Accelerating CCS Technologies

D E T E C T

INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

Work Package 5

Qualitative & Quantitative Risk Assessment

The project has been subsidized through the ERANET Cofund ACT (Project no. 271497), the European Commission, the Research Council of Norway, the Rijksdienst voor Ondernemend Nederland, the Bundesministerium für Wirtschaft und Energie, and the Department for Business, Energy & Industrial Strategy, UK.

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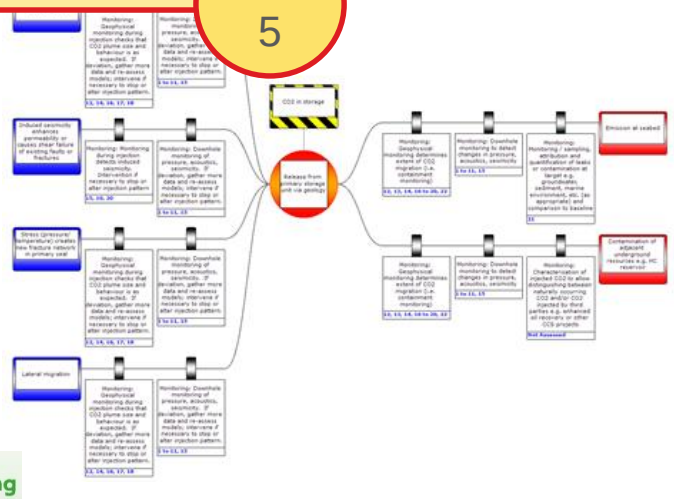
DETECT workflow

The goal of DETECT is to assess geological leakage risks related to fault and fractures in caprocks

Geological Leakage Risk Assessment

Incorporate all modelling and monitoring barriers in a qualitative bowtie risk assessment framework with associated quantitative scenario modelling tool

WP 5



Identify active monitoring barriers relevant for site and expected leakage rates

Modelling results inform effectiveness of passive barriers (in seals and secondary storage units)

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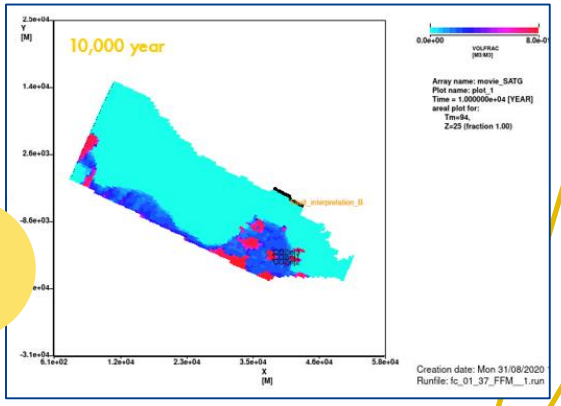

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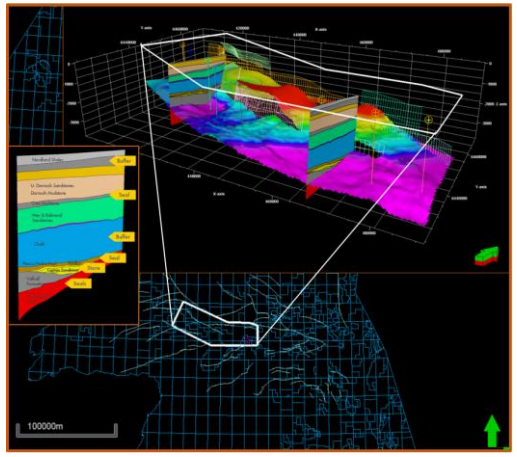

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Effective fracture + matrix vertical permeability, RLP, CPR for each cell in seal derived from numerical up-scaling

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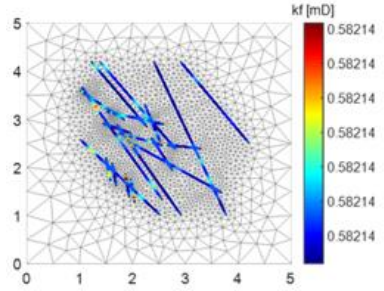
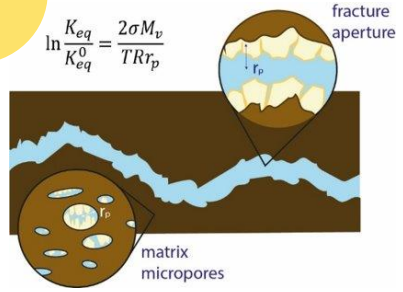


WP 2

Experimentation and numerical modeling to characterise single fracture processes



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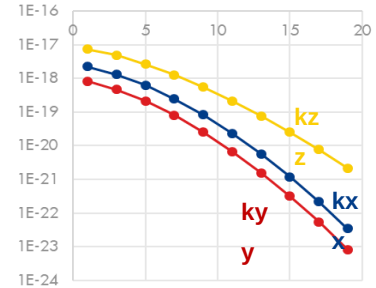

Characterise fault-fracture networks using analogue derived scaling relations: fault throw-length-frequency

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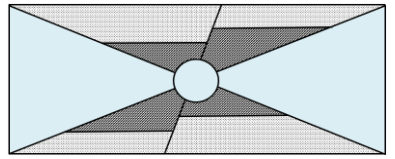

INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

WP5 objectives

- Generate guidance bowties for
  - providing an overall picture of the paths via which CO_2 could leak from subsurface storage
  - improving efficiency, as a starting point for future risk assessment
  - communicating subsurface storage risks and prevention/mitigation measures
- Develop a quantitative risk assessment model aligned to the bowtie to calculate relative risks of CO_2 leaking through fractures in the caprock
- Integrate learnings from other work packages

