VoGERA

Vulnerability **O**f shallow **G**roundwater resources to deep sub-surface **E**nergy **R**elated **A**ctivities

Final GeoERA meeting

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

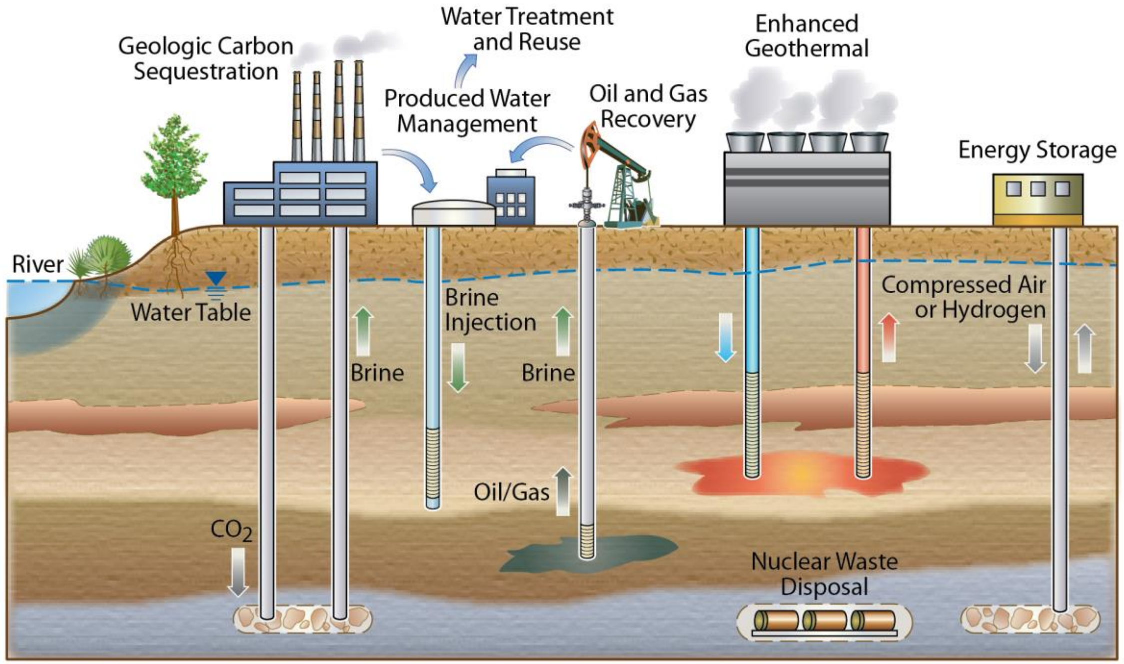
GeoERA GROUNDWATER

Energy related activities in the sub-surface

1. *Conventional oil and gas*
2. *Shale gas*
3. *Coal bed methane*
4. *Geothermal (low/high enthalpy)*
5. *Energy and gas storage*

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

Impact on groundwater quality?



