An Environmental Risk Assessment for shale gas exploratory operations in England

Version 1, August 2013

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

Published by:

Environment Agency
Horizon house, Deanery Road,
Bristol BS1 5AH
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Further copies of this report are available from our publications catalogue:
http://publications.environment-agency.gov.uk
or our National Customer Contact Centre:
T: 03708 506506

Publication code: LIT 8474

Email: enquiries@environment-agency.gov.uk.

Contents

Why produce an Environmental Risk Assessment?

There's little practical experience of shale gas exploration in the UK and as yet no definition of Best Available Techniques (BAT). This Environmental Risk Assessment (ERA) helps us understand the important environmental risks and supports aspects of our technical guidance for onshore oil and gas operators.

Method

We decided to focus in the ERA on the exploration phase to match the current stage of development of the UK's shale gas industry. We also limited its scope to our regulatory and geographical remit.

To carry out the ERA we searched for relevant global peer-reviewed and 'grey' literature, consulted other regulators in the UK and abroad, and used our own operational and regulatory expertise in related fields. Work commissioned to fill gaps in our evidence base resulted in reports on fugitive methane emissions and well casing design.

The ERA covers the following stages in the shale gas exploration process:

- baseline monitoring
- water acquisition
- chemical mixing
- borehole integrity
- well injection
- flowback fluid management including residual material left in the well
- gas management
- offsite disposal or reuse
- well decommissioning

We used a well-established approach to determine the potential risks from to shale gas exploration using a standard source–pathway–receptor model. This approach can be summarised as follows:

- identification of hazards
- identification of consequences
- estimation of the probability of the hazards occurring
- estimation of the magnitude of the unmitigated risk
- identification of risk management options
- estimation of the residual risk after the use of regulatory controls

To help us in this process we produced a conceptual model of the environmental risks posed by a single well pad and borehole. This model, shown in Figure 1, identified the main sources, pathways and receptors presented during the shale gas exploration process.

The magnitude of the unmitigated risk is a combination of the probability or likelihood of an event occurring and the consequences for people and the environment if it does. The risk magnitude matrix is shown in Figure 2.

