Fact Sheet: Development and the Drilling Process

What are the different stages of development of an onshore oil and gas field?

Operators will ensure that the different stages of development of unconventional sites and economic outcomes are explained to their local communities. Each site will have individual characteristics but for the general purposes of this document, operations have been grouped into the following three broad stages of activity. It should be noted that stages 1 and 2 could be a continuous process. It should also be noted that not every site will go through all the stages below. Operators will ensure that communities are aware of potential variations from these principles for specific local reasons and will ensure that such variations are adequately explained.

Stage 1 – Exploration	Stage 2 - Appraisal	Stage 3 – Production
Exploration typically takes the form of an Operator seeking planning consent to drill a well, which will normally consist of a vertical well and potentially a small number of lateral extensions. These wells are designed to log and take samples of rock ('core') in order to acquire the geological data from the potential hydrocarbon layers of interest. Typically, operational activity at an exploration site spans two to four months. The site is normally vacated after that.	Following data appraisal, Operators may then decide to flow test the well before making any further commercial decision. This may also involve at this stage undertaking one or more hydraulic fracturing procedures, depending on geology. Hydraulic fracturing will typically involve an additional planning consent and a full environmental impact assessment. Surface operations typically last between four and six months, with on-site activity diminishing as longer-term flow testing is undertaken.	Once commerciality of the development has been determined, planning consent will be sought for a full production site and a pad development plan (PDP), or field development plan (FDP), will be submitted to the Department of Energy and Climate Change (DECC). The submission of the PDP/FDP by the Operator marks the start of the production phase. Production pads may be different sizes from location to location, depending on the specific geology and surface location, but will typically contain a number of vertical wells and associated underground laterals on a site, which would be about two hectares (five acres) in size. At this stage, associated equipment, such as pipelines and gas processing facilities, will be constructed, subject to additional planning app-lications. Once drilling has been completed, surface activity will diminish significantly as wells start to produce gas.

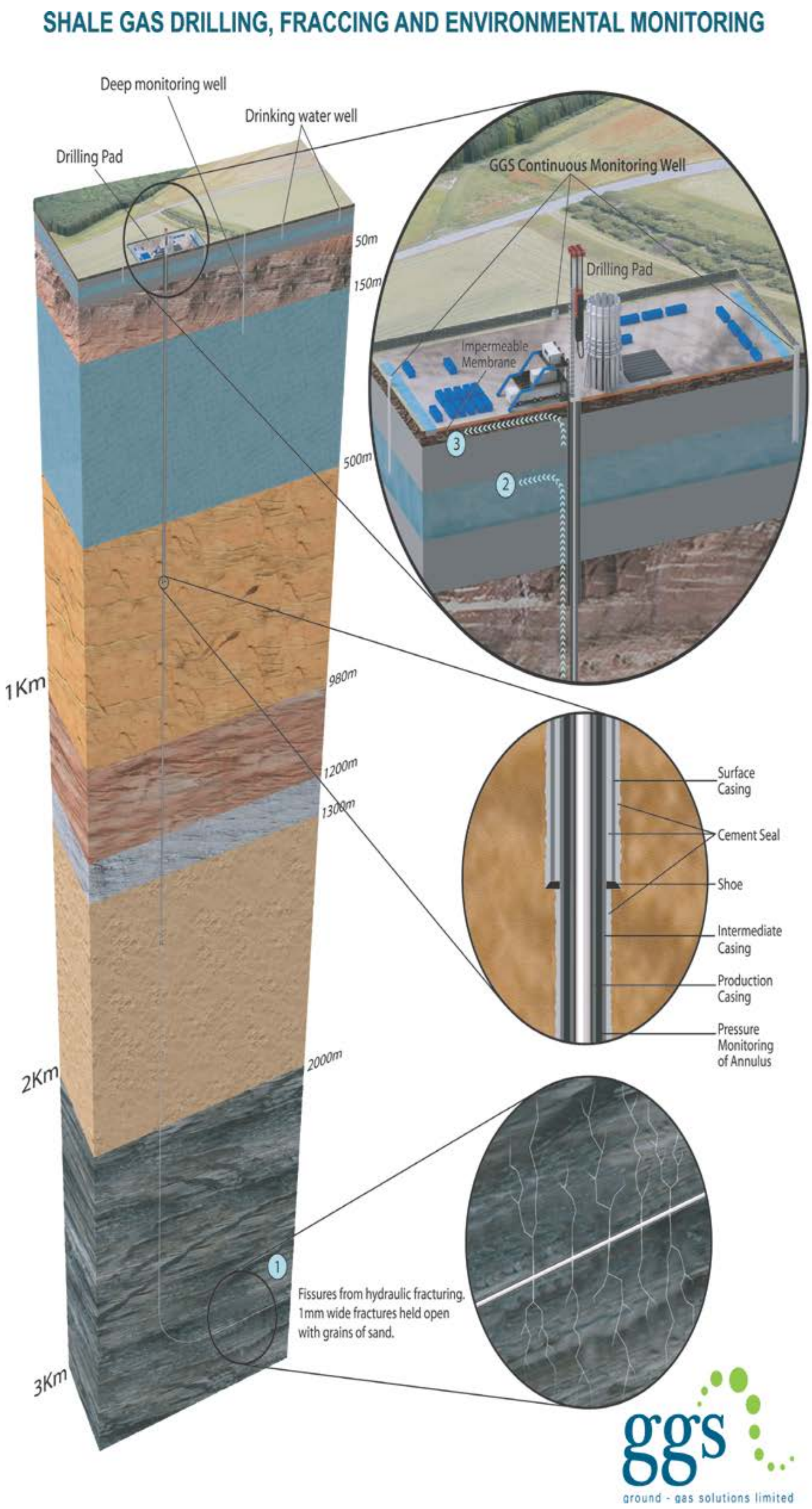
How is gas extracted from the ground?

