Crowdsourced Bathymetry

Utilising the Crowd to obtain high quality depth data

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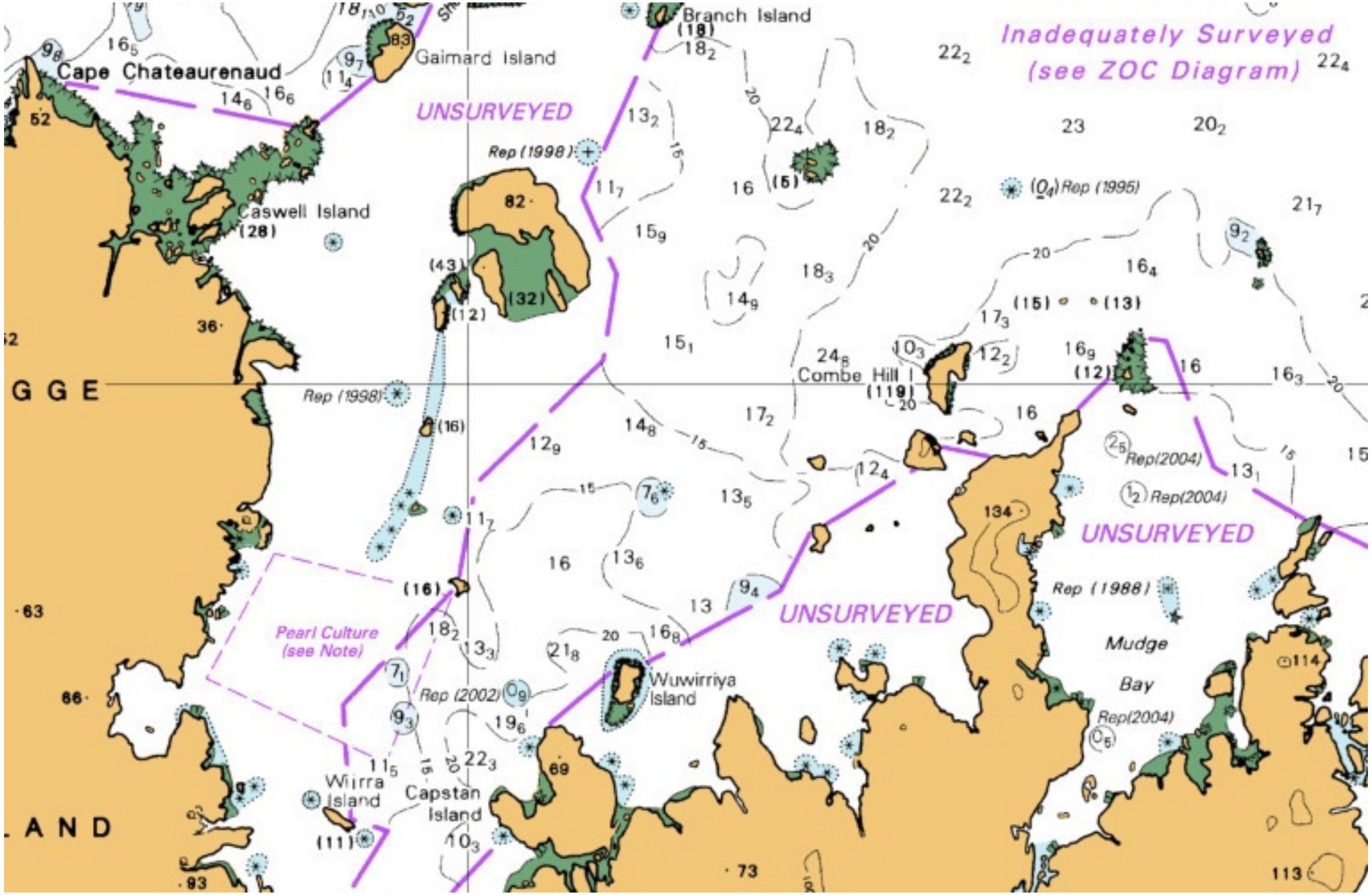
With Additional Material Provided by Tim Thornton

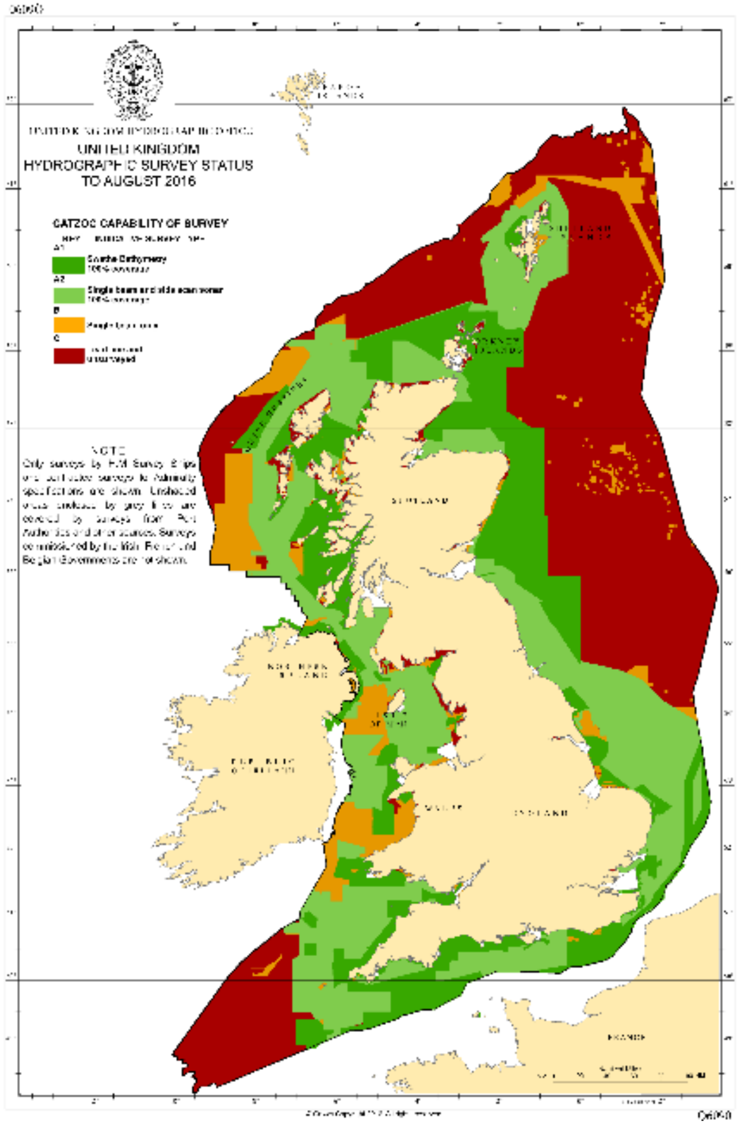
Project Aim

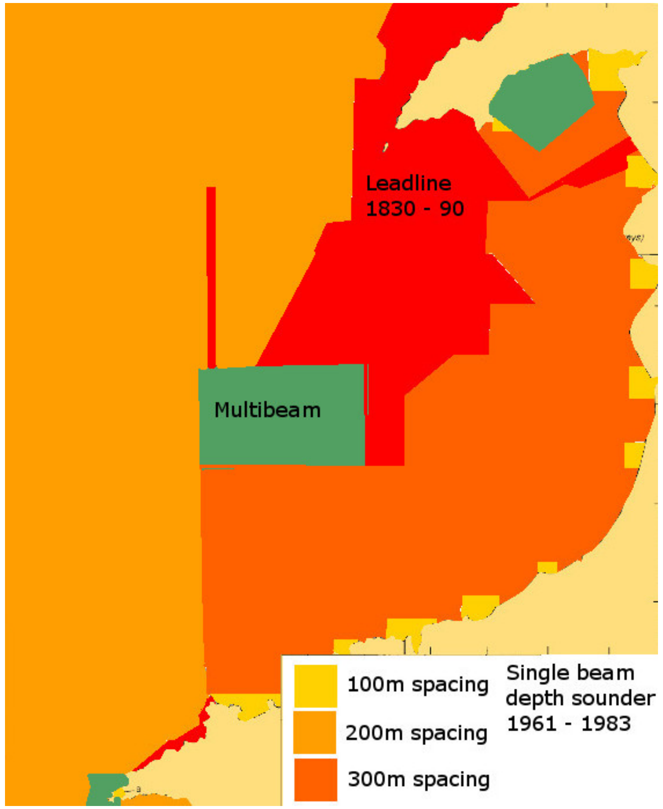
Can Crowdsourced Bathymetry (CSB) data obtained from non-survey vessels, if collected in enough density and validated, be used as a reliable source of bathymetric data to update navigation charts.

Lack of Coverage



Lack of Coverage





Cardigan Bay

Within the UK EEZ (0-200 m)

- 49% Adequately Surveyed
- 22% Require Re-Survey
- 29% Never systematically surveyed

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Lack of Coverage

Reductions in Capability

In the last 30 years the number of survey vessels has fallen:

Down 34% in Offshore Survey

Down 35% in Costal Survey

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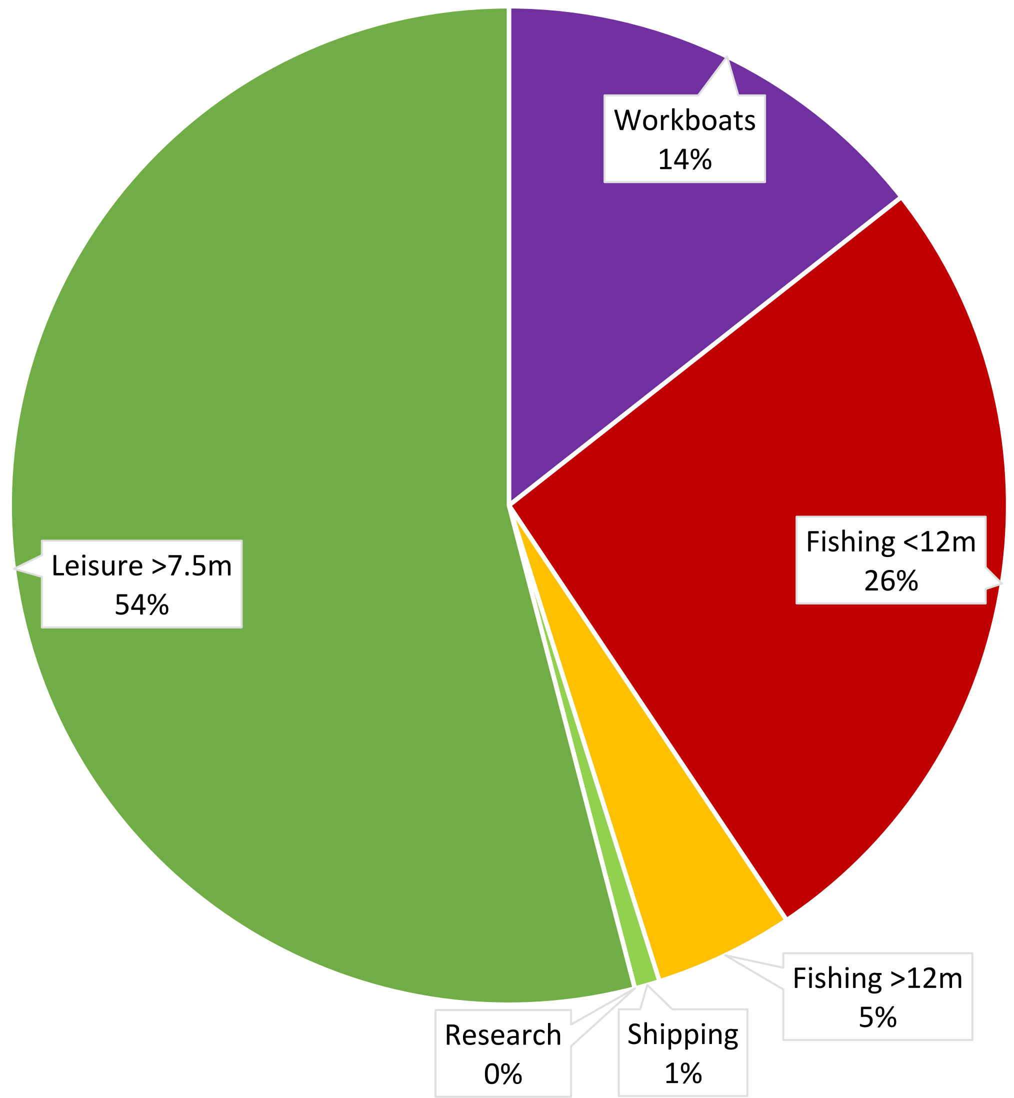
Fleet Sizes