Figure 1: Environmental risks from shale gas exploratory activities

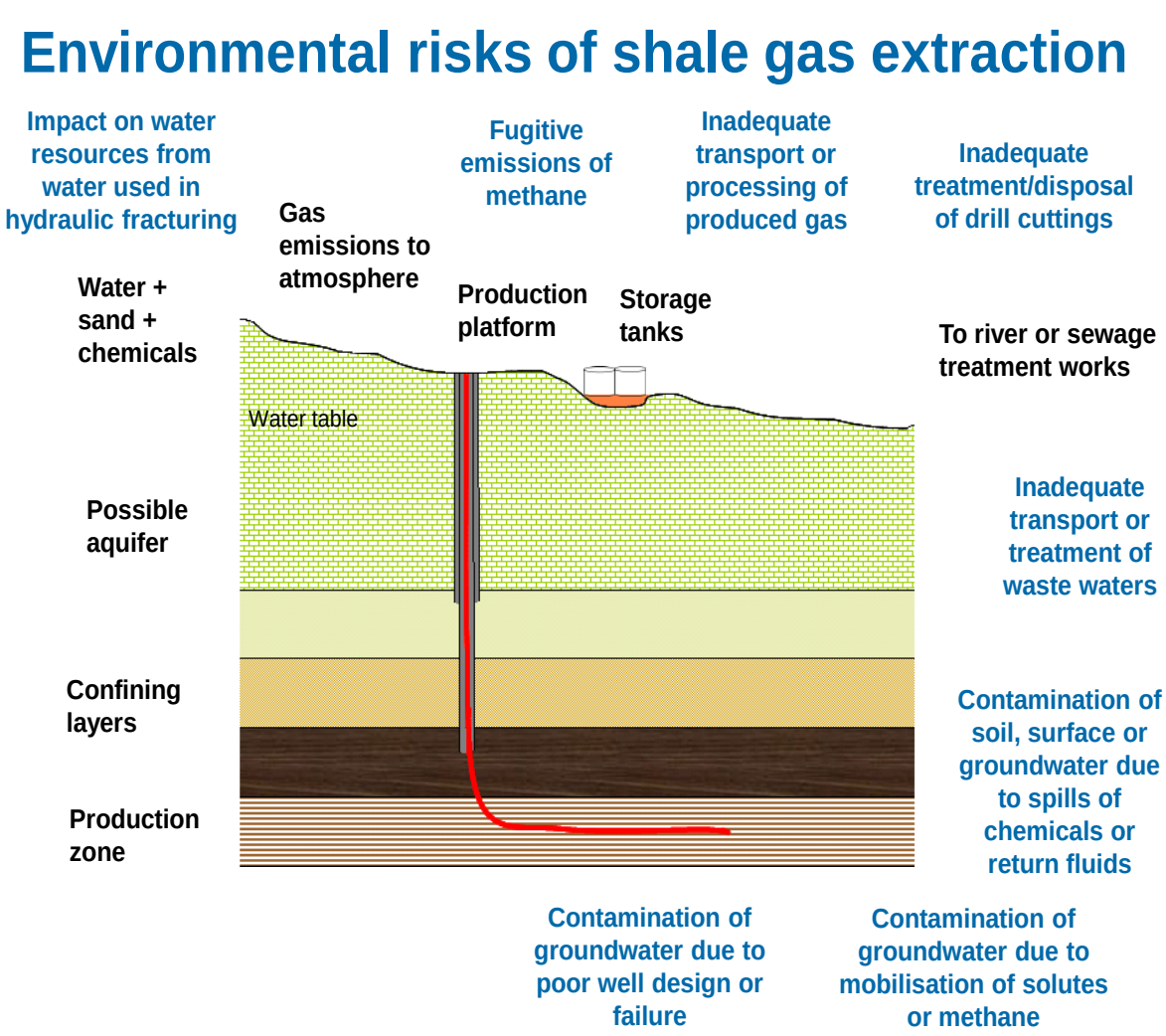

Figure 2: Risk magnitude matrix

Consequence	Probability			
	Very low	Low	Medium	High
Very low	Low	Low	Low	Low
Low	Low	Low	Medium	Medium
Medium	Low	Medium	Medium	High
High	Medium	Medium	High	High

Definitions

- Probability categories: very low – rarely encountered, never reported or highly unlikely; low – infrequent occurrences; medium – can be expected to occur several times per year; high – repeated occurrences.
- Consequence categories: very low – slight environmental effect that does not exceed a regulatory standard; low – minor environmental effect which may breach a regulatory standard but is localised to the point of release with no significant impact on the environment or human health; medium – moderate, localised effect on people and the environment in the vicinity of the incident; high – a major environmental incident resulting in significant damage to the environment and harm to human health.

Results

Overall environmental risks from shale gas exploratory operations

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by a substance released during the exploration process is significant enough to cause a breach of an existing environmental standard
Pathway – How might the receptor come into contact with the source?	Exposure to releases into air or water, or contact with materials transported to and from the site.
Receptor – What is at risk?	Local population and surrounding environment.
Harm – What are the harmful consequences if things go wrong?	Exposure to released gases and harmful substances brought to the surface, air pollution, surface or subsurface contamination, injury, ill health or death, loss or damage to a habitat or resource.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	The process is new to the UK and its particular geology. There is mixed evidence from overseas activity. Independent experts note the potential consequences are high if the process is not regulated properly or industry best practice is not followed.
Current regulatory controls – On what regulatory basis can we impose controls?	Water Resources Act 1991 Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 The Waste (England and Wales) Regulations 2011 – registration of waste carrier and brokers
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011 Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 Borehole Sites and Operations Regulations 1995 The Hydrocarbons Licensing Directive Regulations 1995

	The Petroleum Act 1998 The Coal Industry Act 1994
Residual risk – What is the magnitude of the risk after management?	Low. We will use appropriate controls under the legislation above to manage the identified risks, supported by monitoring and compliance work (eg site inspections).

Groundworks

Materials released during site preparation

Source (hazard) – What is the agent or process with the potential to cause harm?	**Pollution caused by materials released during site preparation**
Pathway – How might the receptor come into contact with the source?	Exposure to releases to air, land and water.
Receptor – What is at risk?	Surface waters, aquifers, wildlife and their habitats, contractors and staff, local community.
Harm – What are the harmful consequences if things go wrong?	Contamination and loss of resource, injury, ill health, death, loss of habitat.
Probability of exposure – How likely is this contact?	Very low
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	This phase of operations is not new to the UK. The risks are well understood and readily controllable by operators.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011
Residual risk – What is the magnitude of the risk after management?	Low

