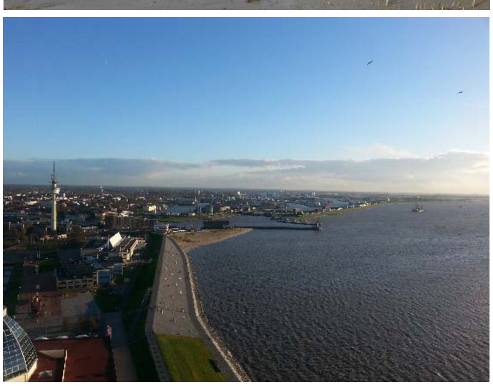
EMOVE

Estuaries on the move

Work Package 3 – European Joint Fact Finding

Part 2

Description of State, Impacts and Solutions



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The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

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1 Introduction

This Report documents the outcomes of the Estuaries on the MOVE partnership EMOVE elaborated in Work Package 3. The aim was a European Joint Fact Finding on the most urgent problems occurring in the estuaries of the partner countries. Three of them will be investigated extensively: Göta Älv (S), Scheldt (NL/B) and Weser (GER). The partnership consists of four organisations and institutions Dutch Rijkswaterstaat – Dienst Delta en Zee, the Flemish Department of Mobility and Public Works (MOW), the German Federal Waterways Engineering and Research Institute (BAW) and the Swedish company COWI AB.

To ensure a cooperative working environment and a comparable structure for the achieved outcomes it was necessary to apply a collaborative investigation approach. The EMOVE partnership selected the Driver-Pressure-State-Impact-Response (DPSIR) concept as joint approach for the “European Joint Finding” task. In a first step the most urgent problems of each and their partner estuary have been identified. This provided insight in the comparability of the estuaries. This first step was done by an analysis of the processes and anthropogenic activities which cause pressures on the estuaries (Drivers). The identified Drivers and Pressures (direct stresses caused by the Drivers) have been documented and discussed in the first part of the Joint Fact Finding Report (EMOVE 2014).

This report comprises the outcomes of the description of State, Impacts and Responses on the most important problem (Prioritised Pressure) identified for each partner estuary. To operationalise this every partner conducted a complete analysis on this three DPSIR phases. This leads to comparable structure of the gathered information and enables a direct involvement of the regional stakeholders. Analysing and reporting was done by each partners for their estuary by themselves. The outcomes of the Göta Älv were generated by COWI. The Scheldt analysis was carried out by the Rijkswaterstaat and MOW with Deltares as a subcontractor being responsible for the reporting. Responsibility for Weser part and the structuring of the DPSIR approach and the reporting of WP 3 was the BAW getting support by its subcontractor Küste und Raum.

2 Objectives of Work Package 3 - Joint Fact Finding

The objective of this Work Package (WP) is to identify the most urgent problems in the estuaries of the partner countries. The process of the identification of similarities and differences between the estuaries is facilitated by the application of the DPSIR-approach (Driving force-Pressure-State-Impact-Response)(Pirrone et al. 2005; Kristensen 2004; Borja et al. 2006; Nobre 2009; Bosch 2000; Aliaume et al. 2007). This approach leads to a Joint Fact Finding that is able to identify the *Prioritised Pressures* of the EMOVE estuaries (see EMOVE Project 2014).

The application of this approach is possible due to the comparability of the dominant land use pattern (Driving Forces) and resulting Pressures in all estuaries. The most relevant direct stresses affecting the environment (Pressures) and the processes and anthropogenic activities (Driving Forces) triggering those Pressures have been identified and subsequently called *Prioritised Pressure*.

Each of the partners performed a complete DPSIR approach for its *Prioritised Pressure*. This encompasses a system description (State) containing the main environmental compartments affected (e.g. salt concentration, morphology, hydrological situation) and estimation on the impacts triggered by this identified *Prioritised Pressure*. Finally, already existing solutions that are suitable to respond to the problems (Responses) were documented and assessed for each estuary.

3 Methodology

DPSIR was used as an integrating method to merge the outcomes of the particular estuaries. Therefore, the different project activities mentioned in the application form were allocated to the several steps of the DPSIR-approach (The five DPSIR phases: Driving force-Pressure-State-Impact-Response) built the template for the analysing steps in each estuary (see Table 3-1: Schematic workflow of WP3-Join Fact Finding integrating DPSIR phases and WP-Activities and used criteria and parameters contents. TWS: Transnational Joint Fact Finding Workshop. Complete table for each partner estuary in the annex.

Activities EU	1) Problem identification							2) Impact identification				3) TWS	4) Identification of existing solutions	5) Documentation & evaluation of existing solutions	
DPSIR-Phase	Driving force	Pressure	State					Impacts				Responses - Analyses		Responses - Assessment	
Criteria, Content		Saltwater-Intrusion	Compart-ment	Ecology - System description	System description - Parameter	Socio economic - Description user-demands	System description - parameter	Impacts on ecosystem	System description - parameter	Impacts on socio economy	System description - parameter	Legal frame-work, laws, guidelines Regulations - (agency)	Use-dependent framework-individual adaptability	Legal frame-work, laws, guidelines Regulations	Use-dependent framework-individual adaptability
Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table 3-1: Schematic workflow of WP3-Join Fact Finding integrating DPSIR phases and WP-Activities and used criteria and parameters contents. TWS: Transnational Joint Fact Finding Workshop. Complete table for each partner estuary in the annex.

To facilitate the outcomes of the different DPSIR phases some additional subcategories have been introduced. The description of the State and the evolving Impacts of the reviewed *Prioritised Pressure* (e.g. Salt water Intrusion, column 2, Weser Estuary) are divided into two parts: the ecological and the socio economic system (see Table 3-1: Schematic workflow of WP3-Join Fact Finding integrating DPSIR phases and WP-Activities and used criteria and parameters contents. TWS: Transnational Joint Fact Finding Workshop. Complete table for each partner estuary in the annex..

For the ecological physiological system description the describing disciplines (e.g. hydrology, column 4) and the specifying parameters are identified (e.g. tidal curve, runoff, column 5). The Impacts triggered by the Pressure (Salt water Intrusion) describe the alteration of the discipline triggered by the impact (e.g. change of hydrology, column 8) and its parameters (change of tidal curve, runoff, column 9). Basement of the socio economic State analysis was the demands of the users (e.g. space for infrastructure, column 6) and their parameters (e.g. costs space for infrastructure, column 7). The impacts were sorted for the different user perspectives (e.g. Water Management, Nature Conservation, column 10) specifying problems or losses occurring (e.g. loss of habitats, column 11).

Additionally, specifications concerning the affected compartments were given (e.g. hydrology of surface or ground water, column 3). The Responses reflect the stakeholders' opinions on existing solutions. In a first step all options that could improve the current situation were gathered (column 12, 13) and in a second step these were assessed by the stakeholders (column 14, 15). The Responses were sorted whether their provenance is by legal frameworks or even use dependent.

This schedule is the methodological frame to integrate the outcomes of the fact finding process in the different partner estuaries. A complete table for each estuary, the Prioritized Pressures and the identified compartments, descriptions and parameters is provided in the annex.

The stakeholder involvement in each estuary leads to an identification and assessment of the potentially existing solutions. The outcome of these analytical steps is at least one practical example to solve the problems of the identified pressure in each estuary.

4 Results

This report focusses on the description of the DPSIR phases linked to *Prioritised Pressures* of each estuary. The following Prioritised Pressures have been identified by the involved experts (EMOVE 2014).

Göta Älv

- **Increased Flooding**: increased frequency due to climate change
- **Disposal of Masses**: excavated masses for sea disposal

Scheldt

- **Tidal intrusion**: amplification of the tidal range with related problems: loss of estuarine dynamics, import of fine sediments, higher flood risk

Weser

- **Salt Water Intrusion**: Encroachment of Salt Water into ground- and surface water bodies and soils of coastal landscapes and river banks

In every estuary a complete DPSIR analyses of the *Prioritised Pressure* was conducted. The outcomes are summarised in this chapter reflecting the following three DPSIR phases State – Impact -Responses.

State

Issue of this chapter is a short pregnant description of the current State of the estuary concerning the identified Prioritized Pressure in the partner estuaries. This enfolds the spatial scale of work as well as the system compartments affected. The description is divided into ecological, morphological and hydrological items as well as the socio economic system.

Impacts

Issue of this chapter is to identify the extent of the effects of the *Prioritised Pressures* in the different estuaries due to changes in the state of environmental system. These impacts could be divided into the affected systems: the ecosystem and the socio-economic system.

Responses

The **Response** is the evaluation of actions; oriented to solve environmental problems in terms of management strategies. Goal of this chapter is to identify existing solutions that are able to mitigate or to solve the existing problems. These solutions could be established by individual adaptability or refer to legal framework like Guidelines or other regulations.

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4.1 Göta älv

4.1.1 State

4.1.1.1 Spatial extension of the investigation Area

Göteborg is situated at the west coast of Sweden and the Göta river flows through the city. The city centre is exposed to high water flows of the river and flooding's through the North Sea. The Göta River splits up north of Göteborg into Nordre älv and Göta älv. Nordre älv estuary is mainly rural. The Göta älv runs south (Göta älv estuary) through Göteborg where it is trafficked by cargo ships, international ferries and ferries across the river (Figure 4-1). The southern part of the Göta älv estuary has no agriculture driving force.

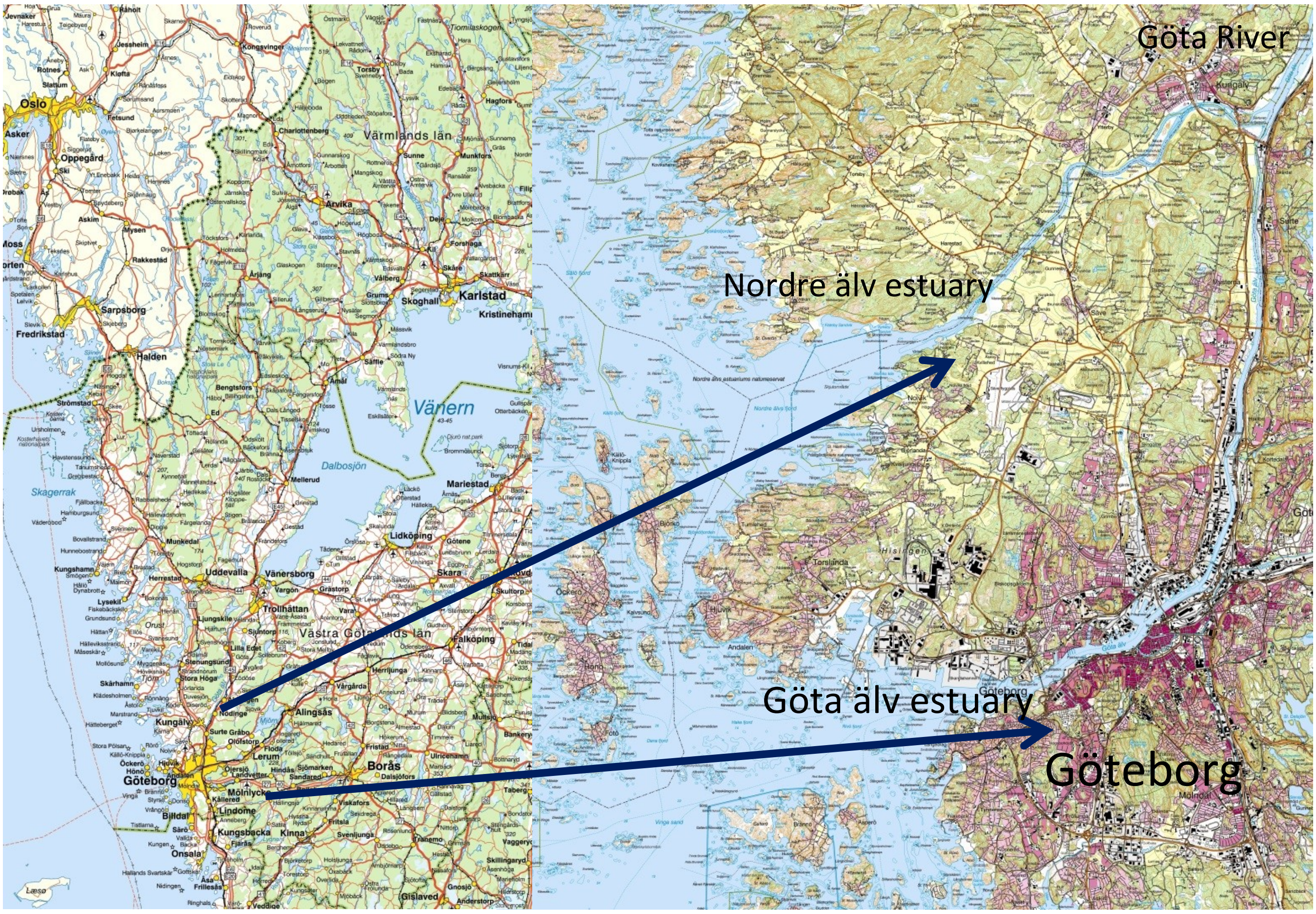

Figure 4-1: The Göta River runs from Lake Vänern (left figure). It splits north of Göteborg and ends in the Nordre älv and Göta River estuaries (right figure). Lantmäteriet ©

Prioritised Pressure: Increased Flooding - increased frequency and extended areas affected

Already today the central parts of Göteborg face impacts of flooding caused by increased sea level rise during, low pressure westerly wind, storm events. An example is the flood event in December 2103 when the storm Sven hit the region (Figure 4-2).

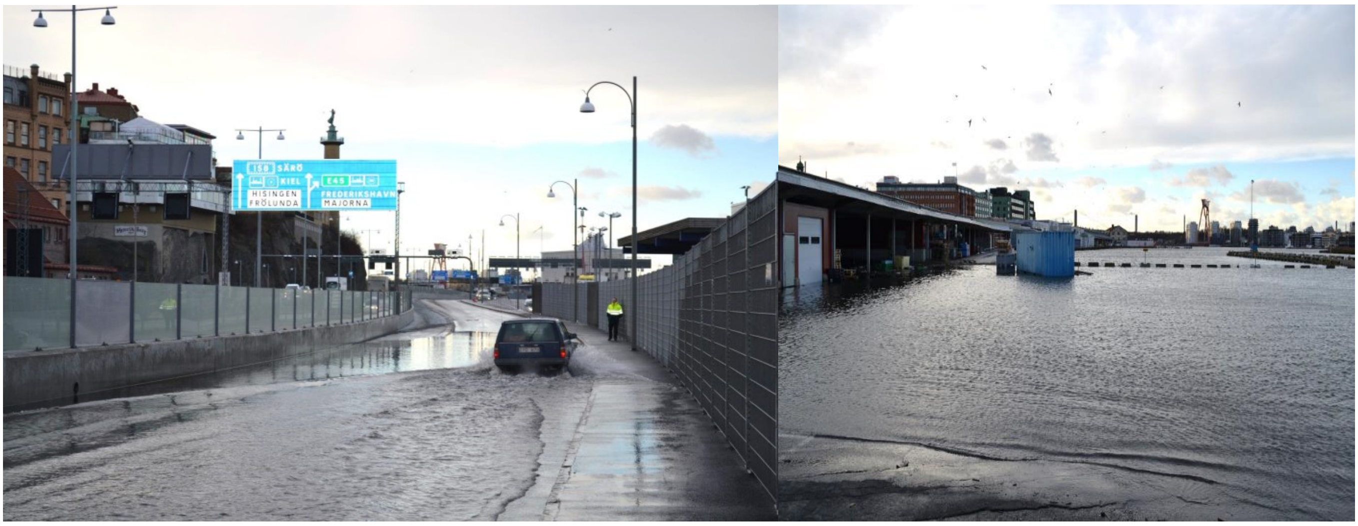

Figure 4-2: Increased sea level in the Göta älv estuary due to the extra-tropical cyclone Sven, Göteborg December 2013. Photo: Susanna Gelin

The city is managing the current events relatively well as most parts of the city has been built and adapted for such sea levels. Climate change will result in a 1 m sea level increase, which in combination with storm events are expected to have costly impacts on the central parts of Göteborg (buildings, infrastructure). In parallel, the central parts of Göteborg along the Göta Älv estuary shore line is planned to be exploited (densified) and the consequences of flooding will increase even more. In order to allow for the exploitation the planners of Göteborg are hoping and working for the construction of an operable barrier (such as the Themes barrier or the Storm Surge Barrier Rotterdam) up- and downstream city centre parts of the Göta älv. The city administration is assessing the costs and benefits of such for Göteborg municipality but not the impacts on the Nordre älv estuary. In a recent EU project, i.e. Architecture and roadmap to manage multiple pressures on lagoons (ARCH), impacts of sea level rise and the barriers have been identified. In this project, we have made a primary multi criterion assessment and identified additional potential impacts. The works has been through literature review, expert judgements and GIS-based information. The result has been compiled in a diploma work report (Norén, 2014).

In addition to flooding due to increased sea level rise during low pressure events, Göteborg and the surrounding region also face flooding due to heavy rain events. These events cause both an increased pressure on the water and sewage system plant located in the Göta Älv estuary as well as direct contaminant loads to the estuary. This pressure will increase both due to increased exploitation in Göteborg and increased precipitation due to climate change. There are some potential solutions, such as: increasing the current piping system which will need the waste water plant to expand, i.e. this would require another new built plant; construction of water magazines; retention areas such as wet or dry dams.

Prioritised Pressure: Disposal of Masses - excavated masses for sea disposal in the Göta Älv estuary

The planned exploitation will need new infrastructure. The ongoing plans is to construct a train tunnel system that will result in ca 2millions m³ of excavated masses. The excavated masses will consist of rock (82 %) and fine sensitive clay (Trafikverket 2014). The volume of the excavated clay masses may be up to 400 000 m³.

About a quarter of the masses will be reused within the tunnel project, but the remaining masses (ca 1 500 000 m³) has to be removed. The rock will be used within other infrastructure projects, while it is less certain how to manage the fine sensitive clay. The clay could be used for expanding central parts of Göteborg in the Göta älv by stabilisation/solidification, it could also be used for expanding the port (also by stabilisation/solidification), it could be used as a basic material for other purposes such as producing bricks, or it could be disposed at sea or landfilled. Here we investigate the impacts of such alternatives on the estuary.

There are two locations considered for the disposal. Both are currently in use for disposal of dredges masses from keeping the Göta Älv estuary open for shipping activities. The current sites covers an area of more than 5 km² of which Trafikverket already today has allowance for disposal on ca 2 km² (Trafikverket 2014). Keeping the total disposal within the 2 km²area would result a need to add additional 0. 15 m of fine clay, which is well in line with allowed level below the current sea level.

4.1.1.2 System description: Hydrology – Morphology – Ecology

Göta älv

Hydrology, Morphology

Göta älv is the richest in water compared to other rivers in Sweden. The average flow is 550 m³/s. The water flow has is highly varying since the regulation in 1937. Before the regulation, the flow rarely exceeded 800 m3/s, and the variations were very small in relation to other bodies of water, while it today often exceeds 1000 m³/s and it may even exceed 1300 m³/s. Of the river's total flow, 2/3 to 3/4 is through the Nordre älv.

Water quality

The Säve river/stream inflow to the estuary at the Älvsborg bridge – insufficient ecological status, does not meet the prime objective of good chemical status due to mercury and TBT compounds. Changed habitats through physical impacts like dredging, building and heavy boat traffic. Occurrence of foreign species. Insufficient hydrological regime and several point sources of TBT.

Habitats

The Säve river/stream inflow to the estuary at the Älvsborg bridge – Extensively modified habitat. Part of Göteborgs Hamn with lots of boat activities, docks and bridges and almost no natural habitats in the shore line. Contiguous areas constitute of 99% blacktoped surfaces.

Species

Göta älv – The Säve river/stream inflow to the estuary at the Älvsborg bridge – Populations of salmons migrate through the river in both ways. Precense of mussles in the harbour area.

Göta älv estuary

The Göta älv estuary is, on the contrary to the Nordre älv estuary, busy and there is frequent dredging. The port is largest in Scandinavia. It is a combined river and seaport, with a total quay length of 13.1 kilometres a trading volume of 39.9 million tonnes (in 2006). The inner parts are resorted bronwfields, or brownfields that will be restored, holding buildings for housing and business.

Water quality

Göta älv esturary: outside the Älvsborg-bridge Rivö fjord – moderately good ecological status but extensive eutrophication problems, chemical contaminants in general mercury, changed habitats through physical impacts like dredging, expanding of the harbour and heavy boat traffic. Impacts from several industries in the nearby area. Occurrence of foreign species. Partly stratified because of differences in salinity.

Habitats

Göta älv esturary outside the Älvsborg-bridge Rivö fjord – Shallow area 6 m average depth, apart from the dredged waterways. Mixed kinds of sediments.

Species

Göta älv esturary: outside the Älvsborg-bridge Rivö fjord – Moderate status in benthic fauna. Presence of invasive species like Round goby. Populations of Harbour seals.

Nordre älv

Hydrology, Morphology

The Nordre älv estuary comprises the lower part of the Nordre älv and the shallow fjord into which the river empties. In the estuary, there are plenty of shallow bays, islands and skerries (see Figure 4-3 below).The landscape is flat with meadows and, occasionally flooded, beaches surrounds the bays. Nordre Älv is one of the few, or the only, rivers/estuaries Europe that has not yet been dredged.

The estuary is dominated by a freshwater outflow, with little tidal influence and a large width to depth ratio. Seawater pushes up as a wedge along the bottom, without interfering with the overlying freshwater as the freshwater outflow increases the friction against the underlying water, so waves are formed and salt water are captured.

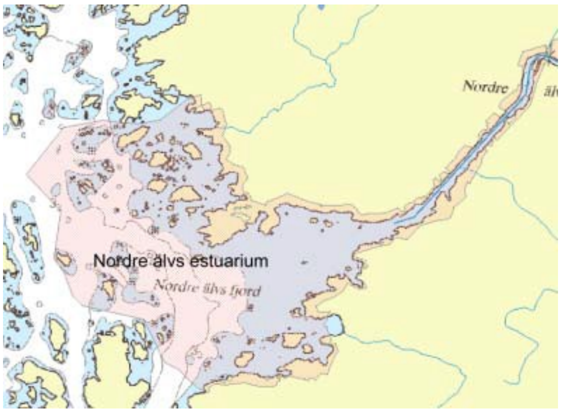

Figure 4-3: The Nordre älv estuary

Water quality

Nordre älv – currently good ecological and chemical status including eutrophication, acidification and chemical contaminants in general but mercury is found in to high concentrations

Habitats

Nordre älv – grazed shore meadows, wetlands and deciduous forests, croplands and some shell gravel. The seabed is partly soft sediments. Very good circumstances because of the upwelling of salty, clear water. Almost all of Nordre älv estuary is classified as Nature 2000 under the bird and art and habitat directives (Figure 4-4).

Figure 4-4: Nature 2000 areas in the Nordre Älv estuary. © Naturvårdsverket, Lantmäteriet, Geodatasamverkan, 2014.

Species

Nordre älv – High biological productivity, very rich fauna and flora both in fresh water and marine species, for example sea eagle, lampreys and eel. Present is also invasive species such as Canadian goose and Chinese mitten crab. High botanical value in the terrestrial areas, like orchids. On the soft sediments one can find eelgrass and blue mussels.

