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Carbon Storage and Management

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A Comprehensive Analysis of CO_2 Plume Monitoring and Containment Strategies from Geophysical Perspectives

Salbiah Mad Sahad*, Pankaj Kumar Tiwari, Prasanna Chidambaram, M. Rashad A. Rashidi, Awang Amirul Zakry Awang Bujang, Koon Hong Ho and Nor Farrah Diana Nordin

Petronas Research Sdn. Bhd. (PRSB), Exploration Geophysics Solution (EGPS)

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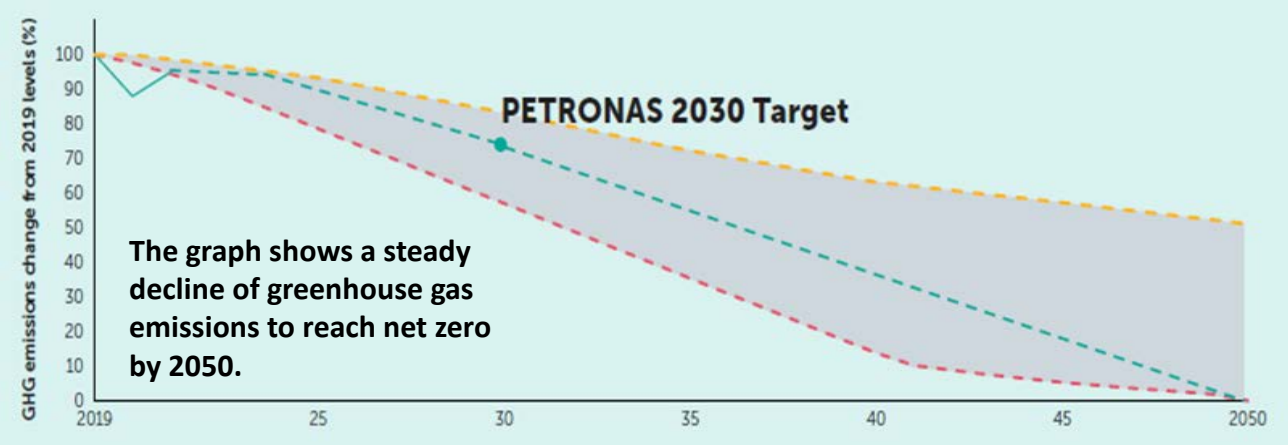
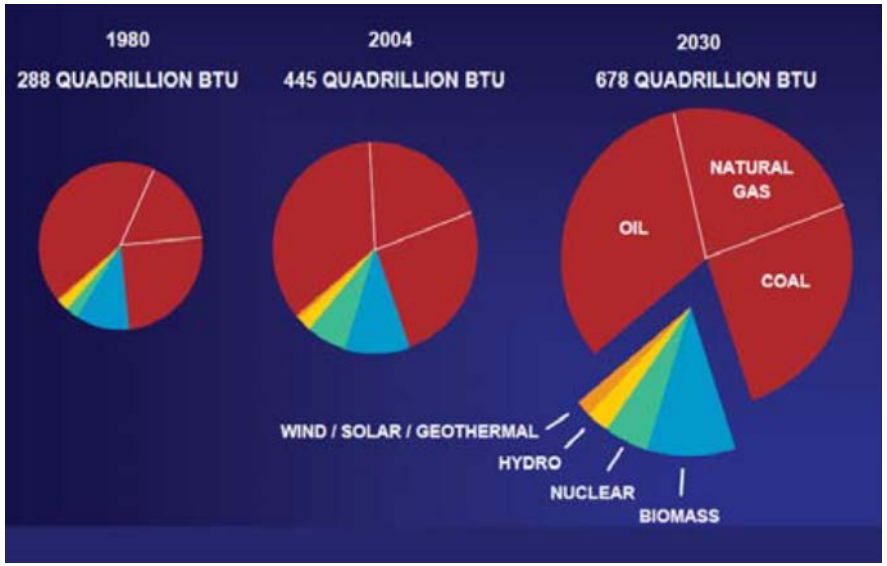
Motivation

PETRONAS is committed in addressing climate change and maintaining a reliable and secure energy supply consideration of national circumstances, balancing requirements of local laws, economic needs of the countries we serve, both in developed and developing countries.



PETRONAS Net Zero Carbon Emissions 2050 Illustrative Pathway

- IPCC 1.5°C
- IPCC 2.0°C
- PETRONAS actual emissions
- PETRONAS NZCE 2050 illustrative pathway
- Paris pathway range



Source: IEA Report

Current supply and demand prediction. Alternate energy have been predicted in coping demands in future, hydrocarbons remain as important source in future sustainability.