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

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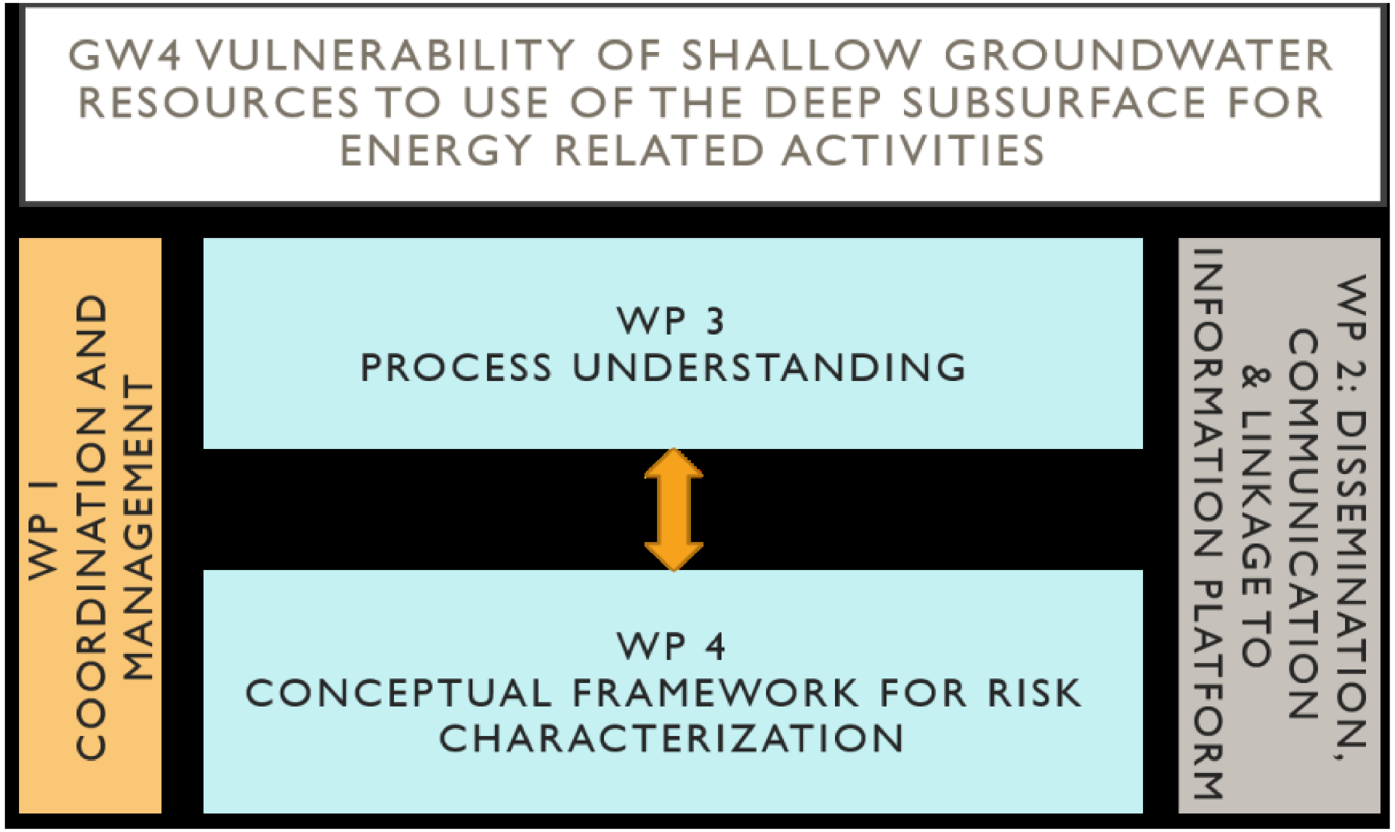
GeoERA GROUNDWATER

