

Indicators for the Scheldt estuary

Morphology and dynamics in the estuary



The ecotopes and habitats in the Scheldt estuary were subjected to great changes over the last 50 years. In 2004, the mud and sand flats area in the Westerschelde and Zeeschelde decreased by 20% compared to the 50s, a loss of more than 1,000 hectares. In 2004, the salt marsh area was only 66% of the area in the 50s, a decline of around 1,500 hectares. The subtidal habitats increased during the same period by 325 ha. In general, the channels in the Westerschelde are characterized by a deepening and widening since 1951. The average high water level in the Scheldt estuary reveals a rising trend from 1888 onwards. The position of the maximal mean high water level and the minimal mean low water level shifted upstream since 1888. The evolution of the salinity gradient in the Scheldt is difficult to interpret and requires further investigation.

Why monitor this indicator?

The Scheldt estuary Long-term Vision (LTV, [1]) for 2030 targets a healthy and dynamic estuarine ecosystem. The Scheldt represents one of the most important estuaries in Europe, characterized by a tidal regime and a complete transition from fresh- to seawater. Therefore, its habitats and communities should be preserved and even strengthened. The most important management and policy issues, with respect to the ecological state of the Scheldt, concern the impact of human interventions on the estuarine ecosystem.

In the following, various aspects will be addressed to evaluate the objectives of the LTV: the evolution of the area of ecotopes and habitats, the development of the tilt coefficient which reflects the depth ratio of the channels in the multichannel system, changes in the water levels, tidal asymmetry and the salinity gradient. Potential links between human activity and its effects on the properties and preservation of the estuary (food, nutrient cycling and hydro- and morphodynamics) will be discussed further in this document, as well as in other indicators.

Changes in one of the characteristics of a habitat, can affect the present animal populations and may even attract new species. The ecologically valuable habitats in the Scheldt estuary are the low dynamic (characterized by a low current velocity), shallow water and intertidal areas (mud and sand flats) and the salt marshes. The mud and sand flats are usually rich in benthic organisms and represent an important food source for birds. Especially the areas with a medium dryfall-percentage, i.e. the percentage of time during which the mud or sand flat is above the water level, are the most interesting from an ecological point of view [2, 3]. Shallow water areas, characterized by low dynamic conditions, are crucial as reproductive and breeding areas for fish, crustaceans and molluscs. Salt marshes provide breeding areas for birds. Moreover, they serve as a refuge during high water.

An ecotope system, i.e. a (hierarchical) classification of ecotopes, is used to track changes in different habitats throughout time, to predict the impact of certain variations in the system on the present habitats and to evaluate effects on communities.

The multichannel system of the estuary, characterized by a gradual transition between sand flats, mud flats, salt marshes, channels and shallow water, is important for a safe and efficient vessel traffic



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(separation of traffic flows), provides protection against floodings (water storage), the diversity of ecotopes or habitats, the inland penetration of the tide, the sediment dynamics and turbidity, and the ecological functioning of the estuary. Hence, the target of the LTV 2030 requires the maintenance of this multichannel system.

The presence of a tidal regime is one of the most important characteristics of the Scheldt estuary. The effect of the tides can be detected far inland, even as far as the locks at Merelbeke (160 km upstream from the mouth of the Scheldt). Also, (parts of) the tributaries are influenced by the tidal regime. The tide exerts a significant impact on the development of ecotopes, the distribution of species and habitats, the ports and vessel traffic (e.g. waiting times, currents,...), recreation, nature and flood protection. The tidal asymmetry (in the present document, the ratio between the duration of flood and ebb is used as an indicator for tidal asymmetry), the sediment transport and the large-scale morphology of the Scheldt estuary are assumed to influence each other.

The salinity gradient in the estuary of the Scheldt is, comparable to the silt dynamics, mainly controlled by the tide, the upstream drainage of the river and the morphology or shape/structure of the soil. These factors are responsible for temporal and spatial variations in the amount of salts dissolved in the water (salt concentration). Besides these parameters, soil sealing of the river banks and basin areas and the construction of dams, also exert an influence on the salinity. For the classification of the ecotopes in the Scheldt, salinity is an important characteristic as it determines, along with the tide, the distribution of species. Besides the average salt concentration, local variations in the salinity, including extreme values, determine the occurrence of species. The salinity also affects other factors such as the oxygen concentrations, and the uptake of heavy metals and other chemicals by plants and animals.

The Scheldt estuary is by nature a very dynamic system, strongly influenced by the tidal regime and variations in salinity. Mud flats, salt marshes, sand flats and channels are constantly subjected to changes. This [link](#) provides an overview of changes in morphology during the past two centuries. As a result of this dynamic nature, it is difficult to assess whether systematic changes in the characteristics of the estuary are the result of human activities or the natural variation of the system.

What does the indicator show?

Both Flanders and the Netherlands are currently developing an ecotope system. At the moment, ecotope maps and surface data are available for the Dutch Salt Water Ecotope System (ZES.1) for the years 1996, 2000 and 2004 [4]. The ZES.1 ecotope maps are produced every two years in the framework of the third expansion of the navigation channel of the Scheldt. In this document, long-term data, collected for the Environmental Impact Assessment (EIA) 'expansion of the navigation channel' [2], is used to reveal historical trends in the ecotope areas. These ecotope areas are based on global or simplified ecotope maps (in their turn based on the ZES.1). The different types of ecotope maps are not intended for comparison, however, the overall trends of the ecotope areas in both systems are largely the same. The ecotope data of Flanders are also available in several reports [5, 6]. The Flemish ecotope system is still being developed and more detailed ecotope areas are expected in 2010. It is proposed that the ecotope map of the Beneden-Zeeschelde will be reported every three years, and every six years for the Boven-Zeeschelde including the Rupel, the Durme and other tributaries. The Dutch and Flemish ecotope systems are subjected to further assessment, i.e. with respect to the parameters that support the classification systems and the ecological relevance and validation of the ecotope classes (see also technical fact sheet of the measurement [8]).

At present, no general ecotope system exists which covers the whole Scheldt estuary. However, for salt marshes an attempt has already been made [7]. Flanders and the Netherlands agreed after a joint consultation (November 2009) that the Flemish ecotope system [6] will be used in the area between Gent and Doel and the Dutch ZES.1 system [4] will be used between Doel and Vlissingen. The boundary between both systems is based on the transition from the salt water-dominated part of the estuary, with mud flats and sand flats, towards the fresh water-dominated part of the estuary which features solely mud flats.



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In order to provide an overall picture of the developments in the entire Scheldt estuary, a number of ecotopes or ecotope groups from the different systems are discussed together in the following. The methodology is further discussed in the technical description of the measurement 'development of ecotopes in the Scheldt estuary' [8]. The discussion section for the Westerschelde and the Zeeschelde further elaborates on the details of these general trends and their potential causes.

Evolution of the principal ecotopes in the Scheldt estuary

In 2004, the mud and sand flat areas in the Scheldt estuary (Westerschelde and Beneden-Zeeschelde) revealed a decrease of 21% compared to the 50s, a loss of over 1,000 ha. At the end of the 80s, the salt marshes were reduced to only 64% compared to the salt marsh area during the 50s, a decrease of around 1,500 ha. However, a slight increase of 72 ha could be observed in 2004. The subtidal and sublittoral ecotopes increased during the same period by 324 ha (see figure 1).

