

Shale Gas Inquiry

Energy and Climate Change Committee

Written Evidence from Cuadrilla Resources Holdings Limited

13 January 2011



1 EXECUTIVE SUMMARY

- 1.1 Cuadrilla Resources Holdings Limited (“Cuadrilla”) is an English independent oil and gas company based in Lichfield, Staffordshire, pursuing an unconventional hydrocarbon exploration programme in selected European geological formations. The company’s most advanced activities are located in the Bowland Shale in Lancashire, in the north-west of England.
- 1.2 Cuadrilla welcomes the opportunity to discuss prospects for European shale gas, our own operations, and the potential risks associated with shale gas exploration. We commend the Energy and Climate Change Committee for embracing this important topic.
- 1.3 Cuadrilla believes that prospects for shale gas in the UK and parts of continental Europe are promising. This assessment is based on the presence of a number of geological formations that are similar in several important respects to geological formations located in the United States and Canada, where significant deposits of natural gas have been discovered.
- 1.4 Natural gas produced from shale is commonly referred to as ‘unconventional’. **It is critical to highlight that the only unconventional aspect of shale gas is the reservoir or rock type in which it is found. Shale gas exploration techniques, including directional drilling and hydraulic fracture stimulation (“fracing”)¹, are conventional and have been used across the oil and gas industry (including previously in the UK) for many decades.** What has changed is that these techniques have become progressively more technologically advanced and lower cost over time, allowing exploitation of shale gas at scale to become increasingly economically viable.
- 1.5 Cuadrilla believes that shale gas can offer a ‘triple win’ for governments, including the UK government, contributing to the three key policy objectives of (1) enhancing energy security, (2) lowering the cost and price volatility of energy to consumers and (3) reducing greenhouse gas emissions.
- 1.6 Cuadrilla also recognises the potential for an emerging shale gas industry to create new jobs and inject investment into local economies, for example in the north-west of England, thereby helping governments pursue broader economic growth and industrial rebalancing objectives. By being a first mover in shale gas, the UK could be at the forefront of a potentially significant new European energy industry, bringing multiple economic benefits for the north-west of England and for UK Plc.
- 1.7 Shale gas has low carbon content compared with several other fossil fuels. Carbon dioxide emissions can be further mitigated by adopting certain production processes, such as drilling multiple wells from the same ‘pad’.
- 1.8 Shale gas exploration and production sites typically occupy a small geographical footprint and their visual impact can easily be minimised.

¹ “First hydraulic fracturing treatment was pumped in 1947 on a gas well operated by Pan American Petroleum Corporation in the Hugoton Field”; Gidley, *SPE Monograph 12*, 1989; further quoted in Department of Energy, *EPA 816-R-04-003 – Hydraulic Fracturing White Paper*, June 2004.

- 1.9 All hydrocarbon exploration, including shale gas exploration, involves potential health, safety and environmental risks. However, these potential risks, **which are not unique to shale gas and are common to all hydrocarbon exploration**, are mitigated through stringent regulatory requirements and through established operating processes, procedures and controls. With around 200 years of cumulative experience, including involvement in the drilling and/or fracking of more than 3,000 wells, Cuadrilla's management team is implementing industry leading health, safety and environmental risk mitigation practices across all its activities.
- 1.10 We would be happy to provide further information to the Energy and Climate Change Committee should this be requested.

