Onshore oil and gas: risks to groundwater

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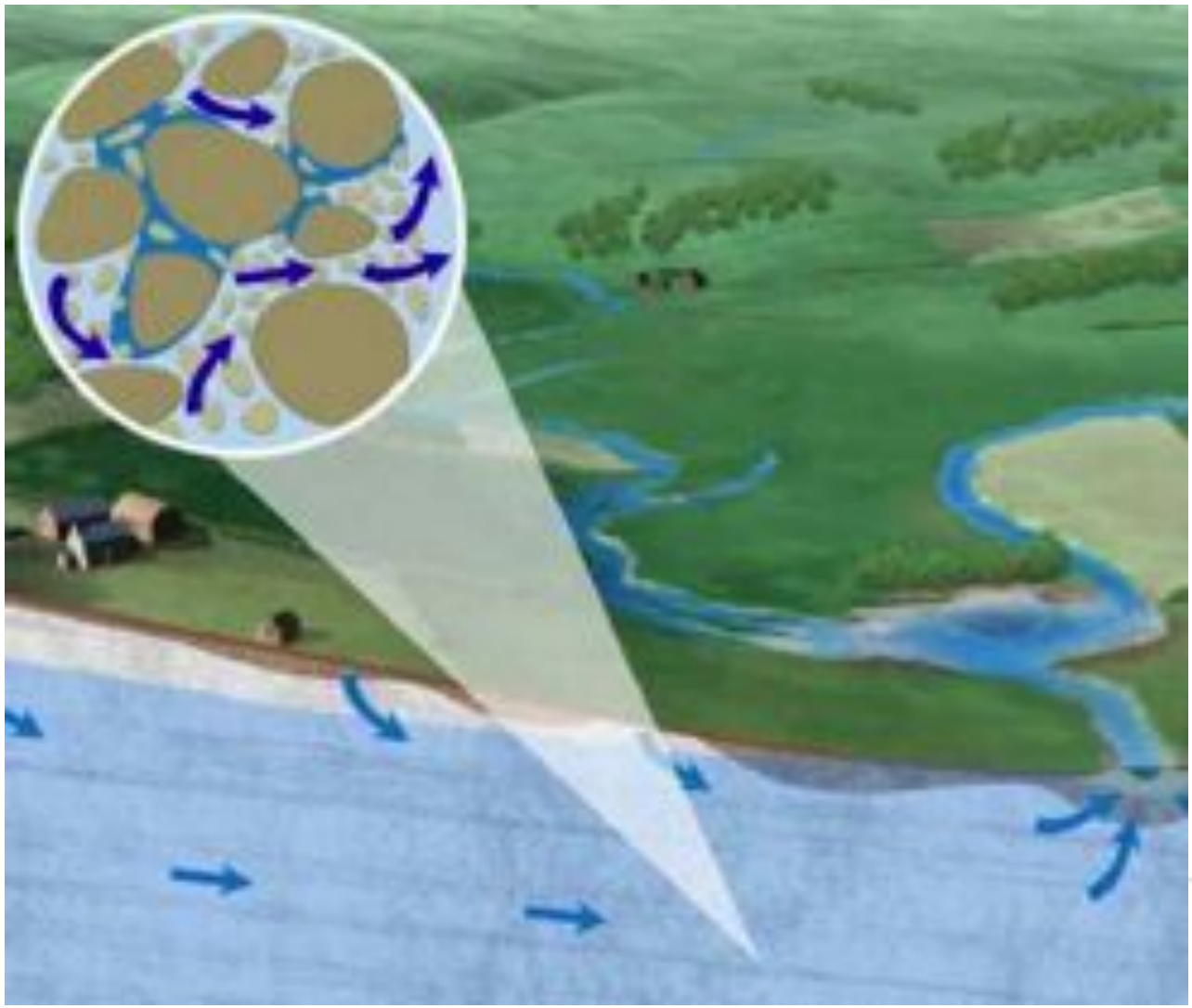
Environment Agency

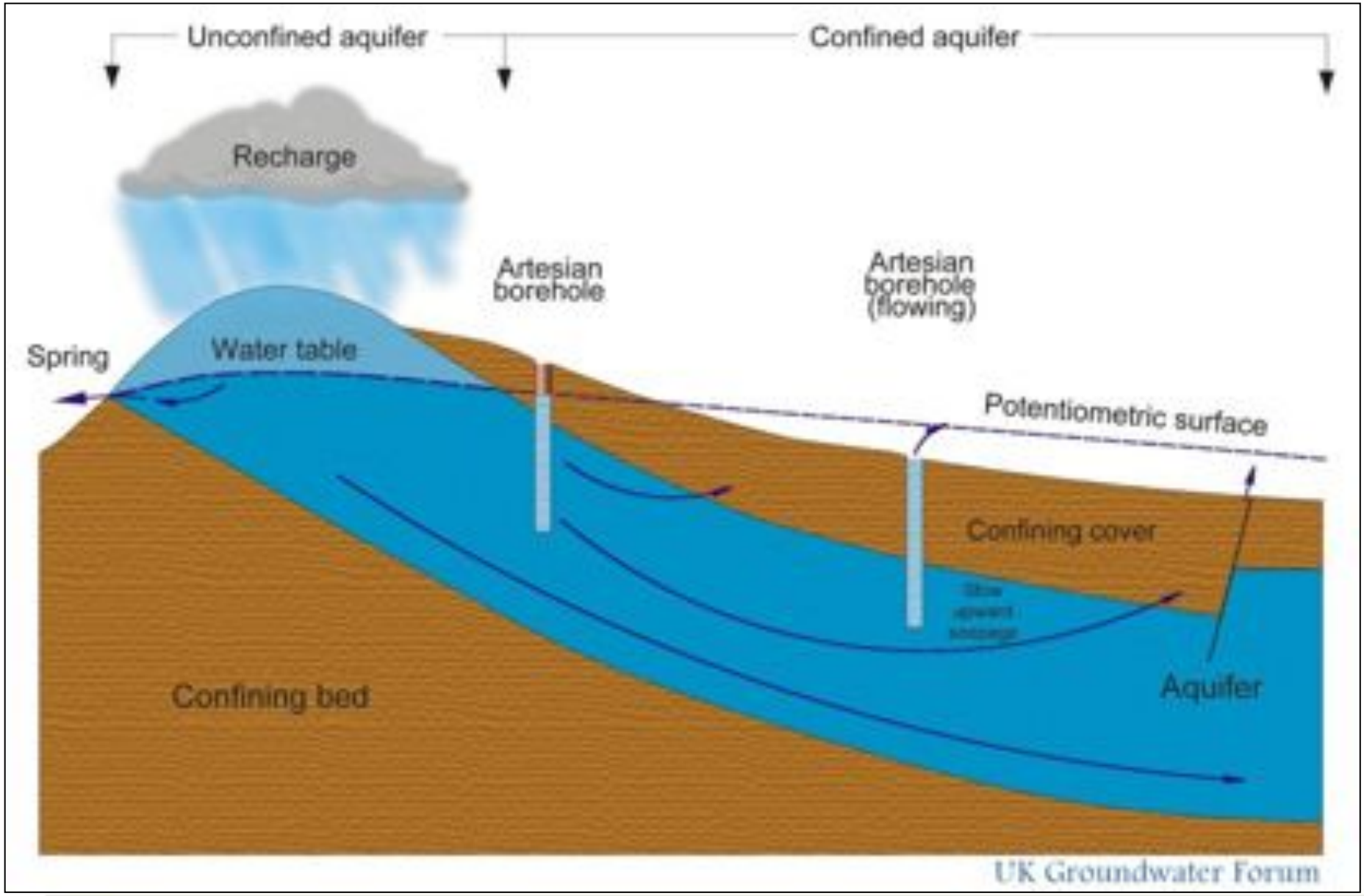
EOSCA, 3 November 2015, Manchester

Summary

- What is groundwater?
- How do we protect groundwater?
- Risks from onshore oil and gas
- Assessment of risks from chemicals
- Ongoing research

Where is groundwater?





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What does groundwater look like?

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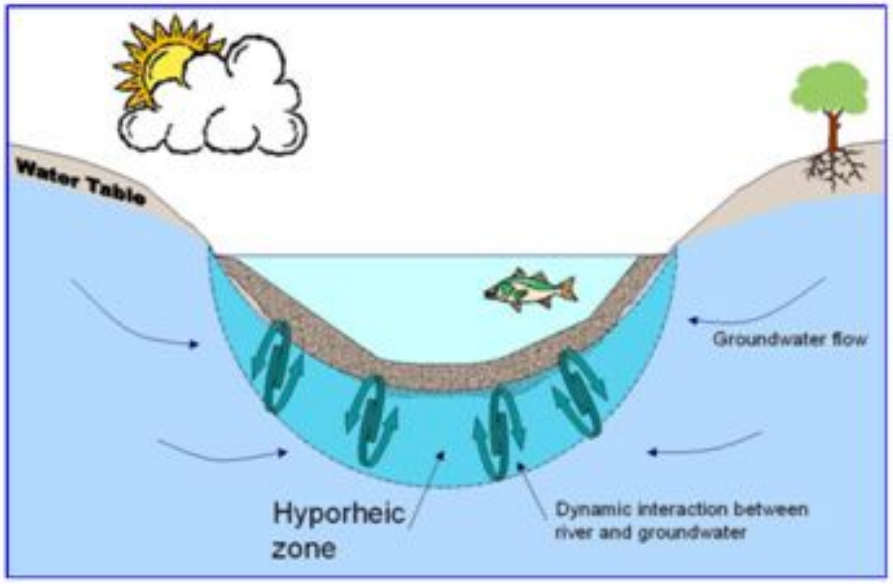
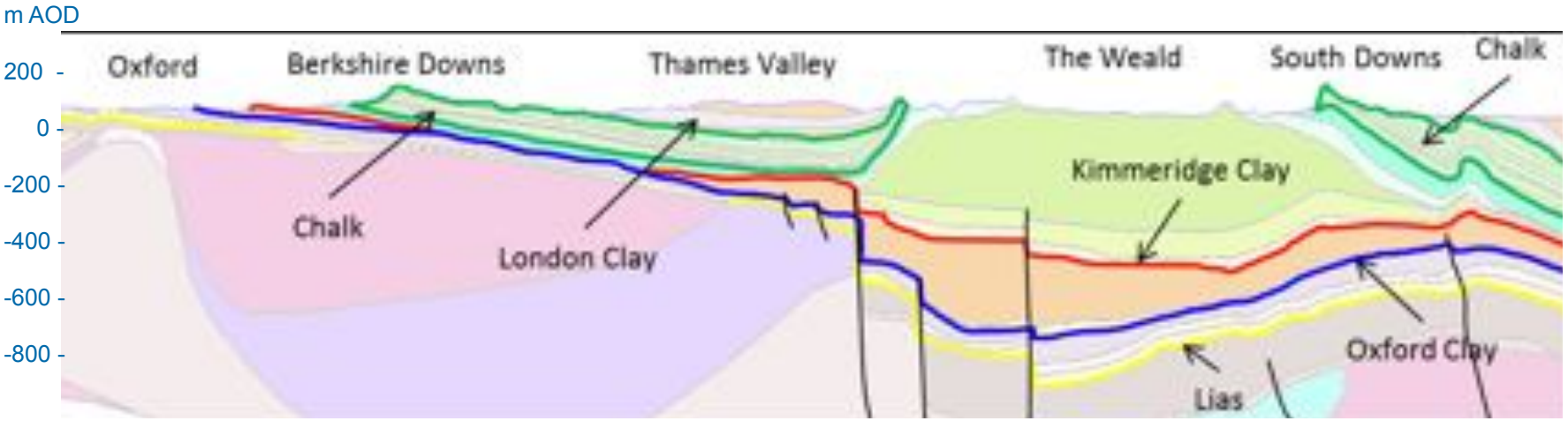
Groundwater maintains rivers



