CO2CRC Otway Stage 2: CO_2 Storage in Saline Formation

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CO2CRC

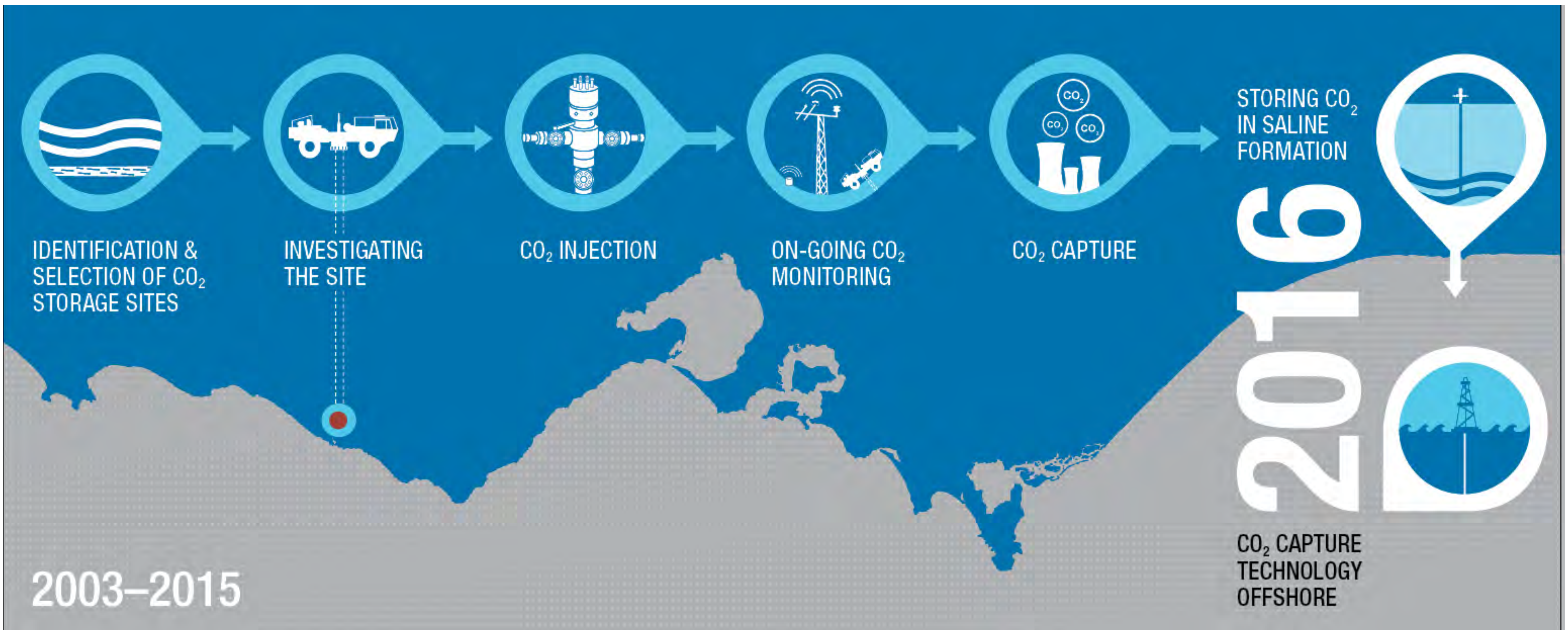
CSLF Projects Interaction and Review Team
01 November 2015, Riyadh, Saudi Arabia

Presentation Outline

- CO2CRC and its Otway Research Facility
- Past Major Project – Otway Stage 1
- Basis of Otway Stage 2
- Completed Appraisal Activity
- Injection and Monitoring Activity
- Anticipated Outcomes
- Future of the Otway Research Facility

CO2CRC – Who we are and what we do

CO2CRC undertakes research that is focused on de-carbonising our environment on an industrial scale. We originate and co-ordinate research programs with researcher partners locally and globally, developing technologies to reduce risk and/or cost in CCS, and validate at scale.



The CO2CRC Otway CCS Research Facility

- Australia's only CO_2 sequestration facility
- Conceptualised in 2003, characterisation since 2004, operating since 2008
- Varying storage options within simple geological structure
- Multiple CO_2 sources and transport options
- Comprehensive & expanding datasets and infrastructure
- Supportive local community
- Politically stable and supportive government

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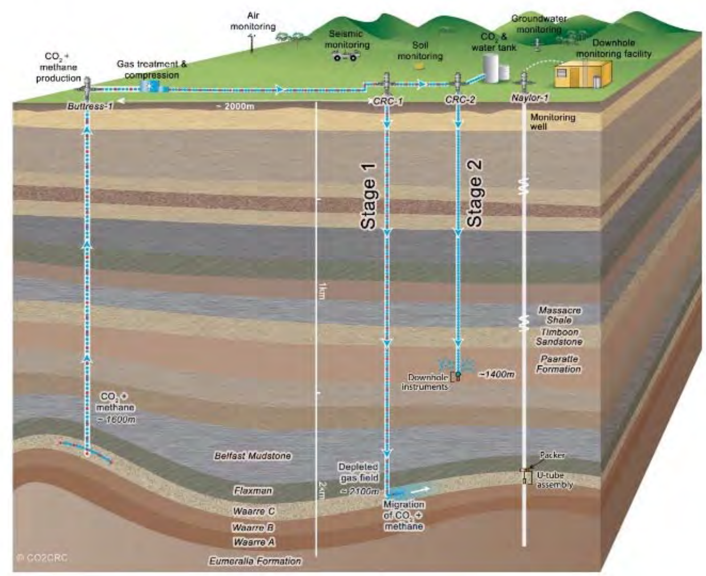
Overarching Otway Research Facility Principles

- Ensure human health and safety is protected at all times
- Safeguard ecosystems throughout facility lifetime
- Ensure no impact to underground sources of drinking water and other resources
- Engage openly with community
- Comply with regulations
- Meet scientific objectives



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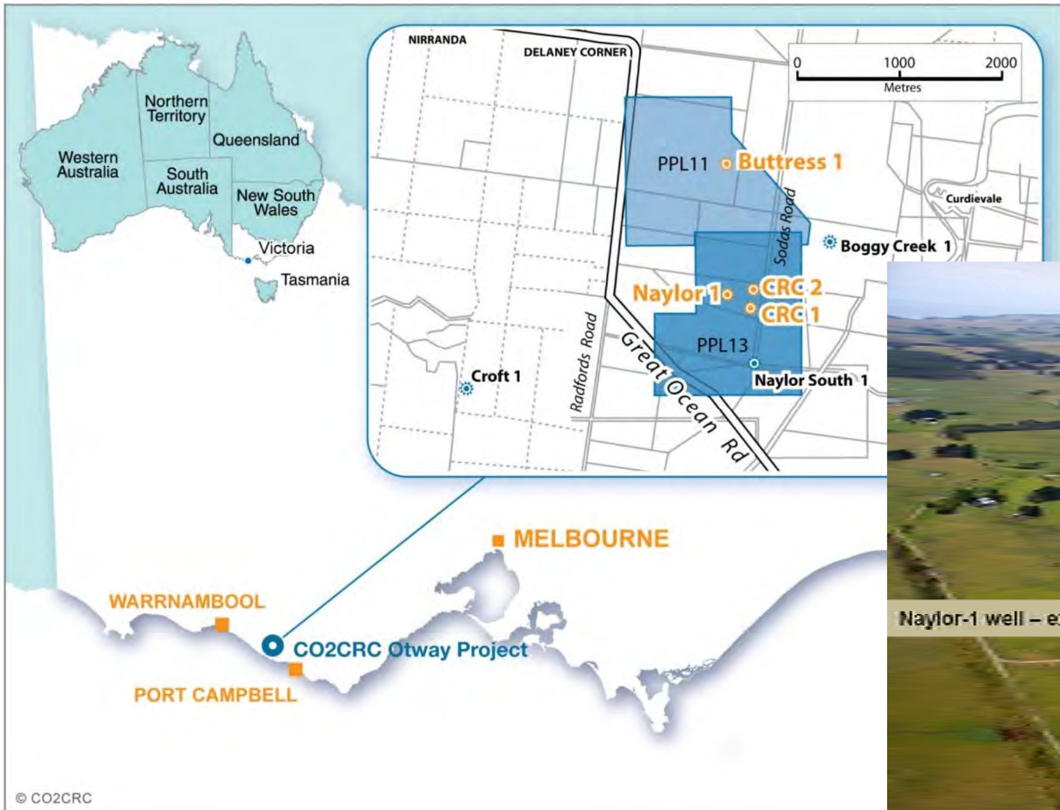
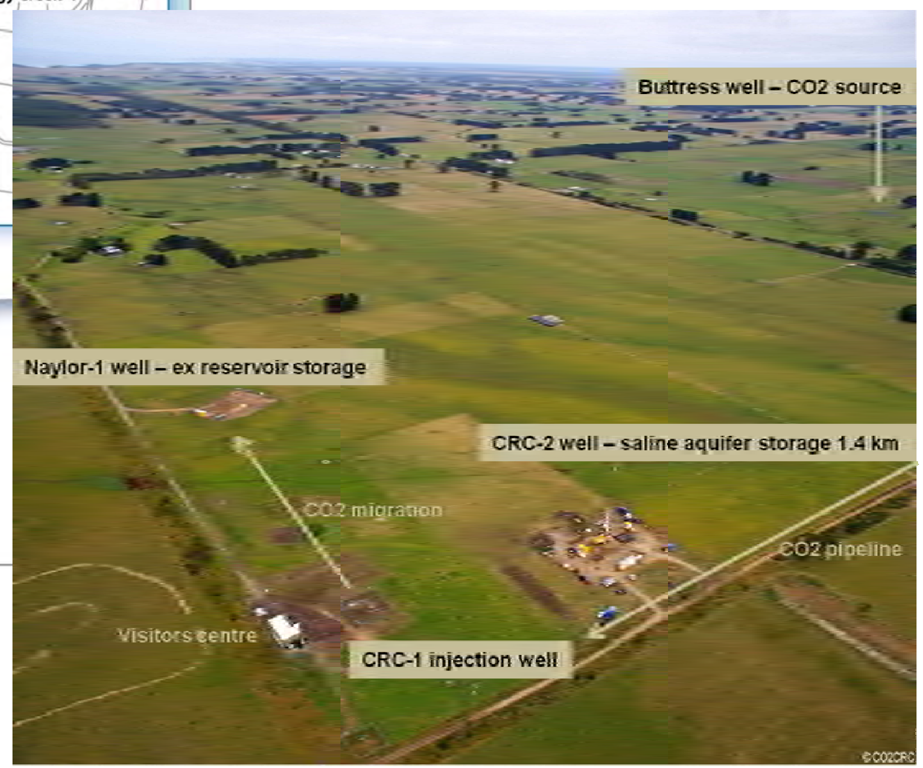
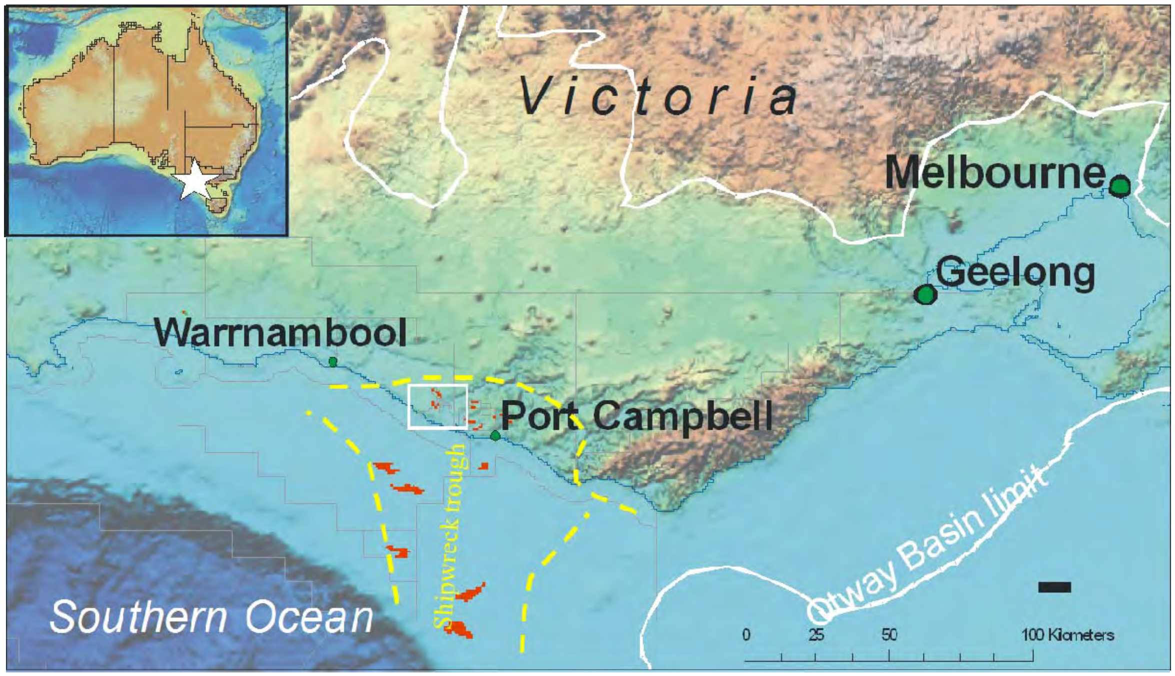
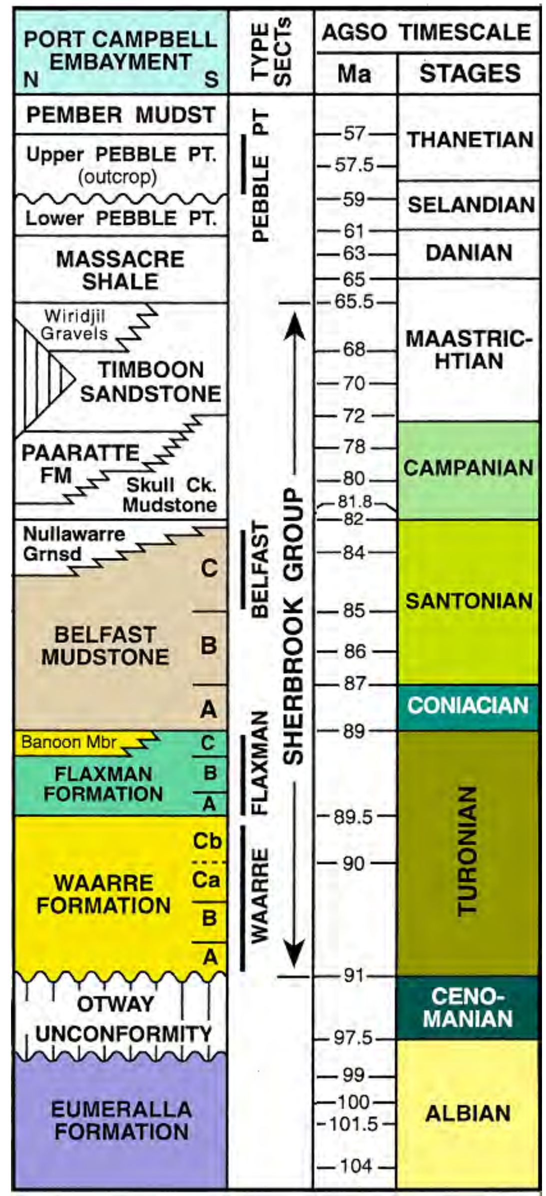
Location of CO2CRC Otway Facility