4.1.1.3 System description – Socio Economic System

Identification of Stakeholders

Climate change

Several stakeholders of different levels have been involved to work on the items of climate change

Göteborg and Nordre älv Estuary:

National/regional level administrations

- The Maritime Administration - responsible for the marine development, nature conservation (marine environment)
- County administration board -responsible for the county development, responsible for nature conservation (terrestrial and estuary)

Municipalities

- Göteborg city (Strategic city planning) – responsible for the management of climate change impacts and driver for operable barriers/ports + south part of the Nordre älv estuary
- Kungälv municipality – responsible for the management of climate change impacts in the municipality and will (more or less) be impacted by potential operable barriers/ports (north part of the Nordre älv estuary).

Other

- Göta älvs vattenvårdsförbund (Water Resources Association – quality insurance and monitoring of Göta älv)
- Naturskyddsföreningen (Environmental NGO on nature conservation)
- University of Göteborg (Albin Norén –diploma works, Rodney Stevens – professor and co-supervisor)

Climate Change and Exploitation (Water Management)

With the following Stakeholders there had been consultations referring the specific items water management.

National/regional level

- County administration board – policies and control
- Municipalities
    - Göteborg city
        - Strategic city planning – densification and exploitation interests
        - The city management of waste, reuse and water – owner and responsible for the storm and sewage water piping system Göteborg city.
        - The storm and sewage plant of Göteborg – owner and responsible for the treatments before the water is reaches the Göta älv (located in the western part of central Göteborg)
        - Urban parks and environment administration (responsible for management and maintenance of blue-green water management solutions in areas where the municipality is land-owner, responsible for the green plans of Göteborg city

- Other
    - Göta älvs vattenvårdsförbund (Water Resources Association – quality insurance and monitoring of Göta älv)
    - Environmental NGO (nature conservation interests), Social/environmental NGO (våtmarkens betydelse för ett pedagogiskt och social intresse)
    - Chalmers University (Nathalie Bergqvist – master thesis, Andreas Lindhe- Associate Professor, co-supervisor)

In general, both with regard to the impacts on Nordre älv estuary and the storm water management, there are other networks that may be relevant such as fishing and sport fishing networks, specific habitats and cultural interest networks.

Disposal of masses

The following stakeholders have been involved working on the Prioritised Pressure Disposal of masses

National/regional level

- The Road and Transport Agency – responsible for the infrastructure project "Västlänken" in Göteborg, creator of masses that may be disposed
- The Maritime Administration – responsible for the marine development, nature conservation (marine environment)
- Sjöfartsverket maritime and river transportation - dredging interests in the estuary and creator of masses that are likely to be disposed in the estuary.
- County administration board -policies and control

- Municipalities
    - Göteborg city (Strategic city planning, environment and urban environment)
    - Öckerö municipality
- Business related organisations in the region
    - Port of Göteborg – interests of dredging and expansion of activities
    - Region Västra Götaland (West Götaland region) – business interests, i.e. interests of well-functioning infra-structure (road, rail, shipping)
    - Göteborg Region (GR) – business interests, i.e. interests of well-functioning infra-structure (road, rail, shipping)
- Other
    - Göta älvs vattenvårdsförbund (Water Resources Association – quality insurance and monitoring of Göta älv)
    - Naturskyddsföreningen (Environmental NGO on nature conservation)
    - Yrkeshögskolan via Västerbergslagens utbildningscentrum (Polytechnical University) (Emma Wieslander- ongoing short diploma work)

Demands of the Stakeholders at Göta älv

Climate change and exploitation

Göteborg (Göta älv estuary)

- Protect the central parts of Göteborg, allow exploiataton in central parts of the city (e.g. along the Göta älv estuary) with regard to flooding

- Need of increased capacity to cope with the increasing storm-water amounts

Nordre älv

- Minimise the impacts of climate change on morphology, habitat, ecological and chemical status of Nordre älv

Disposal o Masses at sea

Need to get rid of soft clay from the infrastructure projects may result in need to dispose the excavated clay masses at sea. Other alternatives are preferred, but needs to be found feasible. There is a need to certify that the disposal only will have minor impact on the morphology and that benthic organisms only are affected for some months to a few years after disposal. Recent studies in the area show no changes of habitat and biodiversity in a long-term perspective due to the disposal under similar conditions. There are no other demands, than legislative we have identified.

4.1.2 Impacts

4.1.2.1 Impacts on the ecosystem

Climate Change and Exploitation

Göta älv:

Surface Waters - Hydrology

Climate change will increase the flow in the river, which in turn will increase the sediment transport and leaching of nutrients and contaminants to the Nordre älv estuary. Because the estuary is relatively shallow (almost half of the estuary has a depth of 2-3 m) it is extra vulnerable towards eutrofication and increased sedimentation. The increased sea level will also result in increased leaching of nutrients and contribute to increased erosion. Increased sea level due to projected climate change, combined with storm events, will also increase. The stormwater will increase both in total amount over the year and the amount per occasion. This will increase the runoff into the river which will impact the water. The area of flooding in the central parts of Göteborg. This includes planned and existing buildings, infrastructure and not restored brownfield areas will be flooded impacting the water quality.

Göta älv estuary

Surface Waters – Water quality

Increased contaminant load will also be seen in Göta älv estuary due to increased run off from the city caused by densification/exploitation and climate change. The current status of the estuary is improving due to water emission regulations from industries, central storm water and sewage treatment upstream the river and in the region and dredging of contaminated sediment. The trend of improvement will stop or become opposite unless measures are taken. The increased contaminant load will have impacts on the recent establishments of fauna and flora but also the almost reached criteria for swimming and other recreational activities in the estuary. Among the potential alternatives are: to increase the allowed first flush into the river during heavy rain events which will increase the load of chemical and biological contaminants; to expand the piping capacity which will need a new sewage plant; or to find other solutions.

Nordre älv

Most effected are riparian strips and surface waters: with consequences on the compartiments *Water quality, habitats, species*

In the conservation plan for the Natura 2000 area pointed to a number of risks that could result in a negative impact on protected **biotopes**. In addition to increased exploitation the estuary is considered vulnerable to eutrofication, contaminants/pollutants, tides and currents . According to recent assessments the estuary is most sensitive to changes in nutrient leaching and particle transportation with the river will, as this will likely cause negative impacts on the current **fauna and flora**. The land areas in the estuary are sensitive to hydrological changes (Länsstyrelsen Västra Götalands län, 2005b i Norén, Haeger-Eugensson et al., 2013).

Climate change – sea level rise

Göta älv estuary and Göteborg city

The impacts, of potential flooding, on buildings and infrastructure are regarded by the city of Göteborg to be that severe and costly that two ports (operable barriers), upstream and downstream the city centre are suggested to reduce the consequences on buildings and infrastructure of the city. Currently the pros and cons of this is investigated through several assessments by the Göteborg city. The ports will result in increased water flow in the Nordre älv as all the Göta älv will need to pass this way instead of the Göta älv estuary when the ports will be closed due to high sea levels.

Impacts of measure to protect buildings and infrastructure in Göteborg (e.g. Ports/operable barrier). The impacts in Nordre älv will be similar as climate change. (Impacts on the Göta älv estuary is more complex and currently the city is running several investigations through several consultants regarding the potential impacts for the Göteborg city/municipality)

Hydrology, Morphology

Increased river flows and estuary flooding – increased erosion in the Nordre älv estuary, increased sediment transport.

Water quality

The changes in hydrology and morphology will lead to increased leaching of nutrients and contaminants that will increase the contaminant load in the estuaries reducing not only the water quality but also the conditions for bottom living organisms.

Habitats and species

Especially Nordre älv is unique as it still is one of the few natural estuaries in Europe and at the same time the ecosystems and habitats are sensitive to the expected changes. The impacts are expected to increase with time.

Disposal of Masses

Göta älv estuary

Morphology

The dumping will be done as suggested by Helcom (2009) and current regulations to minimize the impacts on turbidity, erosion, streams etc. which includes that the dumped masses shall be spread evenly on accumulation bottoms. DHI (Danish Hydrological Institute) has done simulations on the impact of a dumping of 70 000 m^3 masses in a recent dispensation application[2]. The simulatations have been done for windy conditions and the sediment change over the first two months will be 10 mm. The erosion will be reduced by time. The impact on nearby sediments is said to be not significant/measurable. As the dumping will be done to max 0.5 m below sea level, and evenly spread over the area, the streams are not expected to be impacted/changed (Application for dispensation for dumping dredging spoils of clean masses - Ansökan om dispens för dumpning av rena muddermassor). Despite this, the recommendations, policies and regulations are in favor for other uses of the masses if possible. And potential other uses are or port expansion, exploitation, or production of bricks etc.

Surface Water

Disposal of fine clay will provide a reduced water quality due to the increased turbidity during the dumping activity. After disposal there may be erosion and resuspension, and thereby increased turbidity, if the masses are not disposed on accumulation bottoms. If the masses are disposed on accumulation bottoms there will not be any significant erosion or resuspension. Disposal of masses that are not contaminated will not leach any pollutants. The masses may instead be used to cover contaminated sediment, reducing the current and/or potential leaching of contaminants.

Habitats (marine, limnologic and terrestrial) and Species

- short term – may be significant impacts (fauna, flora, morphology)
- long term – habitat recover within years to few decades based on reference projects of 12 million m^3 in the area (Naturvårvårdsverket (Swedish EPA) 2009, Hydro GIS, 2009) and literature review (Andersson-Sköld et al., 2014).

The impacts of disposal of excavated fine clay from infrastructure projects, when done according to best practise, has been found to impact fauna and flora and especially bentic organisms, but unless dumping is continuously done the fauna and flora will, according to recent studies in the area, recover within some years (Andersson-Sköld et al., 2014).

The impact of the alternative handling strategies of clay from the infrastructure activities will result in different impacts on the estuary depending on which strategy is considered. For example using it for expanding central parts of Göteborg in the Göta älv and/or expanding the port will contribute to increase the accessibility to the estuary either by increased accessibility by the citizens or shipping activities. It will also cause dusting and other emissions during construction and usage and change the current landscape in the Göta älv estuary. In the potential application as basic material for other purposes such as producing bricks the estuary may be impacted through increased sea based transportation to production plant which in turn may impact the area by increased emissions over a limited time. Landfill will have very little impact on the estuary while disposal at sea will bury Benthos fauna and change the landscape.

4.1.2.2 Impacts on socio economic system

Climate Change

- Social and economic impacts (Stakeholder interviews, previous assessments)
    - Increased Flooding – unless measures are taken the central parts of Göteborg will face frequent flooding events impacting existing buildings and infrastructure. The costs can already under current conditions be high. The costs, if measures are not taken, will increase as it may limit the city's attractiveness and business establishments in Göteborg. Flooding in Nordre älv will have impacts on farming, nature and recreation. The impacts may be both positive as it will have positive impacts on bird habitats and thereby ornithologists and some recreation, but negative as it will bury some land areas.
    - Ports/barriers: will protect Göteborg but increase the streams and potential flood level upstream and in Nordre älv.
    - Doing nothing with regard to storm water management will reduce the attractiveness of the city and increase the pollutant load in the estuary which will reduce the ability to continue the current increase in water quality and thereby the potentials for recreation and other water activities such as swimming and social meeting points in the estuary, i.e. the central parts of the city.

Appraisal of the importance of impacts

Impacts of barriers on Nordre Älv estuary

		Biological diversity: Aquatic environment				Biological diversity: Terrester environment	
		Turbidity	Nutrient leaching	Salinty	Pollutants	Flooding	Erosion
Doing nothing	Short term	0	0	0	0	0	0
	Long term (2100)	-1	-1	-1	-1	1	-1
Barriers and slusses	Short term	-1	-1	-1	-1	1	-1
	Long term (2100)	-2	-2	-1	-2	1	-1

Very good	
Good	
No impact	
Negative	
Very negative	

Table 4-1: Impacts of barriers on Nordre älf estuary

A summary of the impacts of increased sea water level and barriers (operable ports) in Göta älv down- and upstream Göteborg is provided above. The impacts have been compiled based on literature review, site investigations, expert judgments through interviews with terrestrial and marine experts (Kungälv municipality, Göteborg City, Göteborg University, COWI) and the previous compilation performed in the EU project ARCH (Haeger Eugensson et al., 2013, Norén, 2014) (Table 4-1: Impacts of barriers on Nordre älf estuary.

Climate change and exploitation (Water management)

A similar summary has been compiled in another diploma work (master thesis) within EMOVE om alternative methods to manage increased stormwater due to climate change and increased exploitation including the impact on estuary due to potential changes in storm water runoff (Bergqvist, 2014). The compilation is based on a brief literature review, expert judgments (i.e. the water and management departments in Göteborg, Gryaab, Chalmers University and COWI) and storm water simulations under current conditions and increased precipitation (25%) as projected as a consequence of climate change (COWI). The study includes the alternatives:

Business as usual which implies expanding the current combined piping system, which would demand a new storm water treatment plant, in order to achieve the same water quality in the Göta älv estuary as today;

A storm water basin (of macadam) under a parking area instead of expanding the piping system;

A dry pond that will work as a storm water reservoir, thereby reducing the acute storm water pressure on the current piping system during extreme weather events.

The impacts to be considered were decided through literature investigations, and further refinements and relevance for the case study area were achieved through interviews and workshops with experts and civil servants that would be responsible for, or affected by, the different alternatives. The resulting impact categories were included in the multicriteria analysis of environmental, economic and social impacts. The resulting environmental criteria included in the assessment are provided in (Table 4-2) below.

Envrionmental criteria included in compilation	Parameters analysed	Description
Environmental impact on recipients downstreams	• Drinking water quality and water status	Estimation of pollution concentration present in stormwater on site (after transport through stormwater facility), influencing drinking water quality for humans and water quality for recipients downstream of site.
	• Regulation of pollution transport downstreams	Estimation of stormwater solutions capacity to reduce and/or detain pollutions in combination with vegetation on site (i.e. some stormwater solutions in combination with vegetation may help contain some pollutants through; dilution, filtration and sequestration on site and lower the pollution load transported downstreams to recipients).
	• Impact on European Water Framework Directive	Potential to affect the chemical and ecological status in downstream recipients.
Environmental effect on sewage sludge at the WWTP	• Regulation of pollution transport downstream (combined drainage system).	Potential to influence the WWTP sewage sludge quality if the stormwater is connected to the combined system.
Impact on local ground- and surface water cycle	• Impact on local water cycle	Potential impact on ground- and stormwater flows in the area (i.e. change in groundwater levels, increased runoff to local rivers).
Potential to delay stormwater on site	• Impact on stormwater flow.	Potential for decreasing the volume of wastewater transported to the WWTP.
	• Impact on flooding events.	Potential of decreased water flow through stormwater solution, resulting in fewer flooding intervals.
Soil quality and erosion potential	• Impact on urban soil quality and erosion potential.	Estimation of effect on soil quality on site, sediment retention and erosion potential.
Ecological diversity potential	• Impact on the ecological habitat.	Potential for change in biological diversity at site.

Table 4-2: Environmental impact categories, i.e. the environmental criteria, considered in the multicriteria analysis

Prioritised Pressure: Disposal of masses

- The infrastructure projects are regarded as important for the socioeconomic system in Göteborg. The dumping will, according to recent studies e.g. (Naturvårvårdsverket (Swedish EPA) 2009, Hydro GIS, 2009, Andersson-Sköld et al., 2014) and recent simulations[2] have little impact on the socioeconomic system. Alternative uses may, however, contribute to positive socioeconomic impacts as. Currently investigations on health and wider environmental impacts such as energy and natural resources is being investigated for the different management alternatives (dumping, port/exploitation, bricks etc.) of the excavated masses.

In the same way, an integrated assessment is being done for dumping and different management alternatives of excavated clay masses caused by infrastructure projects. The assessment is based on literature review, people's perceptions of disposal, and life cycle assessments.

4.1.3 Responses

4.1.3.1 Identification of solutions

Climate Change

Solutions supported by legal frameworks (WFD, Nature 2000. etc.)

Sea level rise

There is an approach to merge the user demands of different sectors (e.g. Port of Göteborg, Environmental NGO, municipal civil servants) based on stakeholder interviews a meeting is planned early next year.

Climate change and exploitation – causing load of pollutants in the estuary. There is an approach to merge the user demands of different sectors (e.g. Water management plant, Göteborg waste and water management, parks and nature management, NGO) based on stakeholder interviews a meeting is planned early next year (date not set, was planned for in January, but it had to be postponed).

The workshop agenda will include presentations of rough assessments with the impacts of the different solutions with regard to the affected compartments as well as rough integrated assessments aiming for agreements and/or common plans for concretization of potential business ideas.

Disposal of Masses

Potential management strategies – (fine clay) excavated masses

- Dumping at sea
    - Short term: Potentially severe consequences on the marine environment (recent studies in the area suggest 6 months to 1 year- see above) (not recommended based on policies and regulations)
    - Long term: Previous studies show system recoveries within a few decades (see above) (not recommended based on policies and regulations)
    -
- Landfill coating (previous projects: Stabcon and SMOCS) (most likely based on time demands, policies and regulations)
- Stabilization/solidification (limestone, fly ash, …)
    - Central city densification – Possible (Previous projects: Stabcon and SMOCS) (In line with some regulations, but may be against due to waste legislation)
    - Port expansion – Positive response (Göteborg port, previous projects: Stabcon and SMOCS) (In line with some regulations, but may be against due to waste legislation)
- Production of (In line with some regulations, but may be against due to waste legislation)
    - Bricks –positive interest from producer (material tests needs to be done) – interviews with producer in Sweden (in line with regulations)
    - Tiles – no positive response – interviews with producer in Sweden
    - Ceramic Tiles - Likely possible– interviews with producer in Sweden
    - Glass – no positive response – interviews with producer in Sweden
    - Cement – no positive response – interviews with producer in Sweden

There will be workshops held early 2015, the first one within EMOVE, in which the road administration, the port are aimed to participate. Thereafter, also meetings with the brick producers and/or ceramic tile producer will be set up. The workshop agenda will include presentations of rough assessments with the impacts of the different solutions with regard to the affected compartments as well as rough integrated assessments aiming for agreements and/or common plans for concretization of potential business ideas.

Agreed on workshop held with the road administration Dec. 15, 2014, COWI, Göteborg).

4.1.3.2 Assessment of solutions

Climate change and exploitation

Protection of Göteborg

Operable barriers/ports will be effective with regard to protecting Göteborg city from flooding. As shown above, however, such a solution will have several negative impacts on the Nordre älv estuary. The solution to set up a shareholder group, will allow for a better understanding of the positive and negative impacts of both operable barriers/ports as it will create a platform for identifying and assessing other potential risk reduction measures between a larger group of stake- and shareholders.

Water management

A quantitative/ semi quantitative assessment of each of the criteria was done based on modelling, expert judgements (the water and management departments in Göteborg and Gryaab), and previous experiences and perceived impact by other stakeholders (civil servants) that would be affected by the measures. The results is a ranking of the total impacts on environmental criteria, social and economic criteria. Further details can be found in Bergqvist, 2014. As can be seen from the compilation of the results provided in (Table 4-3) below, the dry pond will result in both most positive impacts and least negative in comparison to business and usual and the macadam basin.

Option	Environmental criteria	Social criteria	Economical criteria	Sum
Dry pond (Long Term)	0.29	0.20	0.00	0.49
Dry pond (Short Term)	0.29	0.13	-0.06	0.36
Macadam basin (ST)	0.23	0.00	-0.13	0.10
Macadam basin (LT)	-0.12	0.00	-0.32	-0.44
Business as usual (LT)	-0.29	0.00	-0.19	-0.48
Business as usual including investment in new waste water plant (ST)	0.05	0.00	-0.13	-0.08

Table 4-3: Compilation of quantitative/semi quantitative assessment of the waterman agent alternatives impact on environment, social and economic criteria (for further details see Bergqvist, 2014)

To achieve the implementation of dry ponds and other blue/green/grey solutions in the city planning increased communication among stakeholders is needed. Therefore the already initiated solution with a stakeholder network is very promising. In this network currently Gryaab is not included, but communications paths are being set up and the communication among different parties are increasing.

Disposal of masses and alternative management strategies

In Table 4-4 below a compilation of the integrated assessment of the different solutions is provided. The assessment is based on three in depth studies on the local environmental and ecological impacts of sea disposal, a life cycle assessment and the impact on the air quality in the estuary, due to the different alternatives and the related transportation (Andersson-Sköld et al., 2014, Hammarstrand and Millander, 2015, Haeger Eugensson, 2015) compiled in Andersson-Sköld, 2015. The assessments are based on literature reviews, modelling and simulations and expert judgments.

As can be seen from (Table 4-4) below, the utilisation of the clayey masses for tile production or similar uses is brick and/or ceramic tile production. Therefore, to set up meetings between the Road Administration (owner of the clay) and the brick and ceramic tile producers is the first step for such utilisation. In addition, tests of the clay needs to be done. This is to certify that the clay is not reducing the quality or functionality of the final products.

Alternative	Impact on the natural environment		Influence on air quality in the estuary and the Gothenburg area		Contribution to the greenhouse gas emission		Contribution to resource-consumption	
Sea disposal Short term	Covering of the bottom	-2	Transport by barge involves large emissions of NO_2, and particulate matter (PM10)	-2	No significant contributions	0	No significant contributions	0
Long term	Recovery is assumed	0	No impact	0	No impact	0	No impact	0
The disposal on land Short term	Requires land	-1	Transport by truck increases emissions of NOx and particles	-1	Short-distances, very small negative contribution	-1	Small contributions to the resource consumption (solely as a result of transport)	0
Long term	Require land, which limits other uses	-1	No impact	0	No impact	0	No impact	0
Stabilisation/solidification for harbor contrsuction or other constructions Short term	The action would be taken anyway, but to save land that would otherwise be needed to take out stone crusher. Requires space for storage of smiling lots.	1	Transport by truck increases emissions of NOx and particles (transportation by barge results in even higher emissions)	-1	Very large impacts of cement production required for the stabilisation process, transport of cement	-2	Operation save Virgin resources because stone crusher would otherwise be needed	2
Long term	Ground for raw material (stone crusher) would otherwise not been restored.	2	No impact	0	No impact	0	No impact	0
Brick manufacture instead of juvenile clay resource use Short term	The action would be taken anyway, but that would otherwise need juvenile clay Requires space for temporary storage of the clay, but this can be at the current supply.	1	Transport by truck to the transhipment by rail means increased emissions of NO_2, and particles.	-1	Brick production in itself requires a lot of energy, but production would still have occurred. Transport by train, gives no contribution to the greenhouse effect.	0	Operation save s virgin resources.	2
Long term	Ground for raw material (clay excavation) would otherwise not been restored.	2	No impact	0	No impact	0	No impact	0

Table 4-4: Summary of the environmental impacts of management options of clayey excess loads from infrastructure projects. The assessed environmental impacts is indicated on a scale from-2 (very undesirable effect) to 2 (very much the desired effect) where zero indicate very little or no effect.