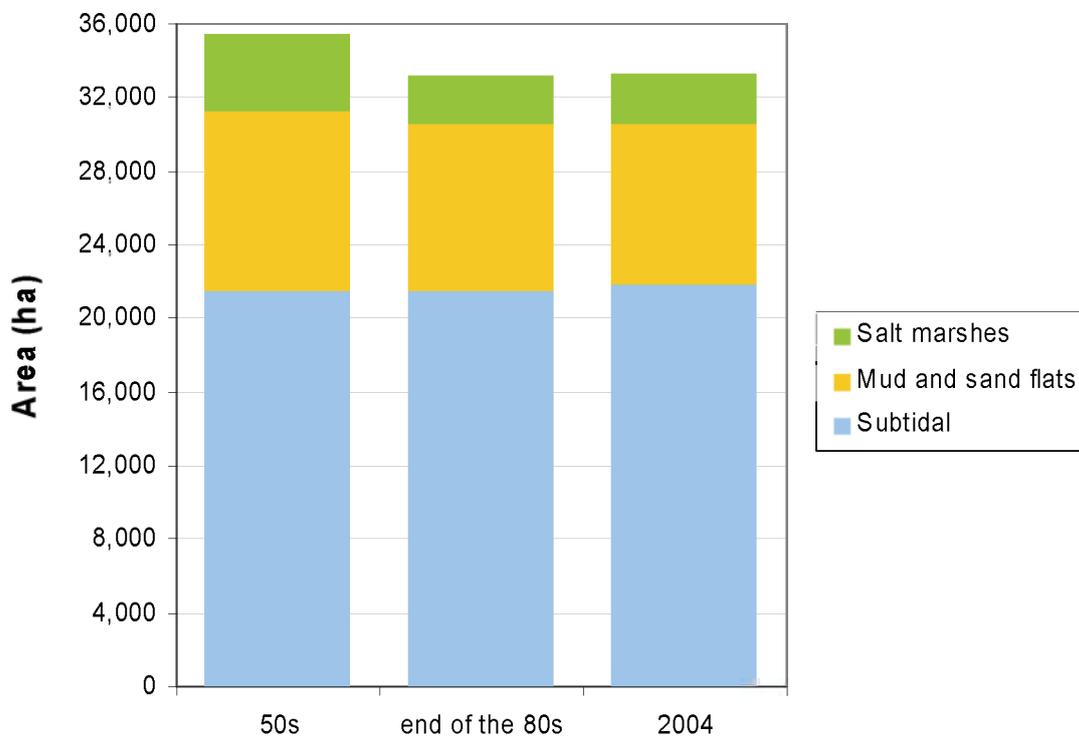
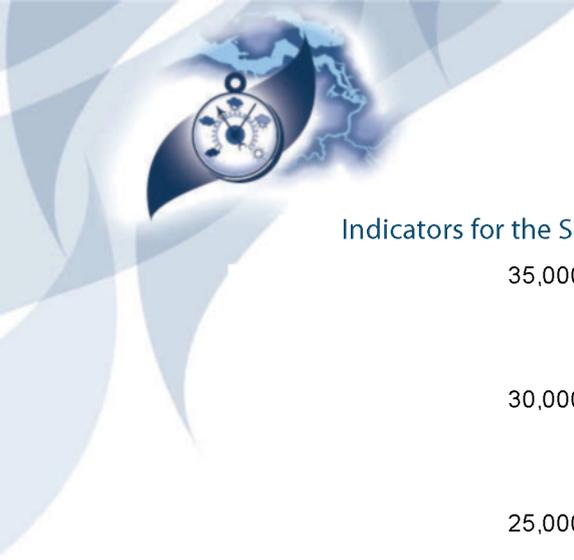


Figure 1: The evolution of the principal ecotope areas (ecotope groups) in the Scheldt estuary (Westerschelde and Beneden-Zeeschelde). Source: Alkyon, Research Institute for Nature and Forest (INBO) and the Directorate General for Public Works and Water Management (RWS).

Evolution of the ecotope areas in the Westerschelde

The most recent situation in the Westerschelde is represented by means of the detailed ZES.1 ecotope map from 2004 (see figure 4). In order to describe the trends of the ecotope areas more simplified ecotope maps are used (see figure 2 and 3).



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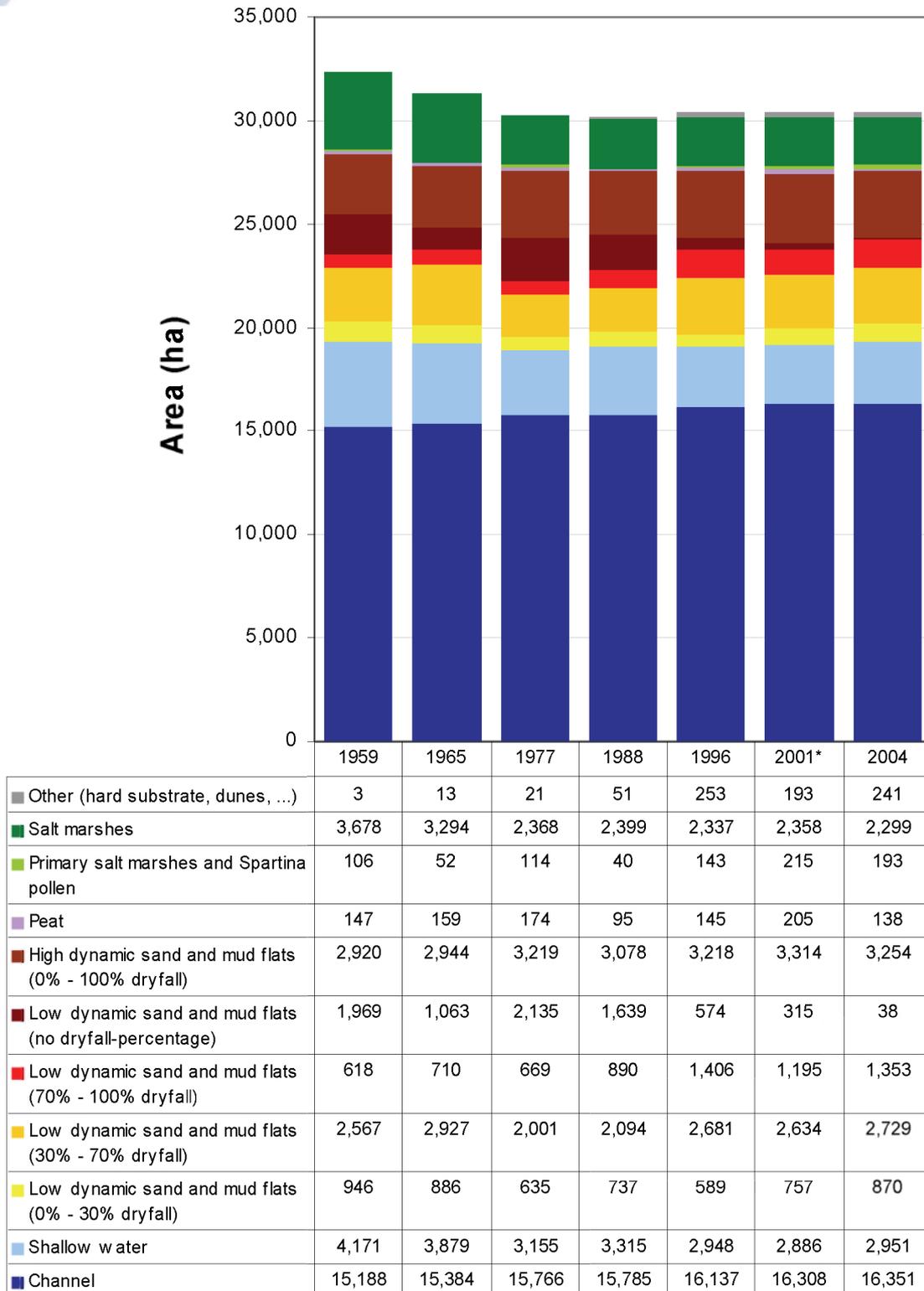


