Water Quality Computer Modelling in The Solent

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https://www.mts-cfd.com/
https://claws-scot.github.io/

MTS

- CLAWS – Chemicals for Lice and Waste from Salmon Farms.
- Motivation – give coastal communities and individual citizens access to state-of-the-science marine environmental computer models.
- Similar data to that produced by industry/SEPA/DEFRA environmental modelling.
- Allow communities to challenge developments/assumptions based on sound science.
- New suite of open-source, particle-based software tools to model:

1. Chemical treatments (Pesticides for sea lice - Compare with SEPA standards).
2. Nutrients (Flushing time, capacity to absorb organic load P, N – Langstone Harbour)
3. Solid waste - Deposition footprint of salmon farm waste - feed/faeces – impact on benthic flora/fauna. Can be any solid particulate waste.
4. Oyster larvae – The distribution in estuaries for rewilding efforts – Solent Oyster Restoration.
5. Salmon Lice – State-of-the-science biological model based on most recent scientific trends (Norwegians).
6. Plastics/Litter – Arrochar litter sink, UK coastline, includes beaching model.
7. E.coli – Sewage spills from combined sewer overflows, runoff, Fife, Edinburgh, S@S.
8. Hydrodynamics – interrogate our data to directly compare flow currents, direction, sea level etc. with industry-standard calibration and validation criteria.

- Tom is a chartered professional engineer with over 25 years' experience in applied computational mechanics.

- After a first degree in Environmental Engineering at the University of Strathclyde, Tom undertook a Ph.D in Computational Fluid Dynamics (CFD) Studies at the same university.

- Subsequently, he was awarded a JM Lessels scholarship from the Royal Society of Edinburgh for a one-year post-doctoral position at the Institute de Mécanique des Fluides de Toulouse, France in the field of numerical oceanography.

- In 2013 Tom returned from an EPSRC-funded sabbatical in the USA, where he carried out fundamental research in rarefied gas dynamics at the University of Michigan and the Lawrence Berkeley Laboratory in California.

- From 1994-2017 he was a Senior Lecturer in the Department of Mechanical and Aerospace Engineering at the University of Strathclyde specialising in environmental computer modelling. His work is reported in over 50 refereed journal and conference publications.

- He is currently a director at the engineering consultancy firm MTS-CFD.

Computer Modelling – Is it realistic?

- George Box – *"All models are **wrong**, but some are **useful**."*
- ***Wrong**? – Based on certain underlying assumptions – we cannot model every single atom deterministically.*
- ***Useful**? – Does it provide a **reasonable** interpretation of what happens in physical reality?*
- ***Reasonable**? Has your model been **validated** against physical observation?*
- *Who sets the **validation** criteria? In our case statutory bodies – SEPA.*
- *If your model produces results that lie within a range of acceptable tolerances then it may be considered as a **validated** model. If not, then it is open to challenge – not taken seriously.*
- *All of our models in CLAWS use hydrodynamics (current speeds, sea levels) that are validated against SEPA criteria.*
- *ALWAYS ask how any model has been validated and against what criteria.*
- *Take care with the adjective "accurate" – "reasonable" is better.*
- *Take care with "verification" against "validation".*
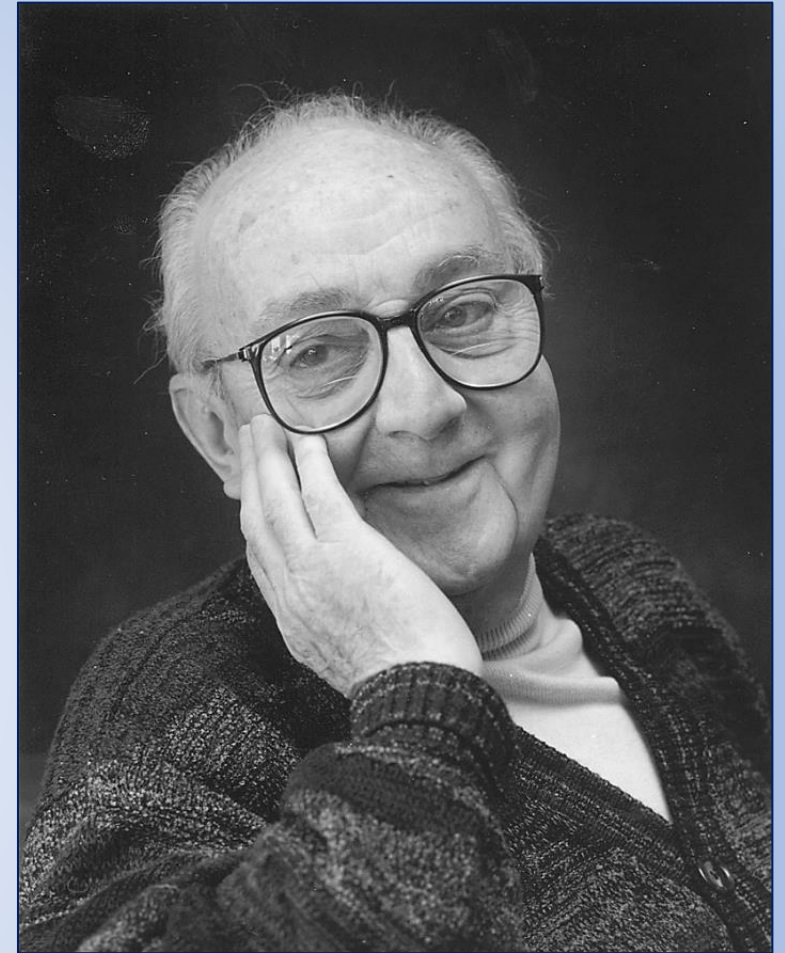
George Box, British Statistician
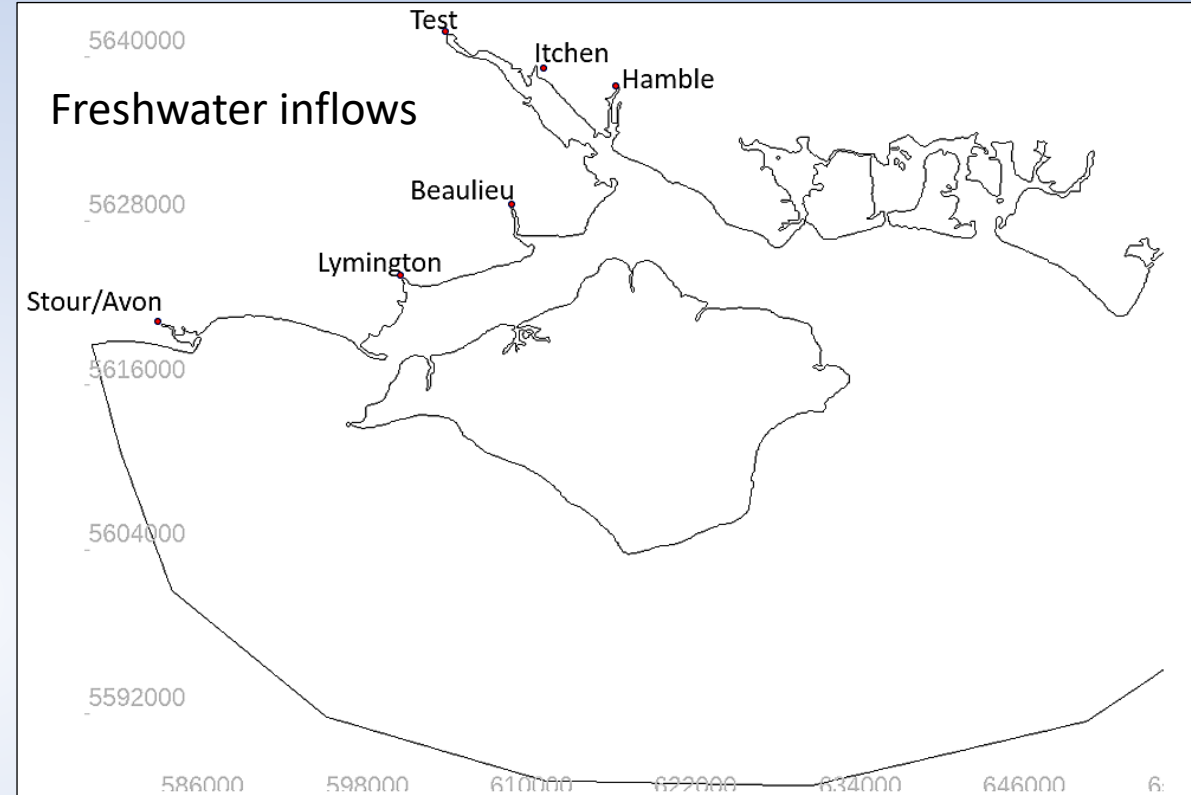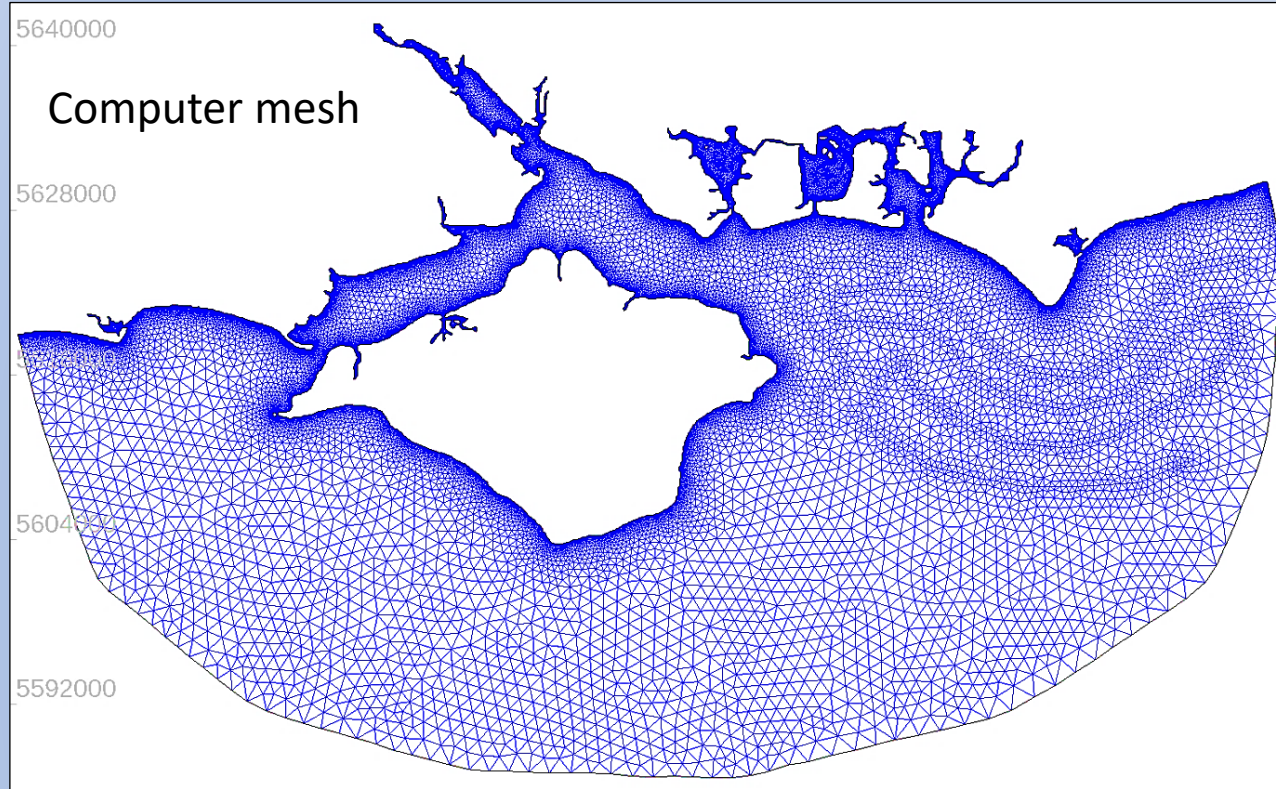*1919-2013*