2. ABOUT CUADRILLA RESOURCES

- 2.1 Cuadrilla Resources Holdings Limited (“Cuadrilla”) is an English independent oil and gas company based at Lichfield in Staffordshire, formed in 2008 by a group of veteran unconventional gas explorers from the US and the UK with the support of specialist energy investors. The company is currently assembling an extensive exploration portfolio of shale gas, tight gas sand and oil-from-shale plays in established hydrocarbon provinces located in several European countries including the UK, Poland and The Netherlands. The company’s most advanced activities are located in the Bowland Shale in Lancashire, in the north-west of England.
- 2.2 Cuadrilla employs 14 people full time: 9 based in the UK, 3 in the US and 2 in Poland. In addition, the company currently uses 19 consultants and 7 contractors, employing roughly 40 people who regularly work on Cuadrilla projects. The company considers its investment in local services to be of significant economic benefit to the local communities where it operates, in turn underpinning further employment.
- 2.3 The majority of Cuadrilla’s shares are owned by two energy specialist investors, Riverstone and A.J. Lucas, which each hold a 41% stake in the company. The remainder of the equity is held by the senior management team. More information on the two main investors is available at www.riverstonellc.com and www.lucas.com.au.
- 2.4 With deep technical expertise and an extensive and proven track record, Cuadrilla is poised to become a leading European unconventional hydrocarbon explorer. The company also owns and operates the only integrated drilling, cementing, fracing and well testing equipment currently available in Europe. This equipment includes the latest technology from North America.
- 2.5 Cumulatively, Cuadrilla’s six-person senior management team, led by Mark Miller and Dennis Carlton, have nearly 200 years of natural gas exploration experience and have played leadership roles in the drilling and/or fracing of more than 3,000 natural gas and oil wells. Members of the senior management team previously led Evergreen Resources Inc., a US-based company which has drilled and/or fraced more than 1,500 unconventional gas wells in the US, Canada and Europe. Fourteen of these wells were drilled in the UK. Based on this extensive experience, Cuadrilla is implementing industry leading drilling, fracing and health, safety and environmental practices throughout its exploration programme (discussed further in Section 5 below).
- 2.6 In the United Kingdom, Cuadrilla has received full local and national regulatory approvals, including planning permissions, environmental authorisations and health and safety approvals, to explore for natural gas at five onshore locations in Lancashire. We maintain active and positive relationships with the Department for Energy and Climate Change, the Health and Safety Executive and other UK regulatory bodies.
- 2.7 Cuadrilla began drilling at its first location, Preese Hall 1, located approximately five miles east of Blackpool, in August 2010. The company completed its first phase of exploration at the Preese Hall 1 site, which

involved drilling a vertical exploratory well with total depth of around 9,000 feet, in December 2010. During the drilling process Cuadrilla encountered indications that natural gas is present in the rocks through which the well has been drilled.

- 2.8 Phase 2 of the Preese Hall 1 exploration programme, which the company expects to commence in the first three months of 2011 and to last 3 to 6 months, involves stimulating rocks surrounding parts of the vertical well at depths greater than 5,000 feet. Cuadrilla is using fracing techniques which have an extensive, safe and proven track record in the North America, as discussed further in Section 5 below. Only after this second phase is complete will Cuadrilla be able to determine with confidence whether commercial quantities of natural gas are present at its first drilling site.
- 2.9 Once drilling and fracing activities are completed at the Preese Hall 1 site, Cuadrilla intends to redeploy its drilling equipment to commence drilling at one of the other four sites in Lancashire where it has received full local and national regulatory approvals.

3. WHAT ARE THE PROSPECTS FOR SHALE GAS IN THE UK & WHAT ARE THE RISKS OF RAPID DEPLETION OF SHALE GAS RESOURCES?

- 3.1 Cuadrilla believes that prospects for shale gas in the UK and parts of continental Europe are promising. This assessment is based on the presence of a number of geological formations in Europe that are similar in several important respects to geological formations located in the North America where significant deposits of unconventional gas have been discovered.
- 3.2 The most important variables in determining where unconventional natural gas is present and the scale of the resource are as follows:
- *Thickness.* In general, a thicker section of shale is preferred as it provides more potential gas bearing zones, increased gas storage and greater recoverable reserves.
 - *Natural Fracture Intensity.* Because shale typically has very low permeability and porosity, natural fractures are important in providing a route for the natural gas from the shale rock to the well shaft. In addition, natural fracture intensity aids the fracing process, which works most effectively when the artificial fractures created intersect with existing natural fractures in the shale. Of particular importance in estimating natural fracture intensity are the width of the natural fractures (ranging from micro-fractures thinner than a grain of sand to wider fractures of approximately 1mm width), their length, and the number of connections between them. High fracture intensity allows for increased production rates and recoverable reserves.
 - *"Frac-ability".* In general, the fracing process generates more artificial fractures in more brittle shales, allowing a larger proportion of the gas reserve to be recovered. The degree of brittleness is determined by the chemical composition of the shale, for example silica and carbonates make it more brittle. Laboratory measurements on shale material collected during drilling operations are used to determine the

natural stresses in the shale and how easily it will crack during the fracking process.