Geologists have known for years that substantial deposits of oil and natural gas are trapped in deep shale formations. These shale reservoirs were created tens or hundreds of millions of years ago. **[See Geology Fact Sheet].**

Around the world today, with the use of modern horizontal drilling techniques and hydraulic fracturing, the trapped oil and natural gas in these shale reservoirs is being safely and efficiently produced; gathered and distributed to customers.

During the past 60 years, the oil and gas industry has conducted fracture stimulations in more than two million wells around the world.

Shale reservoirs are usually 5,000 feet or more below the surface. This is well below any underground sources of drinking water, which are typically at depths no more than 300 to 1,000 feet. Additionally, steel pipes called casing, cemented in place, provide a multi-layered barrier to protect fresh water aquifers.



With the permission of Ground Gas Solutions

The drilling process of a typical oil and natural gas well is similar for conventional and unconventional wells:

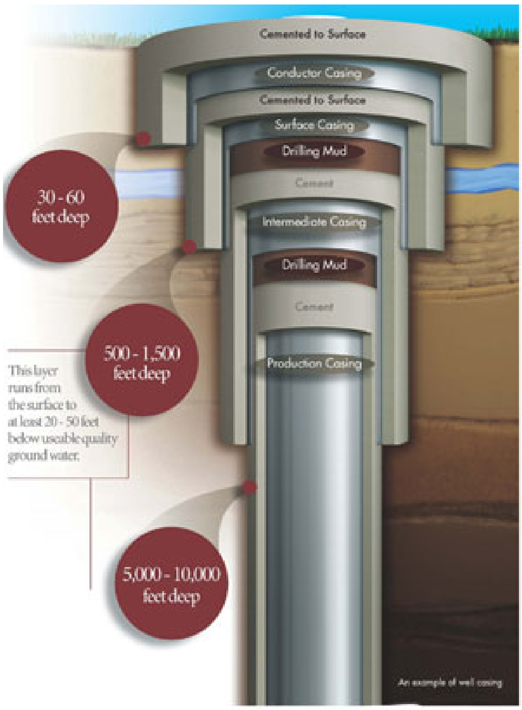
Preparation
Preparing a drilling location is a process that includes the construction of roads to the pad site and the proper grading of the area where the rig and other equipment will be placed. Drilling pads and roads must be built and maintained, including the spreading of stone on an impermeable liner to prevent impacts from spills and must allow precipitation to drain properly.

Drilling

Vertical Drilling
A hole is drilled straight down using drilling mud that cools the drill bit, carries the rock cuttings back to the surface and stabilises the wall of the well bore. Once the hole extends below the deepest freshwater aquifer, the drill pipe is removed and replaced with steel pipe, called ‘surface casing’.