Aquifers

- Principal aquifers
  - Provide significant quantities of water for people and may also sustain rivers, lakes and wetlands
- Secondary aquifers
  - Provide modest amounts of water
  - Nature of the rock or the aquifer's structure limits their use
  - Remain important for rivers, wetlands and lakes and private water supplies in rural areas
- Unproductive strata
  - Generally unable to provide usable water supplies and are unlikely to have surface water and wetland ecosystems dependent upon them

Depth of groundwater bodies



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UK and Ireland Generic types of aquifer	UK and Ireland examples	Formation Type - EU CIS criteria	Depth of main part of the GWB* - CIS criteria
Porous superficial	Sand & Gravel	Porous aquifer – highly productive	0-20 m
Dominantly porous bedrock	Sherwood Sandstone	Porous aquifer – highly productive	50-200 m
Dual porosity high transmissivity	Chalk	Porous aquifer – highly productive	50-200 m
Moderate transmissivity bedrock	Carboniferous sandstones	Fissured aquifer – moderately productive	50-200 m
Low transmissivity bedrock	Dalradian	Insignificant aquifers – local and limited groundwater	20-50 m
Karst	Carboniferous limestones	Fissured aquifer – highly productive	50-200 m

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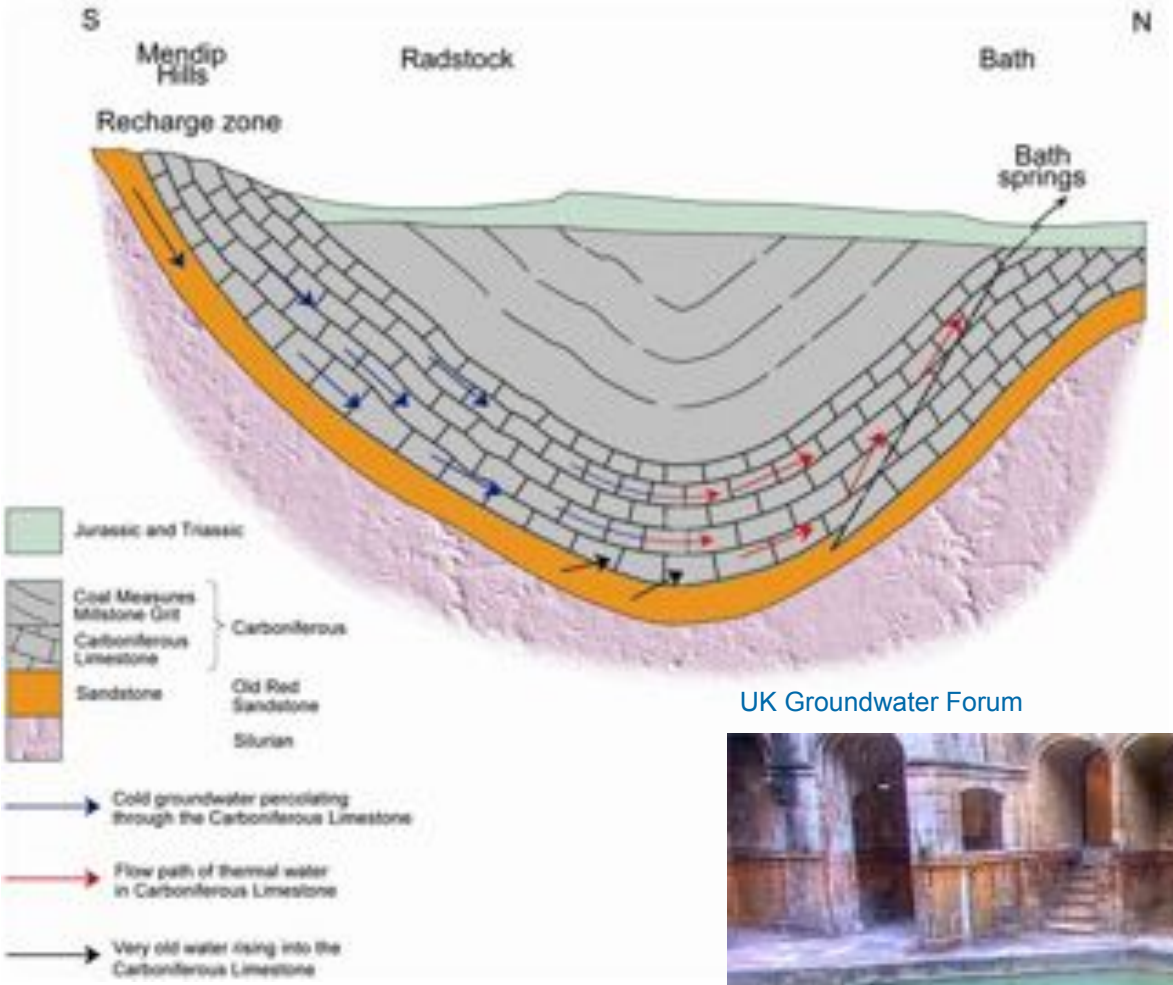
UKTAG 2012

Groundwater at depth



2500 metres

UK Groundwater Forum

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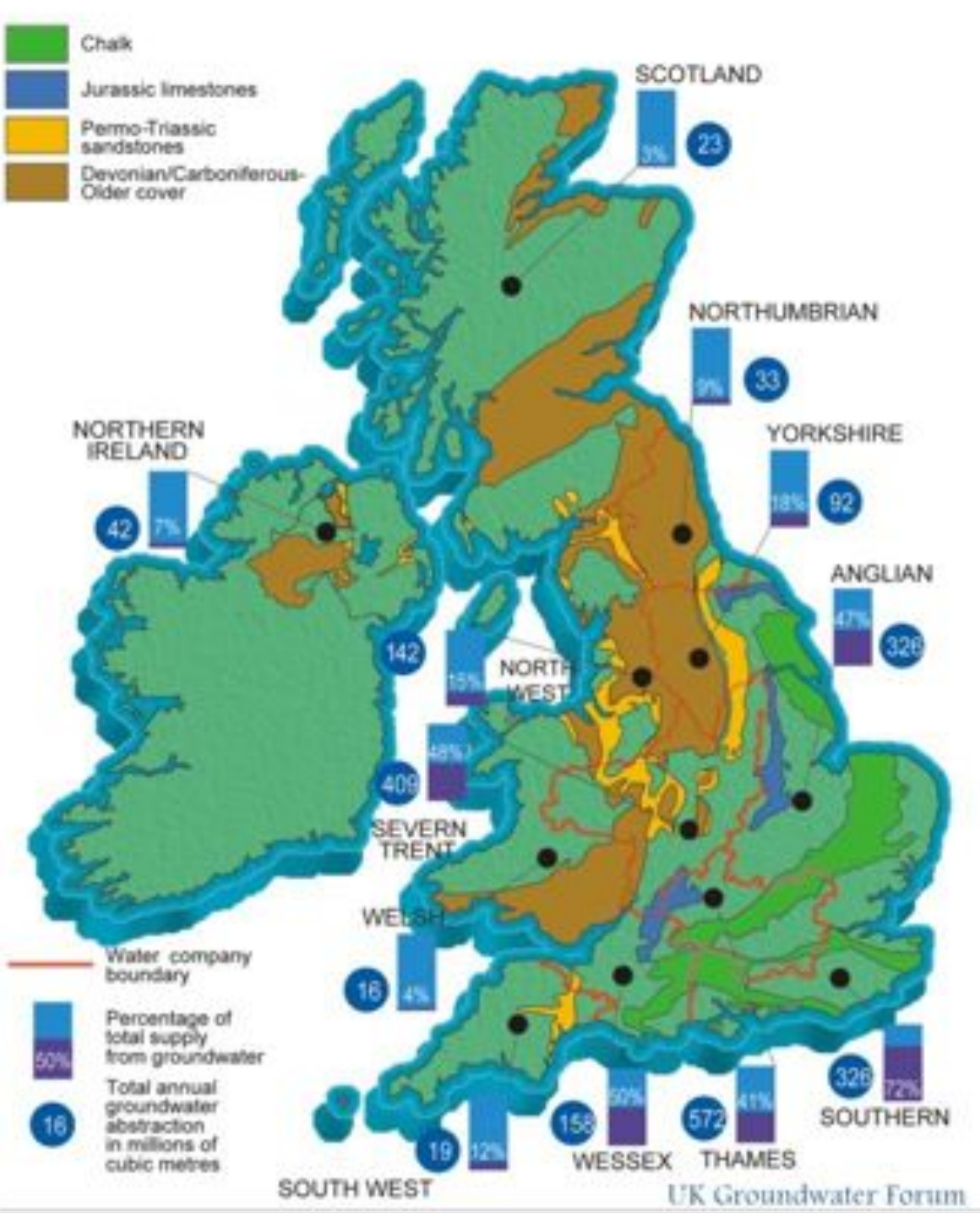
Public water supply



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Water stress

- Water exploitation index
- % effective rainfall abstracted
- > 20% is ‘under stress’

