

# Brine Management for CCS - practical challenges



8<sup>th</sup> International Workshop on  
Offshore Geological CO2 Storage

Based on the paper SPE 225523, first  
presented at SPE Europe Energy 2025

Hans Sizoo (presenting), Ross Nickson, Michael  
Grocott, Alex Villalobos, Paul Page, Rachel Utley, bp;

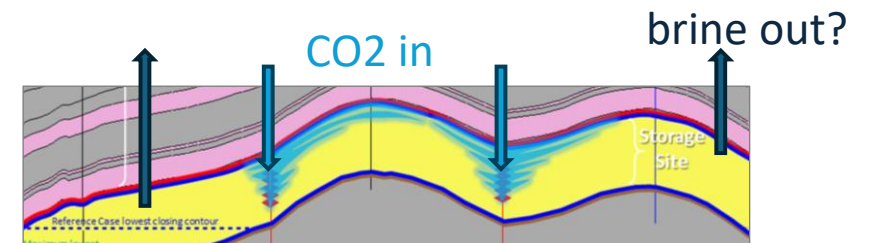
Andrew Woods, University of Cambridge; Marius  
Dewar, Plymouth Marine Laboratory; William  
Stubblefield, Oregon State University



## Offshore saline aquifers for carbon capture and storage (CCS)

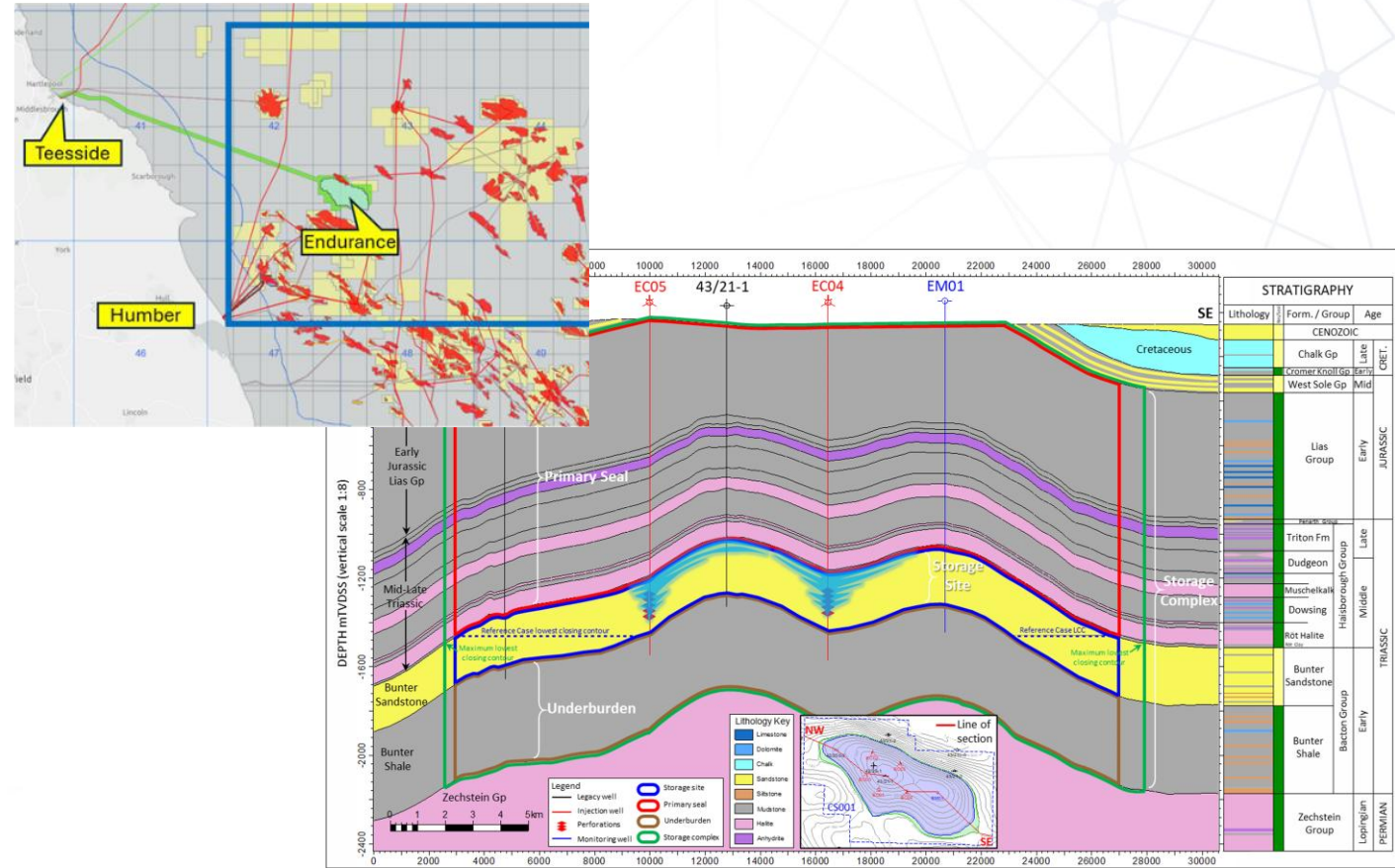
- Saline aquifers are widespread, have large capacities and are used for CO<sub>2</sub> storage in most currently operating CCS projects (such as Sleipner, Snøhvit, Quest and Gorgon)
- For the United Kingdom it is estimated that 89% of capacity in stores > 20Mt is in saline aquifers, with 11% in depleted hydrocarbon fields
- Storage is dependent on available pore and pressure space
- In saline aquifers the initial pressure is at hydrostatic conditions and storage efficiency of saline aquifers in structural traps is in the order of ~5%
- Capacity can be limited by the fracture pressure of the caprock and the lateral dissipation of reservoir pressure in the storage formation

