The Scheldt estuary

General Characteristics of the Scheldt estuary

Topography

The river Scheldt has a length of 355 km from source to mouth (the line Vlissingen-Breskens). The source is situated in the north of France (St. Quentin) about 110 m above sea level and the estuary becomes much wider beyond Vlissingen (The Netherlands), where the mouth of the estuary gradually turns into the North Sea. The total catchment area is approximately 21863 km². About 10 million people (477 inhabitants per km²) live in the river basin. The Scheldt is a typical rain fed lowland-river.

The inner estuary extends from Vlissingen (km 0) to Ghent (km 160), where sluices impair the tidal wave (Figure 1) in the upper Scheldt. The tidal wave also enters the major tributaries Rupel and Durme, providing the estuary approximately 235 km of tidal waters. The Zeeschelde (105 km), the Belgian part of the estuary, is characterized by a single ebb/flood channel, bordered by relatively small mudflats and marshes (28 % of total surface). The surface of the Zeeschelde amounts to 44 km². Agglomerations, cities and industries are historically developed close to the riverbanks of the Zeeschelde. The intertidal zone is often absent (e.g. quays, docks and wharfs) or very narrow. Upstream of Dendermonde, the estuary is almost completely canalized.

The middle and lower estuary, the Dutch part of the estuary called the Westerschelde (58 km), is a well-mixed region characterized by a complex morphology with flood and ebb channels surrounding several large intertidal flats and salt marshes. The surface of the Westerschelde amounts to 310 km², with the intertidal area covering 35 %. The average channel depth is approximately 15 – 20 m., with some deep pits of 40 m. The mouth of the estuary, beyond the line Vlissingen –Breskens, is the largest part, with an almost completely marine environment. The two main entrances to the river (the fairways to Antwerp and Vlissingen) are separated by a large subtidal flat: the Vlakte van de Raan. The surface of this part of the estuary amounts to 950 km².

Freshwater flow and tidal influence

The long-term yearly averaged river discharge at Schelle, amounted to 104 $m^3.s^{-1}$ with a maximum recorded value of 207 $m^3.s^{-1}$ (in 1966) and a minimum of 43 $m^3.s^{-1}$ (in 1949). Being a typical rain-fed river, river discharge varies among seasons. During winter, the mean river discharge amounts to 180 $m^3.s^{-1}$, with exceptional values up to 600 $m^3.s^{-1}$. Average summer values decrease to 60 $m^3.s^{-1}$, with minimal values down to 20 $m^3.s^{-1}$. The residence time of the water ranges from one to three months, depending on the river discharge. The tidal volume at Vlissingen amounts to 220 million m^3 per tidal cycle (13 h), with an average total freshwater discharge of only 5 million m^3 in that period.

Due to the funnel-shaped morphology of the estuary, the mean vertical tidal range is maximal in the freshwater tidal reaches (average tidal range at Schelle: 5.24 m). The ratio between the duration of rising and falling tide decreases from 0.88 at Vlissingen to 0.75 at Schelle and 0.39 at Ghent. The maximum tidal velocity during an average tidal cycle at the mouth is about 0.9 $m.s^{-1}$, in the Beneden Zeeschelde 1.1 $m.s^{-1}$ and between Antwerp and the Rupel is 1.2-1.3 $m^3.s^{-1}$.