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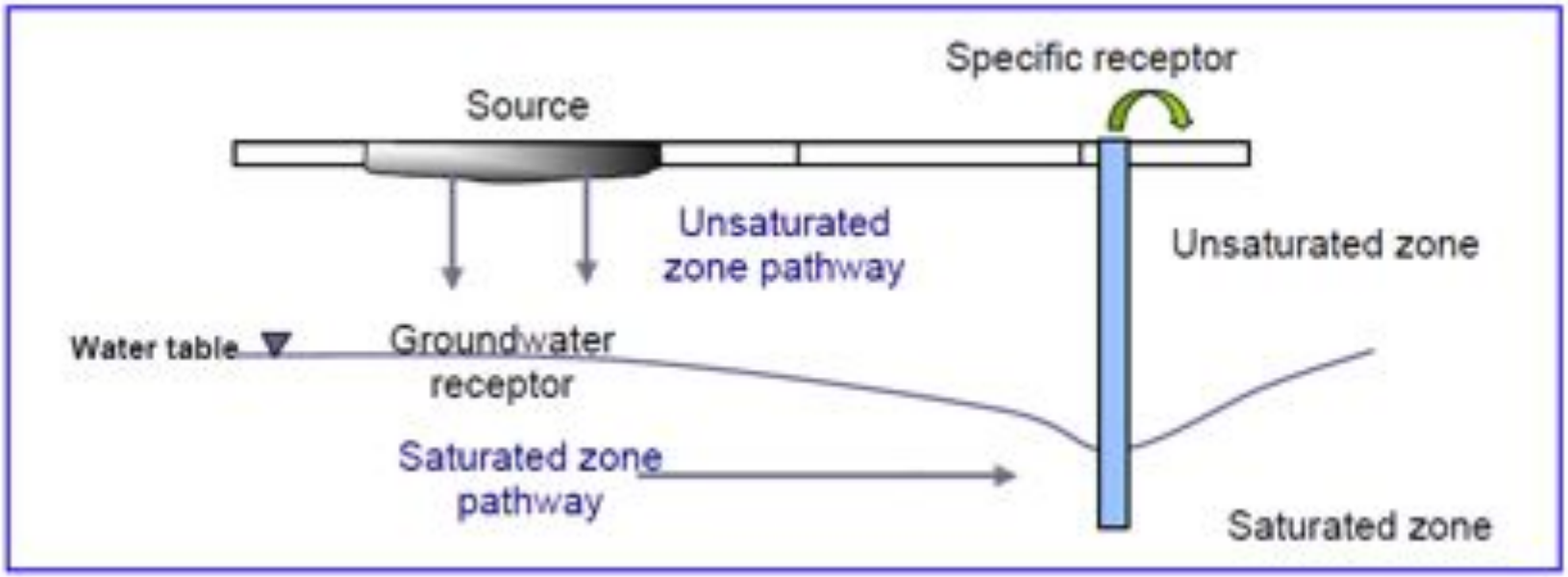
Pollution risks to groundwater



Water Framework Directive
Groundwater Daughter Directive

- Prevent entry of hazardous substances
  - Persistent, bioaccumulative, toxic
- Prevent pollution by non-hazardous pollutants
- Applies to all groundwater
  - “all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil”
- Defra – it is for EA to determine if groundwater is present
  - E.g. no groundwater in evaporites, dense crystalline rocks, clays
- Environmental Permitting Regulations
  - Groundwater, mining waste, radioactive substances

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Risks to groundwater quality

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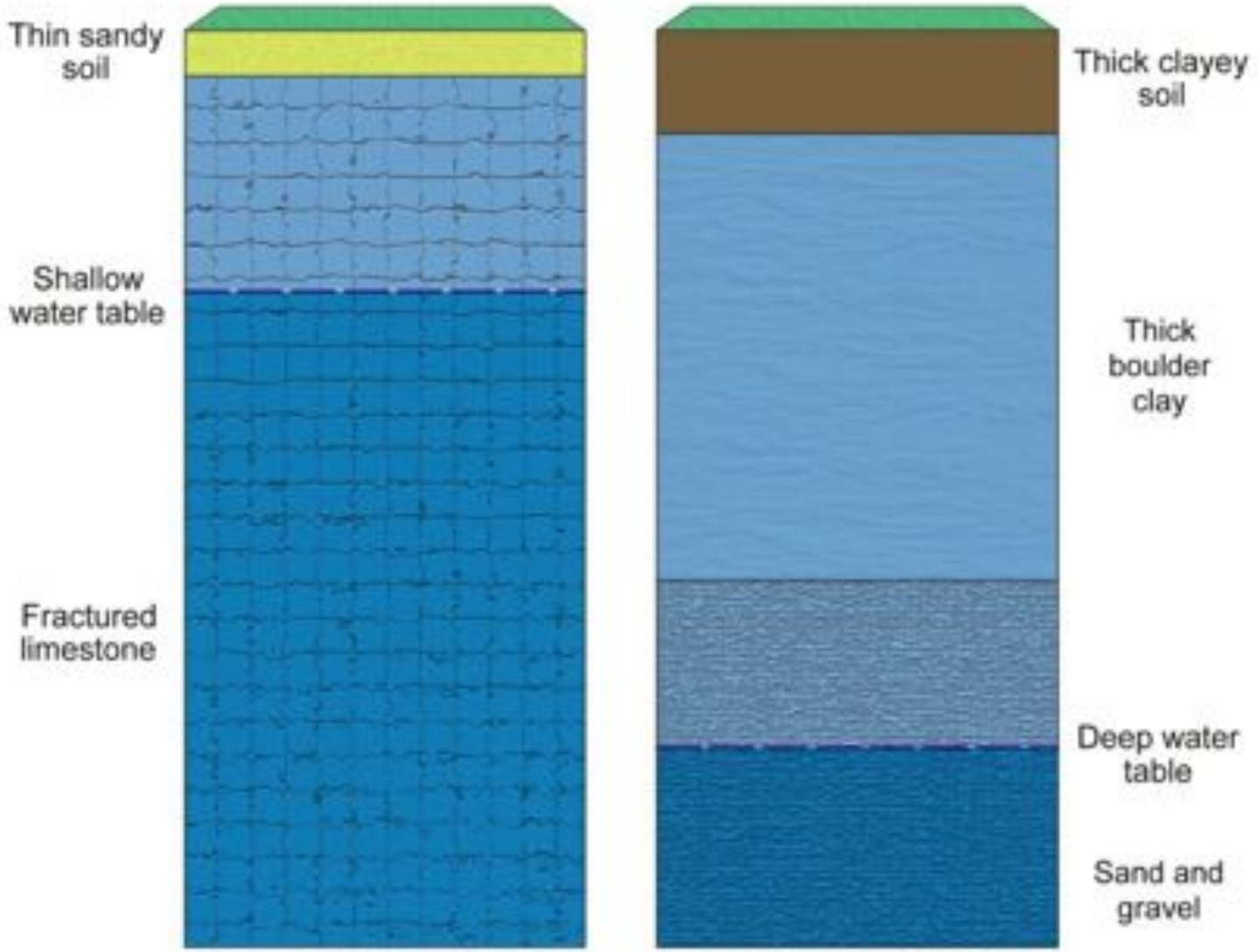

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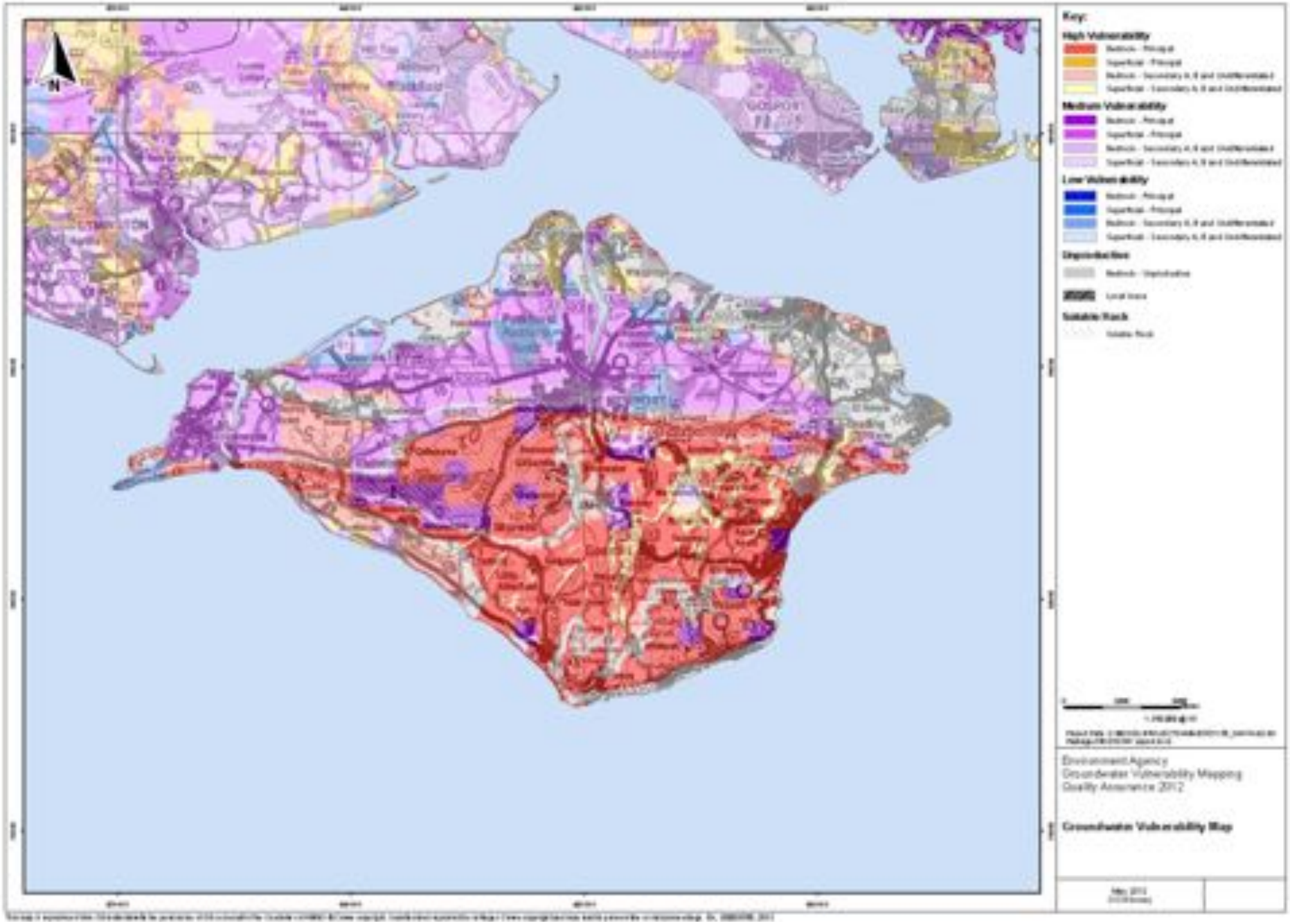
UK Groundwater Forum


