

## A SMOOTH SCHELDT

JELMER CLEVERINGA<sup>(1)</sup> & MARCEL TAAL<sup>(2)</sup>

<sup>(1)</sup> ARCADIS BV, Amersfoort, The Netherlands,  
jelmer.cleveringa@arcadis.nl

<sup>(2)</sup> Deltares, Delft, The Netherlands,  
marcel.taal@deltares.nl

### ABSTRACT

The Western Scheldt is the seaward part of the Scheldt estuary with a pronounced multichannel morphology and extensive intertidal flats. Observations of the bathymetry and aerial photographs of the intertidal and supra-tidal environments over the last 60 years reveal distinct transformations of the morphology on various spatial scales. The overall change is from an irregular distribution of intertidal flats with branching channels and shallow areas towards smooth tidal flats in between the main channels. A decline in the number of small tidal channels – ebb- and flood chutes and channels that connect the main ebb- and flood channels, is observed throughout the Western Scheldt. The large number of small tidal flats have merged into a limited number of bigger entities, and the jagged edges of the flats have given way to almost straight water lines. The surface area of the intertidal flats that is covered with mega-ripple fields has decreased. Mechanisms that account for the changes on all scales throughout the Western Scheldt have not been recognized. So far intrinsic pattern development and/or the closure of branching tidal basins are recognized as candidates to explain the changes.

*Keywords:* Estuary, Morphology, Bed forms

### 1. INTRODUCTION

The Scheldt estuary is one of Europe's larger estuaries. The estuary has its seaward part – The Western Scheldt- in the Netherlands and the landward parts in Flanders (figure 1). The estuary serves as a shipping lane and hosts major harbors. The estuary is recognized as a wetland of international importance and protected under EU-legislation (the Habitat- and Bird-Directives). The estuary funnels storm surges to the hinterland and thus requires flood-protection schemes to protect the inhabitants and economic activities on its banks. The important (ecosystem) services provided by the estuary require a careful management to balance their often contrasting needs. Ongoing studies of various aspects of estuarine development are an essential element of the estuarine management and this study is one example from many, executed in cooperation between the Netherlands and Flanders.

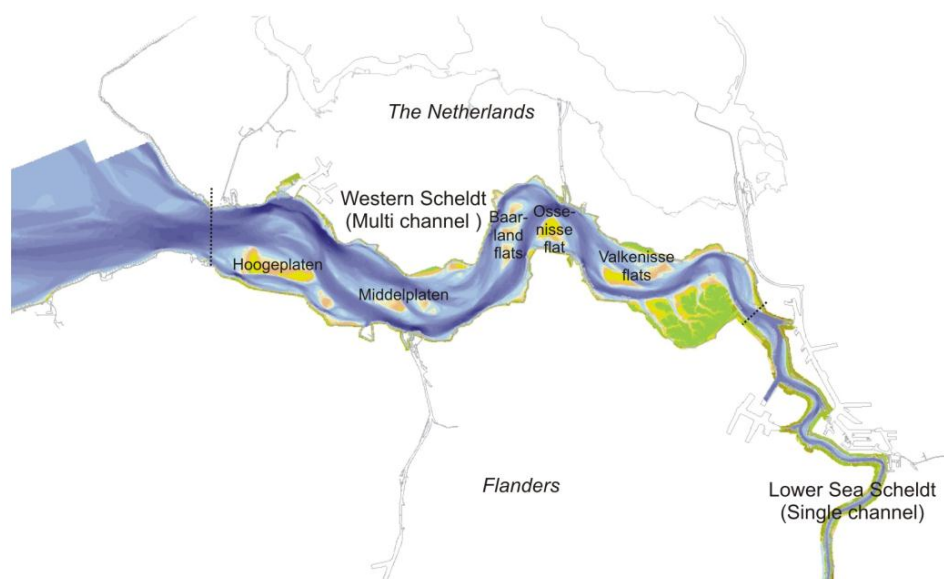


Figure 1. Map of the Scheldt-estuary. The dotted lines mark the boundaries of the Western Scheldt.