Total fleet ~10 million



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Crowdsourcing Bathymetry: the exploitation of a well dispersed but underutilised resource and make collective use of the data that is being gathered.

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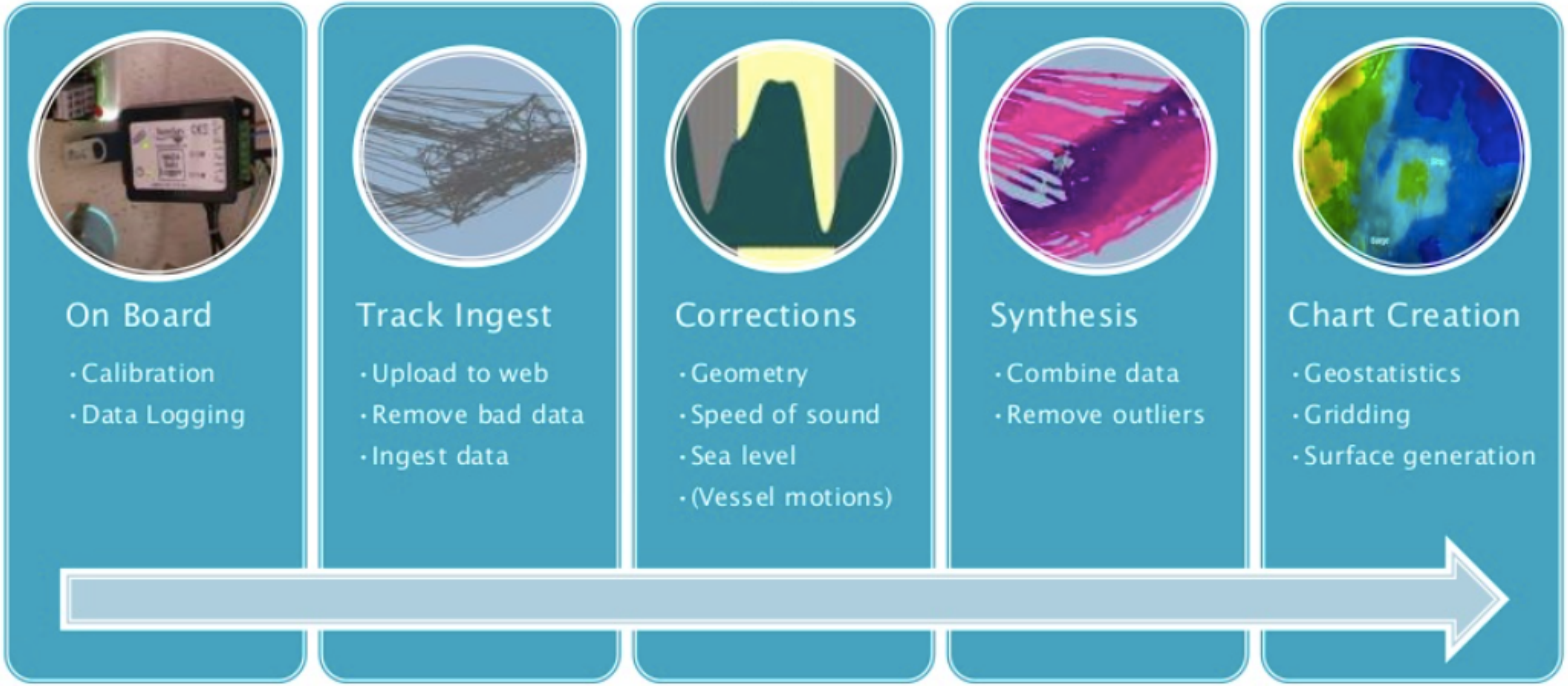
The Kit You Need

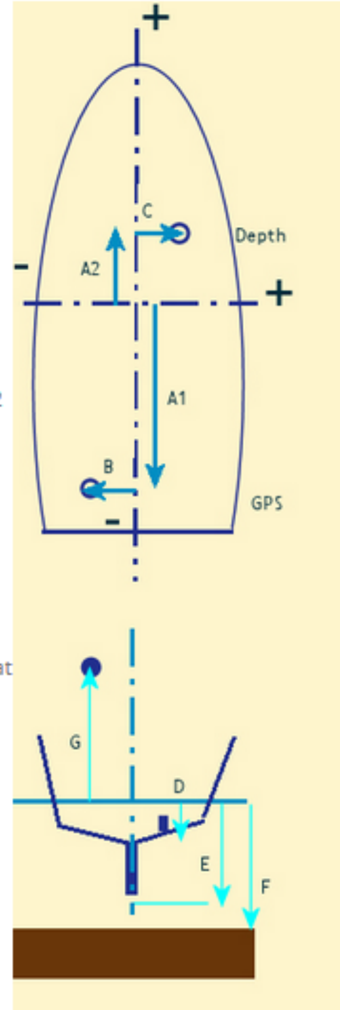
Data Cleaning & Calibration



Calibration

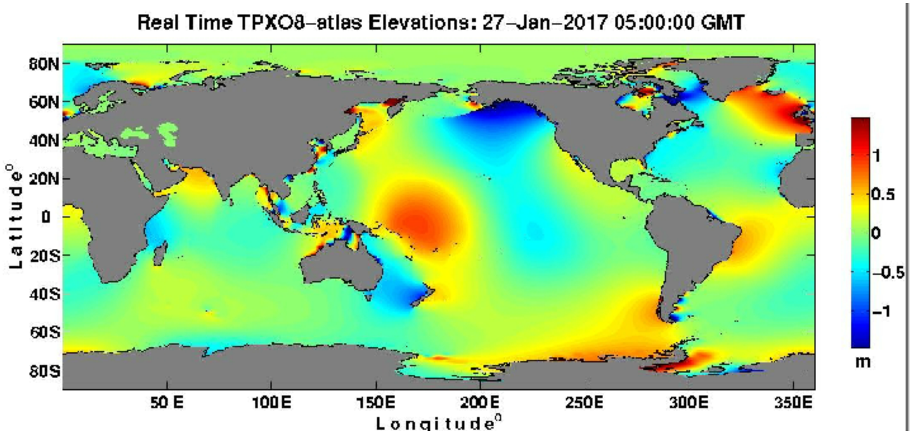
Older >>

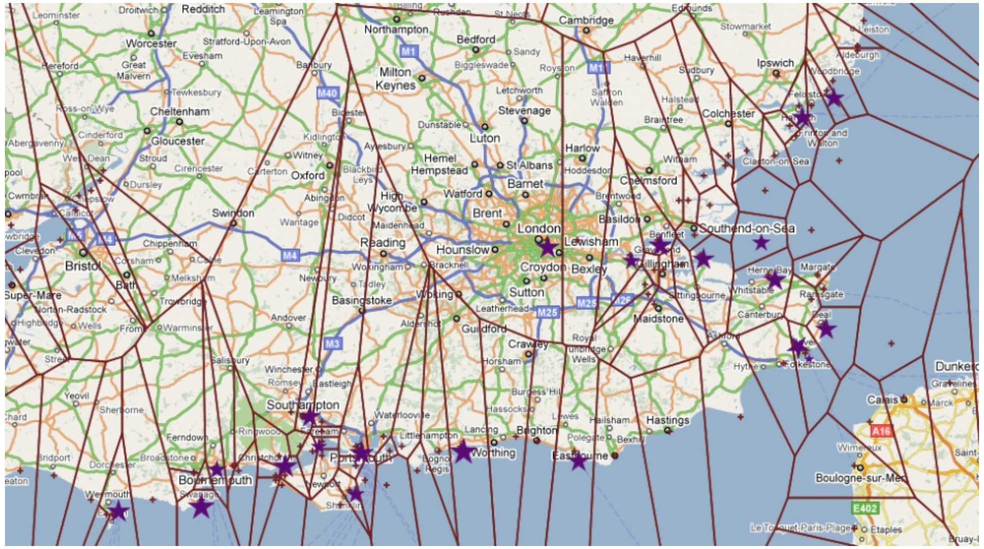
Submission date/time	2016-11-20 16:39		
GPS antenna			
GPS make	Garmin	Metres forward of reference position (A1)	7.1
GPS model	GPSMap 4000/5000 Series	Metres starboard of centreline (B)	-3.2
Uses differential GPS (DGPS)	No	Metres above sea level (G)	12
Uses EGNOS/WAAS	Yes		
Depth sounder			
Sounder make	Lowrance	Metres forward of reference position (A2)	9.3
Sounder model	HDS-8 Fishfinder/GPS Chartplotter	Metres starboard of centreline (C)	0.1
Sounder transducer	P79 in-hull		
Depth calibration			
Transducer depth below waterline (D)	3.08	Vessel Type	Boat
Vessel draft (E)	3		
Depth of water (F)	4		
Transducer depth below waterline in instruments (m)	3		



- Models of GPS and depth sounder
- Depth transducer offset
- Relative positions of GPS antenna and depth transducer