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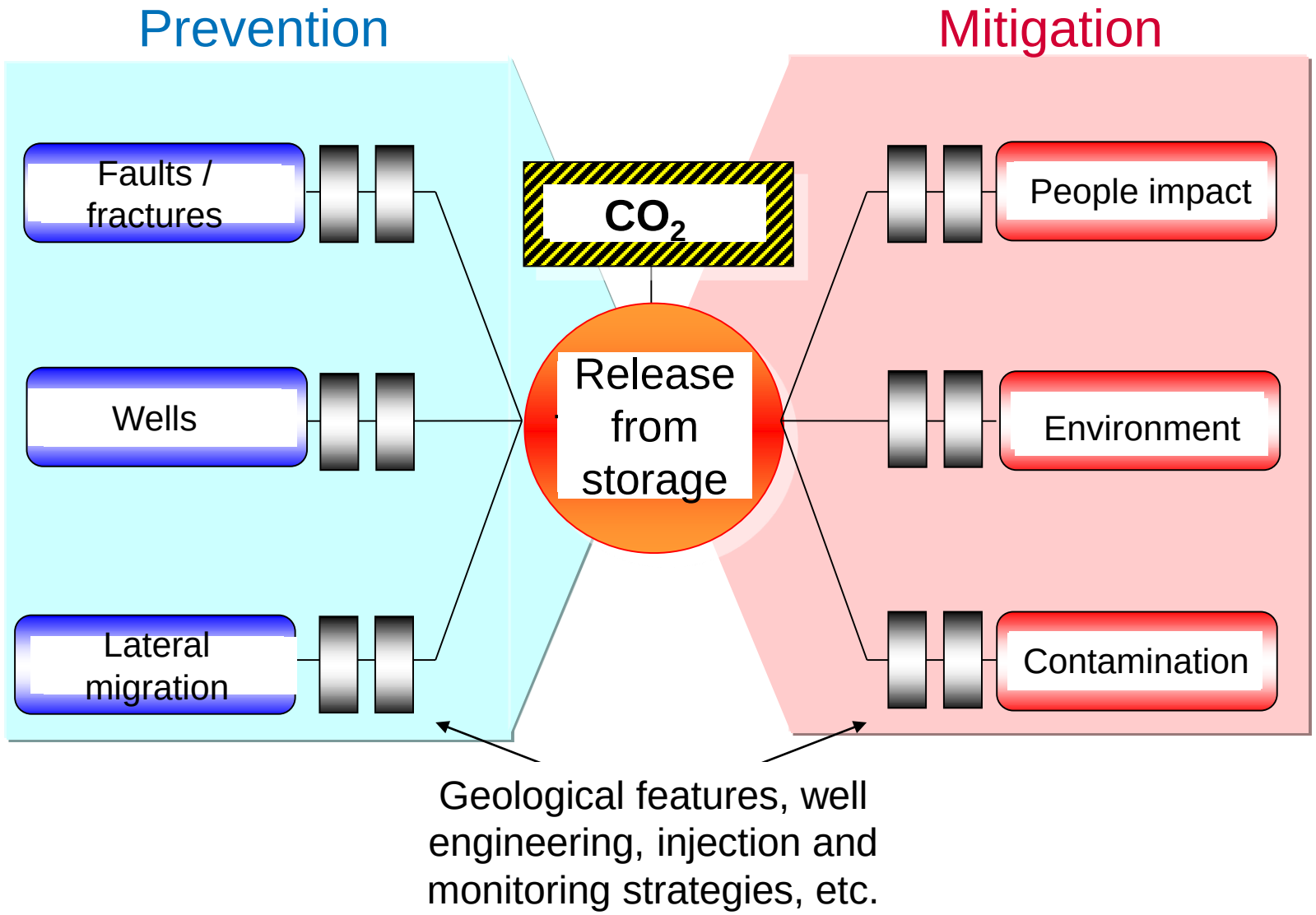
Bowtie analysis - introduction



- Communication
- Understanding
- Holistic representation
- Weaknesses

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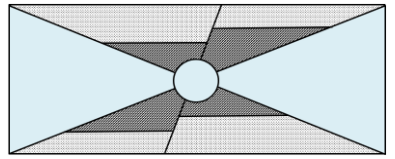

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Bowtie analysis – bowtie model

