The Langeled pipeline extends from Norway’s gas fields to the east coast of the UK. Shown here, the onshore pipeline being welded at the tie-in pit (see page 12).
CONTENTS

EDITORIAL 2

MORPHODYNAMIC-NUMERICAL SIMULATIONS OF DREDGED MATTER OPEN DISPOSAL
ANDREAS WURPTS

This study analysing changes in the bottom-topography at dredged material disposal sites and the interaction between disposed matter and the surrounding density currents received the IADC Award at the CEDA Dredging Days.

LANDFALL AND SHORE APPROACH OF THE NEW LANGELED PIPELINE AT EASINGTON, UK
WOUTER VERCRUYSSE AND MICHAEL FITZSIMONS

The shore approach for a new offshore pipeline from Norway’s gas-rich fields to the eastern coast of the UK required tunnelling to protect vulnerable eroding clay cliffs and dredging at great depths, between two existing live pipelines.

FEASIBILITY STUDY OF THE CONTINUOUS GEOTUBE®
P.M.N. VAN ZIJL, W.J. VLASBLOM, J.G. DE GIJT, E.J. BROOS AND J. DE BOER

Geotextile tubes or Geotubes® have been applied in coastal engineering for shore protection and breakwaters, and have been used on land and in shallow water. A new method of filling a continuous Geotube® would allow them to be used in rough and relatively deep water.

RECLAIMING THE INITIATIVE: REMARKS ON THE FORM OF CONTRACT FOR DREDGING AND RECLAMATION WORKS, FIRST EDITION
NICHOLAS A. BROWN

The long-awaited FIDIC form for dredging and related works (FCDR) is analysed by a practising infrastructure lawyer, and found to be user-friendly and a welcome instrument for formalising existing usage in the industry.

BOOKS/PERIODICALS REVIEWED
The Handbook Quay Walls, edited by CUR and newly translated into English, is reviewed by Nick Bray.

SEMINARS/ CONFERENCES/ EVENTS
A quick review of upcoming conferences for 2006, including WEDA XXVI in San Diego, California in June.
EDITORIAL

The new tag-line of Terra et Aqua, “Maritime Solutions for a Changing World”, better expresses the true nature of dredging in the 21st century. With populations along the coasts and rivers increasing, deltas becoming more vulnerable because of climate changes, and our dependence on offshore energy supplies growing, the challenges are bigger than ever. Dredging nowadays clearly encompasses a very broad range of maritime solutions, and continuing technological research is an absolute necessity.

The articles in this issue of Terra reflect this dedication to ongoing research. We start with the paper that received an IADC Award at CEDA Dredging Days in which careful studies were conducted for the disposal of dredged material in the rivers Elbe and Weser. If the port of Hamburg is to remain one of the leading ports of Europe, then understanding the dynamics of dredged material disposal is a must.

In our second article, the challenge of laying pipelines from the Norwegian gas fields to the east coast of the United Kingdom is presented. This was an effort that required a unique solution to prevent further erosion of the vulnerable cliffs along the coast. The importance of the successful completion of this pipeline is reflected in the predications that it will ultimately supply the UK with 20 percent of its energy needs. And lastly, we present research that has been conducted to extend the value of the innovative use of geotextiles for shoreline protection by the invention of a “continuous” geotextile tube that can be applied in deeper waters further out to sea.

Each of these reportages demonstrates the vital core of the modern dredging industry: Research and development. R&D leads to finding technological solutions for improving the world’s infrastructure. These infrastructure improvements do not occur overnight. They are long-term, well-planned projects which take into account the particularities of a given situation. They are complicated and difficult, but they are essential for ensuring strong economic development.

On another aspect of renewal, there has been a noteworthy change in our book review section. For some fourteen years, Charles W. Hummer, Jr. (retired, USACE) faithfully ploughed through pages and pages of conference proceedings and volumes of books on a variety of dredging related subjects. He has recently decided to step down and pass the pen on. Unable to find one person to fill his shoes we have enlisted the aid of several experts in the field. Starting in this issue, the book reviews will be written by several different colleagues examining the newest literature on offer. We thank Chuck Hummer for his years of service and look forward to working with our new team of “critics”.

Robert van Gelder
President, IADC Board of Directors
MORPHODYNAMIC-NUMERICAL SIMULATIONS OF DREDGED MATTER OPEN DISPOSAL

ABSTRACT

Open disposal of dredged matter in coastal areas is common practice all over the world. Especially if cohesive sediment is considered, it is a known fact that the location where the long-term deposition takes place may essentially differ from the disposal site. Knowledge of the transport and fate of disposed sediment improves the economic and environmental aspects of off-site disposal.

Dredged matter which is placed at a disposal site usually differs from the local bottom-sediment with respect to grain sizes and grain size distribution. Moreover the bottom-topography at the disposal site changes as a result of the added sediment. The two aspects mentioned above usually lead to a “violation” of the local morphodynamic equilibrium state which is followed by a “reaction” of the topography (e.g. increased erosion, changing sorting of the local sediment-mixture). Another important aspect related to unconfined disposals is the interaction between the disposed matter and the surrounding flow-field (e.g. density currents) which can become a dominant transport mechanism in the nearfield of the placement site.

This contribution deals with the development of a morphodynamic-numerical simulation model. SMOR3D consists of several modules which are fully coupled in a time-explicit mode. The model-approach consists of a 3D flow solver which is coupled with several transport modules for suspended sediments, bed-load sediment and salt. The movable bottom topography is balanced by a bed-model. All sediments (natural background and disposed matter) are represented by several fractions of different properties. The model allows the discrimination of disposed matter from the natural background sediment at every location and time. Results of numerical simulations of disposals by means of bottom doors and split barges are shown. The results are in good agreement with SPMC measurements carried out in the nearfield of different disposal locations.

The author wishes to thank Dr Peter Mewis, Chief Engineer and Prof Dr Ulrich Zanke both of the University of Technology Darmstadt, TUD, Germany for their collaboration and support. This paper was presented at the CEDA Dredging Days, November 2005 in Rotterdam, the Netherlands and appears in the conference Proceedings. It is reprinted here in a slightly revised form with permission.

INTRODUCTION

The present paper deals with numerical simulations of the near-field and thus short-term distribution of suspended sediment and shows the capabilities of three-dimensional morphodynamic-numerical modelling. It is part of a research project dealing with the enhancement of a three-dimensional hydro- and morphodynamic model in order to numerically reproduce observed spatial turbidity distributions which were measured during the disposal of dredged matter and to predict the fate of the disposed matter under complex hydrodynamic conditions. The numerical model results shown here are compared to field measurements. These were carried out in the nearfield of disposal-events of fine-grained, silty dredged sediment. Spatial and temporal distribution of suspended particulate matter concentration (SPMC) was measured.
The resulting SPMC-values at the disposal site are usually much higher than the natural background concentration and therefore induce strong local density gradients which lead to density currents of suspended sediment. These are dominated by gravity forces and thus move according to local bottom gradients which can significantly differ from the surrounding flow direction. Depending on the properties of the disposed matter (grain-sizes, settling velocities, density) deposition and sorting take place which lower the suspended sediment concentration with time. In case of cohesive sediment, settling velocities are also concentration-dependant as a result of effects like flocculation and hindered settling.

A second considerable stratification can be found in most estuaries resulting from the mixing of fresh water from river-inflow with salt water from the sea. These mixing processes, if superimposed with tidal motion, can lead to large-scale density effects like vertical gravitational circulation (VGC). In areas of VGC an intensification of near-bottom net landward flow occurs which leads to altered sediment-transport patterns compared to unstratified conditions. Both effects, SPMC- and salinity-induced stratification, have to be modelled, if simulations in estuarine environment are considered.

**Numerical Model**

SMOR3D is a three-dimensional time-explicit morphodynamic-numerical model. It consists of a 3D instationary flow solver which is directly coupled with several transport modules for salt, suspended and bed-load-sediment at every calculational time-step. Sediment transport is balanced by a bottom evolution model, which provides bottom level changes and local resuspension properties as well as strict sediment continuity checking. Sediment is described by multiple fractions with different properties (e.g. grain size, settling velocity, cohesion). Local effects like hiding/exposure and armouring is accounted for by the bottom evolution model. The model allows sediment transport in areas of restricted erodibility and is capable of sediment-transport on fixed beds. For calculations in tidal areas a robust wetting/drying-scheme is implemented to consider moving boundaries within the calculational domain.

The flow-solver calculates the instationary three-dimensional Reynolds-averaged Navier-Stokes-equations (RANS) in a time-explicit way. Spatial discretisation is done by the method of finite elements, in time domain a three-level leap-frog scheme is implemented. SMOR was originally developed by Mewis and was validated for scouring at alluvial river bends considering single-fraction sediment (Mewis 2002).

For the calculation of dredged matter disposals several extensions and modifications were added:
- The single-grain-size sediment transport was replaced by a multi-fraction-approach.
- The bed-evolution model was replaced by a multi-fraction multi-layer model which allows the evaluation of every (disposed) fraction at every calculational time-step.
- Salinity transport was added for calculations in estuarine environments and a recoupling with the turbulence-model to consider density-stratification was implemented.
- An abstracted initial condition for the disposal process was implemented which allows disposed matter to be added to the water column and the bottom-sediment layer.

