

A FIRST PHASE IN THE HABITAT CLASSIFICATION FOR THE ZEESCHELDE : BED FORM CLASSIFICATION.

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ABSTRACT

Within the scope of the long term vision of the Schelde estuary and the Development Outline 2010 low dynamic intertidal and shallow water areas are considered to be of high ecological value. These areas are in fact linked to eutrophic foraging zones for birds and young fish and to refugees for tidal migrators. However, this assumption is based on experiences in other areas and there is no evidence that all parts of the shallow water area are equally valuable. Little is known about the occurrence of such valuable areas in the Schelde estuary, nor are the physical and morphological processes which determine the occurrence of these areas fully understood.

Following research on this topic on the area near the Walsoorden Sandbar in the Westerschelde (the Netherlands) in 2008-2009, a new research project was defined to determine relationships between physical, sedimentological and ecological characteristics in the Zeeschelde (Belgium) and to set up a classification of undep subtidal and intertidal areas.

A first step in the habitat classification comprised of a detailed analysis of 5 sub areas, each characteristic for a certain salinity zone. The first phase of the analysis of the subareas consisted of an analysis of multibeam echo sounding data in respect to the occurrence of bed forms, which resulted in a classification of each sub area in a limited amount of bed form classes.

In a second phase a numerical hydrodynamic model was used to determine hydrodynamic characteristics for each of the subareas. Based on the results of the first two phases, accordance between hydrodynamic and physical characteristics was sought, but none could be found. However more insight was obtained about the range of bedform sizes and the configuration of hydrodynamic zones. In a last phase data from the first two steps will be combined with ecological parameters to try and find relationships and develop a map of the spatial variation of the ecological value for the different sub areas.

Keywords: Habitat classification, Zeeschelde, Bed forms, Hydrodynamics, ecology

INTRODUCTION

Within the scope of the long term vision of the Schelde estuary and the Development Outline 2010, low dynamic intertidal and shallow water areas are considered to be of high ecological value. These areas are in fact linked to eutrophic foraging zones for birds and young fish and to refugees for tidal migrators as shrimps. However, this assumption is based on experiences in other areas and there is no evidence that all parts of the shallow water area are equally valuable. Little is known about the occurrence of such valuable areas in the Schelde estuary, nor are the physical and morphological processes which determine the occurrence of these areas fully understood. Therefore, a research project was defined in 2008-2009 to investigate the relation between on one hand the bed forms, hydrodynamics and sediment properties and on the other hand the ecological value of the shallow water areas (Plancke, Y. 2009). The project was conducted by NIOO-CEME in collaboration with Flanders Hydraulics and IMARES, and focused on the area near the Walsoorden Sandbar in the Westerschelde (the Netherlands).

This study resulted in a criterion based on abiotic parameters (depth and duration during a full tidal cycle in which flow velocity exceeds 65 cm/s) that was able to predict habitats with a high ecological value. Where this criterion was found for only one specific area of the Schelde estuary, a validation is necessary. Therefore 2 new studies were started: one to validate the criterium in the Westerschelde, a second one to validate it in the Zeeschelde. This paper describes the results of the abiotic analysis in the Zeeschelde. In a first phase a bed form classification was made for 4 specific subareas (spread over the full salinity gradient), based on multibeam echo sounding data. In a second phase the hydrodynamics were analyzed, while in the third phase it was investigated whether relations existed between bed form and hydrodynamic characteristics.

BED FORM ANALYSIS

1.1 Study Area and used data

Within the Zeeschelde detailed research will be conducted in 4 subareas. These subareas were selected in such a way that within each of the salinity zones in the Zeeschelde a vast undeep water area could be analyzed. The selected subareas are (Figure 1):

- Mesohaline : Schaar van Ouden Doel and Galgenschoor
- Oligohaline : Notelaer and Ballooi
- Freshwater with long residence time : Branst
- Freshwater with short residence time : Appels

