River Engineering Measures for Economy, Environment and Society

Kirsten Wolfstein[1], Boris Hochfeld[1] & Henrich Röper [1]

KEYWORDS

Elbe estuary, river engineering measure, economy and environment, working with nature

ABSTRACT

The port of Hamburg, located at the Elbe estuary in Northern Germany, is challenged by a high maintenance dredging effort due to sediments which are transported by a powerful flood current from the North Sea into the upper estuary and port area. This leads to high costs for the port, but also to unfavorable environmental conditions for protected nature areas in the estuary. Therefore, the development of a profound sediment management strategy is essential to address these challenges. The main parts of the sediment management strategy, set-up by Hamburg Port Authority (HPA), consisting of several pillars, will be described. One of these pillars in order to amend the transport of sediments is the implementation of river engineering measures such as the realignment measure "Kreetsand/Spadenlander Busch" in Hamburg. Also, essential for a successful strategy is an appropriate communication strategy in order to create understanding and acceptance and support for plans and activities that might affect stakeholder and residents. This paper (1) introduces the main pillars of HPA´s sediment management strategy, (2) describes the construction and actual status of the pilot project "Kreetsand/Spadenlander Busch", a realignment measure, as an example for "Working with Nature" and (3) informs on the communication process within the estuary partnership "Forum Tideelbe" aiming at assessing and ranking further river engineering measures.

1. INTRODUCTION

The port of Hamburg is the third largest European (in TEU) and the largest German sea port. It functions as an important hub for import and export of German goods. Its location far in the Elbe estuary in Northern Germany, approximately 120 km away from the North Sea, provides excellent connections to the German hinterland. Also, more than 30% of the goods stay in the region. However, this location comes with a high maintenance effort due to high amounts of marine sediments which are transported upstream from the North Sea into the upper estuary and port area by a powerful flood current – and which the weaker ebb current is only partially able to transport back downstream, back to the sea (Figure 1). This phenomenon is called ´tidal pumping´ and is common in many estuaries with strong tidal influence. At the Elbe, it is intensified by the fact that the morphology of the estuary has significantly changed over the past centuries – due to natural effects and man-made modifications such as land reclamation, deepening of the fairway and cut-off of tributaries for flood protection.

The port does not only receive marine sediments, but also fine sediments, suspended matter respectively, from the river basin upstream. Natural erosion leads to a suspended matter input of roughly 600.000 tons per year. Transportation and mixing processes (with the marine sediments) depend strongly on the headwater discharge. In case of high discharge volumes, larger amounts of sediments are moved towards the sea, whereas during times of low discharge intensified sedimentation processes take place in the upper estuary and the port area.

1 Hamburg Port Authority, Neuer Wandrahm 4, 20457 Hamburg, Germany.
kirsten.wolfstein@hpa.hamburg.de

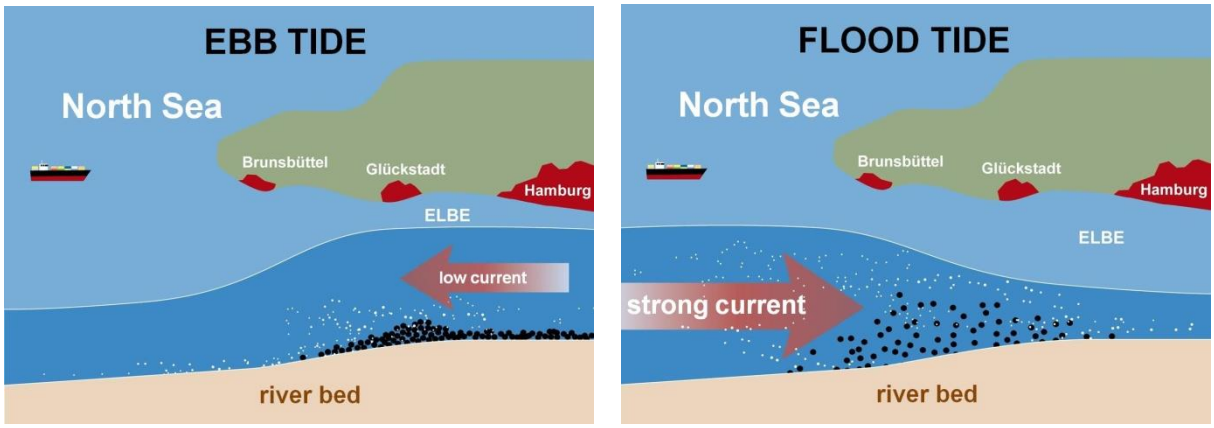

Figure 1. The tidal-pumping effect; low current during ebb tide (left); strong current during flood tide (right)

The ´tidal pumping´ effect resulted in increased sedimentation rates, especially during the last four years with very low headwater discharges, that eventually lead to unfavorable consequences for economy and ecology, i.e. high maintenance costs for the port and declining environmental conditions for protected natural habitats, especially the shallow water areas, in the estuary.

