



xand

Optimizing Infrastructure Solutions

In partnership with
Schlumberger

CO₂ Storage - Managing the Risks of Wellbore Leakage over Long Timescales

Simeo Stor

New Search

Simulator
P&R analysis for
CO₂ geological storage

Copyright © 2007 Oxand S.A. - All rights reserved.

	Gravity					
	I	II	III	IV	V	VI
F	2					
E	14				2	
D	76			9	27	
C						
B	16			2	11	3
A						

Jérôme Le Gouévec, Yvi LE GUEN, V. Meyer, O. Poupard

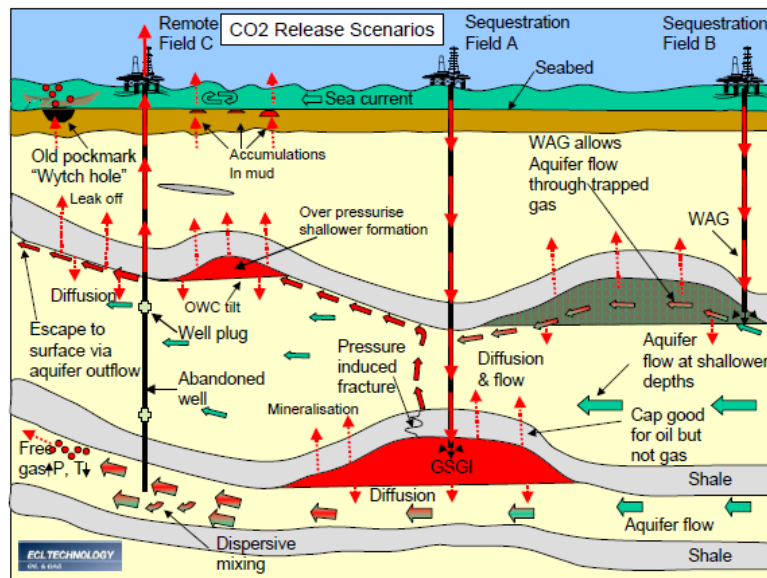


Table of content

- 1. Context and objectives**
- 2. P&R™ approach**
- 3. A 2-flow coupled model**
- 4. Simulations – case study**
- 5. Conclusion - A tool as Decision Making Support**



1. Context – well integrity, a key challenge



NGCAS Project :Wikramaratna & Lawrence, ECL. Dec-2003

Focus on wellbore integrity

- Poor quality or aging of existing wells (injection, monitoring)
- Surrounding abandoned wells

Is CO₂ likely to leak through wells?

How? What pathways?

How much?

When? During injection? In 100 years? 1000 years?