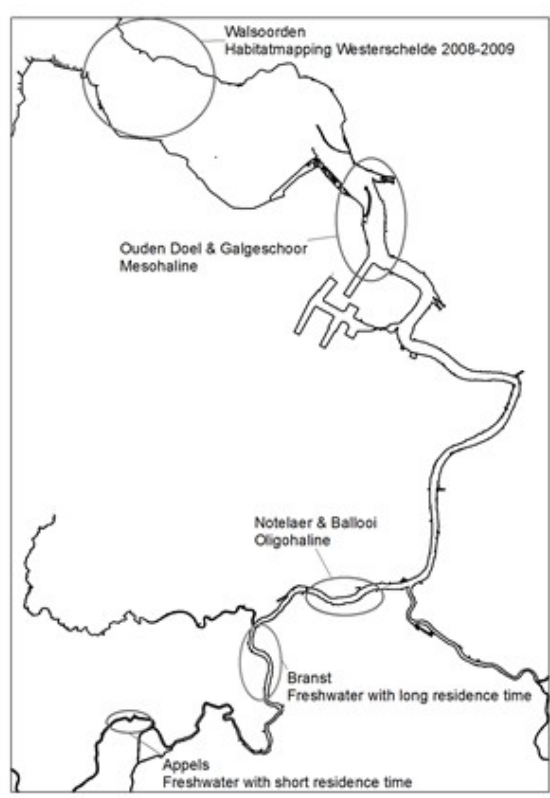


Figure 1. Location of analyzed subareas in the Schelde estuary.

The bathymetry for the Beneden Zeeschelde is based on multibeam echo sounding measurements from 2011, the bathymetry for the Boven Zeeschelde was composed of data from 2009, 2010 and 2011. For the intertidal area LIDAR data from 2011 was used.

1.2 Methodology

The analysis was executed using the following steps:

- 1 Visual classification in zones, starting from the shaded view image of the area
- 2 Selection of zones without bed forms
- 3 Definition of several longitudinal transects (along the direction of the flow) within each zone with bed forms
- 4 Analysis of each transect for following parameters: average length, average height, average asymmetry and average steepness of the bed forms
- 5 Classification of the sub area in a limited amount of bed form classes

1.2.1 Visual classification in sub areas

A so-called "shaded view" map was used as a base for the visual classification in sub areas. This computer-generated map shows a simulated cast shadow of sun upon a raised bathymetry. The angle from which the light shines on the bathymetry was chosen so as to be able to discern the bed forms optimally. The optimal angle was found to be parallel to the direction of the flow, because the direction of bed forms is expected to

be perpendicular to the direction of the flow. Based upon this “shaded view” images, different sub areas were delimited (see zoom detail in Figure 3). Boundaries were defined visually in those places where differences in bed forms appeared to occur.

1.2.2 Selection of zones without bed forms

While determining the zones without bed forms, a distinction was made between flat zones and zones with irregular bed forms (caused by geological hard layers or human interference such as sediment disposal or extraction). The difference between zones without bed forms is not always clear on the basis of topobathymetric maps. Especially the recognizing of hard layers, which can have both an irregular as a flat gradient, is often not easy. The in situ sediment sampling campaign that was conducted in the scope of this research, made this distinction clearer.

1.2.3 Definition of longitudinal transects

Within every subarea some longitudinal transects were defined, assuming that these sections are representative for the whole subarea. If possible, the length of the transects was made long enough to ensure a sufficient number of bed forms was included in the transect, in order to be able to conduct a representative analysis. The depth values of these sections were exported from a 1m*1m raster covering the study area using GIS-software.

1.2.4 Analysis of the transects to obtain characteristic parameters

For every longitudinal transect following characteristics were deduced:

- Length of the individual bed forms
- Height of the individual bed forms
- Asymmetry of the individual bed forms
- Average steepness of the bed forms per transect

