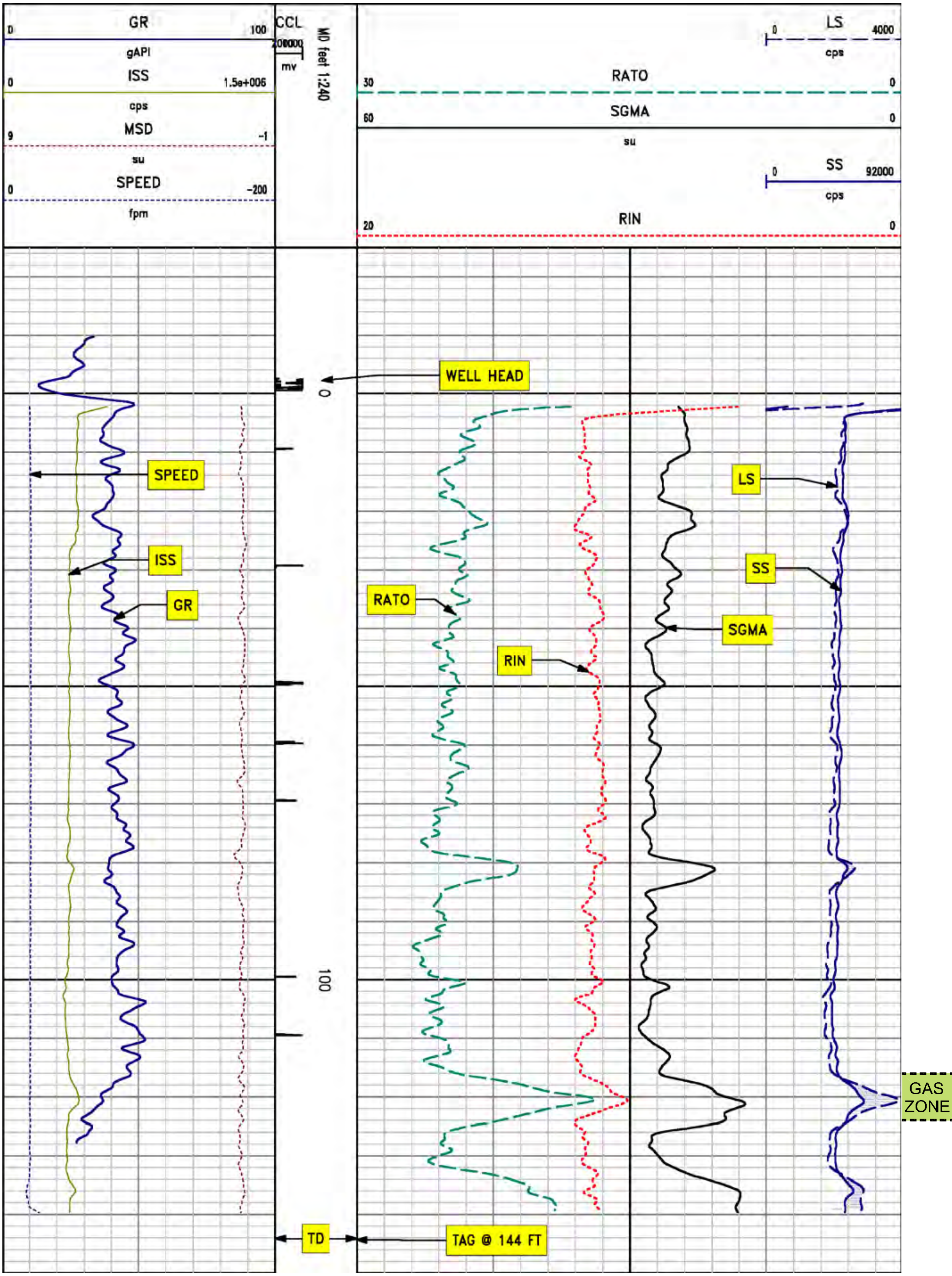


Figure 1. PDK log for ORW-42 showing inferred gas interval at top of MRAA.

TETRA TECH

P:\ACAD\0504-124-BAYO\0504124073A.DWG

P:\ACAD\0504-124-BAYO\0504124076A.DWG

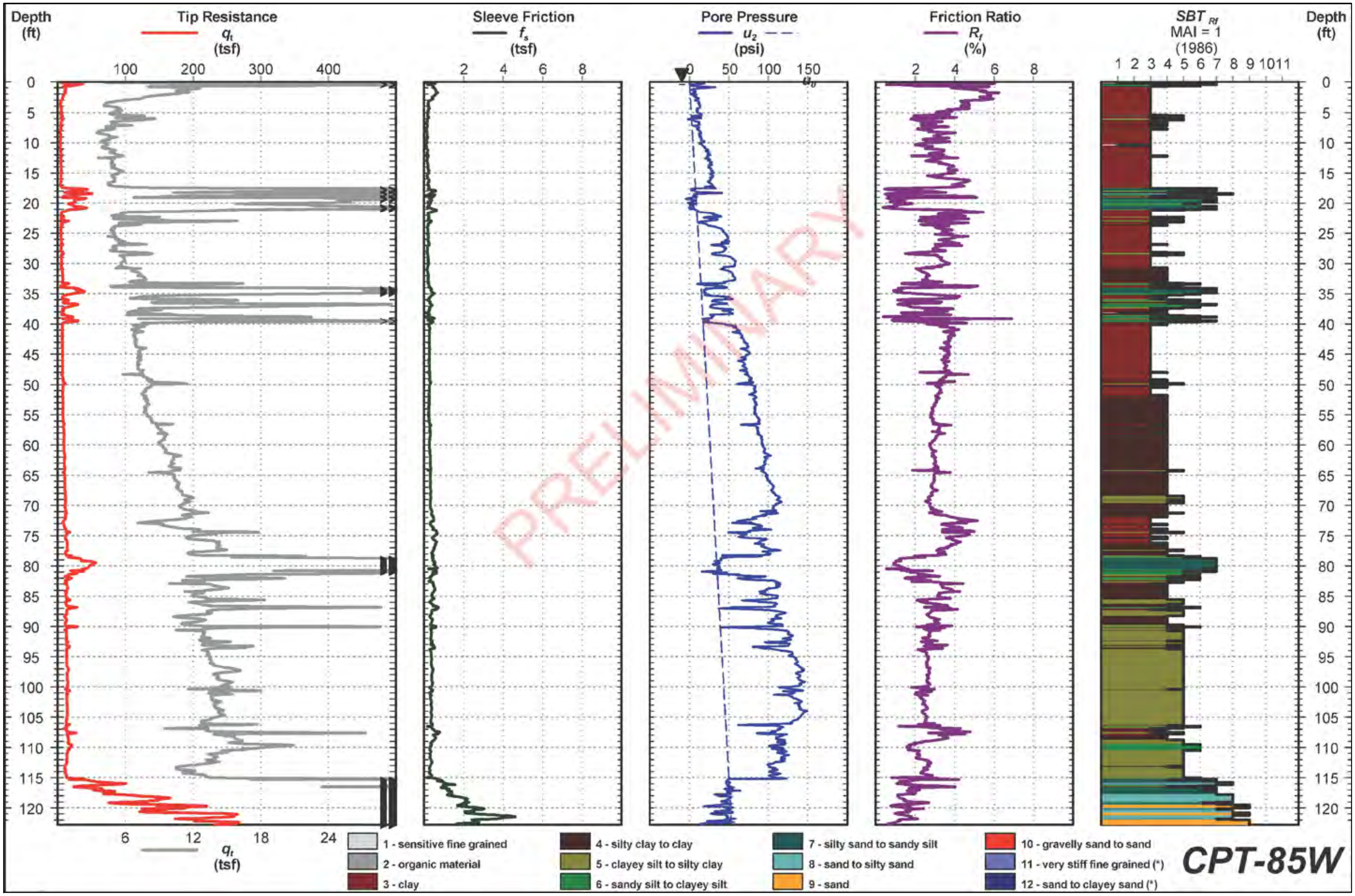
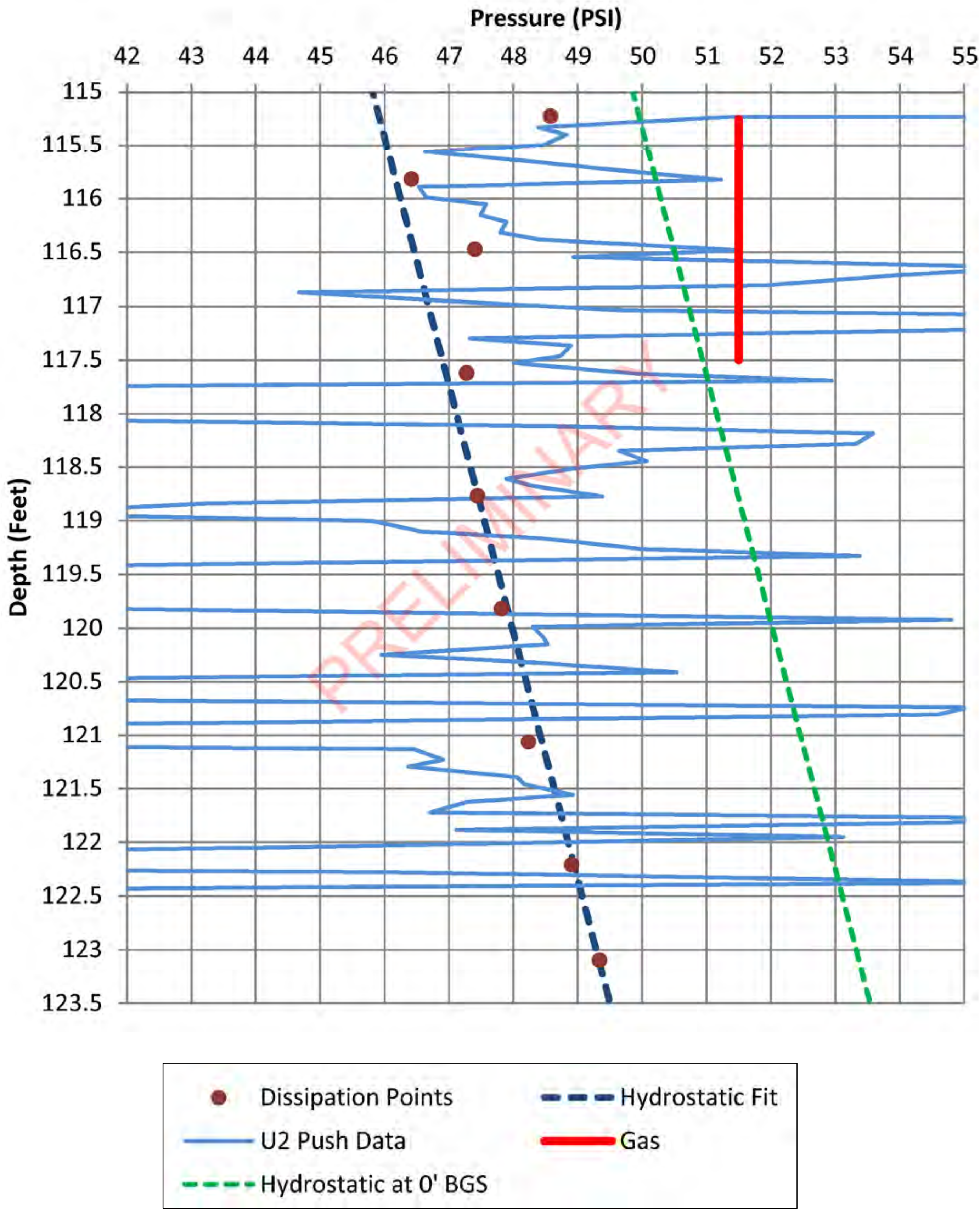


Figure 2. Summary plot of CPT-85 cone penetration test, near ORW-42.

TETRA TECH



P:\ACAD\0504-124-BAYO\0504124075A.DWG

Figure 3. Dissipation points and interpretation of gas at top of MRAA for CPT-85W, near ORW-42.

TETRA TECH

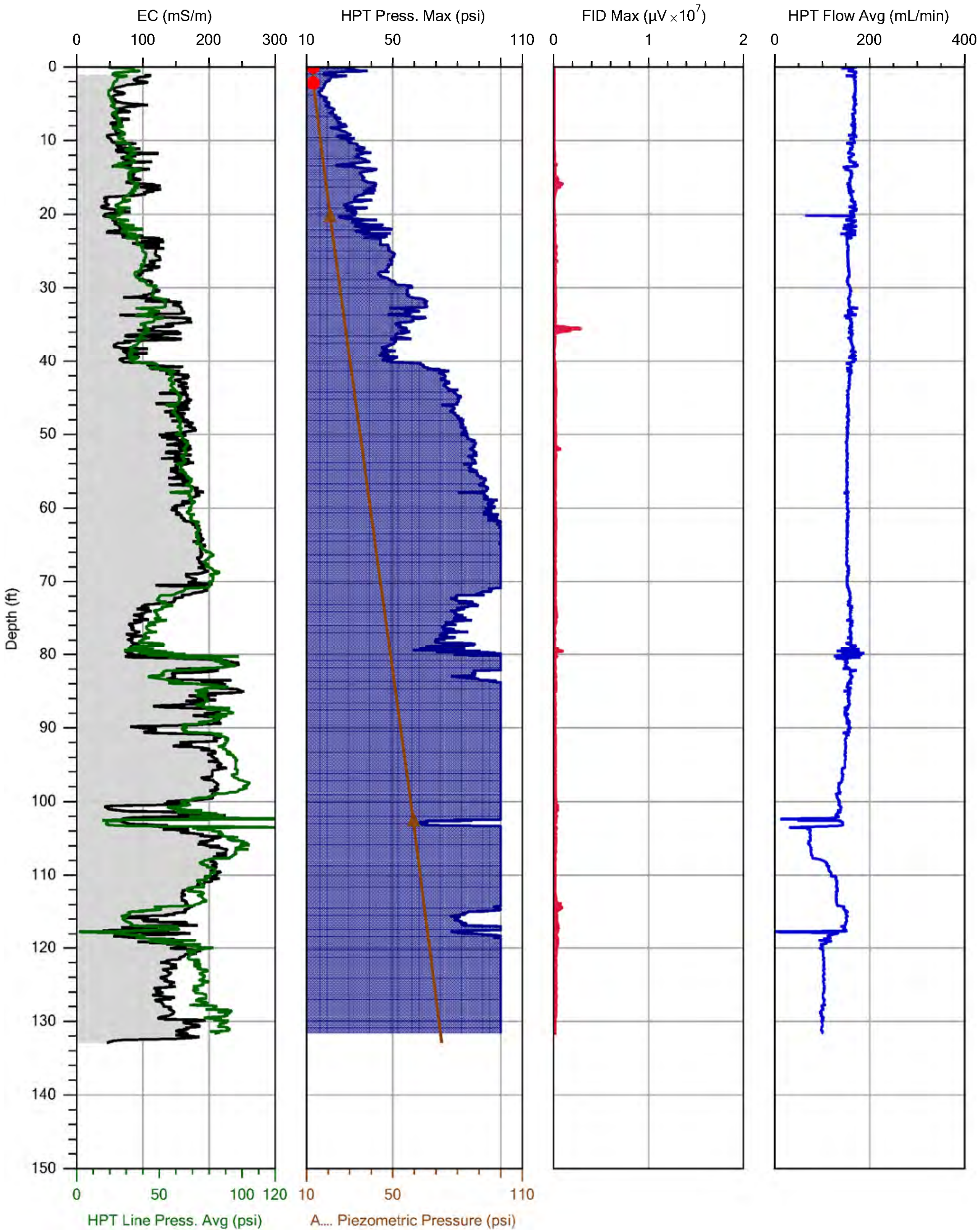


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Figure 4. Summary results of MiHPT testing MiHPT 011, near ORW-42.

TETRA TECH

TABLES

Table 1. Comparison of Investigation Methodologies.

Investigation Methodology	Benefits	Limitations
PDK	• Identifies gas bearing intervals and qualitatively characterizes gas saturation • PDK logs taken at different times can illustrate gas depletion adjacent to a well • Logging depth is typically 15-20 ft below the MRAA in most Site wells (total log depth access is 8 ft above total well depth) • Minimal risk for loss of well control	• High associated costs as an investigation tool, including road and pad building and well installation • Poor resolution of strata and gas zones thinner than approximately three feet
CPT	• Provides representative and defendable geologic stratigraphy with resolution down to approximately inch-thick layers • Provides accurate and precise soil pore pressure measurements • Identifies gas bearing intervals and qualitatively characterizes gas saturation • Data interpretation can positively identify producible gas zones • Portable and accessible to both terrestrial and aqueous applications • Small profile borehole, causes less subsurface disturbance	• Poor tool penetration in dense MRAA sands • Requires significant operator training to identify where and how to collect real time dissipation tests • Moderate risk for loss of borehole control during advancement and one-pass grouting on the trip out • Less effective on gas zones thinner than 6 inches • Sounding deviations from vertical are common and will bias measurement depths slightly deeper
MiHPT	• Identifies intervals containing some amount of methane in solution or free gas • Actual in-situ methane molecules can be captured anywhere present during the push and subsequently tested analytically, including fingerprinting for thermogenic or biogenic origins • Portable and accessible to both terrestrial and aqueous applications • Small profile borehole, causes less subsurface disturbance	• Does not quantify the relative amount or thickness of producible methane • HPT water injection impacts in-situ pore pressures qualifying results from any subsequent pore pressure dissipation test • Technology with the lowest MRAA penetration depth capability tested • Moderate risk for loss of borehole control during advancement and one-pass grouting on the trip out • Sounding deviations from vertical are common and will bias measurement depths slightly deeper

Table 2. Kriging Parameters Used in Preparation of Maps

Subject	Plate	Variogram Model	Range	Nugget	Partial Sill	Points
MRAA Elevation	1	Spherical	1000	1	9.61	12
MRAA Gas Bearing Zone Thickness	2	Spherical	800	1	5.18	12

Table 3. CPT Gas Zone Summary.