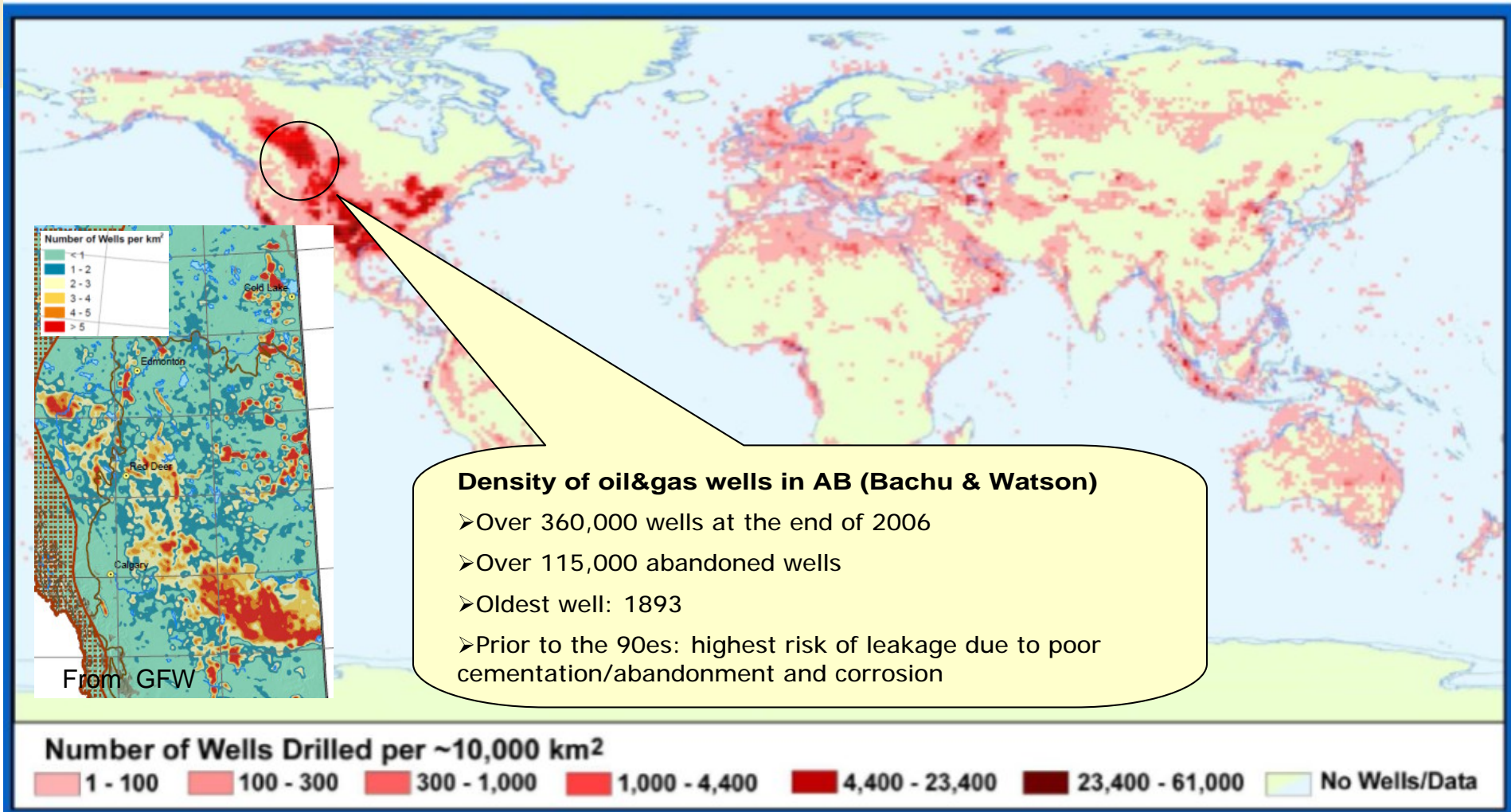
What is an acceptable level of leakage ?

What should be done to mitigate critical risks on the long term?

How am I going to demonstrate CO₂ long term confinement to authorities?



1. Context – wells density



Sources: IPCC Special report 2005, ERCB, AGS, GFW

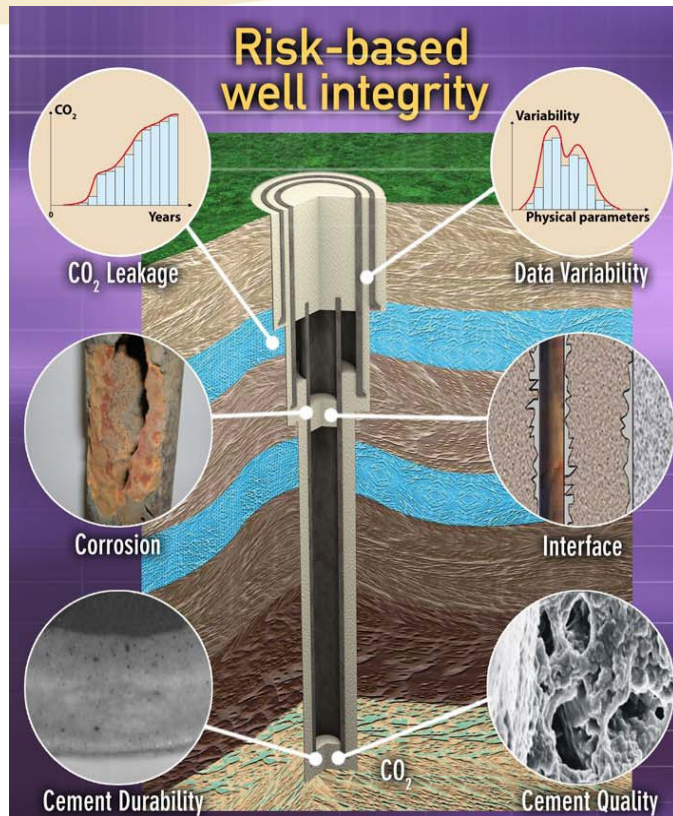


1. Objectives

- ✚ **Estimate the possible CO₂ leakage through the wells, thanks to advanced flow well simulations**
- ✚ **Create a project-specific scale of severity levels associated with CO₂ leakage, through involvement of stakeholders**
 - Health & safety, technology, financial, public acceptance, environmental, image ...
- ✚ **Combine probability of occurrence & severity levels to assess risks and deliver an overall risk profile of the well relative to CO₂ leakage**
- ✚ **Recommend action plans to address critical risks, and lay the foundations of a tailored MVA protocol from WI issue**



