Hydrogeological assessments for shale gas exploration

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Jenny Lightfoot
Outline

- Shale gas in the UK
- Cuadrilla and exploration in Lancashire
- Proposed scheme
- Groundwater and ground gas risk assessments
  - Surface activities
  - Drilling and well integrity
  - Hydraulic fracturing and fracture propagation
- Conclusions
Existing UK onshore oil and gas

- >2000 wells
- DECC register
- Largest onshore oilfield in Western Europe – Wytch Farm
- Many similarities – drilling, well integrity, surface activities
- Some differences - fracture propagation in shale, flowback management
Potential shale gas in the UK
Cuadrilla

- Private upstream oil and gas company
- Ownership – Cuadrilla Management, AJ Lucas, Riverstone LLC
- Most advanced exploration group in emerging UK shale gas sector
- Owns drilling and fracturing equipment
- Cuadrilla / Centrica are Pendle PEDL165 Licence holders
PEDL165 exploration

(Cuadrilla 2013)

(Cuadrilla 2013)
Injection volume (blue line) plotted against local magnitude ($M_L$) (De Pater and Baisch 2011)
Regulator roles

DECC
Energy development & licensing
- Licensing energy development
- Carbon emission targets
- Fracturing plan for induced seismicity
- Resource management (venting, flaring etc)
- Environmental Risk Assessment

DEFRA & Environmental regulators
Environment
- Environmental permits
- Water abstraction licensing
- Groundwater and aquifers
- Fracking fluid additives
- Flow back disposal
- Fugitive emissions to air (also DECC, LAs)

DCLG & Local Authorities
Minerals planning
- Planning consent
- Environmental Impact Assessment

HSE
Safety
- Well integrity
- Well design and construction
- Safety of workforce & personnel
Regulatory approvals for a well

DECC: award of exclusive Petroleum Exploration & Development Licence after open competition

DECC: online well application for <96 hr testing

DECC checks with HSE/EA/SEPA before issuing well consent

Local Authority Planning Permission

HSE Notification

EA/SEPA Statutory Consultee

EA/SEPA
- Notices
- Abstraction licences
- Discharge and radioactive substances regulations permits

DECC: 90-day extended well test (EWT), if required, setting limit on hydrocarbons produced, vented or flared.

Exploration Well
Groundwater Protection: Regulation

- Environment Agency
  - Onshore oil and gas exploratory operations: technical guidance
  - Environmental permitting, waste management, groundwater protection
- EA Position Statement C6 – not within SPZ1 or where unacceptable risk to groundwater
Guidance

- UKOOG – shale gas well guidelines
- Oil and Gas UK – well integrity; suspension and abandonment
- International guidance eg Alberta
- Environmental reviews by EA, Public Health England, Royal Society and Royal Academy of Engineering, British Geological Survey and many others…

(Green et al. 2012).

(UKOG 2013).

(RS and RAE 2012).

ARUP
Cuadrilla proposals

- Planning applications for temporary exploration of shale gas at two sites, Preston New Road and Roseacre Wood
- To determine whether or not the Bowland Shale can provide a commercially viable source of natural gas

(Arup 2014)
Proposed exploration
The planning applications
Cuadrilla proposals

- Construction
- Drilling
- Hydraulic fracturing
- Well testing
  - Suspend and apply for production
  - Decommission wells
Project proposals

Video – ‘A Surface Story’

Arup involvement

- Environmental Risk Assessment
- Environmental Impact Assessment
- Public Information Days and other stakeholder liaison
- Planning applications
- (Environmental permits)
Arup Environmental Statement

Technical Chapters:

- Air Quality
- Archaeology and Cultural Heritage
- Community and Socio-economics
- Ecology
- Greenhouse Gas Emissions
- Hydrogeology and Ground Gas
- Induced Seismicity
- Land Use
- Lighting
- Noise
- Public Health
- Resources and Waste
- Transport
- Water Resources
Hydrogeology and Ground Gas Assessment

- Baseline conditions
  - Geology
  - Groundwater
  - Ground gas

- Surface activities
- Drilling and well integrity
- Hydraulic fracturing and fracture propagation
Superficial geology

- Extensive glacial till
- Middle Sands
3D seismic survey

- 100km² survey by CCG in 2012
- 91% explosives and 9% vibroseis sources
- Arup / DMT GmbH review of Cuadrilla’s 3D seismic survey

(Cuadrilla 2013)
Local structural geology

- NNE-SSW trending extensional faults
- Woodsfold Fault
Bedrock geology
Groundwater abstraction
Geological, hydrogeological and ground gas baseline

- Middle Sands
- Sherwood Sandstone (>250m depth and poor quality)
- Manchester Marl
- No regional faults
- Woodsfold Fault
- Gas baseline – local sources, BGS, existing potential pathways (deep wells and MM fault offset)