Key:
High Vulnerability
Medium Vulnerability
Low Vulnerability
Unproductive
Soluble Rock
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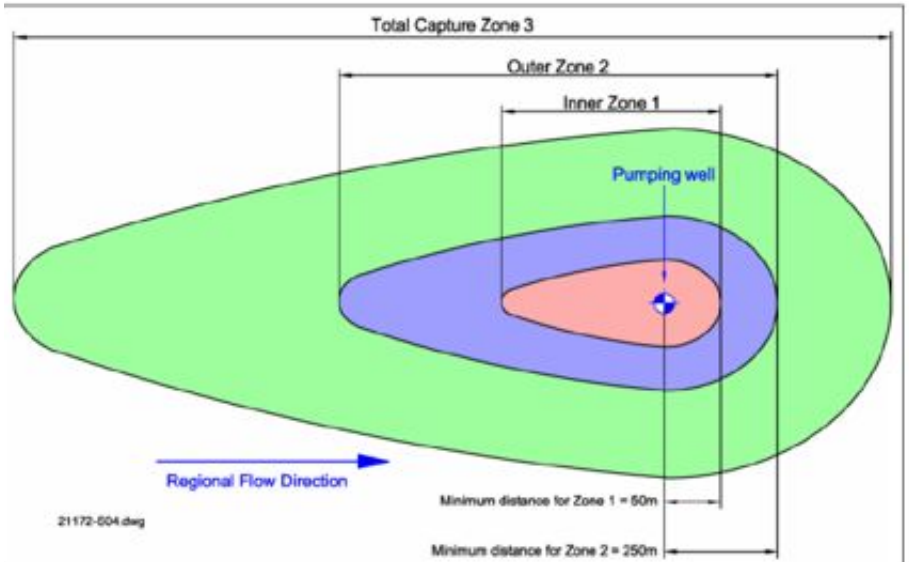
Groundwater Vulnerability Mapping
Quality Assurance 2012
Groundwater Vulnerability Map

Groundwater source protection zones



	Area	
	km2	%
SPZ 1 (Unconfined)	1830	1.4
SPZ 2 (Unconfined)	7365	5.5
SPZ 3 (Unconfined)	19065	14.3
1c (subsurface)	332	0.2
2c (subsurface)	1421	1.1
Total mapped SPZ	20486	15.4
Private Supplies SPZ1	265	0.2
Private Supplies SPZ2	6614	5.1
Grand Total	27100	20.4

Area of England 132937 km2

Zone 1: 50 day travel time and minimum 50m radius
Zone 2: 400 day travel time and minimum 250m radius
Zone 3: capture zone of source

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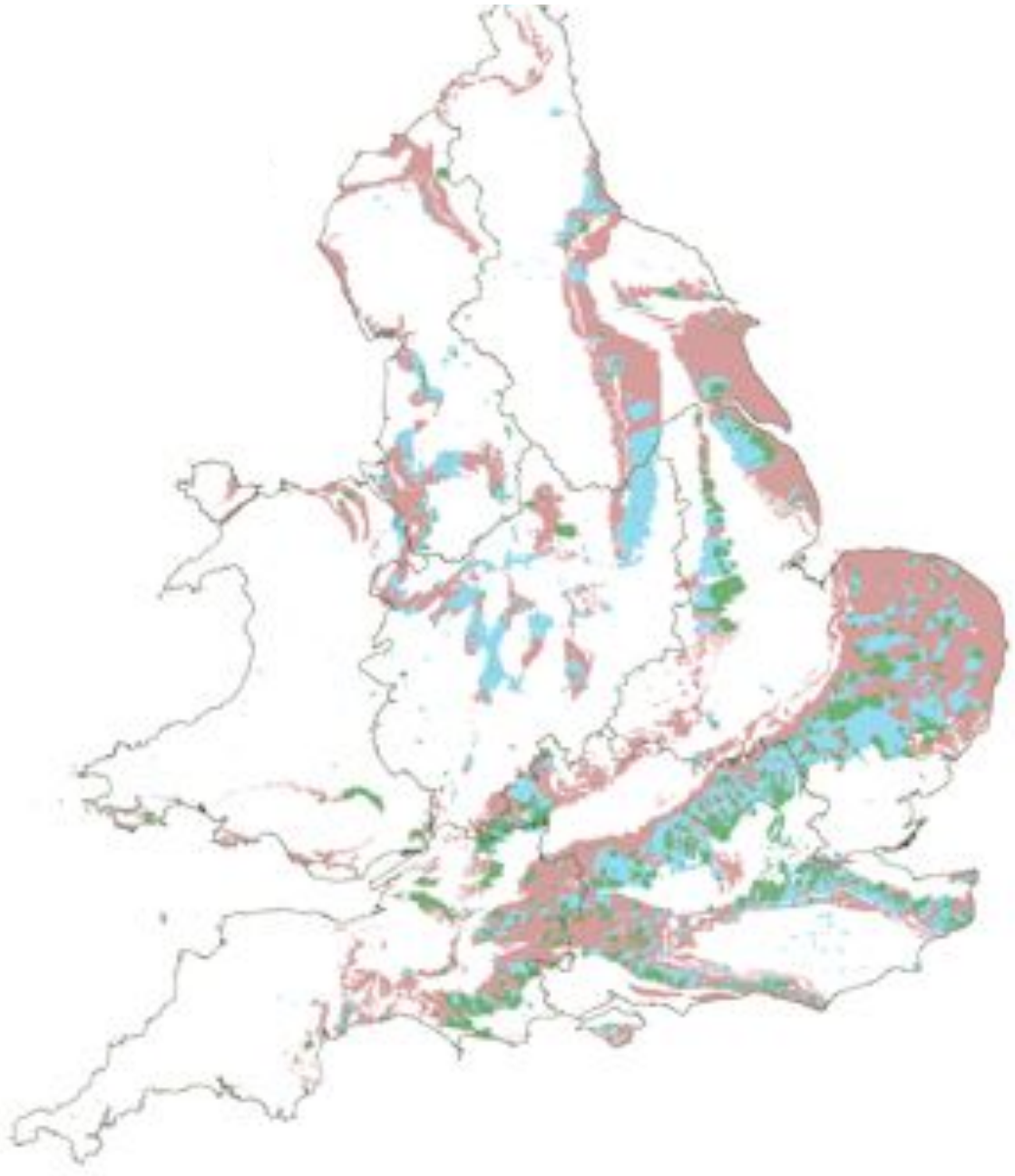
See http://maps.environment-agency.gov.uk/wiyby

Principal aquifers and source protection zones



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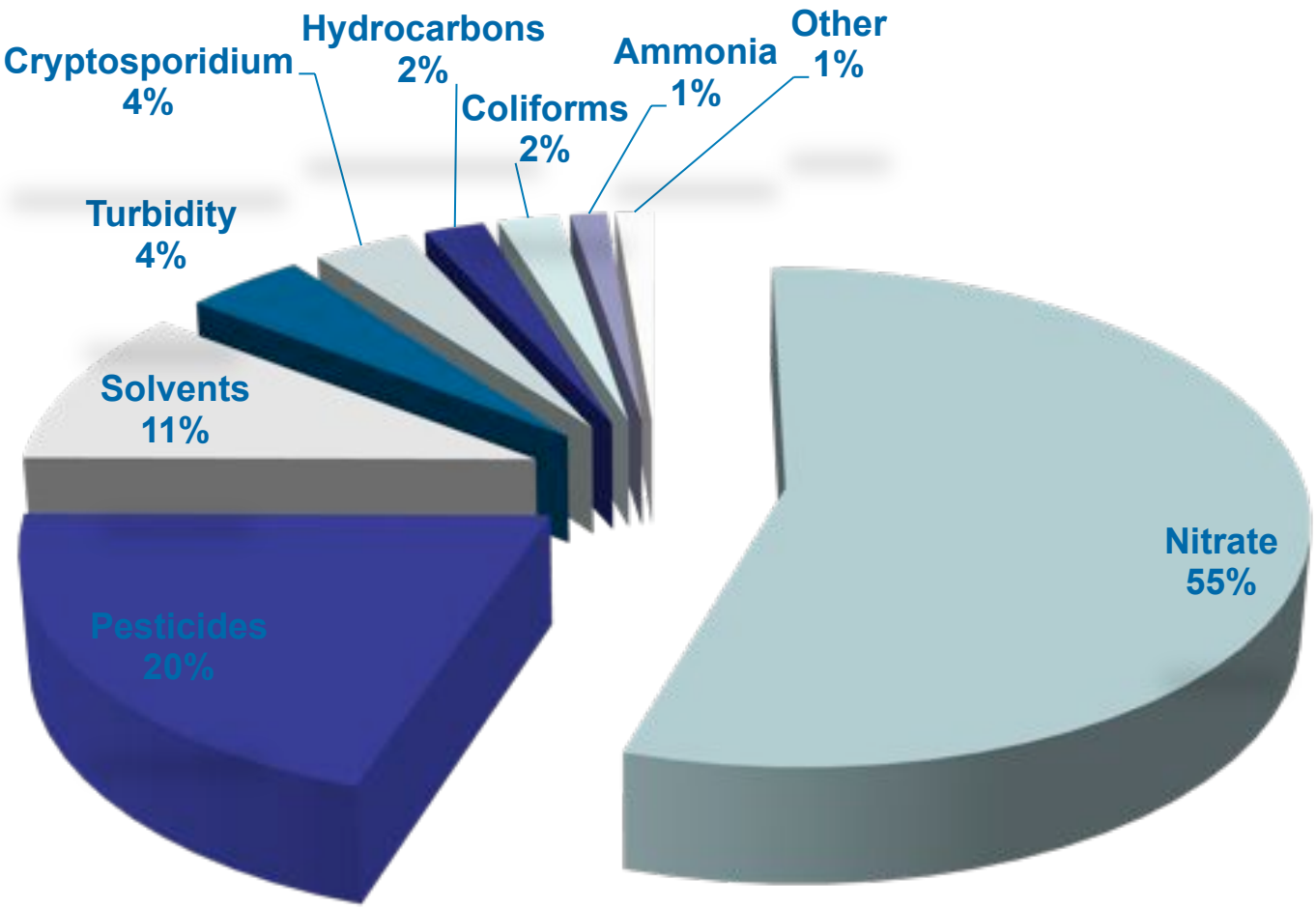
Groundwater safeguard zones[1]