Project structure



6 Partners:

- BGS
- TNO
- VMM
- SCK CEN
- MBFSZ
- GEUS

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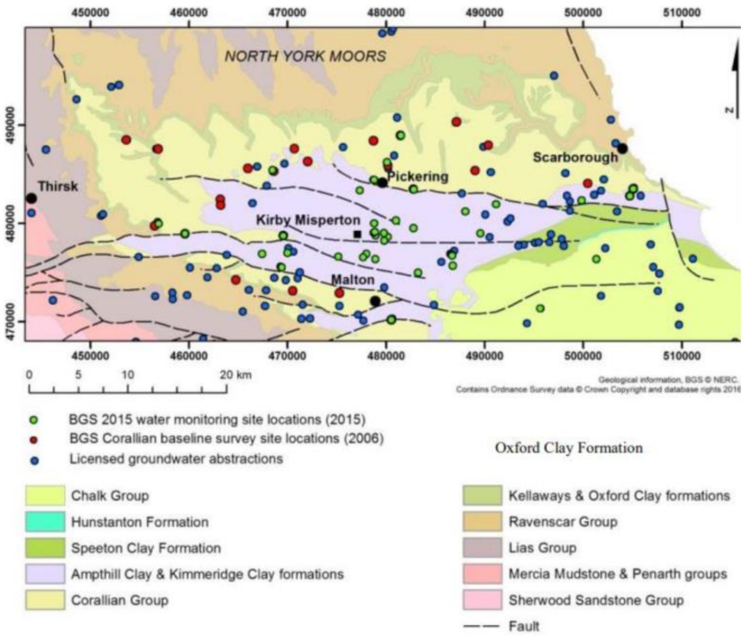
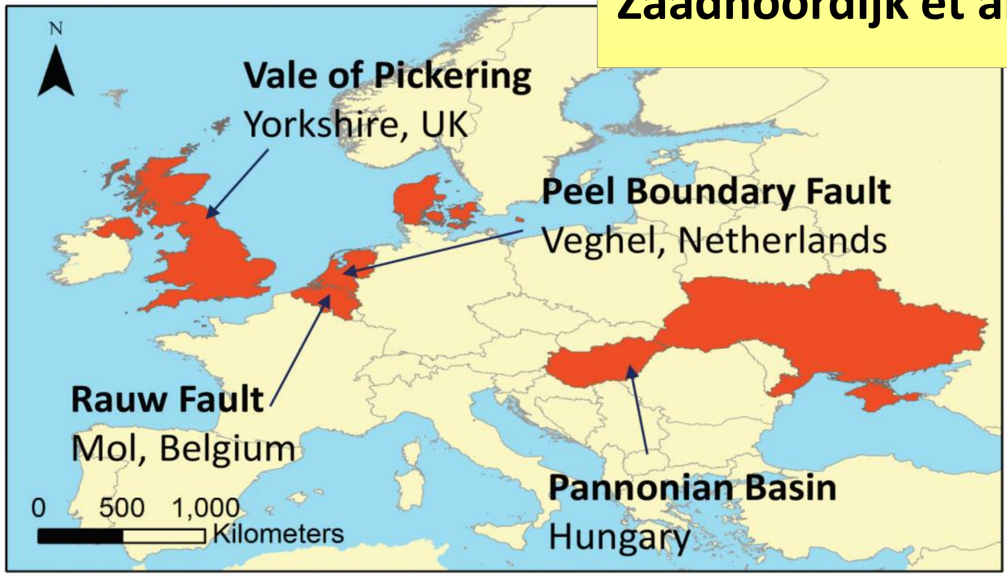
WP 3 – Process understanding

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

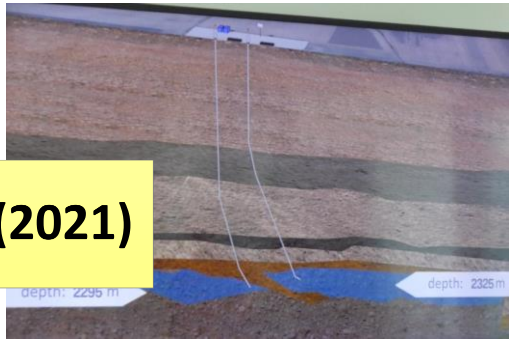
Zaadnoordijk et al. (2021)