1. *Hydrodynamics*

West Coast Model

- 3 main HD models – *West Coast, Firth of Clyde and Northern Isles*.
- Open source Telemac software used in 3D and 2D.
- Computational mesh – solve equations of motion at each node.
- 10 terrain-following vertical layers in 3D study.
- Water currents driven by tides, wind, Earth spin, salinity and temperature.
- 139 Freshwater inlets in West Coast model.
- Meteo wind data from ERA5.
- Models validated against SEPA calibration/validation criteria.
- Models used to drive PT code for bath treatments, nutrients, solid waste, sea lice and oyster larvae.
- HD model takes around 1-week to run on large computer (32-cores).

Firth of Clyde Model
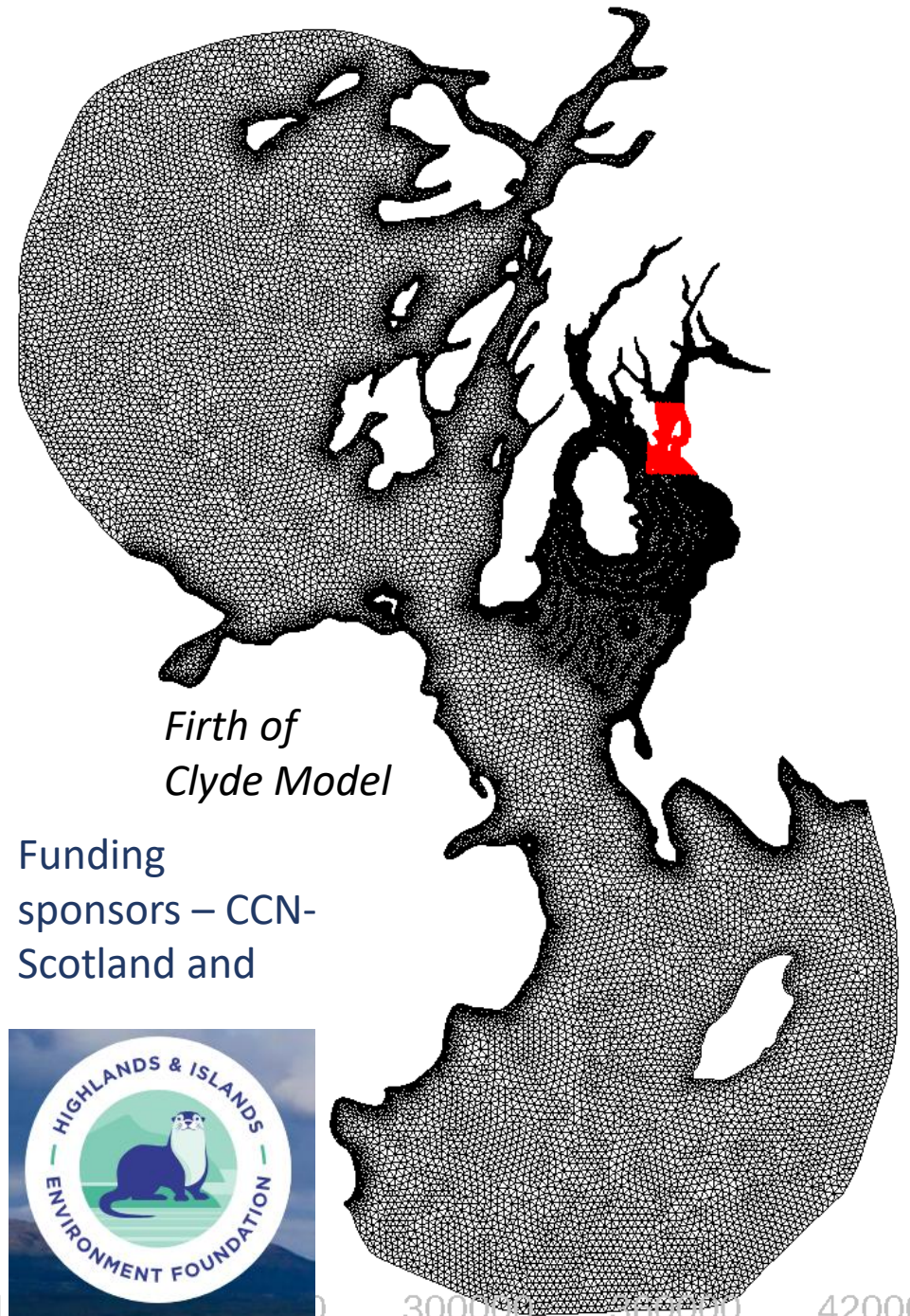
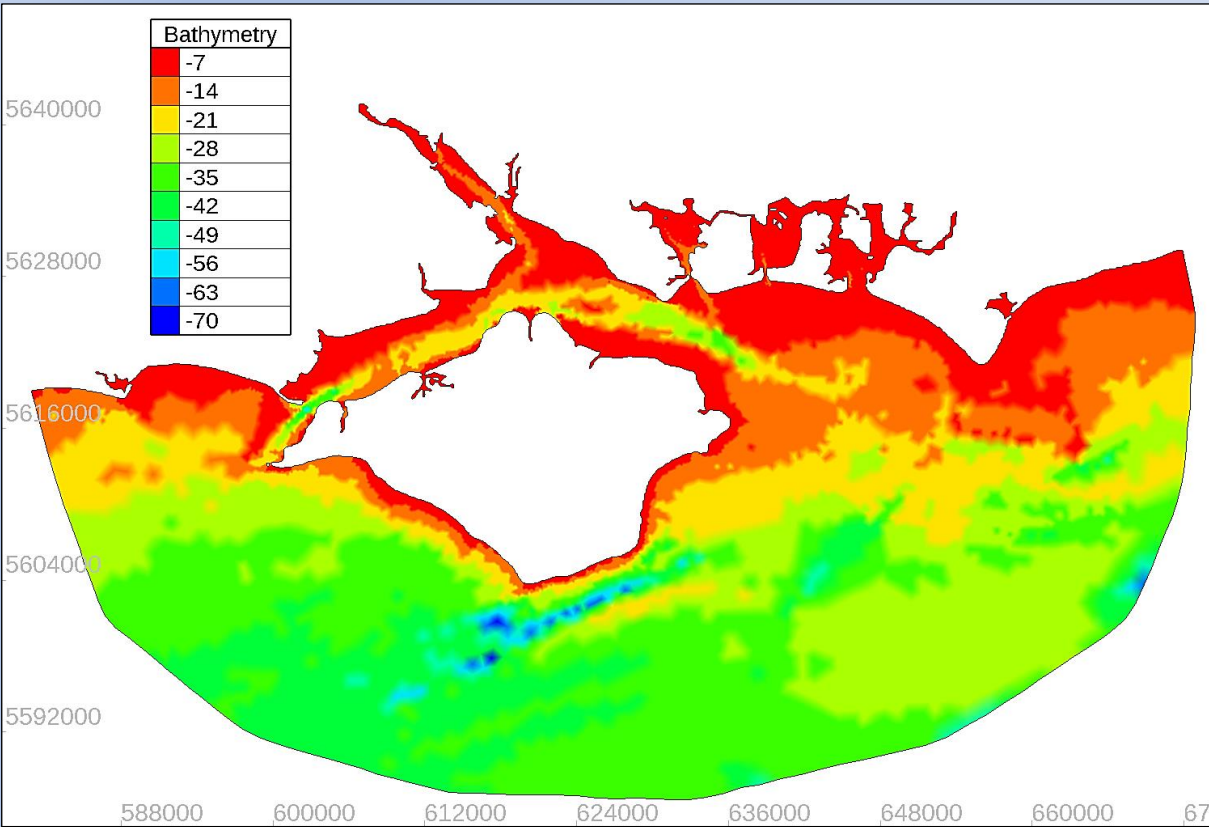Funding sponsors – CCN-Scotland and