One of the main tasks for the Hamburg Port Authority (HPA) is to ensure accessibility by providing sufficient water depths for easy and secure navigation in the shipping channel within the area of the City of Hamburg and harbor basins. This results in continuous and increased dredging and disposal necessities. Since the estuary not only functions as the seaward access to the port, but at the same time is a valuable nature area that is protected by national and European legislation (EU 1992, EU 2000), HPA operates in the middle of a complex area of conflicting interests such as (1) economic and infrastructural demands of the clients of the port, (2) ecological requirements of protected species and habitats, and (3) societal interests of various stakeholders along the estuary. Therefore, HPA developed an integrative sediment management strategy which aims at addressing the described challenges, and which finally should lead to a decrease in the amount of sediments that have to be dredged.

Among other measures, sediment transport can be influenced by river engineering measures (Wurms 2017), which give more space to the river and increase the roughness of the riverbed dissipating tidal energy and reducing tidal currents. At the same time, these measures can provide benefits for nature and society. Therefore, some years ago, HPA started with the planning and construction of the pilot project “Kreetsand/Spadenlander Busch”, as a realignment measure. As this measure is meant to be only the beginning of more river engineering measures in the future, an estuary partnership has been founded with representatives of all relevant stakeholders along the Elbe estuary in order to choose, examine and propose further measures to the responsible authorities.

2. OBJECTIVE

This paper introduces the main pillars of HPA´s sediment management strategy, describes the construction and actual status of the pilot project “Kreetsand/Spadenlander Busch” (as a part of one of the three pillars) and informs on the communication process within the estuary partnership “Forum Tideelbe”.

Already in 2008 HPA and the national Waterways and Shipping Administration (WSV) who both are responsible of the maintenance of the tidal river Elbe set up a sediment management and river engineering concept (HPA & WSV 2008) to address the challenge of high amounts of sediments that had to be dredged and disposed. Recently HPA advanced that strategy for her area of responsibility. The current strategy consists of the three pillars “Remediation”, “Maintenance” and “River Engineering”, but it also includes close cooperation with relevant stakeholders and seeking for (scientific and technical) innovation (Figure 2).

