

Lowering the risk of legacy wells with a risk& trigger-based CCS monitoring strategy

CCS Legacy Wells Seminar – FORCE



SPOTLIGHT
The CCS Surveillance company



FORCE

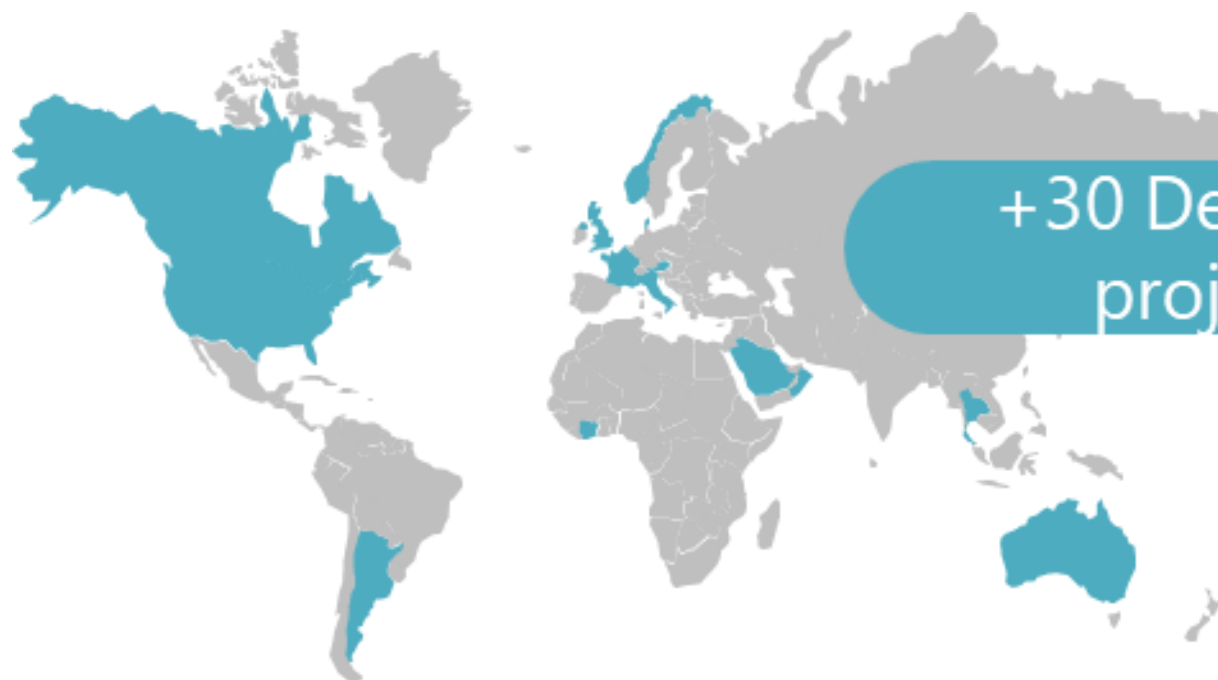
November 2025
Elodie MORGAN
Habib AL KHATIB



A few word about us



- **Crazy company** –Geophysicists that don't do “images” since 2017
- **Pioneers:** Denmark, UK, Texas...
- **Recognized:** Global CCS Institute's State of the Art report, and as a Top Innovator by Darcy Partners.



+30 Delivered
projects



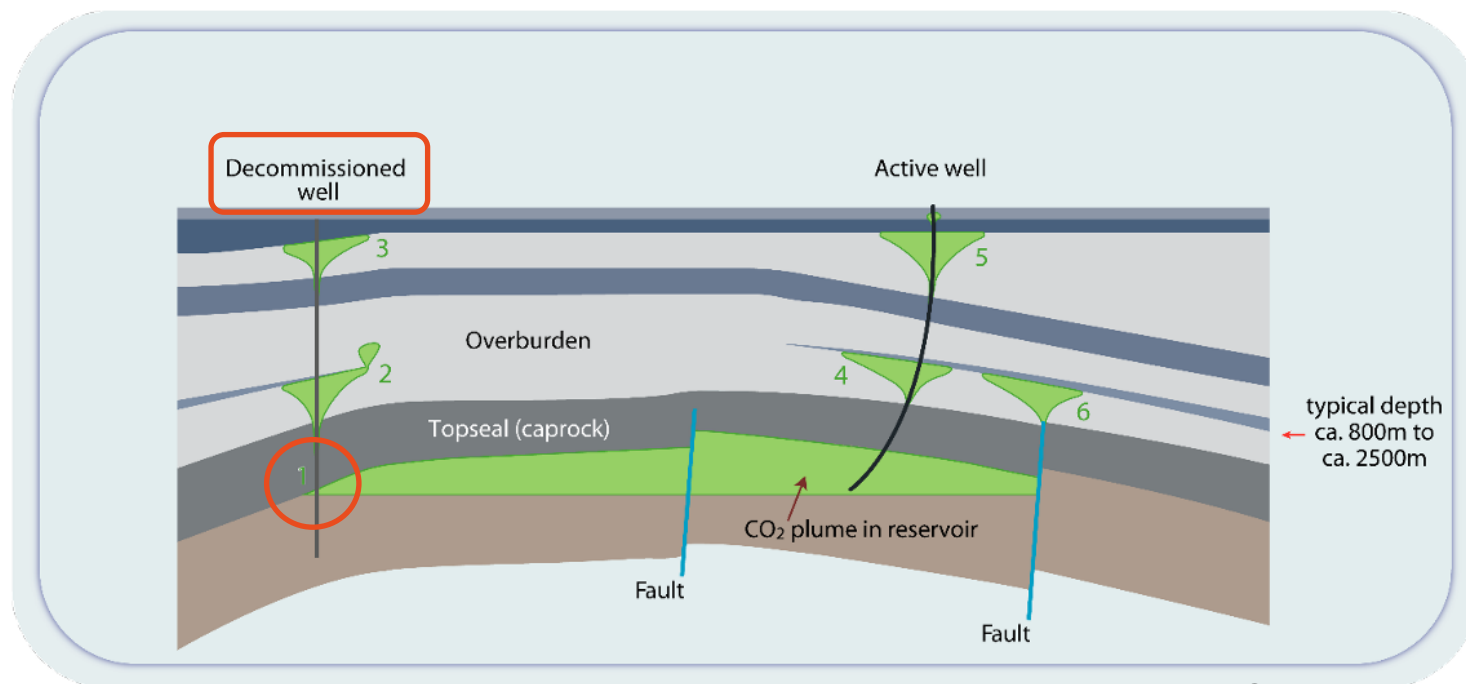
Why are we monitoring?