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Computer mesh

Freshwater inflows

- Model extends from beyond Selsey Bill in the East to around Bournemouth in the West.
- Freshwater inflow data from UK National River Flow Archive (NRFA).
- Main drivers for flow currents are tides, winds, Earth spin and salinity/temperature differences.
- Model has depth (3D) with 10 terrain-following vertical layers down to sea bed.
- Sea bed bathymetry (depth) from publicly-available data sets (GEBCO, UKHO) and digitized Admiralty charts.
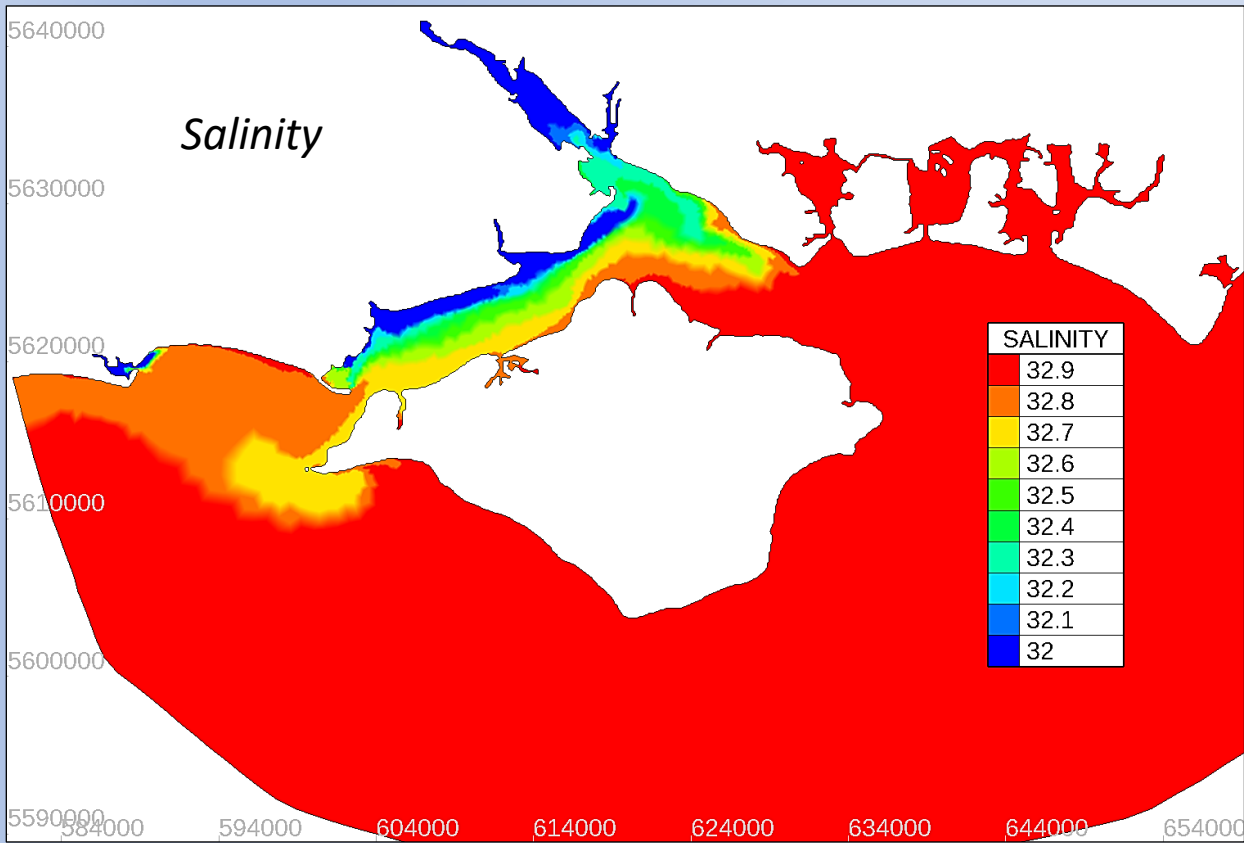
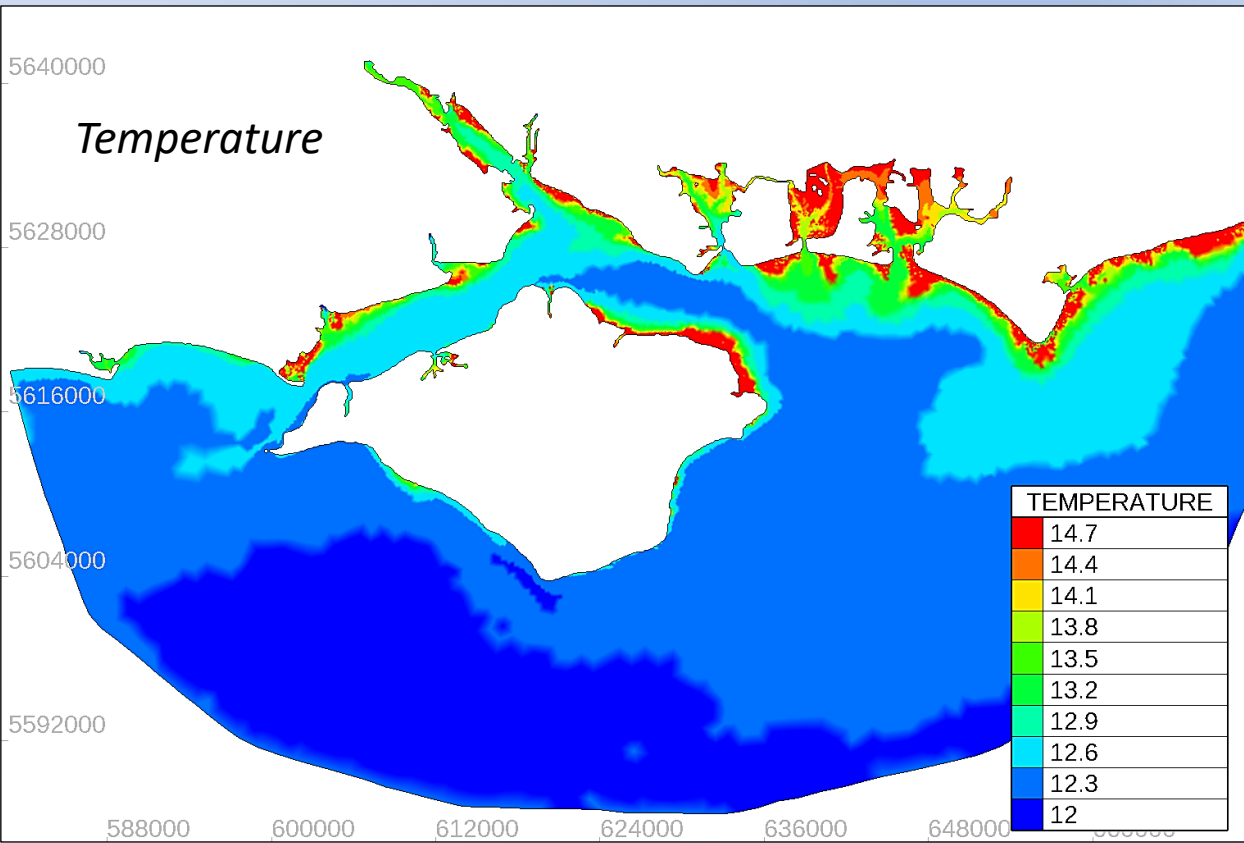*Sea bed depth (m) across The Solent model area*
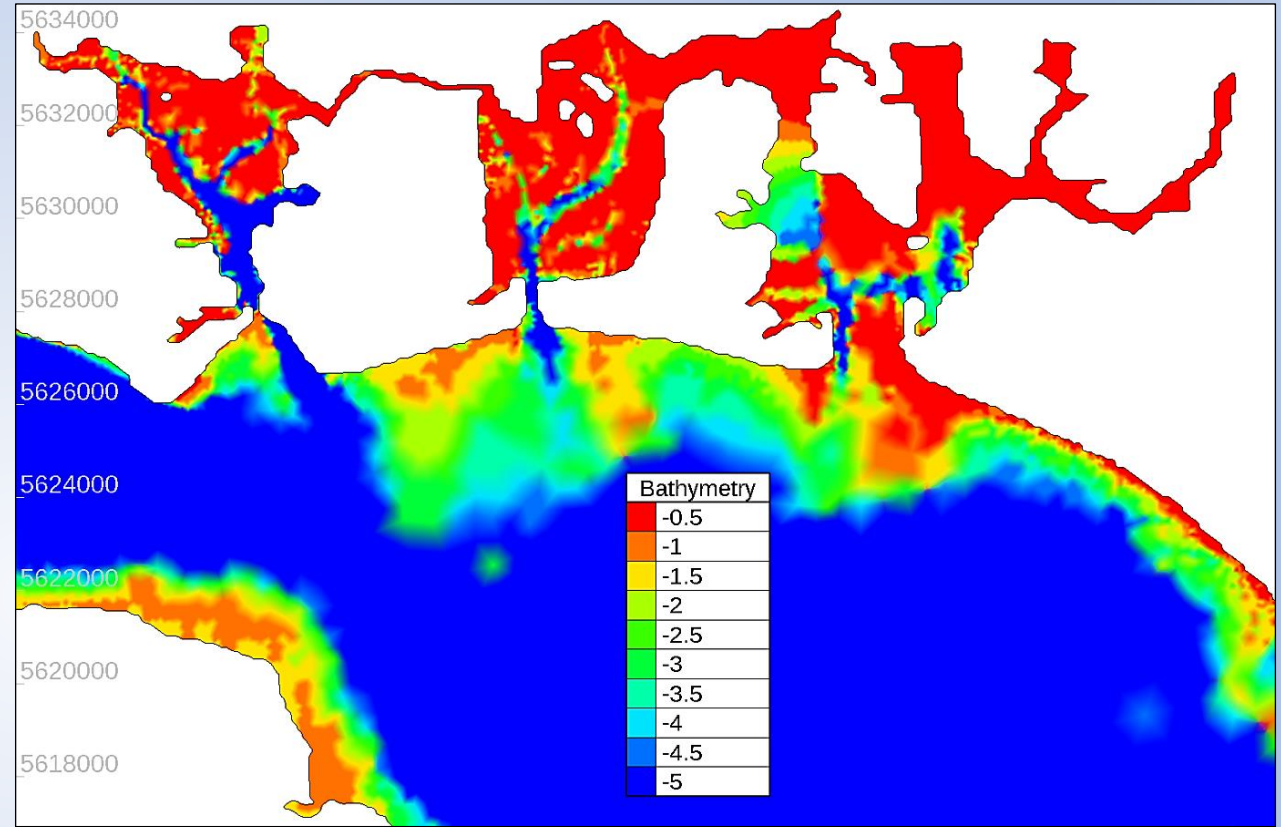
Sea bed depth (m) focused on Portsmouth, Langstone and Chichester harbours.
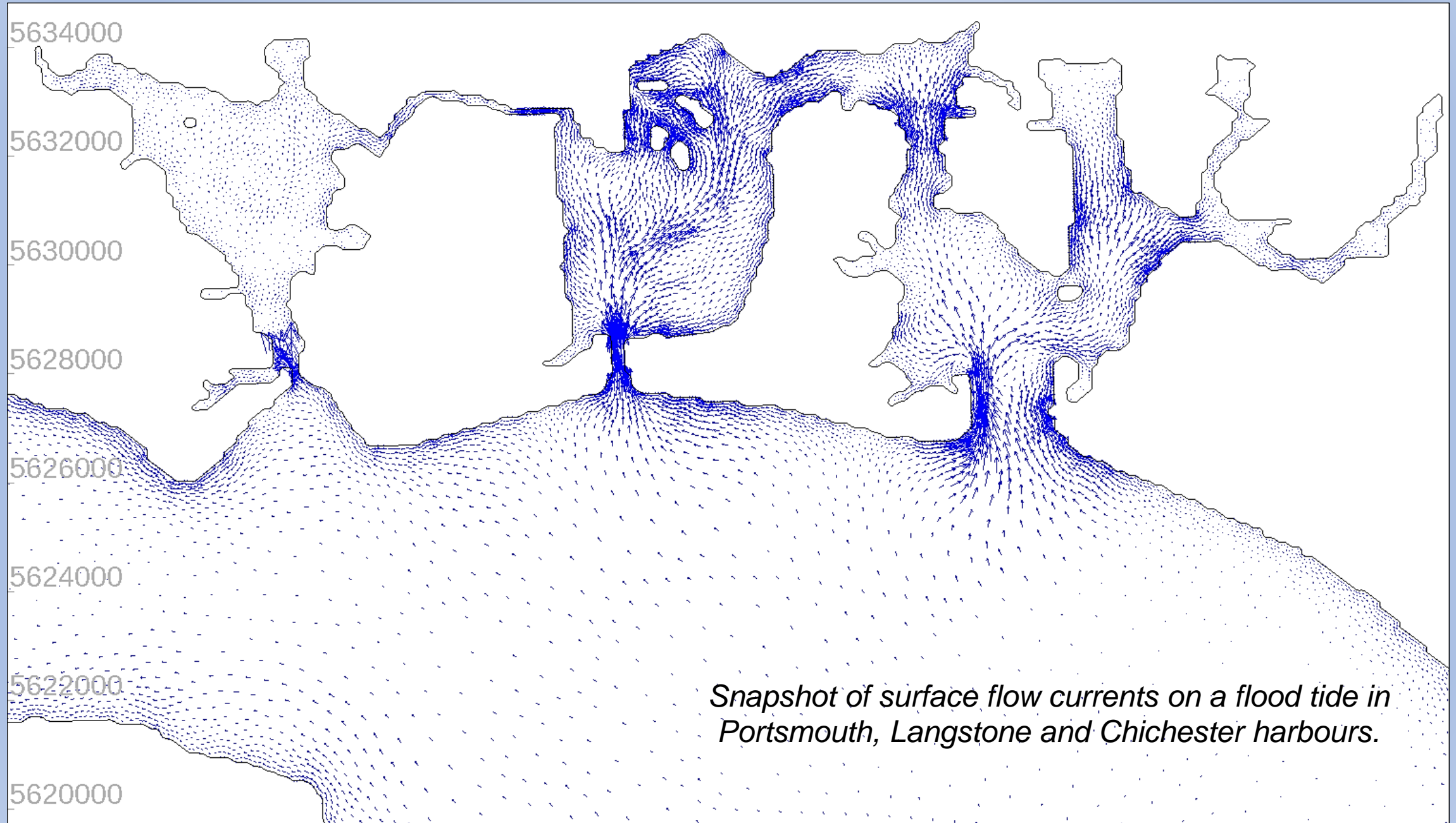
2. Solent Model Development