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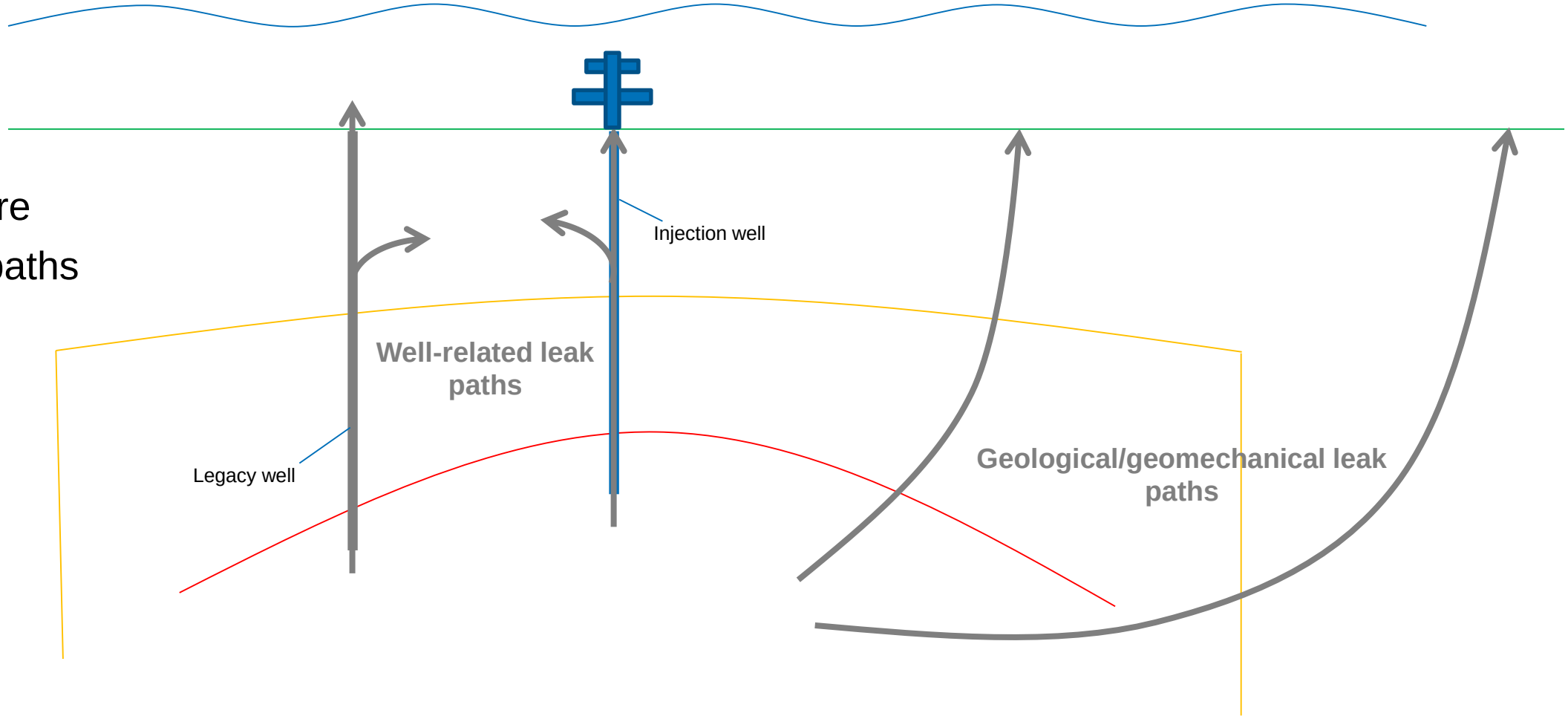
INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