The structure of the information-flow inside SMOR3D is given by Figure 2.

**Hydrodynamic Model**

The 3D RANS-Equations with additional terms for bottom-friction, density-stratification and Coriolis-forces are given in equations (1) to (3)

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} = f_v - \frac{1}{\rho} \frac{\partial p}{\partial x} + \frac{\partial}{\partial x} \left( \nu \left( \frac{\partial u}{\partial x} - \psi_{x} \right) \right) + \\
\frac{\partial}{\partial y} \left( \nu \left( \frac{\partial u}{\partial y} - \psi_{y} \right) \right) + \frac{\partial}{\partial z} \left( \nu \left( \frac{\partial u}{\partial z} - \psi_{z} \right) \right) - \tau_{x} \right] \tag{1}
\]

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} = -f_u - \frac{1}{\rho} \frac{\partial p}{\partial y} + \frac{\partial}{\partial x} \left( \nu \left( \frac{\partial v}{\partial x} - \psi_{x} \right) \right) + \\
\frac{\partial}{\partial y} \left( \nu \left( \frac{\partial v}{\partial y} - \psi_{y} \right) \right) + \frac{\partial}{\partial z} \left( \nu \left( \frac{\partial v}{\partial z} - \psi_{z} \right) \right) - \tau_{y} \right] \tag{2}
\]
where $u$, $v$, $w$ are the directional flow-velocities for resp. $x$, $y$ and $z$ direction, $g$ acceleration of gravity, $\nu$ turbulent diffusivity and $\rho$ fluid-density.

By neglecting dynamic pressure, equation (3) becomes to (5) (hydrostatic pressure approximation) and after integration over the vertical to (6).

$$0 = -g - \frac{1}{\rho} \frac{\partial \rho}{\partial z}$$

(5)

Turbulence closure is achieved by an eddy-viscosity-approach. Horizontal and vertical directions are treated separately which accounts for the different dimensions of the calculational domain in horizontal and vertical direction (anisotropy of turbulence). Vertical turbulent diffusivity is calculated by a density-modified mixing-length-formulation, equation (11), which can handle density-stratified flows.

The continuity-equation reads:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

(4)

where $u$, $v$, $w$ are the directional flow-velocities for resp. $x$, $y$ and $z$ direction, $g$ acceleration of gravity, $\nu$, turbulent diffusivity and $\rho$ fluid-density.

By neglecting dynamic pressure, equation (3) becomes to (5) (hydrostatic pressure approximation) and after integration over the vertical to (6).

$$0 = -g - \frac{1}{\rho} \frac{\partial \rho}{\partial z}$$

(5)

$$p = g \rho z$$

(6)

This assumption is valid for all cases, where (especially vertical) accelerations in the flow-field can be neglected, i.e. for large-scale calculations, and is used here because of its considerable saving of calculational effort.

Bottom-friction is implemented by means of a Newton-Taylor-Coefficient, equation (7) with $\rho$ flow-density, $H$ flow-depth, $u$ flow-velocity and $\tau$ friction-stress.

$$\frac{\tau}{\rho} = r_f \frac{\nu^2}{H}$$

(7)

Coriolis-force must not be neglected in wide channels (i.e. estuaries), thus coefficient $f_c = 2 \omega \sin \phi$ times the component-wise flow-velocity gives the additional momentum in the RANS-equations with $\omega$ angular velocity and $\phi$ geographical latitude.

Turbulence closure is achieved by an eddy-viscosity-approach. Horizontal and vertical directions are treated separately which accounts for the different dimensions of the calculational domain in horizontal and vertical direction (anisotropy of turbulence). Vertical turbulent diffusivity is calculated by a density-modified mixing-length-formulation, equation (11), which can handle density-stratified flows.

The basic Prandtl mixing-length-approach

$$v_{\kappa} = \kappa^2 z \left( 1 - \frac{z}{H} \right) \frac{\partial u}{\partial z}$$

(8)

reproduces the logarithmic velocity-profile, with $\kappa$ Karman-number. To account for density-induced effects the local gradient-Richardson-number $Ri$ is calculated according equation (9):

$$Ri = \frac{g \rho}{\rho} \left( \frac{\partial u / \partial z}{u} \right)^2$$

(9)
Equation (8) is modified according to (10) and (11) (Orton 2001; Smith and McLean 1977) with: $\gamma, \sigma, \rho$ empirical stratification coefficients.

$$\gamma = \frac{\sigma Ri}{1 - \sigma \gamma_{strat} Ri}$$ (10)

$$v_{strat} = \frac{v_i}{1 + \gamma_{strat} \gamma}$$ (11)

Given $\gamma_{strat} = 4.0$ as suggested by Smith and McLean, equation (11), describes a linear decrease of $v_{strat}$ over $Ri$ with complete decoupling for $Ri$-values of 0.25 and above.

Salinity-Transport

Salinity-transport is modelled by an advection-diffusion-type equation

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} + w \frac{\partial C}{\partial z} = \frac{\partial}{\partial x} \left( K_{h,av} \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_{h,av} \frac{\partial C}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_{h,av} \frac{\partial C}{\partial z} \right) + Q_s + S_s$$ (12)

With: $C$ local salinity concentration, $K_{h,av}$ turbulent diffusivity. The turbulent Schmidt-Number is assumed to be 1. This means turbulent diffusivity of dissolved substances is assumed equal to that of momentum. Salt is transported conservative, which means that there are no sinks or sources except at open boundaries of the model domain.

Sediment-Transport

Entrainment of non-cohesive sediment is calculated according to (Van Rijn 1994a), equation (13).

$$E_{len} = \frac{p_i \cdot 0.00033 \cdot \rho_{vs}}{(\Delta g D_*)^{0.5} \cdot D^{0.3} \cdot T_i^{0.5}}$$ (13)

Van Rijn originally derived his entrainment formulation for single-grained Sediment. Equation (13) therefore shows a modification for multi-fraction sediment, where $D_*$ is the dimensionless sediment diameter after Bonnefille and $T_i$ “transport stage”-parameter after Van Rijn and $p_i$ local availability of fraction $i$.

For cohesive sediment a friction-stress-based approach yields equation (14) after Partheniades, with: $\tau_c$ critical shear-stress for initiation of erosion, $E_0$ entrainment-rate.

$$E_{len} = E_0 \exp \left( \alpha (\tau_c - \tau) \right)^{0.5}$$ (14)

Suspended sediment transport is calculated by means of an advection-diffusion-type equation:

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} + w \frac{\partial C}{\partial z} = \frac{\partial}{\partial x} \left( K_{h,av} \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_{h,av} \frac{\partial C}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_{h,av} \frac{\partial C}{\partial z} \right) + Q_s + S_s$$ (15)

Turbulent diffusivity of suspended sediment is assumed equal to that of momentum. Equation (15) is balanced by sinks and sources at the bottom boundary represented by entrainment and deposition.

Deposition of non-cohesive sediment is calculated by grain-specific settling velocity after (Zanke 1982):

$$w_i = \frac{1}{d} (1 + 0.01D_i - 1)$$ (16)

Equation (16) provides a good transition to the stokes-range, with: $v$ dynamic viscosity, $D_i$ dimensionless particle diameter after Bonnefille.

In case of cohesive sediment concentration-dependant settling velocities $w_{i,n}$ have to be considered due to effects like flocculation and hindered settling, equations (17) and (18):

$$w_{i,n} = k \cdot C^n$$ if $C < 10000 \text{[mg/l]}$ (17)

$$w_{i,n} = w_i (1 - \alpha C)^{\beta}$$ if $C > 10000 \text{[mg/l]}$ (18)

Deposition is calculated according equation (19)

$$S_{gen,\text{max}} = \sum_i w_{i,n} \cdot C_{i,f}$$ (19)

Bed-Load-Transport

Equation 13 describes total sediment transport. By multiplication with a characteristic, sediment-depending step-length $\lambda$ one obtains a bed-load-transport per unit-width. In fraction-wise formulation this can be written as equation (20), where $p_i$ denotes the portion of fraction $i$ from the total sediment load.

$$q_{i} = E_{len} \cdot \lambda \cdot p_i$$ (20)

with:

$$\lambda = 3 D_i^{0.6} \cdot T_i^{0.9}$$ (21)

Bed-Evolution Model

The bed-evolution model calculates bed-level-changes resulting from local erosion and deposition. Local sediment continuity is described by the Exner-equation, where $n$ describes the porosity of the local sediment mixture:

$$(1 - n) \frac{\partial a}{\partial t} = \frac{\partial q_{i,\text{gen}}}{\partial x} + \frac{\partial q_{i,\text{dep}}}{\partial y} + Q + S$$ (22)

$Q$ and $S$ are sources and sinks with respect to suspended sediment transport. Variable $a$ denotes the actual bed-level elevation.

Disposal Process

Disposal with hopper barges is a very dynamic process where the hydrostatic pressure assumption may be (weakly) violated. Modelling the disposal process in detail (beginning with opening the bottom doors) would require a different modelling approach, i.e., a multiphase transport formulation as well as solving the momentum equations including the dynamic pressure distribution. The latter point forces to solve an elliptic problem or at least iterative pressure correction method at much higher computational costs.