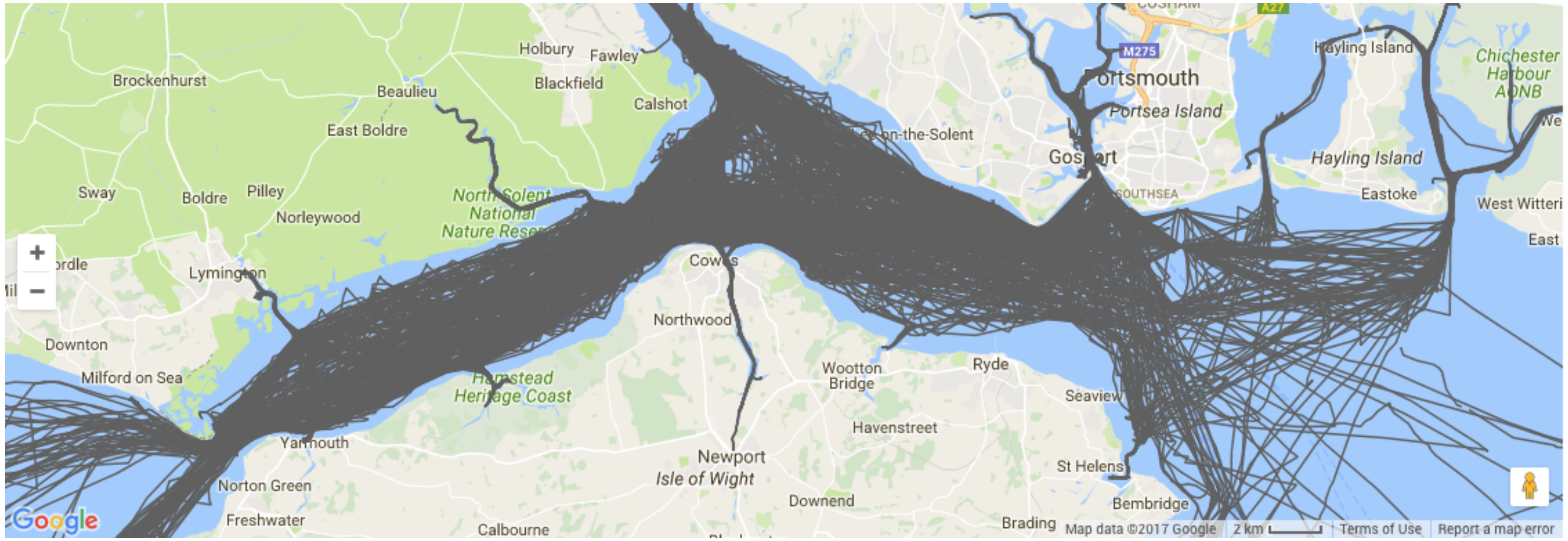
Corrections

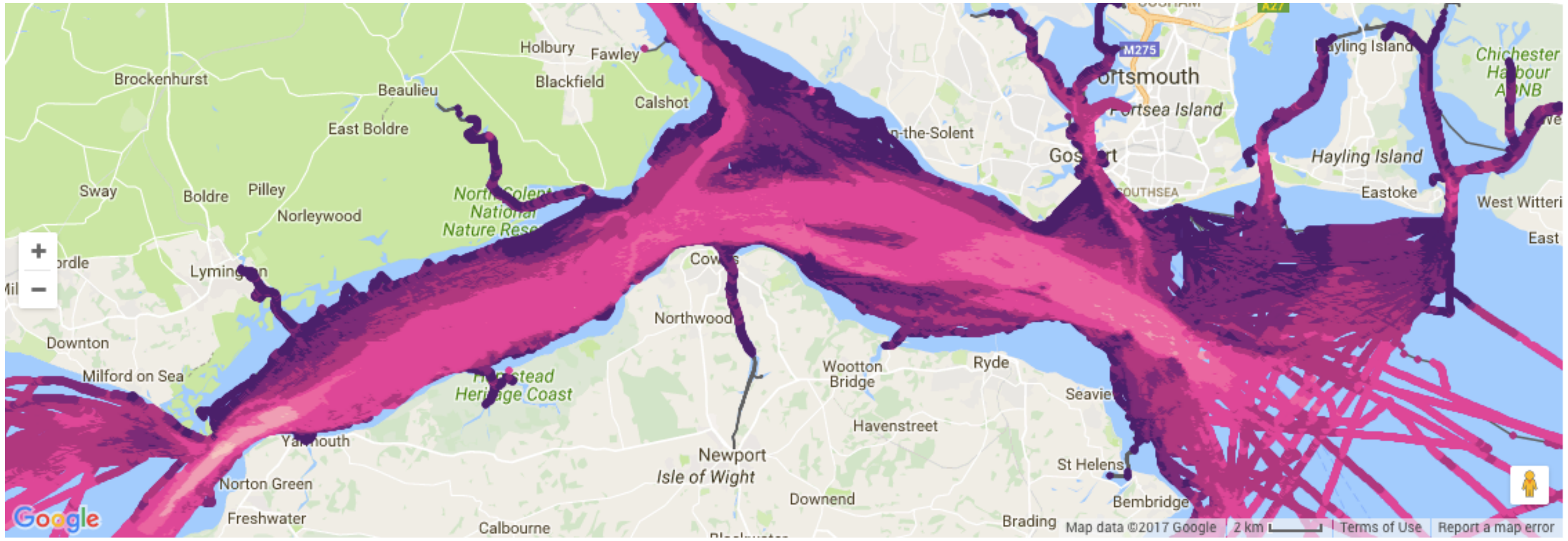




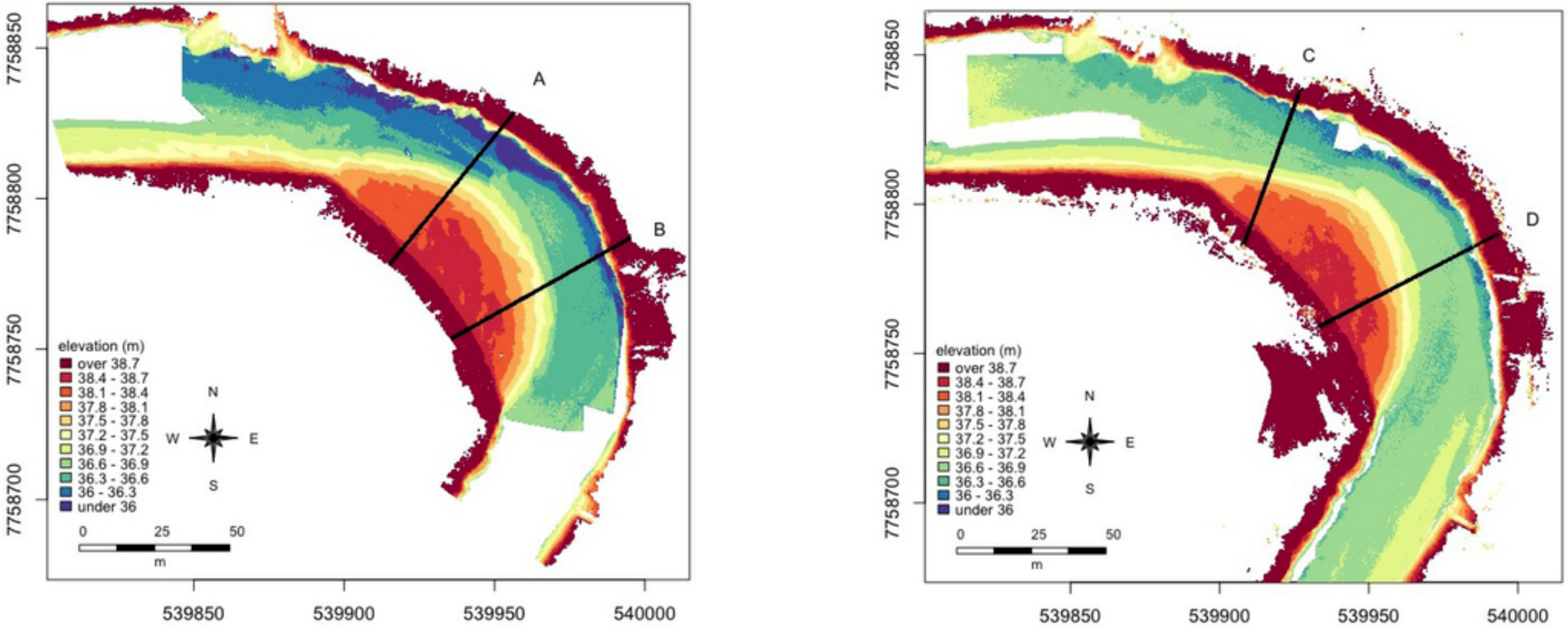
- Global tide predictions, combining TPX08 gridded model and coastal tide stations
- Secondary tide correction by determining the residual between predicted and actual tides at tide gauges, and interpolating the difference
- Weather corrections are implicit in the tide gauge corrections – pressure corrections relate to mean atmospheric pressure at the tide gauge, but that value isn't defined anywhere!

