Tidal River Development

Pilot project „Evaluation of the sediment trap near Wedel“

by Hamburg Port Authority

Hamburg Port Authority

Project part-financed by the European Union (European Regional Development Fund)

The Interreg IVB North Sea Region Programme

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This English report summarises the results of a comprehensive study (in German), which was carried out by the Federal Institute of Hydrology (BfG).

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A. Introduction

The construction of a sediment trap in the Elbe estuary near Hamburg is a major cornerstone of the “River Engineering and Sediment Management Concept for the Tidal River Elbe” (RESMC, see http://tideelbe.de/files/sb_sm_konzept_hpa_wsv_elbe_en.pdf). The sediment trap aims at the improvement of sediment management by facilitating a concentration of dredging activities and, functioning as a large scale experiment, at the same time it is the basis for knowledge acquisition in the field of sediment transport. Therefore the evaluation of the sediment trap near Wedel has been chosen as a TIDE pilot project. The evaluation was done on the basis of the outcomes of a large monitoring program that was developed to fulfil the reporting demands towards the administrative bodies concerning the environmental impacts of the trap. Additionally the monitoring data should promote the general understanding of the system, therefore parameters like turbidity, sediment content and SPM were measured and analysed as well.
The analyses of the monitoring data, as well as the compilation of the outcomes, were contracted to the BfG [Federal Institute of Hydrology]. The final report on the outcomes of the sediment trap monitoring and the subsequent evaluation of the functioning was published in September 2012 (in German language).
Due to the fact that the TIDE pilot project focuses on the evaluation of the project with regard to the examination on further implementation possibilities, only the relevant parts of the report were translated into English language.

Content of the full report (full report in German language only)
(Chapters that were translated in English are marked in yellow)

B Evaluation of the sediment trap

1 Background

The Elbe estuary is designated as a federal waterway which, apart from smaller ports such as Cuxhaven, Brunsbüttel, Glückstadt or Stade, connects the port of Hamburg to the North Sea *(see Figure 1-1).*

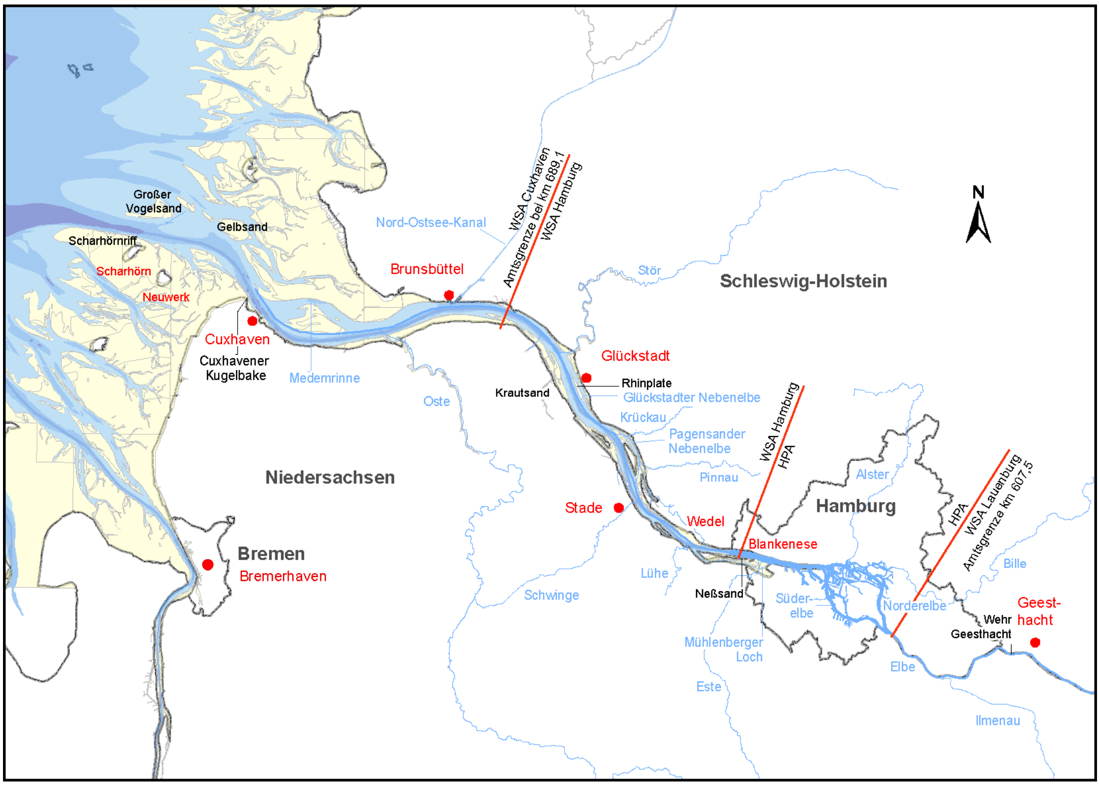

Figure 1-1: Overview map of the tidal Elbe (BfG, 2008d)

Due to the last fairway deepening in 1999, today ships with a maximum draught of 14.80m (incoming vessels) and 13.50m (outgoing vessels) or - independent of the tide - vessels with a maximum draught of 12.50m can be accommodated. In order to ensure the water depths as planned continuous maintenance dredging always needs to be performed both in the main channel of the tidal Elbe and in the port of Hamburg. The material dredged is mostly relocated within the system, i.e. it is relocated to another area in the course of the tidal Elbe.

Since 2000 dredged material volumes in the HPA-managed section of the river (the federal waterway section Hamburg is in charge of maintaining, including the port of Hamburg, see Figure 1-2) have risen considerably compared to the past and main dredging areas have shifted further upstream (section near Wedel) within the river section the Wasser- und Schifffahrtsverwaltung des Bundes (WSV) [Federal Waterways and Shipping Administration] is responsible for.

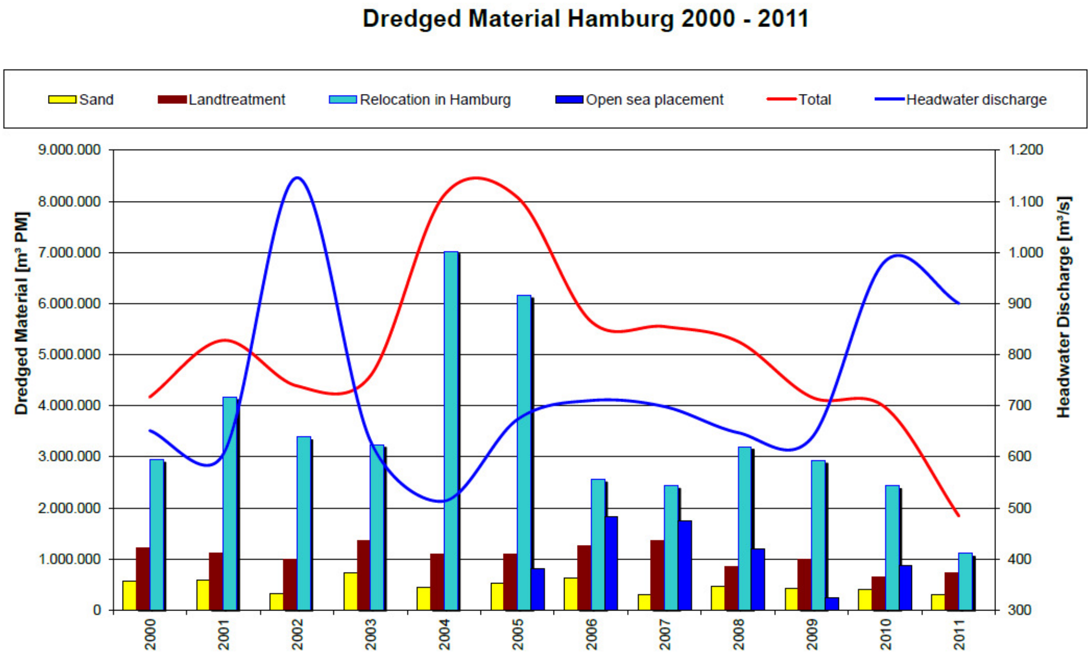

Figure 1-2: Dredged material volume development in the river section Hamburg is in charge of maintaining (source: HPA)

The rise in dredged material volumes and the shifting of main dredging areas to the upper reaches of the tidal Elbe not only presents an economic challenge but it should also be examined more closely from an ecological and nature conservation point of view as well as against the background of the implementation of European and national water protection, marine and nature conservation directives. Each maintenance dredging that entails the relocation of sediments to another spot within the water must be assessed taking into account the development of the oxygen regime and existing contamination levels of the fine-grained fraction, including the resulting environmental entry of such matter, though there has been a substantial decline in contamination levels since the German reunification.

The knowledge about solid matter dynamics in the tidal Elbe and the dredging section near Wedel at the time of the planning phase in 2007/2008 has been summarised in the system study of the BfG [Federal Institute of Hydrology] (BfG, 2008). The data obtained within the scope of the Wedel sediment trap monitoring and evaluation programme substantially advanced and fine-tuned such knowledge. The current understanding is outlined in detail in the partial reports.

At the beginning of 2012, the WSV and the HPA requested the BfG to prepare an “extended system study” based on the results described in BfG (2008). This study (as per the confirmation letter dated 10 February 2012 by the WSA Hamburg [Hamburg Waterways and Shipping Authority]) focuses on the management of the fine-grained fraction of the sediments dredged during maintenance operations. The study will present data from the entire tidal-influenced Elbe all the way to the North Sea. The results of this study will form the basis for recommendations to implement an adaptive, flexible and environmentally friendly sediment management. Sediment traps as a measure to further optimise sediment management strategies will be explicitly included in the analyses. The change in boundary conditions due to the implementation of the planned fairway deepening of the lower and outer Elbe to accommodate container ships with a draught of 14.5m will also be considered. The analyses, scheduled for the second half of 2012, will base on the results of this report series. This report series looks at the sediment trap near

Wedel as a locally effective individual measure, which also has an impact on the port of Hamburg, and evaluates it accordingly. Within the scope of the preparation of the “extended system study” the effectiveness of the Wedel sediment trap as well as other sediment traps installed at other potential sites - e.g. in the Juelssand Elbe section - is looked at on a large scale within the context of a tidal-wide sediment and dredged material management concept.

