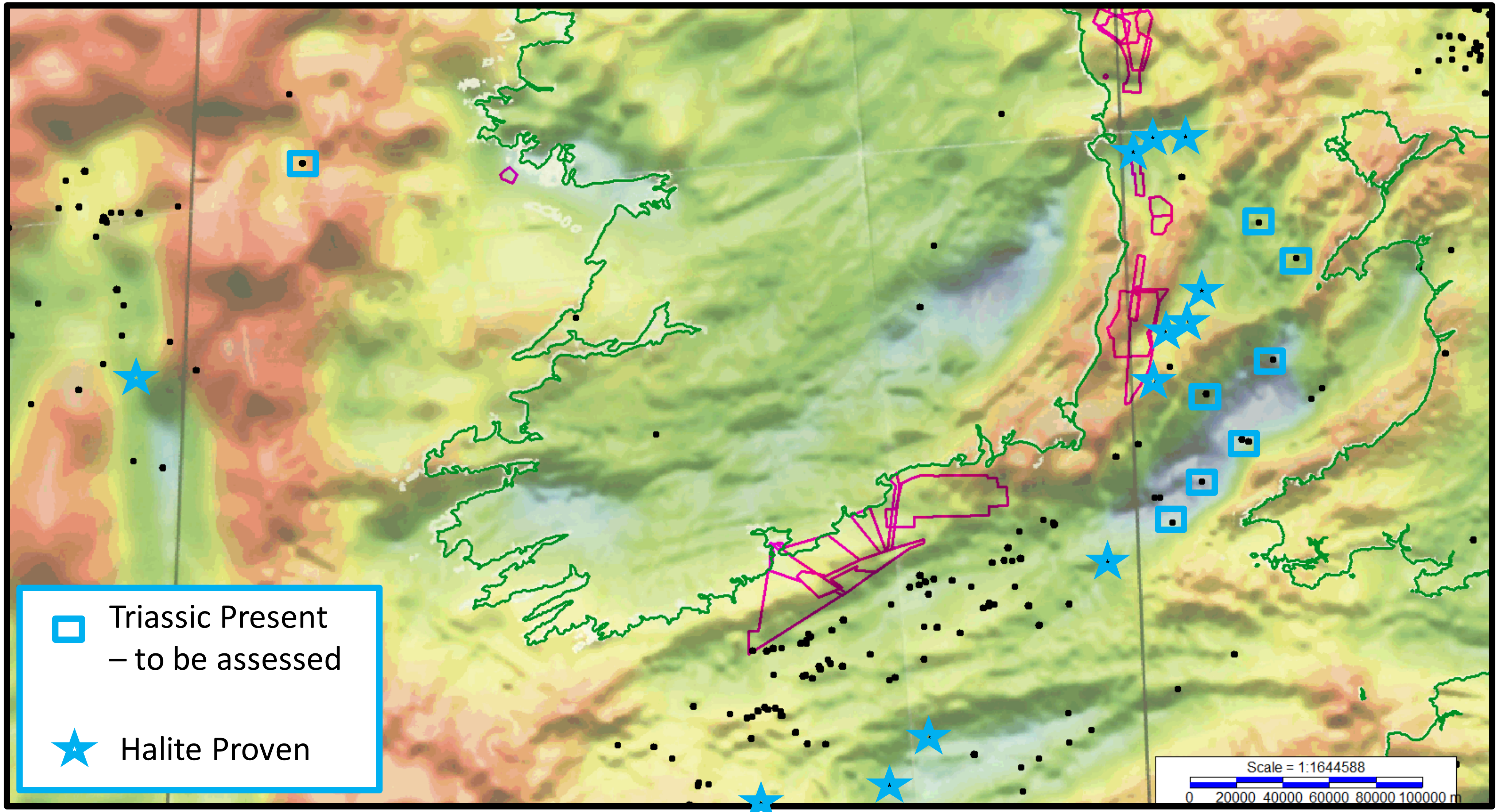
Hydrogen Salt Storage Assessment (HYSS)
Grant Agreement – 21/RDD/673

