THE HIDDEN RISKS OF H₂S
toxic, flammable and explosive

ESTUARIES ARE ELUSIVE
how to manage sediments on the move

TO DREDGE OR OVERDREDGE?
when design depth is not deep enough
COVER

Although modern dredging vessels have undergone great advances in horizontal and vertical dredging accuracy, many variables remain. These can result in the need for overdredging. If financial expectations about overdredging are not specified in the contract, conflicts may arise (see page 24).
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“A well-executed dredging project has positive effects on the area’s economy, its environment and the quality of life of its residents. This was the important message expressed to the 22 key staff and decision makers from port management, public authorities and consultancies who attended a week-long course on dredging and reclamation at the International Institute of Hydraulic and Environmental Engineer (IHE) in Delft, the Netherlands”.

So began an article in Terra et Aqua describing the very first International Seminar on Dredging and Reclamation held in March 1993. Developed and sponsored by the IADC in cooperation with IHE, it would turn out to be the first seminar of many. But at the time it was an experiment. And no one knew for certain whether interest in ‘dredging and reclamation’ would continue and where it would lead.

Over the next 22 years three things became obvious: First of all, the seminar was indeed well received and continues to this day to attract participants eager to learn about dredging. Since its launch, this intensive course has been successfully presented to diverse groups of people from many, many countries – from Africa, Asia and the Americas – in a variety of locations such as Singapore, Dubai, Argentina, Brazil and Delft. In June of this year the seminar will be presented for the 50th time in Delft. Certainly reason to celebrate.

Secondly, the core value of the seminar remains the same. Over time, of course, the seminar has been updated regularly by dedicated engineers, so that it reflects the ‘state-of-the-art’ dredging industry. But, as indicated in the first paragraph, the IADC’s commitment to education, to encouraging young people to enter the field of dredging, and to improving knowledge about dredging throughout the world remains constant. More than 1000 people from a wide variety of backgrounds have gained understanding of dredging works, equipment and modern dredging techniques from the IADC seminar.

And thirdly, well-executed dredging projects continue to improve the quality of life for people all over the globe. To name a few elements of progress: Capital dredging projects that create more land for airports and ports, for residences and recreation and whilst doing so create jobs as well. Maintenance work to keep access channels open and canals like the Suez and Panama able to accommodate ever larger cargo ships. And innovative constructions for coastal defense and flood protection, as well as remediation dredging that cleans rivers and harbours suffering from industrial wastes. In this year of the IADC’s golden anniversary it is entirely appropriate that also its seminar, a cornerstone of its educational efforts, will be presented for the 50th time (see page 32).

The articles in this issue of Terra also represent the advancements of the industry’s capabilities and concerns. In the first article, the safety risks of H2S accumulation are addressed. In the second article the Elbe estuary in northern Germany demonstrates the data, modelling and analysis tools that can help manage sediment transport. And lastly, contractual specifications regarding overdredging are suggested so as to avoid conflicts and unnecessary costs. In all three cases, ongoing research has led to the development of new technologies that make the industry ever more efficient and effective. With, as stated above, “positive effects on an area’s economy, its environment and the quality of life of its residents”.

Participants in the first seminar came from 13 different countries including Sri Lanka, Indonesia, Iran, Vietnam, Philippines, India, Pakistan, China, Cuba, Trinidad, Mexico and the Dominican Republic.
ABSTRACT

The release of H₂S (Hydrogen Sulphide) is a known risk in the dredging industry. It is a highly toxic and flammable gas (flammable range: 4.3-46%). Being heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. In addition, it is very pungent at first, but quickly deadens the sense of smell, so that it may easily go unnoticed and victims may be unaware of its presence until it is too late. H₂S is highly poisonous with both long- and short-term effects similar to those of carbon monoxide.

This article focuses on the H₂S exposure which can occur during traditional dredging works and suggests some possible preventive measures such as recognising the H₂S risk during the tender phase and taking measures to minimise it. As well, alerting crews to the risk and training them to prevent H₂S risks are crucial.

INTRODUCTION

The first step is to understand Hydrogen Sulphide (H₂S). The release of H₂S is a known risk in the dredging industry. The gas typically accumulates in certain layers of the seabed, where organic material is decomposing in anaerobic (absence of oxygen) conditions. Known H₂S sensitive areas are mangrove ecosystems in river estuaries, harbours with an extensive history of fishing activities and PASS (Potential Acidic Sulphate Soils).

Hydrogen Sulphide is a highly toxic and flammable gas (flammable range: 4.3-46%). Being heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. Although very pungent at first, it quickly deadens the sense of smell, so victims may be unaware of its presence until it is too late. Hydrogen Sulphide is considered a broad-spectrum poison, which means that it can poison several different systems in the body, although the nervous system is most severely affected. The toxicity of H₂S is comparable with that of carbon monoxide.

RECOGNISING POTENTIAL H₂S RISKS

Long-term, low-level exposure to Hydrogen Sulphide may result in fatigue, loss of appetite, headaches, irritability, poor memory and dizziness. Short-term, high-level exposure can induce immediate collapse, with loss of breathing and a high probability of death. The recognised effects on the human organism of increasing concentration of H₂S are:

• 0.0047 ppm is the recognition threshold, the concentration at which 50% of humans can detect the characteristic odour of Hydrogen Sulphide, normally described as resembling "a rotten egg".
• 5 ppm is the long-term exposure limit (8 hour time-weighted average).
• 10 ppm is the short-term exposure limit (15min period).
• 10-20 ppm is the borderline concentration for eye irritation.
• 50 ppm is the acceptable maximum peak above the ceiling concentration for an 8 hour shift, with a maximum duration of 10 minutes.
• 50-100 ppm leads to eye damage.
• At 100-150 ppm the sense of smell disappears, often together with awareness of danger.
• 320-530 ppm leads to pulmonary oedema with the possibility of death.

Note that the exposure to H₂S risks in the dredging industry comes in two different forms:

- during traditional dredging works, e.g., dredging by means of a cutter suction dredger (CSD), trailer suction hopper...
dredger (TSHD) or backhoe dredger (BHD), the H2S release is caused by the vessel’s seabed disturbing activities,
- during works near offshore platforms (e.g., rock installation, cable laying, and such), H2S release is associated with the client’s offshore drilling activities.

This article focusses on the H2S exposure during the traditional dredging works and possible preventive measures.

**Characteristics of H2S**
H2S is slightly heavier than air ($\rho = 1,36 $ kg/m$^3$), so once released as a result of dredging activities it will descend to the lower parts of the vessel.

H2S has a moderate solubility in water. Depending on the water temperature, this varies from 7 g/kg at 0 °C to approximately 1.5 g/kg at 60 °C. This means between 7000 ppm to 1500 ppm H2S is dissolvable in one litre of water (Figure 1).

In the liquid phase, different forms can occur:
- H$_2$S as the non-dissociated form (volatile);
- HS$^-$ or S$^{2-}$ as the two dissociated forms (non-volatile)

Neutral water has a pH value of 7 and at this value there is equilibrium of 50% H$_2$S and 50% HS$^-$. As from pH 5, 99% will be non-dissociated meaning that slightly acid to acid water will contain mainly volatile H$_2$S (Figure 2).

**The stripping effect**
A volatile compound is characterised by its
RECOGNISING POTENTIAL H₂S RISKS ON DREDGING PROJECTS

When a project is being tendered for, the potential for H₂S presence has to be determined. Geographical and geologic information will already give a good indication for potential H₂S presence at the dredging location. Certain eco-systems are more likely to contain large quantities of H₂S piled up in particular layers of the geologic profile. Clay soils pose a higher potential for H₂S risks because its compact/dense structure allows for anaerobic decomposition. Dredging sand almost never releases large amounts of H₂S, as sand is very porous and thus allows gases to migrate.

If not already done on behalf of the client, soil samples can be analysed and scanned for H₂S presence. In the case that the presence of H₂S is indicated, then the project safety plan should define the technical and strategic measures to be implemented, e.g., detection systems and technical adaptions to the vessel. Emergency procedures should include responses to H₂S release and intoxication.

H₂S is a very reactive/corrosive gas. It affects metals like copper and brass, causing short-circuits on electrical components. This has been identified as the direct cause of fires on dredging vessels (Figure 3). Limiting the turbulence inside the hopper (of a TSHD or SHD) is the keystone of the H₂S-preventing strategy on board dredging vessels.

Henry’s law constant which is a criterion for describing air–water partitioning of solutes such as H₂S (known as the stripping effect). This value will reduce as the water temperature decreases, implying that colder water means less stripping, i.e., H₂S that stays dissolved in liquid condition.

Two other important factors have a significant impact on the stripping effect:
- The amount of H₂S in gaseous condition above the water surface (more H₂S in the air results in a reduced stripping effect).
- Contact-surface: increasing turbulence in water holding H₂S means an enlarged contact-surface which results in more H₂S migrating towards the gaseous condition.

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A Common Sense Approach for H₂S Release During Dredging
LIMITING H$_2$S RELEASE

Although there are a variety of theoretical options to limit the exposure to H$_2$S on a dredging vessel, the practical and feasible options are limited to a few engineering and procedural controls. These effective measures to limit a H$_2$S release are: covering the hopper; limiting the turbulence in the hopper; and diverting the airflow intakes on board.