- Big picture
- All leak paths



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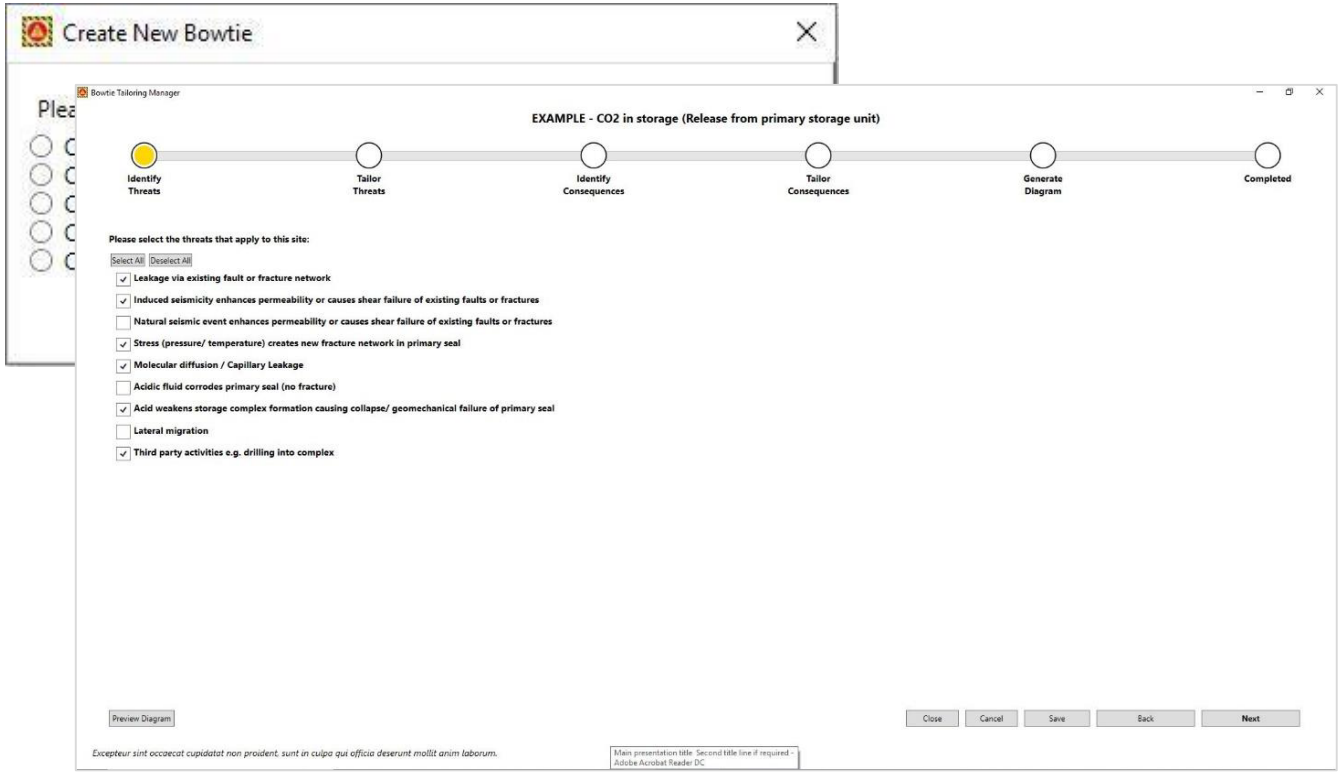
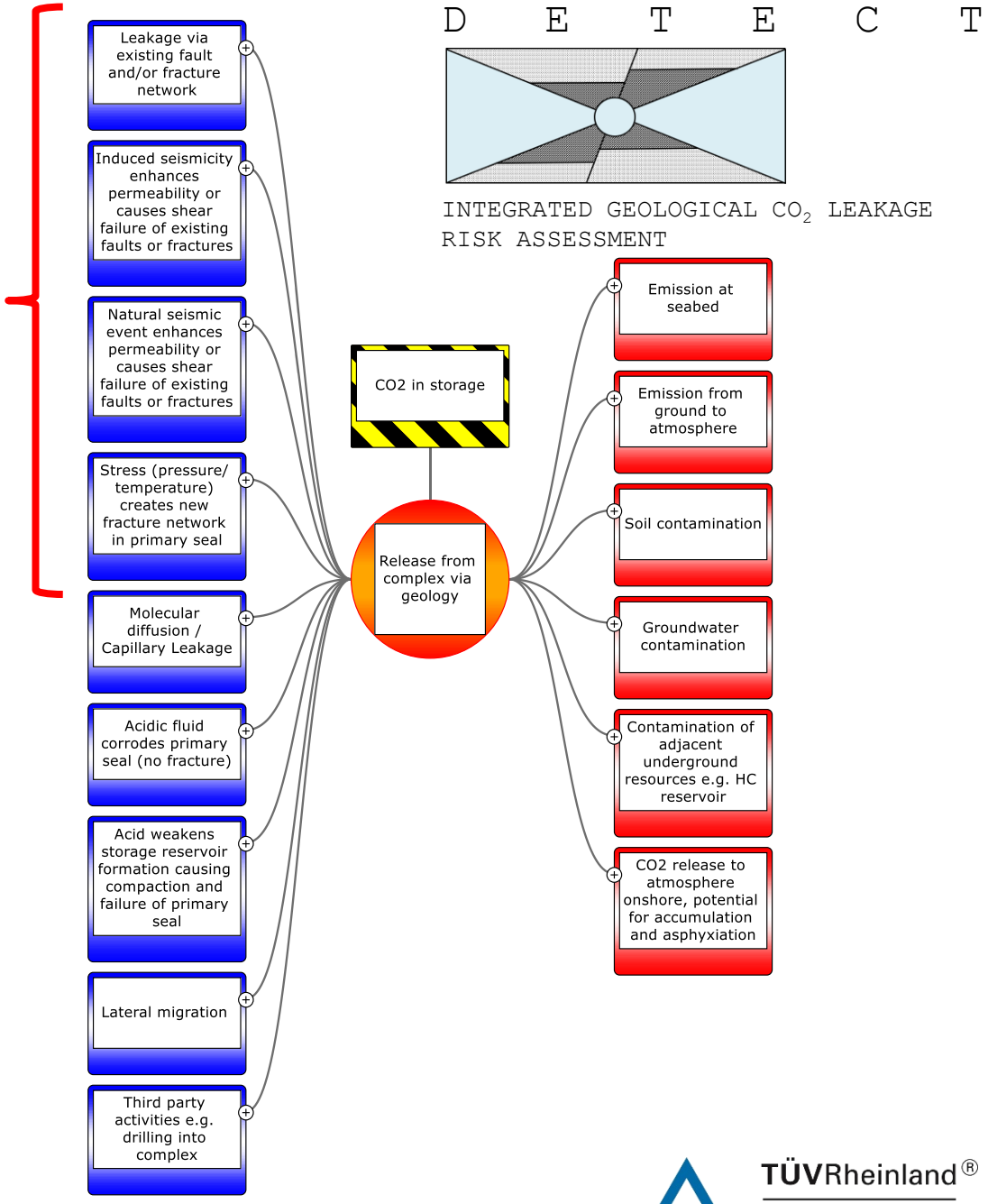
Bowtie analysis – template bowties

- Transferrable
- Starting point
- Guidance



CO_2 flow through fractures



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Bowtie analysis – template bowties detail

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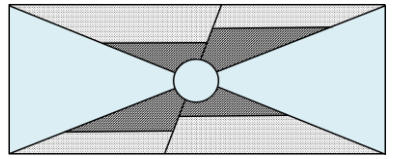

INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

Leakage via existing fault and/or fracture network

Well positioning: Wells positioned away from existing faults

Geological Properties: Fracture network connectivity - size, density and orientation of fractures to provide a pathway out of the storage complex

Geological Properties: Geological properties of existing faults and fractures act to limit vertical flow up towards the surface

⊕

alter injection

UNCERTAINTY (quality and completeness of supporting activities)	
Low	Data from supporting activities have been obtained in accordance with accepted good practice using effective and reliable systems and techniques.
Med	Data from supporting activities have been obtained in accordance with accepted good practice using generally reliable systems and techniques, but may have some weaknesses or areas of omission.
High	No data is available or data from supporting activities have been obtained using generally unreliable systems and techniques or have significant weaknesses or areas of omission.

BARRIER EFFECTIVENESS (presence and inherent properties)	
Good	Disconnected fracture network below percolation threshold. No fractures/faults observed in the reservoir or top-seal and (based on scaling relation and/or analogues), sub-seismic faults are unlikely to have a fracture network above percolation threshold.
Fair	Fractures and faults observed in the reservoir. Some faults/fractures may be observed in the top-seal, but no throughgoing faults, and (based on scaling relation and/or analogues), sub-seismic faults are unlikely to have a fracture network above percolation threshold. There is no evidence of historical leakage through faults and fracture networks, for example CO2 plumes, gas in overburden.
Poor	Highly connected network above percolation threshold. Throughgoing faults and/or high-density fractures observed in the top-seal. There is evidence of historical leakage through faults and fracture networks, for example CO2 plumes, gas in overburden.