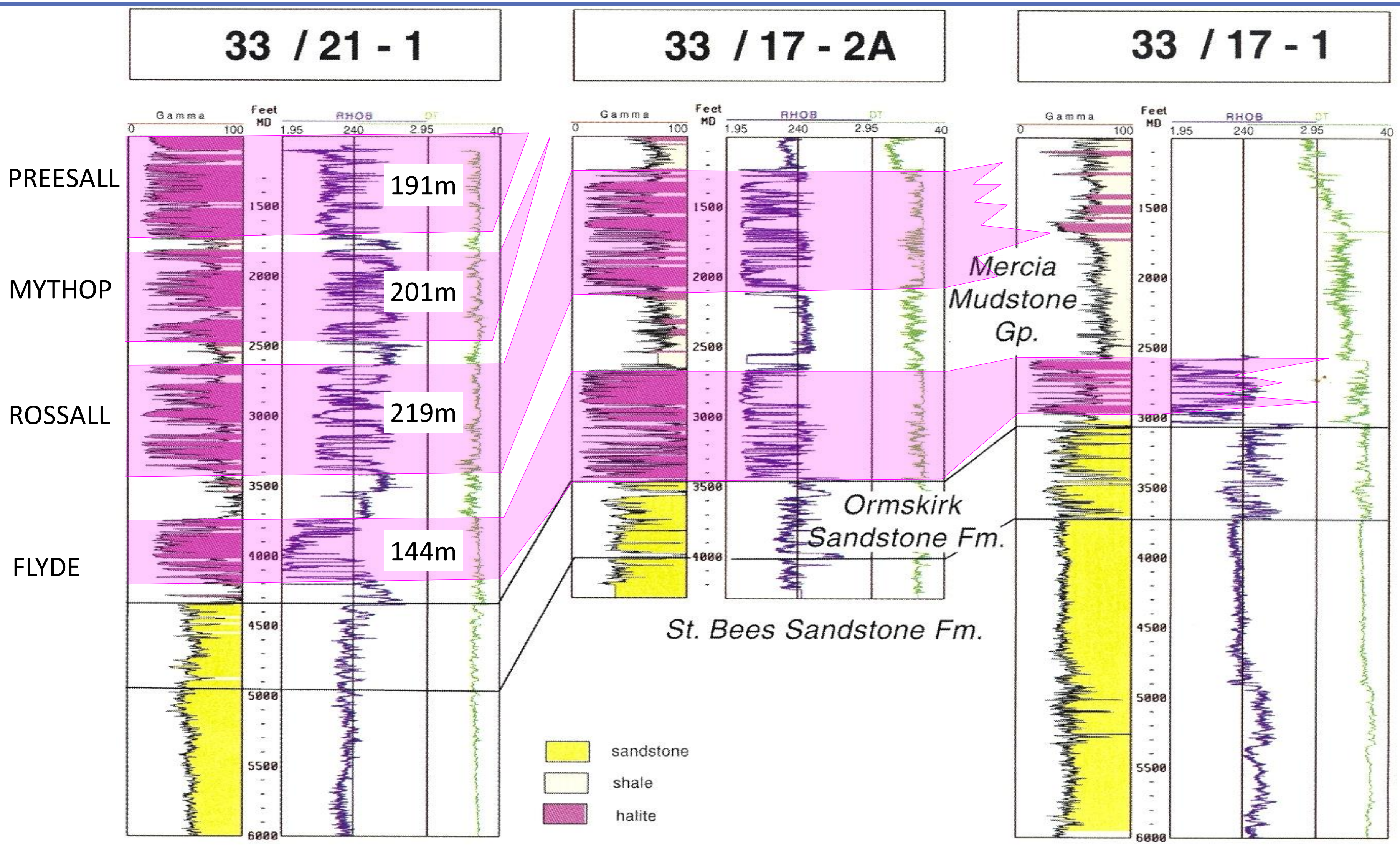
All-Energy 2023

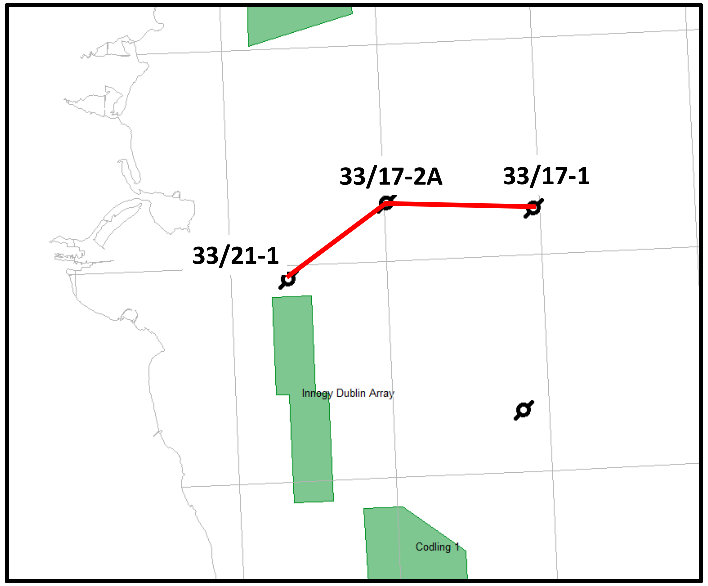
10th May 2023

Known Halite in existing wells



Known Halite in Kish Bank

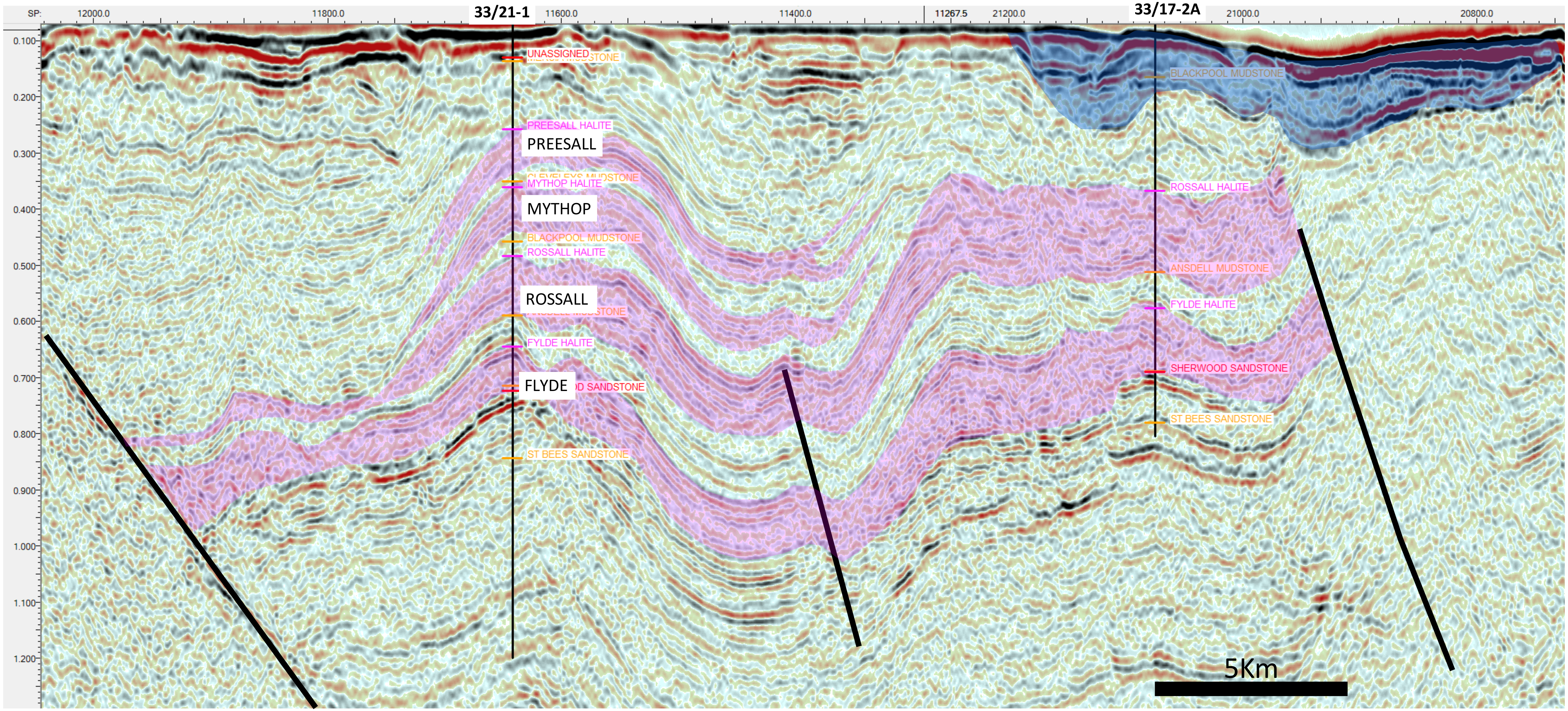




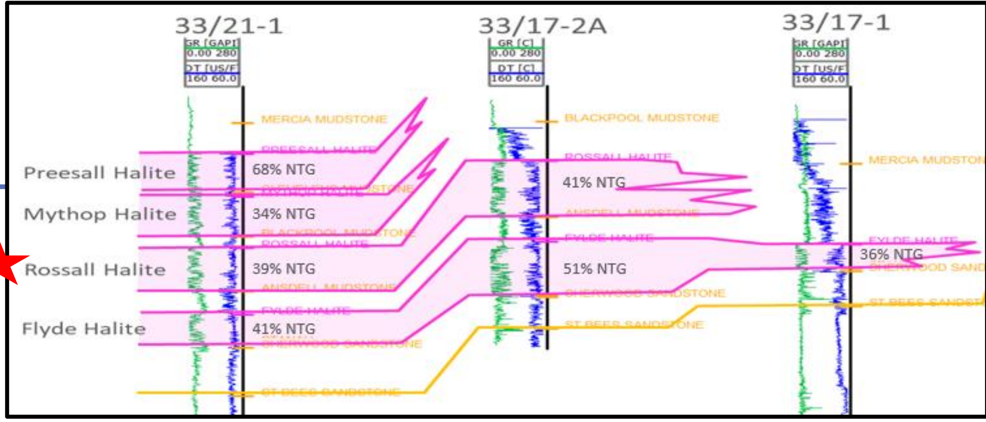
* Note saline aquifers in yellow

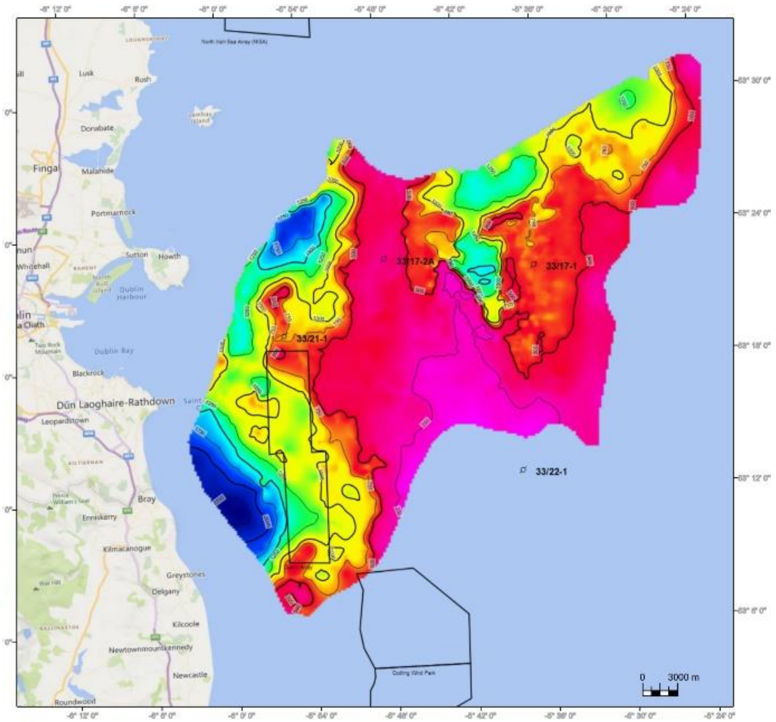