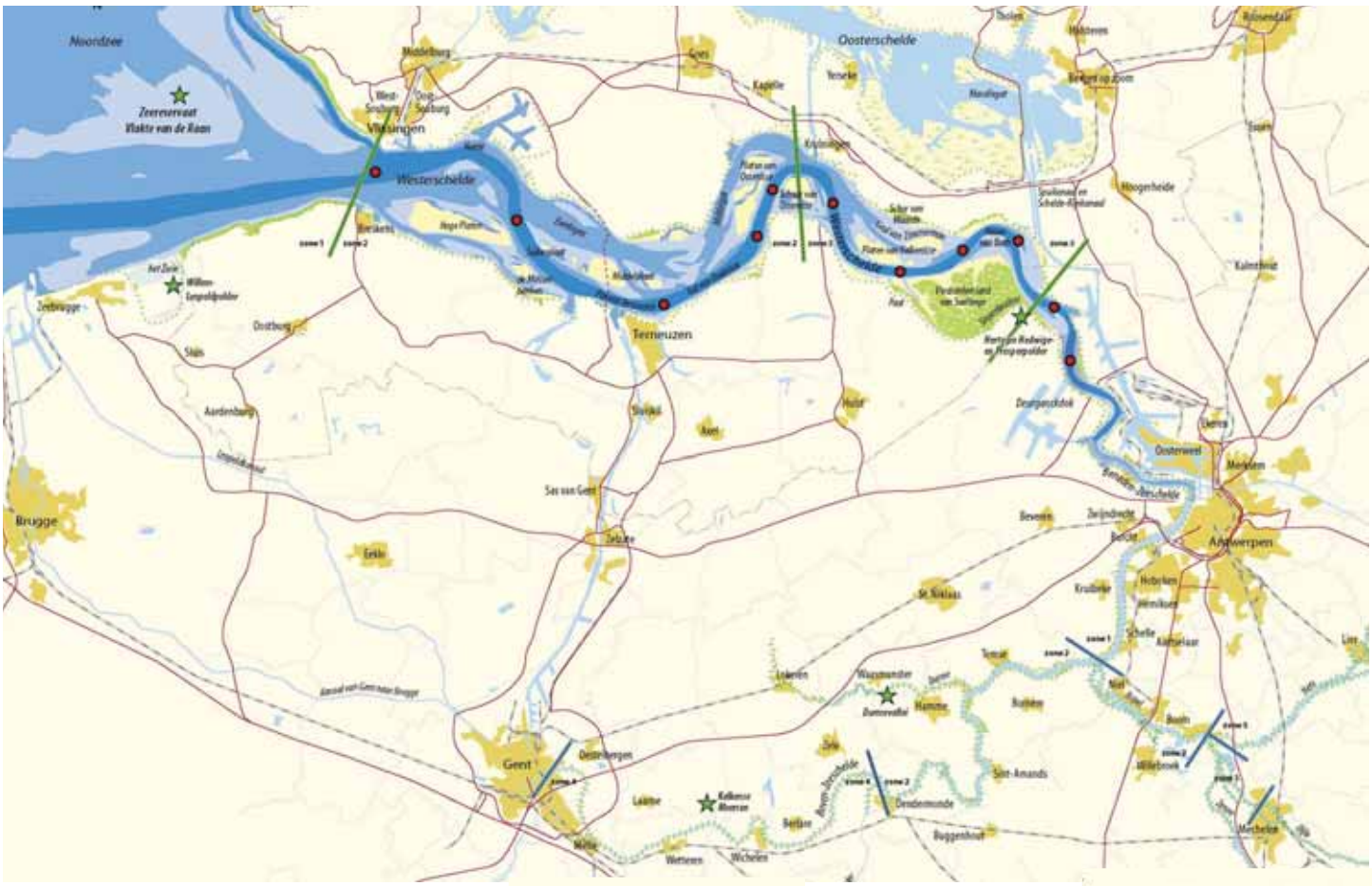

Figure 1. Map of the Scheldt estuary.

Salinity

The longitudinal salinity profile of the Scheldt estuary is primarily determined by the magnitude of the river discharge, with the transition between fresh and salt water being particularly variable. The estuary is well mixed (except during peak discharges), which means that vertical salinity gradients are small or negligible. A polyhaline zone stretches out from the river mouth (Vlissingen; km 0) to the vicinity of Hansweert (km 40). Between Hansweert and the Dutch-Belgian border (km 58) a mesohaline zone is located. The section between the border and the vicinity of Antwerpen is characterized by a steep salinity gradient. Upstream of the Rupel is the fresh water tidal zone. Salinity there varies between 0 and 5.