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Bowtie analysis – link with monitoring (WP4)

- Red barriers = monitoring

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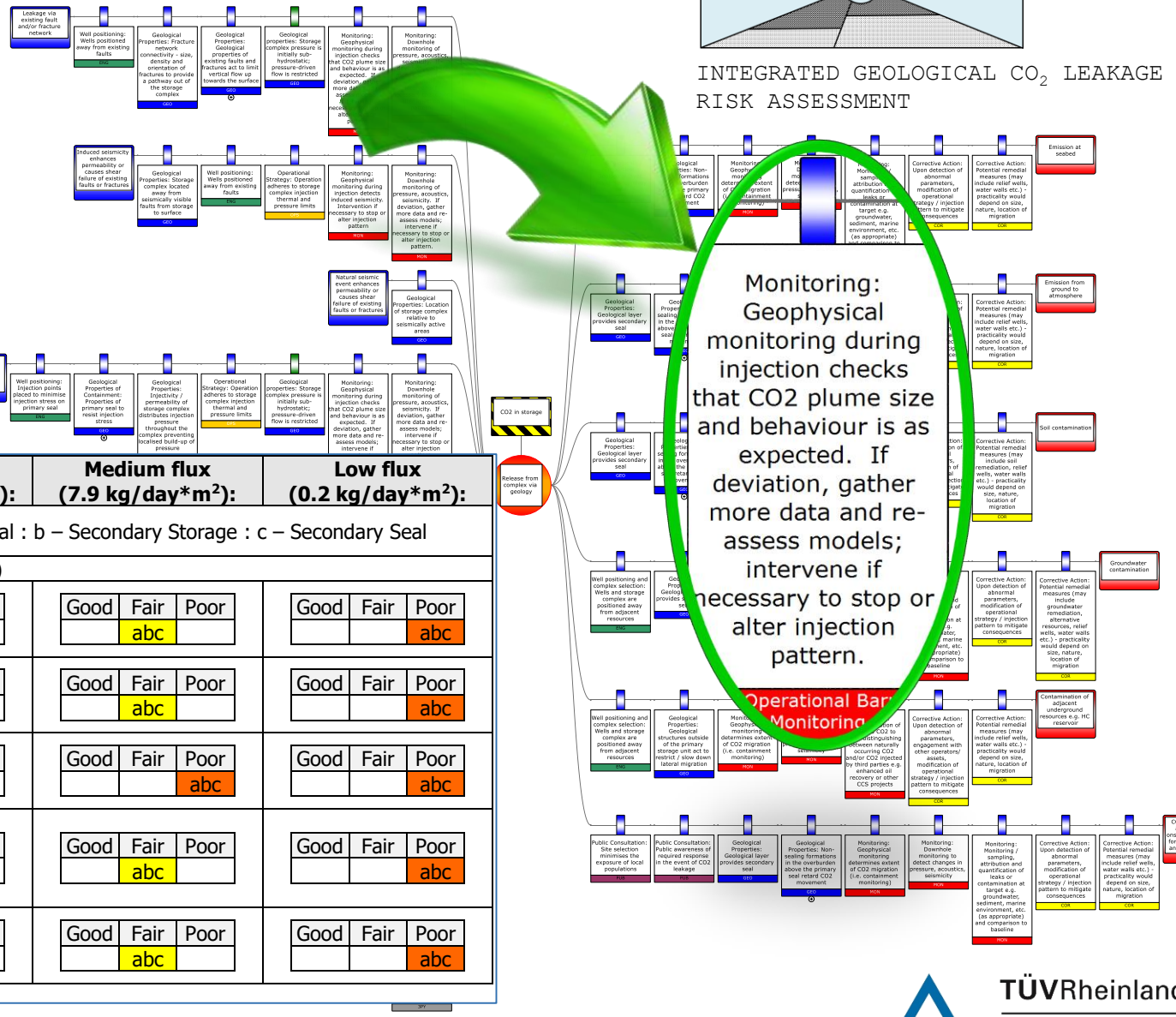
INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT



Bowtie : Release from primary storage unit via geology		**High flux (1363 kg/day*m²):**	**Medium flux (7.9 kg/day*m²):**	**Low flux (0.2 kg/day*m²):**
Monitoring barrier on bowtie	**Potential Monitoring Technology**	a – Primary Seal : b – Secondary Storage : c – Secondary Seal		
Release from primary storage unit via geology – prevention measures (left side of bowtie)				
Geophysical monitoring during injection checks that CO_2 plume size and behaviour is as expected. If deviation, gather more data and re-assess models; intervene if necessary to stop or alter injection pattern. (12, 14, 16, 17, 18)	12 Time-lapse DAS VSP reflection survey	Good: b; Fair: a c; Poor:	Good: ; Fair: abc; Poor:	Good: ; Fair: ; Poor: abc
	14 Time-lapse cross-well seismic	Good: b; Fair: a c; Poor:	Good: ; Fair: abc; Poor:	Good: ; Fair: ; Poor: abc
	16 Time-lapse surface seismic with streamers (narrow azimuth)	Good: ; Fair: abc; Poor:	Good: ; Fair: ; Poor: abc	Good: ; Fair: ; Poor: abc
	17 Time-lapse Ocean Bottom Nodes (OBN) or Ocean Bottom Cables (OBC) or Permanent Reservoir Monitoring (PRM)	Good: ; Fair: abc; Poor:	Good: ; Fair: abc; Poor:	Good: ; Fair: ; Poor: abc
	18 Time-lapse high resolution seismic	Good: ; Fair: abc; Poor:	Good: ; Fair: abc; Poor:	Good: ; Fair: ; Poor: abc