Regional Setting





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Core Enabling Legislation – CO2CRC Otway Project

Environmental Portfolio Approvals

- *Environment Protection Act 1970 - Research Demonstration & Development*

Impact Assessment and Planning Approvals

- *Environment Protection and Biodiversity Act 1999* - not a controlled action
- *Environmental Effects Act 1978* - no environment effects statement
- *Planning and Environment Act 1987* - planning scheme amended

Petroleum Portfolio Approvals

- *Petroleum Act 1998 - various petroleum related activities approved*

Water Portfolio Approvals

- *Water Act 1989 - various drilling and injection activities approved*

Land Access

- *Planning and Environment Act 1987*
- *Land Acquisition and Compensation Act 1986*

& Common Law

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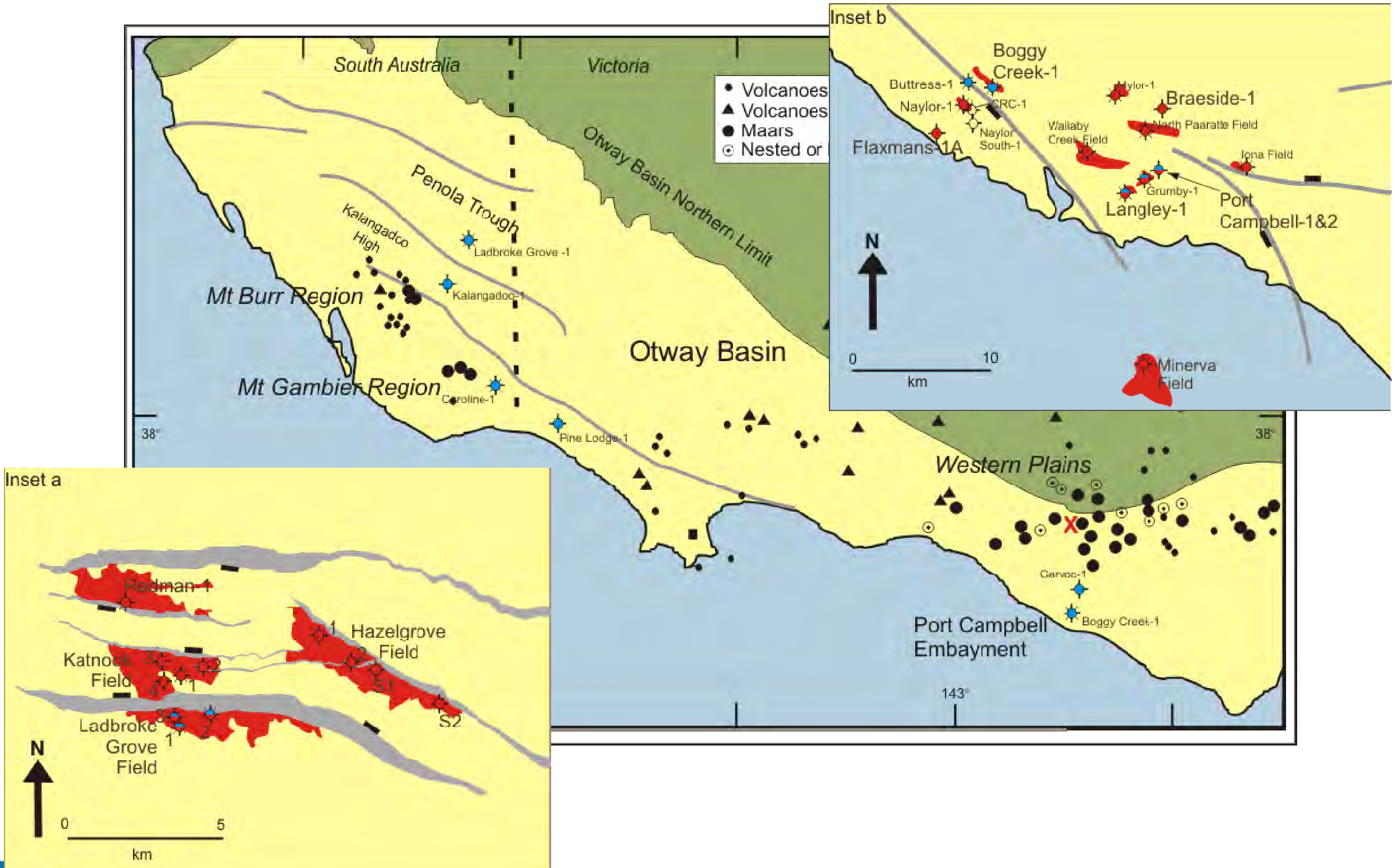
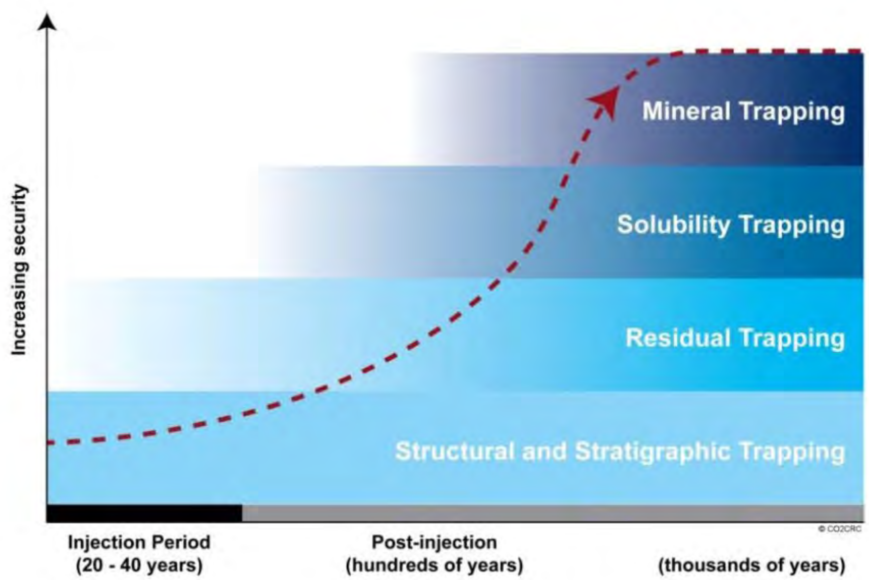
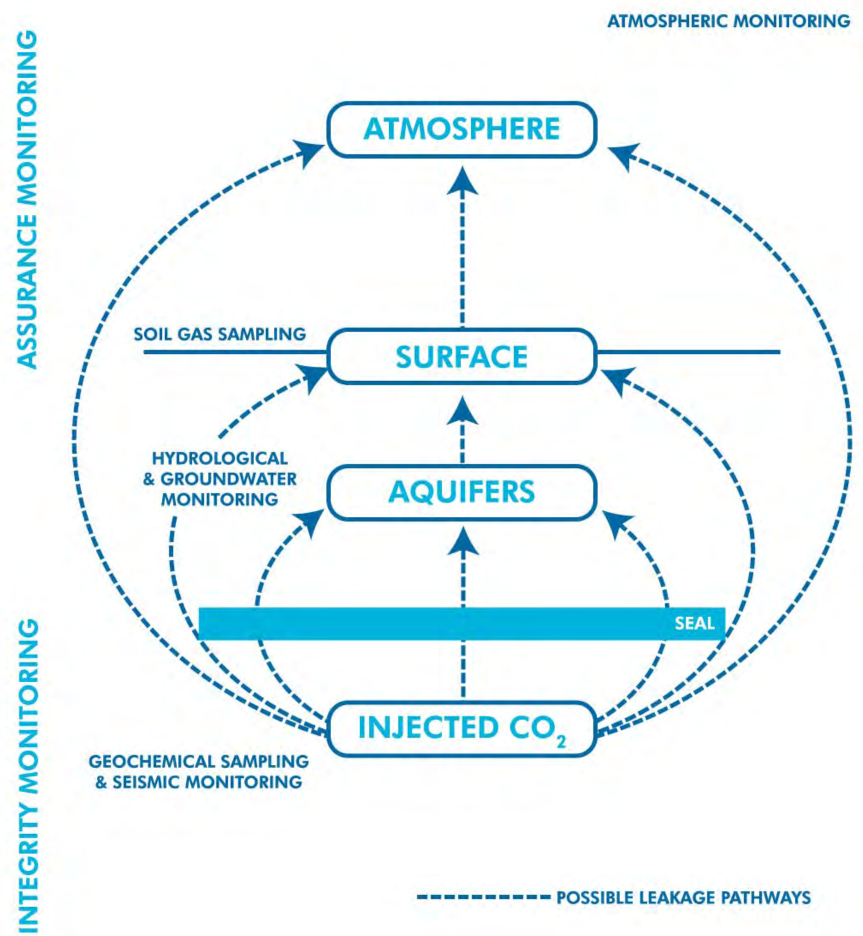
Permitted area as per GGGS Exemption Regulations 2009

Natural CO_2 Accumulations



Characterising CO_2 Storage Processes and the Monitoring Capabilities to Validate Safe Storage





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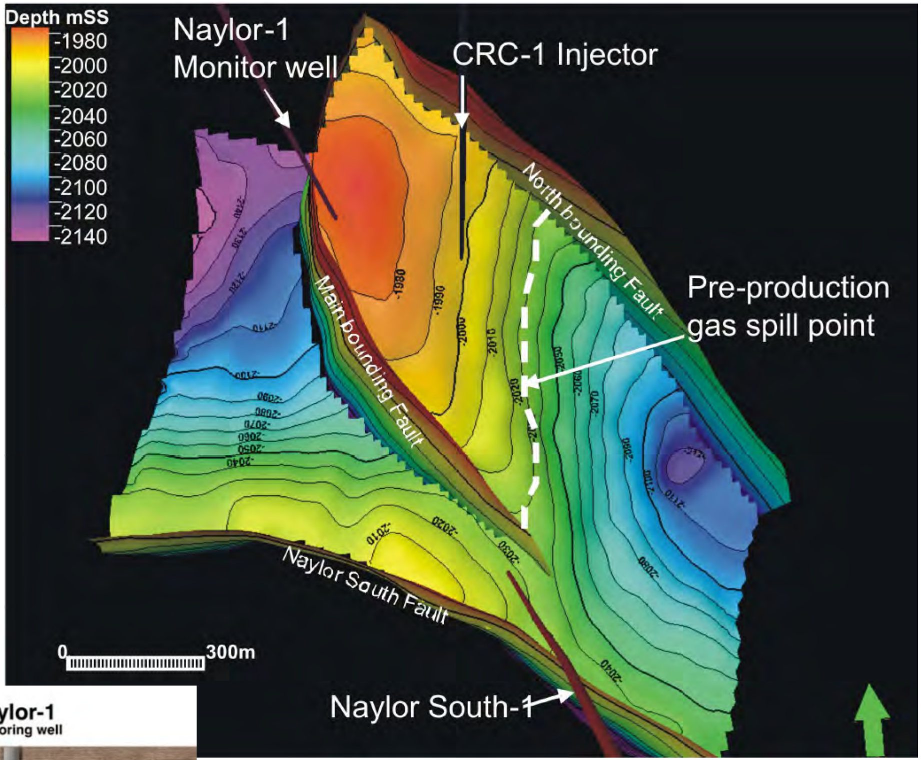
Otway Stage 1 – Complete

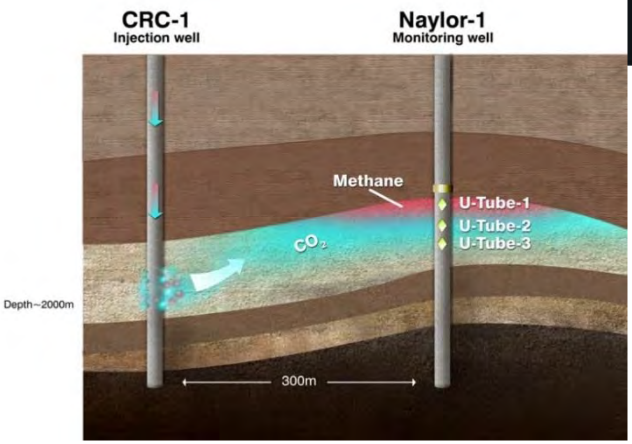
Science Outcomes

Demonstrated safe transport, injection and storage of >65,000 tonnes of CO_2-rich gas into a depleted gas reservoir.