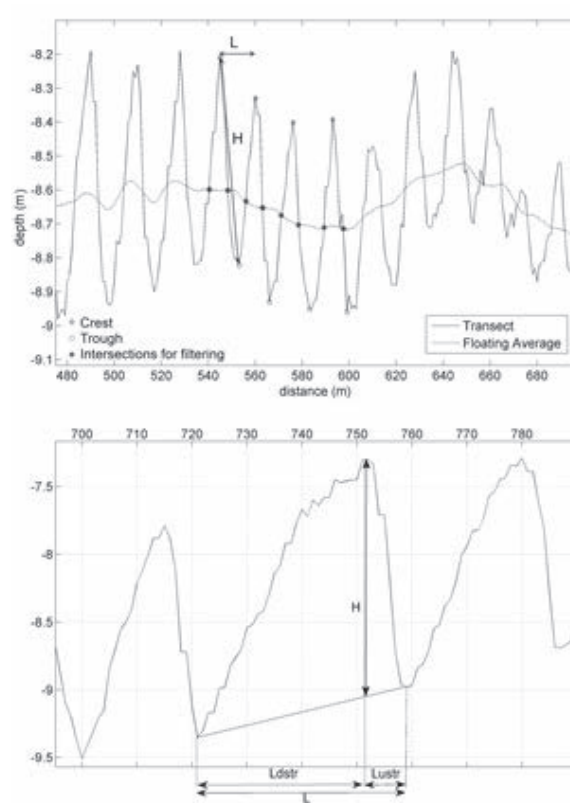


Figure 2. Methodology for determining characteristic parameters, above: step 1 – 4, below: step 5 – 7.

This analysis was executed using a self developed Matlab routine, based on the methodology used in the Bed form Tracking Tool (van der Mark et al. 2007). This routine consists out of the following steps to define the characteristic parameters of the bed forms in a certain transect (Figure 2) :

- 1 Choosing a period for a floating average to remove trends (large scale depth variation) from the section without losing the individual bed forms.

- 2 Detrending of the section by subtracting the floating average from the original data.
- 3 Determining the intersections of the detrended signal and the zero-line.
- 4 Determining the crests and troughs, based upon the assumption that between two intersections with the zero-line, a crest or a trough can be found.
- 5 Determining the length of every individual bed form, defined as the distance between 2 successive crests.
- 6 Determining the height of every individual bed form, defined as the difference between the height of a crest and the following trough.
- 7 Determining the asymmetry of every individual bed form, defined as the ratio between the inclination length (Ldstr) and the declination length (Lustr) of the bed form (from trough to trough).
- 8 Determining the average steepness per transect, defined as the ratio between the average height and the average length of the bed forms (from trough to trough) in that section.

Next, the characteristics of the individual bed forms were averaged per transect. The resulting average values for length, height and asymmetry were filtered to minimize outlier-effects : all values outside the interval $[0,25 \cdot \text{average} : 1,75 \cdot \text{average}]$ were discarded and a new average was calculated using the remaining values.

The transects were always defined from down-estuary to up-estuary side. Thus, an asymmetry value greater than 1 implies a bed form where the seaward side is longer than the landward side. This indicates flood dominance. A value smaller than 1 indicates ebb dominance.

1.2.5 Classification of the study area in a limited amount of bed form classes

In order to group the different sub areas in a feasible amount of classes, the averaged characteristics were compared to each other and classified according to the classification used in the 2008-2009 Walsoorden research project. This makes it easier to compare the results of the Zeeschelde research project with those of the Westerschelde research project. Table 1 shows the classification based on length and height of the bed forms, table 2 shows an overview of the asymmetry classes.

Table 1. Overview of length/height classes

| Class | Length | Height |
|-------|-----------|--------------|
| 1 | < 10 m | < 5 cm |
| 2 | ~ 10 m | 15 – 30 cm |
| 3 | 10 – 15 m | 30 – 50 cm |
| 4 | 15 – 25 m | 50 – 100 cm |
| 5 | 15 – 30 m | 100 – 150 cm |
| 6 | > 30 m | > 150 cm |
| 7 | > 30 m | < 100 cm |

Table 2. Overview of asymmetry classes

| Class | Asymmetry |
|-------|---------------------------------|
| 1 | < 0,90 (ebb dominance) |
| 2 | 0,90 – 1,10 (no dominance) |
| 3 | 1,10 – 1,50 (flood dominance) |
| 4 | > 1,50 (strong flood dominance) |

1.3 Results

Based on the mean length, height and asymmetry of the bed forms per transect, each of the zones is attributed to one of the bed form and asymmetry classes. A class 0 is also defined, holding the zones with irregular bed-surface. Where small bed forms are superposed on larger ones (e.g. dunes of class 5 with superposition of ripples of class 2), a combined class number is attributed (e.g. class 5,2). In figure 3 an example of the length/height classification for the subarea Notelaer/Ballooi can be found, figure 4 shows the length/height classification for the subarea Appels.