Snapshot of near-surface **salinity** (PSU) on the 3rd June 2023 at 7 a.m.

Snapshot of near-surface **temperature** (ºC) on the 3rd June 2023 at 7 a.m

Snapshot of surface flow currents on a flood tide in Portsmouth, Langstone and Chichester harbours.

3. Solent Model Validation

- *Is your model a reasonable interpretation of reality?*

- *Sample output of model predictions versus physical observation.*

- *Models validated successfully against SEPA validation criteria.*
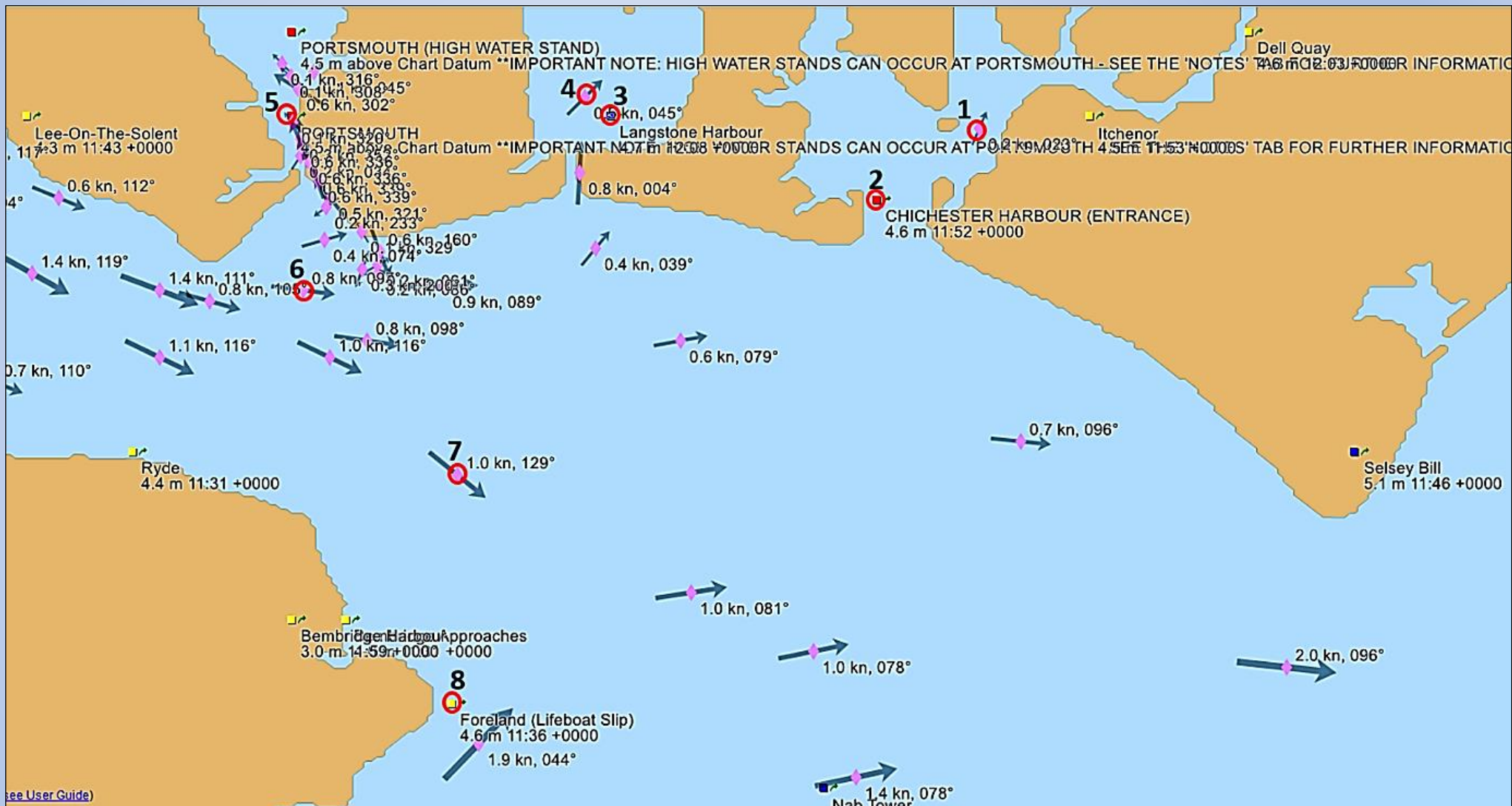
Site locations 1-8 for validation of the hydrodynamic model (red circles).
Observed data from UK Admiralty Total Tide (ATT) package.

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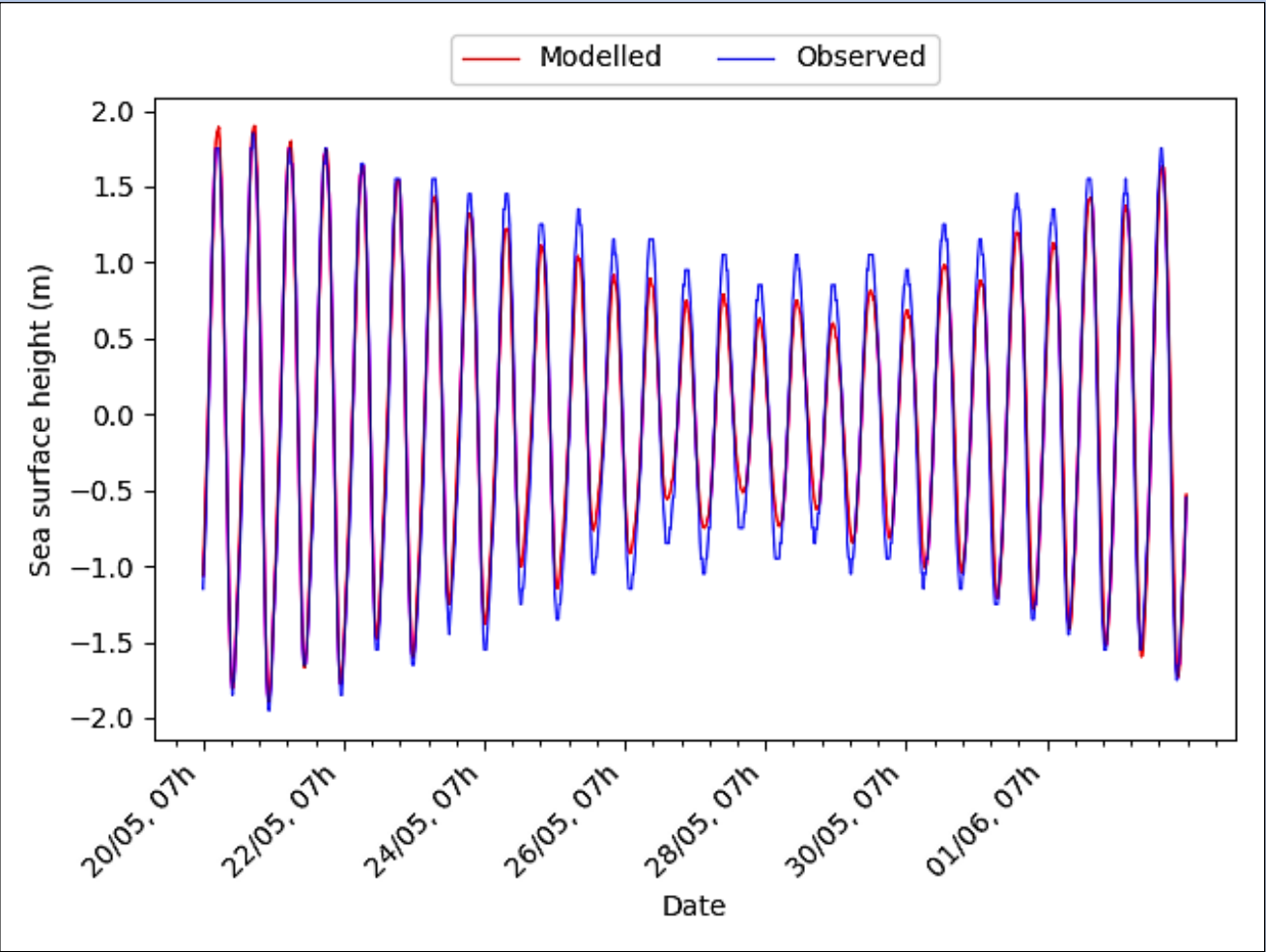
Comparison between observed and modelled sea surface level (m) at the measurement location Site 2, Chichester harbour, between 20th May and 3rd June 2023. Model skill d2 = 0.99.

