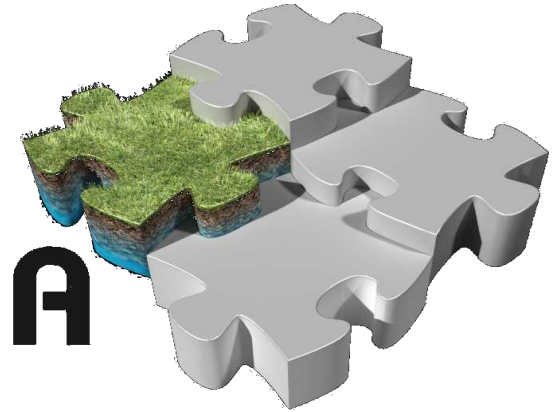


VoGERA



Vulnerability Of shallow Groundwater resources to deep sub-surface Energy Related Activities

Final GeoERA meeting



TNO innovation
for life



Vlaamse
overheid

SCK • CEN



G E U S



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166



Energy related activities in the sub-surface

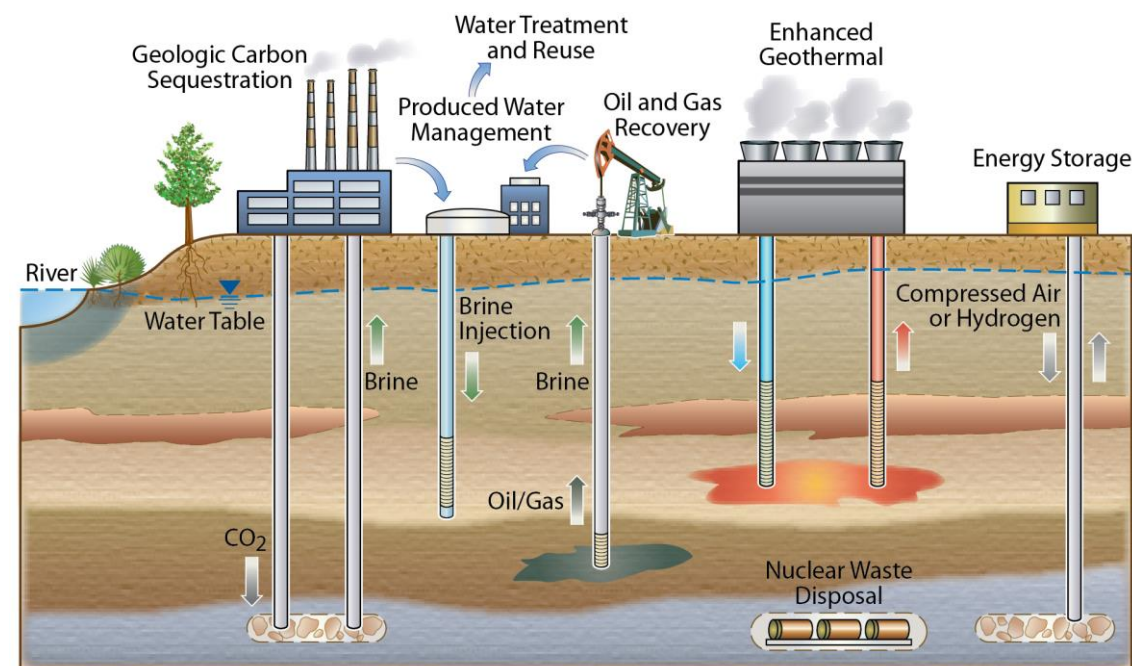
1. *Conventional oil and gas*
2. *Shale gas*
3. *Coal bed methane*

- induce physical and chemical changes
- introduce new chemical substances
- cause the movement of pre-existing fluids



Impact on groundwater quality?

4. *Geothermal (low/high enthalpy)*
5. *Energy and gas storage*



<https://eesa.lbl.gov/>



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Objectives VoGERA

To improve understanding of vulnerability of shallow groundwater from deep sub-surface energy-related activities