Containment
Conformance
Confidence

Avoid leakages
Compared actual vs modeled
Build trust

Potential risks



And meet the **regulation**
requirement...



Matching regulation requirement



DIRECTIVE 2009/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 April 2009

on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006

Article 13

Monitoring

1. Member States shall ensure that the operator carries out monitoring of the injection facilities, the storage complex (including where possible the CO₂ plume), and where appropriate the surrounding environment for the purpose of:

- (a) comparison between the actual and modelled behaviour of CO₂ and formation water, in the storage site;
- (b) detecting significant irregularities;
- (c) detecting migration of CO₂;
- (d) detecting leakage of CO₂;
- (e) detecting significant adverse effects for the surrounding environment, including in particular on drinking water, for human populations, or for users of the surrounding biosphere;
- (f) assessing the effectiveness of any corrective measures taken pursuant to Article 16;
- (g) updating the assessment of the safety and integrity of the storage complex in the short and long term, including the assessment of whether the stored CO₂ will be completely and permanently contained.



North Sea Transition Authority

Multiple monitoring methods and technologies should be selected based on the most appropriate, existing, new, or emerging technologies and where possible use existing operational carbon storage projects for lessons learned and best available techniques and technology.

The MP should utilise the dynamic modelling and forecasts from the Carbon Storage Development Plan as a reference and guide for monitoring data where applicable.

In the scenario where a leak from the storage complex is detected, the Licensee should demonstrate how the deployed monitoring technologies will be used to measure and quantify the leakage event and therefore assess the level of leakage. This may in cases require a combination of techniques and methods but is essential to inform the CMP and for quantification and accounting purposes.



NORWEGIAN OFFSHORE DIRECTORATE

Section 5-4. Monitoring

The operator shall monitor the injection facilities and the storage complex, including the dispersion of CO₂ in order to:

- a) Compare the actual and modelled behaviour of the CO₂ and the formation water in the storage location,
- b) Identify significant irregularities,

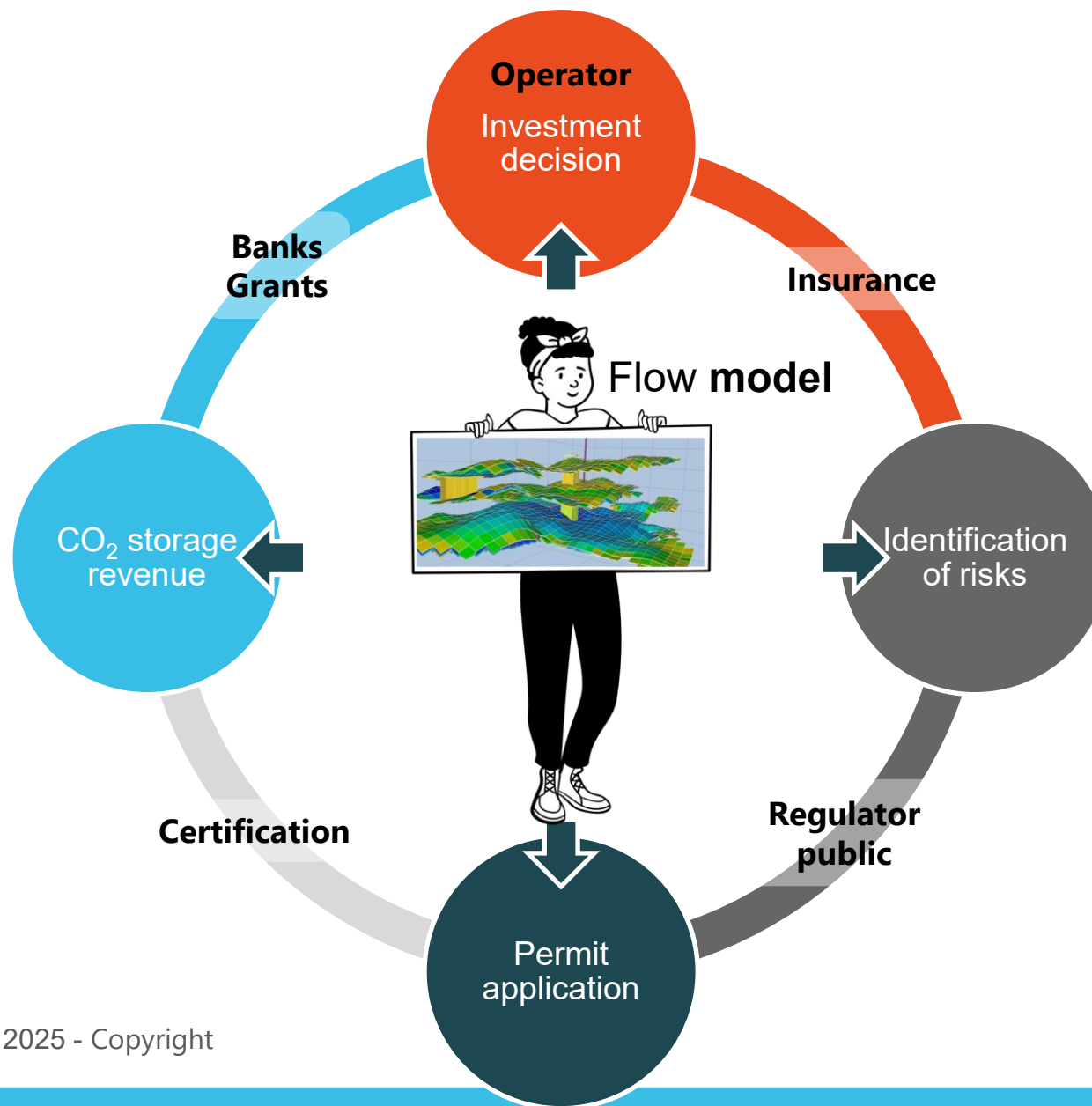
Section 5-5. Regulatory supervision

The Ministry or the entity it authorises shall superintend the storage location at least once per year up to three years after shutdown, and then every five years until the responsibility has been transferred to the State, represented by the Ministry. During