- *Present Day Structural Setting.* Shales can be found either in an extensional setting, in which they are being geologically ‘stretched’ apart, or a compressional setting, in which they are being geologically ‘pushed’ together. Those in an extensional setting exhibit more open natural fractures, allowing more natural gas to migrate from the rock to the well shaft, and increasing the amount of recoverable reserves. The Bowland Basin’s present day structural setting is extensional.
- *Gas Content.* The gas content of a particular shale is the amount of gas stored within the shale pore spaces and the naturally occurring fractures. Measured in cubic feet of gas per ton of shale, it is crucial in estimating the likely scale of a particular reserve. This measurement is conducted at the well site through laboratory analysis of the rocks.
- *Total Organic Content (TOC).* The TOC of a shale is the amount of carbon material remaining in the rock and indicates its potential to have generated hydrocarbons in the past. There is a range of TOC values which are optimal and determine how prospective the shale is for a given geologic basin.
- *Maturity Level (“Ro value”).* The hydrocarbon bearing potential of a shale depends on the temperature and depth at which it has spent its history. If it has been too cool then few hydrocarbons will have been generated; if it has been too hot then they will have been degraded or destroyed. A key tool for assessing a shale gas reserve is thus the determination of the ‘Ro’ value.
- *Reservoir Pressure.* Under a higher natural reservoir pressure more gas molecules can be stored and therefore ultimately recovered. Doubling reservoir pressure approximately doubles gas reserves. Study of surrounding wells to identify reservoir pressure is also important in preventing well control concerns, as described in Section 5.

3.3 Natural gas produced from shale is commonly referred to as ‘unconventional’. **It is critical to highlight that the only unconventional aspect of shale gas is the reservoir or rock type in which it is found. Shale gas exploration techniques, including directional drilling and fracking, are conventional and have been used across the oil and gas industry (including previously in the UK) for many decades.** What has changed is that these techniques have become progressively more technologically advanced and lower cost over time, allowing exploitation of shale gas at scale to become increasingly economically viable.

3.4 In both conventional and unconventional oil and gas exploration and development around the world, it is very common to drill a number of wells in different directions from a single drill pad to target specific positions in the subsurface. Directional drilling uses “off-the-shelf”, proven and safe technologies. A good example in the UK is Wytch Farm near Poole in Dorset, where wells were drilled significant distances (in excess of 10km) from an

onshore location to hydrocarbon deposits located offshore in order to minimise visual impacts along the coastline.

- 3.5 Cuadrilla's exploratory well programme at the Preese Hall 1 site employs vertical rather than directional drilling. However, Cuadrilla expects to use directional drilling in the future as its exploration programme develops. This technology will be used to minimise surface disturbance during drilling, fracing and production operations as well as to reduce the overall cost of exploration and development activities.
- 3.6 Fracing involves pumping fluid, more than 99% (in Cuadrilla's case 99.85%) composed of water and sand, under high pressure to open up millimeter sized gaps or cracks in shale rock formations typically found at depths greater than 5,000 feet.² **We discuss the composition of fracing fluid in greater detail in paragraph 5.6.1 below.** The cracks are held open by the particles of sand (as a "proppant") contained in the fluid. Fracing increases the number of pathways a well bore has to the surrounding natural gas-bearing rock formation and thereby provides numerous channels through which natural gas can flow into the well. As discussed in greater depth in Section 5 below, fracing takes place thousands of feet below the shallow water table. **As of 2009, out of hundreds of thousands of fracing operations that have taken place in the United States, US regulators have confirmed no cases of hydrocarbons or fracing fluid leaking into shallow water aquifers as a result of fracing.**³ Cuadrilla is not aware of any incidents since 2009.
- 3.7 Cuadrilla does not have a detailed proprietary view of the full potential of shale gas outside North America. The shale gas industry in Europe and Asia is at a very early stage with a small number of exploration projects currently taking place. As well as Cuadrilla's exploration activities in the UK, The Netherlands and Poland we are aware of other companies exploring for shale gas in Poland, Sweden, Australia and China.⁴
- 3.8 Cuadrilla has undertaken its own analysis of the UK's onshore shale gas resource potential. It is worth noting that these same shales are the source of hydrocarbons found in most of the UK's conventional oil and gas fields. As a result of its analysis, Cuadrilla has targeted the Bowland Basin in the north-west of England (which is also the source of the natural gas currently being produced from beneath the Irish Sea) for its first European drilling