**Brine extraction is a way to maximize CO<sub>2</sub> storage, through managing the reservoir pressure**



## The Endurance store

- Located 63 km from the nearest coastline off Flamborough Head
- The best appraised large scale saline aquifer for CO<sub>2</sub> storage in the offshore UK Continental Shelf
- The first phase of the Northern Endurance Partnership CCS project was sanctioned in December 2024 (paper SPE-225484 | The UK's First CO<sub>2</sub> Transportation & Storage Project Takes FID)
- Phase 1 will store up to 100 Mt of CO<sub>2</sub> over 25 years



Source: Site Characterisation of the Endurance CO<sub>2</sub> store (2024).

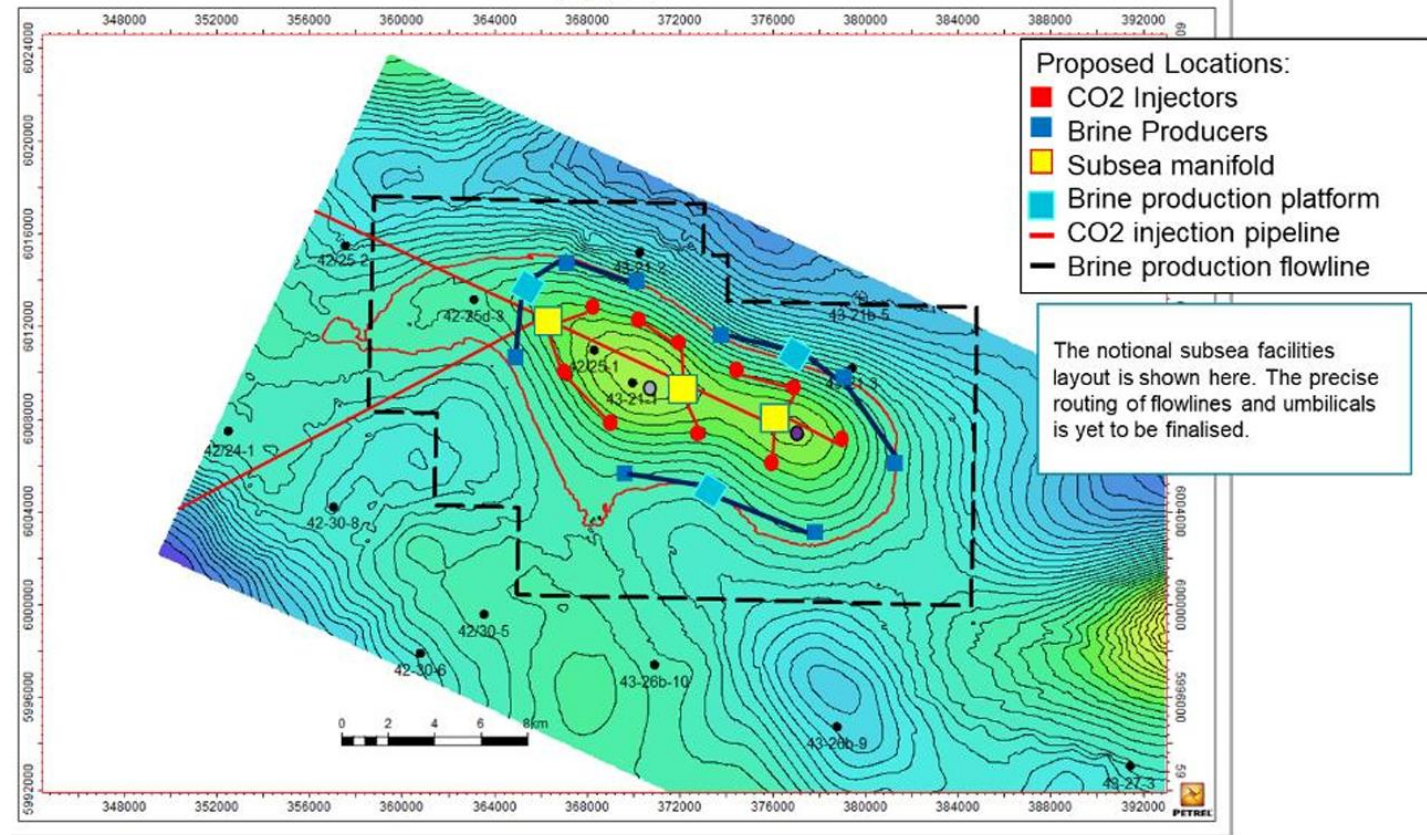
## The potential prize

Increase annual CO<sub>2</sub> injection from 4 to 10 mtpa, through:

- 6 additional CO<sub>2</sub> injectors
- 8 brine production wells, extracting 25,000 m<sup>3</sup> / day