Introduction

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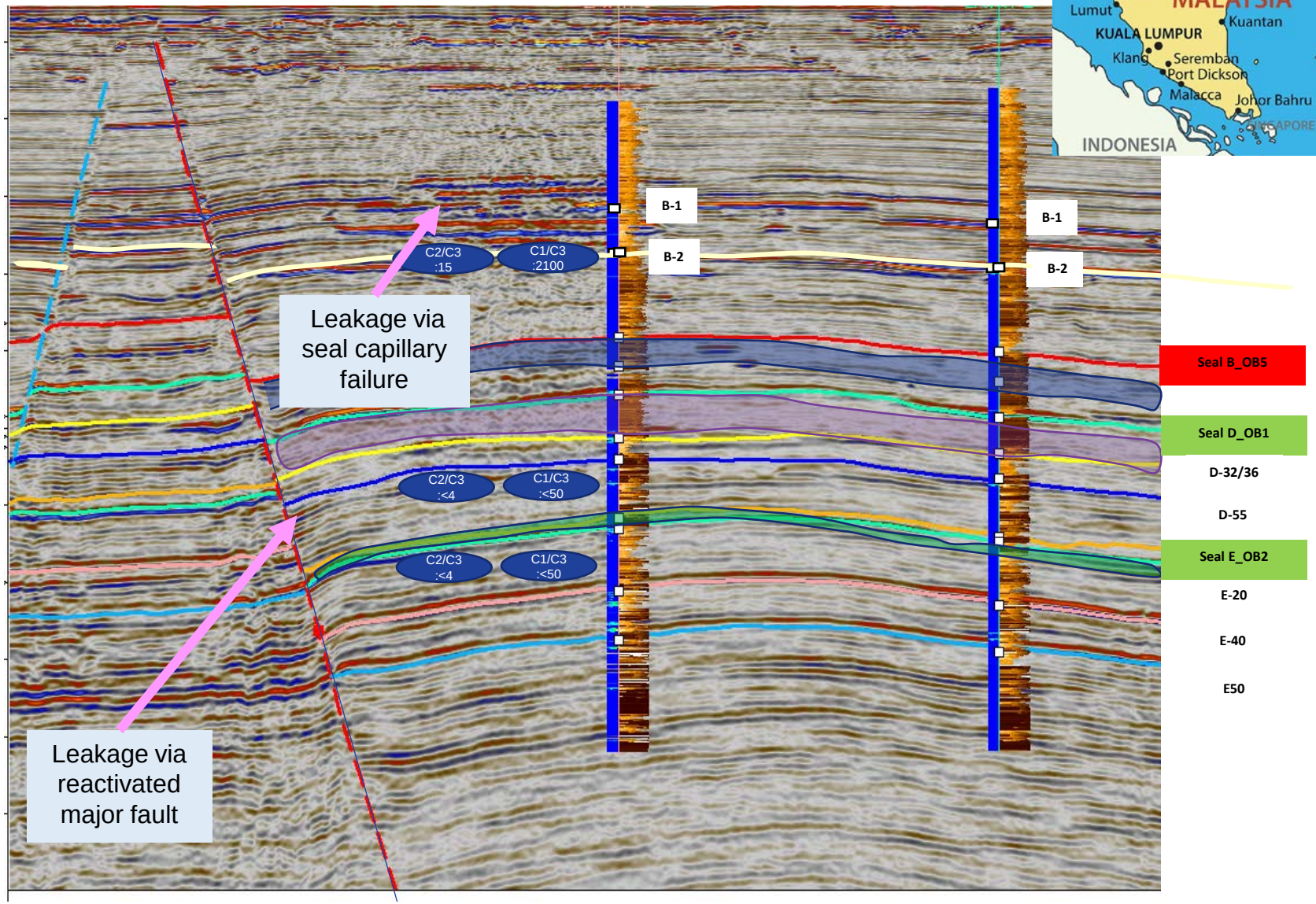