4.1.4 References

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4.1.5 Annex

Activities EU	1) Problem identification						
DPSIR-Phase	Driving force	Pressure	State				
Kriterium		Climate Change	Compart-ment	Ecology - System description	System description - Parameter	Socio economic - Description user-demands	System description - parameter
Column No.	1	2	3	4	5	6	7
	Climate change	Increased precipitation (annual + extreme events)	Surface Water	Hydrology, Morphology	tidal curve, runoff, water-level, seasonal change	sufficient flood protection	flood exposure and consequences of flooding
		Increasing Sea Level Rise		Water quality	load of pollutants in the estuary	currently insufficient water treatment capacity, need of increased storm water capacity	insufficient capacity of water treatmant plants
			Estuarien habitats aquatic, terrestr.	Habitats	Presence and composition of characteristic habitats, vegetation		
			Estuarien species aquatic, terrestr.	Biodiversity, characteristic species	Composition and abundance (fish, birds, invertebrats) neozoa,		
	Exploitation	Modification of hydrology by exploitation (Göteborg)	Surface Water	Hydrology	Risk of flooding	sufficient flood protection	flood exposure and consequences of flooding
				Water quality	load of pollutants in the estuary	sufficient water treatment	capacity of water treatmant plants

Activities EU	1) Problem identification						
DPSIR-Phase	Driving force	Pressure	State				
Kriterium		Disposal of masses	Compart-ment	Ecology - System description	System description - Parameter	Socio economic - Description user-demands	System description - parameter
Column No.	1	2	3	4	5	6	7
	Exploitation	Need to use current land areas for construction of undergound infrastructre	Surface Water	Morphology	currents, turbidity, erosion	In general disposal of excavated masses is regarded as not naturla, and therefore not supported. Little impact at site.	The disposal is not expected to cause significant long-term chagnes, but regulators and policies, as well as publics perceptions are in favour of other solutions, ie that the excavated masses will be used instead of disposed.
				Water quality	Load of susoended matter	Derogation of water quality	
			Estuarien habitats aquatic, terrestr.	Habitats	Presence and composition of characteristic habitats,	Short term not wanted impacts	
			Estuarien species aquatic, terrestr.	Biodiversity, characteristic species	Composition and abundance (fish, invertebrats)		

Table 4-5: Complete DPSIR table for the Göta Älv.

Activities EU	1) Problem identification		2) Impact identification			
DPSIR-Phase	Driving force	Pressure	Impacts			
Kriterium		Climate Change	Impacts on ecosystem	System description - parameter	Impacts on socio economy	System description - parameter
Column No.	1	2	8	9	10	11
	Climate change	Increased precipitation (annual + extreme events)	Changes in flooding	Increased flood exposure and increased consequences of flooding	Increased flooding	Costs for affected infrastructure and functions
		Increasing Sea Level Rise	Derogation of water quality	Increasing load of nutrients and contaminents	Recreational activities	Criteria for activities for swimming and other activities
			Habitat changes	Characteristic habitats, vegetation	Nature conservation	Göta älv: Loss of habitats Nordre älv: increase of bird habitats
			Changes in species distribution and abundance	Loss of characteristic species and communities (fish, birds, invertebrats), dispersal of neozoa	Recreation	Loss of characteristic values due to altered waterconditions, species and community presence
	Exploitation	Modification of hydrology by exploitation (Göteborg)	Changes in flooding	Increased flood exposure and increased consequences of flooding	Increased flooding	Costs for affected infrastructure and functions, Problems with abstraction of raw water
			Derogation of water quality	Increasing load of nutrients and contaminents	Water supply	

Activities EU	1) Problem identification			2) Impact identification			
DPSIR-Phase	Driving force	Pressure	State	Impacts			
Kriterium		Disposal of masses	Compart-ment	Impacts on ecosystem	System description - parameter	Impacts on socio economy	System description - parameter
Column No.	1	2	3	8	9	10	11
	Exploitation	Need to use current land areas for construction of undergound infrastructre	Surface Water	Limited changes in currents, turbidity, erosion as the disposal will be done on accumulation bottoms at levels that are not expected to have significant impacts on the morphology.	No significant changes expected	In general disposal of excavated masses is regarded as not naturla, and therefore not supported. Little impact at site.	little impact because alternative uses may contribute values
			Estuarien habitats aquatic, terrestr.	Habitat changes due to covering	Characteristic habitats, vegetation	Nature conservation	loss of habitatquality
			Estuarien species aquatic, terrestr.	Changes in species distribution and abundance due to covering	Short term loss of characteristic species and communities (fish, invertebrats)		

Table 4-5: Complete DPSIR table for the Göta Älv (continued)

Activities EU	1) Problem identification			3) TWS	4) Identification of existing solutions	5) Documentation & evaluation of existing solutions	
DPSIR-Phase	Driving force	Pressure	State	Responses - Analyses		Responses - Assessment	
Kriterium		Climate Change	Compart-ment	Legal framework - laws, guide-lines Regulations - (agency)	Use-dependent framework- individual adaptability	Legal framework - laws, guide-lines Regulations	Use-dependent framework- individual adaptability
Column No.	1	2	3	12	13	14	15
	Climate change	Increased precipitation (annual + extreme events)	Surface Water	No regulation apart from the flood directive and the building act: natural hazards shall be regarded in building plans	Risks are currently mapped and assessed and potential measures being investigated and assessed by the Göteborg city. Minimum building level has been set by the city. Additional solutions are walls, operable barriers/ports		
		Increasing Sea Level Rise		WFD	New water treatment plant or water retention solutions		
			Estuarien habitats aquatic, terrestr.	WFD Natura 2000,	Increased communication, cooperation and awareness in the Nordre älv region		
			Estuarien species aquatic, terrestr.	WFD, Natura 2000	Measures to protect species and communities (pressure groups nature conservation)		
	Exploitation	Modification of hydrology by exploitation (Göteborg)	Surface Water	WFD, Flood directive WFD	Minimum building level has been set by the city. Additional solutions are walls, operable barriers/ports		

1) Problem identification			3) TWS	4) Identification of existing solutions	5) Documentation & evaluation of existing solutions	
Driving force	Pressure	State	Responses - Analyses		Responses - Assessment	
	Disposal of masses	Compart-ment	Legal framework - laws, guide-lines Regulations - (agency)	Use-dependent framework- individual adaptability	Legal framework - laws, guide-lines Regulations	Use-dependent framework- individual adaptability
1	2	3	12	13	14	15
Exploitation	Need to use current land areas for construction of undergound infrastructre	Surface Water	Policies, regulations and perceptions are not in favour of disposal at sea of excavated masses. Other alnteratives such as use for constructions etc are in favour and disposal is only allowed if other alternatives dont exist	Masses used for the production od bricks, glass, cement	Policies, regulations and perceptions are not in favour of disposal at sea of excavated masses. Other alnteratives such as use for constructions etc are in favour and disposal is only allowed if other alternatives dont exist	
		Estuarien habitats aquatic, terrestr.	WFD Natura 2000,	Implementation of dumping in harmony with nature		
		Estuarien species aquatic, terrestr.	WFD, Natura 2000			

Table 4-5: Complete DPSIR table for the Göta Älv (continued)

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4.2 Scheldt

4.2.1 State

4.2.1.1 Spatial extension of the investigation Area

The Scheldt estuary covers a surface area of approximately 33,000 hectares and lies in the Flemish Region of Belgium and in The Netherlands. Based on its physical characteristics and administrative differences, it is often divided into several areas, all taken into account in this report:

- The Upper Sea Scheldt (stretching from Gent to the confluence with the Rupel) and the Lower Sea Scheldt (from the confluence up to the border), forming the tidal river, in Flanders;
- The Western Scheldt, in The Netherlands, from the border to Vlissingen, which is a multiple channel system;
- The mouth, with distinct channels, but without intertidal areas, stretching North and South along the coastline. The towns of Zeebrugge and Westkapelle delineate the outer boundary.

Figure 4-5: The Scheldt estuary. As border between the mouth and the Western Scheldt usually the line Vlissingen-Breskens is used. The federal border of Netherlands and Flanders is also the border between Western Scheldt and Lower Sea Scheldt. The Upper Sea Scheldt starts at Rupelmonde.

The estuary resides in a densely populated area, with heavily industrialized areas and important trading activities. It contains the principal navigation route to the port of Antwerp and contains areas of recognized ecological importance that are protected by national laws within the EU N2000-framework. The estuary is embanked to prevent flooding and there is agriculture in numerous polders along the estuary.

4.2.1.2 General System description (Physical and ecological system)

Flanders and Netherlands do joint research to support policy and management issues on the Scheldt estuary. This is laid down in one of the treaties (see 'description of the socio-economic system'). From 2011 to 2013 a research program named 'Safety and Accessibility' was executed within this framework. The program focused on the physical characteristics of the Scheldt Estuary in relation with estuary management and provided an overall system description on morphology and hydrodynamics (Consortium Deltares-IMDC-Svašek-Arcadis, 2013 a – j, Taal et al, 2013). This system description is summarised in this chapter. The relation between the morphological and geometrical development and the tidal evolution is crucial in this system description. Ecological functioning is described more concise in this report, addressing only the relation with the prioritised pressure: 'tidal intrusion'.

Sea Scheldt (tidal river)

The Sea Scheldt, with its two main branches Durme and Rupel, is a tidal river with a strong meandering planform. Though the bed of the Sea Scheldt is mainly sandy, large concentrations of suspended fine sediment are found in the water column. The river banks and tributaries are quite muddy. During the last 150 years the Sea Scheldt and its branches have changed, as result of port developments at Antwerp, normalisations (especially upstream Dendermonde and along the Durme), embankments, deepening of the navigation channel and sand mining. At the moment the system of tidal areas with summer dikes had disappeared completely. Steep transitions from marshes to the channel prevail (e.g. Van Braeckel, 2006).

Western Scheldt (multiple channel system)

The Western Scheldt is characterised by a multiple channel system. Several 'cells' can be observed, consisting of an ebb-channel and a flood-channel with large intertidal flats in between and along the embanked shores. The intertidal areas provide most of the ecological values. At places where ebb- and flood-channels join highly dynamic shallows develop. These shallows are the origin of most of the sills in the navigation route, where dredging works are executed. (See e.g. Jeuken, 2000, Winterwerp et al., 2001, Swinkels et al, 2010, Jeuken and Wang, 2010, Consortium Deltares-IMDC-Svašek-Arcadis, 2013i). The development of the Western Scheldt is relatively recent on a typical timescale that encompasses the entire Holocene for estuaries. During this evolution the channels have followed the embankments, rather than the other way round. The curves in the Western Scheldt may seem to resemble the remains of a meandering river, but they are not. An accepted hypothesis is that the multiple channel system is self-preserving, due to the large gross sediment transport rates through the channels and its overall asymmetry (Winterwerp et al., 2001). The large-scale development of the multiple channel system during the last centuries restrained the choices for the navigation route. Nowadays embankments and maintenance of the navigation route determine the space for large-scale estuarine dynamics.

Physical and ecological System description prioritised pressure ‘tidal intrusion’

Observed evolution

The pressure with highest relevance for the Scheldt estuary is already identified and described in the First Interim Report on Drivers and Pressures. This is ‘tidal intrusion’. It is described below in more detail, taking the amplification of the tidal range as its indicator. The tidal regime has strong impacts on the prioritised user functions by both Flanders and the Netherlands: safety against flooding, accessibility and ecological values. More tidal intrusion increases the boundary conditions for design of flood protection works, due to higher water levels and changes in the ‘forelands’. The navigability depends on the duration of high and low water and dangerous local currents (during spring tide). The ecological values of the Scheldt estuary are strongly related to the available habitat area, gradients between these and to small scale patterns. In the Western Scheldt one can find a clear influence on the ecological value of the maximum flow velocities that occur on intertidal areas (e.g. Ysebaert et al, 2009).

At present the mean tidal range increases from about 3.8 m at Vlissingen to almost 5.5 m at Tielrode (20 km upstream of Antwerp), then decreases again to 2.3 m at Melle near the sluices of Gent. Figure 4-6 (Consortium Deltares-IMDC-Svašek-Arcadis, 2013c) summarizes the tidal evolution along the Scheldt estuary between Westkapelle (along the mouth) and Melle. The most distinct feature in Figure 4-6 is that, going from the mouth in upstream direction, the tidal range has continuously increased over the past century. At the same time the location with maximum amplification shifted in upstream direction over a length of 40 km from Liefkenshoek to Tielrode. The enhanced intrusion of the tide is even noticeable in Melle, where the tidal range increased with 1 m during the last 100 years. During the last 15 years, the amplification of the tidal range is still increasing, especially upstream of Hansweert.

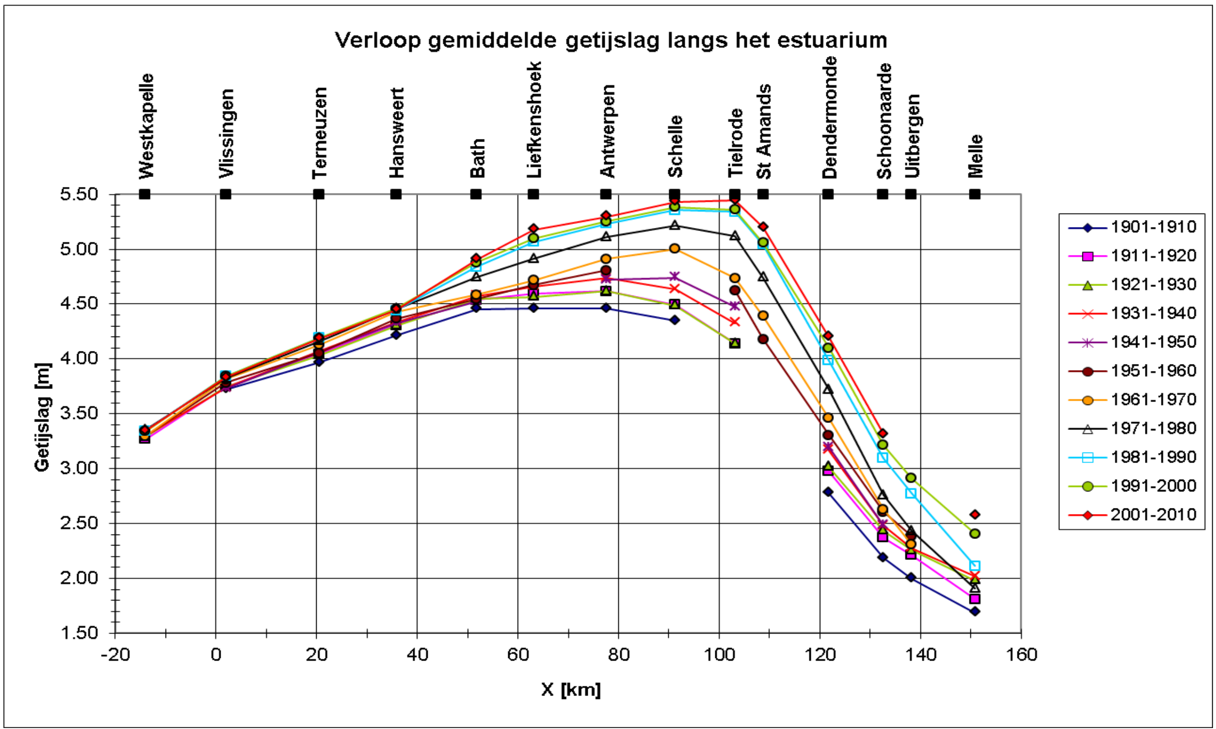

Figure 4-6: Tidal evolution in the Scheldt estuary.

Identification of most important driving forces

The prioritised pressure is, as described, tidal intrusion. Many studies (e.g. Dronkers, 1964, Prandle and Rahman, 1980, Jay, 1991, Friedrichs and Aubrey, 1994, Friedrichs, 2010 and Savenije, 2001, Consortium Deltares-IMDC-Svašek-Arcadis, 2013d, Van Rijn, 2011) focus on the determining factors for tidal response in estuaries and give as factors:

- Channel or estuary convergence (is the funnel shape of the estuary strong or weak?)
- Water / Channel depth (increasing the depth causes usually more amplification of the tidal range)
- Presence of Intertidal area (although depending on the location along the estuary, in general more intertidal areas leads to less amplification)
- Bottom friction (less friction means that the tidal wave can come in more easy, hence more amplification). Human interferences are normally not directed to the hydraulic smoothness of the bed. They may induce however changes in the hydraulics and fine sediment dynamics that again cause less resistance for the tidal wave. It is hypothesized that this has happened in the Ems river (e.g. Winterwerp, 2011, 2013a, 2013b)

The creation of embankments have made the estuary more funnel-shaped (for centuries people have been cutting off parts from the estuary by dykes, transforming these into polders). Deepening and maintenance of the navigation route made it relatively more deep (in combination with sand mining and disposal strategies that bring sediment more downstream). These developments are the main causes of the tidal intrusion in the Scheldt estuary. Dredging- and disposal-works to deepen and maintain the navigation route to the port of Antwerp gradually became the most dominant of these two types of human interferences, especially in the Western Scheldt and the lower Sea Scheldt during the last fifty years (e.g. Consortium Arcadis-Technum 2007, Consortium Deltares-IMDC-Svašek-Arcadis, 2013g).

Conclusion is that the **driving forces** that are most important in determining the tidal intrusion are:

a. Embankments (coastal protection)

b. Fairway deepening and maintenance (Transport Sector)

Physical and ecological System description according to DPSIR framework

Driving Forces, related pressures and triggered first and higher order changes

As most important Driving Forces triggers for tidal intrusion the sectors coastal protection and *t*ransport sector have been identified (Driving Forces, first column in DPSIR-Table, Table 4-17). The related Pressures that are *triggering the Prioritised Pressure Tidal Intrusion are (*Pressures*,* second column in DPSIR-Table, Table 4-17)

- Changes in morphology due to Fairway deepening and maintenance
- Embankments that inhibit large scale morphology and hydrodynamics

Fairway maintenance and embankments trigger first order changes. They directly influence morphology. Due to the changes in water movement (hydrodynamics) as result of a different morphology, there will a different sediment transport resulting in more adaptations in morphology. This is illustrated in Figure 4-7.

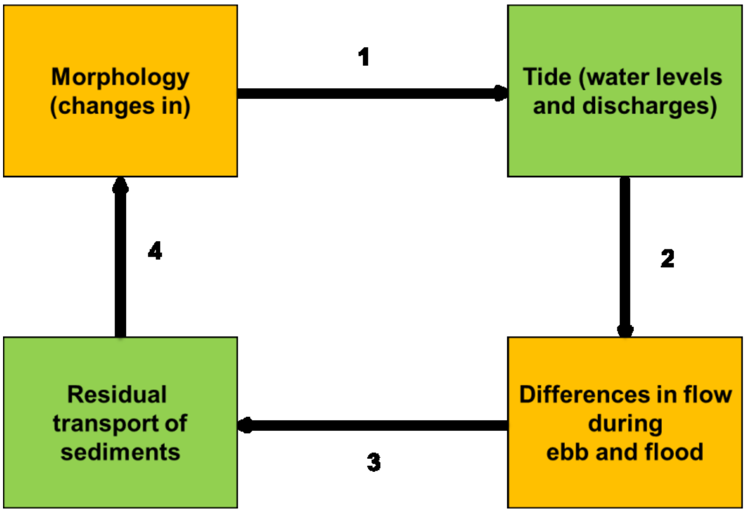

Figure 4-7: Schematic representation of interaction between morphology and tidal asymmetry (see e.g. Wang et al., 2002, Consortium Deltares-IMDC-Svašek-Arcadis, 2013g.). Changes in morphology immediately affect the tidal response. This will induce changes in the net sediment transport, with different residual transport and gradual (sometimes on decadal timescales) adaptation of the water bed.

Selected system description parameters, also per compartment

The DPSIR-approach requires that impacts of the prioritized pressure are identified both on the natural system (physical, ecological values) as on the socio-economic system (sectors). First the parameters that are selected to describe the impacts on the natural system / ecological values are given (sub-sections below). In a next section parameters and demands of the various socio-economic sectors are described.

For the evaluation of the development of the Scheldt estuary in view of 'naturalness' a methodology has been developed (Holzhauer et al, 2011). Naturalness was distinguished in five categories. These five are used in the DPSIR-table as compartments and/or system description of the compartments:

- Intertidal flat and Channel System (morphological naturalness)
- Water Quality
- Living Environment (distinguishing area, quality and turn-over of various habitats)
- Flora and Fauna
- Ecological Functioning

In the third column in DPSIR-Table there is made a distinguishment in compartments, in order to get a more clear sorting of the System Parameters. The described system compartments are restricted to the area that is not protected by embankments (all outside the dikes) and are:

- Water body (surface waters)
- Water bed (especially channels) and intertidal flat (providing the most estuarine habitats)
- Flora and Fauna

The system description parameters that are affected by tidal intrusion are (fourth and fifth column in DPSIR-Table, see Table 4-17) are, with a specification to both compartment and subarea:

System description parameter / subarea	**Mouth**	**Western Scheldt**	**Sea Scheldt**
Water body			
High and low water, during average and during extreme conditions	minor	strong	strong
Flow velocities	minor	strong	strong
Tidal duration		strong	
Salinity intrusion		minor-strong	strong
Tidal asymmetry changing fine sediment dynamics			strong
Water bed and Intertidal flats			
Sand balance, Channel depth	minor	minor-strong	minor
Channel or estuary convergence	minor	minor-strong	minor
Presence of Intertidal area	minor	minor-strong	minor
Bottom friction	minor	minor	
Sand transport to and from intertidal areas and Flooding regime		Strong	
Flora and Fauna			
Composition and abundance	minor	minor-strong	minor-strong

Table 4-6: Affected parameters by tidal intrusion per compartment and sub-area of the Scheldt estuary, with indication of how strong the effects are of tidal intrusion (a.o. based on Consortium Deltares-IMDC-Svašek-Arcadis 2013g; Depreiter et al. 2014)

Literature where more extensive state descriptions can be found is VLIZ, 2010. Consortium Deltares-IMDC-Svašek-Arcadis, 2013g; Depreiter et al. 2014, Holzhauer et al. 2011.

4.2.1.3 System description – Socio Economic System

Most important Stakes and stakeholders and their demands considering Tidal Intrusion

The most important stakeholders in the Scheldt Estuary, with reference to whether 'tidal intrusion' is affecting their interests (derived from: Technical Scheldt Committee 2001, VLIZ 2010, Vlaams-Nederlandse Schelde Commissie, 2013, Ellen 2014, unpublished interviews as preparation of EMOVE-workshops Scheldt), are:

Stakeholder	Affected?	Demands / Clarification
Governments: Execution of Scheldt-treaties	Medium to strong	• The joint vision states 'preservation of the physical characteristics'. Tidal intrusion is an indication of decreased estuarine dynamics on large scales of time and space • Sustainable development given the fact of the desired accessibility for ships. • Availability of suitable measures for management of the estuary.
Shipping / Transport	Medium	• Sufficient depth of waterways, no lowering of low waters • Not too much lateral currents in the shipping lane • The tide-dependent accessibility of the port of Antwerp may decrease due to a change in tidal duration. • Space for disposal of sediment that is available after maintenance of the fairway and port areas
Water boards (incl. Coastal protection)	Medium	• Influence on investments in embankments may be needed (demands on heightening embankments due to changes in normative water levels, wave height etc) • Foreshore protection needed due to eroding outer bends of the (main) channels. • Non-erosive or accreting forelands/intertidal areas decrease the demands in height and strength of the embankments
Nature conservation	Strong	• Decrease od characteristic patterns and gradients of the estuary, especially the intertidal areas • Changes in habitats with their natural biodiversity
Industry	Not	• Demands are port-related
Agriculture	Low	• Not directly affected by changes in the tidal regime, but it may make the need to prevent /cope with salt water intrusion/drought more difficult.
Tourism, recreation	Low	• Most of this is on embanked land. Mostly general demands, including natural landscape and ecology.

Table 4-7: Demands of stakeholders with references whether 'tidal intrusion' is affecting their interests.