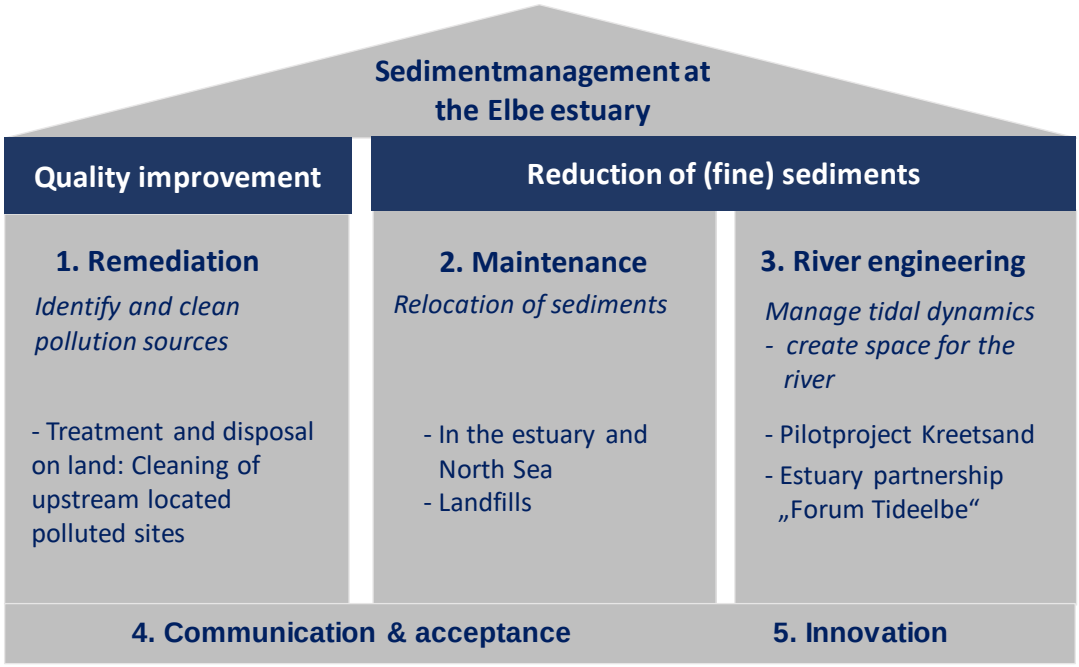

Figure 2: Sediment management strategy of HPA

The pillar “Remediation” is related to the fact that after the reunification of the two German states in 1989 water quality has greatly improved. But sediments are still contaminated with heavy metals and organic pollutants that originate from mining operations, industry and wastewater discharge and contaminated areas in the middle and upper river Elbe and its tributaries of the international catchment area (Figure 3). Depending on the amount of headwater discharge, these pollutants, bound to suspended matter, are transported to the estuary where they settle in areas of low turbulence such as the harbor basins or the shallow side areas – or eventually end up in the North Sea.

Figure 3: Map of the river Elbe and its catchment (adapted from Google maps)

The sediments that settle in the port area and shipping channel have to be dredged and treated, i.e. either relocated in the water or treated on land, depending on their degree of pollution. Due to the international regulations of the London Convention, the Oslo-Paris Convention (OSPAR, https://www.ospar.org/) and the Helsinki Convention (HELCOM, www.helcom.fi/) that were transposed into a German directive for dredged material management in estuarine and coastal areas under federal administration, sediments having a certain degree of pollution are not to be relocated in the Elbe estuary or the North Sea. But alternative treatment and placement on land leads to high costs for HPA and is not suitable for vast quantities. Therefore, the City of Hamburg and HPA took responsibility and provided 11 Million € for the project ELSA (Elbe Sediment Pollution Clean Up) which aims at the identification and remediation of polluted sediments at the sources in the upper catchment area in order to achieve, that fever contaminants reach the estuary and the port area.

The pillar „Maintenance“ aims at an adaptive and flexible dredging and disposal of the sediments. Clean sediments should be relocated to different locations within the estuary or the adjacent North Sea, depending on the hydrological situation and their characteristics. Only significantly polluted sediments are to be removed and disposed of on land, using HPA's special treatment plant METHA (METHA is the acronym of **ME**chanical **T**reatment of **HA**rbor sediments).

With the pillar "River Engineering Measures" the unfavorable hydromorphological conditions are addressed that sustain the intensive tidal energy and upstream sediment transport, leading to high maintenance costs but also to unfavorable conditions for nature. In this context, measures such as the pilot project "Kreetsand/Spadenlander Busch" are planned and conducted to contribute to the reduction of tidal energy and the related heavy sedimentation and the improvement of environmental conditions for protected species and habitats. Since the Elbe estuary is an area of high economic and ecological importance, many different uses and interests have to be distinguished. Hence a close cooperation with relevant stakeholder groups is mandatory to create acceptance and avoid delays when sediment management and river engineering measures are planned and implemented. This considered, the City of Hamburg and HPA founded the estuary partnership "Forum Tideelbe" in 2016 to account for all the stakeholder's interests when suitable locations for further measures will be investigated.

Innovative technical ideas for maintenance and sediment treatment as well as the increase of scientific knowledge to understand the estuarine system and processes are also crucial. Therefore, HPA cooperates with national and international scientists and institutions and participates in (inter)national bodies and organizations.

Finally, an appropriate communication strategy to create understanding and acceptance for HPA's activities that can affect stakeholder and residents, nowadays is essential.

3. PILOT PROJECT "KREETSAND/SPADENLANDER BUSCH"

Set-up

For a couple of years, it is very well documented, especially in the US, Netherlands, Belgium, UK and other countries (Scott et al. 2011, www.tide-projcect.eu, Saathoff et al. 2013, PIANC 2018) that river engineering measures such as realignment measures are suitable to affect respectively improve hydromorphological conditions of water bodies and hence the sensitive ecological conditions of estuaries. Often, they also provide benefits for society, the so-called "Ecosystem Services" (flood protection, storage of pollutants, nutrients and CO_2, erosion and sedimentation regulation, recreation opportunities, etc., see also MA 2005). When conducting river engineering measures, concepts such as "Working with Nature" (PIANC 2018) became increasingly popular. The objectives of "Working with Nature" are consistent with those of the "Building with Nature" initiative of the EcoShape Foundation, and the "Engineering with Nature" initiative of the US Army Corps of Engineers (PIANC 2018).