Nonetheless in the present context the most important aspect of modelling the disposal process is the conservation of both the mass of fluid and (disposed) sediment involved. This in particular applies since in most cases no detailed data on the initial sediment composition in the hopper is available.
The disposal process is implemented by means of an abstracted initial condition which allows matter to be added to the water-column and the active bottom-sediment layer. This is done over a period of time which corresponds to the duration of the disposal. The ambient flow field is not explicitly changed by initial conditions but begins to “react” implicitly as the increasing density gradients more and more impact the flow. Disposed matter this way can be added to the water column according to constant or parabolic distributions over depth. The aforementioned approximation can be shown to reproduce the overall dynamics of the disposal process in the nearfield of the disposal site reasonably well (Figure 4).

**MEASUREMENTS**

Measurements of time- and space-dependant SPM concentrations were carried out under tidal (River Elbe near Hamburg) as well as estuarine (outer estuary of River Weser) situations by subcontractors. The disposed matter was followed by a moving vessel equipped with broad band ADCP and CTD profiler instrumentation. The CTD carried optical attenuation and backscatter sensors. SPMC-values were derived from the optical signals and the ADCP backscatter intensities by calibration with samples repeatedly taken in parallel. ADCP-based SPMC-values were calculated from acoustic backscatter-intensities by an inverse modelling technique (SEDIVIEW). The combination of the three methods mentioned above allows nearly continuous SPMC determination between 20 and 3000 mg/l throughout the whole water column except the most upper and lower 0.5 m. Further information on the measurements and the instrumentation used can be found in Witte (1996) and Riethmüller (2005).

**MODEL RESULTS**

Simulation results for disposals at River Elbe and outer estuary of River Weser are shown.

**Tidal Environment (River Elbe)**

The hydrodynamic situation at the disposal site (blue rectangle in Figure 3) is dominated by tidal currents up to 2 m/s. Salinity is not present. The measurement shown took place at beginning ebb flow (from right to left). Four split-barges loaded with cohesive matter dredged some miles upstream were synchronously emptied. After holding position 3 directly downstream of the disposal position for some minutes the survey vessel sailed downstream along the crossing course-line shown in lower Figure 3.

The measured (right column) and calculated (left column) SPMC-profiles along the transsections numbered with 4 to 8 are shown in Figure 4. The time of the vertical profiles in minutes with respect to the beginning of the disposal are associated to the middle of each plot. The measured and calculated SPMC-values are given by the legend above each column.

A clear stratification of the water column can be observed after the first minutes since the start of the disposal. Moreover the resulting density-current after 8 minutes already crossed two thirds of the channel width while moving almost rectangular to the ambient flow. The situation (especially the time-dependency) is well reproduced by the numerical model.

The situation mentioned above lasts for almost an hour after which the SPMC-values become too low for further
stabilising the stratification because of the continuous deposition of disposed matter.

At this point the remaining sediment suspension becomes mixed into the whole water column. This process is calculated in a more averaged manner than the measurements show mainly as a result of local turbulence effects not resolved by the chosen numerical method and element mesh. Nonetheless the model reproduces the time- and space-dependant spreading of the disposed matter within agreeable precision.

Figure 5 shows 3D-iso-surface-plots of SPMC-values. The situation for three points of time is given.

Estuarine Environment (Outer Weser Estuary)

Figure 6 gives an overview of the Jade-Weser Estuary. The German North Sea coast consists of mudflats of some 5 to 20 km wide. The flats are crossed by deep tidal
channels which provide tidal flooding and drying. River Weser as one of three major rivers disemboguing in the German Bight discharges fresh water into the above-mentioned area, leading to a partially stratified estuarine situation. The main flow at the disposal site (blue circle) is confined between longitudinal embankments. Additional groins orthogonal to the embankments intensify the currents in the deep channel which closely follows the southwest embankment.

The disposal site is located at the northeast border of the confined area close to the northern embankment. The deep channel near the disposal site provides an average flow depth of 18 m to 22 m. At disposal location the water depth is about 8 to 12 m below chart datum, slightly sloping towards the deep channel. Dredged matter was disposed of through a hopper-dredger’s bottom doors. It consisted of a major amount of fine-grained silt which was dredged some miles upstream.

The local hydrodynamic situation at the disposal area is dominated by tidal currents and barocline stratification effects as a result of the presence of salinity gradients which vary in time and space. The tidal range at the disposal location varies between 2.5 to 3.5 m, the local salinity between 8 to 30 ppt. The disposal site is located at the outer edge of the average turbidity maximum.

For the local hydrodynamic situation measurements have shown a distinct vertical gravitational circulation because of barocline stratification effects. Near-bottom the flood starts about 1.5 hours earlier than the surface. As a result during low-water slack and for the first 3 hours of the flood period a clear stratification can be observed in the deep channels. For the residual part of the tidal cycle the water column is fully mixed. The mentioned mechanism causes longer and stronger inward flow periods in the near-bottom area which also affects net sediment transport capacity and direction.

To be able to consider the VGC within the numerical simulations the model area had to be extended to the whole estuary including the complete tidal-influenced part of River Weser (approximately 1000 km²).

Figure 7 shows the detailed near-field topography of the disposal site. The survey vessel sailed along the shown track, continuously taking measurements as described above. The disposal was started at about 14.20h close to the end of ebb tide. The upper left corner shows a deep scour near a groin head which was crossed by the survey-vessel two times (see Figures 7 and 8). The disposal position is marked by the red circle.

Figures 8 to 10 compare observed and calculated values along the track. One has to consider the plots implicitly showing a variation in space and time. All time-values are given in hours UTC with decimal hours instead of minutes.
Figure 8 shows observed vs. calculated SPMC-values along the surveyed track. The vessel first entered the turbidity cloud at approx. 14.45h. The corresponding vessel position can be seen from Figure 7.

The massive local entry of momentum and turbidity resulting from the disposal accounts for a gap in the measured concentrations because of an exceedance of the ADCP working range. The lower image of Figure 8 shows calculated SPMC values resulting from the disposed matter. Turbidity of the natural background is blanked out.

When first entering the turbidity cloud at 14.45h the water column appears fully mixed. After a short way upstream (Figure 7) the vessel altered its direction to northwest (downstream direction) and reached the groin head scour at approx 14.70h. The measurements as well as the calculations show an increased agglomeration of suspended sediment in the lower water column. Increasing SPMC values in the upper column are found towards the 14.75h turn at the groin head scour.

The same pattern with lower concentrations is passed at the subsequent course in upstream direction. After reaching the upstream edge of the turbidity cloud around 15.00h a new course in downstream direction is taken. The cloud is passed again and concentrations decreased.

Attention should be paid on the skew distribution near and in the scour hole around 15.20h with higher SPMC near-surface than near the bottom. The measured as well as calculated turbidity-distribution show this pattern which is a result of a salt-water “bubble” that remained in the scour hole.

The turbid water does not enter the scour as the saltwater is denser (Figure 9) and deflects the disposal-induced turbidity.

The simulation shows that the accumulation of water with higher salinity in the scour persists until approx. one hour after low-water slack (15.50h). This detail shows the good quality of the numerical simulation.
CONCLUSIONS

The present paper shows the model capabilities of an extended 3D-morphodynamic model to reproduce measured nearfield distributions of disposal-induced suspended sediment. The model calculates a 3D flow field as well as transport of salt, suspended and bed-load sediment. Sediment is represented by different fractions. The observed processes are fully three-dimensional and require a direct coupling of all relevant processes especially between momentum exchange and local density-gradients. Based on a local density-dependant approach, the near-field spreading of disposal-induced turbidity-plumes can be qualitatively well reproduced. The disposal process is implemented by means of an abstracted initial condition. A proper numerical representation of the overall hydrodynamic situation is very important. This in particular applies for estuarine environments, where wide area density effects like vertical gravitational circulation have major influence on the flow- and sediment-transport situations.

Measurements in the extended nearfield of disposal-induced turbidity are compared to numerical simulations. The results are in good agreement and confirm the validity of the initial sediment disposal assumption. The model-approach allows predictions of the near-field spreading as well as the long-term fate of disposed matter. For the latter case field measurements for comparison purposes are hard to get because of the difficulties regarding the discrimination of disposed matter against the natural sediment in the farfield. SMOR3D can help to improve economical and ecological aspects of off-site disposal of dredged matter.

REFERENCES


ABSTRACT

To meet the growing energy requirements of the United Kingdom, a decision was made to lay a new offshore pipeline from Norway's gas-rich fields to the eastern coast of the UK. The pipeline would cross 1200 km from Nyhamna, Norway to Easington, UK, making it the longest offshore pipeline ever built. This article discusses the shore approach and landfall works which presented several unique challenges. These included environmental concerns because of the rapidly eroding clay cliffs along this section of the UK coastline, and technical demands to dredge at great depths in difficult soil and between two existing live pipelines.

INTRODUCTION

The 1200-km, 44-inch diameter Langeled pipeline from Nyhamna in Norway to Easington on the east coast of the United Kingdom is the world's longest offshore pipeline (Figure 1). Statoil ASA executed the work on behalf of Norsk Hydro. The new pipeline will provide up to 20 percent of the UK's gas requirement from October 2006.

