1. Introduction

Early on the morning of December 15, 2007, an explosion occurred in the home at 17975 English Drive, Bainbridge Township, Geauga County, Ohio. Miraculously, no one was seriously injured even though the house was extensively damaged. The cause of the explosion was determined to be overpressurization of the surface-production casing annulus in the English #1 gas well, owned by Ohio Valley Energy Systems Corp. (OVE), during post-stimulation work and the subsequent migration of natural gas into nearby water wells and homes. The local fire department, Geauga County Health Department, and the Division of Mineral Resources Management (DMRM) of the Ohio Department of Natural Resources (ODNR) immediately responded to the incident. Emergency response officials evacuated residents from 19 homes. All residents returned to their homes by December 24 except the family living in the damaged home (Figure 1-1). In the ensuing weeks, 26 residential water wells were disconnected and temporary water tanks installed to provide water supplies.

Figure 1-1. Area of Bainbridge Township impacted by subsurface gas invasion.

In September 2008, DMRM published its account of the events; causes of overpressurization, natural gas invasions, and the explosion; regional geologic and hydrogeologic information; background and site-specific water-quality data; and recommendations in a document titled, "Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township, Geauga County Ohio." In January 2009, Thrasher, Dinsmore & Dolan (TD&D), representing 42 property owners, filed suit in Geauga County Common Pleas Court against OVE and six other parties involved in the leasing, drilling, and construction of the English #1 well. The lawsuit claims that actions and inactions stemming from drilling the gas well caused the explosion at 17975 English Drive and contamination of the plaintiffs' properties and the groundwater aquifer, which serves as the drinking water supply for the plaintiffs' properties. TD&D hired Eckstein & Associates (E&A), a geological engineering firm, to evaluate the overpressurization of the

English #1 well, the gas invasion incidents, and the severity and duration of health and safety issues. In May 2009, Dr. Yoram Eckstein, principal scientist at E&A, made a PowerPoint presentation titled "Wellhead LEL Records in Bainbridge Residential Water Wells" that described his methods of analysis and conclusions concerning the consequences of the English #1 gas well overpressurization on local residential water wells. His findings were based on data in the 2008 DMRM report, records of methane gas concentrations in water wells posted on the DMRM website, and environmental scanning electron microscope energy dispersive x-ray spectroscopy (ESEM-EDS) analyses of black sediments from water samples taken from wells and plumbing fixtures. Both of these documents can be downloaded at www.ohiodnr.com/mineral.

In May 2009, DMRM assembled a panel of expert geologists and engineers to evaluate the incongruent, deeply divided professional opinions proffered by DMRM and E&A regarding how the gas migrated to some but not all local water wells, the areal extent of invasive gas, and the future duration of gas invasion. The panel is composed of five experts, each possessing a broad understanding of the dynamics of fluid flow, aqueous geochemistry, and practices in the oil and gas industry, and each possessing a specialty in one or more aspects of the gas invasion problem. Appendix A contains the resumés of the five panel members. The panel consists of (in alphabetical order):

- Professor Scott Bair, Ohio State University (hydrogeology, petroleum geology)
- Professor David Freeman, Marietta College (petroleum engineering, hydrofracing)
- Dr. Ralph Haefner, U.S. Geological Survey (groundwater chemistry, statistics)
- Ms. Martha Jagucki, U.S. Geological Survey (hydrogeology, water chemistry)
- Professor John Senko, University of Akron (geomicrobiology, water-rock interactions)

The tasks given to the expert panel by DMRM were (1) to evaluate the disputed issues, (2) determine what conclusions reached by E&A, DMRM, or by the panel itself best explain the irregular distribution of residential water wells impacted by invasive gas, (3) determine the most likely forecast of the long-term consequences of the gas well overpressurization incident, and (4) to recommend any measures that could help remediate the impacted area. Thus, our report deals strictly with the scientific aspects of the problem. The report does not contain an abundance of background information, which can be found in the DMRM (2008) report.

Approach to Evaluating Dissimilar Interpretations

The expert panel chose not to approach its tasks as would a group of jurors. Rather, the panel chose to apply the scientific method to test the dissimilar conclusions reached by DMRM and E&A. The two types of tribunals, trial by jury and scientific evaluation, reach decisions in very different ways. It is important that these differences are recognized so the conclusions made by the expert panel are taken in the context of the process used to reach them.

In the legal arena, evaluation of testimony presented to a judge or jury is immediate and the final decision to accept or reject the plaintiff's complaint is made by non-experts and is reached quickly. In contrast, evaluation of an hypothesis in the scientific arena is slow, is made by expert scientists, and the final decision to accept or reject the hypothesis may not be reached for years as other scientists gather more data and try to replicate or repudiate the work (Bair and Wood, 1999). Unlike a trial by jury, which is a linear process, the scientific method contains feedback loops that enable the hypothesis to be modified by new observations. The

power and the beauty of the scientific method lie in the requisite hypothesis testing by the original investigator and the re-testing of the hypothesis by subsequent investigators.