CSB comes from many Individuals



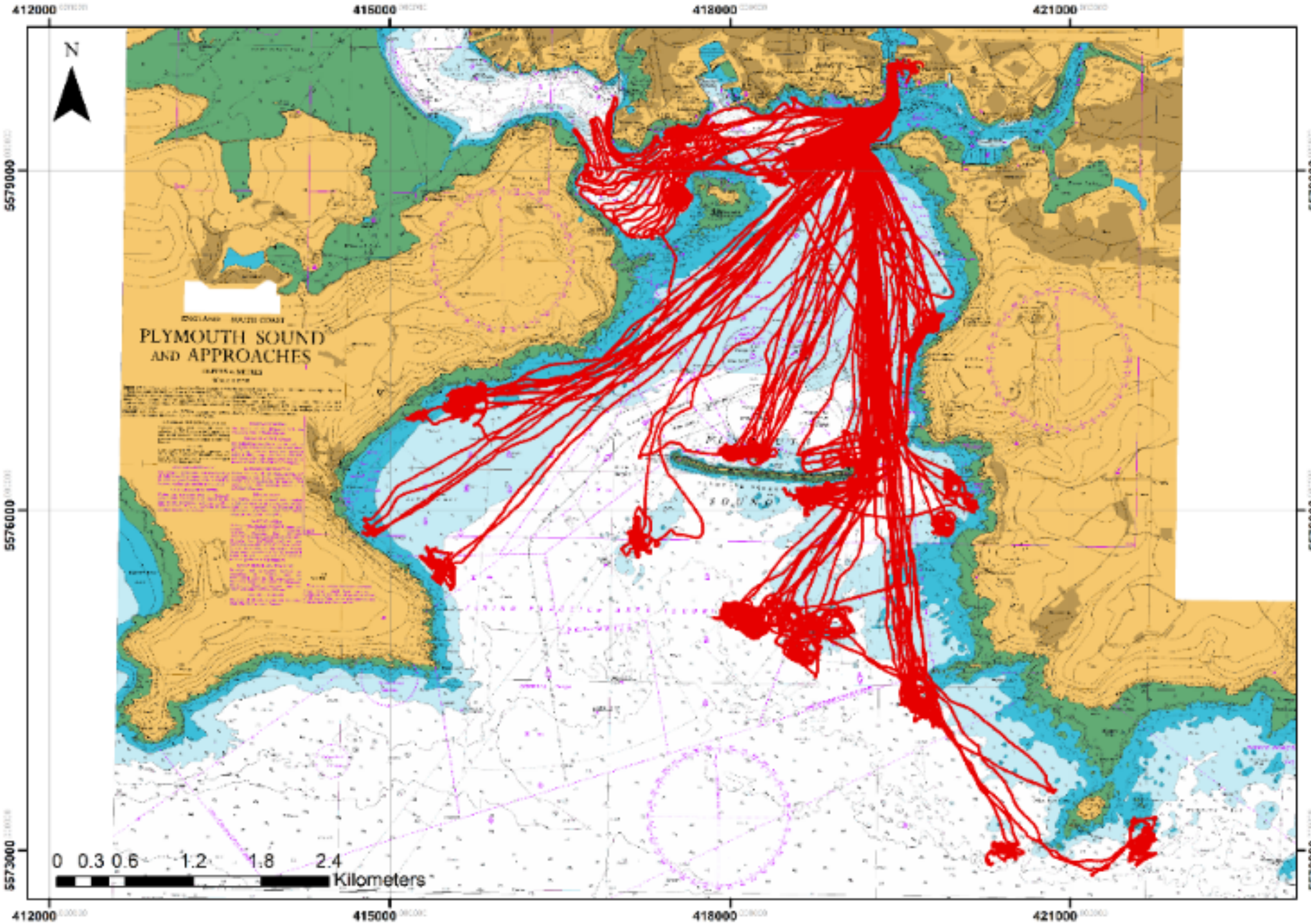


Continuous Resurvey

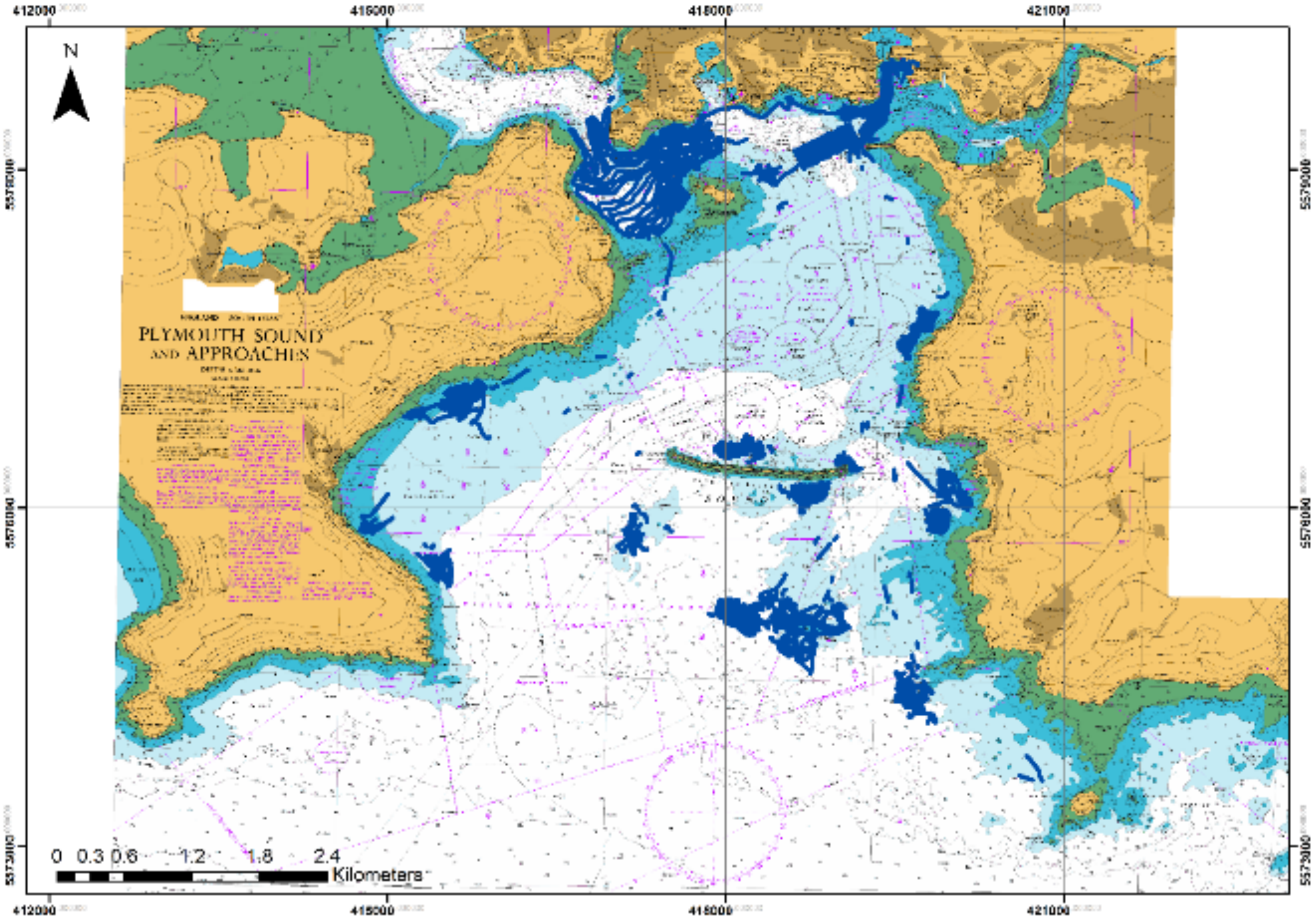


- Logging fleet gives a continuous resurvey of the sea bed
- Time slice the data to give changes in the sea bed
- More timely and more spatially targeted detection than relying on periodic resurveys of a given area, given enough vessels logging data in the area

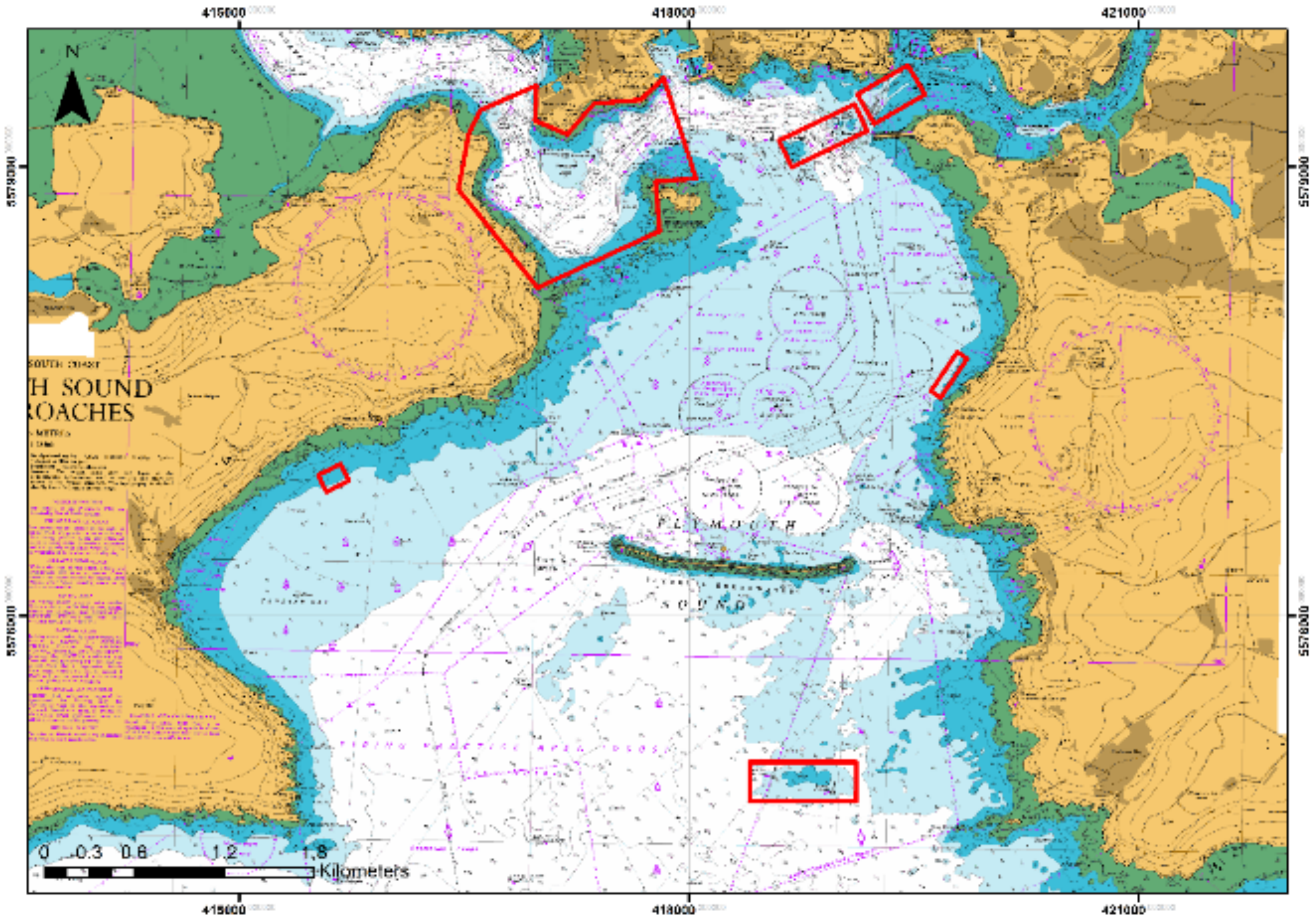
All Data Collected (since May 2016)



Accepted Data



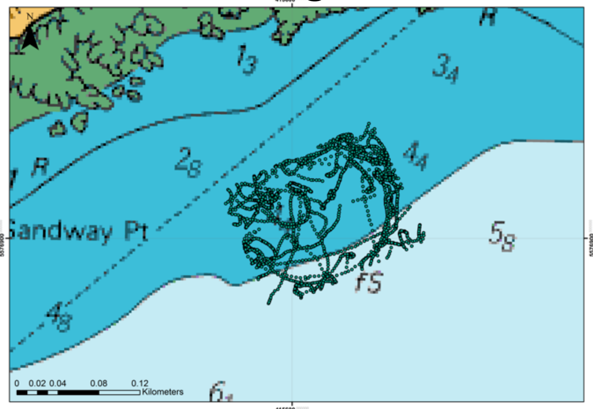
Sites for Comparison



6 sites in Plymouth Sound chosen: Cobbler Channel, Smeatons Pass, Drake Channel, Jennycliff Bay, Kingsand Bay and Tinker Shoal.