Loss of fracturing fluid

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by the introduction of chemicals to the environment through the loss of fracturing fluid
Pathway – How might the receptor come into contact with the source?	Leaks and spills into surface water drains, direct spills onto the ground or leaks from damaged drainage systems.
Receptor – What is at risk?	Groundwater and surface water.
Harm – What are the harmful consequences if things go wrong?	Pollution of groundwater and surface water restricting its use as a resource or requiring clean-up prior to use Potential impacts on human health or natural ecosystems in the event of exposure to contaminated waters.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	Although concentrations are likely to be measured in parts per hundred, this could be significant for sensitive groundwater or small streams where impacts can occur at concentrations of parts per million or even parts per billion.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 Substance assessment following the requirements of the Groundwater Daughter Directive (2006/118/EC) Notice of intention under Section 199 of the Water Resources Act 1991(as amended by the Water Act 2003)
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011 The Environment Agency is a statutory adviser to the Minerals Planning Authority on planning applications and Environmental Impact Assessments
Residual risk – What is the magnitude of the risk after management?	Low

Water acquisition

Source (hazard) – What is the agent or process with the potential to cause harm?	**Increased water demand from surface waters, groundwater, river or the sea, which may include the use of potable supplies**
Pathway – How might the receptor come into contact with the source?	Potentially reduced water availability for the natural environment and increased competition for limited supplies of water that can be sustainably abstracted.
Receptor – What is at risk?	Environments dependent on water resources (eg wetlands and aquatic ecosystems) and potentially other industrial water consumers
Harm – What are the harmful consequences if things go wrong?	Damage to local ecosystems and interruptions either to the supply to other industrial water consumers or the shale gas operators themselves.
Probability of exposure – How likely is this contact?	Medium (though very geographically dependent – some regions in England are already water scarce while others have water available for abstraction).
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	Over 1,000 cubic metres (m^3) of water are needed to hydraulically fracture a well and each well may need to be fractured many times. However this is not a continuous requirement and the number of wells in a local area in the exploratory phase is unlikely to be large. The amount of water required could pose a local issue unless properly managed, but would not significantly affect water resource demands on a regional or catchment basis. The total potential amount of water used in exploratory operations over a period of years is likely to be low compared with other industrial uses and potable supply. However the use of water for hydraulic fracturing may be of concern in areas where water is already scarce.
Current regulatory controls – On what regulatory basis can we impose controls?	Water Resources Act 1991
Residual risk – What is the magnitude of the risk after management?	Low

Chemical mixing

Use of proprietary chemicals

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by the use of proprietary chemicals (the chemicals used will depend on factors like the fracturing fluid requirements of the shale gas formation)
Pathway – How might the receptor come into contact with the source?	Spills at the surface, followed by infiltration into groundwater and surface waters.
Receptor – What is at risk?	Surface waters and groundwater and any user of those waters or habitats relying on them.
Harm – What are the harmful consequences if things go wrong?	Contamination and loss of resources, injury, ill health or death, loss of or damage to a habitat.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	The chemicals used to make up the fracturing fluid are delivered in concentrated form, and need to be stored and handled appropriately. There is the potential for spillages at the delivery, storage and mixing stages.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 Substance assessment following the requirements of the Groundwater Daughter Directive (2006/118/EC)
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011 The Environment Agency is a statutory adviser to the Minerals Planning Authority on planning applications and Environmental Impact Assessments
Residual risk – What is the magnitude of the risk after management?	Low

Proppant delivery and mixing

Source (hazard) – What is the agent or process with the potential to cause harm?	Proppant delivery and mixing – a range of proppants are in use globally, with sand currently favoured in the UK
Pathway – How might the receptor come into contact with the source?	Breathing in dust and airborne particulate matter (PM) categorised as PM10 and PM2.5, and potentially containing silicates.
Receptor – What is at risk?	Employees, visitors and the local community.
Harm – What are the harmful consequences if things go wrong?	Risk of silicosis or other respiratory disease.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	Sand is normally delivered in a bulk tanker and pumped by the transport operator to a silo for storage pending use. This happens infrequently, particularly during the exploration phase. Standard items of equipment in the construction sector are used and the only likely releases are during the filling of the silo when some dust may be produced through the top breather valve as the sand displaces air. Mixing with water is normally automated and self-contained.
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011
Residual risk – What is the magnitude of the risk after management?	Low