The scientific method is an informal set of rules for formulating questions, making observations, developing hypotheses, and then testing the hypotheses by experimentation and further observation. Figure 1-2 shows the general steps involved in applying the scientific method.

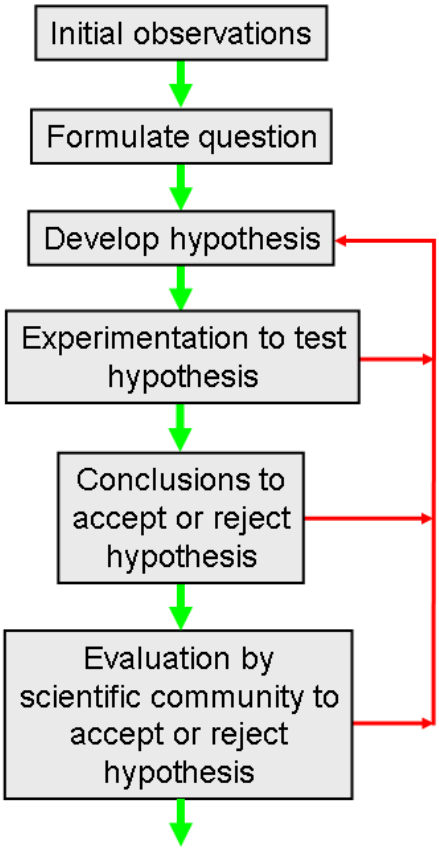

Figure 1-2. Common steps in the scientific method (Peters, 1996).

Responding to a period when standards for admission of expert testimony in trials were lax, in 1993 the U.S. Supreme Court in *Daubert v. Merrel Dow Pharmaceuticals, Inc.* held that under Rule 702 of the Federal Rules of Evidence, scientific knowledge presented as testimony must be derived by the scientific method and that evidentiary reliability is to be based on scientific validity. Under the *Daubert* ruling, the judge is given the responsibility of gatekeeper to make the preliminary evaluation as to whether the reasoning and methodology underlying the expert testimony is scientifically valid or reliable (Foster and others, 1993). In essence, the gatekeeper's role is to determine whether experts used valid scientific reasoning and principles to reach their conclusions and to screen out expert opinions based on conjecture and speculation (Blauvelt, 1999).

Within the context of the dissimilar interpretations of the data from the subsurface gas invasion in Bainbridge Township, the expert panel accepted the findings in the 2008 DMRM report and in the 2009 E&A PowerPoint presentation as hypotheses that needed to be tested before being accepted or rejected by the expert panel as scientifically reasonable explanations for the phenomena observed during and after the subsurface gas invasions.

Based on this scientific approach, DMRM gave the expert panel the ability to request that DMRM staff, under the direction and supervision of panel members, perform additional field and lab tests and make geologic maps and cross sections for the panel's use in testing the hypotheses of DMRM and E&A. At the request of ODNR-DMRM, OVE hired the outside contractors that assisted in the field work including well and pump services and routine measurement of LELs in the network of water wells. DMRM compensated the expert panel for its time. Our requests to DMRM, the additional data obtained from the requests, our analyses and interpretations, and the conclusions we reached are presented in Chapters 2, 3, and 4 of this report.

Members of the expert panel met as a group three more times to discuss what additional data to collect, how best to collect and analyze it, how to format our final report, and best to describe our interpretations and findings. Panel members spent approximately 160 hours doing field work in the Bainbridge area. Most of this time was spent measuring bearings of rock joints at outcrops and quarries, taking borehole videotapes, and collecting sediment and water samples in residential wells.

Time Line of Events

The chronology of events during drilling, construction, and completion of the English #1 gas well and the events leading up to, during, and following the explosion at the Payne house (17975 English Dr) are all relevant to the formulation and testing of hypotheses regarding the cause and impacts of the subsurface gas invasion. The events listed in Table 1-1 include those that can be used to test the dissimilar hypotheses of DMRM and E&A.

