



**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Geoscience for our changing Earth

Storage site characterisation to meet regulatory requirements

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Objectives of site characterisation

- Demonstrate understanding of the site for a CO₂ storage permit
- Regulator(s) must be satisfied that:
 - Permit applicant has sufficient understanding of the site
 - Proposed site operation will securely contain CO₂
- Application must comply with regulators requirements (e.g. European CO₂ Storage Directive)

Role of risk assessment in site characterisation

- Site characterisation is:
 - All about understanding the risks to secure containment of CO₂ at a specific site
 - Not to discover interesting things about the geology
- Characterisation is led by risk assessment to
 - anticipate risks,
 - reduce risks
 - mitigate risks
 - monitor unmitigated risks
- Project risk assessment determines what site characterisation activities are needed and not needed
- Ensures resources, time and effort are focused to meet the objective of a storage permit

Risk assessment-led site characterisation, SiteChar project



Characterisation of European CO₂ storage

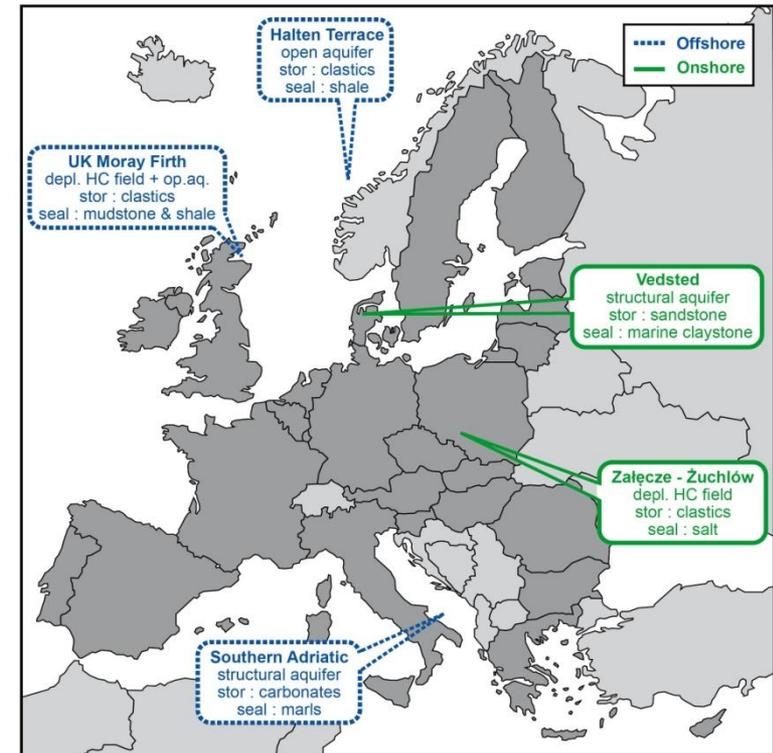


SiteChar project www.sitechar-co2.eu



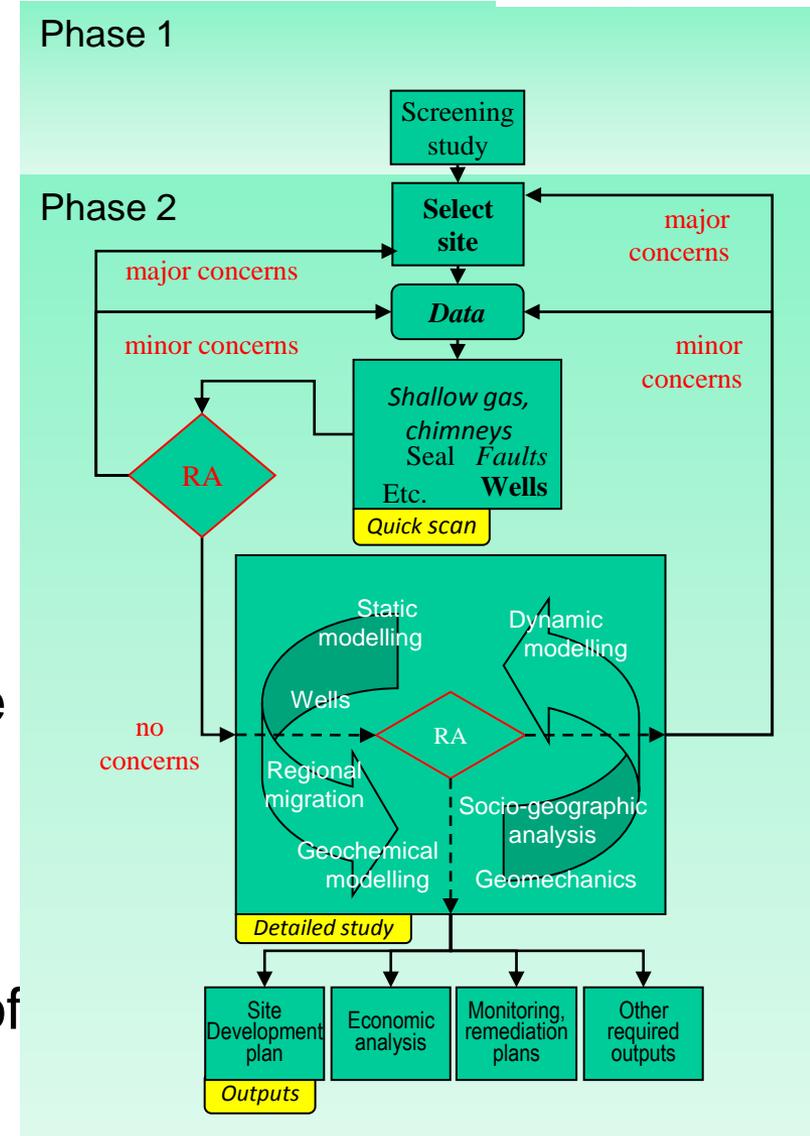
Provide the key steps for large-scale implementation of CO₂ storage in Europe:

- Demonstrate geological site characterisation to meet regulators requirements (EU CO₂ Storage Directive)
- Present a workflow for site characterisation
- Test workflow at 5 feasible European sites
 - Italy, UK, Norway, Denmark & Poland
 - Onshore and offshore
- Develop a method for preparation of a CO₂ storage permit



Workflow for EU site characterisation

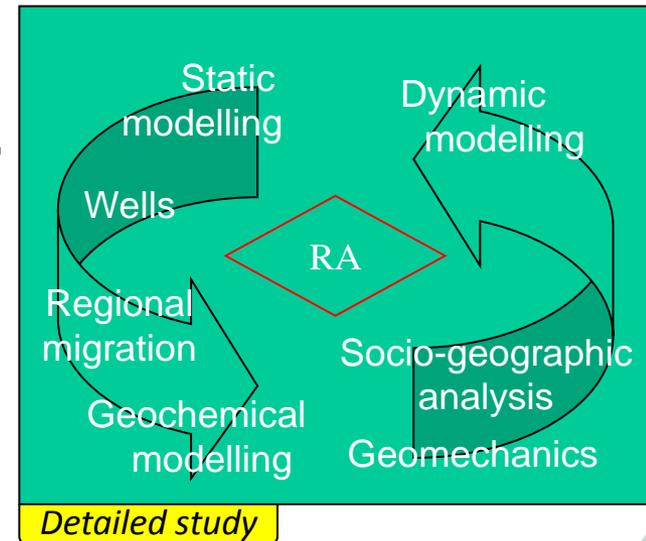
- Workflow illustrates a continuous risk assessment process
- Phase 1 is a screening study for suitable sites
- Phase 2 starts with selection of a site, collection of available data, a quick analysis and first qualitative Risk Assessment
- If there are no concerns then detailed site characterisation study takes place
- Risk assessment continues as characterisation activities targeted to reduce risks
- Results inform required components of a CO₂ storage permit.