Figure 2: The evolution of the areas of the simplified or global ecotopes of the Westerschelde. *For channel and shallow water, data from 2000 was used (cfr. data availability). Source: Alkyon and the Directorate General for Public Works and Water Management (RWS), [2].

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The total area of ecotopes in the Westerschelde decreased in the period 1959 - 2004 from over 32,000 ha to around 30,000 ha (see figure 2). Especially, the salt marshes lost a significant area of almost 1,300 ha. In the period 1856 - 1960 the salt marsh areas increased by more than 850 ha due to the introduction of *Spartina* sp [van der Pluijm & de Jong, 1998]. Due to land reclamation, many areas which could have evolved to salt marshes have disappeared since 1950 (see further). Furthermore, the shallow water area declined with more than 1,200 ha and the mud flats decreased by 776 ha. On the contrary the channel area increased by more than 1,100 ha.

Land reclamation along the Westerschelde and erosion due to migration of the channels explain the decreasing trend (1959 - 1996) in the mud flat and salt marsh areas. The construction of the 'Sloehaven' (macrocell 1, the position of the macrocells is discussed in the indicator 'Soil interfering activities' [9]) and the land reclamation at the 'Appelzak' area, along with other factors, are responsible for the decrease of respectively 500 and 940 ha. The stop of land reclamations and the fixation of the channels halted this trend and in some places an increase in the mud flats and salt marsh area was observed after 1996.

In 1959, 87% of the total area of mud flats consisted of low dynamic mud flats whereas this percentage decreased to 80% in 2001 and subsequently increased to 83% in 2004. The dryfall-percentages of the mud flats are not discussed here, due to a lack of data.

The decrease of shallow water area has been mainly concentrated in the sand flat complexes, as a consequence of the disappearance of connecting channels in most of the sand flats. Hence, the sand flats have become generally higher and dryer: a shift from low to high dryfall-percentages.

In addition, the number of sand flats per sand flat complex and the irregular shape of the sand flat edges (see figure 3) revealed a decrease due to the decline in the number of connecting channels.

The total number of sand flats per sand flat complex in the Westerschelde decreased in the period 1959 - 2000 from 52 to 19. Subsequently, the number increased again to 25 in 2004. The area / contour ratio of all sand flat complexes along the Westerschelde increased from 217 m to 354 m between 1959 and 2004. As a consequence of these developments, there are fewer opportunities for birds (waders) to forage along the waterline.

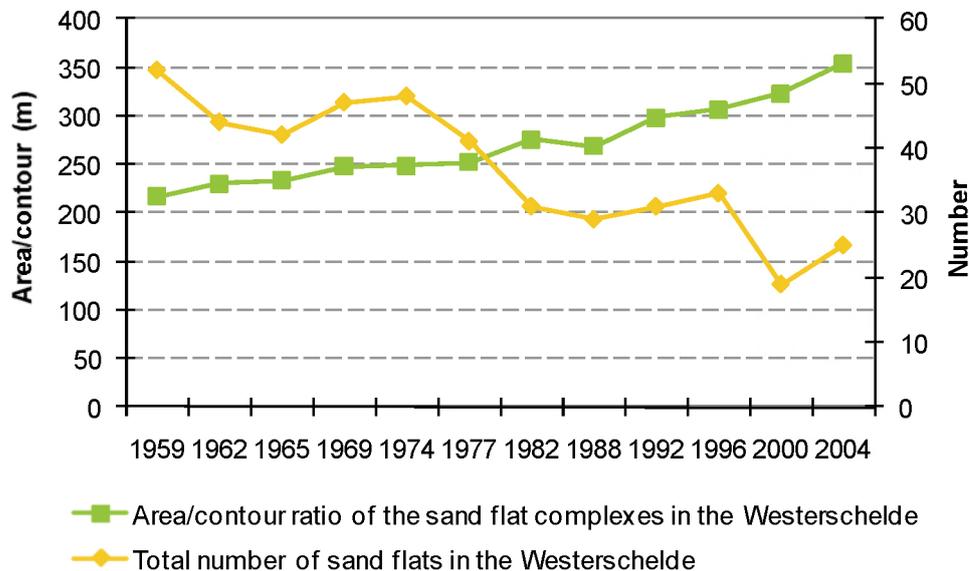
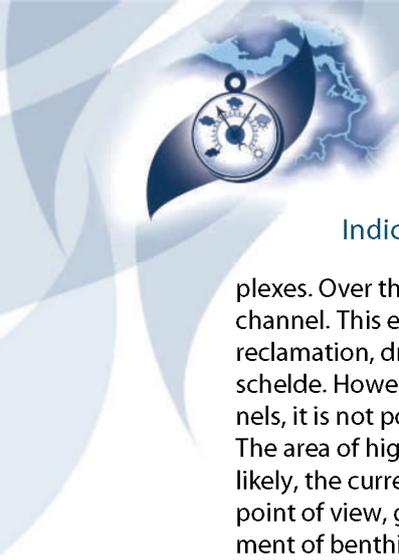


Figure 3: Evolution of the total number of sand flats in the sand flat complexes of the Westerschelde and the area / contour ratio of all complexes along the Westerschelde. Source: Alkyon and the Directorate General for Public Works and Water Management (RWS), [2].

Important changes in the water movement and the location and development of the channels in the Westerschelde are probably the cause of decline in connecting channels that crosscut the sand flat com-



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plexes. Over the past centuries, the water movement became increasingly concentrated in the main channel. This evolution can be attributed to several factors: natural dynamics, embankments and land reclamation, dredging of channels, disposal of dredged material and changes outside the Westerschelde. However, due to the strong coupling between water movement and the development of channels, it is not possible to disentangle the triggers and consequences [2].

The area of high dynamic sand flats increased, whereas the low dynamic sand flats reveal a decline. Most likely, the current velocity increased [2]. This evolution is regarded as unfavourable from an ecological point of view, given that the high dynamic sand flats represent a less attractive habitat for the establishment of benthic fauna. The Westerschelde as a whole, including the mud flats along the edges of the Westerschelde, will not be addressed here due to an absence of data (see above).