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-01		4/23/2013	ORW-27	1.21	155.9	140	--	--	--	--
CPT-02		5/7/2013	ORW-5	2.11	134.1	130	--	--	101 - 102	130.5 - 131
CPT-03		5/9/2013	ORW-14	5.75	140.0	134	--	89-93	111-114.5	135-140
CPT-04		5/13/2013	ORW-33	-0.42	146.4	142	--	--	--	143.5 - 144
CPT-05		5/14/2013	ORW-13	5.55	153.7	145	--	--	135.6 - 135.8	--
CPT-06		5/16/2013	ORW-31	4.04	134.6	127	--	78.0 - 79.5	124.9 - 125.2	--
CPT-07		5/24/2013	ORW-11	3.35	130.8	129	20.3 - 23.3	--	100.5 - 102.5	130.2 - 131+
CPT-08		5/28/2013	ORW-2	4.40	117.3	--	19.0 - 19.7	--	110.3 - 113.3	--
	8R	8/16/2013	ORW-2	4.40	129.1	126.5		98.0-98.9	111.3-111.5	--
CPT-09		5/29/2013	OXY LA-15S	0.62	110.3	--	34 - 35	110+	--	--
	9R	9/5/2013		--	112.8	--	--	--	--	--
CPT-10		5/30/2013	BC-2 North 75 ft	3.60	125.9	124	17. 5- 18.5	--	107.7 - 110.3	124.0 - 125.9
CPT-11		6/6/2013	ORW-1	3.87	129.8	129		98.9 - 99.9	126.1 - 126.8	--
CPT-12		6/7/2013	Cell Tower Rd, south of 3	3.53	127.9	127	--	--	118.9 - 119.1	127.8 - 127.9+
CPT-13		6/8/2013	Cell Tower Rd, center of 3	6.78	134.7	129	--	--	--	--
CPT-14		6/9/2013	Cell Tower Rd, north of 3	7.52	133.2	132	--	--	--	--
CPT-15		6/10/2013	B-10	5.06	117.0	--	--	--	--	--
	15R	9/3/2013			151.0	143.5	--	--	--	--
CPT-16		6/11/2013	B-11	3.10	138.0	136	--	--	--	138.0 - 138.5
CPT-17		6/12/2013	~200' NNW ORW-22	3.56	125.2	124.5	--	--	121.1 - 122.0	--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-18		6/13/2013	OXY LA-15N	-0.10	141.6	141	--	--	--	141.5+
CPT-19		6/14/2013	~600' NNW ORW-22	2.71	128.3	127	--	--	--	--
CPT-20		6/17/2013	~500 ft N ORW-23	1.31	125.7	124.5	--	--	--	--
CPT-21		6/17/2013	~750 ft NE of ORW-24	1.46	133.5	131.5	--	--	--	--
CPT-22		6/18/2013	N Access Rd Pad to S.H.	3.19	134.9	133.5	--	105 - 106.5	123 - 125	--
CPT-23		6/19/2013	Between Pad 2 and Pad 3	5.63	116.5	--	--	--	--	--
	23R	8/29/2013	Between Pad 2 and Pad 3	5.63	133.7	132	--	--	--	132-133.3
CPT-24W		6/19/2013	NW Corner TBC Ops	4.90	116.0	111	--	--	--	--
	24WR	8/28/2013	NW Corner TBC Ops	4.90	115.3	111	--	--	--	--
CPT-25W		6/20/2013	B-3	4.41	135.7	128.5	--	--	119 - 119.7	133.5 - 134.5
CPT-26		6/20/2013	B-2	4.58	133.8	132	37.0 - 38.9	--	118.4 - 120.0	130.6 - 131.4
CPT-27		6/21/2013	B-4	6.61	133.6	131	--	--	--	132.5 - 132.7
CPT-28		6/22/2013	ORW-16	4.76	131.0	130	20 - 21	--	94.1 - 94.6	131+
CPT-29		6/23/2013	GEO-1	6.15	132.1	131	--	62-62.6	--	131.6+
CPT-30		6/24/2013	On berm next to TBC Pond	4.70	115.1	--	--	--	--	--
	30R	8/26/2013	On berm next to TBC Pond	4.70	144.0	144.7	--	--	--	--
CPT-31W		6/24/2013	ORW-8	2.19	133.1	125	--	--	--	--
CPT-32		6/25/2013	Crawfish Stew St East	1.52	123.6	122	--	--	98.9 - 99.3	--
	32R	8/30/2013	Crawfish Stew St East	1.52	132.6	123.5	--		98-99.2	123.9-124.2
CPT-33-W		6/25/2013	ORW-7	1.80	137.3	133	--	--	--	--
CPT-34		7/3/2013	Crawfish Stew St. North end	1.90	127.0	124	26.2-27.0	--	--	--
CPT-35W		6/26/2013	Corner of circle on Crawfish Stew St NE	2.45	127.8	124	--	--	109 - 109.2	--
CPT-36W		6/27/2013	Northern end of Crawfish Stew St	3.50	128.4	125	--	--	--	--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-37W		6/28/2013	Crawfish Stew St NE	4.48	131.0	128	--	--	--	--
CPT-38W		7/1/2013	Crawfish Stew St. South end	4.23	123.1	121	--	--	--	--
CPT-39WR		7/8/2013	Sauce Piquante - West end	3.99	127.6	124	26.9-28.1	--	--	--
CPT-40		7/8/2013	Sauce Piquante - Middle	3.71	131.1	127.5	--	--	--	--
CPT-41		7/11/2013	Sauce Piquante- West	3.56	126.0	122	23.9-24.1	--	80.9-81.2	122.3-122.9
CPT-42W		7/9/2013	Sauce Piquante - Middle	4.05	131.1	128	24.7-25.0	--	--	--
CPT-43W		7/10/2013	Intersection of Maurice Rd & Flare	3.54	136.1	133	--	--	--	--
CPT-44WR		7/13/2013	Jambalaya St. East End	4.43	126.5	123.5	--	--	123.9-124.5	126.2-126.5
CPT-45W		7/12/2013	Jambalaya St. East End	4.16	133.4	129.5	--	--	78.0-78.5	--
CPT-46		7/12/2013	Jambalaya St. Middle	4.35	132.6	129	24.0-25.0	--	--	--
CPT-47W		7/13/2013	ORW-17	3.23	131.1	128	--	--	--	--
CPT-48W		7/14/2013	ORW19	3.56	131.3	128	--	--	--	--
CPT-49		7/14/2013	ORW-37	4.75	129.8	124.5	--	--	115.0-116.3	124.5-125.0
CPT-50W		7/15/2013	ORW-18	3.13	131.9	129	--	--	109.7-110.3	--
CPT-51		7/15/2013	Jambalaya St. Middle	4.47	129.8	129	--	--	--	--
CPT-52		7/16/2013	Jambalaya St. West	4.52	127.2	126.5	--	110.6-111.4	122.1-122.6	--
CPT-53W		7/16/2013	ORW-10	3.87	131.7	128	--	--	--	--
	53WR	7/22/2013	ORW-10	3.87	133.2	125.5	--	--	--	125.5-126.5
CPT-54		7/17/2013	ORW-15	3.48	131.7	130	--	--	96.1-96.4	--
CPT-55		7/18/2013	ORW-6	3.76	130.2	123	--	--	--	123-126
CPT-56		7/24/2013	ORW-30	3.91	129.6	126.5	--	--	--	--
CPT-57			ORW-26	3.98	129.5	123.5	--	95.8-96.8	--	124.7-125.7
	57R	8/13/2013	ORW-26	3.98	130.7	128	--	--	--	--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-58		7/26/2013	ORW-4	3.06	133.8	131.5		89.9-91.6	99.8-100	--
CPT-59		7/28/2013	ORW-32	4.62	126.2	125.5	--	--	--	--
CPT-60		7/29/2013	ORW-29	4.79	128.9	128	--	--	--	--
CPT-61R	61R	8/1/2013	ORW-24	4.69	126.8	124	--	--	--	--
CPT-62R	62R	9/11/2013	ORW-23	4.21	126.6	125.5			113.8-114	125.6-126.1
CPT-63		7/8/2013	ORW-22	4.08	124.6	123.5	--	112.9-113.2	121-121.3	--
CPT-64		8/12/2013	Between ORW-5 and ORW-9	6.45	137.0	136	--	100-100.8	--	--
CPT-65W		7/23/2013	ORW-9	3.60	129.5	123.5	--	--	95.8-96.8	124.7-125.2
CPT-66		9/10/2013	~Midway between ORW-16 and ORW-37 along HWY 70	5.14	133.7	132.5	22.2-22.5	--	--	--
CPT-67W		9/10/2013	~150 ft north northeast of ORW-37	3.70	125.2	119	--	--	--	120-123.2
CPT-68		8/25/2013	ORW-36	4.42	113.6	110	--	--	110.0-113.6	--
CPT-69		8/22/2013	134 Sportsman's Drive	4.31	132.6	108.3	--	95.8-98.4	--	108.3-117.3
CPT-70		8/21/2013	144 Sportsman's Drive	4.30	114.3	108.3	--	--	--	108-114.3
CPT-71		8/9/2013	ORW-46	3.89	129.5	125	13.7-14	--	108.5-111	125-125.2
CPT-72		8/20/2013	Near ORW-38	4.06	127.4	125	--	--	--	--
CPT-73		8/19/2013	ORW-21	4.35	132.6	131	--	110.2-110.5	115.3-117.0	--
CPT-75		9/16/2013	~1400 North of HWY 70, along access road to Crosstex Property.	3.20	130.7	130	--	--	--	--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-76W		9/5/2013	700 north of HWY70, 1600 ft east of ORW-28	3.41	129.9	124	--	--	--	--
CPT-77W		9/6/2013	~50 ft north of HWY 70, 700 ft east of TBC Access Road	3.58	136.9	134	--	--	--	--
CPT-78W		9/20/2013	~800 ft south of HWY 70, ~400 ft east of Texas Brine Access Road (near southwest corner of rectangular pond)	2.75	145.0	144	--	--	--	144.2-144.6
CPT-79W		9/19/2013	~1200 ft south of HWY 70, ~500 ft west of Grand Bayou	2.69	142.5	138	--	--	--	138.2-138.4
CPT-80W		9/18/2013	~800 ft northeast of ORGW-1	2.96	145.7	140	40.4-40.6	--	--	144.4-144.9
CPT-81		9/6/2013	~1200 feet east of OGRW-1. 170 ft west of Grand Bayou	3.17	140.0	135	--	--	--	--
CPT-83W		9/22/2013	~200 ft north of HWY 70, 900 ft west of Grand Bayou	2.89	148.0	144	--	--	--	--
CPT-84		8/6/2013	225' south of ORW-16	4.16	133.3	130.5	--	--	--	131.0-131.5
CPT-85R	85R	8/7/2013	300' southwest of ORW-29 near LA 70	3.94	120.6	116.5	--	79-79.7	--	116.7-119.3
CPT-85W		9/23/2013	300' southwest of ORW-29 near LA 70		122.8	116.5				115.2-117
CPT-86R	86WR	8/26/2013	~100 ft west of Bayou Corn, ~200 ft south of HWY 70	3.67	131.6	126	--	--	--	--
CPT-87		8/25/2013	CPT-3	3.24	127.2	125.5	--	96.0-96.9	--	--
	87R		CPT-3	3.55			--	--	--	--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-88W		8/20/2013	~500 ft east of east edge of sinkhole	3.29	133.7	132	--	60.2-60.6 & 110.7-111.3	129.25-131.25	133-133.7
CPT-89W		9/11/2013	~600 feet south of HWY 70; 75 feet west of Bayou Corne	1.66	110.6	106.5	--	--	--	107-111
CPT-90W		9/30/2013	ORW-53	3.34	121.7	110	--	--	--	110.8-113.8
CPT-91W		10/1/2013	ORW-52	3.63	116.6	111	--	92.5-93.7	107.6-108	111-114.5
CPT-92W		9/24/2013	~100 ft north of HWY 70, 250 ft east of Bayou Corne	5.54	130.1	127	22.8-23.1	109.6-110.5	115.8-118.2	--
CPT-93W		10/14/2013	Mid-point between ORW-17 & -18	3.65	130.7	126	--	--	--	--
CPT-94W		10/15/2013	Mid-point between ORW-18 & -19	2.95	129.5	126	--	--	--	126.5-127
CPT-95W		10/23/2013	144 Sportsman Drive	4.36	118.3	111	--	--	--	111.3-116
CPT-96W		10/22/2013	134 Sportsman Drive in the backyard	5.20	118.8	110	--	--	95-95.7	110.8-117
CPT-97W		10/17/2013	121 Sportman's Drive in the backyard	4.54	129.2	127.5	--	--	110.0-110.6	--
CPT-98W		10/16/2013	Mid-point between ORW-52 & -53	2.61	120.1	110-116??	--	--	--	--
CPT-99W		11/19/2013	Sauce Piquante 400 feet west of Gumbo St	--	126.8	123	--	--	--	--
CPT-100W		7/17/2013	400 feet west of Pad 10	-1.49	145.4	143	--	--	111.5-113	143-143.7
CPT-101W		7/18/2013	500 feet south of Pad 10	-0.77	148.1	146	--	--	--	--
CPT-102W		7/19/2013	700 feet southwest of CPT-16	-1.00	123.0	--	--	--		--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
	102WR	7/20/2013	700 feet southwest of CPT-16	-1.08	138.4	120	--	--	--	--
	102WRC	8/2/2013	700 feet southwest of CPT-16	--	121.8	122	--	--	114.9-116.4	--
CPT-103W		7/21/2013	600 feet southwest of ORW-5	-0.49	129.6	125	--	--	--	--
	103WR	8/1/2013	600 feet southwest of ORW-5	-0.21	128.3	127	--	--	--	--
CPT-104W		7/27/2013	850 feet west of ORW-5	-0.63	96.5	--	--	--	--	--
	104WR	8/3/2013	850 feet west of ORW-5	-0.56	129.5	125	--	107.9-108.5	123.5-124.5	--
CPT-105W		7/28/2013	850 feet west of ORW-7	-1.21	127.3	127	43.6-44.1	44.4-44.9	--	--
CPT-106W		7/29/2013	1525 feet west of ORW-7	-0.79	126.5	124	--	--	124.1-125.2	125.8-126.4
CPT-107W		7/31/2013	3150 feet southwest of ORW-5	-1.77	113.3	108	--	--	--	108-113.5
CPT-108W		7/30/2013	3850 feet southwest of ORW-5	-0.80	129.7	129.6	--	94-94.5 95.1-95.5	107.5-107.8 111-111.5	--
CPT-109W		8/17/2013	~75 feet north of HYW 70 and 400 feet west of Texas Brine Access Road	3.35	136.3	115.7119	--	--	115.7-119--	115.70-123.0
CPT-110W		8/12/2013	700 feet northwest of ORW-22	-2.65	125.3	123	--	--	--	--
CPT-111W		8/13/2013	500 feet west of CPT-110W	-0.80	123.0	122	--	--	--	--
CPT-112W		8/14/2013	~400 feet west of CPT-111W	-1.27	76.8	--	--	--	--	--
	112WR	8/15/2013&	~400 feet west of CPT-111W	-1.27	123.7	120	--	101.2-102.2	103.5-105.5	--
CPT-113W		8/17/2013	~1600 feet north of HWY 70 and ~500 feet east of the eastern arm of Bayou Corne	-0.94	125.9	123	--	--	--	--
CPT-114W		8/27/2013	~1200 feet north of HWY 70 and 500 feet east of east arm of Bayou Corne	-1.51	124.3	120	25.6-26.1 28.4-29.5	89.7 (very thin)	112.1-112.5	--

Boring No.	Re Push	Date Installed	Location Description	Surface Elevation (FT, NAVD 88)	Depth of Boring (FT BGS)	Top MRAA (FT BGS)	Noted Gas Zones (FT BGS)			
							Shallow	Intermediate		MRAA
CPT-115W		8/26/2013	~2400 feet north of HWY 70 and ~100 ft west of an eastern arm of Bayou Corne	-0.86	136.5	134	--	--	--	--
CPT-117W		8/17/2013	~250 feet south of HWY 70, 150 feet west of Grand Bayou	1.78	167.8	165	--	--	--	--
CPT-118W		8/7/2013	970 feet west of ORW-14	0.04	128.1	126	17.5-18.5	--	123.2-125.2--	123.25-128.2
CPT-119W		8/16/2013	400 ft north northwest of CPT-42W	-0.82	125.5	122	--	--	--	--
CPT-120W		11/18/2013	"~ 175 feet northeast of ORW-37	--	127	124	--	--	118-118.2	--
CPT-121W		11/21/2013	~ 850 feet west of ORW-19 on the west side of Bayou Corne	--	114.2	108	--	--	--	107.8-109
CPT-122W		11/22/2013	~550 feet southwest of ORW-19 on the west side of Bayou Corne	--	112.6	103.5	--	--	--	103.5-109.5
CPT-122WR		12/3/2013	~550 feet southwest of ORW-19 on the west side of Bayou Corne	--	111.9	106			89.5-93	106-112
CPT-123W		11/22/2013	~725 south of ORW-19 on the west side of Bayou Corne	--	97.8	~90	--	--	--	--
CPT-123WR2		12/3/2013	~725 south of ORW-19 on the west side of Bayou Corne	--	129.4	~125	--	--	--	--
CPT-124W		12/3/2013	~725 south of ORW-19 on the west side of Bayou Corne		129.4	~125	--	--	--	--

Table 4. Pre- and Post--CPT Gas Production.

Recovery Well	CPT Sounding	Pre-CPT Installation Gas Production (MCF)	Post-CPT Installation Gas Production (MCF)	Total Gas Produced (MCF)	12/11/2013 Flow Rate (MCF/D)
OGRW-01	CPT-88W	3368.9	1293.5	4662.4	12.2
ORW-01	CPT-11	1088.8	0.3	1089.1	0.0
ORW-02	CPT-8	1679.8	0.0	1679.8	0.0
ORW-04	CPT-58	863.9	113.7	977.5	0.6
ORW-05	CPT-2	984.6	41.7	1026.3	0.0
ORW-06	CPT-55	926.0	134.8	1060.8	0.4
ORW-07	CPT-33W	56.7	0.0	56.7	0.0
ORW-08	CPT-31W	149.3	0.0	149.3	0.0
ORW-09	CPT-65W	1031.2	4.5	1035.7	0.0
ORW-10	CPT-53W	528.3	32.7	561.0	0.0
ORW-11	CPT-7	111.6	0.0	111.6	0.0
ORW-13	CPT-5	0.1	1.1	1.2	0.0
ORW-14	CPT-3	978.2	489.3	1467.5	1.6
ORW-15	CPT-54	1379.6	92.9	1472.5	0.3
ORW-16	CPT-28	189.7	0.0	189.8	0.0
ORW-17	CPT-47W	50.6	0.0	50.6	0.0
ORW-18	CPT-50W	15.9	30.6	46.4	0.1
ORW-19	CPT-48W	154.7	36.8	191.5	0.1
ORW-22	CPT-63	1009.5	45.0	1054.5	0.2
ORW-23	CPT-62R	108.3	0.0	108.3	0.0
ORW-24	CPT-61R	218.7	59.3	278.0	0.5
ORW-26	CPT-57R	164.5	1.0	165.5	0.0
ORW-29	CPT-60	57.7	0.2	57.9	0.0
ORW-30	CPT-56	37.9	3.8	41.6	0.0
ORW-31	CPT-6	3.9	8.9	12.8	0.0
ORW-32	CPT-59	160.1	85.8	246.0	0.0
ORW-36	CPT-68	600.9	871.2	1472.1	8.8
ORW-37	CPT-49	124.2	121.8	246.0	0.1
ORW-38	CPT-10	0.0	1.4	1.4	0.0
ORW-39	CPT-25-W	0.0	100.7	100.7	0.4
ORW-40	CPT-26	0.0	49.5	49.5	0.0
ORW-41	CPT-25-W	0.0	0.2	0.2	0.0
ORW-42	CPT-85R	0.0	229.7	229.7	0.0
ORW-43	CPT-88W	0.0	12.6	12.6	0.0

Recovery Well	CPT Sounding	Pre-CPT Installation Gas Production (MCF)	Post-CPT Installation Gas Production (MCF)	Total Gas Produced (MCF)	12/11/2013 Flow Rate (MCF/D)
ORW-46	CPT-71	0.0	348.9	348.9	2.4
ORW-48	CPT-109W	0.0	427.8	427.8	6.7
ORW-49	CPT-95W	0.0	65.6	65.6	2.9
ORW-50	CPT-96W	0.0	91.3	91.3	9.0
ORW-52	CPT-91W	0.0	67.3	67.3	3.1
ORW-53	CPT-90W	0.0	42.6	42.6	0.7
ORW-54/ PMW-12S	CPT-85R	0.0	699.4	699.4	6.09
		Total	5,605.9	21,649.5	

Table 5. Post-CTP Recoverable Gas Volumes.

Area of Interest	Gas Zone Thickness (ft)	Recoverable Gas Volume* Millions of Cubic Feet
Scenario 1: Entire Site Including Statistical Uncertainty Zone	> 0.25	20.4
	> 0.50	18.9
	> 1.00	15.4
Scenario 2: Entire Site Excluding Statistical Uncertainty Zone	> 0.25	16.7
	> 0.50	15.2
	> 1.00	11.8
Scenario 3: Entire Site Excluding Area South of Sportsman's Landing	> 0.25	15.2
	> 0.50	13.7
	> 1.00	10.3
Volume Based Upon porosity - 25% recoverable gas - 50%		

Note: These volumes do not include the gas vented prior to CPT soundings

Appendix 5
Current Conditions Report, Bayou Corne Sinkhole, Assumption Parish, Louisiana

Current Conditions Report

Bayou Corne Sinkhole

Assumption Parish Louisiana

January 17, 2014

This report is being submitted in response to a request from Travis Williams of the Department of Natural Resources ("DNR"), Environmental Division. Mr. Williams is the Project Lead for DNR over the response to Oxy Geismar #3 sinkhole incident. The information provided in this document may be subject to the work product and other privileges. Disclosure of the information is made only under Texas Brine's obligations to supply information requested by designees of the Commissioner under the provisions of LAC 43:XVII:Sec 113. Disclosure of the information in this document is not intended to be a waiver of the right to assert any applicable privilege in any pending or future administrative or judicial action.

For organization and concision, the report is formatted to respond to each element of the request, in the order they occur in the document attached to Mr. Williams' electronic correspondence of November 11, 2013 which was entitled, *Request for Investigation Reports Addressing Outstanding Recommended Requirements and Current Status Document*. To protect content authenticity of each section and its respective author(s), subtle differences in formatting and writing style may be observed. Figures and tables referenced in the text appear in close proximity to the text in which they are referenced, and numbering is not serial throughout the document. As expected, there are certain conclusions, beliefs, and positions that remain speculative and, by virtue of litigation constraints, must be excluded from this report. Texas Brine welcomes this opportunity for cooperation with the BRC and we look forward to future opportunities for the exchange of information, ideas, and technology in this very challenging situation.

I. Cause of Oxy 3 Cavern Collapse

Texas Brine's legal counsel has retained a number of experts in the field of geology and related subspecialties who are investigating the cause of the formation of the sinkhole. The information gathered to date has not resulted in any conclusions as to the cause of this incident. The issue of causation is the subject of pending litigation. The information obtained by Texas Brine regarding the issue of causation will be disclosed pursuant to applicable privileges and limitations in the course of those proceedings.

II. Status of Collapse and Associated Stability Concerns

a. Interpretation and analysis of Oxy 3 cavern fill and pressure data and implications for cavern stability

The Oxy 3 cavern-fill assessment is based on well log data collected every two weeks. Two different logs, the Baker-Hughes PRAL™ and the TD Check Log, both suggest that, for all practical purposes, the cavern may be filled with material. Well depths for both logs are reported in total measured depth (TMD) along the Well 3A deviated well bore.

Recent Baker-Hughes PRAL™ logs performed on December 5th and 20th, 2013, and January 3rd, 2014, are shown in Figure PRAL. The PRAL™ logs recorded an abrupt density change from about 1.2 g/cm^3 (roughly that of brine) to 1.6-1.8 g/cm^3 at the cavern roof [approximately 3,636 feet total measured depth (TMD)]. This can be interpreted as the top of infill. The average density measured from the top of the cavern to the bottom of the logging interval is 1.69 g/ cm^3.

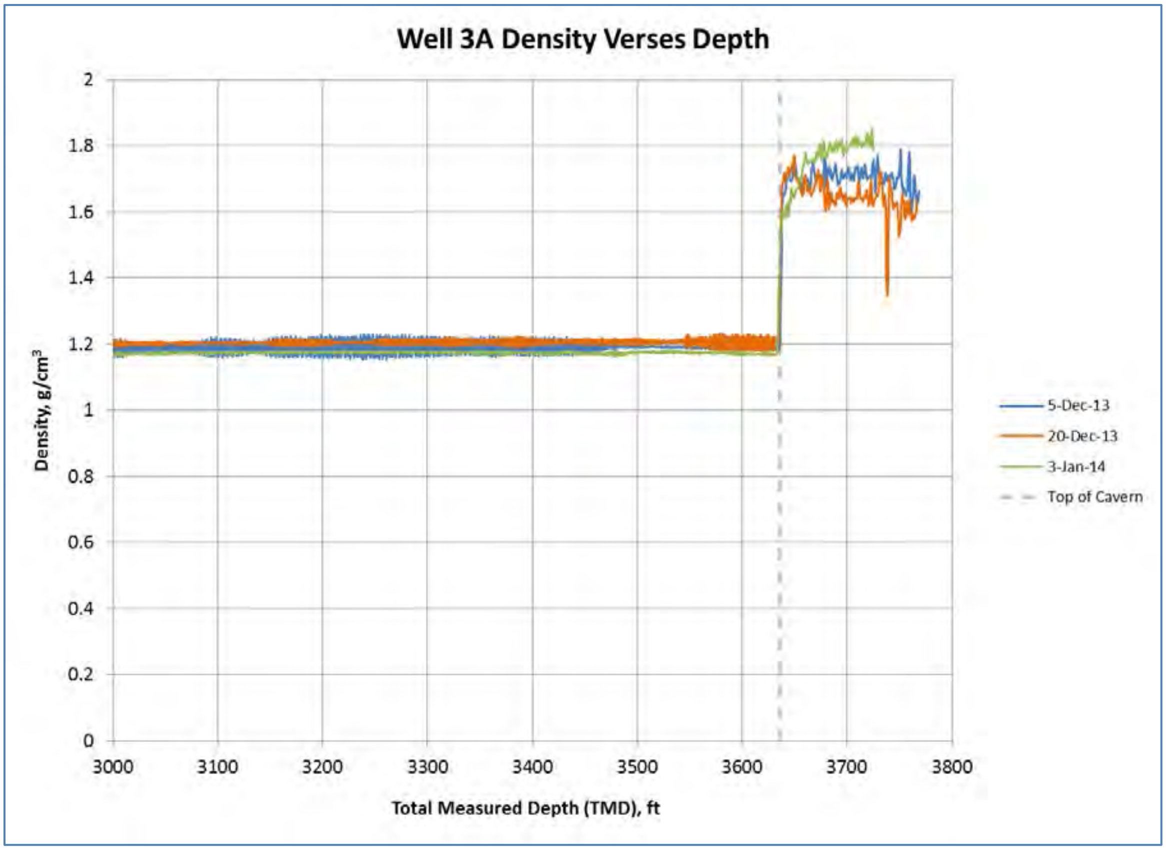


Figure PRAL. Recent Density versus Depth Logs from Well 3A. Logs indicate a sharp density increase at the top of the Oxy-3 cavern (3636 ft TMD).

There are no data confirming the density of the sediments at greater depths in the cavern, although it is reasonably hypothesized that the density of the sediments increases with depth but does not exceed the estimated in situ sediment density of about 2.6 g/cm^3 for the deep flanking deposits. The deeper cavern fill may have experienced a more modest bulking factor than the overlying slurry, but continued compaction of the cavern fill material is likely. The influence of ongoing compaction processes on cavern behavior may be evaluated using long-term wellhead/cavern pressure monitoring data if other controlling variables are constrained and independent corroborating evidence is available.

Logging deeper than 150' below the cavern roof with the Baker-Hughes PRAL™ tool has proven to be difficult. The tool becomes suspended in the dense material below the cavern roof. Baker-Hughes personnel are reporting that the fill material is also clogging the gradiometer, inhibiting the gradiometer's ability to detect a gradient and thus record density.

Density values that are returned by Baker-Hughes PRAL™ tool are of the material in direct contact with the tool. Unlike a gamma or sonic tool, the Baker-Hughes PRAL™ tool does not produce density data for surrounding material. Assuming that the density value at depth represents a homogeneous fill may be incorrect. Dense clays have been found stuck to the tool and various plant materials have been pulled up with the tool. The increasing difficulty of advancing the Baker-Hughes PRAL™ tool below the cavern roof, combined with the concern that the density data may not be an accurate representation of the overall fill material, renders PRAL logging unreliable and future PRAL logging unnecessary.

Whereas the Baker-Hughes PRAL tool has been able to penetrate the cavern infill material to relatively similar depths for successive runs, the TD check log's hard tag depth widely varies. The TD check log is essentially a weight on the end of a line and it only produces data when there is tension on the line applied by that weight. The inconsistent hard tags determined from depths at which tension decreases suggest that the fill material is not homogeneous. Figure HardTag [referenced in True Vertical Depth (TVD)] shows no consistent pattern or trend for depths where hard tag is found although the brine fill interface remains the same. The TD check log has been run with the same tool configuration and at the same speed since July 5, 2013 in order to limit the effects of variable technique and maximize log response to the infill materials in contact with the weight.

Figure HardTag.

Observations of the fill in the cavern are limited to samples pulled from the cavern via a bailer. Due to the size of pipe, the size of the bailer has been restricted. The opening on the bailer that collects the sample has been 2", limiting the samples to liquids and suspended solids. It is unknown whether there is conglomeratic material (i.e. coarse clasts within a finer-grained matrix) within the fill. Because clays have been observed stuck to the tool and plant materials have been pulled from the cavern, it is likely that similar infill materials are providing resistance to the downward movement of the sinker bar. Heterogeneity in the distribution of these clay materials may be responsible for the variability in the hard tag depths. The increase in hard tag depth in June 2013 may be due to density stratification of sediment-fluid mixtures in the cavern, allowing lower density, slurry-like mixtures to rise above heavier, sediment-dominated infill material.

Soft bottom, brine-slurry interface and hard bottom data trends suggest that the cavern is significantly infilled with sediment exhibiting heterogeneous density. A general prediction is that the Oxy 3 cavern will attain maximum stability once higher density materials fill the cavern to the roof line. Although the hard bottom data have been erratic, the data do suggest that there has been an increase in the elevation of the stiff sediment floor since at least July 2013. Recent, preliminary tagging results suggest the sediment is now very near the cavern roof, (Baker Hughes logged the well on January 16, 2014). The cavern will likely attain its maximum stability once that small remaining cavern volume is filled with denser material.

Pressure Data

Currently the Oxy 3a wellhead tubing and casing each have a continuously-recording pressure monitoring device. Figure Pressure shows a graph of the historical pressure record from January 2013 to the present. Blue represents the casing pressure at the wellhead, and red is tubing pressure. Pressure jumps may be attributable to sediment flowing into the cavern; however, field observations and wireline logs have demonstrated that the largest jumps in pressure typically correspond to migration of hydrocarbons into the casing. Hence, migration of sediment into the cavern may not be the prime influence on casing pressure.