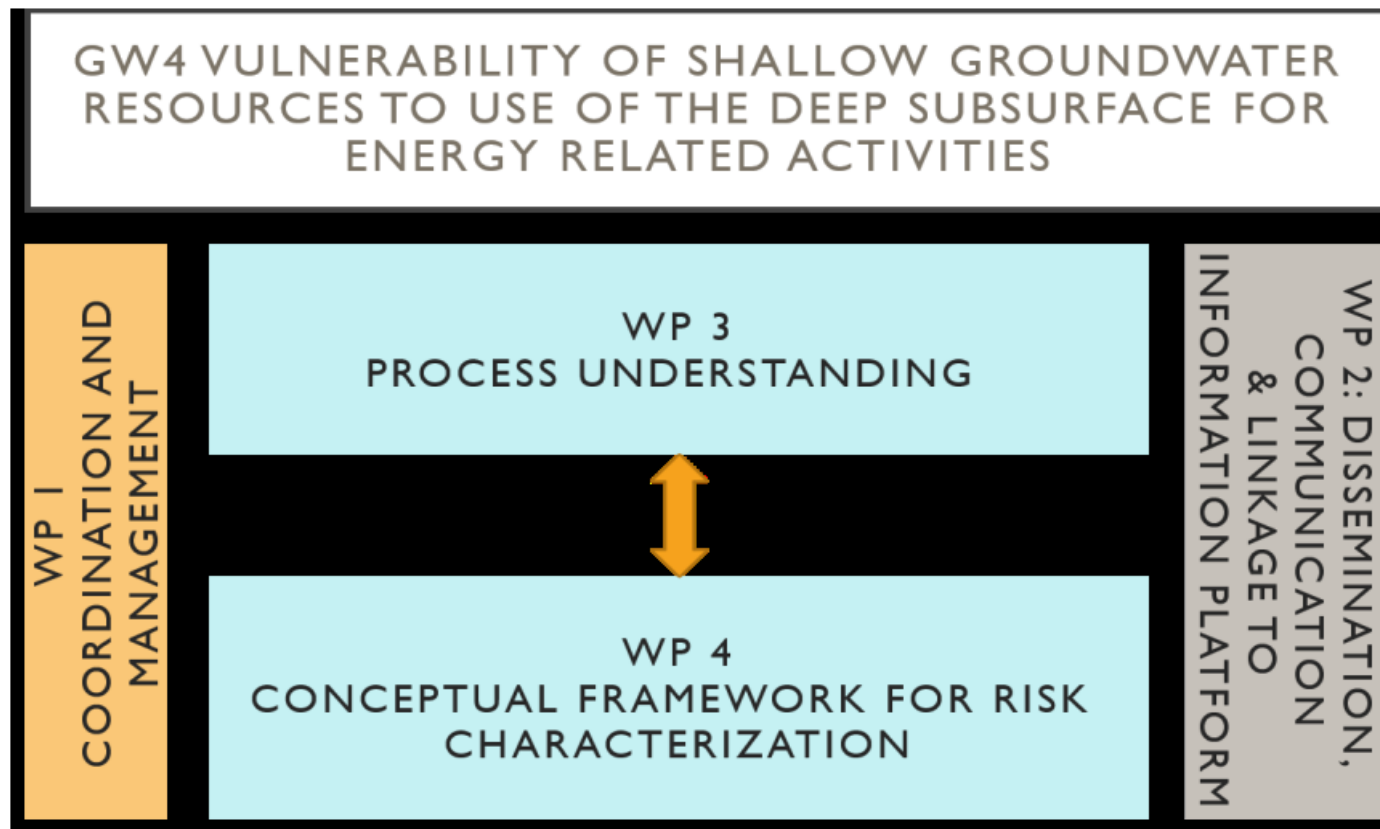
- Protect groundwater resources
- Allow informed and responsible use of the deep sub-surface
- Develop a European-wide approach that is consistent across energy activities

Vulnerability Of shallow Groundwater resources to deep sub-surface Energy Related Activities



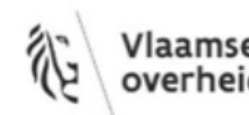
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Project structure