Borehole installation and integrity

Fugitive releases of methane and other gases

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by fugitive releases of methane and other volatile organic compounds (VOCs) from the borehole
Pathway – How might the receptor come into contact with the source?	Vertical migration from the borehole via gaps between the casing and the bore leading either to emissions to air or to groundwater.
Receptor – What is at risk?	The atmosphere, property, wildlife, employees, visitors and the local community.
Harm – What are the harmful consequences if things go wrong?	Respiratory illnesses caused by VOCs, asphyxiation, explosion and fire risks from methane Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	Groat and Grimshaw (2012) indicated that a significant percentage of offshore wells have shown some degree of well integrity issues. Considine et al. (2012) reported similar evidence for onshore shale gas wells in the USA. However, our well casing report shows that HSE's design and construction requirements provide a high degree of environmental protection (Environment Agency 2012).
Current regulatory controls – On what regulatory basis can we impose controls?	Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 Notice of intention under Section 199 of the Water Resources Act 1991(as amended by the Water Act 2003)
Current regulatory controls – On what basis can others impose controls?	Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 Borehole Sites and Operations Regulations 1995
Residual risk – What is the magnitude of the risk after management?	Low

Disturbance of in situ substances

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by the disturbance of in situ substances, including gases, by the drilling process
Pathway – How might the receptor come into contact with the source?	Release of pollutants into the well bore during the drilling process and from there emissions to atmosphere and/or groundwater.
Receptor – What is at risk?	The atmosphere, property, wildlife, employees, visitors and the local community.
Harm – What are the harmful consequences if things go wrong?	Contamination and potential loss of any water resources encountered, loss of or damage to a habitat, respiratory illnesses caused by VOCs, asphyxiation, explosion and fire risks from methane. Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	There are no reports of impacts like this being associated with drilling boreholes.
Current regulatory controls – On what regulatory basis can we impose controls?	Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 Notice of intention under Section 199 of the Water Resources Act 1991(as amended by the Water Act 2003)
Current regulatory controls – On what basis can others impose controls?	Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 Borehole Sites and Operations Regulations 1995 The Coal Industry Act 1994
Residual risk – What is the magnitude of the risk after management?	Low

Drill cuttings and spent drilling muds

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by inappropriate management of drill cuttings and spent drilling muds
Pathway – How might the receptor come into contact with the source?	Surface contamination of the well pad followed by infiltration into groundwater and surface waters Also direct contact with wildlife, employees and visitors.
Receptor – What is at risk?	Groundwater and surface water resources and wildlife that depends on them. Health of employees and site visitors.
Harm – What are the harmful consequences if things go wrong?	Contamination and potential loss of any water resources encountered, loss of or damage to a habitat, potential illness as a result of exposure.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Low
Justification for magnitude	It is common practice to store drill cuttings and spent drilling muds onsite pending disposal.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Residual risk – What is the magnitude of the risk after management?	Low

High volume hydraulic fracturing

Impacts of seismic activity

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by the impacts of seismic activity generated by high volume hydraulic fracturing
Pathway – How might the receptor come into contact with the source?	Through damage to onsite infrastructure (including but not limited to the borehole), resulting in loss of containment Also potentially through damage to offsite infrastructure.
Receptor – What is at risk?	Aquifers (both potable and saline), groundwater, surface waters, ecosystems that rely on these sources of water Offsite structures.
Harm – What are the harmful consequences if things go wrong?	Contamination and potential loss of any water resources encountered, loss of or damage to a habitat, release of fugitive gas emissions with attendant risks (see above), damage to property.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	Low level seismic activity resulting from activities in the oil, gas and geothermal energy sectors is well known. The level of seismicity means that impacts are generally minimal, though there are circumstances in which the consequences could be more severe.
Current regulatory controls – On what regulatory basis can we impose controls?	We do not regulate seismic activity directly but do regulate its environmental impacts through: Water Resources Act 1991 Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Current regulatory controls – On what basis can others impose controls?	The Hydrocarbons Licensing Directive Regulations 1995 The Petroleum Act 1998
Residual risk – What is the magnitude of the risk after management?	Low