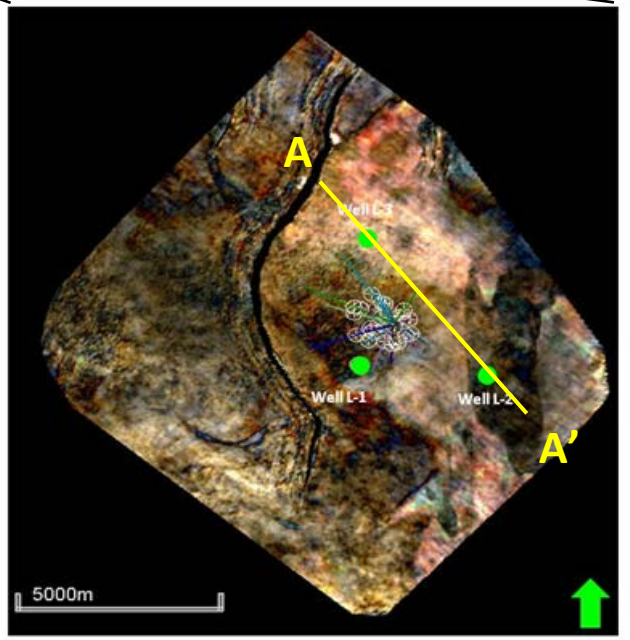

Horizon probe shows domal anticlinal closure, separated by major N -S fault

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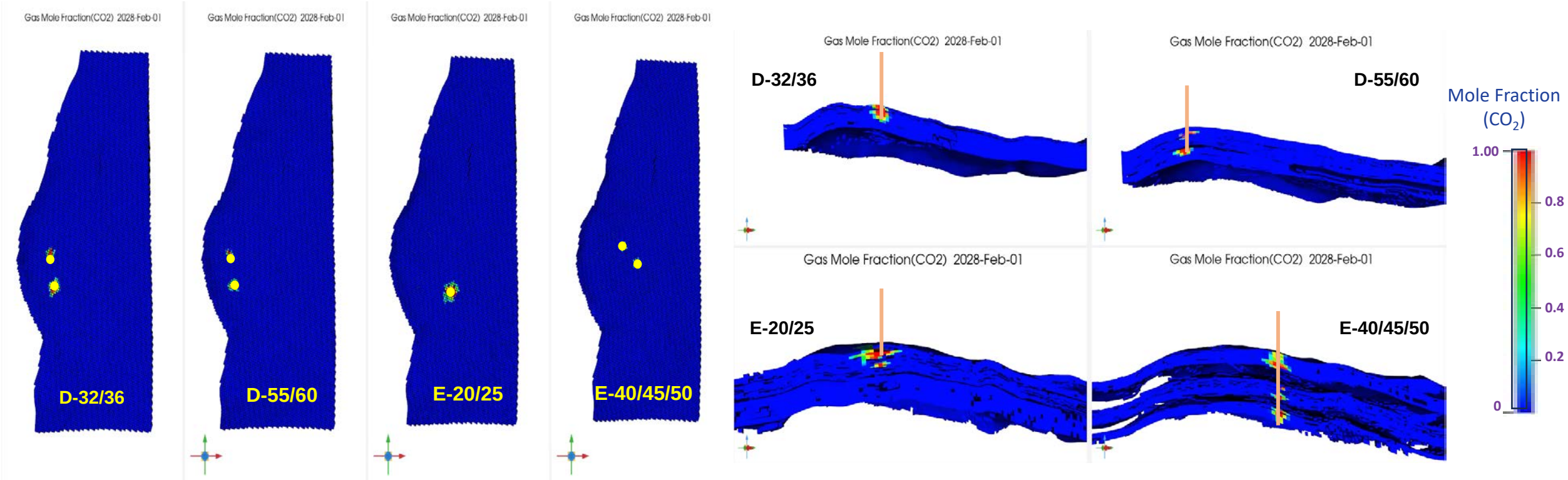
CO2 Plume Migration Simulation Scenario



- CO_2 plume starts migrating downward after a few years of injection and will be periodically monitored through out injection period

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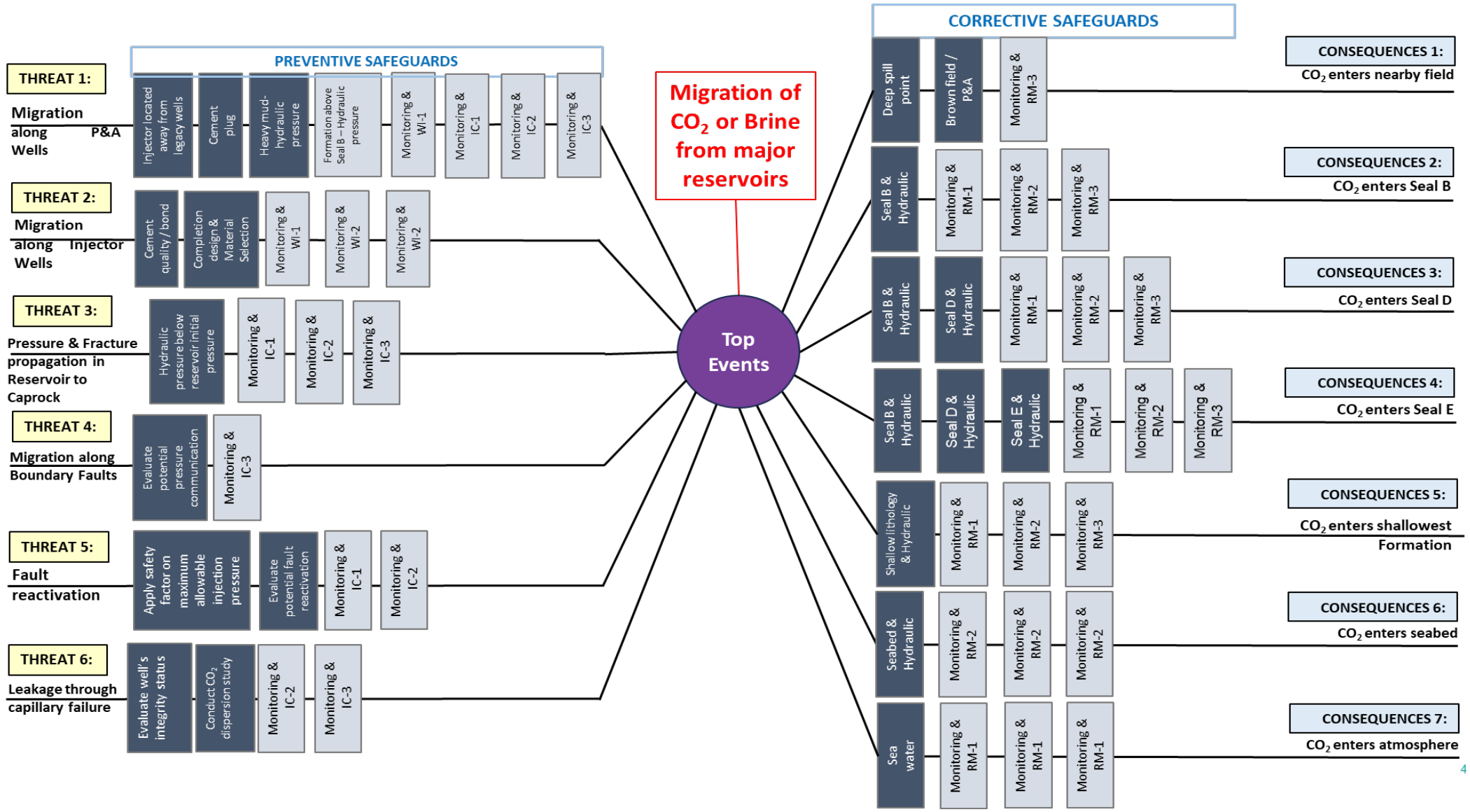
Identified Risks Assessment