1.1 Planning of and agreement on the sediment trap

As a response to the increase in dredged material volumes in the port of Hamburg and the shifting of the main dredging areas to the upper reaches of the tidal Elbe since 2000 the HPA and the Wasser- und Schifffahrtsverwaltung des Bundes (WSV) developed a joint Tidal Elbe River Engineering and Sediment Management Concept (HPA & WSV, 2008). This concept is fully supported by the Free and Hanseatic City of Hamburg as well as the federal states of Lower Saxony and Schleswig-Holstein (Free and Hanseatic City of Hamburg et al., 2008). It provides for a “wide range” of measures, among others the initial installation of a sediment trap downstream of the Hamburg state boundary. The concept is based on an agreement dated 23 April 2008 concluded between the HPA and the Wasser- und Schifffahrtsamt Hamburg (WSA Hamburg) on the installation of a sediment trap within the context of maintenance dredging (WSA Hamburg & HPA, 2008). The trap was planned to be deployed near Wedel in the fairway at about Elbe-km 642 to 644 (WSA Hamburg & HPA, 2008). Legally, the sediment trap is deemed a measure to maintain the waterway.

1.2 Sediment trap monitoring concept

The Wedel sediment trap is a pilot project and at the same time a large-scale practical test to find out whether it is possible to realise this innovative module of a holistic river engineering and sediment management concept. No comparable experience is available for a measure of this kind in the tidal Elbe or other river sections influenced by the tide (HPA, 2008), which is why the HPA, in consultation with the Wasser- und Schifffahrtsdirektion (WSD) Nord [Waterways and Shipping Administration/Directorate North], the WSA Hamburg [Waterways and Shipping Administration/Department Hamburg] and the WSA Cuxhaven [Waterways and Shipping Administration/Department Cuxhaven], the Bundesanstalt für Wasserbau (BAW) [Federal Waterways Engineering and Research Institute] and the Bundesanstalt für Gewässerkunde (BfG), decided to implement a monitoring concept specially designed for the sediment trap to control and assess the potential impact of its installation and operation as well as to evaluate its effectiveness (WSA Hamburg & HPA, 2008). The monitoring concept comprises the assessment of the morphological and, in part, ecological impact and has been described in detail in the first partial report (BfG, 2009). The results of the ongoing evaluations have been continuously outlined in the subsequent partial reports. For an overview, please refer to Table 1-2, Chapter 1.3 below.

1.2.1 Structure of the evaluation programme

Since March 2008 investigations have predominantly focused on the impact of the sediment trap on hydrology and morphology, nutrient and oxygen regime, pollutant concentrations, ecotoxicological effects and, in as far as possible, nature conservation in the surroundings of the sediment trap. The monitoring concept comprises a subsequent evaluation programme divided into 3 levels which also contains aspects that fall into different legal categories. The chapters of the overall report (not included in this translated abridgement) provide a summary of the results at all investigation levels.

Level 1 (release testing) comprises binding release testing to be carried out based on the instructions given by the WSV on the handling of dredged material in coastal waters - HABAK-WSV (BfG, 1999) and the BLABAK-TBT concept [Joint Recommendations on the Implementation of the International Guidelines for the Management of Dredged Material on State and Federal State Level-TBC] (BMVBW, 2001)[1] prior to the installation of the sediment trap and each maintenance campaign [2].

Level 2 (impact prognosis) comprises the evaluation of the monitoring data. The evaluation analyses the monitoring data for the morphological effectiveness of the Wedel sediment trap with regard to the success of the measure as well as for the ecological issues and relevant impact of the sediment trap on the tidal Elbe nature habitat (including Natura2000/FFH).

Level 3 (improvement of process understanding) comprises an advanced evaluation programme which is to enhance in principle the understanding of the sediment transport system in this section of the tidal Elbe.

1.2.2 Monitoring programme undertaken

The monitoring concept describes a measurement programme that provides for the repeated application of different sampling and measurement techniques. The specific requirements of the 3-level analysis and evaluation programme set the outline conditions to select the measurement techniques and carry out the programme. Based on the results obtained and the new insights gained, the original monitoring concept and programme was modified. The modifications to the monitoring concept and programme have been continually described and explained in the partial reports[3]. Table 1-1 provides a summary of all the modifications. The agreed monitoring programme for levels 1 and 2 of the evaluation programme was completed by the end of 2011.

[1] Future releases will take place in accordance with the decree on the “Joint Transitional Provisions on the Management of Dredged Material in Coastal Waters” by the BMVBS [Federal Ministry of Transport, Building and Urban Development] of 18 November 2009.

[2] In January 2011 the WSA Hamburg, in consultation with the BfG, consented to a proposal by the HPA to carry out extensive release sampling prior to maintaining the sediment trap every 3 years only. The first release sampling pursuant to this decision was performed retroactively on 03 March 2010. The next release sampling will hence be due in 2013.

[3] For an overview of the partial reports please refer to Table 1-2, Chapter 1.3.

Table 1-1: Overview of the Wedel sediment trap monitoring programme; total number of nature measurement programmes up to and including December 2011 and overview of the modifications made to the monitoring concept and programme respectively

No.	Measure	Description and place of action	Total number of nature measurement campaigns within the scope of sediment trap monitoring	Modifications made
1	Sediment sampling (grab samples)	Sediment sampling: grab samples taken at 31 points ▪ 17 samples within the sediment trap ▪ 5 samples upstream or downstream of the sediment trap ▪ 6 samples in the marginal areas of the sediment trap ▪ 3 samples in entry area to Hahnöfer Nebenelbe	*17 Campaigns*	*- Continued sampling at all 31 points, however from 2011 laboratory analysis only of the 17 samples collected at points located within the sediment trap (see BfG, 2012a)* *- Last regular sampling in September 2011*
2	Sediment sampling (core samples)	Core sampling at 16 points within the sediment trap (within the scope of release sampling / level 1 of the evaluation programme)	7 Campaigns, of which 5 release samplings and 2 additional samplings in 2010 and 2011 (see BfG 2012a)	- From 2010: reduction of the ecotoxicological analyses from 16 to 10 sediment samples (see BfG, 2010a) - Pursuant to the WSA Hamburg's decision upon application by the HPA: last release sampling in August 2010; the result of this sampling is generally valid for 3 years; if operation of the Wedel sediment trap is continued, next release sampling in 2013 (BfG, 2012a).
3	Equipment carriers	Equipment carrier installed close to the bottom of the water and as close as possible to the fairway.	*Period: 93 days spread over 5 campaigns*	*Continued without changes; last campaign in May/June 2011*

Table 1-1 continued

No.	Measure	Description and place of action	Total number of nature measurement campaigns within the scope of sediment trap monitoring	Modifications made
4	Permanent measurement stations at 4 points	Permanent measurement of turbidity and current (point measurements every 5 minutes, close to bottom and surface) in two measurement profiles upstream and downstream of the sediment trap, in addition measurement of oxygen concentrations at point D1	*Continuous measurement at 4 stations since 28 March 2008; from January 2011 measurements continued at station D1 only*	*- Stop of measurement operations at the permanent measurement stations at SF West, SF North and SF South by the end of 2010.* *- Continuation of measurements in 2012 at re-equipped permanent measurement station D1 (Aanderaa RCM9 multi-sensors replaced by Seaguard RCM)*
5	Use of acoustic Doppler current profiler (ADCP)	Turbidity and flow conditions in two cross-sectional profiles upstream and downstream of the sediment trap	*8 Campaigns*	*- Last ADCP measurement within the scope of the sediment trap measurements on 29 March 2011* *- Continuation of ADCP cross-sectional measurement at the permanent measurement point D1 by the WSA Hamburg within the scope of gathering evidence regarding the last fairway adjustment, measurement interval: 1*annually until at least 2015*
6	Sampling of suspended particulate matter	Suspended particulate matter content in 3 cross-sectional profiles from various depths	*6 Campaigns*	*- Last sampling of suspended particulate matter on 15 March 2011*

Table 1-1 continued

No.	Measure	Description and place of action	Total number of nature measurement campaigns within the scope of sediment trap monitoring	Modifications made
7	Echo-sounding of large areas	Hydrographic mapping of the bottom of the water	85 Echo-soundings	*- From 2010: echo-sounding of a more extensive area upstream and downstream of the sediment trap (see BfG, 2010a)* *- From 2010: capturing of the morphologically less active marginal areas every 2 months only (see BfG, 2010a)* *- Last monitored with echo-sounder on 17 April 2012, afterwards echo-sounding continued by WSA Hamburg every 4 weeks to ensure safe navigation*
8	Multi-beam echo-sounding	Recognition of density horizons in the bottom of the water body within the sediment trap area	*26 Echo-soundings*	*-Last multi-beam echo-sounding on 10 November 2011* *- One-time measurement campaign on three fixed dates in 2010 using additional measurement systems to gather data on sediment densities and horizons (see BfG, 2012a).*
9	Sediment echo-sounding	Parameterised multi-beam echo-sounding using the ADMODUS method	*4 Campaigns*	

Since 2008 monitoring of the sediment trap action area has captured in detail both the natural processes and the processes influenced by the measure itself. The measurement data is the basis for analysing the impact prognoses made (level 2). From a scientific point of view the evaluations of this database made so far have considerably enhanced the understanding of sediment transport and sedimentation processes in this section of the Elbe near Wedel, which is also one of the dredging hot spots of the WSA Hamburg when it comes to maintaining water depths. The key aspects of this enhanced process understanding are described and summarised in BfG (2011a) in the overall German report.

1.3 Contents and structure of the overall report

The overall report is composed of several partial reports, which inform, at regular intervals, about the dredging works carried out to restore and maintain the sediment trap, the accompanying monitoring programme and the evaluation results obtained in levels 1 to 3. The present final report comprises a reporting period that starts in March 2008 - the reference state - prior to the initial installation of the sediment trap and continues until the end of 2011 depending on the relevant monitoring campaign. Table 1-2 below provides an overview of the partial reports issued prior to this final report as well as their thematic priority.