Dunford *et. al*, 2001

Seismic data showing halite thickness

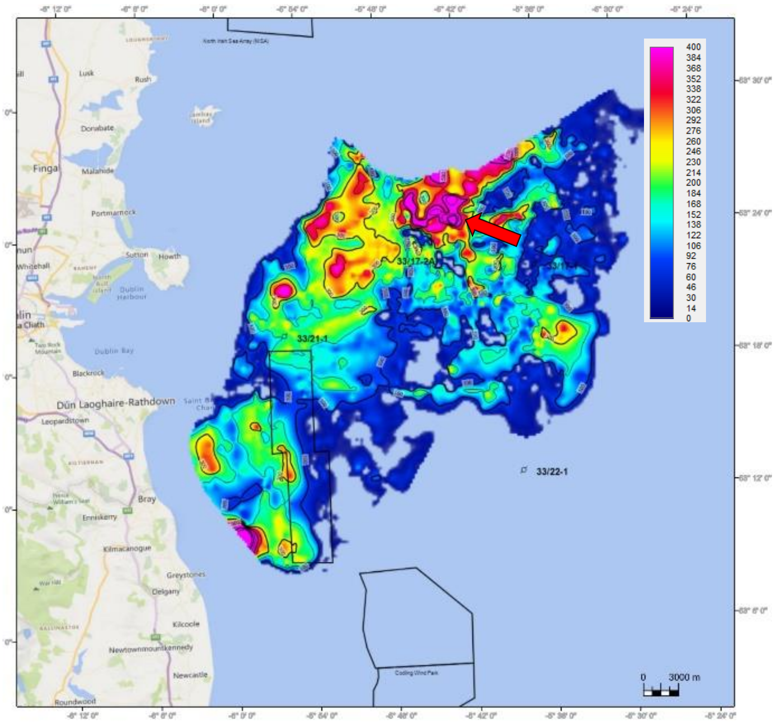


Rossall Halite



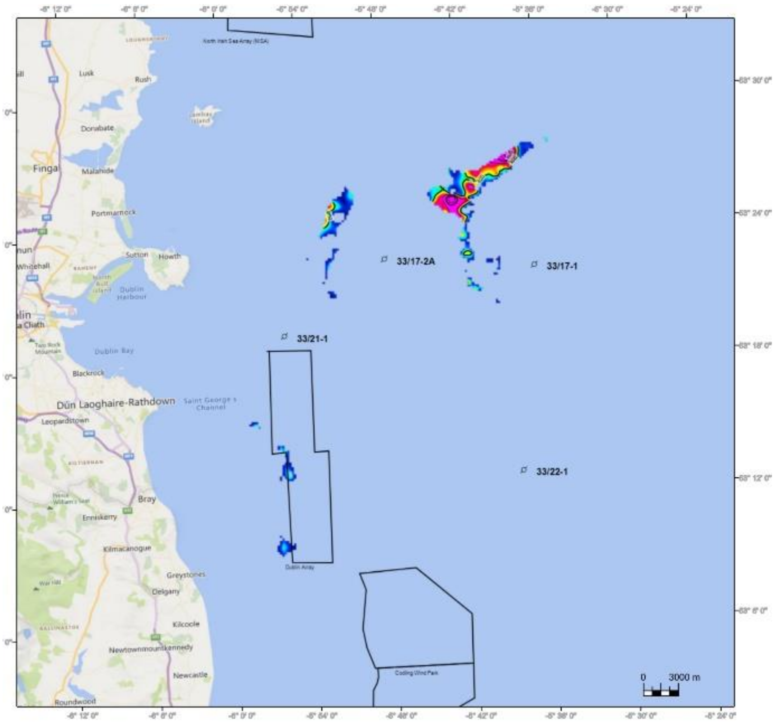


Depth



Thickness

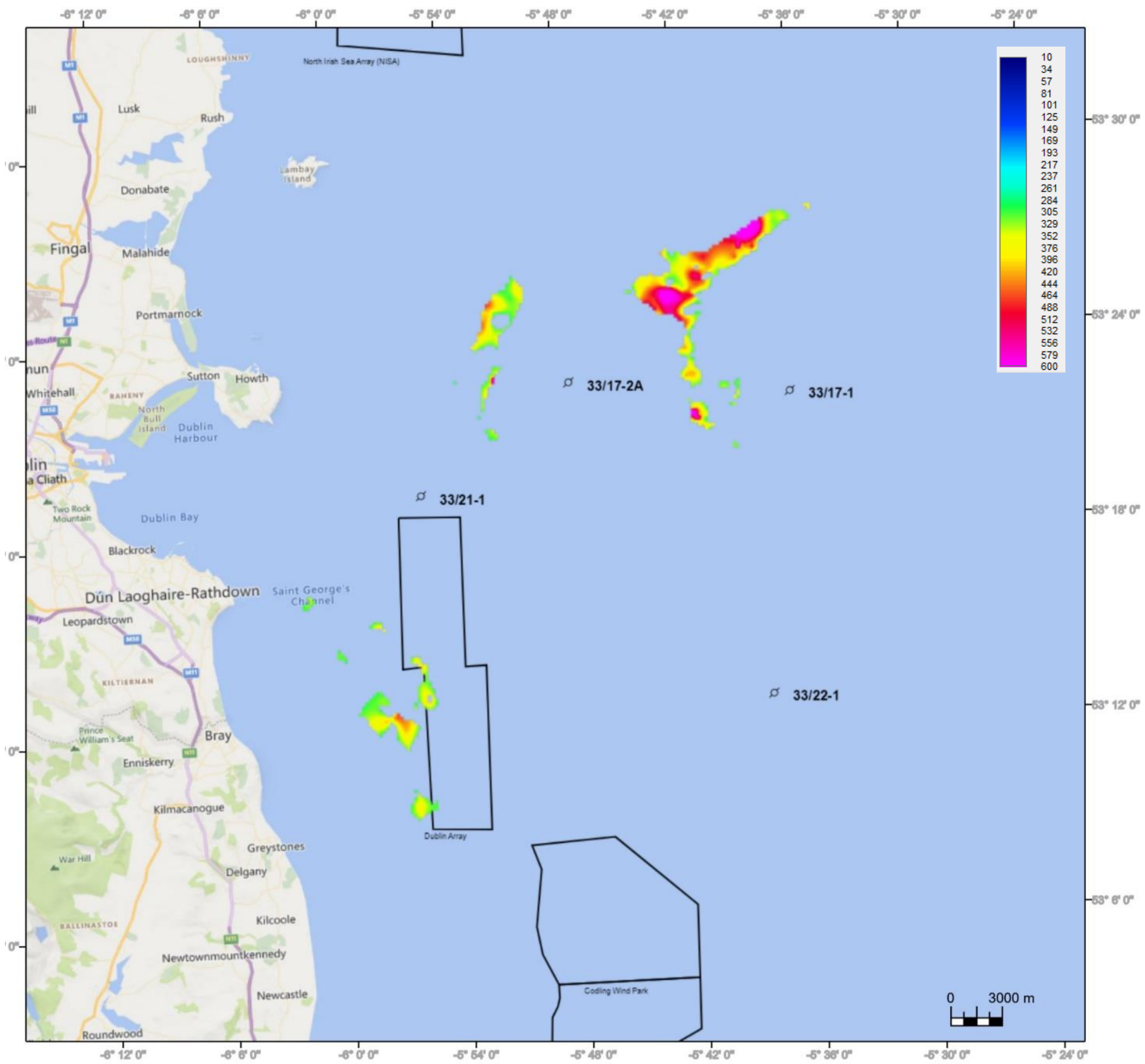
Halokinesis evident, no halite in 33/17-1, remobilised to NW, see red arrow.