Propagation of fractures beyond the target zone

Source (hazard) – What is the agent or process with the potential to cause harm?	Propagation of fractures beyond the target zone which then create vertical and horizontal pathways for pollution to travel into other geological strata
Pathway – How might the receptor come into contact with the source?	Fractures propagating beyond the target zone.
Receptor – What is at risk?	Groundwater aquifers (both potable and saline), adjacent boreholes and potentially surface waters, with attendant risks to wildlife and water users.
Harm – What are the harmful consequences if things go wrong?	Contamination and potential loss of any water resources encountered, loss of or damage to a habitat, potential illness as a result of exposure.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	Davies et al. (2012) found the chance of a fracture extending>600 metres (m) upwards was exceptionally low and the probability of fractures more than 350 m long was 1%. Thus there may be a material risk if the target formation and sensitive water resources or pathways to such resources are separated by <600 m. As exploration progresses, further UK studies are needed as current evidence is from the USA and Norway.
Current regulatory controls – On what regulatory basis can we impose controls?	Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 Notice of intention under Section 199 of the Water Resources Act 1991(as amended by the Water Act 2003)
Residual risk – What is the magnitude of the risk after management?	Low

Leakage from the borehole

Source (hazard) – What is the agent or process with the potential to cause harm?	**Pollution caused by gases, fracturing and flowback fluids leaking from the borehole**
Pathway – How might the receptor come into contact with the source?	Vertical migration from the borehole via gaps between the casing and the bore leading either to emissions to air or to groundwater.
Receptor – What is at risk?	The atmosphere, property, wildlife, employees, visitors and the local community, groundwater aquifers (both potable and saline), adjacent boreholes and potentially surface waters, with attendant risks to wildlife and water users.
Harm – What are the harmful consequences if things go wrong?	Contamination and potential loss of any water resources encountered, loss of or damage to a habitat, respiratory illnesses caused by volatile organic compounds, asphyxiation, explosion and fire risks from methane Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	Our well casing report shows that HSE's design and construction requirements provide a high degree of environmental protection (Environment Agency 2012).
Current regulatory controls – On what regulatory basis can we impose controls?	Water Framework Directive (2000/60/EC) Groundwater Daughter Directive (2006/118/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 Notice of intention under Section 199 of the Water Resources Act 1991(as amended by the Water Act 2003)
Current regulatory controls – On what basis can others impose controls?	Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 Borehole Sites and Operations Regulations 1995
Residual risk – What is the magnitude of the risk after management?	Low

Management of flowback fluids

Release of gases dissolved in flowback fluids

Source (hazard) – What is the agent or process with the potential to cause harm?	Short-term releases of methane and VOCs dissolved in flowback fluids
Pathway – How might the receptor come into contact with the source?	Emissions to atmosphere.
Receptor – What is at risk?	The atmosphere, employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Potential harm to health or amenity from VOCs Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	High
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	Standard practice in some parts of the USA is to store flowback fluids in open lagoons. While this is unlikely in the UK, the risk still exists.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Residual risk – What is the magnitude of the risk after management?	Low

Surface spills of flowback fluids

Source (hazard) – What is the agent or process with the potential to cause harm?	Surface spills of flowback fluids
Pathway – How might the receptor come into contact with the source?	Accidental releases through defective pipework and/or storage tanks, well blowout or spills when transferring the fluids from storage into a tanker.
Receptor – What is at risk?	Groundwater and surface waters.
Harm – What are the harmful consequences if things go wrong?	Pollution of groundwater and surface water restricting its use as a resource or requiring clean-up prior to use Potential impacts on human health or natural ecosystems in the event of exposure to contaminated waters.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium (though very dependent on the size of the leak)
Magnitude of risk – What is the overall magnitude of the risk?	Medium (see above)
Justification for magnitude	Our experience of regulating industrial sites is that accidents can and do happen. However there are few reports of significant pollution incidents from this source in the USA.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 Substance assessment following the requirements of the Groundwater Daughter Directive (2006/118/EC) Notice of intention under Section 199 of the Water Resources Act 1991(as amended by the Water Act 2003)
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011
Residual risk – What is the magnitude of the risk after management?	Low

Build-up of naturally occurring radioactive material (NORM)

Source (hazard) – What is the agent or process with the potential to cause harm?	Build-up of NORM in site infrastructure (eg tanks and pipework)
Pathway – How might the receptor come into contact with the source?	NORM brought up in flowback fluid can collect in storage tanks and pipework, ether as sediment or scale.
Receptor – What is at risk?	Employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Exposure to accumulated NORM.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	This is a recognised issue in the oil and gas industry for both conventional and unconventional developments.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Residual risk – What is the magnitude of the risk after management?	Low

