EXHIBIT "A"

RRD-GAS-09

MRAA GAS PRESSURE MONITORING

RECOMMENDED REQUIREMENTS DOCUMENT

Subject: **MRAA Gas Pressure Monitoring**

1.0 Background

The Blue Ribbon Commission (BRC) Gas Group has agreed to recommend that reducing and maintaining methane gas formation pressures in the Mississippi River Alluvial Aquifer (MRAA) to equal to or less than hydrostatic pressure across the Bayou Corne gas area as one metric necessary in order to lift the mandatory evacuation order (**Figure 1**). This Recommended Requirements Document (RRD) defines the technical requirements for installing additional pressure monitoring wells to monitor gas pressure and Observation Relief Well (ORW) gas venting efforts. The intent of this RRD is to provide recommended requirements for use by the appropriate state agencies when directing the development of a comprehensive work plan for addressing the RRD objective.

Technically, the gas pressure in the MRAA only has to be reduced to a pressure that is less than the pressure required for the gas to flow through the aquitard to the surface. However, determining a value for this pressure requires substantial characterization of subsurface geologic conditions and multiphase gas flow parameters. Such characterization is not presently available so hydrostatic pressure was defined by the BRC as the appropriate benchmark pressure. As the mitigation and characterization efforts progress and a multiphase gas flow numerical model is developed based on site conditions, it may be possible to define a MRAA gas pressure greater than hydrostatic pressure that is an appropriate benchmark to protect human health and the environment.

This RRD for upgrading the existing pressure monitoring network has been prepared with consideration of the following site conditions and existing ORW monitoring program:

- There are currently four pressure monitoring wells installed in the MRAA—TBC-01, TBC-02, and TBC-03 installed on the Texas Brine Company (TBC) property near the sinkhole and TBC-BC-02 installed in the Bayou Corne community (**Figure 1**). TBC-01, TBC-02, and TBC-BC-02 appear to be functioning properly as pressure monitoring wells but TBC-03 has never had pressure even though MRAA groundwater monitoring well MRAA-01D showed gas during drilling and on the geophysical logs.
- All three pressure monitoring wells (TBC-01, TBC-02, and TBC-BC-02) with pressure have wellhead pressures between 45 and 58 pounds per square inch (psi).
- The gas in these wells has been classified as thermogenic and as having virtually the same isotopic signature as the gas in the Oxy 3 cavern by Dr. Jonathan Myers (Myers, 2013).
- Over 15 million cubic feet of methane gas have been removed through MRAA vent wells. There has been no apparent corresponding decline in pressure in the three pressure monitoring wells. While TBC-01 and TBC-BC-02 are some distance from vent wells, TBC-02 is less than 50 feet from ORW-12 on the Oxy 3 well pad and has shown no pressure decline.

- Attempts to use shut-in ORWs as pressure monitoring wells are hampered due to a lack of water level data. Many of the shut-in wells have recently been reconfigured with 2-inch tubing and bladder pumps. It may be possible to use some of the shut-in ORWs as pressure monitoring wells if they are reconfigured as specified in RRD-03 ORW operational data.

This RRD is prepared as part of the overall GAS-11 BRC task. This BRC task addresses the need for an expanded pressure monitoring network in the MRAA including the installation of new pressure monitoring wells. This RRD establishes the procedures and equipment required for these data.

2.0 Objective

The technical objective of this RRD is to upgrade the existing gas pressure monitoring network in the MRAA to provide data for:

- Monitoring of gas pressure reduction between vent wells.
- Define the gas pressure distribution across the gas area for use in gas behavior/ migration modeling and assessments.
- Evaluating performance of the ORWs.