Table 1-1. Time Line of Events

Yr	Mo	Date	Description of Event
2007	Oct	2	● Permit to construct English #1 well issued by ODNR-DMRM
		18	● English well spudded; set 88 feet of 11¾ inch conductor steel pipe
		19	● Set 263 feet of 8⅝ inch steel pipe into top of Ohio Shale, below bottom of lowest USDW and cemented to the surface; Berea Sandstone at depth of 170-200 feet
		20 - 26	● Drilled to total depth (TD) in Clinton Sandstone at 3926 foot depth
		26	● Cemented 4½ inch production casing; sour gas smell at TD; lost circulation at 3640 foot depth in the "Packer Shell"
	Nov	1	● Cement bond log run; top of cement at 3640 foot depth
		5	● Perforated Clinton sandstone from 3720-3740 foot depth ● Breakdown Clinton sandstone; displacing 7750 gallons of acid and freshwater
		12	● Swabbed well to 3600 foot depth; fluid level at 1500 foot depth; shut-in well
		13	● Clinton production zone hydraulically fractured; stopped when oil and brine circulated out of the open valve on the surface-production casing annulus
		13 - 16	● Pressure testing; swabbing of frac fluid; well shut-in at 5 p.m. on 11/16
		17 - 30	● Noise from releasing pressure build-up inside casing annulus reported

Table 1-1 continued on next page

Table 1-1 continued

Yr	Mo	Date	Description of Event
2007	Dec	1 - 12	● No activities reported; reports of blow-down noise
		11	● Payne's water turns cloudy
		12	● Gas in police station water well described as more than normal
		14	● Reports of gas in residential water wells on English Drive ● OVE measures 360 psi in 8⅝ inch casing; 720 psi in 4½ inch casing ● OVE tried to blow off overpressures; well flowed brine and gas from 8⅝ inch casing
		15	● Payne home gas invasion; explosion at 2:45 a.m.; blue flames around outside of house; three basement walls cracked or blown outward ● Jordan well blows water approximately 15-18 feet above land surface for several hours; then blows gas for several days ● Gas detected in some residential wells on English Dr, Scotland Dr, and Kingswood Dr; 26 homes evacuated by Fire Department; neither locations of readings nor readings themselves are recorded ● Squeeze job #1; perforated 3600 - 3602 foot depth; squeezed cement up 944 feet to depth of 2656 feet (top of Silurian salt section). According to consulting geologist on site, the first squeeze job reduced gas flow by 95-98% and eliminated the distinctive odor of hydrogen sulfide.
		17	● Squeeze job #2; perforated 2628 - 2630 foot depth
		19	● Minor gas flow from 8⅝ inch casing; cement bond log shows channelized cement from ≈ 550 feet to surface
		21	● Gas emissions at police station well described as subsiding
		25	● Weber well muddy water prior to date; gurgled late Dec. to early Jan.
		?	● Flame ignited at vent from Kukoleck well, gas venting at Czernicki well
		?	● Czernicki well observed venting gas
2008	Jan	1	● Mesmer well turbid for Jan and Feb; replacing filters often; low LELs ● Ohara well turbid; no record of gas perturbation
		2	● Gaub well run all day to help purge gas; prior turbidity and bubbling
		3	● Jordan well run all previous night; gurgling sounds from gas ● Czernicki well run in afternoon to flush gas
		4	● Gaub, Cooper, Mason, and Kukoleck wells run entire previous night
			● Bastifell well spouting water; Jordan and Calo wells running to purge gas ● Jordan, Bastifell, Mason, and Kukoleck wells shut off at noon; Jordan well turned back on at 1:10 p.m. and pump lowered 8 feet
		5	● Jordan well water cloudy
		7	● Jordan well water clear, less audible gurgling
		8	● Donaldson, Gaub, and Mason wells run to purge gas
		9	● Kukoleck, Glavik, and Jordan wells running to purge gas
		10	● Sanborn, Glavik, and Jordan wells run for one or more hours
		11	● Jordan and Glavik wells run previous night; gas enters at 135 feet (OVE) ● Johnson well on to purge gas, Calo well gas enters at 95-105 feet (OVE) ● Jordan well borehole videotape; deepest gas source bed intercepts borehole at depth of 134 feet; 4 shallower gas source beds found
		12	● Jordan well running all weekend at 6-7 gallons per minute (gpm)
		13	● Calo well borehole video; deepest gas source bed at 113 feet; 1 shallower
		14	● Jordan well purging with larger (1 hp) pump ● de Gaetano, Sanborn, and Cooper wells running to purge gas