6 Partners:

BGS
TNO
VMM
SCK CEN
MBFSZ
GEUS



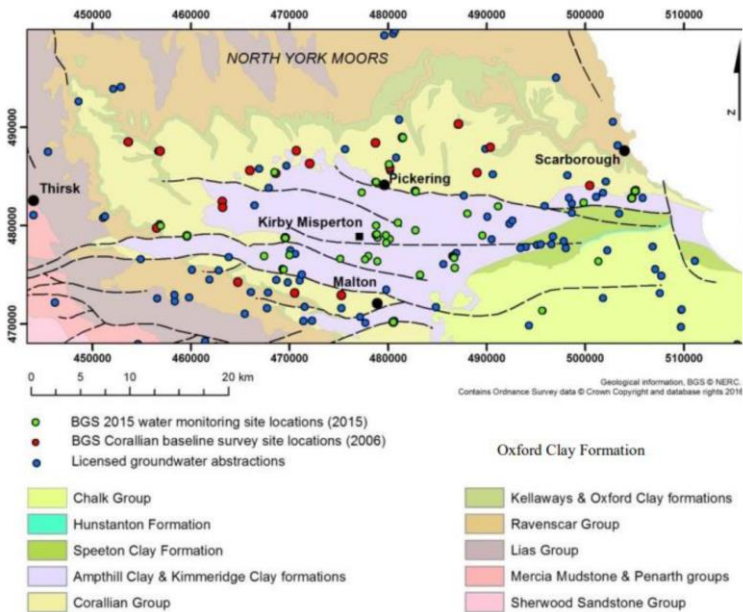
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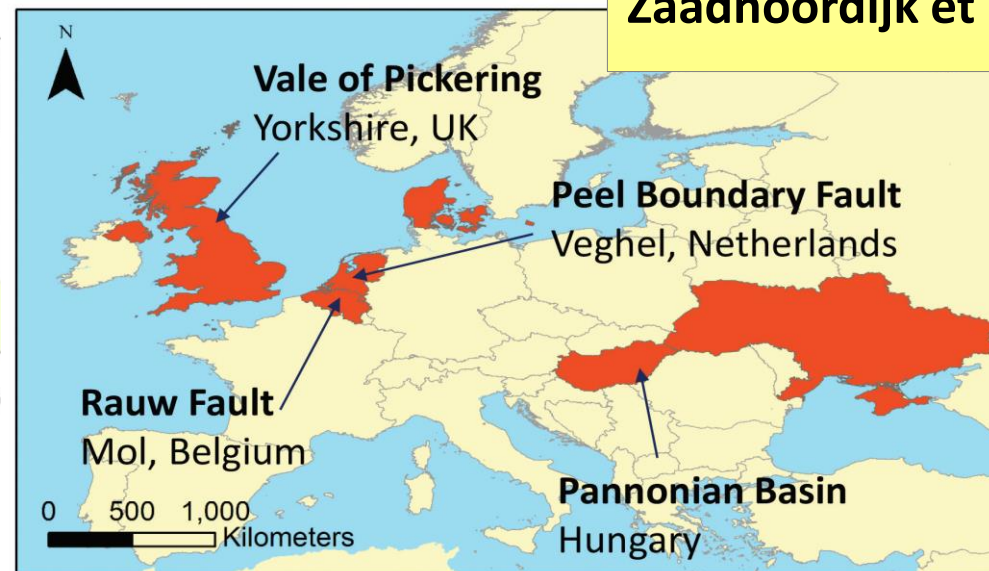
WP 3 – Process understanding

Characterisation of pathways (e.g. fault zones, abandoned wells) between deep systems and shallow groundwater receptors at four pilot locations

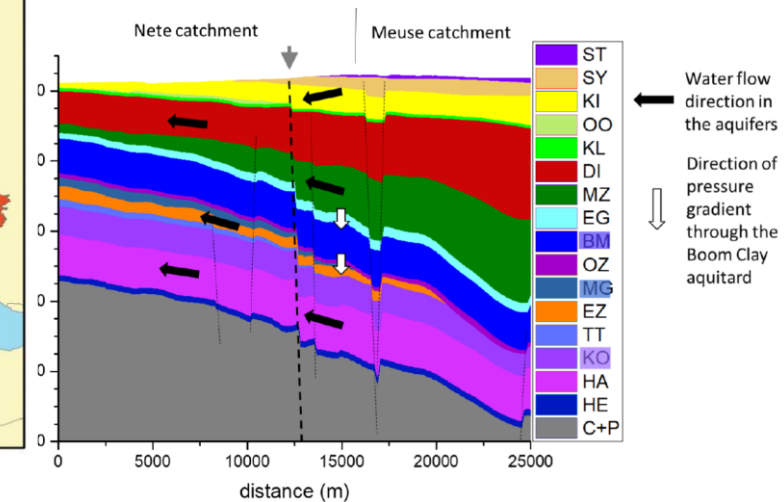
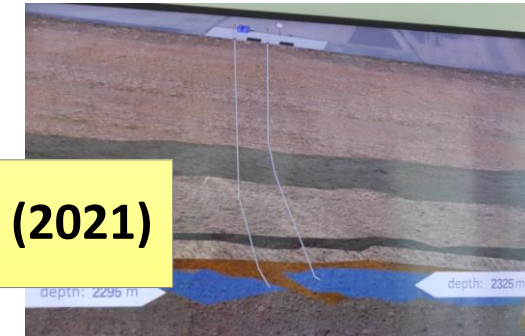
Zaadnoordijk et al. (2021)