River engineering measures have already been part of earlier plans. First in the sediment management concept (HPA & WSV 2008), the main focus was on reducing the tidal energy and unfavorable sedimentation. But it was recognized, that such measures could also have positive outcomes for nature and society, a so-called ´win-win´ situation. Hence the Natura 2000 integrated management plan for the Elbe estuary, issued 2012, also acknowledged river engineering measures as essential. In 2008 HPA started the planning for the pilot project "Kreetsand/Spadenlander Busch", and in 2012 the construction

works began (see also PIANC 2018). The site, located in the state area of Hamburg, between the northern and southern branch of the Elbe estuary (Figure 4), was already transformed by a dike realignment carried out in 1999. However, the excavation of the high lying new foreland, a former dredged material disposal site, was not executed at that time, so that it lacked the influenced of daily tidal inundation.

Figure 4. Location of the site (©adapted from Brockmann Consult & Waddensea Secretariat)

The measure had three objectives:

- It should contribute to reducing the tidal energy by creating approximately 1.1 mill. m^3 of additional tidal volume.
- Valuable natural habitats like shallow water areas, mudflats, reed and floodplain forests should be created.
- Parts of the area should function as recreational area for residents where they will get the opportunity to experience a tidally influenced landscape.

Approximately 47 hectares of the former flushing field were chosen to become reconnected to the estuary and influenced by the tides again (Figure 5a & b). From this area, 17 hectares were maintained as land and 30 hectares were transformed into a shallow water zone. During the planning and construction HPA already worked according the PIANC guidelines of “Working with Nature” (2018) that have been set up only recently. The approach combines social, environmental, and economic considerations into decision making, providing an integrated approach to project development and management to achieve win-win solutions for (navigational infrastructure) projects through careful consideration of natural processes, ecosystem impacts, stakeholder participation and strategies to maximize opportunities for navigation and nature. Detailed information of the planning and the subsequent construction of the measure, which received the PIANC-Award „Working with Nature“ in 2014, can be found on www.pianc.org and PIANC (2018).

Figure 5a and b. The area of "Kreetsand/Spadenlander Busch" before the start of the works (©HPA) and in during the works in 2017 (© Holger Weitzel)

When works will be finished in 2020, natural processes are allowed to form the embankments inside the area by erosion and sedimentation and thus create naturally changing habitats.

However, due to the project's location in an area subject to heavy sedimentation, routine maintenance work may be necessary, prospectively every 5 years, to remove excess sediment deposits from the site. The development of the pilot project will be monitored annually for first six years, followed by an evaluation every five year. Monitoring will include topography and bathymetry measurements, habitats assessment, and the development of protected species. To better understand the impacts of the pilot project on tide surges and sedimentation the results must be analyzed in relation to monitoring results of the whole estuary.

Ecosystem Services

Meanwhile, it is widely accepted that the provision of many natural resources, which are supplied by natural ecosystems, lead to benefits for societal economy, health and survival, although often indirectly (MA, Millennium Ecosystem Assessment 2005). The capacity of ecosystems to regulate essential ecological processes through their structure, functions and biogeochemical cycles generates many Ecosystem Services (ES) (Rönnbäck et al. 2007).

Also, PIANC established in 2016 a working group that should apply Ecosystem Services Approach for Waterborne Transport Infrastructure Projects (see WG195, An Introduction to Applying Ecosystem Services for Waterborne Transport Infrastructure Projects, http://www.pianc.org/envicomactivewg.php).

In the frame of the European Interreg IVb project TIDE (Tidal River Development, http://www.tide-toolbox.eu/), the Ecosystem Services Approach was used among others by the project partners to evaluate the success of management measures within the four European estuaries Elbe, Humber,

Scheldt and Weser. This assessment offered a first screening of the potential impact on ES delivery due to the management measure. It was based on the importance of the different habitat types for the delivery of estuarine ES. Its result depended on the habitat changes caused by the measure (Figure 6). Hence, a measure will generate a positive effect on ES delivery when a habitat type with a higher importance (score) is created, as in the case of "Kreetsand/Spadenlander Busch", when adjacent land not contributing to the delivery of estuarine ES has been transformed into different estuarine habitat types, such as shallow water or marsh area which both contribute to the delivery of many different ES (see below).