Table 1-1 continued on next page

Table 1-1 continued

Yr	Mo	Date	Description of Event
2008	Jan	15	● Jordan well running at 8 gpm all previous night; gurgling sound
		16	● Jordan well running at 6-8 gpm
		18	● Jordan well pumped at 4-6 gpm previous night; pump on/off during day
		21	● Jordan well pumping at 14 gpm; periodic gurgling sounds
		22	● de Gaetano well pumping to flush gas; Jordan well pumping at 14 gpm
	Feb	21	● Calo and de Gaetano wells pumping to purge gas
		28	● de Gaetano well pumping to purge; Jordan well pumping at 14 gpm
		29	● Jordan well pumped all previous night; shut off at 2:00 p.m.
	Mar	3	● Jordan well started at 8:35 a.m.
		7	● Jordan well turned off at 12:30 p.m.
		10	● Jordan well pumping at 20 gpm at 8:30 a.m.
		14	● Jordan well still running and gurgling
		17	● Kukoleck well pumping;gas entering well at 92 to 98 feet (OVE) ● Borehole videotapes taken at de Gaetano, Johnson, Jordan, Komocki, and Kukoleck wells
		18	● Jordan well run all previous night with gas gurgling; Kukoleck well pumping
		19	● Kukoleck and Jordan well pumping all previous night
2009	May	14	● Borehole videotapes taken at Adams and Buddenhagen wells
	Jun	11 15	● Field work in Bainbridge measuring joint azimuths ● Field work in Geauga and Cuyahoga counties measuring joint azimuths
	Sept	2	● Repeat borehole videotapes taken in wells at de Gaetano, Johnson, and Jordan. First borehole videotape taken in Stover well.
		3	● Burns and Mowery wells borehole videotaped ● Repeat borehole videotape in Komocki well
		1 - 30	● Local water wells sampled for sediment and water
	Oct	15	● Borehole videotapes in Bastifell, Calo, McGee, and police station wells wells
		27	● Measurement of joint azimuths in local quarries
	Dec	1	● Borehole videos taken in Cloninger, Buddenhagen, Czernicki, Kukoleck, and old Payne and new Payne wells
2010	Apr	1	● Borehole videotapes taken in Adams, Mechler, and Szabo wells
		15	● Borehole videotapes taken in Pierce and Maguire wells

Editorial Note: Normally, scientific reports do not use the names of property owners to identify wells because properties change hands over time. In this table, and in this report, property addresses and homeowners' names are both used because of the familiarity of properties using the names of homeowners and the ease of remembering names instead of four and five digit street numbers. Appendix B lists the addresses, names of homeowners, and characteristics of water wells of selected properties.

Sources of information for Table 1-1 include: field notes from Tom Hill and Ahmad Hawari (DMRM), Ted Hill (OVE), Dwight Williams (KU Consultants), and Dr. Scott Bair (expert panel); and meeting and telephone notes from Scott Kell (DMRM). The dates and chronology of events in Table 1-1 are frequently cited in Chapters 2, 3, and 4.

Major Issues and Hypotheses to be Tested

The dissimilar interpretations reached by DMRM and E&A are grouped into four major disputed issues. The overall concept defining each disputed issue and the fundamental differences between the DMRM statements and those of E&A are presented here. The expert panel recognizes that neither DMRM nor E&A presented their interpretations in the form of hypotheses. As such, the assignment of specific statements to a specific group is artificial. It was done to merge the large number of incongruent statements into a manageable number of hypotheses.

To place the dissimilar interpretations expressed by DMRM and E&A into the four topical groups, the expert panel collected statements from several sources, including:

- the 2008 DMRM "Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township, Geauga County Ohio,"
- the 2009 DMRM internal report "Natural Gas Monitoring, Bainbridge Township Investigation,"
- the 2009 E&A PowerPoint presentation "Wellhead LEL records in Bainbridge residential wells,"
- written and email correspondence between Mr. Markowitz (TD&D), the plaintiffs' attorney in the civil lawsuit, and DMRM
- email correspondence between E&A and DMRM and the expert panel
- statements published in local and regional newspapers made by Mr. Markowitz expressing the findings of E&A and made by DMRM expressing its professional opinions
- inquiries of invited experts during scheduled panel meetings
- DMRM investigation file records

The following sections present the four main disputed issues, specific statements within each group defining the dissimilar interpretations, and the hypotheses formulated from these statements by the expert panel. These sections apprise the reader of the major disputed issues and the specific differences of opinion, and help explain why the expert panel requested specific types of data and tests during the spring, summer, and autumn 2009, and early 2010. Chapter 4 of the report contains detailed accounts of the dissimilar hypotheses presented below and their testing and evaluation by the expert panel.

Disputed Issue No. 1 – Overpressuring English #1 Gas Well Fractured Ohio Shale

This topical group comprises statements about the subsurface impact of overpressurization of the annular space in the surface-production casing of the English #1 gas well on the integrity of the bedrock surrounding the well.