Maximum turbidity zone & sediments

In the Scheldt estuary, the turbidity maximum is situated at about 110 km from the mouth during dry periods and about 50 km during wet periods. The combination of favourable hydrodynamic conditions, several fine suspended matter sources, and the flocculation process, led in the salinity zone 2-10 to bottom sediment that contains locally a high percentage of fine material. Bottom sediments of the Westerschelde in general consist of sand, except in the tidal flats and marshes, where also muddy sediments occur.

Changes in intertidal areas

Major changes in the morphology of the estuary occurred during the last centuries. In 20th century still about 16 % of the total surface were lost, due to industrial, agriculture and urban developments. As mainly mature marshes are embanked, the relative contribution of intertidal areas decreases in the same period from 27 to 17 % (excl. sand flats). Due to dike enforcement, many of the marshes in front of the seawalls have disappeared. This disrupted the connectivity of marshes along the salinity gradient.

The recent evolution of habitat area in the Westerschelde is characterized by a decrease of low dynamic area (e.g. mud flats and shallow water characterized by low physical stress) and an increase of high dynamic area (e.g. deep water and sand flats characterized by high physical stress). Most marshes in the estuary are of a mature type; young marshes become scarce.

Changes in gullies

To guarantee the safe access to the port of Antwerp forever-larger ships, large scale dredging of the shipping lane in the Westerschelde and the Zeeschelde is required. Most dredging takes place at the bars (or sills) where ebb and flood channels merge and at port sluices. Some bars have been deepened more than 5 m and a further deepening is required. Although some sand is extracted from the estuary, most dredged material is relocated within the estuary at some specified dumping locations.

Trophic status

Due to high input of allochtonous organic matter and nutrients in the upper and freshwater tidal estuary, microbial activities are intense and oxygen depletion occurs frequently. Although improvements have been made, oxygen conditions are still low in the upper estuary, especially during summer. Along the longitudinal axis, the oxygen conditions improve considerably towards the Dutch/Belgian border. In the Westerschelde the water column becomes fully oxygenated. The improvement in water quality resulted in a first recovery of fish life in the Zeeschelde, mainly near the Dutch/Belgian border.

Biodiversity

Bad water quality severely impacted benthic invertebrates and fish. The freshwater part of the estuary harboured less species than normally expected (Remane's curve). Despite the geomorphological changes in the lower estuary and the bad water quality in the upper estuary, the Scheldt estuary is one of the most important estuaries along the NW-European migration route for water birds, maximum numbers reaching up to 230000 individuals. For 21 water bird species, the Scheldt has international importance.

Level of scientific knowledge

An extensive literature about the Scheldt estuary has been published. From the late 80's up till now the number of peer-reviewed articles per year was about 20 to 40. Many Scientific Institutes and Universities do research in this area. To name the most important:

- Netherlands Institute of Ecology (NIOO-KNAW), Centre for Estuarine and Marine Ecology, Yerseke;
- Department of Biology, Ecosystem Management Research Group, University of Antwerp;
- Research Institute for Nature and Forest, Ministry of Flemish Community, Brussels;
- National Institute for Coastal and Marine Management, Middelburg .

The special Issue of Hydrobiologia "Ecological Structures and Functions in the Scheldt Estuary: from Past to Future"(volume 540, may 2005) gives the latest overview of the current knowledge of the Scheldt estuary.

Problems and dysfunctions of the system

Safety

Zeeschelde: flood protection is presently inadequate. Safety has been improved by establishing the Kruibeke-Bazel-Rupelmonde controlled flooding area, but is still inadequate, and during the coming century it will decline in effectiveness due to climatic change and rising sea levels.

Westerschelde: flood protection is presently adequate, but long-term safety is inadequate due to climatic change and rising sea levels.