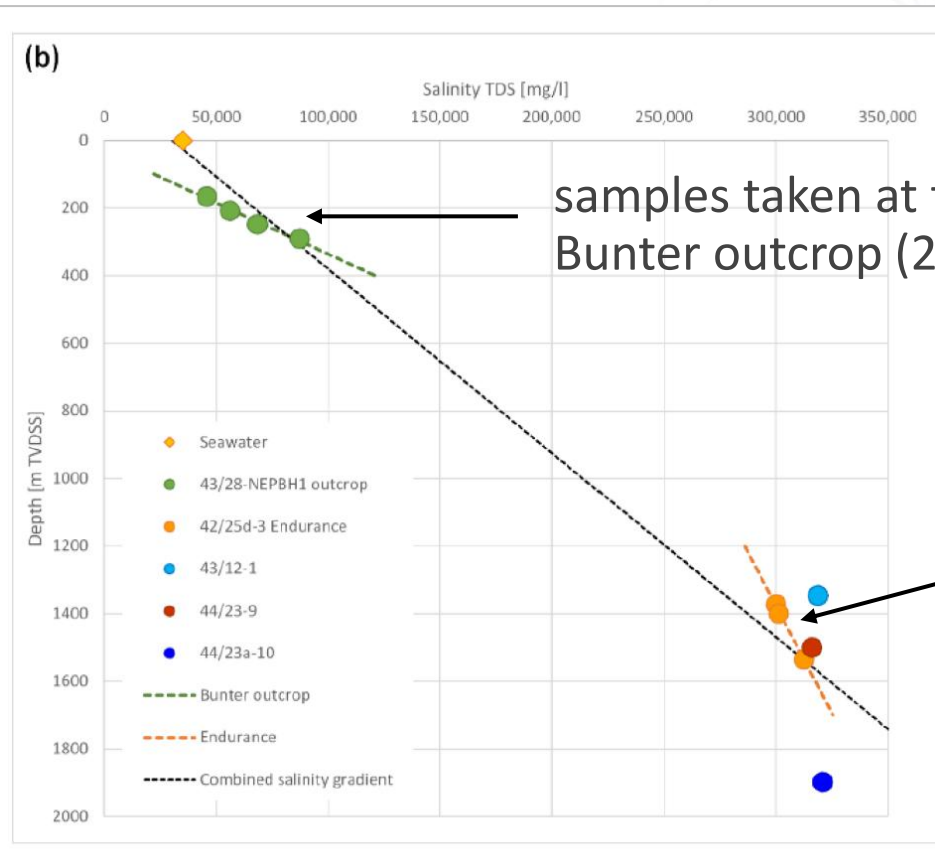
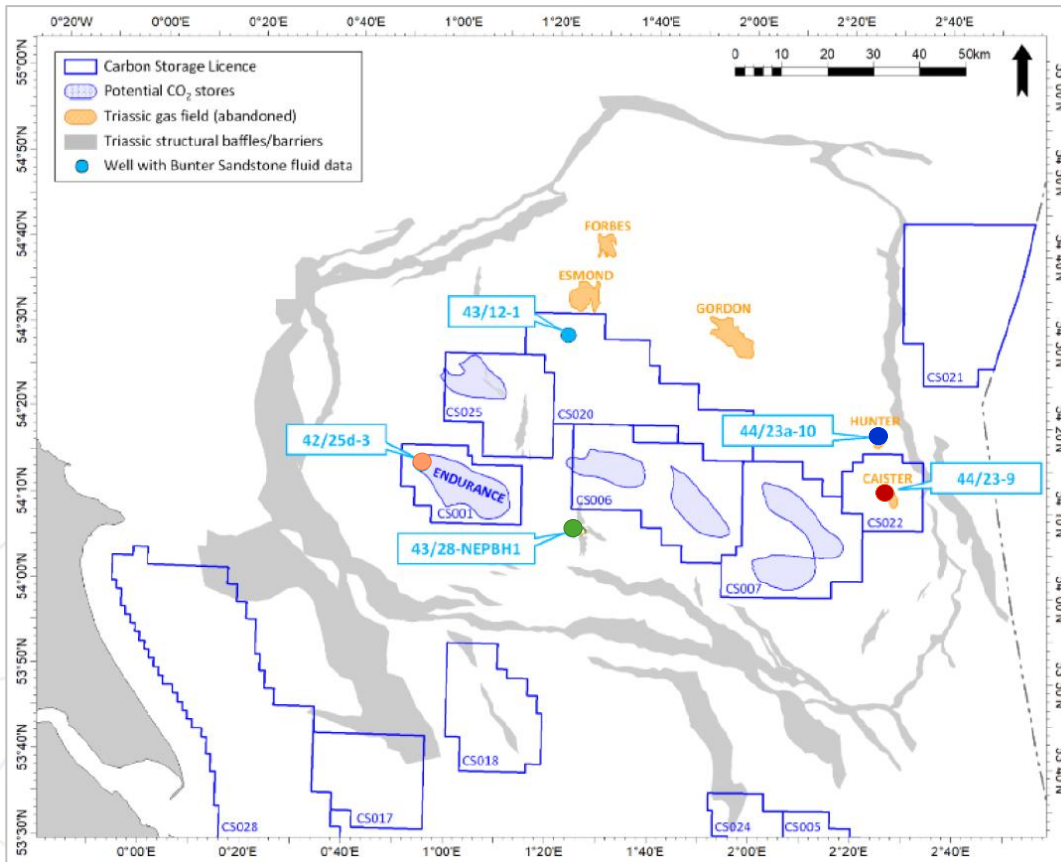
Storage efficiency factor

~3% → ~7.5%



Source: Multi-Store development philosophy (2021).