The pipeline was pulled ashore in June 2005. Shore approach and landfall works were executed by Jan De Nul (UK) Ltd which was the principal contractor for the landfall works. The European Dredging Company (EDC), another member of the Jan De Nul Group, was responsible for the offshore dredging and rock placement. The offshore trench was excavated using the cutter section dredger, the JFJ De Nul, and backfilling the trench was performed using the trailing suction hopper dredger Filippo Brunelleschi. This TSHD also carried out pre-sweeping of offshore sand dunes. Rock placement at the Langeled-Cleeton pipeline crossing and in the nearshore section was executed with a side stone dumping vessel with rock imported from Norway.

CHALLENGES

Numerous challenges were taken into account during the execution of this landfall and shore approach operation. Amongst them were the unstable cliffs along the coastline at Easington which are subject to high erosion, with the land retreating at around 1-2 m per year. To allow for this and to minimise disturbance at the cliff face, a 380-m-long, 2-m-diameter curved tunnel beneath the cliff was built in order to contain the pipeline on its route from the beach into the terminal.

Above, work progresses off the UK's eastern coast at Easington, preparing the cofferdam and tie-in pit for landfall of the new pipeline.
WOUTER VERCRUYSSE
Wouter Vercruysse graduated in 1992 with an MSc in Mechanical Engineering from Louvain University (Belgium) and joined the Jan De Nul Group in the same year. For the last 10 years he has been Project Manager on many pipeline projects in the North Sea, Singapore, Indonesia, Argentina, Taiwan and Sakhalin (Russia). For the Langeled Project, he was Project Manager for the offshore part, including shore approach trenching, offshore presweeping and gravel placement. He is now working as Project Manager of the Dolphin Pipeline Project in the United Arab Emirates at the Das Island Shipping Channel.

MICHAEL FITZSIMONS
Michael Fitzsimons graduated in 1975 with a Bachelor in Civil and Structural Engineering from Sheffield University (UK) and worked in the civil, marine and pipeline industry for more than 20 years before joining Jan De Nul in 2002. Since then he has been employed on many pipeline projects in Singapore, Indonesia and Sakhalin (Russia). For the Langeled Project, he was the Project Manager for the onshore and related pipeline works. He is presently project managing a pipeline project in Mauritius.

Another challenge was the presence of several marine pipelines at Easington also making landfall along the beach and land pipelines that feed gas from the terminals into the UK transmission grid (Figure 2).

The new 44-inch diameter gas line approaches the shore in a pre-excavated offshore trench some 20 km long and 1.5 to 2 m deep, sited between two existing live pipelines. This required trench excavation in open sea conditions through hard boulder clay at 37-m water depth at the offshore end which was previously unachievable by any dredger. For the shore crossing, a 240-m-long cofferdam plus a temporary beach platform were constructed to provide access in the intertidal zone to a tie-in pit, where the offshore pipeline section is connected to the onshore section.

ENVIRONMENTAL PROTECTION
The installation of pipelines from offshore through shallow water to a beach always poses challenges, but the rapidly eroding clay cliffs along this section of the UK coastline made the Langeled pipeline a special case (Figure 3). Each year, approximately 1 to 2 m of cliff disappears into the sea. This has been going on for thousands of years, removing numerous villages from the map. In Roman times the coast was three miles further offshore.

Protecting the Langeled landfall section of this erosion called for particular measures.

Engineering studies of the erosion required that the pipeline be installed deep within the cliff. With minimum environmental impact being a prerequisite, open excavation was not an option. The solution was to install a tunnel to carry the pipeline from the new gas terminal (sited 380 m safely inshore of the eroding cliff) to a tie-in pit on the beach, passing under existing pipelines, roads and other land features.

A sheet piled cofferdam extended the pipeline trench from the tie-in pit through the tidal zone of the beach to 60 m beyond the low water level (Figure 4).
Another option that was considered, but rejected, included extending the tunnel offshore so the pipeline could be pulled directly from the lay barge. However, the combined risk of constructing a longer tunnel with the marine challenges was considered to be unacceptable. To ensure there would be no delay, both the tunnelling and cofferdam were scheduled to be completed in advance of the arrival of the lay barge and this was executed as planned.

**TUNNEL CONSTRUCTION**

Work on the tunnel started in Autumn 2004 with the clearance of the site and the installation of the tunnel shafts. The tunnel, with a 2.4 m outside diameter, was installed using a tunnel-boring machine (TBM). Concrete pipes, 2.5 m long, were lowered into the entry shaft where powerful jacks pushed the pipes and the TBM forward to form the tunnel (Figure 5). The TBM was able to steer its way and a vertical curved alignment was followed that avoided the need for a deep entry shaft.

The soil conditions were stiff clay with occasional boulders. The forward face of the TBM’s earth balanced shield was set up with picks and water jets to cut the clay and cutting discs to break up the boulders. To minimise ecological impacts, seawater was pumped down to the face of the TBM, which flushed out the sediment as a mixture with seawater.
Tunnel Soil Treatment Plant
Envisan, Jan De Nul’s environmental branch company, was subcontracted to design, build and operate the tunnel soil treatment plant (Figure 6). First, the tunnel sediment mixture was collected in purpose-built settlement lagoons. The clay and crushed rock were then removed from the seawater by a combination of natural settlement and flocculents; the remaining water was returned to the sea with less than 5 g/L of sediment. The settled clay was treated and reused at the beach site, while the remaining slurry soil was transported to licensed landfill sites. In this way some of the sediment from the tunnelling had a beneficial use.

CONSTRUCTION OF COFFERDAM AND TIE-IN PIT
With the tunnel activities progressing, a separate team formed an access point from the cliff top to the beach, where a platform was established to provide a safe working area above the high tide level. Within this platform, the 13 m deep tie-in pit was sheet piles ready for the arrival of the TBM. Extending 220 m from the beach platform, a sheet-piled cofferdam was installed by land-based equipment working at low tides from a causeway constructed alongside the cofferdam (Figure 7). As a result of the stiff clay, pre-augering had to be executed over most of the length in order to allow the sheet piles to be installed at the required depth.

TRENCH DREDGING AND MARINE BACKFILLING
Beyond the cofferdam the pipeline trench was formed by dredging and, given the size of the project, a powerful cutter suction dredger had to be enlisted to carry out this work. The CSD JFJ De Nul, 27 240 kW vessel, was able to excavate the trench, even in very hard clay with boulders, in weeks rather than months. This contributed to lessening the environmental impact of the project (Figures 8, 9 and 10).

The CSD JFJ De Nul was connected to a 500-m-long floating hose, which deposited the soil to one side of the trench to be used later for backfilling. To stabilise and protect the nearshore pipeline, the trench was extended 22 km offshore from the cofferdam where dredging took place up to 37 m deep, a depth previously unreachable by any other dredger in these soils. For the first kilometre, gravel was placed by side stone dumping vessel to provide added stability and to protect against frost upheaval. Gravel was also placed in the cofferdam section of the pipeline trench.

The marine trench has been backfilled with the dredged clay from the stockpile using the JFJ De Nul for the first 1.5 km and the 11,300 m³ capacity trailing suction hopper dredger Filippo Brunelleschi for the remaining trench.
OFFSHORE PRE-SWEEPING

The TSHD Filippo Brunelleschi was also used offshore to level pre-sweeping sand waves to prepare the seabed in order for the pipeline to be installed within allowable stresses and free-spans. These pre-sweeping works were executed in water depths up to 70 m (Figures 11 and 12). Real-time stress and free-spans analysis were performed on board of the dredger in order to verify the dredged longitudinal profile. This provided day-to-day on-line information for the project team onboard the dredger.

PIPELINE CROSSING AND GRAVEL INSTALLATION

Another challenge at Easington was the presence of several marine pipelines making landfall along the beach and land pipelines that feed gas from the terminals into the UK transmission grid. The new works were executed in between two existing live pipelines, one of which had to be crossed approximately 6 km from the beach. At the crossing, mattresses were installed to separate the pipelines and following the laying of the new Langeled pipeline, rock was placed to provide protection. The rock, imported from Norway, has been installed by a dynamic positioned side stone dumping vessel (SSDV) (Figure 13). Inside the cofferdam and over the nearshore section of the trench, the pipeline was also covered with gravel in order to avoid frost heave.
High tidal currents appear at the east coast of the UK. Therefore, an acoustic Doppler current profiler was installed on the SSDV to profile the currents. Based on these measurements, the position of the SSDV was adjusted continuously resulting in improved placement accuracy during high tidal currents.

**PIPELINE INSTALLATION IN THE TUNNEL AND TO THE TERMINAL SITE**

On completing the installation of the 380-m-long tunnel, a 60-m-long, 6° ramp with a rail track was constructed from the terminal end leading into the tunnel. At the far end of the tunnel, a winch system was set up in the tie-in pit on the beach. Four 12.2-m-long pipe sections could be positioned on the ramp. With a cycle time of 24 hours for the welding, non-destructive testing and coating, the pipeline was progressively pulled into the tunnel (Figure 14).