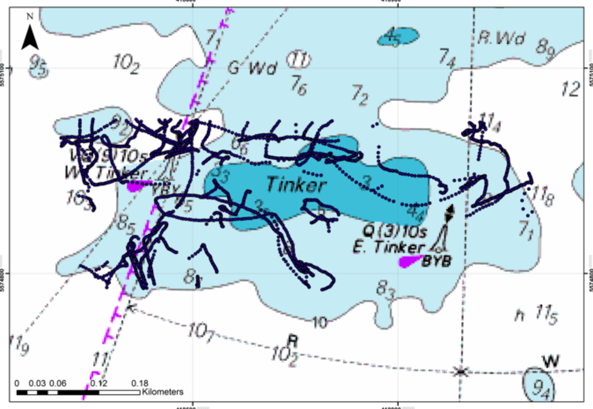
CSB Soundings

Kingsands



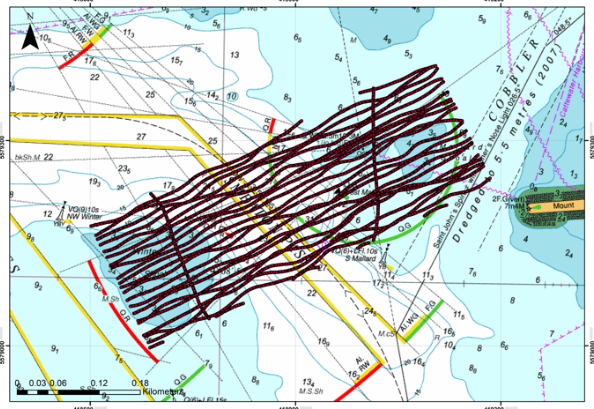
3559 soundings

Tinker Shoal



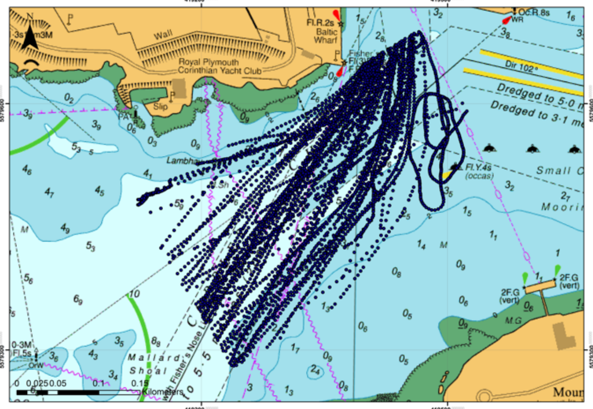
3627 soundings

Smeaton Pass



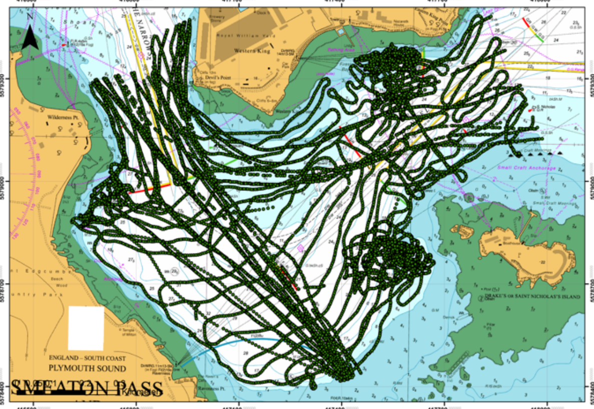
6183 soundings

Cobbler Channel



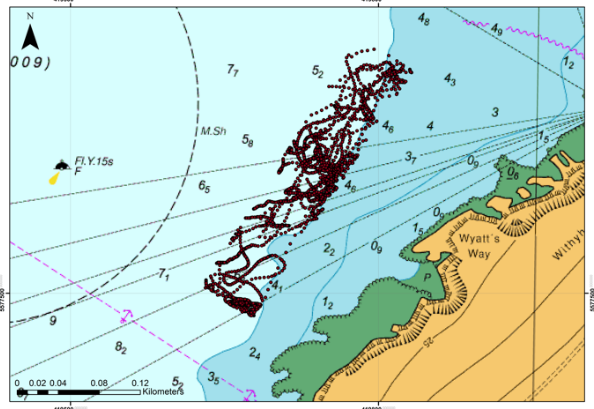
4937 soundings

Drakes Channel



24806 soundings

Jennycliff Bay



3560 soundings

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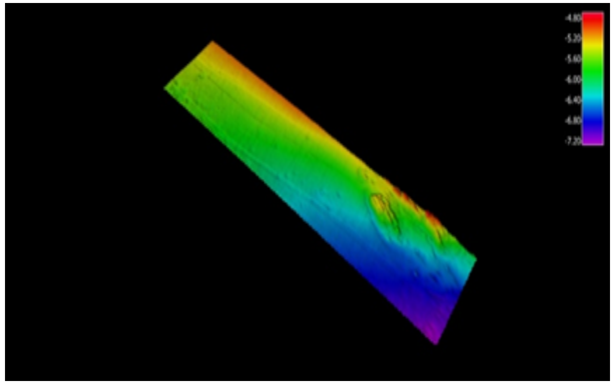
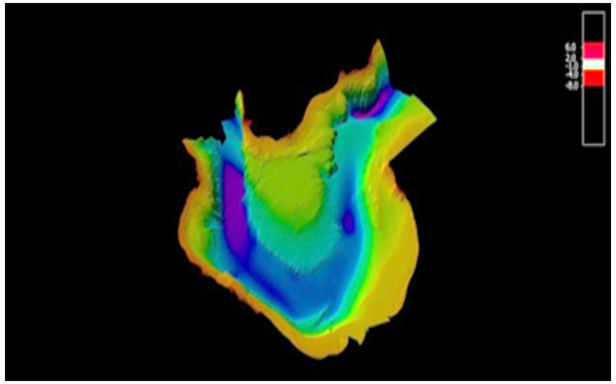
Multibeam and CSB DTMs

Jennycliff Bay



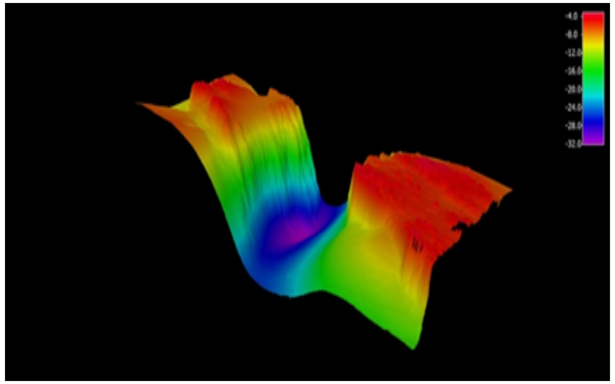
Multibeam gridded at 1m

Drake Channel

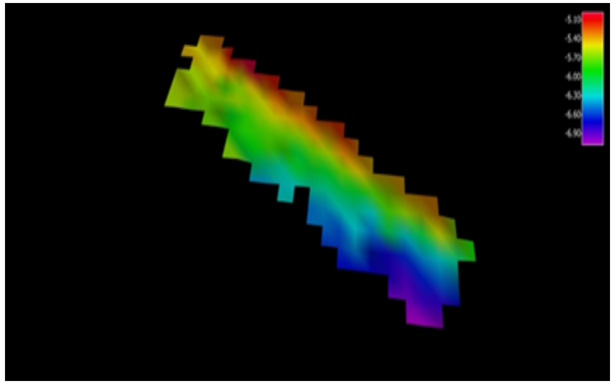


Multibeam gridded at 1m

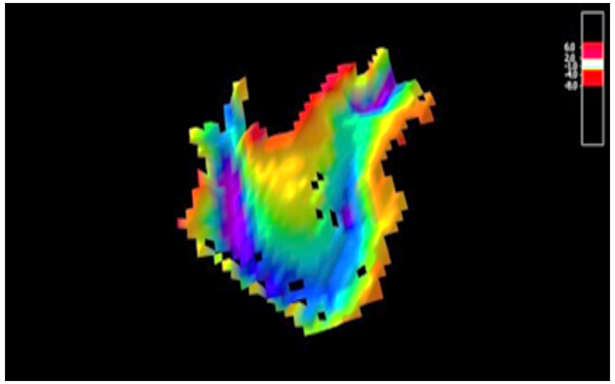
Smeaton Pass



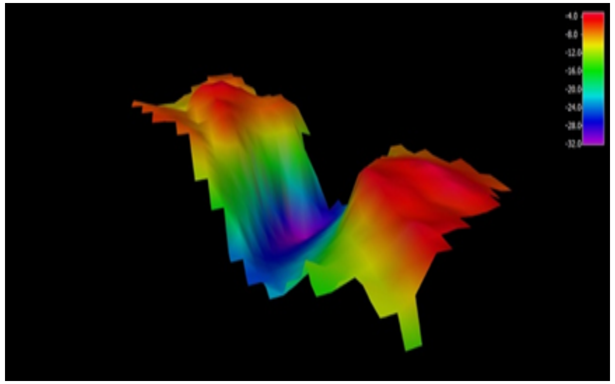
Multibeam gridded at 1m



CSB gridded at 17m



CSB gridded at 37m



CSB gridded at 12m

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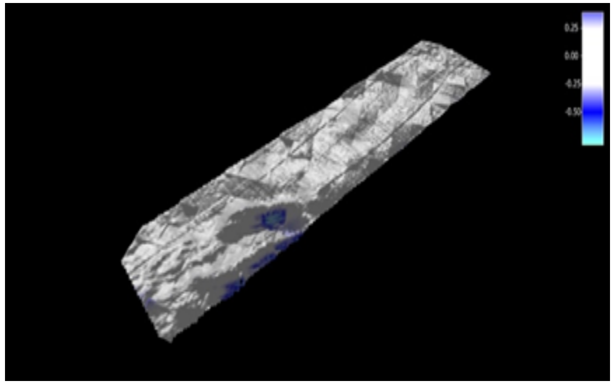
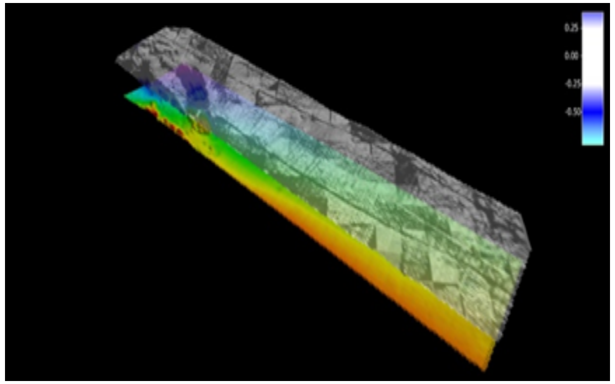
Surface Difference Models