The black data points in Figure Pressure are pressures measured at the casing shoe of the 7-inch string using the PRAL tool. In contrast to the striking variation in tubing and casing pressures measured at the wellhead, pressures at the casing shoe remain fairly constant. Because the tubing and casing pressures measured at the wellhead are affected by hydrocarbon movement into the wellbore, pressure data measured at the 7-inch shoe must be used to characterize the effects of cavern fill and other influences on cavern pressure.

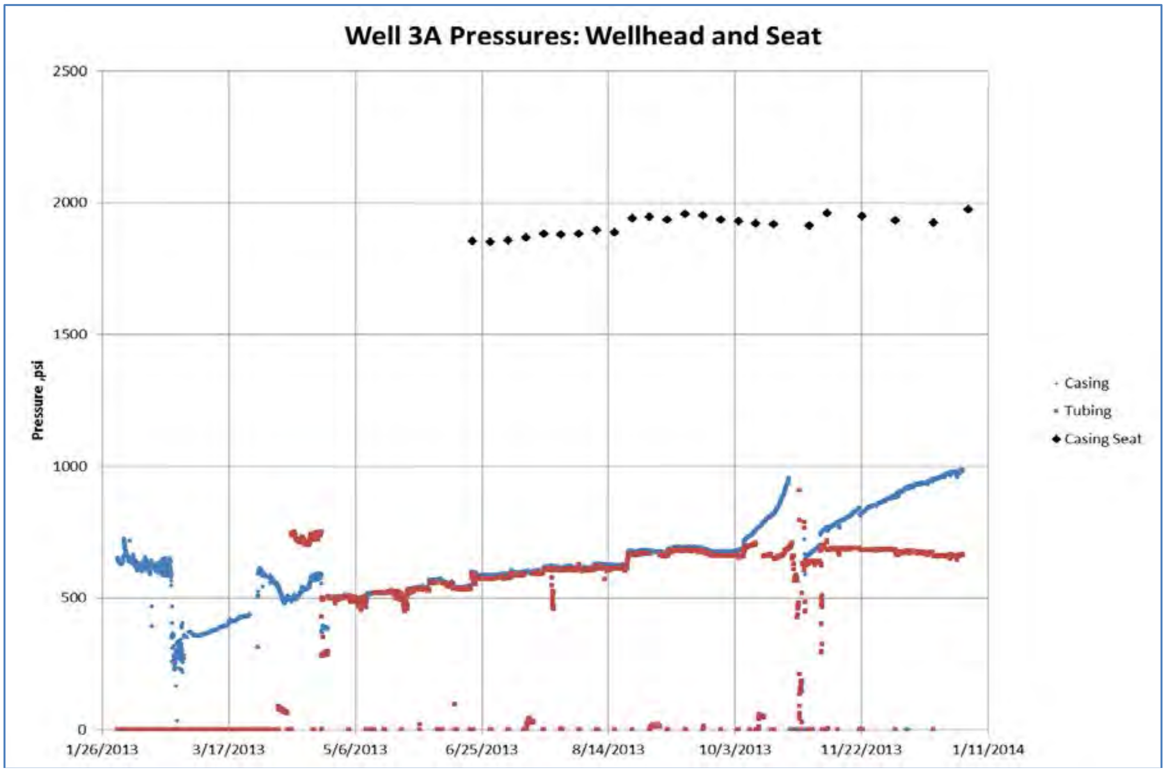


Figure Pressure. Casing and Tubing Pressure Measured at Wellhead 3A, and Borehole Pressure Measured at Casing Seat (2660' TMD).

b. Interpretation and analysis of ongoing micro earthquake and VLP activity including MEQ locations and an estimate of the magnitude

Seismic monitoring in Bayou Corne has been ongoing continuously since July 2012, starting about a month before the formation of the sinkhole in August 2012. The seismic monitoring capability has dramatically improved from the initial surface seismic array relied upon in 2012, to near-surface instruments in 80 foot boreholes in early 2013, to a fully buried array of sensors in the salt from 1000 to 3000 feet depth in October 2013. This high-sensitivity seismic monitoring system is capable of providing real-time warning of seismic activity that may portend instability in and around the TBC Cavern field.

The seismic signals recorded at Bayou Corne can be broadly be divided into two categories, high-frequency “sharp events”, also referred to as microearthquakes (MEQ) and Very Long Period (VLP) events. MEQ locations derived from the deep borehole seismic array data reveal two recent swarms of microseismicity since October 2013 in the near-surface environment (<600 ft) south of the sinkhole, in addition to microseismicity in and around the brine and storage caverns near the failed Oxy Geismar 3 cavern, and on neighboring solution and storage caverns west of the failed cavern. Background MEQ activity is associated with normal solution-mining activities. At this time, the microseismicity detected by the new borehole seismic array shows no anomalous pattern that suggests potential deep cavern-related subsurface instability. VLP activity, which has been likened by others to activity associated with movement of fluid magma in volcanic settings, was first observed after the formation of the sinkhole on the surface broadband seismic stations. Recorded VLP activity has drastically declined since July 2013, even with improved broadband seismic monitoring capability.

<u>Seismic Instrumentation at Bayou Corne</u>

In response to the concern in the local community regarding feeling seismic tremors, a local seismic network was installed in the Grand Bayou area by the United States Geological Survey (USGS) in conjunction with the University of Memphis Center for Earthquake Research and Information (CERI) (Horton, 2012), referred to as the USGS network (Figure 1). The network installation started in mid July 2012. The array was six surface stations with broadband sensors, sampled at 40 Hz. Analysis of data from the USGS array show increases in seismicity rates on July 24, 2012, which stayed at a consistent high level until a steep drop off in seismic events just prior to the formation of the sinkhole during the night of August 2-3, 2012 (Horton, 2012). Chevron, a storage cavern operator on the Napoleonville dome, installed three surface seismic stations with equipped with a 4.5 Hz 3C geophone and a triaxial forced balanced accelerometer (operated by ESG Solutions, Canada) which were operational from late October 2012 to mid-May, 2013 (Figure 1). Texas Brine drilled a 455 ft deep seismic observation well (LA10, Figure 1) directly over OG3 cavern and installed a borehole seismic station. A temporary 2 Hz gimbaled geophone was installed which operated for about six weeks, and replaced with a permanent three level seismic array in mid-February 2013. The USGS array continued to operate until the end of January 2013, when it was replaced by a new near-surface array operated by Texas Brine (TBC) consisting of broadband stations sampled at 200 Hz (Figure 1). The TBC sensors were installed in 60 to 80 foot boreholes. A 1000 foot borehole was drilled in the sediment NW of the sinkhole and 2 sensors were operational in April 2013, a 2Hz geophone at 932 feet and a broadband sensor at 609 feet depth (LA17, Figure 1). The TBC surface array was reconfigured in October 2013 to improve the signal quality, removing two stations to the east of the sinkhole, adding a backup station to station LA12. A 4.5 Hz 3C geophone (LA21) in G-01 seismic observation well was placed to offset the potential loss of the cap rock sensors at station LA10 (See Replacement of LA10 with LA21 report, 6 Nov 2013). Seismic station information is listed in Appendix, Table 1. The TBC near-surface seismic network is operated by Nanometrics.

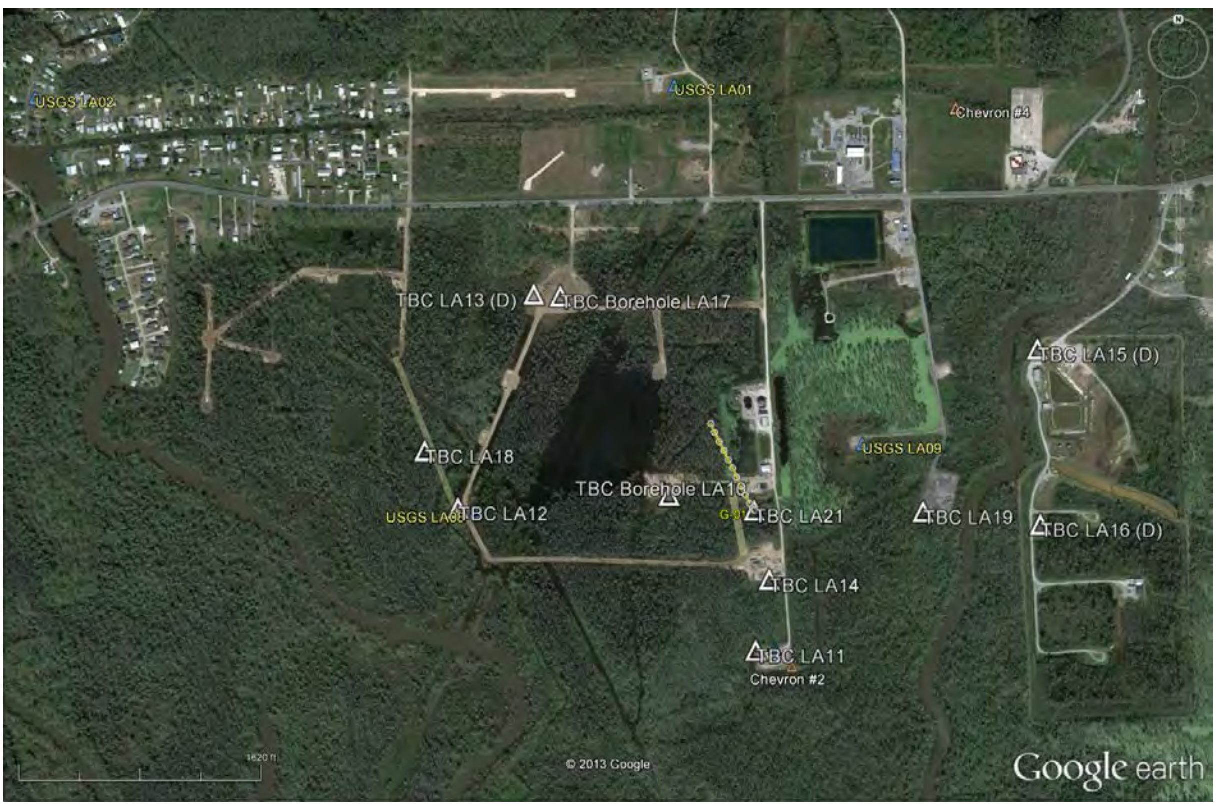


Figure 1. Google earth image of Grand Bayou area, the triangles indicate the station locations of the USGS, ESG and TBC seismic arrays, as labeled (not shown is ESG 8 is located in Bayou Corne, 2.5 mile west of the OG1 cavern). The letter "D" indicates a decommissioned Texas Brine station. The aerial Google Earth image shows the sinkhole geometry on 12 March 2012. Table 1 in the Appendix contains additional details on the seismic stations.

Geophone Well G-01

To further augment the seismic monitoring at Bayou Corne, a well (G-01) was drilled specifically for placing seismic sensors deep into the salt near Oxy Geismar 3. See the RRD-1 2 report for details on the G-01 well and instrumentation. Figure 2 is a map and cross section of the G-01 well location.

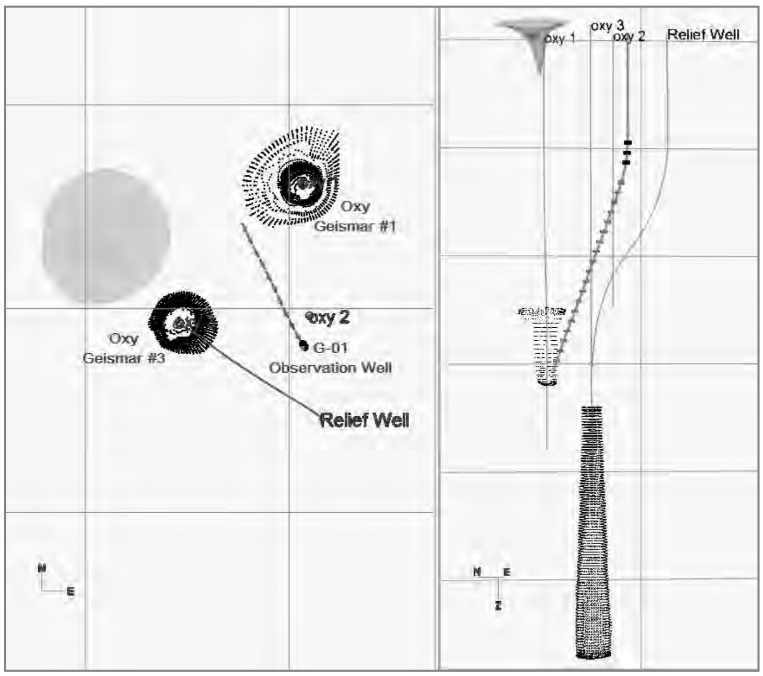


Figure 2. G-01 well location map (left) and a vertical cross section, looking from the south (right). The Oxy Geismar 1 and 3 solution cavern outlines and the approximate location of the sinkhole are shown; grid on map and side view is 1000 feet.

Character of the seismic Signals at Bayou Corne

The seismic signals recorded at Bayou Corne can be broadly be divided into two categories, high-frequency "sharp events", also referred to as microearthquakes (MEQ) and Very Long Period (VLP) events, although many sub classifications of seismic character are evident within each of these groups. Representative examples of these seismic waveforms of these events are shown in Figure 3.

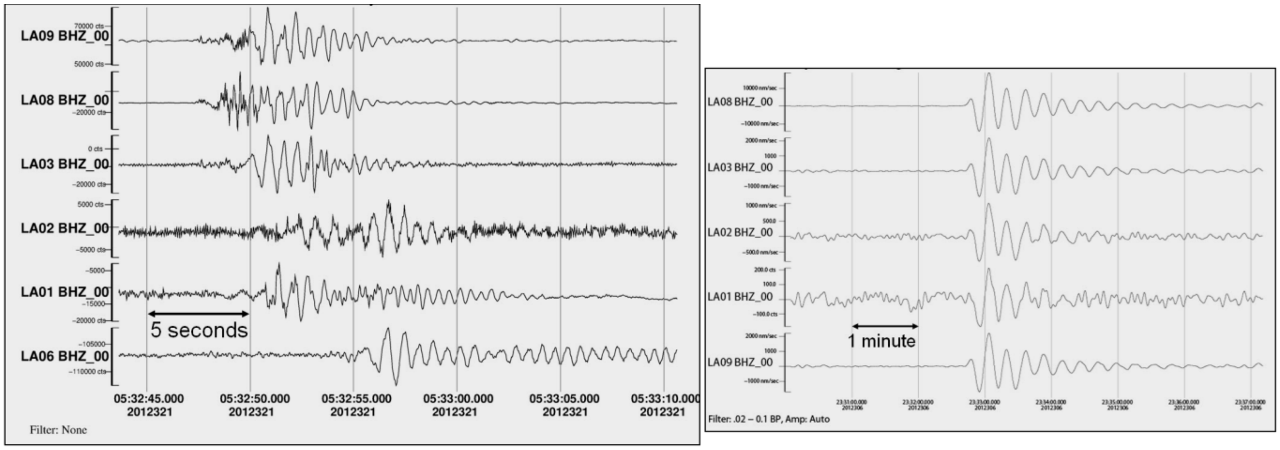


Figure 3 . Examples of seismic signals recorded at Grand Bayou USGS seismic array broadband stations (vertical component). Left plot is an example of a high frequency "MEQ" seismic signal (recorded 16 November 2012 at 5:32 UTC). Right figure is a VLP seismic signal (recorded on November 3, 2012, at 23:35 UTC). Records are from the USGS surface seismic array (see Figure 1 for station locations).

MEQ Events: detection, location, and magnitude estimates

Seismic events with P- and S-waves are commonly observed on the Bayou Corne seismic stations; the events recorded on the near surface broadband stations typically have weak body waves and a large amplitude surface wave (Figure 3). The weak P- and S-wave onsets from the near surface stations are most likely due to the high attenuation in the poorly-consolidated sediments in the near surface.

The surface seismic array data are currently processed by CERI for earthquake locations. No official report on earthquake location analysis, or the details of the ongoing location analysis from CERI was available at this time of this paper. Preliminary MEQ event locations provided in September 2013 for MEQ activity from July 2012 to mid-August 2013 by Dr. Stephen Horton of CERI show MEQ's located SE of the sinkhole and Oxy Geismar cavern (Figure 4).

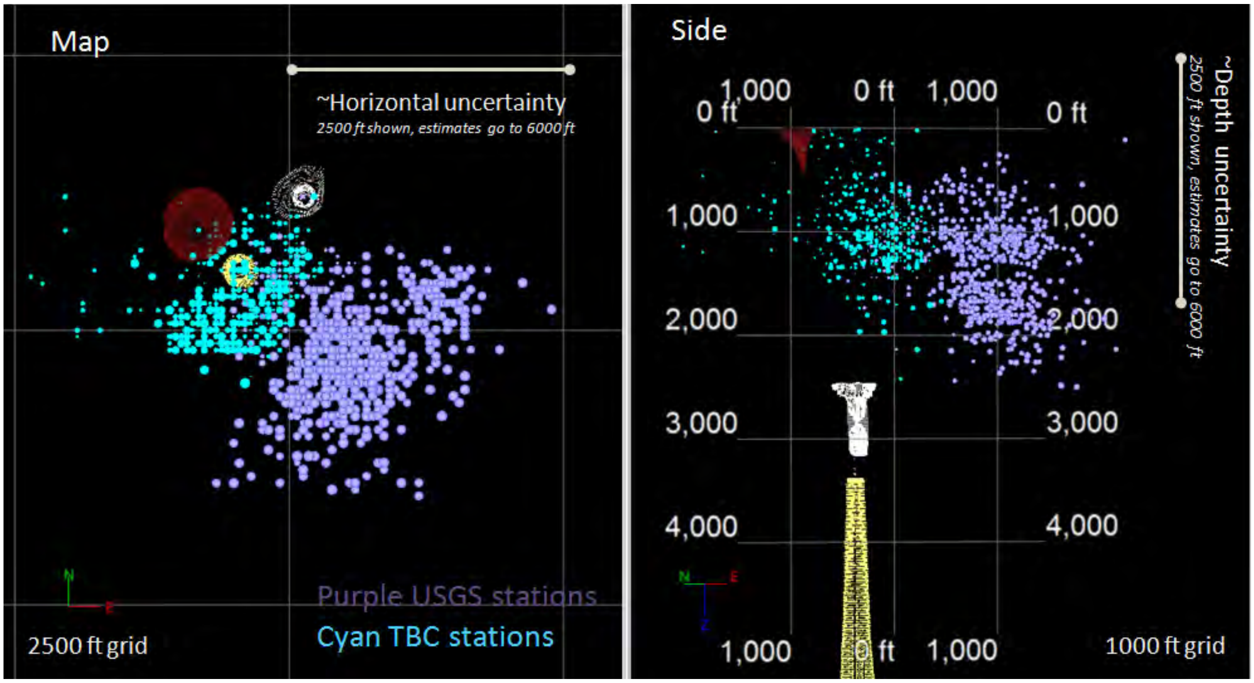


Figure 4. Upper plots show a map (left) and cross section (right) of CERI event locations provided in September 2013 using the USGS surface array (purple dots) and the TBC surface array (cyan dots) for MEQ events located in July 2012 to mid August 2013. An estimate of the average horizontal and vertical event uncertainties are displayed and labeled by white bars. Lower plot are the event uncertainties in depth (y axis) and horizontal position (x axis) for the CERI MEQ locations from USGS array (purple) and TBC (cyan) surface stations. Oxy Geismar Caverns 1 and 3 (pre-failure) are shown with small dots, the approximate sinkhole location with red shading.

MEQ's monitored on G-01 borehole instruments have clearly recorded with distinct P- and S-waves (Figure 5). MAGNITUDE, a seismic vendor located in Ste Tulle, France processes the G-01 data in real-time. A detailed description of the MEQ event location technique and uncertainty estimates is in RRD-12 Salt Microseismic Array report to the BRC.

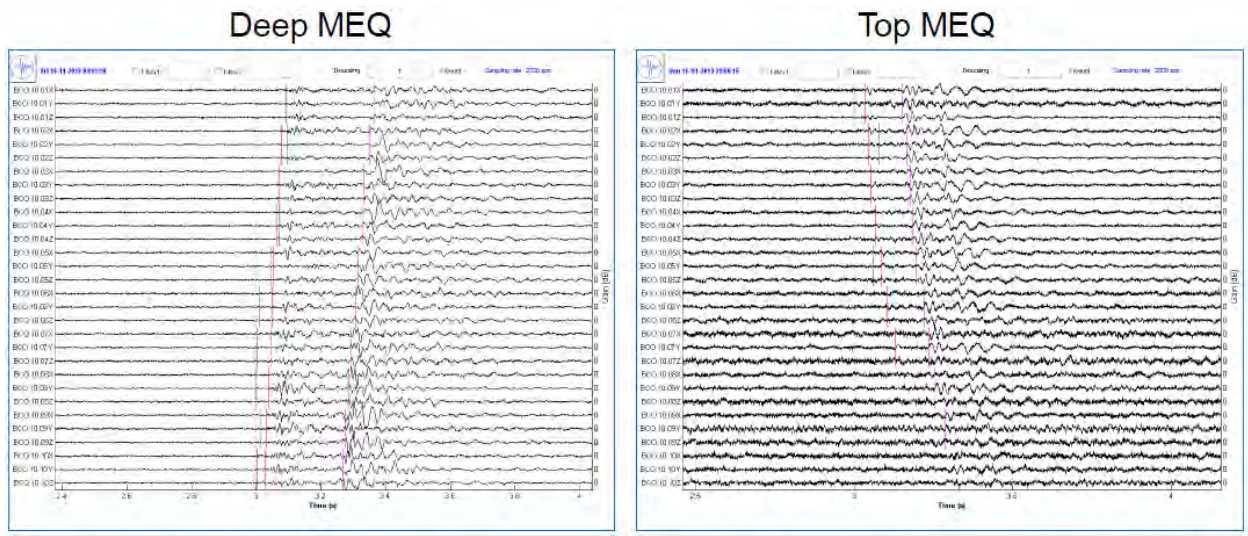


Figure 5. Seismic waveforms (time x axis and depth of geophone, top array show on top of the plot) recorded on the G-01 array showing examples of microseismic events detected below the array (left) and above the array (right). The direction of the energy, the "move-out" of seismic energy recorded on the borehole array was used to classify MEQ detections above and below the array.

The G-01 borehole seismic array was operational starting on October 18, 2013. 13,311 MEQ's were detected since installation to December 31, 2013 on the G-01 array (Figure 6). The MEQ detections are subdivided into seismic energy arriving above the array, indicating the MEQ was located less than 1000 foot depth, and seismic energy below the array, indicating the MEQ was located below 1000 feet (Figures 5 and 6). During the monitoring period, 88% of the MEQ detections were above the array (11,729 total detections above the array) and 12% (1,582 detections) were from MEQ's below the seismic array.

From the detected MEQ events, seismic events with signal to noise ratios greater than 3 and separation between MEQ's to allow for distinct picking of P and S-wave arrival times are located, as described in the RRD-12 Salt Microseismic Array report. From the start of the G-01 array on 18 October, 2013 to December 31, 2013, 919 MEQ's were located: 540 in the TBC target zone and 379 MEQ's near neighboring caverns or outside the target zone.

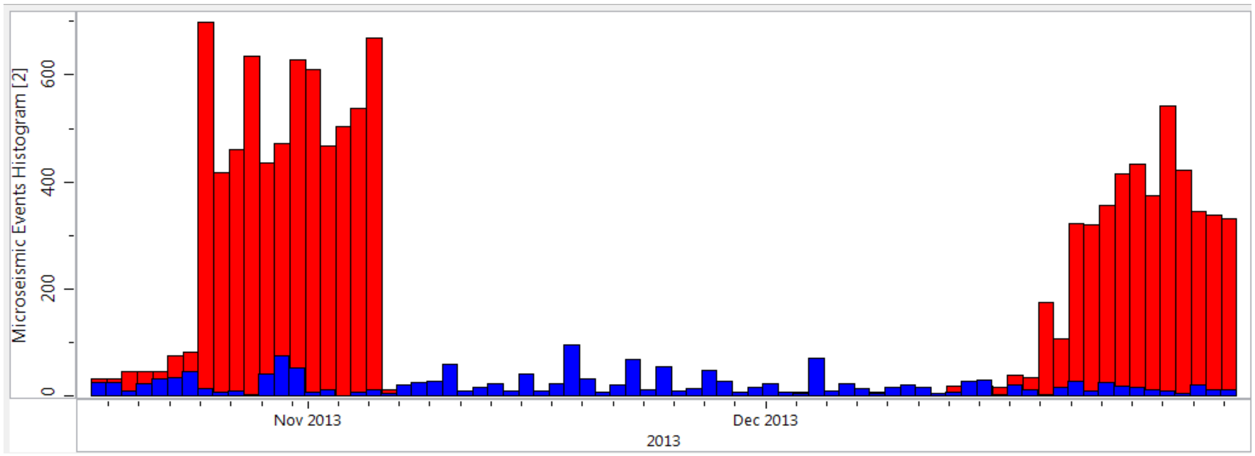


Figure 6. Histogram of the number of shallow (<1000 ft) MEQ (red) and deep (>1000 ft) MEQ (blue) detections per day from 18 October to 31 December 2013 reported by MAGNITUDE from G-01 borehole seismic array.