TransparenCCS – Trust the model

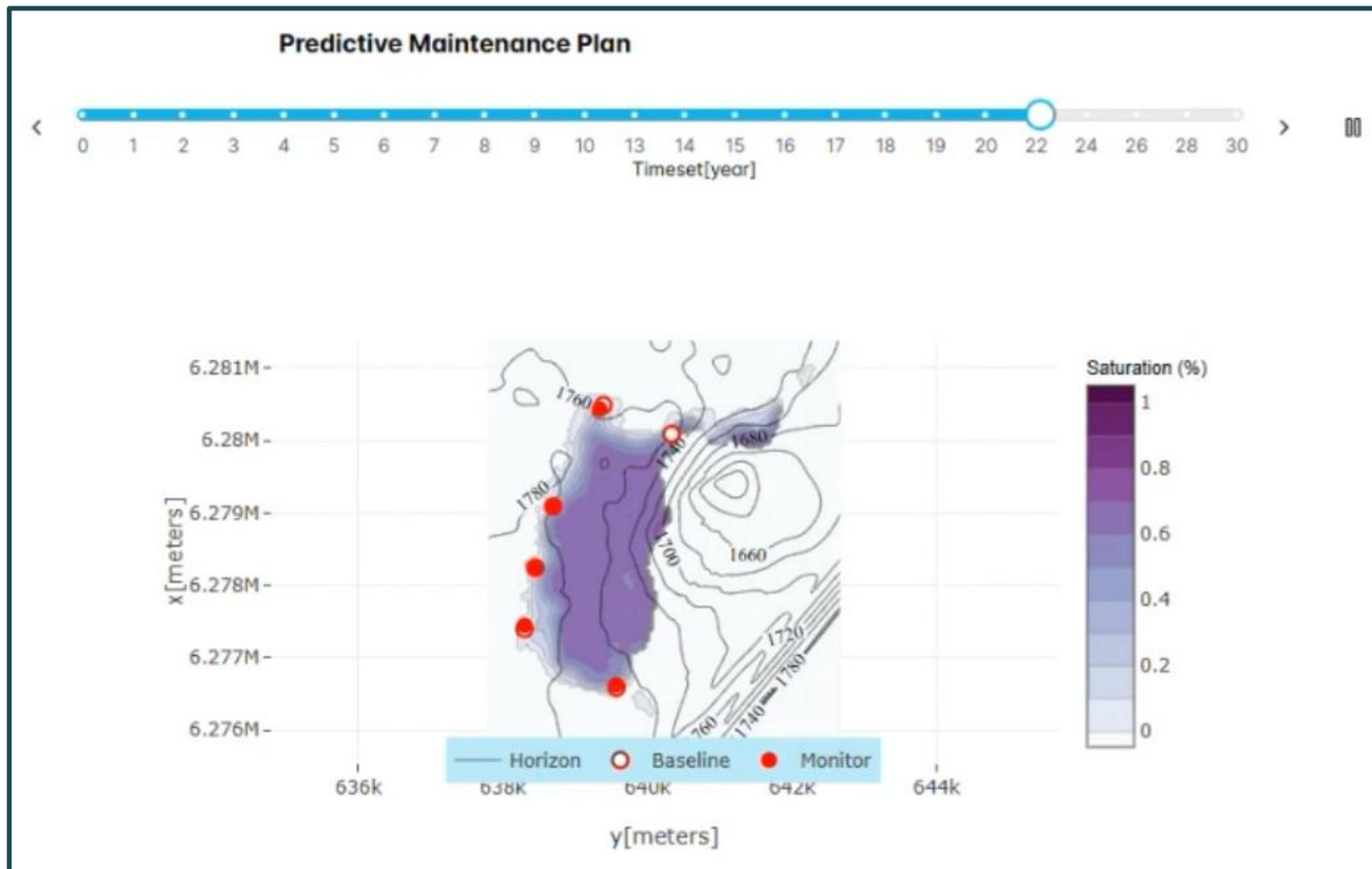
Containment
Conformance
Confidence





Predictive Monitoring – ~~Trust~~ Test the model

Conformance
Confidence

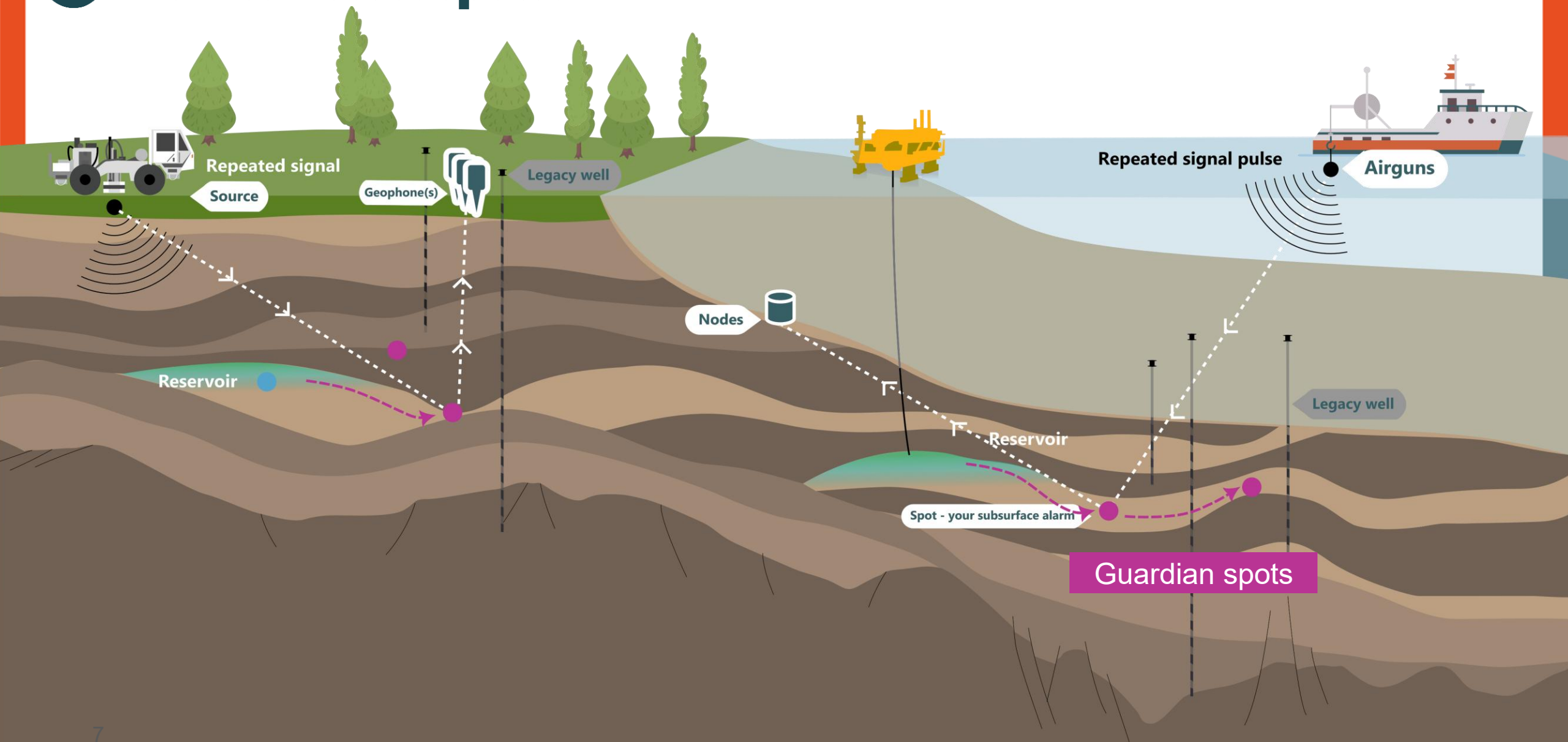


Detect **significant**
irregularities
early on





How to detect spots?