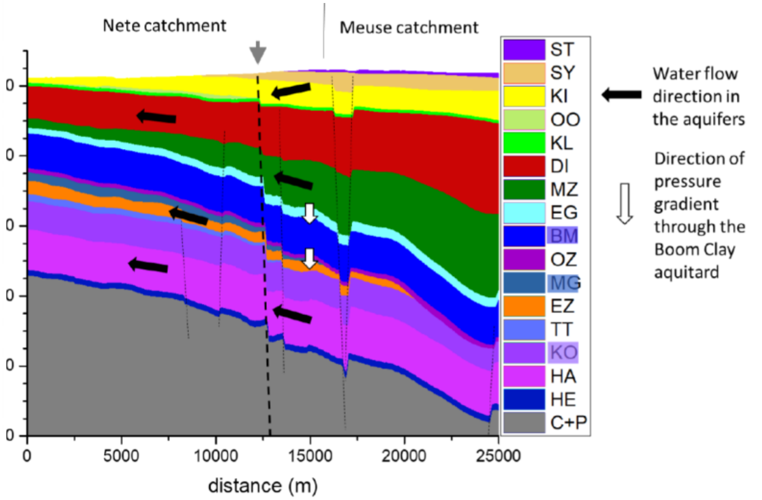


Conventional + unconventional O&G



Geothermal





Storage + Geothermal

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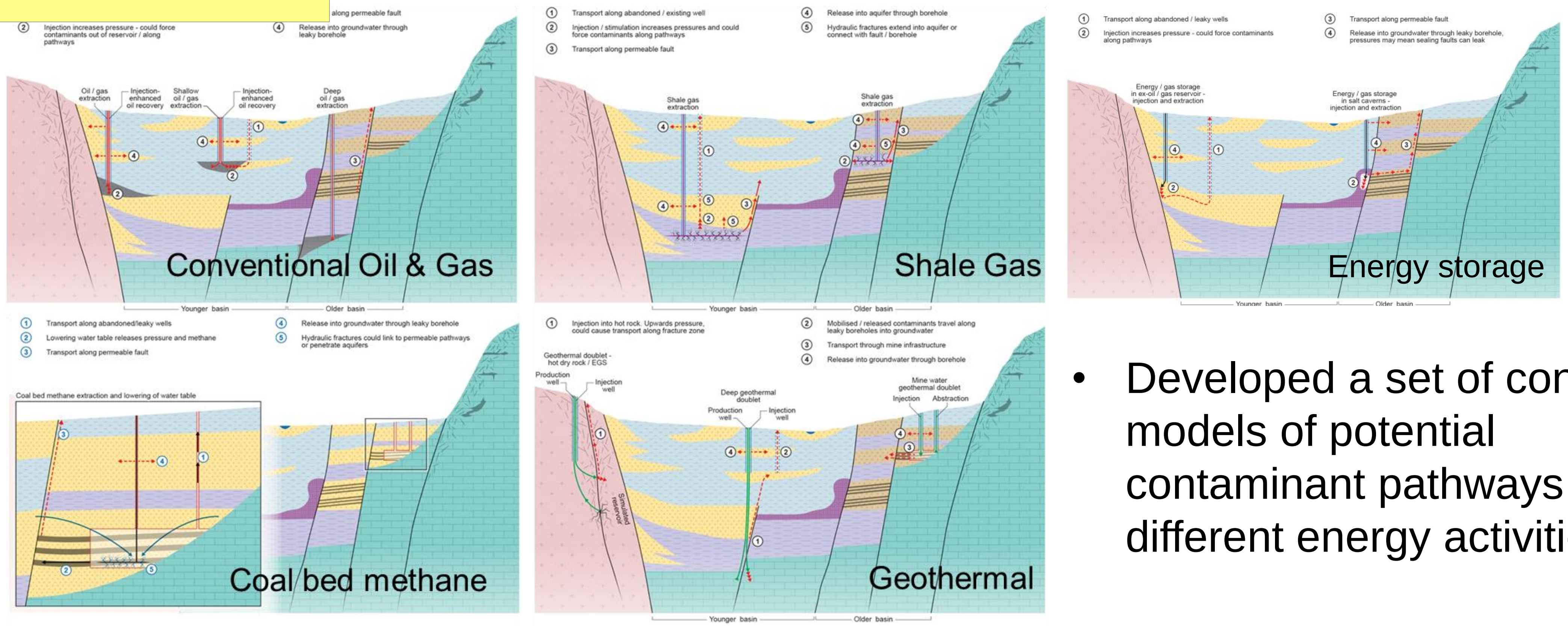
GeoERA GROUNDWATER

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

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Contaminant Pathways comparison

	Activity			
Pathway	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 infrastructur e	
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

Loveless et al. (2019)