Risk-led EU regulatory requirements

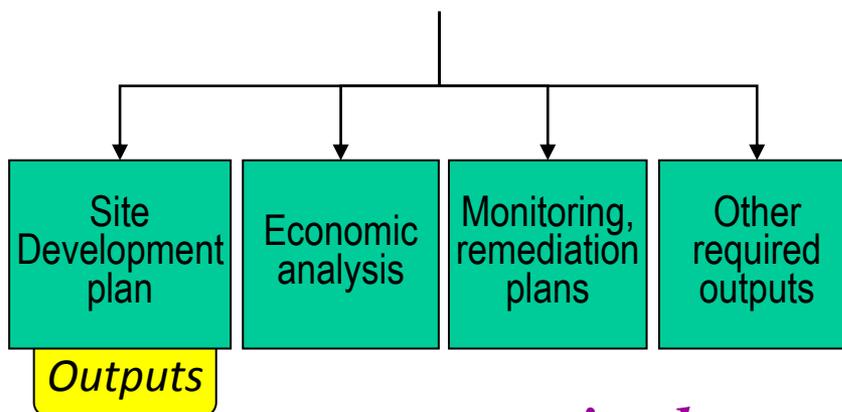
Storage permit components required by EU are determined by risk assessment

- Project description
 - *Injection strategy* - how much CO₂, what rate of injection and for how long
 - *Site design* – definition of the storage site, number of injection and monitoring wells
 - *Storage performance forecast* – predicts the migration of the injected CO₂ and the pressure footprint.
- Site description
 - Geological character of the storage site
 - Storage reservoir strata, primary cap rock, secondary storage strata and secondary cap rocks



Risk-led EU regulatory requirements

- Storage permit components required by EU informed by results of risk assessment
 - *Preventative Measures Plan* – what we will do to mitigate risks and reduce uncertainties
 - *Monitoring Plan* – how we will monitor unmitigated risks
 - *Corrective Measures Plan* – what we will do if our predictions are not correct
 - *Post Closure Plan* – how we will demonstrate the site is suitable for closure



Storage permit application for a multi-store site, northern UK North Sea



Assessment of a multi-store site, comprising

- A depleted hydrocarbon field: *early storage capability*;
- The host saline aquifer sandstone: *greater storage potential, later in the storage cycle*.

Objective:

Characterise a multi-store site sufficient for a 'dry-run' storage permit application

- *All components of a storage permit developed as far as possible by a research project*