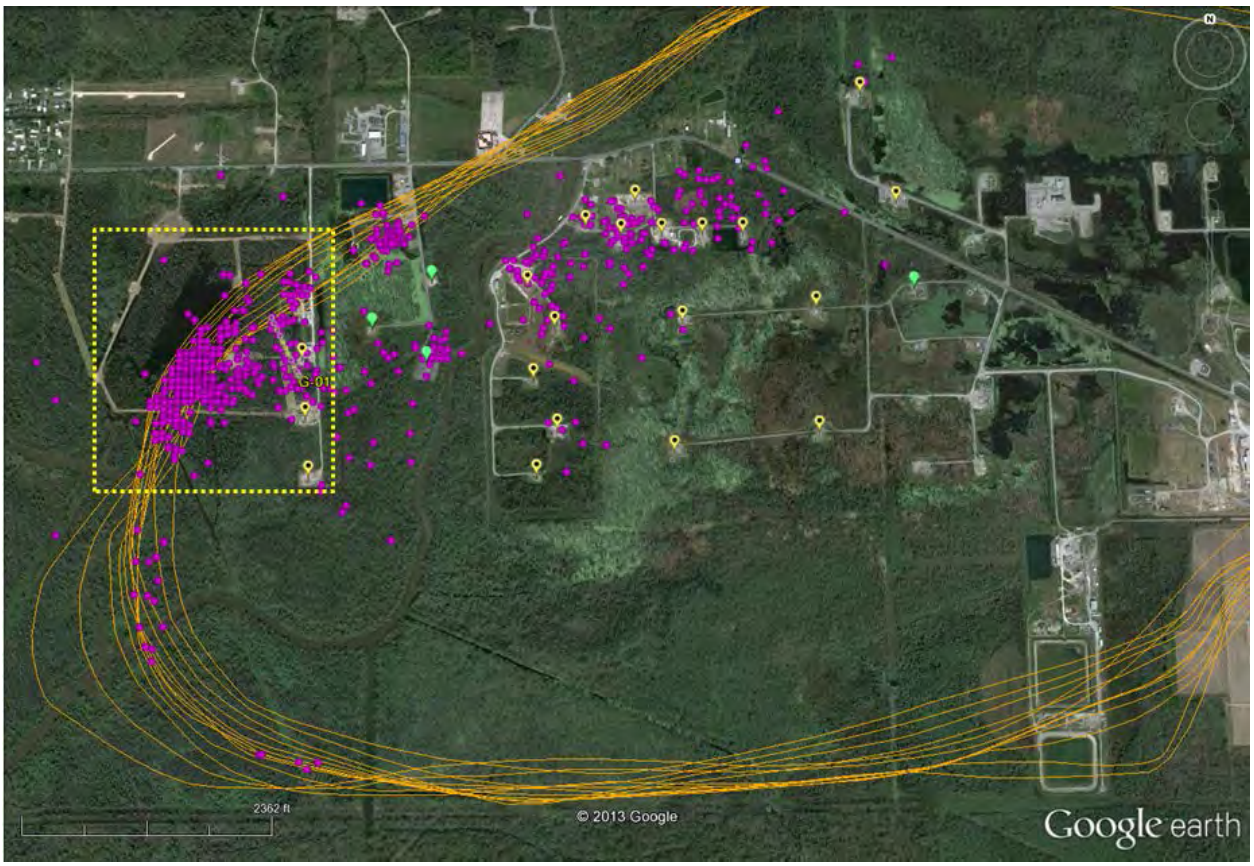
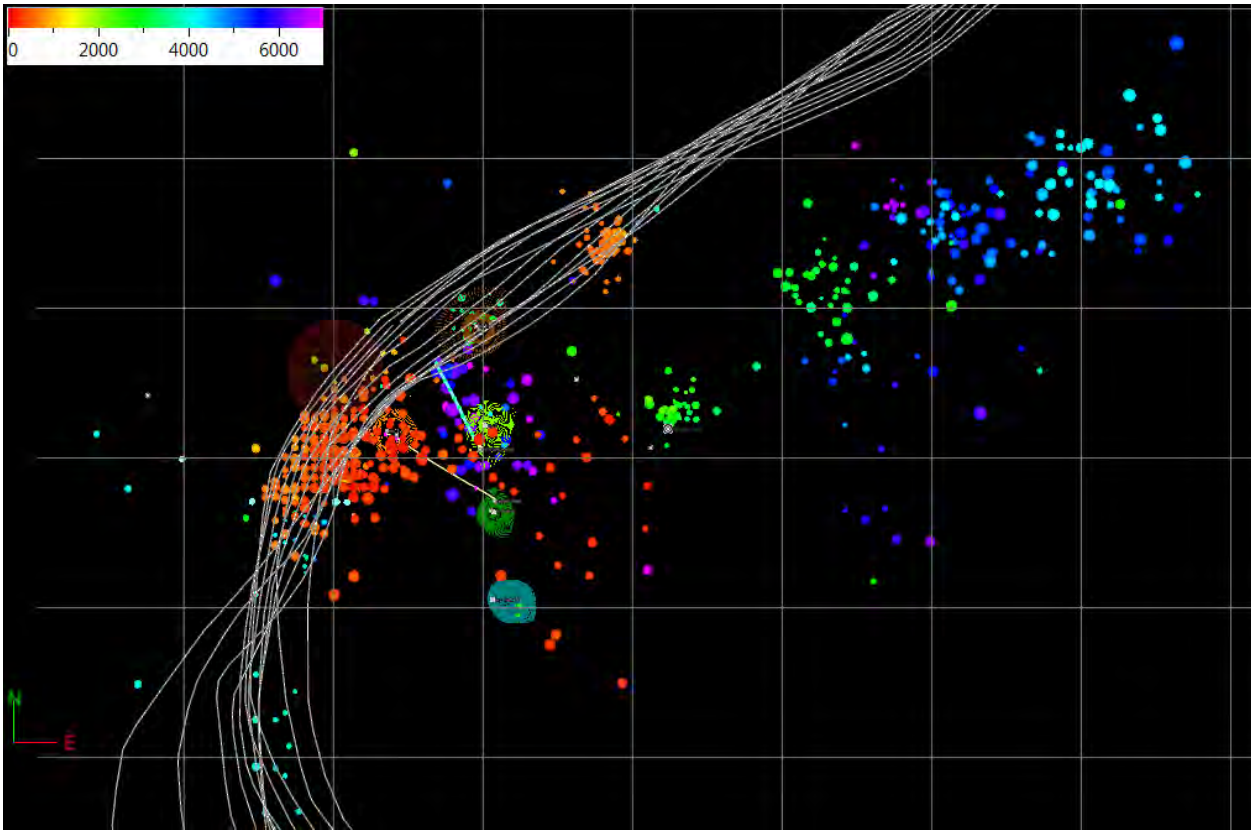
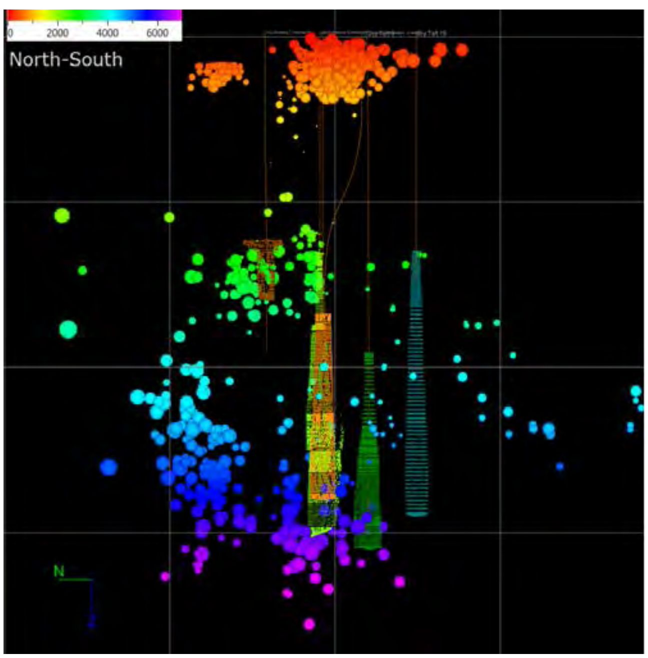


Figure 7. Map microseismicity (pink spheres) located by MAGNTIUDE from 18 October to 31 December, 2013 using the G-01 array. The TBC seismic monitoring target is shown by yellow dotted box, the G-01 borehole seismic array is labeled and sensors are shown by circles. Top salt contours >1000 feet of the Napoleonville salt dome is indicated by orange contour lines. The cavern well locations are indicated by small tear-shaped symbols, yellow indicates brine cavern, green storage cavern. The well locations obtained from LDNR website (http://sonris-www.dnr.state.la.us/gis/OC/).





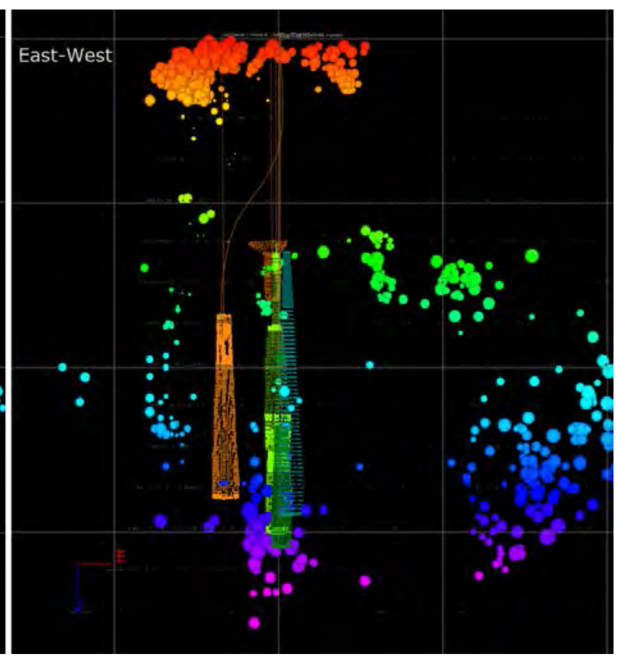


Figure 8. Map view, upper plot and cross sections (north-south section on the left and east-west section on the right with salt picks from 3D shown with dark gray dots) of MEQ events reported by MAGNITUDE with G-01 array with TBC cavern outlines. MEQ events colored by depth and sized by magnitude. Grid lines are 2000 feet. White contours in map view are the Napoleonville salt dome edge of salt picks from the 3D seismic >1000 ft.

Within the TBC target zone, the located MEQ events are mostly concentrated in the upper 600 feet and occurred in two distinct seismic swarms, the first from October 25 to November 5, 2013, and a second from December 18, 2013 to January 4, 2014 (Figures 7 and 8). The remainder of the microseismicity below 1000 feet is concentrated from 2,500-3,500 feet depth and somewhat evenly distributed from 4,000 to 6,500 feet subsea (Figures 7 and 8). The well pads for neighboring caverns seen in the satellite image suggest the MEQ events located outside the TBC study area could be related to neighboring cavern operations (Figure 7). For MEQ's deeper than 1,000 feet, the G-01 array has located more MEQ activity outside the TBC monitoring area than within (Figure 8, right graph).

The MEQ size reported by MAGNITUDE from the G-01 array of the MEQ's range in magnitude from approximately -1.5 to 0.5, with the average about magnitude -1 (Figure 10). The magnitudes reported by CERI mapped with the surface array (which includes MEQ's before the formation of the sinkhole), are generally larger than those computed from the G-01 array data by MAGNITUDE (Figure 11).

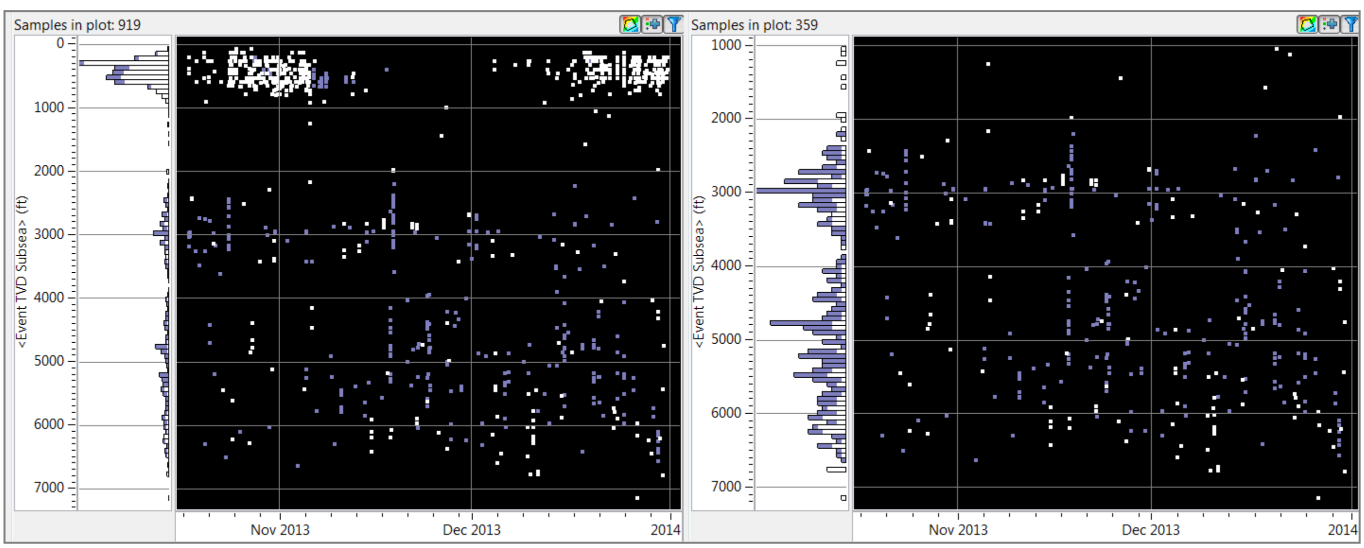


Figure 9. Time versus depth for all MEQ's located by G-01 array. White dots/histograms indicate events occurring within the TBC target zone defined by LDNR. Left plot shows all depth ranges, right plot, only events below 1000 feet to show detail of the microseismicity >1000 feet depth.

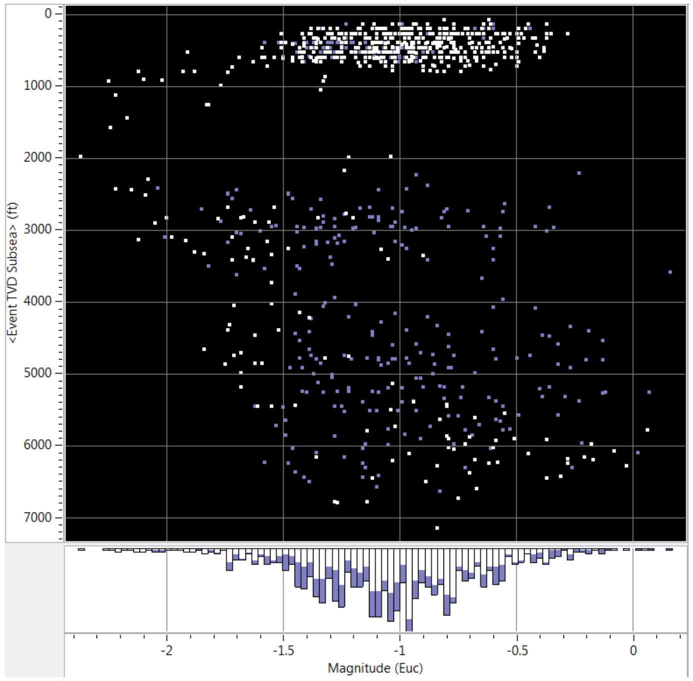


Figure 10. The distribution of Magnitude vs TVD depth for all located MEQ. The white dots and histogram bars represent MEQ in the TBC-target zone and the purple dots and histogram MEQ events located outside the TBC monitoring area.

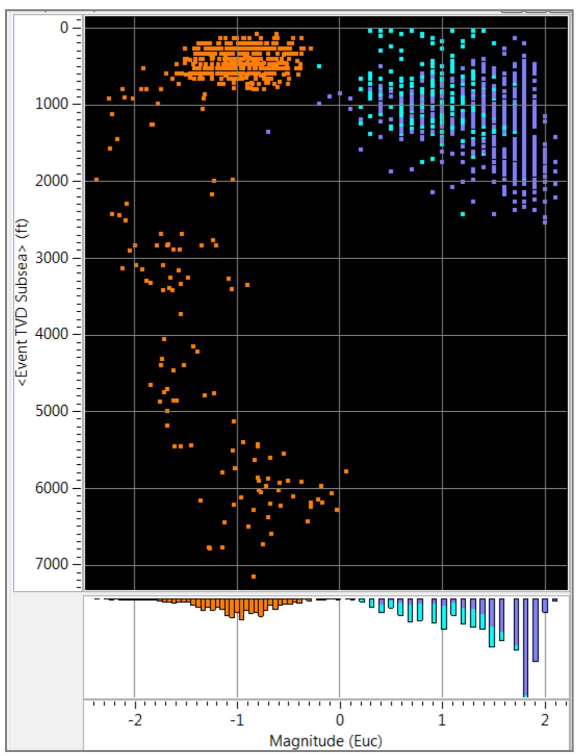


Figure 11. Comparison of MEQ depth and magnitude estimates using G-01 borehole array (orange) and CERI provided locations (TBC array data indicated by cyan dots, USGS array purple dots) depth and magnitude. Lower plot is a magnitude histogram comparison of the data sets.

Location uncertainties estimated for both CERI and G-01 processing by MAGNITUDE are suggesting the borehole array has improved spatial resolution compared to the surface locations (Figure 12).

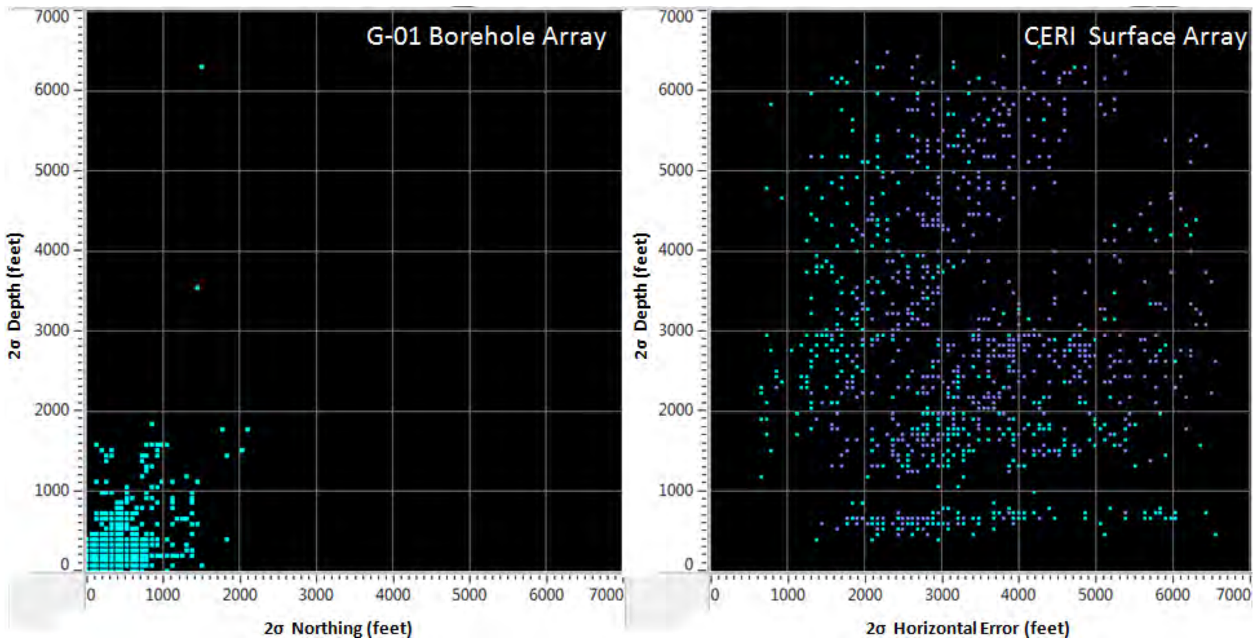


Figure 12. Comparison of estimated MEQ 2σ location uncertainties in depth and horizontal position from G-01 array (left) and CERI surface locations of USGS (purple) and TBC (cyan) surface array. Graphs are scaled the same for comparison purposes. The uncertainties represent 2 standard deviations.

The density of the MEQ distribution from 18 October to 31 December 2013 in the TBC monitoring area is shown in Figure 13. The MEQ density is shown by the number of MEQ's, and the MEQ's are scaled by magnitude to examine the spatial distribution of the largest MEQ's. The microseismicity during this time period is dominated by the two shallow MEQ swarms mentioned previously. The active solution mining caverns Oxy Geismar 2 and Taft 9 have MEQ activity near the base of the caverns. Small MEQ's were imaged near the western salt-sediment boundary, midway between the span of cavern field at depth, as well as near Oxy 1 cavern, these events are among the smallest microseismic events observed on the array.

Figure 14 shows detections by Nanometrics of MEQ, VLP analyzed from both the near surface array and detections G-01 array reported by MAGNITUDE. The borehole array appears to detect more MEQ activity, thus the sensitivity of the seismic monitoring has continued to improve with the installation of the deep seismic array.

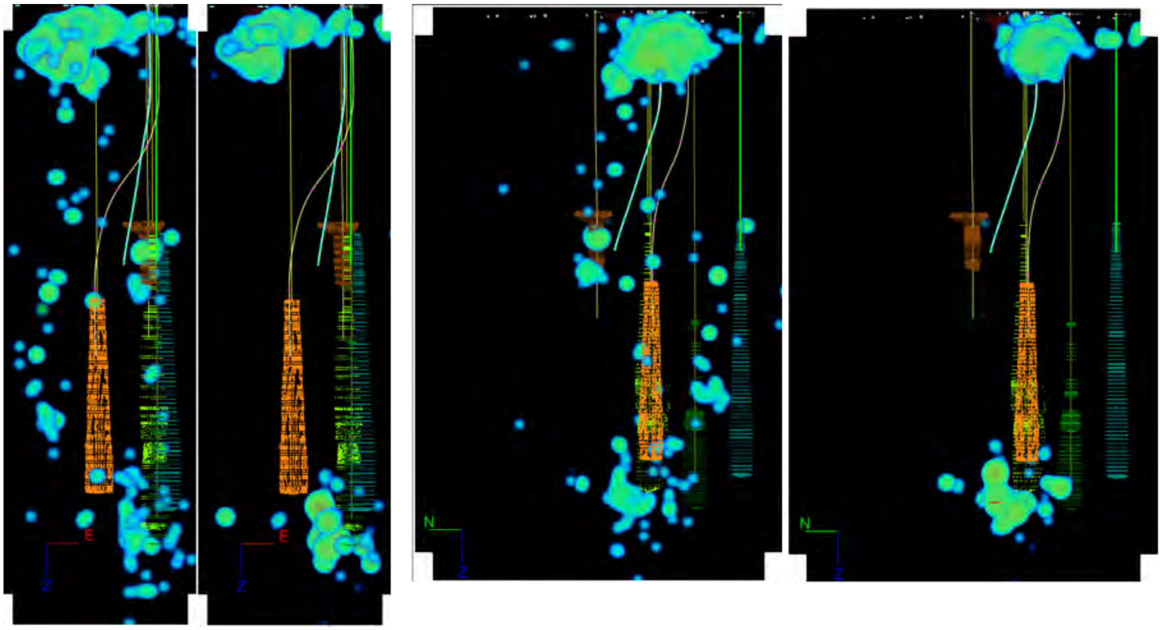


Figure 13. E-W (left plots) and N-S (right plots) cross sections of MEQ event density mapped using G-01 array scaled by number of MEQ events (left plot in the pair) and magnitude of the MEQ events (right plot in the pair).