Covering the hopper

Covering the hopper of a TSHD or SHD with a fabric restricts H$_2$S from reaching vulnerable areas. When the air above the water is saturated with H$_2$S gas, no more H$_2$S can be stripped from the dredged material into the air. In conjunction with covering the hopper, the air below the cover must be discharged at one side of the vessel. Therefore:

- the cover must have proper sized inlet vent(s) to get the hopper in an ‘under-pressure’ situation (inlet needs to allow a flow of at least 0.5 to 1 m/s);
- the mechanical fans to blow the H$_2$S containing air form below the cover, must be large enough to keep a sufficient under-pressure;
- mechanical fans and inlet vent(s) need to be of appropriate size; and
- special attention must be given when opening the bottom doors of the hopper as this creates a high under-pressure.

Emptying the hopper at a reduced speed and opening the hopper cover partially are crucial to the process.

Limiting turbulence in the hopper

Dissolved H$_2$S is released much faster as turbulence increases. Inside the hopper the main sources of turbulence are:

- dropping the dredged material from a high height in the hopper while loading (Figure 4) and
- discharging through the overflow system.

Both features cause agitation on the water surface, air-bubbles in the dredged material and an increasing contact surface between water/air. Dropping the dredged material from a lower height causes less oxygen to get absorbed and thus less stripping of H$_2$S. The effect of turbulence is further reduced if the discharge takes place below the water surface.

Taking into account the various types of dredging equipment, dredging by means of a backhoe or dipper dredger is considered as the best option to reduce H$_2$S release as the dredged material is not subjected to heavy turbulences and it can be kept in underwater or submerged conditions.

During loading of a TSHD or SHB, the use of a “deep load installation” strongly reduces the H$_2$S stripping effect. Lowering the discharge point to +/- 2 m from the bottom (preferably...
Diverting the active carbon (A/C) intake(s)

With large flexible or hard ducts it is possible to divert the active carbon (A/C) intake to known places with much less H₂S (fore ship, monkey bridge, behind accommodations and such). Below mentioned measures can further reduce the risk to H₂S reaching the vessel’s interior:

- Dredging with a TSHD in a direction perpendicular to the wind direction
- Providing an A/C system with adjustable intake positions
- When filling up the hopper the A/C shall be switched to recirculation
- Keeping all exterior doors, hatches and windows closed during dredging.

Filtering the A/C intake(s)

There are various techniques available on the market to filter the accommodation air. Only a few however are feasible on board a dredging vessel. The most interesting technique is adsorption of H₂S by a suitable adsorbent, such as NaOH, KOH or K₂CO₃ impregnated active carbon. By utilising custom-made filters, the air can be purified prior to entering the accommodation.

A Common Sense Approach for H₂S Release During Dredging

below water surface from the start) at the centre of the hopper is most effective. Keeping a certain space between the bottom of the hopper and the discharge point, prevents the pipe from getting clogged-up by solid materials.

Also limiting the discharge velocity prevents H₂S stripping. This can be achieved by using a larger pipe diameter and/or making certain adaptations to the end discharge point of the pipe.

The pictures in Figure 5 illustrate adaptations made on board of TSHDs. They range from simple modifications of the discharge pipe (extending + metal diagonal insert) to placement of a complete “deep load installation”.

AVOIDING THE ENTRANCE OF H₂S GAS INTO THE INTERIOR SPACES OF THE VESSEL

Through the air intakes (e.g., air supply for the air-condition system) or simply through door and hatch openings, H₂S gas can easily migrate from the exterior towards the inside of the vessel. Two proven methods to avoid H₂S being sucked into the vessel’s interior spaces through air intakes are diverting air intakes to locations where H₂S is not present and filtering of the A/C intake by means of active carbon filters. In addition to these measures, all other openings such as doors and hatches shall be kept closed during dredging.

Note that based on this understanding, the standard position of accommodation A/C intake on new vessels is located at the side or front of the vessel instead of above the hopper (Figure 6).

Filtering the A/C intake(s)

There are various techniques available on the market to filter the accommodation air. Only a few however are feasible on board a dredging vessel. The most interesting technique is adsorption of H₂S by a suitable adsorbent, such as NaOH, KOH or K₂CO₃ impregnated active carbon. By utilising custom-made filters, the air can be purified prior to entering the accommodation.

MONITORING H₂S RELEASE

Having proper gas detection on board is essential to monitoring H₂S release. Measurements can be personal or on fixed places on board the vessel. All gas detection equipment has built-in alarms according to Time Weighted Average (TWA) and Short Term Exposure Level (STEL) values, defined by European legislation:

- TWA* = Time Weighted Average = long term exposure = 8h period = 5ppm
- STEL = Short Term Exposure Level = 15min period = 10ppm

*Other ways to express TWA are MAC (Maximum Acceptable Concentration) or TLV (Threshold Limit Value).
Personal detectors
To warn crew for H2S, small single gas detectors such as type ToxiRAE III can be used. Single gas detectors are mostly non-pumped and do not have the capability to log the measured data. Multi-gas detectors such as type QRAE II can also be provided with an H2S sensor and have an in-built pump, which makes it's more suitable for outdoor measurements. The QRAE II does data-logging (Figure 8).

Fixed detection
A fixed detection system consists of multiple detectors which are strategically placed (in the hopper, A/C inlets, ER, ECR,...). These fixed detectors are connected to each other and are communicating with a central alarm box (often placed on the bridge). The connections can be either wireless or via fixed cabling. The advantage of wireless systems is that they can be easily relocated from one vessel to another (e.g., after a project is finished) but they have a limited battery life which is regarded as a disadvantage. H2S Meshguard system kits are another system being used on various vessels.

Default the kit comes with 6 H2S detectors, a router (signal seeker/enhancer) and an FMC2000 controller/alarm box. A Meshguard network can be established and expanded up to 26 detectors.

Data logging
When using devices that have data logging, it is possible to monitor certain locations on board for longer periods or even on a permanent basis. The portable QRAE II devices can be connected to a computer and by using the provided software and measured data can be consulted for interpretation. Via the internal modem, the wireless Meshguard H2S sensors are sending their data to the central controller on the bridge, where it is stored on an SD memory card. Depending on the used detection mode, this can be either 24/7 or with a pre-set interval (default every ½ min) and/or whenever an alarm value is detected (Figures 9 and 10).

CONCLUSION
The release of H2S (Hydrogen Sulphide) is a known risk in the dredging industry. It is a highly toxic and flammable gas and can cause debilitating health conditions. The exposure to H2S risks in the dredging industry comes in two different forms, during traditional dredging works and as a result of the client's offshore drilling activities. The situation addressed here was that caused by traditional dredging. In this case recognising the H2S risk during the tender phase is essential and possible.

Knowing the risk early on allows the contractor to prepare a safe work environment and to include the costs for required measures such as detection systems in the price offer. Also, if an increased H2S risk is determined, the initial dredging method can be substituted by a safer method (e.g., backhoe dredger) or engineering controls can be put in place, e.g., by installing a deep load box on a TSHD within a reasonable timeframe.

When a risk is possible, use of gas detection equipment on board to measure H2S is crucial. It helps to monitor the effectiveness of the H2S prevention measures and gives timely warning to the crew when these are failing. And last but not least: Every crewmember needs to be made aware of the H2S risk and trained in preventive measures including the use of specific personal protective equipment (PPE).
ABSTRACT

The tidal Elbe estuary in northern Germany serves as an example to show the kind of data, modelling and analysis tools that are required for a qualitative and quantitative description of sediment transport in an estuary. These methods can be used to investigate sediment management options. First a brief overview of the historic development of the Elbe estuary is presented, followed by a description of the modelling system used in this study. Thereafter measurements and model results for sediment transport in the Elbe estuary are reported. Lastly the article looks at specific model applications for sediment management tasks.

INTRODUCTION

Estuaries are strongly influenced by tidal waves on the one hand and salt water, mixed water and freshwater zones on the other and they transport large volumes of sediment along with their alternating currents. The deeper the water in fairways, the higher the tidal exchange volume and the higher the amounts of sediment that can be transported with the flowing water mass. As a result, dredging operations become more intensive.

In Germany, for example, more than 45 million m³ of sediment material are dredged every year to maintain the required fairway depths. With over 40 million m³, the material dredged in sea waterways and seaports accounts for the major share of dredging operations. Considering these volumes it is clear that sediment transport processes in estuaries are of eminent importance. One of the main objectives is to stop the continuing increase in the amount of dredging material and rising dredging costs – even if the trend towards greater ship sizes continues unbroken.

Most of the dredged material is transported to temporary disposal sites in the estuary. This means that the material remains in the system, thus influencing sediment transport rates and consequently also the estuary’s morphological development. When choosing a disposal site, hydromorphological criteria as well as nature conservation aspects have to be considered. As a rule, the spreading of the relocated dredged material is considered a desired effect, for instance, while resedimentation in dredged areas should be avoided since this would encourage repeated sediment and dredging cycles. By choosing suitable disposal sites and times, it might also be possible to promote beneficial morphological developments. The evolution of the Wadden Sea, for example, is extremely important as it compensates for the impact of the sea level rise.