Legend

- Passive Safeguards
- Active Safeguards

a) Preventive control for Well Interventions	
IC-1	Re-distribute injection across existing injectors.
IC-2	Drill new injectors.
IC-3	Stop injection.
WI-1	Repair leaking well by squeezing and/ or re-plugging with cement or patch casing.
WI-2	Repair leaking well by replacing completion.
WI-3	Plugged & abandoned (P&A) leaking wells that cannot be repaired.

b) Corrective control for Well Interventions	
RM-1	Repair leaking well by squeezing and/or re-plugging with cement by direct intervention. In the case of uncontrolled flow/blow-out at leaking well (if necessary), interception with a rescue well to reduce leaking well bottom hole pressure prior to repair works.
RM-2	Repair leaking well by replacing completion.
RM-3	Plugged & abandoned (P&A) leaking wells that cannot be repaired.

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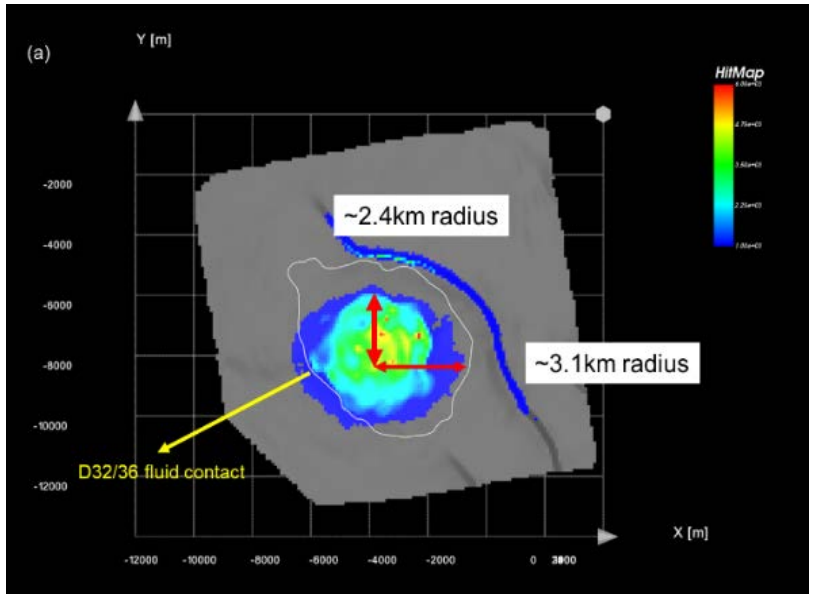
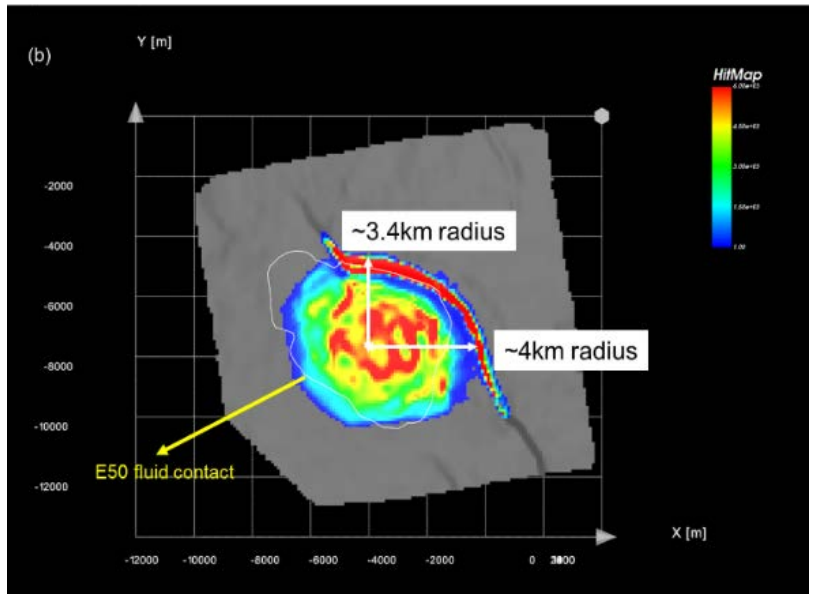
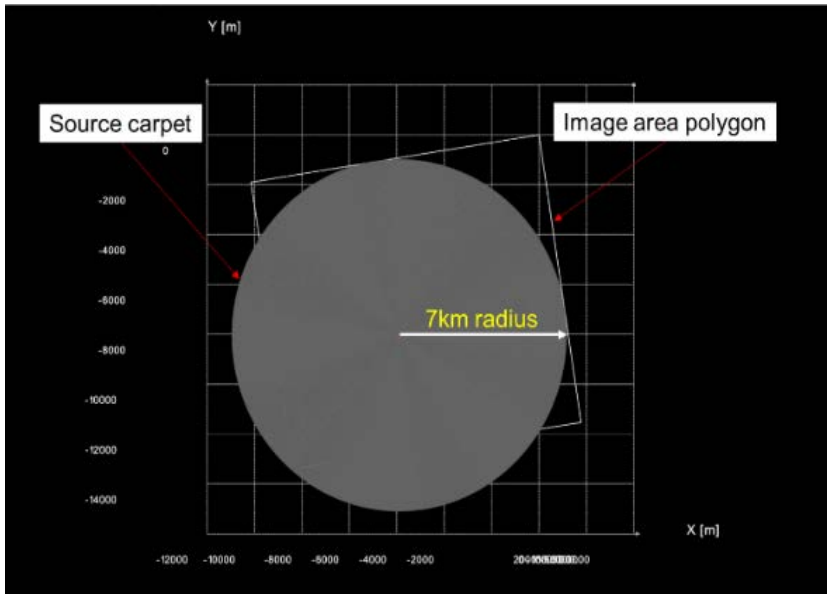
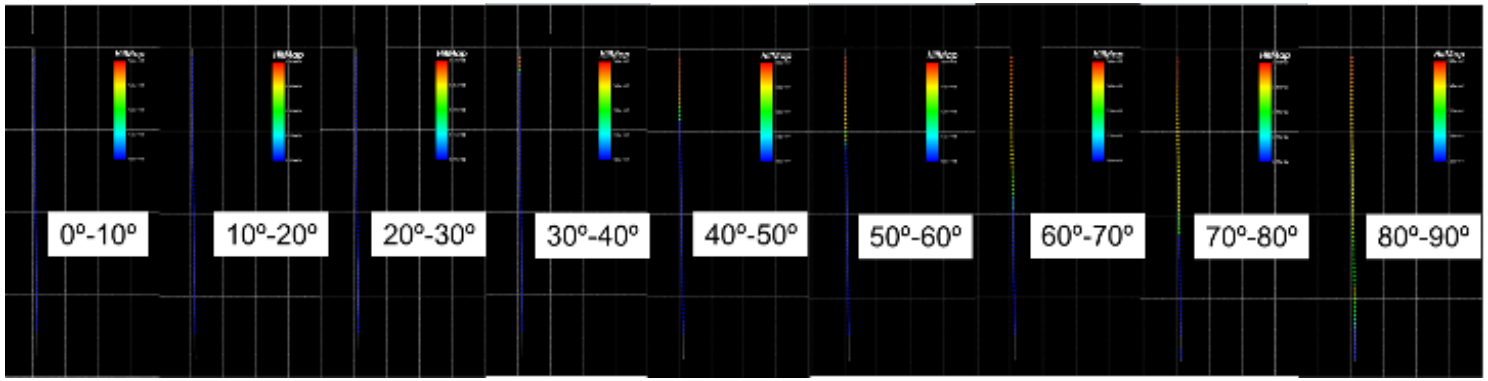
4D DAS VSP Illumination Modelling