The subareas Ouden Doel and Galgeschoor in the Beneden Zeeschelde are strongly influenced by human interference (disposal/sand extraction). This means only few zones contain bed forms, which makes it difficult to draw general conclusions on the occurrence of bed forms. Most of the bed forms in this area are small ripples (class 2).

In the other sub areas, in the Beneden Zeeschelde, bed form characteristics are more diverse. Next to zones with smaller ripples, sub areas Notelaer/Ballooi and Branst also contain dunes and dunes with superimposed ripples. In sub area Appels no dunes can be found, but ripples from class 3 are present, next to the small class 2 ripples.

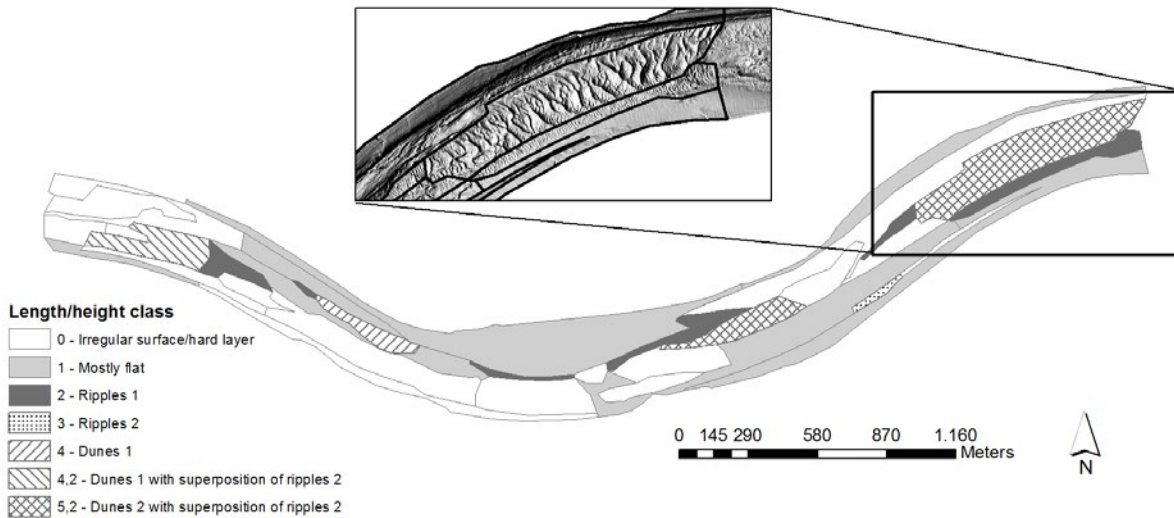


Figure 3. Notelaer and Ballooi: classification in length/height classes, based on shaded view map.

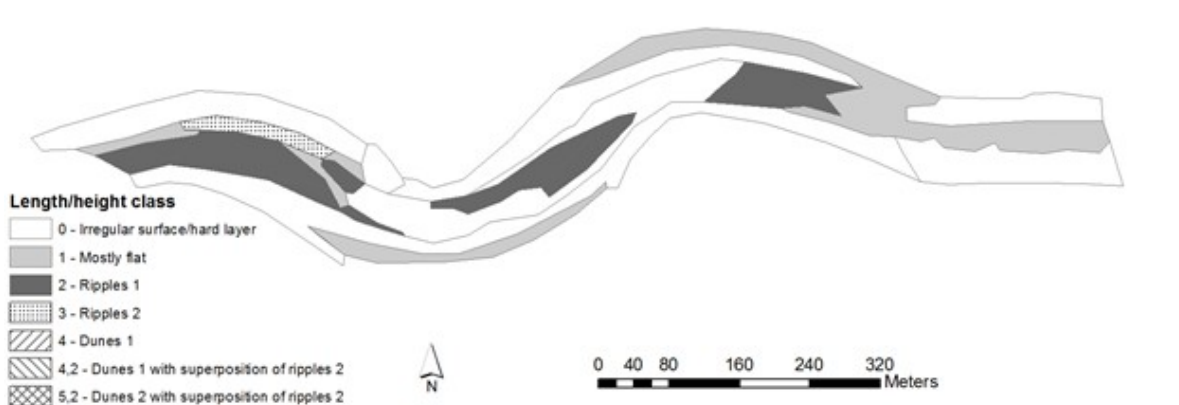


Figure 4. Appels: classification in length/height classes.