Jennycliff Bay

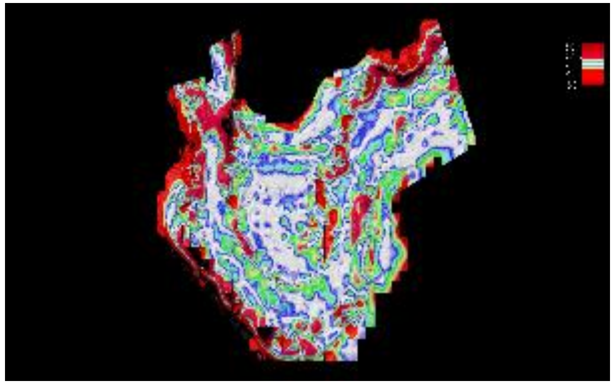


Surface Difference Model

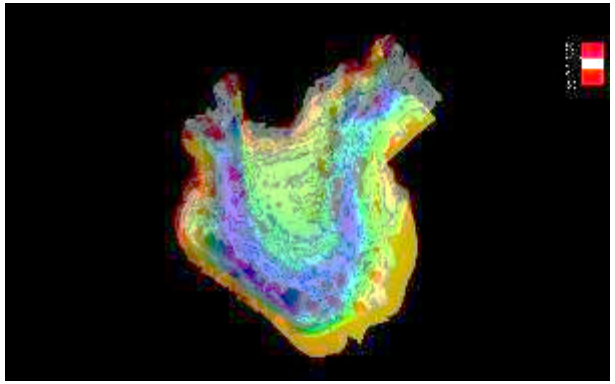


Surface Difference Model
Overlaying Multibeam DTM

Drake Channel

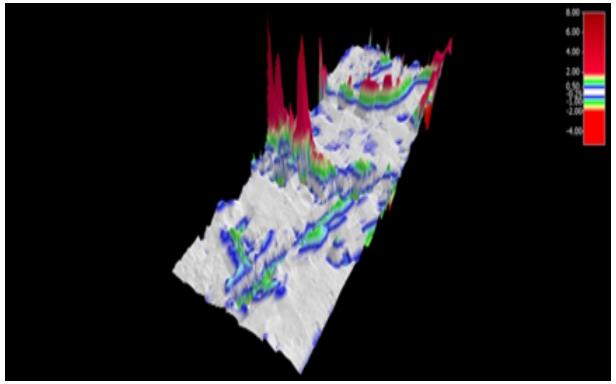


Surface Difference Model

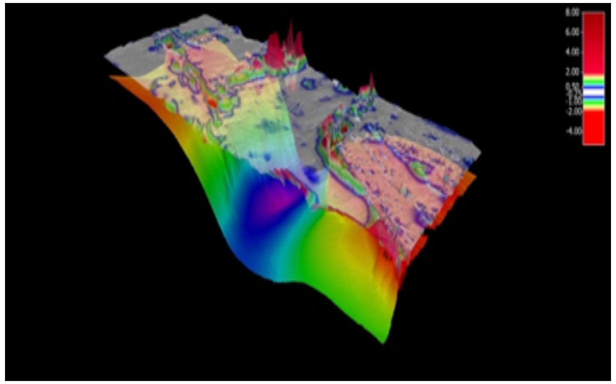


Surface Difference Model
Overlaying Multibeam DTM

Smeaton Pass

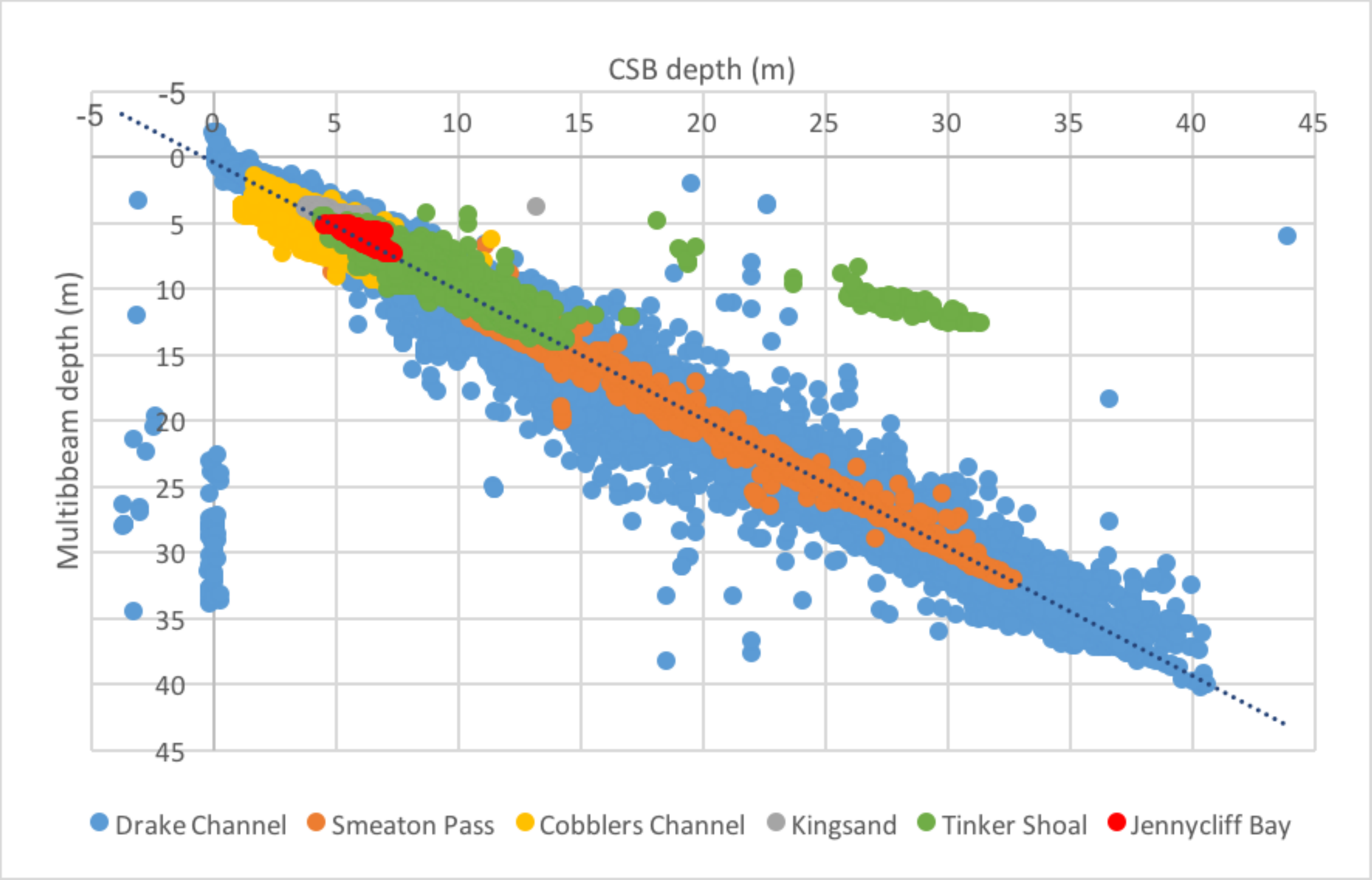


Surface Difference Model



Surface Difference Model
Overlaying Multibeam DTM

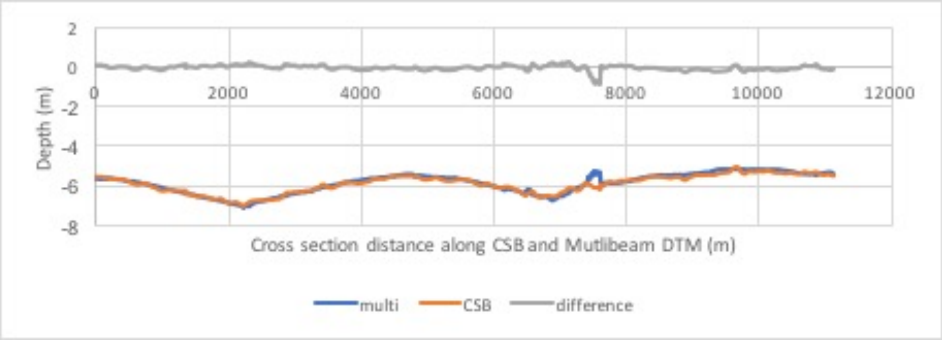
Determination Scatter Graph

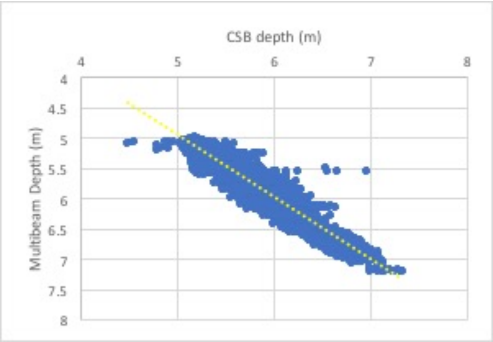


A Coefficient of Determination Scatter Graph showing the strength of the relationship between Multibeam and CSB datasets across all six sites with the vast majority of data points congregating around the line of regression, achieving a Pearson Correlation of 0.983.