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Bowtie analysis – child bowtie

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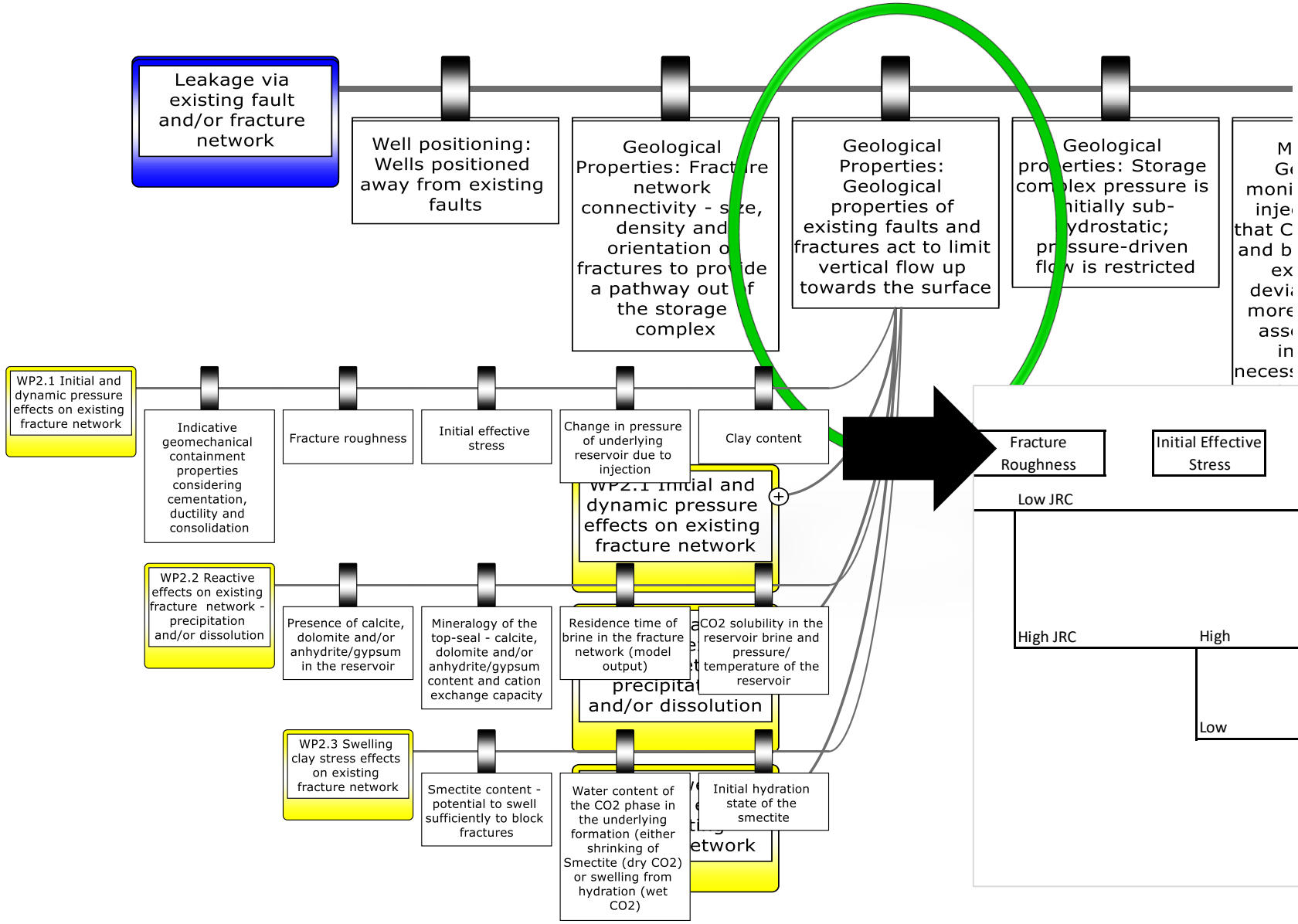