Governments: Execution of Scheldt-treaties

The Scheldt estuary plays a crucial role in the relationship between the Netherlands and Flanders. As sketched before, joint stakes are flood protection, access to large ports (Antwerp, Gent, Terneuzen, Flushing) and the ecological value of one of the few remaining natural estuaries in North West Europe. A crucial element in the relationship is the evolution of the Western Scheldt, in relation to the maintenance of the navigation route, in light of the necessity of the Flanders government to obtain permits on Dutch territory. This resulted in the past in long-lasting negotiations. In 2001 a long-term vision was developed and implemented in cooperation between the two countries (Technical Scheldt Committee, 2001). Both countries stated that 'preservation of the multiple channel system' is an important policy objective. The long-term vision accelerated decision making for a third deepening, as it was now part of an integrated plan for the development of the whole estuary. The cooperation was formalized in a treaty (December, 2005) including a list of projects that should be executed, the development sketch 2010 (Proses, 2005).

Besides this important stake of fulfilling the demands of the treaties, being a good neighbour and the guaranteed access to the Seaports, there are various other stakeholders. Since April 2014 an official advisory board for the Ministers of Water Management of Flanders and the Netherlands has been (re-)established. The organizations that are represented in the Scheldt Council (Schelderaad) (Table 4-17) Members of this board were invited to join the Scheldt case study that were organized to 'get from stakeholders to shareholders'.

Shipping / Transport

Shipping independent of the tide requires the navigable depth as agreed in treaties. The last deepening resulted in a tide-independent navigation of vessels from a draught of 13.1 m., which translates to an intervention depth along the channel of -14.5 m below average low low water (Lowest Astronomical Tide - LAT). Should lowering of low waters occur, this would result in more dredging works.

Shipping bound by tide requires a water depth which is larger than the navigable depth and which is only available during part of the tide, i.e. the tidal window. A larger draught of a ship means a smaller tidal window. The tidal window is determined by the duration of the tide, which is in its turn determined by the high and low water levels, the propagation speed of the high and low water levels, and the shape of the tidal curve. A higher propagation speed means a shorter duration of the tide and a smaller tidal window and hence a reduced navigability of the estuary.

Lateral currents in the shipping lane give additional problems for ships navigating through the estuary. During the last decade incidents have been reported with ships during extreme spring tide in the eastern part of the Western Scheldt, more specific the channel 'Zuidergat'.

In order to obtain the needed permits enough space for disposal of dredged sediment is required. The available space in the eastern part of the Western Scheldt and in the lower Sea Scheldt is limited. Presently the options of 'disposing sediment westward' and 'sand mining on the disposal location' are used in the Western Scheldt and Lower Sea Scheldt respectively.

Water boards

The Water boards (In Zeeland: Waterschap Scheldestromen) and Waterwegen en Zeekanaal NV (Flanders) are responsible for investments for safety against flooding. Changes in tidal intrusion may affect these investments. Higher or stronger embankments may be needed if the demands increase due to higher water levels and waves during storms, changes the normative sets. The presence of forelands/intertidal areas decrease the demands in height and strength of the embankments (see e.g. Deltaprogramma 2015). The presence of forelands/intertidal areas is influenced by tidal intrusion (see e.g. Consortium Deltares-IMDC-Svašek-Arcadis, 2013 g and i). Furthermore the migration of the large channels may lead to erosion of the outer bends. This may lead to investments to protect the foreshore (like strengthening channel faces).

Nature conservation

In general the stakes of 'nature conservation' are similar to the ecological parameters described in 4.2.1.2. The birds association has published its vision and puts much emphasis on the characteristic patterns and gradients of the estuary, especially the intertidal areas (Herman & Stive 2011). Legal demands are found in various documents, like the formal decision of assignment as N2000) Programmadirectie Natura2000, 2009) and the concept managementplan Natura 2000 Deltawateren (Anonymus, 2013). In general focus is on preservation and development of N2000-habitats H1130 (estuaries) and H1330 (salt marshes) with a focus on low-dynamic intertidal and undeep areas, and their natural biodiversity

Industry

Assuming industry is on embanked land, it is not affected by changes in the tidal regime. The demands are port-related and are e.g. illustrated in the chapter Socio-economic importance of ports of VLIZ 2010, containing a.o. the Table 4-8 below.

Total added value		2002	2003	2004	2005	2006	2007
Million euro (current values)	Antwerpen	14.345	14.148	16.424	18.720	19.247	20.487
	Gent	5.868	5.935	6.871	7.000	7.200	7.692
	Terneuzen	3.522	3.712	4.127	4.437	4.852	5.534
	Vlissingen	1.317	1.364	1.437	1.618	1.759	2.064

Table 4-8: Evolution of Total added value of the Scheldt ports

Agriculture

Assuming agriculture is on embanked land, it is not directly affected by changes in the tidal regime. However, with a policy to restore ecological values and the Long Term Vision stating that 'the physical characteristics should be preserved, there has been a pressure on agricultural land to be moved 'outside the embankments' (depoldering). This has led to protest. Hence: less tidal intrusion would mean less pressure to execute depoldering.

Furthermore the participants of agriculture in EMOVE-workshops have stated that salt water intrusion (of ground water) and drought is felt as an increasing pressure. Only salt water intrusion is (though slightly) related to tidal intrusion. Also is feared that depoldering would increase seepage of saline waters in the polders which are aside the new (more landinward) embankments

Tourism and recreation

There are general demands: possibilities for enjoying nature, landscape, watersports, sport fishing, etc. Although a reduction of naturalness is however, usually, regarded as negative for recreation, it is the possibility to access and enjoy the values that actually drives the demands.

4.2.2 Impacts

4.2.2.1 Impacts on the ecosystem

Before describing the socio economic impacts an overview is given of the impacts caused by tidal intrusion, on all selected system description parameter of the estuarine system.

Impacts tidal intrusion on physical and ecological system description parameters

System description parameter	Impact of Tidal Intrusion
High and low water, during average and during extreme conditions	More tidal intrusion is characterised by higher high water and lower low waters during average conditions. It will also slightly enhance high water during extreme conditions.
Flow velocities	Flow velocities increase on average, especially in the channels
Sand balance, Channel depth	There is a complex interrelation between the tidal characteristics and the residual sand transport. Sand balance is strongly governed by the net result of dredging, dumping and sand mining
Channel or estuary convergence	The convergence influences tidal intrusion, more than the other way around
Presence of Intertidal area	Decrease in quantity and quality of intertidal area is expected
Bottom friction	Bottom friction influences tidal intrusion. There may be feedbacks by means of the fine sediment concentration.
Flora and Fauna	Bottom fauna is affected as intertidal areas are affected. In the pelagic areas sediment concentrations influence extinction and primary production.
Tidal duration	More tidal intrusion is characterised by a faster progression of the tidal wave and shorter tidal duration available for shipping.
Salinity intrusion	Increases with tidal intrusion
Sand transport to and from intertidal areas and Flooding regime	There is a complex interrelation between the tidal characteristics and the residual sand transport, even more for the exchange with intertidal areas. In the Scheldt estuary an average rise of intertidal flats is observed, with vegetation on shoals that used to be bare until a decade ago.
Tidal asymmetry changing fine sediment dynamics	Tidal pumping leading to increased suspended sediment concentration. This is especially observed in (parts of) the Sea Scheldt

Table 4-9: Impacts of tidal intrusion on physical and ecological system description parameters

This can be elaborated using the Evaluation Methodology for the Scheldt Estuary. The methodology has been applied for the baseline report (T2009, see http://www.vnsc.eu/uploads/2014/05/t2009-rapport-schelde-estuarium-7-mei-2014-077698096-va-.pdf, reference: Depreiter et al, 2014). It contains an overview of state parameters, their trends and evaluation of this. Out of this and the various reports of the research program named 'Safety and Accessibility' (Consortium Deltares-IMDC-Svašek-Arcadis, 2013 a - j) the impacts per category are summarized as:

Category	**Impact from (higher) tidal intrusion**
Intertidal flat and Channel System	Tidal intrusion is interrelated with the reduction of large scale estuarine dynamics, with shoals that are higher and more smooth and less connecting channels
Water Quality	Increased concentration of suspended sediments, increasing risks of developing hyper turbid system (as e.g. in Eems)
Living Environment	The area of low dynamic habitat decreases
Flora and Fauna	Changes in diversity, distribution and abundance of species as result of changes in living environment and water quality
Ecological Functioning	See Flora and Fauna

Table 4-10: Impacts of strong changes in tidal intrusion on physical and ecological system description parameters

4.2.2.2 Impacts on socio economic system

Based on the system parameters the most important impacts on stakeholder demands of more tidal intrusion are (derived from: Technical Scheldt Committee, 2001, VLIZ, 2010, Vlaams-Nederlandse Schelde Commissie, 2013, Ellen, 2014, unpublished interviews as preparation of EMOVE-workshops Scheldt):

Stakeholder	Impact on stakeholder demand
Execution of Scheldt-treaties	• The state of 'preservation of the physical characteristics' is most likely worse, making new, jointly agreed, measures necessary • The desired accessibility for ships is more difficult to establish
Shipping / Transport	• Lowering of low waters leads to less accessibility • More lateral currents in the shipping lane due to increased flow velocities • The tide-dependent accessibility of the port of Antwerp may decrease due to a change in tidal duration. • The space for disposal of sediment may decrease
Water boards (Coastal protection)	• Investments in embankments increase due to changes in normative water levels, wave height etc) • Foreshore protection needed due to eroding outer bends of the (main) channels.
Nature conservation	• Decrease of characteristic patterns and gradients of the estuary, especially the intertidal areas, too dynamic circumstances, • Changes in habitats with their natural biodiversity, decline in less dynamic natural habitats • Increase in threatened species and habitats
Industry	• Less accessibility (see shipping) • reduced expansion possibilities when 'state' in terms of N2000 is 'not good'
Agriculture	• More fresh water demands due to salt water intrusion/drought • decrease in harvest • changing landscape due to (de)poldering.
Tourism, recreation	• decrease in recreation possibilities

Table 4-11: The most important impacts on stakeholder demands triggered by tidal intrusion.

The described changes are summarized in the columns 8 to 11 of the DPSIR-table (Table 4-17) in the Annex (chapter 4.2.5).

4.2.3 Responses

4.2.3.1 Identification of solutions

As stated earlier the factors determining tidal response are:

- Channel or estuary convergence
- Water / Channel depth
- Presence of Intertidal area
- Bottom friction

In Deltares (2011) an elaboration was given of all possible physical measures to reduce tidal intrusion in order to come to nature restoration based on changing large scale estuarine processes. The study was executed to find alternatives for depoldering. It is summarised here:

Large scale measures can be focused on, see Figure 4-8(out of Deltares (2011) and based on: Consortium Arcadis-Technum, 2007c):

1. Reducing the effect of amplification due to funnelling by (a combination of) enlarging the tidal prism and restoring intertidal areas (more space for the river / estuary). A in Figure 4-8;
2. Increase the resistance for the tidal movement in the channel(s) B and C in Figure 4-8;
3. Changing the balance between main and secondary channels B and C in Figure 4-8.

At the same time measures will be needed to restore estuarine processes on the smaller scales, i.e. shoals and connecting channels (second order changes). This relates to D in Figure 4-8. It is expected that for proper restoration both large scale measures as ‘a push in the right direction on the smaller scales’ are needed. The latter can be both by adding sediment (e.g. smart disposal along shoals) and by local distraction of sediment (e.g. enlarging secondary channels or restoring connecting channels).

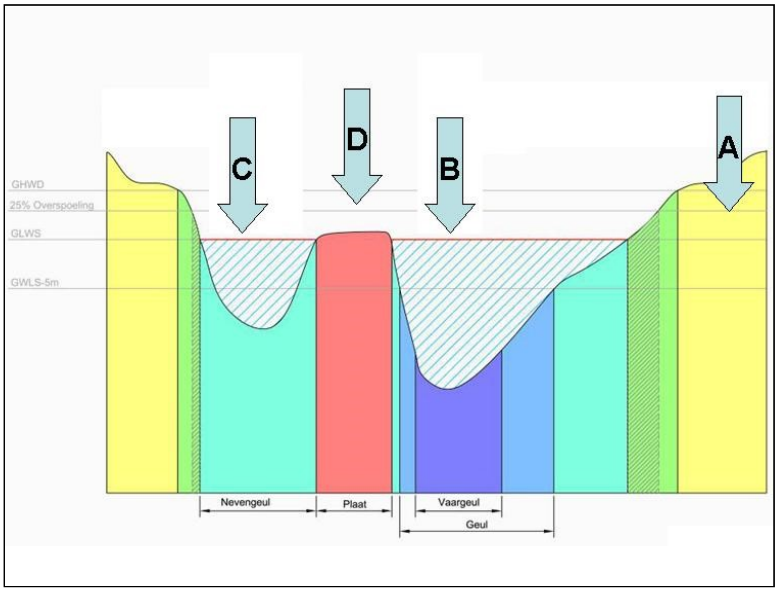

Figure 4-8: Four types of measures influencing morphology and geometry. One can interfere with the embankments (A), the main (B) or the secondary (C) channel or in the intertidal areas.

The possible measures to influence large scale estuarine hydrodynamics (hence: tidal response) was elaborated distinguishing (i) 'Soft measures' (working with sediment, especially applicable in B, C and D and (ii) 'Hard' measures (structures, dams, embankments; construction or removal). This is due to the more irreversible (and therefore less sustainable?) character of 'hard' measures. The latter must be done 'right at the first time', while soft measures can be adapted more easily when e.g. insights or conditions change.

	Mouth	**West and central part of Western Scheldt**	**Eastern part of Western Scheldt (and Lower Sea Scheldt)**
Soft	• Large scale sediment supply • Spatial developments	• Flexible disposal: - Disposal in deep parts or along channel face of main channel - Adapt disposal in secondary channel - More on intertidal area • Creating connecting channels • Lower intertidal area to reduce tidal range	• Flexible disposal: - Disposal in deep parts or along channel face of main channel (though little space) - Adapt disposal in secondary channel - More on intertidal area - Remove fine sediments • Creating connecting channels • Lower intertidal area to reduce tidal range
Hard	See 'soft, but with structures instead of sediment	• Space for the estuary / river • Increase resistance by specific elements in the channels	• Space for the estuary / river • Increase resistance or adjust hydrodynamics by specific elements in the channels or at harbour docks • Remove structures

Table 4-12: Possible measures to influence large scale estuarine hydrodynamics

Responses / Solutions of Tidal Intrusion supported in legal Frameworks

The existing responses within legal frameworks are below, per driver, as far as they can be related to influencing tidal intrusion as first order effect. Not listed are all measures to mitigate the existing problems that are related to the socio-economic sectors themselves and/or the ecological valuable areas, even though the tidal intrusion is (one of) its causes. This relates to columns twelve and thirteen of the DPSIR-table

Morphological management (dredging, disposal and sand mining), related to driver 'shipping'.

- permits for dredging, disposal and sand mining, with flexible disposal

Coastal protection

- nature restoration by 'giving space to the river/estuary' (including depoldering, setbacks of embankments)
- strengthen embankments when calculated safety is below legal standard
- channel enforcements when channels erode and threaten embankments

Policy frameworks are available for both countries, as well as frameworks for long and short term planning (like Anonymus, 2013, Department Mobiliteit en Openbare Werken, Afdeling Maritieme Toegang, 2014, Gedeputeerde Staten Zeeland 2011, Ministerie van Infrastructuur en Milieu 2014). (See column twelve and thirteen in table Table 4-17).

Responses / Solutions suggested by stakeholders in EMOVE-workshops

This section gives an introduction to the various adaptation responses that have been discussed in the 'Scheldt estuary workshops' (see notes of the workshops; Ellen 2014)

At the workshops the description of the physical functioning was the starting point. This enables participants to understand the demands of other sectors. The joint understanding stimulated stakeholders to think of how their individual adaptation options (measures) could be framed into more integrated solutions (connecting to demands of other stakeholders). Taking the system description as a starting point the focus was put on the sustainability of the whole estuary (hence long time scales). The cooperation that evolved is the first step in their change to 'shareholders'.

The suggested solutions that were in- and output to the workshops relate only on an overall level to the problem of Tidal Intrusion (by definition as this is an indicator for sustainable evolution of the estuary). The solutions were in fact primarily triggered by the whole range of sectoral needs, which are usually (also) related to other pressures than tidal intrusion.

In the workshops several steps were taken, including a longlist of possible projects (Table 4-13) and an inventory of opportunities for integrated management due to socio-economic developments (Table 4-14) as well as things that presently hamper integrated solutions (Table 4-15).

Suggested project	Relate to stakeholder /demand	Expected Impact
Growing Land by Shifting Reclamation ('wisselpolders'): bring back tidal dynamics in agricultural polders and let the land grow again with sediment from the estuary and create at the same time more safety, fertile agricultural land and, while under tidal influence, nature areas. At the same create agricultural polders from nature areas. How to arrange that nature can become agriculture again and vice versa?	- Give execution to Scheldt treaties - Nature conservation - Agriculture	- Creation of estuarine dynamics - Renew agricultural land
Dealing with Salt Intrusion for agriculture: experiments (salt crops) and innovative income from fisheries.	- Agriculture - Water Boards	- Support for nature restoration
Helping farmers whose land is needed towards work related to the estuary.	- Nature conservation - Tourism	- Support for nature restoration
More cooperation between harbours: Develop a joint vision and plan for sustainable development.	- Shipping / Transport - Give execution to Scheldt treaties	- Insight in options to reduce tidal intrusion
What to do with a maximum 10 million m3 sediments from the new lock at Terneuzen?	- Nature conservation - Shipping / Transport	- Insight in option to reduce tidal intrusion
Room for the River experiment; interaction nature, agriculture.	- Nature conservation - Agriculture	- Creation of estuarine dynamics
Research on the potential for recreation in the Scheldt.	- Tourism	- Insights in what triggers attractivity
Experiments with creating low-dynamic areas in the estuary with hard structures, also lowering concentrations of mud	- Shipping / Transport - Water Boards	- Creation of low-dynamic areas - Higher forelands

Table 4-13: several projects out of the longlist of possible projects after first EMOVE-workshop

Harbour of Antwerp wants to cooperate on knowledge, finances and cooperation process;
Acknowledgement of knowledge of harbour organisations;
Wish for follow-up projects on ecology and the physical system: get clear about the N2000 state and on realistic goals together with Europa
Use recreation as an opportunity in relation to agriculture;
Learn and use other EU-projects (e.g. www.tide-toolbox.eu);
Involve the reclaimed land of the estuary: the economic and landscape values of agriculture including the added values in derived products and also of the other ecosystem services.
Invest together in creating a plan by the Scheldt (stakeholder) Council, and thus increase it's legitimacy.
Look over the barriers: connect land and water
Start with small projects having an frontrunner effect

Table 4-14: Opportunities for integrated management and turning stakeholders into shareholders, as identified during the first Scheldt-EMOVE-workshop

Thinking on long timescales is difficult. Taking such viewpoint enhances adaptive management and cope pro-actively with system shifts as a result of changes in sediment household
The rather strict regulation (as Natura 2000 is elaborated for more stable and terrestic systems) is difficult to implement in a dynamic estuarine system;
A reality check on policy from the past seems needed. Decision makers cannot find out if we are on track towards sustainable development and which uncertainties are involved.
The decision making is, even when integrated planning is applied, often dependent on policy and jurisdiction that is elaborated for a specific. Which governance arrangements are needed (and proven succesfull) to come to the integration?
New solutions give changes that lead to fear and uncertainty among inhabitants and politicians, even though 'business as usual' may induce even larger changes in the long run.

Table 4-15: Challenges, presently hampering more integrated management and stakeholders turning into shareholders, as identified during the first Scheldt-EMOVE-workshop

4.2.3.2 Assessment of solutions

After four workshops the group of stakeholders of the Scheldt identified four projects. Their aim is to elaborate these jointly, trying to become shareholders. These projects are listed in Table 4-16.

Suggested project	Relate to stakeholder /demand	Expected Impact
Growing land by 'shifting reclamation': Bring back tidal dynamics into agricultural polder areas for decades to silt them up with a new fertile clay layer for agriculture again after 50 – 100 years (necessary period of time to be investigated). In the mean time being nature areas. At the same time create new agricultural land from high silted up nature areas. This fulfills the needs from the functions flood safety against sea level rise (heightening the borders along the estuary), agriculture (higher lying new fertile agricultural land), nature/ecological functioning (getting into the wanted better state) and shipping and harbours (space for development when the ecological functioning and nature areas are in good condition).	- Give execution to Scheldt treaties - Nature conservation - Agriculture	- Creation of estuarine dynamics - Renew agricultural land
Hydro-morphological measures that contribute to the strengthening of eco system services concerning nature, accessibility and safety in the Scheldt Estuary	- Shipping / Transport - Water Boards - Nature conservation	- Creation of low-dynamic areas - Higher forelands
Creating a cross boundary nature park including recreational functions	- Nature conservation - Tourism	- Support for nature restoration
'Outside Engine' for the Scheldt Council: Finding financial and institutional arrangements to continue the working groups and projects that were created in EMOVE	- Give execution to Scheldt treaties	- Increase feasibility of projects above

Table 4-16: Selected projects after the fourth and final EMOVE-workshop for the Scheldt

The business ideas have been created in stakeholder workshop on joint-fact-finding on Schelde estuary functioning and measures for sustainable development of the Schelde estuary.

During the second workshop we showed the stakeholders the list of ideas/business cases they wrote down the first workshop. After that we gave them the opportunity to change or add to this list. We did this because new stakeholders had joined the workshop, and we wanted to prevent that these new stakeholders could not add/comment on the ideas on the table.

As the goal of EMOVE was to create shareholders out of stakeholders we wanted to tap into the energy/vitality/entrepreneurship of the stakeholders. We then decided that we could to this the best way by just asking them where they wanted to put their energy in. To do so we gave them three green stickers and one yellow to let them vote. We asked them to put the green stickers on the project that they were most willing to put their time and effort in. The yellow sticker they could place on the project idea that they thought might be not such a good idea. After the vote we discussed which initiatives had been selected and why people voted for them.

Finally we wanted to let the stakeholders take up the ideas/initiatives that they came up with themselves. For this reason we placed instructions for the next step on the table and asked the stakeholders who wanted to go on with one off the projects to take the instructions and invite others to form a coalition. We also stated that if they picked up the instructions they could join us for a working session.

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b. Grootschalige sedimentbalans van de Westerschelde (G-2)
c. Data-analysis water levels, ebb and flood volumes and bathymetry Western Scheldt (G-5)
d. Tidal Phenomena in the Scheldt Estuary, part 2 (G-7)
e. Aanvullend onderzoek historische ontwikkeling getij en toepassingen analytisch model. (G-8)
f. Simulaties met effectanalyse op schaal estuarium (G-11)
g. Synthese en conceptueel model (G-13)
h. Response of tidal rivers to deepening and narrowing (G-14)
i. Samenhang ontwikkelingen tijd- en ruimteschalen (K-17)
j. Simulaties met effectanalyse op mesoschaal (K-20)

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4.2.5 Annex

Activities EU	1) Problem identification						
DPSIR-Phase	Driving force	Pressure	State				
Kriterium		Tidal Intrusion	Compart-ment	Ecology - System description	System description - Parameter	Socio economic - Description user-demands	System description - parameter
Column No.	1	2	3	4	5	6	7
Parameter / Institution	Transport sector (Maritime Traffic, Accessibility)		Water body	Tidal response Water quality	tidal curve, average high and low water, Salinity intrusion, fine sediment dynamics	Transport sector: sufficient depth of waterways	Tide-dependent and tide-independent accessibility
	Coastal defence (Safety)	Changes in morphology due to Fairway deepening and maintenance Embankments inhibits large scale morphology and hydrodynamics	Water Bed	Morphology	channel depth, sand balance, Presence of Intertidal area, Sand transport to and from intertidal areas, bottom friction, fine sediment dynamics	Safety for land behind the embankments	Meeting to the legal standards
			Intertidal areas	Habitats / Intertidal areas	Total area, inundation regime, flow velocities, length of waterline	Costs of safety measures	yearly investments
			Flora and Fauna	Biodiversity, characteristic species, Ecological Functioning	Composition and abundance (fish, birds, invertebrates)		
	Sand Mining	Changes in sand balance	Water Bed	Morphology	channel depth, sand balance	Sediment available of right quality	sediment parameters
	Climate change	Sea level rise	Water body	Average water level Tidal response	tidal curve, water-level	Long term safety	Loss of lives and capital
		changes in storm and wave climate	Water body	Meteorology	Wave heigth, Storm frequency	Long term safety	Loss of lives and capital

Table 4-17: Complete DPSIR table for the Scheldt.