|	SEPA Standard	Telemac3D	Result
SSH	+/- 10 % of Spring range (m)	4.2 %	✓
SSH	+/- 15 % of Neap range (m)	8.8 %	✓

Model performance against SEPA standards for sea surface height (SSH) at the measurement location Site 2, Chichester harbour, between 20th May and 3rd June 2023.

3. Solent Model Validation
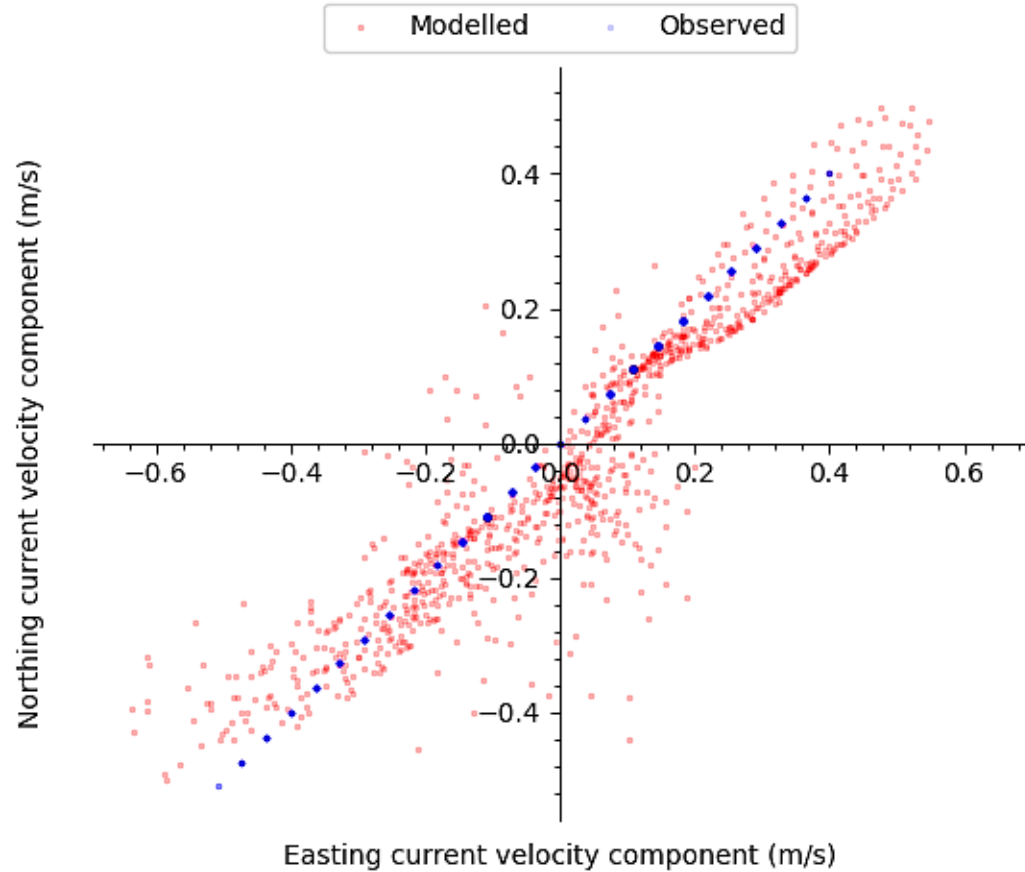
Scatter plot of observed and modelled velocity at the measurement location Site 4, Langstone harbour, between 20th May and 3rd June 2023.
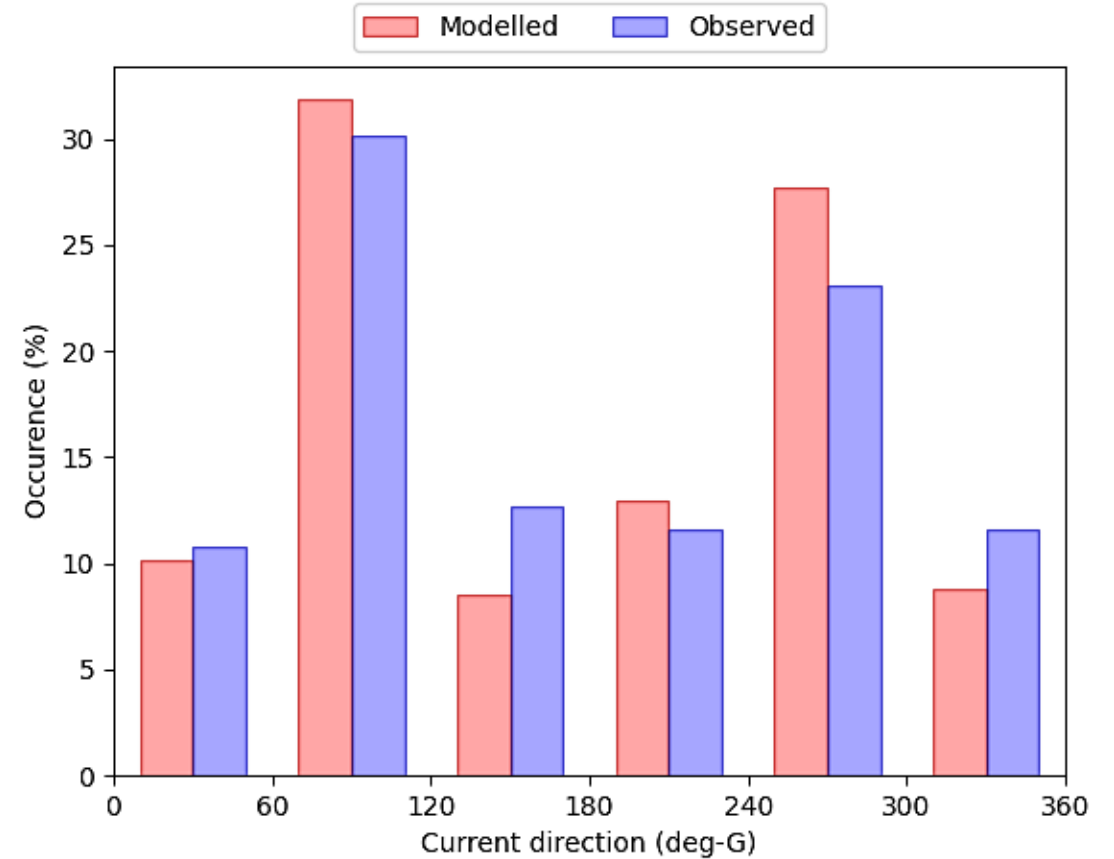
Histogram of observed and modelled current direction at the measurement location Site 7, east of Isle of Wight, between 20th May and 3rd June 2023. Model skill d2 = 0.97.

4. Solent Model Applications – *Oyster Larvae*
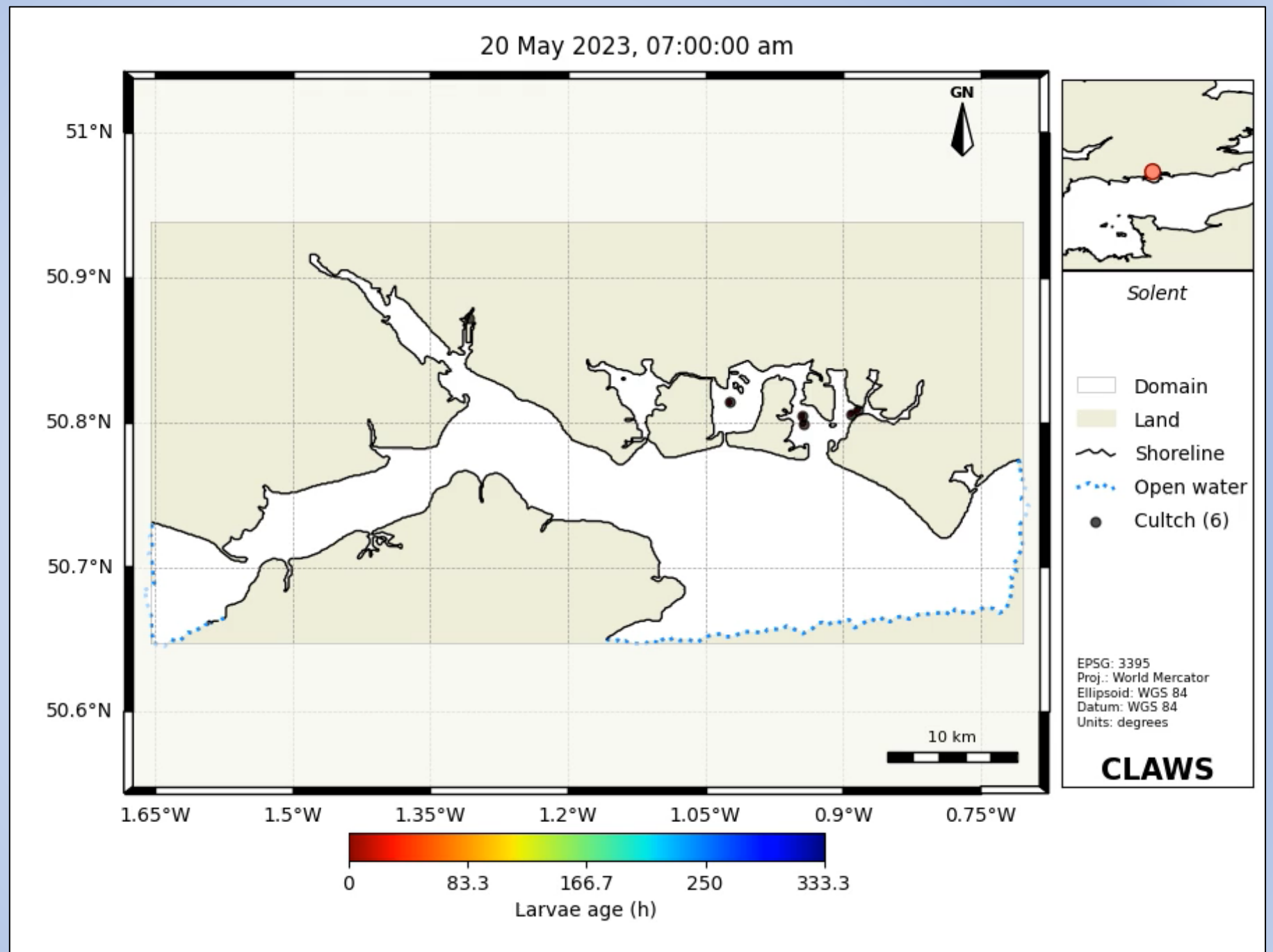
- *Solent Oyster Restoration Project.*