[1] Non-statutory zones to focus measures to protect water abstracted for human consumption

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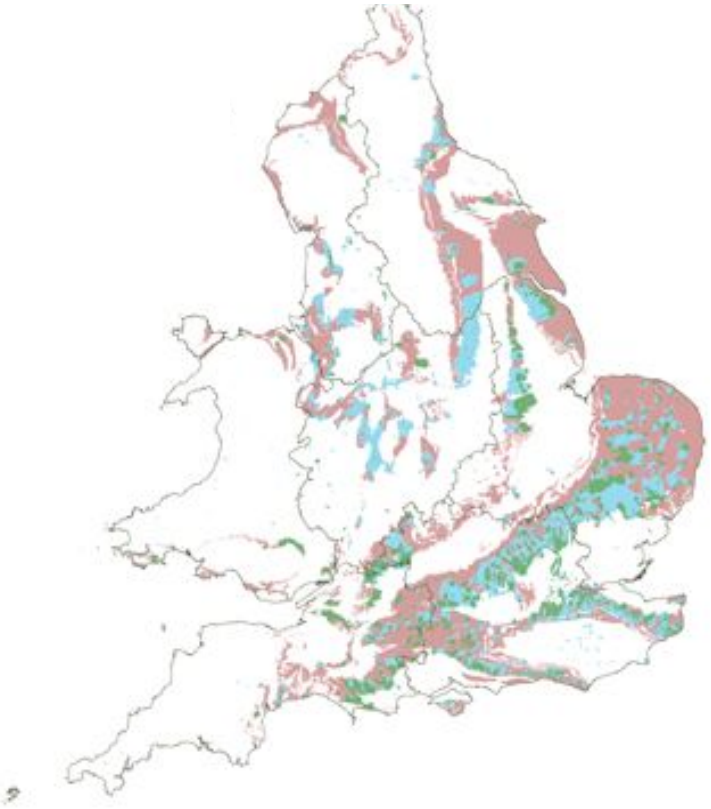
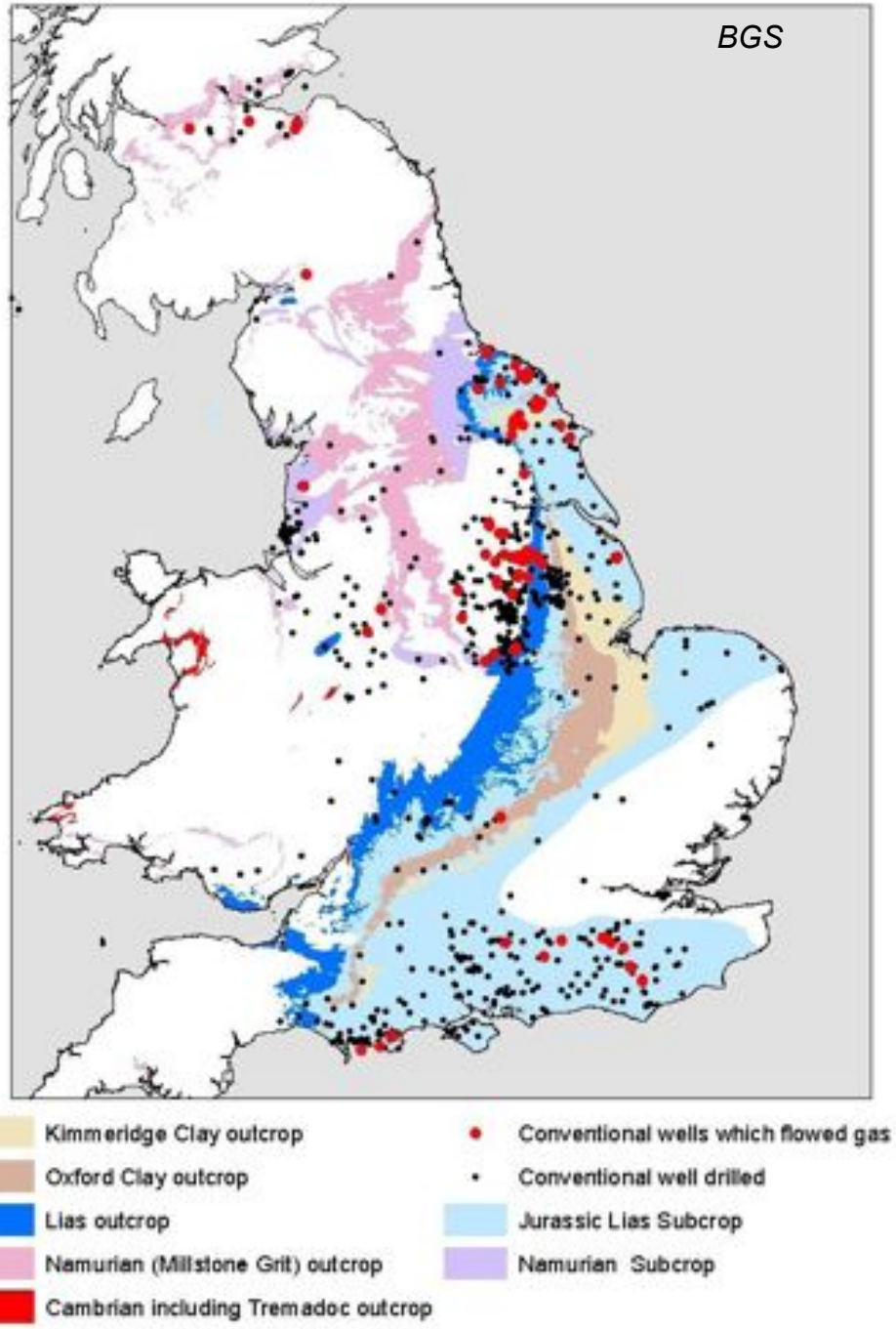
Oil, gas & water





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Royal Society & Royal Academy of Engineering Report, June 2012

Detect groundwater contamination	National baseline surveys; monitoring before, during and after operations, inc. abandoned wells.
Ensure well integrity	Health and safety and environmental protection
Mitigate induced seismicity	Characterise rock stresses; traffic light monitoring controls
Detect potential gas leakage	Monitor emissions before, during and after operations
Integrate water management	Minimise, recycle, treatment and safe disposal
Manage environmental risks	Assess risks across the lifecycle of shale gas activity
Best practice for risk management	Risk assessment, guidance, ALARP
Regulation of industry	Regulatory needs, skills, resources
Coordination of regulatory bodies	Integration – information, working practices
Coordinate research	Cross-Research Council programme.

Trust and risk

4th most expensive real estate in the world (reputedly)