² "Water typically makes up 99 percent of the liquid phase of fracturing fluids"; American Petroleum Institute, *Hydraulic Fracturing at a Glance*, 2008

³ "Of the responses received, no state has reported verified instances of harm to groundwater as a result of hydraulic fracturing. Responses were crafted by the state oil and gas regulatory official in each state."; Interstate Oil & Gas Compact Commission, *IOGCC Hydraulic Fracturing Survey Facts 2002 and 2009*, June 2009. A similar conclusion was included in an earlier report by the Environmental Protection Agency on the impact of coal bed methane exploration and production, which uses similar fracing techniques but normally at shallower depths; "In its review of incidents of drinking water well contamination believed to be associated with hydraulic fracturing, EPA found no confirmed cases that are linked to fracturing fluid injection into CBM wells or subsequent underground movement of fracturing fluids."; *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*, June 2004

⁴ The relative immaturity of detailed scientific knowledge on the extent and location of European shale gas reserves is discussed in a recent study by the The Oxford Institute for Energy Studies; e.g. "Europe has little knowledge about the potential, quality, precise location, and location of sweet spots of its unconventional gas resources."; Florence Gény, *Can Unconventional Gas be a Game Changer in European Gas Markets*, December 2010

programme. Cuadrilla believes gas-in-place volumes in the Bowland Shale could be substantial. However the volume of this resource that could be recovered economically has not yet been established and will not be known until further exploration and testing is complete.

- 3.9 In terms of depletion of shale gas resources over time, there are two key factors: production rates and recovery factors. The only scientific method currently available to estimate these factors for UK shale formations is by analogy to commercial North American shale plays.
- 3.10 Given the relative immaturity of even shale plays with the longest production record, such as the Barnett Shale, long-term shale gas production decline rates remain projections rather than based on scientific facts. These projections depend on a number of assumptions such as well operating costs and natural gas price forecasts.
- 3.11 Cuadrilla's expectation, informed by experience in North America, is that a typical shale gas well, in common with other unconventional gas wells, will witness steep early production decline rates – typically of around 30% to 40% for one to two years – followed by up to 50 years of commercial life at low decline rates – typically 5% to 7%. It is possible that UK shales may have a steeper decline rate than this, which would reduce their production rates and economically recoverable reserves. However it is also possible that UK shales may have lower decline rates and thus better economic recovery factors. This will become clearer over time after further exploration activity and geological testing in UK shale formations is completed.

4. WHAT ARE THE IMPLICATIONS OF LARGE DISCOVERIES OF SHALE GAS AROUND THE WORLD FOR UK ENERGY AND CLIMATE CHANGE POLICY? HOW DOES THE CARBON FOOTPRINT OF SHALE GAS COMPARE TO OTHER FOSSIL FUELS?

- 4.1 Cuadrilla believes increased penetration of shale gas in the energy mix increases energy options, thereby improving energy security, has the potential to lower natural gas prices (tending to reduce electricity prices), and reduces carbon dioxide emissions compared with other types of fossil fuel based power generation. Shale gas can therefore offer a 'triple win' for governments pursuing the three key policy objectives of enhancing energy security, lowering the cost and price volatility of energy to consumers and reducing greenhouse gas emissions.
- 4.2 In addition, Cuadrilla recognises the potential for an emerging shale gas industry to create new jobs and inject investment into local economies, for example in the north-west of England, thereby helping governments pursue broader economic growth and industrial rebalancing objectives. By being a first mover in shale gas, the UK could be at the forefront of a potentially significant new European energy industry, bringing multiple economic benefits for the north-west of England and for UK Plc.
- 4.3 The shale gas revolution in the US in recent years has probably already had a positive impact on the UK energy system. With the US now self-sufficient in natural gas, more liquefied natural gas (LNG) has become available on world

markets.⁵ This has offered consuming countries such as the UK more options to source natural gas, enhancing energy security, while at the same time reducing global natural gas prices from highs of around \$12/mmbtu in 2008 to around \$4 more recently. Since natural gas fired power plants tend to set electricity prices in the UK, this in turn has reduced wholesale electricity prices compared with previous levels. Further discoveries of shale gas outside the US would enhance these trends.

