# Well remediation or 'do nothing' – a risk perspective

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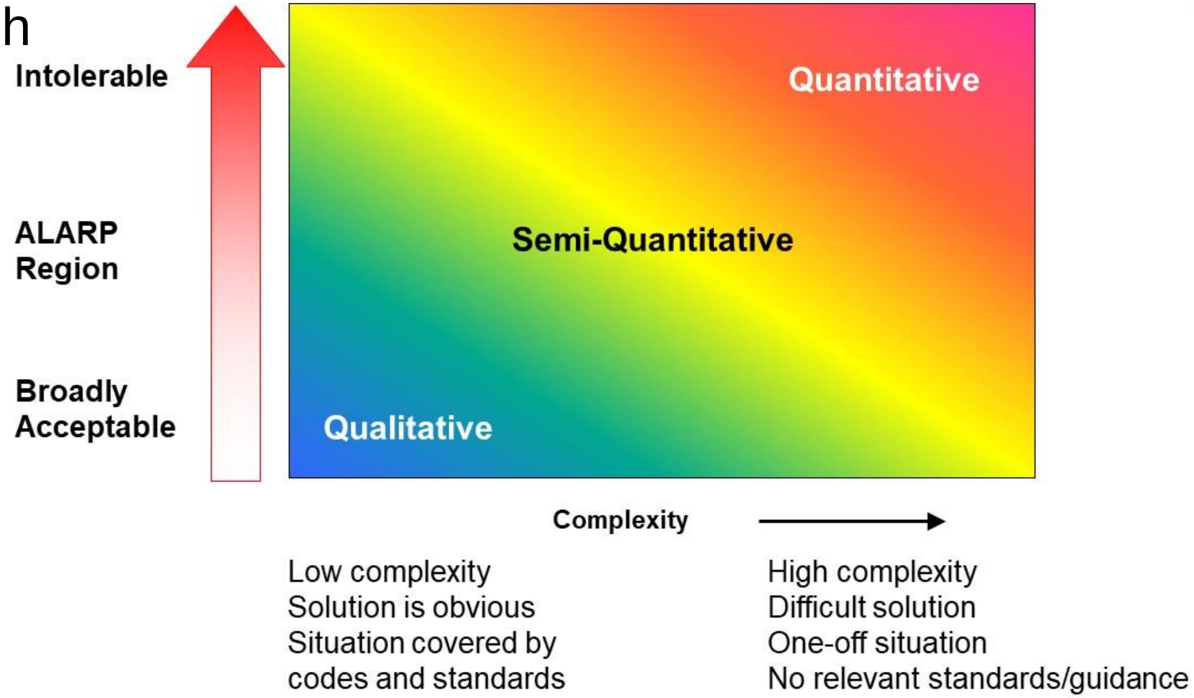
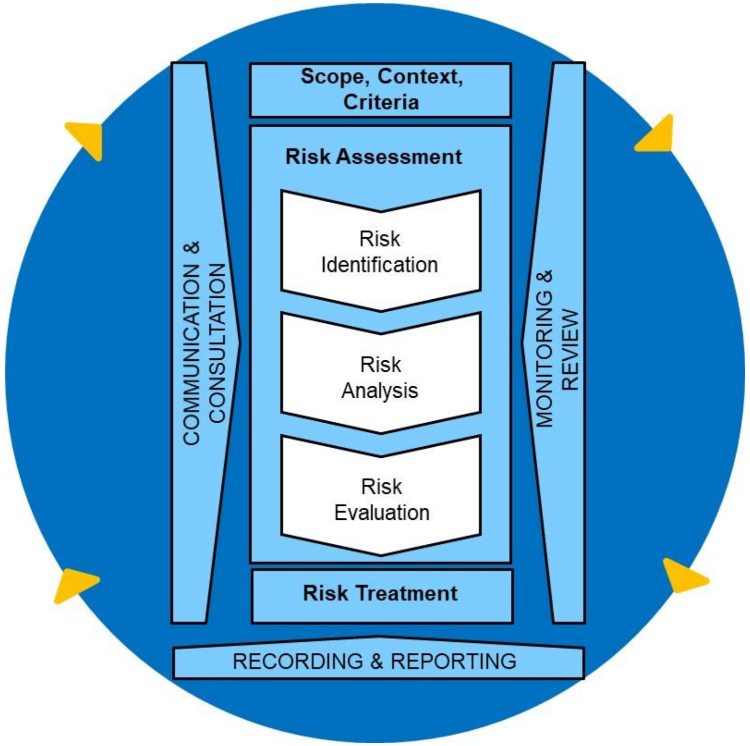
# Risk Management Concepts

Successful risk management requires:

- A structured approach
  - Identification
  - Analysis
  - Evaluation
- A proportionate approach




*After: Guidance on Risk Assessment for Offshore Industries HSE 3/2006*




*From ISO 31000:2018*

**What helps you reach a decision?**

# Five-step approach to legacy well risk assessment

1. Identify all wells
2. Screen for exposure to $CO_2$, brine, pressure
3. Screen for well integrity
4. Detailed analysis of highest risk wells
5. Evaluate risk reduction options



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# Step 1 – Identify all legacy wells

- All wells **inside licence area**
- Those wells **outside licence area** that could see formation water, pressure or inadvertently, $CO_2$
- Sources, e.g.:
  - [Interactive Energy Map for the UKCS - The North Sea Transition Authority (nstauthority.co.uk)]()
  - [UK NDR - National Data Repository (nstauthority.co.uk)]()
  - [Factpages – Norwegian Offshore Directorate (sodir.no)]()
  - [https://welldatabase.com]()
  - Internal company data
  - US data?