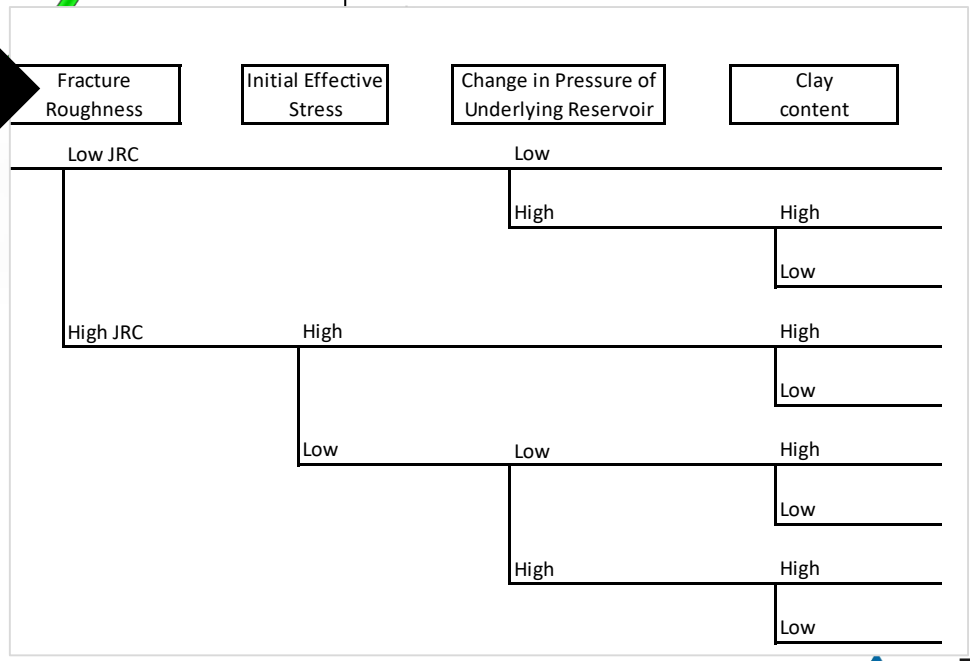

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Quantitative risk tool

- Documented process so users can develop their own site-specific quantitative tool
- Not constrained to using MoReS

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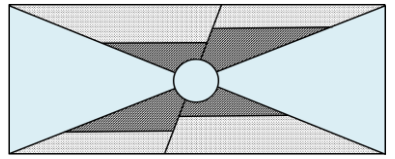

INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

User inputs sampled, appropriate data store cases identified, distribution of outputs generated using Monte Carlo Analysis.

User interface
Input Parameters
(low, high, best estimate, N iterations)

Predictive module
Sample Parameters
Predict & Record Flow

Output display
Flow Distribution

Uncertainties in outputs determined from input parameter distributions

Predictive module output is fitted to the training data using a Bayesian approach (Gaussian Process Regression)

Sampled data used to train predictive module. Sampling strategy based on Sobol sequences.

Fitted models – used for predictions

Data store - flow simulation results for credible range of all input parameter values

Pre-prepared data store using MoReS (from WP3)

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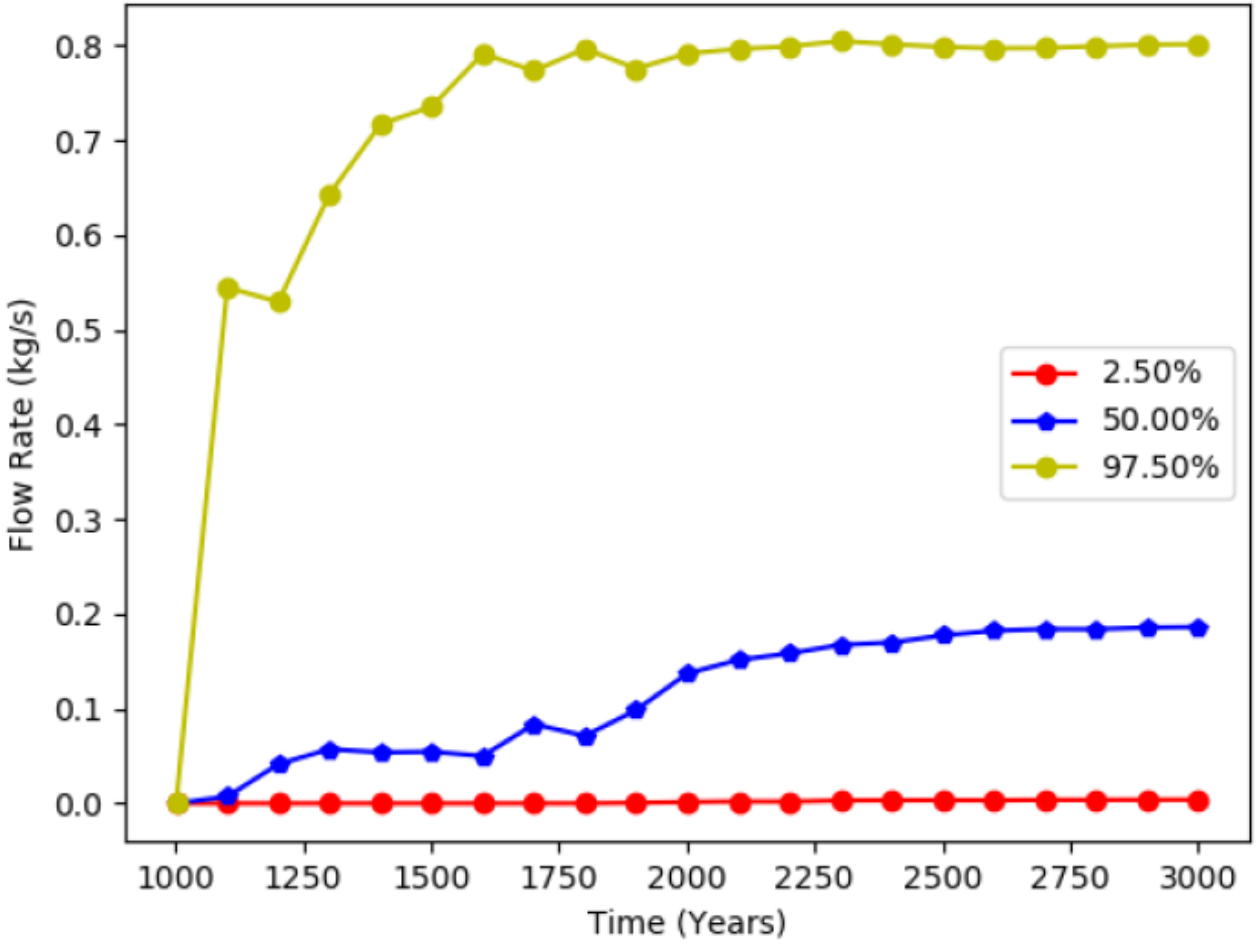
INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