Thickness within AOI

1 to 1.5km & >300m thick

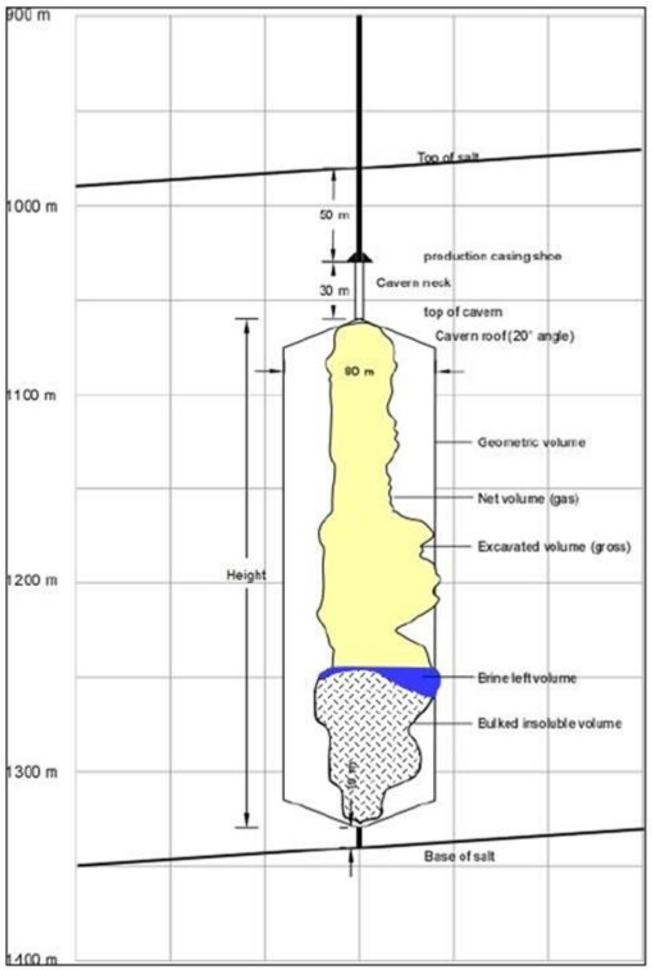
Cavern Potential Locations



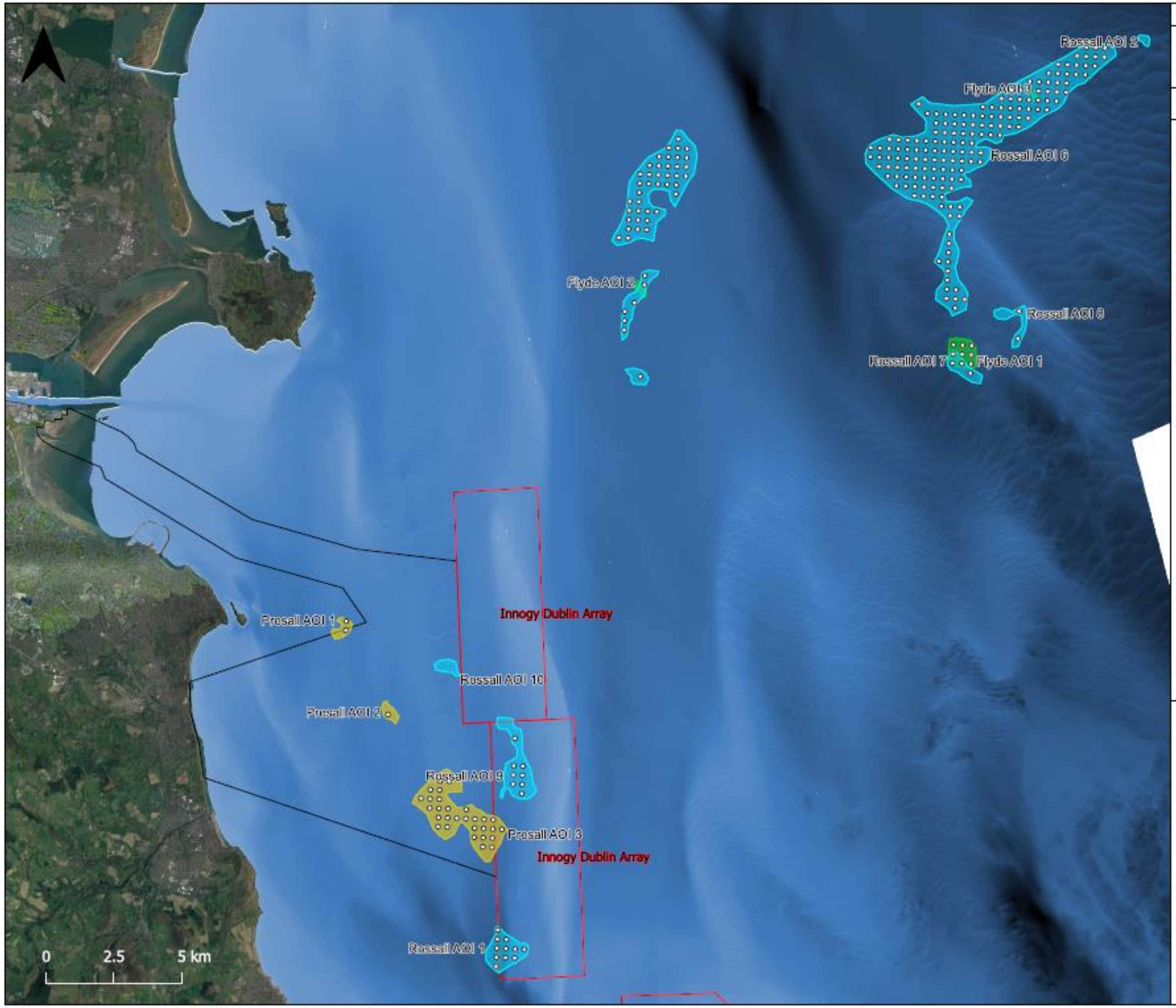
Areas with colours have >300m of salt, at a depth of 1000m to 1500m.

We estimate that 300m gross halite interval will yield ~200m of net halite, suitable for a 120m high potential cavern development.

With each potential cavern of 85m diameter, with a 330m standoff between caverns, we estimate a first pass potential of >200 caverns.



Cavern Geometry. Source: Hystories



NOTES

1. Ordnance Survey Ireland Licence no. CYAL50167032
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2. Base Mapping Google Satellite
3. INFOMAR 10m Bathymetry data

LEGEND

Salt Caverns within Areas of Interest
Flyde Halite Area of Interest (AOI)
Presall Halite Area of Interest (AOI)
Rossall Halite Area of Interest (AOI)

Dublin Offshore Wind Farms

Innogy Dublin Array

Innogy Dublin Array
Dublin Array Cable

Codling Wind Park

Codling Wind Park

Area of Interest	Number of Caverns
Flyde AOI 1	8
Flyde AOI 2	0
Flyde AOI 3	0
Presal AOI 1	2
Presal AOI 2	1
Presal AOI 3	29
Rossall AOI 1	11
Rossall AOI 2	0
Rossall AOI 3	40
Rossall AOI 4	6
Rossall AOI 5	1
Rossall AOI 6	159
Rossall AOI 7	4
Rossall AOI 8	2
Rossall AOI 9	8
Rossall AOI 10	0
Total	**271**

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SEAI
Hydrogen Salt Storage Assessment (HYSS)

DUBLIN BAY

Presall Halite Locations

FIGURE 3

Scale	Date
1:22000 @ A3	February 2023

Map of Halite areas with >300m of halite interval, at a depth of 1,000m to 1,500m showing number of salt caverns in each zone of interest.

In the zone of interest A09, which lies beneath the offshore wind licence area for the Dublin Array, 8 standard size salt caverns can be developed for hydrogen storage.

This is equivalent to approximately 1.0 TWhH2.

Conclusion and Questions?

