

Developments in North Sea wide resurveying and charting of dynamic sand wave areas

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Abstract

We discuss two cases of international cooperation between hydrographic offices. The first case is the unified approach to populate the CATZOC indicator for bathymetric quality in nautical charts, in the presence of sand wave fields. The second case is the North Sea wide formulation of resurvey policies. The two cases can only be successful if it is understood and agreed how the sea floor develops. For both of the cases, it is very relevant to distinguish between the growth of a pattern, and its migration. Therefore, hydrographic offices need accurate morphodynamic models, an appropriate set of methods for the analysis of time series of bathymetric data, and versatile remote sensing techniques.

The two cases are discussed using the example of a sand wave field near the Port of Rotterdam, in the Southern North Sea. The development of the field is potentially influenced by the maintenance of dredged channels and an emergency turning zone; extensive sand pits; and two infrastructural projects in the coastal vicinity: Maasvlakte 2 and the Zandmotor.

1. INTRODUCTION

Hydrographic offices around the North Sea are faced with the challenge to resurvey and rechart areas with rhythmic patterns on the sea floor. Especially tidal sand wave fields, with wavelengths of several hundreds of metres and heights of up to several meters, are found at many locations. It is mostly unknown whether the observed patterns are dynamic, although time series of modern high resolution surveys have become available for more and more areas [Van Dijk et al., 2012a].

The most common change of a sand wave pattern is a migration, due to e.g. asymmetries in the tidal currents [Németh et al., 2002]. In such a situation, the charted depth values remain constant, according to the nautical charting principle of shoal biasing [Smith et al., 2002]: the shallowest values are selected for visualisation in the chart, implying that these values represent the shallowest

values that are likely to appear in the surrounding area. Consequently, the mariner will not notice the migratory character of the sea floor, and has to trust the prudent monitoring of pattern development by the hydrographic office.

This practice is acceptable as long as the hydrographic office is able to maintain a safe resurvey frequency for the area, and as long as there are no large-scale human interventions in the greater region of the sand wave field, with the potential to disturb the morphodynamic processes that have created the migratory sand wave field. National hydrographic survey budgets are under pressure though, which translates into a reduction in bathymetric survey capacity [Ward, 2012].

Yet the mariner expects accurate and recent information. Users of digital products, a group that grows fast now that this is mandatory for certain types of ships, are often not even aware that the source data could be less accurate due to survey age. Ship owners are aiming for a maximum

quantity of cargo, allowing for a minimum under keel clearance, also along coasts with heavy maritime traffic, sensitive ecosystems and a flourishing tourism industry. The Southern North Sea is a perfect example of such a combination of risks.

The hydrographic offices that constitute the North Sea Hydrographic Commission (NSHC) have reacted to these developments by intensifying their cooperation. This takes place on different levels. We present some developments on three levels: global, European, and North Sea wide.

2. AN EXAMPLE: THE PORT OF ROTTERDAM APPROACH

An example of an area with a challenging mix of human activities and critical depth values is the approach area to the Port of Rotterdam. The larger ships can only enter during high tide, which puts serious constraints on the quality of the survey and the chart, both in terms of measurement accuracy and in terms of update frequency. The sea floor is characterised by a dredged channel through an extensive field of rhythmic patterns with different wavelengths [Knaapen et al., 2001].

An example of a survey of the area and the large-scale chart is given in Figure 1, and the contents of the bathymetric database in Figure 2. Obviously, the sand pits are not relevant for navigation at sea. Hence they did not generate new editions of nautical charts or Notices to Mariners.

The patterns in the deeper, Western part of the area are found to be hardly dynamic [Van Dijk et al., 2012b; Dorst et al., 2011], while the pattern in the shallower Eastern part shows a clear migration [Van Dijk et al., 2012b; Dorst et al., 2008]. The heights of the sandwaves are generally found to be constant [Van Dijk et al., 2008; Knaapen, 2005], which implies that the shallowest likely depth values in the area do not change [Dorst et al., 2012a]¹.

In the area of the example, several human interventions are in progress. The coastline changes, due to the Maasvlakte 2 extension to the Port of Rotterdam and the Zandmotor megascale

beach nourishment project, are of such a scale that the tidal currents change [Dorst et al., 2012b]. The sandy sediment that the two projects use is taken out of sand pits (Figure 1) that are sufficiently extensive to affect the hydrodynamic conditions, potentially inducing a corresponding change in morphodynamic conditions [Roos et al., 2008].