Two morphological characteristics of the Western Scheldt are regarded essential for its ecological value. The presence of multiple channels (the main eb- and flood channels and connecting channels) results in intertidal flats that have no connection to the main land and are thus difficult to access. These intertidal flats provide undisturbed feeding grounds for waders during low water. The quality of the intertidal feeding grounds is determined by the presence of macrobenthos (bivalves, worms, crustaceans). One factor that limits the presence of macrobenthos is the reworking of the sediment by tidal currents. Reworking is eminent in areas with migrating mega ripples. Reworking is also thought to limiting the abundance of macrobenthos in areas without distinct bed forms.

The character of the intertidal flats in the Western Scheldt has changed over the past century. The number of interconnecting channels has decreased and the surface area covered with mega ripples has decreased. While the total surface area of the inter tidal flats has been relatively stable, the number of inter tidal flats has decreased and the length of the (low) water line has decreased. The overall appearance of the Western Scheldt inter tidal flats has changed from small with jagged edges to large and smooth. In this extended abstract the observation will be presented along with hypotheses on its origin.

## **2. DATA AND APPROACH**

The data used for the analysis consists of digitized and digital bathymetric data (these cover 1818 to 2012) and the geomorphological maps (1959 to 2012).

The bathymetric data cover the entire Western Scheldt: tidal channels, intertidal flats and supra-tidal areas. The frequency of the soundings has increased over the centuries and since 1996 a bathymetric dataset of channels and intertidal flats is made annually. The digital bathymetric data from 1955 on have an accuracy that is sufficient for quantitative morphological analysis, including the development of the height of intertidal flats, the depths of channels and the development of the sediment volume. The bathymetric data prior to 1955 is used for the comparison of channel patterns, but lacks the accuracy for quantitative morphological analysis.

For this study a visual comparison of the distribution of intertidal flats and connecting channels has been performed. In earlier studies the number of inter tidal flats, the length of the circumference of the intertidal flats and the meso-scale index (= tidal-flat surface area/circumference) have been calculated.

The geomorphological maps cover the intertidal flats and supra-tidal areas and are based on aerial photographs. Different types of photographs have been used for the analysis, from black and white for the older datasets via color images to the false color images that are used from 1996 onwards. Image analysis of the photographs reveals distinct patterns that are mapped and attributed to classes. The geomorphological classes include the presence of marsh vegetation, rocks (artificial), Holocene peat and clay deposits, sandy or silty bed composition and the presence or absence of mega ripples and other large bed forms. Small bed forms (current and wave ripples) cannot be detected because these are smaller than the resolution of the imagery. In the present study the absence or presence of mega-ripples in the geomorphological maps is used. The geomorphological maps from 1996 to 2012 have been used for quantitative comparison, the older maps are used for pattern evaluation.

## **3. THE EDGE OF THE FLATS**

The intertidal flats regarded primarily in this study the complexes surrounded by tidal channels indicated with their names in figure 1. In the detailed map of the Middelplaten complex in figure 2 these areas are marked with 1. The intertidal flats on the banks of Western Scheldt (marked 2 in figure 2) have displayed less marked changes over the years. The number of intertidal flats that are surrounded by tidal channels has decreased from over 50 in 1959 to over 20 in 2004 (Cleveringa, 2007). The total length of the waterline surrounding these intertidal flats has decreased. The geometry of the tidal flats and their number is primarily determined by the tidal channels that surround the flats.

A short introduction in to the typology of the channels helps to understand which changes have occurred. The tidal channels are marked in figure 2, with a subdivision in:

- A. The main ebb- and flood channels of the estuary;
- B. Connecting channels that connect main channels and thus intersect the intertidal-flat complex;
- C. Ebb- and flood chutes.

All of the above channels have undergone changes that have affected the geometry of the tidal flats. The main channels have become more continuous throughout the estuary over the years, because many of the shallows ('drempels') that used to exist where the main ebb and flood channels meet have been dredged. With the disappearance of most of the shallows the number of ebb- and flood chutes has also drastically reduced. Ebb- and flood chutes were not restricted to the shallows, they pinched into the flats in other places as well. Such indentations into the flats by ebb- and flood chutes have become rare. The number of connecting channels has also decreased and in fact the map in figure 2 displays all but one of the remaining connecting channels.