*North Sea Transition Authority UKCS Lease Arrangements*

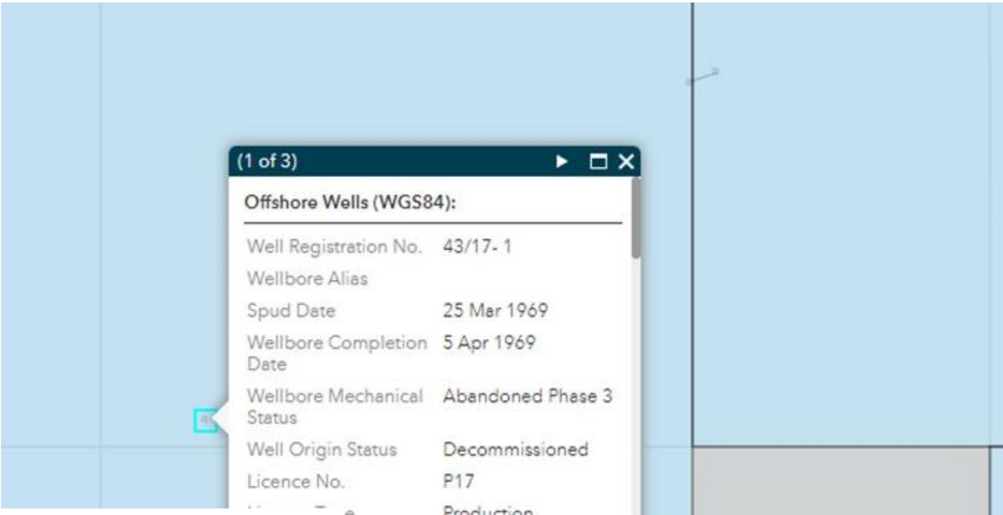



*Fig. 2 Goldeneye Wells, Peterhead CCS Project, Petrophysical Modelling Report 2015*

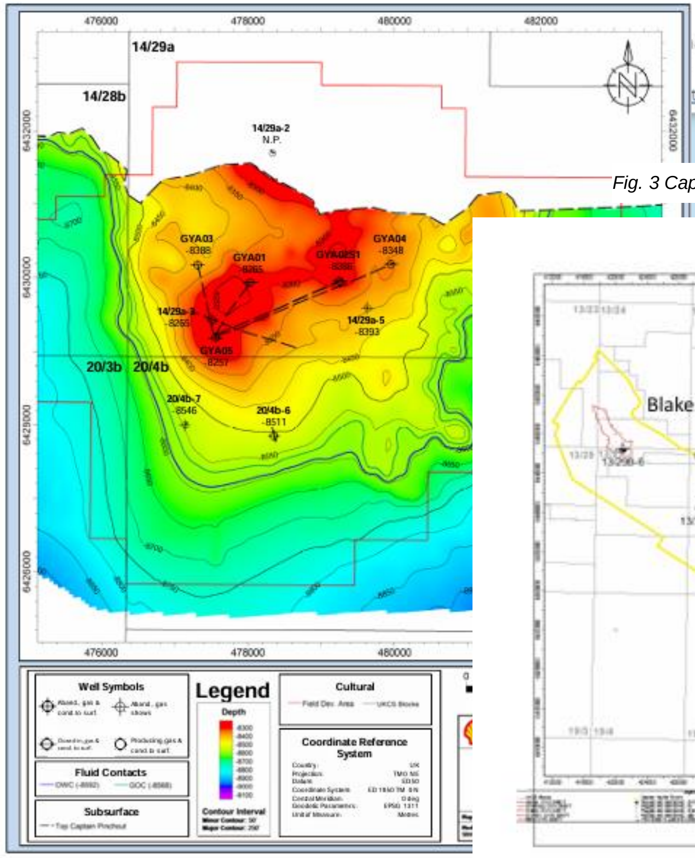
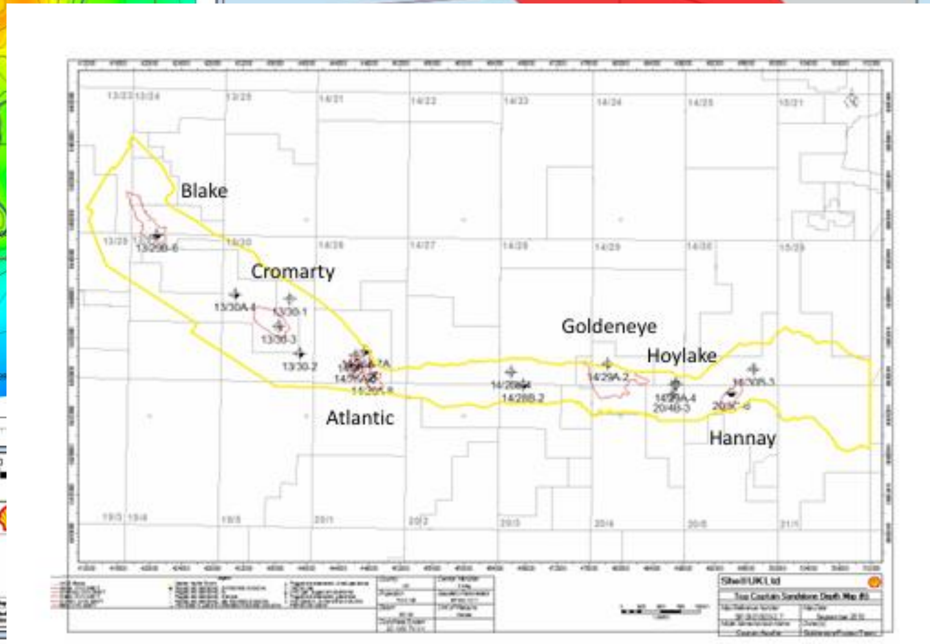
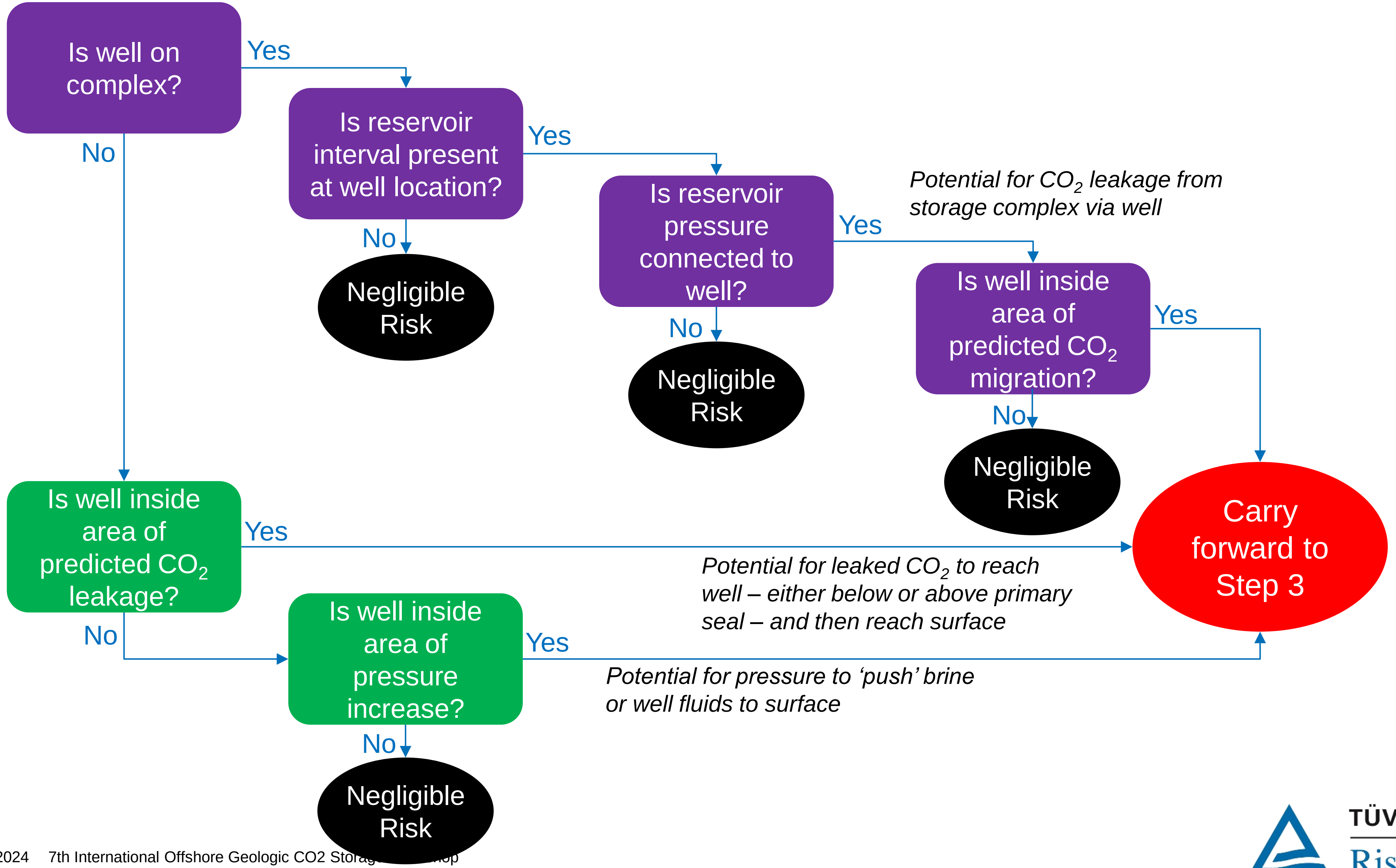