Predictive maintenance requirement

Confidence



Minimal
Environmental
& societal
impact



Co-location



Keeping up
with
innovations



Low cost



Transparency

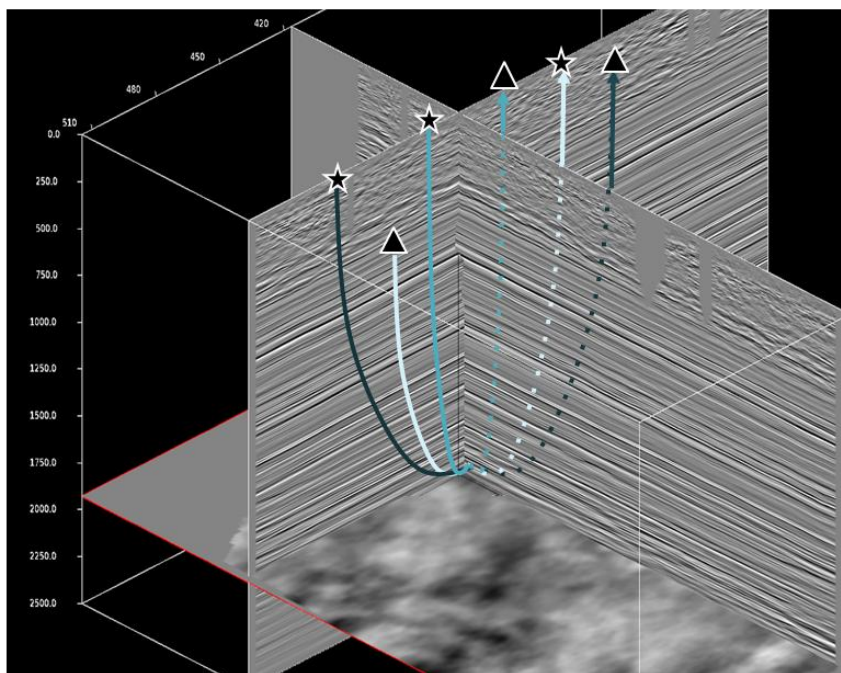
Nice **story**, now show
me the **data**





Ray tracing algorithm

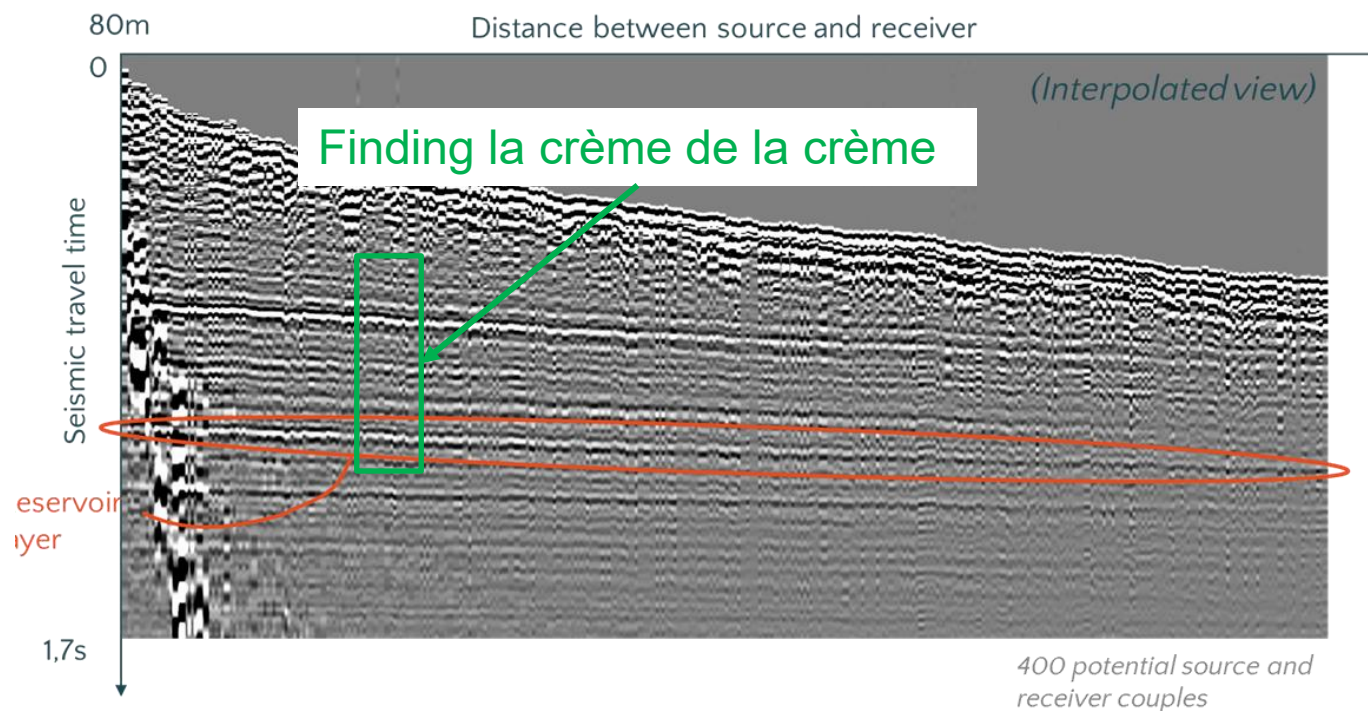
Example for 3 source-receiver combinations but we extract plenty of combinations ! 400 in this case.