An understanding of the hydrodynamic and morphodynamic influences in an estuary and knowledge about the relationships with water quality parameters are therefore an essential scientific prerequisite for the optimum management of sediment. An example is the upstream transport of sediments caused by tidal pumping and the influence of baroclinic processes on the water flow and sediment transport in the estuary’s gradient zone. Both are crucial factors in sediment transport and are the main cause of potential sediment cycles. Consequently, they need to be taken adequately into account when designing and implementing a sediment management strategy.
In this article the tidal Elbe serves as an example to show which kind of data, modelling and analysis tools are required for a qualitative and quantitative description of sediment transport processes in an estuary. These methods can be used to investigate sediment management options. In the second section, a brief overview of the historic development of the Elbe estuary is provided followed by a description of the modelling system used in this study. The next section presents measurements and model results for sediment transport in the Elbe estuary and finally, specific model applications for sediment management tasks are considered.

**THE ELBE ESTUARY – A BRIEF OVERVIEW**

The Elbe estuary is a very important German waterway. Its mouth is situated in the south-east of the German Bight, with the weir in Geesthacht defining the tidal limit. The entire length from the weir to the mouth, which has a width of approximately 15 km, is more than 160 km (Figure 1).

Over the centuries, the Elbe estuary has been modified several times to meet the changing requirements of maritime traffic. Between 1860 and 1999 the fairway was deepened up to 10 m. Furthermore, a range of measures, such as the construction of the weir in Geesthacht, the cut-off of tributaries, the backfill of harbour basins, as well as diking and poldering, have been carried out in the last 50 years. Today the morphology of the Elbe estuary is characterised by a deep fairway leading to the Port of Hamburg and a complex system of islands, tributaries and branches in the landward section of the estuary as well as extensive tidal flats and tidal creeks in the seaward section.

Anthropogenic measures have given rise to changes in tidal characteristics and sediment transport processes. Figure 2 shows the mean high water and the mean low water at a tidal gauge in St. Pauli, Hamburg, from 1900 to 2010. The tidal range has increased considerably (1 m in the last 35 years) owing to a fall in the low water level and a rise in the high water level. The asymmetry of the tidal curve is enhanced, i.e., the flood current has become shorter but now reaches higher velocities, the slack tide between flood current and ebb current has become longer, and the ebb current has also become longer with smaller current velocities. This hydrodynamic behaviour is probably the main reason for the enhanced “tidal pumping” of sediment upstream. Sediment is transported upstream with the strong flood current and then settles during the slack tide with less sediment mass being transported downstream with the weaker ebb current. The net transport of sediments depends on strength of the head water discharge (see below, ‘Sediment transport in the Elbe estuary: Model results’). Ongoing maintenance dredging of the channel has been necessary in order to...
guarantee the safety of shipping traffic. The amount of maintenance dredging has increased significantly since the last deepening in 1999, especially in the upper region of the estuary near Hamburg (see Figure 3). Figure 3 also shows a change in the management strategy for fine sediments. Since 2008, all fine sediments dredged downstream of Hamburg have been disposed on sites located in the turbidity zone (Figure 1) in order to enlarge sediment cycles. As a consequence, the amount of dredging near Osteriff has increased.

Another noticeable peak can be seen in a section in the outer estuary called “östliche Mittelrinne”. The amount of dredged sediments doubled in 2008 and more sediment also needs to be dredged in the neighbouring sections. The reason for this strong increase can be found in the large-scale morphodynamics of the Outer Elbe caused by a chain of pronounced hydrological and meteorological events. In the winter season 2007/2008 the number of tidal high water events (Thw > 2.40 m NHN) was significantly larger than usual (BAW, 2013). Thus the hydrodynamic load on the shallow areas in the Wadden Sea owing to wave and current actions was higher and more sediment was moved.

Morphological development in the Outer Elbe is a very important issue, not only with respect to dredging amounts, but also for the evolution of the Wadden Sea as an important habitat and its meaning for coastal protection and of course for the hydrodynamics of the whole tidal Elbe because of the dissipation of tidal energy in the outer area. The morphological development of the last 40 years is shown in Figure 4. It is strongly influenced by the longitudinal dike “Kugelbake” north of Cuxhaven. On the one hand, millions of cubic metres of sediment are lost in some areas and, on the other, millions of cubic metres of sediment must be dredged every year to maintain the fairway.

All of these issues require monitoring, scientific investigation and system analysis of sediment transport processes using modern numerical methods. A better understanding of the cause-and-effect chain which has brought about these apparently anthropogenic driven changes to the estuary is required.

MODELLING SYSTEM
The model runs described below are performed with the UnTRIM hydrodynamic and suspended transport model in combination with the SediMorph morphological model and – for some applications – in combination with the dredging module DredgeSim:

- **UnTRIM** is a computational model for solving a variety of two- and three-dimensional differential equations relating to hydrostatic and non-hydrostatic free-surface flow and transport in water bodies (Casulli and Walters, 2000; Casulli and Zanolli, 2002, 2005; Lang, 2005).
- **SediMorph** is a software package for the two- or three-dimensional simulation of fractioned sediment transport processes within the bottom and at the bottom surface bodies (BAW, 2005).
- **DredgeSim** can be used to take account of dredging and disposal actions in free surface flows. This allows the anthropogenic influence on sediment transport and morphology to be considered and maintenance strategies to be developed and evaluated focusing on different optimisation criteria (e.g., minimising dredging costs). DredgeSim can be used in two different modes. In each case the user has to define dredging and disposal areas. The date, time and amount of dredged material and its deposition is prescribed by the user in the time controlled maintenance mode. In this criterion controlled maintenance mode dredging is initiated according to prescribed dredge criteria, for instance if a deposition area in the shipping channel affects navigability. This simulation module was developed in cooperation with BAW and the University of the Armed Forces, Munich (Maerker and Malcherek, 2007).

The interaction of the simulation modules...
used in the applications is shown schematically in Figure 5. The modelling system contains all the necessary simulation modules which will enable it to be used as a tool for predicting estuary responses to proposed management options. Results presented in this article are produced with validated models from the Elbe estuary (BAW, 2006, 2012).

**SEDIMENT TRANSPORT IN THE ELBE ESTUARY**

**Measurements**

Field data of sediment concentrations and transport rates, which can be used for calibration and validation purposes, must be collected in special measurement campaigns. A medium-term field programme was initiated in 2006 (and repeated in 2010 and 2011) with the aim of improving the understanding of the suspended sediment regime and of building up a database for validation of the numerical model.

The field data collection programme covers the entire Elbe estuary and provides data on suspended solid concentrations and transport rates. Acoustic Doppler Current Profilers (ADCPs) are used for the measurements as these can provide data over (nearly) the whole depth range in a temporal and spatial resolution which is very suitable for numerical models. Some results of measurements along cross-sections are presented in this chapter. Further results and more detailed technical information can be found in Maushake and Aardom (2007) and Mol (2007).

The measurements were carried out in autumn 2006. The head water discharge in this period was below 400 m³/s. A total of three cross-section measurements have been performed, each representing a characteristic hydrographic regime (Cuxhaven: marine zone; Rhinplatte: turbidity zone; Hamburg: fluvial zone). In total, the cross-section measurements comprise more than 200 ship-mounted crossings on three transects, each one covering the period of one tide with around 160 calibration sites and more than 300 water samples.

Some measured distributions of suspended sediment concentrations for three cross-sections are shown in Figure 6. Each case, the maximum concentration during ebb and flood currents has been selected for each profile. Transport rates and transport fluxes can be computed directly from the collected datasets as ADCPs combine a current sensor and a SSC sensor in a single device which provides velocity and suspended sediment concentration profiles in the same area. Measured sediment concentrations, transport rates and velocities are shown as cross-section integrated values in Figure 7.

**Cross-section at Hamburg**

The maximum flood concentrations at the entrance to the Port of Hamburg (Hamburg profile) are much higher than the maximum ebb concentrations. Peak values of mean measured concentrations of more than 0.4 g/l are reached during flood, followed by a decrease to 0.05 g/l during slack water at high tide (Figure 7). The ebb current is slower than the flood current owing to the significant tidal asymmetry in this part of the estuary. Thus the sediment concentrations during ebb are lower than those during flood and reach maximum values of 0.2 g/l. The concentrations again decrease to 0.05 g/l during slack water at low tide. The calculated sediment flux is a distinct indicator of the flood-dominated transport regime in this area: During flood current the transport of 27000 t suspended sediment was measured, during ebb current only 13000 t.

**Cross-section at Rhinplatte**

In the turbidity zone of the Elbe estuary (Rhinplatte profile) the concentration in some areas sometimes increases to over 2 g/l, for example at the sides of the navigation channel (Figure 6). Higher values probably occur near the bottom, but the measurement method is not valid for this reach. Thus the real sediment fluxes must be higher than calculated fluxes based on measurements. Values of mean (cross-section integrated) measured concentrations of more than 0.6 g/l are reached during flood peak, followed by a decrease to 0.10 g/l during slack water at high tide (Figure 7). The sediment concentrations during ebb are higher than during flood and reach maximum values of 0.7 g/l. This peak concentration at the end of the ebb current is probably caused by a muddy area located a few kilometres upstream of this cross-section. This does not necessarily indicate an ebb-dominated transport regime because the length of the cross-section navigable with the vessel was shorter during the ebb and thus lateral areas with lower sediment concentrations are not taken into account. During both flood and ebb current the transport of 72000 t
suspended sediment in each tidal phase was measured.