Accessibility

Antwerp port: seagoing vessels with a draught of up to 11.85 m can now sail as far as Antwerp regardless of the tide. Ships with deeper draughts must wait for a favourable tide so they can sail over the various bars in the shipping channel. In the future, shipping lines will shift to relatively larger container ships. They will also operate using tighter schedules in order to reduce costs. Long waiting times make Antwerp Harbour unattractive, which is undesirable since a flourishing harbour is important for prosperity in the Scheldt estuary.

Risks from transport of hazardous materials: transport of hazardous materials over the Scheldt creates risks for the

surrounding area. In the Netherlands, the risks comply with the standards for 'external safety'. No standards have been set in Flanders. The governments have agreed that in the future, the risk must remain at the 2000 level.

Natural environment

Environmental habitats: the total area of salt marshes, mud flats and shallow water has decreased dramatically during the last century. The estuary has too little space and too much tidal energy to allow such areas to develop or allow existing areas to be maintained. This causes a decline in the environmental diversity of the Scheldt estuary.

Flora and fauna: salt marshes, mud flats and shallow water are important to many species as feeding areas, breeding areas, and rest areas. The living conditions of a wide variety of species are diminishing when such shore regions are lost. As a result, important links in the food chain are threatened.

The natural environment of the Scheldt estuary is not sufficiently robust to enable it to absorb the impact of human interventions.

All of the remaining salt marshes, mud flats, shallow water and gullies in the Scheldt estuary fall under the protection of the European Habitat Directive and the Ramsar Convention.

Finding solutions: ProSes into action

To guarantee sustainable development in the future, a target for 2030 was already set and subscribed by the Dutch and Flemish governments in 2001 (the Longterm Vision Scheldt estuary). It focuses on five objectives: preservation of the geomorphology, safety against floods, optimal accessibility of the ports, a healthy dynamic ecosystem and transboundary cooperation. However, the target of 2001 does not propose elaborated projects. To define more precise projects, ProSes (Schelde Estuary Development Project) was established in March 2002. ProSes' main task was to make a solid, broadly supported development plan, so that a step towards the target for 2030 will be achieved.

The project management was focussed on being an intermediary between the various interests and ambitions, aiming to present proposals that can count on both political and social support and understanding.

Method of solution

The approach in preparing the development plan was two-pronged: research and advisory consultation. Both routes, research and advisory consultation, have resulted in political decisions on the Scheldt Estuary development plan by the Flemish and Dutch governments in 2005. Hereafter, the development plan formed the basis for further decision making on the implementation and realization of the chosen measures and projects.

Research included:
• comparing the desired situation with the situation without extra measures: the problem analysis;
• drawing up projects and measures to solve the bottlenecks emerging from that comparison;
• describing the effects of these projects and measures in a Strategic Environmental Assessment (SEA) and a societal cost-benefit analysis. These two instruments provided information in order to evaluate projects and measures as objectively as possible. The SEA mainly concerned effects of projects and measures on nature (including geomorphology), environment, landscape and spatial quality. The societal cost-benefit analysis aimed to give a qualitative or quantitative indication of costs and benefits of projects and measures and an indication of welfare for the community;
• drawing up a nature development plan. This plan has provided the SEA and the social cost-benefit analysis with nature projects and measures. It has also served as a building block and touchstone for the development plan;
• testing the projects and measures against the European Bird and Habitat directive to protect valuable natural life.

During the research process, parties involved in the development of the Scheldt, such as national and regional authorities and research institutes were consulted. Via joint fact finding existing research results were collected and new research projects were executed. Various groups reviewed the preparation of the SEA, a societal cost-benefit analysis and the nature development plan during the whole project. In these groups, representatives from universities, independent organisations and authorities of both Flanders and the Netherlands participated. An independent commission also assessed the final result of the SEA. A Dutch-Flemish scientific body assessed the societal cost-benefit analysis.