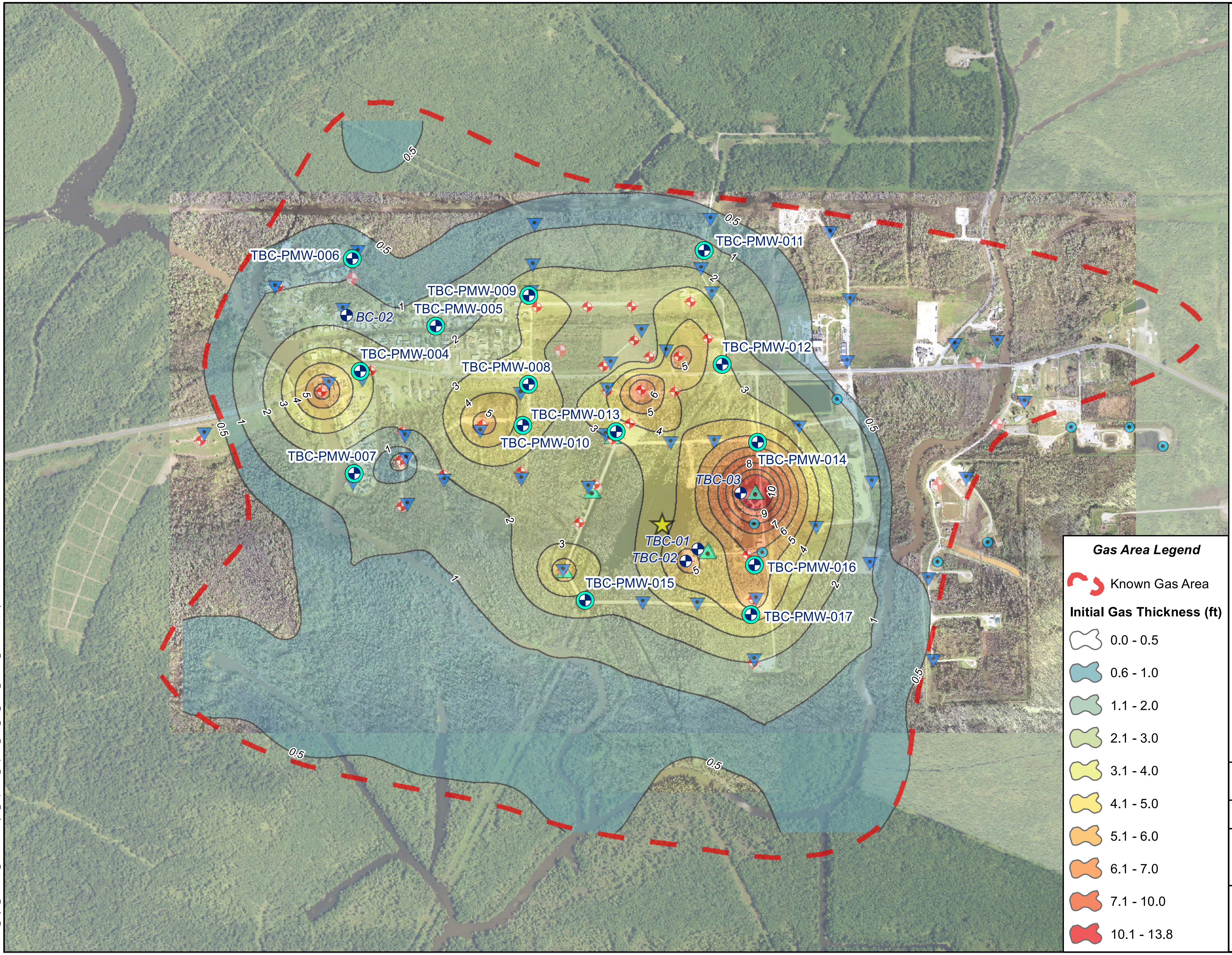
3.0 Requirements

The requirements for upgrading the pressure monitoring network consistent with this RRD are:

- Installation of additional MRAA pressure monitoring wells as presented on **Figure 1** is recommended based on the results of preliminary gas behavior analyses (Charbeneau, 2013) (**Attachment 1**) and current ORW operational data. Additional pressure monitoring network wells are necessary in the MRAA to adequately monitor the gas pressures, independent of the ORW wells.
- The pressure monitoring wells must be installed using methods that result in good communication between the well screen and the MRAA gas interval and have a grouted annular seal. Before well installation, it is recommended that CPT borings be installed to define the lithology at each location.
- Installation of wellhead pressure gauges and recording pressure transducers in the pressure monitoring wells to directly measure formation pressures. Pressure measurement instrumentation should be selected to provide accurate readings based on the actual pressure ranges observed or expected at the site wells.
- Routine operation and maintenance (O&M) of the pressure monitor wells and surface and downhole pressure measurement equipment to maintain continuous operation.
- Data generated as part of the MRAA pressure monitoring activities shall be submitted on a daily basis.
- Quarterly report documenting the gas pressure changes in the MRAA and associated flaring operations shall be submitted.

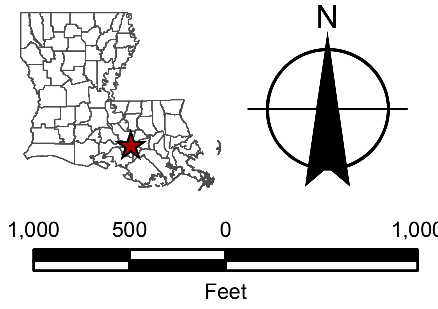
Appendix 1 presents suggested procedures for data collection to meet the above objective and requirements. These procedures can be modified or replaced as appropriate to meet the objectives and requirements.

FIGURE 1



Legend

- Recommended Pressure Monitor Well
- Existing Pressure Monitor Well
- Sinkhole Location
- CPT
- Installed Observation/Relief Well
- Proposed Observation/Relief Well
- MRAA Monitor Well
- Industrial Water Well



LOUISIANA DEPARTMENT OF NATURAL RESOURCES

BAYOU CORNE/NAPOLEONVILLE SALT DOME EMERGENCY RESPONSE

FIGURE NUMBER 1

RECOMMENDED MRAA PRESSURE MONITOR WELLS

Shaw Environmental & Infrastructure, Inc.
A CB&I Company
4171 ESSEN LANE
BATON ROUGE, LOUISIANA 70809
www.CBI.com

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APPENDIX 1
SUGGESTED PROCEDURES

1.0 Introduction

This appendix is intended for use as a procedural reference for obtaining the data required in the RRD. The procedures in this section have been used by one or more Blue Ribbon Commissioners to obtain or generate the data required in Section 2.0 of the RRD. In preparing the work plan to address this RRD, substitute procedures can be used as long as the requirements in Section 2.0 are met.

2.0 Contract Services

A licensed drilling contractor will be required to install the pressure monitoring wells recommended in this RRD.

3.0 Specialized Field Equipment

3.1 Pressure Gauges

Pressure gauges are currently mounted on the wellhead at each well and should be installed on each new pressure monitoring well. These allow for daily pressure observation of wellhead pressures. Pressure measurement instrumentation should be selected to provide accurate readings based on the actual pressure ranges observed or expected at the site wells.

3.2 Pressure Transducers

Downhole recording pressure transducers eliminate the need for calculating formation pressures by directly measuring formation pressures in the well perforations. A transducer is installed at the same depth as the pressure monitoring well screen interval and records pressures of a predetermined schedule. For the pressure data, formation pressures on a 15-minute basis are probably sufficient but more frequent data may be necessary depending on the observed responses. **Attachment 2** presents examples of stand-alone downhole recording transducers and installation equipment for pressurized wells. Other vendors also provide similar recording transducers. The selected pressure transducer should be capable of measuring pressure to a minimum accuracy of 0.1 psi.

4.0 Definitions

The following definitions are applicable to this appendix:

- *Formation pressure:* Pressure in the gas interval in the geologic horizon of interest. This can be measured directly or calculated from the wellhead pressure and the water level in a well.
- *Wellhead pressure:* Pressure at the wellhead; this pressure is determined by the gas pressure in the MRAA less the hydrostatic pressure due to the water level in the well. In a given well, as the water level rises, the wellhead pressure will decline.

5.0 Procedure

The expansion and monitoring of the pressure monitoring network includes the following steps.

5.1 Installation of Pressure Wells

Install 11 additional MRAA pressure monitor wells at the general locations (**Figure 1**) based on the previously-referenced results of preliminary gas behavior analyses and site ORW operational data.