E&A Statements and Formulated Hypothesis

"The gas pressures that reportedly developed (360-380 psi) within the sealed annulus of the English 1 gas well as high enough to generate fractures in the Ohio Shale as well as in large portions of the 'Big Lime,' thus providing far-reaching conduits for gas migration from the deep bedrock." (PowerPoint slide 30, E&A presentation, May 2009)

"Such random occurrence of high LEL readings in residential water well heads can only occur as a result of gas being channeled through fractures developed in the bedrock by the over pressuring of the annulus of English 1 well." (PowerPoint slide 6, E&A presentation, May 2009)

"The over pressuring of the English 1 annulus produced fractures throughout the bedrock of Ohio Shale. The bedrock fractures developed during over pressuring of the English 1 annulus spread laterally and downwards far away from the English 1 gas well, and they continue to introduce gas to the shallow aquifer." (PowerPoint slide 36, E&A presentation, May 2009)

"Such random occurrence of high LEL readings in the residential well wellheads can occur only as a result of gas being channeled through fractures developed in the bedrock by the overpressuring of the annulus of English 1 well… While some of the records indicate direct connection to the English 1 annulus, other records points to direct communication between the shallow aquifer and the gas producing formation." (PowerPoint slide 4, E&A presentation, May 2009)

"Ohio Shale (between Berea Sandstone) and the Big Lime is known to produce non-commercial low-pressure quantities of gas. However, development of fracture system in the formation would enhance gas production. Such deep- and far-reaching fractures can serve as a long-term source of gas penetrating into the shallow aquifer. Water wells penetrating the shallow aquifer (above the Berea Sandstone) were not known to produce gas prior to the English 1 mishap. The fact that these wells currently show high wellhead LELs indicates that that the English mishap caused such deep- and far-reaching fractures into the Ohio Shale and the Berea Sandstone." (PowerPoint slide 31, E&A presentation, May 2009)

"Gas in the overpressured annulus of the English 1 gas well generated fractures through the large, or entire section of Ohio Shale." (PowerPoint slide 32, E&A presentation, May 2009)

"[A] 'circular pattern' would suggest a two-dimensional spread of the fractures while I believe that the fractures spread in three-dimensional pattern. But it is not cylindrical pattern either. I believe that it is an 'inverted cone' pattern, as the radial distance of the fractures increases from the deepest parts of the Ohio Shale to the shallow (upper) sections that are closer to the ground surface… The fractures unquestionably radiate to different distances in different lithologies; e.g., in Berea Sandstone as opposed to Ohio Shale or Cuyahoga Shale." (email to Scott Kell, DMRM, August 11, 2009)

The expert panel reviewed these and other statements, and formulated the following hypothesis for testing and evaluation.

DISPUTED ISSUE No. 1 – HYPOTHESIS FORMULATED from E&A STATEMENTS

Overpressurization of the annular space in the English #1 gas well caused the Ohio Shale to fracture creating a far-reaching, conical network of fractures extending downward through the Big Lime and throughout the Ohio Shale.

DMRM Statements and Formulated Hypothesis

"The DMRM determined that accumulation and confinement of deep, high-pressure gas in the surface-production casing annulus of the English #1 well, between November 13 and December 15, 2007, resulted in over-pressurization of the annulus. This over-pressurized condition resulted in the invasion, or migration, of natural gas from the annulus of the well into natural fractures in the bedrock below the base of the cemented surface casing." (DMRM Report, 2008, p. 4)

"Gray (1982) lists southwestern Geauga County as an area favorable for gas production in the Cleveland Shale Member, the uppermost member of the Ohio Shale. Natural gas is most likely to occur where closely spaced natural fracture systems intersect within organic rich source beds (Janssens, 1976; Schwietering, 1979; Gray, 1982)." (DMRM Report, 2008, p. 22).

"As pressure on the annulus built up, the gas migrated laterally and vertically through natural fractures in the surrounding bedrock." (DMRM Report, 2008, p. 47).

"This gas migrated vertically through fractures [in the Ohio Shale] into the overlying aquifers and discharged, or exited, the aquifers through local water wells." (DMRM Report, 2008, p. 4-5)

"These deep fractures [in the Ohio Shale] are oriented preferentially as a result of tectonic stresses." (DMRM internal report, 2009. p. 6)

The expert panel reviewed these and other statements, and formulated the following hypothesis for testing and evaluation.

DISPUTED ISSUE No. 1 – HYPOTHESIS FORMULATED from DMRM STATEMENTS

Overpressurization of the surface-production casing annulus in the English #1 gas well caused gas to migrate upward along existing, natural vertical and horizontal fractures in the surrounding bedrock below the base of the cemented surface casing. The overpressurized gas did not create new fractures.

Disputed Issue No. 2 – Fracturing Created a Perpetual Source of Invasive Gas

This issue includes statements concerning the longevity of the period of subsurface gas invasion. In science and engineering terms, whether the incident represents a *one-time pulse of methane* that will pass through the subsurface, after which conditions will return to normal, or whether the incident represents a *continuous source of methane* from creation of new, permanent subsurface conditions.