Monitoring techniques:

- DH pressure, seismic, gas and formation water sampling (inc. tracers)
- Surface: Groundwater, soil, atmospheric, active seismic, micro-seismic





Additional Outcomes

- Positive regulatory environment
- Successful outreach program to stakeholders and local community

Highlights

Exceptional Datasets

- Atmospheric (continuous monitoring)
- Soil Gas
- Seismic
- Reservoir fluids

Field Validation

- Validation of models in actual field tests
- Fully permitted and operational site
- Availability of CO_2
- Globally unique advantage

First of its kind experiments

- First CO_2 storage demonstration project in Australia
- Reducing risk and uncertainty
- Advising regulators and project proponents in Australia and world wide
- A go-to project

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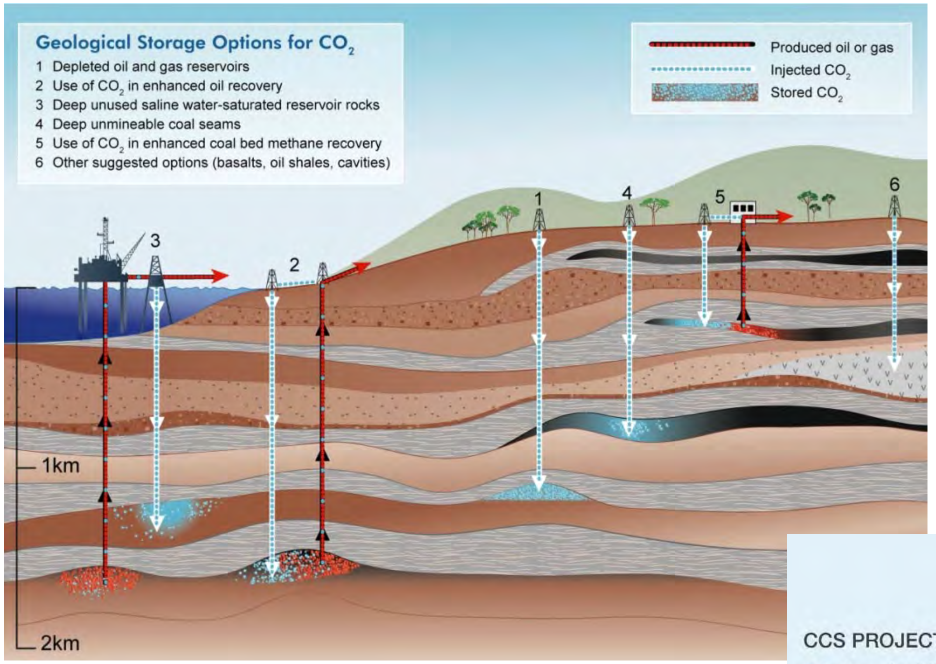
Australia's CCS Demonstrated Capabilities



Depleted Field Storage –

Otway Stage 1 ✓

Saline Formation Storage –

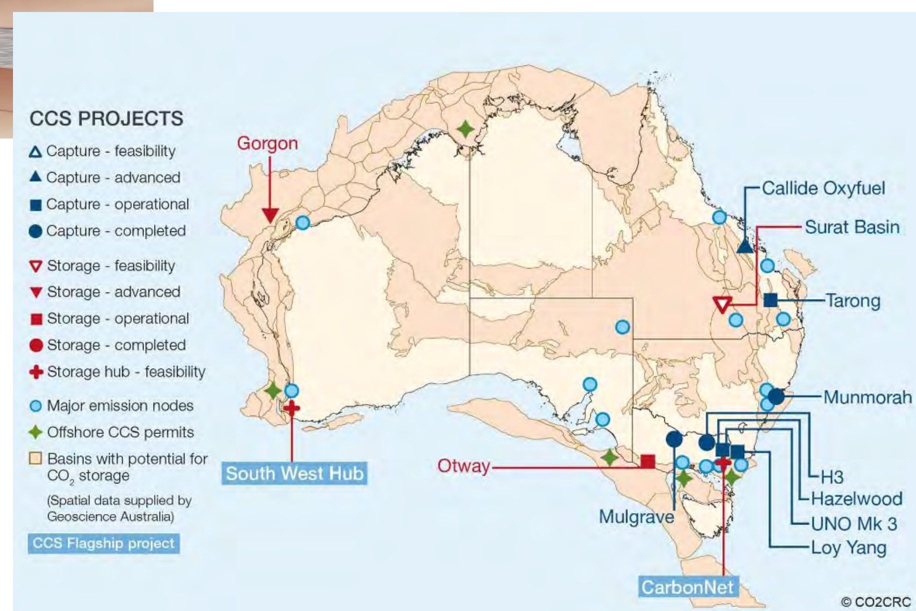
Major storage option

- i.e. Gorgon, South West Hub, CarbonNet, Surat Basin

Not demonstrated in Australia

Large scale storage options in Australia

- Depleted oil and gas fields (10s of yrs)
- Saline formations (100s yrs)



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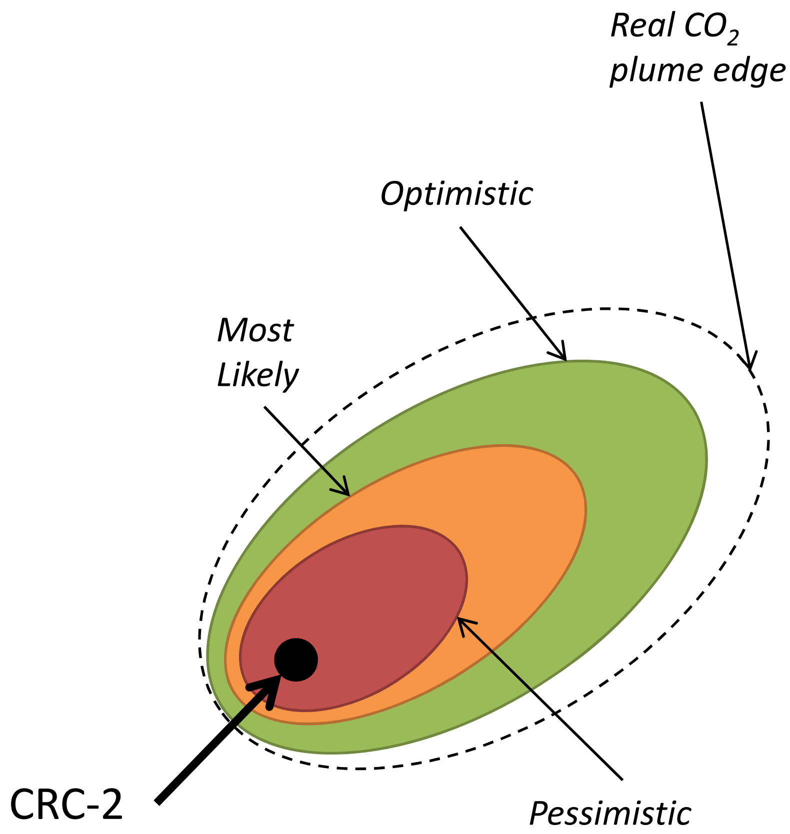
Understanding a CO_2 plume



- Improving Seismic Detection Limits
- Demonstrating Plume Stabilisation
- Increasing Technology Thresholds
- Reducing Surface Footprint
- Reducing Cost

The CO2CRC Otway Project Stage 2

Stage 2: 2007 – 2020

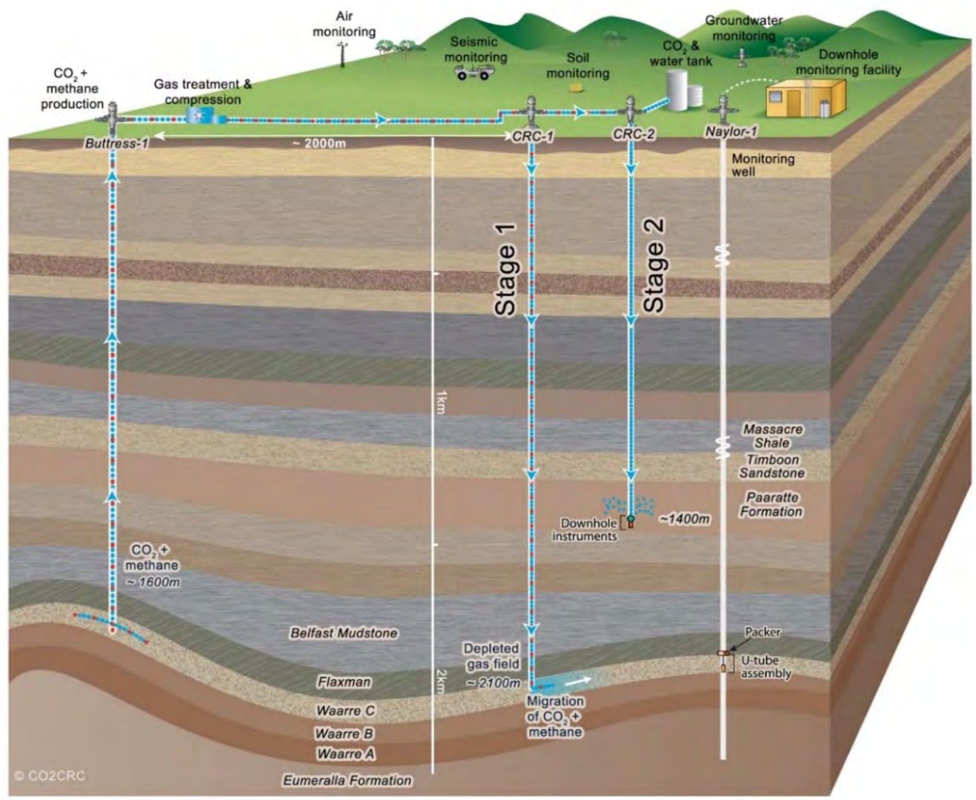
Demonstrate that CO_2 storage can be safely conducted at scale within a Saline Formation

Appraisal

- ✓ 2A :Drill CRC-2
- ✓ 2B: Measure parameters affecting residual and dissolution trapping in a saline formation
- ✓ 2B Extension: interactions with impurities & well test refinement

Operation

- 2C: Spatially track injected CO_2 in a saline formation
    - Minimum detection limit
    - Migration behaviour
    - Stabilisation



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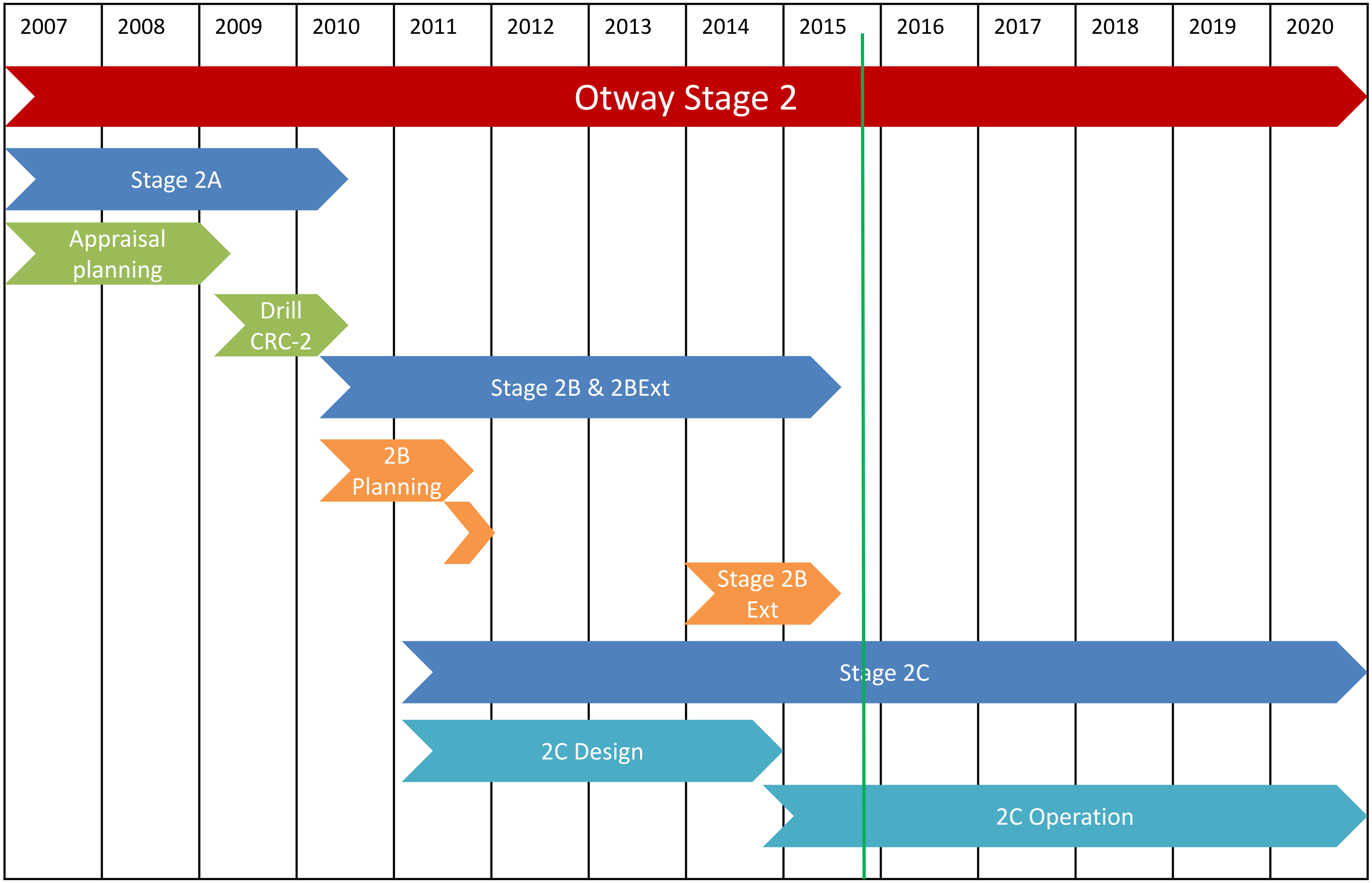
Stage 2 Timeline