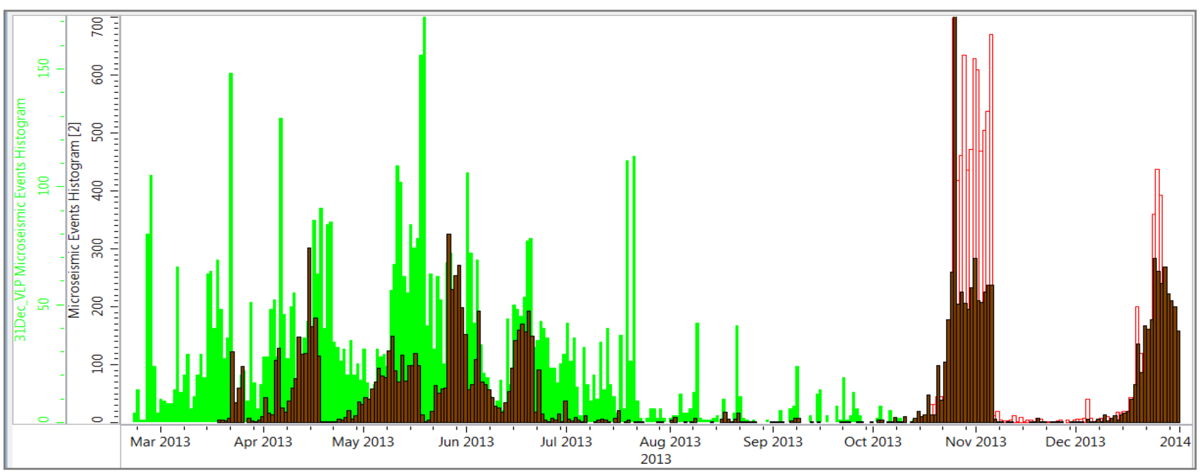


Figure 14. Histogram of MEQ and VLP detections from March-December 2013. Brown is MEQ counts from Nanometrics using the surface array. Green indicates VLP counts from Nanometrics. Red indicates shallow detections from G-01 array.

VLP Signals

One of the unique seismic signals observed at Bayou Corne is the Very Long Period (VLP) event. The first detected VLP event occurred on August 6, 2012 at 06:10 UTC, 3 days after sinkhole formation. VLP activity continued episodically through 2012 and 2013, and has dramatically decreased since late July 2013 and has been almost absent to the end of 2013 (Figure 14).

Since the initial formation of the slurry hole in August 2012, the affected area experienced periodic episodes of disturbances of swirling water, increased bubbling and hydrocarbon expulsion, as well as edges sloughing in which trees were pulled into the expanding sinkhole. In the days leading up to various sinkhole events, VLP activity would often increase, sometimes over 100 VLP events per day (Figure 14).

Some key observations regarding the VLP events include:

1. **VLP signals are best recorded at an individual station (LA12) to the southwest of the sinkhole.**
2. **First VLP event detected 3 days after the sinkhole formed, months after the first seismic events.**
3. **VLP event counts often increase dramatically in the days preceding sinkhole activity.**
4. **Area near LA12 has undergone at least 2 m of subsidence.**
5. **VLP activity has decreased markedly since late July 2013.**

Broadband seismic station LA08 was installed by the USGS on July 30, 2012 and was the primary station for detecting VLP events until it was replaced by the Texas Brine Corp. (TBC) LA12 station at the end of January 2013 (Figure 1, Appendix Table 1). The largest amplitudes of the VLP events are detected by Station LA12. Strong amplitude decay observed with distance suggests that the source of the VLP events is very shallow (Appendix, Figure A2).

VLP events were initially characterized by an impulsive onset, narrow-band dominant period of 15-20 seconds, and exponential amplitude decay. The VLP events lack distinct seismic phases and therefore are difficult to locate with traditional earthquake location methods. Figure 15 shows what is termed a “classic” VLP and other VLP variations, two common variations are an impulse with no ensuing resonance and a “hybrid” VLP-MEQ in which a higher frequency event that usually includes distinct P and S phases, similar to an MEQ, occurs and appears to trigger the VLP (Figure 15). The hybrid VLP-MEQ events often have a larger first few pulses relative to the resonance than classic VLP events. Locations of some of the “hybrid” VLP-MEQ events resulted in depths between 50-300 m and locations near the flank of the salt dome to the south of the sinkhole (Figure 16).

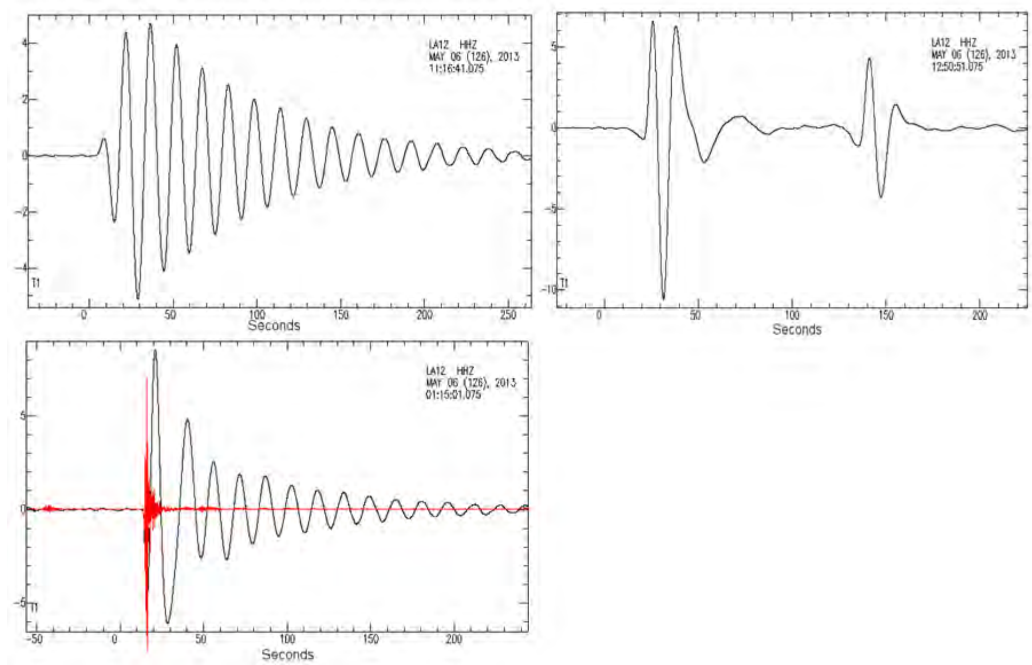


Figure 15. Examples of VLP recorded on broadband station LA12. Upper left, a “Classic” VLP with impulsive onset and exponential resonance decay, upper right, two VLP events with impulsive onset but no trailing resonance. Lower left figure is a “Hybrid” VLP-MEQ event, the red waveform is unfiltered data showing high frequency MEQ “trigger” event at onset of VLP, the VLP shown by filtered black waveform and the amplitudes have been normalized.

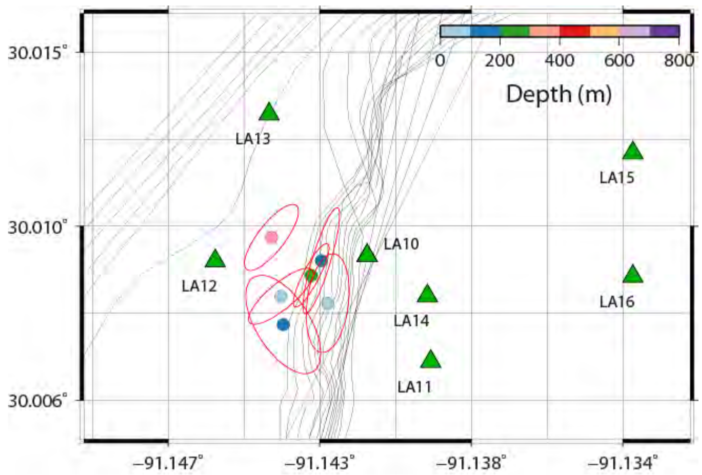


Figure 16. Event locations and depths for trigger events of hybrid VLP events computed by Weston Geophysical. Event uncertainty is indicated by ellipse surrounding each event. Gray lines mark the approximate salt boundary as mapped by vintage 3D seismic data. Green triangles mark the seismic stations used to compute the event location.

A cross-correlation analysis was conducted for each VLP type and found that the waveforms were nearly identical in shape and frequency. This important observation suggests that the same source is responsible for generating VLP events and that the process is repeatable. A moving source location or variations in the source geometry would result in different VLP signal shapes. VLP activity dramatically decreased after July 2013 and relatively few VLP events have been detected through after late July 2013 (Figure 14).

Summary

A robust and highly sensitive seismic monitoring system is in place at Bayou Corne. A broadband seismic array and high-frequency deep seismic array operated by Texas Brine provides real-time assessment of MEQ and VLP seismic activity.

Microseismicity located from the G-01 array from mid-October to December 2013 reveals two shallow microseismic swarms located directly southeast of the sinkhole, along the western flank sediments. Deeper microseismic events are located near the base of caverns Oxy Geismar 2 and Taft 9, as well as neighboring cavern operations. Magnitudes computed for these data range from approximately -2 to -0.5, with the average magnitude ~-1.0 (representing seismic events with energy equivalent to the energy of a 150 lb. person jumping down 10 feet).

The seismic arrays provide for active hazard assessment of both near surface and deep subsurface, for both low frequency (VLP) and high frequency (MEQ) seismic signals. Hazard assessment, as outlined in the RRD-12 report will to provide accurate and real-time hazard analysis for MEQ activity for the local community and field operations.

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Appendix

Table 1. Seismic Instrumentation at Bayou Corne.

Station	Operator	Instrument Type/Installation	Dates operational	Comments
LA01, LA02, LA03, LA06, LA08, LA09	USGS- CERI	Broadband Nanometrics Trillium and Episensor FBA Accelerometer, buried several feet.	First station 14 July 2012, Array decommissioned late January 2013	installed and operated by USGS and CERI, sensors on surface.
ESG2, ESG8, ESG4	Chevron	4.5 Hz sensors buried 2 feet.	Installed Stations late October 2012 removed mid May 2013	
LA10	Texas Brine	Broadband Nanometrics Trillium at 455 ft, 2 Hz geophones at 384 and 174 feet	2 Hz temp geophone 15 December 2012, full array mid February 2012.	Texas Brine drilled 455 ft observation well above Oxy Geismar #3
LA11, LA12, LA13, LA14, LA15, LA16	Texas Brine	Broadband Nanometrics Trillium in~80 foot boreholes	LA11, LA12, LA14 mid January 2013, LA15 and LA16 operational 28 April, LA13 decommissioned April 27, 2013. LA15 and LA16 decommissioned 14 October 2013.	Texas Brine drilled ~80 foot cased shallow boreholes for sensor deployment to reduce cultural noise levels. Installed under orders of LNDR. LA13 replaced by LA17.
LA17	Texas Brine	Broadband Nanometrics Trillium at 609 feet, 2 Hz 3C Geophone at 932 feet	Borehole array operational 28 April 2013.	Replaces LA13. Installed under orders of LDNR.
Oxy 1	Texas Brine	12 level, 15 Hz, 3C geophone array, 100 ft spacing installed in Oxy 1 cavern well from 1820-2362 feet.	15 Feb - 27 March 2013	Removed to allow stabilization of Oxy 1 cavern.
G-01	Texas Brine	Three 4.5 Hz 3C Geophone, two cabled arrays (8 element and 9 element, ~193 foot spacing) 15 Hz 3C Omni 2400 Geophones	Operational October 16,2013.	G-01 borehole is a 3105 foot well 20 degree deviated between Oxy Geismar 1 and 3 caverns. Arrays installed in salt from 1000 to 3000 feet depth.
LA18, LA19	Texas Brine	Broadband Nanometrics Trillium in 80 ft borehole	Operational October 17-18, 2013	LA18 Intended as back up station to LA12. LA19 Relacement for LA15 and 16, closer to source on quieter location.
LA21	Texas Brine	4.5 Hz gimbaled 3C geophone in G-01 wellbore at 295 m ss.	Operational October 18, 2013	Replacement for LA10 in case caprock site is lost to sinkhole.

c. Interpretation and analysis of growth of sinkhole, subsidence area, and underlying disturbed rock zone, (DRZ)

See the discussion in section d for interpretation and analysis of sinkhole and subsidence area growth patterns. The Disturbed Volume (DV) is referred to by some parties as the Disturbed Rock Zone (DRZ), but the former term is preferred because there is likely no lithified sediment outside the salt stock between the base of the cavern and the sinkhole at surface. The DV is the suspected feature formed by downward migration of sediment from the sinkhole environment as deeper sands and clays infilled the void of the Oxy 3 cavern.

The DV is interpreted to be a deeply penetrating, but very narrow feature. The DV is sufficiently small that it cannot be imaged in the 3D seismic data. The DV thus is smaller in diameter than the sinkhole itself. TBC's geophysical consultant concludes that the feature is unlikely to be wider than two bins of data or about 75 feet; otherwise it would be visible in the seismic data. On this basis, TBC concludes that the DV is likely confined to the shale sheath formed against the salt stock; there is no apparent change in the character of reflectors representing dome flanking sediments between the 2007 Legend 3D data and the 3D data collected after the sinkhole formed. Thus, the DV does not extend beyond the immediate margin of the salt stock.

Some geologic heterogeneity observed along the salt/sediment interface at substantial depth in the seismic data has been interpreted by others to evidence of an hour-glass-shaped sinkhole-DV system where the DV narrows considerably below the sinkhole but flares out again at more substantial depths (1.2 to 1.5 seconds two-way-travel time, or about 4,000 feet to 5,000 feet below surface). The heterogeneity observed along the salt/sediment interface at depth in the recent 3D seismic data is also present in the 2007 Legend data. Consequently, this heterogeneity predates, and is therefore unrelated to, the August 2012 cavern failure and sinkhole event.

The DV can remain active only as long as sediment continues to infill the Oxy 3 cavern. In as much as the cavern is nearly full at the present time, activity in the DV and concomitant loss of sediment from the sinkhole is expected to wane.

d. Including an assessment of the volume balance or volume ratio: initial cavern volume as compared to the total volume of the sinkhole plus actual subsidence

RESPEC has calculated the sinkhole volume to be approximately 91.8 million ft^3 based on the November 11, 2013 survey performed by Miller & Associates. This volume estimate is based on an assumption of an original ground surface of 0 feet above mean sea level (amsl) at the sinkhole. The estimation of an original ground surface of 0 ft amsl is higher than has historically been reported by Miller & Associates (-2 ft amsl), but is less than the average ground surface elevation reported at borings (3 ft amsl). The calculated sinkhole volumes for most of the Miller Surveys are displayed in Figure Volume.

The original Oxy-3 cavern volume is estimated about 108 million ft^3 based on 2007 sonar data. Using an "exceedingly conservative" assumption [Van Sambeek, 2013a; Brandshaug, 2013] that there is no sediment bulking in either the cavern or the Disturbed Volume within the shale sheath of the dome, the maximum sinkhole volume will be equal to the pre-collapse cavern volume. The pre-collapse cavern volume is also indicated Figure Volume. The sinkhole volume was 85% of the pre-collapse cavern volume based on the November 11, 2013 survey data. If a modest bulking factor (5%) is applied to the cavern fill and an assumed DV (calculated as a cylinder with a height of 3,400 ft. and diameter of 75 ft.), the ratio of sinkhole volume to pre-collapse cavern volume is 90%.

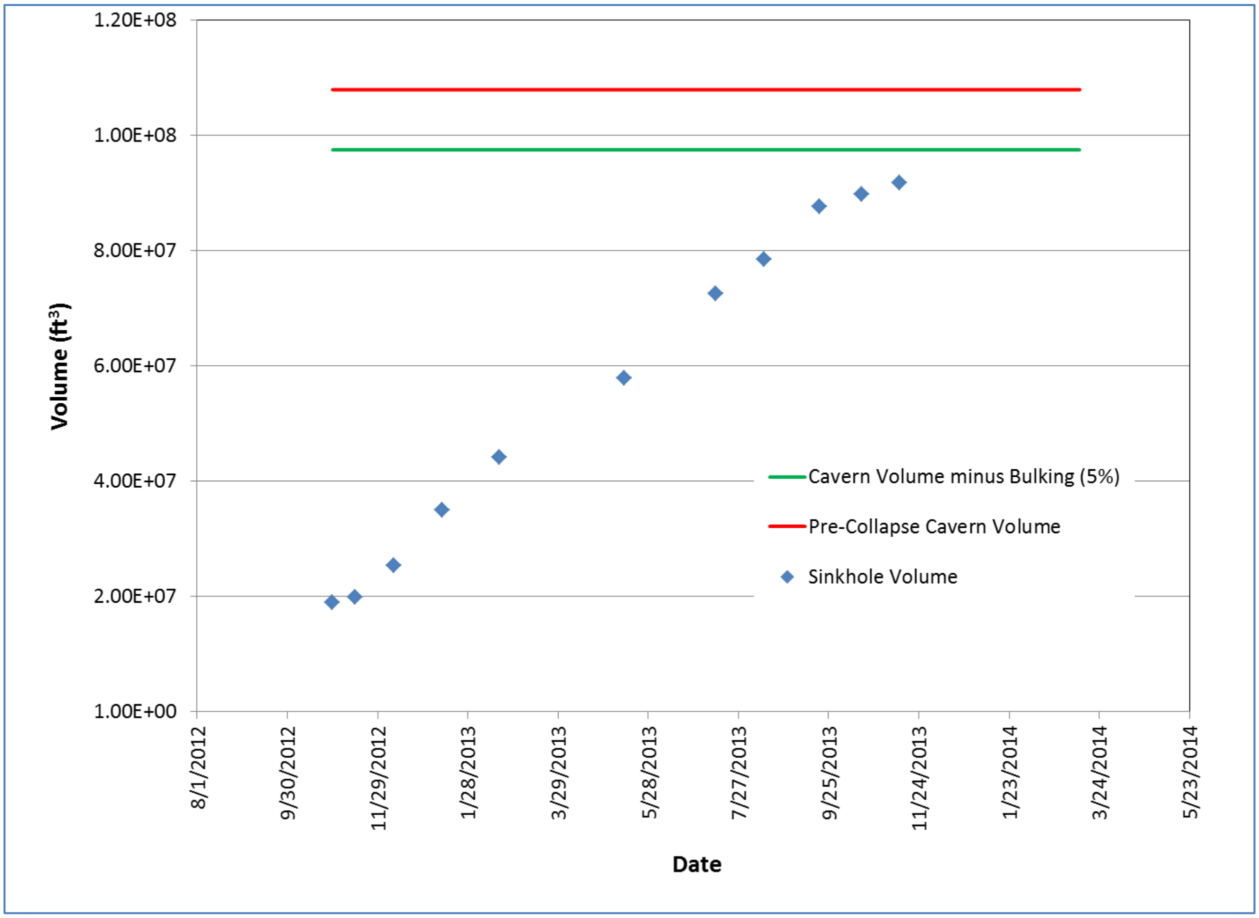

Figure Volume. Temporal Trend of Sinkhole Volume Shown Approaching Pre-collapse Cavern Volume.

Linear and non-linear line-fitting was applied to the calculated sinkhole volume using a least-sum-of-squared-errors approach. The equations developed can be used to approximate future sinkhole growth. The developed equation plots are displayed in Figure LineFit which shows the percentage of the maximum possible sinkhole volume based on two assumed scenarios: 1) the final sinkhole volume will be equal to the pre-collapse cavern volume (dashed lines), and 2) the final sinkhole volume equal to the pre-collapse cavern volume minus a modest bulking factor described above (solid lines). For each of the two scenarios, three separate lines were fit: 1) a linear fit to all of the data (green lines), 2) a linear fit to the most recent data (purple lines), and 3) a non-linear fit to the most recent data (red lines). These estimates are considered a likely range of future sinkhole growth, with the non-linear approximations considered to be the most probable. The non-linear approximations suggest that 98% of the maximum sinkhole volume will be reached by May 2014 (cavern volume minus bulking) or September 2014 (cavern volume), as shown in Figure Linefit. Comparisons of the current sinkhole volume and the pre-collapse cavern volume indicate that there is limited opportunity for the sinkhole volume to increase significantly in the future. Under either of the two scenarios, the sinkhole essentially reaches the cavern volume by mid-year 2015.

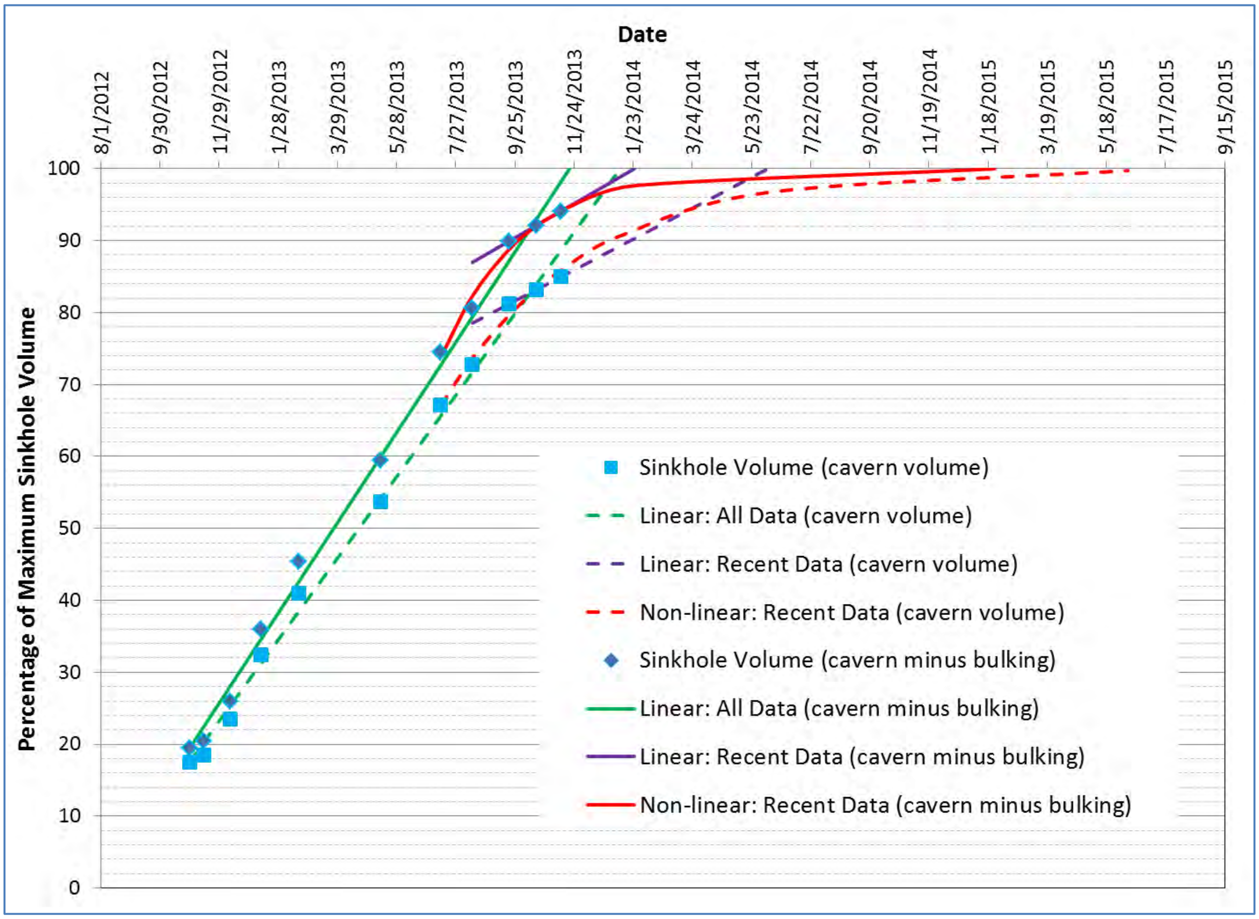

Figure LineFit. Temporal Trend of Sinkhole Volume based on Various Regression Techniques

e. Prognosis for reaching stability of the collapsed cavern DRZ, sinkhole, and surrounding subsidence area particularly as such stability may affect Highway 70, the Bayou Corne community, and Bayou Corne waterway

Applying very conservative, worst case conditions, there is little evidence to suggest either Highway 70 or Bayou Corne will be impacted by sinkhole growth. Other components of this request are addressed in the Section II c and in the following sections.

f. Potential sinkhole growth over the next year and next five years

Even after the sinkhole volume stabilizes, there is a possibility that the shape of the sinkhole will continue to evolve over time as the long-term angle of repose is achieved. Brandshaug [2013] considered sinkhole expansion uniformly as well as nonuniformly and preferentially in an unfavorable direction (expanding only to the north toward Highway 70 or only to the southwest toward the waterway). As Brandshaug [2013] states, "because the sinkhole appeared one year ago, and has been developing (i.e., widening) since then, its development shape is considered somewhat mature in the sense that it will probably continue to grow and develop much in the same proportions." Itasca's analyses of the maximum extent of the sinkhole led to their conclusion that Highway 70 and the Bayou Corne Waterway would not be encroached upon even using "exceedingly conservative" conditions. Moreover, two of their assumed, worst-case conditions or factors (a 15 percent increase in cavern volume by salt dissolution and zero bulking factors for the sediments) are considered even "worse than possible" or unrealistic in short time periods of a decade or so [Van Sambeek, 2013a].