E&A and Markowitz Statements and Formulated Hypothesis

"The continued occurrence of methane in the water wells of Bainbridge is uncharacteristically persistent, implicating other than the 'natural' 'regional' pattern of fractures and joints in northeastern and north-central Ohio as the conduits/sources of the gas in these water wells." (email to Scott Kell, DMRM, August 11, 2009)

"Dr. Eckstein believes that it is highly likely that the problem will not go away any time soon and that this is a long-term condition that will exist unless some solution can be found to reduce or eliminate the exposure to the community." (Mr. Markowitz, letter to DMRM dated March 24, 2009)

"Gas will continue to flow from the bedrock fractures into the shallow aquifer, presenting continuous danger of igniting upon possible penetration into the basement of the residences in the area for an inestimable period of time." (PowerPoint slide 42, E&A presentation, May 2009)

"The Ohio shale formation that was fractured by OVE drilling may be leaking into other people's homes, and it's a problem that can last forever, or more than our lifetimes." (Mr. Markowitz, The News Herald, May 26, 2009)

"The 'squeeze job' in English 1 gas well has eliminated gas flow only through fractures directly connected to the English 1 annulus. It did not have any effect on the deeper, and farther away fractures developed between the gas producing Ohio Shale and the shallow aquifer… Gas will continue to flow from the bedrock fractures into the shallow aquifer, presenting continuous danger of igniting upon possible penetration into basement of the residences in the area for an unestimable period of time." (PowerPoint slide 42, E&A presentation, May 2009)

The expert panel reviewed these statements and others, and formulated the following hypothesis for testing and evaluation.

DISPUTED ISSUE No. 2 – HYPOTHESIS from E&A and MARKOWITZ STATEMENTS

Overpressurization of the annulus of the English #1 gas well created a network of shallow and deep fractures enabling methane gas to migrate into residential wells and basements of homes that is a long-term condition that can last forever.

DMRM Statements and Formulated Hypothesis

"The deepest water wells in the investigation area are developed in the Berea Sandstone – Bedford Shale sequence that is underlain by the Devonian Ohio Shale. The Ohio Shale is a known natural gas reservoir that is over 1800 feet thick in the vicinity of the investigation area. The occurrence of natural gas in ground water for wells developed in the Berea – Bedford sequence is common in Geauga County." (DMRM Report, 2008, p. 6)

"Water well drillers and well owners have noted occasional shows of low-pressure naturally-occurring natural gas in some Berea water wells in Geauga County before December 2007." (DMRM Report, 2008, p. 22)

"Gray (1982) lists southwestern Geauga County as an area favorable for gas production in the Cleveland Shale Member, the uppermost member of the Ohio Shale… While the gas is not present in commercial quantities, it is commonly encountered and vented to atmosphere or flared during air rotary drilling operations in northeastern Ohio." (DMRM Report, 2008, p. 22)

"Below the Ohio Shale is a sequence of… carbonate (limestone and dolomite) and evaporate (salt and anhydrite) known to drillers as the 'Big Lime.' The 'Big Lime' is approximately 1600 feet thick in Bainbridge Township. Within the 'Big Lime' there are two zones that are generally porous and permeable brine-bearing zones, but locally can contain natural gas… These zones are the Devonian Oriskany Sandstone and the Silurian 'Newburg' dolomite… Gas from the 'Newburg' often has a distinctive odor that can be sour and hydrogen sulfide bearing." (DMRM Report, 2008, p. 22)

"Below the 'Big Lime' there is a relatively thin (approximately 100 feet thick) sequence of shales and limestones that overlie the 'Clinton.' This sequence includes the driller's 'Packer Shell,' typically an impermeable limestone that constituents part of [the] 'caprock,' or confining unit over the 'Clinton' sandstone. (DMRM Report 2008, p. 22)

"Remedial cementing operations completed by OVESC in mid-December, 2007 have effectively isolated and sealed deep, high pressure gas bearing zones. As a result, natural gas from deep formations can no longer migrate up the surface-production casing annulus of the English #1 well and migrate into local aquifers. The 'Clinton' sandstone and 'Newburg' are effectively sealed behind cemented production casing." (DMRM Report, 2008, p. 5)

"The source of natural gas charging the aquifers has been eliminated and the volume and pressure of charged gas originating from the English No. 1 well is dissipating." (DMRM internal report, 2009, p. 8)

The expert panel reviewed these and other statements, and formulated the following hypothesis.

DISPUTED ISSUE No. 2 – HYPOTHESIS FORMULATED from DMRM STATEMENTS

The "Big Lime," Clinton sandstone, and Ohio Shale were not fractured by overpressurization of the English #1 gas well. Since December 17, the source of the fugitive gas has been cemented behind casing and is terminated. Overpressured gas escaped from the surface-production casing annulus of the English #1 gas well for 31 days beginning November 13, 2007.

Disputed Issue No. 3 – Wellhead LEL Readings Reveal Subsurface Conditions

This issue encompasses statements regarding interpretation of the lower explosive level (LEL) measurements made in wellheads in the investigation area.