The wells shall be installed in accordance with standard acceptable and/or modified drilling practices to include appropriate safety precautions with respect to the presence of elevated gas pressures in the MRAA and overlying aquitard. Techniques/methodologies used to install additional pressure monitor wells shall be consistent with practices that provide accurate and reliable measurements of pressures from the gas interval in the MRAA. The pressure monitoring wells should to be installed in a manner that controls gas pressure at all times.

Prior to installation of each pressure monitoring well, it is recommended that CPT borings be installed at each location to define the lithology for use in well design. In the event that there is an existing CPT boring near a proposed pressure monitoring well location shown on **Figure 1**, the well location can be moved to the vicinity of the existing CPT location.

5.2 Installation of Pressure and Water Level Equipment

The pressure gauges should be installed above the master valve on each pressure monitoring well.

The transducers can be installed using a simple pressure pass-through fitting shown in Attachment 2 that will serve as a stuffing box allowing the transducer and cable to be lowered into the well. The pass-through should be installed when the cables are assembled by the vendor. The pass-through is attached to a short lubricator-type assembly so that the transducer, cable, and fittings can be installed on the wellhead while the master valve is closed. Once the wellhead assembly is set up, the master valve is opened and the transducer lowered into the perforations. For safety purposes, the flow valve should be open while the transducer is lowered into the well. This will reduce pressure on the transducer pass-through during installation. Because the transducer cable will need to pass through the master valve, the transducer will have to be pulled up into the lubricator-type assembly before closing the master valve.

5.3 Data Collection

Wellhead pressures should be recorded daily. The pressure transducer data should be downloaded weekly.

5.4 Operation and Maintenance

Complete routine O&M of the pressure monitor wells and surface and downhole pressure measurement equipment to maintain continuous operation and provide accurate and reliable pressure and water level data.

5.5 Data Submittal and Reporting

All data, including but not limited to well construction diagrams, CPT data, flow rates, pressures, water levels, formation pressures, and operation and maintenance records, should continue to be submitted to the LDNR in an organized format once per day or as specified by LDNR emergency order amendments and associated directives.

TBC should submit operational quarterly reports to LDNR on gas removal efforts including ORW flow rates and formation pressure changes during the quarter, maintenance performed on the recommended equipment, water produced, and any work-over activities performed on the ORWs or pressure monitoring wells. The quarterly reports should be submitted within 30 days after the end of a quarter.

6.0 Attachments

- ***Attachment 1***—Model Analysis of Methane Gas Behavior at Bayou Corne by Dr. Randall Charbeneau
- ***Attachment 2***—Examples of recording pressure transducers and high-pressure pass-through fitting

7.0 FORMS

No forms are provided but it is recommended that forms be developed (if not already developed) for documenting and submitting the information.

8.0 References

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

Myers, J., 2013, Interpretation of Analyses of Gas Samples Obtained from the Bayou Corne Area as of May 10, 2013: CB&I.

ATTACHMENT 1

MODEL ANALYSIS OF METHANE GAS BEHAVIOR AT BAYOU CORNE BY DR. RANDALL CHARBENEAU

NOTE: This material was developed to provide a quantitative framework for assessing methane gas behavior associated with the Bayou Corne sinkhole. In current form, the material is not based on any site-specific data.

Model Analysis of Methane Gas Behavior at Bayou Corne

Quantify Methane Quantity in the Gas Cap

One of the first quantities that must be determined is the amount of methane gas that is present in the gas cap under different environmental conditions including gas pressure, aquifer water pressure, and soil characteristics. This is difficult because methane is compressible and forms a non-wetting fluid. The approach developed calculates the "standard specific methane volume", which corresponds to the volume of methane contained in the gas cap under conditions of standard atmospheric pressure, per unit plan area of the aquifer. The standard specific methane volume, designated D_m, has units of feet or meters (cubic feet per square foot plan area, or cubic meters per square meter plan area). For the purpose of this calculation, the soil is characterized by van Genuchten capillary pressure model parameters (α, N, M and S_{wr}).

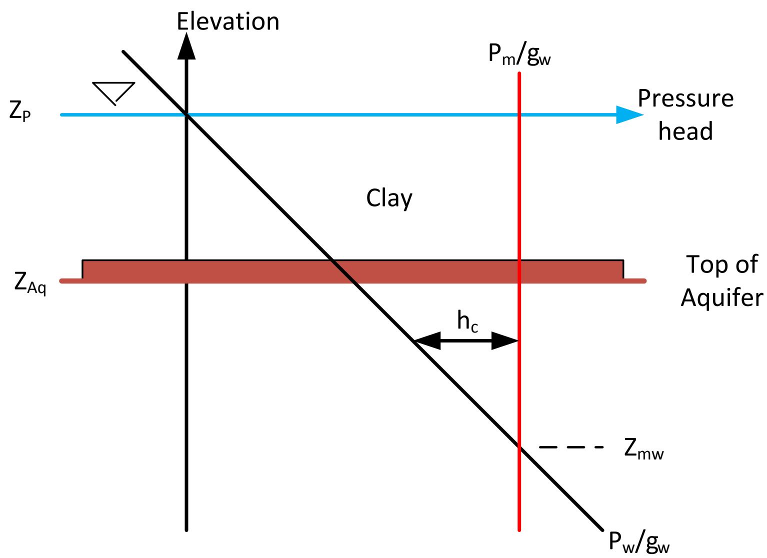


Figure 1: Pressure distribution for water (P_w) and methane (P_m) at the gas cap located adjacent to the top of aquifer

Figure 1 is presented as a basis for discussion. Pressure head (gage) is shown for water and methane as a function of elevation. The elevation Z_P corresponds to the potentiometric surface (water pressure equals atmospheric pressure) for the confined aquifer (MRAA), and the water pressure head is zero at this elevation. Water pressure increases hydrostatically with depth, so that the slope of the pressure head-elevation line is equal to -1. The methane is assumed to have constant pressure P_m. It does not show a hydrostatic increase with depth because the methane density is so small (compared to liquid water). At elevation Z_{mw} the methane and water pressures are the same. Pressures are normalized by the specific weight of water γ_w (pressure → head). The elevation Z_{Aq} corresponds to the top of the aquifer, with clay aquitard material located above. The methane gas cap is located between elevations Z_{mw} and Z_{Aq}, where the methane-water capillary pressure is positive and does not exceed the entry pressure for methane into the overlying clay. Capillary pressure is the pressure difference between the nonwetting fluid (methane) and the wetting fluid (water). Expressed in terms of head, $h_c = P_m/\gamma_w - P_w/\gamma_w$. The capillary pressure head h_c is shown on Fig. 1 within the gas cap region. h_c increases from zero at Z_{mw} to a maximum value at the top of the aquifer (base of the clay), Z_{Aq}.