Activities EU	1) Problem identification			2) Impact identification			
DPSIR-Phase	Driving force	Pressure	State	Impacts			
Kriterium		Tidal Intrusion	Compart-ment	Impacts on ecosystem	System description - parameter	Impacts on socio economy	System description - parameter
Column No.	1	2	3	8	9	10	11
Parameter / Institution	Transport sector (Maritime Traffic, Accessibility)	Changes in morphology due to Fairway deepening and maintenance Embankments inhibits large scale morphology and hydrodynamics	Water body	Changes in tidal response	changes in tidal curve, average high and low water, Salinity intrusion, fine sediment dynamics	Accesibility of harbors	channel depth and tidal duration
	Coastal defence (Safety)		Water Bed	Changes of Morphology	Changes of channel depth, sand balance per compartment and macrocell; changes in Intertidal area ; changes in hydraulic smoothness of the bed	Policy	Meeting demands of the treaties between Netherlands and Flanders
			Intertidal areas	Habitat loss	Loss characteristic habitats, vegetation	Agriculture	Land needed for estuarine restoration
			Flora and Fauna	Changes in species distribution and abundance	Loss of characteristic species and communities (fish, birds, invertebrates)	Nature conservation	Loss of habitats
						Recreation	Loss of characteristic values
	Sand Mining	Changes in sand balance	Water Bed	Changes of Morphology	Changes of channel depth, sand balance per compartment and macrocell	see combination transport & coastal defence	
	Climate change	Sea level rise	Water body	Changes of water level and tidal response	changes in tidal curve, runoff, water-level	Policy	Long term safety Resilience natural system
		changes in storm and wave climate	Water body	Hydrodynamics	Changes in Wave heigth, Storm frequency		

Table 4-17: Complete DPSIR table for the Scheldt (continued).

Activities EU	1) Problem identification			3) TWS	4) Identification of existing solutions	5) Documentation & evaluation of existing solutions	
DPSIR-Phase	Driving force	Pressure	State	Responses - Analyses		Responses - Assessment	
Kriterium		Tidal Intrusion	Compart-ment	Legal framework - laws, guide-lines Regulations - (agency)	Use-dependent framework-individual adaptability	Legal framework - laws, guide-lines Regulations	Use-dependent framework-individual adaptability
Column No.	1	2	3	12	13	14	15
Parameter / Institution	Transport sector (Maritime Traffic, Accessibility)	Changes in morphology due to Fairway deepening and maintenance Embankments inhibits large scale morphology and hydrodynamics	Water body	RWS, AMT permits for dredging and disposal	Flexible disposal		
	Coastal defence (Safety)		Water Bed	Water Safety legislation	Channel enforcements		
			Intertidal areas	Sigmaplan (Sea Scheldt)	Enforcements of enbankments		
			Flora and Fauna	N2000-legislation	Poldering and depoldering		
	Sand Mining	Changes in sand balance	Water Bed	RWS, AMT permits for sand mining	Integration with Flexible disposal		
	Climate change	Sea level rise	Water body	NL: Delta Programme			
		changes in storm and wave climate	Water body	VL: 'Vlaamse Baaien'			

RWS: Dutch Ministry of Infrastructure and the Environment, Rijkswaterstaat Zee and Delta
AMT: Flemish Authorities, Department of Mobility and Public Works, Maritime Access Division

Table 4-17: Complete DPSIR table for the Scheldt (continued).

Alfaport, Vlaamse Havenvereniging	Provincie Antwerpen
Algemeen Boerensyndicaat Oost-Vlaanderen	Provincie Oost-Vlaanderen
ARK Natuurontwikkeling	Provincie Zeeland
Benelux Unie	VeGHO
Boerenbond	Vertegenwoordiger van de Vlaamse Steden
Brabants-Zeeuwse Werkgeversvereniging BZW	Vlaamse Havenvereniging
Gemeente Borsele	Vogelbescherming Nederland
Havenbedrijf Antwerpen	Waterschap Scheldestromen
Haven Gent	Zeeland Seaports
Natuurpunt Vlaanderen	Zeeuwse Milieu Federatie
	Zuidelijke Land en Tuinbouworganisatie

Table 4-18: Composition of Schelderaad

Author: *Jürgen Meyerdirks, Frank Ahlhorn (KuR)*
Reiner Schubert, Holger Rahlf (BAW)

4.3 Weser

4.3.1 State

4.3.1.1 Spatial extension of the investigation Area

After the Elbe, the Weser is the second-largest estuary in Germany discharging into the North Sea. The barrage in Bremen-Hemelingen defines the tidal boundary. The Tideweser can be subdivided into the sections Lower Weser (Unterweser: Bremen – Bremerhaven) and Outer Weser (Außenweser: Bremerhaven – open sea) (Figure 4-9). Bottom sediments of the Lower and Outer Weser consist mainly of medium and fine sands.

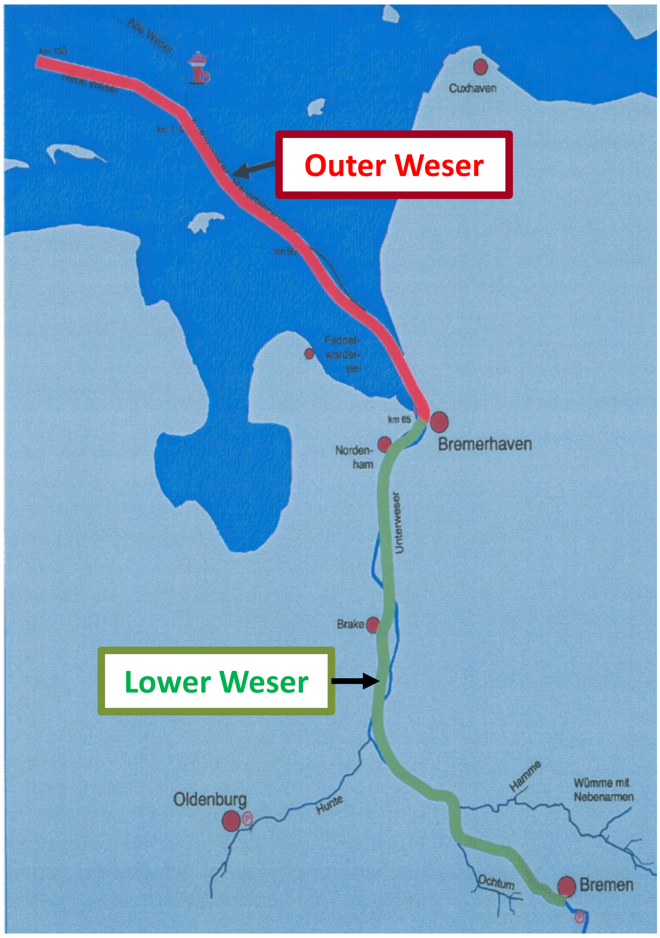


Figure 4-9: The Weser estuary. The tidal part with the Lower Weser from Bremen to Bremerhaven (green signature) and the Outer Weser from Bremerhaven seawards (red signature).

The entire length of the Tideweser is classified as a federal waterway (Bundeswasserstraße) for the transport of goods by barges and sea-going vessels. Inland navigation vessels can directly go from the Lower Weser to the Ems, via the river Hunte and the 'Coastal Canal (Kustenkanal)'. Sea-going vessels can call on the Lower Weser ports Bremen and Bremerhaven (City of Bremen) as well as Nordenham and Brake (Lower Saxony).

Bremerhaven is one of the most important Container terminals of the world. After completing construction works in 2008, the river-parallel container quay has an overall length of 5.4 km. Improvement and deepening of the navigation channel and the most modern quay equipment enable the currently largest container ships to call on Bremerhaven. Turnover figures in Bremen/Bremerhaven had two-digit growth rates during the past few years and amounted to approximately 5,000,000 TEU in 2007. In addition to containers, cars are the most important cargo handled in Bremerhaven. In 2007, a turnover of 2,000,000 cars has been exceeded the first time.

The privately managed port of Nordenham excels in bulk goods. Mainly coal is transhipped here (import); iron and steel are growing factors. The growth rate of exported goods amounted to 8 % in the years 1998–2005.

The port of Brake is a hub for the import and export of animal feed and grain. A strong increase can be noticed with lumber export and steel turnover. The growth rate for outgoing traffic was at approx. 6 % in the years from 1998 to 2005.increase can be noticed with lumber export and steel turnover. The growth rate for outgoing traffic was at approx. 6 % in the years from 1998 to 2005.

In addition to the utilization of river and estuary as a traffic artery, fisheries out of the small coastal harbours, energy production (wind power stations and cooling water for power stations) and an increasing tourism are other economic sectors.

4.3.1.2 System description: Hydrology – Morphology – Ecology

Main channel of the Weser - Surface Waters

In the last 150 years, the Weser was adapted to the economic needs and flood protection. For this purpose, the fairway was widened and deepened (Table 4-19), the banks were fortified and the dikes were increased.

1887-1895:	5m deepening Lower Weser
1891-1895:	deepening Outer Weser to 7,3m u. MTnw
1913-1916:	7m deepening Lower Weser
1921-1924:	7m optimize deepening Lower Weser
1925-1929:	deepening Lower Weser to 8,0m vessel draft
1953-1958:	deepening Lower Weser to 8,7m vessel draft
1954-1967:	deepening Outer Weser to SKN-10,0m
1969-1971:	deepening Outer Weser to SKN-12,0m
1973-1978:	deepening Lower Weser to SKN-9,0m
1998-1999:	deepening Outer Weser to SKN-14m
today:	Plan to deepening Weser estuary (Lower and Outer Weser)

Table 4-19: Timetable of deepening the Weser estuary

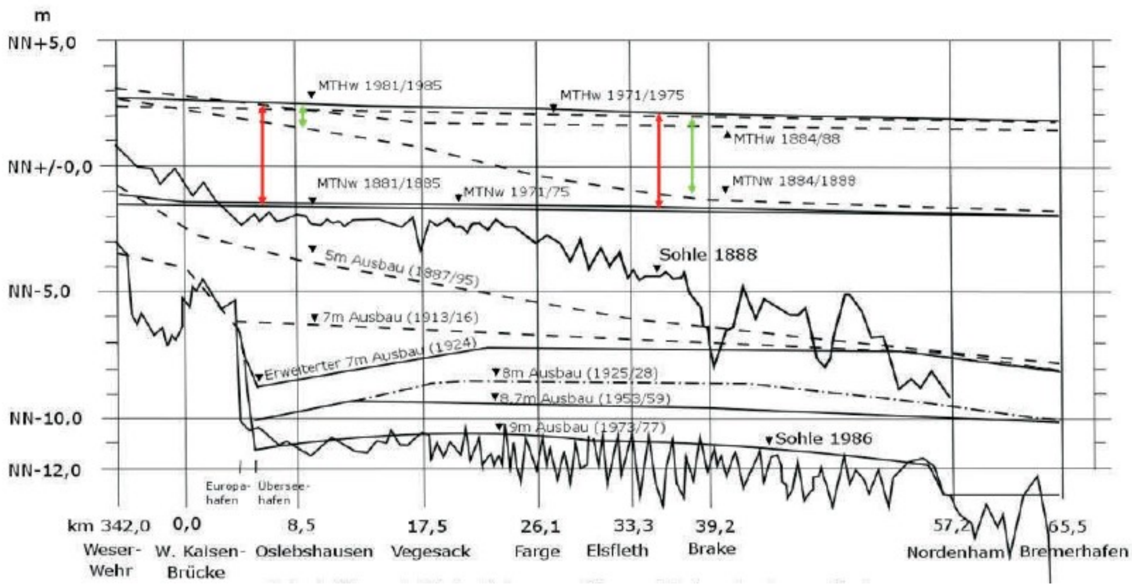


Figure 4-10: Longitudinal section of the Weser for different stages of expansion (HTG, 1968)

As a result, in Bremen at the tidal high water increased and the tidal low water decreased (Figure 4-10). In the last 150 years, also the increase in the salt water intrusion was largely controlled by the deepening of the river Weser (Table 4-19

1887-1895:	5m deepening Lower Weser
1891-1895:	deepening Outer Weser to 7,3m u. MTnw
1913-1916:	7m deepening Lower Weser
1921-1924:	7m optimize deepening Lower Weser
1925-1929:	deepening Lower Weser to 8,0m vessel draft
1953-1958:	deepening Lower Weser to 8,7m vessel draft

1954-1967:	deepening Outer Weser to SKN-10,0m
1969-1971:	deepening Outer Weser to SKN-12,0m
1973-1978:	deepening Lower Weser to SKN-9,0m
1998-1999:	deepening Outer Weser to SKN-14m
today:	Plan to deepening Weser estuary (Lower and Outer Weser)

Table 4-19.

The balance between fresh water and salt water is displaced by the increased water depth in favor of the salt water. Furthermore, the tidal range increases significantly in the estuary. For these two reasons, the salt water penetrates much further into the estuary.

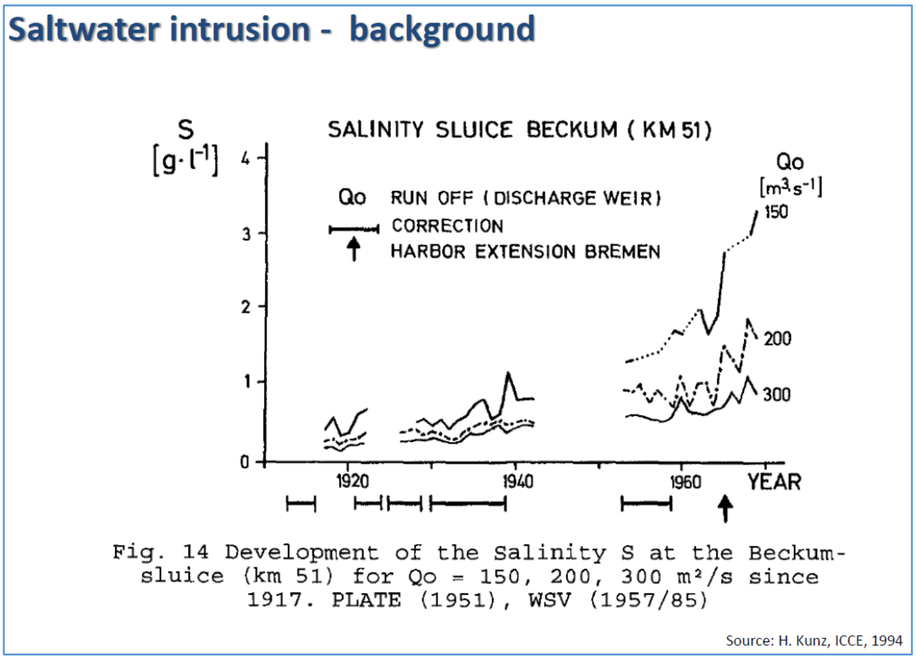


Figure 4-11: Development of the salinity S at the Beckum-sluice for Qo=150, 200 300 m3/s since 1917 (Source: H. Kunz, ICCE, 1994)

Figure 4-11 shows the increase of salinity on Beckum sluice of 0.5 to 3.5 due to the deepening of the Weser (Qo=150 m^3/s). The salt water intrusion varies with the headwater drainage and with the tide. Particularly high salinities are observed in storm surges, when the Low Water is very high. The seaward salt content is pushed into the estuary. Figure 4-12 shows the average position of salinity by capsizing of the flood flow (Smax) and by capsizing the ebb flow (Smin). The tide way of salinity is about 15 km.

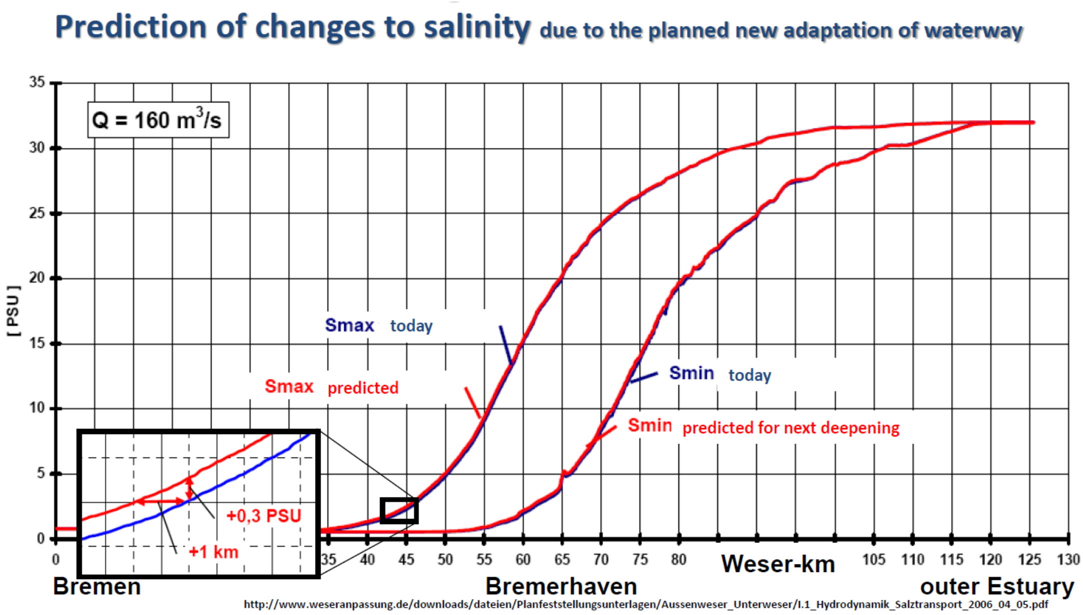


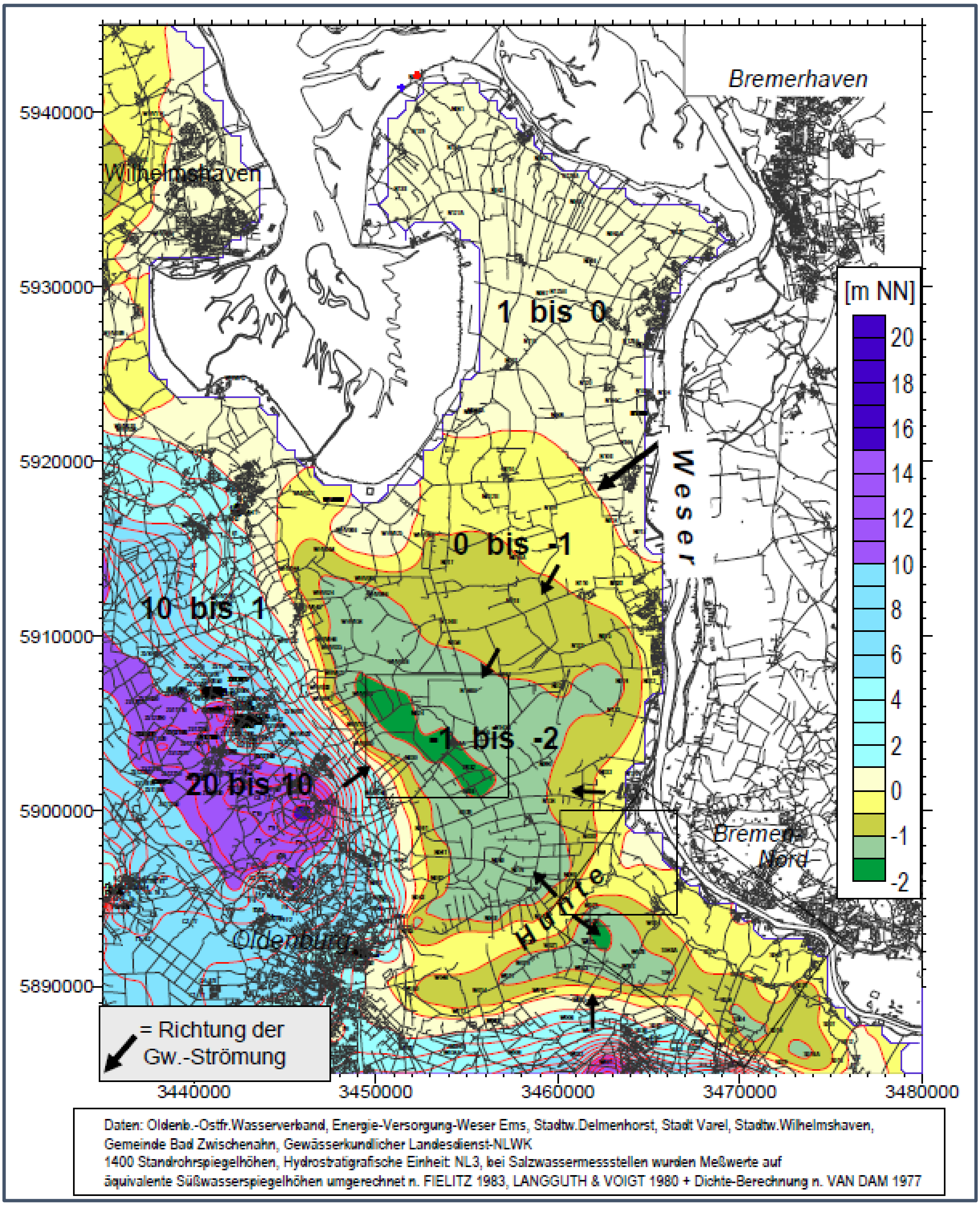
Figure 4-12: The average position of salinity by capsizing of the flood flow (Smax) and by capsizing the ebb flow (Smin).

Ground water: Equilibrium of fresh- and saltwater

The intrusion of salt water into ground water bodies partly caused by river works has already been documented in the 19th century – see Gwinner (1945). Gwinner (1945) described the development of the relation between the ground water situation and the fairway deepening's since 1885 based on observations. Further investigations on reasons and consequences of salt water intrusion into the ground water bodies of the Weser can be found in e.g. Kunz (1993, 1995), Hoffmann & Meinken (1999), Hoffmann et al. (2005) and Maniak et al. (1999, 2005).

A detailed description of the characteristics of the soil and the subsoil in relation to the salt water intrusion by the currently planned fairway deepening can be found in e.g. BAW (2006b) and GfL et al. (2006). In Fig. xx1 the water table contour lines and the flow direction of the ground water in the county of Wesermarsch is shown. The height of the water table in these low lying marshes is partly a result of the intensive drainage activities to enable living and working, i.e. safety against flooding and allowing intensive agricultural use. The dark green zones in Fig. xx1 are very low lying peaty areas in front of the moraine where intensive drainage activities are necessary to allow agricultural use. Here, the height of the ground level is up to 3 m below sea level (German: NN – Normal Null).