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Stage 2 Appraisal

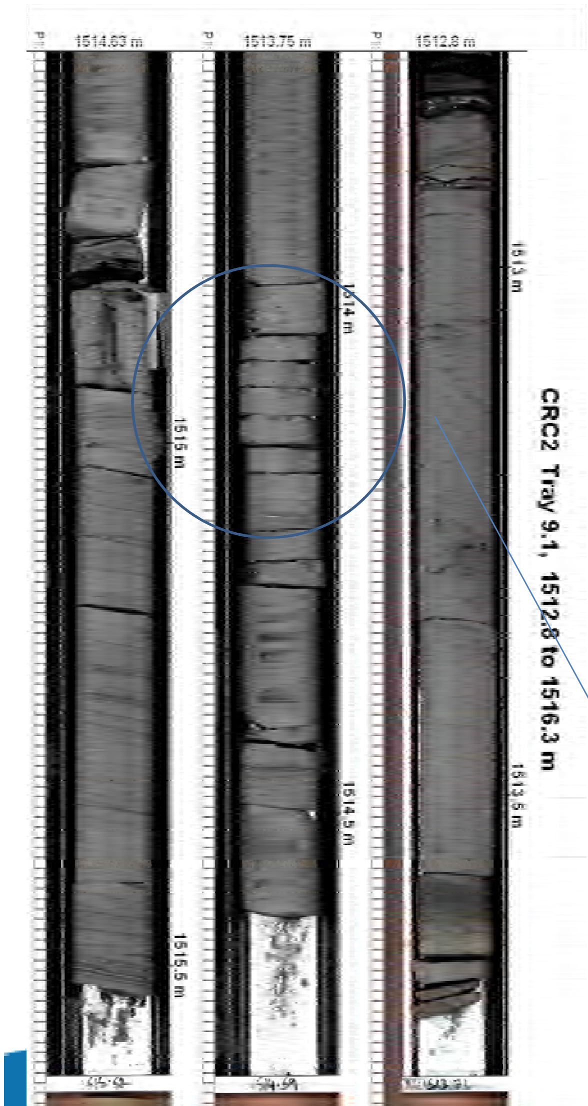
Development of an injection plan that ensures:

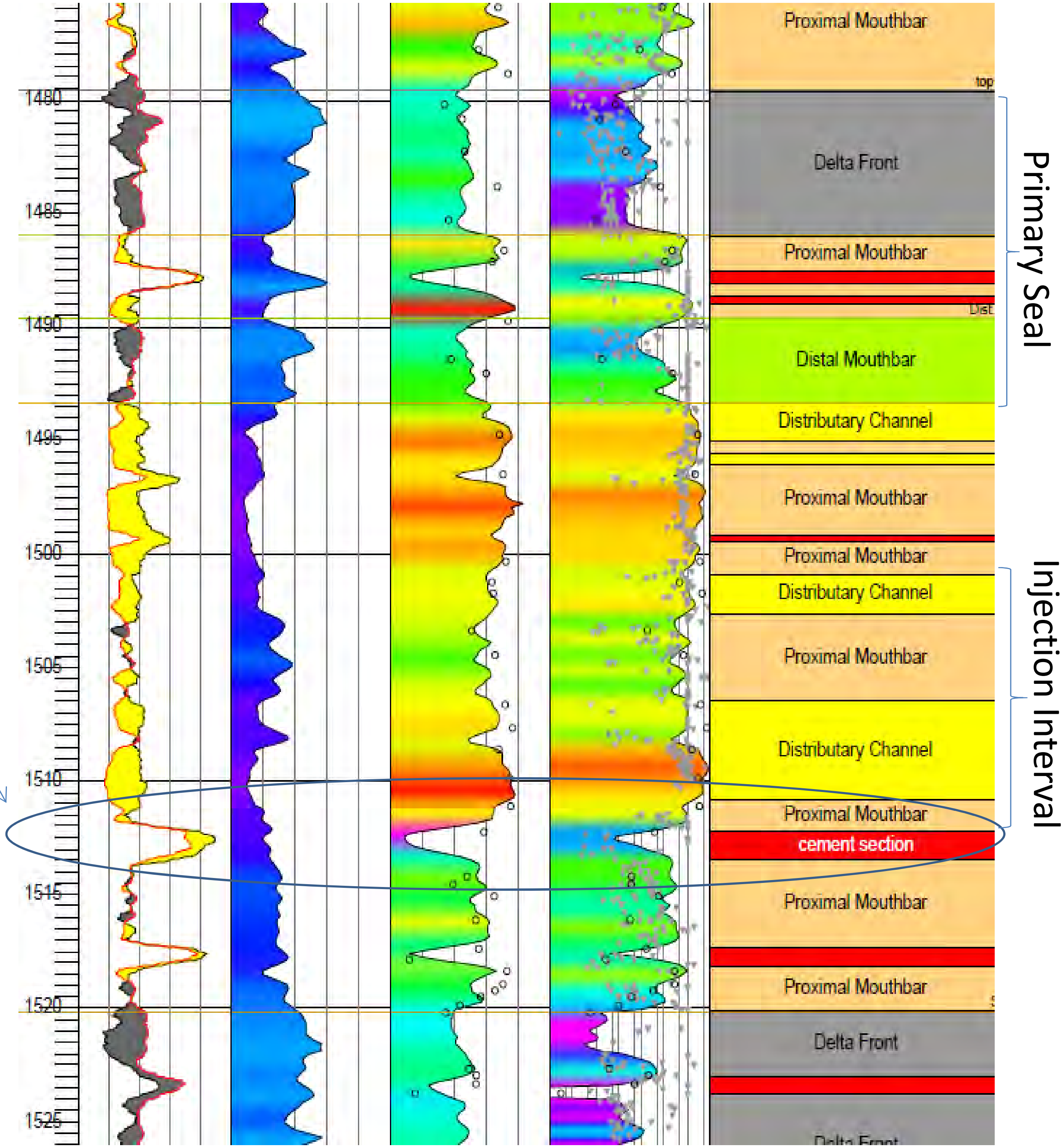
- CO_2 containment within storage complex
  - Within tenement
  - Below primary seal
- Suitable plume distribution for meeting science objectives
  - Detectable plume
  - Moderate migration
  - Short time to stabilisation

Development of a monitoring plan that ensures:

- Monitoring coverage across entire plume
- Monitoring resolution at highest level
  - High Signal to Noise
  - High repeatability
- Overarching Otway Research Facility Principles are maintained

Stage 2A – Drill CRC-2





Stage 2B: Residual Gas Trapping Characterisation (2009 – 2011)

Volumetric equation for capacity calculation

G_{CO_2} = Vo

A = Ar

h_g = Gr

ϕ = Av

ρ = De ... nation

E = Storage “efficiency factor” (fraction of total pore volume filled by CO_2)

Objective: Test capabilities to determine residual gas saturation?

NETL DOE, 2006

Residual trapping measurements trialled

- Five (5) independent measurement approaches to determining residual trapping:
- The methods deployed have different depths of investigations, supply different information, and have difference benefits and limitations

Pressure response (<20 m)

Pulsed neutron logging tool (RST) (<1m)

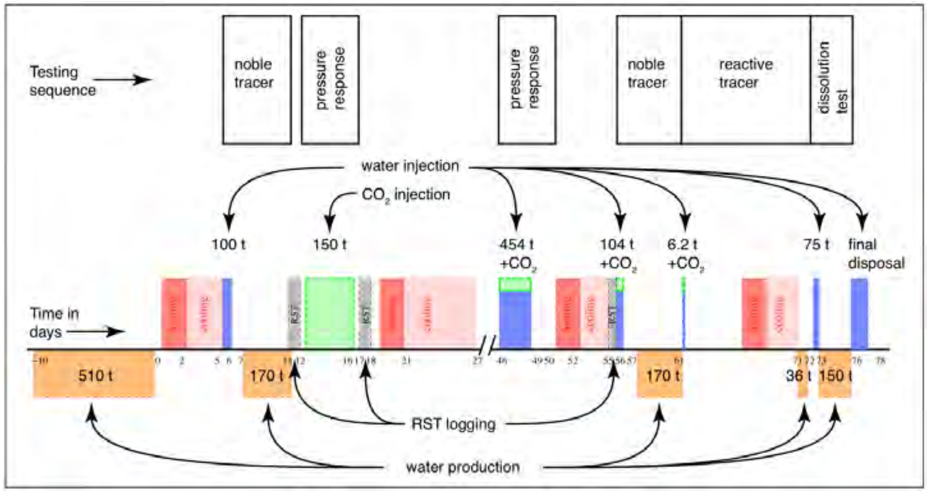
Thermal testing (Fibre Optics) (1 - 2 m)

Noble gas tracer testing (KR-Xe) (4 - 10 m)

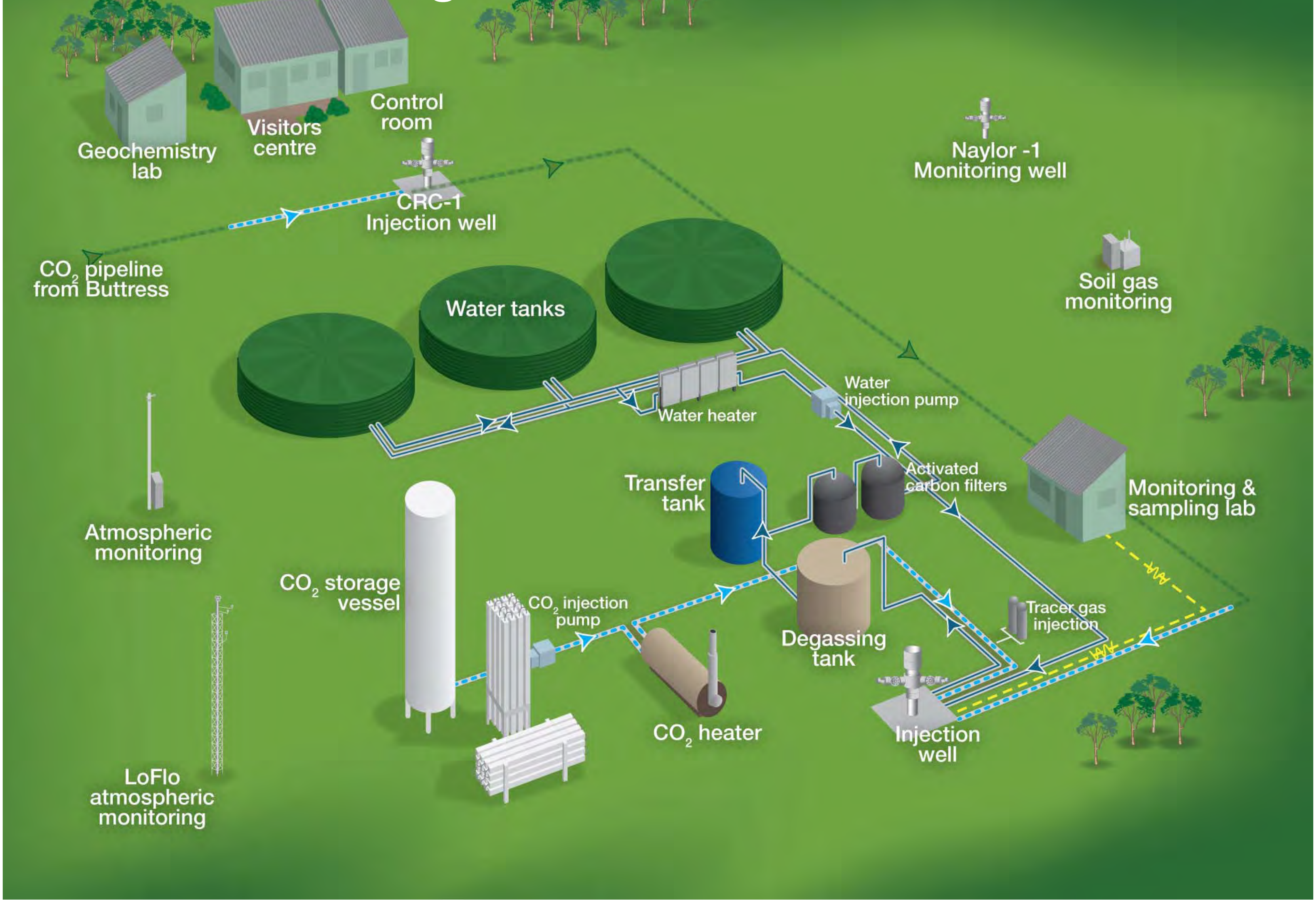
Liquid tracer (reactive ester tracer partitioning) (4 - 10 m)

Dissolution testing (<1 m)

Laboratory core testing



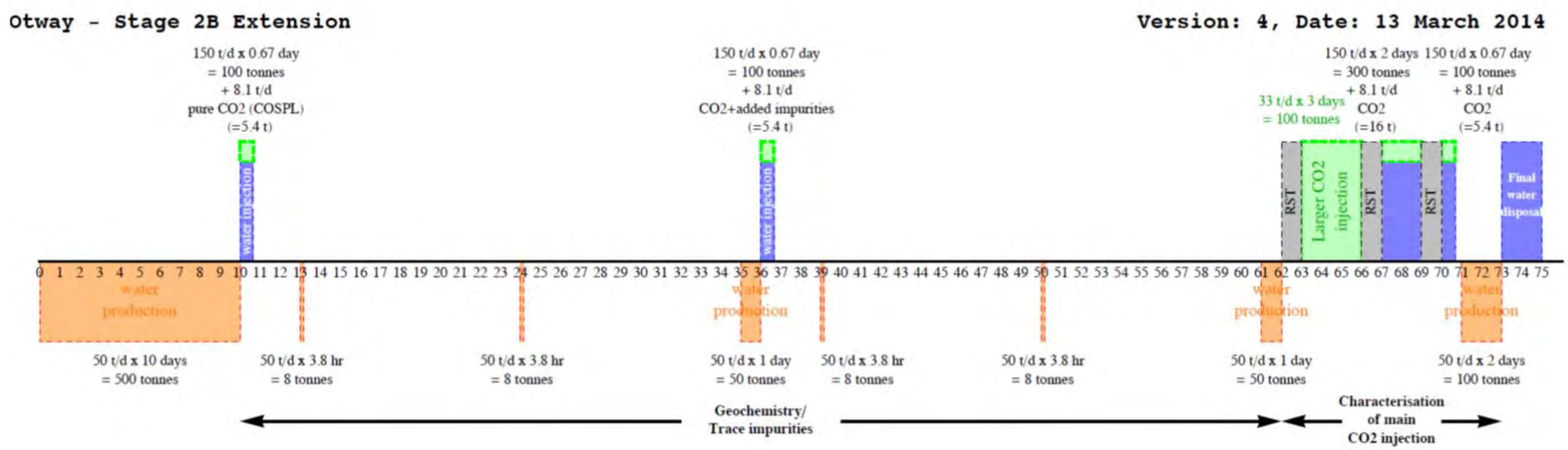
Stage 2 surface facilities



Stage 2B Extension (2014 – 2015)