3. GLOBAL DEVELOPMENTS

Within the International Hydrographic Organization (IHO), there is consensus that the visualisation of the quality of bathymetric data in Electronic Navigational Charts (ENCs) needs to be improved [Dorst & Howlett, 2012]. For future ENCs, the S-101 data model containing a hierarchical series of new quality indicators is under development. For current ENCs, produced in the S-57 data model, the “Zone Of Confidence” indicator will be populated in a more consistent manner by the national hydrographic offices.

An important consistency aspect is the assignment of a category for the Zone Of Confidence (CATZOC) in case of a mobile seafloor. Six categories can be distinguished, five of those ranging from A1 (best quality) to D (worst quality), and the sixth being U (unassessed) [Johnson, 2004]. Currently, a proposal to degrade CATZOC to category C in this case of seafloor mobility is under discussion, even in case of a recent, accurate survey without gaps. This category is described with the words “depth anomalies may be expected”.

For a migrating sand wave field, different arguments about the appropriate CATZOC value can be made. On one hand, one may argue that depth anomalies cannot be expected, as the charted depth values remain constant. Such an argument ignores the changes in surveyed depth values, which it justifies by pointing out that CATZOC applies to the charted product, not to the observed data set. Advocates of this argument even fear that degradation of such a “safe” sand wave area to a CATZOC of C could tempt mariners to enter other CATZOC C areas with insufficient care.

On the other hand, one may argue that the mariner should be informed about the mobile character of the sea floor, especially if human activities may change the hydrodynamics that drive the sea floor dynamics. Hydrographic offices may not have the resources to resurvey the area with a sufficiently

¹ In the terminology of Dorst et al. [2012a], the overall shoaling rate of the area is zero, while the maximum shoaling rate at a location within the area is larger than zero.

high frequency to detect changes in the behaviour of the pattern in time, or may otherwise not be willing to accept the risk of assigning the area with a CATZOC value of A or B. This argument would satisfy the desire to indicate the potential danger of mobile areas, rather than give a potentially false indication of a highly accurate depiction of the seafloor.

Given the challenges that the example provides, we are inclined to, at least, allow hydrographic offices to artificially degrade CATZOC to a category C for areas with dynamic patterns. Perhaps the ideal of an internationally fully consistent assignment procedure is not feasible for CATZOC, and the specifics of each sea area, as known at the national hydrographic office, have to be taken account.

4. EUROPEAN DEVELOPMENTS

On the European scale, the INSPIRE directive contributes to a European Marine Spatial Data Infrastructure (SDI) by setting requirements to publish bathymetric data in a unified and automatic way. The European EMODNet project will take this one step further by creating a single portal² from which marine datasets, like bathymetry, can be viewed and downloaded [Longhorn, 2012]. These facilities will create new opportunities for morphodynamic research, provided that researchers have powerful tools for the analysis of large volumes of spatial data.

5. NORTH SEA DEVELOPMENTS

The North Sea Hydrographic Commission (NSHC) established a Resurvey Working Group, which has been active since 2007. National hydrographic offices share their resurvey plans, with the aim to unify survey efforts at their maritime boundary areas and for international shipping routes. These routes cross several international maritime boundaries, which makes access to all major ports dependent on the survey and charting efforts of neighbouring countries³. It is a potential waste of

resources to survey more frequently than your neighbour, and a potential risk to survey less frequently.

At present, Belgium, Germany, the Netherlands and the United Kingdom have agreed to publish their resurvey prioritization together, in a single online map, for at least a part of their North Sea area. The current status of this plan is shown in Figure 3.

6. APPLICATION OF THE DEVELOPMENTS TO THE EXAMPLE

The dredged channel to the Port of Rotterdam currently has a CATZOC value of A1, and the sand wave field a CATZOC value of A2. Category A indicates that “significant seafloor features [were] detected and [their] depths measured”. Subcategory A1 and A2 differ only in their requirements for survey accuracy [Johnson, 2004]. The Netherlands Hydrographic Service is confident that these requirements are met, as frequent resurveys are done by Rijkswaterstaat (the dredged channel, several times a year to once a month) and the Hydrographic Service (the sand wave field, once every other year).

Deep draught ships are led into the channel by pilots, taking advantage of the maintained depths in the channel. This guarantees that ships with a critical depth will not access the sand wave field. Although considerations like shipping intensity and draught are not included in the assignment process of an indicator in a nautical chart, they do play a role in the determination of a safe resurvey frequency, especially when such information is available through AIS data [Ward & Gallagher, 2011; Van Dijk et al., 2011].