2. P&R™ approach



▶▶ A risk-based approach

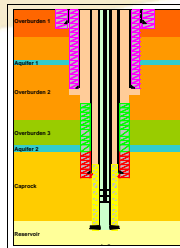
- A well-structured and objective process
- Functional analysis
- Scenarios identification & quantification
- Risk mapping
- Acceptance level

▶▶ Quantitative CO₂ flow model along the wellbore

- Well, flow and ageing models
- Uncertainties
- Prognosis
 - Leakage rates towards sensitive zones
 - No predefined migration pathways along wellbore



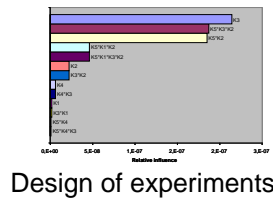
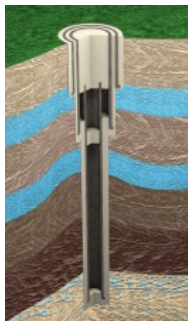
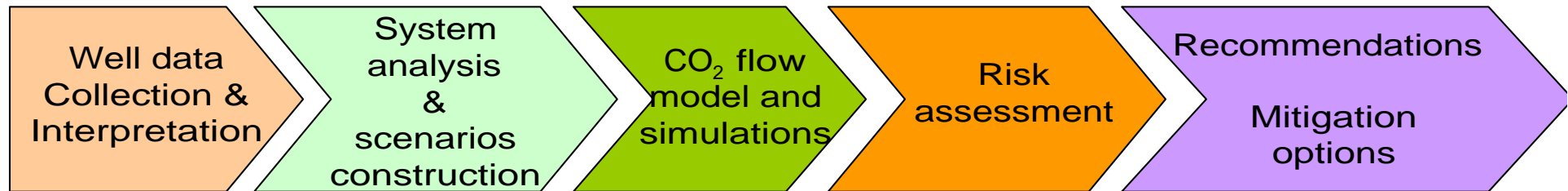
2. A quantitative approach for specific well



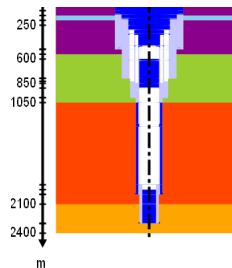
Static and dynamic model

Consequence grid

	Stakes	Safety/ Health	Environment
Severity levels	1: Minor		
2: Low			
3: Serious			
4: Major			
5: Critical			
6: Extreme			

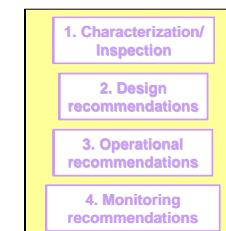


Design of experiments



		Severity					
		1	2	3	4	5	6
F _h	6	7	8	9	10	11	12
	5	6	7	8	9	10	11
	4	5	6	7	8	9	10
	3	4	5	6	7	8	9
	2	3	4	5	6	7	8
	1	2	3	4	5	6	7

Risk level of each scenario



Action plan

Uncertainties



3. A coupled model : flow + degradation

Fluid flow model

2D axisymmetric
2-phase flow (gas, liquid)



Corrosion

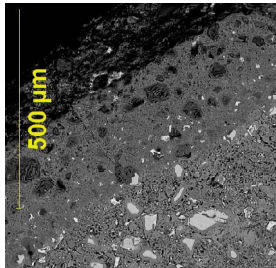
pH, P, T,
chlorides, CO₂...

Cement degradation

Leaching / Carbonation
pH, P, T, flow...

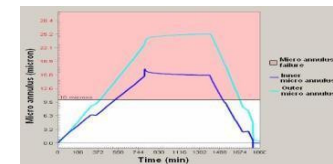


Carey et al., 2006

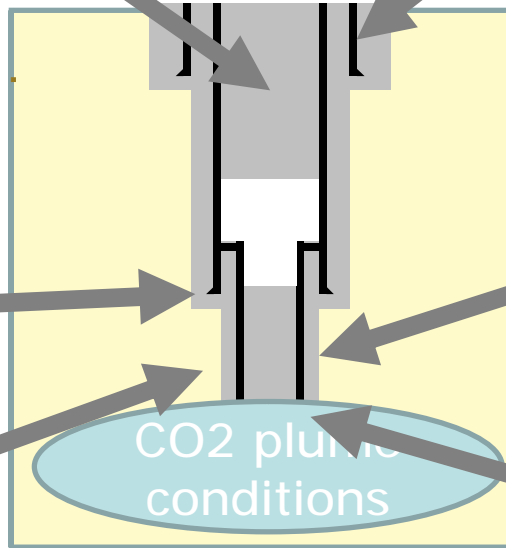


Kutchko et al., 2007

Thermo-mechanical effect (micro-annulus)



CemSTRESS™ (Schlumberger)



CO₂ plume
conditions

Dry out

Creep of geology, others ...