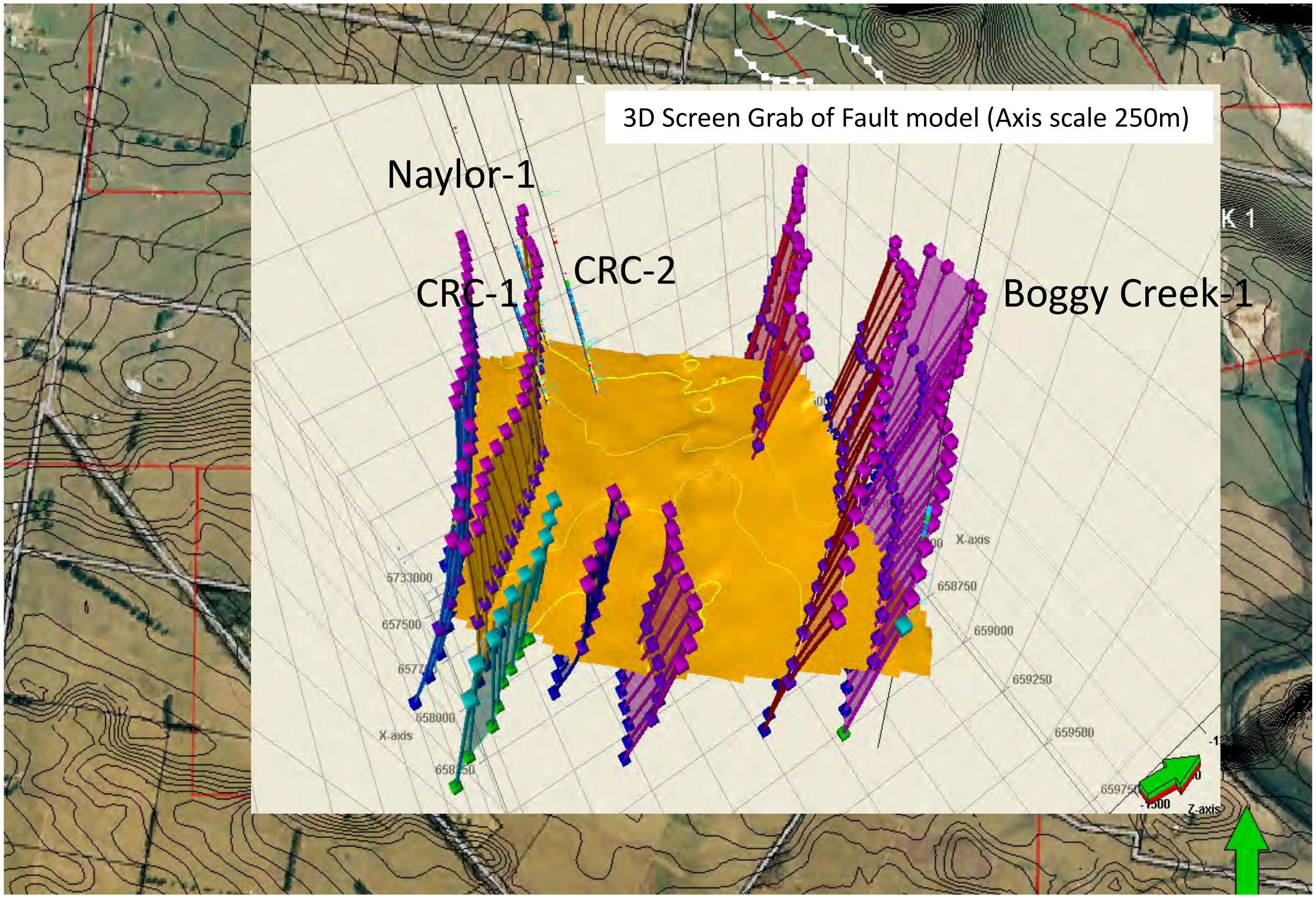
Part 1: Investigate the impacts of gas impurities on the formation water

Part 2: Further characterize residual saturations, evaluate techniques



- Part 1 funded by COSPL (Callide Oxyfuel Services Pty Ltd) and utilised CO_2 captured at the Callide Oxyfuel project
- Research is a collaborative effort between CO2CRC and its research partners, University of Edinburgh (funded by UKCCSRC) and Lawrence Berkley National Laboratories.

Stage 2C - Far Field Appraisal



Plume Modelling

Questions addressed:

How does plume distribution influence:

- Seismic response?
- Containment risk?
- Tenement boundaries?

When does plume stabilise?