*Cross-section at Cuxhaven*
The lowest concentrations were measured in the marine transect near Cuxhaven. The maximum of the ebb current is located in the western area of the profile and during flood the maximum current velocities occur at the eastern area of the profile. Thus the pattern of suspended sediment concentration looks different (Figure 6). Because of the high current velocities in this area, the morphology is mainly affected by sand transport. The averaged measured sediment concentrations are small and vary between 0.02 g/l and 0.11 g/l with a tidal-averaged value of 0.07 g/l (Figure 7). During flood current as well as ebb current the transport of 30000 t suspended sediment was measured.

**Model results**
These data were used in a calibration process. The site-specific model was first calibrated using bathymetric and hydrologic conditions from 2006. During the calibration process the influence of settling velocity formulations was also investigated. This process cannot be described here in detail. One of the main findings was that none of the tested settling velocity formulations works well for the whole estuary. The model set-up using two suspended sediment fractions each with constant settling velocities delivered the best results. However, flocculation processes, which are probably responsible for the strong decrease in sediment concentrations during slack tides, have not yet been considered satisfactorily in the model. Despite this weakness, mean sediment concentrations and transport rates calculated from the model are qualitatively and quantitatively in an acceptable range for the entire Elbe estuary, i.e., the model reproduces, in a broad sense, the general nature of sediment dynamics in the estuarine system.

Figure 8 shows a comparison of measured and modelled current velocities and sediment concentrations at the cross-section Glückstadt/Rhinplatte. In general, measured values are more scattered and modelled values are smoother. The vertical distribution of sediment concentrations is more pronounced in the measurements. High concentrations near the bottom seem to be underestimated by the model, but on the other hand measured data are often not valid in this region.

Results of measurements and model results for a similar set-up of the Elbe model 2010 are shown in Figure 9. Measured and modelled current velocities, sediment concentrations, discharges and sediment fluxes at the cross-sections at Elbe-Km 689 are averaged over the cross-section area. Note that with this calibration procedure the model ran already nearly 6 months until it was compared with measured data, i.e. the hydrologic history is inherent in the model results. Overall the model fits the measured data well. This model is used for the morphodynamic application described under “Modelling in dredging situations” below.

In further specific model applications only the head water discharge is varied (Q = 180, 720 and 1260 m³/s) in order to investigate the influence of head water discharge on hydrodynamic and sediment transport processes. All other model steering parameters, including initial conditions such as sediment and salinity distribution and other boundary conditions and values, were uniform for all model runs.

The model runs cover a four-week simulation period (June 2 to June 30 2006). The analysis of the model results starts after nine days of simulation (June 11 2006 to June 25 2006). During this period (one spring-neap-cycle) all model results are stored every ten minutes. In several post-processing steps these data are analysed to calculate the minimum, mean and maximum values of water level, current velocities, salinities and sediment concentrations for each element. In addition, the sediment transport across defined cross-sections and along defined long-sections is calculated for each model run. This analysis provides a set of metrics which are useful to describe the system behaviour and provides a
suspended sediments. Together with the knowledge about absolute transport rates, this ratio constitutes an important criterion, for example, for assessing placement sites. The highest values of this ratio occur near the Port of Hamburg at low discharges.

There are two hydrodynamic reasons for this basis for comparison between model runs. Figure 10 shows, on the right side, suspended sediment concentrations along the fairway. These are time-averaged values of three-dimensional model results for one spring-neap-cycle. A turbidity maximum exists in all model runs. A higher fresh water discharge flushes the suspended sediments to the sea. Higher sediment concentrations occur in these runs. On the left side the ratio between the suspended sediment transport rates during flood current and during ebb current is shown. This value does not provide any information about quantities, but instead characterises the transport regime of suspended sediments. Together with the knowledge about absolute transport rates, this ratio constitutes an important criterion, for example, for assessing placement sites. The highest values of this ratio occur near the Port of Hamburg at low discharges.

There are two hydrodynamic reasons for this
Figure 7. Measured current velocities, sediment concentrations and sediment fluxes at the cross-sections Hamburg / Blankenese (upper graph), Glückstadt / Rhinplatte (middle graph) and Cuxhaven (lower graph). The values are averaged over the cross-section area.
transport behaviour – baroclinic effects owing to density gradients and tidal pumping, both indicated in Figure 10. The influence of baroclinic processes on the sediment transport is high. The strong dominance of the near-bed transport in flood direction between Cuxhaven and Brunsbüttel, which is also visible at higher head water discharges, may indicate further sediment cycles in the Elbe estuary. Furthermore the model runs for low or mean head water discharge predict distinct sediment transport in flood direction, at least upstream of Brunsbüttel. This transport characteristic is caused by tidal asymmetry, already described above in the overview of the Elbe. Owing to these transport characteristics fine sediments accumulate over the long term in this part of the Elbe and lead to an increase in the amount of maintenance dredging.

Monitoring of dredging activities
Dredging and disposal actions lead to changes of morphology, of sediment concentrations and thus to changes in the net transport of sediments. The spreading of sediments and changes in sediment concentrations may offer economic and ecological criteria for comparing and evaluating realistic dredging and disposal scenarios (location, tidal phase, sediment properties and such). Detailed data of real dredging and disposal actions, or at least information about the applied sediment management strategy, are also needed for mid-term or long-term morphodynamic simulations.

Usually only information about the yearly amount of dredging volume for certain sections of the waterway are available (Figure 3). A detailed spatial and temporal analysis of these data is not possible and this kind of data is therefore not appropriate for use in a numerical simulation.

Dredging data which can be used for a model run must describe the dredging and disposal action in great detail:
- A polygon to describe the dredging area
- Date and time of dredging
- Volume and density of dredged sediments
A polygon to describe the disposal area
• Date and time of disposal
• Several identification numbers for a distinct description of the dredging cycle.

If these data are available, dredging and disposal actions can be considered in detail during a numerical simulation. Since 2009, most of the dredging vessels working in the Elbe estuary have been equipped with the sensors needed for operational monitoring purposes and the data is now available for further investigations. If the morphodynamic model is only driven by dredging data, only that part of the bottom evolution becomes visible which is influenced by dredging operations. Figure 11 shows dredge polygons near Osteriff and resulting bed evolution based on monitoring data from the year 2010.
Figure 12. Schematic view of the management concept for fine sediments, applied 2005-2011.

Figure 13. Spreading of fine sediments from the disposal site at Elbe km 738, indicated by maximum sediment concentrations of coarse silt eroded from the disposal site.
the incoming tidal energy. Possible measures include construction of hydraulic structures, the enlargement of shallow water areas in the Outer Elbe and the construction of additional tidally influenced areas in the upper part. Further, optimised dredging and disposal strategies are aspired to reduce volumes of dredged material. This includes identifying and enlarging or destroying dredging cycles, where dredged material which is disposed in the estuary is transported back to dredging sites. This can be achieved by disposing of fine sediments in a more ebb-dominated transport regime. Coarse particles, in contrast, can be used in construction measures. Further, the influence of the head water discharge as well as the time-dependent change of the flow regime can be used to optimise dredging and even more disposal activities.

Construction measures are mainly investigated to overcome the negative effects arising from flood dominated tidal characteristics and associated sediment transport. This can be achieved by creating a bigger tidal volume upstream and by increasing the dissipation of near Osteriff and the resulting bed evolution based on monitoring data from the year 2010.

APPLICATION TO SEDIMENT MANAGEMENT TASKS

Sediment management concept

Currently, the maintenance concept for the Elbe estuary is a sediment management system combining different hydraulic engineering activities. It includes construction measures and optimised dredging actions and was developed in cooperation with all the associated authorities (HPA and WSV, 2008). This concept is in a continuous process of ongoing development and completion (BAW, 2013, BfG, 2014).

Construction measures are mainly investigated to overcome the negative effects arising from flood dominated tidal characteristics and associated sediment transport. This can be achieved by creating a bigger tidal volume upstream and by increasing the dissipation of areas. This enables the sedimentation processes to be steered in the estuary and the entry of fresh sediments in polluted harbour basins to be avoided. Currently, most dredged material is disposed of within the estuary (Figure 12). Furthermore, the Hamburg Port Authority has had temporary permission to dispose of a certain amount of fine sediments in the North Sea. As a result, around 1 million m³ of fine sediment was removed from the estuary every year between 2005 and 2011. A smaller amount, polluted by different contaminants which are transported and accumulating in the harbour from sources upstream, has to be treated and deposited landside.

This management concept still requires the treatment and deposition of polluted sediments. The improvement of the water quality of the river Elbe and its sediments is still an important goal and one which can only be fully achieved by stopping the emission of contaminations along the upstream
Modelling dredging activities

Finally the modelling system (see above) was applied to simulate hydro- and morphodynamics for the year 2010, whereby all known dredging and disposal operations were included. Figure 14 shows the modelled bottom evolution in the mouth of the Elbe estuary. Dredging sites as well as disposal sites are recognisable. Some larger scale morphological trends correspond well with observed changes (Figure 15), but overall the model set-up used for this run appears to overestimate erosion in some areas. Nevertheless the model is an indispensable tool for evaluating different sediment management strategies. It can be used to test management options and the difference between two model runs shows the impact of the variation.

