Characterisation of European CO_2 storage

Risk-led site characterisation

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Objective of site characterisation

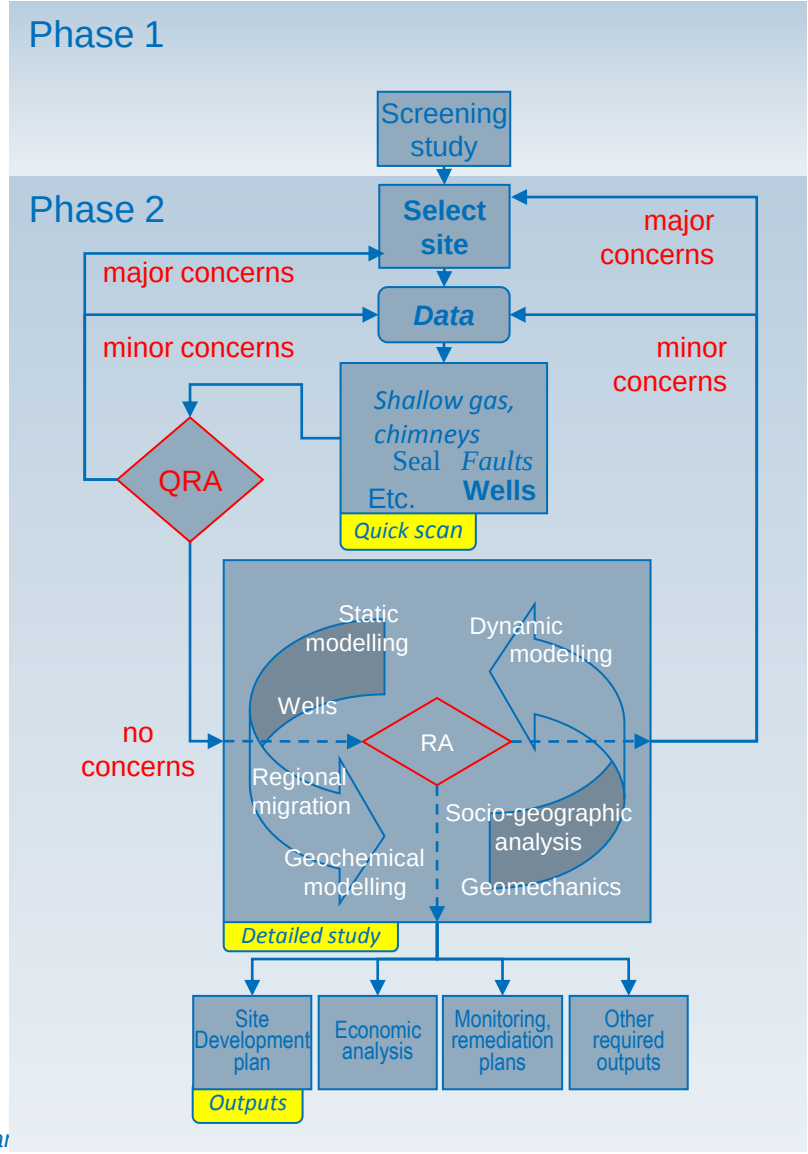
- **Demonstrate understanding of the site for a CO_2 storage permit**
- **Competent Authority must be satisfied that:**
  - **Permit applicant has sufficient understanding of the site**
  - **Proposed site operation will securely contain CO_2**
- **Application must comply with requirements of EC Directive**

Role of risk assessment in site characterisation

- **Site characterisation is about understanding the risks to secure containment of CO_2 at a specific site**
- **Characterisation is led by risk assessment to**
  - **anticipate risks,**
  - **reduce risks**
  - **mitigate risks**
  - **monitor unmitigated risks**
- **Determines what site characterisation activities are needed**
- **Ensures resources, time and effort are focused to meet the objective**