- 4.4 Shale gas, like all natural gas, has a significantly lower carbon content per unit of energy generated compared with other fossil fuels such as coal. This is shown in the table below:

Fossil Fuel Emission Levels - Pounds per Billion Btu of Energy Input			
Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

- 4.5 As with all hydrocarbon production there are some additional carbon dioxide emissions associated with processing at the surface. However these relatively low emissions can be minimised through production efficiencies. Pad drilling is very common in the development of a multi-well shale gas field. In some cases up to 16 shale gas wells can be drilled from a common well pad. Multi-pad drilling increases the efficiency of gas gathering and production facilities compared with drilling a large number of single-well pad gas fields individually, reducing carbon dioxide emissions.
- 4.6 Multi-well pad drilling also significantly reduces the visual impact of shale gas production at the surface. Shale gas exploration and production sites typically occupy a small footprint and any visual impact can be minimised relatively easily.

5. WHAT ARE THE RISKS AND HAZARDS ASSOCIATED WITH DRILLING FOR SHALE GAS?

- 5.1 As with all hydrocarbon exploration programmes, there are potential health, safety and environmental risks associated with shale gas exploration. However these potential risks, **which are not unique to shale gas and are common to all hydrocarbon exploration**, are mitigated through stringent regulatory requirements and strict operating processes, procedures and controls.

⁵ IHS CERA, *Fueling North America's Energy Future: The Unconventional Natural Gas Revolution and the Carbon Agenda*, 2010.

- 5.2 We discuss three potential risks from hydrocarbon exploration, including shale gas exploration, below: 1) leakage of hydrocarbons or, where it is used, fracturing fluid into shallow water aquifers, 2) well control failure, and 3) personal injury. Although these potential risks are relatively low, and no greater for shale gas than for other forms of hydrocarbon extraction⁶, we consider them to be significant enough to deserve discussion in this submission. These three potential risks, and their mitigations, are discussed in detail in paragraphs 5.6.1, 5.6.2 and 5.6.3 respectively below.
- 5.3 Cuadrilla's exploration activities in the Bowland Shale have received all necessary planning, environmental and health and safety permits from the competent local and national authorities.
- 5.4 The UK possesses a strict regulatory framework governing onshore oil and gas exploration, including unconventional gas exploration. All UK hydrocarbon exploration projects require planning permission from the local planning authority, e.g. Lancashire County Council in the case of the Bowland Basin. Local planning permission comes with a number of project-specific requirements including ecology studies, and transportation, lighting and noise surveys. The planning permission process also requires approval from the UK Environment Agency affirming that the impact of the project on the local environment is minimal and that any environmental risks have been minimised. In addition to the local planning process, approval to drill for natural gas requires an exploration license from the UK Department of Energy and Climate Change and permission from the UK Health and Safety Executive.
- 5.5 As well as strict regulatory requirements, effective day-to-day operating processes, procedures and controls are critical to ensuring a safe and incident-free shale gas exploration project. As detailed in paragraphs 5.6.1, 5.6.2 and 5.6.3 below, Cuadrilla uses robust risk mitigation approaches throughout its activities, implementing industry leading practices which the management team has acquired from more than 120 years of cumulative unconventional gas exploration experience around the world (200 years of total oil and gas exploration experience, including leadership roles in the drilling and/or fracturing of more than 3,000 wells).
- 5.6.1 Leakage of hydrocarbons or fracturing fluid into shallow water aquifers. All hydrocarbon exploration, including shale gas exploration, carries the potential risk that hydrocarbons or, in cases where it is used, fracturing fluid leak into shallow water aquifers. Although facts from extensive shale gas exploration experience in North America suggest that such leakage is highly improbable⁷, Cuadrilla is nonetheless implementing a number of precautionary steps to manage this potential risk.

⁶ "[The main sets of issues] are risks also embedded in conventional onshore gas activities" ; Florence Gény, The Oxford Institute for Energy Studies, *Can Unconventional Gas be a Game Changer in European Gas Markets*, December 2010.

⁷ "Oil and gas operations are widespread throughout North America, and drinking water supplies have been appropriately safeguarded from contamination from these activities for many years. This suggests that the risks can be managed and that shale gas development can proceed safely, with proper industry management and regulatory safeguards in place."; IHS CERA, *Environmental Issues Associated with Shale Gas Development*, September 2010.