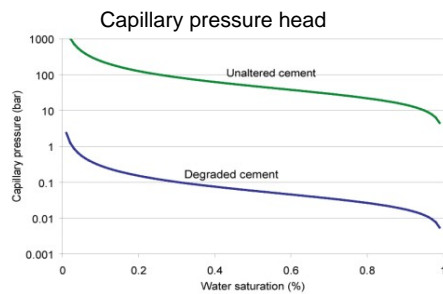
A 2-phase flow model

- 2D axisymmetric well representation
- 2 phases flow – darcy law
- Relative permeabilities: Van Genuchten and Mualem's model

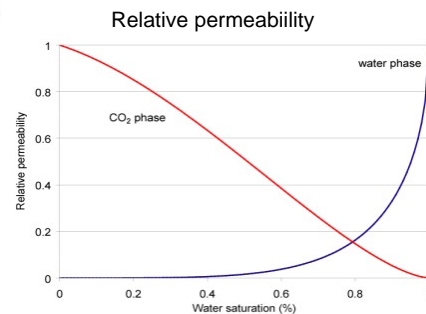
$$q_{nw} = -\frac{kk_{rw}}{\mu_{nw}} \left[\vec{\text{grad}}(p_{nw}) + \rho_{nw} g \vec{k} \right]$$

$$\begin{cases} k_{r,nw}(\Theta) = \sqrt{1-\Theta} \cdot (1-\Theta^{1/M})^{2M} \\ k_{r,w}(\Theta) = \sqrt{\Theta} \cdot (1 - [1-\Theta^{1/M}]^M)^2 \end{cases} \quad \left(1 + \left(\frac{p_c}{p_{ec}} \right)^N \right)^M = \frac{1}{\Theta}$$

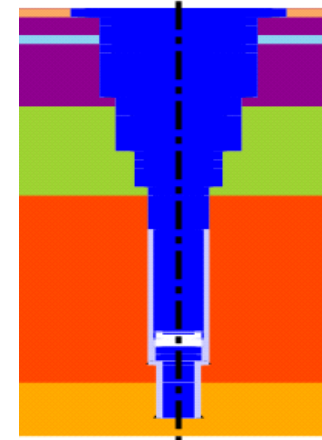
$$\Theta = \frac{S_w - S_{rw}}{1 - S_{rw}}$$



From Mainguy, 1999

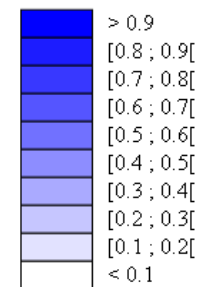


CO₂ migration within the wellbore



At a time *t*

Legend for Water Saturation [-] :