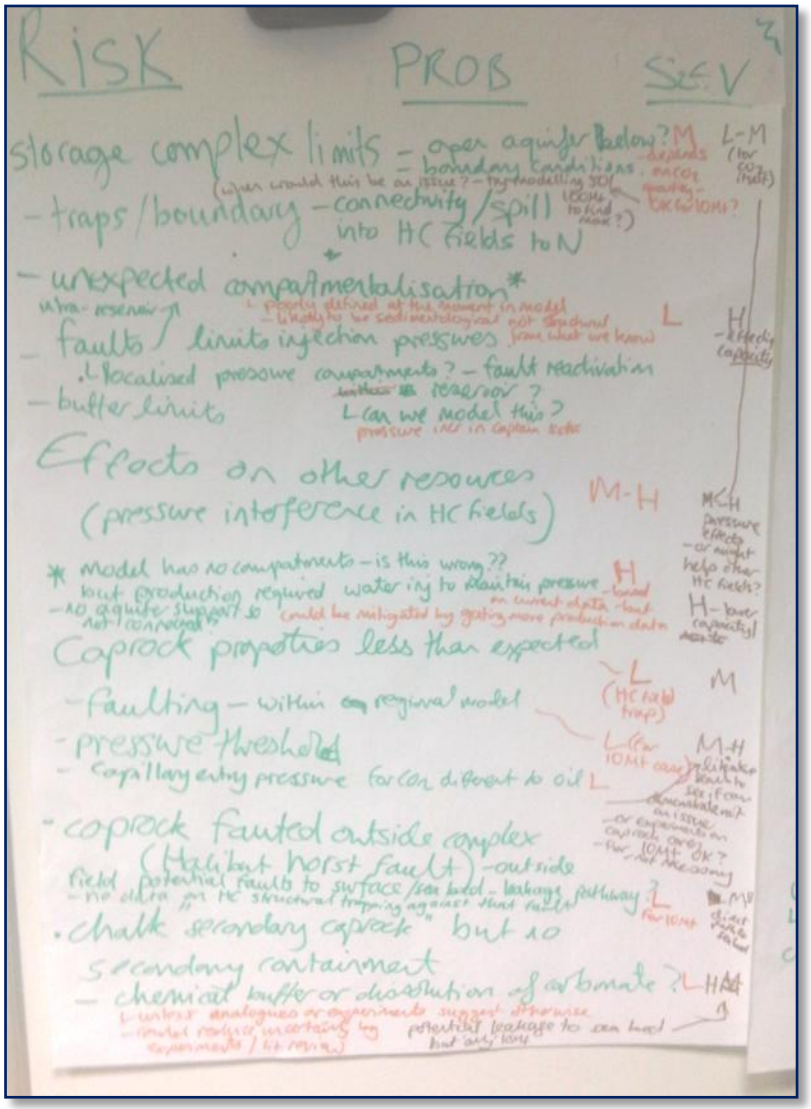
Risk-led permit requirements

- **Required components determined by risk assessment**
  - **Project description (injection strategy & site design)**
  - **Site description**
- **Informed by results of risk assessment**
  - **Preventative Measures Plan**
  - **Monitoring Plan**
  - **Corrective Measures Plan**
  - **Post Closure Plan**
- **Workflow illustrates a continuous risk assessment process**



Risk-led characterisation in SiteChar

- **Risk Assessment workshop**
- **First project activity**
- **Participation by all experts**
- **‘Brainstorming’**
- **Anticipate risks**
- **Initial assignment of probability & severity**



Risk-led characterisation in SiteChar

- **Initial risk register (list of 79 risks)**
- **Each described and categorised,**
  - **12 categories**
  - **5 overarching risks**
- **Ranked by probability & severity**
- **Highest ranked risk addressed by SIteChar researchers**