Dynamic parameters analysed

Geological realisations

Dolomite cement distribution

Model gridding

Relative permeability

Capillary pressures

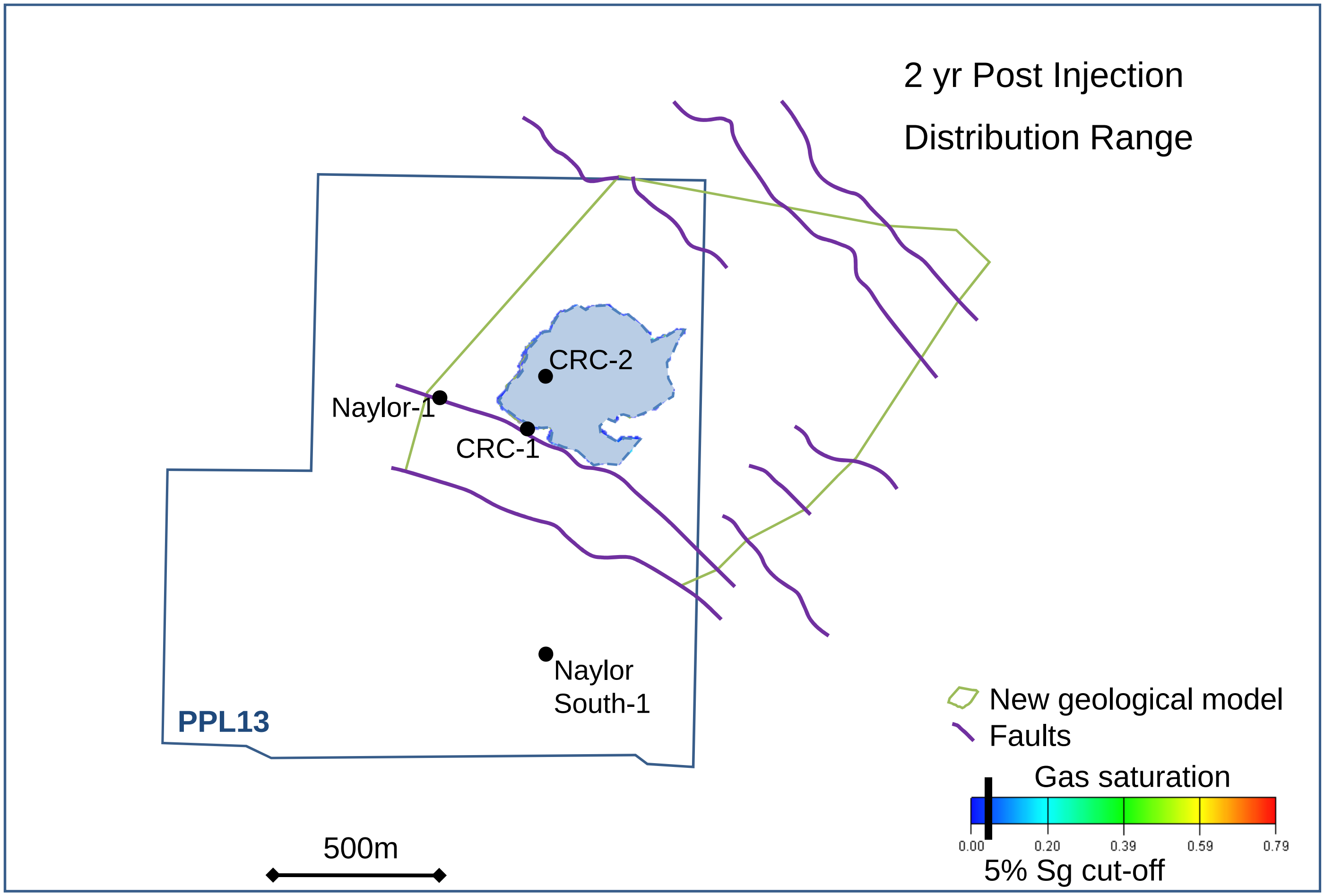
Injection horizons

Injection rates

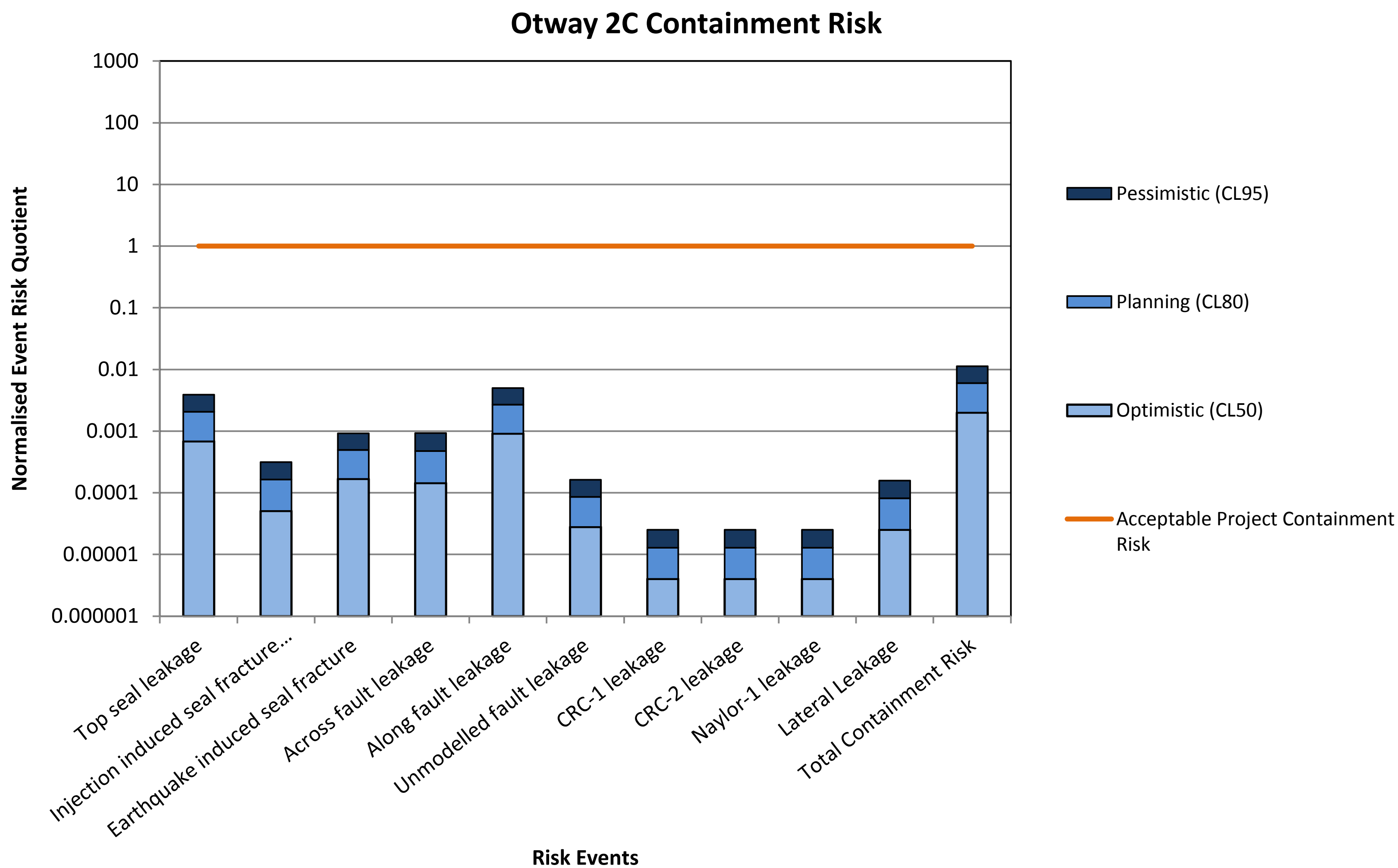
Pressure changes

Thermal changes

Likely plume distribution range

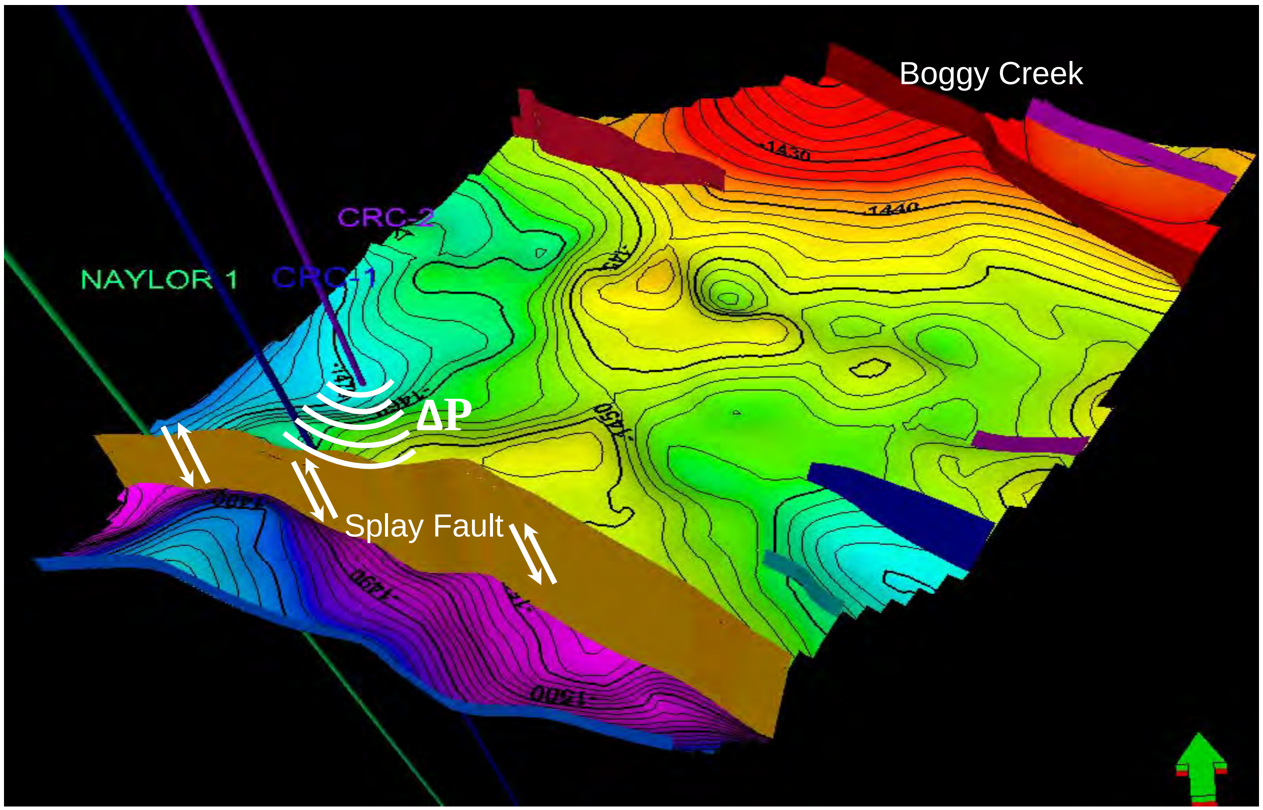


Containment Risk Analysis



Fault Risk Assessment: Question 1

What fluid pressure can the fault support before shear reactivation potentially occurs?



Paaratte Fm at injection horizon,

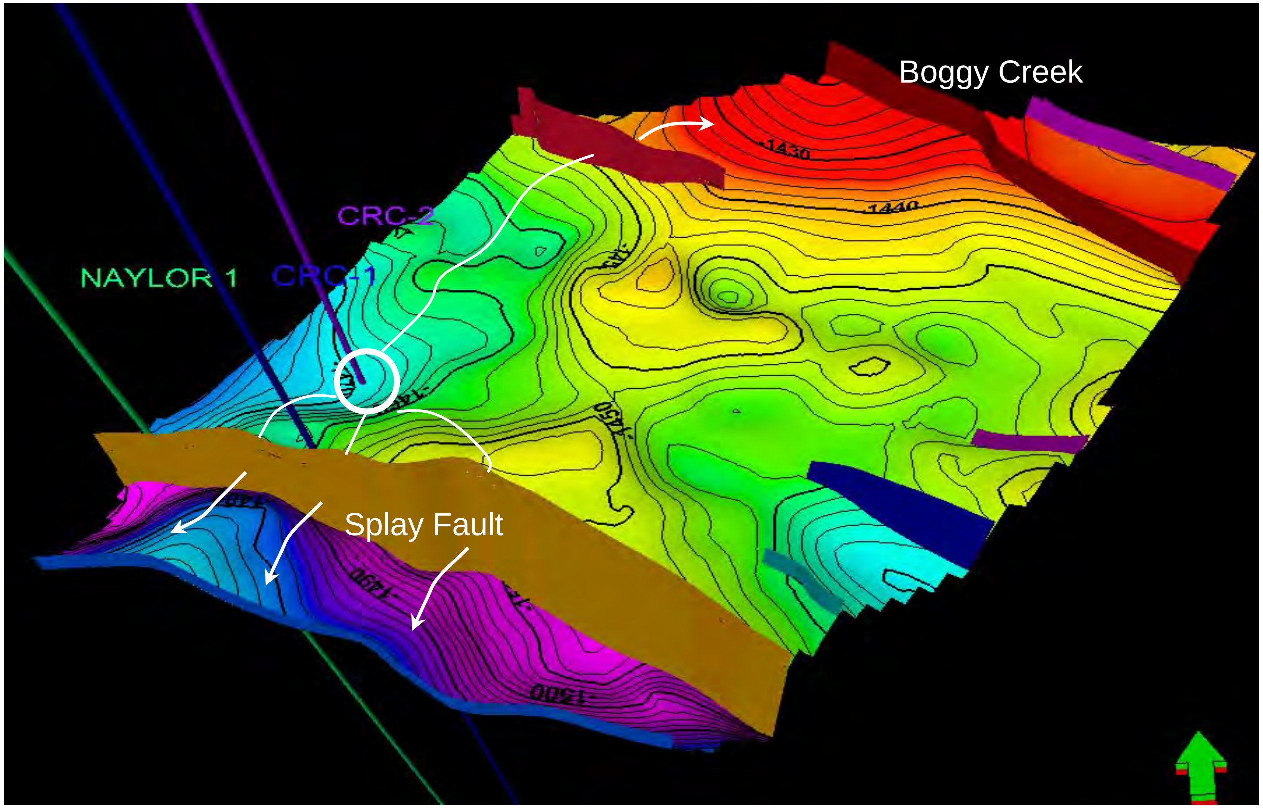
For worse case fault scenario >1MPa needed for potential fault reactivation

According to reservoir models, pressure build up at splay fault is ~ 0.05 MPa

∴ Risk of fault reactivation is very low

Fault Risk Assessment : Question 2

Will the faults act as a barrier for CO_2 flow, or will CO_2 migrate readily across the fault?



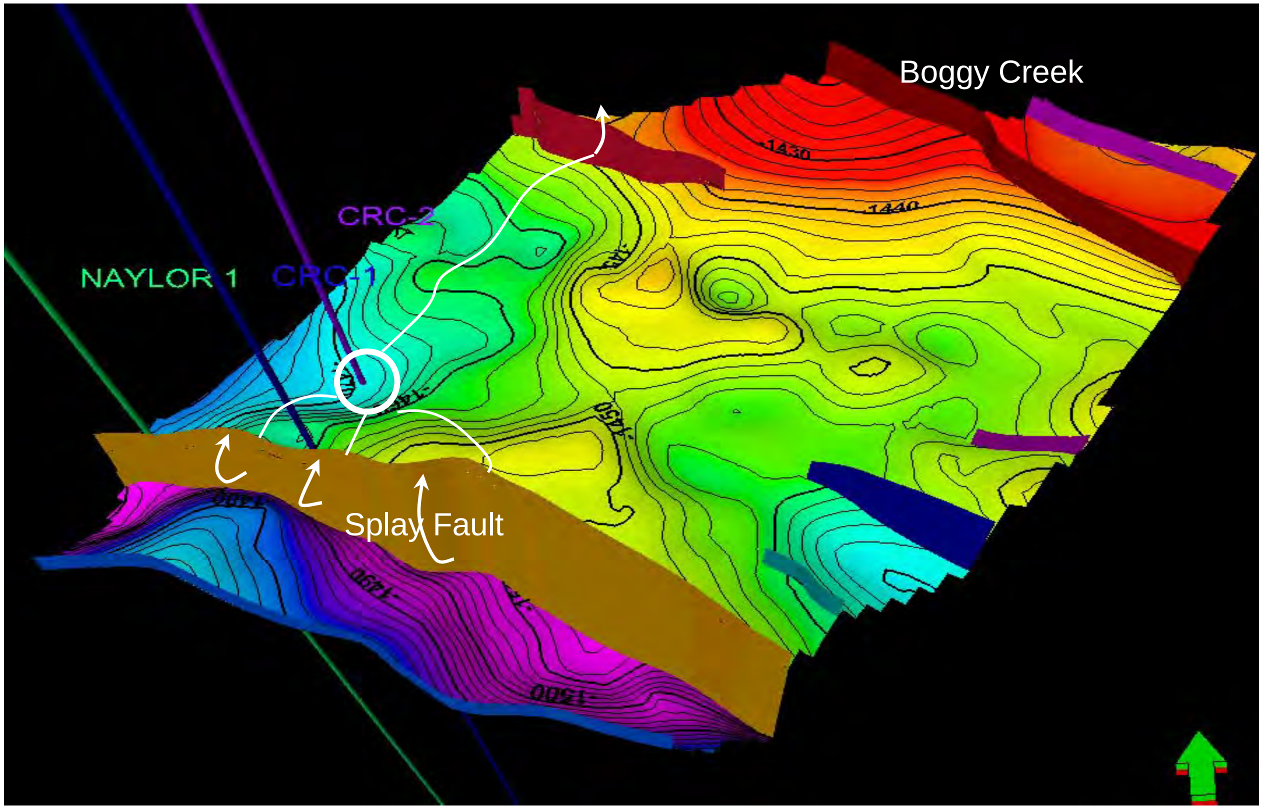
Fault Shale Gouge Ratio (SGR) is >25% ∴ faults are sealing

In specific scenario modelling, '*no fault seal*', CO_2 migrates into abutting fault block and contained within the Paaratte, and within tenement.

∴ Risk of across fault leakage is very low

Fault Risk Assessment : Question 3

Will CO_2 migrate along faults and if so, how far?



Splay fault does not extend through Paaratte vertically

In specific scenario modelling, '*permeable fault*', CO_2 migrates partly up splay fault only, and is contained within the Paaratte and within tenement

∴ Risk of along fault leakage is very low

What happens to CO_2 over time?

Timeline	Mobile (%)	Residually trapped (%)	Dissolved (%)
End injection	36	36	28
1 yr	21	37	42
10 yr	18	35	47
20 yrs	18	34	48
100 yrs	12	26	62

Example calculation from the CO2CRC Otway Stage 2C. These parameters are depending on characteristics of storage reservoir and are ONLY representative for the reservoir modelled.

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Stage 2C Injection Plan

Parameter	Description
Injectant	Buttress-1 gas
Injection Interval	1501 – 1512 mRT in CRC-2
Injection Mass	15,000 tonnes
Injection Rate	111 tonnes/day for 135 days
Injection Period	19^{th} November 2015 – 4^{th} May 2016

Stage 2C Operation (2015 – 2020)

GOAL

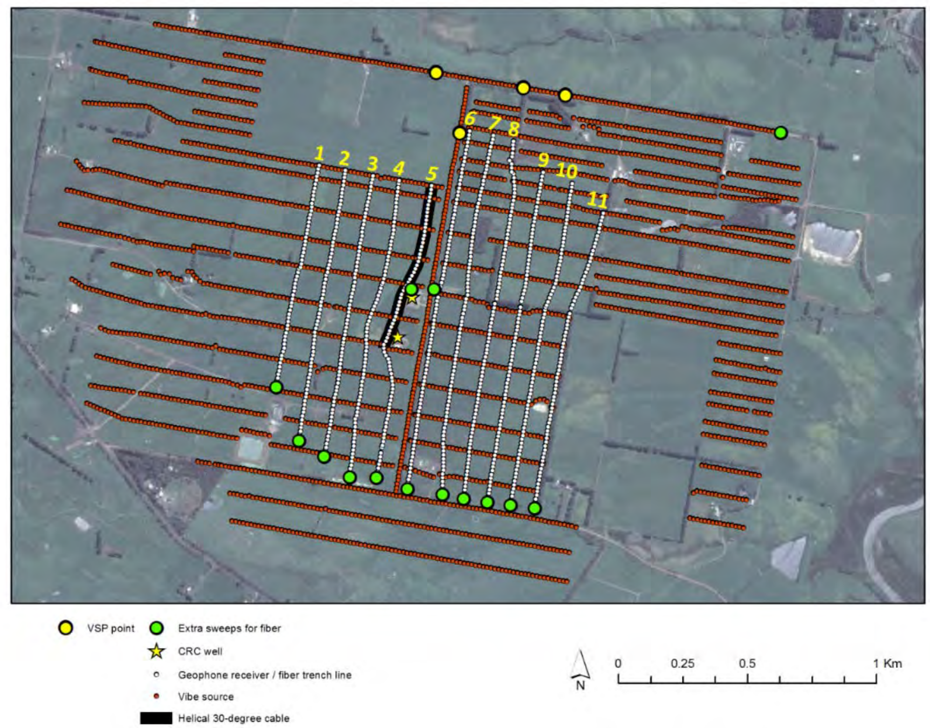
Safely complete seismic-focused, 2C injection experiment in a saline formation, such that it is meets the scientific objectives and the results provide high quality research value to CCS knowledge.