Figure 15 shows the difference in topography from the year 2011-2010. Dredging sites are indicated as green polygons. The bottom evolution in the vicinity of the disposal sites is obviously influenced by disposal operations.

Investigation of disposal sites

The modelling system was applied to investigate the function of the disposal sites used in the Elbe estuary. The set-up of the model for this application is nearly identical to the studies described above in “Model Results”, but in addition to the initial sediment inventory three more sediment fractions are taken into account. These sediment fractions (fine, mean and coarse silt) have physical properties which are identical with the background inventory. These sediments are located at disposal sites and can be eroded and transported by the tidal current.

This kind of model application allows for detailed analysis of the transport behaviour of different types of sediments from different locations in the estuary. The spreading of the marked sediments shows the extent of influence of the investigated disposal site. This information, together with knowledge of dredging and disposal strategies, can be used to recognise sediment cycles.

This method was applied not only to all recent disposal sites in the Elbe estuary, but also to potential new sites, which may be more convenient (BAW, 2012, 2013). An example from this investigation is the spreading of coarse silt from the disposal site at Elbe km 738 as shown in Figure 13. The preferred transport direction is indicated by maximum sediment concentrations of coarse silt eroded from the disposal site. This is a proper site from a hydraulic engineering point of view because most of the sediments are transported in a south-east direction towards shallow areas, but not in the fairway, indicated by the black line. Thereby the formation of the Wadden Sea is supported or at least the erosion of sediments from this region is compensated.

Modelling dredging activities

Finally the modelling system (see above) was applied to simulate hydro- and morphodynamics for the year 2010, whereby all known dredging and disposal operations were included. Figure 14 shows the modelled bottom evolution in the mouth of the Elbe estuary. Dredging sites as well as disposal sites are recognisable. Some larger scale morphological trends correspond well with observed changes (Figure 15), but overall the model set-up used for this run appears to overestimate erosion in some areas.

Nevertheless the model is an indispensable tool for evaluating different sediment management strategies. It can be used to test management options and the difference between two model runs shows the impact of the variation.

Figure 15 shows the difference in topography from the year 2011-2010. Dredging sites known from monitoring data are indicated as green polygons. The bottom evolution in the
vicinity of the disposal sites is obviously influenced by disposal operations, as already seen in Figure 14. However, some larger morphological trends also appear to be influenced by the disposal sites, e.g., the depositions are south-east of the disposal site at Elbe km 738 (Figure 13).

Large morphological changes were observed in the mouth of the Elbe estuary. The reasons for these changes need to be better understood given that the morphological state of the Outer Elbe has a strong impact on the tidal dynamics of the whole estuary. If possible proper morphological developments should be supported by a flexible and adaptive sediment management strategy.

**CONCLUSIONS**

Especially in the region of the North Sea estuaries, a profound understanding of sediment processes and expert sediment management are indispensable. It follows from the relationships discussed above that it is advisable to pursue an optimisation strategy for handling the dredged material which fulfils several purposes: minimising costs and dredging volumes, but also meeting other objectives.

Optimised sediment management takes account of all the processes referred to above. At present, little is known about the long-term effects of the repeated removal of sediments.

More scientific and practical basic knowledge is needed. Such knowledge would be of direct benefit for sediment management and would contribute to understanding the system. Hence, there is a need for further development of existing approaches. Given the permanent hydromorphological changes in estuarine systems caused by both anthropogenic and natural influences, adapting and optimising sediment management strategies is a never-ending task.
ABSTRACT

Despite significant improvements in the past thirty years in precision of the dredging process and accuracy of hydrographic survey information overdredging is still an inherent part of dredging. Both port developers and contractors alike have to deal with the allowance for dredging beyond the Client’s design dredge depth. The two issues of dredging to design only and the operational capabilities of the dredge equipment and (unavoidable) overdredging need to be considered. Clear wording is required in contract documentation to deal with this aspect and in particular whether the overdredge volume is paid or included in the Contractor’s rates and prices. Disputes can and do arise when dealing with overdredging caused by the lack of clarity in the contract’s technical specifications and Preambles.

INTRODUCTION

Overdredging refers to the depth of dredged material removed from below a specified or required level. When designing a dredged channel, trench or berthing area the port authority needs to consider the required water depths and the navigation constraints of the vessels operating in and using the port when assessing its ‘design’ level. By ‘design level’ is meant the optimum dredge level which meets the needs of the largest vessels entering the port. This means due consideration must be given to the length, breadth and side slopes which may be needed in order to meet those needs. This in turn has an impact on the dredging Contractor and its ability to carry out the proposed dredging works.

Dredging tolerances come up at an early stage of the design process as once the port authority has decided its minimum design depth to accommodate future port users it will have to consider the likely dredge vessels to be deployed and their operating capability. The port authority will have to factor in to its environmental and resource permits not just what the design depth will be required but the likely final dredging depth following completion of the dredging works. Regulators need to know the total volume of material which is to be removed and set parameters in the extraction permits as well as any resource permit holder knowing if the volume of material is available and the total royalty amount that may need to be paid. Therefore adequate thought must be given to the factors which may influence the amount of overdredging which may ultimately result so that the permits accurately reflect the likely dredge depth which is finally achieved.

ACCURATE SPECIFICATIONS

The port designer when specifying the nominal (design) level would be well advised to consider the nature of the material to be dredged and well as the vertical accuracy of the likely dredging vessels under various site conditions as well as sounding accuracy and the likely sediment deposit between the port’s maintenance dredging campaigns. There is little literature available for the port designer to determine these factors other than that of PIANC and British Standards – BS 6349: Part 5 Code of Practice for dredging and land reclamation: 1991 sections 3.3 to 3.5 which deals with the horizontal and vertical accuracy of dredging equipment in various soil and rock conditions with adjustments for sea and current conditions (See BS 6349: Part 5, 1991: Tables 12 and 13).

This operational accuracy of dredging equipment is also referred to in Dredging: A Handbook for Engineers (Bray, Bates and Land
The port authority when selecting its overdredging tolerance also needs to be mindful of the likely type of equipment which may be selected for the dredging operation. For instance, a different degree of vertical and horizontal accuracy exists between say a grab dredger and a trailing suction hopper dredger. So the technical specification and measurement preamble should reflect the operational limitations of the equipment which may be selected and ultimately deployed on the project.

As part of this process a determination can be made of the nett and gross volumes, that is, the dredging to design level (nett) and the total dredging including overdredging (gross). When planning the execution of the dredging works the Contractor will be mindful of the gross dredging volumes as this is what needs to be dredged to achieve the design level. And it is the total gross volume to be dredged that will determine the total duration of the work as the planning of the works and any completion dates will be on the basis of gross volumes.

**PAYMENT**

As part of the contract documentation the port authority needs to deal not only with the issue of the likely amount of overdredging but also the volumetric measurement and payment for the work performed. The contract drafter may consider to base measurement under a contract on nett volume to be dredged: that is the quantity to be removed to design level, based on pre-dredge hydrographic surveys which establish the seabed levels before dredging. In order for contractors to achieve design levels however they will have to over-dredge; that means contractors need to remove more quantity than the nett quantity.

Whilst the dredging Contractor will be dredging gross volumes, the port authority wishes only that the works are dredged to the required design level and no further. This gives a potential area of conflict with the dredging Contractors wanting to be reimbursed for all work performed but the port authorities only wanting to pay up to the design level.

The two issues of dredging tolerance (dredging to design only), operational capabilities of the vessels to be deployed and (unavoidable) overdredging can become intertwined so it is therefore vital to clearly identify the dredging tolerance and what volume is subject to re-measurement. This can then be properly described in the technical specification and any payment preamble.

With major advances in vessel development and operational positioning with increasing...
use of GPS and vessel automation coupled with increasing use of high resolution single and multi-beam echo-sounders there have been significant improvements in accuracy of the dredging process. Likewise the quality and accuracy of hydrographic survey information, sounding work and data processing has also increased so real-time feedback on the precision of the dredging process by the dredge master has improved to an extent unimaginable over thirty years ago. The dredge operator now has real-time information on the depth and volumes of material removed and can thus minimise the amount of overdredging whilst still achieving the required levels of productivity (Figure 2).

One could then think that dredging tolerances could ultimately be done away with so that the design depth is the same as the dredging tolerance (zero deviation). Not so. The simple fact is that as the dredging operation taking place is unseen, many factors still remain – such as the type and properties of soil/rock, prevailing wave and tidal climate, type of equipment chosen and the experience of the dredge operator – which make the need for a dredging tolerance a reality.

So if the port designer has followed the guidelines, based on the correct selection of likely equipment, then an optimum for both horizontal and vertical tolerances will have been determined and listed in the technical specification (Figure 3). The horizontal tolerance will need to take into consideration not just the limitation and accuracy of the dredge equipment’s own positioning system but should build in a safe margin when the dredge equipment is required to work near adjacent structures such as quay walls, jetties to avoid these being undermined and destabilised with potentially catastrophic consequences. Rectification works may be determined by the Client, but generally consist of back-filling the overdredge area in an approved and timely manner using selected material.