The pressure distribution and capillary pressure distribution are independent of soil material properties. However, soil material properties are essential for establishing the relationship between the capillary pressure distribution and the amount of the different fluids (methane and water) present within the soil pore space. The soil characteristic curve expresses the fundamental relationship between fluid saturation (fraction of pore space occupied) and capillary pressure. Figure 2 shows a representative example for sand texture soil, based on the USDA Rosetta database. The capillary pressure head is measured in feet. At zero capillary pressure the soil is 100-percent saturated with water, the wetting fluid. At a capillary pressure head of about 0.5-ft, the water saturation starts to decrease while the air (methane) saturation increases. At capillary pressure head exceeding about 3-ft, the water saturation approaches its irreducible value (residual water saturation) while the air saturation approaches its maximum value.

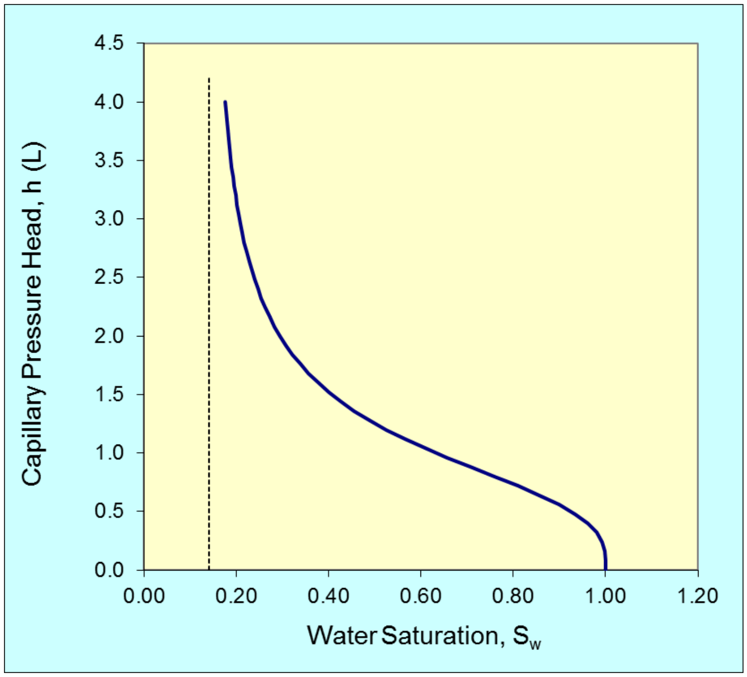


Figure 2. Representative soil characteristic curve for sand texture soil

The soil characteristic curve shown in Fig. 2 is expressed mathematically using the van Genuchten model as follows:

$$S_e = \frac{S_w - S_{wr}}{1 - S_{wr}} = \left[1 + \left(\alpha\, h_c\right)^N\right]^{-M} \qquad (1)$$

Model parameter values used in Fig. 2 are α = 1.07 ft^{-1}, N = 3.18, M = 1 – 1/N = 0.68, and S_{wr} = 0.14.

The soil characteristic curve model is combined with the capillary pressure distribution to calculate the distribution of methane in the gas cap. The methane saturation S_m is calculated from

$$S_m = 1 - S_w = \left(1 - S_{wr}\right)\left(1 - S_e\right) \qquad (2)$$

With porosity n, the specific volume of methane-filled pore space is calculated from

$$n \int_{Z_{mw}}^{Z_{Aq}} S_m\, dz = n\left(1 - S_{wr}\right)\left(Z_{Aq} - Z_{mw} - \int_{Z_{mw}}^{Z_{Aq}} S_e\, dz \right)$$

Using Boyle's law to translate from the in-situ methane pressure P_m to atmospheric pressure P_{Atm}, one finds for the Standard Specific Methane Volume:

$$D_m = \frac{n(1-S_{wr})P_m}{P_{Atm}}\left(Z_{Aq} - Z_{mw} - \int_{Z_{mw}}^{Z_{Aq}} S_e\,dz\right) \qquad (3)$$

From Fig. 1, one can see that $h_c = z - Z_{mw}$. Thus, in Eq. (3), one can use

$$\int_{Z_{mw}}^{Z_{Aq}} S_e\,dz = \int_{0}^{Z_{Aq}-Z_{mw}} \left[1+(\alpha z)^N\right]^{-M} dz$$

Example One: Assume that $Z_P - Z_{Aq}$ = 110 ft and that P_m = 50 psig (P_m/γ_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 π * 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.

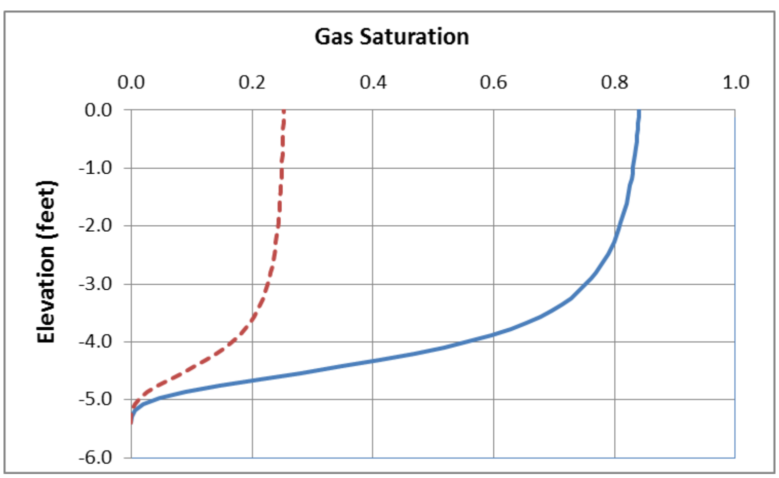


Figure 3. Calculated gas cap saturation distribution based on a gas pressure = 50 psig