The assignment of a CATZOC value of C to the mobile sand wave field would require an assessment of a line where the migration becomes significant. This could for instance be done by a comparison of the CATZOC position accuracy requirements to the expected migration between

² A comprehensive bathymetric data set at a coarse resolution is directly available at the portal www.emodnet-hydrography.eu, for high resolution sub-datasets it refers to the relevant authorities.

³ Until 2012, the four countries around the English Channel had a shared policy on transboundary surveys around the

selected track for deep draught ships. The so-called Dover Strait Survey Policy was revised, in order to better reflect the national responsibilities of each country to survey its own waters.

consecutive surveys. This immediately leads us to a requirement to accurately predict migration rates. As it currently is not feasible to make reliable predictions for large parts of the sand wave fields in the North Sea, we either need to set CATZOC to a value of C for all these sand wave fields, or accept that sand wave migration is excluded from the assignment process of a CATZOC value. We reject the option to only assign a CATZOC value of C to areas, like our example, where the migration is known and deemed significant, as this option would indicate the areas of known migration as less safe to the mariner than areas of unknown migration.

The area of the example does not only facilitate intercontinental shipping through the English Channel. There is an inshore traffic zone towards Belgian and French ports, the Maas Northwest Traffic Separation Scheme (TSS) towards English and Scottish ports, and the Maas North TSS towards German and Danish ports⁴.

In the virtual case that the Netherlands were to decide to reduce resurveying efforts, there would come a moment that it is no longer defensible to classify the area with a CATZOC value of A. It would be in the interest of the national economies around the North Sea to prevent such a reduction in accessibility of their ports. But, in the absence of accurate predictions on the development of the sand wave field in the presence of the sand pits, the moment that the CATZOC value has to be degraded cannot be determined with any certainty, and such a decision cannot be discussed between the North Sea countries with factual evidence.

7. CONCLUSIONS

We discussed two cases of international cooperation between hydrographic offices: the unified approach to populate the CATZOC quality indicator for sand wave fields and the North Sea wide formulation of resurvey policies. The two cases can only be successful if it is understood and agreed how the sea floor develops. For both of the cases, it is very relevant to distinguish between the growth of a pattern, and its migration.

Within the North Sea, all national hydrographic offices have an interest in the decisions that the

other hydrographic offices make. Poor decisions may jeopardize the coasts around the North Sea, or limit the accessibility of the ports of each country. Scientific progress will enhance the insights of the hydrographic community into marine sand wave behaviour, opening up opportunities to improve survey efficiency and correct use of quality indicators in nautical charts. Hydrographic offices need accurate morphodynamic models, an appropriate set of methods for the analysis of time series of bathymetric data, and versatile remote sensing techniques.

Meanwhile, European policy decisions allow scientific institutions easier access to the bathymetric data that hydrographic offices possess. This could facilitate further progress in scientific knowledge on sand wave dynamics, satisfying the need for accurate hydrodynamic models.

8. ACKNOWLEDGMENTS

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⁴ The TSS structure in the Netherlands EEZ will change per 1 August 2013.