Table 1-2: Overview of schedules, time periods and the main contents of the reports on the Wedel sediment trap

Report	Key topics and allocation to the levels	Reporting period & (*publishing date*)
Report 2008 **(published)**[4]	▪ Explanation: - backgrounds - overall report - monitoring concept ▪ Evaluation programme ▪ Reporting level 1: - release testing - installation of sediment trap - allocation of monitoring measures to evaluation programme levels	Beginning of 2008 until installation of sediment trap in June 2008 (***October 2009***)
Interim report 2009 **(published)**[4]	▪ Definition of reference state prior to installation of sediment trap ▪ Reporting level 1: - release testing - maintenance of sediment trap ▪ Reporting level 2: - review of impact prognosis	March 2008 to December 2009 (***July 2010***)
Report 2009 / 2010 **(published)** [4]	▪ Interim results of the evaluation of solid matter transports and suspended particulate matter dynamics (level 3) ▪ Preliminary conclusions	March 2008 to December 2010 (***October 2010***)
Interim report 2010/2011 **(published)**[4]	▪ Reporting level 1: - release testing ▪ Reporting level 2: - review of impact prognosis	January 2010 to December 2010 (***February 2012***)
Final report **(this report)**	▪ Final assessment - effectiveness and impact of the sediment trap (levels 1 to 2) ▪ Outline of an extended knowledge basis on solid matter transports and suspended particulate matter dynamics (level 3) ▪ Conclusions ▪ Final recommendations and outlook	March 2008 to August 2011 ***(August 2012)***

[4] The partial reports that have already been published are available for download on the internet at:
http://www. tidal Elbe.de/167-0- sediment trap.html
http://www.Portal- tidal Elbe.de/Projekte/StromundSediTideelbe/SedWedel/index.html

2 Final assessment of the effectiveness of the Sediment Trap (chapter 5 of full report in German language)

The installation and maintenance of a sediment trap near Wedel forms an integral part of the Tidal Elbe River Engineering and Sediment Management Concept. This concept was decided by the WSV and the HPA as a joint response to rising dredged material volumes in the port of Hamburg and the shifting of main dredging areas to the upper reaches of the tidal Elbe. The relocation of material dredged in Hamburg to the North Sea, Tonne E3 (carried out from 2005 to 2010) and the establishment of a central relocation site located between Elbe-km 686 and 690 (subsequently referred to as VSB 686/690) for all sediments dredged in the area the WSA Hamburg is in charge of are additional components of the River Engineering and Sediment Management Concept. Against this background the term “effectiveness of the Wedel sediment trap” is to be seen in an overarching context.
Effectiveness can best be defined by the options and possibilities available to further optimise the tidal Elbe sediment and dredged material management strategy currently in place. The report series, which concludes with this report, first looks at the Wedel sediment trap as an individual measure with a mostly local impact aiming at the port of Hamburg and its seaward assess. At the same time, fine-sand/silt sediment dredged from the trap for maintenance purposes was relocated to VSB 686/690 located approximately 50km downstream; since 2008 a total of 6.2 million m³ (hopper capacity) from six dredging campaigns[5] has been relocated. That is why this final report takes a look at the impacts associated with the relocation of dredged material to VSB 686/690. Within the scope of the “extended system study” commenced at the beginning of 2012 (see Chapter 1) the effectiveness of the Wedel sediment trap and possibly other sediment traps such as, for example, traps located downstream in the Juelssand dredging section is to be analysed on a large and holistic scale within the context of a tidal-Elbe wide sediment and dredged material management concept.

2.1 Overview of the objectives to be reviewed and effects

The sediment trap near Wedel was first installed in June 2008 within the scope of a pilot project. Until then, no comparable data had been available on the tidal Elbe or other river sections influenced by the tide. The project was based on the principal assumption and process understanding that a sediment trap would “catch more” of the sediments carried in by the flood current from downstream

[5] 5 dredging campaigns to maintain the sediment trap took place from October 2008 to April 2011; a 6th dredging campaign to maintain the sediment trap took place after the reporting period ended in the spring of 2012.

before they reached the port of Hamburg and mixed with the more polluted sediments carried in from the River Elbe catchment area (see HPA, 2008). The larger cross section and lower flow velocity achieved through the installation of the sediment trap were supposed to catch these sediments and increase sedimentation rates. The planning phase to implement this measure was based on the following objectives or “effects” (see HPA & WSV, 2008; HPA 2008; BfG, 2009):

1) **Reduction of dredged material volumes in the port of Hamburg**

   Increased sedimentation in the sediment trap action area was to reduce dredged material volumes in the area of the port of Hamburg.

2) **Relief for the Wedel dredging hot spot**

   The Wedel Elbe section produces the highest volumes of fine sediments within the Elbe dredging section managed by the WSV. With the sediment trap in place it is possible to stretch the frequency of maintenance dredging and to combine dredging campaign schedules (see Tidal Elbe River Engineering and Sediment Management Concept of the HPA & the WSV, quoted as HPA & WSV, 2008), whereby one aspect to be taken account of in the assessment is the potential impact of the relocation of the dredged material to VSB 686/690. The impacts have been analysed and described in detail in BfG (2012b).

3) **Lower contamination levels in newly deposited sediments**

   Due to their high marine fraction the degree of pollution of sediments dredged from the sediment trap is relatively low so that they can be relocated to sites comparatively further downstream.

4) **No detrimental effect on the environment and nature conservation areas**

   The objectives mentioned under 1) to 3) can only be achieved if it is ensured that the installation and maintenance of the sediment trap does not have any detrimental effect on ecological and nature conservation issues. A part of the monitoring programme was specifically designed to review the prognoses made on measure-related impacts on the environment and surrounding conservation areas.

This chapter discusses, step by step, the achievement of the objectives mentioned under 1) to 4) taking into account the results of the monitoring and evaluation programme. Within the scope of the sediment trap project reporting other effects have been observed and it was possible to define the aforementioned effects and objectives in more detail. They are described and explained in the text.

2.2 Effectiveness as to the reduction of dredged material volumes in the port of Hamburg

Sedimentation rate analyses revealed that in a fully operable sediment trap sedimentation rates increase. At the same time, the measurement data collected at the entry and connecting areas of Köhlfleet and Parkhafen indicated a decrease in sedimentation rates. Therefore, it may be plausibly concluded that these additional sediment quantities, instead of settling upstream in the harbour basins, accumulated in the Elbe section near Wedel as a result of the measure. Estimating the quantities on the basis of the monitoring results obtained or based on the results of an evaluation of the dredged material statistics however was possible to a limited extent only due to other impacting boundary conditions (e.g. degree of consolidation of sediment deposits or maintenance state in the harbour). A rough calculation of the HPA showed that the Wedel sediment trap helped reduce the amount of fresh sediment deposits in the Köhlfleet and Parkhafen areas by up to 50,000m^3 (river bed volume) per maintenance cycle.

The effectiveness of each sediment trap is always reduced by the amount of sediments that would have settled there “naturally”, i.e. without the sediment trap in place. Increasing the size and / or depth of the Wedel sediment trap would further enhance its overall effectiveness with regard to the port of Hamburg.

2.3 Effectiveness as to relief for the Wedel dredging hot spot

The Wedel sediment trap is located in a fine-sediment settlement and dredging hot spot in the section managed by the WSA Hamburg, which is why this area has been chosen as a sediment trap site (see BAW, 2008 and BfG, 2009). Maintenance dredging is performed by the WSV to ensure fairway depths. Figure 2-1 shows the development of dredged material volumes (fine sediments only) in the tidal Elbe, inclusive of the volumes dredged in the port of Hamburg. The quantities dredged to install and maintain the sediment trap are shown separately.

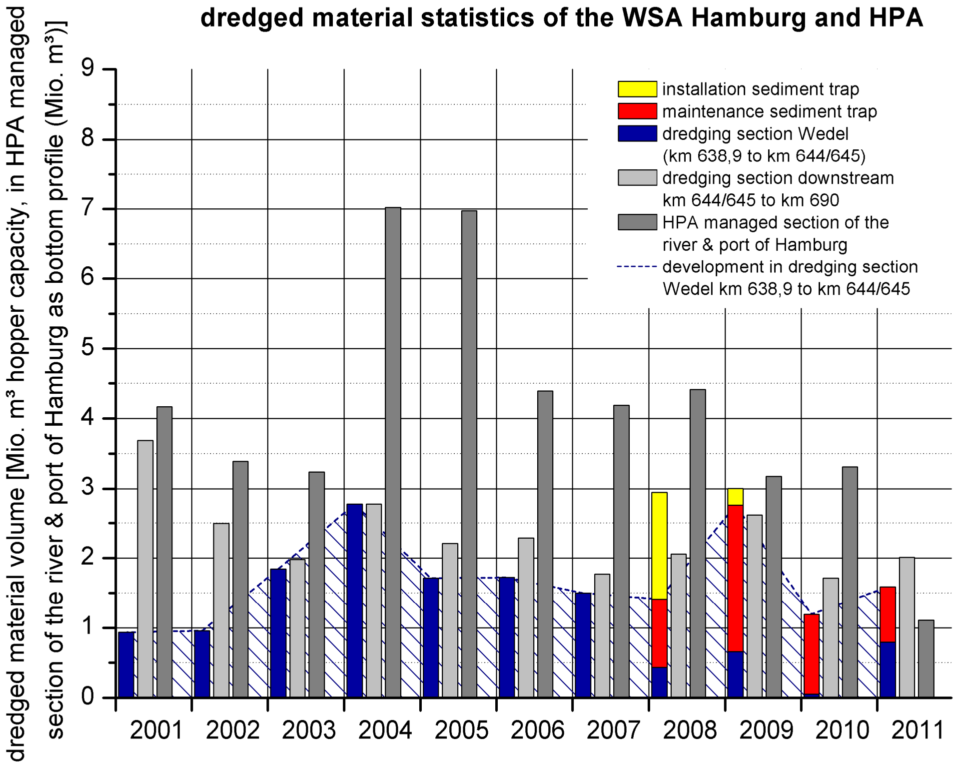

Figure 2-1: Development of dredged fine-sediment volumes (only fine-sand/silt material dredged for maintenance purposes) from 2001 to 2011 in accordance with the dredged material volume statistics of the WSA Hamburg and WSA Cuxhaven as well as the HPA.

Within the scope of maintenance dredging to restore the sediment trap a total of about 6.2 million m³ (hopper capacity) were dredged and relocated in five campaigns from 2008 to the end of June 2011. The capacity of the sediment trap is about 0.8 million m³ if it is fully operable, ie at a mean bottom elevation of -16.30m chart datum. At the time of the first three dredging campaigns to maintain the sediment trap, the trap was full. Some areas showed fresh sediment deposits of more than 2 metres in height. When the 4th and 5th maintenance campaigns started, the sediment trap was not completely filled, only some areas were full. The hydrologic regime of the headwater inflow, which has a decisive influence on the location of the turbidity zone and hence sedimentation processes in the Wedel dredging section and the sediment trap, had been highly extraordinary. Throughout most of the second half of 2010, discharge rates at Q > 1000 m³/s were high resulting in low sedimentation activity and only a slight increase of the mean bottom elevation in the sediment trap action area. The installation of the sediment trap created additional sedimentation space below the fairway bottom. Here, sediments may deposit without the WSV having to dredge them at short notice for navigational reasons. Interfering is required only if the sediment deposits exceed the TARGET elevation of the fairway bottom. Since the initial installation of the trap

in 2008, the dredged material statistics shows a substantial reduction in volumes dredged by the WSV in the Wedel section compared to the previous years. In 2010 dredging carried out by the WSV could be reduced. High headwater conditions present throughout have significantly contributed to that.
As in 2010, the sediment trap was dredged once only in the spring of 2011 - a fact that presumably caused the increase in WSV-dredged volumes in relation to the overall volumes dredged in the Wedel section. One WSV-managed dredging hot spot to ensure the fairway depth was the north-western tip of the sediment trap. Here, sediment accumulations of more than two metres were not unusual even while maintenance dredging to restore the sediment trap was underway which, in turn, required the WSV to carry out dredging work for navigational reasons. The installation depth, the time of maintenance of the sediment trap and the knowledge about localised sedimentation hot spots within the sediment trap are sediment-trap specific planning values that could further optimise the aforementioned effect of reduced WSV-managed dredging to ensure the fairway depth. This idea is developed further in Chapter 3. Another effect of the measure is that the frequency of dredging fresh sediments settled in the sediment trap action area can be stretched and dredging schedules can be combined. This option is available only because the additional sedimentation space created by the sediment trap functions as a buffer in time terms: sediments can accumulate without the need to dredge them immediately to maintain the minimum water depth. This offers several advantages with regard to planning and dredging campaigns.