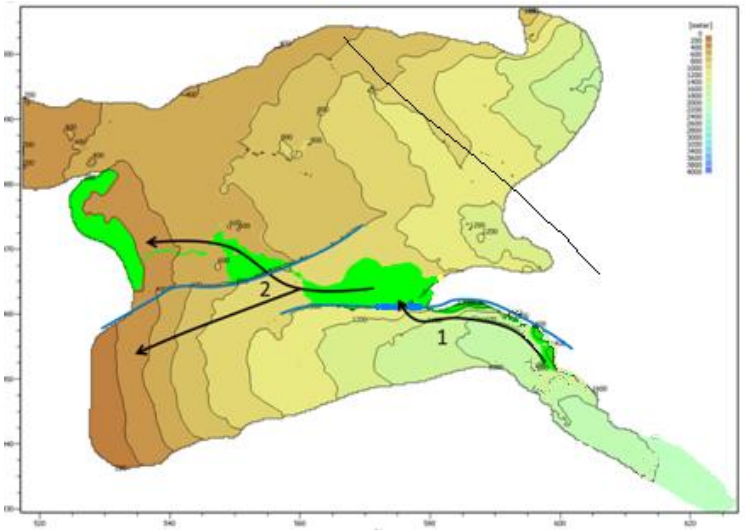
Containment risks	Migration / leakage of injected CO_2
	Loss of injected CO_2 to biosphere
	Displacement or alteration of brines
Adverse effect on other resources	Hydrocarbon fields
	Others
Reduced technical performance	Reduced Injectivity
	Reduced capacity
Monitoring / Regulatory	Monitoring issues
	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

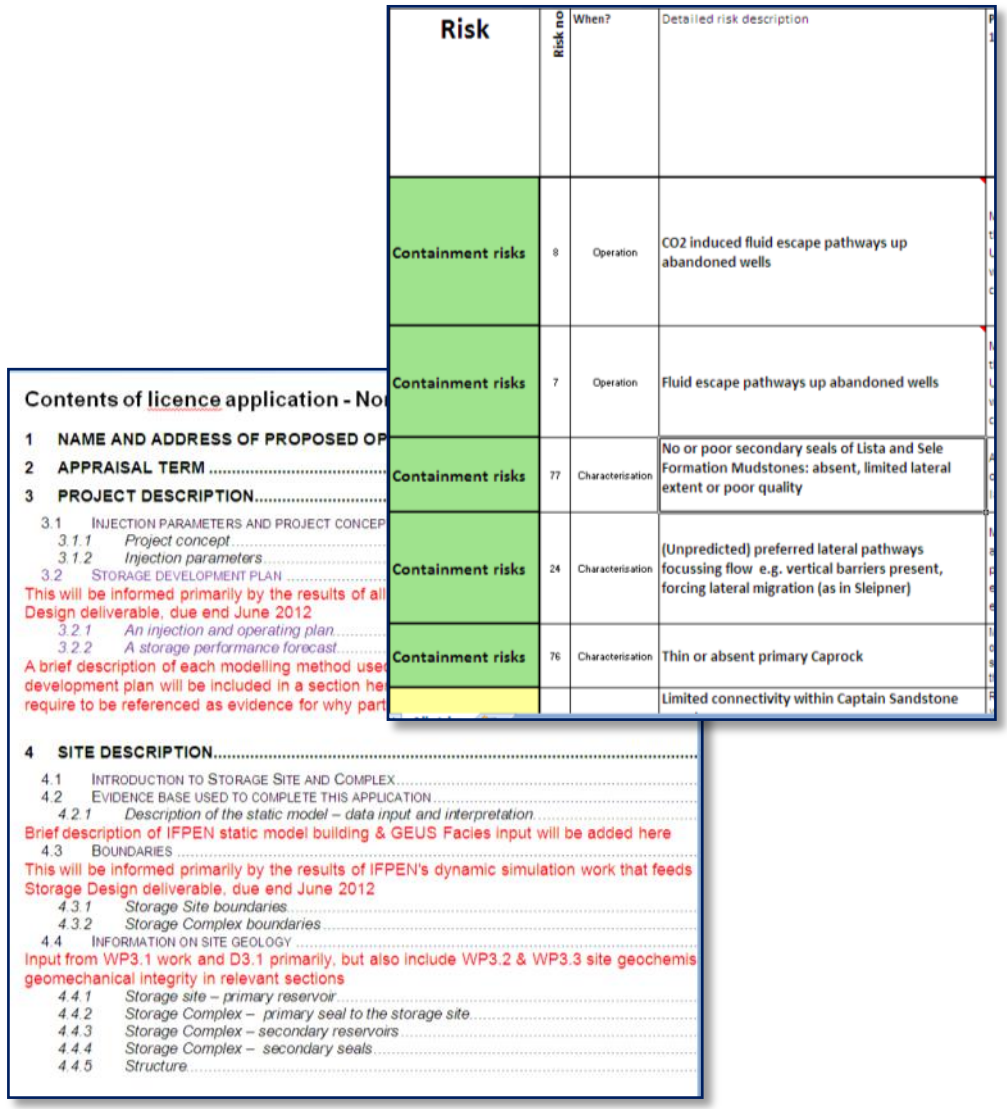
Risk reduction activities
Outer Moray Firth site