The current situation of the ground water in the Lower and Outer Weser estuary is a consequence of different factors of influence, e.g. precipitation, ground water recharge, tidal characteristics in the river Weser and drainage activities (Kunz 1993, 1995, Hoffmann & Meinken 1999, Hoffmann et al. 2005, Maniak et al. 1999, 2005). In 1974 the investigations on the saline-fresh water boundary by administrative institutions in the Lower Saxonian coastal aquifer resulted in a map showing the concentration of Chloride (Figure 4-14). As result of the interaction of different factors of influence. Figure 4-13 shows the current situation of the coastal aquifer around the



Weser estuary. In the county of Wesermarsch the ground water is in the upper layer totally and in the lower layer partly saline. Consequently, the ground water can't totally or only very limited be used for drinking water purposes and it isn't suitable even for watering purposes of the swards and cattle's.

Figure 4-13: The water table contour lines and the ground water flow direction for the county of Wesermarsch. Source: adapted from Weustink (2008) based on data from NLWKN, May 2000.

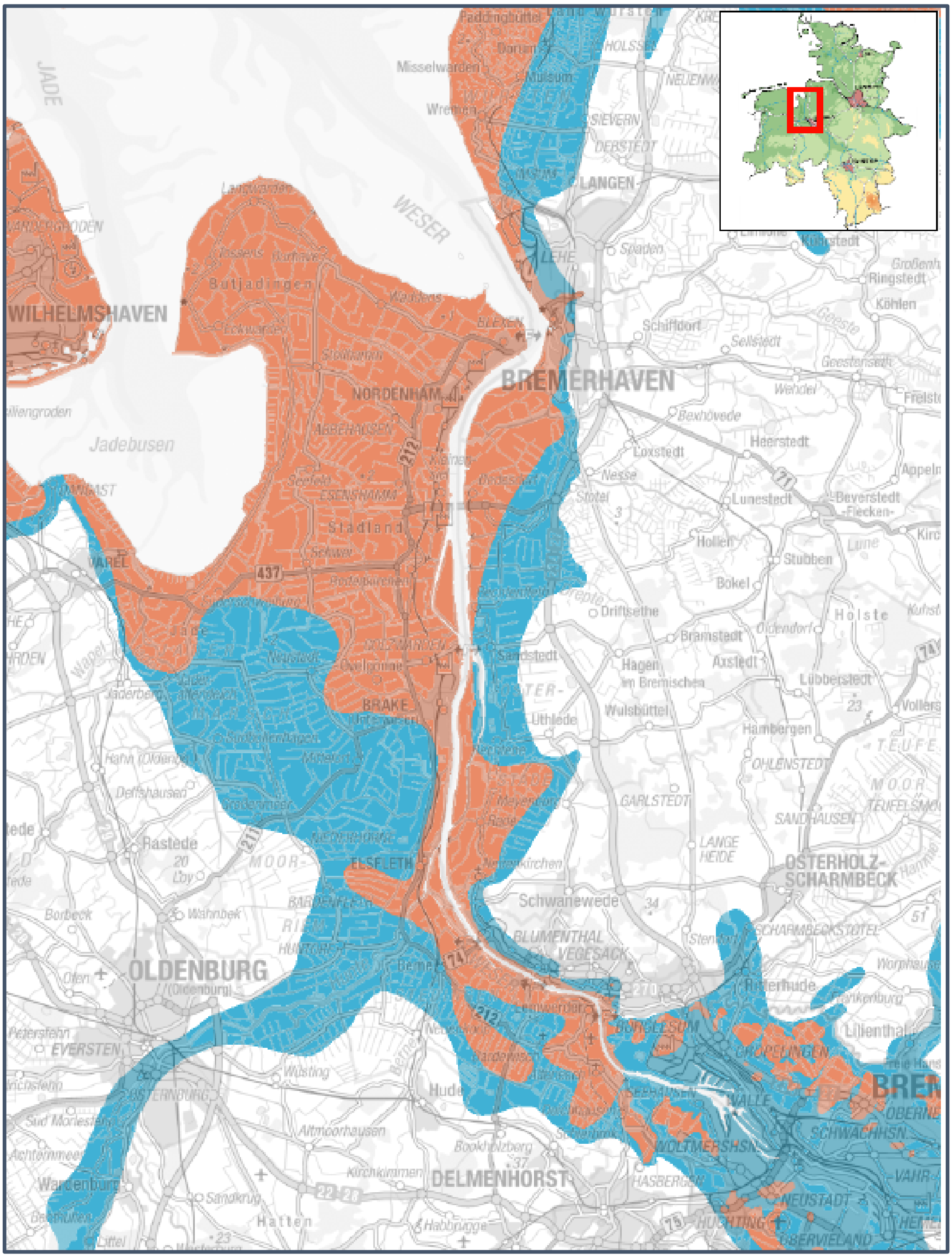


Figure 4-14: Boundaries of the extension of the saline ground water body at the Weser [orange: entirely or almost entirely saline ground water (> 250mg/l Chloride): impossible for drinking water abstraction; blue: saline ground water (> 250 mg/l Chloride): limitations for drinking water abstraction]. Source: LBEG, 2014 (accessed: Jan 2015)

Habitats: Presence and composition of characteristic habitats, vegetation

An estuary forms an ecological unit with the surrounding terrestrial and subtidal coastal habitat types. In terms of nature conservation, these different habitat types should not be separated. In contrast to other habitats estuaries have to be considered as a complex of habitats originated by ecological processes such as tide or salinity (EUROPEAN COMMISSION 2009, THE N2K GROUP 2009, NLWKN 2010a). The habitat type *Estuary* (Natura 2000 Code 1130) spreads from the freshwater border upstream to the end of influence of the freshwater charge. It encompasses all littoral zones from the deep sublittoral to the border of the flood plain. (EU 2007, SSYMANK et. al. 1998, DRACHENFELS 2008). Nevertheless estuaries could be related to other habitats e.g. coastal lagoons (1150 = habitat Type Natura 2000) or to large shallow inlets and bays (1160). Sand banks (1110), sandflats and mudflats (1140), reefs (1170) and salt marshes (1310 to 1330) that may also be a component part of habitat *Estuaries* (1130). (EU 2007)

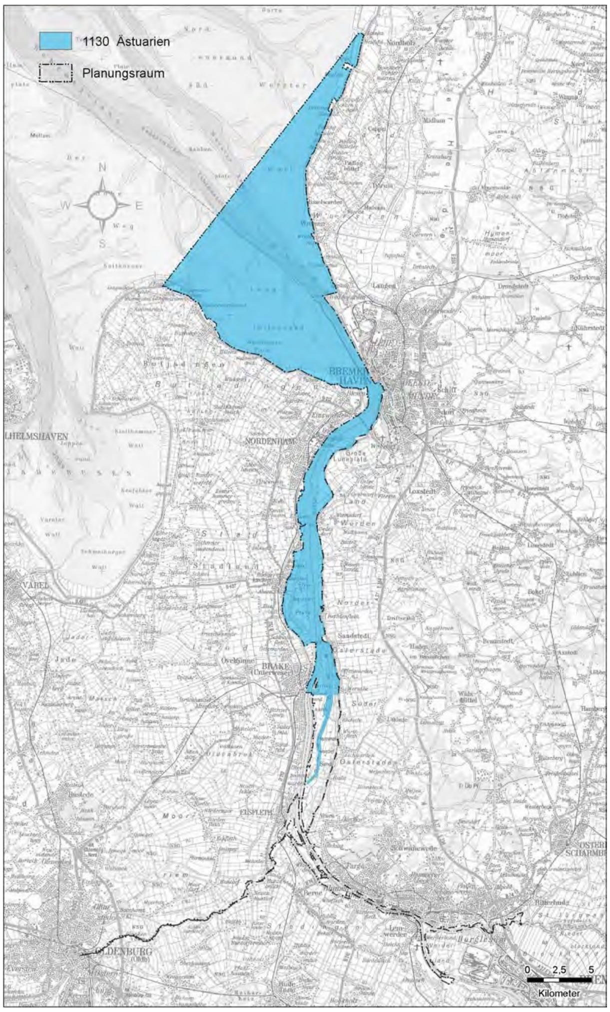


Figure 4-15: Extend of the Natura 2000 Habitat type Estuary in the Weser

At the Weser, the habitat type *Estuaries* reaches from the mouth up to the Unterweser-km 40 near Brake. In the side channel of the Rechter Nebenarm the influence of salinity occurs upstream up to Unterweser-km 33 (Figure 4-15, IMP Weser).

In Germany the detailed monitoring and assessment of habitats was operationalised by a scheme using differentiated Biotoptypes as assessment units (Blak 2008, DRACHENFELS, von 2007, 2008). Approximately 82 % of the 124 Biotoptypes of the Weser could be specified as estuarine habitats. They are divided into different characteristic habitat groups (IMP Weser 2012, Fachbeitrag 1).

An Integrated Management Plan (IMP according to the WFD) has been developed to record, assess and protect the existing environment of the Weser in 2012. Additionally to the existing monitoring frame work for characteristic and protected species a complex and operational assessment scheme has been developed (IMP Weser 2012). The completeness of the characteristic habitat structures (hydrology, structures of sub-, eu- and supralittoral and vegetation), the completeness of the characteristic species community (plants, invertebrates, fish, mammals, birds) and the occurring deterioration are assessed (BLAK 2008, Drachenfels, von 2007, 2008, European Commission 2006). The aggregation of those three criteria lead to a specific value assessment for each subspace and offers the opportunity to appraise how close to nature the area is.

Soil characteristics: soil conditions outside the dike

The typology and texture of the soils of (dike fore land) of the main channel of the Weser differ according to their position of height in the littoral and their position according to zonation of salinity of the Weser (see Figure 4-16).

The most important parameter for the texture of the semi-terrestrial soils is the exposition to the currents. The flow velocity stimulates the deposition of sediments. Higher velocities are able to transport particles with higher masses. Therefore, the more sandy structured sediments and soils could be found in the areas of higher current activity. Regions with lower current energy are dominated by fine sediments of silt and clay like they can be found in the higher parts of the littoral.

The higher parts of the intertidal mudflats above the mean high tide level are populated by different characteristic sward, herb and reed communities. The appearance of the plants forming the structure of the different habitats are especially depending on the salinity of the riverine water. Different degrees of salinity lead to the occurrence of different plant associations.

Biodiversity: Composition and abundance of characteristic species (plants, benthic invertebrates, fish)

An important aspect to evaluate the value of a habitat is to specify the occurrence of characteristic species living in this habitat. Therefore, the listing of characteristic species populating estuarine habitats and biotope types are a suitable method to indicate the value of the environment. The IMP Weser (2011) offers several lists for the most important or most indicative species groups (Drachenfels, von 2007, Tesch 2077 BLAK 2008, KÜFOG 2006b, Landesamt für Umweltschutz Sachsenanhalt 2006).

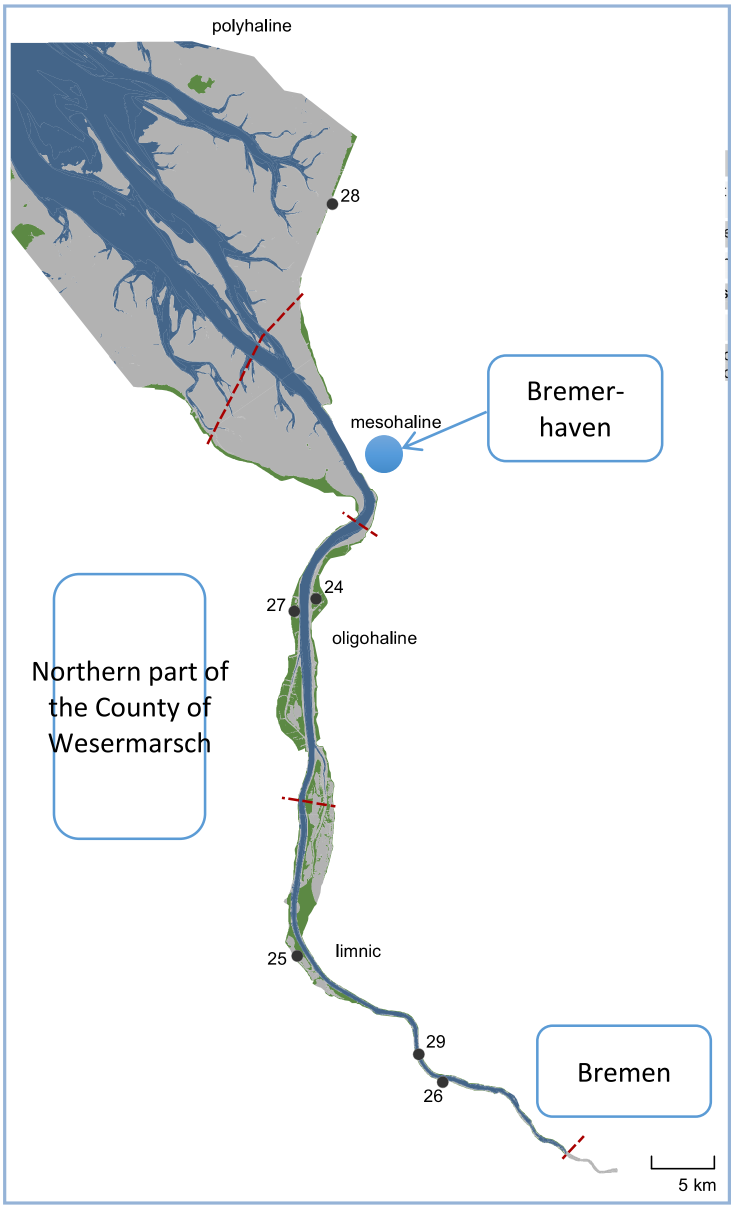


Figure 4-16: The Weser estuary from Bremen to Bremerhaven. The map is showing the different estuarine zones: limnic, oligo-haline, meso-haline and polyhaline (classification according to the EU Interreg IVB project TIDE, source: HPA et al. (2013)

Plants

The basis for the listing of the characteristic plants considers the specific regional situation of the Weser estuary and refers to a reasonable amount of monitoring data (Drachenfels 2007, Tesch 2009, GFL et al 2006, IMP 2011 Fachbeitrag 1)

Benthic Invertebrates

The benthic invertebrates of the haline part of the Weser show characteristic occurrence in many habitats. Estuarine specific habitat conditions enable a benthic fauna with typical species composition and abundance. Benthic invertebrate communities are quit durable, stable in position with many sensitive species that show close habitat bindings. Therefore, benthic invertebrates are important indicators to describe and assess the estuarine environment.

The occurrence of benthic species is basically related to abiotic factors such as salinity, morphology and tidal parameters. Those conditions show a large spatial heterogeneity and dynamic. Therefore, the description of the fauna was done in different partial habitats: different depth zones (navigation channel, channel slope, deep and shallow sublittoral, supralittoral), different sediment types for the eulittoral (sand-, mixed- and mudflats). Additionally, there are specific habitats like water bodies on dike fore lands or tributaries. The benthic populations of these habitats differ due to the different zones of salinity (poly-, meso-, oligo-haline, see Fig. x). A natural morphology and hydrology is the habitat base for a typical benthic coenosis, which is composed of a large number of typical species with a large proportion of sensitive, vulnerable and specialized species.

The data base referring the occurrence and distribution of the benthic invertebrates of the haline part of the Weser documented and assessed in several documents. (IMP Weser, Fachbeitrag 1, Planning Approval Weser 2012). Also several coordinated assessment schemes for the benthic invertebrates exist and offer the opportunity to address the value of different parts of the Weser under different haline situations (BLAK 2008, Krieg 2007).

Fish and species of the fauna and flora directive

In the tidal part of the Weser of the Weser 109 species of fishes and cyclostomes (e.g. river lamprey) could be identified. This comprises 42 limnetic, 11 euryhaline and 56 marine species. Particularly important species to evaluate the estuarine habitat (Habitat Type 1130 Natura 2000) are estuarine resident species which take their entire life cycle predominantly in the brackish water zone (LAVES 2009a).

The migrating fish species are also of particular importance ,i.e. diadromous species which use the estuary for reproduction and as nursery area (Twaite shad, a*losa fallax* and smelt *Osmerus eperlanus)* or as transit area (*Salmo salar*) Sea lamprey *(Petromyzon marinus),* river lamprey *(Lampetra fluviatilis)*. Furthermore, in the tidal part of the Weser several species of mammals that are listed in the Flora and Fauna Habitats Directive (European Commission 1992) occur: common porpoise *(Phocoena phocoena)*, seal *(Phoca vitulina), pond bat* (*Myotis dasycneme*)(IMP 2012).

Landscape on the Weser banks – surface water

Hydrology and Water Quality: flood plains and trenches

Figure Figure 4-17: shows the habitat types on the flood plains and islands of the lower Weser. Parts of the flood plains are protected by summer dikes in order to use it for agricultural purposes.

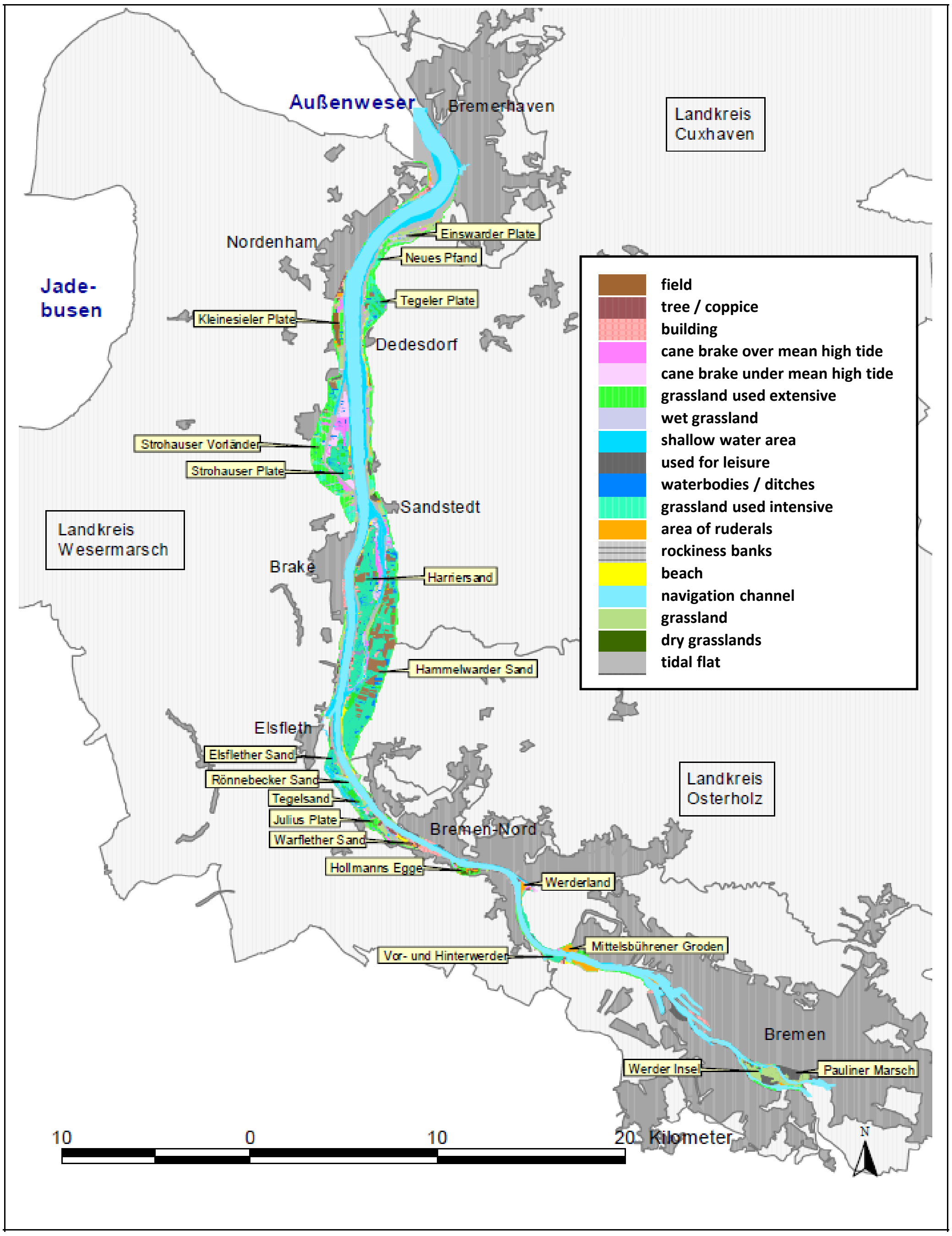


Figure 4-17: Overview of location and distribution of habitat types occurring in the foreland

habitat types	%
rockiness banks	0.2
n.s.	0.9
wet grassland	1.5
trees	1.8
waterbodies / ditches	2.8
area of ruderals	2.9
building	3.4
used for leisure	7.5
field	8.5
cane brake over mean high tide	11.1
grassland used extensive	20.9
grassland used intensive	38.5
grasland	60.9
farming	69.4
land over mean high tide	100

Table 4-20: Surface balance for the uses of the foreshore areas above MHT

area ratios	%
cane brake under mean high tide	6.8
shallow water area	14.2
tidal flat without vegetation	19.7
tidal flat	26.5
river channel	59.3
river channel + shallow water area	73.5
river	100

Table 4-21: Surface balance for the reeds divisions of the Weser below MHT

Table 4-20 and Table 4-21 show the surface portions of the habitat types above and below the MHT. Of a total of 5112 m^2 area above MHT there are 145 m^2 ditches or rivers. The tidal range has been greatly changed by the expansion of the outer Weser and Lower Weser in the last 150 years. Today he is an average of 4 m.

The height of the peak water levels is important for the location and extent of tidal flats and shallow water areas. This results in changing the flooding durations of the shallow water areas and ditches. The increased saltwater intrusion resulted in an upstream shift of the freshwater tidal flats.

Large parts of the flood plains of the Lower Weser are leased to farmers. Because the foreshore is fertile, high quality forage grasses are grown there with appropriate management. The type of land use is primarily dependent on the frequency of flooding, flooding duration and flooding height.

Habitats: Presence and composition of characteristic habitats and vegetation

The influence of salt intrusion in the area of the Wesermarsch is primarily focussed on the surface waters. Two different habitat types could be found. Ditches and fleets or small channels (Sieltiefs). The intensity of salt intrusion differs depending on the localisation of the water bodies according to the longitudinal salinity gradient of the Weser (Figure 4-12). This salinity gradient has an essential influence on the vegetation of the surface waters. Three different subareas could be found. Upstream of the town of Brake (UW-km 40) no distinct influence of salt intrusion could be found in fleets and ditches. Between the tidal outlets "Blexer Siel" and "Braker Siel" (UW-Km 60 – 40) there is a perceptible influence of salt water whereas the highest salt concentrations could be found in the inland water bodies of the northern part of Butjadingen.

Biodiversity: Composition and abundance of characteristic species (benthic invertebrates, fish)

Benthic Invertebrates

The widespread system of channels and ditches in the Lower Weser region is populated by a species and individuals rich fauna of benthic invertebrates. Overall more than 180 species from 13 taxonomic groups can be found (IBL 2011). Despite the high species diversity large spatial differences in the invertebrate colonisation can be found. Generally, the larger channels show clearly lower species diversity than the smaller water bodies with dense vegetation. The downstream part of the Wesermarsch exhibits scarce fauna dominated by brackish water species which can also be found in the main channel of the Weser. The most valuable benthic ceonoses can be found near the town of Brake where the salinity of the water bodies is remarkable lower. (GfL, Bioconsult & KüFoG 2007).