1. Dredging work to ensure minimum water depths takes place at short notice, dredged volumes are comparatively low and dredging fields are usually small. By comparison, dredging campaigns to maintain the Wedel sediment trap can be planned on a long-term basis. The entire campaign takes place at one go (combined schedules) whilst at the same time dredging volumes are high and the dredging field is extensive. An analysis of all dredging campaigns carried out in the Wedel dredging section from 2006 to 2010 in line with Skuppin (2011) illustrates this sediment-trap specific advantage (see Figure 2-2 and Figure 2-3).

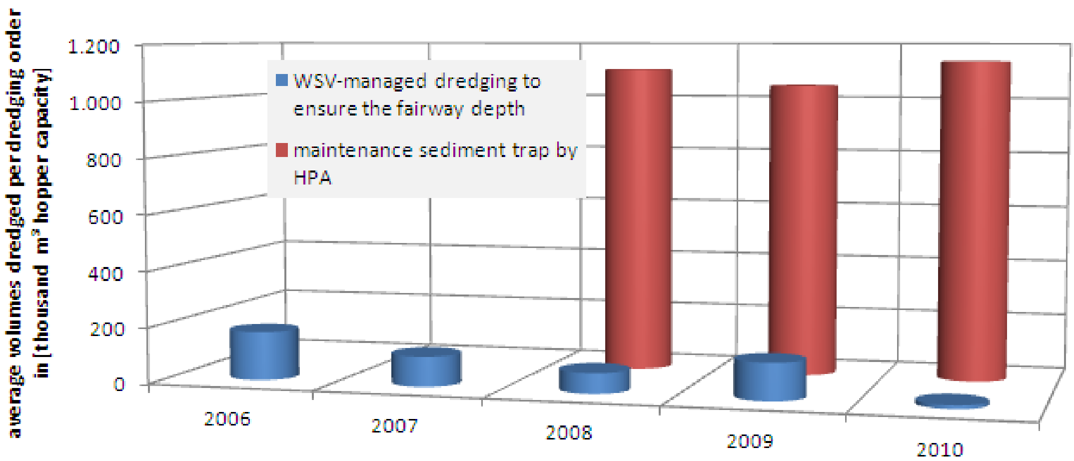

Figure 2-2: Comparison of average volumes dredged per dredging order in the Wedel dredging section / Wedel sediment trap since 2006 (in line with Skuppin, 2011)

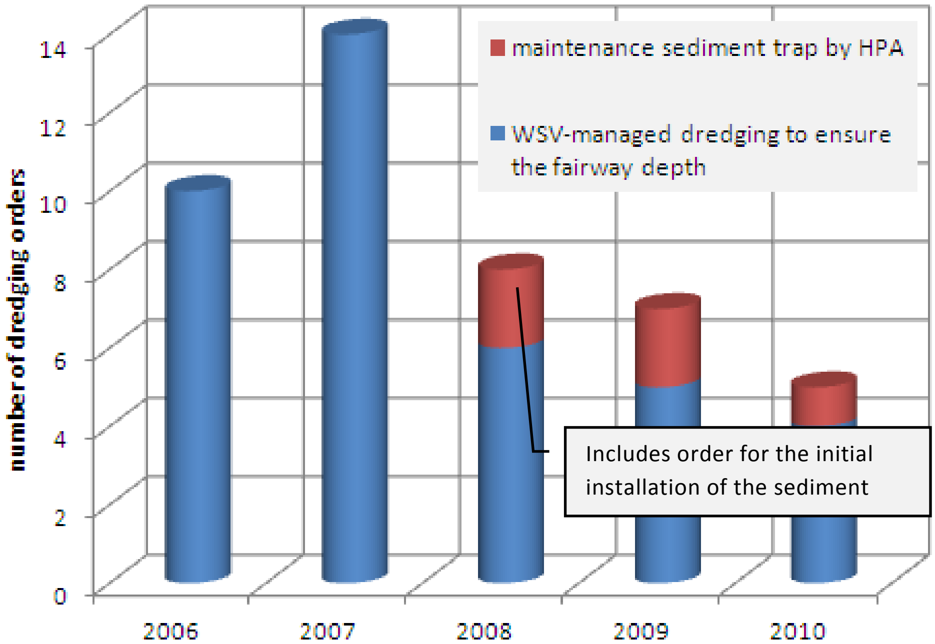

Figure 2-3: Comparison of the number of dredging orders carried out in the Wedel dredging section / Wedel sediment trap (in line with Skuppin, 2011)

2. First analyses on how to make use of the advantages mentioned under 1) and negotiate more cost- efficient contracts with the dredging companies are described in Skuppin (2011). For example, dredging higher total volumes justifies the deployment of hopper dredgers with larger capacities, resulting in lower overall costs per dredging campaign as shown in Figure 2-4 based on one round trip of 92km (i.e. single trip of 46km) which corresponds to the actual distance between the dredging site (sediment trap) and the relocation site (VSB 686/690).

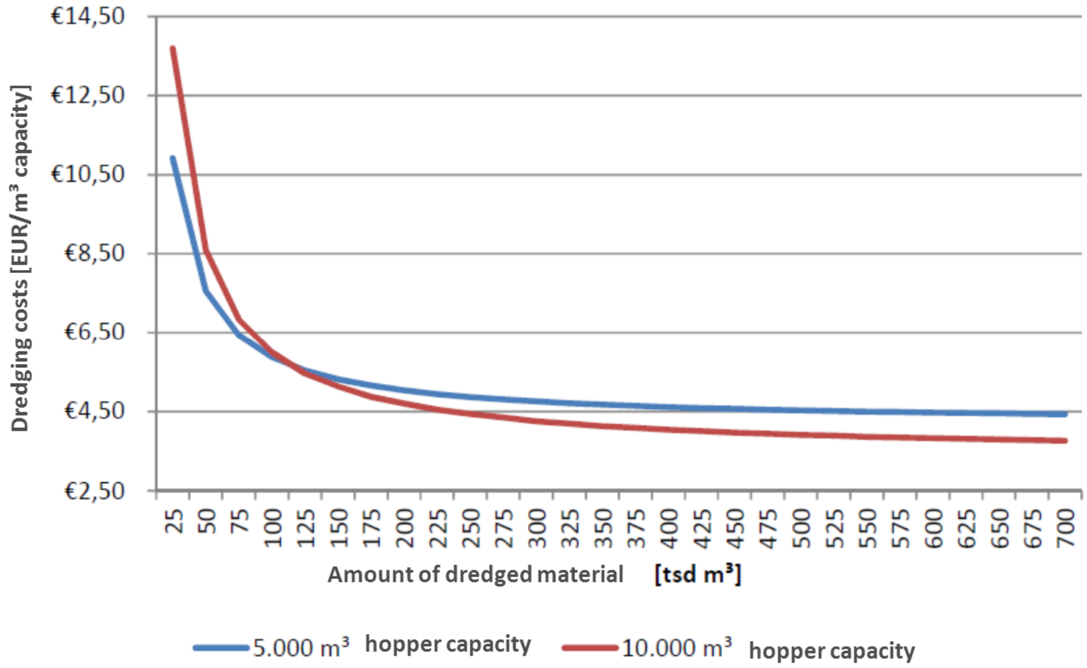

Figure 2-4: Dredging costs [EUR/m³ capacity] in relation to the total volumes dredged per order and the equipment size deployed based on a single-trip distance of 46km (source: Skuppin, 2011)

3. The targeted creation of additional sedimentation capacity below the fairway bottom at the Wedel dredging hot spot eliminates the need for short-notice dredging for navigational reasons in the environmentally sensitive period from April through June when the twaite shad spawns. However, to be able to postpone maintenance dredging, the sediment trap must have adequate dimensions, and it must be restored in time and at a certain depth (see Chapter 3.1) to offer sufficient sedimentation capacity during environmentally sensitive periods.

4. In addition, stretching dredging intervals leads to improved consolidation rates which potentially increases hopper capacities. Even if it is assumed that hold capacities do not change, more material can be dredged and relocated due to lower water content and thus a higher proportion of solid matter. In August 2009 the 3rd sediment trap maintenance dredging had to be stopped because of insufficient consolidation of the sediment deposits (see BfG, 2010a). Grab samples taken during the monitoring confirmed that sediment consolidation rates were lower. The consistency of the sediment samples taken in the summer was very pulpy, which indicates a high content of water. Other indications for consolidation processes were extreme fluctuations in the development of the sediment trap’s mean bottom elevation at times when water temperatures were high and headwater inflows were low). Furthermore, sediment densities in the sediment trap area were the subject of an analysis performed within the scope of a one-time measurement campaign on three fixed dates in 2010.

5. The review of the impact prognosis on “sedimentation rates” in BfG (2012, chapter 3.4.2) revealed that unlike a sediment trap that is full, a fully

restored sediment trap causes sediment deposition rates to increase (see BfG, 2012a, chapter 3.4.2). Relative to the other dredging sections this represents an increase in dredged material volumes in the Wedel Elbe section. These additional volumes however cannot be quantified on the basis of existing data and analysis results as dredged material volumes are influenced by the highly variable hydrological headwater inflow regime. The higher the degree of filling of the sediment trap, the lower the headwater impact will be and volumes in short-notice maintenance dredging carried out for navigational reasons to ensure fairway depths are not expected to increase.

6. There is no indication that at times of high headwater inflow and hence increased downstream sediment transport the latter is obstructed or even completely stopped by the Wedel sediment trap. During such times, low or even negative rates of change in bottom elevation in the sediment trap could always be determined.