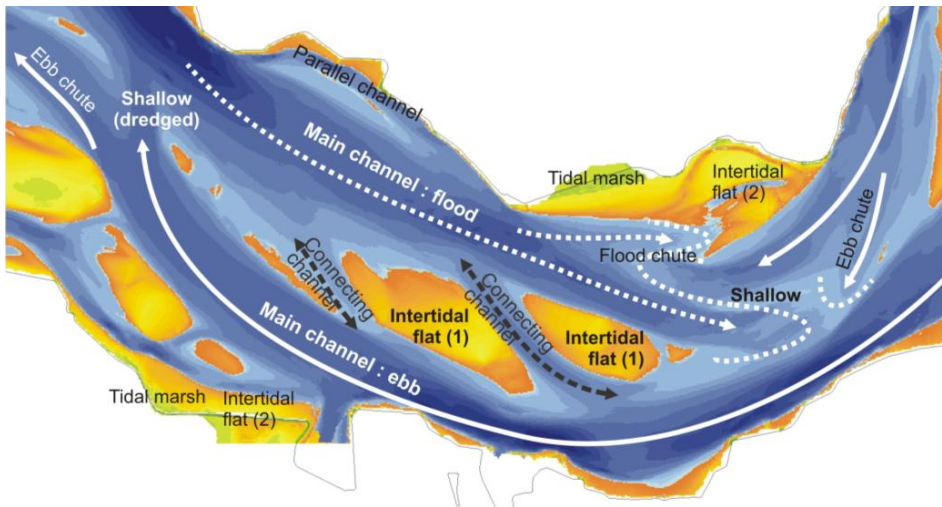


Figure 2. Map of the Middelplaten intertidal flat complex with the surrounding tidal channels (in 2013).

#### 4. MEGA RIPPLE ABUNDANCE

Mega-ripple fields are characteristic elements of the Western Scheldt that range from the intertidal flats into the sub-tidal domain. Western Scheldt scale mapping of the sub-tidal mega-ripple fields has not been performed and therefore the analysis is restricted to the intertidal ranges. The abundance of the mega-ripple fields on the intertidal flats has decreased with several hundred hectares from 1996 to 2012 (figure 3). The graph also shows that the rate of changes varies and includes a massive drop over 400 ha. The recent observations (2011 and 2012) have shown a slight increase in the extent of the mega ripple fields.

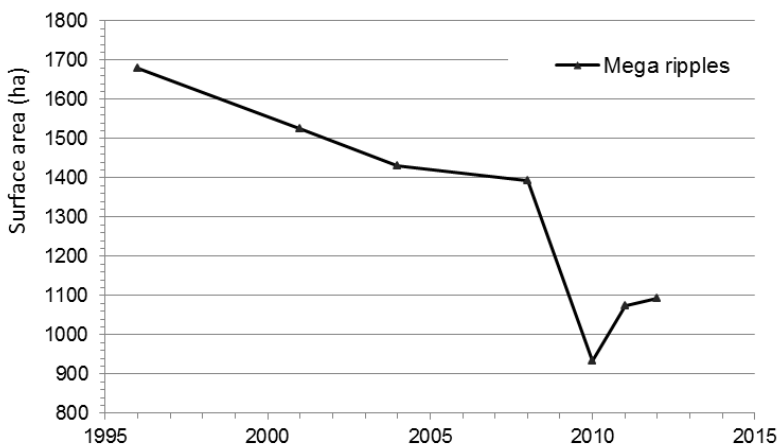


Figure 3. Graph of the extent of mega-ripple fields on the intertidal flats of the Western Scheldt (from the geomorphological maps).

Comparison with the older geomorphological maps shows that prior to 1996 mega-ripple fields were even more abundant. A visual comparison of the maps from 1959 and 2012 in figure 4 reveals the decrease of the mega ripple fields. These maps also reveal that the mega-ripple fields are primarily located on the fringes of the intertidal flats that are surrounded by tidal channels. Mega-ripple fields are scarce along the banks of the Western Scheldt.