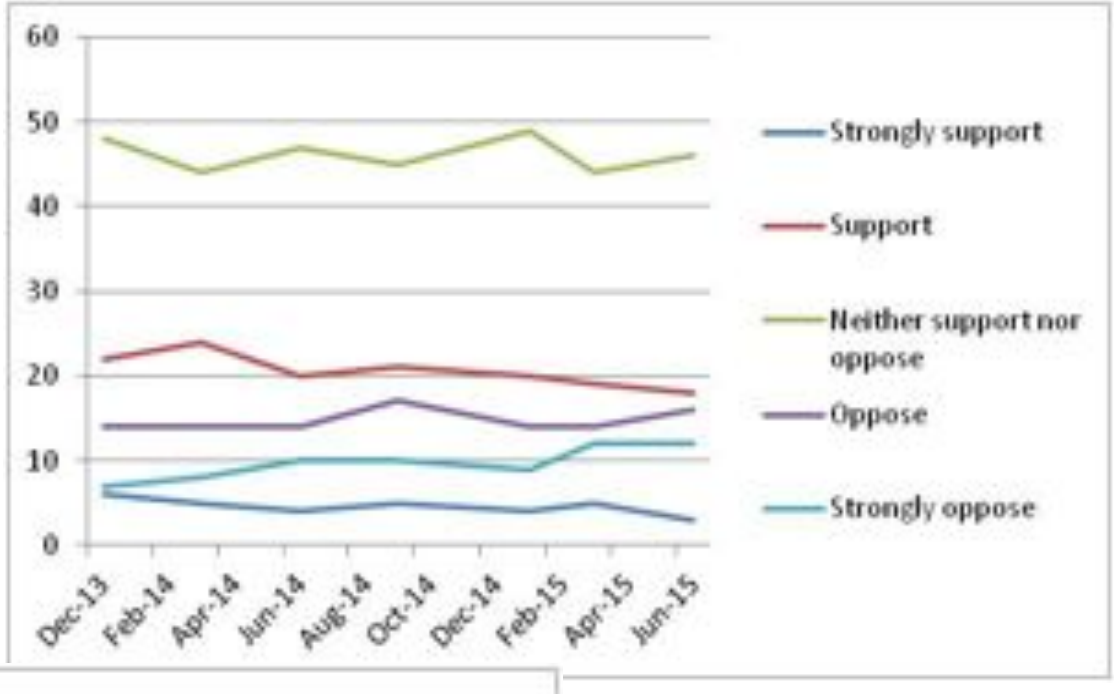
AONB and SSSI

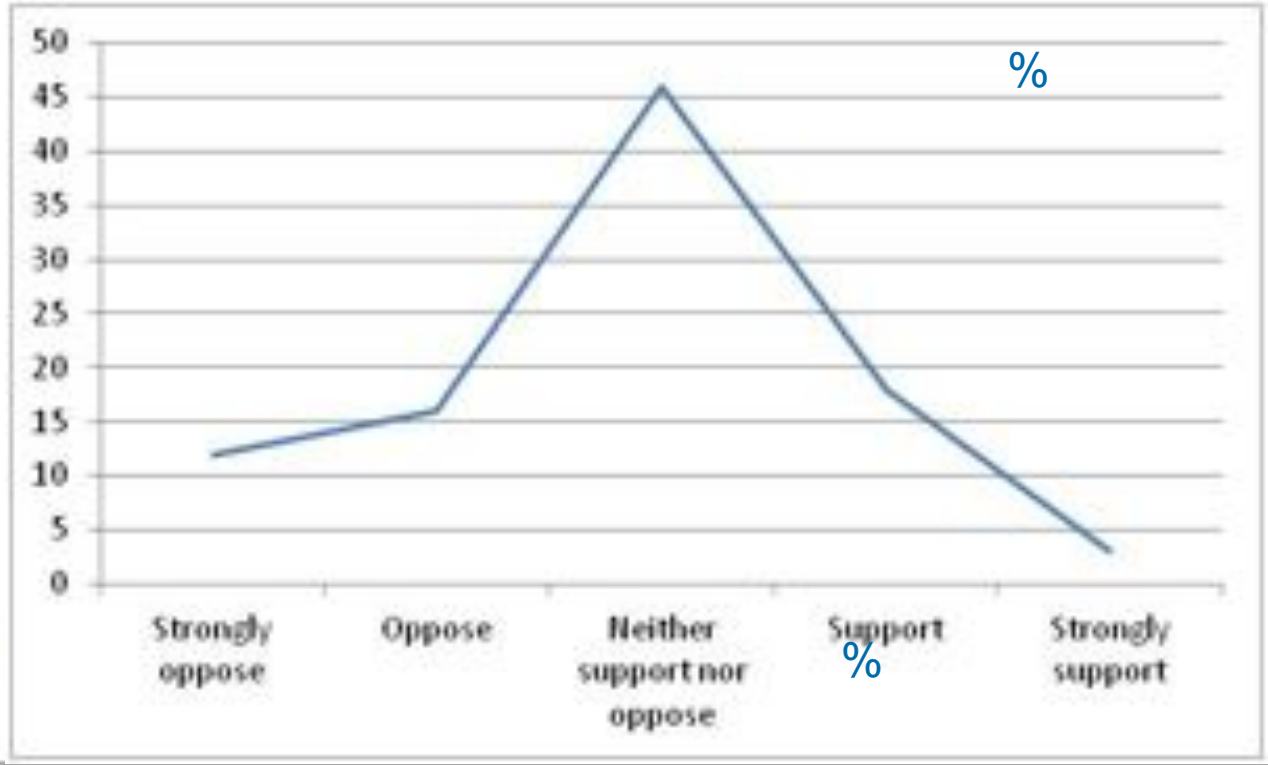
Part of drilling operations at Wytch Farm, Europe's largest onshore oil field

Source: Silson Communications Ltd.

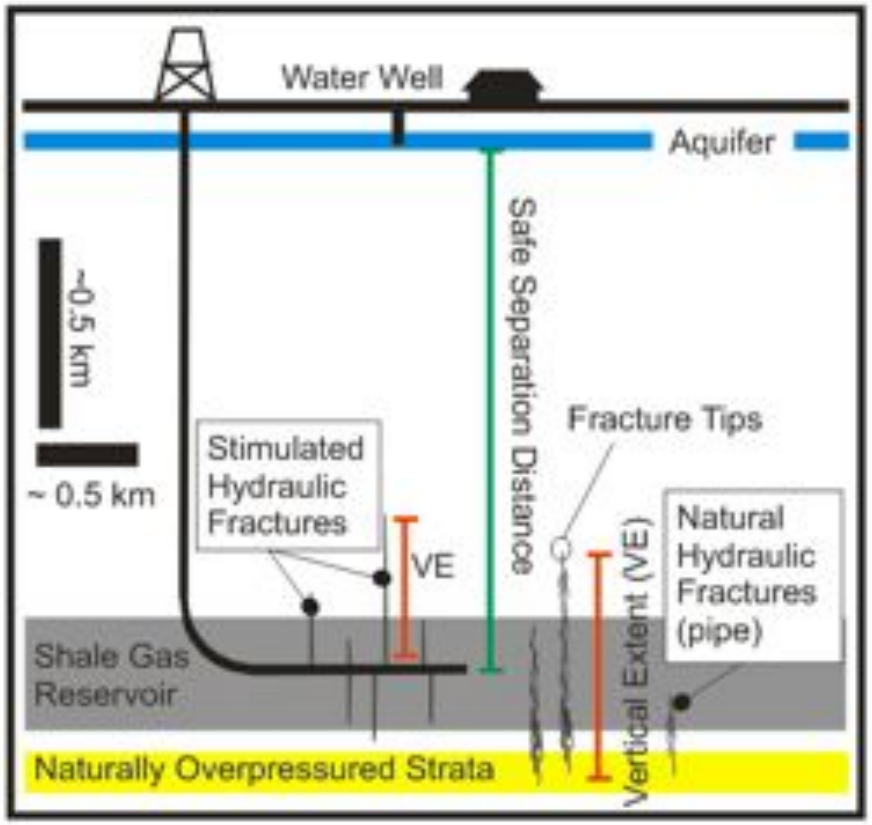
Support for shale gas

DECC Public Attitudes Tracking Survey





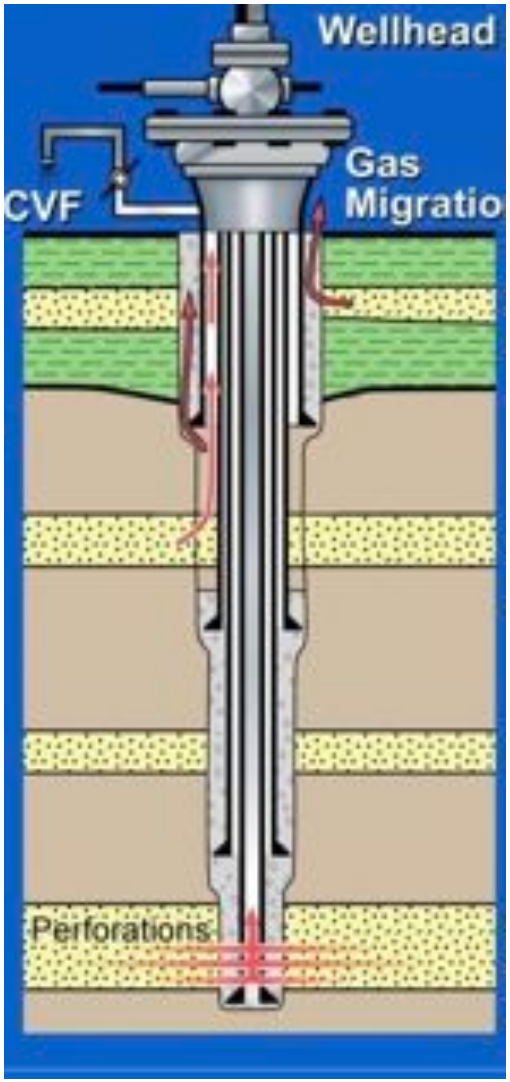
Fracture propagation

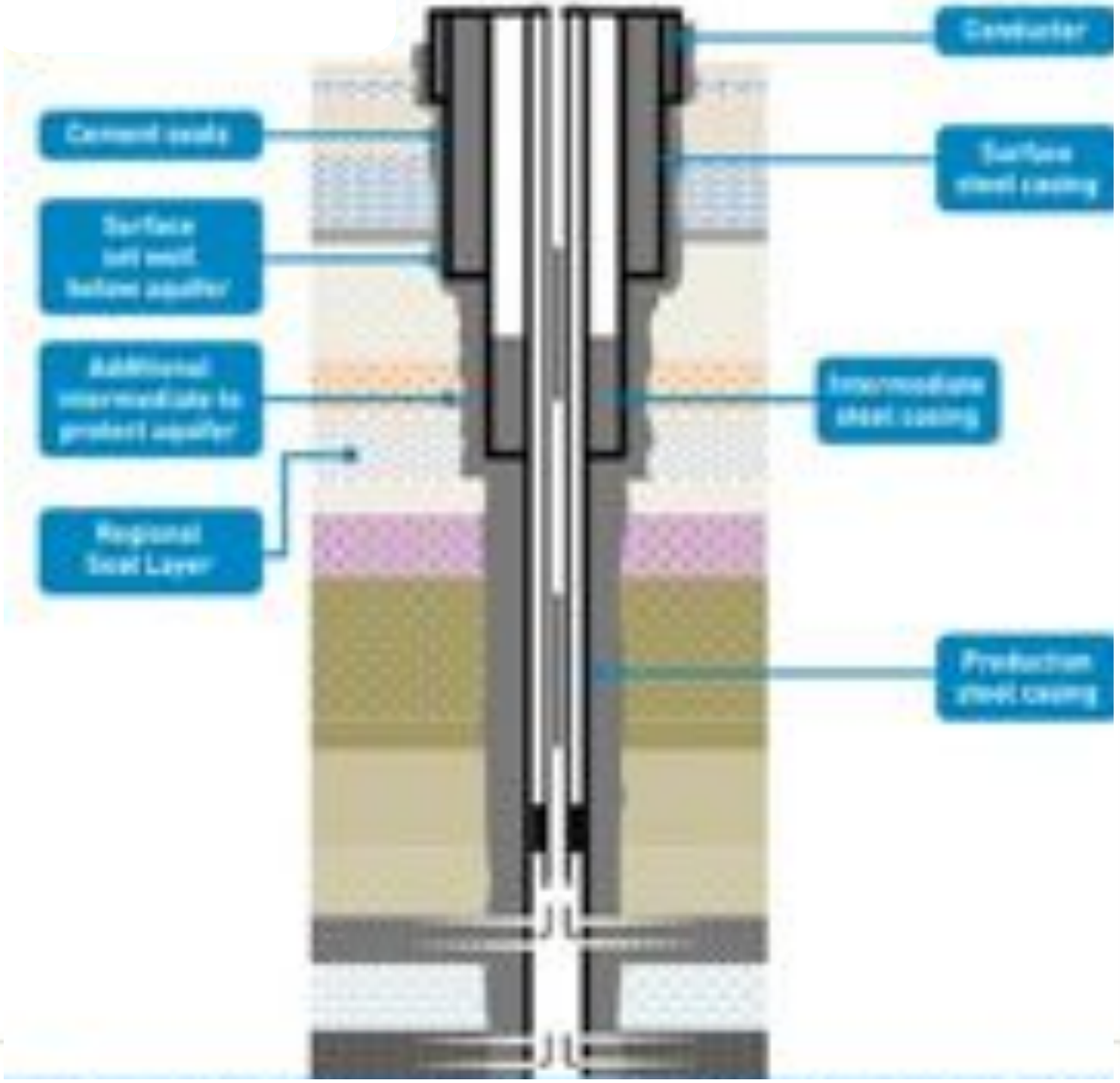


Durham Energy Institute
Science and Society

Davies et al (2012)