Results: Cross Section & Linear Regression Plot

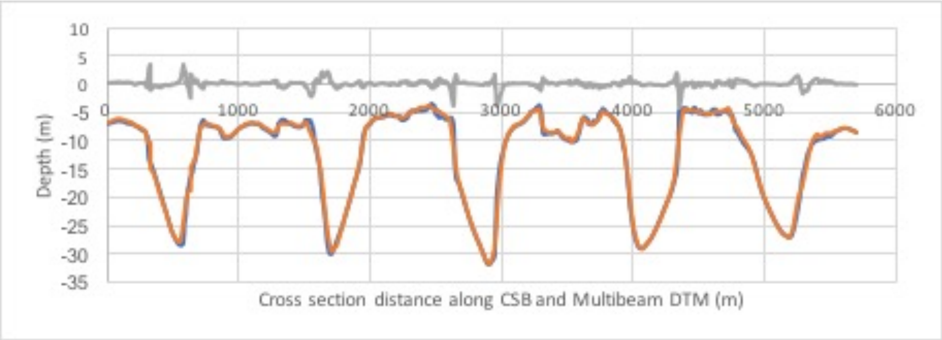
Jennycliff Bay

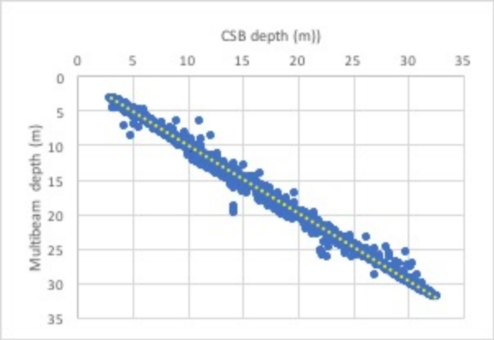




0.951

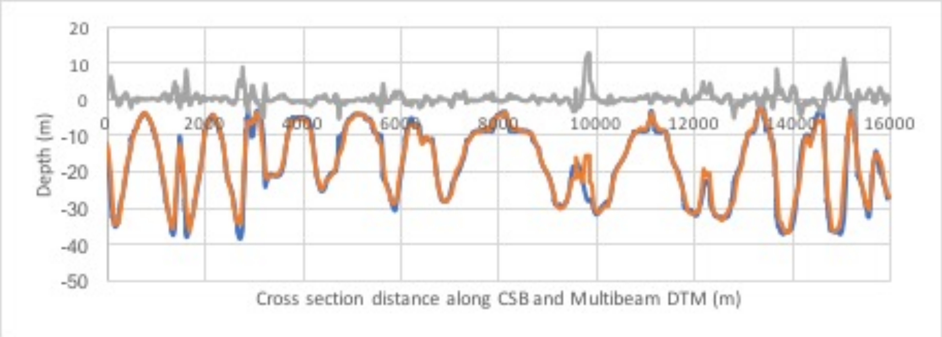
Smeaton Pass

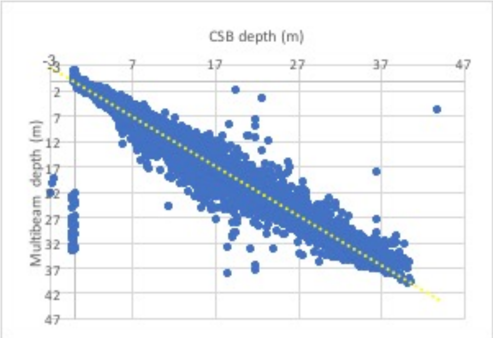




0.999

Drake Channel



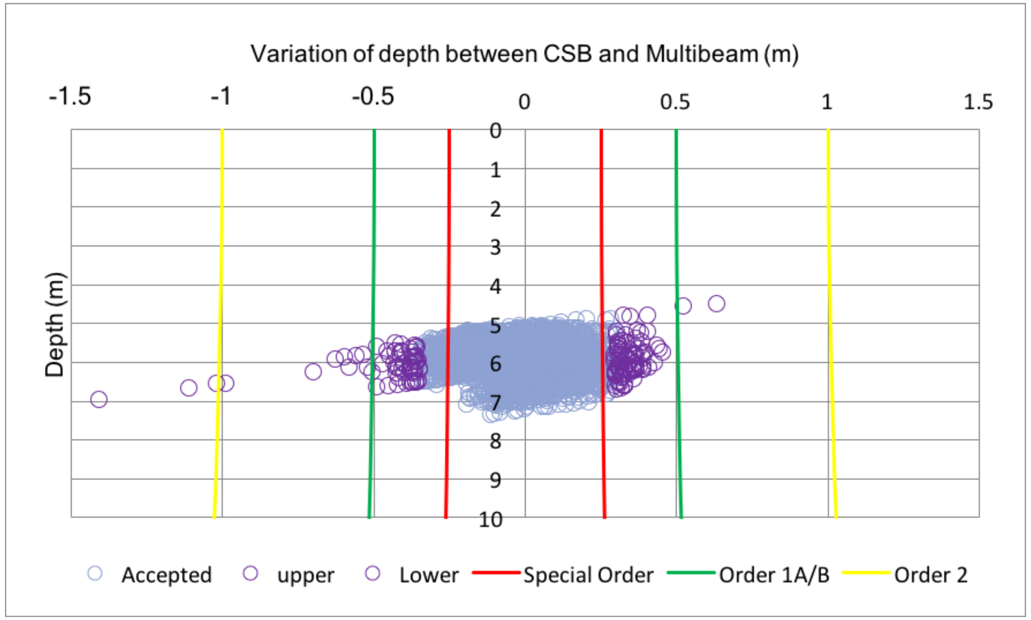


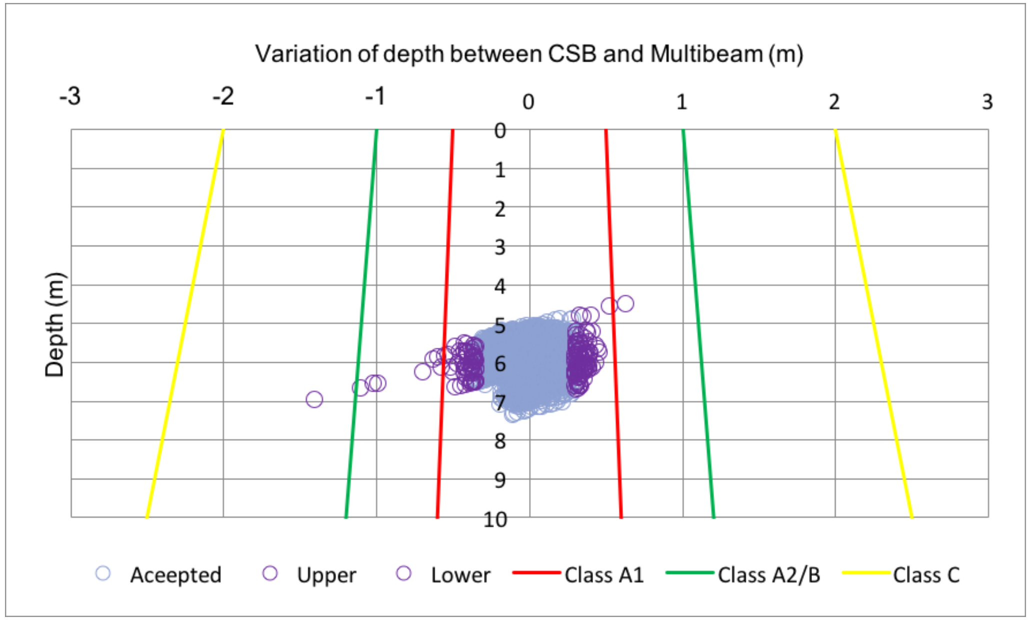
0.893

Comparing Crowdsourced Bathymetry against IHO S-44 & S-57

Results: Total Vertical Uncertainty

S-44 Jennycliff Bay S-57



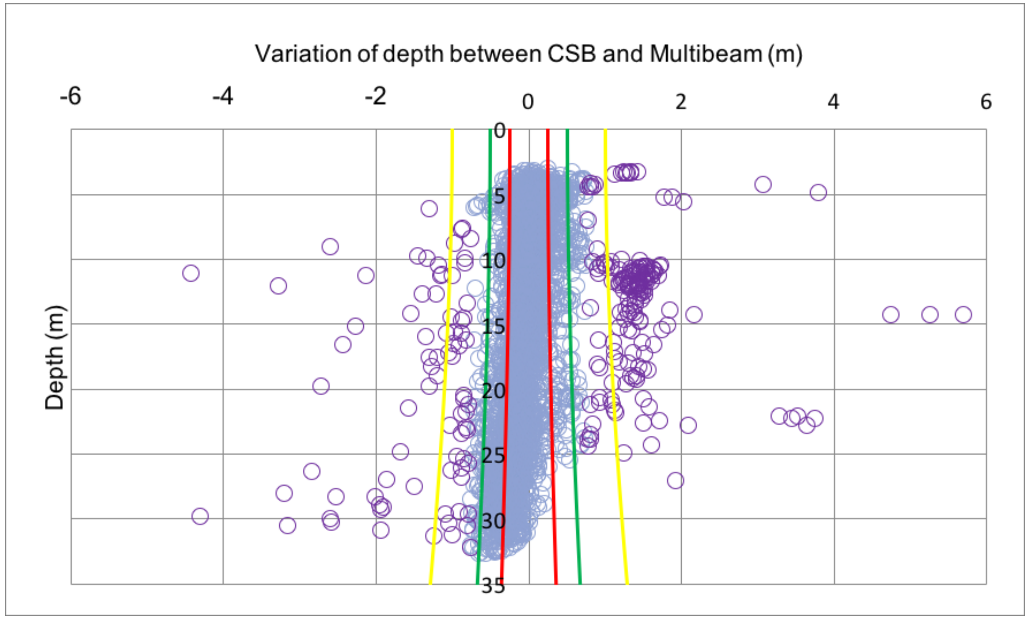


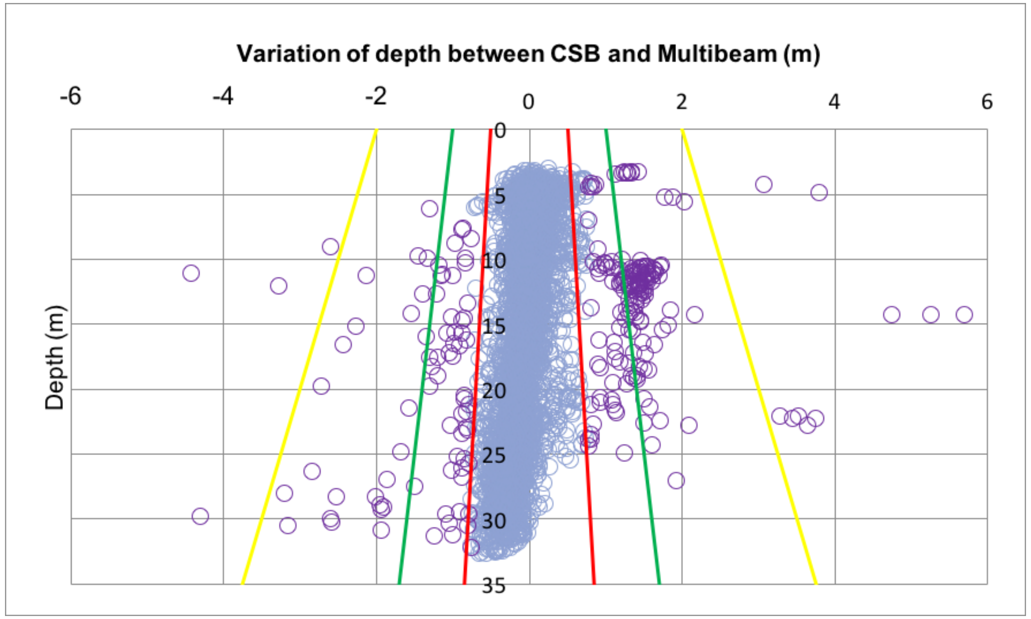
Based upon a 95% Confidence interval calculated as a scale factor of 1.96 x each site standard deviation.

CSB can conform to a S-44 Order or S-57 Class if distribution of points falls within Total Vertical Uncertainty of the relevant class boundaries.