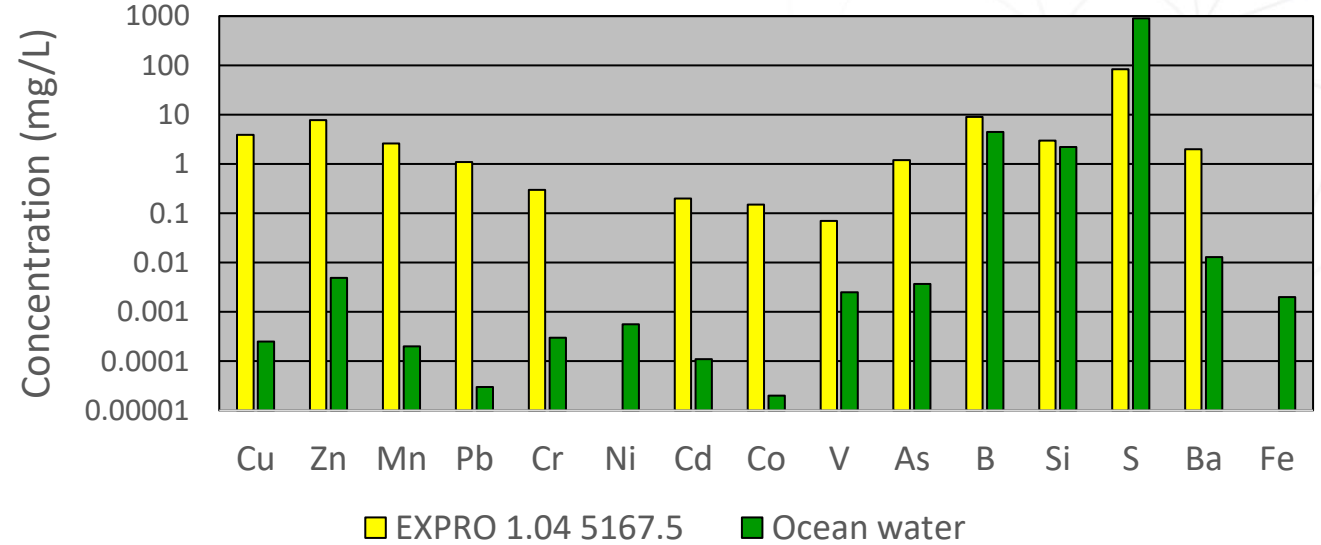
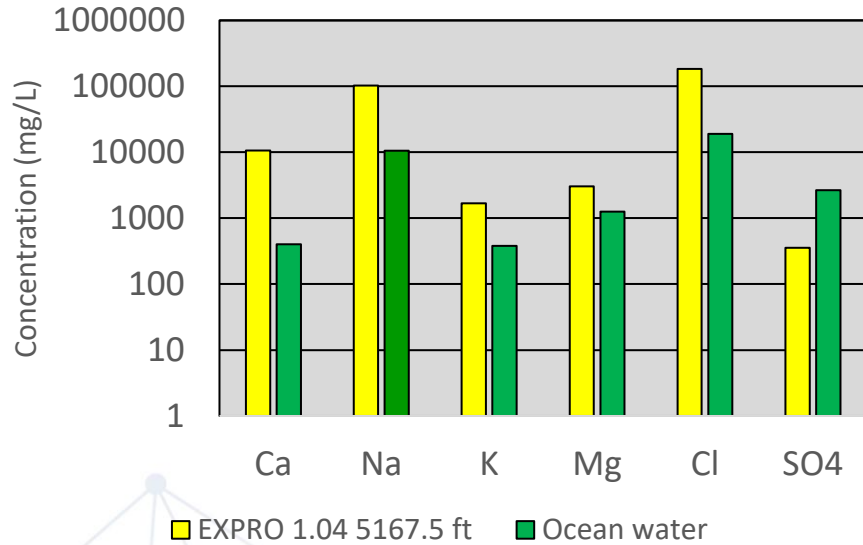
# Formation water samples in and around Endurance



samples taken at the Bunter outcrop (2022)

samples taken at Endurance (2013)

## Endurance formation water - composition



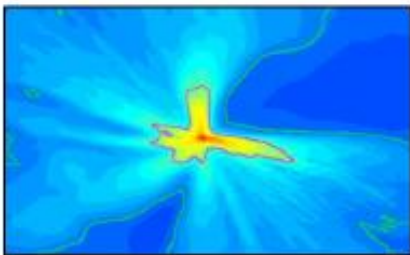
- The Endurance brine is hypersaline (circa 300 ‰) and presents a pH <7
- Open ocean water is typically 34 – 36 ‰
- Metals above concentrations normally present in seawater

## Offshore brine discharge: quantification of impacts

- In the UK, ~270,00 m<sup>3</sup>/day<sup>1</sup> of produced water from oil & gas fields is discharged into the sea
- Could Endurance brine be discharged? How would it mix and dilute with seawater? What would be the impact on the natural environment?

### Discharge mixing: *modelling*

Can natural mixing processes dilute hypersaline brines to below environmental impact thresholds?