Onsite treatment of flowback fluids

Source (hazard) – What is the agent or process with the potential to cause harm?	Onsite treatment of flowback fluids to separate out the solids and gases from the liquid
Pathway – How might the receptor come into contact with the source?	Emissions to atmosphere.
Receptor – What is at risk?	The atmosphere, wildlife, employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Contamination, asphyxiation, odour, fire or explosion Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	High
Justification for magnitude	Releases to atmosphere and 'green completion' technology to capture these releases are common practice in the USA. The volume of methane released, especially during extended well tests, could be significant.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011
Residual risk – What is the magnitude of the risk after management?	Low

Accumulation of solids containing NORM

Source (hazard) – What is the agent or process with the potential to cause harm?	Accumulation of solids containing NORM after separation from flowback fluids
Pathway – How might the receptor come into contact with the source?	Exposure to radiation as a result of onsite storage of NORM or movement of the solids to transport them offsite for treatment.
Receptor – What is at risk?	Employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Exposure to accumulated NORM.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	The volume of solids associated with a single exploratory well is likely to be low. The radioactivity associated with this material, while high enough to trigger the need for a permit, is still relatively low.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Residual risk – What is the magnitude of the risk after management?	Low

Gas management

Fugitive releases of methane and other gases

Source (hazard) – What is the agent or process with the potential to cause harm?	**Fugitive releases of methane and VOCs from site infrastructure after their separation from flowback fluids**
Pathway – How might the receptor come into contact with the source?	Leaks from infrastructure like valves, pipework and flares.
Receptor – What is at risk?	The atmosphere, wildlife, employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Contamination, asphyxiation, odour, fire or explosion Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	UNEP 2012 report that studies cannot agree on the evaluation of GHG emissions from unconventional gas production, with some siting fugitive emissions as being on a par with coal. Some controlled releases of methane are required for the safe operation of equipment and other infrastructure.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Residual risk – What is the magnitude of the risk after management?	Low

Controlled venting of gases

Source (hazard) – What is the agent or process with the potential to cause harm?	Controlled venting of methane, VOCs and gaseous NORM
Pathway – How might the receptor come into contact with the source?	Emissions to atmosphere.
Receptor – What is at risk?	The atmosphere, wildlife, employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Odour, exposure to low levels of radioactivity Methane is a potent greenhouse gas that contributes to anthropogenic climate change.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	The main risk is to the atmosphere.
Current regulatory controls – On what regulatory basis can we impose controls?	Mining Waste Directive (2006/21/EC) The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Current regulatory controls – On what basis can others impose controls?	The Hydrocarbons Licensing Directive Regulations 1995 The Petroleum Act 1998
Residual risk – What is the magnitude of the risk after management?	Low

Exhaust emissions from onsite equipment

Source (hazard) – What is the agent or process with the potential to cause harm?	**Pollution caused by gases released from onsite equipment**
Pathway – How might the receptor come into contact with the source?	Exhausts from engines, generators and similar combustion equipment.
Receptor – What is at risk?	The atmosphere, wildlife, the local community, employees and visitors.
Harm – What are the harmful consequences if things go wrong?	Reduction in local air quality and increased photochemical pollution.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	The risks depend on the type of fuel used for onsite generation (diesel, electricity or liquefied petroleum gas) and on the sensitivity of the local environment.
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011
Residual risk – What is the magnitude of the risk after management?	Low

Offsite disposal

Drill cuttings and drilling muds

Source (hazard) – What is the agent or process with the potential to cause harm?	**Pollution caused through the inappropriate disposal of waste drill cuttings and drilling muds**
Pathway – How might the receptor come into contact with the source?	Direct and indirect contact following land spreading.
Receptor – What is at risk?	People, property and wildlife in or near the site of land spreading.
Harm – What are the harmful consequences if things go wrong?	Local contamination of habitats and resources and exposure of people to that contamination.
Probability of exposure – How likely is this contact?	Medium
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	The likely content of the drilling muds and drill cuttings and their potential impact on the environment is well known.
Current regulatory controls – On what regulatory basis can we impose controls?	The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 The Waste (England and Wales) Regulations 2011 – registration of waste carrier and brokers
Residual risk – What is the magnitude of the risk after management?	Low