Results: Total Vertical Uncertainty

S-44 Smeaton Pass S-57





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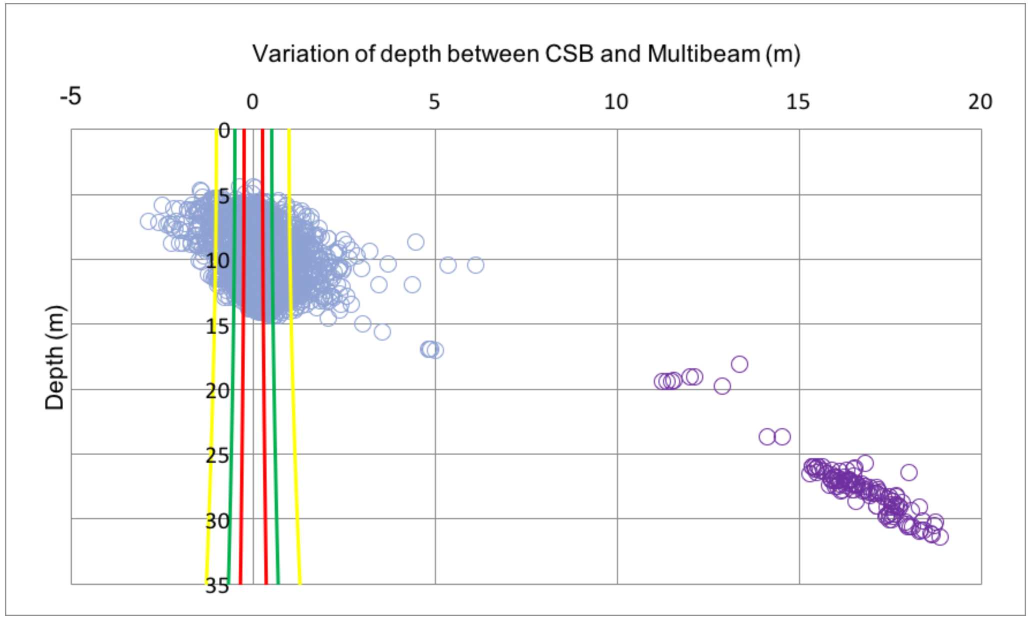
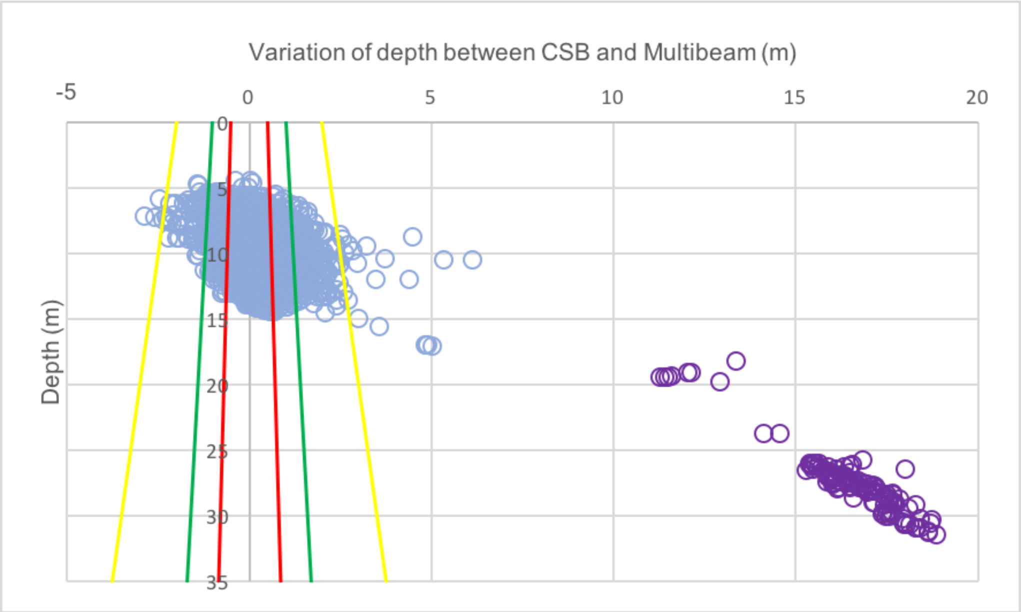
Results: Total Vertical Uncertainty

S-44 Tinker Shoal S-57





Based upon a 95% Confidence interval calculated as a scale factor of 1.96 x each site standard deviation.

CSB can conform to a S-44 Order or S-57 Class if distribution of points falls within Total Vertical Uncertainty of the relevant class boundaries.

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Results: Comparing the Six Sites

	Jennycliff Bay	Kingsands	Smeaton Pass	Drakes Channel	Cobbler Channel	Tinker Shoal	All combined
Soundings	3560	3599	6183	4937	24806	3627	46712
Area (m2)	18085	22539	114223	96611	1027196	149108	1427762
Soundings per m2	0.197	0.160	0.054	0.051	0.024	0.024	0.033
RMSE	0.165	0.359	0.388	0.899	1.943	3.098	1.693
Pearson Correlation	0.951	0.936	0.999	0.893	0.982	0.588	0.983
Mean	0.026	-0.290	-0.050	0.469	-0.076	-0.731	-0.009
Standard Deviation	0.163	0.211	0.389	0.767	1.942	3.011	1.693
95% Confidence Interval	0.319	0.414	0.762	1.504	3.807	5.902	3.318

An average of 95% of depths within 3.318 m of Multibeam, on sites that conform to S-57 Class C or above this increases to 0.5m

UKHO CHP Specification requires density of 2.25 sounding per m^2 CSB sites that achieve S-44 Orders have average 0.136 sounding per m^2

Greatest accuracies achieved on predominately flat seabed's

High data density directly related to overall accuracy

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IHO S-44 Standards of Hydrographic Surveys

Order	Special	1a	1b	2
Examples of typical areas	Harbours, berthing areas, and associated critical channels where under keel clearance is critical	Areas shallower than 100m where under keel clearance is less critical but features of concern to surface shipping max exist	Areas shallower than 100m where under keel clearance is not considered to be an issue for the type of shipping expected to transit the area	Areas deeper than 100m where a general description of the seafloor is considered adequate
Max allowable THU (horizontal accuracy) (95% confidence level)	2m	5m + 5% of depth	5m + 5% of depth	20m + 10% of depth
Max allowable TVU (depth accuracy) for reduced depths (95% confidence level)[3]	a = 0.25m b = 0.0075	a = 0.5m b = 0.013	a = 0.5m b = 0.013	a = 1.0m b = 0.023

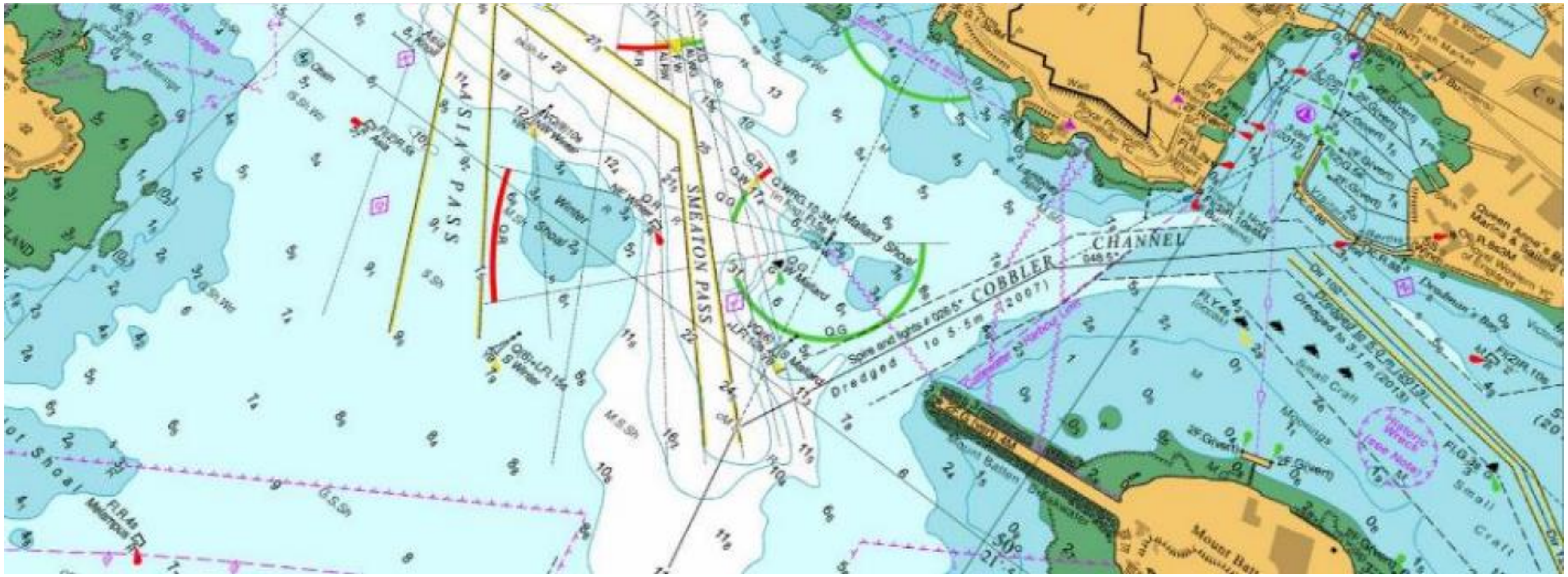
CSB can conform to Order 1b or Order 2, fails to achieve Order 1a as requires 100% seafloor coverage, unachievable with CSB.

IHO S-57 Transfer Standard for Digital Hydrographic Data

1	2	3	4	5
ZOC [1]	Position Accuracy [2]	Depth Accuracy [3]	Seafloor Coverage	Typical Survey Characteristics [5]
A1	± 5 m + 5% depth	=0.50 + 1%d Depth (m) / Accuracy (m) 10 / ± 0.6 30 / ± 0.8 100 / ± 1.5 1000 / ± 10.5	Full area search undertaken. Significant seafloor features detected [4] and depths measured.	Controlled, systematic survey [6] high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.
A2	± 20 m	= 1.00 + 2%d Depth (m) / Accuracy (m) 10 / ± 1.2 30 / ± 1.6 100 / ± 3.0 1000 / ± 21.0	Full area search undertaken. Significant seafloor features detected [4] and depths measured.	Controlled, systematic survey [6] achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder[7] and a sonar or mechanical sweep system.
B	± 50 m	= 1.00 + 2%d Depth (m) / Accuracy (m) 10 / ± 1.2 30 / ± 1.6 100 / ± 3.0 1000 / ± 21.0	Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey echosounder[5], but no sonar or mechanical sweep system.
C	± 500 m	= 2.00 + 5%d Depth (m) / Accuracy (m) 10 / ± 2.5 30 / ± 3.5 100 / ± 7.0 1000 / ± 52.0	Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.
D	worse than ZOC C	Worse Than ZOC C	Full area search not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information.
U	Unassessed - The quality of the bathymetric data has yet to be assessed			

CSB when a great enough density of data is achieved could achieve class A2 however as CSB is not a controlled systematic survey but data collected on an opportune bases its CATZOC class is C.

Why Crowdsourcing



- It’s good to challenge current charting methods
- Low cost system so mass application
- Provides coverage of area’s not usually surveyed
- Get water users invested in improving safety of navigation at sea

Future Applications

Crowdsourced Bathymetry is not a replacement for professional surveys but another tool for the hydrographer, in the same way that Lidar and SDB are. Areas of use include:

- Depth data in non-critical areas, or use as a pre-survey planning tool for a survey vessel
- Monitoring depth changes for resurveys – effectively the CSB fleet gives a continuous resurvey once established
- Ground truth data for SDB
- Feeding into DTMs, e.g. through larger projects like the Base platform project and data going into EMODNet.

Thank you very much for listening.

For further information about Crowdsourced Bathymetry please contact in the first instance :

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Tel 01865 582711
tim.thornton@teamsurv.com

This presentation was based on an article that appeared in the Spring 2017 edition of Soundings, the magazine of The Hydrographic Society UK and can be viewed at:

https://www.linkedin.com/pulse/crowdsourced-bathymetry-utilising-crowd-obtain-high-quality-baxter

For any additional questions or enquires please contact me at:

baxterc99@hotmail.com