### Dilution: flume tank *experiments*

How does hypersaline brine disperse when released into a long flume with a moving fluid source?



### Metal speciation *modelling*

Which metals in the HSB may end up in chemical forms (species) in seawater?

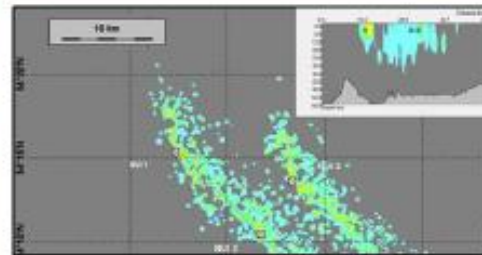
Metals: As, Zn, Cu,  
Cr, Pb, Cd, Ni



Species: Cu<sub>2</sub>S, Cu<sub>3</sub>Se<sub>2</sub>

### Dose related risk and effects *modelling*

What is the environmental exposure scenario from the discharge of HSB to the immediate marine waters and associated sediments. ?



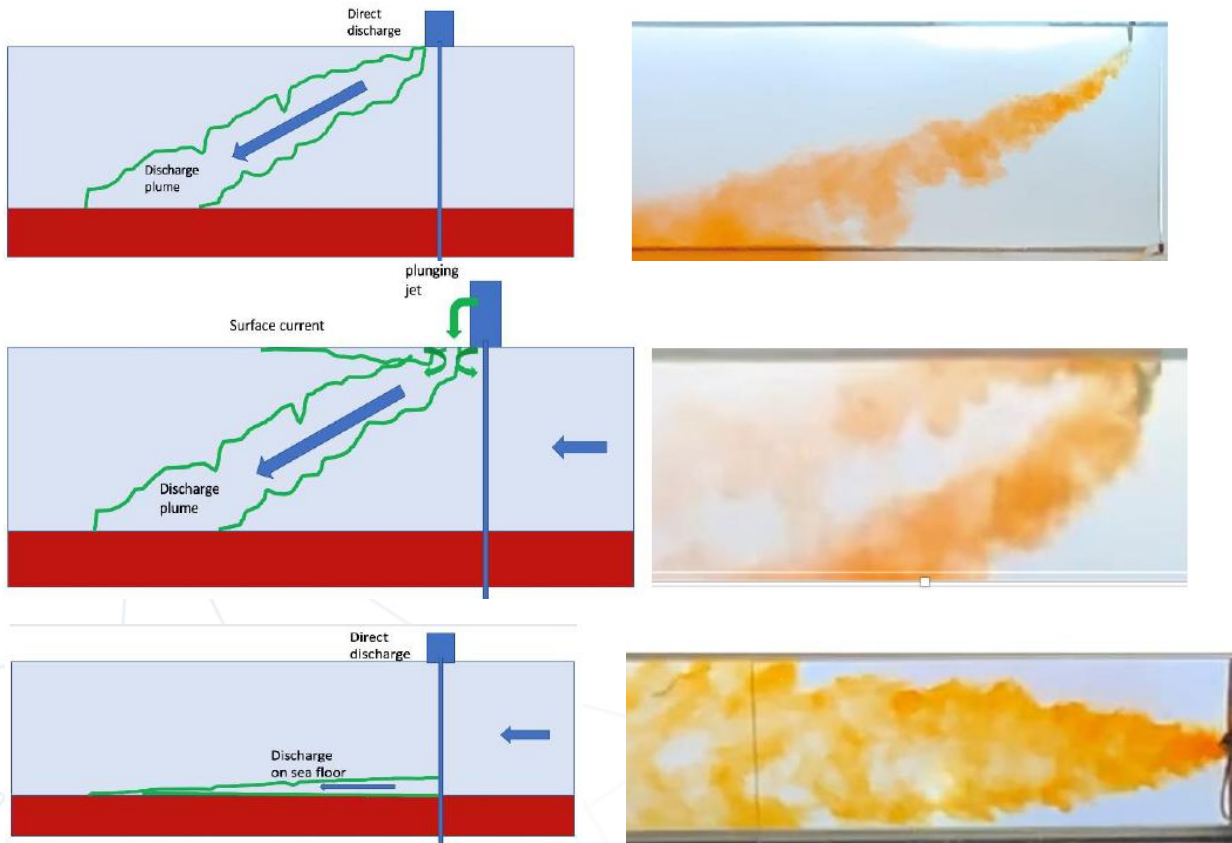
### Whole effluent toxicity *testing*

How sensitive are standard marine organisms to variations in brine salinity and metal content?