- Maximum reported hydraulic fracture heights – 588m
  - *'Chances of going beyond 600 m is negligible'*
  - *Probability of hydraulic fracture extending vertically >350m is 1%*
- Interconnection with natural fissures could extend the potential distance for fluid migration





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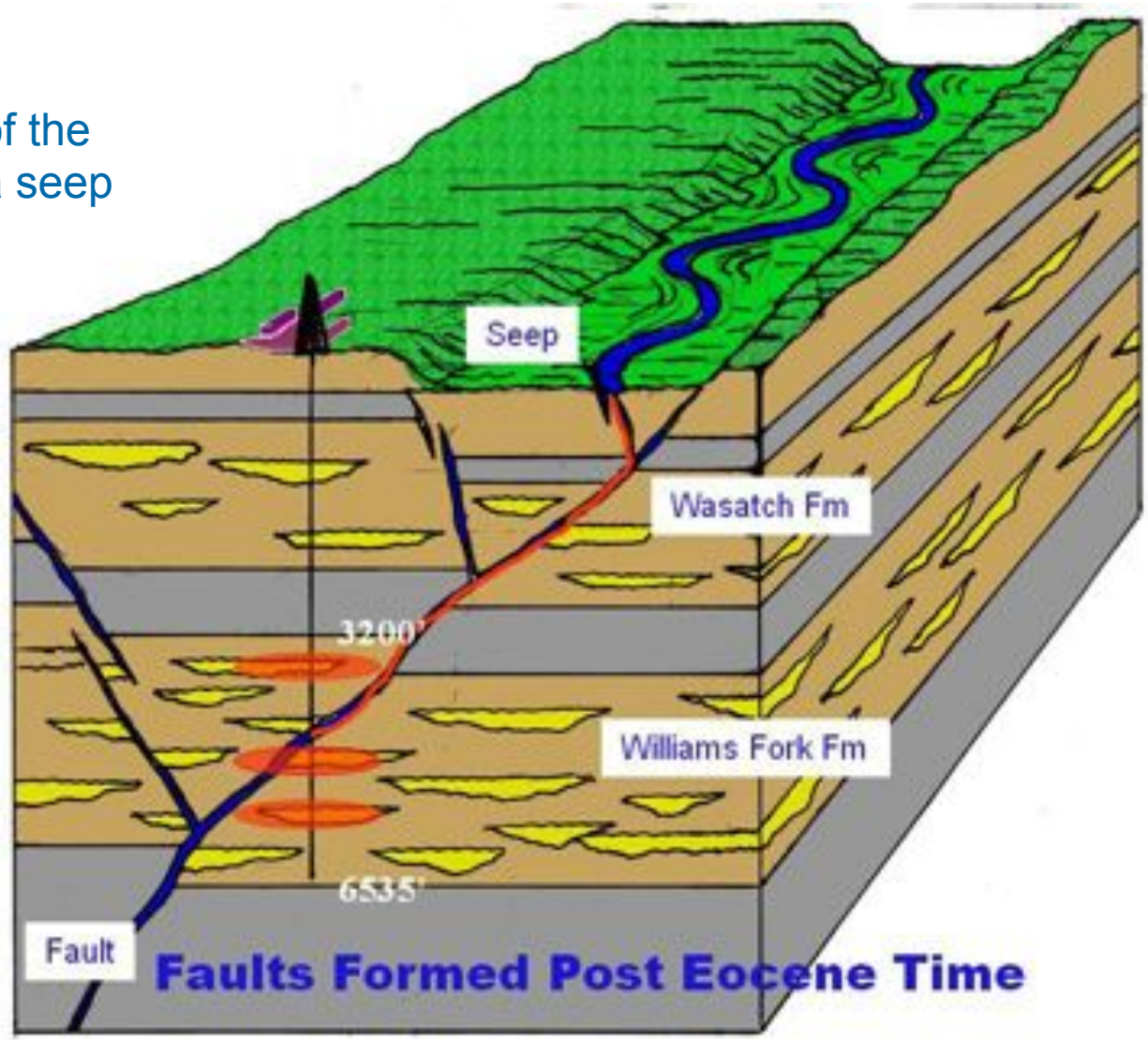
Mamm Creek, Colorado

Conceptual diagram of the process that caused a seep (from EnCana 2005)



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Drilling

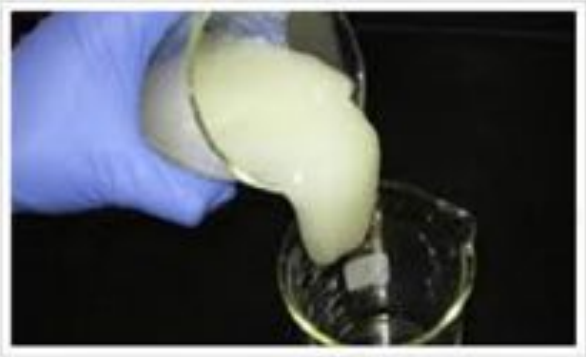
- EA Groundwater Protection: Principles and Practice (2013)
  - We will object to [oil and gas] activity in SPZ1
  - Outside SPZ1 we will object to [oil and gas] activity where there would be an unacceptable impact on groundwater
- In many cases impact from drilling fluids likely to be considered ‘de minimis’
  - Subject to certain restrictions on type of drilling fluid and use of additives
  - Near surface drilling – water based mud with very limited range of additives
  - Deeper drilling wider range of additives/fluids providing cannot cause pollution

Frack fluid – *Ethyl Methyl DEATH!*

- Biocides
  - to kill bacteria whose growth in the fractures might impede the flow of gas,
- Weak acid
  - to clean away drilling mud at the start off the fracture (used only in the initial fracture),
- Gelling agent
  - to hold the proppant in the fluid,
- Liquefier/Breaker
  - to release the proppant when it has penetrated the fractures,
- Friction Reducer
  - to reduce the pressure needed to pump the water in

Frack fluids

- EA approve substances for hydraulic fracturing (IAct)
- Operators to disclose the ingredient list and maximum concentrations to obtain a permit
  - Will be included on the public register
  - Ingredients must be non-hazardous as defined by the Groundwater Directive 2006 (2006/118/EC)



Halliburton

- Hazardous substances:
  - Toxic, persistent, liable to bioaccumulate; or equivalent concern
  - List I substances under GW Directive 80/68/EEC
  - Prevent input to groundwater
- Other substances are ‘non-hazardous’
  - Limit input to groundwater to avoid pollution

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Assessment of fluids

- Criteria for persistence, bioaccumulation and toxicity are based on those used in REACH
  - Looks to guidance published by the European Chemicals Agency and criteria in the CLP regulation (classification, labelling and packaging of substances and mixtures)
- Substances of equivalent concern
  - Very persistent and very bio-accumulative
  - Substances that are mutagenic or have no determinable threshold for adverse effects on human health
  - Chemically analogous substances
- Assessment overseen by Joint Agency Groundwater Directive Advisory Group (JAGDAG)

JAGDAG

Joint Agencies Groundwater Directive Advisory Group

SEPA Scottish Environment Protection Agency

NIEA Northern Ireland Environment Agency www.ni-environment.gov.uk

epa Environmental Protection Agency

Environment Agency

SAGTA

esa environmental services association

WATER UK

Energy UK The trade association for the energy industry

Department for Environment Food & Rural Affairs

Llywodraeth Cymru Welsh Government

Public Health England

Environment Agency

http://www.wfduk.org/stakeholders/jagdag-work-area

JAGDAG: main tasks

- Advise on the process of substance determination and confirm assessment criteria e.g.
  - Chemical structure
  - Intrinsic properties of toxicity, persistence, bioaccumulation
  - Identification of correct CAS registry number
- Peer review provisional determinations undertaken by the Agencies
- Review assessments by the previous GDNAG (Groundwater Directive National Advisory Group for Directive 80/68/EEC)

JAGDAG does not have a role in regulating hazardous substances!

Working with industry

- Develop a better understanding of the risks to groundwater from drilling and hydraulic fracturing products/chemicals
- Review other systems for assessing environmental risks
  - MSDS
  - Offshore Chemical Notification Scheme
- Share knowledge, data and expertise for assessing risks to groundwater from products and chemicals
- Increase industry's role in undertaking assessments
- Compile an inventory of products and chemicals used in onshore drilling and hydraulic fracturing fluids in England and their assessed risks to groundwater