- *Collaboration with University of Portsmouth - Profs Joanne Preston and Gordon Watson.*

- *Understand larvae distribution.*

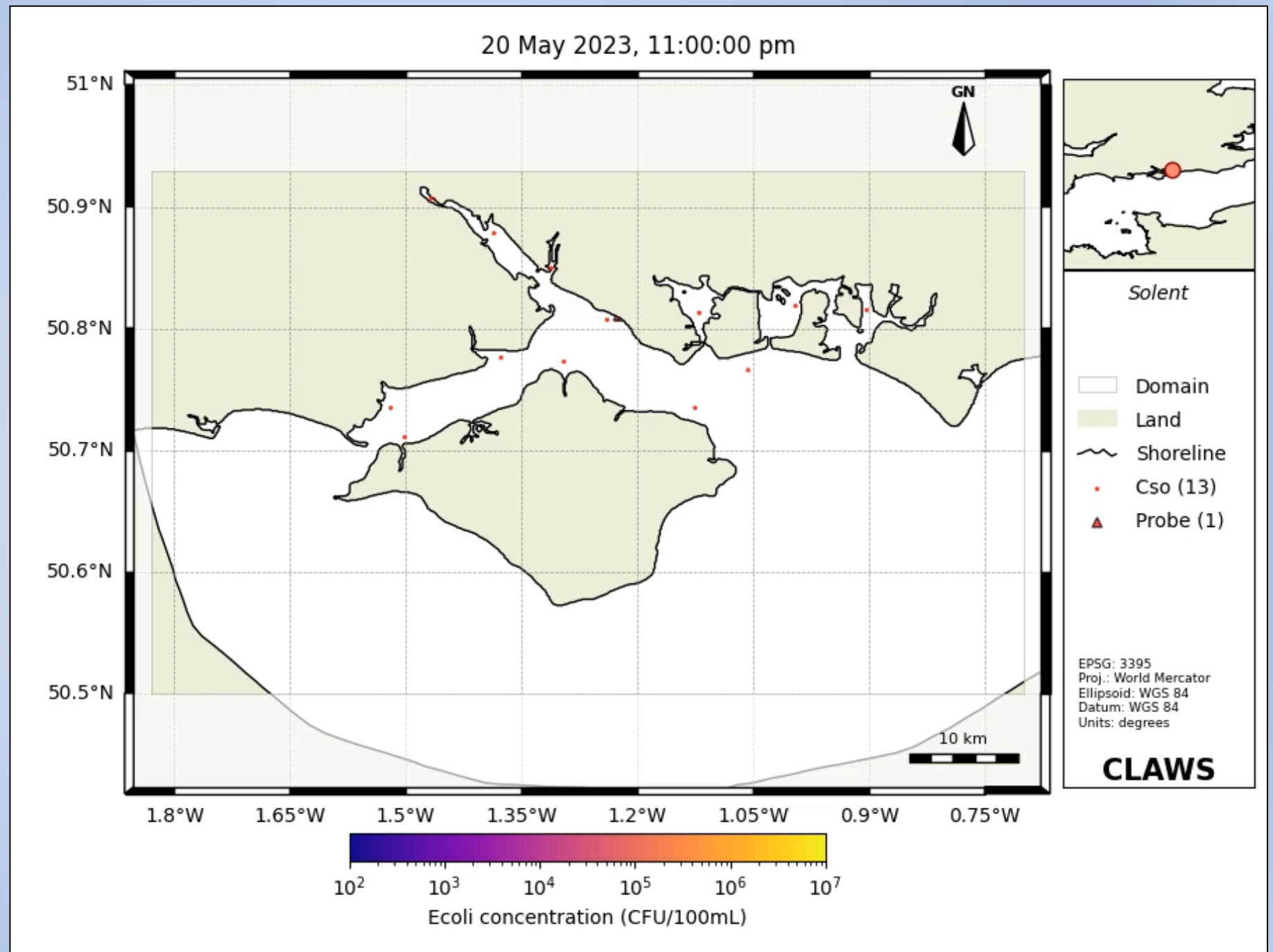- *Larvae swimming and deposition behaviour included.*

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20 May 2023 - 03 June 2023

Larvae average normalised concentration (1/m²)
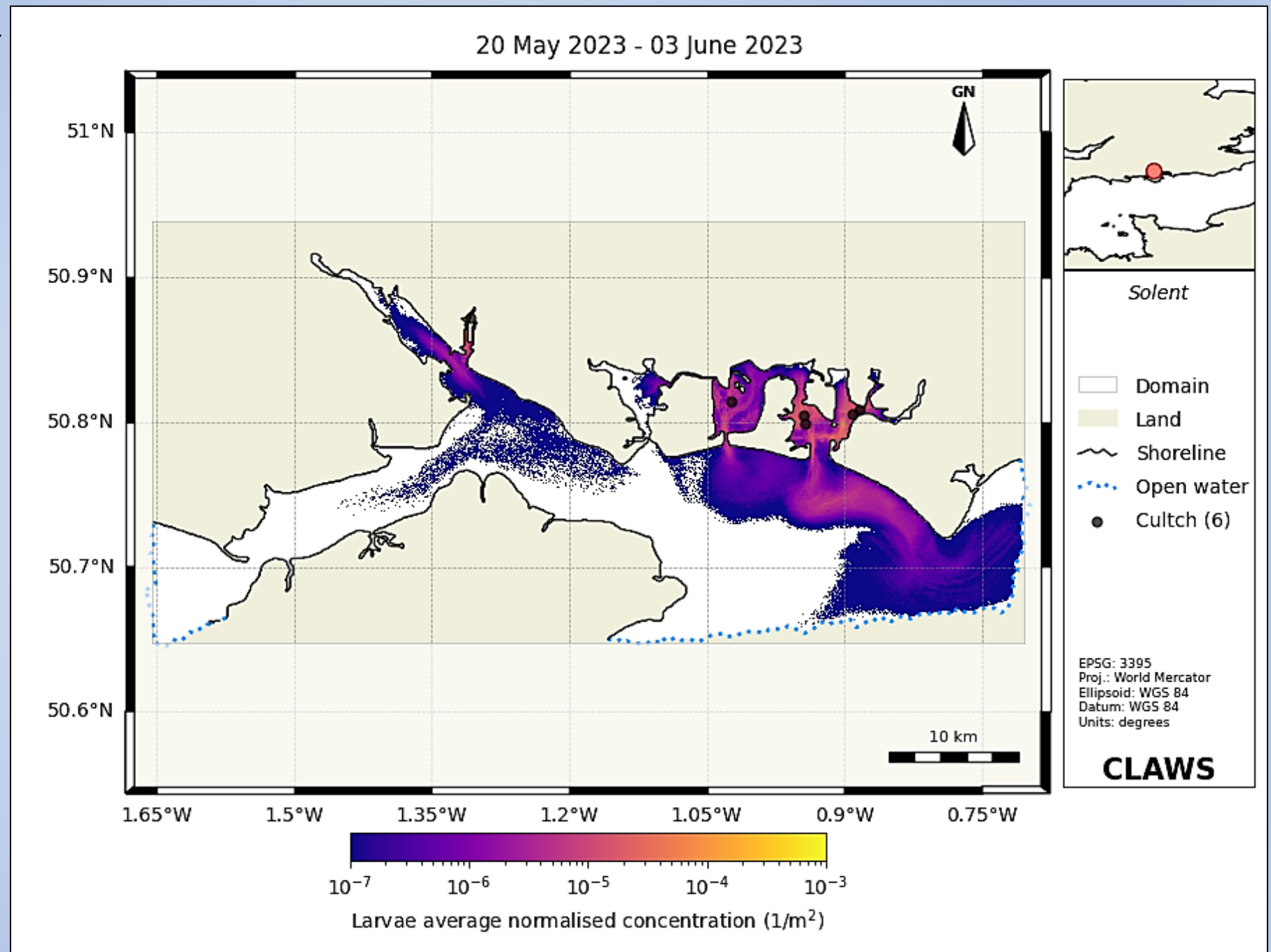
4. Solent Model Applications – E. coli

- Raw sewage spill from 13 CSOs over a 12-hour period.

- E.coli decay depends upon salinity, temperature and light (solar irradiation).

- What time does it take for peak levels in the system to decay to acceptable levels?

- Useful for water recreational users / shellfish farm - oyster locations.