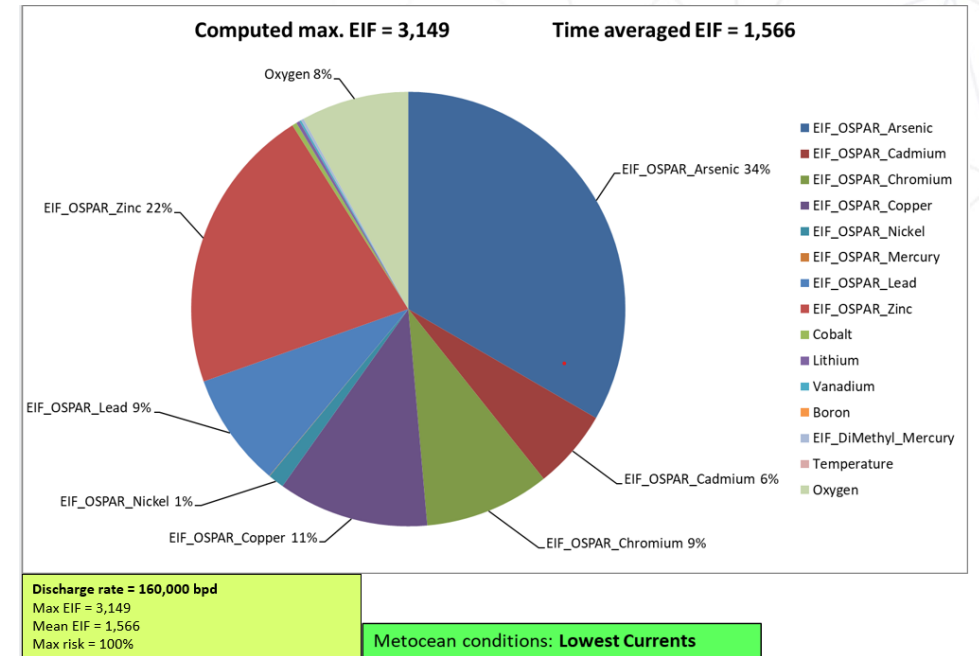
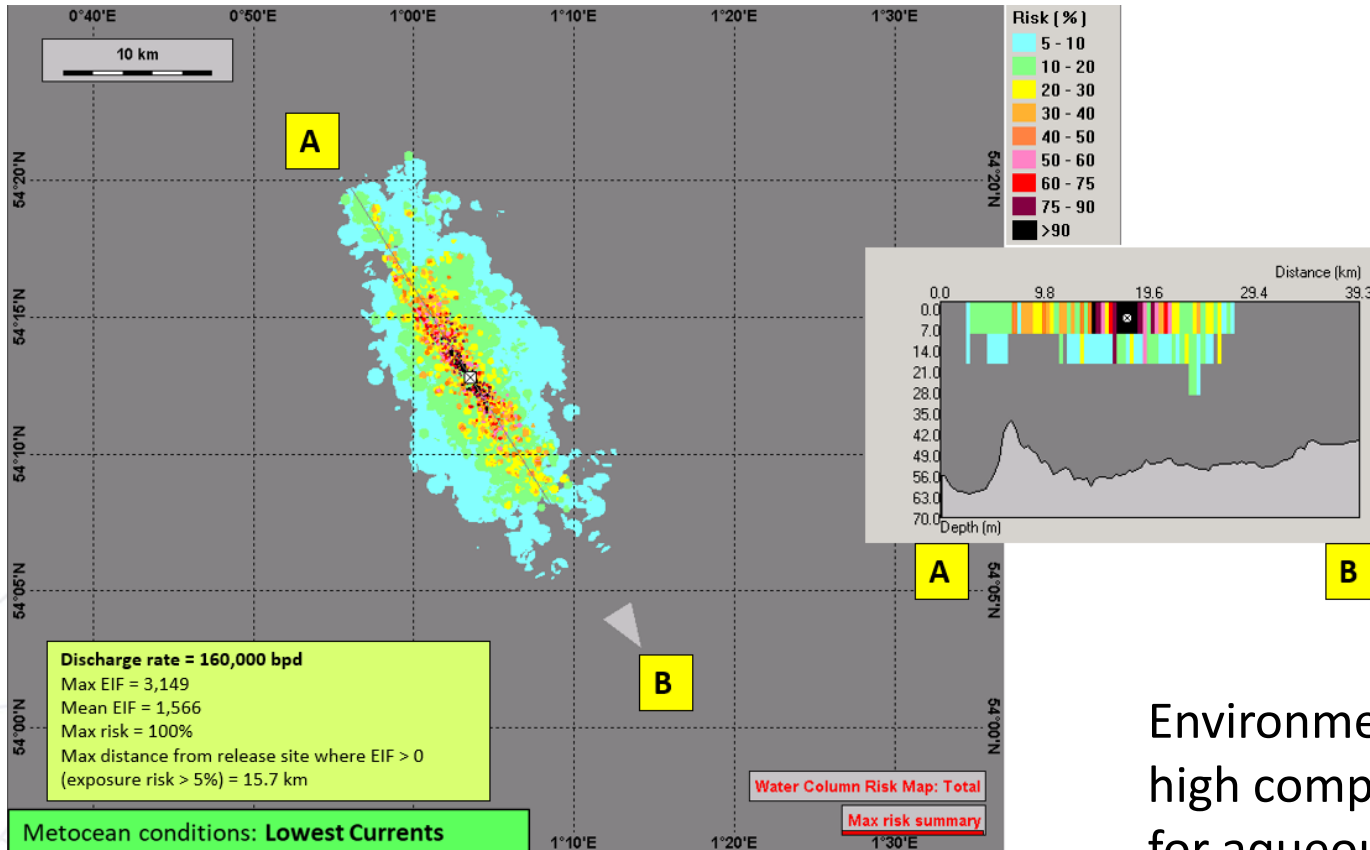
<sup>1</sup> OEUK, 2023

## Dilution flume tank experiments, with University of Cambridge



- Combination of simplified analytical models combined with experiments using a long flume to create scaled models of the mixing and dilution
- Near surface discharge appears to provide a good means of diluting the brine release
- Dilution is largely controlled by mixing in the descending plume but engineered discharge techniques can enhance this