Conventional + unconventional O&G



Geothermal



Storage + Geothermal

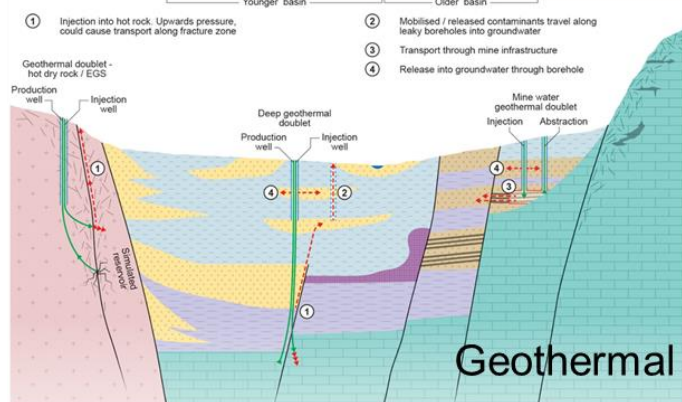
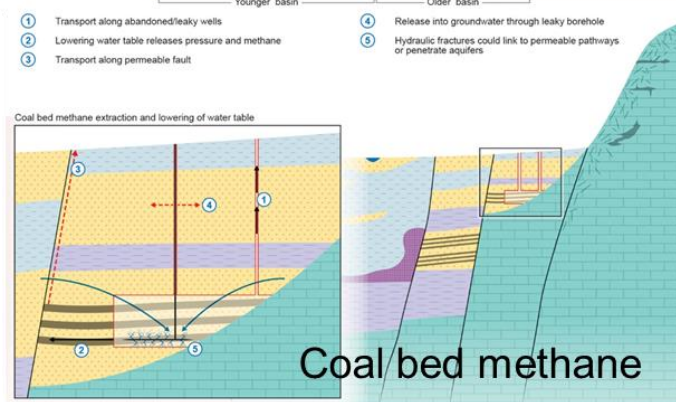
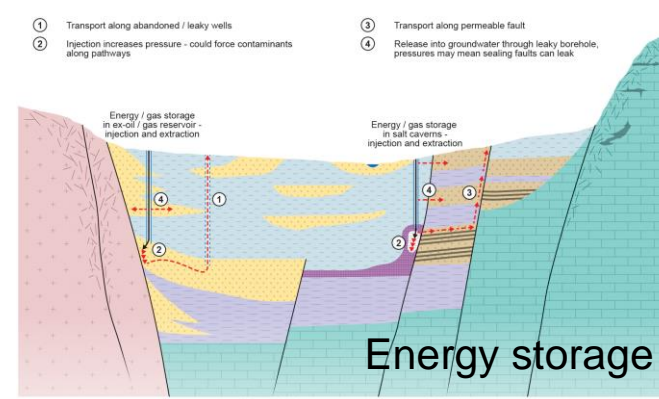
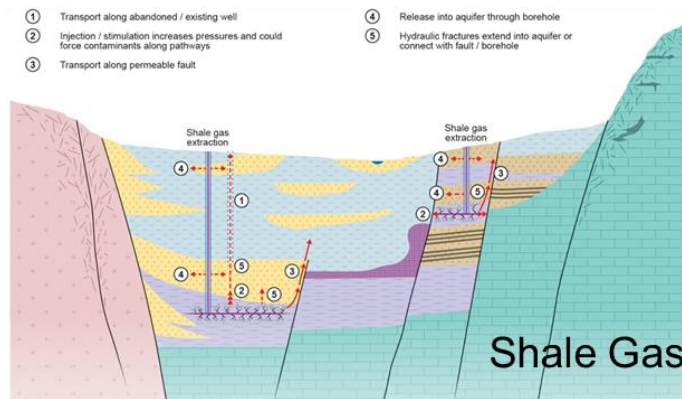
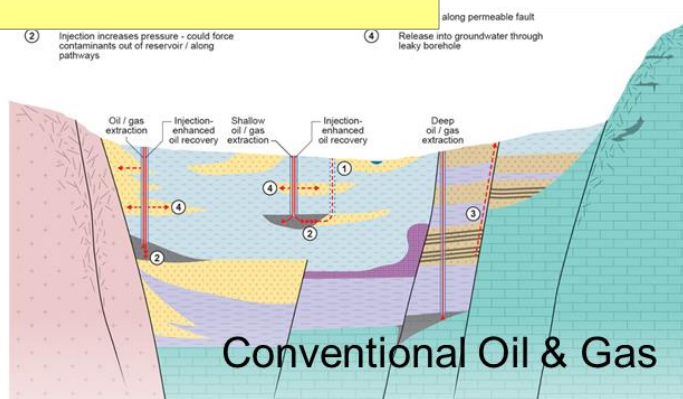