*Fig. 3 Captain Fairway Wells, Peterhead CCS Project, Petrophysical Modelling Report 2015*



# Step 2 – Screen wells for exposure to $CO_2$, brine or pressure



# Step 3 – Screen wells for potential integrity issues

**EFFECTIVENESS**

- Long plug, across reservoir / primary seal
- Short plug across reservoir / primary seal
- Plug above reservoir
- Plug which showed signs of leakage (bubbles) historically
- Plug which currently shows signs of leakage
- Bridge plug
- Plug below reservoir
- Plug where formation strength < $CO_2$ pressure at bottom of plug
- Plug above MSAD
- Environmental plug

**UNCERTAINTY**

- Cement tested and tagged
- Detailed drilling reports / logs
- Cement tested but not tagged, or tagged but not tested
- Cement not tested nor tagged

## Consider:

- Wellbore plugs and annulus cement – **effectiveness** and **uncertainty**
- **Volume of $CO_2$ at risk** – quantity of mobile $CO_2$ at well location available to be released if a barrier fails
- **Driving force** – if the reservoir is below hydrostatic there is no driving force

Sources of information:

- Original drilling reports
- Abandonment reports
- Industry guidelines e.g. NORSOK, OEUK



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# Step 3 – Screen wells for potential integrity issues