Change in Piezometric Surface Elevation

If the piezometric surface elevation changes, then both the methane pressure and thickness of the gas cap will also change. However, since the standard specific methane volume is a measure of the amount of methane present under standard conditions, it will not change. D_m is invariant to changes in Z_P. In terms of absolute pressure,

$$P_m = P_{Atm} + \gamma_w * (Z_P - Z_{mw}) = \gamma_w * (P_{Atm}/\gamma_w + Z_P - Z_{mw}) \qquad (4)$$

Thus, one may write Eq. (3) as follows:

$$\left(\frac{P_{Atm}}{\gamma_w} + Z_P - Z_{mw}\right)\left(Z_{Aq} - Z_{mw} - \int_{Z_{mw}}^{Z_{Aq}} S_e \, dz\right) = \frac{D_m P_{Atm}}{n(1 - S_{wr})\gamma_w} \qquad (5)$$

The only unknown in Eq. (5) is the elevation of the base of the gas cap, Z_{mw}, and this can be found using various means.

Example Two. The elevation of the piezometric surface decreases by 10 feet over Example One. What impact does this have on the gas cap thickness and pressure? For these conditions, the right side of Eq. (5) equals 590. Taking the elevation of the top of the aquifer as the datum (Z_{Aq} = 0, Z_P = 100 ft), one can find that Z_{mw} = -5.65 ft. Thus the gas cap has thickness 5.66 feet and the gage methane pressure is (100 + 5.65) * 62.4 = 6590 psfg = 45.8 psig. There is a very slight increase in gas cap thickness while the gas cap (gage) pressure decreases by a small amount.

Methane Discharge to a Venting Well

The steady radial mass flux, f_r, to a venting well over a gas cap thickness b_a is given by

$$f_r = \rho_m Q_m = \rho_m (2\pi r b_a) q_{mr} = \left(\frac{P_m}{RT}\right)(2\pi r b_a)\left(\frac{k\bar{k}_{rm}}{\mu_m}\frac{dP_m}{dr}\right) = \frac{\pi r b_a k\bar{k}_{rm}}{RT\mu_m}\frac{dP_m^{\ 2}}{dr}$$

The discharge from the venting well to the atmosphere occurs under atmospheric pressure (standard conditions – $\rho_{m,Atm}$ and P_{Atm}) so the radial mass flux $f_r = \rho_{m,Atm} Q_{Atm}$. Integrating this equation from the radius of the well r_w where $P_m = P_{well}$ to the radius of influence R where $P_m = P_{mo}$ gives

$$\rho_{m,Atm} Q_{Atm} \ln(R/r_w) = \frac{\pi b_a k\bar{k}_{rM}}{RT\mu_m}\left(P_{mo}^{\ 2} - P_{well}^{\ 2}\right)$$

This may be written for the volumetric discharge of methane under atmospheric conditions

$$Q_{Atm} = \frac{\pi b_a k\bar{k}_{rm}}{P_{Atm}\mu_m}\frac{\left(P_{mo}{}^2 - P_{well}{}^2\right)}{\ln(R/r_w)}$$

It is convenient to write this in terms of the aquifer hydraulic conductivity to water using $K_w = \rho_w g k/\mu_w$ as follows:

$$Q_{Atm} = \frac{\pi b_a K_w \bar{k}_{rm}}{P_{Atm}\gamma_w \mu_{mw}}\frac{\left(P_{mo}{}^2 - P_{well}{}^2\right)}{\ln(R/r_w)} \tag{6}$$

In Eq. (6), μ_{mw} is the methane-water viscosity ratio (dimensionless), with magnitude approximately 0.0135.

Example Three: For the conditions of Example One with K_w = 5 ft/d, methane relative permeability = 0.66 and r_w = 0.5 ft, what is the venting well discharge? From Eq. (6) the maximum discharge would occur with $P_{well} = P_{Atm}$. However, this corresponds to a pressure head loss of 115.4 ft across the flowing radius, and water upconing cuts the potential discharge. A well-choke is necessary to maintain sufficient pressure at the well and prevent detrimental water buildup. An allowable head loss of 3-ft is reasonable, resulting in a 3-ft water buildup. Thus the well pressure is P_{well} = 9130 psfa. Equation (6) gives

$$Q_{Atm} = \frac{\pi \times 5.4 \times 5 \times 0.66}{2120 \times 62.4 \times 0.0135}\frac{\left(9320^2 - 9130^2\right)}{\ln(200/0.5)} = 18{,}300 \text{ ft}^3\text{/d}$$

Transient Analysis of Methane Venting

Within the area of capture A_c, the continuity equation for methane volume (under standard conditions) is

$$\frac{dV_m}{dt} = A_c\frac{dD_m}{dt} = A_c\frac{dD_m}{dZ_{mw}}\frac{dZ_{mw}}{dt} = -Q_{Atm} \tag{7}$$

To be useful, all variables must be expressed in terms of Z_{mw}. From Eq. (5) one finds

$$\frac{dD_m}{dZ_{mw}} = -\left(\frac{n(1-S_{wr})}{P_{Atm}/\gamma_w}\right)\left[\left(Z_{Aq} - Z_{mw} - \int_0^{Z_{Aq}-Z_{mw}} S_e dz\right) + \left(\frac{P_{Atm}}{\gamma_w} + Z_P - Z_{mw}\right)\left(1 - S_e\big|_{Z_{Aq}-Z_{mw}}\right)\right] \tag{8}$$