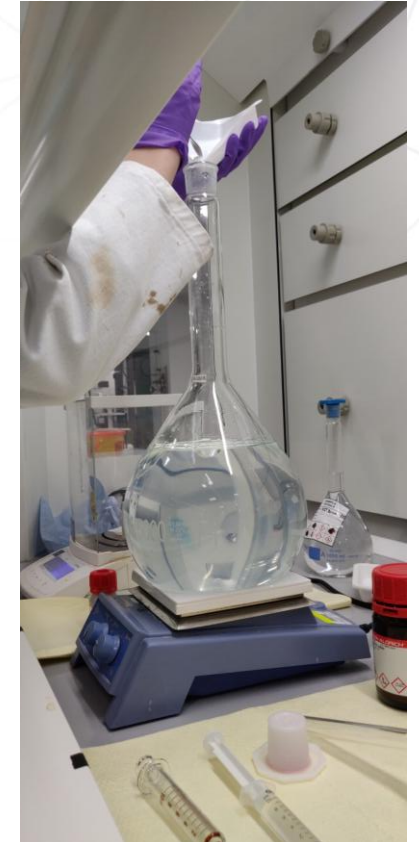
# Dose-related Risk and Effects Modelling (DREAM) modelling



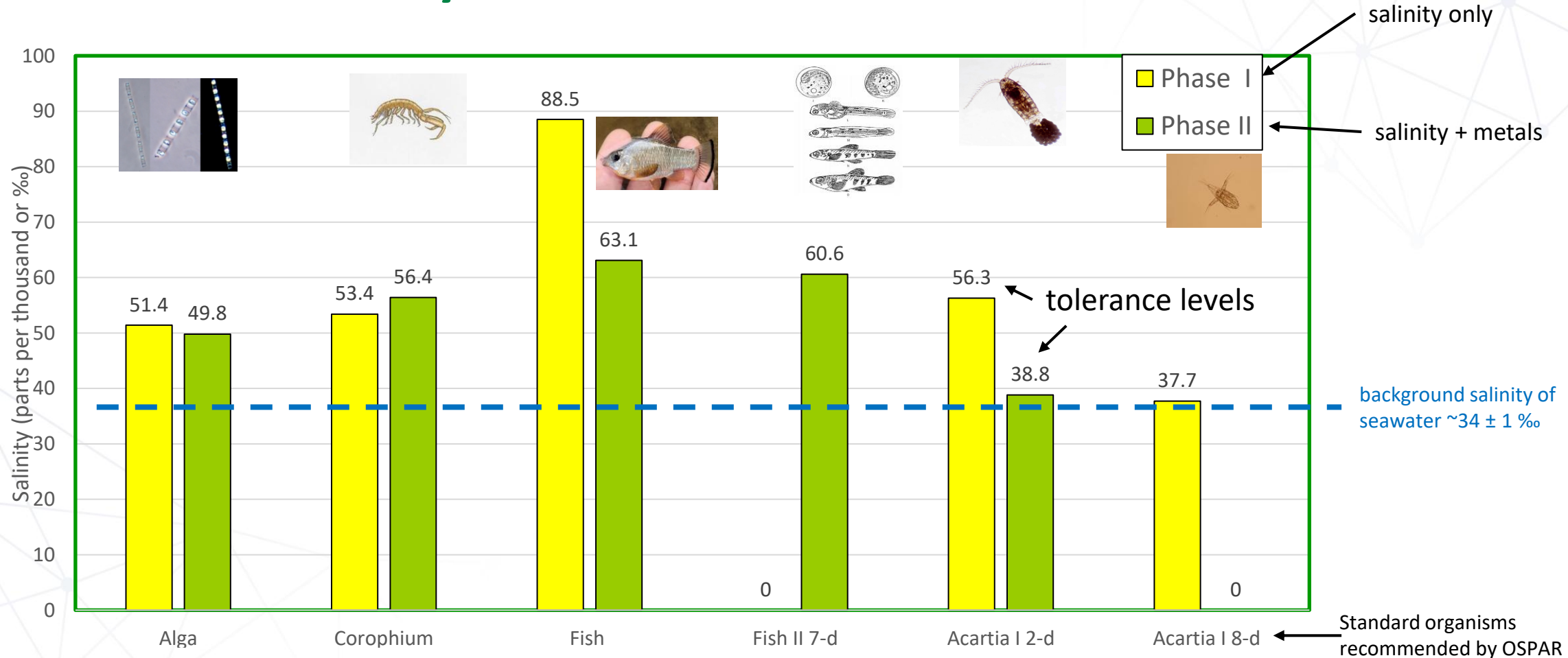
Environment Impact Factors (EIF) are relatively high compared to the limited published EIF data for aqueous discharges like produced water