A rubber neoprene coating was specified for this section of the pipeline to give added corrosion protection in the tunnel. Polyurethane collars were factory fitted to the pipeline to protect the coating as the pipeline was pulled through the tunnel. The landfall scope of work also included a section of trenched pipeline that extends approximately 300 m from the tunnel into the main terminal (Figure 15).

**OFFSHORE-ONSHORE TIE-IN AND BEACH PULL ASSISTANCE**

The 15-km nearshore section of the landfall pipeline was installed by the lay barge *Togmor* from Allseas which entered the floatation channel prepared by the JFJ De Nul and anchored at the end of the cofferdam. A 500 t winch was set up behind the beach platform and the pipeline was pulled from the lay barge, along the cofferdam, and into the tie-in pit (Figure 16).

![Figure 13. Installation of the rock by a dynamic positioned side stone dumping vessel.](image)

![Figure 14. Welding the onshore pipeline.](image)
A seal was made around the pipeline at the entrance to the tie-in pit so it could be pumped dry and the onshore pipeline can be tied into the offshore pipeline. Following the tie-in, the tunnel was grouted to seal the pipeline.

CONCLUSIONS

The need to establish additional gas supplies for the United Kingdom led to the decision to build a new pipeline from Norway to the eastern coast of the UK. A number of challenges were present at Easington, the site chosen for landfall. The shore approach and landfall works had to take into consideration environmental issues, including protection of the heavily eroded cliffs along the coastline. The tunnel construction proved a good solution to this problem.

In addition, utilising a soil treatment plant for processing the soil from the tunnelling allowed the beneficial re-use of sediment on the beach site. This proved to be environmentally sound, efficient and cost-effective.

The need to dredge at great depths as well as to manoeuvre between already existing live pipelines added to the need for extreme care and the use of the latest generation of newly developed seagoing self-propelled cutter dredger.

With the completion of the project, the pipeline and tunnel have been buried and all beach construction work and the access road have been removed to restore the area to its natural state.

Unlike other forms of engineering projects where the finished product can be proudly shown to friends and colleagues, once the Langeled site was reinstated, there were no visible presence and no environmental impact to the shoreline of the landfall that safely feeds the UK with energy.
ABSTRACT

Geotextile tubes have been applied for a number of years in hydraulic and coastal engineering such as shore protection and breakwaters. Based on a concept originally suggested by the Dutch marine contractor ACZ (now Van Oord), the so-called Geotube® was further developed by Ten Cate Nicolon, and has proven successful on land as well as in shallow water. Using Geotubes® in rough and deep water however provides another set of technical difficulties.

Discussions with a commission from CUR (Centre for Civil Engineering Research and Codes) -- comprising several companies and organisations amongst which Van Oord ACZ, Boskalis, IHC, Rijkswaterstaat (RWS), Rotterdam Public Works, the manufacturers of geotextile and TU Delft -- about the potential problems resulted in further study of the feasibility of a continuous Geotube® that could be used in open sea conditions. The report “Praktijkproef continue geotube” is based on the Dutch patent NL 1011043. One of the main problems foreseen by the committee was the simultaneous filling and stitching of the geotextile. This paper describes a folding method (patented) for stitched Geotubes®, which makes it possible to separate the filling process from the fabrication of the tube, the mathematical modelling of a Geotube® during the operation, the performed scale tests and a way the overcome the remaining problems.

INTRODUCTION

For several years geotextile tubes or Geotubes® (a registered trademark of Ten Cate Nicolon b.v.) have been applied in hydraulic and coastal engineering such as shore protection and breakwaters. They have been used on land as well as in shallow water. With the present techniques it is very difficult to apply Geotubes® in rough and relative deep water.

In 2002 the CUR committee C129 presented a report that describes the expected problems in the concept device to fabricate a continuous Geotube® that can be used in open sea conditions. The report “Praktijkproef continue geotube” is based on the Dutch patent NL 1011043. One of the main problems foreseen by the committee was the simultaneous filling and stitching of the geotextile. This paper describes a folding method (patented) for stitched Geotubes®, which makes it possible to separate the filling process from the fabrication of the tube, the mathematical modelling of a Geotube® during the operation, the performed scale tests and a way the overcome the remaining problems.

The following processes take place during installation of the continuous Geotube®:
- On a pontoon a tube is formed from a roll geotextile.
- The edges of the geotextile are sewed together.
- The tube is secured to the pontoon by a clamping system.
- The Geotube® is filled with sand trough the opening.
- During placing the tube is (partly) supported by a slide

The concept of the continuous Geotube® makes it possible to place a Geotube® in deep and rough water (Figure 1). Because the tube is filled before it is placed, the tube is stable after placing. There are several technical difficulties, but the two main difficulties in the concept are:
- The stresses in the geotextile and a clamp system to transfer the forces to the pontoon.
- The integration between sewing of the geotextile and filling of the tube with sand.

Above, Geotube® units were used to outline an area for a wetlands, creating a barrier sufficient to allow the area to develop (Courtesy of Ten Cate).
MATHEMATICAL MODEL

To understand the static stresses acting in the geotextile, a mathematical model was made. The main simplification in the model is that the influence of the sand particles was neglected. The tube is filled with a slurry with a density twice as high as the density of water. The model describes the shape of the Geotube® after placing as well as the tangential and axial stresses in the geotextile when it is placed over a slide to the bottom. The bottom section of the slide is modelled as a quarter of a circle with a 5 metre radius and the top section as straight vertical (Figure 2).

Only the bottom section is considered in the model. This part supports the tube from to vertical position to horizontal position. With the stresses acting on the geotextile, the total axial force on the clamp system can be calculated. For 5 metre circumference Geotube® which is filled at 5 metres above the bottom, the final height after placing will be 1.40 metres and the total static axial force is 85 kN.

The dynamic forces caused by external and internal influences are difficult to describe. A safety factor which includes an aspect for dynamic forces is used to calculate the required geotextile strength. A general used value for the safety factor is 3.

FILLING AND SEWING OF THE GEOTUBE®

The integration between the processes of sewing and filling could not be realised according to the CUR committee. To guarantee the quality of the seam it is necessary that:
- There is no tension differential between the two edges of the geotextile.
- The working area of the sewing equipment is free of sand and water.

These two demands cannot be accomplished onboard a pontoon. The whole process of fabricating and placing the Geotube® is dependent on the process of making the seam. To guarantee the quality of the seam the tube has to be pre-fabricated. A pre-fabricated tube which is rolled up can only be filled through inlet ports. Filling through inlet ports is not an option for the continuous Geotube®.

The solution is to fold the tube in a special manner, so a package with a filling opening is formed (Figure 3). As seen in Figure 3, the first step in the method is folding the tube inwards from two sides, so two parallel folds (4) are made. The size of the filling opening is dependent on the distance between the folds (length of 5). Hereafter the tube is folded inwards (6) from two sides perpendicular to the first step. Then the first step can be repeated. When completed, an opening remains in the middle of the package. In Figure 3, square section 8 is the filling opening.

The ratio between length of the Geotube® and the thickness of the folded package depends on the circumference of the Geotube®, the thickness of the geotextile and the dimensions of the filling opening. With commonly used dimensions of Geotubes®, the theoretical ratio ranges between 100 and 250. For a 5 metre circumference Geotube® of 200 kN/m geotextile with a thickness of 3.3 mm,
Feasibility Study of the Continuous Geotube®

the theoretical ratio is 1:113. A package of 1 metre contains a tube with 113 metre length. When a 100 kN/m geotextile is chosen, the thickness is 1.6 mm and the ratio is 1:234

The method was tested with a 3.5 metre circumference and 5.2 metre length Geotube® (Figure 4). The size of the opening is 0.3 by 0.3 metre and the thickness of the geotextile 1.2 mm. The theoretical ratio is 240, so the calculated height of the package is 22 mm. The measured height was also 22 mm.

CLAMP SYSTEM AND SCALE TESTS

A clamp system is needed to secure the Geotube® to the pontoon and to lower the Geotube® at the same time. A clamp system with the clamp completely outside the Geotube® has the most advantages. The forces acting on the clamp can easily be transferred to the pontoon and the clamp is always accessible for maintenance. The Geotube® is clamped on two sides next to the filling pipe. The clamp will be fitted with a tensioner system to get a continuous process.
Scale tests were performed to determine the maximum axial force that the clamp can transfer and to understand the process of placing the Geotube®.

A model of the clamp was made on a 1:5 scale. The clamp was not fitted with tensioners but with clamping plates for simplicity (Figure 5).

For the strength test, a 1 metre circumference and 25 kN/m strength Geotube® was fixed in the clamp. The other end of the Geotube® was clamped circular (see Figure 6). In the first test the Geotube® tore at the circular clamped end at a load of 12.4 kN (Figure 7). In the following test the maximum load on the geotextile was 19 kN; at that moment the geotextile was about to tear again at the circular clamped end of the Geotube®. The tests showed that a clamp system fixing the Geotube® on only 40 percent of the circumference can transfer up to 75 percent of the total axial strength of the Geotube®.

The filling tests were carried out in a 4 metre deep basin with a 1 metre circumference Geotube®. The tube is placed without a slide for simplicity (Figure 8). The filling height was kept at 1 metre above the bottom. The axial force on the clamp was measured and was equal to the calculated static force with the model. The calculated height of the Geotube® is 0.29 metre while the measured height of the Geotube® varies between 0.25 and 0.29 metre.