Transport, storage, treatment and disposal of wastes

Source (hazard) – What is the agent or process with the potential to cause harm?	Pollution caused by the transport, storage, treatment and disposal of wastes produced by high volume hydraulic fracturing operations
Pathway – How might the receptor come into contact with the source?	Release of pollutants to air, land and water from transport accidents, storage at transfer stations and treatment plants, discharges to water and land disposal sites.
Receptor – What is at risk?	People, property, wildlife and the wider environment along transport routes and near to storage, treatment and disposal facilities.
Harm – What are the harmful consequences if things go wrong?	Local contamination of habitats and resources and exposure of people to that contamination.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	Medium
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	The likely content of the wastes and their potential impact on the environment is well known; the risks will depend on the sensitivity of the local environment. Waste carriers and treatment, storage and disposal sites will already be permitted by us.
Current regulatory controls – On what regulatory basis can we impose controls?	The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013 The Waste (England and Wales) Regulations 2011 – registration of waste carrier and brokers
Residual risk – What is the magnitude of the risk after management?	Low

Well closure and abandonment

Source (hazard) – What is the agent or process with the potential to cause harm?	**Pollution caused by a substance released during the exploration process continues to have an environmental impact beyond the operational phase.**
Pathway – How might the receptor come into contact with the source?	Exposure to releases into air or water.
Receptor – What is at risk?	The local population and surrounding environment.
Harm – What are the harmful consequences if things go wrong?	Exposure to released gases and harmful substances brought to the surface, air pollution, surface or subsurface contamination, ill health, loss or damage to a habitat or resource.
Probability of exposure – How likely is this contact?	Low
Consequence – How severe will the consequences be if this occurs?	High
Magnitude of risk – What is the overall magnitude of the risk?	Medium
Justification for magnitude	This process is well established both onshore and offshore requiring notification to HSE and in accordance with HSE, industry and DECC well abandonment best practice.
Current regulatory controls – On what regulatory basis can we impose controls?	The Environmental Permitting (England and Wales) Regulations 2010 The Environmental Permitting (England and Wales) (Amendment) Regulations 2013
Current regulatory controls – On what basis can others impose controls?	Town and Country Planning (Development Management Procedure) (England) Order 2010 Town and Country Planning (Environmental Impact Assessment) Regulations 2011 Offshore Installations and Wells (Design and Construction, etc) Regulations 1996 Borehole Sites and Operations Regulations 1995
Residual risk – What is the magnitude of the risk after management?	Low

Bibliography

Arthur, J.D., Bohm, B. and Layne, M., 2008. *Hydraulic fracturing considerations for natural gas wells of the Marcellus Shale*. Presented at The Ground Water Protection Council 2008 Annual Forum, Cincinnati, OH, 21-24 September 2008.

COGCC (State of Colorado Oil and Gas Conservation Commission), 2000. *Summary Report of Bradenhead Testing, Gas Well Remediation, and Groundwater Investigations San Juan Basin, La Plata County, Colorado*. Denver, CO: State of Colorado Oil and Gas Conservation Commission.

COGCC (State of Colorado Oil and Gas Conservation Commission), 2009a. *Casing head test report. OGCC Operator Number 26420, API Number 123-11848*. Denver, CO: State of Colorado Oil and Gas Conservation Commission.

COGCC (State of Colorado Oil and Gas Conservation Commission), 2009b. *Sundry notice. OGCC Operator Number 26420, API Number 05-123-11848.* Denver, CO: State of Colorado Oil and Gas Conservation Commission.

COGCC (State of Colorado Oil and Gas Conservation Commission), 2009c. *Colorado Oil and Gas Conservation Commission approved Wattenberg Casing head testing and staff policy. Letter sent to all oil and gas operators active in the Denver Basin.* Denver, CO: State of Colorado Oil and Gas Conservation Commission.

Considine, T., Watson, R., Considine, N. and Martin. J., 2012. *Environmental Impacts during Marcellus Shale Gas Drilling: Causes, Impacts, and Remedies*. Buffalo, NY: Shale Resources and Society Institute, University of Buffalo.

Davies, R.J., Mathias, S.A., Moss, J., Hustoft, S. and Newport, L., 2012. Hydraulic fractures: how far can they go?, *Marine and Petroleum Geology*, 37 (1), 1-6.

Environment Agency, 2012. *Review of Assessment Procedures for Oil and Gas Well Casing Installation.* Bristol: Environment Agency.

Groat, C.G. and Grimshaw, T., 2012. *Fact-Based Regulation for Environmental Protection in Shale Gas Development*. Austin, TX: The Energy Institute, University of Texas.

ICF Incorporated, 2009. *Technical assistance for the draft Supplemental Generic Environmental Impact Statement (SGEIS) on the Oil, Gas and Solution Mining Regulatory Program. Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low permeability gas reservoirs—Task 1*. Albany, NY: New York State Energy Research and Development Authority.