Equation (6) can be written

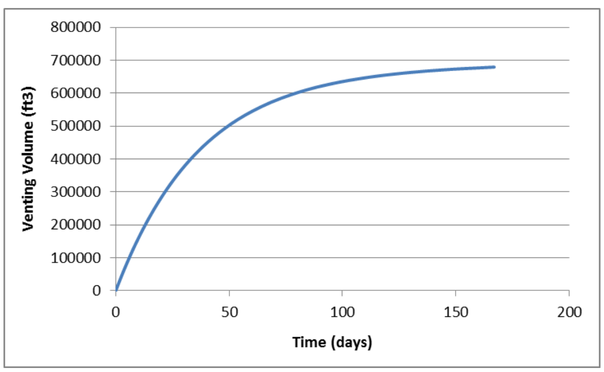
$$Q_{Mo} = \frac{\pi(Z_{Aq} - Z_{mw})K_w \bar{k}_{rm}}{(P_{Mo}/\gamma_w)\mu_{mw}} \frac{\left(((P_{Atm}/\gamma_w) + Z_P - Z_{mw})^2 - (P_{well}/\gamma_w)^2\right)}{\ln(R/r_w)} \tag{9}$$

The resulting continuity equation gives

$$\frac{dZ_{mw}}{dt} = \left(\frac{\pi K_w}{A_c n(1 - S_{wr})\mu_{mw} \ln(R/r_w)}\right)\left(\frac{\bar{k}_{rm}(Z_{Aq} - Z_{mw})\left(((P_{Atm}/\gamma_w) + Z_P - Z_{mw})^2 - (P_{well}/\gamma_w)^2\right)}{Z_{Aq} - Z_{mw} - \int S_e dz + ((P_{Atm}/\gamma_w) + Z_P - Z_{mw})(1 - S_{eT})}\right) \tag{10}$$

Once assumptions are made concerning the time-variation of P_{well}, Eq. (10) is integrated to find $Z_{mw}(t)$. A simple spreadsheet model is used. The gas cap pressure, thickness, venting rate, and cumulative venting volume can be calculated accordingly.

Example Four: Calculate the recovery rate and volume for a methane gas cap with initial pressure = 50 psig (based on Example One). It is assumed that a 3-ft pressure head loss is maintained across the radius of influence R so that both Pm and Pwell decrease at the same rate as methane is vented. During venting, the gas cap thickness and relative permeability decrease. The recovery volume and rate are shown in the Fig. 4. It takes more than 5 months to achieve venting of the gas cap.



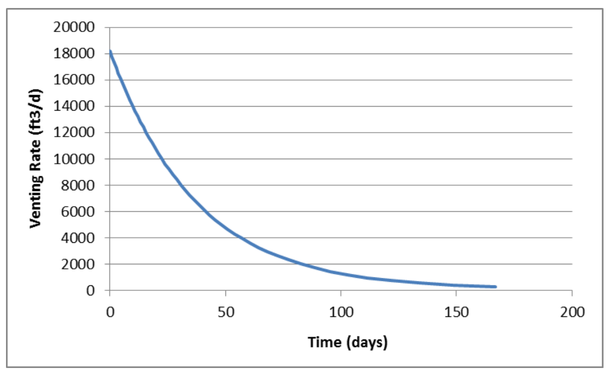


Figure 4. Venting rate and cumulative volume

<u>Groundwater Pumping to Control Water Buildup</u>

Example Four shows control of water table buildup by limiting the pressure head loss across the radius of influence to 3-ft. Larger venting rates can be achieved through use of dual pump systems, with an individual intake to control the water table elevation. While not directly applicable, the API LNAPL Distribution and Recovery Model (LDRM) was used to evaluate this situation. The same soil parameters are assumed for a vacuum-enhanced recovery system with the vacuum screen section = 5.4 ft and vacuum pressure = 0.2 atm, corresponding to an increased head loss of 7-ft. A groundwater pumping rate of 3 gpm over a screened interval of 15 ft is used to control water table buildup. Figure 5 shows negligible impact on the net water table elevation due to combined venting and groundwater production.

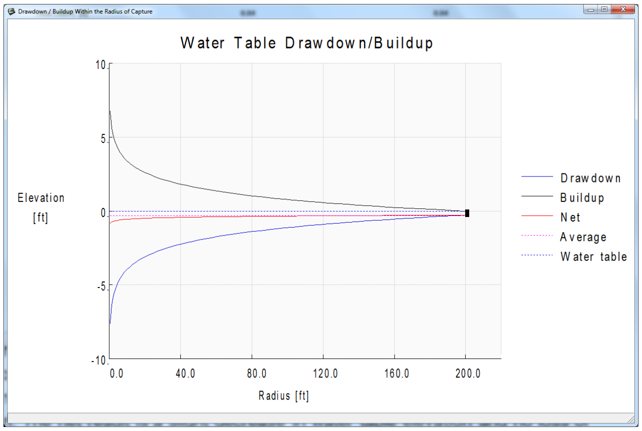


Figure 5. Water-table buildup associated with venting with 7-ft head loss plus groundwater pumping at 3 gpm

Example Five: Repeat Example Four with a venting well pressure corresponding to 0.2 atm (7-ft = 437 psf) below gas cap pressure. Figure 6 shows that venting rates are much larger and the required venting time exceeds 2 months.

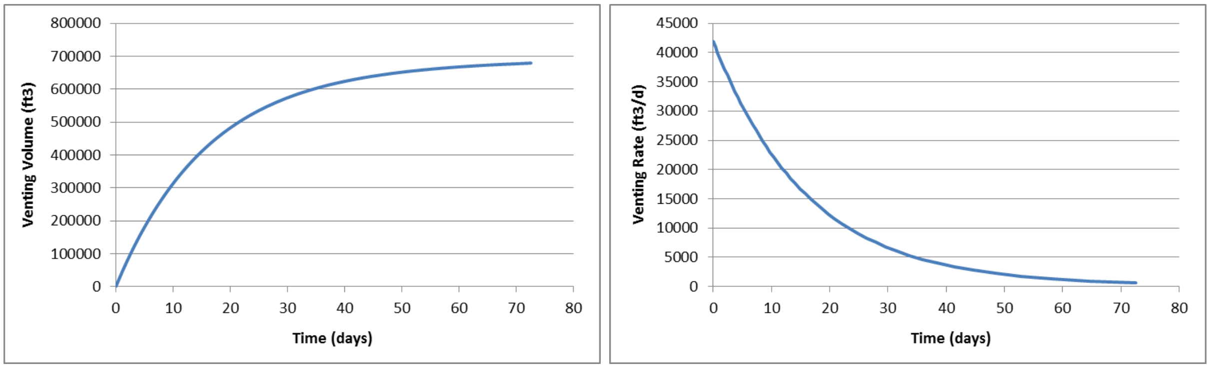


Figure 6. Venting cumulative recovery volume and rate for well pressure combined venting and groundwater pumping system

ATTACHMENT 2

EXAMPLES OF RECORDING PRESSURE TRANSDUCERS AND HIGH-PRESSURE PASS-THROUGH FITTING

In-Situ Inc.