★ Sources & ▲ receivers from 2020 3D seismic

Common Spot Gather (CSG)

Seismic traces useful to see the spot
400 potential source-receiver couples

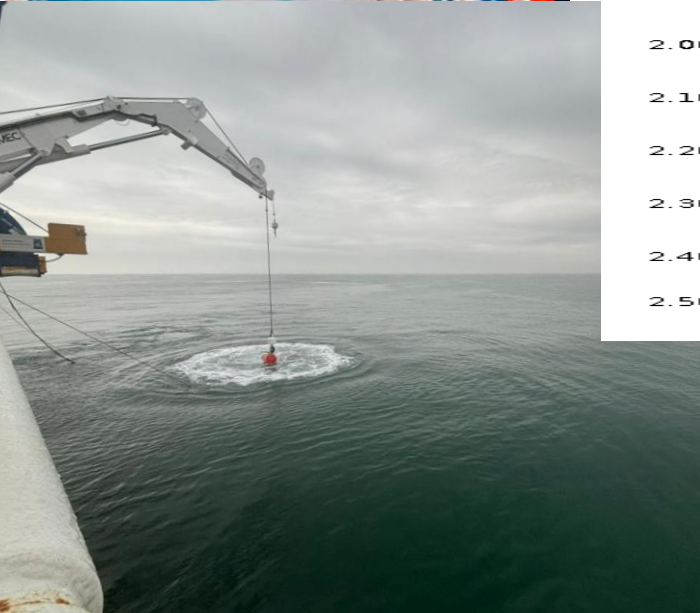


400 potential source and receiver couples

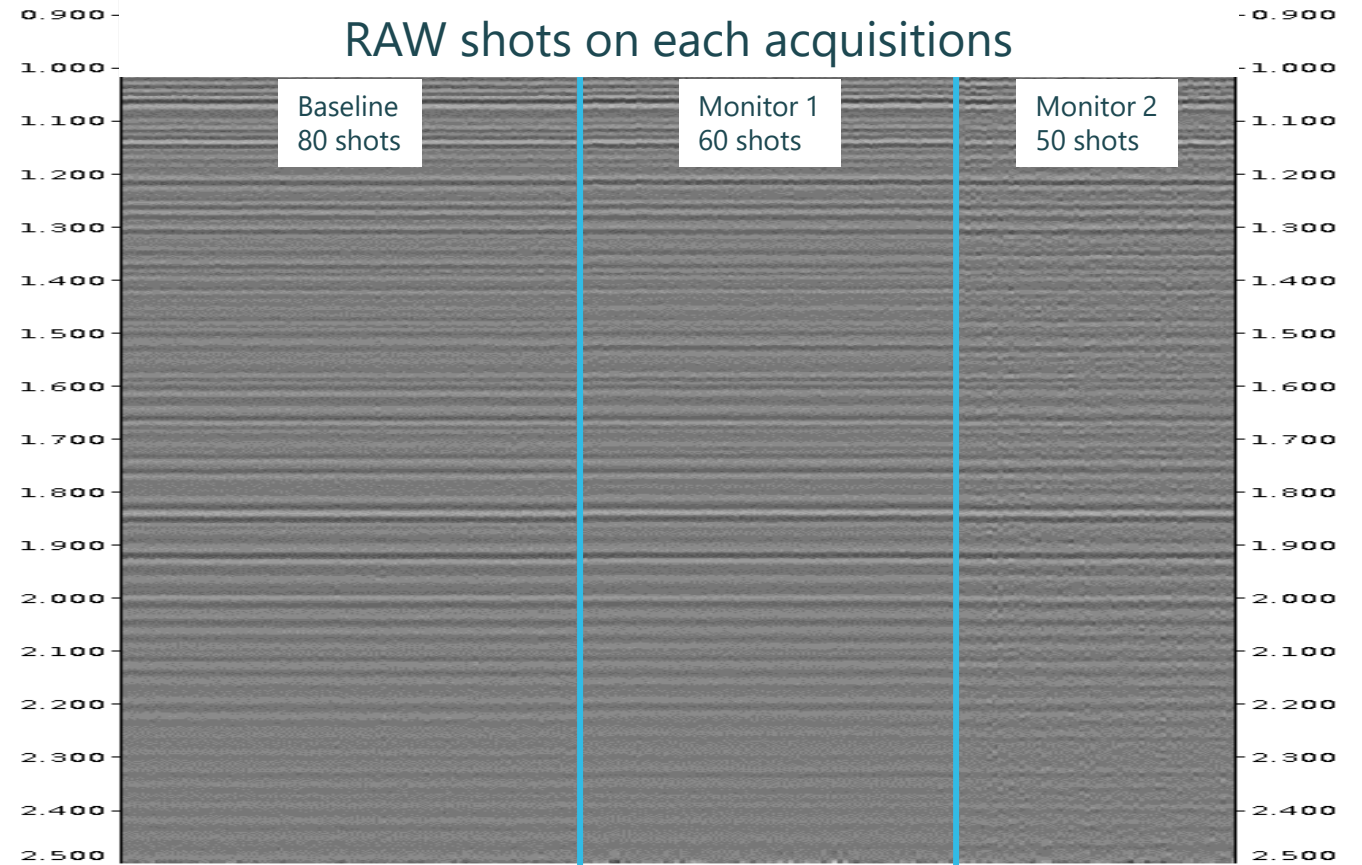


Operational model

Confidence



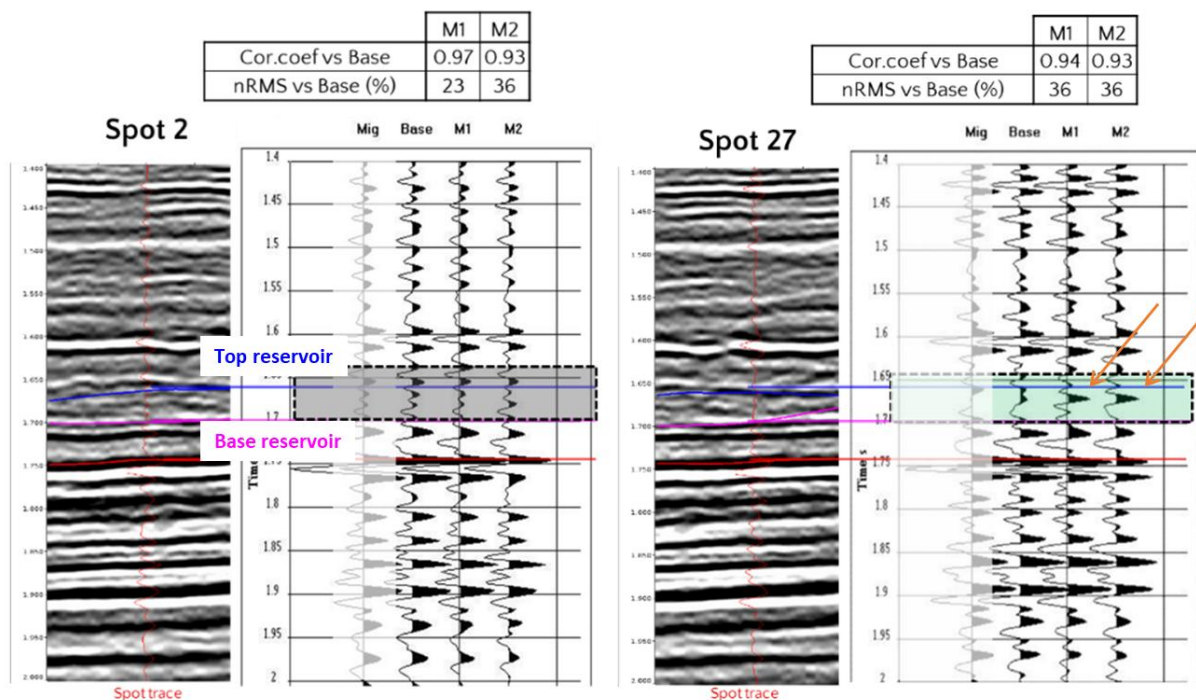
