

A GIS-based hydrographic resurvey strategy of the Belgian Continental Shelf

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Abstract

Using a GIS-based approach, bathymetric surveys and maritime traffic records were combined to determine resurvey priorities within the Belgian Continental Shelf (BCS). Four reference layers were produced: (1) water depth; (2) maximum absolute change in water depth; (3) ship traffic intensity; (4) maximum ship draught. The reference layers were reclassified and merged into a weighted overlay analysis. Two combinations of layers and weight factors were used and resulted in priority maps differing greatly from each other.

The reliability of the analysis depends on the way weight factors are assigned, and on the availability and accuracy of the data. These are limited for bathymetric surveys.

This empirical GIS-based methodology can be applied as a whole to a zone showing various morphodynamic patterns. It can also be automated: additional datasets can be included in the analysis, and different scenarios and assumptions can be easily tested.

1. INTRODUCTION

This study aims at defining a resurvey policy for the Belgian Continental Shelf (BCS). This policy should divide the BCS into zones classified according to their resurvey priority.

2. METHOD

2.1 Study area

The BCS has an area of about 3470 km². Dredging zones (56 km²) were excluded from the study because they are surveyed and dredged on a regular basis. Coastal zones (118 km²) were not considered neither: a 1.5-km wide buffer zone along the Belgian coast was defined (Figure 1).

2.2 Data

2.2.1 Bathymetric data

A series of 38 bathymetric surveys conducted between 1997 and 2011 was provided by the

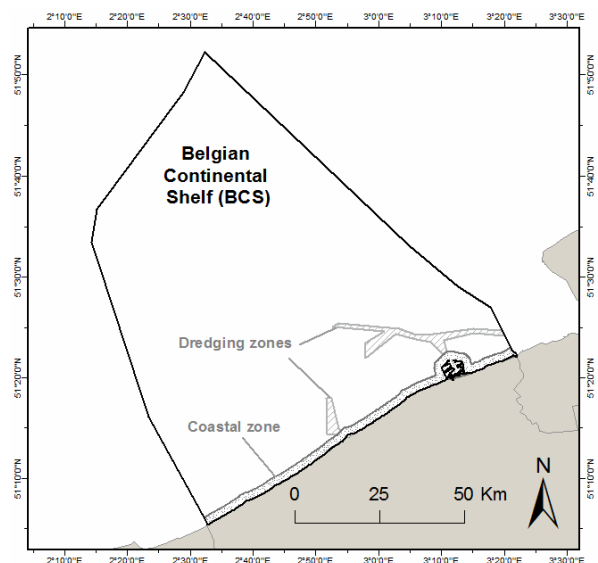


Figure 1. Study zone (Belgian Continental Shelf).

Flemish Hydrographic Service (Vlaamse Hydrografie) for this study. Most of the surveys (32) were carried out using single beam echo sounders (SBES), with a track spacing of 100 or 200 m. The rest of the surveys were carried out using SBES with a narrower track spacing (4 surveys) or using multibeam echo sounders -

MBES (2 surveys). All surveys were provided as tabular files.

2.2.2 Maritime traffic data

Ship traffic intensity and draught are measured by Automatic Identification System (AIS) signals. AIS is an automatic tracking system used on ships for identification and location. AIS signals for the period October 2010 - September 2011 were provided by Agentschap voor Maritieme Dienstverlening en Kust, the agency for maritime services, coastal mobility and public works of the Flemish Government (Maritime Rescue and Coordination Centre or MRCC) as tabular files. This represents about 3,843,000 records within the extent of the BCS.

The source records were filtered by the MRCC so that the minimum distance between two signals from the same vessel is 1 km. But there is at least one signal per hour, which means that records for an anchored vessel are less than 1 km apart.

In order to avoid counting anchored vessels as separate vessels, an extra filtering has been applied to the data. Using a grid of 1 km-wide cells, records were filtered to keep only one signal from each ship per day and per cell. When those signals from the same ship had different draught values, the signal with the largest draught value was selected. This filtering process might delete signals from a ship doing a round trip via the exact same route in the BCS the same day.