#### 5. DISCUSSION

The decrease of the number of intertidal flats and the reduction of the length of their water line may have the same causes as the decrease of the mega-ripple fields. The favored location of the mega-ripple fields are the edges of the intertidal flats. And there are less edges now than 60 years ago. The developments relate to the tidal flow and sediment transport along (through the main channels and connecting channels) and onto the intertidal flats (through ebb- and flood chutes and over the mega-ripple fields). However, a mechanism or mechanisms to explain changes in the tidal-flow and sediment transport along and onto the intertidal flats is missing. The observed increase in the height of the intertidal flats may be a component to include in the explanation.

Mechanisms have to be applicable throughout the Western Scheldt because the developments have occurred in the entire realm. That excludes changes in the tidal range, because these have been small in the western side and larger in

the east. Similarly, dredging and dumping are unlikely candidates to explain these developments because their intensities have varied on the scale of the Western Scheldt. A mechanism that may account for the developments on this scale is the (slow/delayed) response to the closure of the branches over the last centuries. The pattern of branching tidal channels that intersect the flats in 1959 may be inherited from the older situation where these channels diverged into smaller channels in the branches. Our understanding of the patterns and pattern development of channels in tidal basins is evolving and new experiments with numerical and physical models may shed some light on the likelihood of this and other explanations. This also holds for intrinsic pattern development of tidal channels and flats as a potential explanation for the development of the smooth Scheldt.

**1959**



**2012**

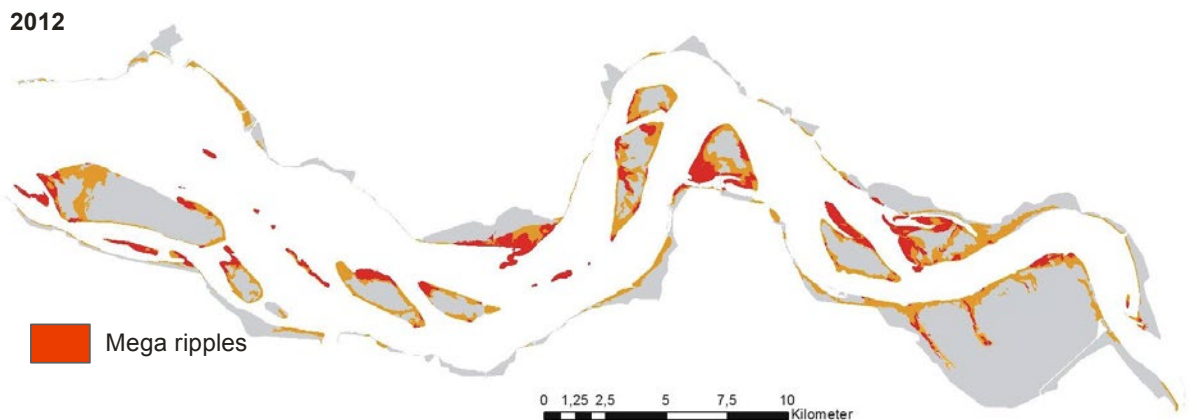


Figure 4. Maps of the intertidal flats and tidal marshes in the Western Scheldt (grey and orange), with the mega ripple fields in red.

It is difficult to assess the appreciation of these developments. The waterline is considered to be of major interest for some waders. Therefore the reduction of its length is not welcomed in view of the ecological value of the estuary. The mega-ripple fields are areas with limited abundance of macro benthos. But the decrease of mega-ripple fields so far has not resulted in an increase of richer feeding grounds for birds and this is as yet not well understood. In terms of policy making and estuarine management the observed developments and lack of explanations make it complex to set goals and realize measures.

## **6. CONCLUSIONS**

The morphology of the Western Scheldt has changed from an irregular distribution of intertidal flats with branching channels and shallow areas towards smooth tidal flats in between the main channels. Small tidal flats have merged and the jagged edges of the flats have given way to almost straight water lines. The surface area of the intertidal flats that is covered with mega-ripple fields has decreased. The developments relate to the tidal flow and sediment transport along (through the main channels and connecting channels) and onto the intertidal flats (through ebb- and flood chutes and over the mega-ripple fields).

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