Social organisations, port managers and local and regional authorities gave advisory consult from the area. The advisory consult was divided in two bodies: the stakeholder's council and the governmental board.

The participants in the stakeholders council provided the Flemish and Dutch governments with independent advice on the development plan, presided by two independent chairmen.

The governmental board consisted of officials from principal authorities, who provided ProSes with essential information. Both the council and the board were involved from the process of formulating the problem definition to delivering the final development plan.

Communications

During the preparation of the Development Outline, interested parties made contributions during working meetings and in other manners. Such contributions could take the form of 'joint conceptualisation', 'joint knowledge', or 'joint participation'. Interested parties were regularly informed of the state of affairs via brochures, newsletters and the website, among other means.

The development plan 2010 for the Scheldt estuary

The governments of the Netherlands and Flanders recently approved the 'Scheldt Estuary Development Outline 2010', which contains dozens of resolutions regarding how the two governments intend to improve the safety, accessibility and natural environment of the estuary.

The basic principal for both governments is to maintain and improve the dynamic characteristics of the Scheldt estuary. Here 'dynamic' means a constantly changing pattern of channels and intertidal flats, regular variation in salinity, and the formation of new salt marshes and mud flats while

old ones disappear. Safety, navigability, and the natural environment all benefit from maintaining the dynamic vitality of this system.

The Development Outline does not deal with all of the problems in the Scheldt estuary. For instance, it does not address the issue of improving water quality. This issue is already being dealt with jointly by Flanders and the Netherlands, along with the other Belgian regions and France, in the International Commission for the Protection of the Scheldt (www.isc-cie.com).

Resolutions

Safety against flooding: increasing dyke heights and establishing flooding areas along the Zeeschelde

The regional and national authorities have decided to increase safety along the Zeeschelde by establishing controlled flooding areas no later than 2030. Where space for flooding areas is lacking, such as in urban areas and industrial areas, the heights of the dykes will be increased. Flanders aims to establish 280 ha of controlled flooding areas by 2010. Of this, more than 200 ha will be configured as estuarine environment areas. The Flemish government will specify the specific locations of the controlled flooding areas, the configuration of the estuarine environment areas, and the increases in dyke heights.

Accessibility: deepening and widening the shipping channel

Flanders and the Netherlands have decided that ships with a draught of 13.1 m must be able to sail as far as the port of Antwerp regardless of the tide. For this purpose, the authorities will lower the level of the sills in the channel by 1.4 m. In the vicinity of the Deurganck Dock, the Zeeschelde will be widened from 250 m to 370 m over a length of 5 km.

Flexible dumping locations

To achieve optimum conditions in the Scheldt estuary, it is important to maintain the vitality of the estuary and its network of multiple channels. Changing the way the shipping channel is maintained can help achieve this objective. Regular dredging is constantly necessary to maintain the sills at the desired depth.

Silting-up of side channels and erosion of salt marshes and mud flats can be avoided by a careful selection of dumping locations. The authorities will make the selection of dumping locations more flexible in order to allow dumping to take place where it is most favourable for the vitality of the estuary. All maintenance dredging will be dumped back into the estuary. To protect the side channels, a larger proportion of the dredging will be dumped in the main channel in the future. In addition, more dredging will be dumped in the eastern part of the Westerschelde and fewer in the mouth region.

Monitoring

So far studies have shown that deepening the channel will have little effect on the vitality and natural environment of the Scheldt estuary, under the condition that the dumping strategy is modified and ecological development takes place. However, this conclusion cannot be stated with absolute certainty. For this reason, the governments will establish a measurement programme for monitoring developments in the Scheldt estuary during and after the deepening of the channel. The governments are still investigating whether measures can be devised in advance of the deepening so that any undesirable effects that may occur can be quickly countered. The party responsible for causing the undesirable effects will pay the costs of the measures. If the responsible party is not known, Flanders and the Netherlands will share the costs.