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WP 4 – Conceptual framework for vulnerability characterisation

Loveless et al. (2019)



- Developed a set of conceptual models of potential contaminant pathways for different energy activities

Contaminant Pathways comparison

Loveless et al. (2019)

Pathway	Activity			
	conventional oil & gas	unconventional gas & oil	coalbed methane	geothermal energy
Release of contaminants into groundwater through leaky borehole	X	X	X	X
Transport along abandoned/existing wells into formations with groundwater	X	X	also through mine infrastructure	
Injection increases pressures and forces contaminants out and along other pathways	in case of enhanced oil recovery, injection of water steam, or CO2 into reservoir			injection into permeable zone, such as fault
Injection/stimulation to increase permeability (e.g. hydraulic fracturing) can increase reservoir pressures and force contaminants out of reservoir and along other pathways		X		
Transport of contaminants along permeable faults	X	X	X	
Transport of contaminants through mine infrastructure				X
Lowering of water table releases pressure and methane			X	
Mobilization/release of contaminants which travel along leaky boreholes into groundwater				X
Fractures could extend into aquifer or connect with a permeable fault		Hydraulic fractures	Hydraulic fractures	Sheared fractures



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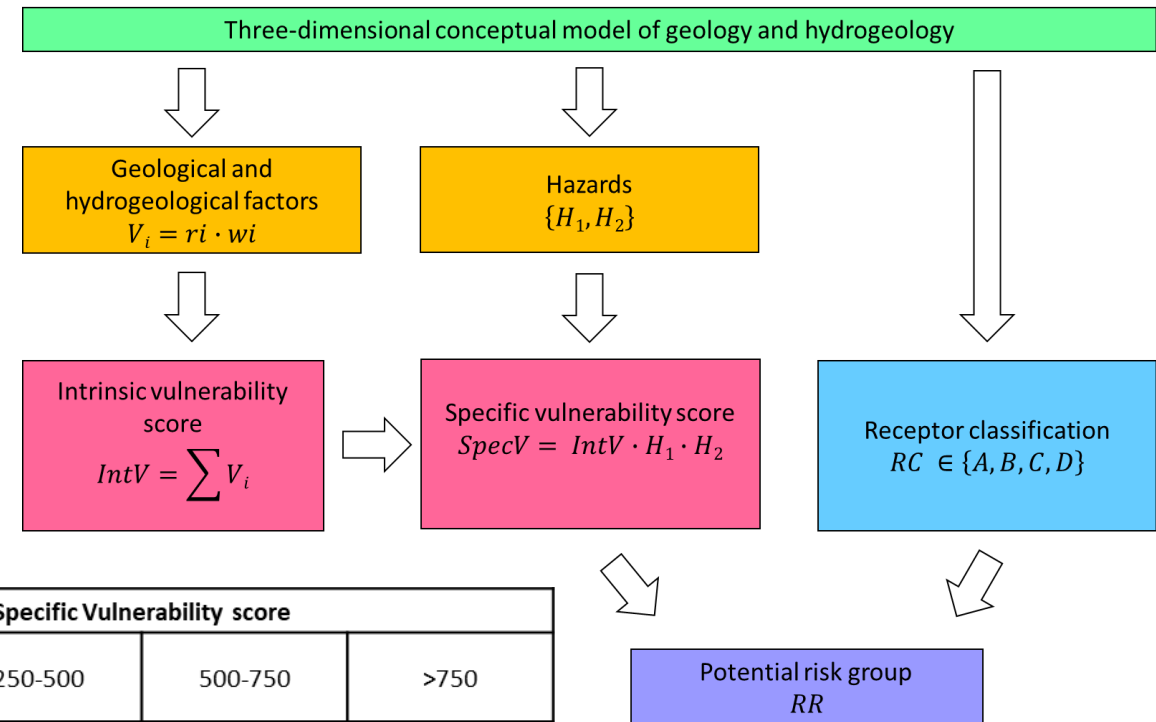


WP 4 – Conceptual framework for vulnerability characterisation

Developed a screening methodology for characterizing the vulnerability of shallow groundwater from deep industrial activities

Testing at the pilot sites

Zaadnoordijk et al. (2021)
Bianchi et al. (2021)