*Fig. 1 Peterhead CCS Project Abandonment Options for Goldeneye Wells*

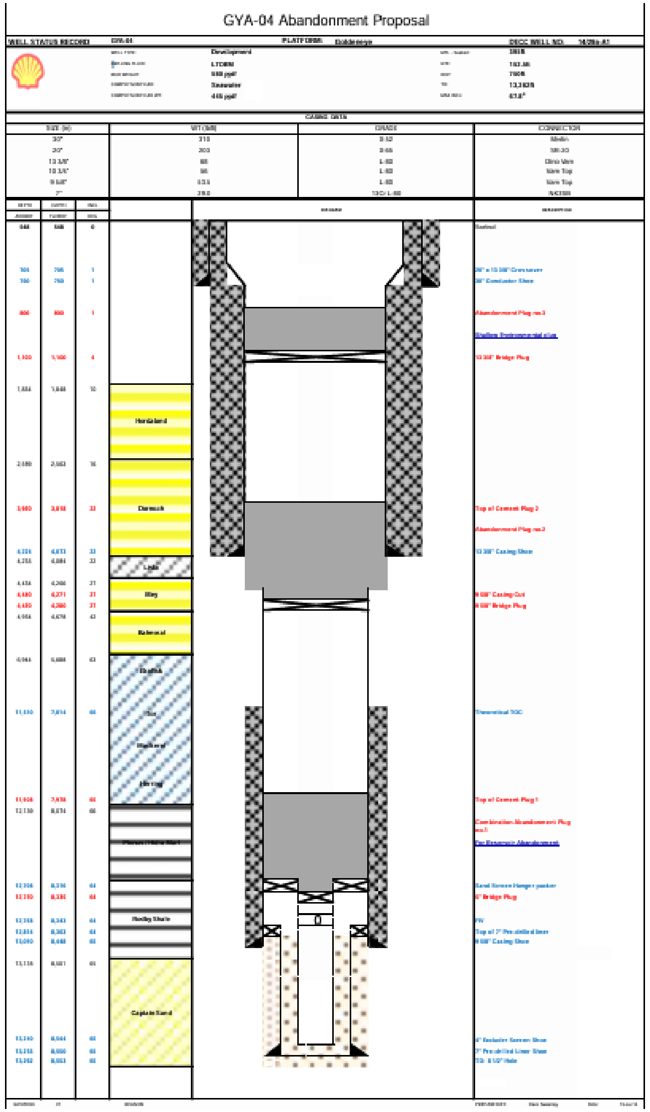
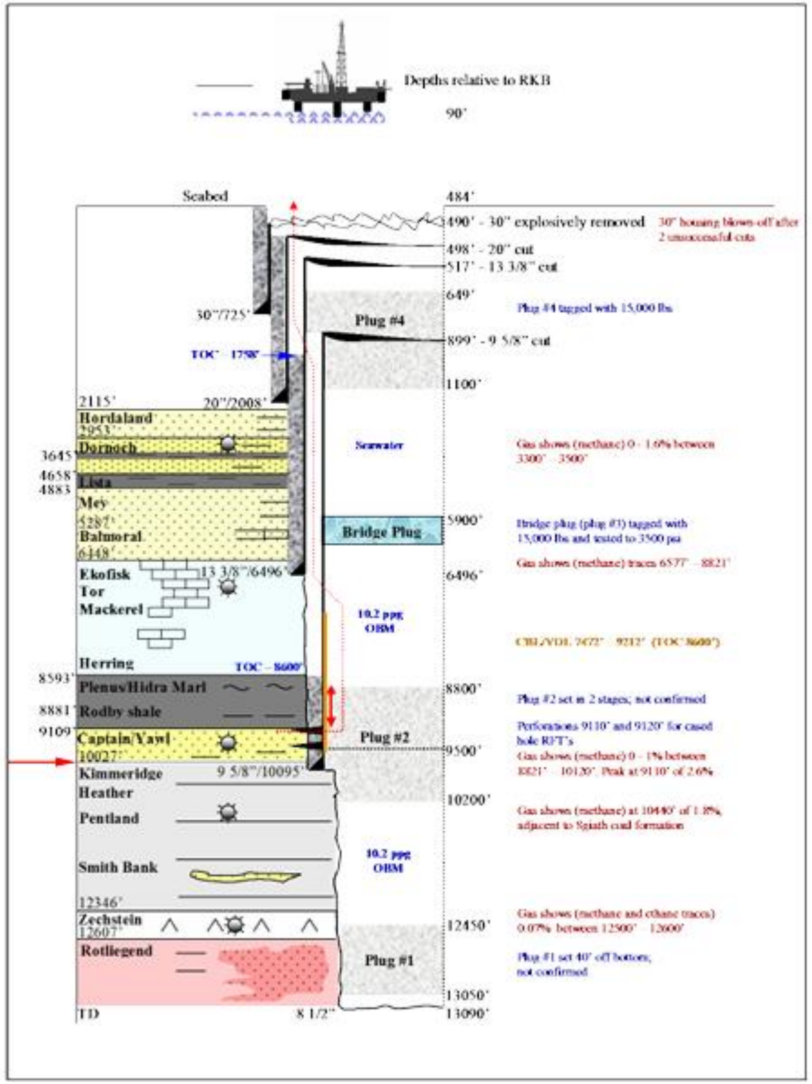



*Fig. 2 Peterhead CCS Project Abandoned E&A Wells Integrity Assessment*




## For example, to meet OEUK Guidelines:

- Over-pressured permeable zones containing water or HC, and normally pressured permeable zones containing HC require a **minimum of two permanent barriers** between permeable zone and surface
- Normally pressured zones containing water require **one permanent barrier**
- Permanent barriers are normally cement, but resin may be considered
- **Pressure** at permeable zone due to $CO_2$ can be calculated and compared with formation strength at bottom of barrier

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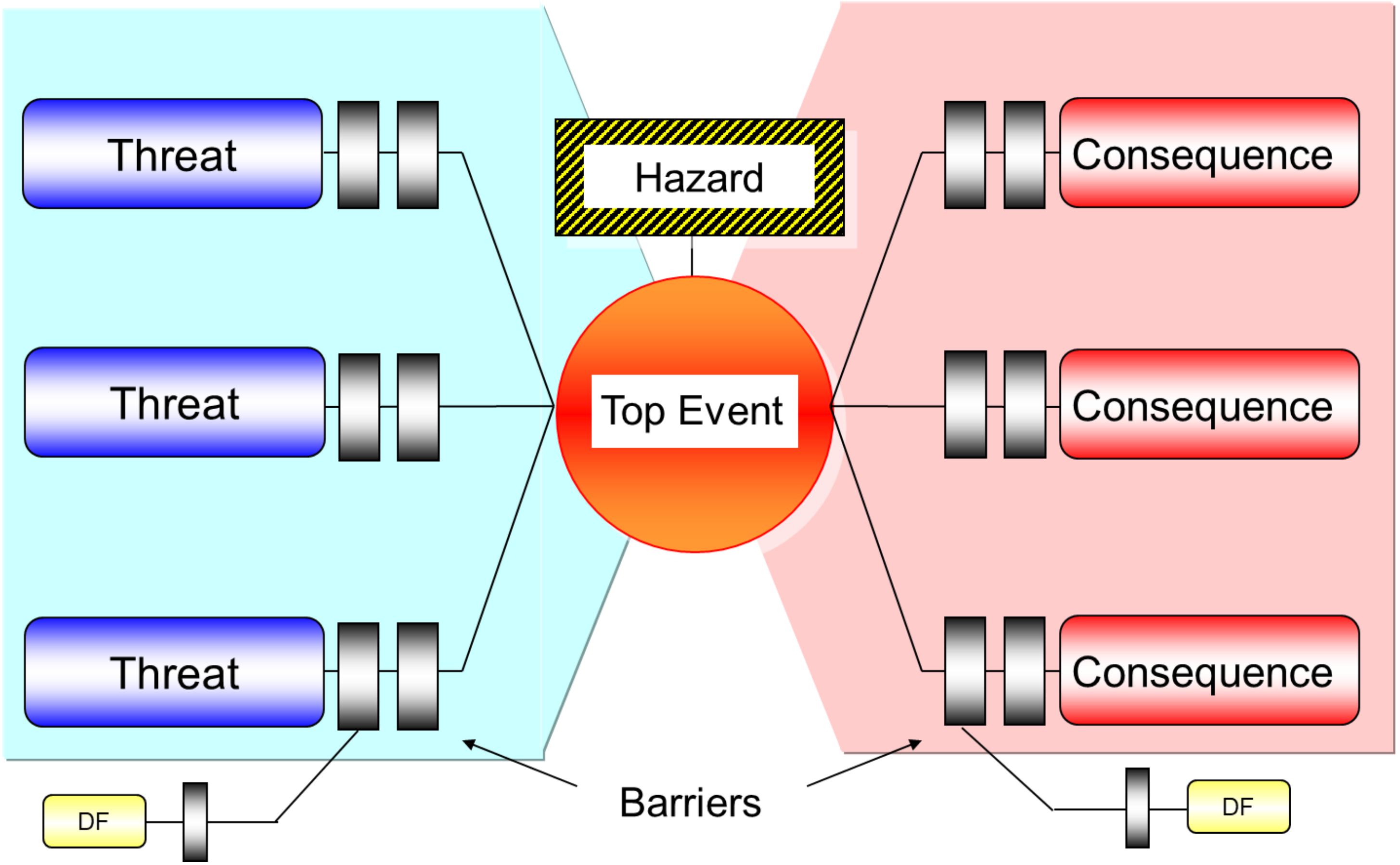
# Step 4 - Detailed qualitative analysis of highest risk wells - bowties

- What controls exist?
  - Operational
  - Engineering
  - Measurement, monitoring
  - Corrective action, intervention
- How good are the controls?
- What is known/unknown?
- What are the leak paths?
- What uncertainties exist?
- What more could we do?