In the study of the EIA expansion of the navigation channel [2], a conceptual model was developed for the sand flats which tries to explain the changes in the morphological evolutions (which in turn determine ecological changes). According to this study, the most attractive ecotopes are the low dynamic sand flats (30-70% dryfall) as they offer relatively good conditions for the settlement of benthic fauna, that in turn serve as food for the birds. Moreover in this kind of ecotope, birds have sufficient time to forage. This ecotope decreased from 1,420 ha in 1959 to 1,075 ha in 2004.

Dredging, disposal and sand extraction activities exert, along with other human and natural factors, an important influence on the diversity of the ecotopes in the Scheldt estuary. The share of these activities in the total package of influencing factors is unknown. However, in some cases, a potential correlation was found between the morphological developments (which are important for the ecological developments), and seabed activities. Below, a discussion for every macrocell is listed. The definition of the macro cells is explained in detail in the indicator 'soil interfering activities' [9].



The effects of dredging, disposal and sand extraction can be connected with changes in the area of ecotopes. According to the EIA, this influence may be regarded as limited in the western part of the study area (macrocells 1, 2 and 3). In macrocell 4, more sediment was deposited compared to the sediment that was removed in the period between 1955 and 2004. It is likely that the morphological changes in this macrocell were also influenced by the dredging and disposal of sediment. In macrocell 5, a net disposal of sediment occurred till the 90s (green frame, see figure 4). The channel area decreased by approximately 250 hectares while the sand flat area increased by 290 ha. The disposal of sediment in the 'Schaar van Waarde' has probably significantly contributed to the increase of the sediment volume of the 'Platen van Valkenisse'. Since the 90s, a net dredging of sediment occurred in macrocell 5 (red frame, see figure 4). The sand flat area decreased slightly whereas the channel area increased again.

Macro cell 5 (Around 'platen van Valkenisse')

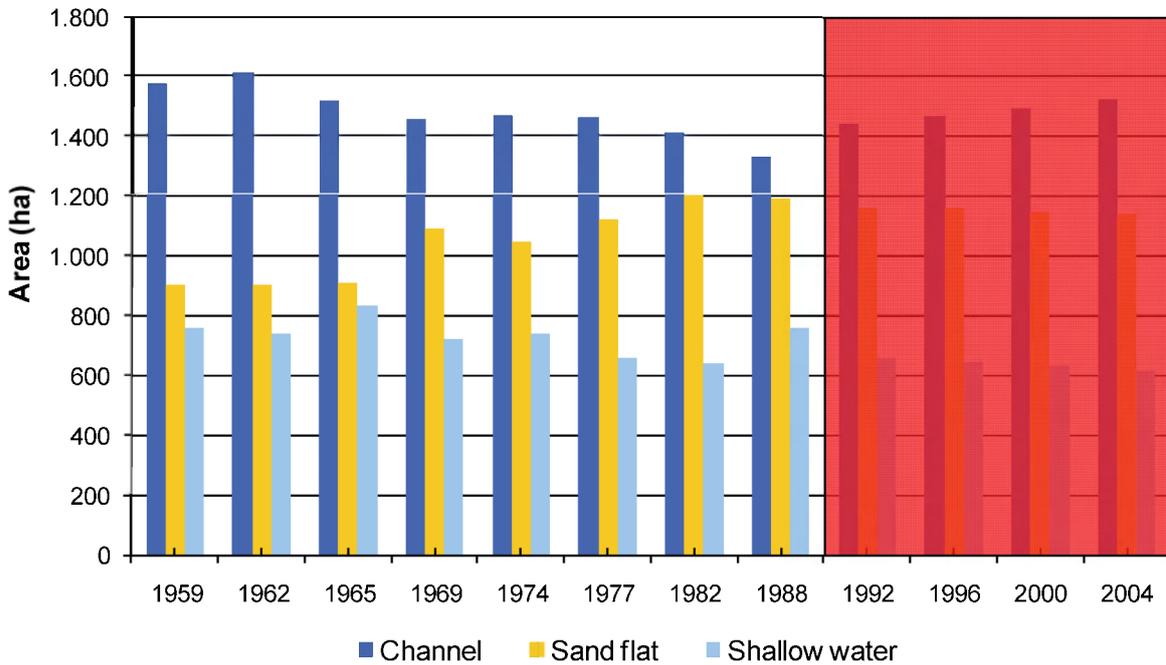


Figure 4: The sand flat, shallow water and channel area in macrocell 5. The green box indicates the years when net disposal of sediment occurred while the red box indicates the years, characterized by net dredging. Source: Alkyon and the Directorate General for Public Works and Water Management (RWS), [2].

In macrocells 6 and 7, human activities also significantly determine the morphological development. The main channel is dredged in order to be coherent with the required nautical width and depth. Near the 'Appelzak', the area of salt marshes was more than halved due to land reclamation.

In figure 5 the location of the different ecotopes from the ZES.1 ecotope system is shown. The ZES.1 ecotope system is more detailed and based on more background information than the simplified ecotope system of the EIA 'expansion of the navigation channel'. The ZES.1 ecotope map of the Westerschelde 2008 is being formatted and is expected to appear in 2010.