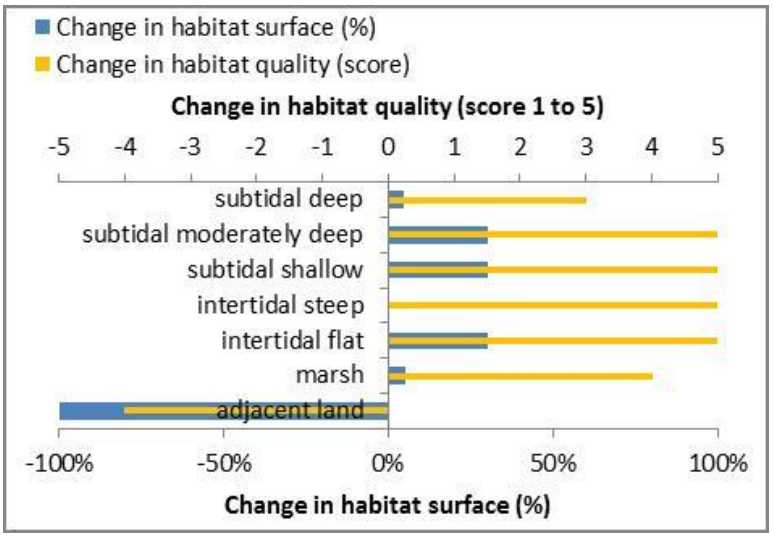

Figure 6: Ecosystem services analysis for "Kreetsand/Spadenlander Busch": Indication of habitat surface and quality change, i.e. situation before versus after measure implementation (from http://www.tide-toolbox.eu/pdf/measures/Measure_Spadenlander_Busch.pdf)

The first development target of the pilot project was the ES "Water quantity regulation: dissipation of tidal and river energy" but the ES assessment revealed that this measure generated overall a positive expected impact for many ES, mainly for:

- Biodiversity,
- Cultural services: Inspiration for culture, art and design; and Information for cognitive development,
- Regulating service: Erosion and sedimentation regulation (by water bodies).

The expected impact for the first development target "Water quantity regulation: dissipation of tidal and river energy" was only slightly positive, but the assessment revealed that the pilot measure had an even larger impact on beneficiaries for nature and society.

4. COMMUNICATION

During the last couple of years, the importance of stakeholder participation as a key to successful project design and implementation became evident, as several projects suffered a delay due to lacking acceptance and even protests from affected stakeholders and residents, for example in Stuttgart, Germany (https://en.wikipedia.org/wiki/Stuttgart_21).

However, the importance of stakeholder participation is meanwhile not only widely acknowledged but also required by environmental legislation (e.g. US National Environmental Policy Act 1970, EU 1992, EU 2000) and an important part of the "Working with Nature" approach (PIANC 2018). The development and application of a communication concept or consultation process, respectively, proved to be successful for HPA, first for the implementation of the pilot "Kreetsand/Spadenlander Busch" and secondly for the implementation of the sediment management strategy.

“Kreetsand/Spadenlander Busch”

In the “Kreetsand/Spadenlander Busch” pilot project, residents and stakeholders, including environmental organizations and local administration, were involved in the planning process right from the beginning in 2008 to inform them on HPA’s plans and to obtain public input and feedback. HPA established a public information exchange and participation process for residents from the onset of the project, to introduce the project and to better understand the requirements and concerns of residents. A first information meeting took place before the planning phase commenced. The project team used public meetings to inform the local community of the project’s progress and to get feedback at various intermediate phases of the work. At the end of the planning process, an overview about the planning steps, the assessment of alternative designs, and computations were provided. In the planning and approval phase, HPA worked with NGOs and regional authorities to identify and to address potential problems that could hinder project implementation. Multiple meetings with NGOs contributed to ease the approval process later, by helping NGOs remain informed of the project and by addressing their concerns. During the construction process the complexity of the tidal dynamics and estuarine functioning as well as the construction of the area itself are explained by informative posters in a publicly accessible information shed located at the site on the dike. Finally, it was planned that a “tidal park” should introduce the tidal influenced landscape and basic tidal phenomena to a wide-ranging public will be developed. The construction of the project will be completed by 2020.