When the port authority only needs a thinner layer of material to be removed then control of the amount of overdredging by the dredge operator is not easy: the depth of material as well as type and variability of material will impact on the volume which may be overdredged. This ratio of dredging to design and amount of possible overdredging needs to be considered when the contract drafter decides whether the overdredging is to be paid or not as the Contractor will have a significant adjustment to its unit rate if any (unpaid) volume has to be absorbed into the paid volume.

**ACCURACY**

As indicated in the publication, *Construction and Survey Accuracies for the Execution of Dredging and Stone Dumping Works* (IADC / Port of Rotterdam/VBKO, 2001), construction accuracy achieved during a project will not only depend on the selected dredge type and its inherent excavation accuracy, but also on:

- Accuracies of the support hydrographic and positioning (two dimensional reference) systems used;
- Level of quality control used to continuously monitor data quality; and
- Experience level of the crew.

The total construction accuracy is therefore dependent upon reference accuracies, steering (operator) accuracy, and excavation point accuracy (IADC 2001). The reference accuracy relates to errors in determining vessel position relative to fixed reference (coordinate) system. Steering accuracy concerns those errors introduced manually by the operator (dredge or pipe operator, and so on.). Excavation point accuracy is related to the dredge type selected (e.g., shape and adjustability of suction mouth, cutterhead/ suction mouth geometry, use of a level cut bucket as opposed to conventional bucket and so on) (Figure 4).

The required accuracy (and respective dredging costs) between general navigation dredging and environmental dredging should also be considered. Environmental dredging refers to the removal of contaminated sediments. Environmental dredging generally...
requires greater precision in dredging as only the contaminated sediments are to be removed as the costs of disposal of such material is huge when compared to general navigational dredging (Figure 5).

In the mid-1990s with the construction of the Ketelmeer environmental depot in the Netherlands for the storage of contaminated material, a detailed study was done into the accuracy of the dredge process (Figure 6). The study found that the inaccuracies became greater in the order of: reference inaccuracies, excavation mouth inaccuracies, and then total construction inaccuracies. During the Ketelmeer dredging there was no factor for steering accuracy as it was performed by stationary cutter suction dredgers but one can assume that steering accuracy will follow reference inaccuracies in its influence on total accuracy.

When dealing with new port construction the accuracy of any side slopes which have been dredged for marine structures can become an issue for any follow-on contractors if for instance a piled jetty is to be built on the dredged slope as the box-cut profile and loose nature of the material forming the dredged slope may cause problems when the follow-on contractor comes to drive the piles. If this is the case the port designer would be well advised to specify a more accurate slope tolerance which would require the dredge equipment to dredge a series of many shallow cuts on the slope profile. If this degree of accuracy is required, this will have significant cost implications in terms of lower productivity of the dredge equipment. Consequently, such requirements need to be clearly addressed in both the technical specification and preamble. A failure to specify such stringent requirements will likely result in a claim from the piling contractor who may be faced with difficulties in those operations.

**PREAMBLE**

Whilst some deliberation by the designer is usually given to the design depth and maximum dredge depth which may be achieved, experience has shown that whether the specified tolerance is paid or not is often an afterthought with little consideration given to clarity in the Preamble of the Bill of Quantities. The Preamble of a Bill of Quantities is usually a summary of the work
requested divided into sections that explain the project, materials needed, unit prices, provisional sums, methods and principles of measurement. In cases in which excavation is included in the project, the way the volume is to be measured is usually outlined in the preamble.

The purpose of a Bill of Quantities is to define the work requested for a project. The aims of a Bill of Quantities are to provide such information of the quantities of work as to enable tenders to be prepared efficiently and accurately. Where a contract has been entered into, the Preamble and Bill of Quantities provide guidance in the methods of measurement and the valuation of work and therefore determine the quantities of work which will be reimbursed. Hence a proper definition of the overdredging allowance is vital.

Since its introduction in 1976, the United Kingdom’s Civil Engineering Standard Method of Measurement (CESMM) has proved to be extremely resilient in meeting the needs of those engaged in preparing contracts based on traditional ‘measure & value’ principles. CESMM4 may be used with any conditions of contract for civil engineering work that includes measurement (Figure 7).

The fourth edition of CESMM4, published in 2012, supersedes the third edition published in 1991 and retains essentially the same principles as when the document was first published. This is a great tribute to the authors of that first edition that they were able to produce a methodology that has proved so resilient to the changing practices and procedures within the construction industry.

Dredging is dealt with under ‘Class E: Earthworks’. Class E: Earthworks states “Items for excavation shall be deemed to include upholding sides of the excavation, additional excavation to provide working space and removal of dead services”. It is a moot point whether a overdredging allowance is ‘working space’ and it would seems to stretch the point for a dredging tolerance to be deemed a form of working space. CESMM4 goes on to say “The location and limits of excavation by dredging shall be stated in the item descriptions where its extent would otherwise be uncertain”. Therefore when using CESMM4 it is important to state the limits of any overdredging and give certainty to whether it is paid or not.

In Australia the Australian Standard Method of Measurement of Civil Engineering Works and Associated Building Works, first published in 1971 with a Second edition in 1982 under Section 7: Dredging under sub-clause 7.4 (d), states “Where dredging is to be measured by soundings, the method of taking soundings shall be stated, e.g. by echo sounding, plate sounding, jetting, lead line, staff. The quantities of dredged material shall be calculated by taking the cubic content of voids formed, i.e. measured in-situ, such quantities being computed by comparing the sounds and levels taken before and after dredging”. So it is clear that in using the Australian Standard Method of Measurement all quantities are paid including the overdredged quantity.

When drafting a contract it is important to outline all work to be completed and how it is to be measured on a periodic and final basis once all the work is completed in accordance with the contract drawings. This allows managers to perform periodic evaluations on the tasks completed and to ensure that these tasks match what was delineated in the Bill of Quantities.

Work must be itemised in the Bill of Quantities as reflected in the Preamble. The itemised list creates the estimated cost of the project and allows contractors to tender on the work on an identical basis. The Bill of Quantities Preamble for a Re-Measured Works Contract may simply refer to measurement by in- and out-survey which would lead tenderers reviewing the contract documentation to reasonably infer that ALL quantities are paid quantities including those quantities below or outside the dredging tolerance. It should be part of a Contractor’s tender checklist to confirm whether overdredging is paid or not and to what extent the Contractor has to absorb overdredging into the unit rates (that is the unit rate under the contract which is applied to the nett quantity).

Clear wording is needed in the Bill of Quantities Preamble to establish what the definition of the paid volume is. It is within this area with poor drafting of both technical specification and preamble that disputes can and often do arise. The mix-up is usually between the tolerance in the technical specification and how the measurement Preamble has been drafted. If it is the Employer’s intention that overdredging quantities are to be strictly minimised (for instance to keep within resource consent provisions), then the consequence in terms of non-payment for overdredging beyond the design depth and any overdredging allowance should clearly be spelt out.

This may be different, however, in a maintenance a dredging campaign where the port owner is seeking to maximise the amount of material to be removed. In such a case it may be appropriate that all measured quantities are paid with no restriction placed on the overdredging allowance in terms of paid or unpaid volume measurement.

A typical dredge tolerance specification would be as follows: Maximum permitted tolerances to achieve design depth in accordance with the dimensions provided on the drawings for the different dredge areas will be as follows:

HORIZONTAL
Toe lines adjacent to any structures: 
-0.0 m / +1.0 m
All other areas: -0.0 m / +3.0 m
VERTICAL
Toe lines adjacent to any structures, to a distance of 5 m off the toe line:
+0.0 m/ -0.25 m
All other areas including slopes:
+0.0 m/ -0.50 m

A dredge tolerance clause in a Bill of Quantities Preamble would state:
“The re-measurable prices shall be based on the quantities and volumes determined by Contractor from the dimensions, levels and elevations as specified on the Drawings together with the allowance for over-dredging to the tolerances stated in the technical specification. The Employer shall not compensate Contractor for any volumes dredged by Contractor beyond the dredge tolerance”.

Figure 8 shows design levels (nett payment line) and overdredging in channel bottom and channel slope. The contractor must make an assessment of how much overdredging will be done and include an allowance for this overdredging in the unit price: that is the unit rate under the contract which is applied to the nett quantity.

CONCLUSIONS
Summarising the above considerations, it is recommended that proper consideration should be given by the contract drafter for how the dredging tolerance and overdredging allowance is managed in the dredging contract. The contract drafter should consider whether overdredging is paid as a measured quantity to the overdredge allowance or to be absorbed in an allowance in the Contractor's unit rates and prices. There is no industry standard or guideline in this respect. Each dredging project should consider the merits of a paid or unpaid dredging tolerance.

Contract drafters should bear in mind that reducing the overdredge allowance tends to slow production rates and increase the time and cost to complete the dredging project.

A well-defined overdredging provision in both the technical specification and Bill of Quantity Preamble clause will take speculation out of the tasks of the Contractor when considering how the measurement preamble is to be interpreted. This will result in less chance of misinterpretation of how the overdredging allowance is to be applied by the Client.

The administration of an overdredging allowance in terms of paid quantities is relatively straightforward if the contract is appropriately drafted. Prior to going to tender Contractors are advised to check how the specific dredging contract deals with the overdredging allowance in terms of the definition in both the technical specification and measurement preamble.