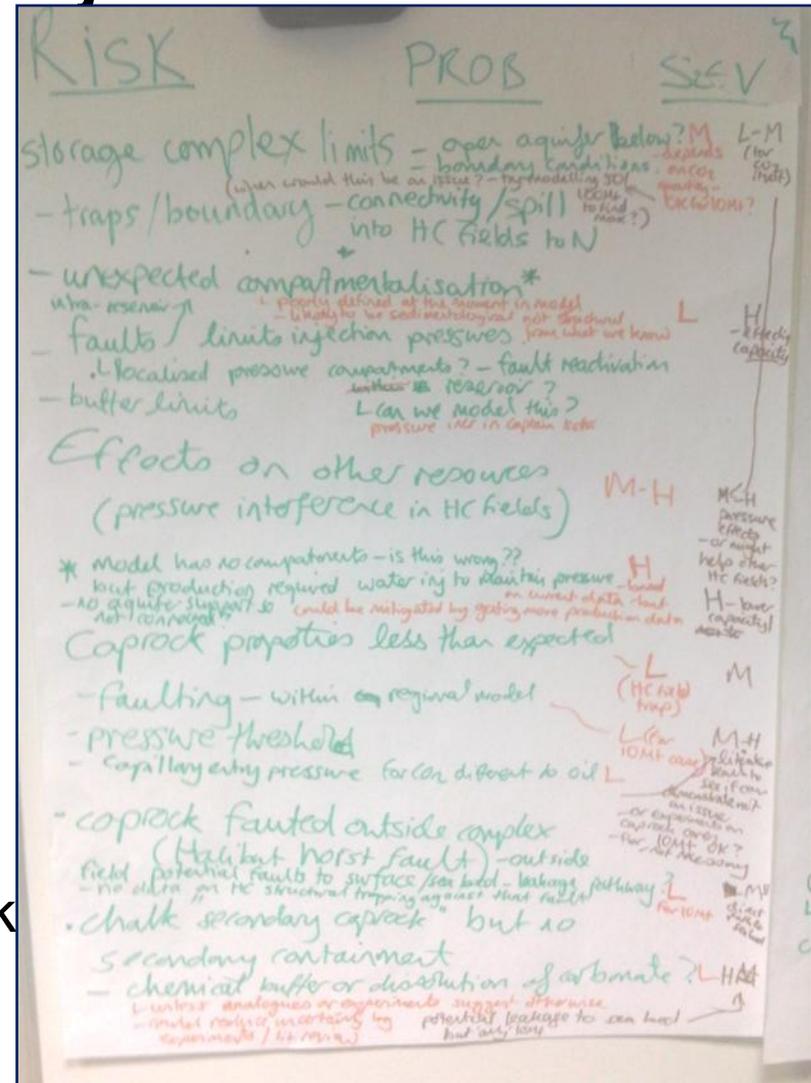


Risk-led characterisation, UK site, SiteChar Project



Risk Assessment workshop

- First project activity
- Participation by all experts including technical and non-technical
- ‘Brainstorming’
- Anticipate risks from existing knowledge and expertise
- Initial assignment of probability of a risk occurring
- Initial assignment of likely severity of consequence if a risk does occur



Risk-led characterisation in SiteChar

- Analyse results from the workshop
- Initial list of 79 risks (risk register)
- Each risk is described and organised into categories
 - 12 categories of risk
 - grouped into 5 overarching risks
 - Ranked by probability & severity
- Highest ranked risk addressed by SiteChar researchers

Containment risks	Migration / leakage of injected CO ₂
	Loss of injected CO ₂ to biosphere
	Displacement or alteration of brines
Adverse effect on other resources	Hydrocarbon fields
	Others
Reduced technical performance	Reduced injectivity
	Reduced capacity
Monitoring / Regulatory	Monitoring issues
	Regulatory issues
Economic / Environmental	Socio-economic
	Storage costs
	Environmental

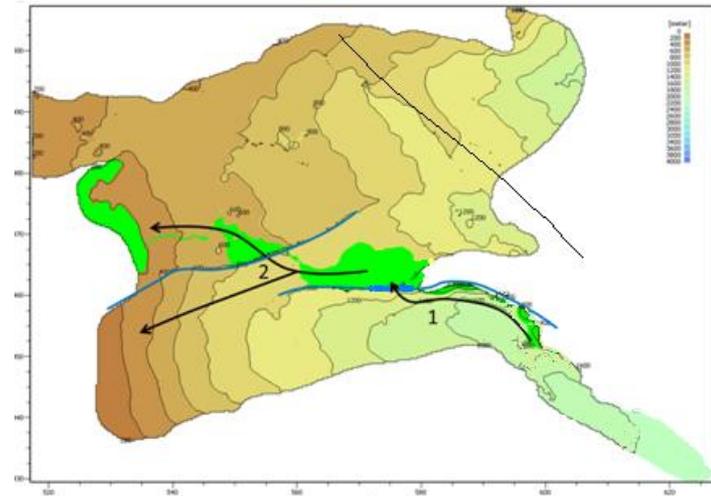
Example risk register

Risk Type	Risk number	Detailed risk description	Probability (very low, 1; low, 2; moderate, 3; high, 4; very high, 5)	Probability ranking	Severity (Very low, 1; low, 2; moderate, 3; high, 4; very high; 5)	Severity ranking	Overall Ranking
Economic / environmental	98	*NEW RISK* Misinterpretation of natural processes as being resultant of the storage site	Highly probable because there is evidence of former (and possibly current) fluid flow at the sea bed	4	H - Public relations impact of an apparent leak very detrimental. It would be difficult to persuade the public it is not the result of CO ₂ storage intervention	4	16
Containment risks	8	CO ₂ -induced fluid escape pathways up abandoned wells	M-H depends on age/ completion and location of them. (abandoned well integrity, CO ₂ resistance) - Unknown abandonment conditions for wells. Poor well construction (injection well and cement corrosion) well ages 1997-2004	4	H - Potential direct pathway to surface and associated environmental impacts.	4	16
Adverse effect on other resources	35	Pressure interference in hydrocarbon fields	M-H	4	M-H because of pressure effects. Currently unquantifiable - needs modelling to see if a small / large positive / negative effect	3	12

Risk reduction activities, UK offshore site, SiteChar



- Dynamic modelling, to simulate CO₂ injection
- Regional flow path migration analysis
- Numerical modelling of well integrity, as wells are potential points of leakage
- Geomechanical modelling
 - Effect of stress changes
 - Shear failure assessment
 - Fracture network probability
- Evaluation of geochemical changes
- Effectiveness of site monitoring by seismic survey
- Assessment of existing shallow geohazards as leak points
- Dialogue with stakeholders to reduce risks from lack of public understanding