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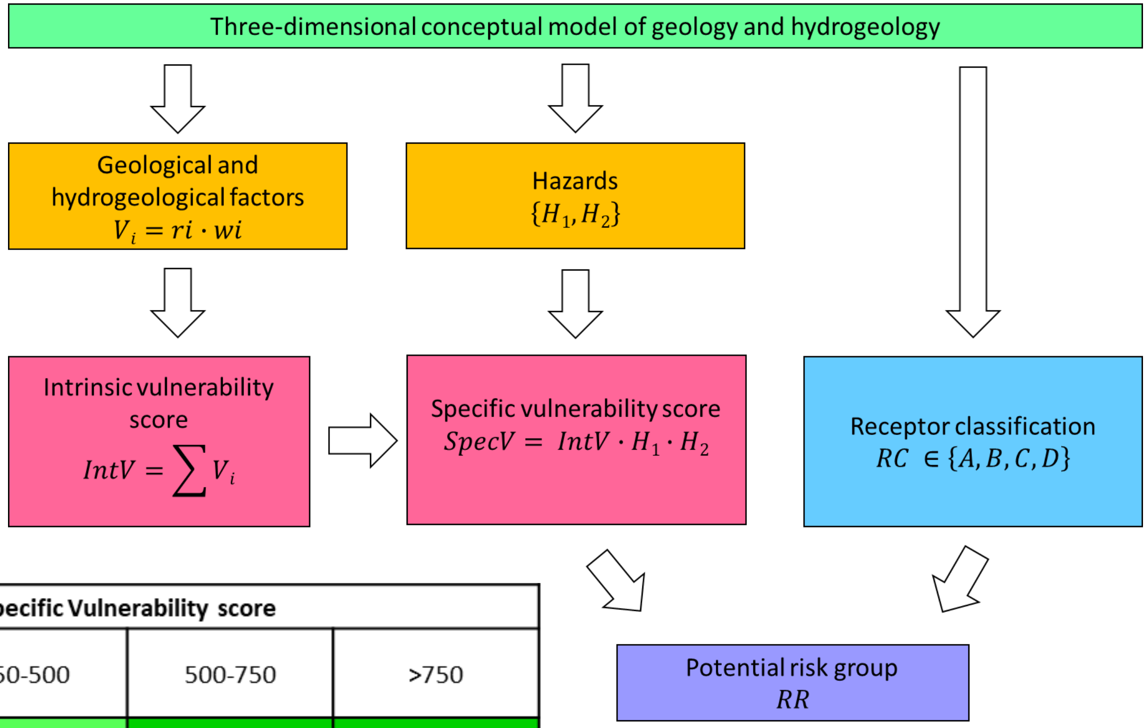
WP 4 – Conceptual framework for vulnerability characterisation

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

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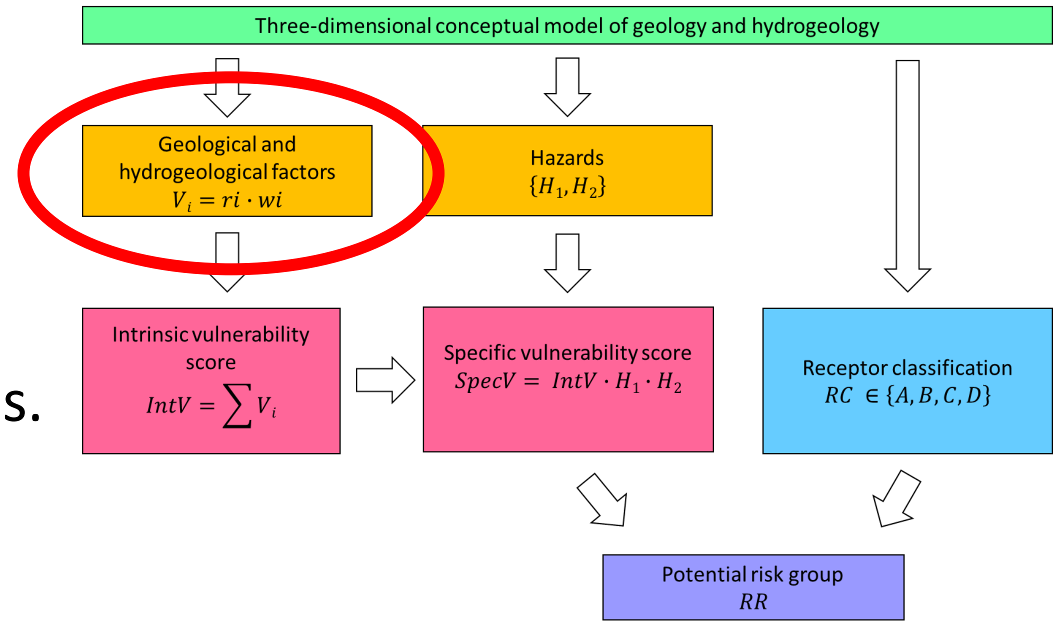
Intrinsic vulnerability assessment