2.3 Coordinate systems

2.3.1 Horizontal coordinate system

The horizontal coordinate system of all data and maps used in this study is WGS 1984 UTM Zone 31N.

2.3.2 Vertical coordinate system

The vertical coordinate system of data used in this study is LAT (Lowest Astronomical Tide).

2.4 Method

The methodology developed here is based mainly on the validation of the resurvey policy of the Netherlands Hydrographic Office (Van Dijk et al., 2011), which is the most advanced study on resurvey strategy available among countries of the North Sea Hydrographic Commission (NSHC).

All data processing was executed using ArcGIS Desktop 10.0, the Esri GIS software.

2.4.1 Bathymetric data

Bathymetric point datasets were converted to DEMs (Digital Elevation Models) using the IDW (Inverse Distance Weighted) interpolation method, with a cell size of 25 m, search radius of 100 m, neighbours comprised between 4 and 15. These parameters were chosen based on the assumptions made by Van Dijk et al. (2011) and on the specificities of the datasets (e.g. track spacing).

A surface of minimum water depth was produced. The maximum absolute change in water depth was also computed. This maximum depth change value allows detecting zones with seafloor dynamics. Due to the lack of available bathymetric data, annual variation rates (m/year) were not calculated. For the same reason, the vertical node approach used by Van Dijk et al (2011) could not be implemented: it requires time series of at least 3 depth values to be reliable.

2.4.2 Maritime traffic data

AIS records were filtered as described in paragraph 2.2.2. Raster grid maps with a resolution of 1 km² were produced for ship traffic intensity (ships/km².year) and maximum draught (m).

2.4.3 Weighted overlay analysis

All four grids (minimum water depth, maximum absolute depth change, traffic intensity and maximum draught) were combined in a weighted overlay analysis. Values were reclassified into five classes prior to overlay in order to avoid a very large number of resulting categories. In a weighted overlay analysis, each parameter is assigned a weight factor, so that it is possible to fine-tune its importance (see equation 1):

$$RP = a*WD + b*DC + c*TI + d*MD \quad (1)$$

where RP = resurvey priority; WD = minimum water depth category; DC = water depth change category; TI = traffic intensity category; MD = maximum draught category; a, b, c and d = weight factors. The sum of all weight factors should be equal to 1. Parameters with a major influence, or with a higher accuracy, should have a greater

weight factor than parameters with a minor influence.

2.5 Results

2.5.1 Bathymetric data

The maximum absolute variation of water depth was calculated for zones with at least two available surveys. Depending on the zone, this variation is observed over a period ranging from 1 to 11 years. Mapping these changes gives a first insight into dynamic and stable zones. Zones covered with less than two bathymetric surveys represent more than half the BCS (Figure 2). The variation of water depth in these zones could not be calculated and has been fixed to a constant value (0.194 m, i.e. mean water depth change for zones with at least two surveys available).

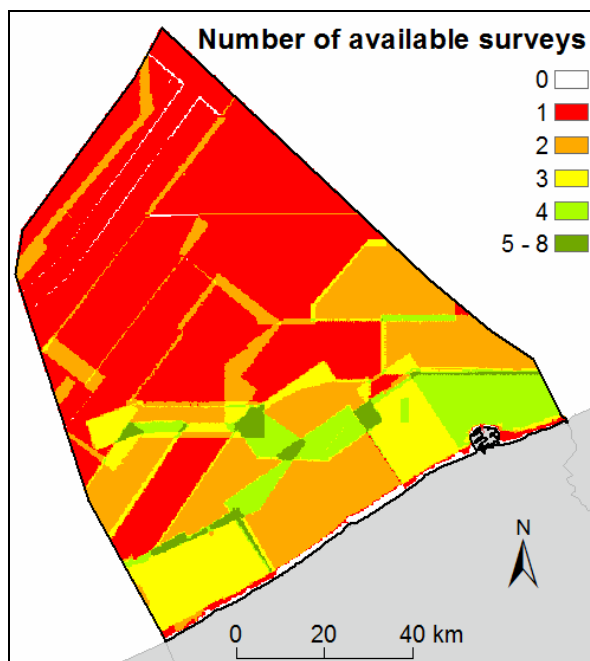


Figure 2. Availability of bathymetric surveys.