As a means to corroborate these predictions, subsidence in the vicinity of the sinkhole has been monitored since August 2012. Monitoring techniques include conventional elevation-surveys using wellheads and benchmarks, water-level transducers in the swamp, as well as satellite-based InSAR/SqueeSAR technology. Efforts have been made to tie these different approaches to subsidence monitoring into an integrated approach. However, complete integration of the conventional elevation-survey, elevation changes inferred from water-level data, and InSAR/SqueeSAR interpretation of the InSAR data can be challenging, because each of the methods have different purposes, elevation references, and time frames. Satellite-based methods identify movement on a regional scale, but local elevation changes are still relative to a reference point that is assumed to be stationary, and time between satellite images does not allow a tight temporal resolution of sudden, large movements. Although conventional elevation-surveys are more robust, the measured movements are relative unless the reference benchmark is stationary. The advantage of conventional surveys is that the reference benchmark is publically available. Real-time elevation change inferences from water-level transducers are used primarily as an early warning system for impending instability; however, they also provide quantitative information on relative elevation changes of the swamp bottom after sufficient data are available.

SqueeSAR interpretations of subsidence rates of InSAR data from two time periods and two different satellite types have been reported by TRE (2012 and 2013). When the SqueeSAR results are compared to conventional elevation-survey measured subsidence rates for the time period of August 12, 2012 to November 11, 2013 (456 days or 1.25 year), a notably smaller subsidence rate is indicated by the SqueeSAR interpretation (-0.75 to +0.2 inches/year) compared to the conventional elevation surveys (-1.75 to +0.5 inches/year). The difference between these rates may relate to the choice of reference benchmarks.

Recently, artificial reflectors (ARs) were installed as control points to improve the InSAR data referencing and accuracy. Of the 20 original ARs installed, 12 ARs have sunk into the sinkhole or have been removed because of potential AR loss into the sinkhole. The most recent installation of an additional 15 ARs (October and November 2013) was too close in time to the end of the current monitoring period (June 12, 2012 to November 11, 2013) for interpretation; their elevation information will be available in the June 2014 analysis.

TRE determined rates for four of the ARs using SqueeSAR technology. These four reflectors had an average subsidence rate of 8.4 mm/year (0.33 inches/year) and are all located on or near the TBC facility area. Four other reflectors were analyzed with a technique called Rapid Motion Tracking; however, rates were not reported for these ARs by TRE.

Twenty-nine water-level gages are deployed in the swamp area around the sinkhole. Due to low water levels, only fourteen of the water-level gages are currently useable for calculating relative subsidence rates. These data are still considered preliminary because of the short time period represented. Water level gauges closest to Highway 70 show relative subsidence between 0 and 1.5 inches per year. Relative subsidence rates inside the sinkhole berm vary from 0 inches per year (near facility) to 6 inches per year (near northwest side of sinkhole). Figure Contours shows a contour plot of subsidence rates based on an integration of water-level transducer data and Fenstermaker and Associates survey data.

The bimonthly conventional elevation-surveys by Fenstermaker and Associates indicate that the subsidence rate along Highway 70 is relatively uniform, and less than 0.1 ft/yr (less than nominally 1 in/yr). The SqueeSAR interpretation of points within 50 meters on either side of Highway 70 along a 7 kilometer-long profile from the Bayou Corne development to the east suggests a trough with a maximum subsidence of 28 mm during the 1.25 year period (22.4 mm/yr or 0.88 inches/year). Generally the measured subsidence was less, between 5 to 10 mm during the 1.25 years, over the majority of the profile.

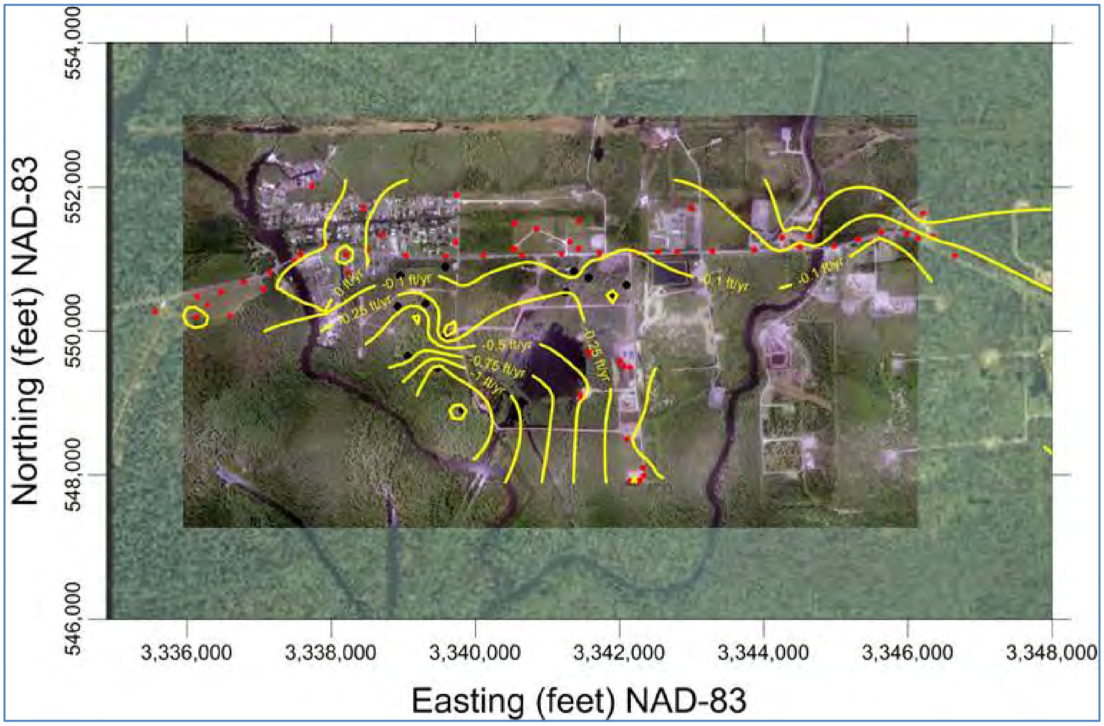

Figure Contours. Subsidence Rate Contours in Feet per Year Based on Fenstermaker Surveys and Water-Level Gauges [Van Sambeek, 2013b].

Comparison of the various subsidence monitoring techniques will continue as additional data are reported. Based on the current information, TBC's conclusion is that:

(1) No accelerated subsidence has occurred year-to-date at benchmark locations outside the immediate sinkhole area, and

(2) No significant changes in trends are observed.

The subsidence along Highway 70 seems uniformly distributed along a substantial length of highway without significant influence from the sinkhole. The measured 1 in/yr subsidence rates along the highway are certainly within the 2 to 33 mm/yr (0.1 to 1.4 in/yr) expectation discussed by Reed and Yuill [2009] and the 1.3 cm/yr (0.5 in/yr) water-level rise presented by Penland et al. [1989] for this deep Holocene sediment and Mississippi River valley setting, which is subject to both compaction and sediment loading. Additional subsidence contributions in this area could be from tectonic influences and from fluid withdrawal related to earlier oil and gas production.

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g. Containment of the sinkhole to the south and protection of Bayou Corne waterway

The Bayou Corne Sinkhole Containment System Maintenance and Contingency Plan (Plan) dated December 13, 2013 provides inspection, monitoring, maintenance and repair procedures that will be implemented by TBC to address the requirements for containment of the sinkhole surface waters per Directive 5. The Plan lists trigger events that would cause relocation of the south berm to be initiated. One of those trigger events was if the elevation of the south berm were to drop by 4 feet or more over a 30-day period. Recently increased subsidence of the south berm has been observed, with over 1 foot of drop occurring in a one week period, and additional drop in elevation over a longer period. Due to this subsidence, TBC has decided to place additional soil and consider deployment of a portable barrier system (Tiger Dam™) as interim measures to raise the subsided section of the southern berm while moving forward with plans for constructing a new south berm.

Figure 4 of the Plan showed a proposed alignment for a new south berm. The south berm alignment is a modification of the one that was included in the originally submitted Plan. The alignment was modified to incorporate corridors that had previously been cleared through the marsh to allow air boats passage as part of other operations associated with sinkhole area exploration and monitoring, such as Cone Penetrometer Testing (CPT) work. By utilizing these previously-cleared corridors, the amount of marsh that will need to be cleared to accommodate the new south berm will be minimized.

The proposed alignment of the new south berm remains between the maximum extent of sinkhole subsidence predicted by DNR's consultant, Itsaca Consulting Group, and Bayou Corne, thus continuing to provide protection of the Bayou Corne waters from the surface waters associated with the sinkhole.

III. Status of Gas Migration and Mitigation

a. Current extent of gas in the MRAA and overlying aquitard including volume and areas of gas accumulation

TBC recently provided this evaluation in a report entitled "INVESTIGATIVE REPORT FOR RRD-08B EXTENT OF GAS" dated 19 December 2013. This report provided figures and tables that showed areas of gas accumulation in the MRAA using the most recent data from CPT soundings. Gas volume estimates for the MRAA were also included in this report. Data for gas in the aquitard was provided in tabular form. Using the same techniques to map gas zone thicknesses for the MRAA as used in the above report, a map of net gas thickness observed in sand strata within the aquitard was prepared and is shown in Plate 1. Volume estimates (also based on the methods used in the above referenced report) for the gas in the aquitard are provided in Table 1.

Table 2. Estimated volume of gas in gas-bearing zones in the aquitard.

Total Thickness of all Aquitard Gas-Bearing Zones (ft)	Volume of Gas (ft^3)
>0	12,106,318.0
>=0.25	11,612,892.3
>=1	6,772,183.3
>=2	2,717,534.0

b. Analysis of gas migration through the aquitard to the surface

During the spring and summer of 2013 Tetra Tech on behalf of TBC hosted webcasts regarding preliminary modeling of gas flow in the MRAA and the aquitard above. A summary of the Tetra Tech modeling presented in those webcasts is included in a separate report entitled "Preliminary Modeling Results at the Napoleonville Salt Dome in Bayou Corne, LA to Assess Gas Cap Evolution and Migration", dated 16 JAN 2014. This report and attached files have been uploaded to the BOX.

Part of the analysis presented in the modeling report addresses gas flow through a 10-foot thick clay confining layer above the MRAA. The modeling results also show that migration of gas out of the MRAA through the clay aquitard above the MRAA can occur over long time periods under certain conditions. In addition, the simulations show that gas migration out of the MRAA and through the clay aquitard in short time frames requires pathways of substantially large footprint through the aquitard with high hydraulic conductivities (> 10^{-6} cm/sec) and low gas entry threshold parameters. The simulation with these properties leaves little gas in the MRAA which is inconsistent with the observed continuing presence of gas in the MRAA. The presence at the site of multiple bubble sites in the vicinity of the Bayou Corne indicates that discrete pathways do exist that can allow gas to migrate either from gas bearing seams in the aquitard or from the MRAA. Because boring and CPT sounding data show that extensive and thick clay layers are present in the aquitard below the entire area of investigation, artificial penetrations (for example, abandoned wells without complete seals or seismic shot holes) are the likely pathways for gas migration to bubble points.

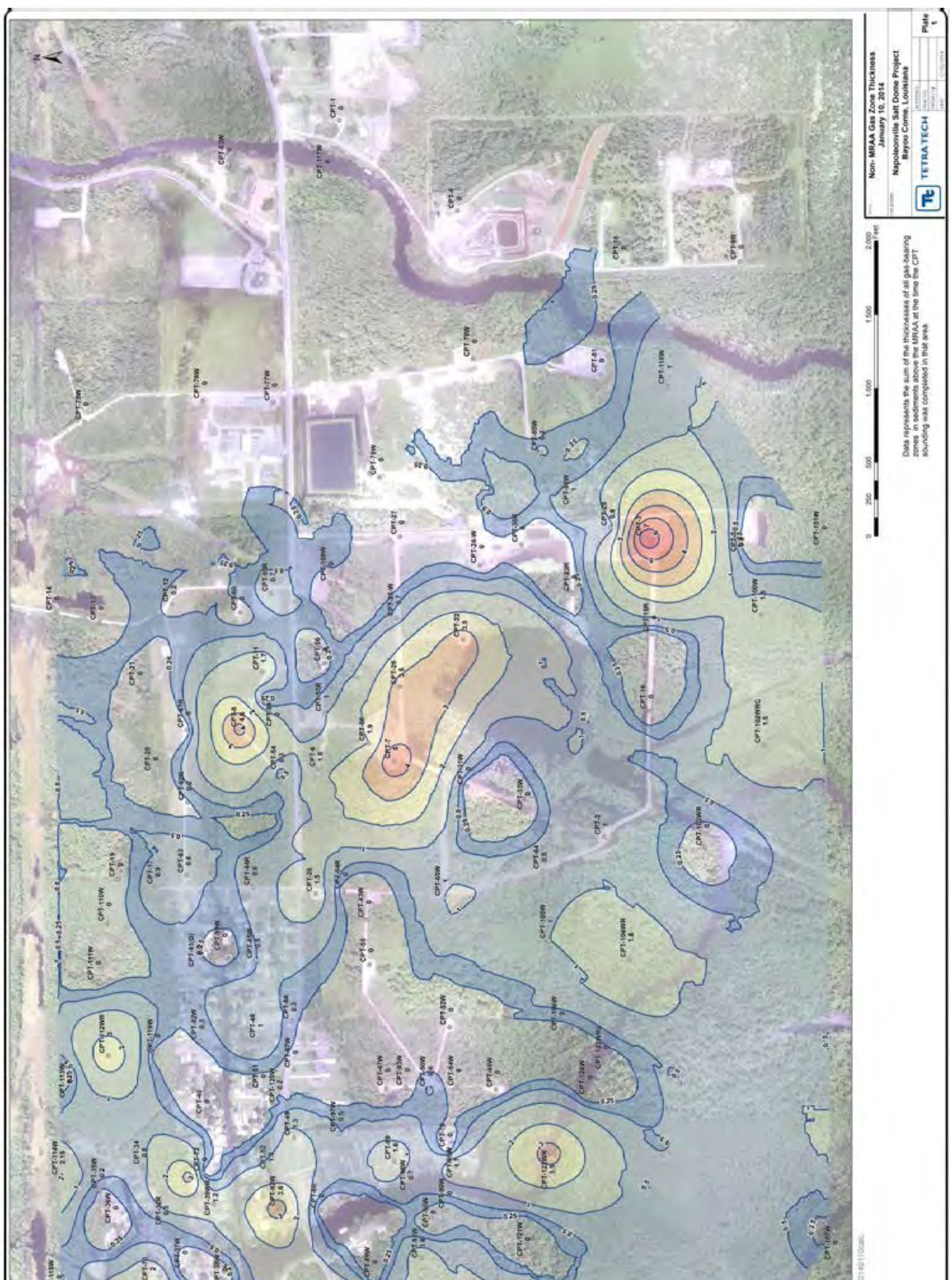
Non- MRAA Gas Zone Thickness
January 10, 2014
Napoleonville Salt Dome Project
Bayou Corne, Louisiana
TETRA TECH
Plate 1
0 250 500 1,000 1,500 2,000 Feet
Data represents the sum of the thicknesses of all gas-bearing zones in sediments above the MRAA at the time the CPT sounding was completed in that area

Plate 1 Map of Net Gas Thickness

c. Original source of gas in the MRAA and overlying aquitard

The molecular and isotopic composition of natural gas samples were used to determine the source of free gas samples and the natural gas dissolved in water samples collected from the MRAA, the overlying aquitard, gas bubble sites/seeps, sub-slab gas samples, the collapsed Oxy Geismar 3 salt solution cavern, and the Napoleonville salt dome. Three types of natural gas generated by microbes in shallow sediments and two types of thermal gas that formed from ancient organic matter (kerogen) in deeply-buried petroleum source rocks have been identified:

- Microbial gas that formed during the decomposition of plant debris <60 years old
- Microbial methane that formed during the reduction of carbon dioxide:
- Thermal gas present in the Napoleonville salt dome and caprock, and dissolved in the Oxy Geismar 1 salt solution cavern (salt dome type gas). This type of thermal gas has been released from the salt dome.
- Thermal gas now dissolved in the sinkhole and the Oxy Geismar 3 salt solution cavern, and present in the MRAA northwest of the sinkhole (Oxy-3 type gas). The type of thermal gas probably has a source outside the salt dome.

Almost all gas samples collected from ORWs completed in the MRAA between the sinkhole and Bayou Corne are mixtures of Oxy-3 type thermal gas and native microbial methane, while ORWs located between the sinkhole and the Napoleonville salt dome vent mixtures of salt dome type thermal gas and native microbial methane (Figure 1). Most GeoProbe wells located in Bayou Corne or along Highway 70 encountered predominantly microbial methane in the MRAA aquitard. GeoProbe wells located near the sinkhole found more thermal gas in the MRAA aquitard. Oxy-3 type gas is present in the aquitard northwest of the sinkhole, while salt dome type thermal gas is present in the aquitard between the sinkhole and the Napoleonville salt dome (Figure 2). The distribution of salt dome and Oxy-3 type thermal gas at gas seeps is more complicated: e.g., salt dome type thermal gas is present in several gas seeps located ≈2,000-4,500 feet west of the sinkhole (Seeps K3, 14, and 23), and Oxy-3 type thermal gas is present in one gas seep located above the salt dome (Seep 2) (Figure 3).

The microbial gas dissolved in the MRAA and the overlying aquitard was generated by methanogenic microbes present in shallow sediments prior to the collapse of the Oxy Geismar 3 salt solution cavern. This type of gas – which informally is named “swamp gas” –commonly forms in sediments that contain a significant amount of organic matter that generates carbon dioxide when it decays. Microbial gas will dissolve in an aquifer until it saturates the water. This explains the origin of the natural gas dissolved in water samples obtained from most Geoprobe wells completed in the MRAA aquitard, and in MRAA water samples collected in several industrial wells: e.g., DNR Well 4; DNR Well 10.

No gas geochemical data are available from the time period before August 2012 to determine the distribution of salt dome and Oxy-3 type thermal gases in the MRAA or in the overlying aquitard prior to the collapse of the Oxy-3 cavern. A salt diapir and the deformed sedimentary rocks adjacent to it are vertical migration pathways for oil and gas generated by much deeper petroleum source rocks. Gas migrating vertically over geological time will migrate laterally when it encounters a permeable bed. Gas migration through the vertical bed will stop if it enters a structural or stratigraphic trap with effective top seals and lateral seals: e.g., the gas accumulation in the “Big Hum” reservoir. However, if the gas encounters a fault, fracture, or improperly-cemented wellbore that penetrates the top seal, it will again migrate vertically. This process can explain the presence of some amount of salt dome or Oxy-3 type thermal gas in the MRAA and in the overlying aquitard prior to the formation of the sinkhole. It is the best explanation for the presence of salt dome type thermal gas in two gas seeps located west of the sinkhole (Seep K3 and 14), where Oxy-3 type gas vents from a nearby well (ORW-19) completed in the MRAA.

Section IIId. Analysis of Ongoing Deep Thermogenic Gas Migration Upward Through the DRZ, Including Analysis of Sources of Gas in the Oxy 3A Well and Bubbling in the Sinkhole and Why the Sources of Gases from the Oxy 1 and Oxy 3 Caverns Appear to be Different.

The C isotopic composition of ethane, propane, and n-butane is principal difference between salt dome type thermal gas and Oxy-3 type thermal gas. The C isotopic composition of ethane in salt dome type gas is slightly heavier than the C isotopic composition of ethane in Oxy-3 type gas. But the C isotopic composition of propane in salt dome type gas is slightly lighter than the C isotopic composition of propane in Oxy-3 type gas. Furthermore, the C isotopic composition of n-butane in salt dome type gas is significantly lighter than the C isotopic composition of n-butane in Oxy-3 type gas (Figure 4).

The C isotopic composition of HC gas compounds is influenced by the type of organic matter that formed the kerogen in a petroleum source rock, and the temperature at which the source rock generated the gas. For example, the C isotopic composition of gas compounds generated by kerogen derived from terrestrial organic matter typically is heavier than the C isotopic composition of gas compounds generated by kerogen derived from marine organic matter. Furthermore, the C isotopic composition of HC gas compounds generated by either type of kerogen becomes heavier as the kerogen becomes more thermally mature. In addition, the difference between the C isotopic composition of different HC gas compounds (e.g., ethane and propane; propane and n-butane) decreases as the kerogen becomes more thermally mature. Therefore, the observed difference between the C isotopic composition of ethane, propane, and n-butane in salt dome type gas and Oxy-3 type gas was controlled by source effects (i.e., the type of kerogen that generated each type of gas) and/or by maturity effects (i.e., the temperature at which kerogen generated each type of gas).

Salt dome type gas was generated by a deep petroleum source rock that has reached a very high level of thermal maturity – probably prolific oil-prone Cretaceous or Jurassic source rock beds that have generated most of the crude oil and natural gas in Louisiana. The evidence supporting this interpretation is the relatively small difference between the C isotopic composition of ethane, propane, and n-butane. In contrast, Oxy-3 type thermal gas probably was generated by a shallower petroleum source rock containing kerogen derived from terrestrial organic matter – probably Paleogene source rock beds that petroleum geologists conclude generated some of the natural gas in Louisiana. The evidence is the presence of isotopically-heavy n-butane in Oxy-3 type thermal gas, and the larger difference between the C isotopic composition of ethane, propane, and n-butane (Figure 5).

Salt dome type gas in the salt diapir also dissolved into the water used to solution-mine the Oxy Geismar 1 and Oxy Geismar 3 salt solution caverns. Some dissolved gas likely exsolved from the brine that was stored in the Oxy Geismar 3 cavern when it collapsed. In contrast, the most likely source of Oxy-3 type thermal gas released during the incident are gas pools that were trapped on the western flank of the Napoleonville salt dome.

The gas dissolved in the water column of the sinkhole that formed after the collapse of the salt cavern contains biodegraded Oxy-3 type thermal gas. Microbes preferentially metabolize ethane, propane, and n-butane relative to methane. In addition, the residual ethane, propane, and n-butane in biodegraded gas is enriched in isotopically-heavy C. The dissolved gas over the depth interval from 25 ft to 100 ft was more biodegraded in September 2013 than it was in July 2013 (a trend that continued in water samples collected during November 2103). This indicates that a significant amount of Oxy-3 type thermal gas did not migrate into the sinkhole after July. If that had happened, the mixture of "old" dissolved gas and "fresh" dissolved gas would be less biodegraded in September that it was in June.

Figure 1. The gas venting from the MRAA at ORWs primary consists of Oxy-3 type thermal gas northwest of the sinkhole, and salt dome type thermal gas between the sinkhole and the Napoleonville salt dome.

Figure 2. The amount of thermal gas dissolved in the MRAA aquitard varies widely, probably because thermal gas cannot migrate efficiently between laterally-discontinuous sand beds.

Figure 3. The type of thermal gas in gas seeps spatially is more variable than the type of thermal gas venting from OWRs completed in the MRAA.

Figure 4. The C isotopic composition of propane and n-butane in salt dome type thermal gas and Oxy-3 type thermal gas is different.

Figure 5. The C isotopic composition of the kerogen that generated thermal gas can be estimated by plotting the C isotopic composition of HC gas compounds on a "Chung Diagram". The line through the values of ethane, propane, and n-butane extrapolates to the C isotopic composition of the kerogen that generated those gas compounds. The slope of that line decreases with increasing thermal maturity of the kerogen that generated the gas.