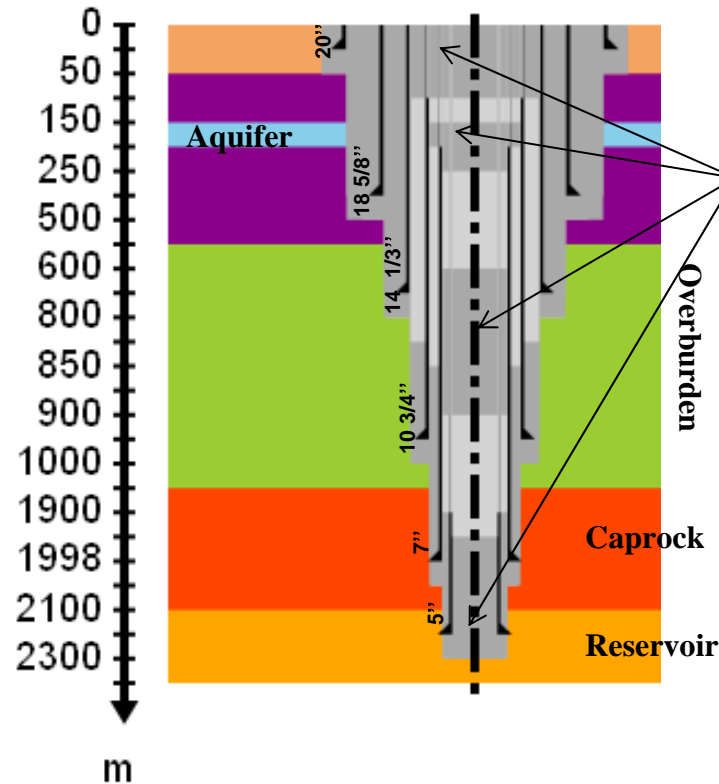
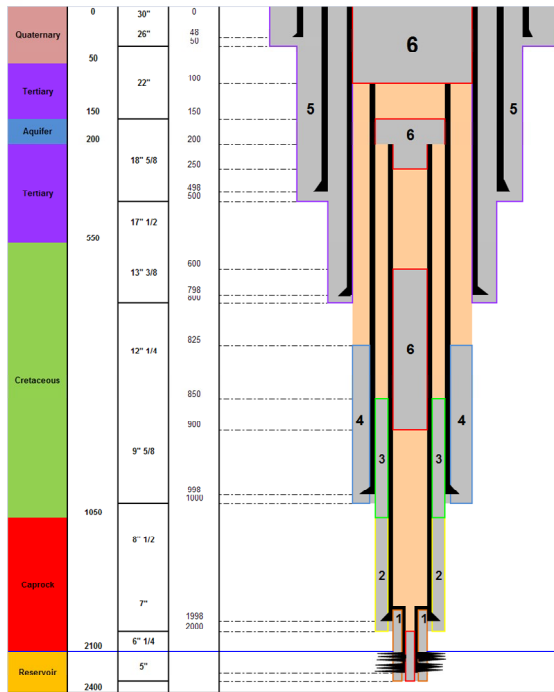




4. Simulations – case study for abandoned well (synthetic)

Static and dynamic model

Well integrity data interpretation



Initial design
Cement plugs quality

Zones	Quality
1	Medium
2	Good
3	Bad
4	Unknown
5	Unknown