- Energy storage enables supply/demand management
- Salt cavern storage of compressed gas is a proven, safe, mature and financeable storage technology successfully used for hydrogen storage since 1972
- The oil and gas sector has the data, skills, and expertise to identify and deliver salt cavern storage

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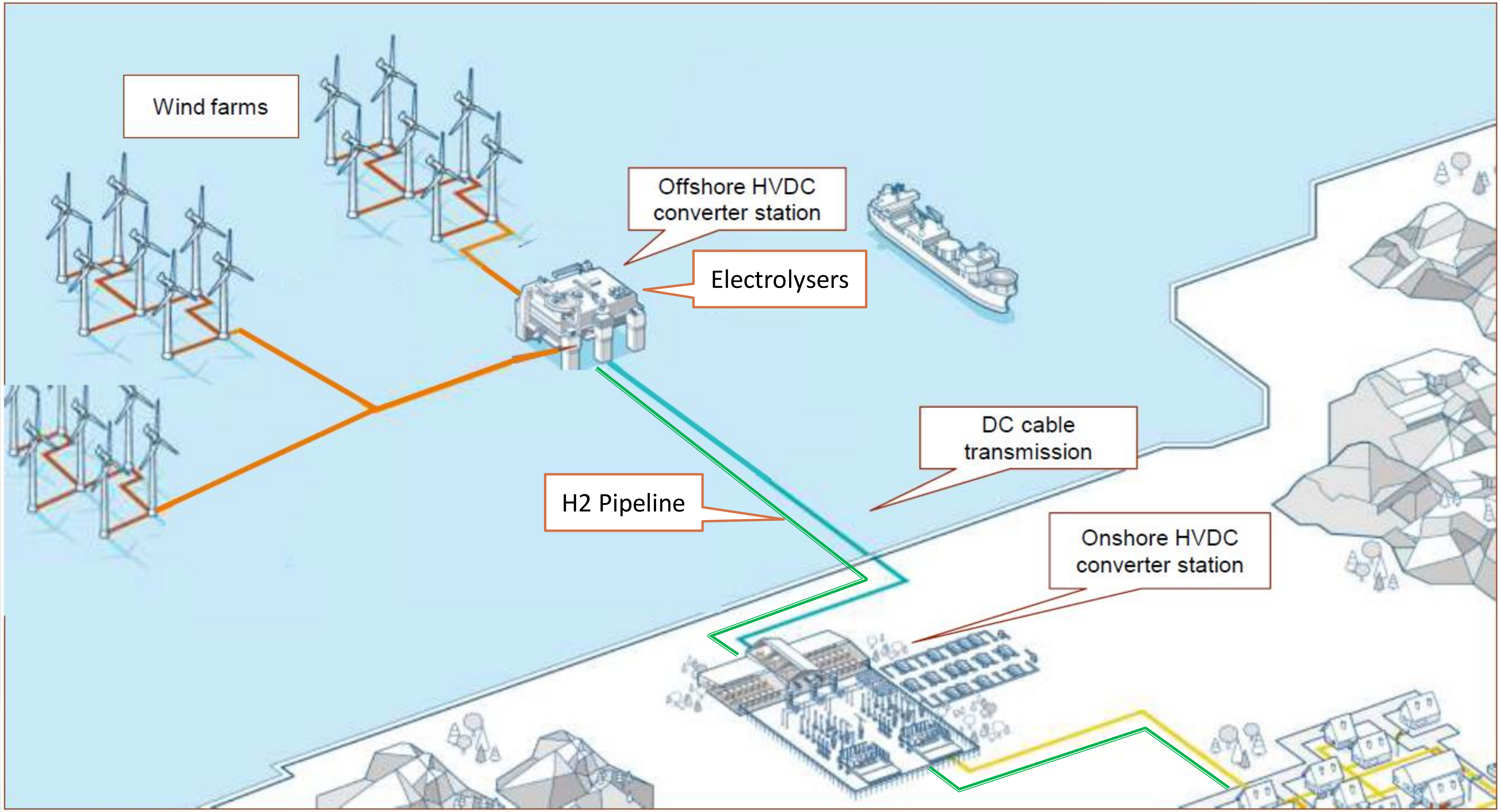
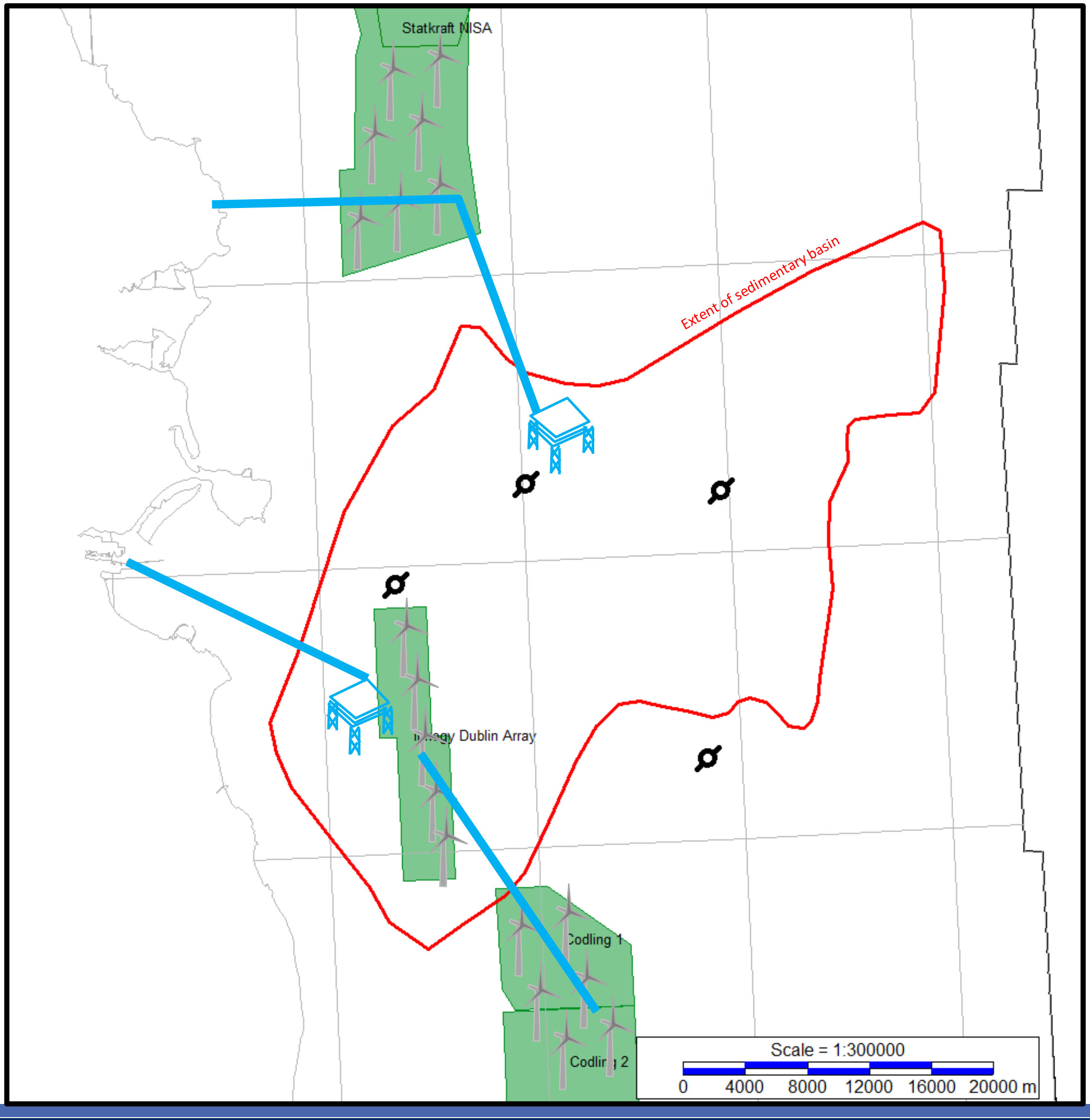
Green Hydrogen Model



Courtesy: ABB Power Systems, Nov 2016; Modified.