7. Since 2008 the fine-sand, silty material dredged during maintenance of the sediment trap has been relocated to VSB 686/690 in accordance with the relocation concept of the WSA Hamburg. The relocation to the site located approximately 50km downstream of the sediment trap is assumed to improve material export rates towards the German Bight and thus ease the burden on the fine-sediment regime. This aim is best achieved if the material is relocated at times of high headwater inflows (BfG, 2012b). Mean discharge rates of Q > 1000 m^3/s are most likely present from February through April (see Figure 3-5 below, Chapter 3.3). In 2009, 2010 and 2011 maintenance dredging of the sediment trap took place from April through the beginning of May. Another two maintenance campaigns took place in October/November 2008 and in August 2009, when headwater inflow was low (mean discharge at Neu Darchau tide gauge: Q = 405 m^3/s and Q = 392 m^3/s). Compared to a maintenance campaign carried out in the spring dredging campaigns and relocations to VSB 686/690 performed later in the year are subject to increased upstream transport (keyword: sediment cycle).

2.4 Reduced sediment contamination levels

The impact prognosis made for planning purposes was based on the assumption of reduced contamination levels in the sediment deposits in the sediment trap relative to the degree of contamination of the material dredged for maintenance purposes in the period prior to the initial installation of the Wedel sediment trap. The objective was to reduce contamination levels by getting more less-polluted sediments of marine origin to settle in the trap. To verify this prognosis, every 2 months grab samples were taken at 17 points in the sediment trap area in addition to the release samplings to analyse the degree of contamination of fresh sediment deposits.
All release testing - performed across the entire cutting depth to determine the mean degree of pollution of the sediments accumulated in the sediment trap - produced the same result: the potential dredged material was classified

material pursuant to HABAK-WSV (BfG, 1999), later replaced by GÜBAK (ANONYMUS, 2009). The same classification applies to the sediments regularly dredged by the WSV in the Wedel area in 2008 as well as to the samples of sediments formed from suspended particulate matter taken at the permanent measurement points (DMS) at Wedel and Bützfleth. Thus the material dredged from the sediment trap for maintenance purposes does not show any action-related reduction but continues to reflect the degree of contamination present in the Elbe typical for the Wedel and Bützfleth section which is strongly influenced by headwater inflow rates. The results of this analysis have been outlined in detail in the partial report that preceded this final report (see BfG, 2009; BfG, 2010a; BfG, 2011a).

The grab samples taken every 2 months provided data on the degree of contamination of the newly deposited sediments in the sediment trap action area in higher temporal resolution. A direct comparison of the values measured in the sediments from the bottom of the water with the results obtained at the Wedel DMS was possible. It is described in detail in Chapter 3.3. Apart from some exceptions, the results of the grab sample analyses were more or less in line with the degree of contamination determined in the samples of sediments formed from suspended particulate matter that the BfG took at the Wedel and Bützfleth DMS (see Chapter 3.3.1 and BfG, 2011a). Despite obvious differences in pollutant concentrations over the course of time and between the various sampling areas (sediment trap, Wedel and Bützfleth DMS), based on the present measurement results a trend towards significantly reduced or even increased pollutant concentrations in sediments from the sediment trap can be excluded. This conclusion refers to the pollution situation captured at the Wedel DMS and Bützfleth DMS as well as to the initial situation after the sediment trap had initially been installed.

2.5 Impacts on the environment and nature conservation areas

At the beginning of the sediment trap pilot project various impact prognoses were made that were reviewed within the scope of the monitoring and evaluation programme (level 2). This review clearly showed that the installation and maintenance of the Wedel sediment trap had neither negative nor significant impacts on the environment and the adjacent conservation areas.

The respective assessment was in particular concentrated on the impact of the sediment trap on the oxygen regime of the water and on pollutant concentrations in the sediments accumulated in the sediment trap. During maintenance dredging no measurable impact on the oxygen regime due to the dredging works could be determined at the permanent measurement point D1 installed close to the bottom. For this measurement point, continuous measurement series to determine oxygen concentrations have been evaluated. The oxygen consumption of the sediment deposits captured within the scope of the release sampling can be classified as low in relation to the mean value in accordance with Müller et al. (1998).

As already mentioned in Chapter 2.5 above, an action-related rise in pollutant concentrations in the sediments accumulated in the sediment trap can be excluded. The results of the ecotoxicological tests performed on samples from

the reference sampling as well as on all subsequent release testing and sediment samples show an ecotoxicological contamination potential similar to previous analysis results (see BfG, 2008). However, to be excluded here is a sediment sampling from August 2010. The analysis of these sediments revealed a trend towards higher pollution potential (see BfG, 2012a). It is not clear why there were differences and/or fluctuations in the pollutant content of the sediments. However the analysis results available so far do no suggest any systematic, longer-term changes in the ecotoxicological pollution potential.
Maintenance dredging to restore the sediment trap as well as maintenance dredging carried out by the WSV to ensure the fairway depth takes place solely in the area of the fairway. Bird resting, sleeping and feeding areas in shallow-water zones, mudflat (tidal flat) areas or grassland areas are not directly affected by it. Furthermore, within the scope of the monitoring and evaluation programme possible risks to the conservation objectives regarding adjacent Natura 2000 areas due to insufficient oxygen levels caused by the sediment trap can be excluded. The sediment trap is not expected to have any relevant impact on fish populations and in particular twaite shad populations. Rather, the installation of the sediment trap significantly reduced maintenance dredging required to ensure the fairway depth in the twaite shad sensitive period from April to June. At this point reference is made to the official approval of the proposed plan to adjust the fairways of the Unterelbe and Außenelbe of 23 April 2012 to accommodate container ships with a draught of 14.5m (regulations set forth in sub-item 4.2.4) according to which maintenance dredging may only be performed in the period from April 15th to June 30th under the condition that no spawning activities take place in the main spawning area of the twaite shad (Schwinge mouth up to Mühlenberger Loch).

2.6 Summary

Table 2-1 summarises the assessment of the various effects of the sediment trap outlined in the chapters above. In addition, it highlights once more the specific advantages/options of the various special aspects and the weaknesses/risks associated with the maintenance and operation of a sediment trap near Wedel.

Table 2-1: Summary of the assessment of the various effects of the sediment trap

Effectiveness of the sediment trap	Advantages/Options ./. Weaknesses/Risks
Impact on ecological and nature conservation issues	**Advantages/Options** ▪ Reduction of the extent and frequency of maintenance dredging for navigational reasons ▪ Avoidance of maintenance dredging during the twaite-shad sensitive period from April 15th to June 30th **Weaknesses/Risks** ▪ The usual impacts of hopper-dredging fine sediments remain
Reduced sedimentation rates upstream in the area of the port of Hamburg	**Advantages/Options** ▪ Current installation depth at 2m below the fairway bottom (equivalent to 0.8 million m³ filling capacity): indication that sedimentation rates in the Köhlfleet and Parkhafen basins are lower

	(areas the HPA is responsible for), rough calculation of the HPA shows decrease in sedimentation volumes in these areas of up to 50,000m³ (bottom volume) per each maintenance cycle **Weaknesses/Risks** ▪ “Natural” sedimentation: sediments which accumulate in the sediment trap reduce the effectiveness of the action ▪ Increased effectiveness possible only through higher filling capacity ▪ Action-related additional volumes in the Wedel dredging section (area the WSA Hamburg is in charge of)
Improved sediment quality	**Advantages/Options** ▪ No indication for a deterioration in the sediment quality **Weaknesses/Risks** ▪ No indication for improvement in the sediment quality
Supports maintenance dredging in the Wedel section to ensure water depths	**Advantages/Options** ▪ Reduction in volumes and frequency of maintenance dredging for navigational reasons, effectiveness depends on sediment trap capacity (depth and area) ▪ More economical and more efficient maintenance of dredging hot spots due to - scheduled and combined dredging orders, resulting in fewer individual orders at different and unknown times - at the same time: higher total dredged volumes and - large dredging fields - improved sediment consolidation rates resulting in increased hopper effectiveness **Weaknesses/Risks** ▪ No effect if sediment trap is full (action failed) ▪ Action-related additional volumes in the Wedel dredging section (area the WSA Hamburg is in charge of)
Management of the relocation site VSB 686/690	**Advantages/Options** ▪ Scheduled relocation of dredged material to VSB 686/690 or another relocation site at times when the downstream net transport is expected to be strong, therefore ▪ Targeted contribution to ease the burden on the fine-sediment regime of the tidal Elbe possible **Weaknesses/Risks** ▪ Maintenance of the sediment trap entails heavy utilisation of VSB 686/690; a lot of material dredged in a relatively short time will promote the formation of deposits on the bottom of the water at the relocation site and increase inputs to the fairway areas (see BfG, 2012b) ▪ More relocation site capacities may be required

3 Recommendations

(chapter 6 of full report in German language)

The knowledge obtained from the monitoring and evaluation programme, supplemented by the experience gained so far in maintaining the Wedel sediment trap, forms the basis for the recommendations given below. The recommendations aim to further improve the effectiveness of the sediment trap measure as an integral part of a holistic sediment and dredged material management. The recommendations are primarily aimed at further improving the future maintenance of a sediment trap near Wedel and if appropriate, they may also be applied to the operation of sediment traps at other sites in the tidal Elbe. This aspect forms part of the “extended system study” commenced in 2012 (see full German report). One of the aspects to be analysed within the scope of this study is the assessment of the potential effects of sediment traps within the context of an estuary-wide sediment and dredged material management concept, whereby the study will also take account of the changed boundary conditions caused by the fairway deepening to accommodate container ships with a draught of 14.5m. After the fairway has been adjusted, the current site of the Wedel sediment trap will be located in the area of the ship meeting & passing point. These new boundary conditions may make it necessary to review once more the recommendations given below.

3.1 Maintenance strategy with regard to the Wedel sediment trap

One result of the sediment trap monitoring is the annual course of the mean and extreme rates of change in the bottom elevation (observation period: June 2008 through August 2011) illustrated in Figure 3-1. This annual course defines an expectation range for sedimentation processes in the Wedel sediment trap action area, which is an important basis for the further planning of the maintenance strategy.