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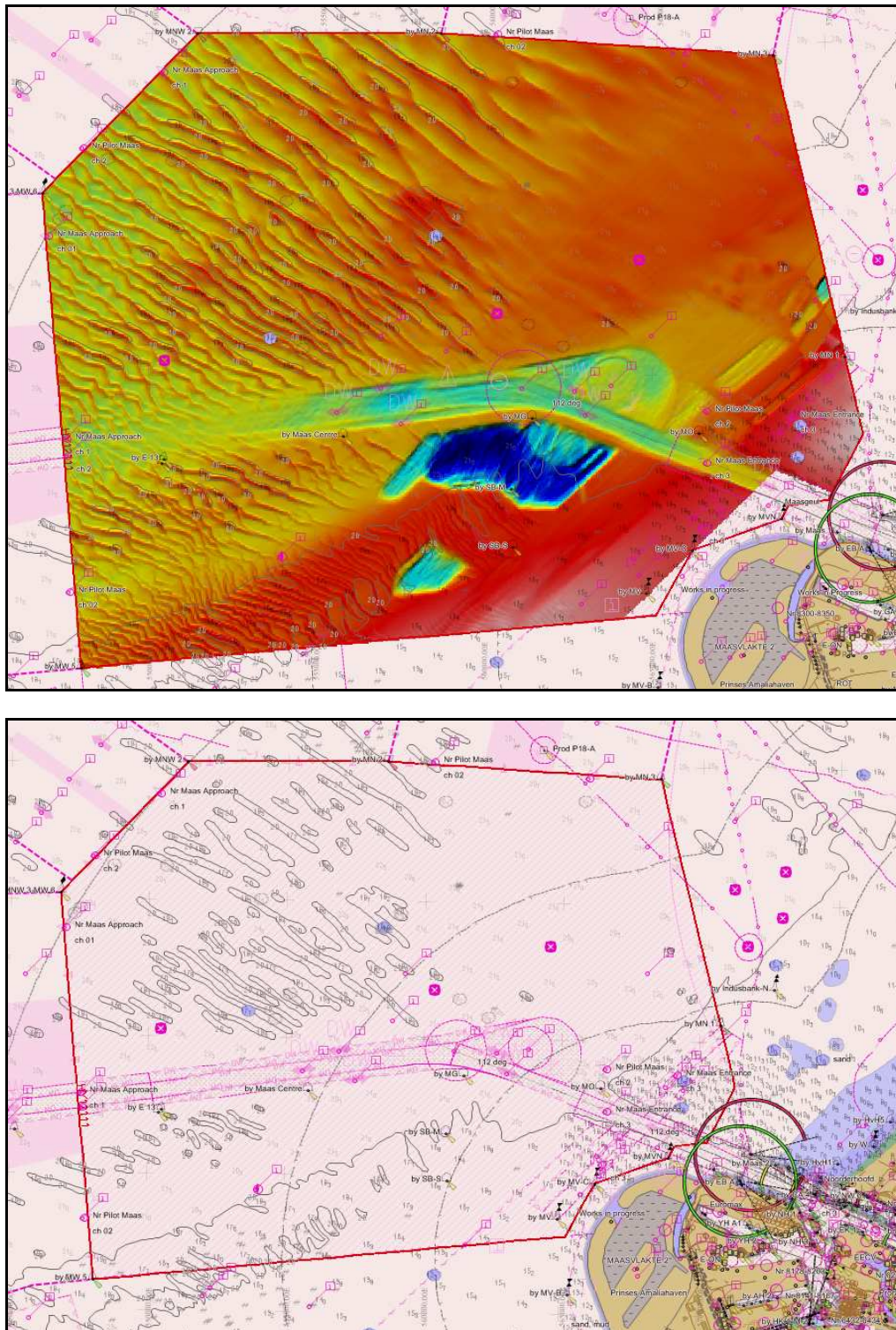


Figure 1. Bathymetric survey of the approach area to the Port of Rotterdam, HNLMS Snellius, May-July 2012 (top): notice the presence of the dredged channels, the emergency turning zone, and the sand pits for infrastructural projects like the Maasvlakte 2 (lower right) and the Zandmotor (not visible) [Dorst et al., 2012b]. Bathymetry of the approach area to the Port of Rotterdam in Electronic Navigational Chart NL400122 (bottom): notice the absence of the rather recent sand pits. A new edition is expected in the Summer of 2013. (figure courtesy of crew HNLMS Snellius)