In deciding whether the measures are actually necessary, the authorities will also take into account the requirements of the EC Birds and Habitat directives. These European directives oblige countries to maintain existing environmental values.

Acceptable risks

The Netherlands and Flanders desire to maintain safety in the Scheldt estuary at an acceptable level. They will request lower-level governments to always assess the effects on external safety when generating new spatial plans. The governments will improve the provision of information regarding safety policy to lower-level governments and the general public. They also wish to see improvements in the options for disaster prevention and relief, and they will request the responsible governmental organisations in Flanders and the Netherlands to take action to achieve this objective.

Natural environment

Flanders and the Netherlands will create more space for estuarine environments. At minimum, they will execute the following projects in the period up to 2010:
Cross-border:
• designation of the Vlakte van de Raan as a 'marine reserve';
• enlarging the Zwin by at least 120 hectares, and possibly 240 ha;
• developing a 465 ha intertidal area in the Hertogin Hedwigepolder and the northern part of the Prosperpolder.

In Flanders:
• restoring the conditions necessary to allow fish migration in the Zeeschelde;
• reconfiguring the Durme and its valley;
• developing 125 ha of estuarine environment in existing controlled flooding areas;
• establishing 600 ha of wetland in the Kalkense Meersen;
• developing 210 ha of estuarine environment in locations still to be chosen, in combination with establishing flooding areas.

In the Netherlands:
• developing approximately another 300 ha of estuarine environment in locations still to be chosen.

In total, at least 1000 ha of new estuarine environment will be added to the Scheldt.

Increased vitality

In combination with activities for improving safety against flooding, accessibility and the natural environment, the governments will also take measures to restore natural vitality where possible. Some examples of such measures are using alternative dredging and dumping strategies, constructing or removing breakwaters, excavating old salt marshes, and increasing or decreasing the depths of channels. Specific plans for such activities will be made during the implementation phase.

Multifunctional environment

Flanders and the Netherlands wish to make the new natural environment areas usable for other purposes where possible. They foresee possibilities for combining natural environments with other objectives such as safety, agriculture, marine aquaculture, recreation, and residential/employment initiatives.

Actors in the management of the Scheldt estuary

The governments have signed a Memorandum of Agreement (in March 2005) in which (among other things) they specify the financing of the resolutions. They have also anchored the most significant resolutions in the Development Outline in a treaty. In addition, the authorities have formulated a treaty regarding how they will further proceed to attain the target situation in 2030. These treaties were signed in December 2005.

A joint board of high officials does the overall management from both the Netherlands and Flanders (the Technische Schelde Commission). The ministeries of Infrastructure, Transport and Waterways as well as the ministery of Agriculre and Nature are represented in this Commission. The Dutch Provence of Zeeland is a new member.

The participants in the stakeholders council, presided by two independent chairmen, will continue to provide the Flemish and Dutch governments with independent advice on the development plan.

The governments have again established a joint project organisation in order to ensure a coordinated approach during the subsequent stage (ProSes2010). The task of ProSes2010 is to coordinate the various measures and procedures and clearly communicate information. New websites for this purpose are available: www.proses2010.be and www.proses2010.nl. Specific implementation of the individual projects is carried out in the regions in question in cooperation with the directly involved and affected parties.

Partners and links with other estuaries

Humber:roger.morris@English-Nature.org.uk; Pbarham@abports.co.uk
Seine: http://seine-aval.crihan.fr
Elbe: Doris.Mueller@hpa.hamburg.de
Paralia: Neumann.imi@planet.nl
DeltaNet: Network of European deltas/ Sustaineble delta management
NewDelta: www.newdelta.org
Rhine-Scheldt Delta co-operation: www.rsdelta.org

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For additional general information about the Scheldt estuary, please visit:
www.ontwikkelingsschets.nl
www.scheldenet.nl
www.scheldenet.be
www.nioo.knaw.nl/CEME

Jon Cosen with the collaboration of S.Verheijen ProSes 2010