20 May 2023, 11:00:00 pm

Solent

- Domain
- Land
- Shoreline
- Cso (13)
- Probe (1)

EPSG: 3395
Proj.: World Mercator
Ellipsoid: WGS 84
Datum: WGS 84
Units: degrees

CLAWS

10 km

Ecoli concentration (CFU/100mL)

4. Solent Model Applications – *E .coli*

- *Average E. coli levels show areas where E. coli likely to be found across the Solent.*
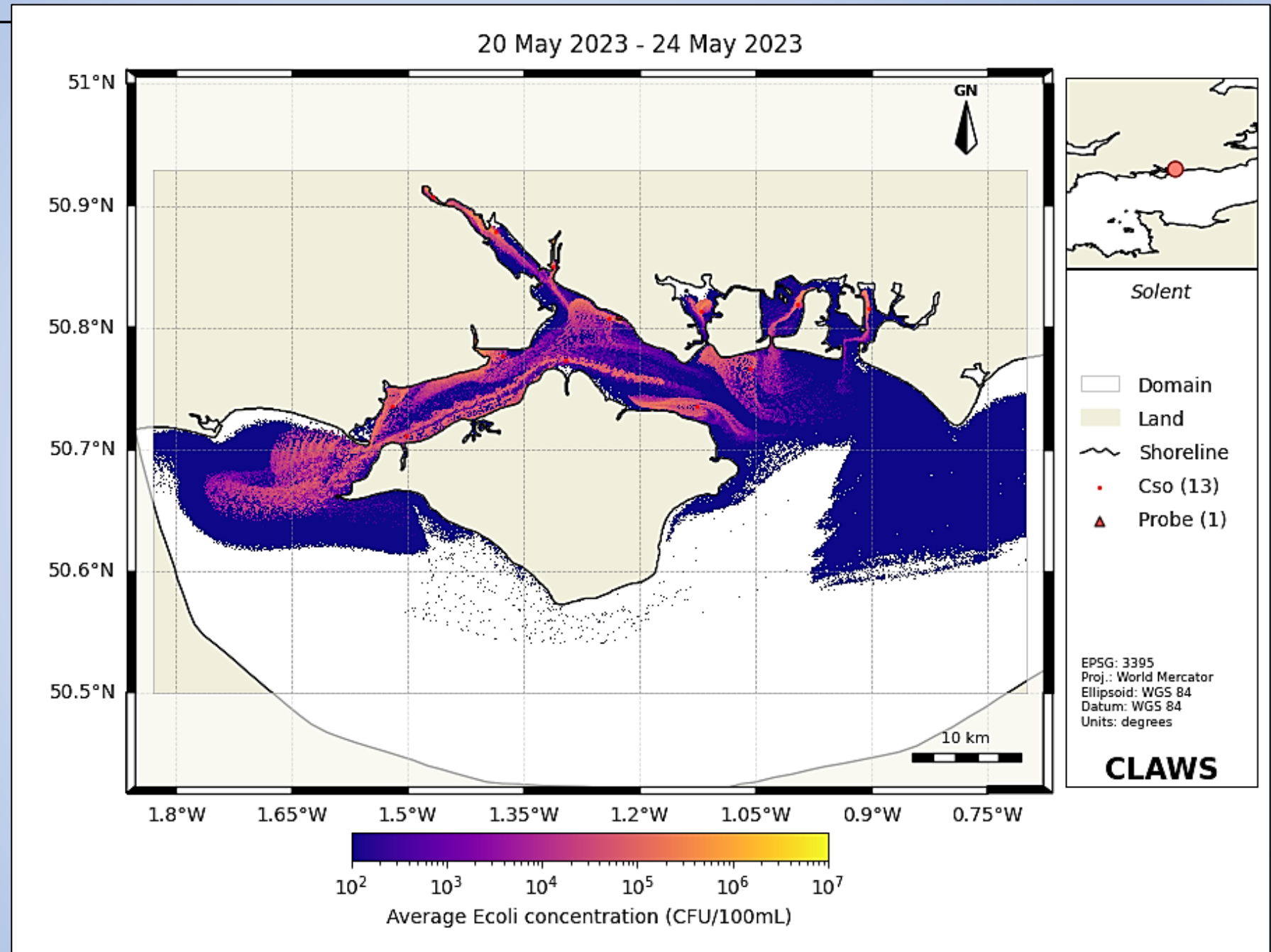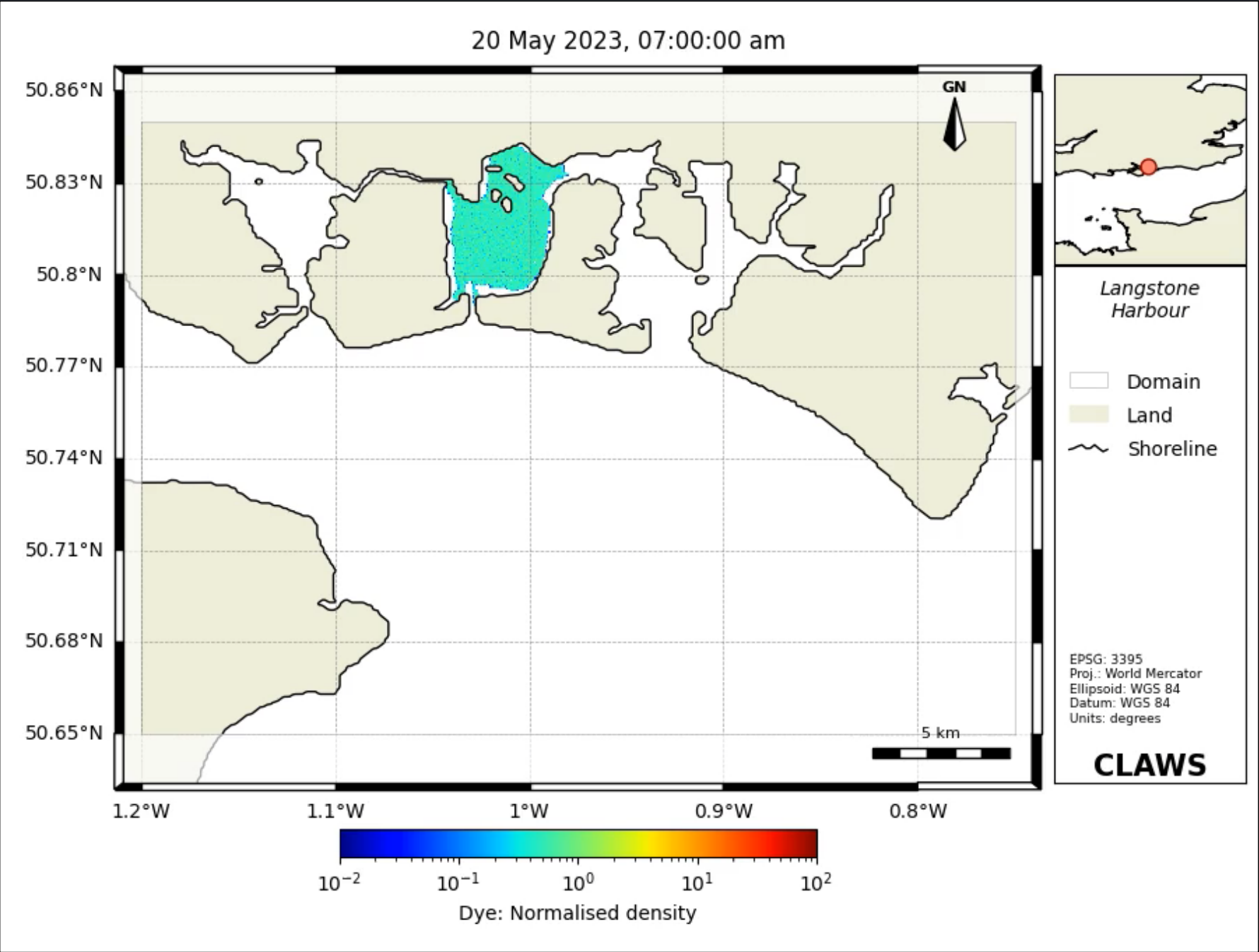
4. Solent Model Applications – *E. coli.*

- *Raw sewage spill from 13 CSOs over a 12-hour period.*

- *E.coli decay depends upon salinity, temperature and light (solar irradiation).*

- *Note night-time effect (flatter curve – no light).*

- *What time does it take for peak levels in the system to decay to acceptable levels?*

- *Useful for water recreational users.*
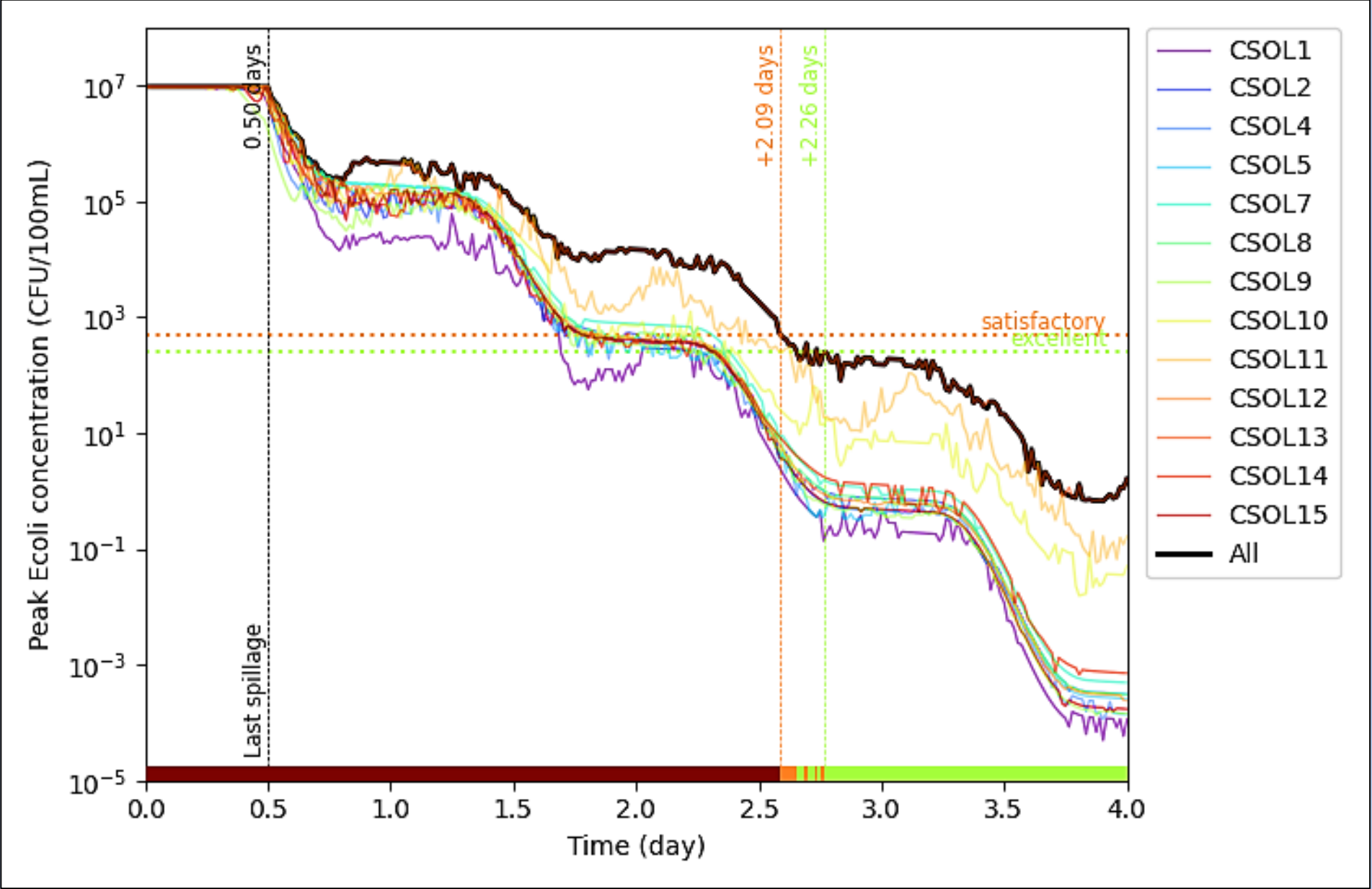
4. Solent Model Applications - *Nutrients*