- 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.



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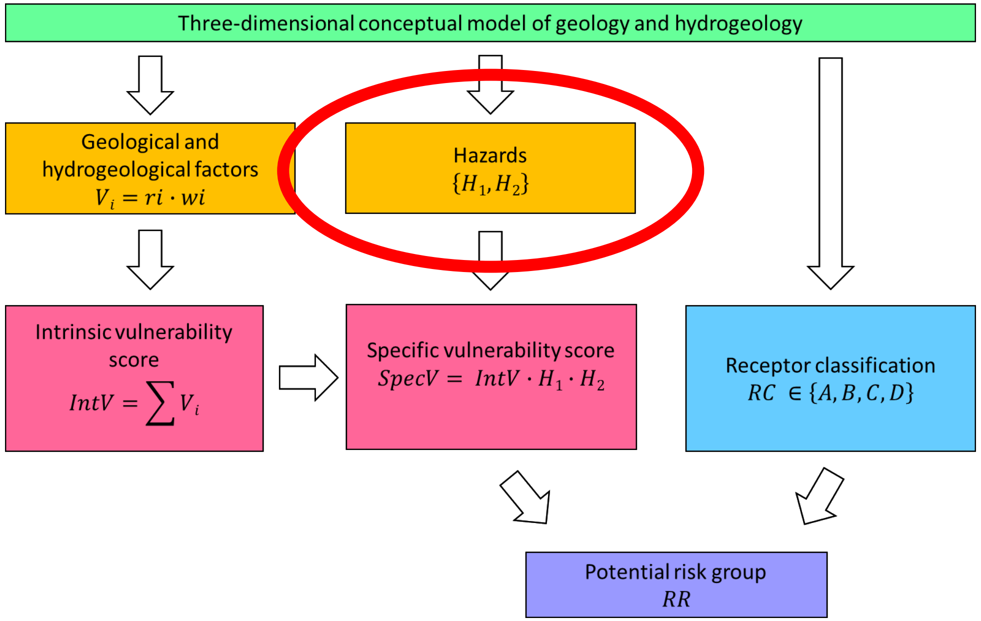
Hazard assessment

- **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)