Kish Bank focus area & proposed ORE



Offshore Wind

Electricity Supply

Hydrogen Storage

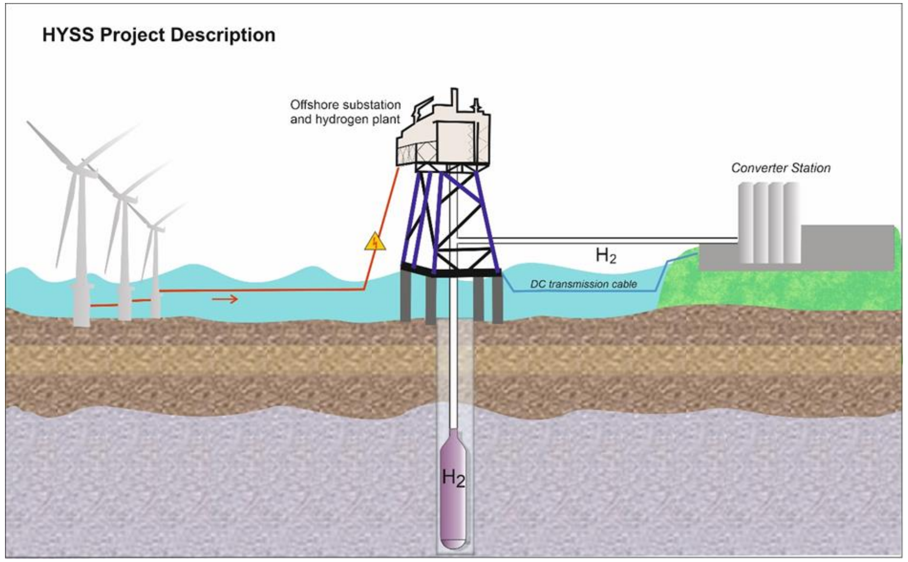
Power Generation

Transport

Dublin Port HGV Hydrogen?

Dublin Airport Hydrogen?

Figure 3 Hydrogen Production Platform. Source Poshydon



Stage 1 Construction of Offshore Wind Farm

- seabed foundations
- turbine installation
- offshore substations
- inter turbine array cables
- export DC cable to shore
- onshore substation

Stage 2 Geological Site Characterisation of Subsea Salt Cavern

- 3D seismic survey acquisition
- 3D processing & interpretation
- drill appraisal well
- data analysis & interpretation
- salt cavern modelling

Stage 3 Cavern Solution Mining and Installation of Hydrogen Plant Offshore Platform

- re-enter appraisal well
- cavern solution mining
- completion of production well
- installation of hydrogen production platform
- export hydrogen pipeline to shore

Figure 5 Kish Basin Offshore Green Hydrogen Production Facility Construction

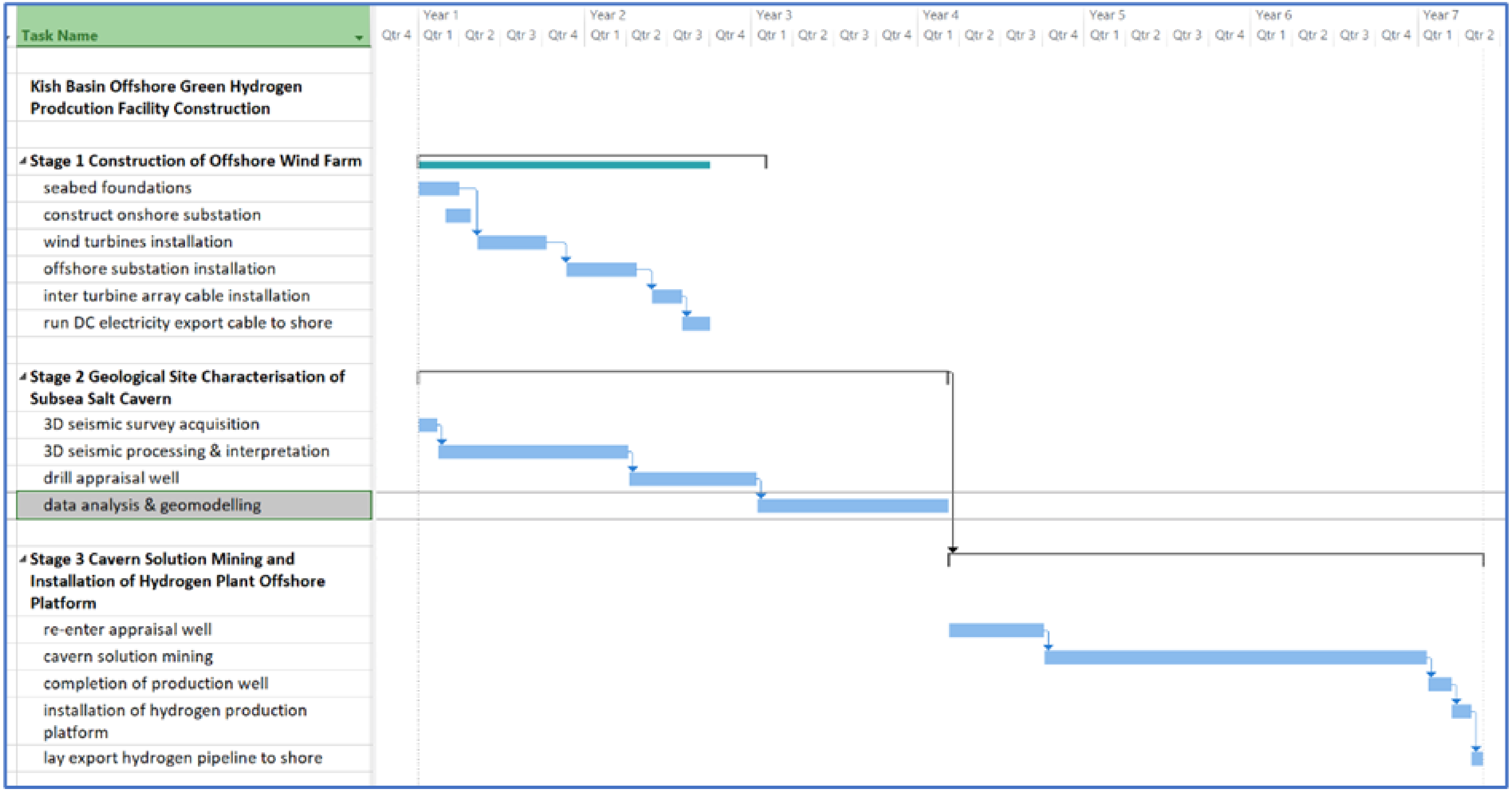
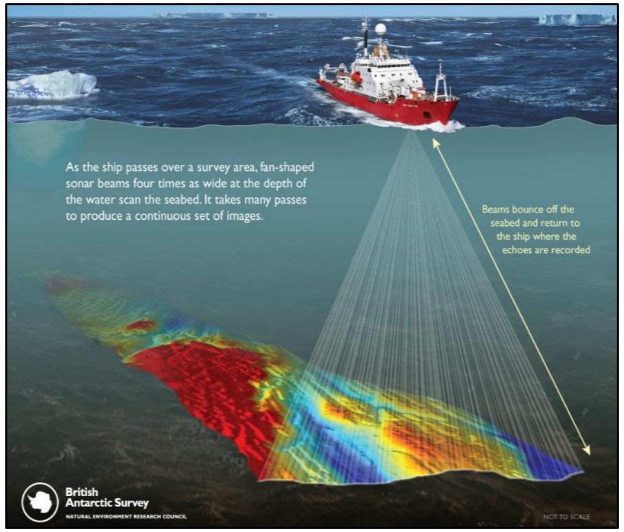
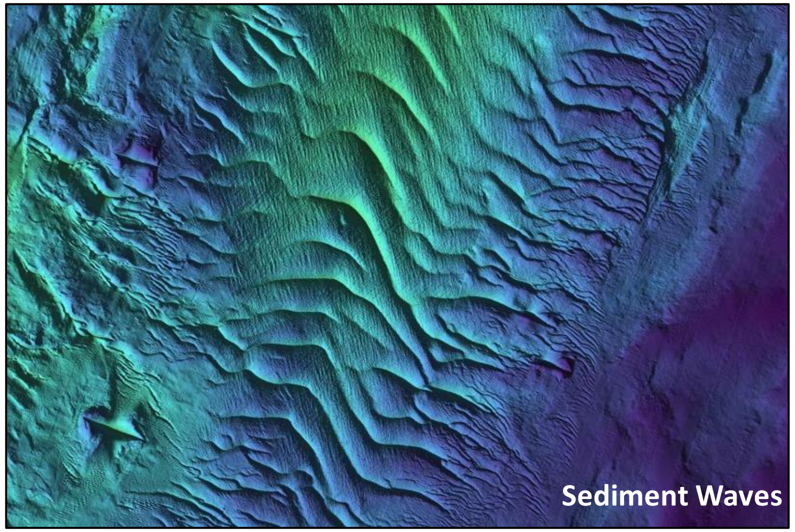
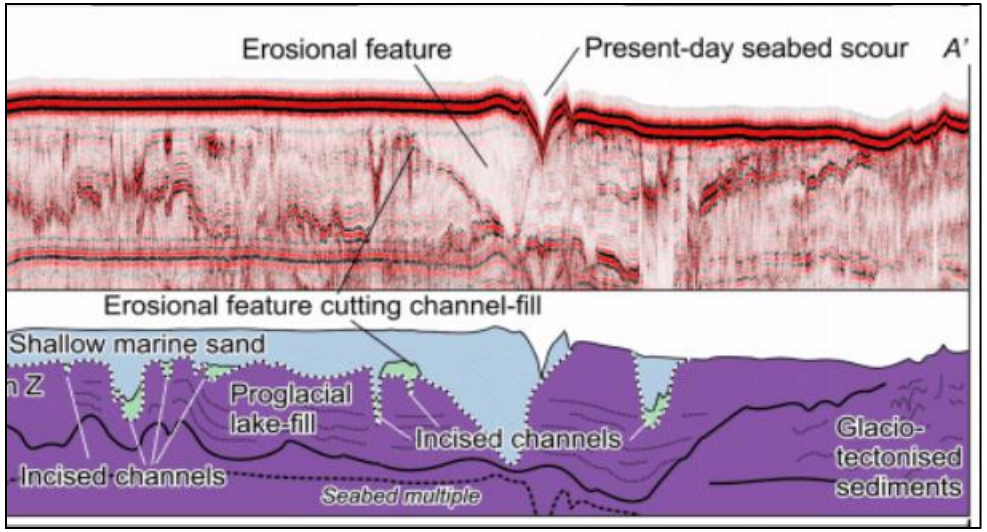