Risk reduction - interaction with researchers



- Interaction with researchers
- Technical research teams each received:
 - Extract of risks from the register relevant to their research
 - Illustration where risk reduction results contribute to the application
 - Written guidance

Risk	Risk no	When?	Detailed risk description
Containment risks	8	Operation	CO2 induced fluid escape pathways up abandoned wells
Containment risks	7	Operation	Fluid escape pathways up abandoned wells
Containment risks	77	Characterisation	No or poor secondary seals of Lista and Sele Formation Mudstones: absent, limited lateral extent or poor quality
Containment risks	24	Characterisation	(Unpredicted) preferred lateral pathways focussing flow e.g. vertical barriers present, forcing lateral migration (as in Sleipner)
Containment risks	76	Characterisation	Thin or absent primary Caprock
			Limited connectivity within Captain Sandstone

Contents of licence application - No

1 NAME AND ADDRESS OF PROPOSED OPERATOR

2 APPRAISAL TERM

3 PROJECT DESCRIPTION

3.1 INJECTION PARAMETERS AND PROJECT CONCEPT

3.1.1 Project concept

3.1.2 Injection parameters

3.2 STORAGE DEVELOPMENT PLAN

This will be informed primarily by the results of all Design deliverable, due end June 2012

3.2.1 An injection and operating plan

3.2.2 A storage performance forecast

A brief description of each modelling method used in the development plan will be included in a section here. This will require to be referenced as evidence for why particular methods were chosen.

4 SITE DESCRIPTION

4.1 INTRODUCTION TO STORAGE SITE AND COMPLEX

4.2 EVIDENCE BASE USED TO COMPLETE THIS APPLICATION

4.2.1 Description of the static model – data input and interpretation

Brief description of IFPEN static model building & GEUS Facies input will be added here

4.3 BOUNDARIES

This will be informed primarily by the results of IFPEN's dynamic simulation work that feeds Storage Design deliverable, due end June 2012

4.3.1 Storage Site boundaries

4.3.2 Storage Complex boundaries

4.4 INFORMATION ON SITE GEOLOGY

Input from WP3.1 work and D3.1 primarily, but also include WP3.2 & WP3.3 site geochemical data to inform the assessment of the geomechanical integrity in relevant sections