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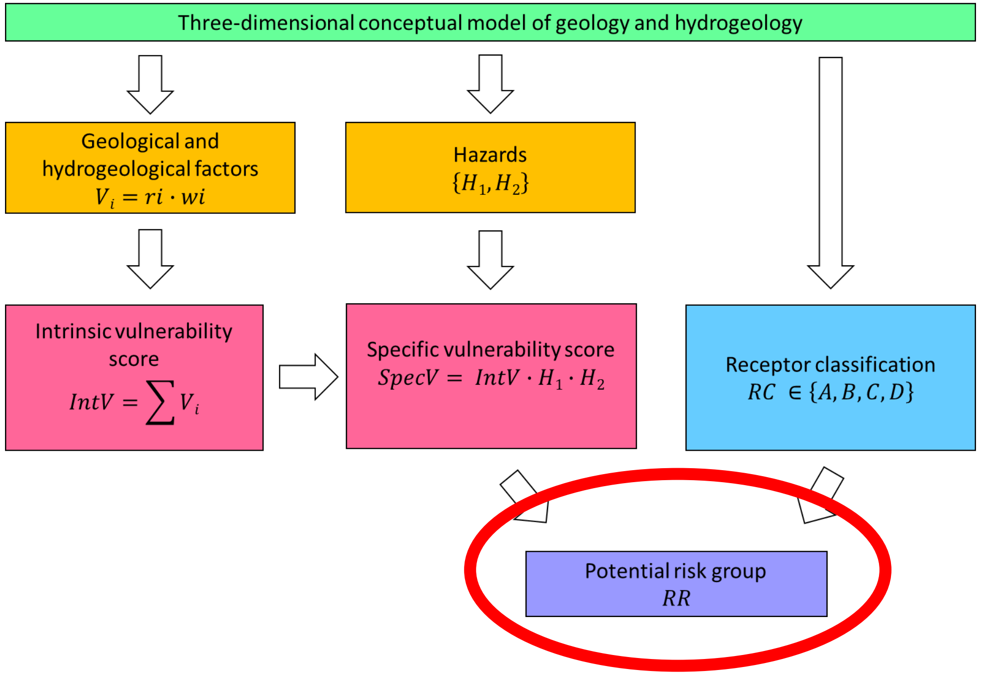
Risk assessment

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



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	

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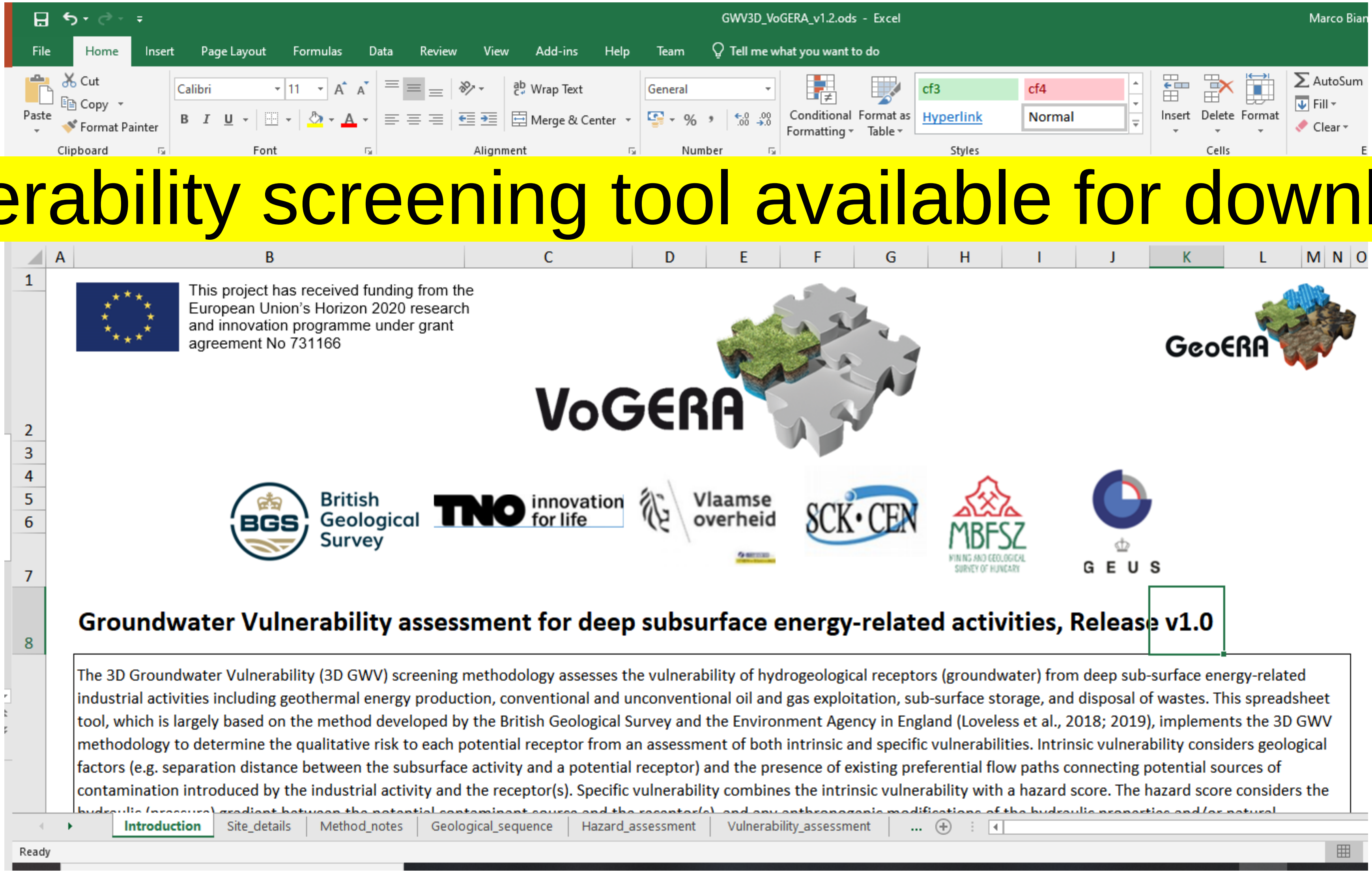
Vulnerability screening tool available for download