6	Excellent - Plugs

1 connected aquifer (freshwater)

Hydrostatic pressure along the wellbore

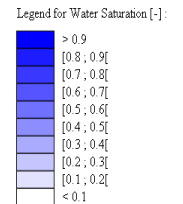
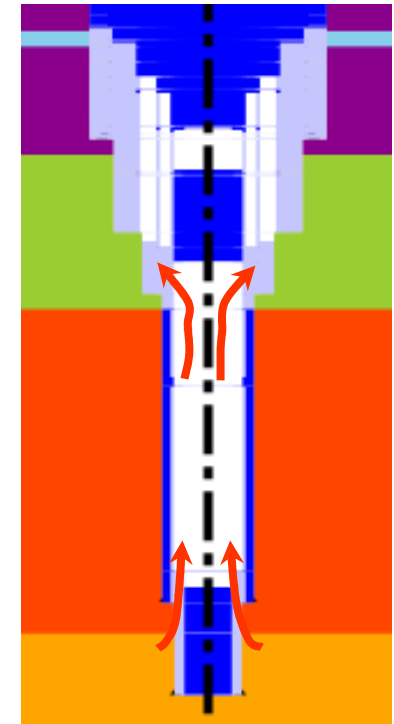
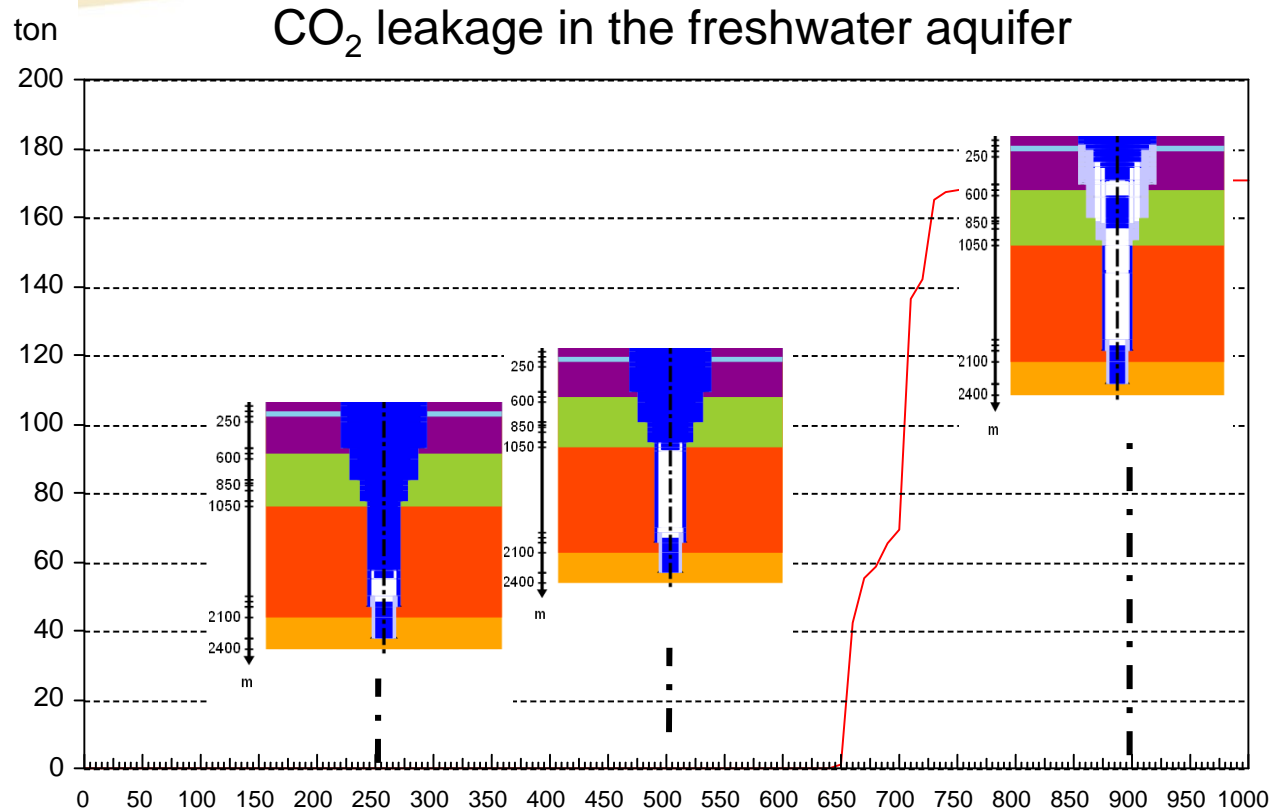
Top reservoir CO₂ pressure in contact to the well: 400 bar (constant over time period)