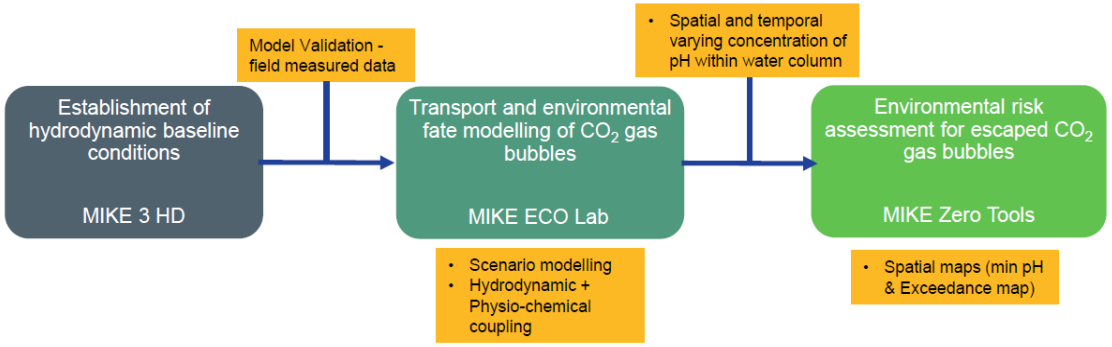


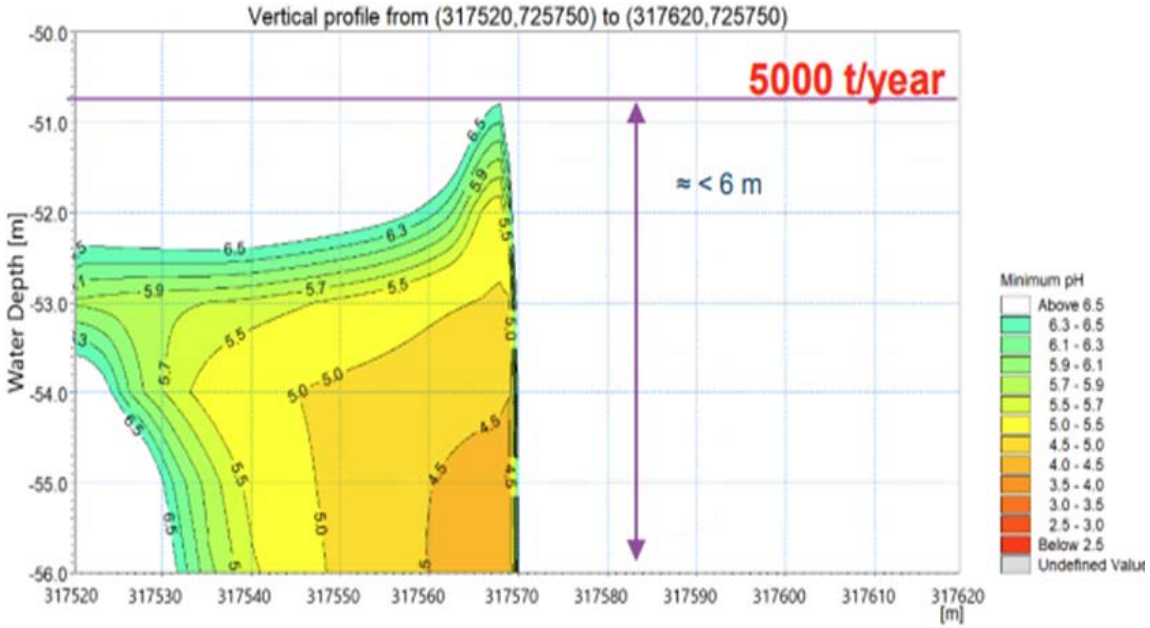


Hit Map displays DAS angle filter using result from individual well of L-A11

CO2 Marine Dispersion Modelling

- Method on CO2 behaviour and interactions in marine environment based on actual field condition.
- Prediction model enables for marine monitoring and mitigation plan.