E&A Statements and Formulated Hypothesis

"The following records clearly indicate that the occurrence of gas in wellhead of the residential water wells is not a function of the distance from the English 1 gas well. Such random occurrence of high LEL readings in the residential well wellheads can occur only as a result of gas being channeled through fractures developed in the bedrock by overpressuring the annulus of English 1 gas well. While some of the records indicate direct connection to the English 1 annulus, other records points to direct communication between the shallow aquifer and the gas producing formation." (PowerPoint slide 4, E&A presentation, May 2009)

"The following are wells [17995 English, 17971 Kingswood, 17939 English, 17938 English, 7950 Scotland, 7867 Scotland] that were affected by the initial penetration of the gas, but improved with the 'squeeze job' at English 1 gas well. These are wells located at fractures fed with gas directly from the English 1 annulus." (PowerPoint slide 5, E&A presentation, May 2009)

"The following are wells [17969 Kingswood, 17990 English, 7969 Scotland, 7955 Scotland] that were affected by the initial penetration of the gas, and improved with the 'squeeze job' at English 1 gas well, alas insignificantly. These are wells located at fractures developed as a result of overpressuring of the gas-producing formation during the English 1 annulus overpressuring. They currently continue to be affected by moderate gas content (15% < LEL < 75%) from fractures that are not physically connected to English 1 gas well" (PowerPoint slide 12, E&A presentation, May 2009)

"The following are wells [7981 Scotland, 17925 English, 7941 Scotland, 7915 Scotland, 7868 Scotland, 7846 Scotland, 7897 Scotland, 7859 Scotland, 17820 English] that were affected by the initial penetration of the gas, but did not improve with the 'squeeze job' at English 1 gas well. These are wells located at fractures developed as a result of deep fracturing of the bedrock during the English 1 annulus overpressuring, down to gas-producing formation. They currently continue to be affected by high gas content (LEL > 75%) from fractures not physically connected to English 1 gas well." (PowerPoint slide 19, E&A presentation,May 2009)

"The fact that these wells currently show high wellhead LELs indicates that that the English 1 mishap caused such deep- and far-reaching fractures into the Ohio Shale and the Berea Sandstone." (PowerPoint slide 31, E&A presentation, May 2009)

The expert panel examined these and other statements, and formulated the following hypothesis for testing and evaluation.

DISPUTED ISSUE No. 3 – HYPOTHESIS FORMULATED from E&A STATEMENTS

Temporal changes in wellhead LELs demonstrate the creation of three types of fractures. A Type 1 wellhead LEL response occurs in wells located at fractures fed with gas directly from the English #1 gas well annulus. A Type 2 wellhead LEL response occurs in wells located at fractures developed as a result of overpressuring of the deep gas-producing formation during the English #1 gas well annulus overpressuring. A Type 3 wellhead response occurs in wells located at fractures developed as a result of deep fracturing of the bedrock during the English #1 gas well annulus overpressuring, down to gas-producing formation.

DMRM Statements and Formulated Hypothesis

"Appropriate Uses of LEL Data: 1. Identify water wells with detectable natural gas." (DMRM internal report, 2009, p. 4)

"Inappropriate Uses of LEL Data: 3. It is inappropriate to draw conclusions regarding the volume or rate of gas release from LEL data. LEL readings do not indicate whether natural gas is present in high or significant volumes or the rates of release. A high reading (100 percent LEL) in the well tells us that there is enough dissolved gas that is exsolving (opposite of dissolving), or stratigraphically trapped free-gas bubbling up through the column of ground water in the well bore, to accumulate in the well bore (a fairly stagnant, non-circulating environment when not pumped) to at least 5 percent by volume or greater." (DMRM internal report, 2009, p. 4)

"Inappropriate Uses of LEL Data: 4. LEL readings do not indicate the source of natural gas. The readings cannot distinguish biogenic methane (released from decaying organic debris, or from the Ohio Shale Shale) from thermogenic methane released from deep sources such as gas released from the 'Newburg' dolomite by the English No. 1 well. Trend data along with other lines of evidence, may be used to infer the source of natural gas." (DMRM internal report, 2009, p. 4)

"The source of natural gas charging the aquifers has been eliminated and the volume and pressure of charged gas originating from the English No. 1 well is dissipating." (DMRM internal report, 2009, p. 8)

"Water wells developed in the underlying Devonian Shale will continue to emit natural gas, periodically, whether they were affected by the English No. 1 charging incident or not." (DMRM internal report, 2009, p. 9)

The expert panel reviewed these and other statements, and developed the following hypothesis for testing and evaluation.