Monitoring is only a barrier if combined with intervention / corrective action



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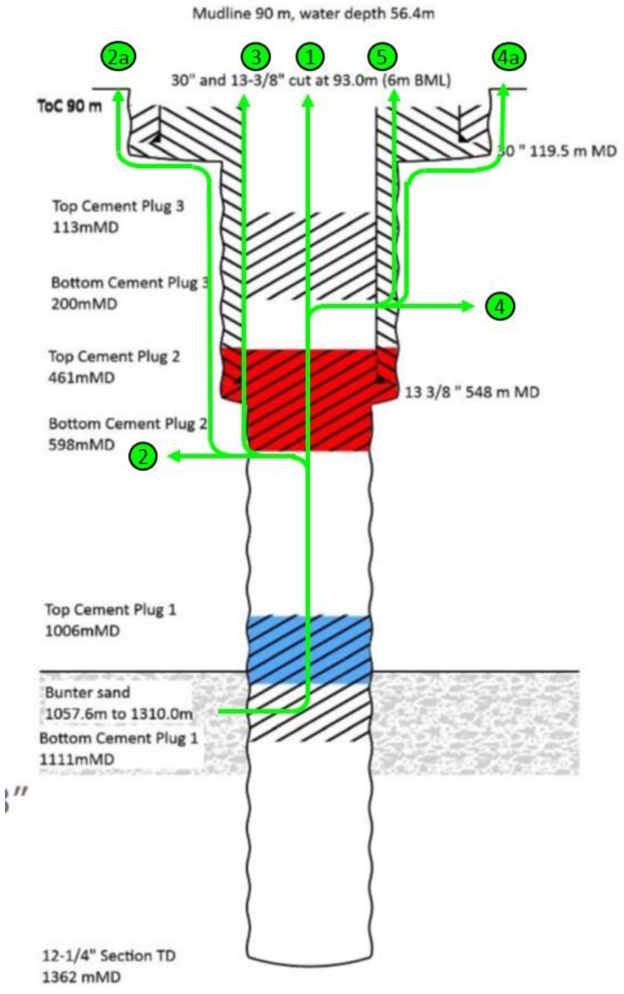
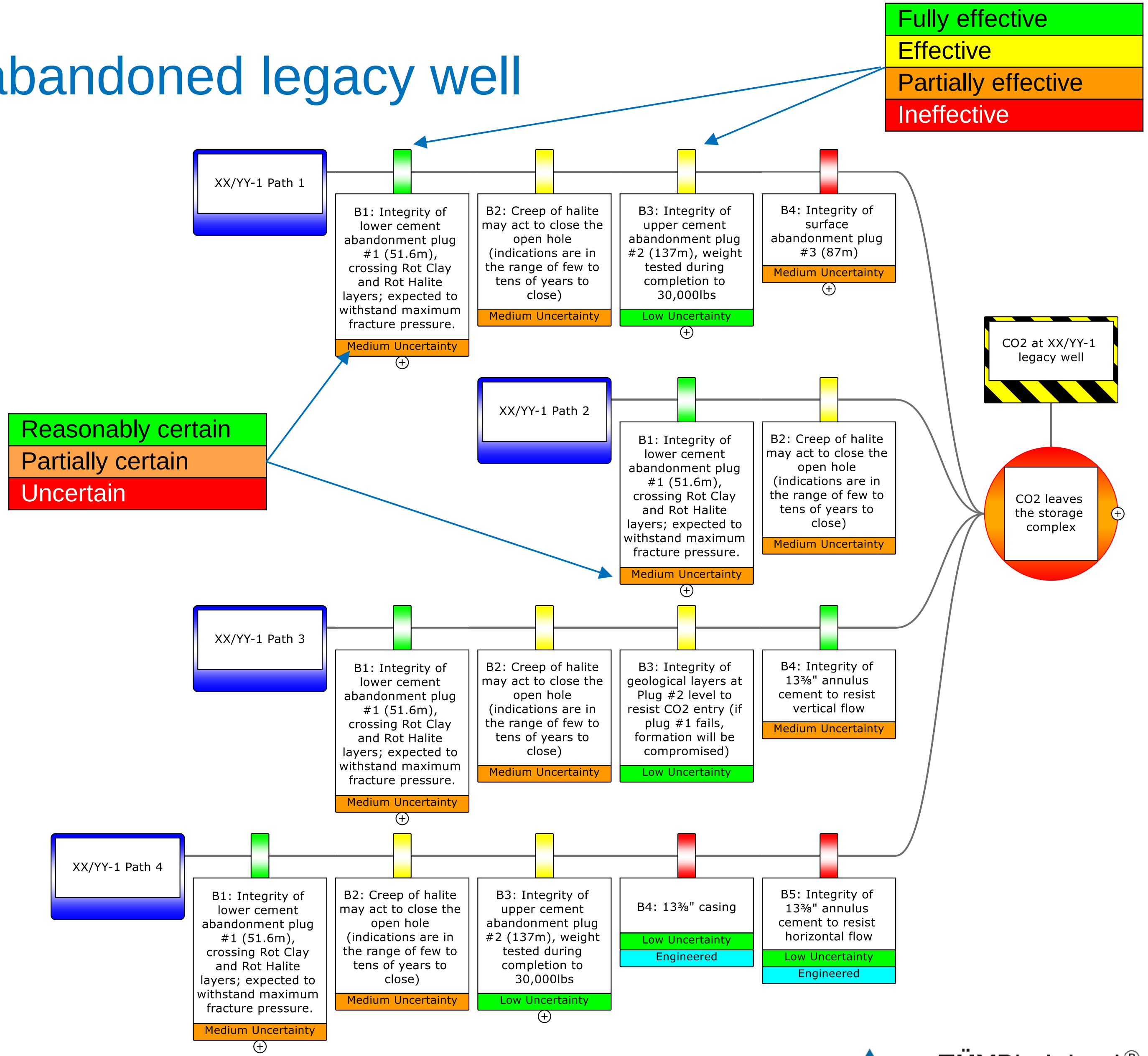
# Step 4 - example bowtie extract, abandoned legacy well