Fracing fluids are more than 99% composed of fresh water and sand (in Cuadrilla's case 99.85% - further details set out in the Annex). This water and sand is supplemented with a mixture of everyday chemicals typically found in people's homes, including: friction reducers (polyacrylamides) used as absorbent material in disposable nappies; surfactants (isopropanol) found in glass cleaner; clay stabilizer (potassium chloride) found in low sodium table salt; dilute acid found in cleaning products and in anti-bacterial agents such as bleach; and viscosity agent (guar gum extract) typically found in food products such as ice cream and salad dressing.

There are two possible routes by which hydrocarbons or fracing fluid could potentially leak into shallow water aquifers as an unintended consequence of hydrocarbon exploration, including shale gas exploration: 1) through leaks in the walls of the drill shaft; or 2) through spilled fluid on the surface that seeps into groundwater. Mitigations to these potential risks are discussed in paragraphs 5.6.1.2 and 5.6.1.3, respectively, below.

5.6.1.1 We do not consider there to be a risk that hydrocarbons or fracing fluid leak into shallow water aquifers as a result of the fracing process.⁸ We note there is no officially documented case of fracing causing leakage of hydrocarbons or fracing fluid into shallow water aquifers in the history of US shale gas extraction.⁹ This is because shallow water aquifers – including shallow water aquifers at Cuadrilla's exploration sites in Lancashire – tend to be located at depths no greater than 1,000 feet below the surface, whereas the shale geological formations where fracing takes place tend to be located at depths of at least 5,000 feet below the surface – as is also the case at Cuadrilla's Lancashire sites. Fractures caused by the fracing process never exceed 200-300 feet upwards in the vertical plane. Thus there are thousands of feet of impenetrable rock between shallow water aquifers and the upper-most point of fractures created by the fracing process.¹⁰

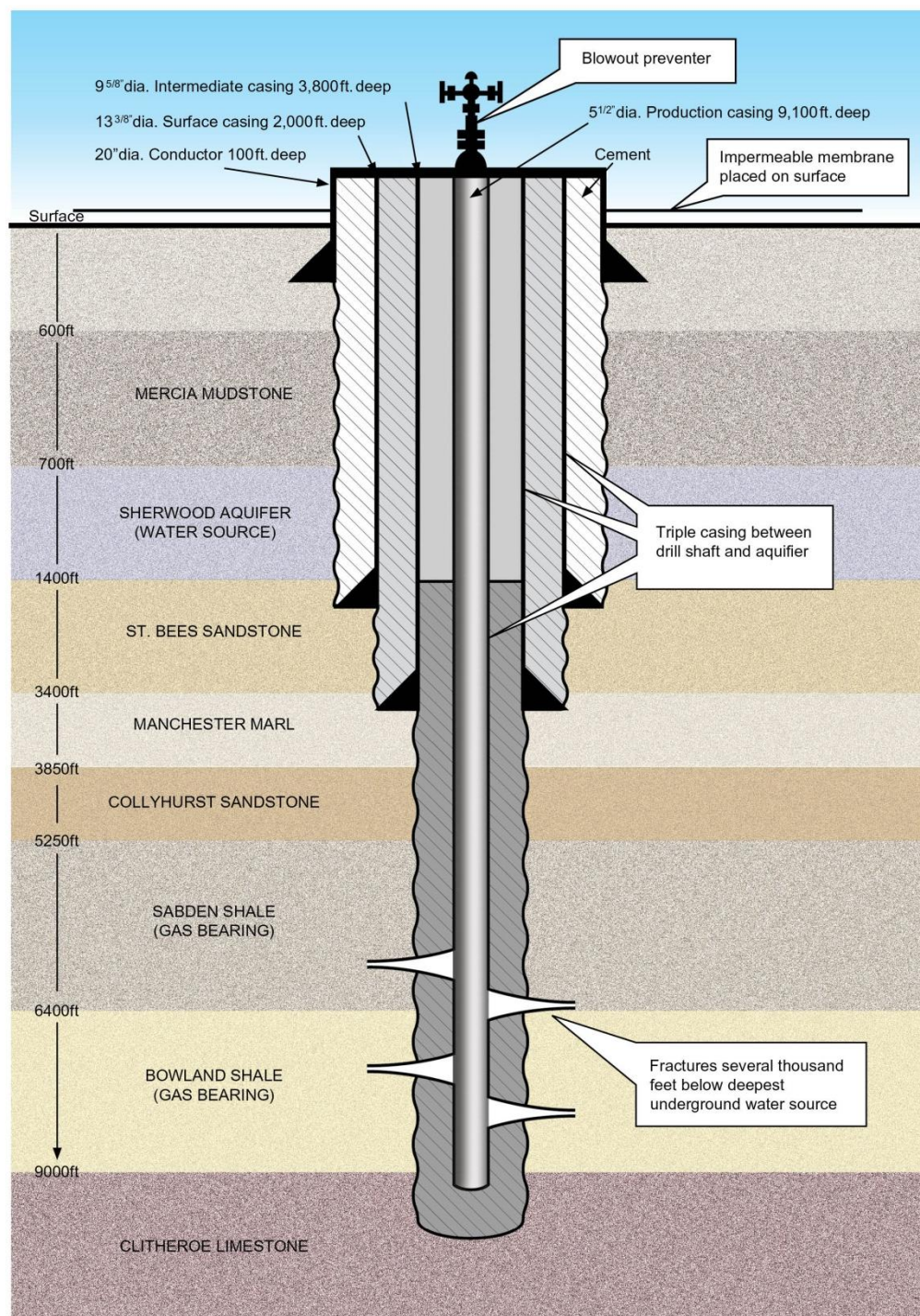
This is shown in the Bowland Shale Well Schematic (Diagram 1) on the following page:

⁸ "The consensus among geologists, petroleum engineers, and government reports is that such an event [the hydraulic fracturing process contaminating drinking water aquifers] is highly improbable."; "At present there is no evidence that liquids used for hydraulic fracturing of deep shales can migrate upward to contaminate drinking water aquifers, and there are strong geological arguments to the contrary"; IHS CERA, *Environmental Issues Associated with Shale Gas Development*, September 2010.

⁹ "Of the responses received, no state has reported verified instances of harm to groundwater as a result of hydraulic fracturing. Responses were crafted by the state oil and gas regulatory official in each state."; Interstate Oil & Gas Compact Commission, *IOGCC Hydraulic Fracturing Survey Facts 2002 and 2009*, June 2009. A similar conclusion was included in an earlier report by the Environmental Protection Agency on the impact of coal bed methane exploration and production, which uses similar fracing techniques but normally at shallower depths; "In its review of incidents of drinking water well contamination believed to be associated with hydraulic fracturing, EPA found no confirmed cases that are linked to fracturing fluid injection into CBM wells or subsequent underground movement of fracturing fluids."; EPA, *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*, June 2004.

¹⁰ "From a geological point of view, such contamination is very unlikely to occur in deep shale formations, as several thousands of feet of rock separate most gasbearing formations from the base of aquifers"; Florence Gény, The Oxford Institute for Energy Studies, *Can Unconventional Gas be a Game Changer in European Gas Markets*, December 2010.

Diagram 1 – Bowland Shale Well Schematic



Note: Not to scale

5.6.1.2 Leakage of hydrocarbons or fracing fluid into shallow water aquifers through the walls of the drill shaft is prevented by the installation of three steel casings, each of which is cemented in place, in the zone of the shaft adjacent to and surrounding the shallow water aquifer. The integrity of the bond between the rock formations and casings is ensured by pressure testing and other verification techniques prior to any fracing operations.

5.6.1.3 In the unlikely event of a spillage on the surface, seepage of hydrocarbons or fracing fluid into shallow water aquifers through the ground is prevented by the installation of an impermeable membrane on land at and surrounding the well site. Surface level drainage is designed such that any spillage will be collected in a sealed pond from which it can be safely removed. Water returned to the surface during the fracing process is stored in steel tanks or sealed ponds and never touches the ground. Some of this water is recycled.

5.6.2 Well control failure. During all hydrocarbon exploration, including shale gas exploration, potential high pressures associated with hydrocarbon extraction must be managed and controlled. In highly rare and extreme cases, improper management and poor well construction may result in loss of well control, with the risk that a potentially explosive and damaging release of fluids occurs. Again, Cuadrilla follows industry leading procedures to manage this potential risk.

Before a drilling operation begins, Cuadrilla undertakes a comprehensive evaluation of geological and drilling records for the local area to determine if a high pressure environment may exist. If this possibility is present, the well is designed and constructed accordingly.

During drilling operations, drilling fluid is used to provide a hydrostatic head on the rocks being penetrated and to constantly monitor temperature, pressure, volume, chemical constituents, geological rock properties, gas liberated during the drilling process and other well characteristics, alerting drilling engineers to any potential problems.