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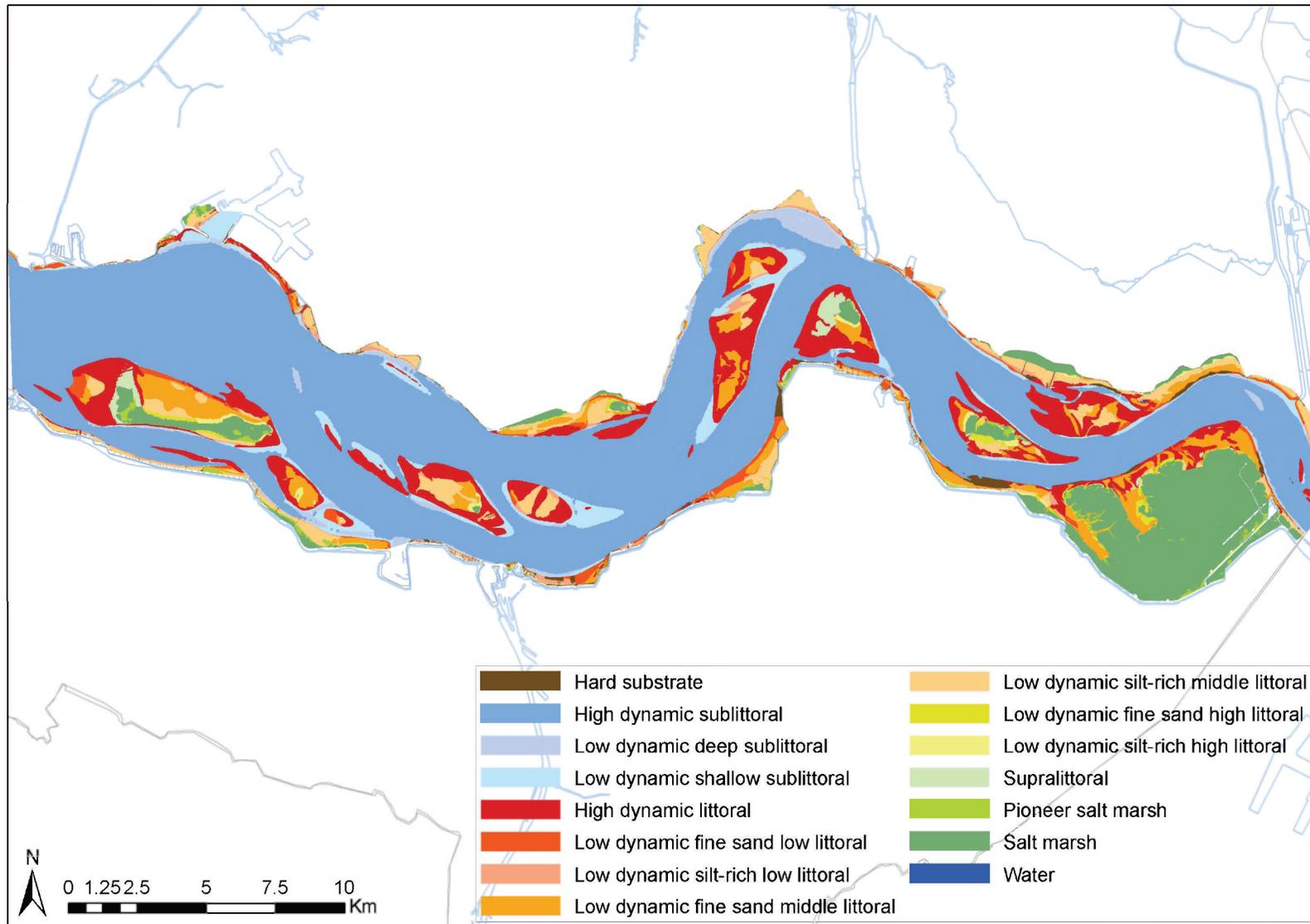


Figure 5: Ecotope map of the Westerschelde (2004). Source: the Directorate General for Public Works and Water Management (RWS).



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Development of the ecotope areas of the Zeeschelde

In 2004, the area of salt marshes in the Zeeschelde was approximately halved compared to 1850 and the mud flat area was only one third of the area in 1850 (see figure 6). In addition, in 2004, the subtidal area increased by approximately 185 ha. Moreover, nearly 60% of this subtidal area is deep, while only 20% consists of shallow area.

The largest share of intertidal area was lost between 1850 and 1950 as a consequence of land or river reclamation. The loss of intertidal area between 1950 and 1990 is mainly due to work on the infrastructure and dikes. In the recent decades, especially erosion is responsible for the loss of habitat [5].

A high sediment supply enables salt marshes to keep up with the increasing high tides (see below). However, since no lateral expansion of the salt marshes is possible due to the dikes, the transition between channel and salt marshes is becoming steeper. This increasing slope creates instability in the salt marshes, mud flats and shallow sublittoral areas. More space for the river (see opportunities and threats) may help to remedy this situation [5].

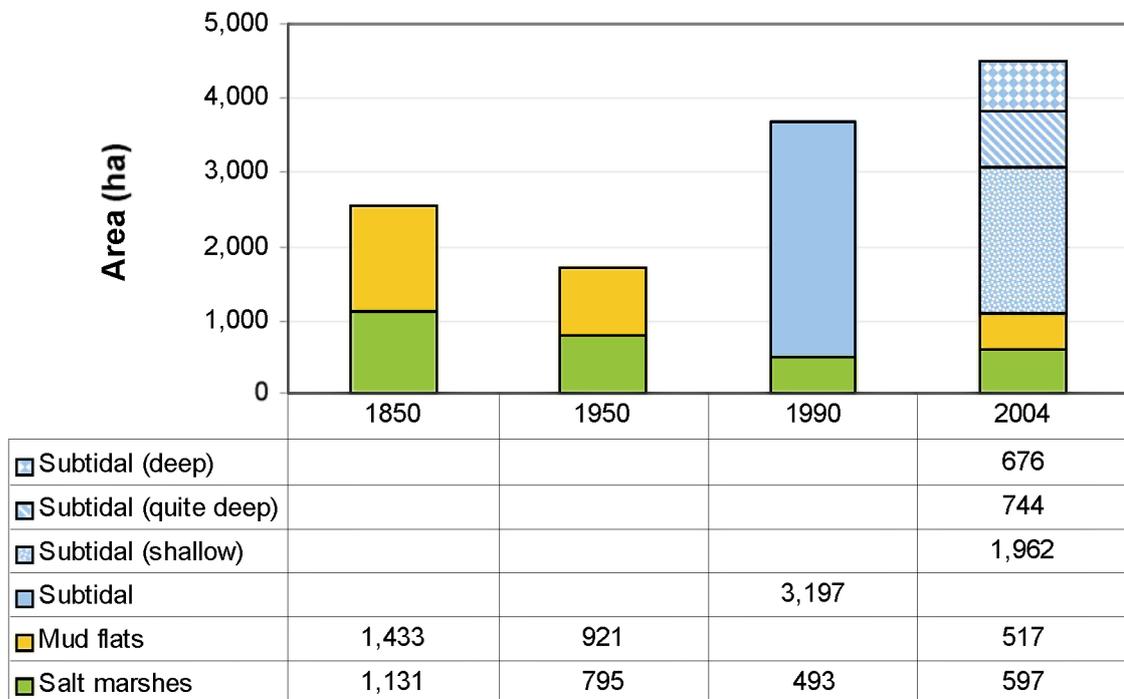


Figure 6: Development of the area of ecotopes in the Zeeschelde (excluding Tidal arm (Tijarm) and tributaries). Source: Research Institute for Nature and Forest (INBO) [5].

In figure 7, the ecotope map for the Zeeschelde is shown (situation 2004). The calculated areas of this detailed ecotope system (on a lower level) will probably become available in 2010.