- Scenarios with higher seepage rate to investigate possible critical rates





Example of Vertical Cross-Section of Minimum pH across Water Depth

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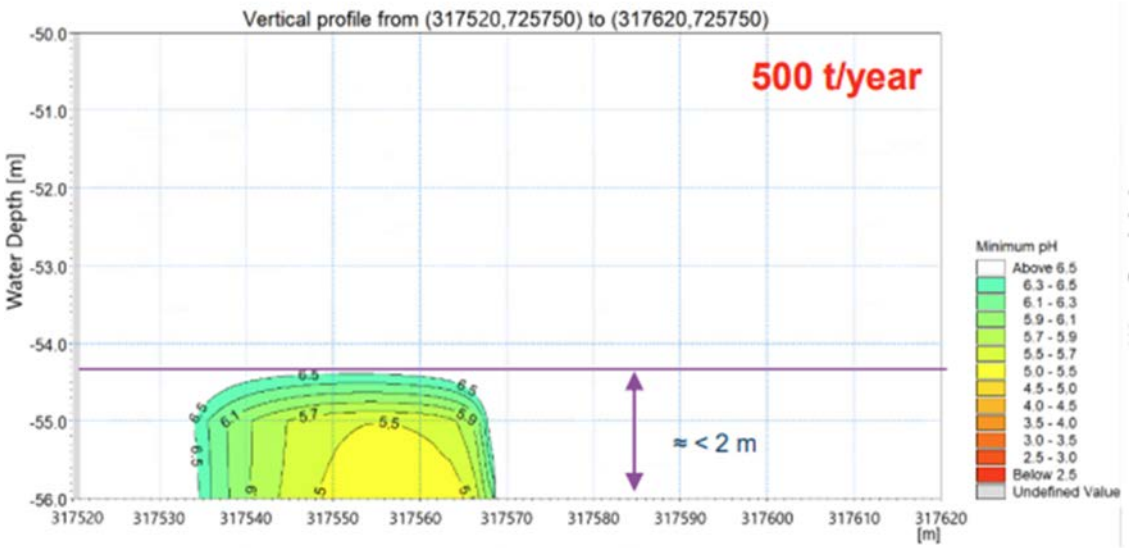
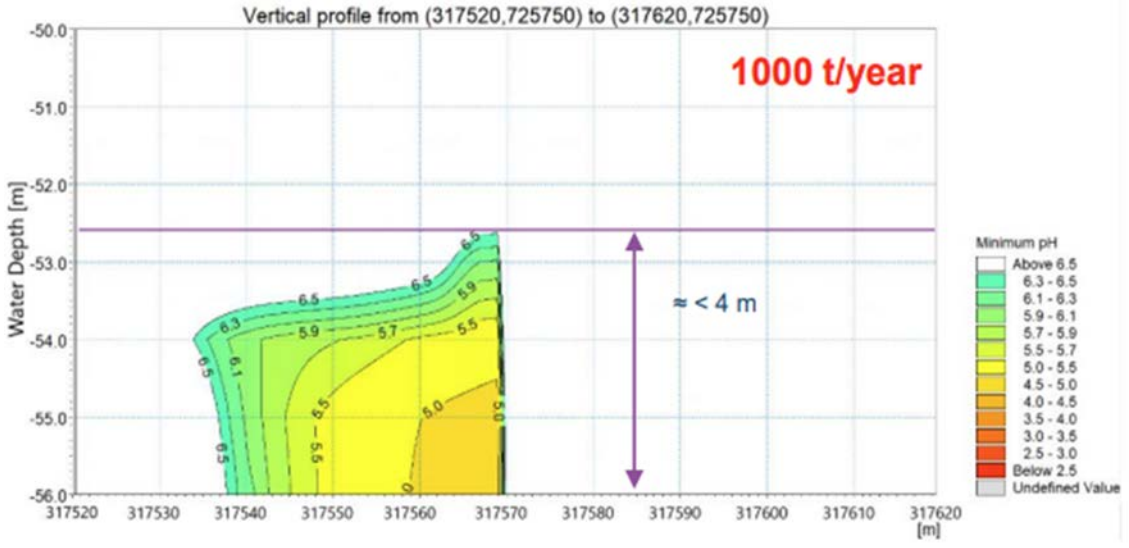
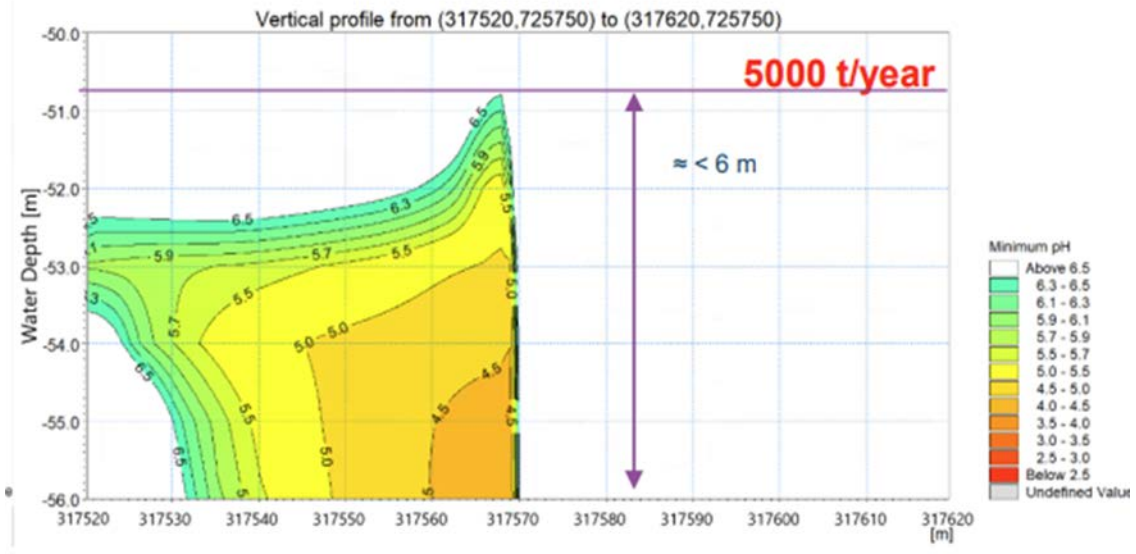
Examples of Vertical Cross-Section of Minimum pH across Water Depth