2.5.2 Maritime traffic data

AIS signal density and maximum draught were mapped after filtering of the anchored or dredging ships. Ship traffic intensity varies from 0 to 31,953 ships/km².year. Maximum draught is comprised between 1.2 and 25 m.

2.5.3 Weighted overlay analysis

Values from each dataset were reclassified into 5 categories, as detailed in Table 1.

Table 1. Initial and reclassified values and weight factors for water depth, water depth change, ship traffic intensity and maximum draught.

Layer	Initial range of values	Reclassified value	Weight	
			1	2
Water depth (m)	< -20	1	0.50	0.50
	-15 - -20	2		
	-8 - -15	3		
	-3 - -8	4		
	> -3	5		
Maximum water depth change (m)	< 0.1	1	0	0.20
	0.1 - 0.3	2		
	0.3 - 0.5	3		
	0.5 - 1	4		
Ship traffic intensity (ships/km ² .year)	< 10	1	0	0.10
	10-100	2		
	100 - 500	3		
	500 - 1000	4		
	> 1000	5		
Maximum draught (m)	< 3	1	0.50	0.20
	3 - 8	2		
	8 - 15	3		
	15 - 20	4		
	20 - 25	5		

The greater the reclassified value and weight, the greater the resurvey priority should be.

The values used to reclassify water depth and maximum draught correspond to the maximum ship draught allowed in the following ports: Nieuwpoort (up to 3 m); Oostende (up to 8 m); Zeebrugge (up to 15 m); Antwerp (up to 20 m); Rotterdam (above 20 m).

Maps of the reclassified parameter values are shown in Figure 3 through Figure 6.

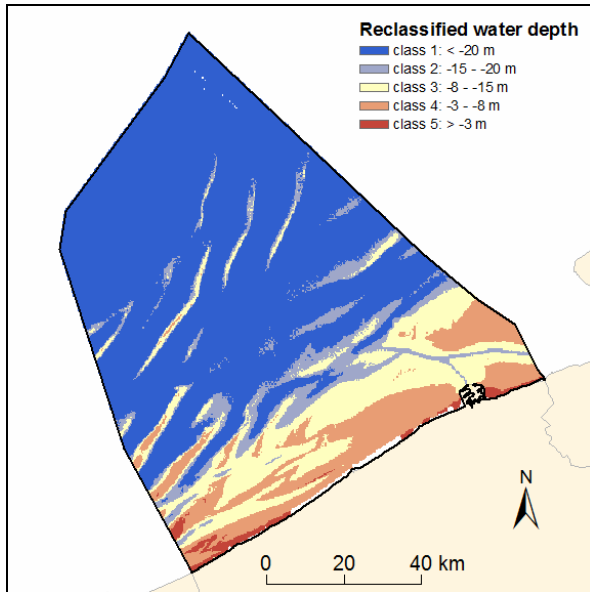


Figure 3. Reclassified water depth values.