SCIENTIFIC OBJECTIVES

1. Detect injected Buttress gas in the subsurface; ascertain minimum detection limit;

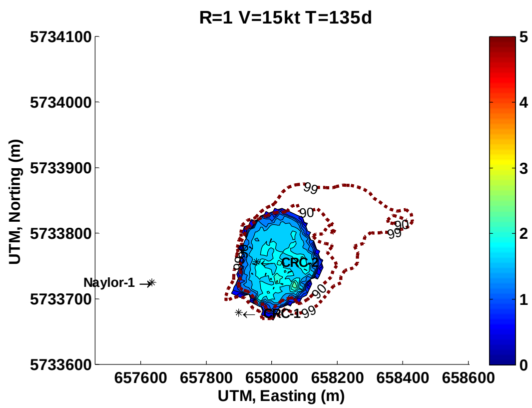
2. Observe the gas plume development using time lapse seismic;

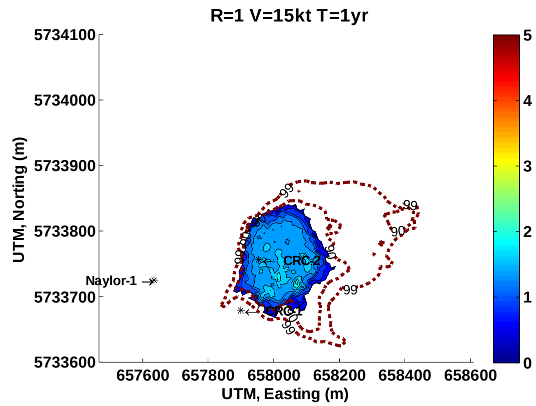
3. Verify stabilisation of the plume in the saline formation using time lapse seismic.

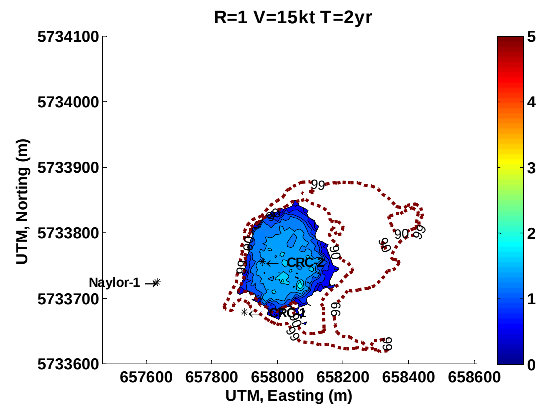


Amplitude of time lapse signal with surface and buried geophone array

Surface





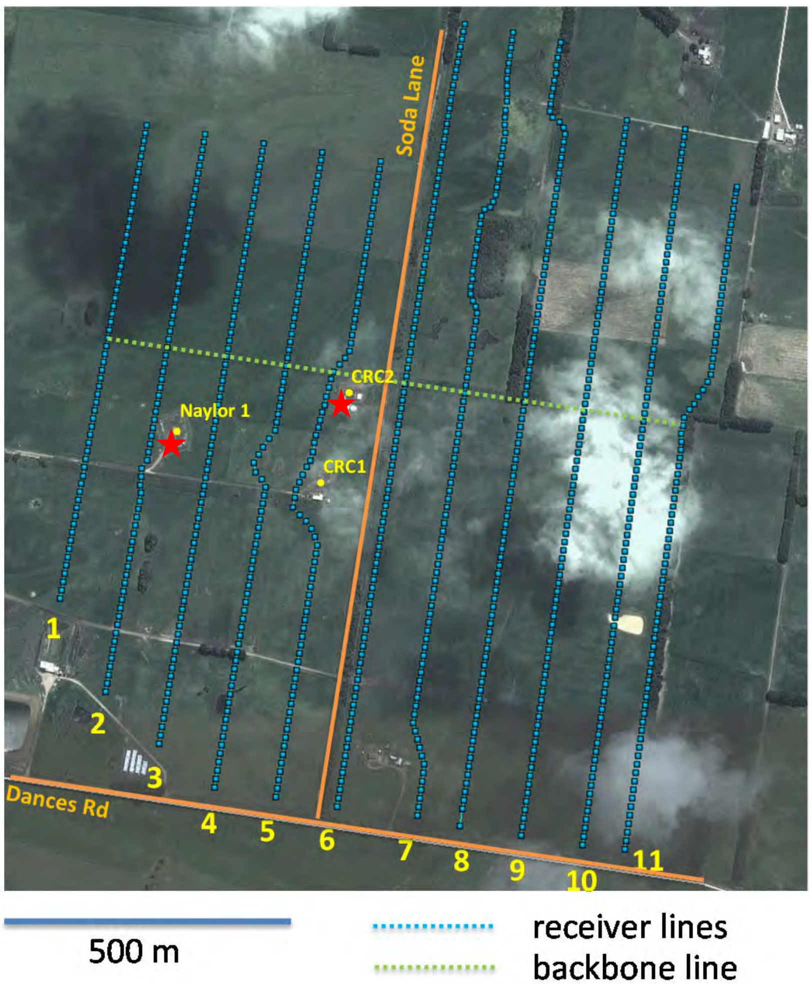


End injection

1 yr post injection

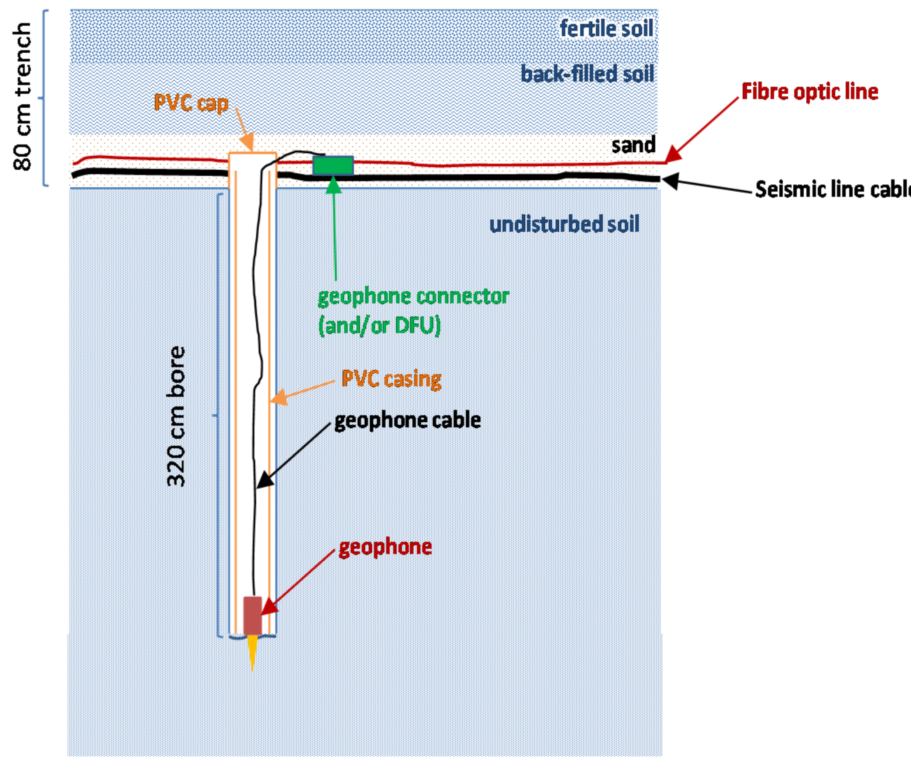
2 yr post injection

Surface Monitoring



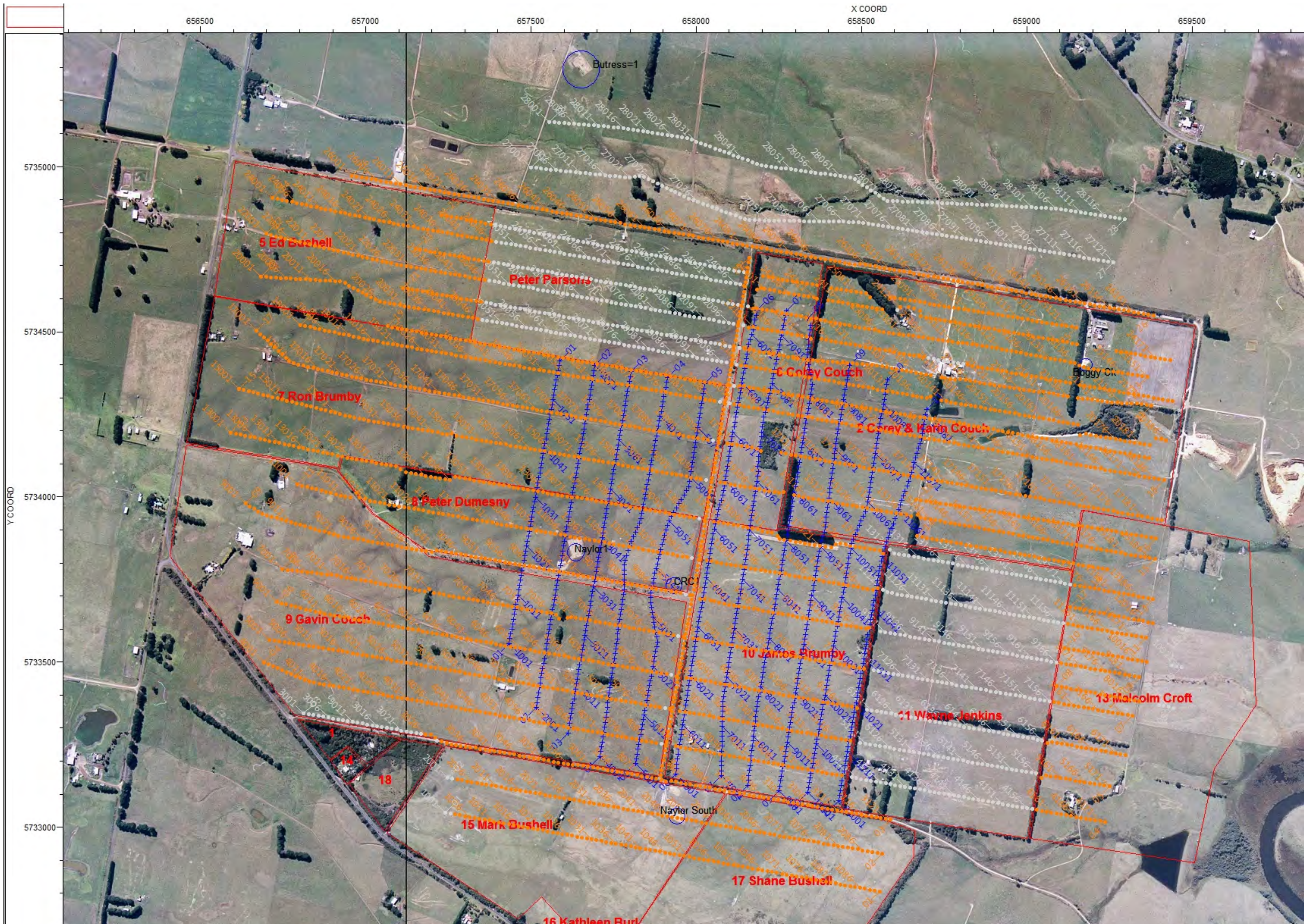
Active & Passive seismic

- Buried seismic receiver array (908 single component geophones & 34 km fibre optic cable)
- Repeat (Vibroseis) & permanent seismic sources



CO2CRC

CO2CRC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5 Ed Bushell
Peter Parsons
7 Ron Brumby
8 Peter Dumesny
9 Gavin Couch
10 James Brumby
11 Wayne Jenkins
13 Malcolm Croft
15 Mark Bushell
16 Kathleen Burt
17 Shane Bushell
2 Corey & Karin Couch
Naylor1
CRC1
Naylor South
14
18

Downhole Monitoring

CRC-2
Completions

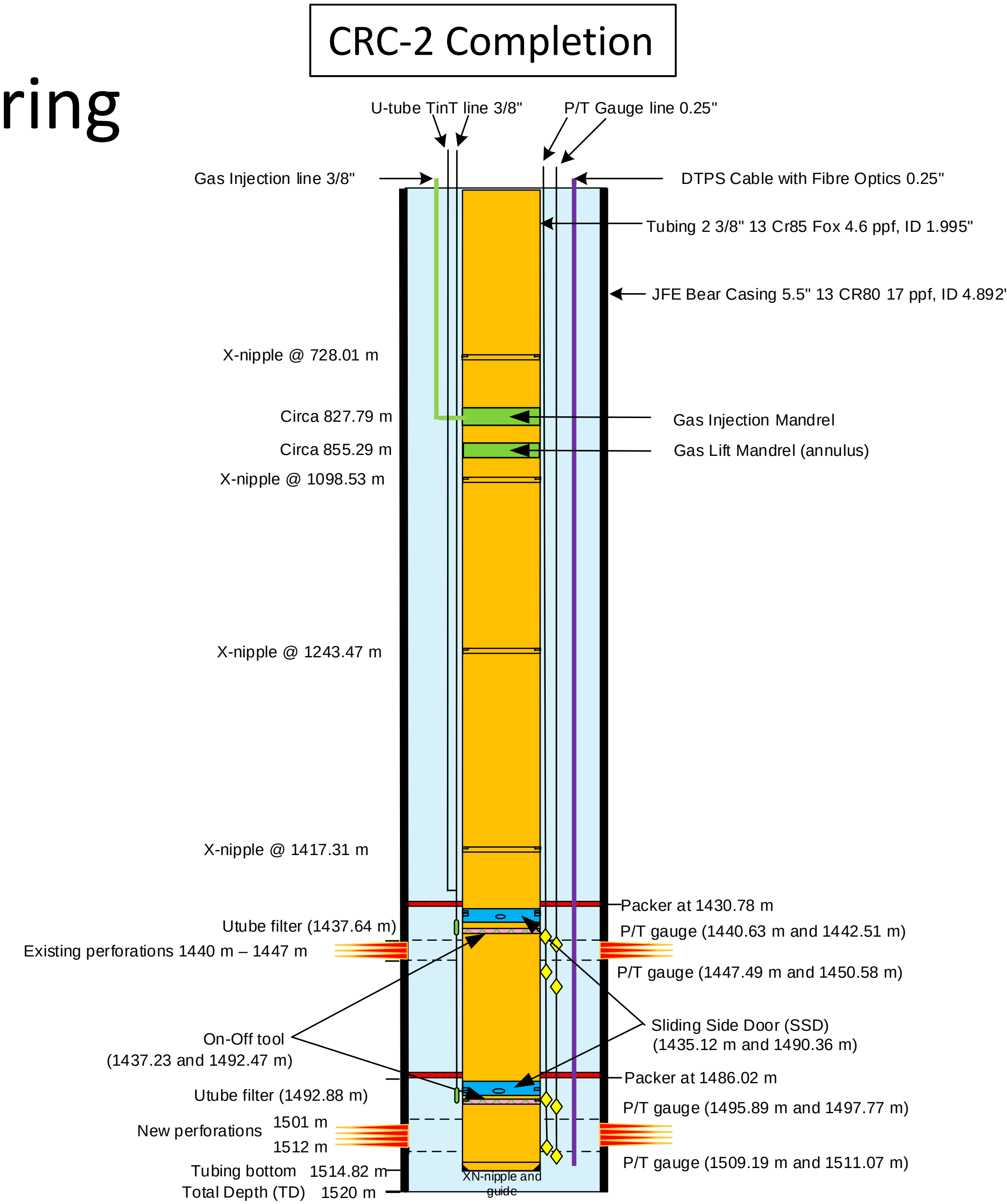
- Injection interval and above zone isolations (SSDs)
- Gas injection and lift mandrels