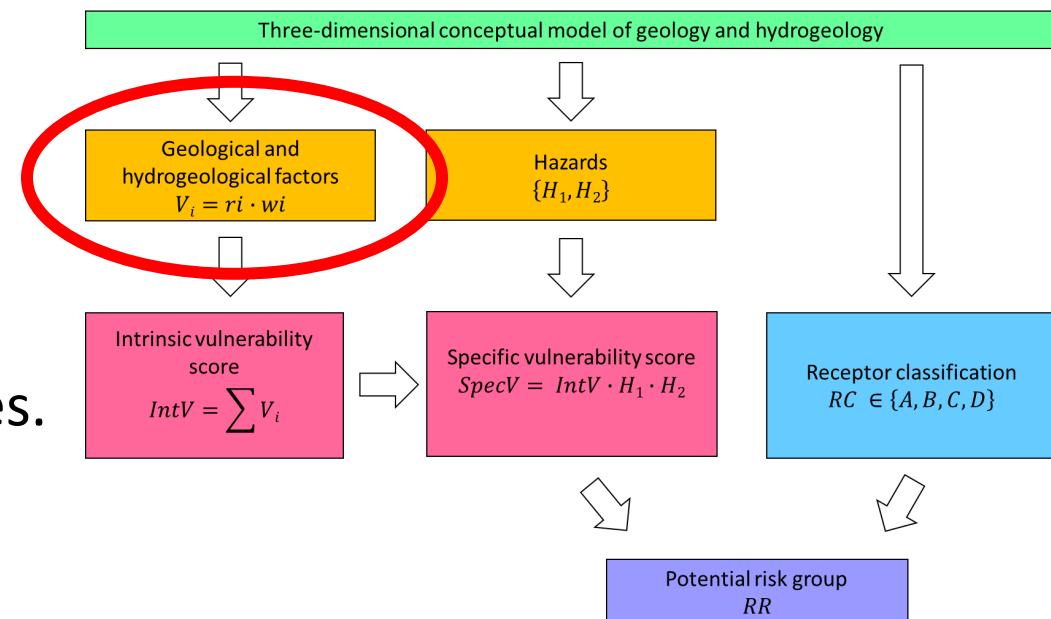


Potential receptor classification	Specific Vulnerability score			
	< 250	250-500	500-750	>750
A	Medium/Low	Medium/High	High	High
B	Low	Medium/Low	High	High
C	Low	Low	Medium/Low	High
D	Low	Low	Low	Low



Intrinsic vulnerability assessment

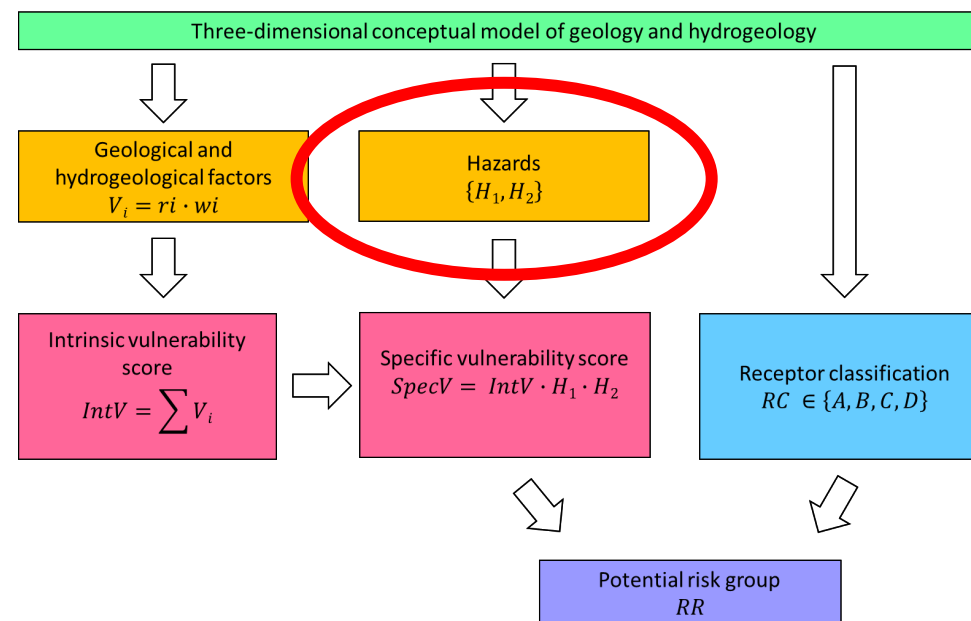
- Intrinsic vulnerability score factors:
 1. Vertical and lateral separation between source and the receptor;
 2. Low perm units (e.g. mudstones) between source and the receptor;
 3. Groundwater flow potential;
 4. Presence of faults;
 5. Presence of solution features;
 6. Anthropogenic features – mines;
 7. Anthropogenic features – boreholes.