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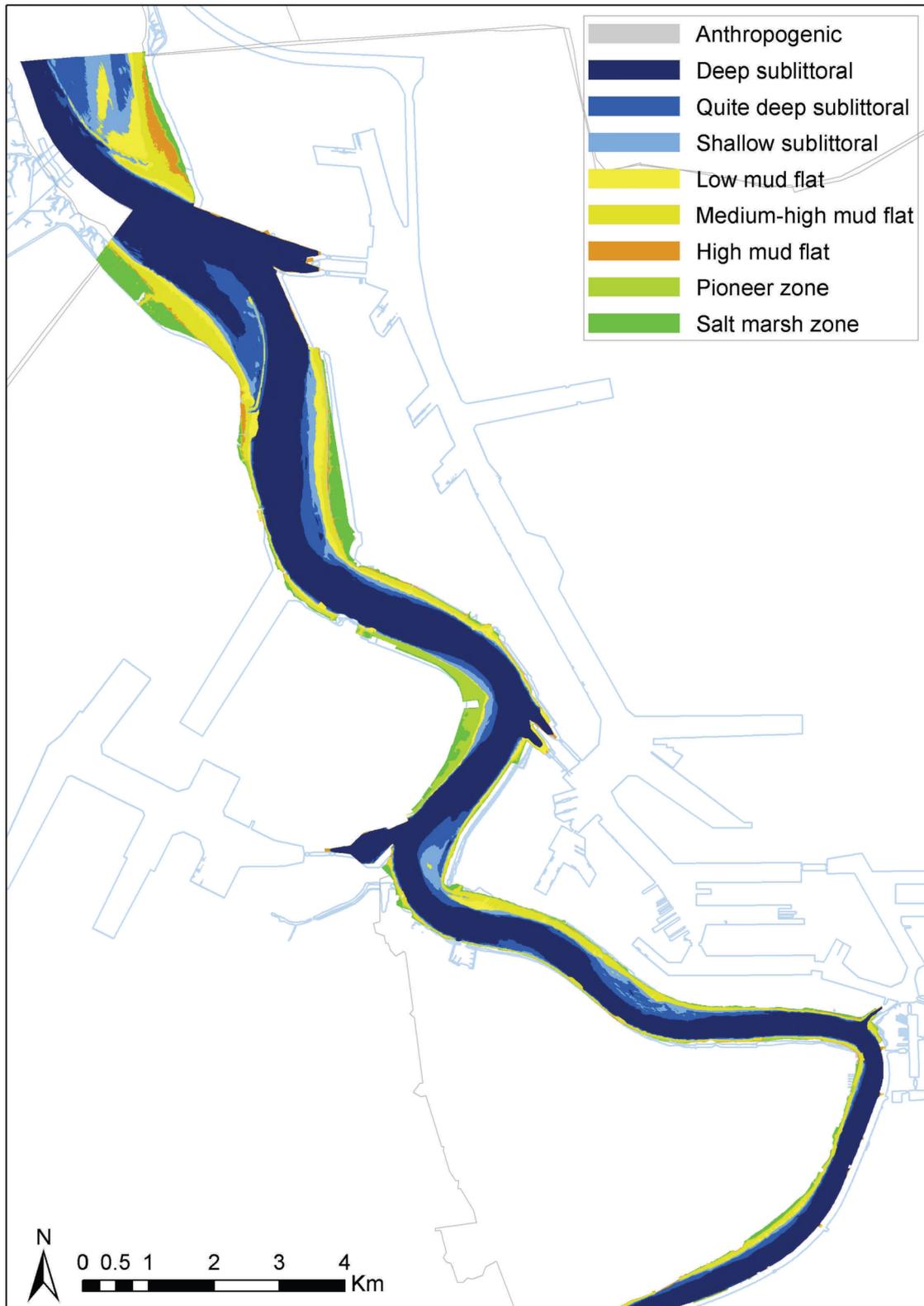


Figure 7: Ecotope map of the Zeeschelde (the Port of Antwerpen region, 2004). The complete map can be consulted on the indicator page: <http://www.scheldemonitor.be/indicatorfiche.php?id=8>. The detailed data that underpin this map, are currently not publicly available but are likely to appear in 2010. Source: Research Institute for Nature and Forest (INBO).

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Development of the channel system

There are various ways to follow up on the development of the channel system in the Westerschelde (in the Zeeschelde, this multichannel system is absent). At present, the most detailed measurement for which a long time series is available, is the ratio between the depth of the ebb and flood channel in a macrocell. In general, these represent respectively, the main and secondary channel (except in macrocell 4). This ratio is known as the tilt coefficient ('kantelindex') $K(t)$. The evolution of the tilt coefficient indicates changes in the stability of the channel system: in which direction the system tilts and how much it tilts. If this ratio becomes systematically larger or smaller, a degeneration of the channel system occurs. A positive value of $K(t)$ indicates that the depth of the ebb channel is greater than the depth of the flood channel.

In the framework of the flexible disposal strategy (see indicator 'soil interfering activities' [9]), quality parameters have been developed which have to guarantee and monitor the conservation of the multichannel system. The development of an evaluation methodology in the context of the Flemish-Dutch integrated monitoring program for the Scheldt estuary will further improve a reliable proxy for the conservation of the channel system.

In general, the channels of the Westerschelde have deepened and/or widened in the period between 1951 and 2002. Due to the dredging of the main channels during and after the first and second expansion of the navigation channel (see purple boxes in figure 8), the main channels (here ebb channels) in the eastern part of the Westerschelde have deepened in the period 1951 to 2002. Hence, this led to an increase of the tilt coefficient for this area (macrocells 5, 6 and 7). In the central part of the Westerschelde (macrocell 4) the main channel is getting deeper (here exceptionally the flood channel) and the secondary channel (here ebb channel) shallower. Therefore, the tilt coefficient reveals a declining value. This process was possibly enhanced by the second expansion of the navigation channel of the Scheldt and points to a degeneration of the channel system according to the definition of the tilt coefficient. In the western part (macrocell 1 and 3), the depth of the main channels (ebb channels) and flood channels (secondary channels) remained stable (see figure 8) [10, 11].

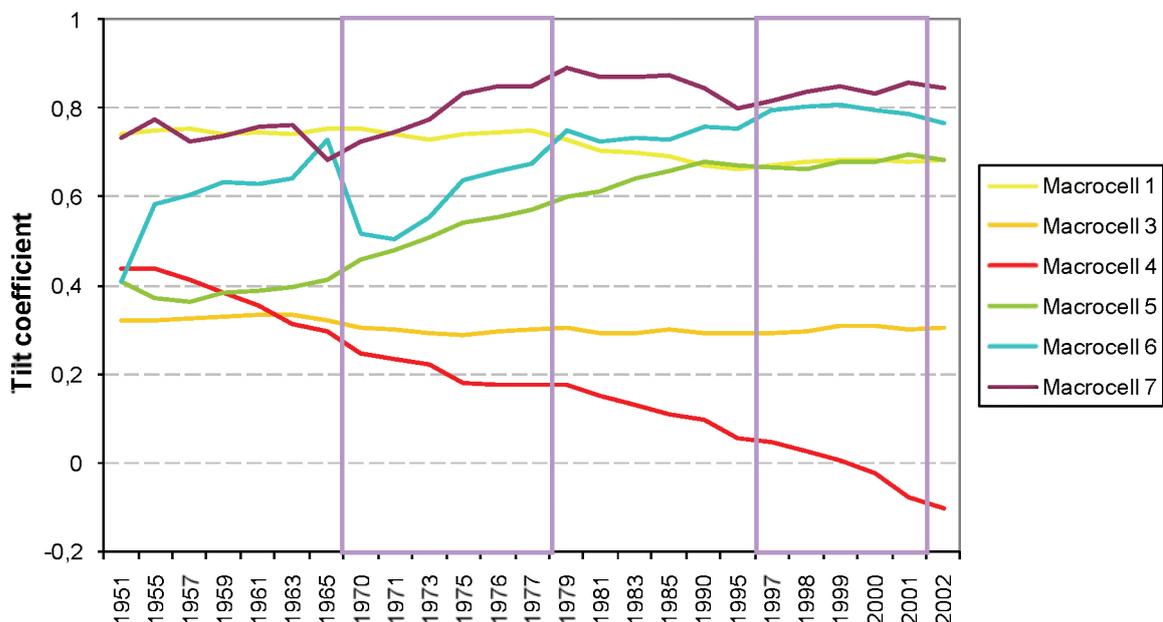


Figure 8: Evolution of the tilt coefficient (ratio of the depth of the ebb tide and flood channel) for the macrocells of the Westerschelde. The years during which the expansion of the navigation channel occurred, are displayed in a purple frame. Source: Deltares [10, 11].