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

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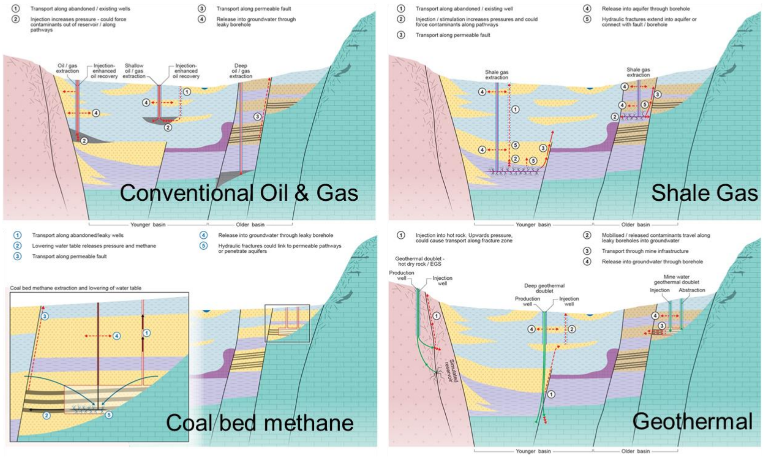
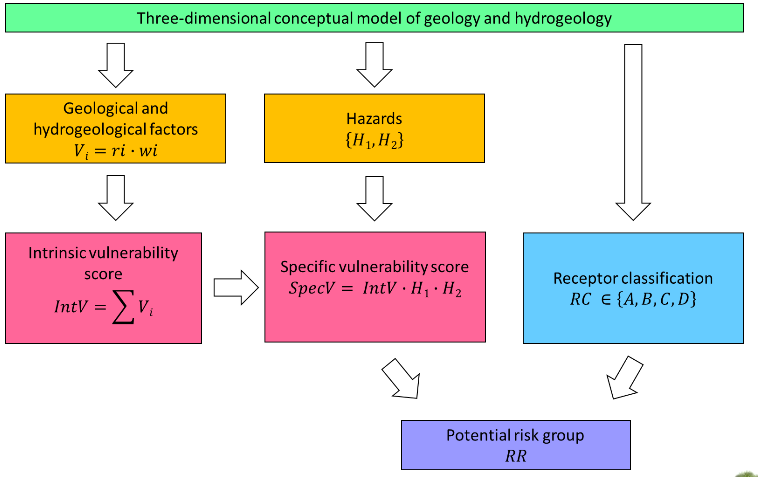
Key project results

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





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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

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