A blowout preventer is installed at the top of the well. It is operated according to strict procedures which include a safety and performance check once every 7 days and a major inspection every 21 days.

5.6.3 Personal injury. Drilling for hydrocarbons and fracing involve high pressures and high liquid flow rates, which could potentially enhance the risk of equipment failure at the surface and resulting personal injury. These potential health and safety risks are mitigated by a number of preventative measures.

Cuadrilla uses state-of-the-art equipment with automatic pressure and temperature shutdown systems to mitigate the potential risk of mechanical malfunction. Required personal protection safety gear is inspected daily.

There is an overriding safety management plan covering all Cuadrilla's operations. Under this plan, all site-based Cuadrilla personnel must undertake rigorous safety training. Detailed risk assessment and safety meetings are held daily for drill rig and well service personnel. Safety meetings are also held before and after every fracing operation. All visitors to the site must undergo a 30 minute training programme in safety.

All fracing operations are controlled and monitored remotely, at a safe distance from the wellhead. The number of personnel near the wellhead and adjacent to the equipment is restricted to the minimum necessary.

Although the chance of encountering dangerous gas compounds during drilling for hydrocarbons is very remote, hydrogen sulphide detectors are located around the site as well as in the mudflow monitoring unit.

- 5.7 In summary, potential health, safety and environmental risks associated with hydrocarbon exploration, including shale gas exploration, are mitigated through stringent regulatory requirements and the implementation of established industry safety processes, procedures and controls. Cuadrilla is a highly experienced unconventional gas explorer and the company adopts a robust approach to mitigating potential health, safety and environmental risks based on this experience.

6. CONCLUSIONS & RECOMMENDATIONS

- 6.1 The prospects for shale gas in Europe in general and the UK in particular are promising by analogy to similar geological formations found in North America that have proven to hold commercially productive quantities of gas.
- 6.2 However it is still early days for the European shale gas industry, in which Cuadrilla considers itself to be a pioneer.
- 6.3 Shale gas exploration techniques, including directional drilling and fracing, are conventional and have been used across the wider oil and gas industry (including previously in the UK) for many decades.
- 6.4 Shale gas offers the potential to be a 'triple win' for the UK, helping to enhance energy security, tending to lower the cost and price volatility of energy to consumers and reducing greenhouse gas emissions, while also promising to be a significant source of new economic activity for the north-west of England and for UK Plc.
- 6.5 The carbon footprint of shale gas is low relative to several other fossil fuels.
- 6.6 Shale gas operations have a small geographical footprint and their visual impact can be minimised relatively easily.
- 6.7 There are strict regulatory requirements in place for shale gas exploration in the UK, to which all Cuadrilla's operations adhere.
- 6.8 Cuadrilla is a highly experienced shale gas explorer. The company adopts a robust approach to mitigating potential health, safety and environmental risks based on this experience, implementing industry leading processes, procedures and controls. The potential risks associated with shale gas exploration are not unique and are common to all hydrocarbon exploration.
- 6.8 Cuadrilla believes 1) science-backed education and 2) supportive fiscal and regulatory frameworks will be critical to the success of the UK shale gas

sector. We would welcome the opportunity to discuss both areas further with the Energy and Climate Change Committee.

- 6.9 We are grateful to the Energy and Climate Change Committee for considering Cuadrilla's responses to the questions posed in its shale gas enquiry. We would be happy to provide further information if requested.

7. ANNEX

Note on the specific composition of Cuadrilla's fracking fluid

Cuadrilla's fracking fluid is a minimum of 99.75% water and sand.

The remaining 0.20% - 0.25% is comprised of three additional ingredients:

- Around 0.075% is a friction reducer called Polycrylamide. Polycrylamide is found in facial creams (available on the High Street and produced by major brand names), soil sealants and contact lenses.

Two other chemicals may be used:

- Around 0.005% is a biocide used at this very low concentration. This will be used if and only if the domestic water from United Utilities is not pure enough. But if it is sufficiently pure the biocide will not be used.
- Around 0.125% is a weak hydrochloric acid to help open the perforations to initiate frac fluid injection and again will only be used if needed. This is the same acid that can be used in 'drinking' water wells to stimulate water production, and in some cases used in swimming pools. It is also the food additive E507 that is commonly used in UK food products.