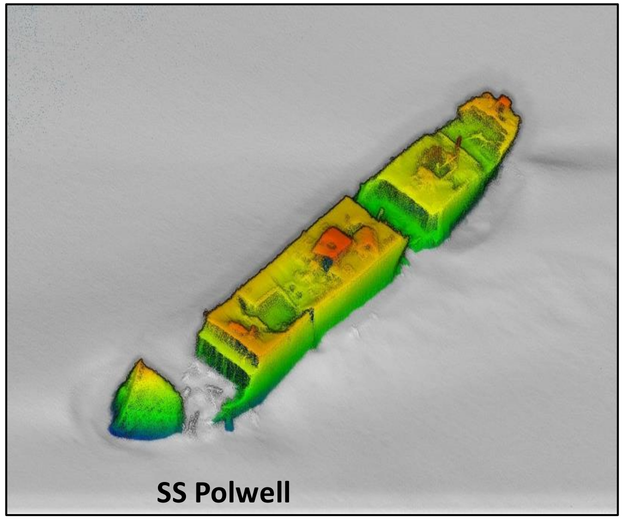
Figure 6 Kish Basin Offshore Green Hydrogen Production Facility Construction Timeline

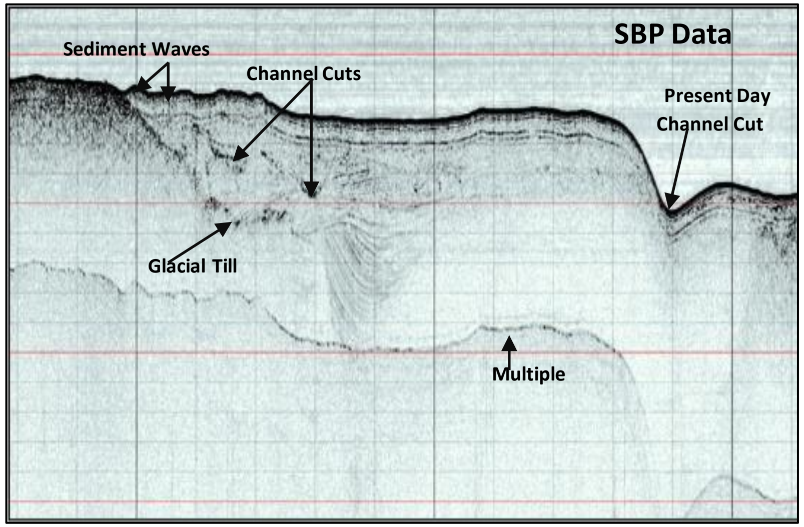
Phase 1: Integrating Geo Datasets





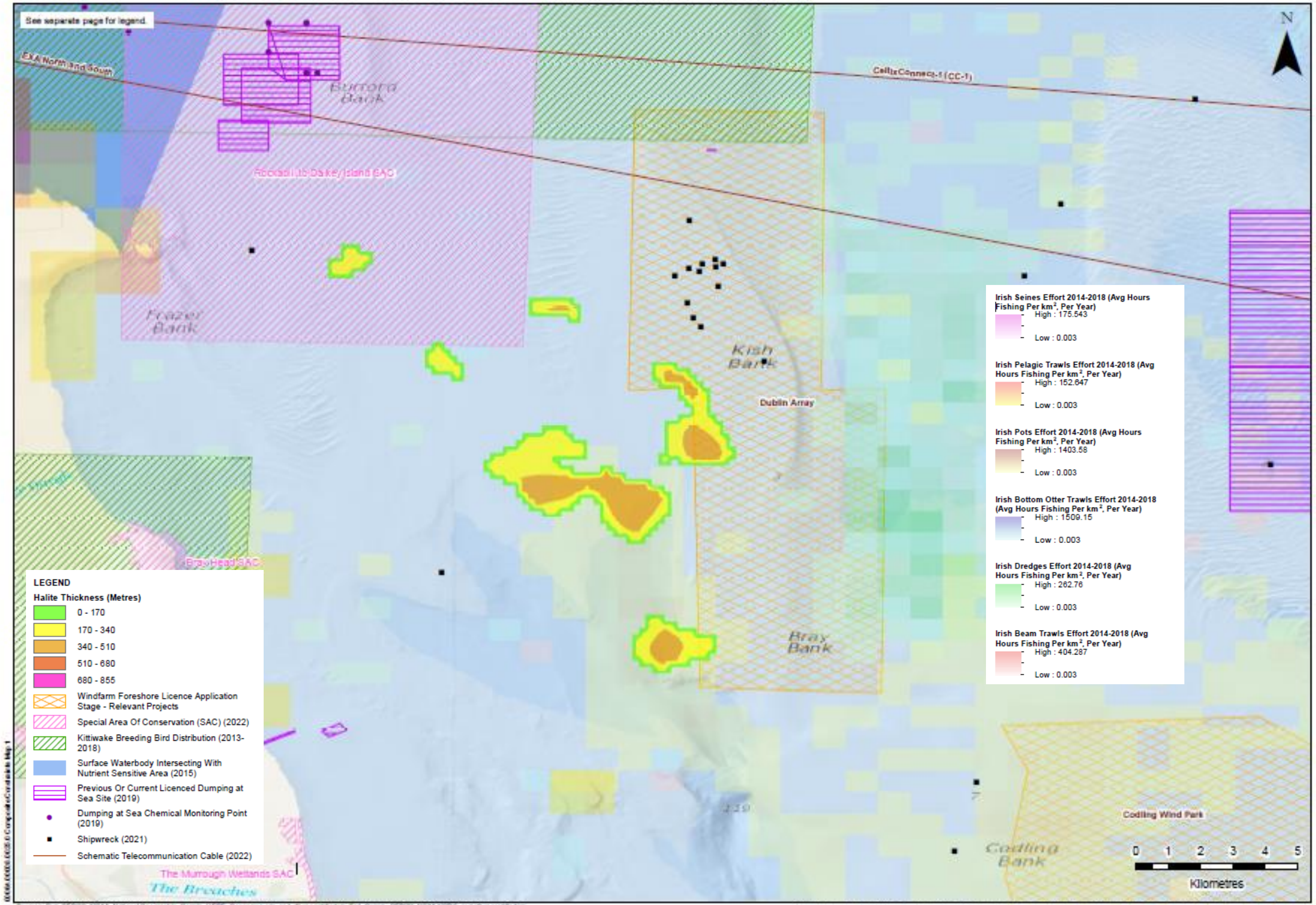






- The primary acoustic devices used by the INFOMAR programme are Multibeam Echosounder (MBES), Singlebeam Echosounder (SBES), Shallow Seismic / Sub Bottom Profiler (SBP), and Side Scan Sonar (SSS).
- The bathymetric data is a dataset that has being acquired and processed is to international hydrographic standards. It produces high quality digital maps that are easily accessible through the INFOMAR data portal.
- The SBP/HRSS are the most valuable geophysical datasets when constructing an accurate ground model particularly for offshore fixed bottom installations and cabling onshore. Data acquisition gaps should be considered, as there are areas where data still needs to be acquired as part of programme strategy to end 2026.