- Monitoring wells
- Surface water monitoring
Groundwater risk assessment:
1. Surface activities
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- Livestock and security fence
- Surface water ditch - drains to interceptor
- Site welfare facilities - separate black and greywater tanks
- Well cell (concrete lined)

2. HDPE membrane
- 300mm depth granular material
- Wellhead surround

3. During drilling phase, drilling rig positioned over hole with mud system, cement system, diesel tanks, chemical store

4. Site environmental monitoring borehole (dual installation)

5. Agricultural land

- Human health offsite
- Ecological receptors

- Upper Boulder Clay
- Middle Sands (Secondary Aqüifer)
- Lower Clay
- Mercia Mudstone

Well extends to Bowland Shale (see separate figure)
Groundwater risk assessment:
1. Surface activities

S-P-R assessment

• Sources – spill of fluids on the well pad, release of contaminated runoff, off site vehicle spill, fire fighting foam, high pressure fluid release

• Receptors - Middle Sands gw, surface water, surrounding farm land, off site human health (contact with contam water)

• Pathways

Probability of S-P-R linkage
Consequence of S-P-R linkage
Evaluate risk magnitudes
Groundwater risk assessment: 
2. Drilling and well integrity

Video – ‘Well Design’

Groundwater risk assessment:
2. Drilling and well integrity

‘Embedded mitigation’

- Wells drilled, constructed and integrity tested in accordance with regulatory requirements and industry best practice
- No hazardous substances in drilling fluids above the Manchester Marl
- Drilling fluid additives identified in the environmental permit
- Well barriers and verification
- Approved abandonment design
Groundwater risk assessment:
2. Drilling and well integrity

S-P-R assessment

- Sources - drilling fluids, naturally poor quality gw, hydraulic fracturing fluid, flowback fluid, ground gases from beneath the Manchester Marl
- Receptors – Sherwood Sandstone gw, Middle Sands gw, off site human health (gas accumulation)
- Pathways – **loss of well integrity**

Probability of S-P-R linkage (multiple failures must occur for environmental release)

Consequence of S-P-R linkage

Evaluate risk magnitudes
Groundwater risk assessment:  
3. Hydraulic fracturing and fracture propagation

Video – ‘What is Hydraulic Fracturing?’

Groundwater risk assessment:
3. Hydraulic fracturing and fracture propagation

‘Embedded mitigation’

- Hydraulic Fracturing Programme
- Fracturing fluid composition
- Sampling of fracturing fluid and flowback
- Monitoring and management of fracture growth
Groundwater risk assessment:  
3. Hydraulic fracturing and fracture propagation

Fracturing fluid composition

- Water
- Sand proppant
- Polyacrylamide
- Dilute hydrochloric acid
- Re-use of flowback fluid

No hazardous substances (GWD)

Full disclosure
Groundwater risk assessment:
3. Hydraulic fracturing and fracture propagation

Flowback composition

- Preese Hall data
- Salinity – 3 to 5 times more saline than seawater
- Liquid hydrocarbons unlikely
- NORM

Flowback management
Groundwater risk assessment: 3. Hydraulic fracturing and fracture propagation

Management of fracture growth

- Hydraulic Fracture Programme
- Predictive modelling
- Microseismic monitoring
- Mini fracture prior to main hydraulic fracture
- Reduced volumes injected compared to Preese Hall
- Flow back between stages

Recorded fracture length

‘Dots in a box’. Microseismic monitoring of fracture evolution (Duncan and Eisner 2010).
Groundwater risk assessment: 3. Hydraulic fracturing and fracture propagation

Microseismic monitoring

- 80 buried seismometers at up to 100m depth
  - 10 real time stations
  - 70 store and harvest stations
- Monitoring fracture growth
  - Location of induced seismicity
  - Magnitude of induced seismicity
  - Extent of fracture growth
  - Orientation of fracture growth

Above: Buried array for PNR (MSI 2014)
S-P-R assessment

- Sources – hydraulic fracturing fluid, naturally poor quality groundwater, ground gases from Bowland Shale
- Receptors – Sherwood Sandstone gw, Middle Sands gw, off site human health (gas accumulation)
- Pathways – fractures propagating beyond target zone connecting to preferential flowpaths

Probability of S-P-R linkage (multiple connected pathways required)

Consequence of S-P-R linkage

Evaluate risk magnitudes
Conclusions
Conclusions

- Groundwater and ground gas risks are highly site specific
- Well design and site implementation (drilling and site management practices) are important
- Risks associated with Cuadrilla’s proposals at PNR assessed as not greater than ‘low/not significant’
- Regulator approval secured
- Monitoring and data collection to build evidence base and public confidence
- Assessments are in the public domain
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Any questions?