RAW shots on each acquisitions



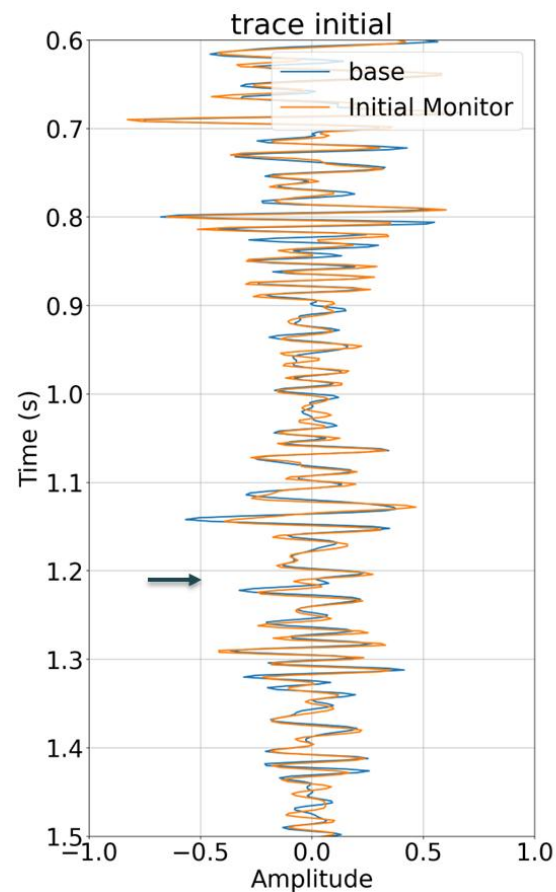


Offshore: Greensand & Perenco example

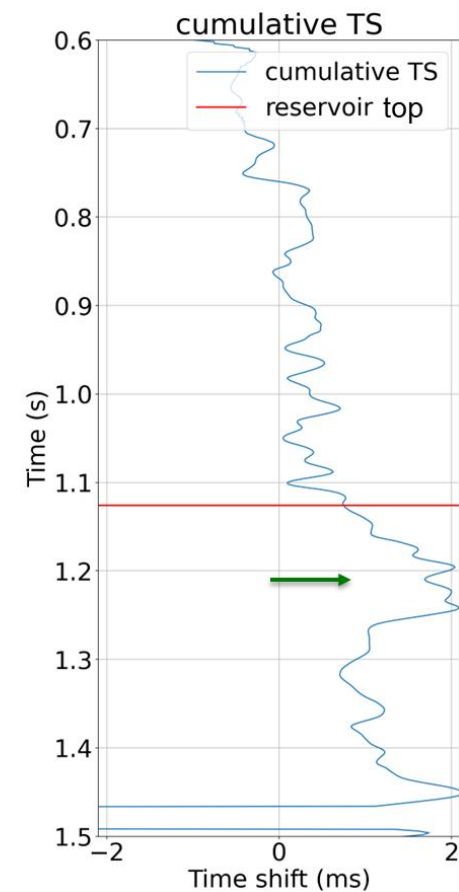
Saline aquifer 2023-2024 - Greensand



Depleted field 2025 - Leman



Confidence





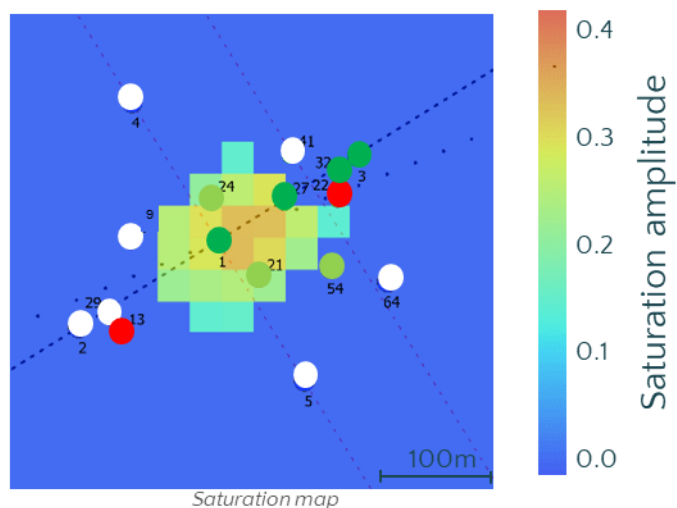
Calibration: How much **MPa** and % of saturation can be detected?