Constraints Map 1 – Fishing, Shipwrecks, SAC, Birds, Dumping at Sea, Telecommunications



Activity		Output	Impacts			Mitigation	
Nature	Duration	Type	Nature	Importance	Type	P/Y/N	Description
Re-enter appraisal well to enable installation of a leaching completion to create the salt cavern	Estimated 10 days using jack up drilling rig	This is an extension of the drilling operation with the same outputs as above – oil spill, engine & solid waste emissions, noise & habitat disturbance	Marine & air pollution, disruption to shipping & fishing operations, impact on biological environment	L-M	D,C	Y	As above for drilling operation
Cavern solution mining dissolves the naturally occurring salt formation using nitrogen gas as a blanket to prevent dissolution in the salt cavern roof	Estimated 2.5 years using jack up drilling rig	Impacts on water quality due to produced brine	Marine pollution, impacts on biological environment & wild life & fisheries	H	D,C	P	Dilute brine with seawater before disposal; disperse brine where currents are strongest;
		Oil spill	Marine Pollution	L	D,C	Y	Oil spill contingency plan in place, Probability of a major accidental spill of hydrocarbons during the exploration drilling is very low therefore little chance of transboundary and cumulative effects.
		Engine emissions	Air pollution	L	D,C	Y	Regular maintenance
		Physical presence	Disruption to fishing/shipping operations	M	D,C	Y	Notifications of operational schedule
		Impacts on water quality due to solid waste	Marine pollution	L	D	Y	Shore disposal at port No Impacts
		Habitat disturbance, pollution, displacement	Marine, air, noise pollution impact on Wild life	L	D,I,C	Y	Implementation of management procedures to ensure environmental controls are operating effectively and efficiently
		Noise	Impacts to Biological Environment	L	D,C	Y	The potential sound impacts from drilling operation are considered to be minimal and will not contribute to cumulative effects.
Completion of production wells	Estimated 10 days per well using jack up drilling rig	This is an extension of the drilling operation with the same outputs as above –oil spill, engine & solid waste emissions, noise & habitat disturbance	Marine & air pollution, disruption to shipping & fishing operations, impact on biological environment	L-M	D, C		As above for drilling operation
Installation of offshore substation and hydrogen production platform	Estimated three months using heavy lift barge to install steel jacket platform	Physical presence	Disruption to shipping & fishing operations,	L-M	D, C	Y	
		Oil spill	Marine pollution	L	D, C	Y	Oil spill contingency plan in place
		Engine & solid waste emissions,	Marine pollution	L	D, C		Regular maintenance and waste disposal to shore
		Noise – pile driving	Impact on cetaceans	H	D	Y	Soft starts, acoustic buffers/screens
		Seabed disturbance	Habitat disturbance	L			Enhanced marine habitat on artificial reef
Lay export hydrogen pipeline to shore	Using pipe laying barge	Physical presence	Disruption to shipping & fishing operations,	L-M	D, C	Y	Notifications of operational schedule
		Seabed disturbance	Impact on marine areas of conservation	L-M	D, C	P	Adjust operational schedule to minimise impact
		Habitat disturbance	SPA, SAC, Annex IV	L-M	D, C	P	Adjust operational schedule to minimise impact
Beneficial impacts							
Substation & H2 production platform	20 years	Physical presence	Impact on marine life	M	D, C		Enhanced marine life habitats due to artificial reef affect

Table 4 Stage 3 Environmental impact of Cavern Solution Mining and Installation of Hydrogen Plant Offshore Platform

Theoretical hydrogen storage potential

Temperature (K)	Overburden Pressure	*Compressibility Factor*	Gas Density (ρ_{H2})	*ρ_{H2} maximum*	*ρ_{H2} minimum*	Mass of Working Gas (kg) (m)	Cavern Capacity (GWh_{H2})
Temperature (T) = 288+0.025(depth-cavern height/2)	Overburden (P) = rock density (ρ) x Gravity (g) x (depth - cavern height)		(ρ_{H2}) = pressure (P) x molar mass (M) / compressability factor (Z) x universal gas constant (R) x temperature (T)	*(ρ_{H2}) = pressure (80% of overburden) x molar mass (M) / compressability factor (Z) x universal gas constant (R) x temperature (T)*	*(ρ_{H2}) = pressure (24% of overburden) x molar mass (M) / compressability factor (Z) x universal gas constant (R) x temperature (T)*	m = (ρ_{H2} max - ρ_{H2} min) x cavern volume (V) x safety factor (0)	working gas (m) x lower heating value of gas (LHV)
K	Pa	Z	kg m^{-3}	kg m^{-3}	kg m^{-3}	kg	GWh_{H2}
316.5	23308560	*1.05(estimate)*	17.852	13.541	4.101	4394270.85	146.418

Table 1: Calculation of cavern storage capacity Source: Caglayan et al 2020

Modelling cavern volumes	*Estimation of hydrogen storage volumes*				*Caglayan*		*Energy Storage Capacity*				
Volume available for storage	Temperature (Midpoint)	Lithostatic Pressure	Max Op Pressure	Min Op Pressure	ρ_{H2Max}	ρ_{H2Min}	Equation of State	Max H2 Density	Min H2 Density	Mass of Working Gas	Energy Storage Capacity (GWh_{H2})
V_{cav} = SCF x (1 - IF x INSF x BF) x V_{Bulk}	$T_{Midpoint} = T_0 + \blacktriangle_T$ x (Z_{Casing} + 0.5 x H_{Cavern})	P_{Casing} = ($\rho_{Overburden}$ x $t_{Overburden}$ + ρ_{Salt} x t_{Salt}) x g	$P_{MaxOperating}$ = 0.8 x P_{Casing}	$P_{MinOperating}$ = 0.3 x P_{Casing}	*(ρ_{H2}) = pressure (80% of overburden) x molar mass (M) / compressability factor (Z) x universal gas constant (R) x temperature (T)*	*(ρ_{H2}) = pressure (24% of overburden) x molar mass (M) / compressability factor (Z) x universal gas constant (R) x temperature (T)*	Williams uses equation of state from Bells et al. to calculate ph2 Max and Min	$m_{MaxOperating} = \rho_{H2Max}$ x V_{Cavern}	$m_{MinOperating} = \rho_{H2Min}$ x V_{Cavern}	$m_{Working} = m_{MaxOperating} - m_{MinOperating}$	E = $m_{Working}$ x (LHV/3,600,000)
m^3	K	Pa	Pa	Pa	kg m^{-3}	kg m^{-3}				kg	GWh_{H2}
318530.01	314.65	26977500	21582000	8093250	16	6		5045234	1891963	3153272	105.074

Table 2: Calculation of cavern storage capacity Source: Williams et al 2020

- The calculations of cavern storage capacity were made using the methodology of Caglayan et al 2020 and Williams et al 2020.
- The extent of salt occurrence in the Kish Basin at the required depth of 1,000m and 200m thickness is such that many salt caverns could be solution mined, sufficient for seasonal hydrogen storage.
- A typical salt cavern can store between 146 GWh_{H2} and 105 GWh_{H2} of hydrogen.

FORWARD PLANS