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Water levels and tidal asymmetry in the Scheldt estuary

High and low water levels

In the summary of the indicator 'safety against flooding' [12], the 10-year average high and low water levels are discussed in detail. The conclusions are summarized here.

The 10-year mean high water levels in the Scheldt estuary show a pronounced increasing trend since 1888. In the period 1991 - 2000, the mean high tide at the various measurement stations was between 37 and 127 cm higher compared to the period 1888 to 1895.

The evolution of the average low water levels is less clear. In the eastern part of the Westerschelde and in the Zeeschelde the low water levels reveal a (limited) decline. On the contrary, the mean low water levels rose in the western part of the Westerschelde.

The difference between the mean high and low tides (or tidal amplitude) for the entire Scheldt estuary, increased since 1888. In the Zeeschelde, this trend seems to be more pronounced than in the Westerschelde.

The position of the maximal average high tide and the minimal mean low tide shifted upstream since 1888.

Tidal Asymmetry

A global measure to monitor the asymmetry of the vertical tide (increase and decrease of the water level) is the ratio between the duration of flood and ebb. In the entire Scheldt estuary the duration of flood is shorter compared to the duration of ebb (flood dominance). In general, this results in higher flood currents. This asymmetry varied slightly over the past decades and the difference in the ratio was highest in the Zeeschelde (see figure 9). Over the past centuries, a prolongation of the flood duration and a shortening of the ebb duration occurred. Hence, the tide became less 'flood dominant' [13].

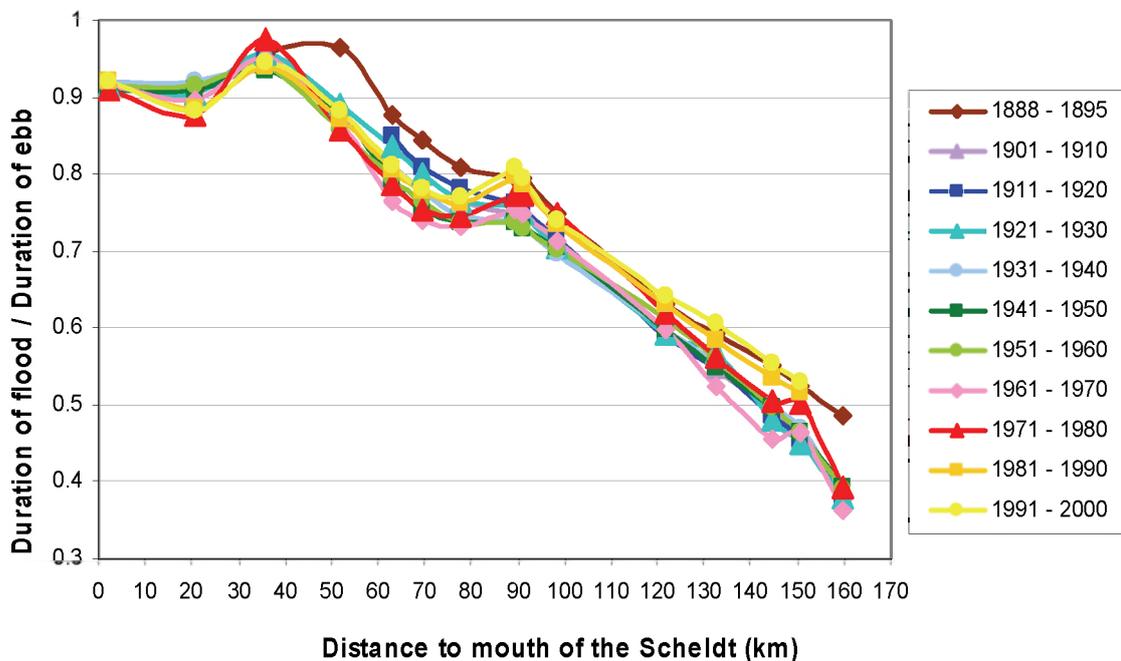


Figure 9: 10-year average tidal asymmetry in the period 1880-2000 (Westerschelde – Zeeschelde).
Source: Flanders Hydraulics Research.



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Salinity gradient

The Scheldt estuary is one of the last estuaries in Europe where a full gradient from saline to fresh water is present. One of the objectives concerning the ecology of the estuary is to preserve this gradient.

There are several possibilities to monitor the evolution of the salinity gradient in the Scheldt estuary. The evaluation framework of the Scheldt estuary [14] suggested to use shifts in the location (distance in km from the line Vlissingen - Breskens) of the transitions between different salinity zones (highly brackish or polyhaline, moderately brackish or mesohaline, slightly brackish or oligohaline and fresh water, determined by the average salinity values for the winter and summer period) in order to evaluate changes in the gradient. The project 'Monitoring the effects of the second expansion of the navigation channel [15]' monitored changes in the annual average salinity at different points in the Westerschelde. In the Strategic Environmental Impact Assessment (S-EIA) for the development outline of the Scheldt 2010 [16], the current length of the gradient (distance between the freshwater / brackish transition and brackish / strong brackish transition, determined by hydrodynamical 2D modeling along with estimations of experts), together with the location of the centre of the gradient (km from the mouth), were compared to a reference situation (1900). This study referred to the annual variation of salinity in certain locations as a potential additional proxy to monitor the salinity gradient. In addition, it was recommended to observe the salinity in three dimensions as in some cases, a layering or vertical variation of the salt concentration may occur. The report 'Salt Dynamics' of the EIA expansion of the navigation channel [17] used a 3-dimensional hydrodynamic model to map the salinity in 2005. In this model horizontal and vertical differences between the maximum and minimum salinity were evaluated. In the ZES.1 ecotope system the salinity variation is used for classification and calculated based on average salinity values and standard deviations [4]. From an ecological point of view, it is also recommended to conduct a frequency analysis of the occurrence of extreme salt concentrations and the period during which these extreme values persist.

Several institutes collect salinity data in the Scheldt estuary (The Netherlands Institute of Ecology, Centre for Estuarine and Marine Ecology; the Directorate General for Public Works and Water Management (RWS); Flemish Environment Agency; Flanders Hydraulics Research ...). In the framework of the Flemish-Dutch commission for research and monitoring of the Scheldt and the integrated monitoring programme [18] monitoring and analytical techniques were compared and integrated. Furthermore, these data are centralized and, if possible, offered as integrated time series in the data portal of the Schelde-Monitor. An analysis of the salinity gradient over a longer period of time (and sufficiently small time intervals) for the entire study area is not yet available. However, this study does not intend to analyse and interpret these data.