Sediment management strategy

Due to Germanys constitution, federal states – including federal city states like the cities of Berlin, Bremen and Hamburg - have a certain sovereignty for their territory. For the management of the Elbe estuary this results in manifold responsibilities (Figure 7). The national Ministry of Transport and Digital Infrastructure is the owner of the federal waterways like the Elbe. In general, the management of the waterways is under the responsibility of the ministry´s authority “Waterways and Shipping Administration” (WSV) - with one exception: the management of the fairway within the city limits of Hamburg was delegated decades ago to the City of Hamburg and is now carried out by HPA. The federal states of Schleswig Holstein (northern shore) and Niedersachsen (southern shore) are responsible for the shores of the estuary, but also for the implementation of the European environmental legislation (EU 1992, EU 2000) within the waterbody of the Elbe estuary and the North Sea coastal water zone.

Figure 7. Location of the site (©adapted from Brockmann Consult & Waddensea Secretariat)

That is why HPA needs approval by the environmental ministry of the responsible state for the disposal of sediments in their areas. Additionally, various stakeholder groups use their influence on the administrative bodies. Therefore, HPA and WSV set up a communication process in 2014 with all the

relevant stakeholders (industry, farmers, tourism, municipalities, water boards, fishermen, NGO´s, administrations of the three federal states, see figure 8) to discuss the situation and improve the sediment management of the tidal Elbe. This was crucial for the Port of Hamburg, since HPA desperately was in need of an effective disposal site outside the city state boundaries. River engineering and remediation measures with a positive effect on sedimentation quantities for the mid- and long-term perspective were also an important part of the dialogue. The character of this forum was that of a consultation body as binding decision can only be made by the responsible authorities. First in the process, a common understanding on the estuary's functioning was established and technical statements were given. Then potential locations for sediment placement and river engineering measures were discussed and finally, unanimous recommendations were given and documented in a report.

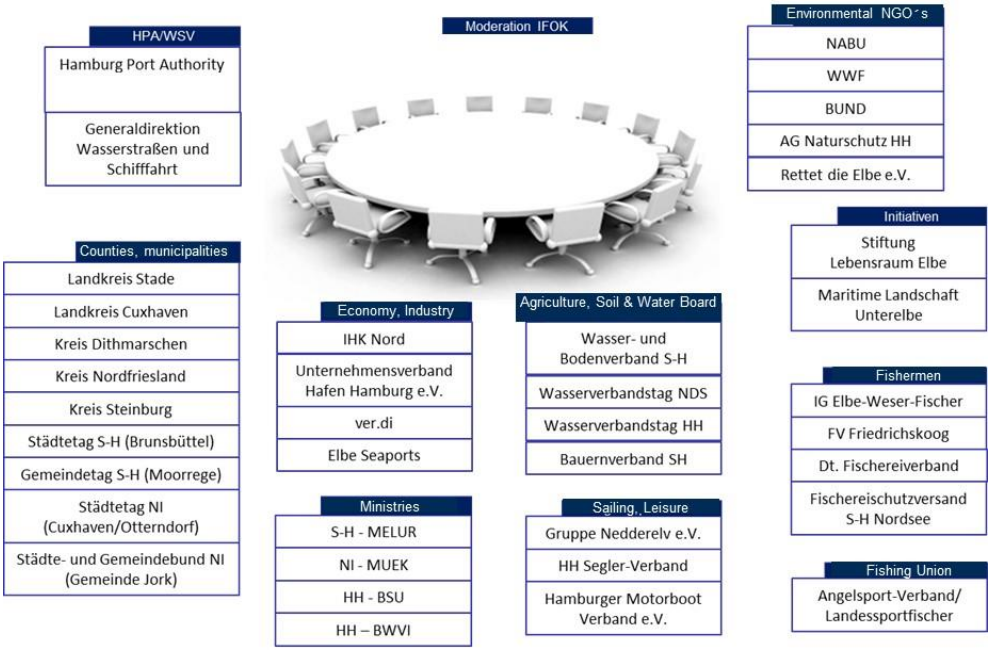

Figure 8. Members of the "Forum river engineering and sediment management tidal Elbe".

5. LESSONS LEARNED

The project "Kreetsand/Spadenlander Busch" is developing very successfully to meet the objectives of creating new aquatic and emergent habitat, and to offer opportunities for the public to interact with this important environment.

The effect of the pilot on the objective of decreasing tidal energy, however, is only marginal due to its size and its location within the estuary. To meet this target there were better locations within the estuary and more space was necessary to achieve a larger effect (Saathoff et al. 2013). However, due to the German system of federal states, this pilot project could at that time only be implemented within area of the City of Hamburg. Also, in a timely manner, there was no other suitable location available within the highly populated city area.