Quantitative risk tool

- Flow rate v probability and time
- User can vary certainty range
- Can predict flow rate at primary caprock, secondary caprock, etc. (depending on underlying data store content)
- Also predicts CO_2 flux (to better link with monitoring plans)
- Simple and quick to use
- Good for comparison purposes e.g. range of input parameters
- Can input into MMV plans



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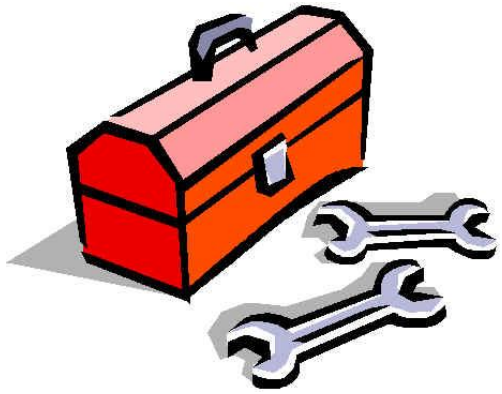
WP5 Deliverables

WP5 has delivered a suite of qualitative, semi-quantitative and quantitative risk assessment tools, integrated with WP2, WP3 and WP4.

- Documents:
  - Literature Survey
  - Quantitative Model Specification
  - Quantitative Model Methodology and Validation
  - Quantitative Model User Guide
  - Bowtie Analysis
  - Risk Assessment Guide



- Tools:
  - Template / guidance bowtie diagrams
  - Bowtie template tool
  - Fault/fracture network child bowtie analyser
  - Quantitative risk tool

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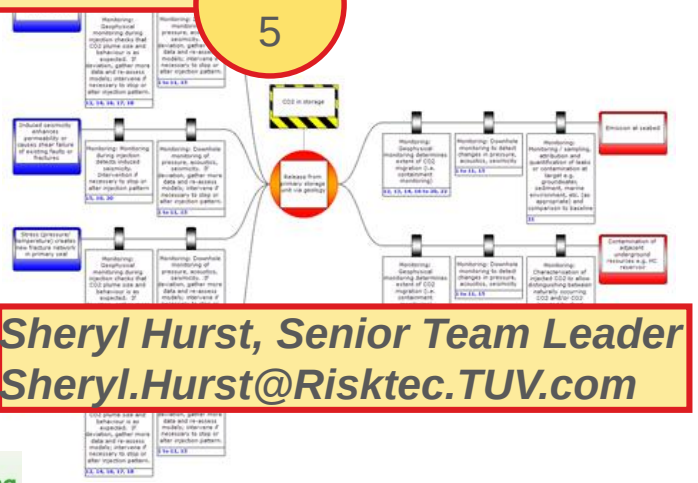

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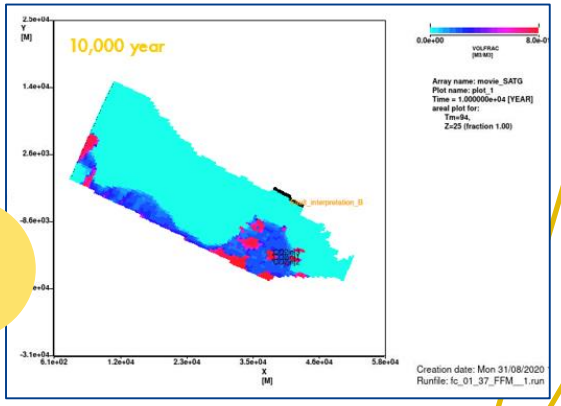

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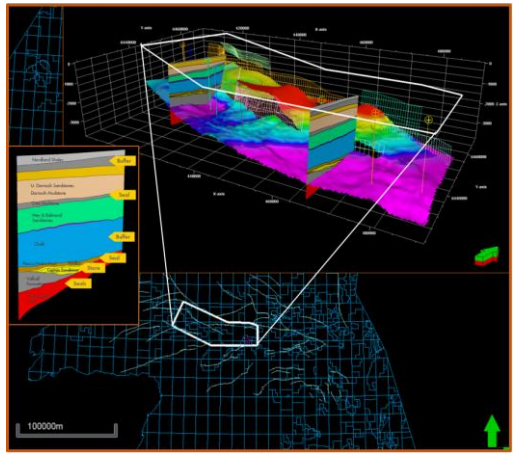

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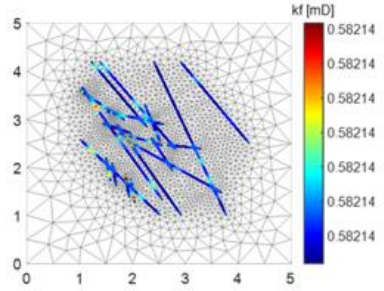

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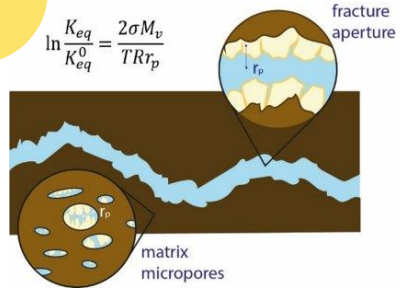

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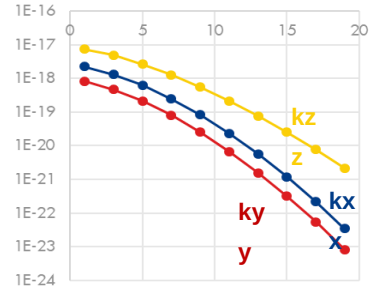

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Sheryl Hurst, Senior Team Leader
Sheryl.Hurst@Risktec.TUV.com

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