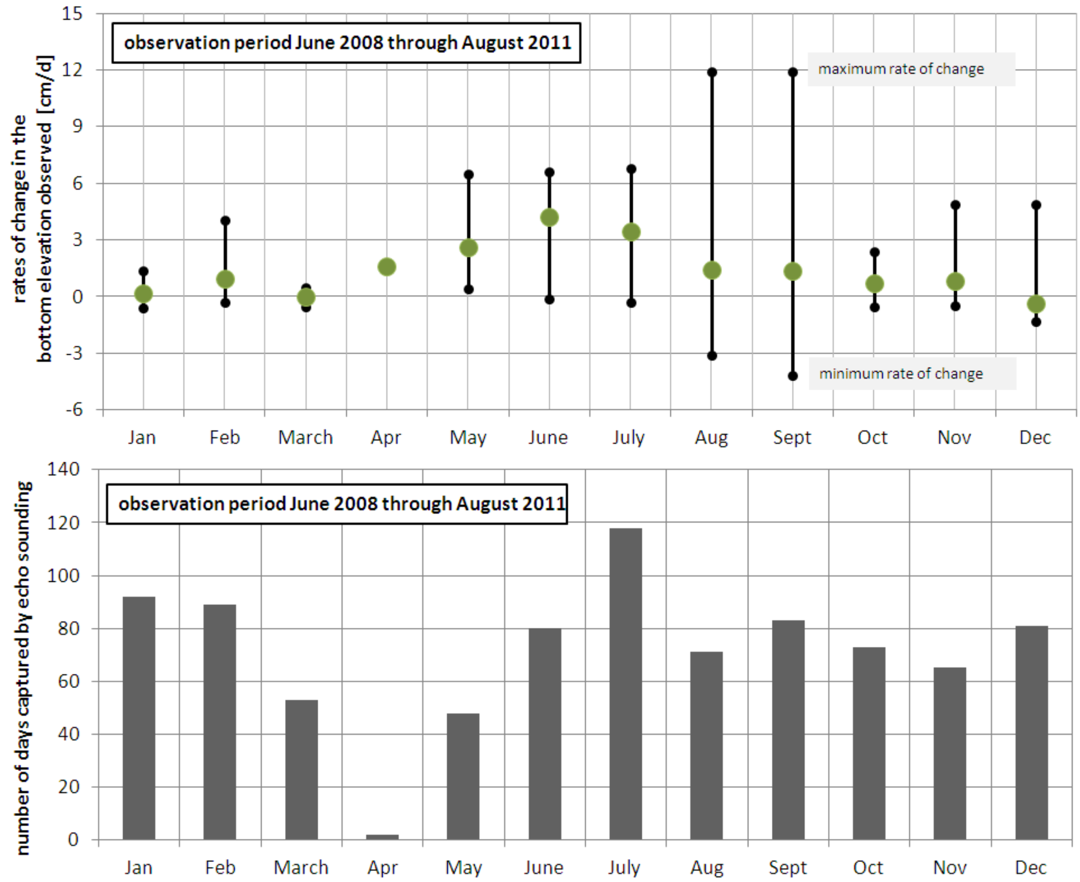

Figure 3-1: Annual course of the rates of change in the bottom elevation observed and averaged on a pro-rata basis over the period from June 2008 through August 2011

In relation to the mean value, maximum rates of change in the bottom elevation can be observed from May through July. The database for May however comprises substantially fewer observation days compared with the months of June and July, which makes this result less reliable. In April changes in the bottom elevation could be observed on some days only. This was due to maintenance dredging which, from 2009 to 2011, was always carried out in April to restore the sediment trap. In the subsequent period from August to September, slight rates of change at a mean value of approximately 1.5cm/d were observed. However processes in this period are extremely dynamic. In August and September both the maximum positive and the maximum negative rates of change were captured, mostly as an extreme increase directly followed by a phase of an extreme decrease in the mean bottom elevation. As already mentioned several times in this report, this dynamics is associated with strong sedimentation at low deposit densities followed by a phase of sudden consolidation. In the subsequent colder months both the average rates of change and the possible fluctuation ranges as to extreme values decrease.
The annual course illustrated in Figure 3-1 is based on an observation series over slightly more than three years. However, relative to the qualitative course, it more or less complies with the annual course showing the volumes dredged per month as a proportion of the annual volumes dredged in the Wedel

dredging section for the preceding period from 2004 through 2007 illustrated in Figure 3-2.

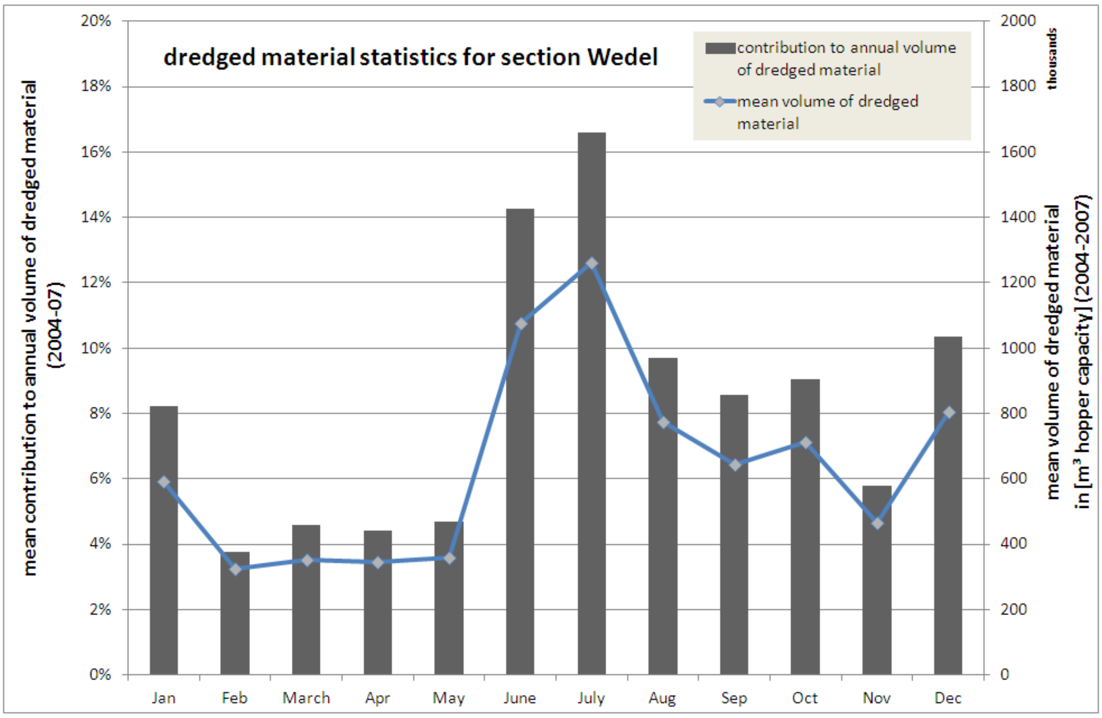

Figure 3-2: Monthly dredged volumes as a proportion of the respective annual volumes dredged for the period from 2004 to 2007

So far dredging to maintain, i.e. restore the Wedel sediment trap has primarily been carried out in April and May. Since 2010 the sediment trap has been restored once per year in April. The only time the sediment trap was dredged for maintenance purposes a second time in the late summer or in the autumn was in 2008 and 2009. The results depicted in Figure 3-1 substantiated by the results shown in Figure 3-2 and the observations at the site the material dredged within the scope of maintaining the sediment trap was relocated to (see Chapter 3.3) confirm the effectiveness of the maintenance strategy in place. It is therefore recommended to continue to dredge the Wedel sediment trap for maintenance purposes once a year. Dredging works must be completed by April 15th. This date is set forth in the official approval of the proposed plan to adjust the fairways of the lower and outer Elbe to accommodate container ships with a draught of 14.5m of 23 April 2012 according to which hopper maintenance dredging may only be performed in the period from April 15th to June 30th if no spawning activities take place in the main spawning area of the twaite shad (Schwinge mouth to Mühlenberger Loch). Based on the results of a spawning activity monitoring, it would be possible to carry out dredging works after April 15th, however, as dredging campaigns to maintain the sediment trap require early planning and fixed scheduling this is not relevant.
If the sediment trap is restored in March and April, the required sedimentation space will then be available in full to absorb the sediments accumulating and hence help to maintain the required fairway depth without the need for further dredging, whereby the focus is on the period from mid April to September. During this period the following events are relevant:

- Maximum sedimentation processes from May to September (see Figure 3-1) that required extensive maintenance dredging by the WSV before the Wedel sediment trap was initially installed (see Figure 3-2).
- The spawning period of the twaite shad: to protect the species (loss of twaite shad eggs sucked in by the hopper) no hopper dredging is to take place from April 15th through June 30th.
- Net sedimentation in the sediment trap action area should be as low as possible during times the transport regime is ebb-stream dominated.

The restoration of the sediment trap volume at a much earlier point in time than March or April would result in a loss of sedimentation volume and hence limit the effectiveness of the sediment trap when it comes to maintaining the Wedel dredging hot spot in the subsequent period. The required restoration depth is the subject of Chapter 3.2.1 below.

3.2 Site and dimensions of the Wedel sediment trap

The results obtained in the evaluation programme as well as the experience gained in the operation and maintenance of the sediment trap underpinned the initial site criteria based on which the sediment trap was installed in the Elbe section near Wedel. The two most important criteria to determine a suitable site for potential other sediment traps hence are:

- The sediment trap action area should be a sedimentation and dredging hot spot where mostly fine-grained and thus cohesive sediments accumulate.
- A sediment trap site should be a site that is usually marked by upstream net transport of sediments.

New insights gained within the scope of the evaluation programme allow for a more suitable dimensioning of the Wedel sediment trap that will further increase the effectiveness of this measure. Criteria are the installation depth and the geometry of the action area.

3.2.1 Installation depth

The installation depth chosen and implemented for the Wedel sediment trap pilot project covers an area at two metres below the fairway bottom (location at -14.30m chart datum). The evaluation of the dredged material statistics presented in Chapter 2.3 revealed that due to the operation and maintenance of the sediment trap maintenance dredging to be performed by the WSV to ensure the fairway depth could be reduced substantially in the period from 2008 to 2011. The installation of the sediment trap creates additional sedimentation space. A further deepening of the sediment trap will further reduce the already reduced residual dredged material volumes; the theoretical maximum target is a section that does not require any maintenance dredging, i.e. no single dredging campaigns are required at short notice for navigational reasons. In 2010, when sedimentation was low, this aim could almost be achieved thanks to the sediment trap.

Table 3-1 shows the maximum values of the theoretically possible height of settled sediments in the Wedel sediment trap action area. The values are depicted separately for the different time periods 1 to 6 which are each separated from each other by one sediment trap maintenance campaign.