It was noticed that most of the classes with bed forms are located in the deeper, central parts of the river.

The classification in asymmetry classes is executed using the classes in table 2. Class 0 is again used for zones with irregular bed surface, while a class 5 was defined for zones where different transects are characterised by different asymmetry.

Most areas are flood dominant, but within each sub area ebb dominant zones (or zones with no dominance) are found. No relationship can be found though between location of the zones and dominance class.

HYDRODYNAMIC ANALYSIS

In a next phase of the study the relation between the occurrence of bed forms and hydrodynamic parameters was analysed.

1.4 Used data

A 2D validated numerical model was used as a base for the hydrodynamic analysis (Maximova, T. 2013). This model is a refined version of the NEVLA-model (Maximova, T. 2009; Verheyen, B. 2012), which was too coarse to be able to predict the velocities in sufficient detail for this study in the upper part of the estuary.

The downstream boundary of the model is located at Walsoorden; the upstream boundary is located at the tidal border. Measured water levels at Walsoorden (HMCZ database) are used as a downstream boundary condition. Measured discharges are used as an upstream boundary condition. The time step used for the model simulations is 3s. For the bathymetry, the multibeam and LIDAR data from the bed form analysis was used in the model.

Every 10 minutes a "map file" with flow fields was exported for the period from 26/06/2009 to 27/06/2009 (spring tide conditions).

1.5 Methodology

Based upon the flow fields, following characteristic hydrodynamic parameters were deduced:

- Average flood velocity
- Average ebb velocity
- Ratio average flood velocity to average ebb velocity
- Maximum flood velocity
- Maximum ebb velocity
- Duration that flow velocities exceed 65 cm/s during one spring tidal cycle (figure 5 shows the duration map for Appels).

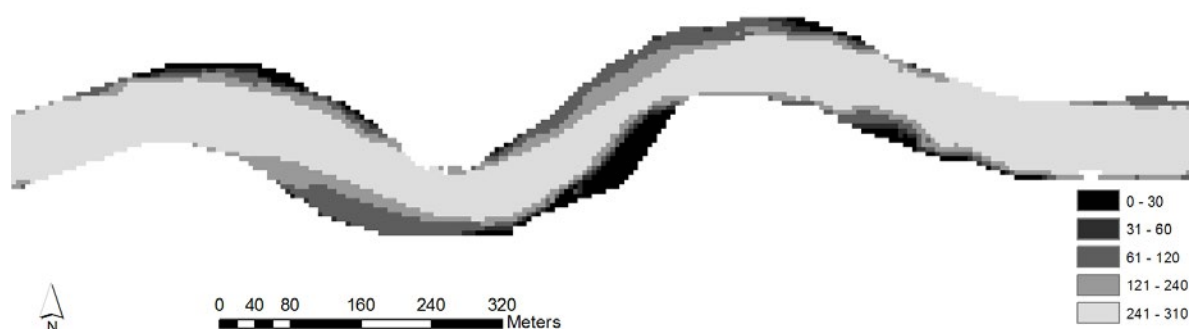


Figure 5. Appels: duration that flow velocities exceed 65 cm/s during one spring tidal cycle.

Similar to the bed form analysis, the hydrodynamic analysis was performed using 2 types of classification: on one hand a classification based on the magnitude of average velocities, on the other hand a classification based on the ratio between average velocities.

For the first classification, the used boundary values are related to characteristic velocity boundaries for e.g. initiation of sediment transport (Flanders Hydraulics Research, 2007) and low vs. high dynamic conditions (Bouma et al., 2005). For every point in the flow field, ebb as well as flood velocity was classified using these boundary values, and based upon the combination of ebb and flood velocity the eventual classification was made.