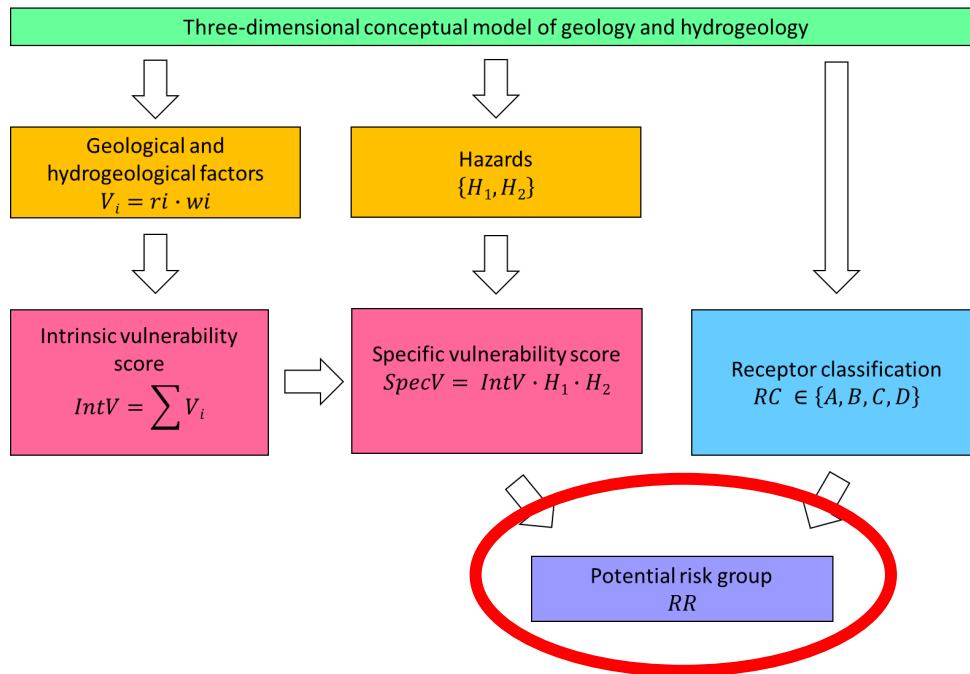
Hazard assessment

- **Specific vulnerability** of receptor depends on the type of energy-related activity; more specifically, on the hazards posed by the activity on the quality of groundwater resources

- Two factors:
 - 1) Release mechanism (H_1)
 - 2) Head gradient driving flow (H_2)



Potential receptor classification	Specific Vulnerability score			
	< 250	250-500	500-750	>750
A	Medium/Low	Medium/High	High	High
B	Low	Medium/Low	High	High
C	Low	Low	Medium/Low	High
D	Low	Low	Low	Low



Risk assessment

Geological unit	Receptor classification	Intrinsic Vulnerability Score (IntV)	Hazard Score (H1xH2)	Specific Vulnerability Score (SpecV)	Risk group
Kimmeridge Clay Fm.	B	33.5	8	268	Medium/Low
Corallian Group	A	41	8	328	Medium/High
Oxford Clay Fm.	D	26.5	8	212	Low
Ravenscar Fm.	B	33.5	8	268	Medium/Low
Lias Group	C	31.5	8	252	Low
Mercia Mudstone Group	C	37	8	296	Low
Sherwood Sandstone Group	B	42	8	336	Medium/Low
Zachstein Group	D	38	8	304	Low
Millstone Grit Group	D	51	8	408	Low
Bowland Shale					
CONFIDENCE		Low	Low	Low	



Vulnerability screening tool available for download

The screenshot displays the Microsoft Excel interface for the file 'GWV3D_VoGERA_v1.2.ods'. The ribbon includes tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, View, Add-ins, Help, and Team. The Home tab is active, showing options for Clipboard, Font, Alignment, Number, Styles, Cells, and AutoSum. The spreadsheet content includes the European Union flag and text about Horizon 2020 funding, the VoGERA logo, and logos of partner organizations: BGS, TNO, Vlaamse overheid, SCK·CEN, MBFSZ, and GEUS. The title 'Groundwater Vulnerability assessment for deep subsurface energy-related activities, Release v1.0' is highlighted with a green box. Below the title, a text box describes the 3D GWV screening methodology. At the bottom, a row of navigation tabs is visible: Introduction, Site_details, Method_notes, Geological_sequence, Hazard_assessment, and Vulnerability_assessment.