Innovations in Water Monitoring

Level **TROLL**® Instruments

Water Level Instruments for Every Application & Budget

*Level **TROLL**® 700 Instrument*

- Optimized for aquifer characterization
- Gauged (vented) and absolute (non-vented) instruments
- Linear, fast linear, linear average, event, step linear, and true logarithmic logging modes
- Rugged titanium probe and sensor (OD: 1.83 cm; 0.72 in)

*Level **TROLL**® 500 Instrument*

- Ideal for groundwater and surface-water monitoring
- Gauged and absolute instruments
- Linear, fast linear, and event logging modes
- Durable titanium probe and sensor (OD: 1.83 cm; 0.72 in)

*Level **TROLL**® 300 Instrument*

- Suitable for fresh water and industrial monitoring
- Absolute instrument
- Linear, fast linear, and event logging modes
- Stainless steel probe and sensor (OD: 2.08 cm; 0.82 in)

Powerful, Accurate, Reliable Performance

- **Superior accuracy**—For guaranteed accuracy under all operating conditions, instruments undergo extensive calibration procedures for pressure and temperature. Each instrument includes a serialized calibration report.
- **Telemetry and SCADA integration**—Access data when you need it. No adapters or confusing proprietary protocols are required. Outputs include standard Modbus/RS485, SDI-12, and 4-20 mA.
- **Low power consumption**—Batteries have a typical life of 10 years or 2 million readings. 8-36 VDC input is compatible with external batteries and solar power.
- **Intuitive interface**—Win-Situ® 5 and Win-Situ® Mobile Software simplify data collection and management. Software features setup wizards, fast data download rates, multiple water level reference options, and more.

Applications

- Aquifer characterization
- Coastal deployments—tide/harbor levels, storm surge systems, and wetlands research
- Construction and mine dewatering
- River, lake, and reservoir monitoring
- Stormwater management

Level **TROLL**® 300, 500 & 700 Instruments

General	*Level TROLL 300*	*Level TROLL 500*	*Level TROLL 700*	*BaroTROLL*
Temperature ranges[1]	Operational: -20-80° C (-4-176° F) Storage: -40-80° C (-40-176° F) Calibrated: -5-50° C (23-122° F)	Operational: -20-80° C (-4-176° F) Storage: -40-80° C (-40-176° F) Calibrated: -5-50° C (23-122° F)	Operational: -20-80° C (-4-176° F) Storage: -40-80° C (-40-176° F) Calibrated: -5-50° C (23-122° F)	Operational: -20-80° C (-4-176° F) Storage: -40-80° C (-40-176° F) Calibrated: -5-50° C (23-122° F)
Diameter	2.08 cm (0.82 in)	1.83 cm (0.72 in)	1.83 cm (0.72 in)	1.83 cm (0.72 in)
Length	22.9 cm (9.0 in)	21.6 cm (8.5 in)	21.6 cm (8.5 in)	21.6 cm (8.5 in)
Weight	245 g (0.54 lb)	197 g (0.43 lb)	197 g (0.43 lb)	197 g (0.43 lb)
Materials	Stainless steel body; Delrin® nose cone	Titanium body; Delrin nose cone	Titanium body; Delrin nose cone	Titanium body; Delrin nose cone
Output options	Modbus/RS485, SDI-12, 4-20 mA	Modbus/RS485, SDI-12, 4-20 mA	Modbus/RS485, SDI-12, 4-20 mA	Modbus/RS485, SDI-12, 4-20 mA
Battery type & life[2]	3.6V lithium; 10 years or 2M readings	3.6V lithium; 10 years or 2M readings	3.6V lithium; 10 years or 2M readings	3.6V lithium; 10 years or 2M readings
External power	8-36 VDC	8-36 VDC	8-36 VDC	8-36 VDC
Memory **Data records**[3] **Data logs**	1.0 MB 65,000 2	2.0 MB 130,000 50	4.0 MB 260,000 50	1.0 MB 65,000 2
Log types	Linear, Fast Linear, and Event	Linear, Fast Linear, and Event	Linear, Fast Linear, Linear Average, Event, Step Linear, True Logarithmic	Linear
Fastest logging rate & Modbus rate	2 per second	2 per second	4 per second	1 per minute
Fastest SDI-12 & 4-20 mA output rate	1 per second	1 per second	1 per second	1 per second
Real-time clock	Accurate to 1 second/24-hr period	Accurate to 1 second/24-hr period	Accurate to 1 second/24-hr period	Accurate to 1 second/24-hr period
Sensor Type/Material	Piezoresistive; stainless steel	Piezoresistive; titanium	Piezoresistive; titanium	Piezoresistive; titanium
Range	*Absolute (non-vented)* 30 psia: 10.9 m (35.8 ft) 100 psia: 60.1 m (197.3 ft) 300 psia: 200.7 m (658.7 ft)	*Absolute (non-vented)* 30 psia: 10.9 m (35.8 ft) 100 psia: 60.1 m (197.3 ft) 300 psia: 200.7 m (658.7 ft) 500 psia: 341.3 m (1120 ft) *Gauged (vented)* 5 psig: 3.5 m (11.5 ft) 15 psig: 11 m (35 ft) 30 psig: 21 m (69 ft) 100 psig: 70 m (231 ft) 300 psig: 210 m (692 ft) 500 psig: 351 m (1153 ft)	*Absolute (non-vented)* 30 psia: 10.9 m (35.8 ft) 100 psia: 60.1 m (197.3 ft) 300 psia: 200.7 m (658.7 ft) 500 psia: 341.3 m (1120 ft) 1000 psia: 703 m (2306.4 ft) *Gauged (vented)* 5 psig: 3.5 m (11.5 ft) 15 psig: 11 m (35 ft) 30 psig: 21 m (69 ft) 100 psig: 70 m (231 ft) 300 psig: 210 m (692 ft) 500 psig: 351 m (1153 ft)	0 to 16.5 psi; 0 to 1.14 bar
Burst pressure	Max. 2x range; burst > 3x range	Max. 2x range; burst > 3x range	Max. 2x range; burst > 3x range	Vaccum/over-pressure above 16.5 psi damages sensor
Accuracy @ 15° C[4]	±0.1% full scale (FS)	±0.05% FS	±0.05% FS	±0.1% FS
Accuracy (FS)[5]	±0.2% FS	±0.1% FS	±0.1% FS	±0.2% FS
Resolution	±0.01% FS or better	±0.005% FS or better	±0.005% FS or better	±0.005% FS or better
Units of measure	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH_2O, inH_2O Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH_2O, inH_2O Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH_2O, inH_2O Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH_2O, inH_2O
Temperature Sensor				
Accuracy & resolution	±0.1° C; 0.01° C or better	±0.1° C; 0.01° C or better	±0.1° C; 0.01° C or better	±0.1° C; 0.01° C or better
Units of measure	Celsius or Fahrenheit	Celsius or Fahrenheit	Celsius or Fahrenheit	Celsius or Fahrenheit
Warranty	1 year	2 years	2 years	2 years
	Up to 5-year extended warranties are available for all instruments—call for details			