1.6 Results

The hydrodynamic analysis shows an increase of velocities with increasing depth. The duration during which flow velocities are higher than 65 cm/s exceeds 240 minutes almost everywhere, except along the river banks and on the leeward side of the guiding wall. Flood/ebb ratio shows a similar pattern in all sub areas, namely an alternating pattern of ebb- and flooddominated zones along each river bank.

ON-GOING RESEARCH

Based on the bed form classification the Research Institute for Nature and Forest took ca. 200 samples, stratified random over the different classes and subareas. At this moment the samples are being analysed on both grain size as the density and number of benthic species. These results will be used to investigate whether relations exist between the abiotic characteristics presented in this paper, and the biotic characteristics.

CONCLUSIONS

Based on the bed form classification and hydrodynamic classification a relationship was sought between both aspects. Therefore the hydrodynamic characteristics were attributed to the bed form classes by calculating the average value per bed form zone for each of the hydrodynamic parameters. Figure 6 shows an example of the classification, based on the ratio between average flood and ebb velocity.

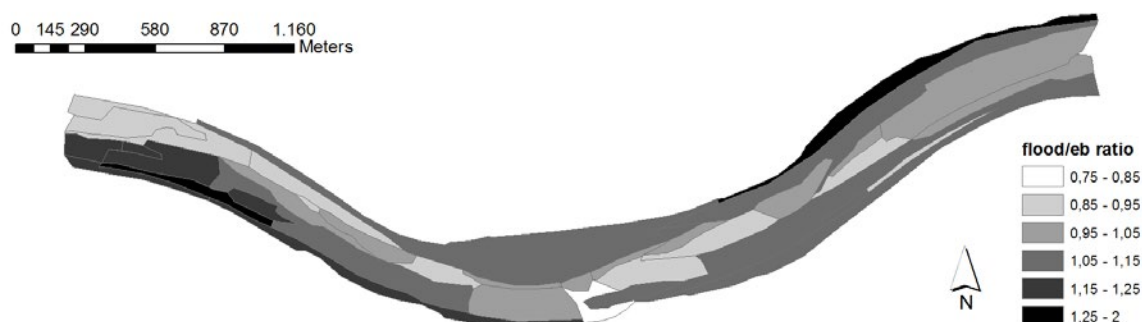


Figure 6. Notelaer and Ballooi: classification in hydrodynamic classes based on flood/eb ratio

Next scatterplots were made to search for a relationship between the occurrence of certain types of bed forms and each of the hydrodynamic characteristics (Figure 7 shows the relationship between height and maximal flood velocity).

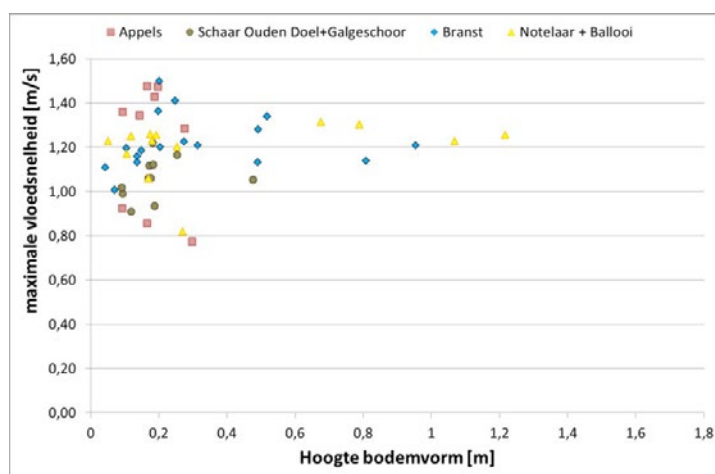


Figure 7. Relationship between height and maximal flood velocity.

A clear relationship between hydrodynamic and bed form characteristics could not be found. A general increase of the size of the bed forms with increasing velocities can be determined, but the scatter is fairly high. However, between depth and bed form size a slightly better relationship can be found ($R^2 = 0,568$).

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