REFERENCES


Construction and Survey Accuracies for the Execution of Dredging and Stone Dumping Works (2001). IADC /Port of Rotterdam/VBKO.


CONSTRUCTION AND SURVEY ACCURACIES FOR THE EXECUTION OF ROCKWORKS: Best practices from the "Maasvlakte 2" Port Expansion Project

In 2001 the booklet Construction and survey accuracies for the execution of dredging and stone dumping works’ was published.

It gave a brief summary of the most important factors regarding construction and survey accuracies. The present guideline is an update of that 2001 booklet and includes a more extensive view on survey technology and on construction considerations. Both booklets are published by SBRCURnet, an independent knowledge institute for the Dutch construction sector.

This new guideline also includes the results of pit trials conducted for the Maasvlakte 2 Project, the 2000-hectare port extension project for the Port of Rotterdam, the Netherlands. It presents the practical experience gained during the execution of the project.

The guideline covers the following three aspects: Construction; Measurement; and Evaluation. In Chapter 2 a brief summary is given of common construction methods in the marine environment, along with a description of the main factors that determine the quality of the rockwork structures. The concept of construction accuracy is explained, with a qualitative and quantitative examination of this accuracy in relation to the various dredging and rock dumping methods.

In Chapter 3 a similar explanation is provided on the concept of surveying accuracy in relation to the various systems for the determination of position and levels.

Chapter 4 addresses the evaluation of completed marine structures. Examples are given illustrating the evaluation of the average layer thickness, the minimum layer thickness and the highest absolute level of a rock layer. Lastly, some concluding remarks and recommendations for the contractual setting between clients and contractors are given.

An extensive list of references and an appendix close out the book. The appendix “Error Summary” explains the difference between systematic and random errors, which from a statistical perspective are two separate sources of error.

The book is primarily intended for clients, contractors and specification writers who are regularly confronted with construction and survey issues. The quantitative information provided must be seen as indicative, as it applies only to the specified situation. Deviations from these indications are certainly not inconceivable for other projects or working methods.

The updated guideline can be viewed at: http://www.sbrcurnet.nl/producten/publicaties/construction-and-survey-accuracies-for-the-executions-of-rockworks

For further information contact: verkoop@sbrcurnet.nl or Ger Vergeer: ger.vergeer@sbrcurnet.nl

MOTION CONTROL IN OFFSHORE AND DREDGING
BY PETER ALBERS

‘Motion Control’ is used in many offshore, subsea and dredging installation. It can be described as a technological solution that is able to control motion, that is, the movement of at least one part of a mechanism relative to another. This book describes how drives of mechanisms in offshore and dredging, which can be very large, are designed and realised. It also gives a practical explanation of the way in which the different mechanisms work.

Although this book was published in 2010, the information remains pertinent and should be read by the target audience. To be clear, it is a highly technical reference work and is aimed at engineers and designers of new drive mechanisms. The author, Peter Albers, has extensive experience in the fluid power industry. He was a co-founder and chair of the Fluid Power Engineering Society, taught at Haze University, Groningen, the Netherlands and is presently associated with the Offshore Engineering Department at Delft University of Technology.

Amongst the subjects covered are hydraulic energy converters, hydraulic energy controls including a variety of valves, fluid conditioners and hydraulic accumulators, AC induction machines and various control technologies. Linear drives both open-loop and closed-loop systems are examined as well as heave compensation and rotating drives. A distinction is made between rotating and linear drives. In the case of rotating drives, the choice for an electrical drive is becoming more and more prevalent. Linear drives remain important, because of the large forces and the highly dynamic behaviour, in the domain of fluid power drive technology. Both these important technologies are comprehensively discussed with design rules and the many installation requirements that are useful for practical application.
In addition, because of the large number of activities in the offshore and dredging industries that take place underwater, specialised subsea drives have been developed and given extensive attention. And finally, essential safety design rules round off the assessment of each particular aspect of the design process of these complicated drive units. These may include legal requirements, certification demands and international norms and standards.

For further information:
Springer Science+Business Media

QUAY WALLS, 2nd EDITION
EDITED BY J.G. DE GIJT AND M.L. BROEKEN

Produced under the supervision of CUR Committee C183 “Quay Walls” (CUR is a unique network of public and private organisations focusing on civil engineering, infrastructure, building techniques and geotechnics), this new edition – as was the first – was peer reviewed by a scientific committee comprised of many Dutch and Belgian experts.

The book gives an overview for the planning, design, execution and maintenance of quay walls. It examines the function of quay walls and describes quay wall construction past and present. It presents the main types of quay walls – gravity walls, sheet pile walls, also with relieving platforms, as well as open berth quays – with examples of each. It elaborates on the importance of a broad realm of investigations comprising surveying and monitoring plans, topographical and hydrographic investigations, hydraulic investigations including water levels, waves and currents, as well as the investigation into ice loads and other meteorological conditions. Morphological and nautical boundary conditions, seismic impacts and a variety of geotechnical, geohydrological and environmental investigations are also covered. Other chapters describe the terms of reference for design and construction and functional and structural design aspects, construction and materials including concrete, steel and corrosion. Cost estimate systems are also explained as well as lessons learnt from various experiences and a discussion of future developments of ports, shipping, logistics and quays.

Since the publication of the first edition of this book in Dutch in 2003 and the English version in 2005, considerable new experience has been acquired by many practitioners. This led to the decision to publish an update. The introduction of the Eurocodes in 2012 was another important reason for a new version resulting in a complete revision of the Design chapter that is compliant with the Eurocodes. Other changes include: Additional recommendations for using FEM analysis with quay wall design and criteria for steel pipe piles. Within the industry, discussions are on-going about buckling criteria for steel pipe piles. Consequently, in the framework of this CUR project, a research programme was carried out on steel pipe piles filled with sand and piles without sand. The results of this research have been incorporated in this new version. Finally, the section on corrosion has been updated to present the latest knowledge and attention has been given to the latest global developments in quay wall engineering.

For further information:
• Email: Pub.NL@taylorandfrancis.com

ONLINE AND INTERACTIVE:
FACTS ABOUT SITE INVESTIGATIONS

A thorough site investigation, prior to tendering, is a crucial first step toward a successful dredging project. Why are site investigations necessary? Although they can be expensive and time-consuming, an inadequate site investigation is one of the most frequent causes of delay and additional unexpected, unbudgeted costs. With modern techniques and computer-based investigation methods, they can be efficiently executed and can prevent unwanted conflicts. They can help minimise the risks of encountering ‘unforeseen’ material and the financial consequences attached to such ‘surprises’. Data collection should include geological and geotechnical evaluations, bathymetric surveys and environmental assessments and should answer certain basic questions like:

What types of soils and material are present? Are these materials dredgeable? What type of equipment and plant will be needed? What will the wear and tear on plant be? Is the stipulated budget feasible for the work to be carried out? A well-designed site investigation informs and helps manage risks for all parties – the contractor, the client and the stakeholders.

Facts About is a series of concise, easy-to-read online brochures which give an effective overview of essential facts about specific dredging and maritime construction subjects. Each brochure provides a ‘management summary’ for stakeholders seeking basic knowledge of a particular issue. These brochures are part of the IADC’s on-going efforts to support clients, consultants and others in understanding the fundamental principles of dredging and maritime construction.

TO SUBSCRIBE: please fill out the form at http://www.iadc-dredging.com/env/84/dredging/facts-about/.
environmental and commercial impacts of dredging. Included in the dredging conversations will be the critical economic need for dredging, the importance of enhancing the marine environment, trends in dredging technology and safety and historical dredging developments.

For further information, including conference registration, exhibition booths reservations and sponsorships contact:
• Email: info@westerndredging.org
https://westerndredging.org/index.php/events/dredging-summit-expo

50TH SEMINAR ON DREDGING AND RECLAMATION
JUNE 22-26, 2015
UNESCO-IHE, DELFT, THE NETHERLANDS

Aimed at (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organisations that have to execute dredging projects, the International Seminar on Dredging and Reclamation has been organised by the International Association of Dredging Companies (IADC) in various locations since 1993.

Often presented in co-operation with local technical universities, the IADC Seminar has provides a week-long Seminar especially developed for professionals in dredging-related industries. These intensive courses have been successfully presented in The Netherlands, Singapore, Dubai, Argentina, Abu Dhabi, Bahrain and Brazil. As is appropriate to a dynamic industry, the Seminar programme is continually updated. In addition to basic dredging methods, new equipment and state-of-the-art techniques are explained.

The Seminars reflect IADC’s commitment to education, to encouraging young people to enter the field of dredging, and to improving knowledge about dredging throughout the world.

Highlights of the programme
To optimise the chances of the successful completion of a project, contracting parties should, from the start, fully understand the requirements of a dredging project. This five-day course strives to provide an understanding through lectures by experts in the field and workshops, partly conducted on-site in order to give the “students” hands-on experience. Subjects include:
• overview of the dredging market and the development of new ports and maintenance of existing ports;
• project phasing (identification, investigation, feasibility studies, design, construction, and maintenance);
• descriptions of types of dredging equipment and boundary conditions for their use;
• state-of-the-art dredging and reclamation techniques including environmental measures;
• site and soil investigations, designing and estimating from the contractor’s view;
• costing of projects and types of contracts such as charter, unit rates, lump sum and risk-sharing agreements;
• design and measurement of dredging and reclamation works; and
• early contractor involvement.