- **Dynamic modelling**
- **Flow path migration analysis**
- **Well integrity modelling**
- **Geomechanical modelling**
  - **Effect of stress changes**
  - **Shear failure assessment**
  - **Fracture network probability**
- **Geochemical evaluation**
- **Effectiveness of seismic monitoring**
- **Shallow geohazards assessment**
- **Dialogue with stakeholders**



Interaction with researchers

- **Technical research teams each received**
- **Extract of risks from the register relevant to their research**
- **Illustration where risk reduction results contribute 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 OP
2 APPRAISAL TERM
3 PROJECT DESCRIPTION
3.1 INJECTION PARAMETERS AND PROJECT CONCEP
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 use
development plan will be included in a section he
require to be referenced as evidence for why part

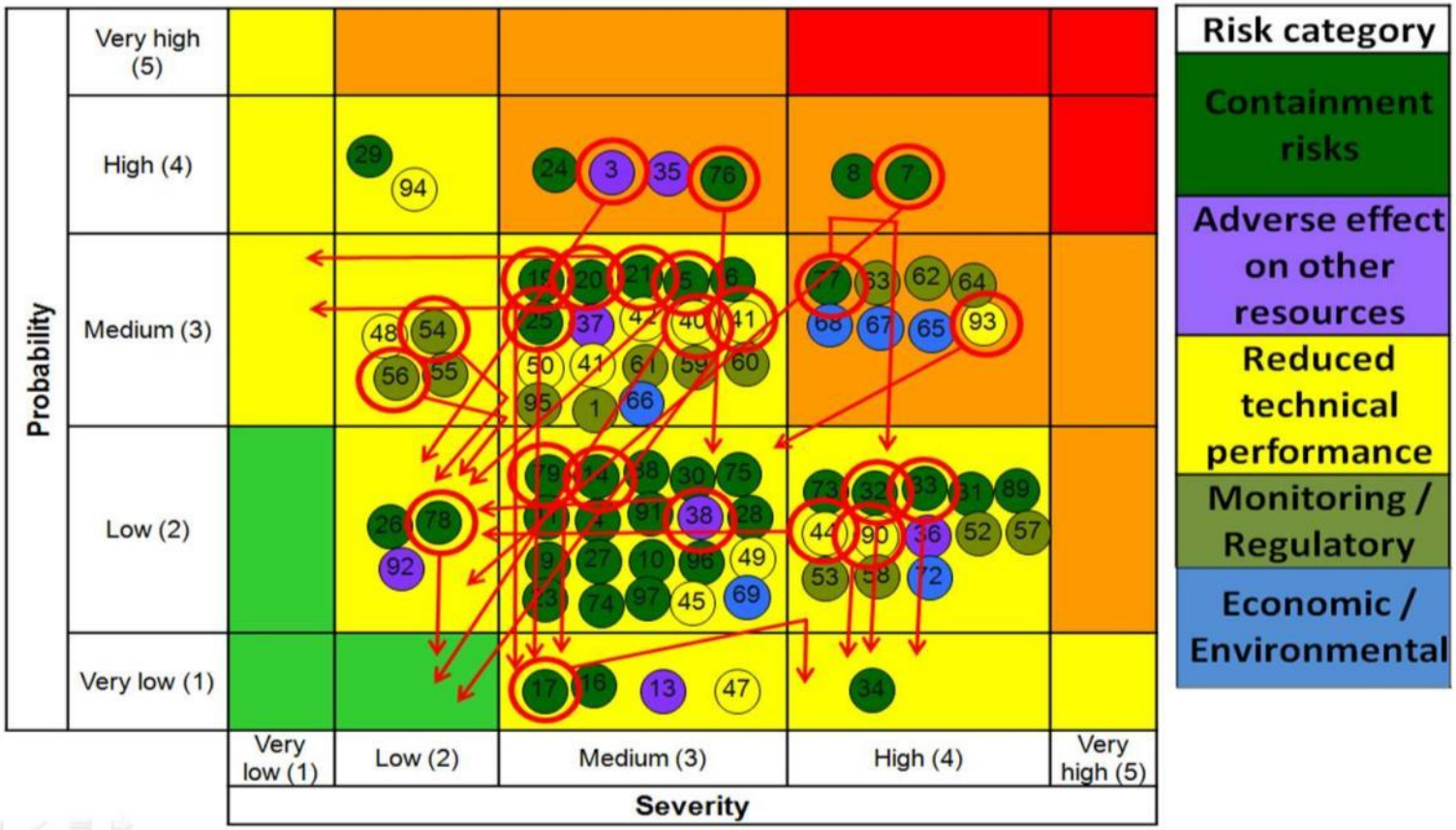
4 SITE DESCRIPTION
4.1 INTRODUCTION TO STORAGE SITE AND COMPLEX
4.2 EVIDENCE BASE USED TO COMPLETE THIS APPLICATION
4.2.1 Description of the static model – data input and interpretation
Brief description of IFPEN static model building & GEUS Facies input will be added here
4.3 BOUNDARIES
This will be 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 geochemis 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 risk-led site charcterisation

- **Risk matrix with the initial ranking of risks (2012)**
- **Plot of likelihood of occurrence and severity of impact**
- **Risks mostly moderate to high**