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Baro**TROLL**® Instrument

The titanium BaroTROLL measures and logs barometric pressure and temperature. Use the BaroTROLL in conjunction with Level TROLL Instruments.

Win-Situ® Baro Merge™ Software simplifies post-correction of water level data. Barometric readings are automatically subtracted from data collected by an absolute Level TROLL to compensate for changes in pressure due to barometric fluctuations.

24/7 Support

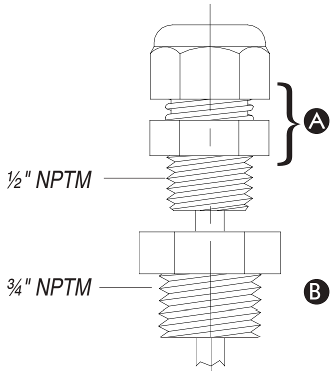
In-Situ technical support specialists assist with instrument setup, application support, and troubleshooting. Call for free technical support.

[1] Temperature range for non-freezing liquids
[2] Typical battery life when used within the factory-calibrated temperature range.
[3] 1 data record = date/time plus 2 parameters logged (no wrapping) from device within the factory-calibrated temperature range
[4] Across factory-calibrated pressure range
[5] Across factory-calibrated pressure and temperature ranges
Specifications are subject to change without notice.
Delrin is a registered trademark of E.I. du Pont de Nemours and Company.

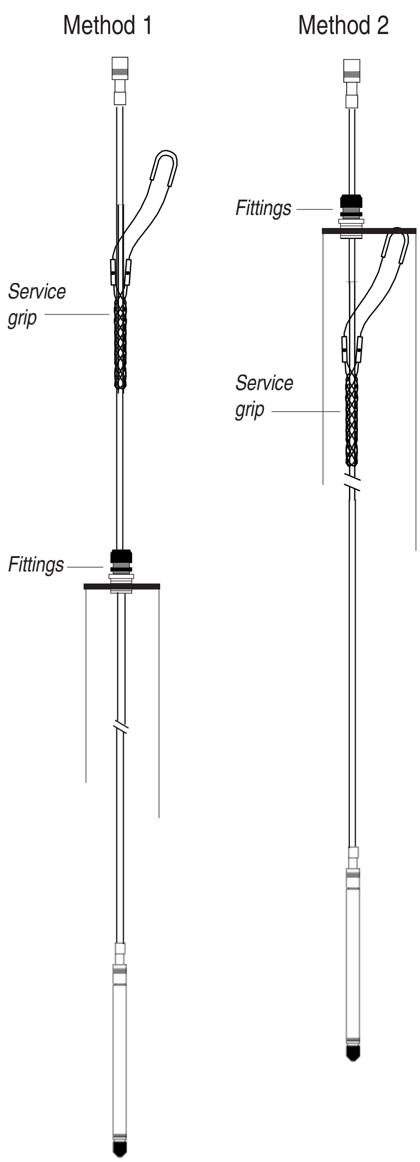
In-Situ Inc.

Call to purchase or rent—www.in-situ.com
221 East Lincoln Avenue, Fort Collins, Colorado, U.S.A. 80524
1-800-446-7488 (toll-free in U.S.A. and Canada)
1-970-498-1500 (U.S.A. and international)

Information Sheet



ARTESIAN WELL CABLE OPTION
(SEALED WELL APPLICATIONS)



APPLICATION

Permits installation of a Level TROLL® or miniTROLL® into a sealed well where the seal is made around the cable. Allows easy removal from a ¾" NPT application. Includes a black dome compression fitting that makes a water- and air-tight seal around the cable.

Components are factory-installed on the Level TROLL RuggedCable™ or miniTROLL Quick-Connect cable

COMPONENTS

Ⓐ Black two-piece dome connector with ½" male threads (NPTM)

Ⓑ White PVC adapter that accepts connector A (interior threads are ½" female, NPTF) and mates with ¾" NPT threads

INSTALLATION

1. Loosen halves of connector A and slide to desired position on cable.
2. Tighten the compression fitting firmly around the cable and screw into PVC adapter B for installation into ¾" NPT fitting.

Additional adapter(s) may be added for installation into 1" or other size NPT fitting.

TIP: *Cable may be ordered with the sealing fittings **below** the service grip (Method 1) or **above** the service grip (Method 2), depending on well configuration.*

1 800 446 7488
(toll-free, US and Canada) or 970 498 1500 **www.in-situ.com**

0027772 rev. 002 07/07

In-Situ High Pressure Transducer Cable Pass-Through Fitting