- Vertical cross section profile was extracted at the lowest current period
- Height of the modelling area with pH < 6.5 for 500 t/year, 1000 t/year and 5000 t/year were predicted to reach up to 2 m, 4 m and 6 m respectively.

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MMV Plan

On Platform / Wellhead

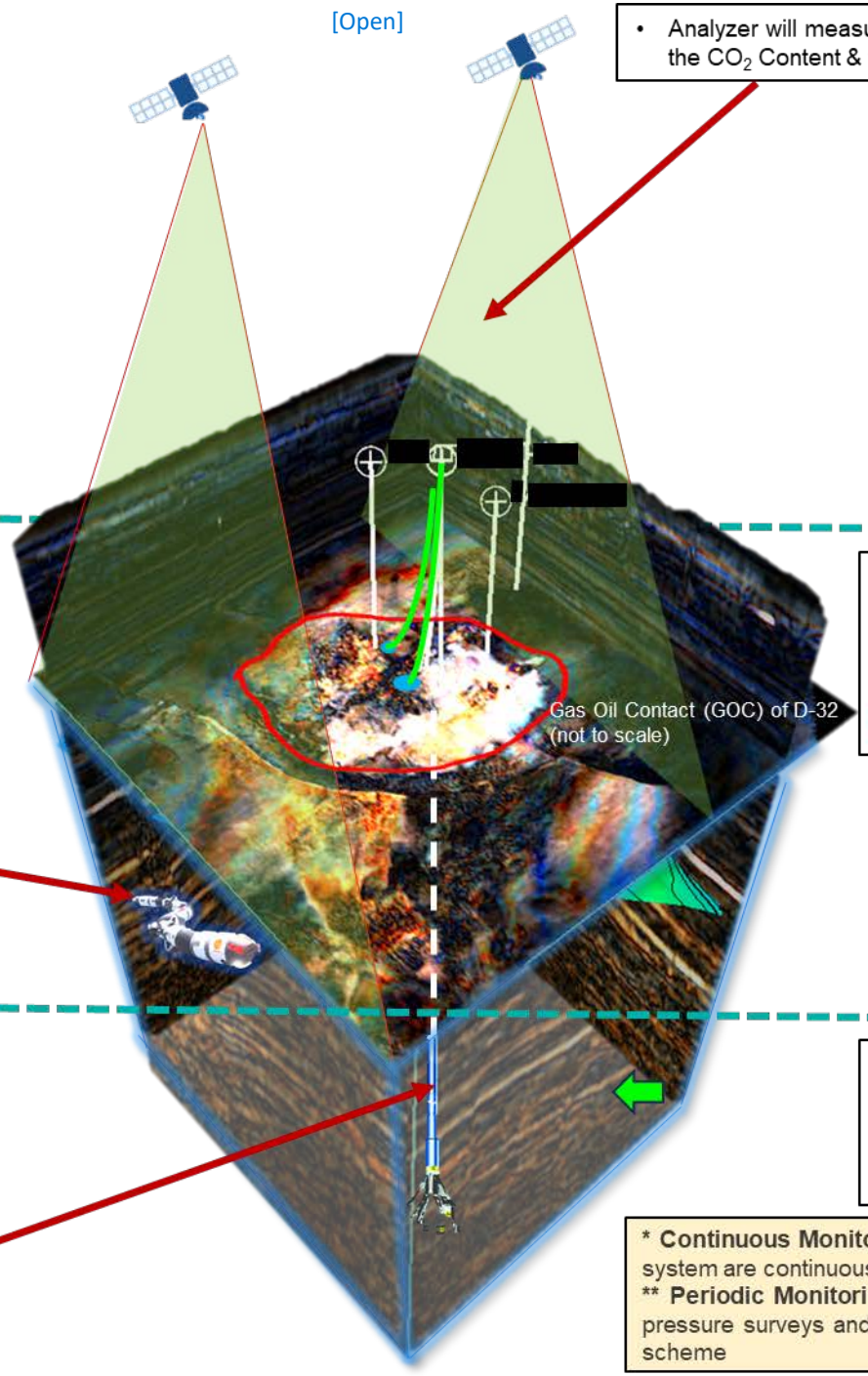
- *GPS*
- *CO2 Detector*
- *Tracer*
- *CO2 Analyzer (Online)*
- *CO2 Sampler (Manual, Periodic)*
- *CO2 Metering (Continuous)*
- *WH Pressure & Temperature Measurement (Continuous)*