Fish

The fish fauna of the ditches and channels of the Lower Weser is moderately rich in species. Nevertheless, those small water bodies provide dense vegetation which serves as important substitute habitats for shallow water areas that have been lost in the main channel.

The larger channels are dominated by species with indifferent habitat requirements, while fish which populate the smaller ditches, need the ability to survive low oxygen concentration occurring in summer. (GfL, Bioconsult & KüFoG 2007, IBL 2011).

4.3.1.3 System description – Socio Economic System

Salt water intrusion is affecting the socio economic system in different ways. It is triggered by demands of different economic sectors. Especially maritime traffic, coastal defence, water management and ground water abstraction show reasonable effects on the situation of salt water intrusion in the Weser estuary.

Stakeholder

To describe the current situation of the interaction of salt water intrusion with the socio economic system a participatory action has been conducted. To gather the knowledge and the demands of different users and experts have been involved. Main objective for the selection of the stakeholders was to integrate all involved groups concerned by the item of salt water intrusion at the Weser (see Table 4-22).

User		
User Perspective	**User Group**	**User (Company, Institution)**
Harbour	Port Authority Lower Saxony	N Ports
Infrastructure Pier	Transshipment (Import/Export)	Müller Brake
Groundwater	Water Supplier User Ground Water (Industry)	SWB AG (supply company) FBG Bremerhaven (Harbour Industry)
Agriculture	Farmers Association	Farmers
Nature Conservation (Organisations)	NGO`s	BUND Bremen Mellumrat e.V. WWF (Worls Wildlife Found)
Tourism	Sailers Association	Regionalverband Segeln Weser-Ems
Water Management	Drainage boards	Kreisverband WaBo Wesermündung Planungsverband WaBo Wesermarsch

Experts / Administration		
User Perspective	**Spatial Unit**	**Authority**
Shipping	Federal Water and Shipping Administration (Germany)	WSA Project Groups for Fairway Deepening
Agriculture	Lower Saxony (Federal State)	Chamber of Agriculture Lower Saxony
Nature Conservation (Authorities)	Lower Saxony (Federal State) Lower Saxony (Federal State)	National Park Authority Biosphere Reserve Authority
Coastel Protection	Lower Saxony (Federal State)	Lower Saxony Water management, Coastal Protection and Nature Conservation Agency (NLWKN)
	Lower Saxony (Federal State)	Coastal Research Department (NLWKN)
Planning	Lower Saxony (Federal State)	State Authority for Mining, Energy and Geology
	Bremen (Federal State)	Geology Authority
	County Cuxhaven	Water Management Natur Conservation
	County Wesermarsch	Nature Conservation Business Development

Table 4-22: List of the approached stakeholders within the German part of the EMOVE project

Stakeholder Demands

In interviews the stakeholders got the opportunity to describe their opinions, demands and feelings concerning the item of salt water intrusion at the Weser. The outcomes were discussed and harmonised in a stakeholder workshop and led to a reviewed list of stakeholder demands sorted for different sectors (see Table 4-23).

User Perspective	**User Demands**	
	socio-economic description	systems description - parameter
Harbour Infrastructure Pier	sufficient depth of waterways	depth at Brake of 12,8m enables the passage for most of the vessels (bulk carrier, animal feed)
Groundwater	waterquality and volume	abstraction of fresh not saline groundwater
Agriculture	**Surface Waters:** Watering with fresh water from the Weser in sufficient quality and quantity	Supply of water with < 2,5 g/l salt concentration as drinking water for cattle (and seperation between the meadows)
Nature Conservation (Organisations)	Re-establishment of near natural conditions	WFD, Natura 2000, Integrated Management Plan (IBP)
Nature Conservation (Authorities)	preserving natural values by implementing and operationlising legal frame works	WFD, Natura 2000, Integrated Management Plan (IMP)
Tourism	**Sailers:** Reduction / avoidance of sedimentation **Recreation:** Protection of characteristic types of land use	**Sailers:** upstream shift of brackish water zone leads to increasing corrosion in formerly freshwater areas. Sedimentation increases in tributaries and harbours **Recreation:** Traditional cattle husbandery, protection of meadows
Water Management	**Surface water.:** Use of fresh water from the Weser to establish sufficient minimum water levels in the ditches, support sufficient water quality and quantity	Supply of water with < 2,5 g/l salt concentration for flushing the ditches

Table 4-23: List of the demands of the stakeholders concerning the item of salt water intrusion at the Weser estuary.

4.3.2 Impacts

4.3.2.1 Impacts on the ecosystem

Main channel of Weser

Changes of hydrology, sediment transport, morphology and salt water intrusion

The most important risk factors for the current state of preservation are the deepening of the fairway, construction and operation of port facilities and dams, embankments, embankments, shipping, intensive agriculture as well as pollutants, nutrients and heat inputs.

The effects of the currently planned fairway deepening on the tidal characteristics of the Lower and Outer Weser are expected as follows (= superposition alternative, BAW 2006a,b):

Superposition Alternative*	Change of Tidal Properties (characteristics?)
Tidal Range [cm]	+9
Tidal High Water [cm]	+3
Tidal Low Water [cm]	-6
Tidal Mean Water [cm]	-1

*Table 4-24: Expected changes of tidal properties for the currently planned fairway deepening of the Lower and Outer Weser (figures for the barrier in Bremen). *Superposition Alternative = Changes according to the fairway deepening's in the Outer and Lower Weser together.*

These figures were the results of detailed investigations of the currently planned fairway deepening's for the Outer and the Lower Weser applying hydrodynamic models (see BAW 2006a). In general, the results of the simulations show (minor) changes in tidal characteristics in relation to the existing tidal range of 4 m at the barrier in Bremen (BAW 2006b). As for the past fairway deepening's the trend of increasing of tidal high water and decreasing of tidal low water is expected to be continued (for historical overview see, e.g. Kunz 1995). Therefore, the major changes of tidal characteristics in the Lower and Outer Weser were consequences of the past fairway deepening's, and the currently planned deepening might lead to a slight change of the tidal properties (see Table 4-24, BAW 2006a,b, GfL et al. 2006).

The planned expansion of the Lower and Outer Weser obtained small changes in flow and sediment transport conditions.

As consequences of climate change higher accruing storm surges, tidal range and an enlarged stronger headwater runnoffs are forecast in the winter months in the future. Higher temperatures and decreased headwater runoffs are predicted for the summer months, the upstream with a further shift in the brackish water limit and longer times low oxygen levels are associated.

In the sediments (except for a shift in the turbidity zone) does not entail any measurable changes in the particle size distribution curves.

The changes in the characteristics of the tide lead to loss of shallow water areas with a simultaneous increase of deep-water areas. The flow of the branches of the estuary is reduced, so the quality of the habitat will be significantly degraded.

The examination results show overall that the planned expansion leads to a strengthening of the flow in the channel and to a weakening in the side and shore areas. Therefore, in the sections of the turbidity zone and in the branches and outdoor lows is an increasing trend in existing siltation expected.
However, no short to medium term measurable expansion-induced change of basic morphological processes along the side areas and banks nor the occurrence of new processes is expected.
In the sediments (except for a shift in the turbidity zone) does not entail any measurable changes in the particle size distribution curves.

As Figure 4-12 shows, the changes in salinity can be regarded as an increase at a fixed position or as an upstream displacement for a fixed salinity.

Fixed life forms are stressed by increased salinity. The in one place increased salt content must therefore be regarded as deterioration of water quality.

Ground water: Impacts on Equilibrium of fresh and salt water

According to Table 4-24 greater changes are expected to occur for the Tidal Low water than for the Tidal High water. Consequently, the expected impact for the ground water (table) is estimated as low during Tidal High water time. The influence of the tidal movement decreases with the growing distance to the embankments of the river Weser (Figure 4-18). In Figure 4-19 the simulated differences are shown for the superposition alternative of the currently planned fairway deepening. There is a slight increase for Tidal High water time and bigger increase for the Tidal Low water time shown. In a distance of more than 400 m from the river embankment only moderate changes of the ground water table are expected. Finally, taking only the currently planned fairway deepening into account the impacts on the ground water will be minor and mainly restricted to the proximity of the embankments of the river (BAW 2006b, GfL et al. 2006).

The changes resulting by the drainage activities in the low lying areas of the county of Wesermarsch were estimated to be more severe than the currently planned fairway deepening.

Recently, further research investigations took place to enhance the knowledge on the possible influences of river works on salt water intrusion in the main channel of the river (i.e. movement of the brackish water zone) as well as consequences for the ground water in the adjacent areas of the river (see e.g. Zorndt et al. 2011).

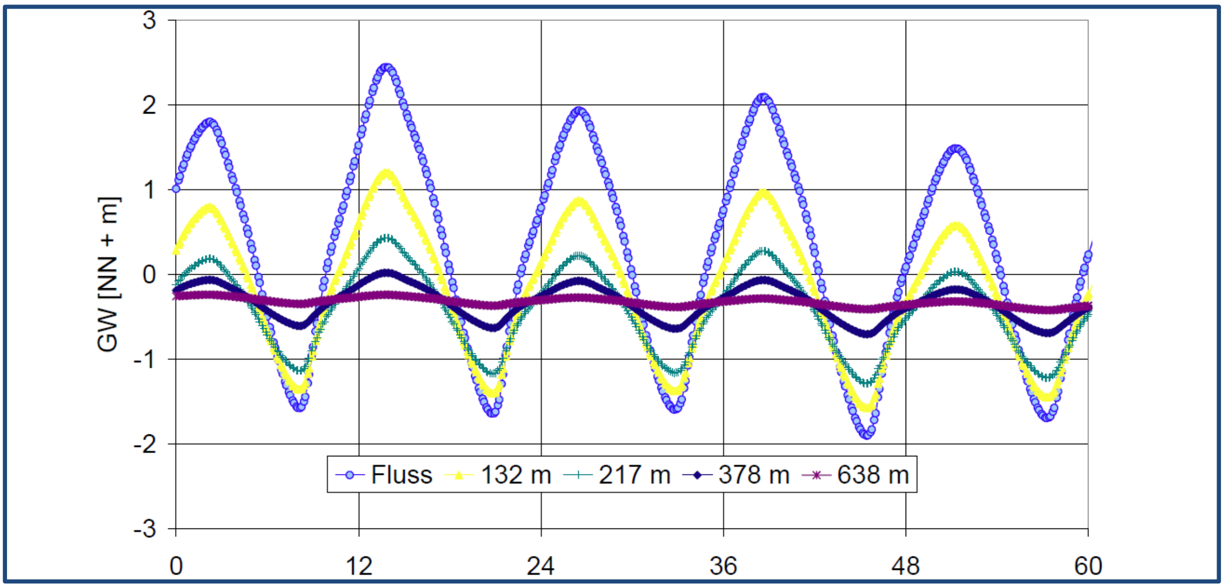


Figure 4-18: Oscillation of the ground water table influenced by the tidal dynamics in the sandy aquifer (distance to the river, state of comparison, date: 31st May 2002). Source: BAW (2006), Appendix 13.

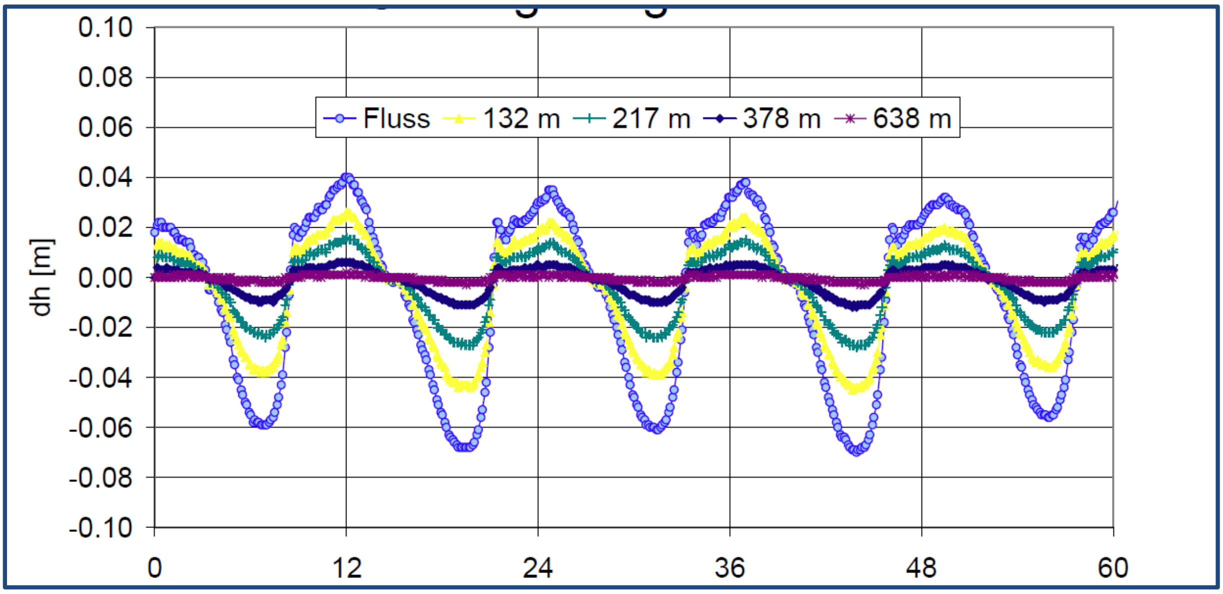


Figure 4-19: Differences of the ground water table between comparison state and superposition alternative in the sandy aquifer (distance to the river). Source: BAW (2006), Appendix 14.

Habitat loss: Loss of characteristic habitats and vegetation

The hydrological change in tidal characteristics like tidal curve, run-off and water levels lead to a change in the position of the brackish water zone in the Weser. This situation is triggered by climate change as well as by morphological changes of the river bed due to the deepening of the main channel.

The main Pressure for the habitats and vegetation at the main channel of the Lower Weser is the encroachment of the salinity gradient further upstream. This impact is stronger at the upper border of the brackish water zone than downstream: For the planned deepening of the main channel of Outer and Lower Weser there are estimations on an upstream shift of the brackish water zone from UW-km 45 to 65 of up to 1,000 m at the upper and up to 500 m at the downstream part (Planning Approval Weser 2012). This salt gradient is triggered by several parameters like runoff, tidal dynamics and seasonal changes. Therefore the position of the brackish water zone in the Weser is not fixed at one position in the Weser and is not forming a sharp border between brackish and limnetic environments.

Nevertheless, an upstream directed shifting of habitats and vegetation zones will be the consequence of these changes. Affected is the whole salinity influenced section of the Weser with all plants living in this area. The distribution of different plant associations will change. The flood barrier in Bremen represents the artificial boundary for this process. Therefore, the extension of the limnetic part of the tidal Weser gets squeezed and decreases. This leads to an expansion of salt tolerant plants against limnetic flora with distinct benefits for facultative halophytes, plants that tolerate limnetic as well as brackish conditions.

To assess that these changes in habitat structures triggered by these processes it is important to know that both, brackish and limnetic habitats represent important values. For an overall summation of the value assessment the whole gradient has to be taken into account. Aside from the expected outcomes of a total assessment it could be considered that several limnetic habitats would decrease. At least the impacts on the effected habitats are seen as a substantial impairment of the system which has to be compensated. (Planning Approval Weser 2011, Accompanying Landscape Conservation Plan 2011)

Changes in species distribution and abundance: Loss of characteristic species and communities

Benthic Invertebrates

The upstream shift of the brackish water zone in the Weser (see above) leads to a shifting of the communities of the benthic invertebrates. The fauna is adapted to specific salt concentration in the water and to the texture of the soil substrate. This is also triggered by the salinity because of the accumulation of soft sediments in the brackish water zone. Different zones of salinity are populated by specific communities of benthic invertebrates. Because of the high dynamic the boundaries between these communities are moving. An increasing amplitude of salinity caused by higher tidal dynamics leads to more salinity stress for the fauna.

The assessment of the impacts has to take into account that both brackish and limnetic benthic communities have high ecological values. Comparable to the habitat situation (see above) the river upward shift takes an end at the flood barrier in Bremen. Therefore, the limnetic fauna has to cope with a decreasing area. This leads to a negative development of the overall dispersal of different benthic communities. Because of the larger plasticity to adapt to the dynamic estuarine conditions the impacts could be seen as less damaging than for the plants and habitats.

Fish

The fish communities will follow the upstream movement of the brackish water zone. This leads to a decrease of the available habitats for limnetic species while estuarine and marine species would spread. The changing salinity gradient affects dispersal, activity and vitality of the benthic fauna which are an important food source for many fish species. The bait movement poses additional stress on the fish populations.

Especially limnetic fish species are sensitive to the salinity conditions in their reproduction areas. Damages on spawn are known for relatively low salt concentrations. Also effected might be the FFH species twaite shad which has its reproduction area in the main channel of the Weser (UW-km 22,5 – 29) slightly upstream of the brackish water border.

Landscape on banks of Weser

Changes of Hydrology and morphology and salt water intrusion

The changes to the tide also have an impact on the hydrology of the trenches in the flood plains. The higher water levels and increased tidal range cause increased flow velocities in the trenches. Especially in the corners are reinforced erosions occur.

The increased salt intrusion results in other ditches in the marshes of the Unterweser to a higher salt content.

The irrigation and drainage is made more difficult due to the changes of the tides. The changes in the tides and the resulting changes in water management also have an impact on groundwater.

Higher salinity and higher concentration of fine sediments lead to a deterioration of water quality.

Habitat loss: Loss of characteristic habitats and vegetation

There is a potential threat for the vegetation of channels and ditches in the region of the Lower Weser to be affected by an increasing salinity. This is due to the behaviour of watering the ditches in dry times with water from the Weser. This ensures the livestock farming while providing drinking water.

Due to an upward shift of the brackish water zone the probability for taking up saline water for watering the ditches would increase. Especially under dry conditions in summer time there is a need for watering. Due to low discharges from upstream the risk of a further upstream shift of the brackish water zone rises. If saline water from the Weser reaches the tidal inlets used for watering (Braker Sieltief, Käseburger Sieltief) this would lead to an increased impact on the water bodies and habitats.

Despite the tolerance of some of the prevailing plants according to temporarily enhanced salinities there will be noticeable changes in species occurrence and the dispersal of different plant associations, including the spatial extinction of some species (GfL, BioConsult, KÜFOG, Januar 2007). In the wet months outside the grazing period and also during rainfall events in summer, the salt concentration is reduced again. The degree of a deterioration of habitats and vegetation depends on the interval, duration and intensity of salt water. Limitation factor is the position of the tidal inlet according to the new position of the brackish water zone. Acknowledging the upstream shift of the brackish water zone due to the deepening of the Weser there will be technical implementations to avoid the salinisation of ditches and channels at UW-km 42 (see avoidance solution, Table 4-25).

Changes in species distribution and abundance: Loss of characteristic species and communities

Benthic Invertebrates

The fauna of the invertebrates of channels and ditches in the Wesermarsch show species-specific differences in the ability to cope with saline water conditions. Areas downstream UW-km 42 and the larger channels often are populated by a fauna which is already adapted to at least temporary higher salinities. Further upstream especially the smaller vegetation rich ditches show an abundant and species rich invertebrate fauna. An intense increase of the salinity would cause at least a reduction in species richness which would especially affect limnetic biota with less salt tolerances. The most valuable invertebrate fauna can be found at the region between UW-km 32-35 (IBL, 2011). An impact due to watering with saline water from the Weser is relatively improbable under current condition. Nevertheless, the impacts would be worse in this area.

Fish

In principle, changes in salinity cause changes in the occurring fish populations. The fish fauna of the ditches and channels is already adapted to occasional salt water conditions due to the watering situation in the northern part of Butjadingen. A potential threat exists when saline water reaches water bodies at the border of the brackish water zone. The effects could be seen as relative moderate because most of the occurring species show an excellent plasticity in bearing occasional salt intrusions of lower levels.

4.3.2.2 Impacts on socio economic system

An alteration of the salt water intrusion shows various effects on the socio economic system. This comprises nearly all stakeholders approached within the EMOVE project in the estuary. The gathered data from the stakeholder interviews (see Table 4-25) is enhanced by expert knowledge and literature. This leads to a complete compilation of the existing impacts triggered by salt water intrusion for each user perspective (agriculture, water management, etc.). A user perspective could be seen as a group of stakeholders formulating the same demands on the functions of the system Weser.

User Perspective	Impacts	
	on socio-economy	systems description single parameter
Harbour Infrastructure Pier	derogation of accessibility Stress for infrastructure	corrosion of steel piles, increased excavations, additional need for coordination with nature conservation, alteration in immersion depth (ships), damages caused by invasive species, salinisation of ground water beyond the pier
Groundwater	Salinisation of dwelling ponds, corrosion of infrastructure	restrictions or loss of ground water abstraction, corrosion of tubes
Agriculture	**Surface waters:** reduction of water quality and quantity	derogation of water quality (drinking water for cattle, flushing, seperation, changing habitat conditions)
Nature Conservation (Organisations)	derogation of natural values	shifting of species destribution, loss of species, un-ecological dynamic and habitats derogate ecology and landscape
Nature Conservation (Authorities)	derogation of natural values	shifting of species destribution, loss of species, un-ecological dynamic and habitats derogate ecology and landscape
Tourism	**Sailors:** upwards shifting of brackish water zone, increasing sedimentation **Recreation:** decrease of characteristic landuse pattern	**Sailors:** increasing corrosion on boats and infrastructure, increasing afford for cleaning harbours from sediment **Recreation:** loss of traditional cattle husbandery, plowing of meadows, cultivation of maize
Water Management	**Surface water.:** derogation of water quality and quantity	decreasing watering times with fresh water cause lower water quality for cattle, flushing, seperation, changing habitat conditions, corrosion)

Table 4-25: List of the impacts triggered by salt water intrusion. Outcome of the stakeholder interviews.

The gathered impacts have been ranked due to their importance reflecting the different user perspectives and compartments of the estuary. The final output is a stakeholder adjusted identification of the important Impacts caused by salt water intrusion (Table 4-26).

System Compartment	Surface Waters – Weser			Surface Waters – Channels / Ditches			Habitats / Landscape	Groundwater	Soil
Impacts	Shifting of Brackish Water Zone			Water Quality		Water Volume		Quality	Quality
User Perspective	Limited Freshwater from Weser	Increased Dredging	Corrosion of Infrastructure	Salt Intrusion	Increased Sedimentation	Reduced Waterlevel	Shifting and Loss of Habitats	Salt Intrusion	Salt Intrusion
Commerse and Industry									
Harbour	0	+++	+	0	0	0	0	0	0
Infrastructure Pier	0	++	++	0	0	0	0	0	0
Groundwater (Use)	+	0	0	0	0	0	0	+++	0
Agriculture	+++	0	0	+++	+	+++	+	0	+++
Nature Conservation	+++	++	0	+++	+	+++	+++	0	++
Tourism	+	0	+	+	0	+	++	0	0
Water Management									
qualitative (Ecology)	++	0	0	++	++	+++	+++	0	0
quantitative (Water Management)	++	0	++	++	++	+++	0	0	0
Groundwater	0	0	0	0	0	0	0	+++	0

0	Without Importance
+	Importance low or indirect
++	Importance high
+++	Importance very high

Table 4-26: Appraisal of the importance of impacts triggered by salt water intrusion.

4.3.3 Responses

4.3.3.1 Identification of solutions

For the Weser estuary a two stage approach has been conducted to identify and to assess the relevant Responses the effects of salt water intrusion. In a first step all known options for solutions have been gathered and described. Main source were the structured stakeholder interviews supported by literature. In a second step this information was sorted and reviewed. The output is a list of possible options that are able to diminish the impacts of salt water intrusion at the Weser estuary.