Next, cement is pumped down the casing and then back up between the casing and the borehole wall, where it sets. This cement bond prevents the migration of any fluids vertically between the casing and the hole. In doing so, it creates an impermeable protective barrier between the well bore and any freshwater sources. Tests are undertaken to confirm the success of this process before drilling further.

Typically, depending on the geology of the area and the depth of the well, additional casing sections will be run and, like surface casing, are then cemented in place to ensure that there can be no movement of fluids or gas between those layers and the groundwater sources.



Graphic Courtesy of Texas Oil and Gas Association

Horizontal Drilling
What makes drilling for hydrocarbons in a shale formation unique is the necessity to drill horizontally. Vertical drilling continues to a depth called the ‘kick off point’. This is where the well bore begins curving to become horizontal.

One of the advantages of horizontal drilling is that it’s possible to drill several laterals from only one surface-drilling pad, minimising the impact on the surface environment.

When the targeted distance is reached, the drill pipe is removed and additional steel casing is inserted through the full length of the well bore and once again, the casing is cemented in place.

Once the drilling is finished and the final casing has been installed, the drilling rig is removed and preparations are made for the next steps, well completion.

Well Completion

The first step in completing a well is the creation of a connection between the final casing and the rock holding the oil and gas.

A specialised tool, called a perforating gun, is lowered to the rock layer. This perforating gun is then fired, creating holes through the casing and the cement and into the target rock. These perforating holes connect the rock holding the oil and gas and the well bore.

Since these perforations are only a few inches long and are performed more than a mile underground, the entire process is imperceptible on the surface. The perforation gun is then removed in preparation for the next step, hydraulic fracturing.

Hydraulic Fracturing

A mixture of mostly water and sand, plus a few chemicals, the stimulation fluid is pumped under controlled conditions into deep, underground reservoir formations. The purpose of the chemicals is for lubrication, to keep bacteria from forming and to carry the sand.

These chemicals are typically non-hazardous and range in concentrations from 0.1% to 0.5% by volume. They help to improve the performance of the hydraulic fracturing.

In the UK, Cuadrilla Resources were granted approval from the Environment Agency (EA) to use the following non-hazardous amounts of chemicals at their Preese Hall exploration.

- Polyacrylamide (friction reducer)
- Sodium salt (for tracing fracturing fluid)
- Hydrochloric acid (highly diluted with water – for improved efficiency)
- Glutaraldehyde biocide (used to cleanse water and remove bacteria)

So far, only a polyacrylamide friction reducer (0.04%) and a miniscule amount of salt have been used. There was no need to use biocide as the water supplied had already been treated to remove bacteria, and diluted hydrochloric acid was not necessary.

Polyacrylamide is a non-hazardous, non-toxic substance which is also used extensively in other industries to remove suspended solids in drinking and wastewater plants, and pollutants or contaminants from soils.

This stimulation fluid is pumped at high pressure from tanks by equipment mounted on lorries or skid mounted on the surface into the well bore and out through the perforations made by perforating gun. This process creates fractures in the shale, containing the oil and natural gas.

The sand remains in these fractures in the rock, keeping them open when the pump pressure is relieved. This allows previously trapped oil or natural gas to flow to the well bore more easily.

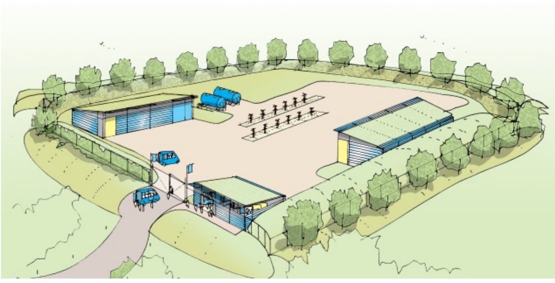
The initial stimulation segment is then isolated with a specially designed plug and the perforating guns are used to perforate the next horizontal section of the well. This stage is then hydraulically fractured in the same manner. This process is repeated along the entire horizontal section of the well, which could extend 1-2 miles.

Production

Once the stimulation is complete, the isolation plugs are drilled out and production begins. Initially fracture fluid, and then natural gas or oil, flows into the horizontal casing and up the well bore.