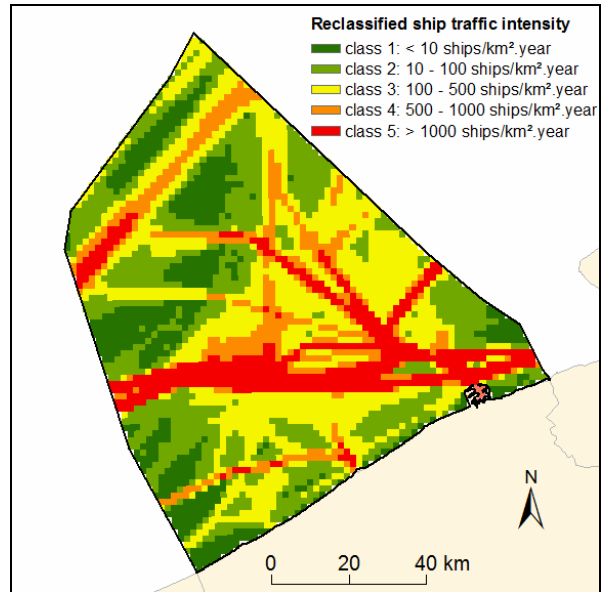


Figure 5. Reclassified ship traffic intensity values.

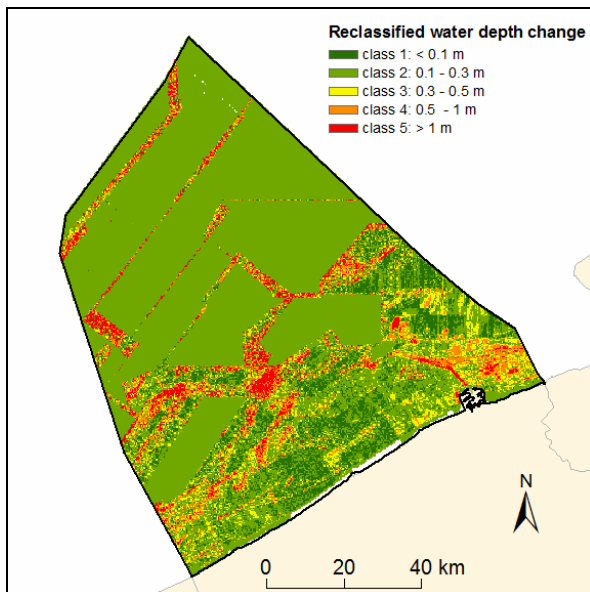


Figure 4. Reclassified water depth change values.

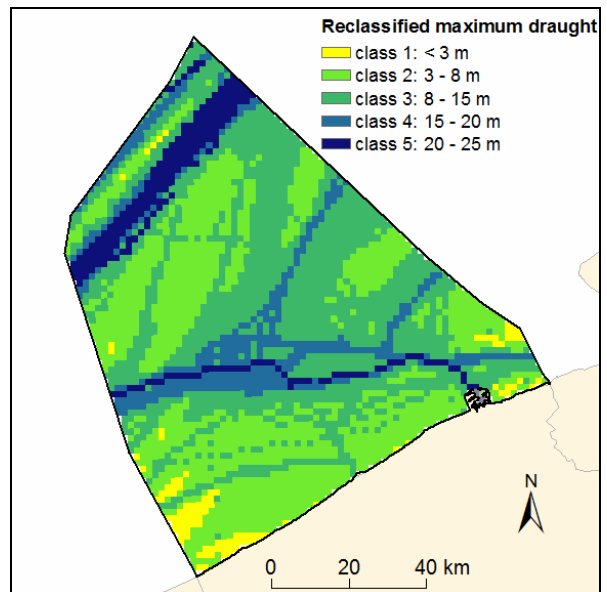


Figure 6. Reclassified maximum draught values.

The weighted overlay analysis was performed using two different combinations of parameters and weight factors: (1) only water depth and maximum draught are considered and have the same influence (50% each); (2) all four parameters are considered and have various weights (see Table 1).

The result of the weighted overlay analyses is shown in Figure 7 and Figure 8.

Priority zones were then drawn manually to fit the limits of the BCS, the dredging and coastal zones, and as much as possible, the overlay layers (Figure 9 and Figure 10). These priority maps show noticeable differences, emphasizing the importance of the choice of parameters to be included in the analysis and of the weight factors assigned to these parameters. Only four categories could be distinguished for both cases.