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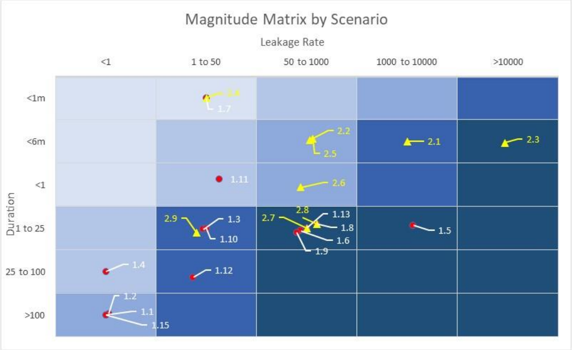
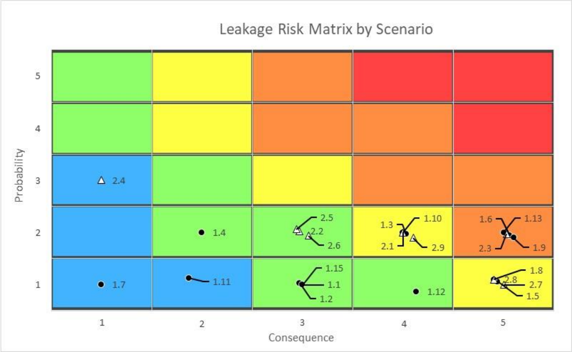
# Step 4 – coarse numerical estimates of leakage risk

Simple estimations, may include:

- Engineering judgement on likelihoods, rates and durations of leakage




- Numerical estimations e.g.

| Leak category | Leak rate (t/d) | Duration (months) | Probability of defined leak rate occurrence/ well/annum Maximum | Probability of defined leak rate occurrence/ well/annum Minimum |
|---|---|---|---|---|
| Minor | 1 – 50 | Up to 6 | 1 in 1000 | 1 in 10,000 |
| Moderate | 50 – 1000 | Up to 4 | 1 in 10,000 | 1 in 100,000 |
| Major | Greater than 1000 | Up to 4 | 1 in 100,000 | 1 in 1 million |

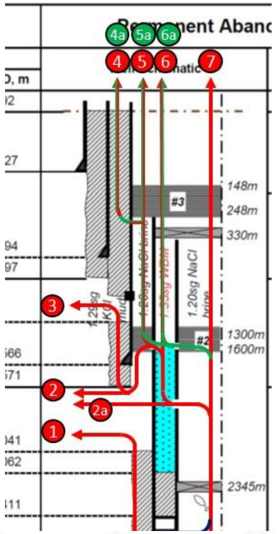
**Table 11. Leakage probabilities for inactive wells at minor, moderate and major leak rates derived from literature review**

*Ref: Deep Geological Storage of $CO_2$ on the UK Continental Shelf*

- NRAP modelling of leakage rates and patterns

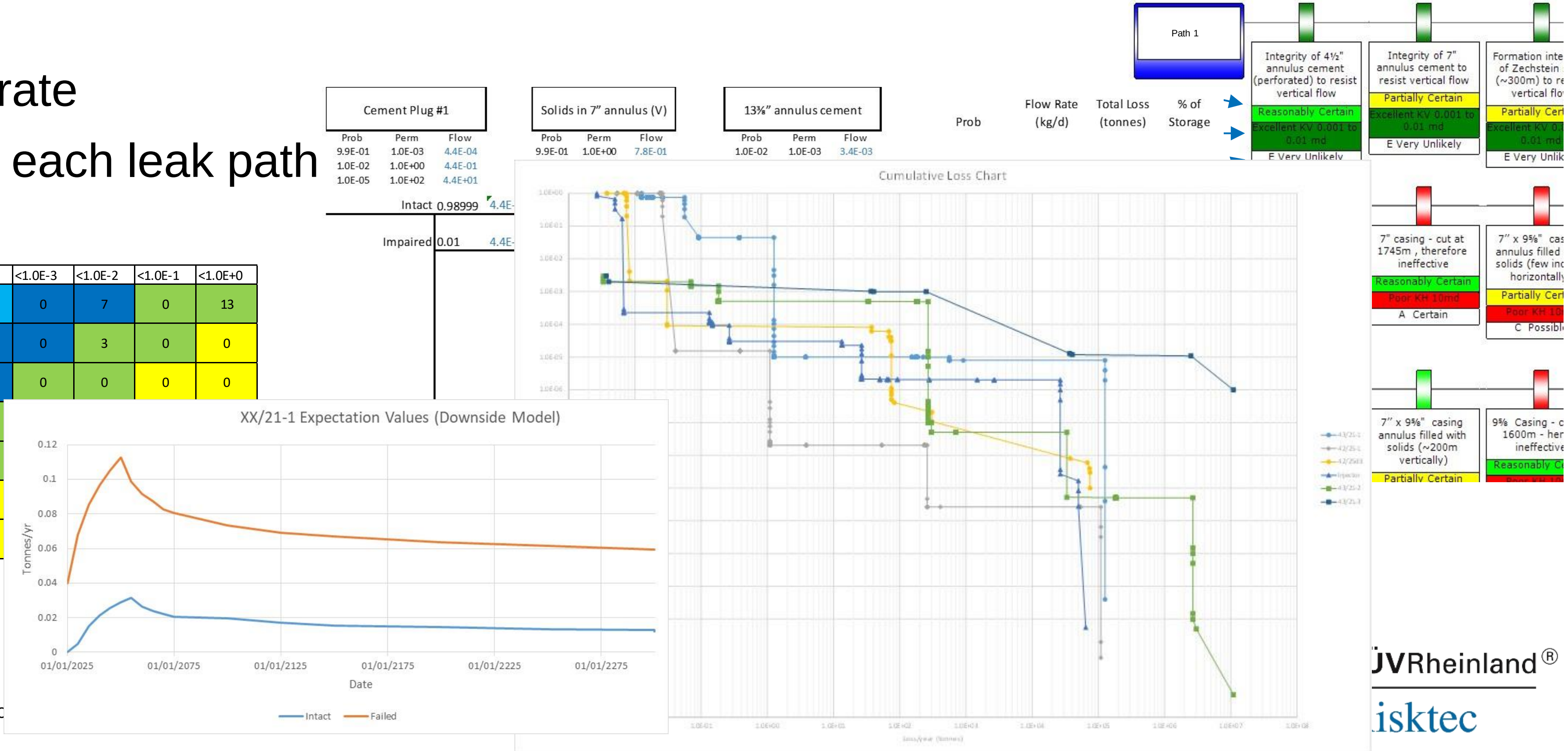
*Limited data sources available which affects certainty of results*