This variation in height is caused by the simplification of the scale model. Because of the clamping plates, the Geotube® has to be lowered after every metre of placed
tube to loosen the clamp plates and re-clamp the tube a metre higher. Hereafter the tube is lifted again, but the decrease in height cannot be undone. Because the Geotube® was placed without a slide, the curve of the tube between the vertical to horizontal position is not circular as presumed in the model. The shape of the curve of the Geotube® somewhat differs from the shape of the slide but the difference is not significant.

Filling of the Geotube® can be done hydraulically or mechanically. The settling velocity of the sand particles is, partly dependent on the influence of process water, too low to fill the Geotube®.

When the tube is filled mechanically, as in the scale tests, the sand will act as one mass and will achieve a much higher settling velocity than an individual sand particle. During the tests this influence was noticed in an increase of the axial force acting on the clamp (Figure 9).

Another result of the test is that a slide is not necessary to place a Geotube®. The Geotube® will curve in a manner so that an equal tension distribution will be achieved. The place of the seam has influence in the tension distribution in the geotextile. The tension distribution will be better when the seam is orientated on top of the Geotube® after it is placed.

From the standpoint of process control, a slide is not even desirable. Without a slide the filling height can be determined by the axial force. With a slide an unknown part of the forces are transferred through the slide, so there is no relation between axial force and the filling height.

**STRUCTURE OF THE INSTALLATION**

The structure of the installation is determined mainly by the presence or absence of swell compensation. When the pontoon is positioned and the clamp is located in the centre of mass of the pontoon, rotation around horizontal axes of the pontoon does not lead to vertical translation of the clamp. Vertical translation of the pontoon can be seen as an increase in filling height. An increase in filling height leads to higher axial and tangential forces which can be taken up by the geotextile, i.e. the geotextile acts as a swell compensator.

As long as the rotations around the horizontal axes of the pontoon are small compared to the water depth, the clamp can be fixed to the pontoon and swell compensation does not seem to be necessary. Gripping the package and the manner of changing the packages also influences the structure of the installation.

There are several options to fulfil these tasks (Figures 10, 11 and 12).

To obtain the desired final product, complete control of the total process of filling and placement of the Geotube® is required. To keep variation in the final height of the Geotube® small, the filling height must be kept as constant as possible. The influence on the filling height of the descending speed can be measured directly from the axial force, while the influence of the filling speed can only be measured with a delay. Therefore the
descending speed is made slave to the filling speed to control the process. Between the folded Geotube® and the clamp is a small buffer, so the supply of Geotube® from the package may differ from the descending speed.

CONCLUSIONS

The main conclusions from this study are:
- By folding the Geotube®, the problem of integration of sewing the geotextile and filling the Geotube® with sand is avoided.
- A clamp system that clamps the Geotube® on 40 percent of the circumference can transfer up to 75 percent of the total strength of the Geotube®.
- The mathematical model can be used to predict the axial force on the Geotube® and the shape of the Geotube® on the sea bottom with sufficient accuracy.

With the information obtained by the scale tests and the solution for the integration problem, a prototype test is now necessary. For the execution of a prototype test the following recommendations are made:
- The clamp should be placed rigidly and without swell compensation on the pontoon.
- Prior to the prototype test, the manner of gripping the package Geotube® and the supply of Geotube® to the clamp has to be tested.
ABSTRACT

The First Edition of the Form of Contract for Dredging and Reclamation Works ("FCDR") has recently been published by the International Federation of Consulting Engineers ("FIDIC"). This is a positive development as there are an enormous variety of contracts in use in the marine related civil works sector, with some forms dating back to the 1970s. This article analyses the new form, from the viewpoint of a practising infrastructure lawyer, by reference to a marine contractor’s top ten concerns, with a view to evaluating the overall contractor friendliness of the form. The author would like to acknowledge the helpful industry insights so generously supplied during the course of writing this article by Mr Kenji Kaga, Administrative Manager of Taisei Corporation (UAE); Mr Gordon Rankine of Beckett Rankine Partnership and Mr Ian W. Brown, Senior Vice President, Asia Infrastructure Practice, Greater China, of Marsh.

INTRODUCTION

After some considerable period of incubation the First Edition of the Form of Contract for Dredging and Reclamation Works ("FCDR") has been published by the International Federation of Consulting Engineers ("FIDIC"). This is clearly a positive development. There is an enormous variety of contracts in use in the marine related civil works sector, with some forms dating back to the 1970s. The publication by FIDIC of a standard form presents a real opportunity for greater coherence and more sensible risk allocations in the contractual framework supporting marine related civil works.

For a most helpful introduction to the form one need go no further than the article entitled, “A Contract for ‘Just Digging a Hole’” which appeared in Number 85 of this journal in December 2001. This article does not seek to repeat that account. Instead, it analyses the form, from the viewpoint of a practising infrastructure lawyer, by reference to a marine contractor’s top ten concerns. This is with a view to evaluating the overall contractor friendliness of the form.

Above, The FIDIC contract should cover dredging works such as those of the cutter at work for the expansion of part of Rotterdam’s harbour.

DISTURBANCE OF THE WORKS

The risk of physical disturbance to the works and site operations presents a first order concern for contractors undertaking dredging and reclamation work. This is because offshore works are notoriously vulnerable to the natural forces of wave action, winds and tidal forces. Yet contractors are still expected somehow to evaluate and budget for the magnitude and likely incidence of these risks on a project-by-project basis. Employers might require this even in circumstances where they have access to better information about the specific conditions of the Site where the project has to be executed.

Despite advances in modern project management and in technology the evaluation of this risk remains problematic, and responsible contractors are left with little alternative to applying a global contingency to their prime cost figures. Even so, this is an area accustomed to ugly arguments concerning the financial impact of unanticipated natural disturbances (Figure 1).

The FCDR recognises this difficulty and responds by providing for two relevant
kinds of Defined Risk, for which, in the event of delay and/or additional costs, the Contractor may recover relief. These take the form of “forces of nature” (Sub-Clause 6.9h) and “climatic conditions” (Sub-Clause 6.9m). The Guidance document explains the difference between what might otherwise seem to be partially overlapping phenomena. On the one hand, the broader term “forces of nature” is not intended to include weather conditions, although in ordinary English usage it would do. Rather, the term is intended to address natural catastrophes such as unseasonable hurricanes, tidal waves, volcanoes suchlike (Guidance, page f). The concept of “climatic conditions” is on the other hand concerned with weather conditions. Taken together, these forms of Defined Risk indeed cover a broad area of the disturbance risk.

In the case of “forces of nature”, the threshold test for qualifying as a Defined Risk differs from that for “climatic conditions”. A force of nature must: (a) affect the Site and/or the Works; and (b) be either unforeseeable or something against which an experienced contractor could not reasonably have been expected to take precautions. This definition calls for an exercise of judgment as to what is objectively foreseeable and, if the force of nature was foreseeable, whether a reasonable, experienced contractor would have taken precautions against it. Such a definition involves a different test to “physical obstructions or physical conditions” and yet it includes the simple foreseeability test employed for “physical conditions” in the Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer (Sub-Clause 4.12).

As for “climatic conditions”, the requirement is that the actual climatic conditions encountered are more adverse than those specified in the Appendix, in what the Guidance refers to as the “weather threshold”. The weather threshold will need to be defined precisely to avoid disputes. The Guidance recommends such precision and gives the example of a weather threshold for wave-heights of up to a 20-year frequency. The Guidance also states that it will be necessary to specify in the Appendix the conditions that are to be at the Employer’s risk. Under many legal systems (for example, those in jurisdictions with an English Law heritage) the risk of climatic conditions will rest with the Contractor by default, in the absence of risk-shifting contractual provisions. In view of this, the Guidance statement may somewhat overstate the position. Clarity in this area is never a bad thing.

**UNANTICIPATED CONDITIONS**

As everyone in the business knows, a bidding contractor is less sure of, and less able to manage, the risks of ground conditions beneath seabed than in the case of terrestrial ground conditions. As Dolmans (2001, p 4.) notes, “[t]he very nature of dredging activities, i.e. at various depths underwater, creates difficulties in obtaining accurate information regarding sub-soil condition.” With good reason, the problem registers high on a dredging contractor’s lists of concerns.

Nevertheless, given their general terrestrial bias, the standard forms in current usage in marine related civil works projects do not provide appropriate and economical standard risk allocations in connection with ground conditions. In this respect, therefore, the specialised focus of the FCDR offers advantages to both parties with its more balanced, realistic approach to the allocation of the risk of adverse subsurface conditions.

The contractual scheme provides for this sharing of this risk by various provisions. First, subject to procedural compliance, the Contractor will be entitled to an extension to the Time for Completion if he is or will be delayed in completing the Works by, amongst other things, “physical obstructions or physical conditions” encountered on the Site during the performance of the Works, which were not reasonably foreseeable by an experienced contractor (Sub-Clauses 6.1 and 7.3).