4.4.1 Storage site – primary reservoir

4.4.2 Storage Complex – primary seal to the storage site

4.4.3 Storage Complex – secondary reservoirs

4.4.4 Storage Complex – secondary seals

4.4.5 Structure

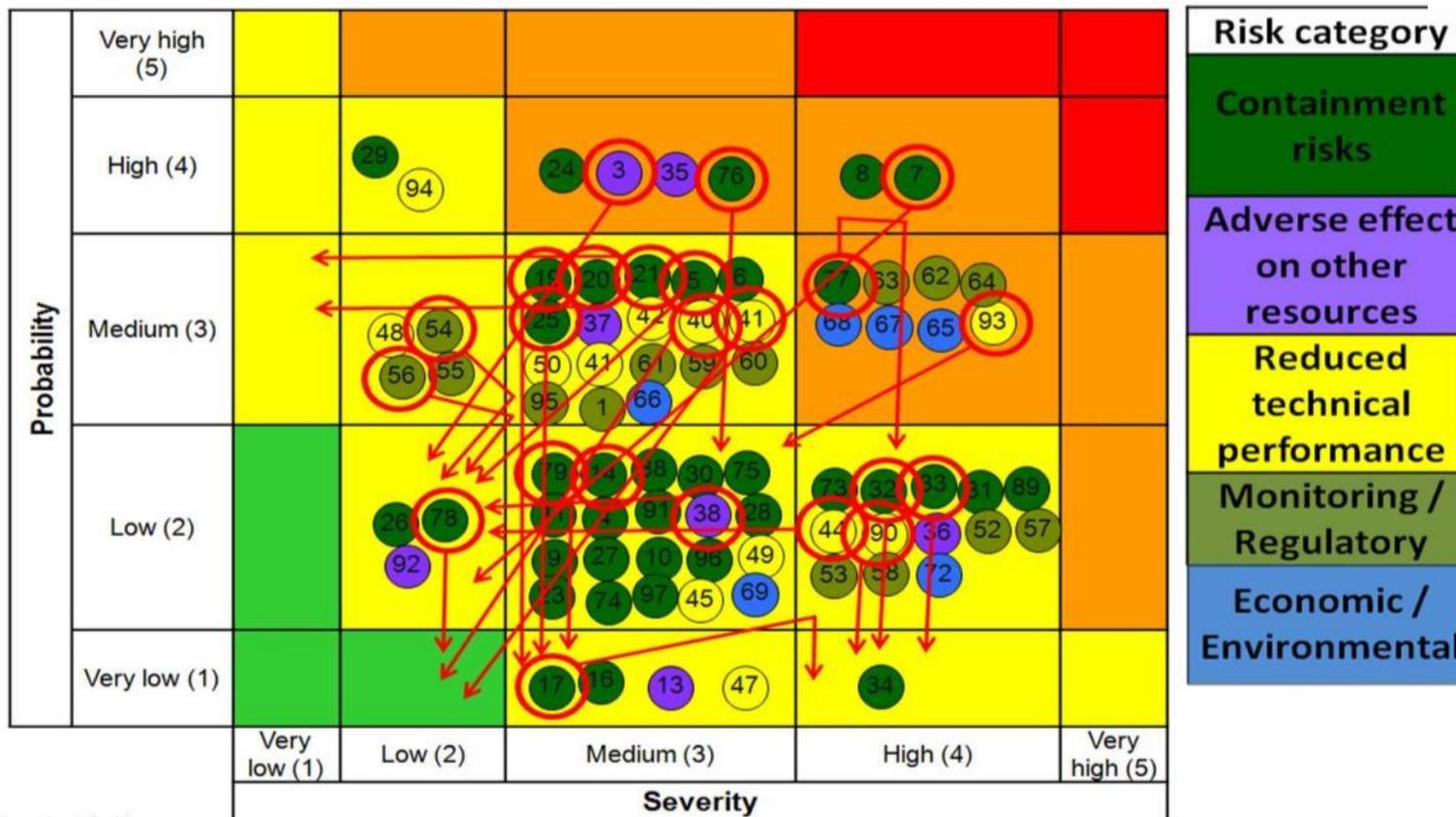


Results of the initial risk ranking

- Risk matrix
- Plot of probability of occurrence and severity of impact
- Risks from the initial ranking in 2011
- Risks mostly moderate (yellow) to high (orange)

Probability	Very high (5)	0	0	0	0	0
	High (4)	0	29,94	24,35,3,76	8,9	0
	Medium (3)	0	48,54,56,55	19,20,21,5,6, 25,37,42,40, 41,50,41,61, 59,60,95,1, 66	77,63,62 ,64,68,6 7,65,93	0
	Low (2)	0	26,78,92	79,88,4,14,1 1,91,27,9,10, 74,75,23,28, 96,97,30,38, 45,49,69	73,32,33 ,31,89,4 4,90,36, 52,57,53 ,58,72	0
	Very low (1)	0	0	17,16,13,47	34	0
		Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
		Severity				