Confidence

Saline aquifer

2023-2024 – Greensand – Saturation effect

Monitor 2

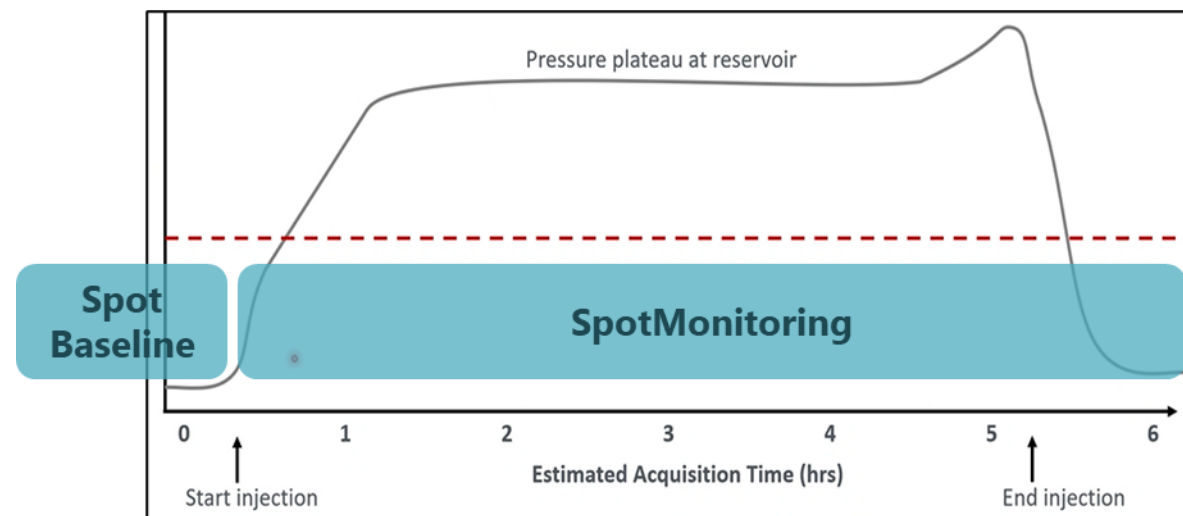


- Subtle CO₂ effect detected
- CO₂ effect detected
- No effect detected
- Data quality issue*

3%

Depleted field

2025 – Leman – “Pore pressure” detection

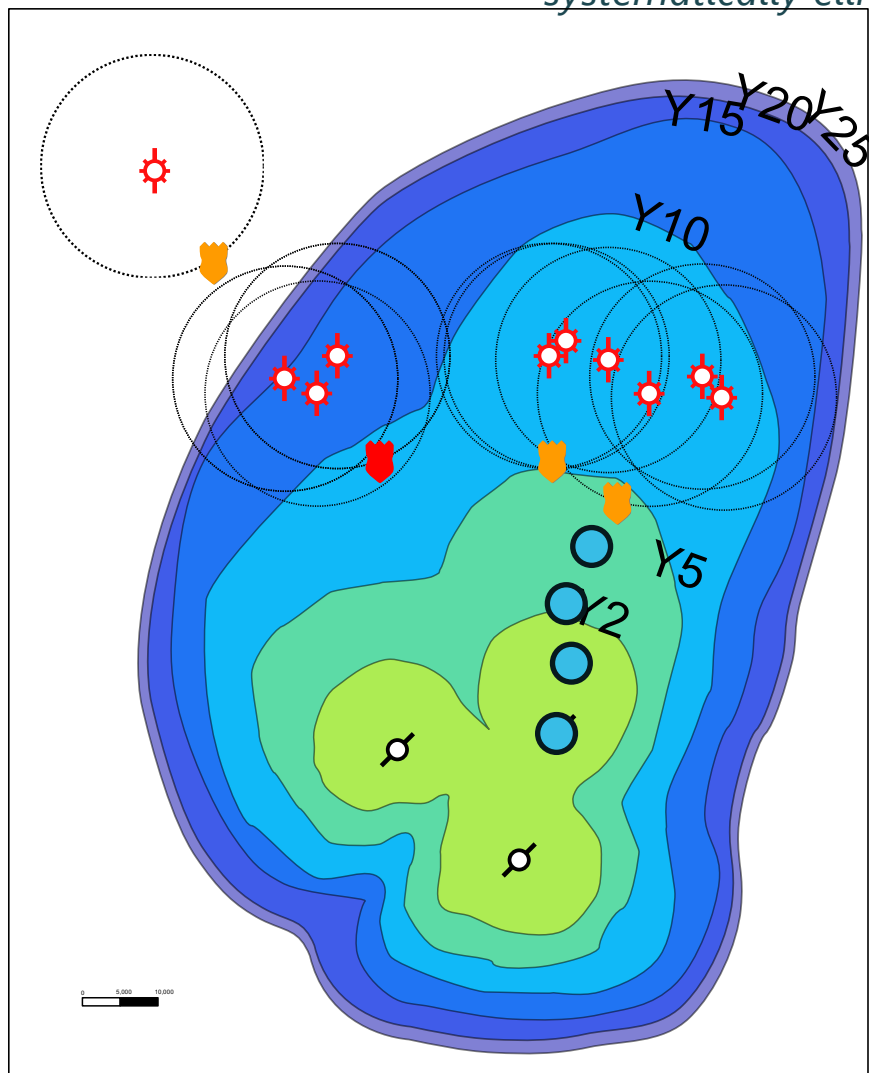


250psi / 1.7 MPa



Guardian spots

"systematically eliminate the unacceptable outcomes, and monitor high risk elements "

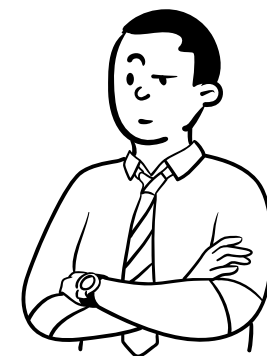


Containment

Containment Confidence

- Injectors
- Legacy wells requiring remediations if reached by CO2
- Guardian spots to trigger the remediation
- 3 years warning limit

What if guardian spots detects CO2?



Legacy wells

3 levels alarm system of guardian spots positioned based on **time** and **distance** criteria to detect plume proximity to the well.