Secondly, and in similar vein, the Contractor will be entitled to the amount of any Cost he incurs because of such physical obstruction or physical conditions subject to any specific provision in the Contract (Sub-Clause 10.4). An example of just such a provision would be a priced item in the bill of quantities for time-related overheads. Adverse ground conditions that do not fit within the elements of the “physical obstructions or physical conditions” extension of time provision will not serve to derogate from the Contractor’s responsibility for timely completion of the Works. In this sense, the risk is shared, since clearly not all ground conditions, nor the circumstances in which they are encountered, will satisfy the tightly defined contractual test.

Thirdly, the Contractor’s general indemnity in Sub-Clause 13.2 does not extend to loss or damage happening because of “physical obstructions or physical conditions” encountered on the Site during the performance of the Works, which were not reasonably foreseeable by an experienced contractor and which were immediately notified to the Engineer.

Fourthly, sub-Clause 2.3 envisages that the Employer has made available to the Contractor for his information prior to
tendering, all data in the Employer’s possession relevant to the execution of the Works, including hydrological, sub-water surface and sub-bottom conditions, and environmental aspects. To the extent the Employer makes good on this assumption, and procures and furnishes basic factual data concerning sub-bottom conditions, the Contractor will therefore be relieved of the information-gathering obligation. He remains responsible however for “interpreting that data and for inspecting the Site and making his own enquiries so far as is practicable (taking account of cost and time) before submitting his tender”.

On the other hand, the Employer may (depending on relevant principles of the Law of the Country) be held responsible for the inadequacy or, more particularly, the unrepresentative character of the basic factual data made available by the Employer prior to tendering. This seems to open the way for claims, not unknown to arbitrators and the courts, based on the provision of inadequate basic factual information by or on behalf of the Employer. Arguments in defence of such a claim, that the Contractor should have spotted the problem with the data, are bound to be met with the refrain that, in the limited time afforded the tendering contractor, “the extent of enquiries required” to uncover such a problem was simply unachievable. It will be interesting to see whether employers will resist the urge to replace Sub-Clause 2.3 with more traditional, less well-balanced provisions.

Lastly, the Employer will be responsible for the Specification and Drawings (Sub-Clause 5.2). and, specifically, insofar as time and delay costs are concerned, the design of any part of the Works by the Employer, the Engineer or others for whom the Employer is responsible (Sub-Clause 6.1g). That this design may be deficient due to problems in site investigation does not detract from the Employer’s responsibility for those problems.

**SITE AND SECURITY**

The nature of the Site in offshore marine related civil works presents obvious challenges to contractors, both in relation to their operations and to their exposure to legal risk. The Site is of course rather fluid (figuratively and literally) and so site security can pose serious challenges to the Contractor’s operations and legal risk exposure. Unlike onshore works, the Contractor cannot secure the site of marine related civil works with hard barricades and fences. Instead, all the Contractor can do is deploy buoys and warning signs which are often only detectable at close range and do not physically prevent strangers from entering the area. Damage caused by incursions into a marine site can directly impact the permanent work. For instance, a boat can do substantial damage to sheet piles leading to highly destructive water incursion. At the same time, contractor’s all risks policies do not ordinarily extend to the economic consequences of these risks, in terms of cost and delay.

In view of these risks, contractual provisions are called for that cater for the issues of demarcation, shipping incursions and, of course, general site security. In this respect, the definition of “Force Majeure” employed in the FCDR seems broad enough to cover accidental site incursions leading to damage and is a welcome provision.

As is normal with FIDIC contracts, the Employer is explicitly required to provide the Site and a right of access thereto (Sub-Clause 2.1). It is envisaged that this may occur in phases, and there is provision for the relevant trigger dates to be set out in the Appendix (Sub-Clause 2.1). The default setting is the Commencement Date and Sub-Clause 1.1.10 defines this as the date 28 days after the date this Agreement comes into effect or “any other date agreed between the parties”, which serves to highlight the lasting wisdom of ensuring clarity as to the purpose of any agreed dates and of getting those dates recorded in writing (Figure 2).

What is “the Site” is defined with suitable flexibility, although interestingly it seems not to accommodate storage areas. Sub-Clause 1.1.20 defines “Site” by reference not only to what places the Contract specifies as forming part of the Site, but also any places provided by the Employer where the Works are to be executed. In other words, the footprint of the Site can be enlarged, subject to one important qualification: if, during the course of the project, the Employer provides the Contractor with an additional area, say for the storage of steel sheets, but not for any work or design operations, then that additional area will not become part of the “Site”. This is because Sub-Clause 1.1.23 defines “Works” in the restricted sense of all work and design (whether permanent or temporary), rather than all things to be done pursuant to the Contractor’s obligations under the Contract. Particular Conditions and associated parts of the Specification and Drawings will need to deal with appropriate countermeasures as the storage security requirements dictate.

**CERTIFYING PROGRESS AND COMPLETION**

In the context of marine related civil works the measurement of completed works is not easy; being neither the subject of any standard method of measurement, nor susceptible to ready agreement. The difficulty and time involved in carrying out a visual or physical inspection of underwater permanent works makes measuring quantities and certifying progress that
particularly difficult to carry out. Whilst the volumetric measurement method has its uses, great care is required in the case of tight tolerances and side slopes and, understandably, contractors might favour the other more expedient approach of measuring material in the hopper or in a reclamation area.

The FCDR offers a flexible approach to price evaluation, by providing for five alternative modes of valuation, namely, lump sum price, lump sum price with schedule of rates, lump sum price with bill of quantities, re-measurement with bill of quantities and cost plus Sub-Clause 11.1).

Notably, all five modes of valuation require some form of assessment of the state of the works on a monthly basis. This means that there is still something to be gained in pre-agreeing a suitable method of evaluating the progressive state of the Works, preferably in the form of corresponding Particular Conditions.

TIME

The FCDR clearly apportions the risk of delay arising during the course of the Work. This is to be commended given the fundamental importance of timeliness in the completion of groundwork. There are numerous dates arising in the General Conditions, two of which are particularly critical, namely, the Commencement Date and the Time for Completion.

As set out above, the Commencement Date is defined to mean the date 28 days after the date the Agreement comes into effect (being when the Contractor receives one original of the Agreement signed by the Employer), or any other date agreed between the Parties. The Commencement Date represents the starting point for several matters. The Employer must provide the Site and the right of access thereto on the Commencement Date. It is also the starting point for the Contractor’s full responsibility for the care of the Works and the required insurances. Last but not least, it is the date on which the Contractor must commence the Works (Sub-Clauses 1.1.8, 2.1, 7.1, 13.1 and 14.1).

In view of the evident importance of the Commencement Date, the Guidance helpfully recommends that the Employer should ensure an adequate official record of the date when the Contractor received the Agreement signed by the Employer.

The Time for Completion is defined to mean the corresponding time stated in the Appendix, within which the Contractor shall complete either the Works, namely, all the work and design (if any) to be performed by the Contractor (Sub-Clause 1.1.23) or, if stated, the corresponding Section (Sub-Clauses 1.1.10 and 7.1).

Thus, as the Guidance points out, the Employer may decide, when preparing the tender documents, to have one Time for Completion for the Works as a whole, or, alternatively, to have Sections of the Works for which separate earlier Times for Completion can be stated as well as for the whole of the Works.

Sub-Clause 7.3 provides that if the Contractor fails to complete the Works or any Section within the Time for Completion, the Contractor’s only liability to the Employer for such failure shall be to pay the amount stated in the Appendix for each day or part of a day for which the Contractor fails to complete the Works or Section. The Appendix, in turn, makes provisions for the Employer to insert a figure. In relation to the Works as a whole, the figure applies to each day of delay or part of a day up to a maximum of 10% of a sum stated in the Agreement (on the basis that the pricing structure may not involve a lump sum contract price).

In relation to each of numerous Sections, the Appendix provides for a corresponding amount payable to be entered; however these figures do not come with a corresponding liability cap for each Stage. Ongoing delay in completing a Section will of course very soon translate into delay in completion the Works to which the 10% liability cap applies, and yet it is unclear whether at the point that liability arises for delay to completion of the Works the accrued liability for delay to completion of a Stage (or Stages) is intended to be extinguished.

The Time for Completion may of course be extended in the event the Contractor is or will be delayed in completing the Works by any of the Defined Risks. The reference to delay in completing the Works suggests that the Defined Risk must have affected Figure 2. Dredging and shipping traffic need to take account of each other, for instance, at this cruise harbour where tourism continues simultaneously with harbour maintenance.
the whole of the work and design (if any) to be performed by the Contractor, rather than just a part thereof. In other words, the delay must be on the critical path of the project (Figure 3).

INSURANCE

The scope of the Contractor’s obligation to effect insurances is defined by Appendix and the terms of those insurances must be approved by the Employer (Sub-Clause 14.1). The Contractor will want some latitude to negotiate those terms, since the requirements of insurers in the area of dredging, re-dredging and reclamation are by no means straightforward. For instance, these works will typically be subject to an exemption from insurers’ liability for damage caused solely by erosion or scour, and for the cost of dredging and re-dredging, overtopping cofferdams and loss of fill directly resulting from normal tidal action and normal action of the sea.