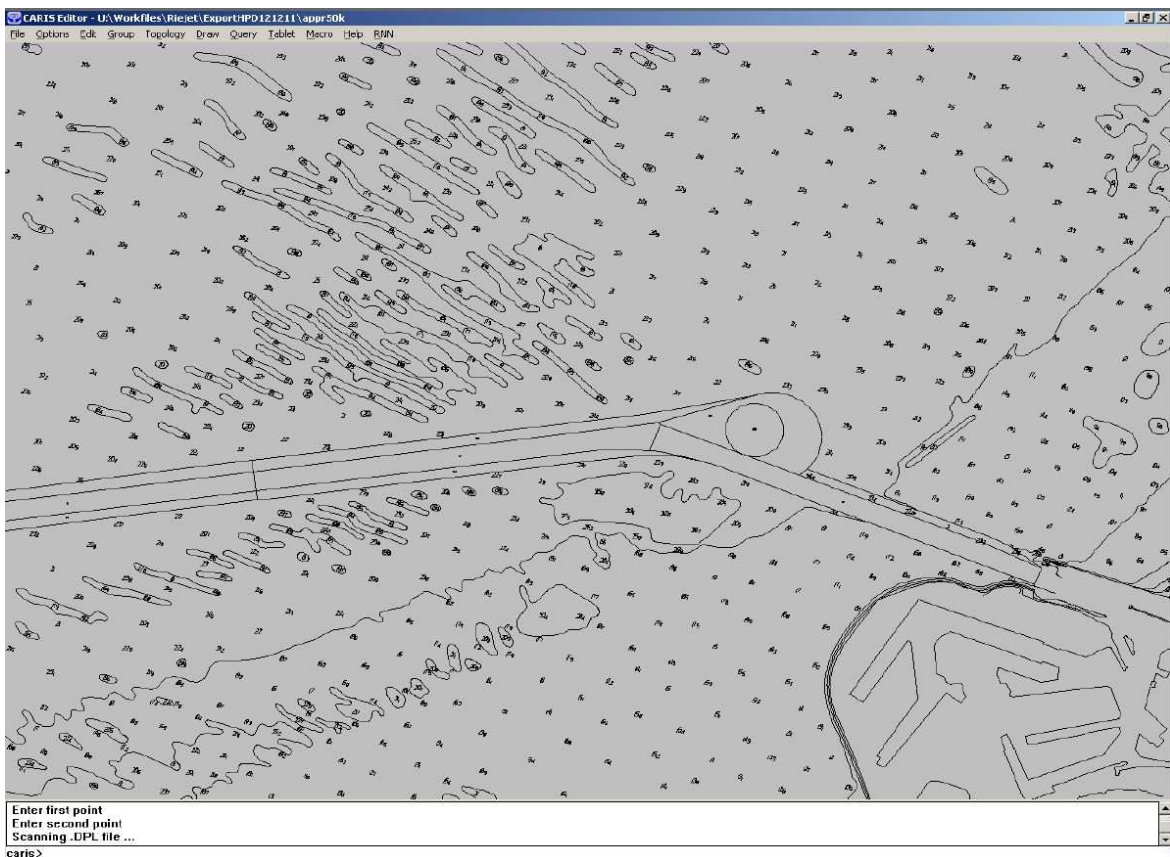
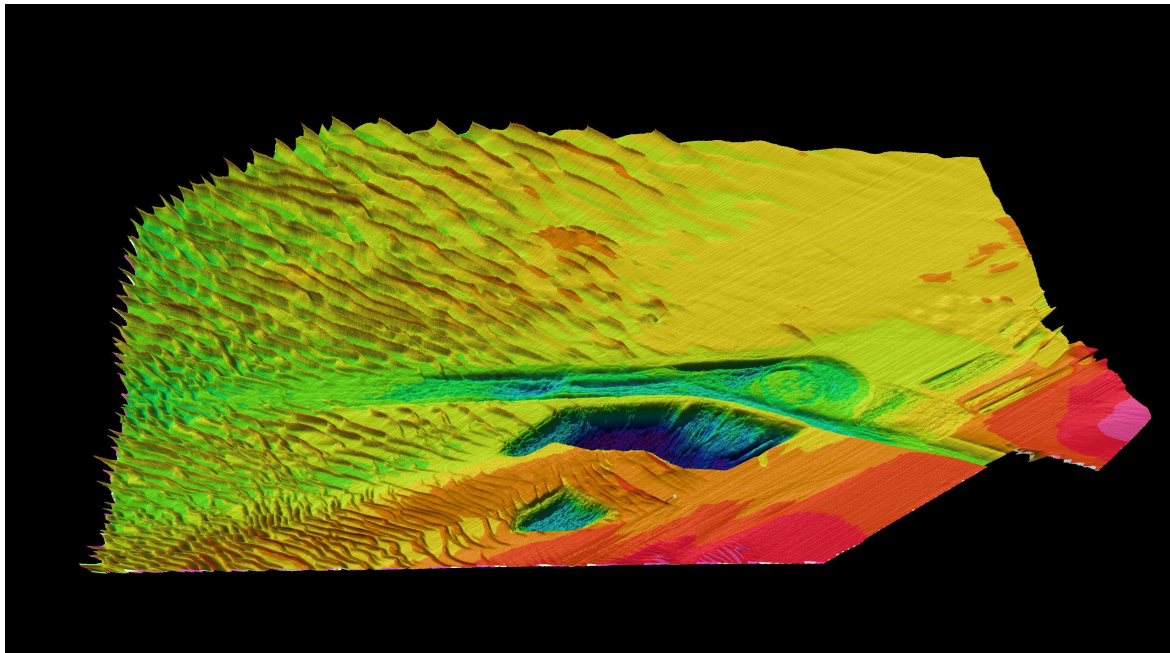