Initial and limit conditions



4. Simulations – CO₂ flow results

▶▶ Simulation results (an example for a 1st scenario)

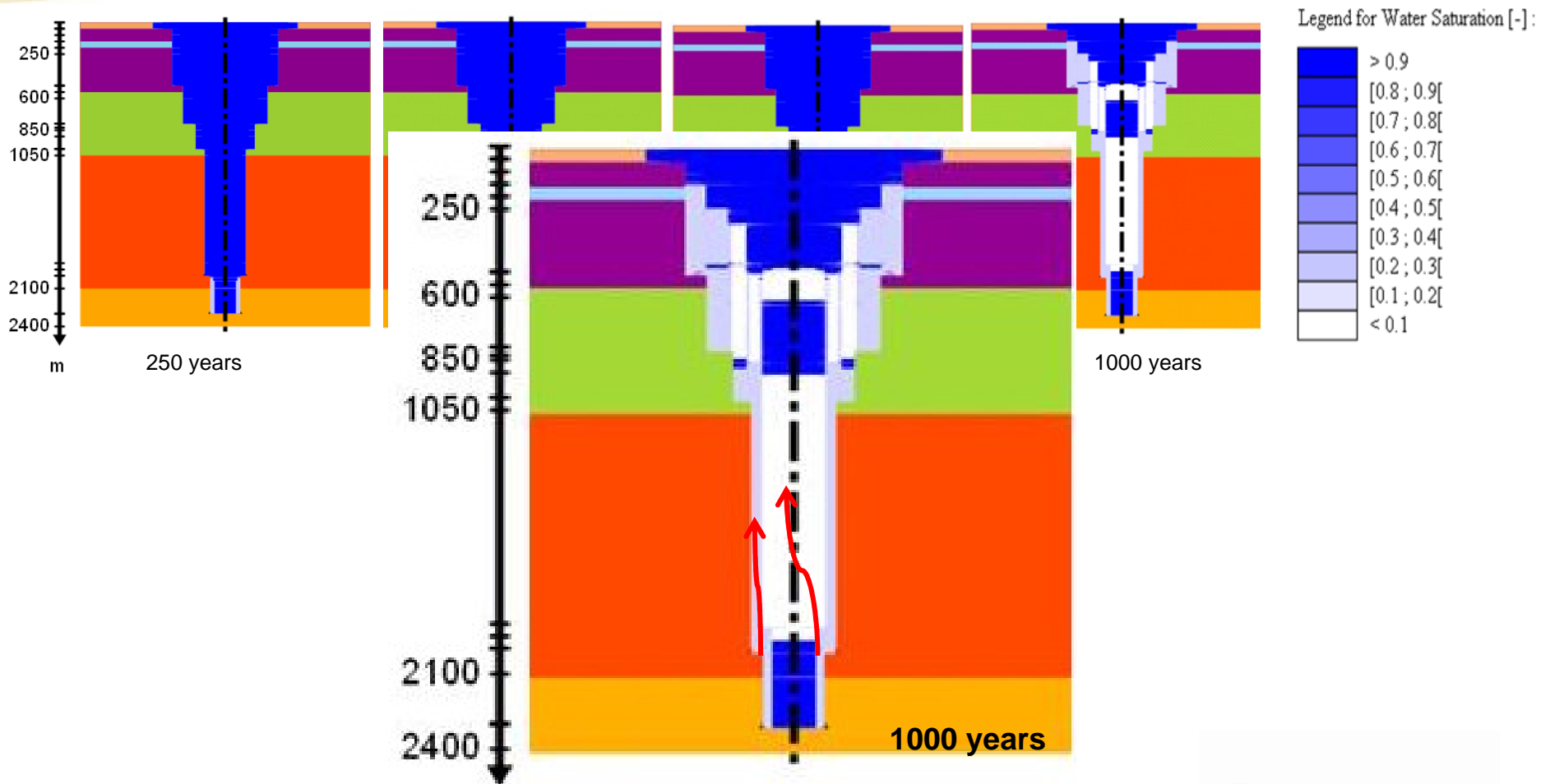


**Despite good quality cementation in 7", CO₂ flows up !
The CO₂ migration paths are not predefined!**



4. Simulations – CO₂ flow results

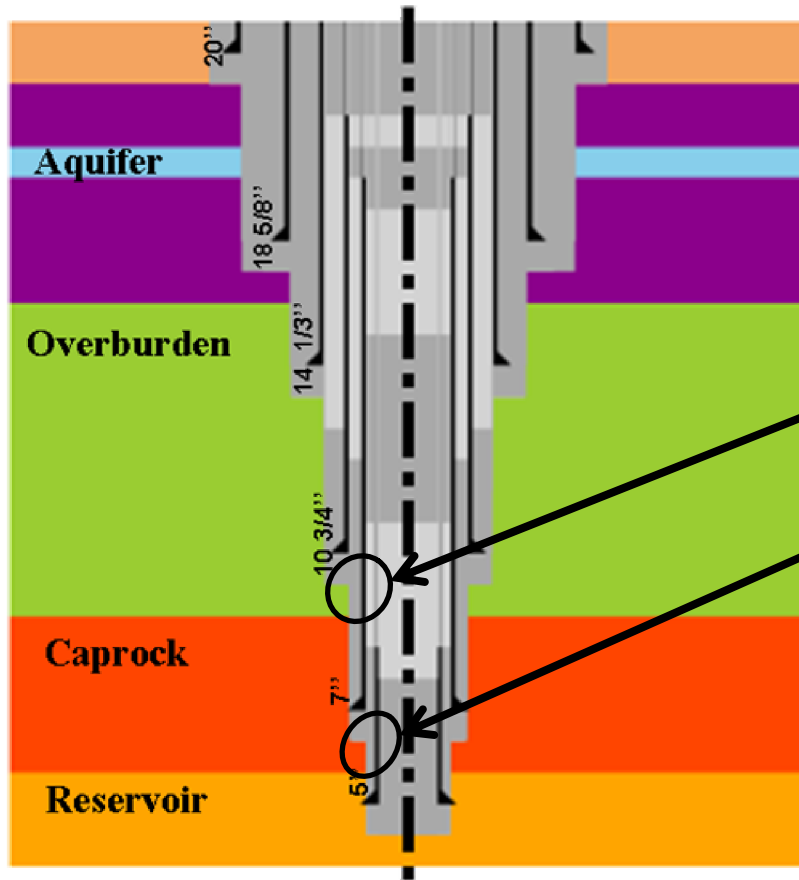
▶▶ Simulation results (an example for a 2nd scenario, with ≠ perm)





4. Simulations – risk mapping

Risk mapping at 1000 years



	6	0	0	0	0	0	
	5	0	0	0	0	0	
	4	64	0	0	8	22	
	3	368	16	48	127	107	
	2	0	0	0	0	0	
	1	0	0	0	0	0	
		1	2	3	4	5	
		Severities					