Monitoring tools

- Permanent pressure & temperature
- U-tube (tube in tube)
- Fibre Optic - DTS & acoustic

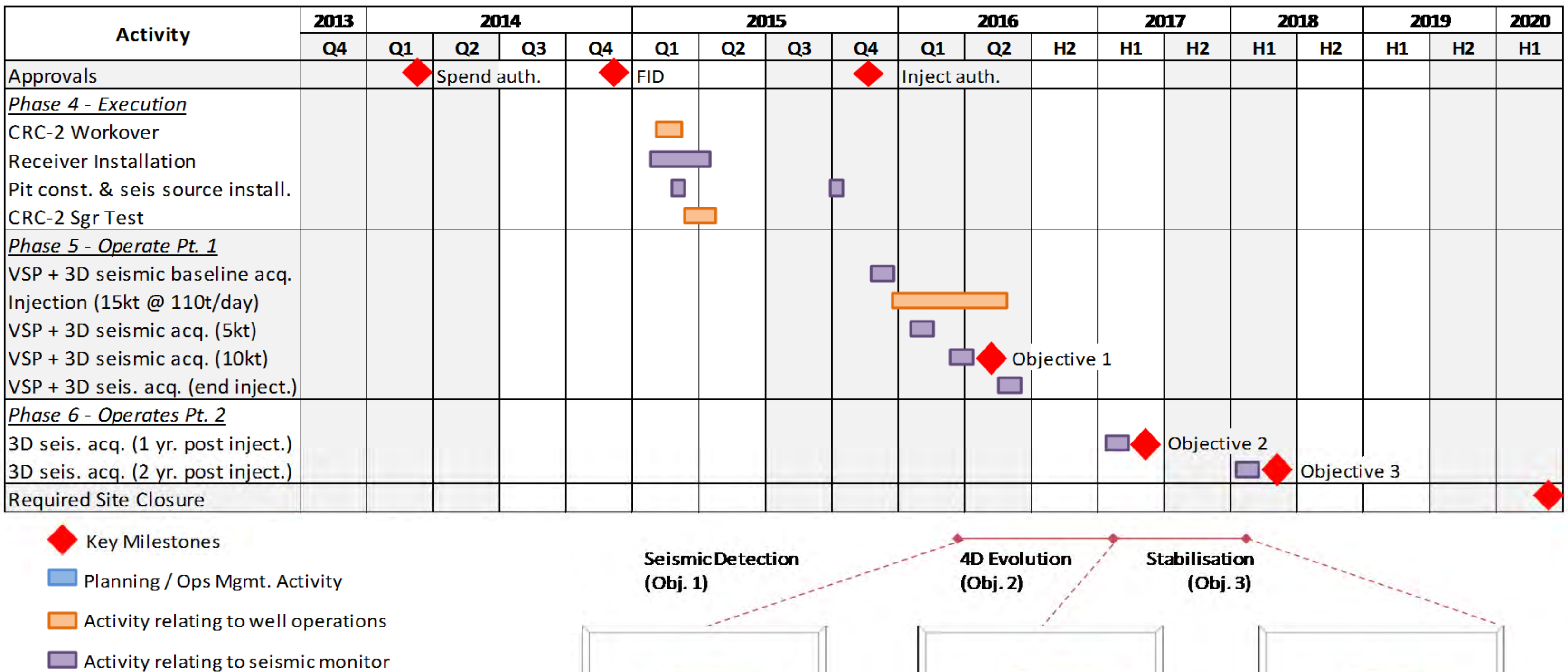
CRC-1

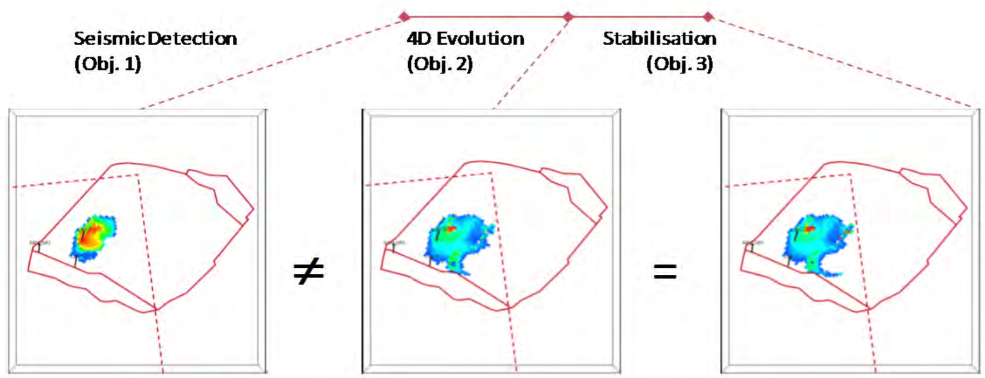
- Seismic geophones (VSP)



Monitoring plan

- Continual pressure and temperature monitoring
- Ongoing passive seismic monitoring
- During injection active seismic acquisition (permanent sources with surface 3D and receiver arrays)
- During and post injection - active seismic acquisition (vibroseis source with surface 3D and VSP receiver arrays)





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Stage 2 - Anticipated Outcomes

- ✓ Methodology for near well characterisation of CO_2 storage
- Demonstrated capability of time lapse seismic for imaging a CO_2 plume
  - Quantified comparison of seismic techniques for the monitoring of CO_2 plume migration
- Method for the prediction of plume stabilization
  - Verification of stabilisation using seismic and pressure monitoring in conjunction with plume modelling
  - Enhanced capability to utilise short term monitoring to calibrate long term model predictions

Participants

Australian Government Geoscience Australia

Australian Government Department of Industry and Science

CSIRO

Curtin University

MONASH University

The University of Adelaide Australia

The University of Melbourne

UNSW Australia

The University of Western Australia

anlecr&d

BG Group

bhpbilliton

bp

Brown Coal Innovation Australia

Chevron

GLENCORE

GNS Science

Government of Western Australia Department of Mines and Petroleum

INPEX

KIGAM Korea Institute of Geoscience and Mineral Resources

NSW Government Trade & Investment

RioTinto

sasol reaching new frontiers

Shell

State Government Victoria

Total

Supporting Partners

CO2CRC

Global CCS Institute

Government of South Australia

Berkeley Lab

process group

SFU

The University of Queensland Australia

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Future Otway Projects: Stage 3

Stage 1: 2004 – 2009

Depleted Field Storage

✓ Demonstrate safe transport, injection and storage of CO_2 in a structural trap

Stage 2: 2009 – 2018

Saline Formation Storage

✓ 2A :Drill CRC-2

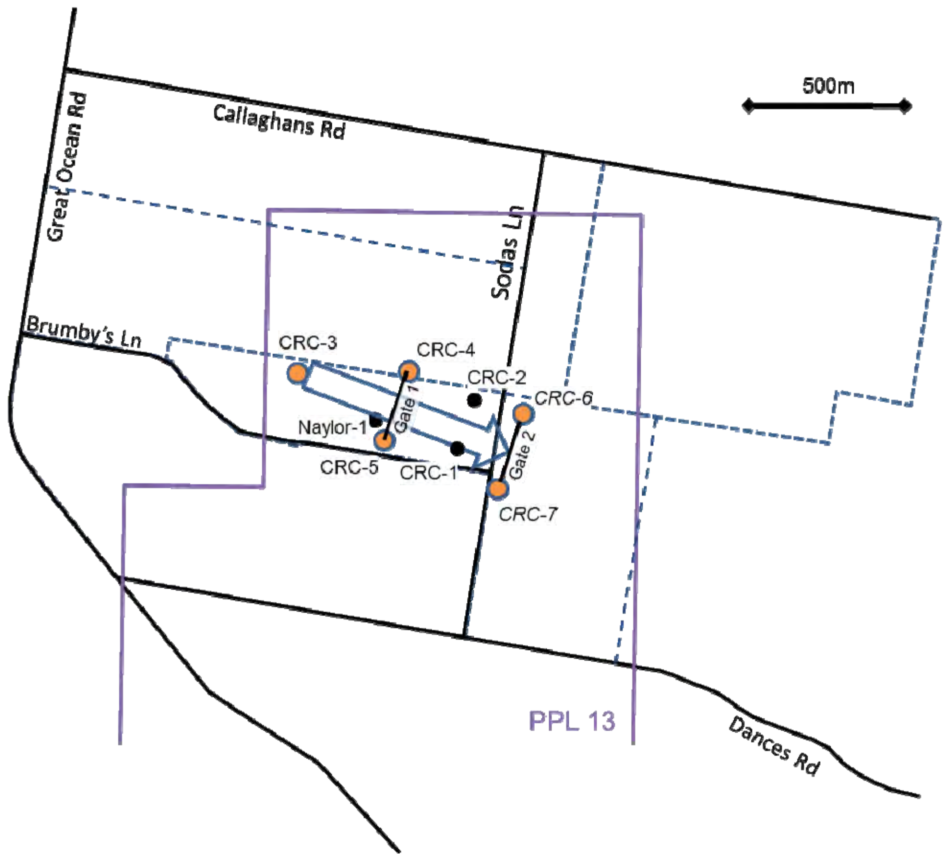
✓ 2B: Measure parameters affecting residual and dissolution trapping in a saline formation

- 2C: Spatially track injected CO_2 in a saline formation

Stage 3: 2014 – 2021+

Otway Subsurface Laboratory

- Validate subsurface monitoring
- Trial storage management processes and technologies



Otway Stage 3 - Project Overview

1 - Problem:

1. Potential cost, geographical, societal, or economic impediments to repeat, surface-based M&V.
2. Insufficient resolution or accuracy across regions of higher risk and uncertainty
3. Effectiveness of subsurface M&V alternatives, is poorly understood
4. Effectiveness of storage management is poorly understood

2 - Objective:

Appraisal, implementation, demonstration and validation of subsurface monitoring of a CO_2 storage system and storage operations at the CO2CRC Otway Facility.

3 - Goals:

1. Validation of subsurface M&V as alternation M&V option (cost, footprint, socio-political)
2. Expanded Otway facility to enable storage management field trials

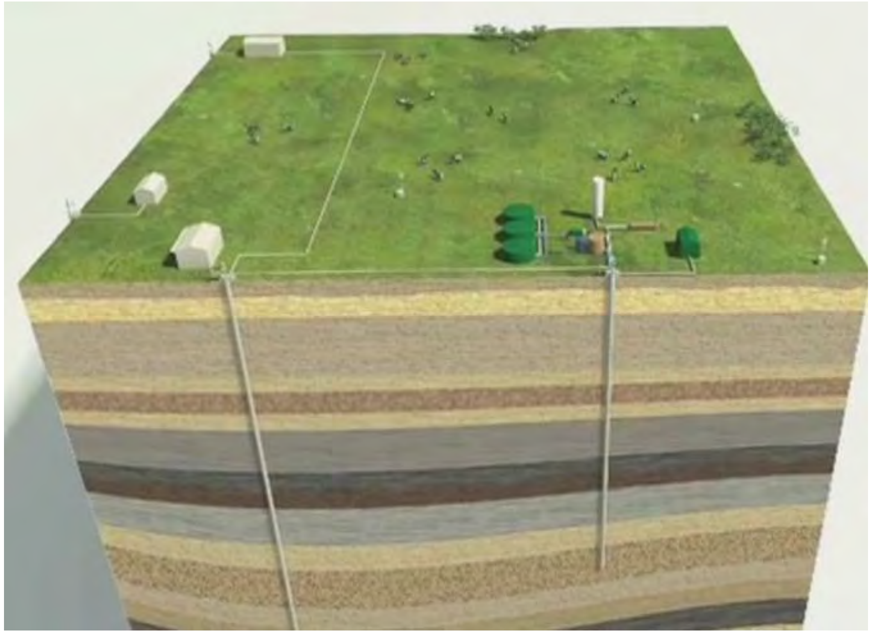
CO2CRC

Utilising the capital at the Otway – A National Deep Earth Research Facility

CO2CRC’s aims to develop innovative clean energy technologies, over the next 10 years, by further understanding and exploiting deep earth processes.

Through international collaborations we wish to establish a **National Deep Earth Research Facility** that will continue to undertake leading CCS research while pursuing opportunities in:

- CCS Water Co-Production Management
- Geothermal
- Energy storage



Modelled Seismic Detection

Key time steps	Relative gas volume detected					
	R1	R2	R3	R4	R5	R6*
end injection	74% (7,892 t)	82% (8,512 t)	84% (8,971 t)	76% (7,820 t)	83% (8,765 t)	70% (7,497 t)
1 year post injection	68% (5,763 t)	71% (6,071 t)	61% (5,408 t)	55% (4,670 t)	65% (5,577 t)	51% (4,567 t)
2 years post injection	67% (5,598 t)	69% (5,817 t)	59% (5,152 t)	53% (4,428 t)	64% (5,395 t)	49% (4,285 t)

*- unlikely case where cements are laterally extensive