Table 3-1: Mean values of the maximum height of settled sediments in the sediment trap (theoretical consideration)

Period	from	to	Duration [d]	Maximum heights of settled sediments			
				Sediment trap, total [m]	Northern strip [m]	Centre strip [m]	Southern strip [m]
1	25.06.2008	16.09.2008	105	8.29	8.29	4.54	5.41
2	24.11.2008	25.03.2009	111	8.13	8.13	3.90	3.96
3	11.06.2009	12.08.2009	63	4.93	4.93	4.92	4.46
4	31.08.2009	17.03.2010	195	7.96	7.96	3.43	3.43
5	29.04.2010	15.03.2011	292	6.51	6.41	6.51	6.46
6	06.05.2011	01.08.2011*	79	8.18	7.00	7.50	8.18

* Next sediment trap maintenance dredging in the spring of 2012 only

The Wedel sediment trap was fully restored at the beginning of each period. The maximum heights of settled sediments shown in Table 3-1 have been determined for both the entire action area and the partial areas of “northern strip” (grid A-north to H-north), “centre strip” (grid B-centre to H-centre) and “southern strip” (grid C-south to H-south). The calculation is based on the bathymetric models produced from 25 June 2008 to 01 August 2011, which have been outlined and illustrated in BfG 2011. As the differential models have been adjusted for the impact of navigation-related dredging carried out by WSV, this is a theoretical consideration which estimates the maximum height of settled sediments. The heights have first been determined separately for each grid field (surface area about 250m * 250m), based on which the respective maximum values per each area have been determined as presented in Table 3-1.

Table 3-1 shows that without the navigation-related dredging works the maximum theoretical height of sediments settled in the sediment trap action area could have reached 8.29m in some areas (period 1). The maximum values mostly occurred in the northern area of the sediment trap. The overall maximum value of 8.29m however should be regarded as a highly conservative estimate. On the one hand, sediment accumulations of this height would have been exposed to increased erosion processes and on the other hand, this is an isolated value which only occurred in the D-north grid field. The maximum mean height of settled sediments in period 1 (25 June 2008 through 16 September 2008, see Table 3-1) was 4.11m. It is not necessary to install the Wedel sediment trap across a large area at a depth of more than 8m as the above would only apply to smaller partial areas.

An advanced dimensioning approach to optimise the installation depth of the Wedel sediment trap is the frequency distribution depicted in Figure 3-3 according to which each installation depth comes with a certain failure probability[6]. The basis to decide which installation depth should be realised is a pre-defined and hence accepted failure probability.

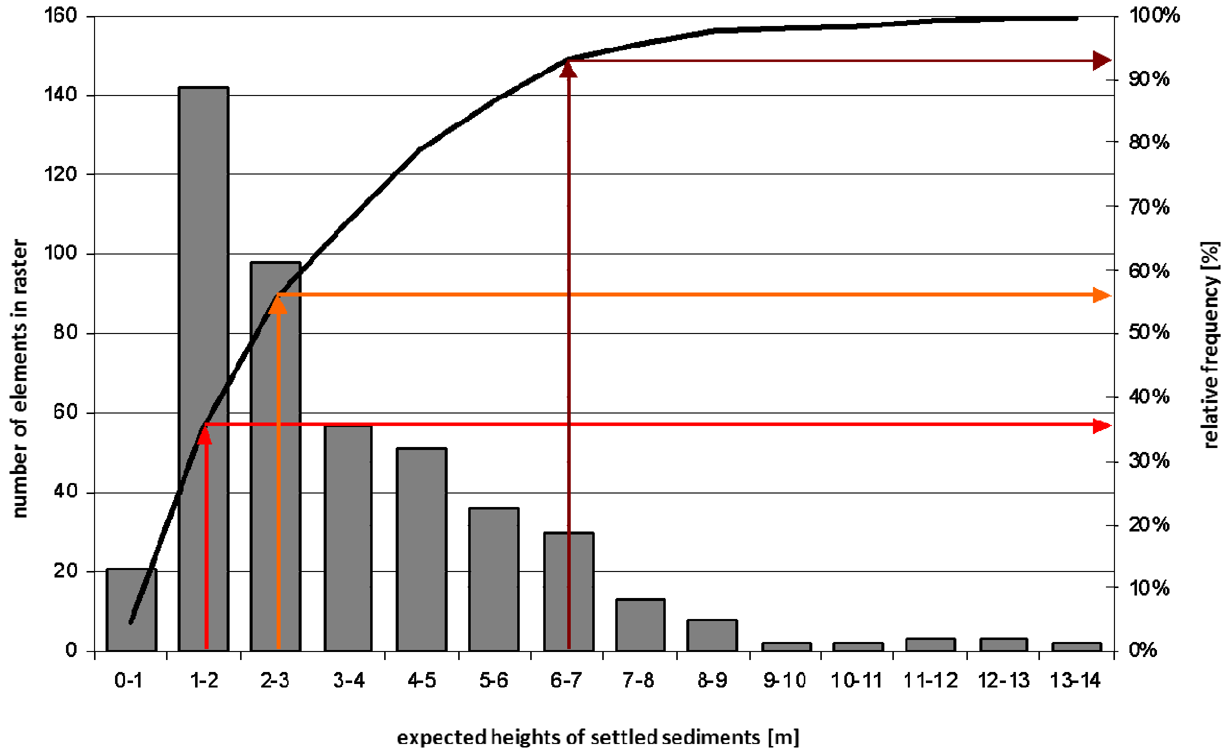

Figure 3-3: Frequency distribution of expected heights of settled sediments in the sediment trap action area

Figure 3-3 shows the evaluation of the development in the individual grid fields[7]; the evaluation period covers the months from April to September. Similar to Table 3-1 the data has been adjusted for the impact of navigation-related maintenance dredging. The evaluation result shows that the degree of effectiveness of the Wedel sediment trap at its current installation depth of 2m below the fairway bottom (-14.30 chart datum) was at about 35%. This result is to be interpreted such that 65% of the data records analysed showed heights of settled sediments of more than two metres. A deepening by one metre to then 3m below the fairway bottom could have increased the degree of effectiveness in the testing period to about 55%, which could have resulted in a significant reduction of WSV-managed maintenance dredging. In theory, an installation depth at 7m could have increased the degree of effectiveness to about 93%. Each further increase of the installation depth would entail only a slight rise in the degree of effectiveness. Furthermore, each increase of the installation depth would entail action-induced higher sedimentation and consequently cause the height of the settled sediments building up to increase. This

[6] The term “failure” as it is used here means that the sediment trap can no longer fulfill its original function as a sedimentation space. The sediment trap fails as soon as it is filled up, which entails the need for navigation-related maintenance dredging.
[7] The sediment trap action area comprises a total of 21 grid fields. For each grid field the settlement heights have been calculated for the 26 periods from April to September, resulting in 21 * 26 = 546 data sets which the analysis is based on.

sedimentation-enhancing effect could already be established in the ongoing pilot project (see BfG, 2012a, chapter 3.4.2). However it was not possible to pinpoint the exact factor causing this.
The installation depth should therefore be increased in steps and in line with the dredging and sediment management/maintenance strategy requirements (among others, also with regard to the impact on the chosen relocation sites; see BfG 2012b, chapter 6). One of these requirements is to avoid maintenance dredging in the Elbe section near Wedel in the twaite shad sensitive period from April 15th to June 30th. It is not possible to achieve that aim if the sediment trap remains at the current depth of -16.30m chart datum. One option to meet that requirement would be to further deepen the currently existing sediment trap near Wedel. This deepening should take place in steps to be able to monitor the development of sedimentation rates analogous to the evaluations made within the scope of the monitoring.
The evaluations made and results obtained so far are based on a sediment trap that has been installed at a uniform depth across a given area. A sediment trap certain areas of which are installed at different depths is an advanced concept to improve the effectiveness of this measure. The sedimentation processes observed during the sediment trap monitoring differed substantially from area to area. The evaluations in Table 3-1, for instance, show a sediment accumulation hot spot in the northern area of the Wedel sediment trap. A sediment trap with some areas at a greater depth would make it easier to take account of locally occurring maximum sedimentation rates. However when implementing this concept, the technical dredging requirements must be considered. It may make sense, for instance, to combine several grid fields into larger dredging fields that will all be dredged at the same depth.

3.2.2 Sediment trap geometry

The sediment trap geometry created from 2008 to today comprises the major sedimentation hot spots near Wedel. Outside of the sediment trap geometry, however, more WSV-managed maintenance dredging was carried out to ensure the fairway depth. The dredging fields in Figure 3-4 illustrate that.

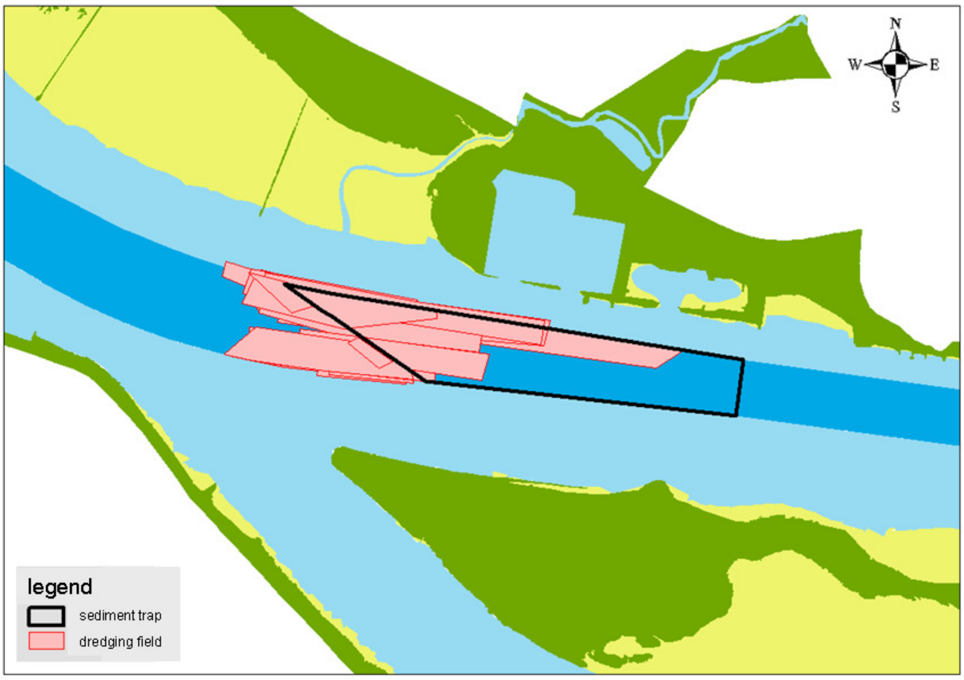

Figure 3-4: Dredging fields to the south-west of the sediment trap

An extension of the sediment trap geometry downstream and into the area of Lower Saxony is recommendable as this would make the Wedel sediment trap even more effective.