Risk sources (scenarios with greater risk level):

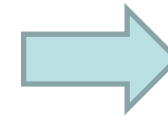
- quality cementation of 5" annulus
- corrosion process above the caprock due to presence saline formation within overburden (aggressive formation fluids)



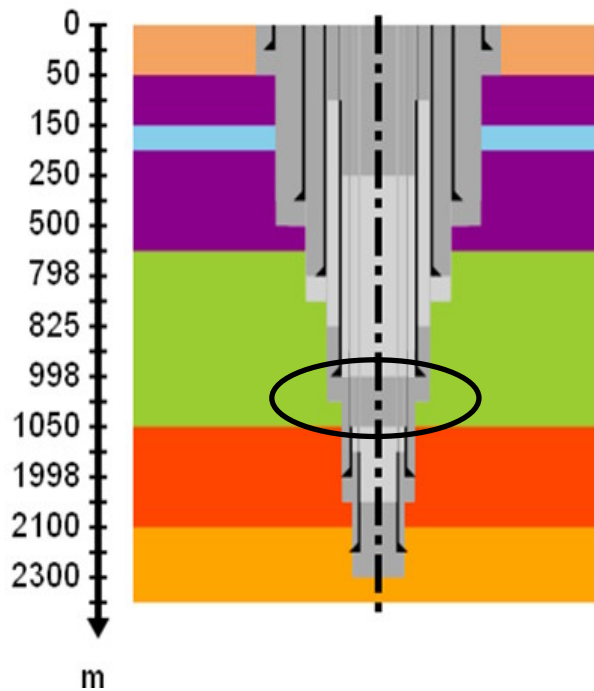
4. Simulations – Recommendations & update

A possible new abandonment design :

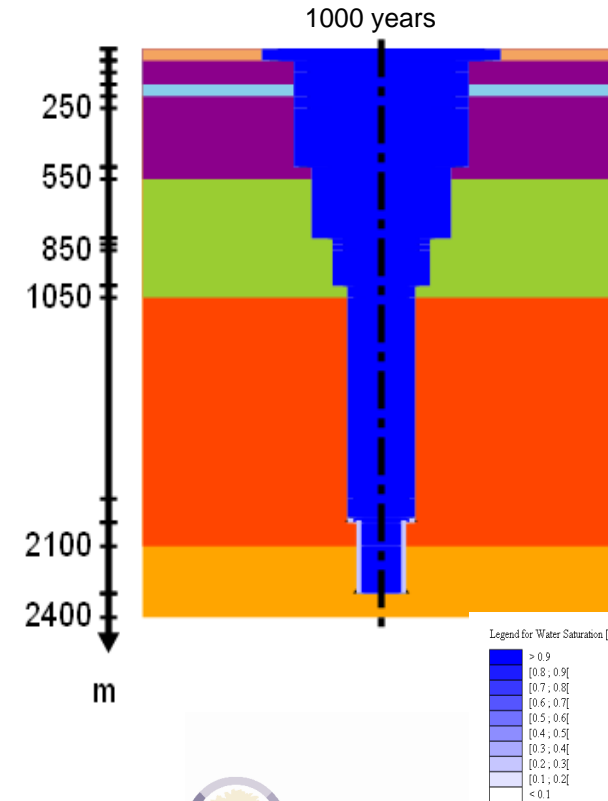
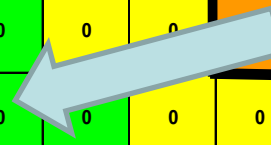
- Mill the 7" casing
- Put a cement plug in front of geological formation layer



Well integrity
QRA
update



	1	2	3	4	5	6
6	0	0	0	0	0	0
5	0	0	0	0	0	0
4	144	0	0	0	0	0
3	1152	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0
Severities						





5- Conclusion - A tool as Decision Making Support

- ▶▶ **A structure and objective process**
 - A well model, update

- ▶▶ **A predictive CO₂ flow model along the wellbore**
 - Leakage rates towards freshwater aquifer or surface
 - No predefined migration pathways

- ▶▶ **A global rating of the risks related to well integrity in CO₂ storage (vs. CO₂ migration)**

- ▶▶ **A powerful support to the decision-making process**
 - Quantitative and objective elements to support to all major decisions:
 - mitigation and monitoring strategy, design strategy,
 - site selection, well selection, MVA procedure



Thank you.

This document was created with Win2PDF available at <http://www.win2pdf.com>.
The unregistered version of Win2PDF is for evaluation or non-commercial use only.
This page will not be added after purchasing Win2PDF.