DISPUTED ISSUE No. 3 – HYPOTHESIS FORMULATED from DMRM STATEMENTS

Wellhead LEL values are a valuable diagnostic tool for determining the presence or absence of methane gas and for determining possible public safety responses to specific LELs. Measurement of wellhead LELs, however, cannot determine the subsurface source of gas or the subsurface conditions that enabled the gas to enter the well.

Disputed Issue No. 4 – Methane Gas, Metals, and Black Goo Contaminate Wells

This issue includes statements about the origin, occurrence, and health effects of black particulates, i.e. "black goo," and dissolved metals in residential wells in the area of subsurface gas invasions and the health effects of methane gas in tap water.

E&A and Markowitz Statements and Formulated Hypothesis

"Many residential water wells began following the English #1 gas well incident to yield water with varying amounts of black suspended particulate matter. Chemical analysis of the particulates conducted at the laboratories of geology departments of the Akron University and Kent State University indicate that the suspended particles consist of variety of heavy metals, including toxic ones, e.g. lead, copper, etc." (PowerPoint slide 38, E&A presentation, May 2009)

"Seemingly, the gas penetrating the shallow aquifer entrains the black particulate matter from the likely source in the Ohio Shale formation." (PowerPoint slide 38, E&A presentation, May 2009)

"Some of my clients have reported to me that they continue to suffer from skin rashes and irritations and a few have noted that their dogs have been losing hair, which is an indication that there may be unsafe levels of arsenic in the ground water." (letter to DMRM from Mr. Markowitz, February 26, 2008)

"And, we expect the test results will confirm gas in the water, and possible some chemicals exceeding maximum contaminate levels approved by EPA." (email to clients from Mr. Markowitz, February 27, 2008)

"A similar, although less dangerous situation, arose in North Royalton, Ohio which was analyzed by ASTDR, the Ohio EPA and the ODNR. Substantially lower levels of methane were found in the homes on Cady Road in North Royalton…" (Mr. Markowitz, letter to DMRM dated January 23, 2009)

The expert panel examined these and other statements and formulated the following hypothesis for testing with the available data and information.

DISPUTED ISSUE No. 4 – HYPOTHESIS from E&A and MARKOWITZ STATEMENTS

Subsequent to the English #1 gas well incident, black goo consisting of toxic metals derived from asperites created during the fracturing of the Ohio Shale is contaminating the water obtained from residential wells. The residential well water also contains arsenic and other toxic metals that cause health risks as a result of the gas invasion.

DMRM Statements and Formulated Hypothesis

"Arsenic is a poor indicator of impacts from oil and gas operations. Arsenic values obtained through investigation water sampling efforts do not by themselves indicate ground water supplies have been impacted by oilfield operations." (DMRM Report, 2008, p. 63)

"Ohio EPA has established a public drinking water standard [for dissolved arsenic] of 0.01 mg/L (10 µg/L). [The] Primary Maximum Contaminant Level (PMCL) is a health-based standard." (DMRM Report, 2008, p. 62)

"Total arsenic [above machine detection limits] was detected in 10 of 79 samples collected [in the area of subsurface gas invasions]. Nine of the samples were well below the PMCL. Concentrations in the nine samples ranged from 2 to 5 µg/L. One sample collected at 17839 English Drive had a arsenic concentration at the PMCL of 10 mg/L." (DMRM Report, 2008, p. 62).

"Natural gas in ground water is a common enough problem in Geauga County. Prior to this [English #1 gas well] incident, DMRM staff met with representatives of the Geauga County Health District to review water well drilling procedures necessary to avoid or control shallow natural gas. This meeting was in response to natural gas in water well complaints referred to DMRM by the health district. Certain complaints were in areas where no oil and gas wells had been drilled." (DMRM Report, 2008, p. 68)

"U.S. EPA has not established a Primary or Secondary Maximum Contaminant Standard for dissolved methane or other components of natural gas. According to the Agency for Toxic Substances and Disease Registry (ATSDR) ingestion of water containing natural gas does not pose a direct health hazard. However, using tap water in the home can allow dissolved natural gas to exsolve, releasing natural gas into rooms where water is used. If natural gas is dissolved in sufficient concentrations, and sufficient volumes of water are discharged there are potential safety issues." (DMRM Report, 2008, p. 71)

The expert panel examined these and other statements and constructed the following hypothesis for testing with the available data and information.

DISPUTED ISSUE No. 4 – HYPOTHESIS FORMULATED from DMRM STATEMENTS

Groundwater in the area of the English #1 gas well was not degraded, contaminated, or polluted by oilfield brine, crude oil, or hydraulic fracturing fluids; nor did invasion of gas into subsurface aquifers (Berea Sandstone, Cuyahoga Shale, Sharon Sandstone) cause local groundwater supplies to exceed Ohio EPA health-based standards for arsenic or other heavy metals.