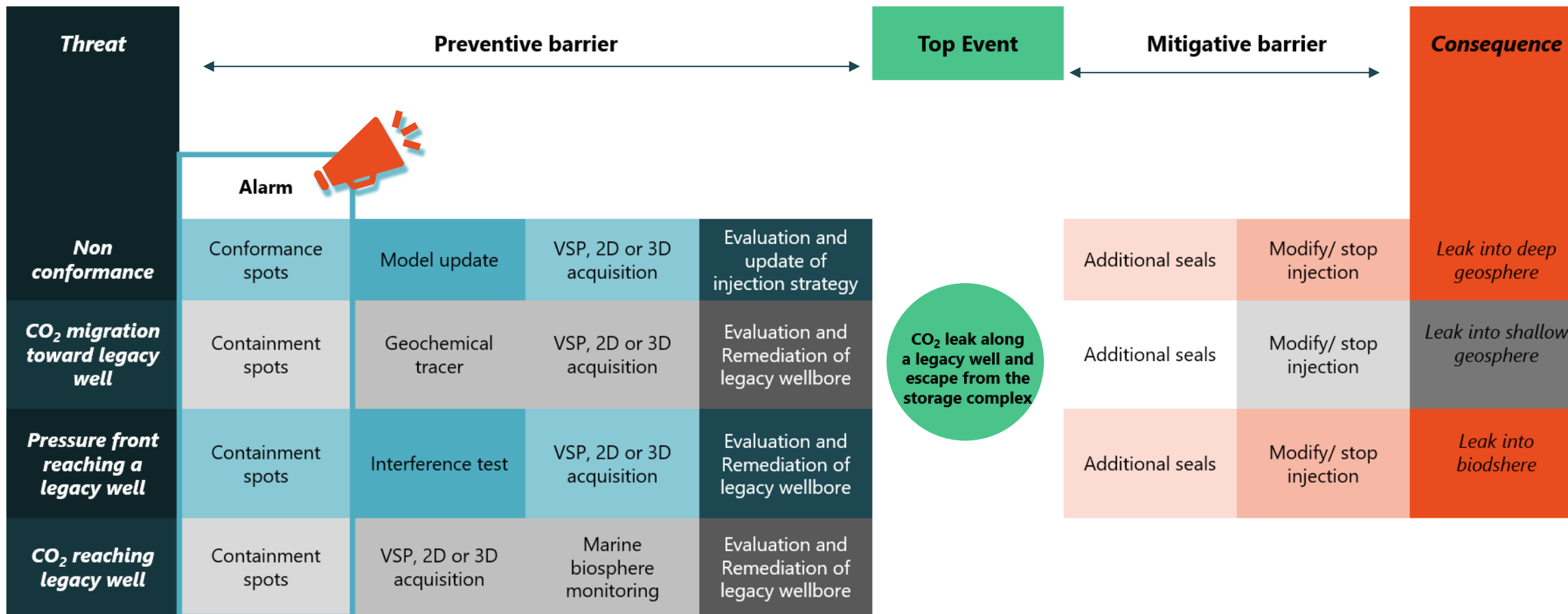
Containment spots are both modeled plume & risk driven to assure the integrity of the storage

**Detectable CO2 as per flow model and calibration*



Trigger & Bowties

Containment Confidence





Conclusion

Monitoring plan with frequent measurements & alarms to convince the regulator corrective measure can be postponed to post injection

Predictive monitoring using spot seismic can provide frequent updates away from wells in a **transparent** way, and is part of a toolbox

Impact assessment & risk tolerance must be taken into account to focus the measurement to when/where it matter.

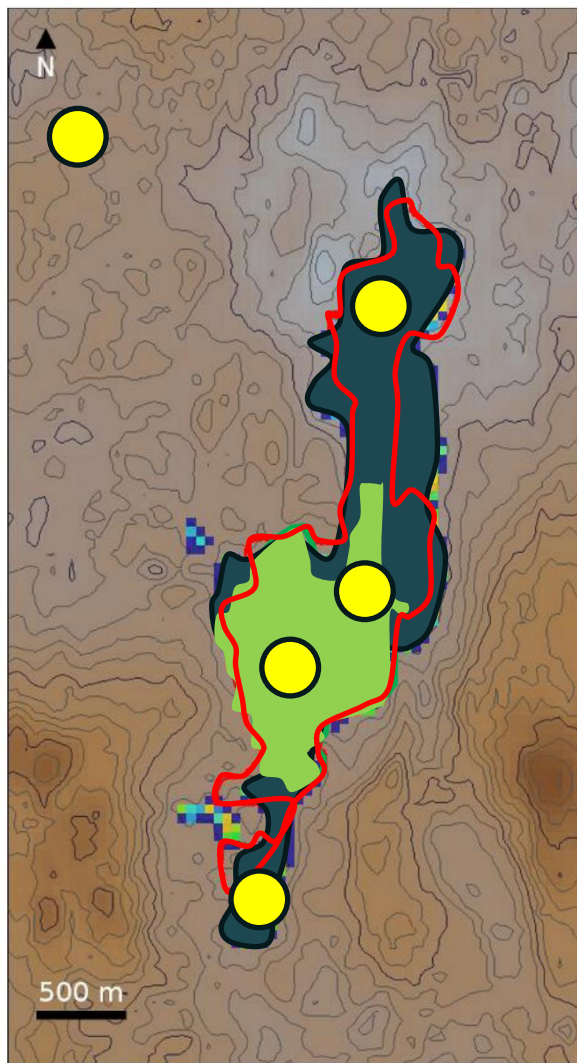
Active seismic like spot seismic need to be calibrated (using direct measurement)

Goal: Inform years in advance when to trigger the corrective measures





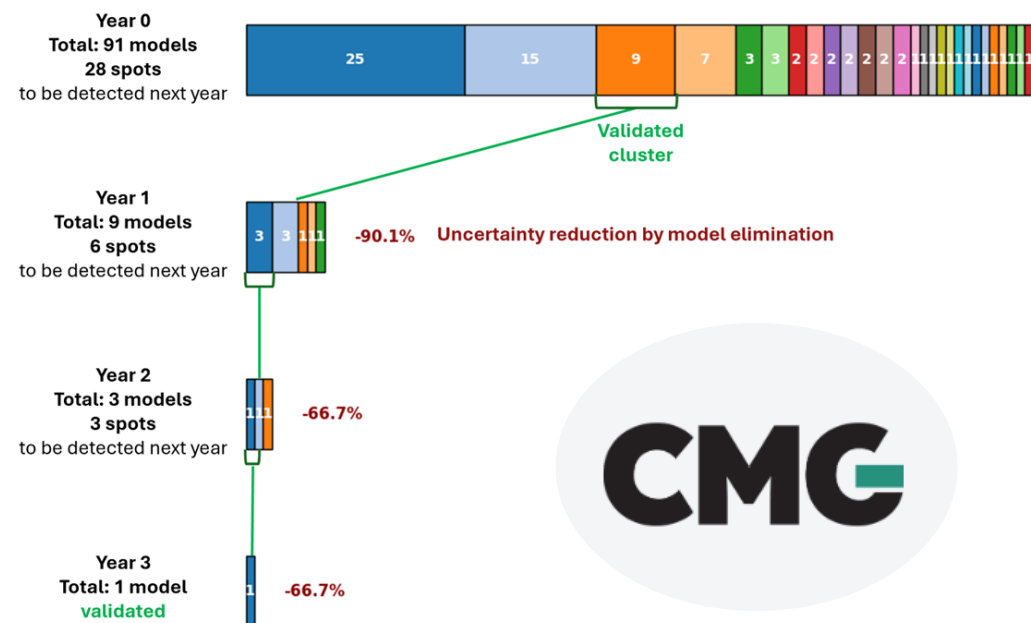
Next steps – Manage uncertainties using assemble models



Example simulations using the Sleipner Layer 9 reference model.

- Simulation #1
- Simulation #2
- 2008 seismic time-lapse amplitude extent

Models and clustering strategy over time



Ringrose, P. & al. (2017).

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