Nevertheless, the measure will lead to better understanding of the relationship between the estuarine system and the effects of management measures, i.e. how to improve the selection and design of a site and hence the success of the measure.

The planned monitoring and evaluation will finally assess the effectiveness of the works against the objectives of reducing the sediment transport, modifying the tidal range, and in the targets of the European Habitats Directive (EU 1992).

"Kreetsand/Spadenlander Busch" was just the beginning, more and larger river engineering measures must be planned and built. In 2015, at the end of the work intensive process of the ´Forum river

engineering and sediment management tidal Elbe´ it became clear that more time was needed to investigate river engineering measures. Most certainly, finding suitable locations for these measures will be complicated by the individual interests of different federal states and various stakeholder groups.

6. FUTURE STEPS

As it became clear, that the effect of the pilot project “Kreetsand/Spadenlander Busch” on the objective „dissipation of tidal and river energy” was only marginal, common agreement rose, that further and larger measures had to be conducted to achieve significant effects. Consequently, the stakeholders involved in the “Forum river engineering and sediment management tidal Elbe” demanded to continue this process.

Therefore, an estuary partnership, the so-called “Forum Tideelbe” was founded in 2016 (http://www.forum-tideelbe.de). It should again function as

- a platform for stakeholder information and exchange of interests,
- a consultation board for the responsible administrations, and
- a trust building institution for the region of the estuary.

However, the prime task of its members is to assess and rank further river engineering measures that can lead to further stabilization of the sediment transport, dissipation of tidal energy and the establishment of valuable nature areas.

Potentially, 23 measures are eligible to contribute to these objectives. Among these, the reconnection of anabranches to the main estuary channel or the realignments of dikes are considered as most effective. All measures are located along the estuary within the area of the federal states of Schleswig-Holstein and Niedersachsen and the City of Hamburg (Figure 9).