Groundwater quality & flowback from depth

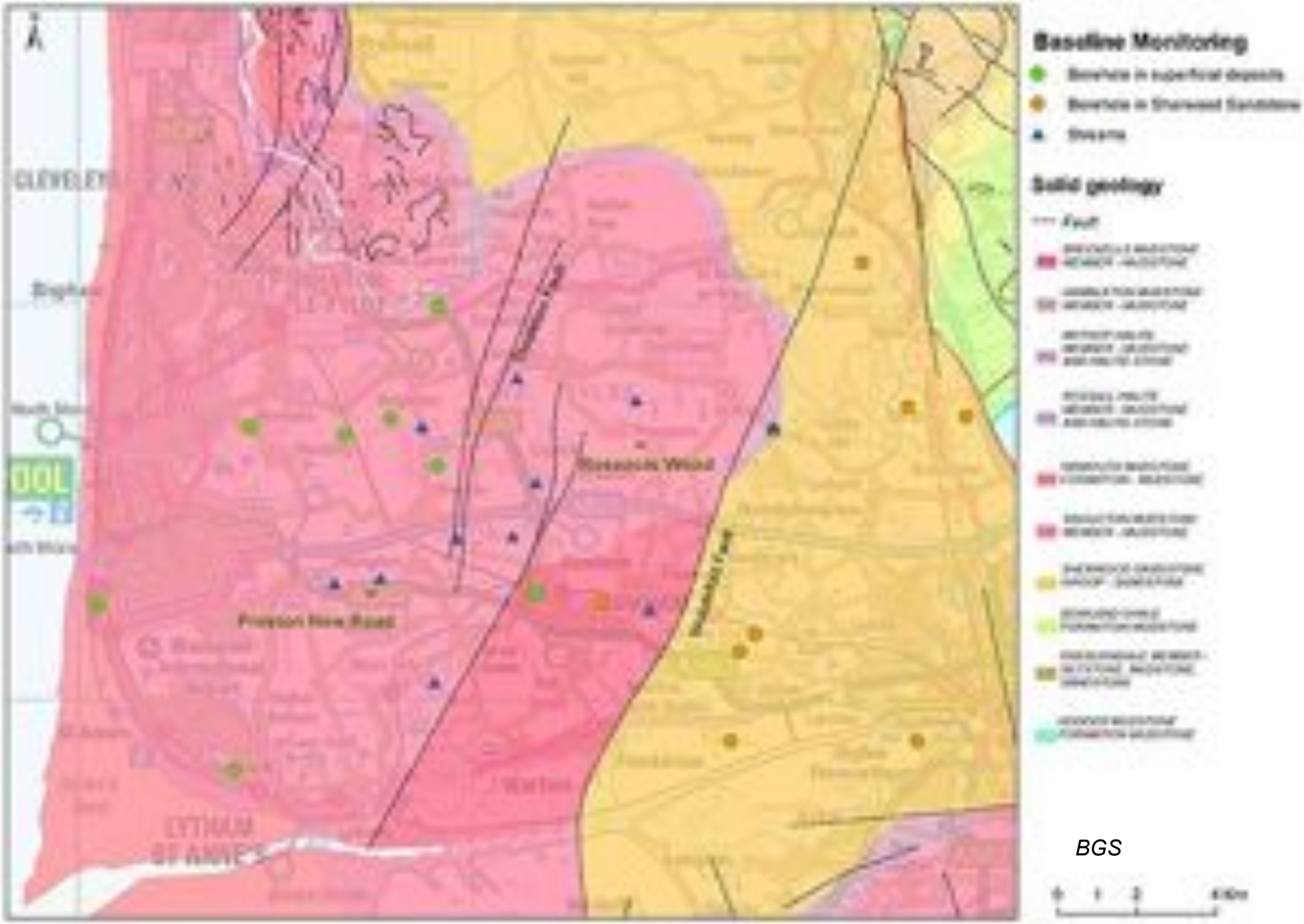
	Sea Water (grams per litre)	The Dead Sea (grams per litre)	Flowback Fluid (grams per litre)
Sodium	10.1	36.3	34.8
Chloride	19.4	230.4 (for chloride plus bromide)	92.8
Bromide			1.0
Magnesium	1.3	45.9	2.1
Potassium	0.4	7.8	0.1

Chemicals additives	Traces of heavy metals
Dissolved and suspended organics (e.g. BTEX, PAH)	NORM – naturally occurring radioactive material

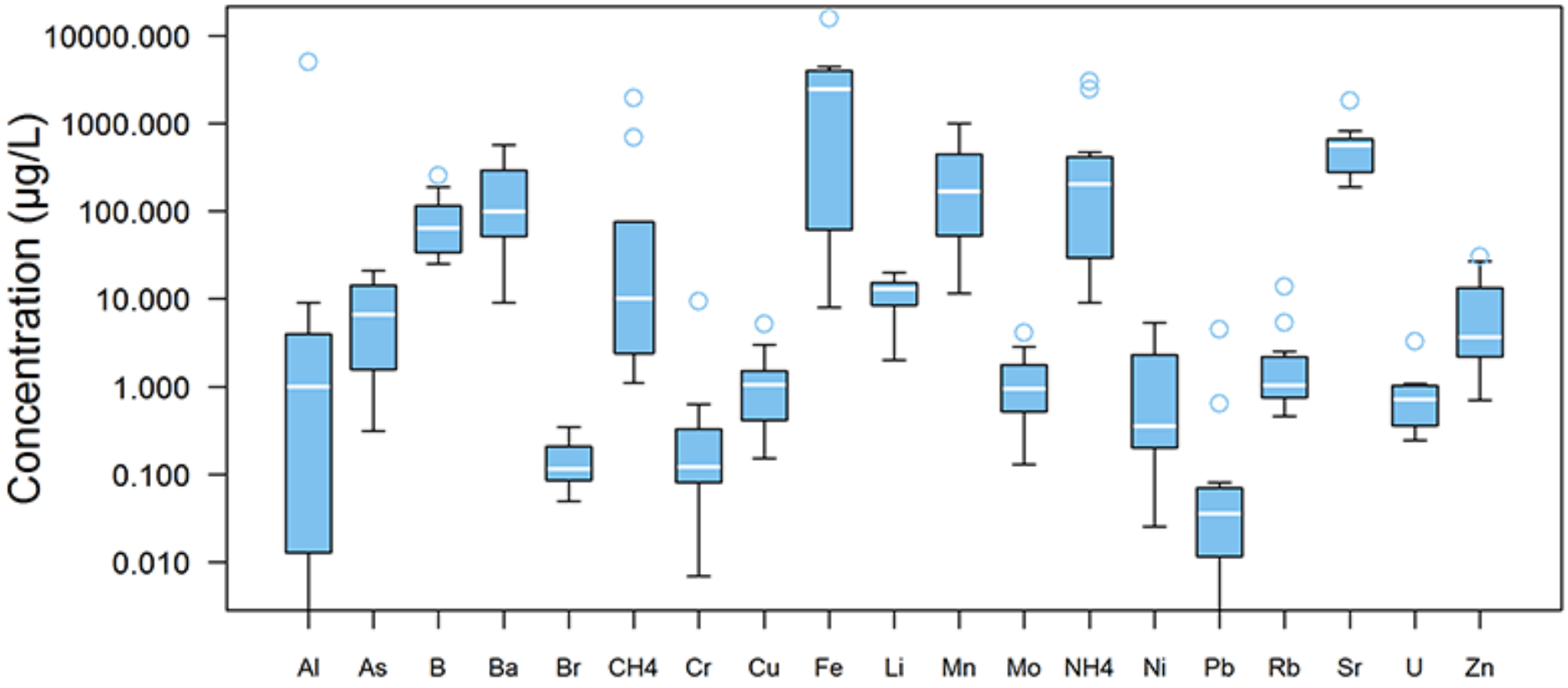
Baselines in Lancs and N Yorks

BGS consortium

- water level
- temperature, pH, conductivity, redox potential
- major ions and trace elements
- dissolved gases (O_2, CO_2, CH_4, N_2, radon, noble gases)
- organic chemicals
- stable isotopes (^{18}O, ^{2}H of water, ^{13}C of inorganic carbon)
- groundwater 'age' indicators (CFCs, SF_6)
- naturally occurring radioactive materials (NORM: uranium and thorium decay series).


Baseline Monitoring
Borehole in superficial deposits
Borehole in Sherwood Sandstone
Streams
Solid geology
Fault
Rossall Fault
Preston New Road
Roseacre Wood
LYTHAM ST ANNES
BGS

BGS Lancashire



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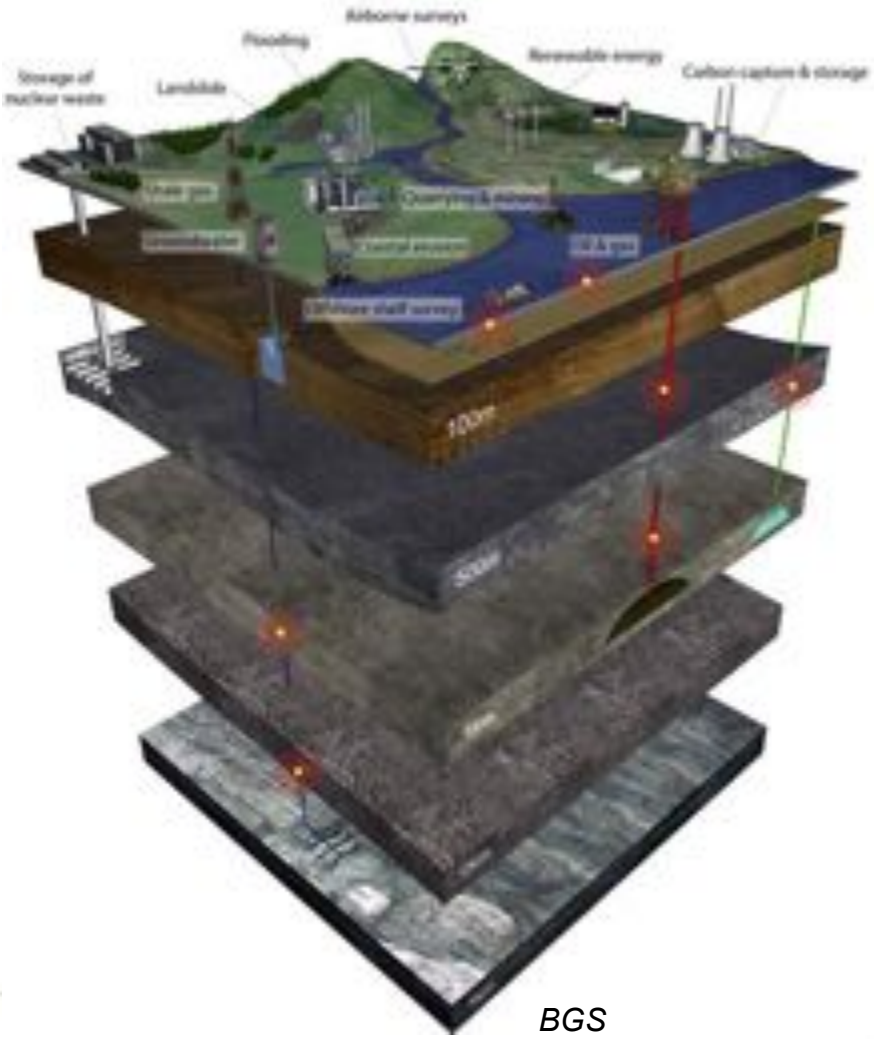
EA research themes

Status	Baseline conditions, ambient air quality, geology and geomechanics, hydrogeology, monitoring, statistical evaluation of data
Pressure/risk analysis	Chemicals, emissions, flaring, fracking, drilling, reinjection, abandoned wells, groundwater vulnerability, risk assessments, fate and behaviour of chemicals, modelling
Impact management	Well design (e.g. cement), BAT, flares, operational guidance, seismicity, monitoring and analysis techniques

Proposed field laboratories

- Energy Security and Innovation Observing System for the Subsurface (ESIOS)
- USEPA and DoE
  - 3 field sites in Texas, Ohio and West Virginia
- Guelph, Canada
  - controlled releases and monitoring of methane in deep and shallow aquifers



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