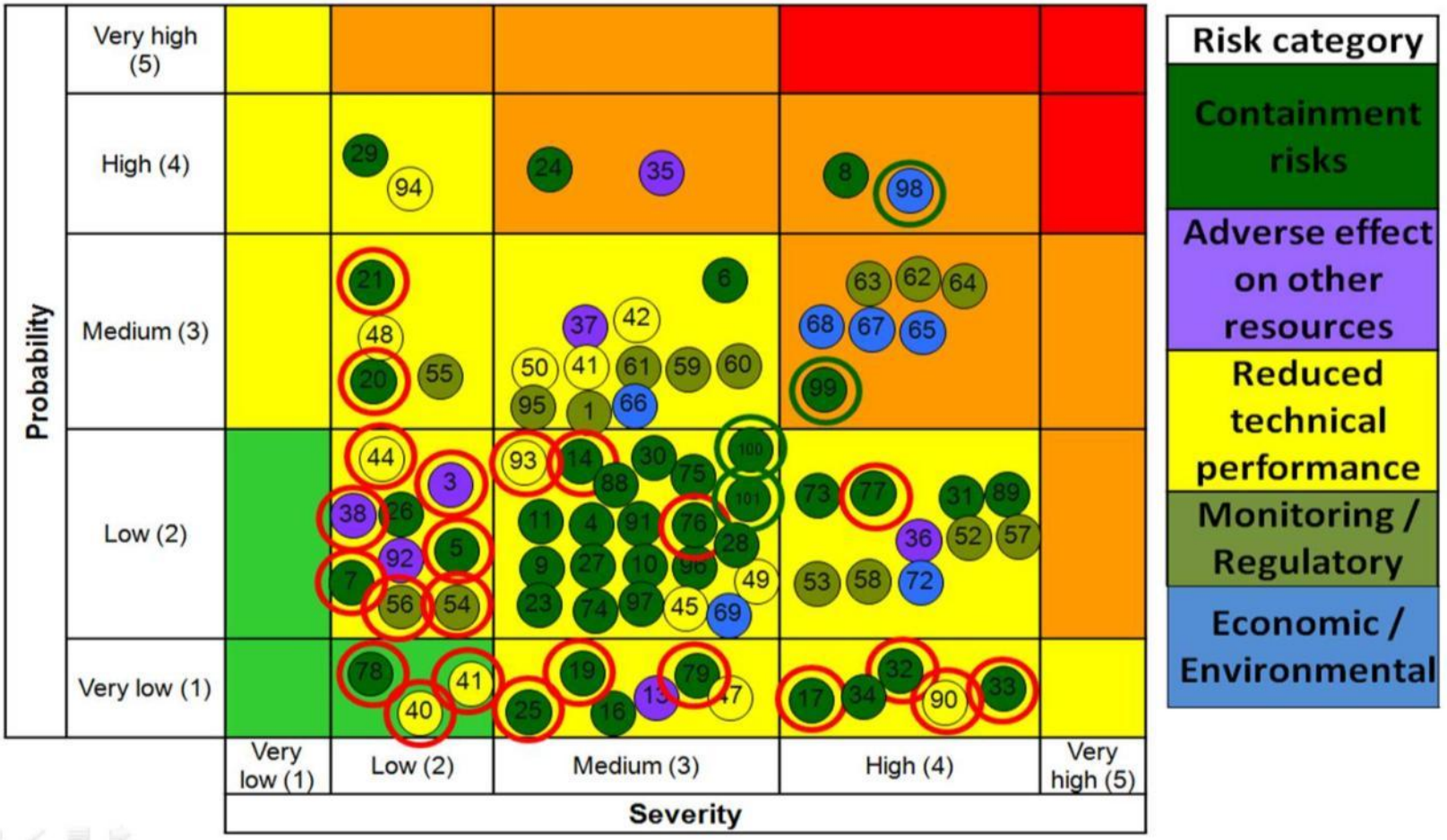
Probability						
	Very high (5)	0	0	0	0	0
	High (4)	0	29,94	24,35,3,76	8,9	0
	Medium (3)	0	48,54,56,55	19,20,21,5,6,25,37,42,40,41,50,41,61,59,60,95,1,66	77,63,62,64,68,67,65,93	0
	Low (2)	0	26,78,92	79,88,4,14,11,91,27,9,10,74,75,23,28,96,97,30,38,45,49,69	73,32,33,31,89,44,90,36,52,57,53,58,72	0
	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 2012)



- **Risks are colour coded by category**
- **Red circles and arrows show SiteChar risk reduction**

Revised risk ranking (January 2013)



- **Risks after the mitigation activities circled in red.**
- **New risks identified during SiteChar circled in green.**

Risk reduction results, Outer Moray Firth

- Risk mitigation and reduction results used to inform ‘dry-run’ storage permit
- Site development plan
  - Injection & operation plan
  - Storage performance forecast
- Preventative Measures Plan
  - Highest ranking risks
  - Mitigating measures identified
  - Feasibility, technical design, construction & testing phases
- Monitoring Plan
  - Monitoring methods and frequency for each unmitigated risk
- Corrective Measures Plan
  - Highest ranking risks
  - How a significant irregularity is detected
  - Corrective measures described
- Post Closure Plan, long term monitoring of specific risks

Summary

- To be completed