# Step 4 - Detailed quantitative risk assessment of highest risk wells




- Based on well specific bowtie
- For each barrier estimation of permeability and probability of failure
  - Intact
  - Impaired
  - Failed
- Estimation of leakage rate
- Event tree analysis for each leak path
- Summation of results

| | <1.0E-9 | <1.0E-6 | <1.0E-4 | <1.0E-3 | <1.0E-2 | <1.0E-1 | <1.0E+0 |
|---|---|---|---|---|---|---|---|
| Loss of ≤0.0001% of injection volume over 1000yrs | 445 | 119 | 37 | 0 | 7 | 0 | 13 |
| Loss of ≤0.001% of injection volume over 1000yrs | 138 | 21 | 7 | 0 | 3 | 0 | 0 |
| Loss of ≤0.01% of injection volume over 1000yrs | 144 | 5 | 0 | 0 | 0 | 0 | 0 |
| Loss of ≤0.1% of injection volume over 1000yrs | 38 | 1 | 1 | [illegible] | [illegible] | [illegible] | [illegible] |
| Loss of ≤0.2% of injection volume over 1000yrs | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | [illegible] |
| Loss of ≤1% of injection volume over 1000yrs | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | [illegible] |
| Loss of >1% of injection volume over 1000yrs | 0 | 0 | 0 | [illegible] | [illegible] | [illegible] | [illegible] |

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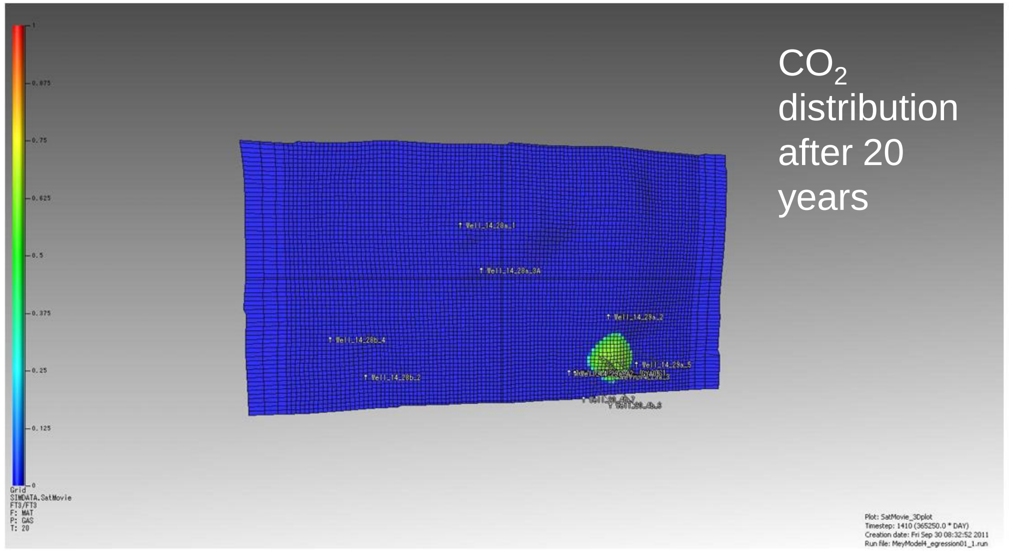
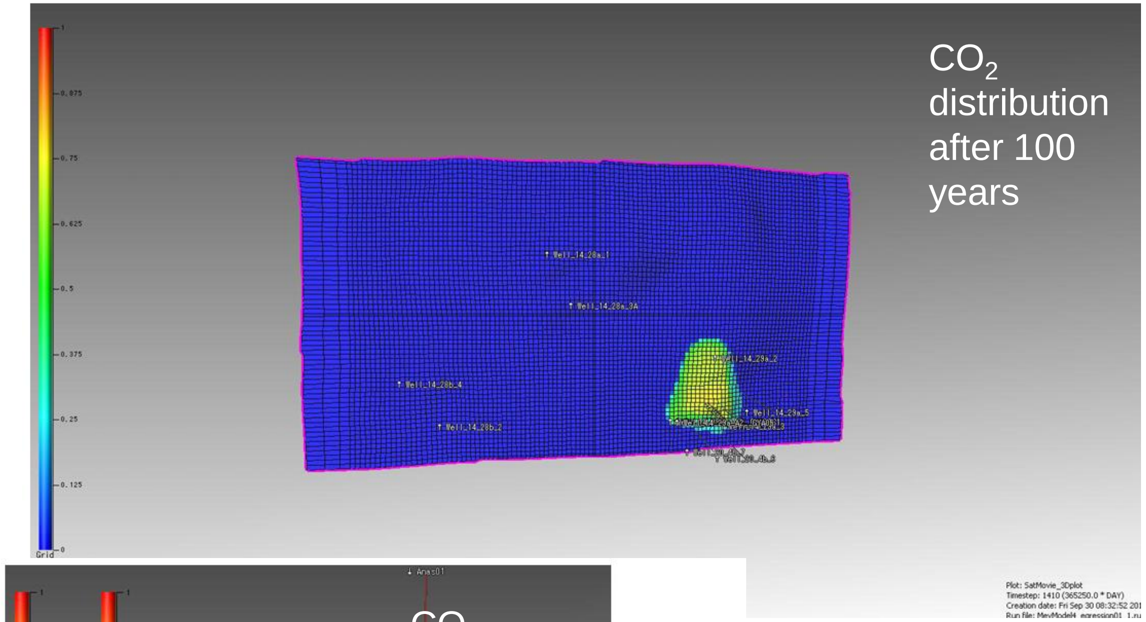
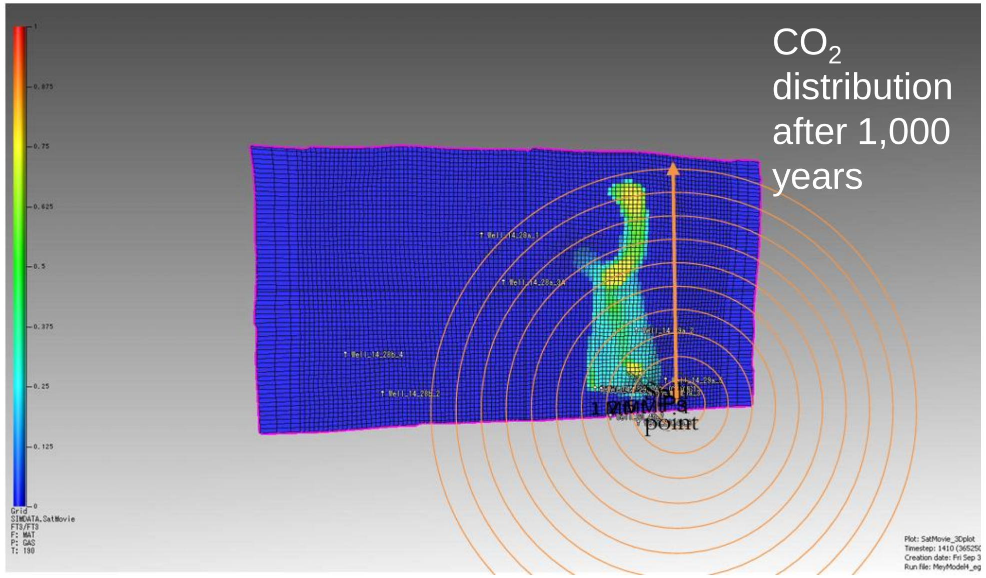
# Step 4 - Detailed quantitative consequence analysis of highest risk wells