In the course of initial production of the well, about 25-75% of the fracturing fluid is recovered. This fluid is either recycled for use on other fracturing operations, or safely disposed of according to government and environmental regulations. This whole process of developing a well typically takes from 3-5 months:

- a few weeks to prepare the site
- eight to twelve weeks to drill the well
- one to three months of completion activities and includes between one and seven days of stimulation.



This initial three- to five-month investment could, however, result in a well that will produce oil or natural gas for 20 to 40 years, or more.

Well Abandonment

When all of the oil or natural gas that can be recovered economically from a reservoir has been produced, the land is returned to the way it was before the drilling operations started.

Wells will be filled with cement and pipes cut off 3-6 feet below ground level. All surface equipment will be removed and all pads will be filled in with earth or replanted. The land can then be used again by the landowner for other activities, and there will be virtually no signs that a well was once there.

Today, hydraulic fracturing has become an increasingly important technique for producing oil and natural gas in places where the hydrocarbons were previously inaccessible. Technology will continue to be developed to improve the safe and economic development of oil and natural gas resources.

How do you test and monitor the casing and cement?

The cement specification and placement of it in the well follows recognised industry best practice as contained in the following American Petroleum Institute (API) documents:

- API Guidance Document HF1 – Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines
- API Specification 10A (ISO 10426-1:2009) Specification for Cements and Materials for Well Cementing
- API Recommended Practice 10B-2 (ISO 10426-2:2003) Testing Well Cements

All of the following tests represent standard oilfield practice for well construction and are not particular to shale gas operations.

Pressure tests are conducted on the casing strings installed in wells to ensure they do not leak, even under high pressure. Leak-off or formation integrity tests are also conducted once the bottom of the casing strings have been drilled out to determine what the strength of the rock is.

A leak-off test is where the rock is subjected to hydraulic pressure until the drilling fluid begins to leak into the rock and it begins to fracture, this determines the “leak off pressure”.

A formation integrity test is where the rock is subject to a predetermined pressure below the leak off pressure to monitor well integrity. Both of these tests provide the Operator with information on the strength of the rock about to be drilled through, but also provide confirmation that the casing is properly cemented into the section of rock that has just been drilled.

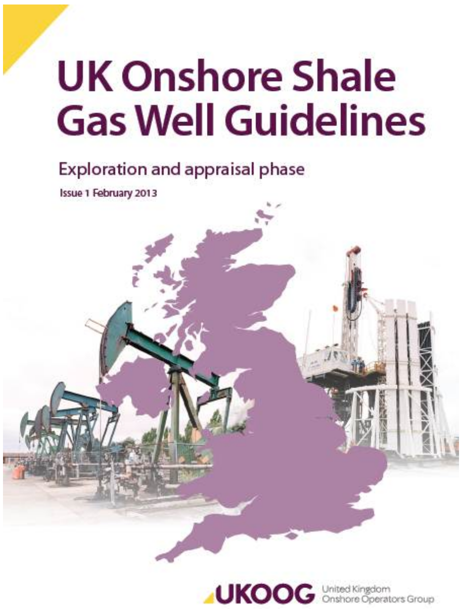
A cement bond log of cemented casing strings can also be conducted to confirm the quality of a cementing operation. This determines where the top of cement is in the casing and confirms that the cement is as designed for the specific location and of the appropriate quality.

The pressures in the spaces between the casings are routinely monitored throughout the life of the well to ensure that integrity is maintained.

Shale Well Guidelines

The Industry published for the first time in February 2013, industry guidelines covering best practise for shale well operations in the UK: http://www.ukoog.org.uk/elements/pdfs/ShaleGasWellGuidelines.pdf

The guidelines, which include hydraulic fracturing and the public disclosure of fracture fluid composition, were developed by a high level workgroup that included operating and service companies, with input from the Department for Energy and Climate Change, the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency.



The first issue of the guidelines relates to the exploration and appraisal phase of shale gas well developments and contains what is considered to be good industry practice. References are made to relevant legislation, industry standards and practices, including Oil and Gas UK Guidelines, particularly to the Well Integrity Guidelines (issued in July 2012), where appropriate.

Critically, the UK guidelines set out that operators must publically disclose all chemical additives to fracturing fluids on a well-by-well basis, including regulatory authorisations, safety data and maximum concentrations and volumes. These disclosures meet or exceed all known standards in the shale gas industry.