An important feature of the Seminars is a trip to visit a dredging project being executed in the given geographical area. This gives the participants the opportunity to see dredging equipment in action and to gain a better feeling of the extent of a dredging operation.

Each participant receives a set of comprehensive proceedings with an extensive reference list of relevant literature and, at the end of the week, a Certificate of Achievement in recognition of the completion of the coursework. The Seminar starts Monday, June 22 at 8:45 hrs and ends Friday, June 26 (date to be confirmed) at 17:30 hrs. Please note that full attendance is required for obtaining the Certificate of Achievement.

Costs
The fee for the week-long seminar is € 3,100.- (inclusive VAT). The fee includes all tuition, seminar proceedings, workshops and a special participants’ dinner, but excludes travel costs and accommodations. Assistance with finding hotel accommodation can be given.

The IADC Seminar will be held at UNESCO-IHE, Delft, The Netherlands in June. A similar Seminar is planned for October 2015 in Jakarta, Indonesia.

For further information contact:
Mr. Jurgen Dhollander
PR & Project Manager
International Association of Dredging Companies
Email: dhollander@iadc-dredging.com
Tel: + 31 70 352 33 34
PIANC-SMART RIVERS 2015 CONFERENCE
SEPTEMBER 7-11, 2015
BUENOS AIRES, ARGENTINA

The SMART Rivers Conference is a biennial forum bringing together those involved in river transport from developing and developed countries in the world. The SMART Rivers Conference started as an initiative of major international organisations in the field of Inland Water Transport to promote transport by barge, the first conference being held in 2005 in Pittsburgh. As from 2011, SMART Rivers is placed under the umbrella of PIANC, the World Association for Waterborne Transport Infrastructure. The organisation is entrusted to PIANC Section of Argentina. Some 300 international participants are expected.

For further information:

9TH INTERNATIONAL SEDNET CONFERENCE
SEPTEMBER 23-26, 2015
KRAKOW, POLAND

The annual SedNet Conference will be hosted and co-organised by the Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology.

Sediments – unseen or unnoticed most of the time – have a variety of impacts on human activities and vice versa, particularly along rivers. If the river is used for shipping, too much sediment may become an obstacle. The foundations of bridges may become unstable if too little sediment is available, creating a safety risk. After flooding, sediments are distributed over flood plains and with increased construction in natural flood plains these sediments add to the clean-up efforts and may become a health issue if contaminated. Even more dangerous are the mud and debris flows that can occur during larger floods. SedNet is dedicated to solving societal challenges as regards working with sediments.

For further information contact:
Marjan Euser
• Email: marjan.euser@deltaros.nl

DREDGING 2015
OCTOBER 19-22, 2015
HYATT REGENCY, SAVANNAH, GEORGIA

PIANC USA/COPRI/ASCE Dredging 2015 Conference with the theme “Moving and Managing Sediments” will take place on the riverfront in Savannah, Georgia, October 19-22, 2015, in the Downtown Historic District. The format will include plenary sessions, concurrent technical sessions, short courses, tours and a large industry exhibit hall. More than a dozen major topics ranging from dredged material management, to regulatory challenges, to working with nature will be covered.

For further information:
Ms. Kelly J. Barnes, PIANC USA Deputy Secretary
USACE, Institute for Water Resources
• Email: Kelly.J.Barnes@usace.army.mil
Tel: +1 703 428-9090
http://goo.gl/Z8wIc “Securing the Nation’s Future through Water”
www.pianc.us

HYDRO 2015
NOVEMBER 23-25, 2015
CTICC, CAPE TOWN, SOUTH AFRICA

The International Federation of Hydrographic Societies will present its 23rd conference and exhibition, at the Cape Town International Convention Centre (CTICC) in November 2015. The event is being organised by The Hydrographic Society of South Africa.

With its theme, “Defining the Extent and Ownership of Maritime Real-Estate for Development in Africa”, the three-day event is expected to attract a wide global audience drawn from all sectors of the hydrographic and related professions. Supported by a major exhibition of equipment and services in addition to in-situ workshops and local technical visits, main conference emphasis will be on addressing the technical and social advancement of the hydrographic industry to suit global needs whilst bolstering developments appropriate to Africa.

Seven scheduled topics are: African Case Studies, Aiding Resource Access, Capacity Building, Data Management, Education & Training, Maritime Boundaries, and New Technology & Equipment Positioning for Surface and Sub-Surface Applications.

For further information contact:
www.hydro2015.org

PORTS® ’16
JUNE 12-15, 2016
NEW ORLEANS, LOUISIANA

The next PIANC USA and the COPRI Ports & Harbors Committee conference PORTS ’16 will be held in cooperation with the ASCE in New Orleans, Louisiana.

Conference topics include: Environmental Issues; Port Planning & Operations; Terminal Planning & Design; Port Engineering & Infrastructure; Equipment & Systems; Landside Connection; Security; and Project Development.

For further information:
Tel: North America +1 800 548-2723
Tel: International   +1 (703) 295-6300
http://www.portsconference.org/
• Email: registrations@asce.org
CALL FOR PAPERS

EUROPEAN DREDGING SUMMIT
OCTOBER 6-8, 2015
ANTWERP, BELGIUM

ACI’s European Dredging Summit 2015 will discuss essential dredging strategies and environmental monitoring for project approval. The meeting will provide a global analysis of dredging projects, environmental regulations and recommendations for dredging activity including equipment and contractor selection. Participants will learn how to solve the major problems when developing a successful dredging project, discover global opportunities of future project locations and their financial value as well as network with industry most experienced individuals.

Exclusive Site Visit
Exclusive APEC-Antwerp/Flanders Port Training Center, DEME Headquarters and Antwerp City Hall Site Visit will take place on Tuesday, October 6. Up to 30 conference attendees will receive a unique opportunity to participate. There is no extra charge to attend the site visit, but spaces are limited and allocated on a first come first served basis. Please register your attendance for the site visit when booking for the conference.

Key topics include:
- How Are Recent Regulatory Changes Affecting Dredging Projects?
- Effective Sediment Balance & Waste Management
- Latest Developments & Innovations in Dredging Technologies & Techniques
- Effective Maintenance Dredging
- Strategies for Trade-Type Dredging Projects
- Qualified Human Resources Training & Development
- Economic Outlook of the Future Dredging Projects (Europe, Global)
- Project Financing & Budget Management

Speakers include Bernard Malherbe, Director Project Development and Conceptual Design, Jan De Nul NV; Michael Costaras, Group Manager, Dredging, HR Wallingford; Lucien Halleux, Director, G-TEC S.A.; Charles Johnson, Director of Sales, DSC Dredge; Paris Sansoglou, Secretary General, European Dredging Association;

Khalid Bichou, Managing Director, K Bichou & Associates Ltd. To be considered as a speaker for the event with a 30-45 minute presentation, please submit an abstract for consideration to: Agnieszka Niemczewska
Tel: +48 6164 670 45
Email: aniem@acieu.net

For further information or to register your attendance contact:
Mado Lampropoulou
Tel: + 44 (0) 20 3141 0607
Email: mlampropoulou@acieu.net

WODCON XXI
JUNE 13-17, 2016
HYATT REGENCY MIAMI HOTEL
MIAMI, FLORIDA, USA

World Dredging Congresses (WODCONS) are organised once every three years by WODA, the World Organization of Dredging Associations. First organised in 1967 in New York and held throughout the world since, this series of congresses has become the most important event for dredging professionals worldwide. WODCON XXI with the theme “Innovation in Dredging” will showcase some 120 technical papers over three days covering all aspects of dredging and maritime construction. All WODCON XXI papers will be peer reviewed and provide up to date, relevant and high quality information. The congress will also feature a technical exhibition and technical visits. These technical programme elements will ensure a complete learning process, while various social events will allow participants to meet fellow professionals from all over the world in a friendly and inspiring atmosphere.

The Western Dredging Association is pleased to announce that the Hyatt Regency Miami Hotel has been selected as the venue for WODCON XXI. Miami, located on the Atlantic coast in southeastern Florida, is a major center and a leader in finance, commerce, culture, media and entertainment. For more than two decades, the Port of Miami has been the number one cruise passenger port.

Call for Papers
Interested authors are invited to submit one page abstracts (less than 400 words). The abstracts must contain a descriptive title, author(s) contact information (name, company, address, phone, email). Deadline for abstracts is September 15, 2015. Abstracts presenting both practical applications as well as applied research are encouraged.

Abstracts are to be emailed to the chair of the respective regions (CEDA, EADA or WEDA). The Technical Papers Committee will review all abstracts and notify authors of acceptance and provide final manuscript instructions for production of the WODCON proceedings on CDs. Submission and acceptance of an abstract means that one or more of the authors must register, attend the WODCON XXI, and give the presentation in English. One full registration with payment must be made when the draft manuscript is submitted.

Important Deadlines
Abstracts Due September 15, 2015
Acceptance Notification /Author Instructions October 15, 2015
Draft Manuscripts January 15, 2016
Reviewer Comments to Authors March 1, 2016
Final Manuscripts April 15, 2016

For further information contact:
Email: info@westerndredging.org
https://www.westerndredging.org/index.php/events/wodcon-xxi
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