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VoGERA

GeoERA

BGS British Geological Survey TNO innovation for life Vlaamse overheid SCK·CEN MBFSZ MINING AND GEOLOGICAL SURVEY OF HUNGARY GEUS

Groundwater Vulnerability assessment for deep subsurface energy-related activities, Release v1.0

The 3D Groundwater Vulnerability (3D GWV) screening methodology assesses the vulnerability of hydrogeological receptors (groundwater) from deep sub-surface energy-related industrial activities including geothermal energy production, conventional and unconventional oil and gas exploitation, sub-surface storage, and disposal of wastes. This spreadsheet tool, which is largely based on the method developed by the British Geological Survey and the Environment Agency in England (Loveless et al., 2018; 2019), implements the 3D GWV methodology to determine the qualitative risk to each potential receptor from an assessment of both intrinsic and specific vulnerabilities. Intrinsic vulnerability considers geological factors (e.g. separation distance between the subsurface activity and a potential receptor) and the presence of existing preferential flow paths connecting potential sources of contamination introduced by the industrial activity and the receptor(s). Specific vulnerability combines the intrinsic vulnerability with a hazard score. The hazard score considers the hydraulic (pressure) gradient between the potential contaminant source and the receptor(s), and any anthropogenic modifications of the hydraulic properties and/or natural

Introduction Site_details Method_notes Geological_sequence Hazard_assessment Vulnerability_assessment

https://repository.europe-geology.eu/egdidocs/vogera/GWV3D_VoGERA.ods

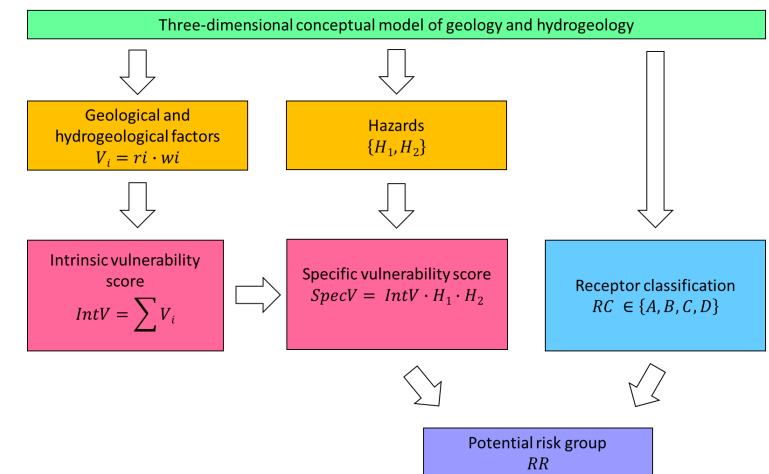
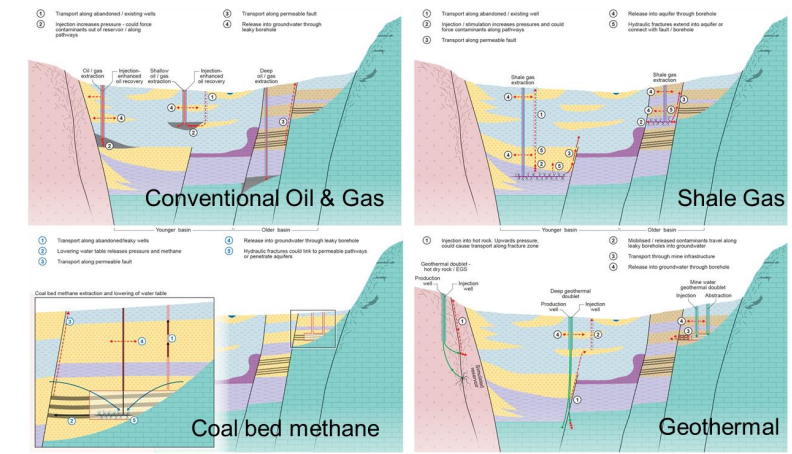


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Key project results

1. Conceptual models to characterize groundwater vulnerability and identify potential contaminant pathways
2. Novel methodology for assessing the vulnerability of shallow groundwater from deep industrial activities
3. Detailed studies of GW vulnerability for four pilot areas across Europe



Project Impact

1. Improved understanding of GW vulnerability in relation to deep energy related activities
2. Introduced a consistent approach and tool
3. Improved cooperation and knowledge-sharing between subsurface experts and stakeholders including regulators and water companies
4. Improved understanding of contamination pathways and impact of subsurface activities on GW in four strategic areas across Europe