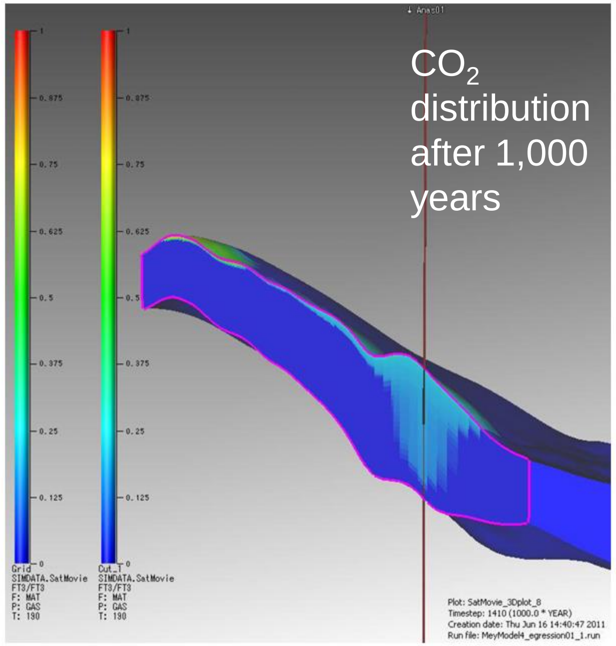
$CO_2$ distribution after 20 years



$CO_2$ distribution after 100 years



$CO_2$ distribution after 1,000 years



$CO_2$ distribution after 1,000 years

*Source, Peterhead CCS Project Dynamic Reservoir Modelling Report 2014*

# Step 5 – Evaluate risk reduction options

Consider

- How likely is it that well(s) will be exposed
- How likely is failure of well integrity such that a release occurs?
- What will be the consequences of a release? e.g.
  - Bubbling $CO_2$ around annulus
  - Full-bore release of $CO_2$/formation water
  - Release of OBM from well
  - Contaminated formation water release
  - $CO_2$ present in aquifer or produced gas
- How much harm may result? e.g. to flora or fauna
- How quickly (if at all) could a release be detected?
- How difficult, how long will it take to fix?
- What are the acceptance criteria?

*What do you know? What don't you know? How certain are you?*



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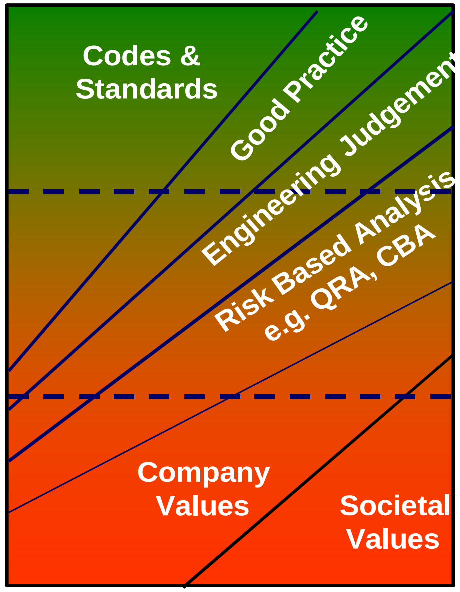
# Step 5 – Decision making




**A**
- Nothing new or unusual
- Well understood risks
- Established practice
- No major stakeholder implications

**B**
- Lifecycle implications
- Some risk trade offs/transfers
- Uncertainty/deviation from standard, best practic
- Significant economic implications

**C**
- Very novel or challenging
- Strong stakeholder views and perceptions
- Significant risk tradeoffs or risk transfers
- Large uncertainties
- Perceived lowering of safety standards

Ref: UKOOA A Framework for Risk Related Decision Support

Sacrifices
- Cost of remediation
- Practicability
- Probability of success
- Ability to locate, re-enter

Benefits; avoidance of
- Environmental damage
- Reputational impact
- Fines
- Loss of carbon credits
- Program delay if have to re-enter later

*<u>NOT</u> just a cost-benefit analysis, also has regulator, public, stakeholder attitude implications*



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# Conclusions

- A structured risk assessment approach is required
- Many different stakeholders
- Most appropriate tools / techniques depend on:
  - Level of risk (generally low)
  - Complexity / uncertainty
  - Available information
  - End use / audience for the assessment
- Bowties provide an easily understood representation of how risks are managed
  - Can accommodate uncertainty
- Quantitative approaches can be used
  - Scarcity of data
  - Indicative only
  - Comparative rather than absolute
  - Infers a degree of accuracy

# Thank you

**Have a safe day!**

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