## Whole Effluent Toxicity

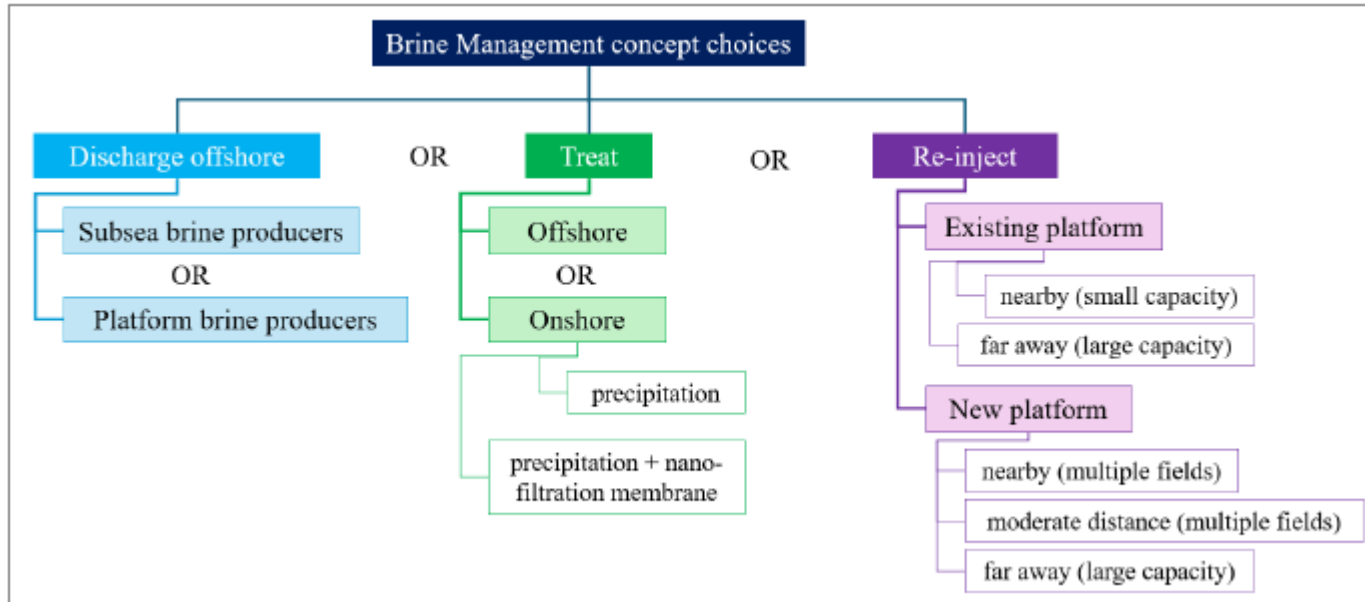
- This considers the effluent as one chemical, with all the contaminants (including water) combined and evaluated as a single component
- Provides a direct indication of the hazardous properties of the discharge as it includes all known and unknown constituents and their interactions
- Multi-tiered research program was undertaken to:
  - Synthesise hypersaline brine for WET testing in the laboratory using appraisal well 42/25d-3 data as a reference;
  - Investigate the environmental effects of brine in a step-wise approach following a series of WET tests to determine tolerance of marine organisms; and
  - Incorporate the results from the WET tests into the DREAM dispersion model to refine the environmental assessment



# Whole Effluent Toxicity results



## Brine Management Concepts



### Discharge Offshore

- Offshore discharge scenarios utilised an eductor to aerate the brine to aid dispersion

### Treat

- Offshore treatment rejected due to the complexity
- Onshore treatment would use metal precipitation to separate metals from the brine
- The use of nano-filtration in tandem with metals precipitation results in a reduced system size

### Re-inject

- Re-injection of brine into a secondary reservoir formed the third set of options
- Brine gathered at a central platform. Processing includes chemical injection to manage flow assurance risks. Pump suction strainers would remove most solids to protect rotating equipment and pipework.

## Option comparison

- To assess trade-offs, the project performed a **Best Practicable Environmental Option (BPEO)** comparison
- This is a method of choosing the most environmentally beneficial option for disposing of waste.
- It is a concept used in waste planning and environmental management

Decision Criteria:		Safety	Technical feasibility	Cost	Reputation	Environment	Social	Regulatory	Overall
Discharge Offshore		negative	positive	positive	negative	negative	neutral	negative	negative
Onshore Treatment	Base case	negative	negative	neutral	negative	negative	negative	negative	negative
	Alternative	negative	negative	neutral	negative	negative	negative	negative	negative
Re-inject	Nearby reservoir, existing platform.	negative	negative	negative	positive	positive	positive	positive	negative
	Nearby reservoir, new platform.	negative	neutral	negative	neutral	neutral	negative	positive	negative
	Reservoir at medium distance from Endurance	negative	negative	negative	neutral	neutral	negative	neutral	negative
	Reservoir far away from Endurance	negative	negative	negative	negative	negative	negative	neutral	negative

positive  
neutral  
negative  
v negative

## Business impact, further work and conclusions

- Rather than pursuing Brine Management, NEP expanded its CO<sub>2</sub> storage acreage, by accessing three additional CCS licenses (CS006, CS007 and CS025)
- This will enable NEP to expand its CO<sub>2</sub> injection capacity in the near term, without the need for brine extraction
- Samples will be obtained during NEP appraisal and development well drilling for further characterisation of the composition and additional testing of these samples has been recommended. Further modelling with improved toxicological data can then be undertaken
- Technical challenges and cost of a 'pre-mixed' discharge concept could be explored further.
- Regulatory clarity on the toxicity assessment techniques and the constraints/limits to be imposed on any brine discharge are required by industry

Maximizing CO<sub>2</sub> storage capacity is not as simple as producing brine to reduce reservoir pressure; the brine must then be dealt with. This introduces a host of technical and non-technical challenges on top of the core CO<sub>2</sub> injection project.