Where do the data come from?

- Data on the ecotopes in the Westerschelde are the property of Directorate General for Public Works and Water Management (RWS), division Zeeland and were provided by RWS division Zeeland and Alkyon. Data on the ecotopes in the Zeeschelde are property of, and provided by the Research Institute for Nature and Forest (INBO).
- Data on the tilt coefficient were provided by Deltares.
- Data on the water levels and tidal asymmetry are from Flanders Hydraulics Research and were digitized by the Flanders Marine Institute (VLIZ).
- Data relating to salinity may be requested from various institutes (the Directorate General for Public Works and Water Management (RWS): Monitoring 'Waterstaatkundige Toestand des Lands', 'Meetnet Zeeuwse Getijdewateren', Flemish Environment Agency, The Netherlands Institute of Ecology - Centre for Estuarine and Marine Ecology,...) or can be accessed via the data portal of the Scheldt Monitor (<http://www.scheldemonitor.org/dataportal.php>).



Opportunities and threats

The efforts to map the morphology and dynamics of the Scheldt estuary have provided a wealth of data and knowledge over the last decades. In the future, this knowledge and data will further increase and support important policy issues.

The ecotope systems of the Westerschelde and the Zeeschelde are an important tool for the management and policy of the Scheldt estuary. They can be used for the preparation of environmental impact assessments (EIA) and the monitoring of the objectives of the LTV. The ecotope systems also provide crucial information for the description of the reference situation of biological quality elements for the EU Water Framework Directive (see indicator 'surface water quality') or for defining conservation objectives in the framework of the EU Habitats and Birds Directives (see indicator 'status of species and habitats'). However, ecotopes become really meaningful when they actually reflect the communities they entail. Therefore, the ecological relevance and validation of the established ecotopes and class boundaries (both in the Zeeschelde and Westerschelde) are further investigated [19, 20]. The current definition of the ecotope systems (and boundaries), may still change as knowledge progresses.

The Sigma Plan aims to create flood control areas which are mainly focused on flood protection (see indicator 'safety against flooding'), and new nature along the Scheldt (mud flats, salt marshes, wetlands). The 'natuurpakket Westerschelde' also wants to realise new estuarine nature (see indicator 'protection and development of natural areas'). A significant part of the area, appropriate as foraging and breeding area for birds and fish was lost due to the decline of low dynamic habitats during the last century. The newly created estuarine nature provides new chances for these species.

Dredging, disposal and sand extraction (see indicator 'soil interfering activities') have affected, along with natural developments and other human activities (land reclamation, infrastructure, ...), the multichannel system of the Westerschelde and also the Zeeschelde. These soil interfering activities carried significant consequences for the present habitats in the Scheldt estuary. On the one hand, maximal disposal capacities have been defined in the framework of the current permits for the expansion and maintenance of the navigation channel in the Westerschelde, in order to preserve the multichannel character. On the other hand, space has been created to maintain a flexible disposal strategy. In this strategy, the disposal locations are constantly adjusted, based on the monitoring of quality parameters in order to prevent undesired effects. The disposal of sediment on the sand flat edges (next to the main and secondary channels) aims to create new ecologically valuable habitats. The first tests at the sand flat of 'Walsoorden' were a success regarding the riverbed morphology and did not have a negative effect on the ecology [21]. Soil interfering activities may also indirectly affect the salinity gradient in the estuary as a result of changes in the geometry of the estuary or disturbance of the mixing processes. To examine the effects of soil interfering activities and other human interventions on the silt dynamics and silt balance in the estuary, a 3-dimensional sediment transport model was developed [22]. Based on this model, it was concluded that dredging activities in the ports have a relatively small effect on the silt levels in the system. However, in the port of Antwerp the human influence can be distinguished from the natural variations [23].

The current rise of the sea level may result in a further inland penetration of the tide, leading to the presence of salt water further upstream. Given that the multichannel system also affects the tidal characteristics, interventions in this system may alter both salinity and tides. Historically, land reclamation has facilitated the further inland penetration of the flood wave. Interventions in the upper basin, or modifications in the lock management have an impact on freshwater supplies and thus also on the salinity gradient. Several measures have been proposed or are being implemented, (e.g. the updated Sigma plan) to maintain a sufficient freshwater supply throughout the entire year: the increase of the retention time by the construction of buffer zones, reducing channeling and preventing distribution of freshwater to other systems [24].

The technical fact sheets from the measurements of this indicator describe the limitations in definitions, data and methodology. The sheets are available at: <http://www.scheldemonitor.org/indicatorfiche.php?id=8>

Integration with other indicators / measurements?

The links between indicators are already discussed in 'opportunities and threats'.

The preservation of the multichannel system of the Westerschelde is important for the separation of traffic flows and contributes to a safe and efficient shipping (see indicator 'nautical management'). Therefore, it promotes the 'socio-economic importance of the ports'. The tidal influence is not only one of the determining characteristics of the Scheldt estuary, it also affects the flood risks along the estuary (see indicator 'safety against flooding'). As already stated in the introduction (why this indicator?), the salinity in the Scheldt estuary affects a number of chemical processes. For example, the solubility of oxygen increases at lower salinity concentrations. Hence, salinity directly influences the oxygen concentration in the water (see indicator 'surface water quality'). The availability of heavy metals for organisms (see indicator 'loads of pollutant substances') is also related to salinity. A sharp change in the salinity gradients or in the daily and / or seasonal fluctuations of salt concentration can affect the typical communities along the Scheldt estuary (see indicator 'status of species and habitats').

Changes in land use (e.g. built-up area, channeling and other water infrastructure), may influence a proper drainage of freshwater and thus exert a control on the salinity in the estuary (see indicator 'population pressure').

How to refer to this fact sheet?

Anon. (2010). Morphology and dynamics in the estuary. Indicators for the Scheldt estuary. Commissioned by the Maritime Access Division, project group EcoWaMorSe, Flemish-Dutch Scheldt Commission. *VLIZ Information Sheets*, 225. Flanders Marine Institute (VLIZ): Oostende. 17 pp.

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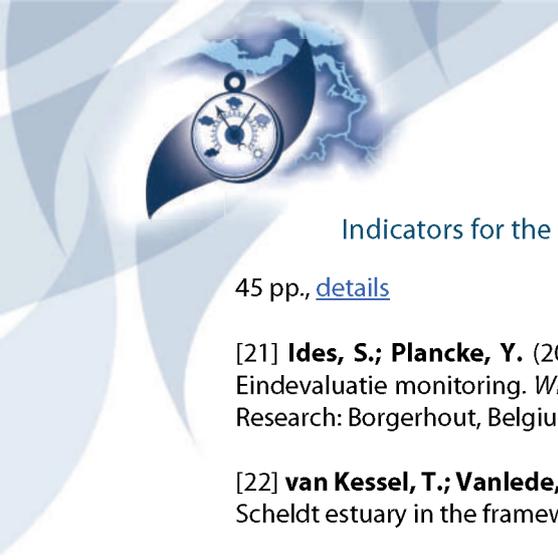
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