User Perspective	User Demand	Solution	Annotation	Active Area
Commerse and Industry				
Harbour	**Depth**	**Integrated concept of hydraulic engineering**	Engineering works required to secure the functions of shipping and harbours are assessed, weighed and implemented in a way that the development goals of WFD and Natura 2000 could be reached as much as possible. Goal: Improvement of hydromorphological and physical / chemical parametersfor a sustainable safeguarding of estuarine functions.	entire Weser estuary
Infrastructure Pier	**Depth**			
Groundwater	**Groundwater Abstraction**	**Decrease of abstraction**	Reduction of abstraction rates to avoid salt intrusion. Closing of wells because of salt intrusion.	Area of Groundwater Abstraction
		Counteractive measures	Stainless steel tubes to avoid corrosion. Barrier layers, steel pilings (local). Improving the management of groundwater use due to better knowledge of groundwater-recharge under the regime of climate change.	Subarea of Groundwater Abstraction
Agriculture	**Drinking water and seperation cattle**	**Avoidance Solution**	Prohibition of deterioration in the planning approval leads to avoidance solution. Impacts for the agriculture triggered by the deepening of the Weser were compensated. tecnical solutions in Butjadingen (heightening of channel dikes) and Stadland (strenghtening of infrastructure, gauges and steering automatically). Additional pumping facilities.	Marsh left Unterweser-km 65-42 right Unterweser-km 65-40
	Drinking water cattle	**Infrastructure (water pipe)**	Drinking water for cattle via water pipe. Improving Water Management for cattle watering.	Marshland both sides of the Weser
	Seperation cattle	**Infrastructure (fence, stable)**	Seperation of cattle with fences instead of ditches. Increasing of indoor livestock farming especially large units. Increased mowing to compensate salt intrusion.	Marshland both sides of the Weser
Nature Conservation	**Occurance of typical species and landscapes**	**Avoidance and Compensation**	Implementation of avoidance and compensation using framework of Natura 2000 and IMP	local in the haline part of the Weser
		"Shallow River"	Stop additional deepening. Start adequate renaturisation. IMP Weser reflects status quo. Hydrodynamic development towards near-natural conditions.	entire Weser estuary
		Contract-based Nature Conservation	Preserving existinbg values by implementing managementplans in coordination with local administration.	local in the haline part of the Weser
Water Management				
qualitative (Ecology)	**Roll back salt water intrusion**	**Flood Barrier**	Flood barrier in the mouth. Sluise provides navigability.	entire Weser estuary
		Management of barrage-systems	Management of barrage systems to provide sufficient runoff. If necessary in combination with Flood barrier	entire Weser estuary
	good ecological potential for: biol. quality- und hydro-morph./phys.-chem. components	**Implementation WFD**	Consistent implementation of WFD. Prevent further deterioration. Start adequate renaturisation. Hydrodynamic development towards near-natural conditions.	entire Weser estuary, Marshland both sides of the Weser
quantitative (Water Manage-ment)	**Drinking water and seperation cattle**	**Generalplan Wesermarsch**	Compensation of the impacts triggered by deepenings of the last 100 Years. Founding of Planungsverband develops integrated structure of drainage boards. Technical solution (channel) for watering with additional utilization of existing channels and ditches.	Marshland in the cunty of Butjadingen
	Drinking water and seperation cattle	**Infrastructure (technic)**	Supply of drinking water for cattle due to improved management of watering from the Weser using modern technics (heightening of channel dikes, strenghtening of infrastructure, gauges and steering automatically - see Avoidance Solution)	Marshland both sides of the Weser

Solution based on use depending adaptability
Solution based on legal framework

Table 4-27: List of promising responses to diminish the impacts of salt water intrusion at the Weser estuary.

During the participation process the identification and sorting of relevant Responses on salt water intrusion many deficits in the current state and under the influence of changing (land) use pattern or climate arose. Deficits are perceived if the formulated user demands referring the functions of the estuary could not be achieved in a way required by the users. These deficits were formulated either sectoral (Water Management, Agriculture) or in a more common way concerning all participants (Table 4-27).

Deficits	generell
Participation	Process of involvement of all parties should begin as early as possible. The goal must be to increase the reliability of statements and the implementation of coordinated decisions.
Hydrology	The availability of processed and usable data must be improved. The goal must be to improve the system knowledge by understanding more about causal relationships in the fields of hydrology and water management.
Communication	The communication between the parties has to be improved. For example, the exchange between water boards and authorities on the state of surveys and the data derived therefrom.

		Deficits	
Nutzungsform	**Affected Compartment**	**Legal Framework**	**Individual Adaptability**
Commerse and Industry **Harbour Infrastructure Pier**	**Weser**	Previously consideration of nature conservation guidelines to avoid legal dispute.	Challenge: increasing competition for land use pattern at banks (natur conservation).
Groundwater (Use)	**Groundwater**	Knowledge of climate and land use-related changes must be available for the management of ground-water. Small-scale, high-resolution moitoring increases effort to deliver representative data.	High costs for technical counteractive measures: Stainless steel tubes to avoid corrosion barrier layers.
Agriculture	**Ditches, Weser, Soil**	Implementation only after the deepening. Integrated concept of hydraulic engineering is missing, contact for users: Authorities: WSA, NLWKN.	Successor government delayed implementation of existing plans. Contact for users: policy, ministries.
Nature Conservation	**Ditches, Weser, Habitats / Landscape, Soil**	No intension to implement large-scale plannings (e.g. IMP). Technical measures are favored. Internal communication in and communication with the authorities has to be improved. Clear definition of nature conservation objectives is needed. Integrated concept of hydraulic engineering is missing.	Deepening of estuaries is still development goal.
Water Management	**Ditches, Weser, Soil**	Implementation only after the deepening. Integrated concept of hydraulic engineering is missing. Contact for users: Authorities: WSA, NLWKN.	Delayed implementation of existing plans. Contact for users: policy, ministries.
Tourism	**Ditches, Weser, Soil, Habitats / Landscape**	Development and implementation of common strategy concerning all land users at Weser is missing.	Sailers: Lower saxony provides no infrastructure (boats) for dredging the marinas.

Table 4-28: List of the deficits concerning salt water intrusion impacts at the Weser. WSA: Federal Water and Shipping Administration - Project Groups for Fairway Deepening, NLWKN: Lower Saxony Water management, Coastal Protection and Nature Conservation Agency

For further implementation it is helpful to know if the envisaged solutions are already referring to legal frameworks like guidelines, laws or other regulations or if they are based on individual adaptability (see Table 4-28).

4.3.3.2 Assessment of solutions

The most promising solutions have been assessed reflecting different criteria to get an overview of divergent opinions of different stakeholders. Main issue was to identify one solution that has the potential to integrate the demands and ideas of several user perspectives in a preferably consensual way. Additionally, it should already be under discussion and some basic works should have been completed. For the solution Master Plan Wesermarsch first feasibility studies have already been conducted and water boards, policy and governmental bodies are in close contact. Therefore, this solution was selected to become a business idea (KuR & BAW 2015).

4.3.4 References

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4.3.5 Annex

Activities EU	1) Problem identification						
DPSIR-Phase	Driving force	Pressure	State				
Kriterium		Saltwater-Intrusion	Compart-ment	Ecology - System description	System description - Parameter	Socio economic - Description user-demands	System description - parameter
Column No.	1	2	3	4	5	6	7
Parameter / Institution	Transport sector (Maritime Traffic)	Changes in morphology, Encroachment	SW	Hydrology	tidal curve, runoff, water-level, seasonal change	sufficient depth of waterways	Development of anabranches (siltation)
	Coastal defence	Changes of hydrology and morphology, encroachment, exploitation of clay	SW, GW	Hydrogeology, Morphology	Character of riverbed and sediment, changes in sedimentation, aquifer	Space for infrastructure, clay/sand exploitation, strength of the substrate	Costs/conflicts with tourism and nature conservation caused by clay exploitation
			SW, GW	Water quality	Equilibrium of fresh+/saltwater, salinity, dissolved substances		
			Soil (Vorland)	Soil characteristics	salt content, soil-substances, texture		
			Estuarien habitats aquatic, terrestr.	Habitats	Presence and composition of characteristic habitats, vegetation		
			Estuarien species aquatic, terrestr.	Biodiversity, characteristic species	Composition and abundance (fish, birds, invertebrats) neozoa,		
	Water management	Modification of hydrology and morphology, encroachment	SW, GW	Hydrology	water-level in ditches, drainage systems	sufficient drainage capability, minimum-water-level, water quantity and quality	Development of nature conservation values caused by changing water levels, development of pumping-costs
				Water quality	Equilibrium of fresh+/saltwater, salinity, dissolved contaminants		
			Soil (binnenland)	Soil characteristics	salt content, soil-substances, texture		
			Habitats of the binnenland aquatic, terrestr.	Habitats	Presence and composition of characteristic habitats, vegetation		
			Species of the binnenland aquatic, terrestr.	Biodiversity, characteristic species	Composition and abundance (fish, birds, invertebrats) neozoa,		
	GW-abstraction	Changes of geohydrology	GW	Equilibrium of fresh+/saltwater	Equilibrium of fresh+/saltwater	water quantity and quality	Rate of GW-abstraction (subsidence, depth to water table)
	Climate change	Sea level rise (see transport sector)	SW	Hydrology	tidal curve, runoff, water-level, seasonal change		Development of anabranches (siltation)
		changes in geohydrology (see GW-abstraction)	GW	Equilibrium of fresh+/saltwater	Change in equilibrium of fresh+/saltwater	water quantity and quality	Rate of GW-abstraction (subsidence, depth to water table)

Table 4-29: Complete DPSIR table of the Weser.

Activities EU	1) Problem identification		2) Impact identification			
DPSIR-Phase	Driving force	Pressure	Impacts			
Kriterium		Saltwater-Intrusion	Impacts on ecosystem	System description - parameter	Impacts on socio economy	System description - parameter
Column No.	1	2	8	9	10	11
Parameter / Institution	Transport sector (Maritime Traffic)	Changes in morphology, Encroachment	Changes of Hydrology	Changes of tidal curve, runoff, water-level, seasonal change, upstream encroachment of saltwater	Policy	Problems to reach QO of World heritage, WFD, Natura 2000, MAB
	Coastal defence	Changes of hydrology and morphology, encroachment, exploitation of clay	Changes of Morphology	Changes of riverbed and sediment, changes in sedimentation and aquifer, damage of riverine colmationlayer		
			Derogation of water quality	shifting of equilibrium of fresh+/saltwater, salinity, contamination with dissolved substances	Water-abstraction	Problems with abstraction of raw water
			Change of soil characteristics	Changes in soil salt content, soil-substances and soil texture, contamination with dissolved substances	Soil function	Damages to forelands, problems with usability (moving)
			Habitat loss	Loss characteristic habitats, vegetation	Nature conservation	Loss of habitats
			Changes in species distribution and abundance	Loss of characteristic species and communities (fish, birds, invertebrats), dispersal of neozoa	Recreation	Loss of characteristic values due to altered waterconditions, species and community presence
	Water management	Modification of hydrology and morphology, encroachment	Changes of hydrology	Strong fluctuations in water-level of ditches drainage systems, increased saltwater intrusion into drainage systems, increasing drying up in summer	Water Management	Problems with abstraction of freshwater
			Derogation of water quality	Increased salinity, contamination with dissolved substances, landward shifting of equilibrium of fresh+/saltwater	Water supply	Agriculture: problems with cattle watering, changes in quality of forage crops
			Change of soil characteristics	Increasing soilsalinity, contamination with dissolved substances, damage of soiltexture	Soil function	Agriculture: problems with usability (moving, grazing, arable farming)
			Habitat loss	Loss characteristic habitats, vegetation		
			Change of species distribution and abundance	Loss of characteristic species and communities (fish, birds, invertebrats), dispersal of neozoa		
	GW-abstraction	Changes of geohydrology	Equilibrium of fresh+/saltwater	landward shifting of equilibrium of fresh+/saltwater	Water supply	Costs/conflict caused by increasing GW-abstraction (subsidence, depth to water table)
	Climate change	Sea level rise (see transport sector)	Changes of hydrology	Changes of tidal curve, runoff, water-level, seasonal change, upstream encroachment of saltwater	Policy	Problems to reach QO of World heritage, WFD, Natura 2000, MAB
		changes in geohydrology (see GW-abstraction)	Equilibrium of fresh+/saltwater	landward shifting of equilibrium of fresh+/saltwater		Costs/conflict caused by incresing GW-abstraction (subsidence, depth to water table)

Table 4-29: Complete DPSIR table of the Weser (continued).

Activities EU	1) Problem identification		3) TWS	4) Identification of existing solutions	5) Documentation & evaluation of existing solutions	
DPSIR-Phase	Driving force	Pressure	Responses - Analyses		Responses - Assessment	
Kriterium		Saltwater-Intrusion	Legal framework - laws, guide-lines Regulations - (agency)	Use-dependent framework- individual adaptability	Legal framework - laws, guide-lines Regulations	Use-dependent framework- individual adaptability
Column No.	1	2	12	13	14	15
Parameter / Institution	Transport sector (Maritime Traffic)	Changes in morphology, Encroachment	WFD (NLWKN), planning approval of Weser deepening (WSA, ML)	Using alternative habor (harbor economy)		
	Coastal defence	Changes of hydrology and morphology, encroachment, exploitation of clay	Master Plan Coastal Protection Lower Saxony (NLWKN), WFD (NLWKN) WFD (NLWKN) WFD (NLWKN) WFD (NLWKN), Natura 2000, BNatSchg, World heritage, MAB (NLPV, NLWKN, county) WFD (NLWKN), Natura 2000, BNatSchg (NLPV, NLWKN, county)	Relocate water abstraction (water boards, dike boards, pressure groups agriculture) Loss of usability, change of use (pressure groups agriculture) Allocation and maintenance of compensation measures (pressure groups nature conservation) Measures to protect species and communities (pressure groups nature conservation)	Identification of most promising solutions	
	Water management	Modification of hydrology and morphology, encroachment	Master Plan Coastal Protection Lower Saxony (NLWKN), NWG (county) WRRL (NLWKN), Natura 2000, BNatSchg (NLPV, NLWKN, county) WRRL (NLWKN), Natura 2000, BNatSchg (NLPV, NLWKN, county)	Relocate water abstraction for watering (water boards, dike boards) Adaptation (water lines for freshwater, fences), changes in land use (pressure groups agriculture) Changes in land use (Power Groups agriculture) Allocation and maintenance of compensation measures (pressure groups nature conservation) Measures to protect species and communities (pressure groups nature conservation)		
	GW-abstraction	Changes of geohydrology	NWG (county)	Counteractive measures: Barrier layers, steel pilings (local). Improving the ma-nagement of groundwater use		
	Climate change	Sea level rise (see transport sector) changes in geohydrology (see GW-abstraction)	WFD (NLWKN), planning approval of Weser deepening (WSA, ML) NWG (county)	Using alternative habor (harbor economy) Counteractive measures: Barrier layers, steel pilings (local). Improving the ma-nagement of groundwater use		

SW: surface water
GW: ground water
NLWKN: Lower Saxony Water management, Coastal Protection
WSA: Federal Shipping Waterways and Shipping Administration WSA
ML: Ministry for Food, Agriculture and Consumer Protection
NLPV: Wadden Sea National Park Authority of Lower Saxony
MAB: Man and the Biosphere Programme
WFD: Water Framework Directive
BNatSchg: Federal Nature Conservation Act
NWG: Lower Saxony Water Act

Table 4-29: Complete DPSIR table of the Weser (continued).

5 Conclusions

The overall goal of the Joint Fact Finding Process in the EMOVE partnership was to identify the most urgent problems occurring in the estuaries of the partner countries. In the course of the project the Göta älv in Sweden, the Scheldt in the Netherlands and Belgium and the German Weser are investigated intensively.

To harmonize the process of identification of problems one collaborative investigation approach was selected. The chosen DPSIR method is a concept approach highlighting the relationship between human activities and environmental degradation. The stepwise analyses of Driving forces, Pressures, State, Impacts and Responses enables the organisation of information about the state of the environment including stresses causing impacts as well as the actions taken to avoid those system changes. DPSIR was used for structuring and operationalising the Joint Fact Finding Process in all investigated estuaries. It is flexible in processing information gained from experts, stakeholders or technical literature and able to illustrate and merge information on the different compartments, processes and structures relevant for the system.

The first phase of the Joint Fact Finding Process was the identification of existing problems in the estuaries. This step was executed by transdisciplinary groups of experts of the EMOVE Partners in each estuary. This leads to a complete list of Driving forces (processes that cause pressures on the system) and Pressures (direct stresses affecting the environment) occurring in every investigated estuary. After harmonising the national results a longlist with at least 120 Pressures spread over 13 Driving forces could be identified. The ranking of those Driving forces and Pressures by the national expert group gives a reasonable description of existing problems and their triggering processes and anthropogenic activities for each estuary.

Reflecting the outcomes of this problem identification there are similarities between the investigated German estuaries (Elbe, Ems, Weser) and the Scheldt, while amount and distribution of Driving forces and Pressures slightly differ at the Göta Älv. This might be attributed to the greater similarities of German estuaries and the Scheldt which give large importance of the alteration of the hydrological and morphological regime. The higher amount of high relevant indicated Pressures in the Göta älv represents also the own background of values and the handling of uncertainty, while assessing Driving forces and Pressures.

Beside this analytical DPSIR approach the long-time experienced interdisciplinary groups of experts almost have already a differentiated view on the problems occurring in the system. To specify this knowledge based and expert oriented approach the national expert groups have filled in a questionnaire in order to get a more concise idea of the most important problem occurring in the estuary. Finally, one issue of interest for every estuary has been identified and described as the Prioritised Pressure. Main goal was to gain better insight into the investigation areas, timelines, problem initiating processes, possible impacts and the people involved concerning this Prioritised Pressure.

This lead to the identification of at least one Prioritised Pressures for each estuary: Tidal intrusion at the Scheldt and salt water intrusion at the Weser. At the Göta älv the focus lies on the Pressures triggered by the Driving force climate change, especially increased flooding. Additionally the Prioritised Pressure disposal of masses for sea disposal of excavated masses from large infrastructure projects is investigated. The application of the DPSIR concept and the questionnaire are able to generate consistent outcomes. This could be justified by the different perspectives of the method. Both approaches enable an appropriate overview of the problems occurring in each of the estuaries.

Achieving this Prioritised Pressures in a second step of the Joint Fact Finding Process every partner conducted an analyses of the State, Impacts, and Results on the specific Prioritised Pressure of his estuary. The operationalisation of this process is done by explicit reflection of both the hydrological / ecological as well as the socio economic system compartments and processes of the estuary. Also the analyses of specific sources of information integrates both: the knowledge of experts and technical literature as well as the experience and demands of land users. The intense involvement of stakeholders from administration and user groups ensure the applied character of the process.

The DPSIR provides a structure to present all process relevant information in a clearly arranged way. For every Prioritised Pressure the affected compartments (e.g. water body, habitats, species), processes (e.g. hydrology, morphology) and their parameters (e.g. tidal curve, runoff) were depicted. If necessary these data is sorted for different Driving forces triggering the Prioritised Pressure. This leads to a consistent presentation in the description of data describing State, Impacts and Responses. The result is one complete DPSIR table providing all the relevant information for the identified Prioritised Pressure of the specific estuary. This is the basement to achieve results without neglect important compartments or processes influencing the overall result. Additionally it operationalises the comparison of different estuaries investigating different issues.

The analyses of the state delivers a comprehensive description of the identified compartments and processes which affecting Prioritised Pressure in the specific estuary. This encompasses different subareas of the estuary or even the accompanying marshes. Beside the description of the current situation also historic developments are mentioned. The description of the socioeconomic system is gained by an intensive stakeholder involvement. In every partner estuary different methods of participatory processes have been conducted. This leads to an extended knowledge of the demands of prevailing user perspectives and gives a good overview about the sectoral (e.g. transport sector, nature conservation) view on the problems occurring.

Despite several similarities in the different estuaries the character and the choice of the prioritised Pressure is individual. The increase of tidal range in the last 100 years for example is noticeable higher in the Weser comparing to the Scheldt. Nevertheless the Prioritised Pressure causing the biggest problems according to all people involved is the tidal intrusion. Even quite comparable are the impacts recognised at Weser and Scheldt concerning the changes of hydrology and morphology. To a smaller extend this is also true for the Göta älv. This is comprehensible due to the same Driving forces like transport sector and climate change triggering these changes in all estuaries. This must not automatically lead to the same deficit perception in all three estuaries. Deficits are perceived when addressed demands could not be implemented. The deficit analyses compiled by stakeholder involvement gives a good impression on the loss of usability for different user perspectives.

The responses identified in the Joint Fact Finding process refer to the legal frameworks on the one hand but also reflect the opportunities of individual adaptability. The stakeholder involvement is an indispensable tool to emerge the most promising solutions on the specific problems in each estuary. In a first step possible solutions for each user perspective where gathered and discussed. Doing the next step towards an adaptive management is to bring the different user perspectives together working on an integrated and consensus oriented solution. This next step towards an active shareholder involvement gaining benefits by joining the process is going to be operationalised by formulating a business idea which has the potential to evolve integrated sustainable solutions in a regional context.

This business ideas could be seen as step stones giving practical advices for an adaptive and sustainable management of estuaries leading to a governance vision to maintain accessible and sustainable estuaries.

6 Summary

To achieve the main objectives on a Joint Fact Finding the different methods, sources of information and prioritised problems in the different estuaries and partner countries have to be merged in one approach.

In the frame work of the EMOVE project this was conducted by a five step approach:

1. **Problem Identification:** Identification of the most important problems of each estuary.
2. **Identification of Impacts:** Which impacts on physical-ecological and socio economic system are triggered by these problems?
3. **Transnational Workshop:** Discussion and comparison of different occurring problems and impacts in each estuary by the EMOVE experts.
4. **Identification of suitable solutions:** Stakeholders and experts identify and discuss existing solutions.
5. **Documentation and evaluation of identified solutions:** Stakeholders and experts work on the identification of the most promising solutions.

To integrate these different steps the DPSIR approach was used in all estuaries. This offers the opportunity to analyse all areas with one approach to achieve comparable outputs. DPSIR is able to indicate the Work Package 3 objectives of a Joint Fact Finding because it is identifying problems, impacts and responses. This approach was conducted in two steps. First a Problem Identification was carried out for all estuaries. This lead to an identification and analyses of the existing Driving Forces and Pressures (EMOVE Project 2014).

In this report (Work Package 3 – European Joint Fact Finding. Part 2) every partner has documented the state of the system and the impacts triggered by one most important problem. This description encompasses the physical and ecological as well as the socio economic view on the estuary. The output derived by using technical literature, expert knowledge and the experience of stakeholders. This leads to sophisticated information on the compartments affected and to a detailed collection of the demands of the involved stakeholders. This information was analysed and supplemented by the identification of exiting solutions and deficits occurring in the estuaries. The intense involvement of stakeholders was used to identify the most promising solutions.

Stakeholders have an important role to achieve appropriate solutions which could be implemented in the near future. This report reflects the first outcomes of this stakeholder driven and consensus oriented approach. After the completion of WP3 in each partner estuary one case study was chosen as business idea to be further worked out in Work Package 4 of the EMOVE project. This business ideas should stakeholders enable to become shareholders.

The joint development and implementation of these business ideas could provide experience for implementing an adaptive estuarine management which offers benefits for all participants.