3.3 Inclusion in the tidal Elbe relocation strategy

Further improvement of the fine-sediment regime can be achieved by a targeted inclusion of the sediment trap maintenance strategy in the large-scale relocation strategy of the WSV and the HPA. Analyses on the inclusion of the Wedel sediment trap in the sediment and dredged material management concept for the entire Elbe estuary forms part of the “extended system study” that is currently being prepared (see Chapter 1). First results that have been evaluated within the scope of the evaluation programme completed with this report are explained briefly below.

The fine-grained material dredged from the restored sediment trap was relocated to VSB 686/690. VSB 686/690 model analyses show that the net downstream transport is significant at times of higher headwater inflows exceeding 1000m³/s (see BAW, 2011 also documented in BfG, 2012b). Under these boundary conditions the relocation of the fine-sand / silty dredged material to VSB 686/690 results in drifting towards the North Sea and hence in an improved fine-sediment regime in the tidal Elbe. If relocations take place during times of low headwater inflow, the model results show substantially

higher net upstream transports of re-suspended dredged material (keyword: sediment cycle).
The long-term mean of the annual course of the headwater inflow (see Figure 3-5) shows maximum discharge activities from February through April. To ease the burden on the fine-sediment regime, the sediment trap should be dredged for maintenance reasons from March to April 15th, taking into account the recommendations given in Chapter 3.1. It is not recommended to additionally dredge the sediment trap for maintenance purposes in August and October/November respectively, as was the case in 2008 and 2009, due to upstream transports of relocated fine sediments expected in the VSB 686/690 area. If the sediment trap is full, navigation-related single dredging should be carried out to the extent required.

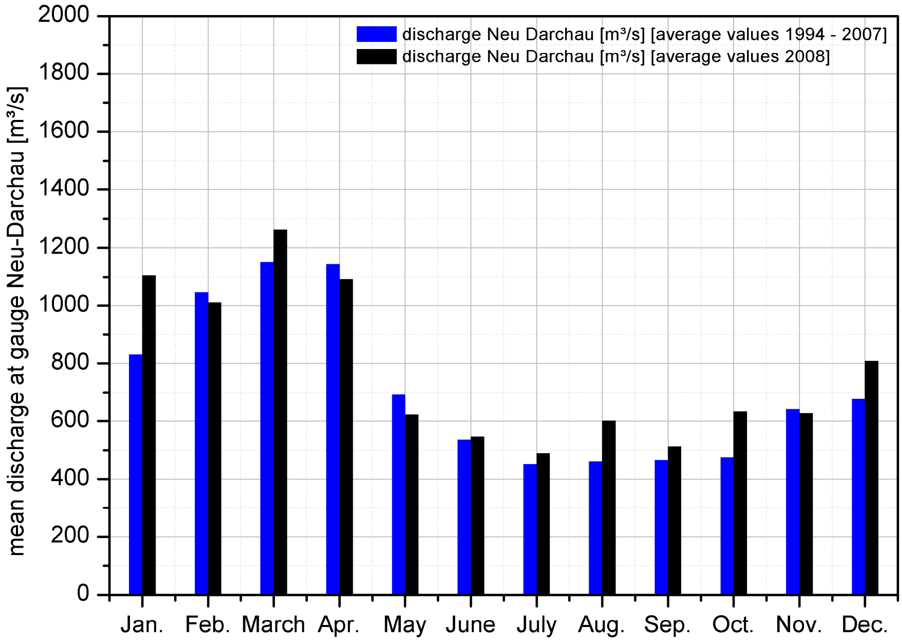

Figure 3-5: Annual course of the headwater inflow (tide gauge at Neu Darchau) from 1994 - 2007 and 2008 - 2011

3.4 Assessment of the monitoring concept

Levels 1 and 2 of the monitoring and evaluation programme already specified most of the required monitoring concept. When it came to the design and performance of other measurement programmes as a part of level 3, more leeway was granted. The aim of the level-3 activities was to widen the existing understanding of sedimentation dynamics and solid-matter transports in the Elbe section near Wedel. The monitoring programmes, designed and implemented based on the requirements of level 1 and level 2 have, of course, contributed to this extended understanding.

From a scientific point of view the monitoring and evaluation programme carried out at the Wedel sediment trap since 2008 has produced an extraordinary database on sedimentation dynamics and the estuarine solid-matter transport in the Elbe section near Wedel both in terms of extent and continuity. The project objectives in levels 1 and 2 could be worked on based on the measurement data gathered. Almost all of the impact prognoses made were reviewed and assessed on closure. As to the sediment trap action area it was not possible to produce a complete sediment balance. In particular, there is a knowledge gap about sediment densities - a subject which in the beginning had only been a side aspect in the monitoring concept but which in the course of the analyses developed into a key issue. A one-time, very extensive sediment density analysis campaign was performed in 2010 among others, because maintenance dredging was stopped in 2009 (see BfG, 2010a, chapter 2.3). The continuation of such measurement campaigns to capture sediment densities therefore is an important component when it comes to the preparation of area-specific sediment balances and, based on that, making improved estimations of sedimentation and erosion rates respectively.
Furthermore, the relatively few data available on the Elbe section near Wedel for the period prior to the initial installation of the sediment trap (reference state) severely limited the evaluation and assessment of the results obtained within the scope of the sediment trap monitoring. The arguably most important method to assess the effectiveness of the sediment trap, namely the comparison of the states measured with the state prior to the initial installation of the Wedel sediment trap, could not be applied. This fact calls for a continuation of the major measurement programmes, also with regard to future issues that may not be known yet. This continued monitoring should be regarded as an investment in the future. Even now, continued monitoring would accomplish the important task of gathering data on volumes, the composition and the quality of sediments at the Wedel dredging hot spot. This data will be the basis for the review and further optimisation of the dredging and maintenance strategy in place. A recommendation on the continuation of the major measurement programmes is given below.
Generally of special significance are the measurements that can be performed directly in the area of the fairway to gather data on solid-matter dynamics right at the sedimentation hot spots. Due to shipping traffic permanent measurement installations are not possible at all or to a very limited extent only. Large-area echo-soundings and regular sediment sampling are key measurement and monitoring campaigns which should be continued to a comparable extent in the future. In addition to echo-soundings performed at regular intervals to ensure navigational safety, the fortnightly measurement intervals can also be ensured by individual campaigns, whereby intense monitoring, for instance, can be confined to the generally warmer months from April to October when sedimentation activities are strongest. Furthermore, it is recommended to continue to gather data on sediment properties in the same period, namely in May, July and September, by taking grab samples at the points used so far. The monitoring programme should be supplemented by a further sampling campaign in the winter months. If maintenance of the sediment trap continues, sediment core samples will be taken every three years across the entire cutting depth of the dredged material within the scope of a release sampling and analysed by a laboratory.

Further scientific measurements were carried out at level 3 of the monitoring and evaluation programme. The frequency of these measurements cannot be compared to that of level 2 so that the development of processes and states in terms of time was not captured here. These measurements focused on understanding processes, in particular with regard to the data gathered on solid-matter transports and sedimentation/re-suspension processes close to the bottom in the lowest range of the water column. So far, it has not been possible to capture this area, in particular the Elbe fairway area, by any measurement technique other than by equipment carrier. The data obtained therefore is unique and of utmost value for basic research. The deployment of the equipment carrier is highly labour and resource-intensive and at the same time, measurement equipment failures and loss of data occurred rather frequently. The further development of this equipment carrier should definitely be pursued, in particular with the aim to simplify equipment installation and removal processes as well as to equip the carrier with robust measurement devices. The research of basic processes can also be carried out with equal success in other, more easily accessible areas. Alternative measurement sites should be contemplated in accordance with objectives.
All in all, the sediment trap monitoring demonstrated the added value of continuous monitoring, deploying various monitoring techniques which may supplement each other as to potential results. The evaluations of all measurements clearly showed that the additional knowledge gained by evaluating one measurement can be increased substantially by data gathered in another measurement performed soon after the first one (e.g. differential model from echo-sounding, substantiated by sediment sampling). The required single-measurement repeat-frequencies are determined either based on experience or the results of ongoing measurement evaluations. Planning should always provide for different measurements to be performed at the same time.

3.5 Summary of the recommendations

The recommendations for the future optimisation of the Wedel sediment trap are described and explained in detail in Chapters 3.1 to 3.4. This chapter gives a final summary of the recommendations given above.

1. To maintain the Wedel dredging hot spot it is recommended to continue to operate the sediment trap. Supported by a sediment trap the WSV is able to reduce or even avoid navigation-related, and hence short-notice, maintenance dredging to ensure fairway depths in the following periods:

   i. April 15th through June 30th: To protect the twaite shad hopper maintenance dredging may only be performed if it is ensured that no spawning activities take place in the main spawning grounds of the twaite shad (Schwinge mouth to Mühlenberger Loch) (official approval of the proposed plan to adjust the fairways of the Unterelbe and Außenelbe to accommodate container ships with a draught of 14.5m of 23 April 2012),

ii. May to September: This is the period that shows maximum sedimentation activities and thus requires extensive maintenance dredging by the WSV. At the same time, efficient high-capacity hopper dredging is more difficult due to low sediment consolidation rates.

2. Maintenance of the Wedel sediment trap is to take place from March to April 15th at the latest. After that, to protect the twaite shad, hopper dredging may only be carried out under certain conditions (see 1i).
3. In order to increase the effectiveness of the Wedel sediment trap in the periods mentioned under 1i. and 1ii., it is recommended to install the trap at a greater depth applicable in particular to partial areas where local sedimentation rates are highest.
4. Furthermore, it is recommended to extend the sediment trap geometry to sedimentation areas not considered so far. These are located directly downstream of the current Wedel sediment trap and there in particular on the Lower-Saxony side of the fairway.
5. The increase of the sediment trap depth and the extension of the sediment trap geometry should take place gradually whilst simultaneously monitoring sedimentation rates.
6. No additional maintenance of the Wedel sediment trap should take place from July through November. Due to low headwater inflows a mostly upstream transport of relocated fine sediments (keyword: dredging cycle) must be reckoned with in the relocation site area (VSB) 686/690[8]. If the sediment trap is full, individual dredging necessary for navigational reasons should be carried out only if and to the extent required.
7. It is recommended to continue the major sediment trap monitoring campaigns:
   i. Capturing of sedimentation processes using echo-sounding and
   ii. Capturing of the sediment inventory by taking sediment samples.

[8] This is based on the assumption that the entire material dredged in the area the WSA Hamburg is in charge of will continue to be relocated to VSB 686/690 as was the case from 2008 through 2011.

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