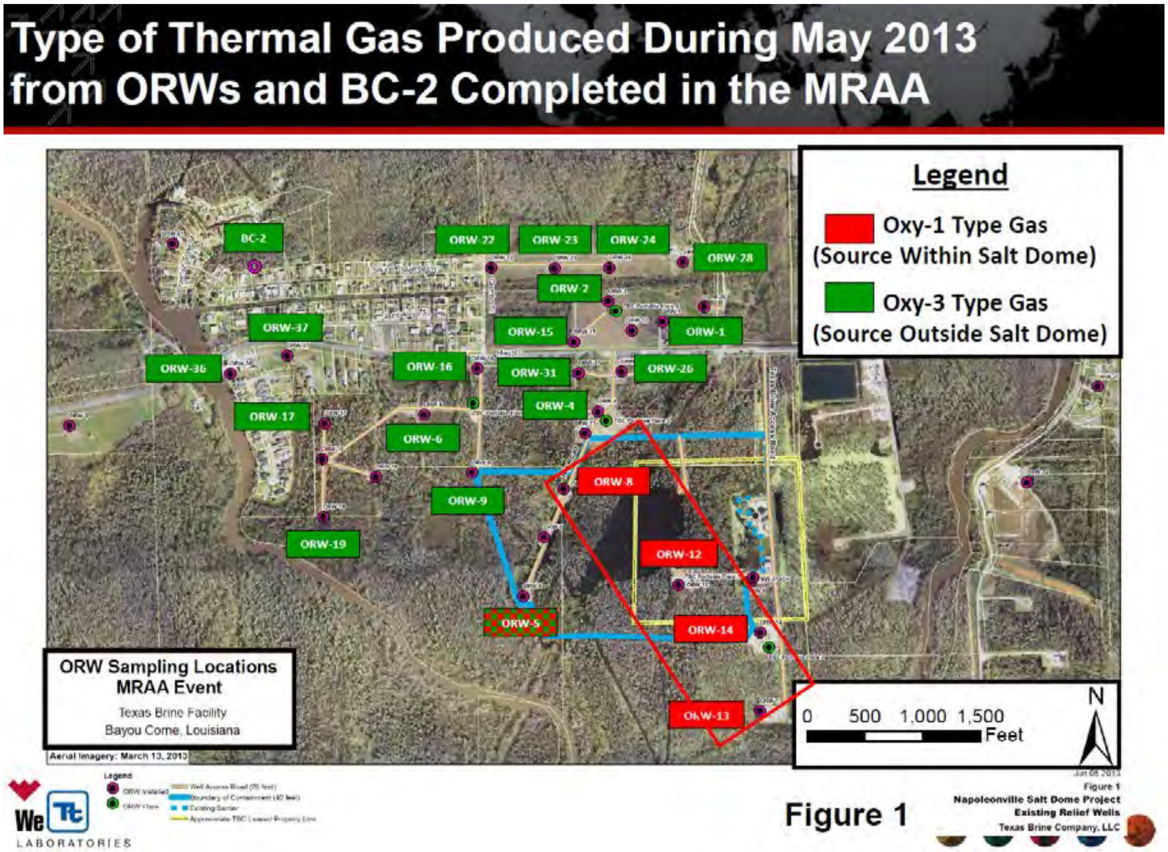

Figure 1. The gas venting from the MRAA at ORWs primary consists of Oxy-3 type thermal gas northwest of the sinkhole, and Oxy-1 type thermal gas between the sinkhole and the Napoleonville salt dome.

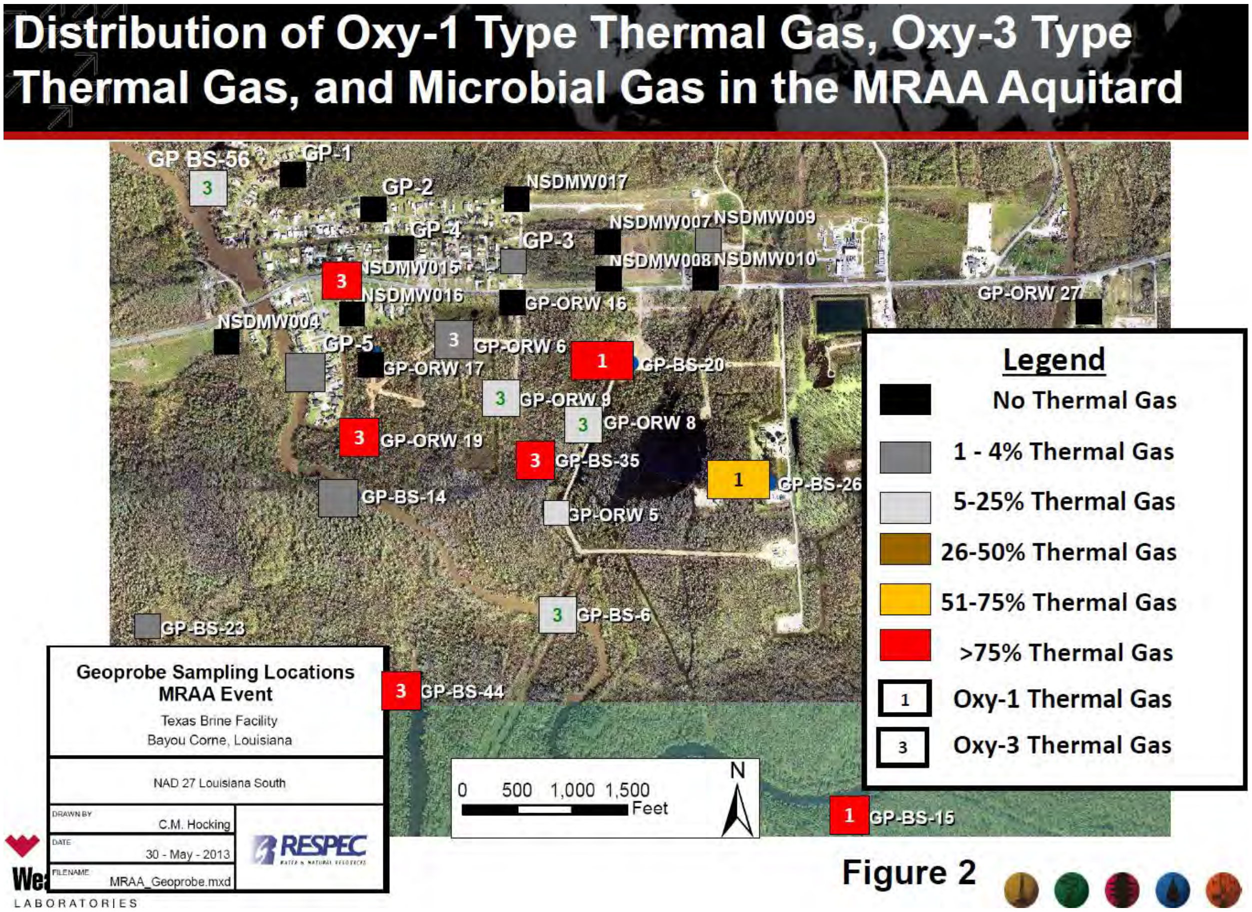

Figure 2. The amount of thermal gas dissolved in the MRAA aquitard varies widely, probably because thermal gas cannot migrate efficiently between laterally-discontinuous sand beds.

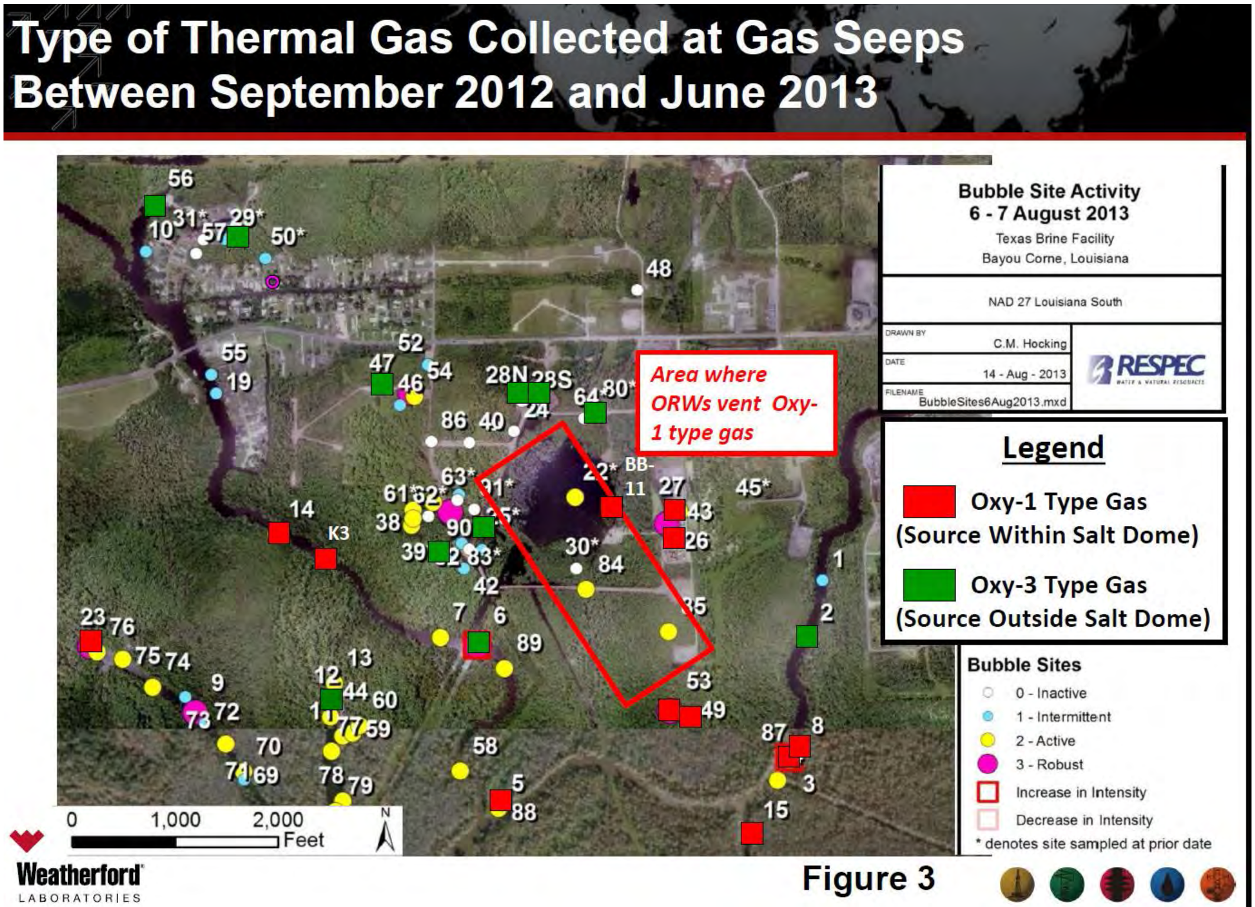

Figure 3. The type of thermal gas in gas seeps spatially is more variable than the type of thermal gas venting from OWRs completed in the MRAA.

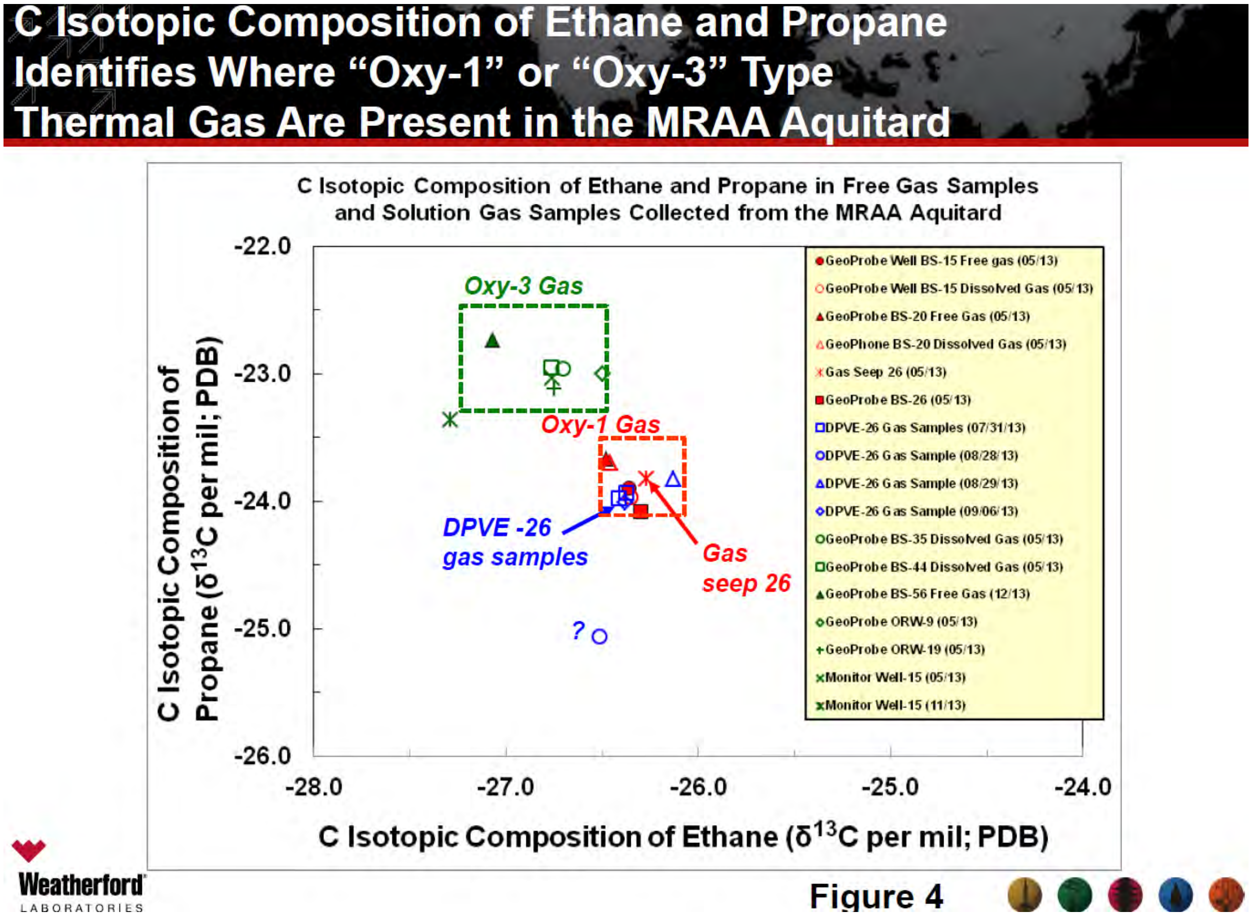

Figure 4. The C isotopic composition of propane and n-butane in Oxy-1 and Oxy-3 type thermal gas is different.

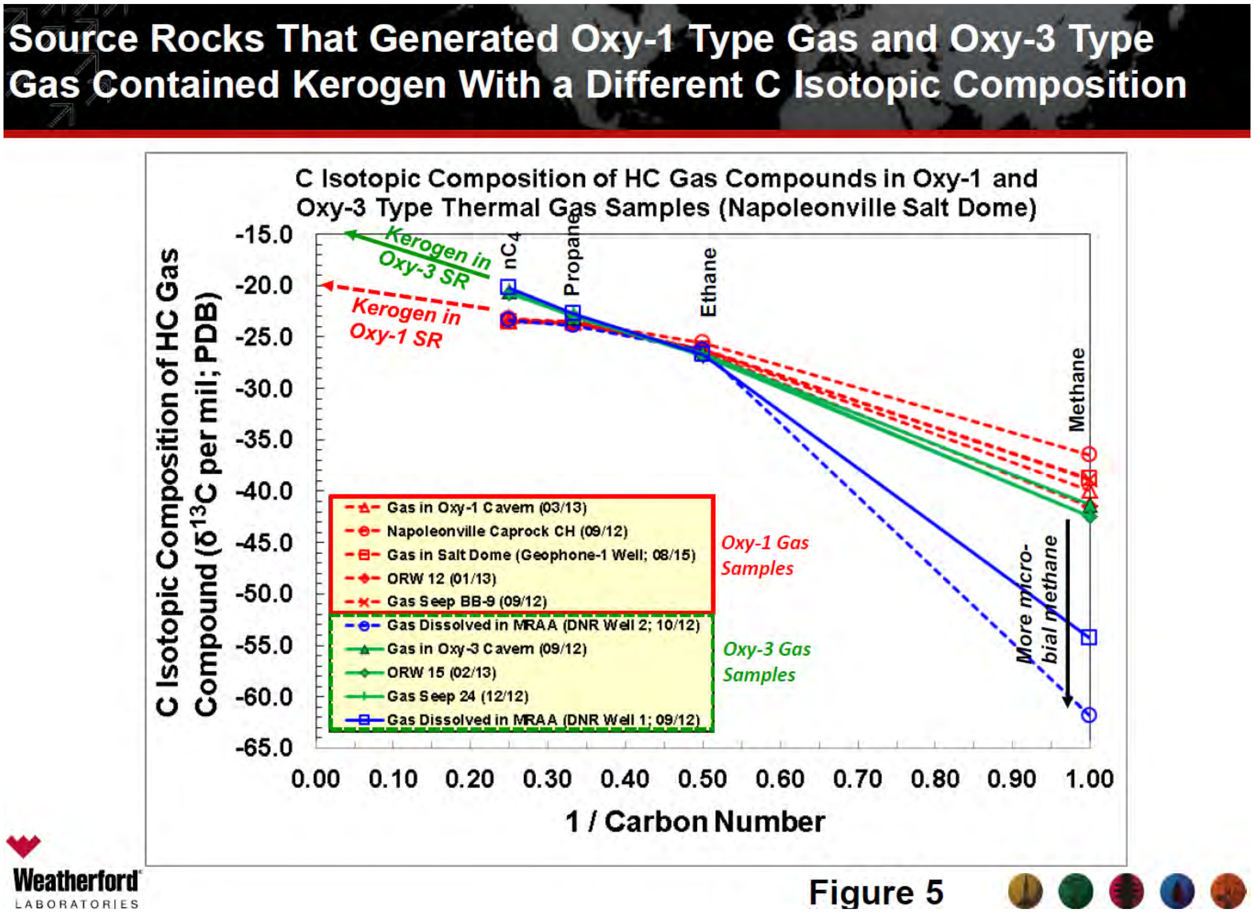

Figure 5. The C isotopic composition of the kerogen that generated thermal gas can be estimated by plotting the C isotopic composition of HC gas compounds on a "Chung Diagram". The line through the values of ethane, propane, and n-butane extrapolates to the C isotopic composition of the kerogen that generated those gas compounds. The slope of that line decreases with increasing thermal maturity of the kerogen that generated the gas.

e. Analysis of current gas mitigation efforts and ORW performance

TBC has installed a total of 47 relief wells (ORWs) to date with 4 more wells planned at this time. Total methane gas production as of December 6, 2010 is calculated to be 23.08 million cubic feet of gas (MMCF), with a current flow rate of approximately 54 thousand cubic feet per day (MCF/d). See Figure 1 for a graph of cumulative gas production since the first wells were installed in early November 2012. Currently eleven ORWs are producing at a gas flow rate greater than 0.5 MCF/d, with flow ranging from 0.5 MCF/d to 11 MCF/d (refer to Table 1 for current well flow statistics).

The *Investigative Report for RRD-08B Extent of Gas* report dated December 19, 2013 contained an estimate of the volume of gas recoverable at the time the CPTs were installed (i.e. post-CPT recoverable gas volume). The estimated range of gas volume is between 10.3 to 15.2 MMCF of methane gas for gas thicknesses ranging from 0.25 feet to greater than 1.0 feet, respectively. More than 6 MMCF of gas has been produced subsequent to installation of the CPTs.

Eleven ORWs have produced in excess of 1 MMCF of gas, with the most prolific well OGRW-1 at almost 5 MMCF of methane. The wells installed within the Bayou Corne community have produced a total of 2.5 MMCF of methane to date and are flowing at a rate of approximately 26 MCF/d, additionally wells immediately adjacent to the community (ORW-22, ORW-16, ORW-17, ORW-18, ORW-19, ORW-52, ORW-53 and ORW-46) have likely removed gas from beneath the community.

The method of well operation employed by TBC has resulted in optimizing the long term cumulative production of gas by individual wells while minimizing operational downtime related to “watering in” of the wells and the associated expense. TBC has operated the wells with a choke setting that controls the pressure drop across the well screens, maintaining gas flow to the well, and minimizing water production.

As shown on Figure 2, Daily Gas Vented, the daily gas volume is decreasing at this time showing a continual depletion of gas in the subsurface. Examples of this decline are nine of the top producing ORWs that have produced over 1 MMCF of gas that are now either shut-in or producing at a flow rate of less than 1 MCF/d. These wells have shut in well head pressure of 0 to 10 psig even though rehabilitation measures have been taken to ensure the perforations or well screens are open and in communication with the MRAA sands.

TBC reported on the pilot test for dewatering ORWs to enhance gas flow rate in its report, *ORW Enhanced Methane Recovery Pilot Test Program* dated November 26, 2013. The dewatering tests showed that dewatering does increase gas venting rates in some wells depending on the site specific conditions. A dewatering test of well ORW-38 is planned next followed by a test at ORW-21. After an evaluation of the tests at ORW-38 and ORW-21, TBC will submit a design plan for dewatering the candidate wells per attached Table 4 from the submitted report, *Phases and Criteria for Operation of ORW's* as updated in TBC's December 27, 2013 response to DNR Comments on the ORW-38 work plan.