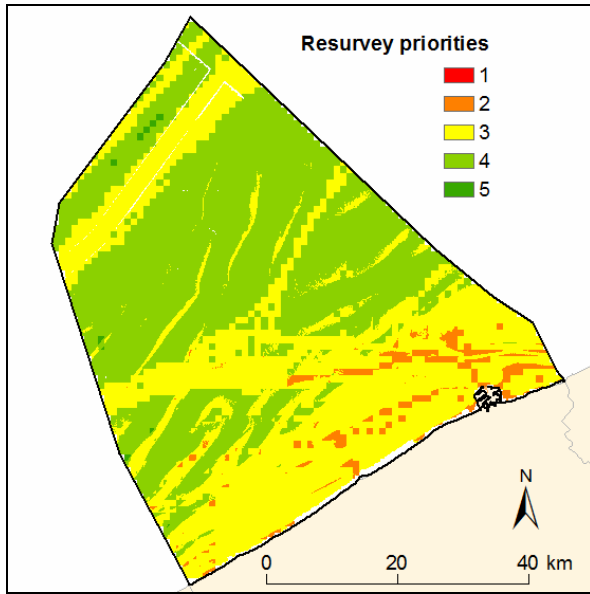


Figure 7. Result of the weighted overlay analysis based on two equally weighted parameters. Category 1 should have the highest resurvey frequency and category 5 should have the lowest frequency.

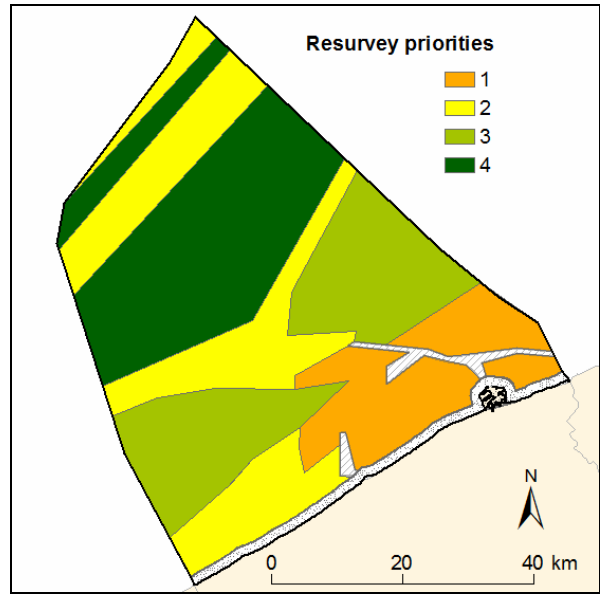


Figure 9. Proposed resurvey priorities based on the 2-parameter weighted overlay analysis. Category 1 has the highest resurvey priority and category 4 has the lowest priority.

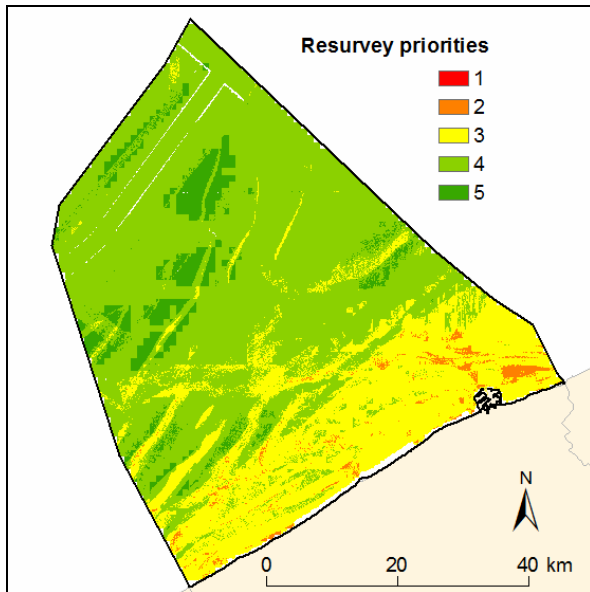


Figure 8. Result of the weighted overlay analysis based on four parameters. Category 1 should have the highest resurvey frequency and category 5 should have the lowest frequency.