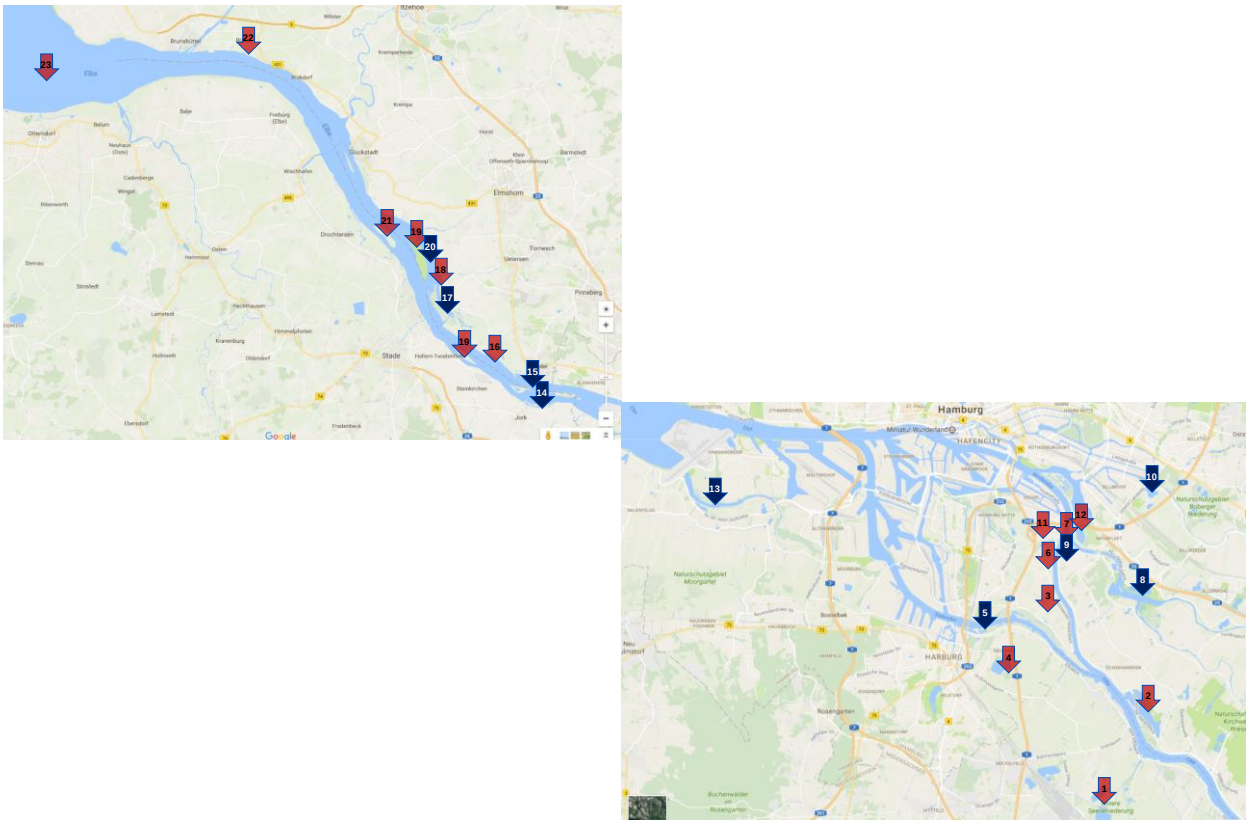

Figure 9. Locations for potential river engineering measures along the Elbe estuary (left side = mouth of the estuary, right side = upper estuary, City of Hamburg, © google maps).

The “Forum Tideelbe” started with establishing a working group to develop a pre-ranking of measures on basis of expert knowledge. This has been completed by the end of 2017. Main criteria have been the contribution of the measures to (1) reducing tidal energy and the related upstream sediment transport, (2) creating ecological valuable habitats, and (3) their feasibility (interference with flood protection, availability of property, legal concerns, etc.). Six measures have been pre-selected. They now will be considered in detail by technical feasibility studies. Also, ecological investigations will be conducted in 2018 and 2019. At the end of the process in 2020, the “Forum Tideelbe” will hand over its findings and its recommendation on the implementation of further river engineering measures to the political-administrative level. The product will consist of a well-documented report on the procedure of the ranking process, the results of the feasibility studies as well as agreements and dissents of the group concerning the proposed measures. Based on these recommendations the responsible administrative bodies will take their decisions.

As of this writing, this kind of process, i.e. involving various societal groups in estuarine management, is rather unique in Germany.

7. REFERENCES

European Commission (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

European Commission (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy (Water Framework Directive). http://ec.europa.eu/environment/water/water-framework/index_en.html

HPA & WSV (Hamburg Port Authority &, Wasser- und Schifffahrtsverwaltung des Bundes) (2008). River Engineering and Sediment Management Concept for the Tidal Elbe. German version “Strombau- und Sedimentmanagementkonzept für die Tideelbe“. https://www.hamburg-port-authority.de/de/hpa-360/

http://www.tide-toolbox.eu/. Accessed on 5 January 2018

http://www.pianc.org. Accessed on 5 January 2018

https://en.wikipedia.org/wiki/Stuttgart_21. Accessed on 5 January 2018

https://www.helcom.fi

https://www.ospar.org/

http://www.dialogforum-tideelbe.de

http://www.forum-tideelbe.de

MA (2005). Millennium Ecosystem Assessment – Ecosystems and Human Well-being. Synthèses. http://www.millenniumassessment.org/documents/document.356.aspx.pdf.

PIANC (2018). Report No. 176-2018. Guide for Applying Working with Nature to Navigation Infrastructure Projects.

Rönnbäck, P., Kautsky, N., Pih,l L., Troell, M., Söderqvist, T. & Wennhage, H. (2007). Ecosystem Goods and Services from Swedish Coastal Habitats: Identification, Valuation, and Implications of Ecosystem Shifts. Ambio 36 (7): 534-544.

Saathoff, S., Knüppel, J., Manson, S. & Boerema, A. (2013). Management measures analysis and comparison. Investigation of measures planned and implemented at the estuaries of Weser, Elbe, Humber and Scheldt. Study report in the framework of the Interreg IVB project TIDE. http://www.tide-toolbox.eu/pdf/reports/Managment_measure_analysis_comparison.pdf

Scott, C., Armstrong, S., Townsend, I., Dixon, M. & Everard, M. (2011). Lessons learned from 20 years of Managed. Realignment and Regulated Tidal Exchange in the UK. ICE Conference Paper.

US National Environmental Policy Act (1970): https://ceq.doe.gov/laws-regulations/laws.html

Wurms, S. (2017). River Rhine between Mainz and Bingen – Morphodynamic analysis of a navigational bottleneck. In: Wieprecht et al. (eds): Proceedings of the 13th International Symposium of River Sedimentation. Taylor & Francis, London. ISBN 978-1-138-02945-3.