Kargbo, D.M., Wilhelm, R.G. and Campbell, D.J., 2010. Natural gas plays in the Marcellus Shale: challenges and potential opportunities. *Environmental Science and Technology*, 44 (15), 5679-5684.

Michaels, C., Simpson, J.L. and Wegner, W., 2010. *Fractured Communities: Case Studies of the Environmental Impacts of Industrial Gas Drilling.* Ossining, NY: New York Riverkeeper.

McMahon, P.B., Thomas, J.C. and Hunt, A.G., 2011. *Use of Diverse Geochemical Data Sets to Determine Sources and Sinks of nitrate and Methane in Groundwater, Garfield County, Colorado, 2009.* US Geological Survey Scientific Investigations Report 2010–5215. Reston, VA: United States Geological Survey.

Myers, T., 2009. *Technical memorandum: Review and analysis of draft supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program. Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permeability gas reservoirs*. New York, NY: Natural Resources Defense Council.

OGS (Oklahoma Geological Survey) 2005. *Petroleum Technology Transfer Council – South Midcontinent Region Regional Update*, Fourth Publication, 2005. Norman, OK: Oklahoma Geological Survey. Available from: http://www.ogs.ou.edu/pttcnewsarchive.php [Accessed 8 July 2013].

Ohio DNR (Ohio Department of Natural Resources), 2008. *Report on the Investigation of the Natural Gas Invasion of Aquifers in Bainbridge Township of Geauga County, Ohio*. Columbus, OH: Ohio Department of Natural Resources, Division of Mineral Resources Management.

PADEP (Pennsylvania Department of Environmental Protection), 2010. *Consent order and settlement agreement (Commonwealth of Pennsylvania Department of Environmental Protection and Cabot Oil & Gas Corporation).* Harrisburg, PA: Pennsylvania Department of Environmental Protection.

PEQB (Pennsylvania Environmental Quality Board), 2009. Proposed Rulemaking [25 PA. CODE CH. 95] wastewater treatment requirements [39 Pa.B. 6467] [Saturday, November 7, 2009]. The Pennsylvania Bulletin, 39 (45), Doc. No. 09-2065.

Stearns, M., Tindall, J., Cronin, G., Friedel, M. and Bergquist, E., 2005. Effects of coal-bed methane discharge waters on the vegetation and soil ecosystem in Powder River Basin, Wyoming. *Water, Air, and Soil Pollution*, 168 (1-4), 33-57.

UNEP (United Nations Environment Programme), 2012. *Gas fracking: can we safely squeeze the rocks? UNEP* Global Environmental Alert Service, November 2012. Sioux Falls, SD: UNEP Earth Resources Observation and Science (EROS) Center.

Urbina, I., 2011. Regulation lax as gas wells' tainted water hits rivers. *New York Times*, 26 February 2011. Available from: http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=1&_r=2&hpw [Accessed 8 July 2013].

USEPA (US Environmental Protection Agency), 2010. *Trip report (EXCO Resources' gas well drilling site, Norris Ferry Road, southern Caddo Parish (Shreveport), LA).* Dallas, TX: U.S. Environmental Protection Agency Region 6

USEPA (US Environmental Protection Agency), 2011. *Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources.* Report EPA/600/D-11/001. Washington DC: US Environmental Protection Agency, Office of Research and Development.

List of abbreviations

BAT	Best Available Techniques
ERA	Environmental Risk Assessment
HSE	Health and Safety Executive
NORM	naturally occurring radioactive material
VOC	volatile organic compound

Glossary

Flowback fluids

Fracturing fluid contaminated with minerals and NORM returned to the surface during and following high volume hydraulic fracturing

Fracturing fluids

Water and additives used at pressure in the high volume hydraulic fracturing of shale beds.

High volume hydraulic fracturing

The injection of 1,000 m^3 of fluid or more at high pressure to fracture a shale bed and release the methane contained within it

Would you like to find out more about us, or about your environment?

Then call us on

03708 506 506 (Mon-Fri 8-6)

Calls to 03 numbers cost the same as calls to standard geographic numbers (i.e. numbers beginning with 01 or 02).

email

enquiries@environment-agency.gov.uk

or visit our website

www.environment-agency.gov.uk

incident hotline 0800 80 70 60 (24hrs)
floodline 0845 988 1188

Environment first: Are you viewing this on screen? Please consider the environment and only print if absolutely necessary. If you are reading a paper copy, please don't forget to reuse and recycle if possible.