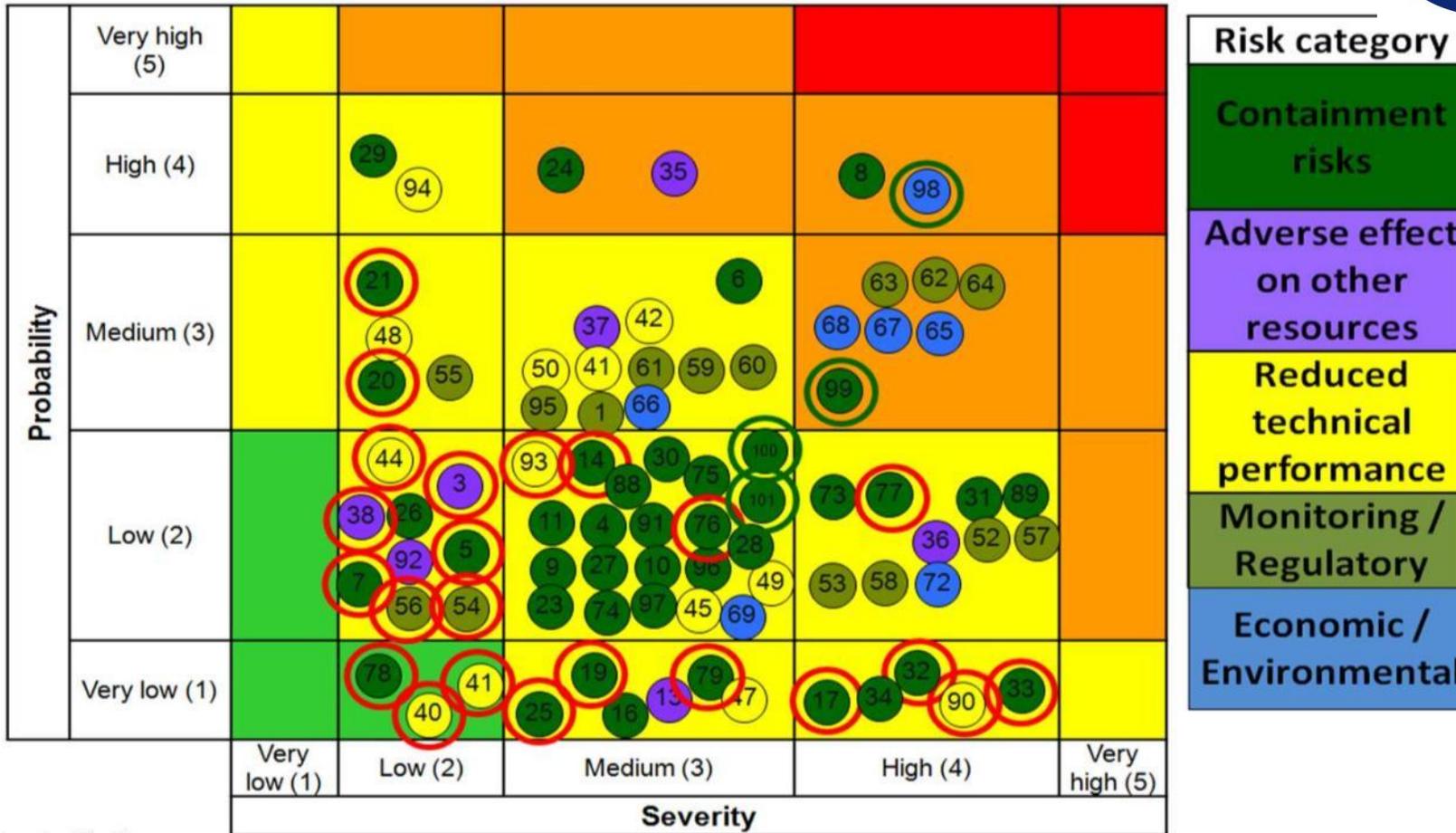
Initial risk ranking - October 2011



- Risks are colour coded by category
- Red circles and arrows show risk reduction by site characterisation
- Not all risks addressed in the resources of a research project



Revised risk ranking - January 2013



- Risks after the mitigation activities circled in red.
- New risks identified during site characterisation circled in green
- Risk reduction would continue for all risks in a real application



Risk reduction results



- Risk mitigation and reduction results used to inform the required components of a 'dry-run' storage permit
- Site development plan
 - Injection & operation plan outlined.
 - Storage performance forecast predicted
- *Preventative Measures Plan*
 - Highest ranking risks
 - Mitigating measures identified
 - Measures proposed during the feasibility, technical design, construction & testing phases
- *Monitoring Plan*
 - Monitoring methods and frequency for each unmitigated risk
- *Corrective Measures Plan*
 - Highest ranking risks
 - Description of how a significant irregularity is detected during monitoring
 - Corrective measures are proposed
- *Post Closure Plan*, long term monitoring of specific risks





Summary

- Objective of site characterisation to demonstrate understanding of the storage site
- Risk-led approach ensures resources, time and effort are focused
- Components of a CO₂ storage permit required by regulators based on risk assessment, mitigation and reduction activities
- Guided and determined by risk assessment and reduction
 - Project description (injection strategy, site design, storage performance forecast) and site description
- Informed by the results of risk assessment
 - Preventative Measures, Monitoring, Corrective Measures and Post-closure plans



SiteChar Workflow

- The workflow is available at <http://www.sitechar-co2.eu/FileDownload.aspx?IdFile=605&From=Publications>