Figure 2. Bathymetry of the approach area to the Port of Rotterdam in the database of the Netherlands Hydrographic Service: digital terrain model (top) and isolines (bottom). Notice the presence of the sand pits. The isolines will be published in new chart editions expected in the Summer of 2013. (figure courtesy of Data processing department, Netherlands Hydrographic Service)

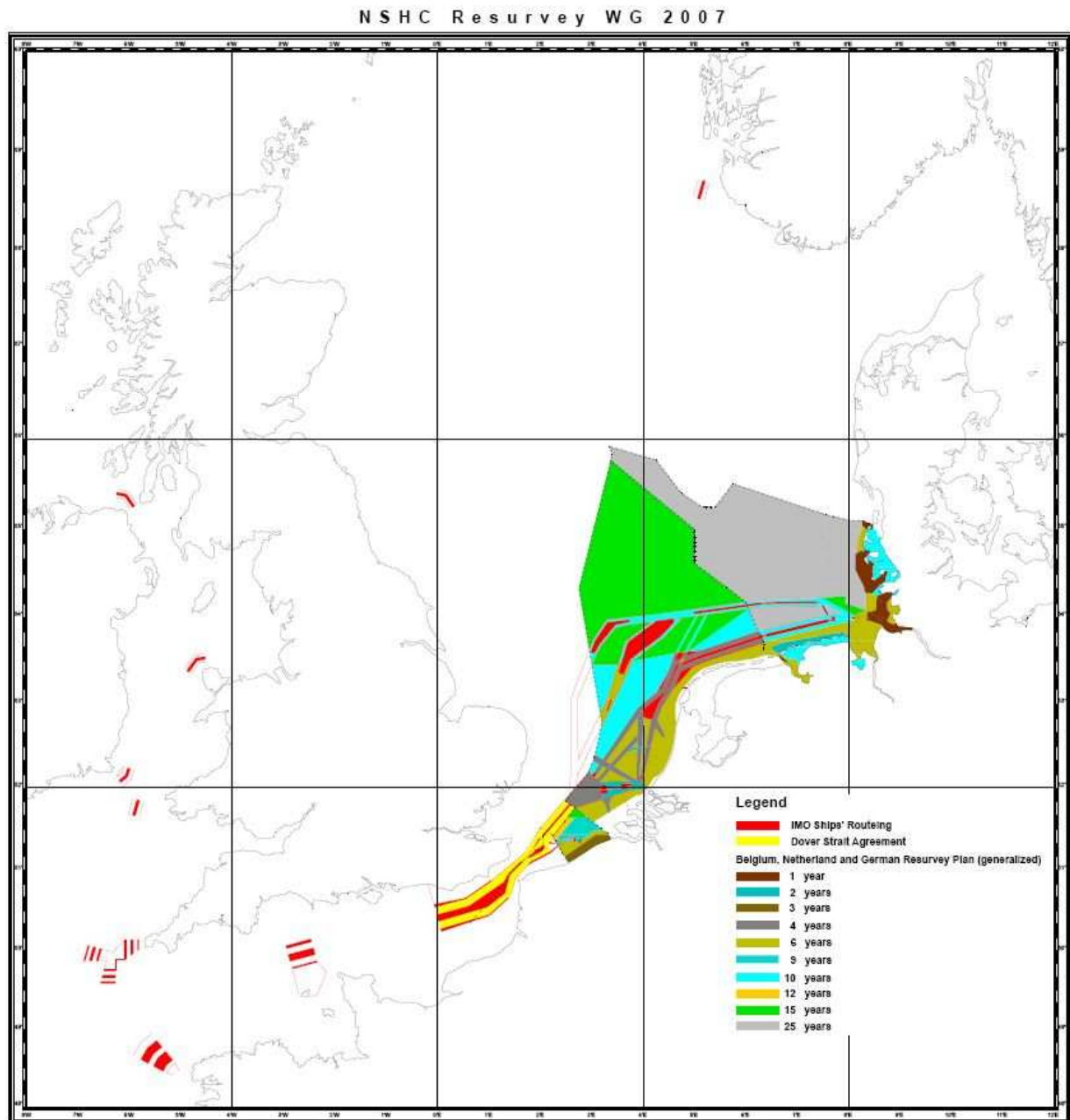


Figure 3. Resurvey prioritization map of the NSHC Resurvey Working Group. (figure courtesy of BSH)