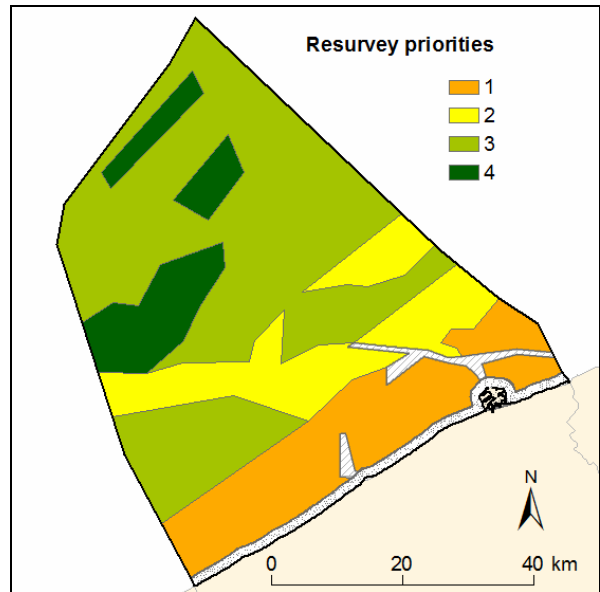


Figure 10. Proposed resurvey priorities based on the 4-parameter weighted overlay analysis. Category 1 has the highest resurvey priority and category 4 has the lowest priority.

The relative area of priority zones is given in Table 2.

Table 2. Relative area of the resurvey priority zones and other activity zones in the BCS.

Zone	Area – Case 1	Area – Case 2
	Percentage of the BCS	Percentage of the BCS
Priority 1	15	18.5
Priority 2	27	16
Priority 3	23.5	50.5
Priority 4	29.5	10
Dredging zones	1.5	1.5
Coastal area	3.5	3.5

3. CONCLUSIONS

A resurvey priority scheme was defined based on bathymetric data and maritime traffic data (AIS). The data was processed using the ArcGIS software and four reference layers were obtained (water depth, maximum absolute change in water depth, traffic intensity and maximum draught values). These reference layers were combined in a weighted overlay analysis to produce maps of the BCS split into zones indicating resurvey priority. The weighted overlay analysis was chosen because it allows modifying the influence of each parameter on the final result. In the future, the following improvements could be brought in order to get a more reliable picture of the resurvey priorities:

- Analyse a larger number of bathymetric datasets. Less than two datasets were available for about half the BCS, making it impossible to detect bathymetric variations in these zones.
- Use MBES datasets instead of SBEs datasets. The accuracy of MB echo soundings is much greater than SB echo soundings.
- Validate the draught values of AIS signal records. These values are entered manually by the vessel staff and are prone to errors. It was not possible in this study to validate the draught values.
- Fine-tune the reclassification of values and choice of weight factors assigned to each parameter in the weighted overlay analysis, to

better reflect the influence of each factor on resurvey priority. This implies a sound understanding of bathymetry, sand dynamics and maritime navigation.

4. ACKNOWLEDGMENT

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- Sandrine Le Jeune, student in Hydrography at ENSIETA and Serge Lannuzel from SHOM, provided information about the resurvey policy of France. Sandrine also sent the questionnaires she developed in the framework of her traineeship.

5. REFERENCES

- Van Dijk, T.A.G.P., Van der Tak, C., De Boer, W.P., Kleuskens, M.H.P., Doornenbal, P.J., Noorlandt, R.P. and Marges, V.C. 2011. The scientific validation of the hydrographic survey policy of the Netherlands Hydrographic Office, Royal Netherlands Navy. Deltares report 1201907-000-BGS-0008, 165 pp.