- *Excess nutrients P, N can lead to eutrophication, algal blooms, O_2 depletion.*

- *Ability of harbours, estuaries, sea lochs to disperse P, N depends on flushing time.*

- *Issue in Langstone harbour due to inlet constriction and agricultural run-off.*

4. Solent Model Applications - *Nutrients*

- *Flushing time is period for 63% of seeded particles to leave the system.*

- *Flushing time of 13.6 days can be used in simple calculation to determine harbour's ability to absorb P, N.*
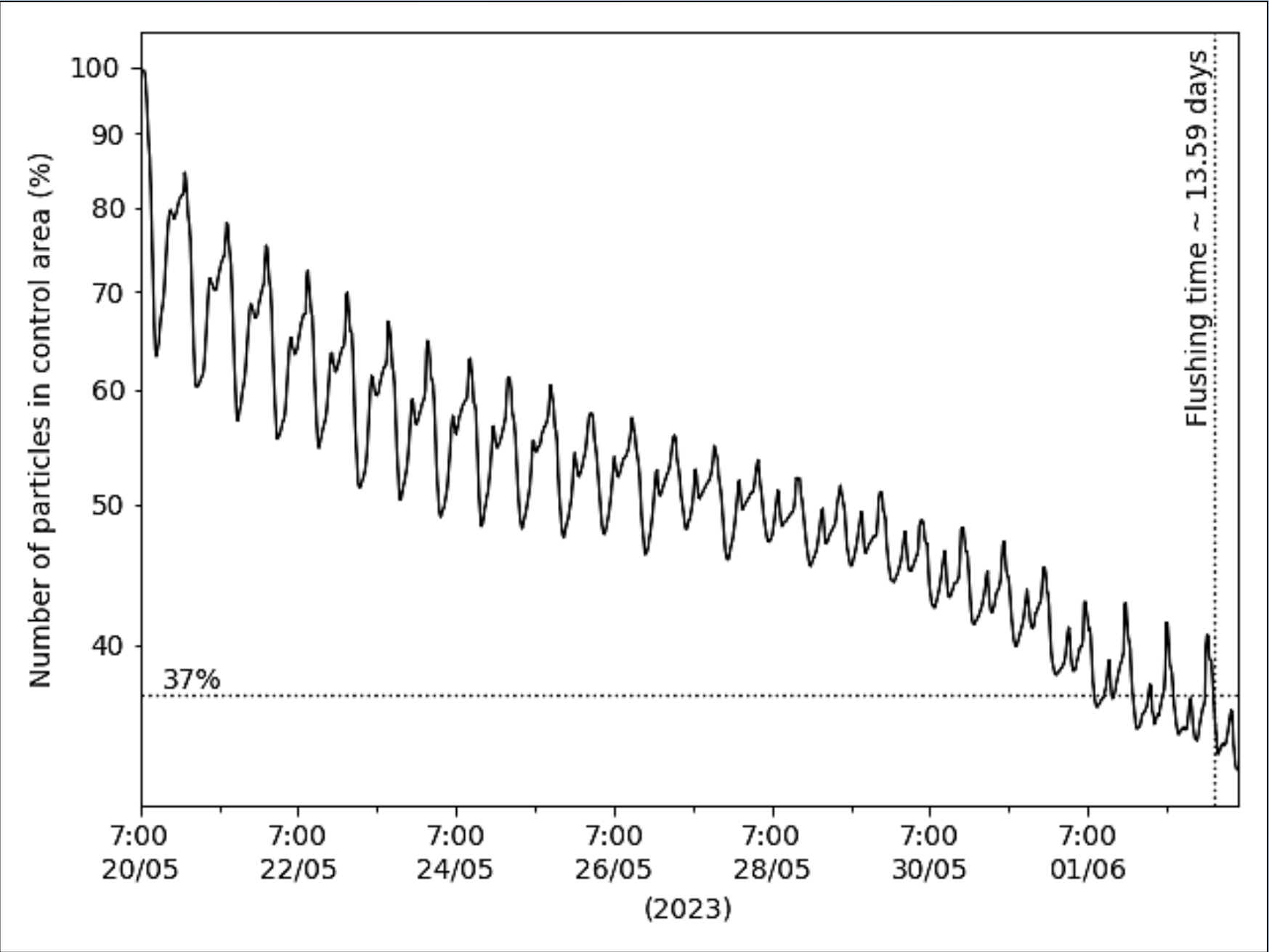
4. Solent Model Applications – *Plastic litter*

- *Floating plastic litter from garbage patch in Southampton water.*

- *Tidal effects appear to drive litter towards Lee-on-the-Solent and Hillhead beaches round towards Southsea and Eastney.*

- *Introducing a beaching model to quantify beached litter.*
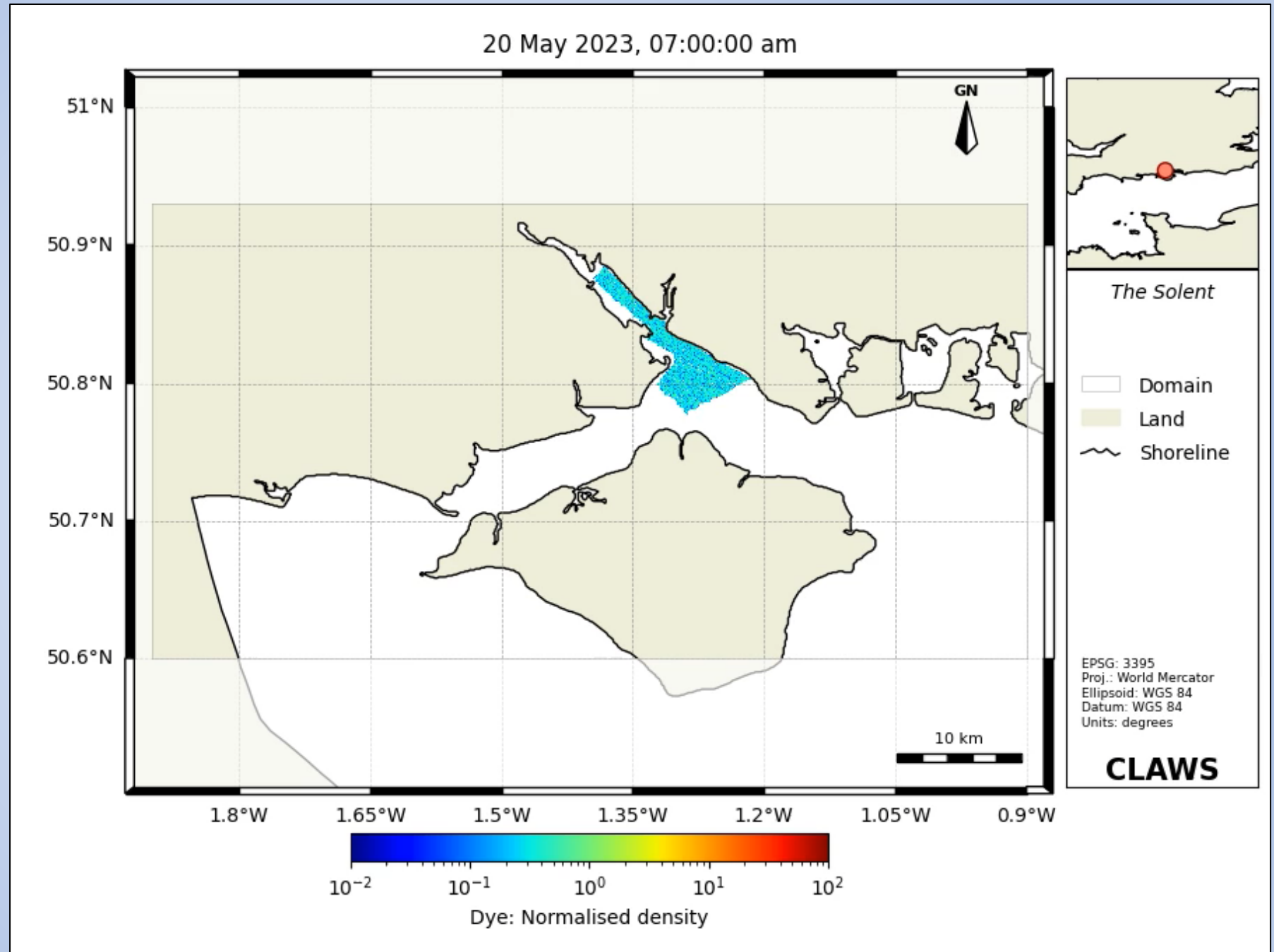
5. *What does this all mean for the Solent Forum and other NGOs/ Coastal Communities?*

MTS

- Coastal communities have access to sophisticated "state-of-the-science" environmental computer modelling with experienced consultants.

- Counter-balance to water industry/DEFRA modelling/reports. Support alternative proposals by SPS/others.

- Extensive track record of successful engagement with coastal communities (CCN – Scotland - johnaitchison1@me.com).

- We are a consultancy and are paid for our engagements (modestly!). Pro-bono possible.

"We are keen to ensure the water company gather all existing and current evidence to support their investigations. It sounds like the research you are undertaking could have many cross overs / provide useful evidence to support the water company investigations. I have raised this with Southern Water in the hope that they will contact yourselves to find out more."

Hazel Stanworth
Freshwater Senior Officer (Thames Solent)
Source to Sea team
Natural England, 24 Feb. 2025