Figure 1. Cumulative gas vented/flared

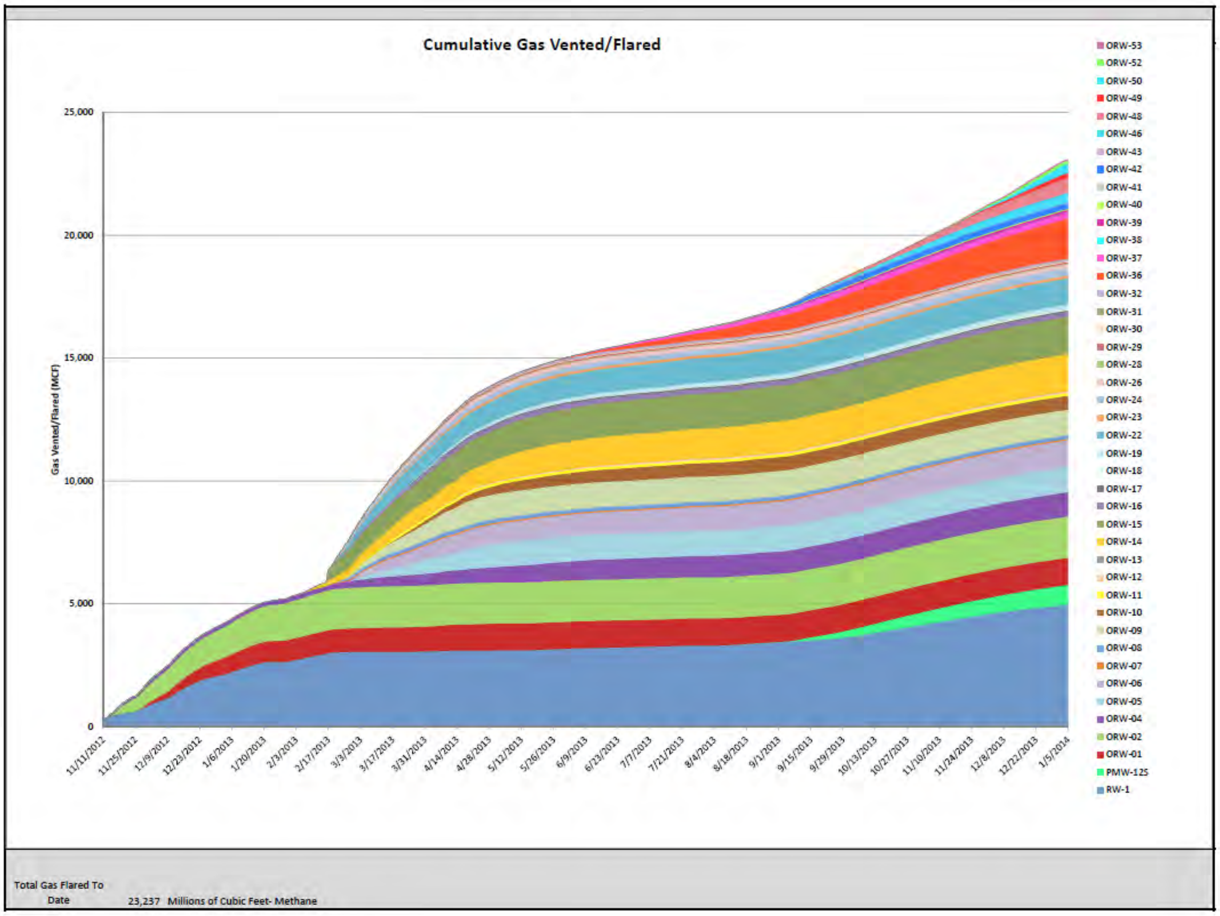

Figure 2. Daily gas vented

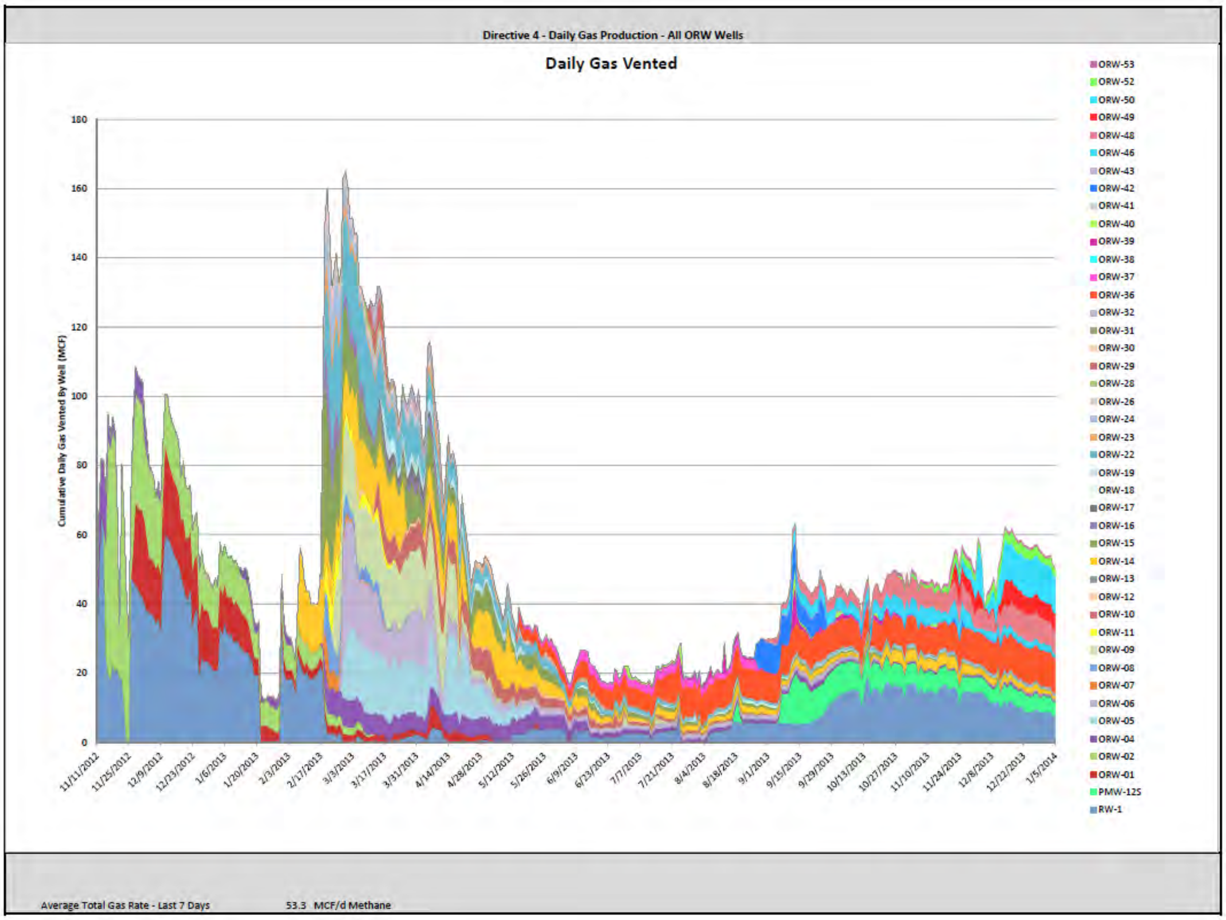

Table 1. Current well statistics

Venting Well and Imported Fill Material Summaries
Current as of 1/6/2014

Directive 4 - ORW Flaring Information (Previous calendar day)					
	FWHP	SIWHP	Choke Size	Gas Rate	Cum. Gas Flared
	(PSI)	(PSI)	(1/64")	(MCF/d)	(MCF)
ORW-01		12	0	0.0	1,099
ORW-02		0	0	0.0	1,682
ORW-04	17.0		1	0.5	990
ORW-05		0	0	0.0	1026
ORW-06	20.0		1.5	0.29	1,092
ORW-07		0	0	0.0	58
ORW-08		0	0	0.0	151
ORW-09		0	0	0.0	1,036
ORW-10		10	0	0.0	568
ORW-11		0	0	0.0	112
ORW-12					78
ORW-13		11	0	0.0	2.8
ORW-14	38.0		4	1.0	1,500
ORW-15	49.00		3.75	0.2	1,519
ORW-16		1	0	0.0	199
ORW-17		0	0	0.0	62
ORW-18	8.0		1	0.1	49.8
ORW-19		22	0	0.00	198
ORW-22	17.0		1	0.1	1,059
ORW-23		12	0	0.0	110
ORW-24	15.0		1	0.5	293
ORW-26		14	0	0.0	172
ORW-28		30	0	0.0	28
ORW-29		1	0	0.0	59
ORW-30		10	0	0.0	42
ORW-31		23	0	0.0	13
ORW-32		0	0	0.0	90
ORW-36	47		6.75	10.2	1,692
ORW-37		14	0	0.0	248.9
ORW-38		0	0	0.0	1.2
ORW-39		6	0	0.0	102.6
ORW-40		3	0	0.0	49.6
ORW-41		0	0	0.0	0.16
ORW-42		0	0	0.0	229.7
ORW-43		4	0	0.0	12.7
ORW-46	48		2.5	2.0	394.3
ORW-48	47.0		5.25	7.0	587.4
ORW-49	46.0		6.25	4.9	182.8
ORW-50	45.6		8.25	11.0	330.3
ORW-52	47.5		4.5	2.5	130.27
ORW-53	22.0		0.75	0.5	56.6
PMW-12S	12		64	4.6	804.6
TBC-RW-1/OGRW-1	19.0		9	8.6	4,917
Totals				**54.0**	**23,081**

*Note: Total daily gas flared and cumulative gas flared is based on data through 3pm of previous day
*Note: ORW-42 became a PMW on 10/2/13 ORW-42 is now PMW-19S
*Note: PMW-12S became a ORW on 9/6/13 PMW-12S is now ORW-54
*Note: PMW-18S Flared for 50 MCF on 11-22-13 through flare 6 during the emergency response to mitigate gas kicks dev
*Note: PMW-18 Flared for 1.53 MCF on 12-3-13 and 12-5-13 for 2.96 MCF for depressurization

f. Prognosis for achieving the stated BRC goal of reducing gas sufficiently that it is equal to hydrostatic pressure and therefore can no longer migrate to the ground surface

The BRC goal of reducing gas sufficiently that it is equal to hydrostatic pressure has significant technical challenges in its application as a mitigation goal. Firstly, it is not clear how the BRC is defining hydrostatic pressure. Hydrostatic pressure in groundwater is a theoretically calculated pressure at an elevation or depth different from a reference point of known (or assumed) pressure and elevation. The calculation is based on the weight of water expressed as the hydraulic gradient (0.433 psi/ foot of elevation change, for pure water at standard conditions). The BRC has set a benchmark based on comparing gas pressures with hydrostatic pressure, but has provided no details on how the comparison is to be made. The BRC has not even specified the reference point to be used for calculating hydrostatic pressure in the gas bearing strata. Options for the reference point could include:

- Ground surface elevation and atmospheric pressure
    - Does not account for seasonal water level changes in MRAA
- Ground water pressures at known elevations in the MRAA where gas is not present.
    - Does not account for short term variations in measured pressures in groundwater or for non-static conditions
- Either of the above with an additional pressure value added to account for uncertainty.

Pressure monitoring data collected from inactive relief wells (ORWs) and pressure monitoring wells (PMWs) have shown both short-term and long-term variations that render comparisons difficult.

Secondly, gas pressures will always be greater than adjacent groundwater pressures in a water wet, two phase system. Dr. Randall Charbeneau prepared Attachment 1 to RRD-09 which includes a graph (Figure 2 in his attachment) of capillary pressure head versus saturation for a sand textured soil. From this graph the pressure head difference at water saturation of 0.67 is about 1 foot or about 0.43 psi pressure difference between gas and groundwater. A water saturation of 0.67 is of interest, because it represents the saturation above which gas is either trapped or otherwise not recoverable. As indicated by Dr. Charbeneau in referring to gas in the

MRAA "Not all of this would be recoverable; roughly 1/3 would be trapped at residual saturation." Therefore, gas pressure will exceed water pressure on the order of 0.4 psi for this example even when gas is no longer producible. Depending on the capillary pressure relationship between gas and water in the fine sands where the gas cap occurs in the MRAA the minimum pressure difference can be smaller or larger than 0.4 psi. Laboratory results for samples collected as part of RRD-05 will provide data to further assess the minimum pressure difference, but even laboratory values will be subject to additional uncertainty.

Because of these limitations to using hydrostatic pressure as a gas mitigation goal, TBC has recommended alternative criteria and testing using a combination of performance data from relief wells and repeat CPT soundings. These criteria have been submitted to LDNR *i*n the Memorandum*, Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations,* November 8, 2013*.* The BRC has rejected the TBC approach without providing any details on how to apply their goal. TBC believes the BRC goal is unworkable and requests a meeting to develop a set of workable goals for determining the end point do gas venting operations.

In summary the prognosis for achieving the BRC's stated goal of reducing gas sufficiently that it is equal to hydrostatic pressure is doubtful at best.

g. Proposed alternative remediation metric, if any, as to when gas mitigation may be terminated

TBC submitted the *Plan for Operating Relief Wells and Conceptual Criteria for Ending Operations* on November 8, 2013. This plan proposes establishing measureable and achievable criteria for ending operations for groups of ORWs with the goal of depleting the MRAA of gas to the extent practicable. Tables 1 to 4 of the above referenced document have been revised since the initial submittal. These updated tables are included below this section.

TBC recommended these alternative criteria due to the problems identified with using hydrostatic pressure as a gas mitigation goal. The alternative criteria offer a direct and measurable methodology for determining a gas depletion end point for individual and groups of ORWs. Please refer to Section III) f) for a more detailed discussion of the difficulties in applying a hydrostatic pressure standard.

Table 1. Phases and Criteria for Operation of MRAA ORWs

	Project Phase	Description	Criteria for Changing to Next Sequential Phase
1)	Well Installation	Using available information and a well spacing of about 500' locate and install wells with perforations or screens open to the top of the gas zone at the upper portion of the MRAA. PDK logs initially used to identify gas intervals are now replaced by CPT soundings to locate MRAA gas zone intervals prior to well installation.	Well is completed to specifications and developed; Well head installed to specifications; and, Piping and connections to flare completed.
2)	Venting from gas pressurized conditions in well	Typically, a newly constructed relief well that is properly developed will build up gas pressures to values slightly less than, to a few PSI greater than, the hydrostatic pressure (computed from groundwater surface) at the screen (or perforation) depth. To avoid water encroachment into the well, the well is vented through a pressure reducing choke valve at the highest sustainable flow rates such that gas pressure in the well is maintained at levels slightly below the initial buildup shut-in pressure. The well is operated such that the optimum balance between gas pressure and flow rate is achieved. Each well is different and a skilled operator uses his or her judgment and prior venting history to adjust the vent chokes and orifice plates through which gas must flow. As the gas flow rates and gas pressure decline, the operator may shut in the well to allow gas pressures to increase and gas flow rates to increase when the well is reopened.	If total gas flowed in a recent 10 day period is less than 5 MCF (or 0.5 MCFD), **and** • Well has been online less than 6 months or • Total flared gas volume is greater than 50 MCF, **then** Initiate a dewatering feasibility study at all wells located outside of the Bayou Corne Community[1] with the potential to produce gas to segregate wells between operational phases 3 and 4. Wells with feasibility results demonstrating gas yield of more than 0.5 MCFD will be placed in the Phase 3 Dewatering program with results used to develop engineering parameters for long term two-phase extraction[2]. Wells that yielded less than a 0.5 MCFD increase from test dewatering will be placed in the Phase 4

Project Phase	**Description**	**Criteria for Changing to Next Sequential Phase**
		Monitoring Program. Wells that are located within the Bayou Corne Community that meets the initial criteria, above, will be placed directly into the Phase 4 Monitoring program.
3) Venting with dewatering	Gas flow rates can be increased by dewatering of wells undergoing two-phase flow. Even with relatively low pumping rates, the water pressure next to the well can be reduced as much as 10 psi; because the well is open only to a very thin interval at the top of the MRAA where the permeability of the aquifer is low. Suitable pumps need to be installed to remove groundwater. Piping or some other means of transport must be constructed and/or available to move produced water from the well to the sink hole containment berm for discharge. Flow rates for water produced are anticipated to be from 0.5 to 5 gpm, based on the successful testing done at OGRW-1 and the ORW dewatering program.	A total gas flow in a recent 10 day period is less than 5 MCF; and Adjustments made to pumping rates and venting equipment do not increase gas flow above 0.5 MCFD, then Phase 4 monitoring
4) Monitoring	Gas pressures and vent tests will be performed to determine if gas in the vicinity is producible due to localized gas accumulation near the well or migration from a continuing gas source. Gas pressure measured by transducers at the well head, will record at hourly intervals and will be downloaded monthly. Analog or digital gas pressure gauge will be installed for visual inspection. Vent test at 6 weeks and quarterly	3 consecutive tests with gas flow rates less than 0.5 MCFD – Phase 5 Maintenance Vent test with initial gas flow >1 MCF will be extended for 10 days and if total >10 MCF return to prior Phase 2 or 3 If extended test total flow is less than 10 MCF, continue monitoring

Project Phase	**Description**	**Criteria for Changing to Next Sequential Phase**
	thereafter will be conducted. Tests will be run for 2 days with venting relying on the gas pressure in the well to yield gas. If no gas pressure had developed in well, one well volume of water will be removed to evidence gas flow.	
5) Maintenance	The wells will be maintained and secured. Gas pressure gauges for visual inspection will not be removed. Other well head equipment may be removed.	Overall venting program completed – Phase 6 plug and abandon Well needs to be plugged and abandoned for some other reason
6) Plug and Abandon	The well will be plugged and abandoned in compliance with state requirements.	

1. Based on access or location, the following Bayou Corne Community wells will not be dewatered primarily because of community concerns over potential excessive ground subsidence: ORW-21, -38, -36, -37, -49, and -50.

2. Dewatering feasibility study is expected to be run at each qualifying well over 5 continuous days and include constant drawdown step tests. Results will include data to size pumps, pipe conveyances, tanks, and initial operating ranges.

Table 2. Assignment of Currently Installed ORWs to Operational Phases

Well ID	**Well Type**	**Installation Date**	**Phase Number**	**Comments**
OGRW-1	A		3B	Currently venting Good accumulation area for methane Ongoing dewatering due to successful pilot test results Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-1	A	10/6/12	3A	Contingent on dewatering feasibility study
ORW-2	A	10/7/12	3A	Contingent on dewatering feasibility study
ORW-3	A	10/8/12	4	No history of gas production from this pile-driven well casing No producible gas zones indicated by multiple CPT and PDK logs Re-perforated once.
ORW-4	A	10/25/12	3A	Currently venting Contingent on dewatering feasibility study CPT results indicate no gas in MRAA; gas inferred in an overlying sand lens within the aquitard where secondary well perforations are present.

Well ID	Well Type	Installation Date	Phase Number	Comments
ORW-5	B	2/25/13	6	Noted gas depletion from successful venting Three associated radius of Influence test MRAA wells show similar gas depletion Prominent communication noted during dewatering without generating gas Proximal to sinkhole with at least 1.5 ft of full well subsidence
ORW-6	B	2/22/13	3A	Currently venting Contingent on dewatering feasibility study Typically generates tubing gas during periodic dewatering Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-7	B	2/14/13	6	Good communication noted during dewatering without generating gas Noted gas depletion from successful venting Proximal to sinkhole with nearly 2.0 ft of full well subsidence No producible gas zones indicated by CPT and PDK logs Located on unmaintained Rig Road Berm
ORW-8	B	2/12/13	6	Noted gas depletion from successful venting Proximal to sinkhole with at least 1.5 ft of full well subsidence Located on unmaintained Rig Road Berm No producible gas zones indicated by CPT and PDK logs Deviated 8 to 10 degrees from vertical via subsidence with top tilting toward sinkhole
ORW-9	B	2/20/13	4	Noted gas depletion from successful venting During operations, thinning gas zone verified by CPT and PDK logs Dewatering Pilot Test demonstrated aquifer communication, but was unsuccessful at maintaining minimal gas flow from reduction in bottomhole pressure Three associated radius of Influence test MRAA wells show similar gas depletion
ORW-10	B	3/10/13	4	Gas flow from the well has not yet been re-established after recent well redevelopment and substantial dewatering efforts Local depression in the top of the MRAA contact precludes it from being a good candidate for enhanced methane recovery
ORW-11	B	2/6/13	4	Noted gas depletion from successful venting Proximal to sinkhole with at least 0.26 ft of full well subsidence Differential subsidence of the top of the MRAA away from the sinkhole may provide a transport mechanism for any remaining mobile gas to migrate away from the well, precluding its use as an enhanced methane recovery well
ORW-12	B	1/10/13	6	Well has been plugged and abandoned due to location on Pad 3 (adjacent to sinkhole)
ORW-13	B	1/22/13	4	No history of gas production No producible gas zones indicated by CPT or PDK Re-perforated once Regional depression trough in the top of the MRAA contact is present and not geologically favorable for trapping mobile methane, if present in the past, or for future enhanced recovery.
ORW-14	B	1/23/13	3A	Currently venting Contingent on dewatering feasibility study Shares a good methane accumulation area with OGRW-1 which is successfully implementing enhanced methane recovery Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-15	B	1/29/13	2	Currently venting Typically generates tubing gas during periodic dewatering
ORW-16	B	2/12/13	3A	Contingent on dewatering feasibility study
ORW-17	B	2/13/13	4	After an initial month of successful venting, gas production dropped off to low and unsustainable levels Dewatering data from seven days of purging over a 2-month period demonstrated communication but did not generate any gas pressure No producible gas zones indicated by PDK and CPT piezocone logs Proximity of adjacent Sportsman's Drive top of MRAA mound is unfavorable geology for trapping mobile gas or for enhanced methane gas recovery.
ORW-18	B	2/24/13	3A	Currently venting Contingent on dewatering feasibility study Dewatering data from six days of purging over a 2-1/2 month period demonstrated prominent aquifer communication and mobilized gas to the well

Well ID	Well Type	Installation Date	Phase Number	Comments
				Typically generates tubing gas during periodic dewatering No producible gas zones indicated by PDK and CPT piezocone logs
ORW-19	B	3/.14/13	3A	Currently venting Contingent on dewatering feasibility study PDK log indicated the presence of MRAA gas No producible gas zones indicated by CPT piezocone log Dewatering data from six days of purging over a 10-week period demonstrated prominent aquifer communication and mobilized gas to the well
ORW-21	B	5/24/13	4	Bayou Corne Community Well No producible gas zones indicated by CPT piezocone and PDK logs
ORW-22	B	2/5/13	3A	Currently venting Contingent on dewatering feasibility study Potential to be considered Bayou Corne Community Well due to proximity Typically generates tubing gas during periodic dewatering Initial PDK log showed substantial methane accumulation while CPT piezocone logged 6 months later showed an aquifer consistent with a depleted gas zone Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-23	B	2/10/13	4	Contingent on adding ORW-22 to the Phase 3 dewatering program, as that adjacent well is a better candidate for dewatering After an initial 5 weeks of successful venting, gas production dropped off to low and unsustainable levels Subsequent CPT piezocone logs indicated no producible gas zones Good aquifer communication established from dewatering tests, which did not promote two-phase flow Local depression in the top of the MRAA surface from wells on either side make this geology unsuitable for primary or enhanced gas recovery
ORW-24	B	2/10/13	2	Currently venting Typically generates tubing gas during periodic dewatering Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-26	B	1/31/13	3A	Contingent on dewatering feasibility study CPT piezocone logs indicate the ongoing presence of gas Dewatering data shows moderate communication with potential for induced two-phase flow and typically generates tubing gas during dewatering
ORW-27	B	2/27/13	4	No history of elevated gas or gas production. No producible gas zones indicated by multiple CPT and PDK logs Regional depression trough in the top of the MRAA contact is present and not geologically favorable for trapping mobile methane, if present in the past, or for future enhanced recovery.
ORW-28	B	3/6/13	4	After an initial several weeks of successful venting, gas production dropped off to low and unsustainable levels Dewatering data shows good communication with low potential for significant induced two-phase flow Top of MRAA is higher to the west and south, closer to the potential source area, indicating that this well would be a poor candidate for enhanced methane recovery
ORW-29	B	3/7/13	4	After an initial several weeks of successful venting, gas production dropped off to low and unsustainable levels No producible gas zones indicated by subsequent CPT piezocone logs Dewatering showed moderate communication with low potential for two-phase flow Top of MRAA is significantly higher immediately to the south (closer to the potential source area) where ORW-54 and ORW-30 are better candidates for primary and Phase 3 dewatering for enhanced gas recovery
ORW-30	B	3/12/13	3A	Contingent on dewatering feasibility study Fringes of local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery from a known area of good gas recovery Typically generates tubing gas during periodic dewatering
ORW-31	B	3/11/13	4	Local depression in the top of the MRAA surface from wells on either side make this geology unsuitable for primary or enhanced gas recovery Good aquifer communication established from dewatering tests, which did not promote two-phase flow CPT logs indicated no producible gas zones
ORW-32	B	3/9/13	3A	Contingent on dewatering feasibility study

Well ID	Well Type	Installation Date	Phase Number	Comments
				Good communication with two phase flow demonstrated during dewatering tests Typically generates tubing gas during periodic dewatering Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-33	B	4/30/13	4	No history of gas production from this region No producible gas zones indicated by multiple CPT and PDK logs Regional depression trough in the top of the MRAA contact is present and not geologically favorable for trapping mobile methane, if present in the past, or for future enhanced recovery.
ORW-36	B	4/29/13	2	Currently venting Bayou Corne Community Well
ORW-37	B	4/29/13	4	Currently venting Bayou Corne Community Well
ORW-38	C	6/21/13	4	Bayou Corne Community Well
ORW-39	C	6/30/13	3A	Currently venting Contingent on dewatering feasibility study Screened in lower confined lens of sand within the aquitard directly above the MRAA Dewatering Pilot Test results inconclusive
ORW-40	C	6/28/13	4	Screened in lower confined lens of sand within the aquitard directly above the MRAA Dewatering Pilot Test unsuccessful at maintain two-phase flow with approximately 20 ft of drawdown
ORW-41	C	8/6/13	4	8-hour pump test demonstrated groundwater well yield an order of magnitude higher than all other tested wells but without any two-phase flow.
ORW-43	C	8/25/13	4	Numerous full-day dewatering tests demonstrated good well communication which did not promote two-phase flow Top of MRAA is significantly higher immediately to the south and east (closer to the potential source area) where OGRW-1 and ORW-14 are better candidates for primary and Phase 3 dewatering enhanced gas recovery
ORW-46	D	8/29/13	2	Currently venting Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-48	C	8/29/13	2	Currently venting
ORW-49	C	11/19/13	2	Currently venting Bayou Corne Community Well
ORW-50	C	11/21/13	2	Currently venting Bayou Corne Community Well
ORW-52	C	10/27/13	2	Currently in the venting program
ORW-53	C	10/25/13	2	Local mound in the top of the MRAA contact provides suitable geology for primary and enhanced methane recovery
ORW-54	C	8/15/13	2	Currently venting

Well Type A: Pile driven casing, perforated across PDK log gas zone(s)
Well Type B: Sonic drilled casing, perforated across PDK log gas zone(s)
Well Type D: Sonic drilled casing (excavation of MRAA soil), perforated across PDK log gas zone(s)
Well Type C: Sonic drilled temporary casing (excavation of MRAA soil), 4" well with screen across CPT determine gas zone(s)

Table 3. Criteria for Ending Venting Operations in the Community and Other Areas

Area Impacted	Criteria
Bayou Corne Community	Venting operations will be considered complete when all Bayou Corne Community vent wells have entered monitoring phase. The areas of concern include North and South of Highway 70, directly east of Bayou Corne; CPT soundings adjacent to and in between relief wells show no evidence of producible gas; and Gas pressures in shut-in relief wells and pressure monitoring well are within a statistically verifiable difference (>) of less than 1 psi relative to hydrostatic groundwater pressure
Areas Outside of Bayou Corne Community	Venting operations will be considered complete when all vent wells have moved into monitoring phase

Table 4. Summary of Proposed ORW Operational Status

Project Phase	Description	Well IDs	Well Type
2	Primary Venting	ORW-15	B
		ORW-24	B
		ORW-36	B
		ORW-46	D
		ORW-48	C
		ORW-49	C
		ORW-50	C
		ORW-52	C
		ORW-53	C
		ORW-54	C
3A	Feasibility Study For Continuous Dewatering	ORW-1	A
		ORW-2	A
		ORW-4	A
		ORW-6	B
		ORW-14	B
		ORW-16	B
		ORW-18	B
		ORW-19	B
		ORW-22	B
		ORW-26	B
		ORW-30	B
		ORW-32	B
		ORW-39	C
3B	Continuous dewatering	OGRW-1	A
4	Shut-in Wells with Monitoring Only	ORW-3	A
		ORW-9	B
		ORW-10	B
		ORW-11	B
		ORW-13	B
		ORW-17	B
		ORW-21	B
		ORW-23	B
		ORW-27	B
		ORW-28	B
		ORW-29	B
		ORW-31	B
		ORW-33	B

Project Phase	Description	Well IDs	Well Type
		ORW-37 ORW-38 ORW-40 ORW-41 ORW-43	B C C C C
5	Maintenance		
6	Plug and Abandon	ORW-5 ORW-7 ORW-8 ORW-12	B B B B