- Analyzer will measure the CO_2 Content & tracer

Surface MMV

Marine Column

- *Soil and groundwater remediation sampling*
- *Subsea CO2 leak detectors*
- *ROV Inspection/Snake Robot*



In Well Technology

- Permanent Downhole P&T Gauge
- PLT / Wireline Logging
- Multi-component Fiber Optic
- Cement Evaluation Logging
- Ultrasonic Casing Imaging

ROV Inspection

Legend:
- Continuous Monitoring*
- Periodical Monitoring**
- Monitoring wells

Subsurface MMV

Shallow Subsurface

- Site Survey Investigation including 3D Ultra High Resolution Seismic
- Bathymetric
- Side Scan Sonar+

Subsurface

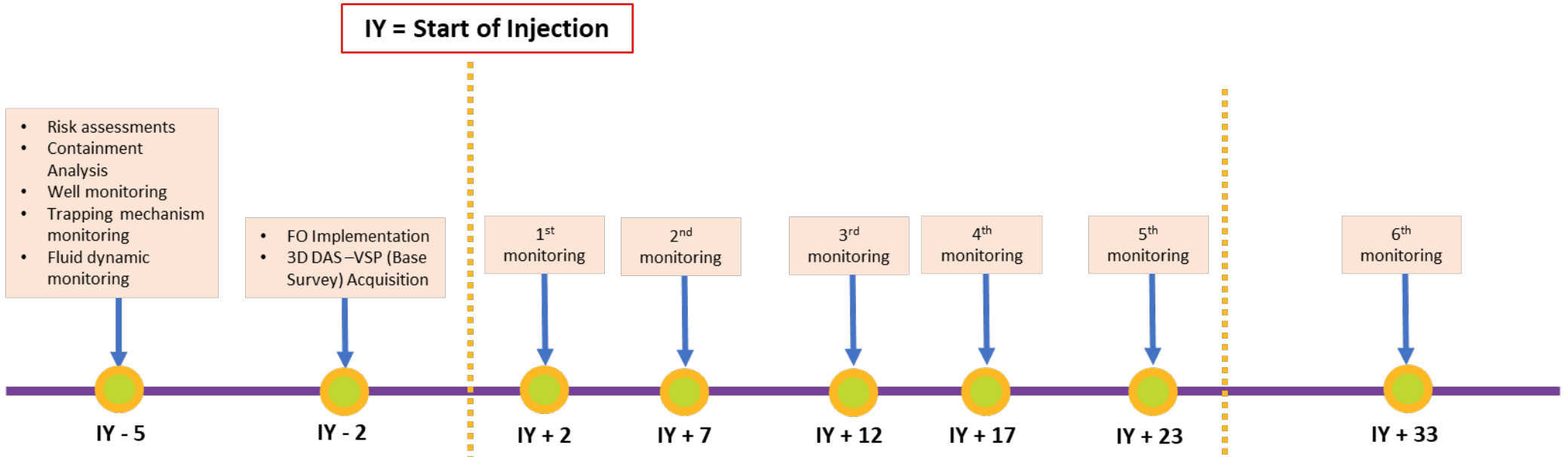
- *4D DAS Zero Offset Vertical Seismic Profile (VSP)*
- *4D Surface Seismic*
- *Tracer*
- *Observation Wells*

Wireline Logging Tool

* **Continuous Monitoring:** The performance of storage site and monitoring system are continuously being evaluated

** **Periodic Monitoring:** Periodic monitoring will be via seismic, well logs, pressure surveys and possibly tracers according to recommended injection scheme

Proposed MMV Plan with Monitoring Frequency



- Technology screening
- Risks and Containment Analysis
- MMV Planning

- CO2 Plume Migration interpretation are based on the 4D-3D VSP (Base and Monitor Surveys)
- Reservoir model updates
- Marine water and soil sampling at identified locations and detailed analysis

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Conclusions

- Fiber Optic System (FOS) installation in injector wells is crucial for well-based and overburden integrity purposes and early CO2 plume migration detection.
- 3D DAS VSP surveys with observation wells may likely to capture CO2 plume migration throughout the injection period
- Minor changes in pH observed near CO2 leakage points at 5000t/year leaking rate
    - CO2 bubbles dissolved in seawater with 6 m from seabed and spread in very limited area