INSTRUCTIONS

The powers of the Engineer and the incidence of accountability for any mis-exercise of those powers is a time honoured concern of the supply side of the industry. Under the FCDR, the Employer appoints an Engineer who carries out the duties assigned to him in the Contract, subject to any express restrictions on his authority. At minimum, that duty involves a power to instruct in connection with the following six matters:

- any ambiguity or discrepancy in the documents forming the Contract (Sub-Clause 1.3);
- submission of revised programmes (Sub-Clause 7.2);
- uncovering and/or testing of any work (Sub-Clause 9.3);
- instructing Variations (Sub-Clause 10.1);
- valuing Variations at day work rates (Sub-Clause 10.2e);
- Contractor’s Equipment to be used until completion of the Work following a termination of the contract (Sub-Clause 12.3).

Sub-Clause 1.5 brings these instructions within the term “communication” and in so doing requires that they not be unreasonably withheld or delayed. The same may be said of notices, consents, determinations and certificates. In many jurisdictions, this requirement is implicit in the vicarious contractual obligations of the Employer, as part of an overriding duty of good faith in the performance of a contract; however, in those many jurisdictions with an English Law heritage that does not support a general implication of good faith, Sub-Clause 1.5 offers the Contractor a welcome degree of comfort.

There is provision in Sub-Clause 3.1 for the Employers to set out in the Appendix any limits they wish to impose on the Engineer’s authority to issue instructions. This is not however limited to Variations as the Notes for Guidance seem to suggest. The Engineer is well advised to minimise the breadth of any requirements for approval from the Employer prior to carrying out any assigned duties. It is envisaged that any such requirements will be stated in the Appendix. The onus is on the Engineer to obtain any such approvals and the Contractor “is entitled to assume” that they have been obtained. In common law jurisdictions, this entitlement to assume is bound to fix the Employer with the consequences of the Engineer’s purported act notwithstanding any want of approval.

The Contractor should be aware that a failure to comply with a valid instruction of the Engineer would trigger the Employer’s right to give a notice of default as the first step toward a determination of the Contract under Sub-Clause 12.1. Nevertheless, one might question what scope there is for a Contractor to challenge a subsequent termination of the Contract on the basis that the only failure that the Employer could reasonably have relied upon was trifling. This is indeed a drastic step to take and a most vulnerable condition in which the Contractor may find himself. That said, in theory at least, the gravity of the circumstances is somewhat tempered by the opportunity that then ensues for the Contractor to regularise the position by taking practicable steps to comply with the instruction within 14 days of receipt of the notice of default.

DEFECTS

Dolmans (2001) has highlighted the exceptionally high cost of remobilisation of high-value dredging equipment, combined with the effects of natural processes on completed Works, leading to unforeseeable defects (or the aggravation thereof). In view of this, the FCDR takes a different approach to that of the terrestrial forms by exempting dredging works from the defect rectification regime. That is to say, the Contractor’s obligation to remedy at no cost to the Employer any defects due to the Contractor’s design, Materials, Plant or workmanship not being in accordance with the Contract (Sub-Clause 9.1), does not apply to dredging works defined in the Appendix notified after the date on which the Works or Section were completed as stated in the Taking-Over Certificate.

In many jurisdictions, the Contractor would of course remain liable to compensate the Employer in relation to any such defects with regard to such dredging works. Although this can hardly have been what was intended, this special treatment of dredging works just might limit the operation of the doctrine of mitigation, whereby the Employer’s damages are reduced by any loss and damage that might have been avoided by reasonable mitigation measures. This is arguable since, typically, in the event of defective works, the Employer’s reasonable mitigation measures would involve giving the Contractor an opportunity to come back and reinstate the defective works.

DESIGN

Sub-Clause 5.1 facilitates the design by the Contractor of the permanent works as may be specified. The extent of permanent design by the Contractor must be stated in the Appendix and Sub-Clause 5.1 provides design review, leaving the design review procedure to be set out in other contract documents.
The issue of responsibility for gap-filling design by the Contractor is not addressed, however this does not seem to matter since the Contractor is responsible for all design (in the broadest sense) other than the Specification and Drawings (Sub-Clause 5.2) and, insofar as time and delay costs are concerned, the design of any part of the Works by the Employer, the Engineer or other for whom the Employer is responsible (Sub-Clause 6.1g).

The Contractor does however take the risk that the Engineer’s instructions to resolve an ambiguity or discrepancy in the documents with which the Contractor must comply (Sub-Clause 3.2) result in unbudgeted for expense. This implicit risk allocation is not unusual. It raises a risk that contractors would do well to manage by checking for such problems in the Employer’s documents at the outset when reviewing for other purposes.

PERMITS, LICENCES AND APPROVALS (Sub-Clause 2.2)

Under the FCDR, the Contractor carries the onus of obtaining – and this appears to include paying for (Sub-Clause 1.6) – all permits, licences and approvals required for the Works, to which the Employer must give reasonable assistance. However, as Dolmans notes, sometimes the Employer is best placed to fulfil an essential condition for the execution of the project. The FCDR recognises a key instance of this by carving-out from the Contractor planning responsibility, any permits, licences or approvals in respect of any planning, zoning or other similar permission required for the Works to proceed, as stated in the Appendix. These things the Employer must obtain and a failure to do so will at some point (presumably when it begins to delay the Contractor in completing the Works) constitute a “failure” within the meaning of a Defined Risk (Sub-Clause 6.1k). Provided this failure delays the Contractor in completing the Works, then this will entitle the Contractor to an extension of time under Sub-Clause 7.3.

Contractors should however recognise that this provision for a sharing of the obligation to obtain permits and so forth does not necessarily exclude the possibility of a withholding of permits, licences and so on. This may occur despite reasonable attempts by the responsible party to obtain the same. This withholding, whatever the justification for it, may qualify as a Force Majeure and in time and with due notification trigger the compensated termination procedure under Sub-Clause 13.4.

CONCLUSION

It is perhaps testimony to the special features of marine related civil works that FIDIC have seen fit to publish a work-type specific standard form. This long awaited development is most welcome, not least because it will formalise its existing usage in the industry. In the honourable tradition of FIDIC civil engineering standard form contracts, the FCDR addresses the major risks and issues of marine related civil works in a manner that is relatively fair and balanced and hence conducive to economic tender prices. If people get to know the FCDR and become comfortable using it, then this will result in greater consistency across industry to the benefit of all participants.

REFERENCE

BOOKS/PERIODICALS REVIEWED

Handbook Quay Walls
EDITED BY CUR, CENTRE FOR CIVIL ENGINEERING RESEARCH AND CODES


This is a translation of a handbook that was originally published in Dutch in 2003. Produced under the auspices of a Steering Committee from CUR (CUR is a unique network of public and private organisations focusing on civil engineering, infrastructure, building techniques and geotechnics) and peer reviewed by an eminent Scientific Committee, it contains a wealth of information on quay walls past and present. The success of the original version prompted the Steering Committee to publish an English version and we should be grateful to them for taking the trouble to do this in such an accomplished manner. It is often said that the camel is a horse designed by committee, but in this case the committee have designed a thoroughbred. This is an extremely comprehensive treatise on the design, construction and maintenance of quay walls. Whilst acknowledging that the main focus of the book is on the Dutch experience, there is much here of interest and use to maritime, civil and port engineers, wherever they might be practising in the world.

After tracing the history of quay wall construction, the book covers the main types and functions of quay walls. The reader is then taken through the processes of site investigation, defining the functions that the quay wall must satisfy and then looking at how the design is to be accomplished. Separate chapters are devoted to quay elements, materials, construction methods and costs. It is pleasing to see that space has been given to dealing with the management and maintenance of quay walls, a subject so often overlooked in designer’s handbooks.

It is also a delight to see a chapter entitled “Lessons from experience”, or, as the first section of this chapter is aptly titled, “You can’t make an omelette without breaking eggs.” Engineers are normally somewhat reticent about admitting their mistakes or highlighting those of others, but making mistakes is how we learn and here the authors have brought together a collection of items illustrating just how things can, and do, go wrong.

This excellent publication is intelligently structured, clearly laid out and translated, and illustrated with numerous high quality line drawings and photographs. It is well referenced and contains a bibliography, references to standards and useful websites, together with a number of technical annexes covering design examples, definitions, safety considerations, calculation examples; contract and conveyance; and the like.

This is a publication that should be found in the engineering section of every technical library and should be purchased by anybody who has a serious interest in quay walls.

The book is available as follows:
International orders: Taylor and Francis (£130.00).
Details and advice on ordering can be found on the following websites:
www.balkema.nl; or www.tandf.co.uk; or by email for Europe and the UK: book.orders@tandf.co.uk;
For the United States: www.crcpress.com and by email: orders@taylorandfrancis.com.
Dutch orders: CUR (tel. 0182-540600) (€ 195.00).
For information about ordering the Dutch version, please send an email to Paulien.brandhorst@cur.nl

NICK BRAY
31st International Navigation Congress 2006
ESTORIL, PORTUGAL
MAY 14-18 2006

Every four years, a PIANC Congress, open to all, is held in one of the member countries for the presentation and discussion of papers on subjects of current significance to waterways and maritime interests. These Congresses are particularly valuable for the exchange of knowledge and opinions for participants of all ages. They are organised in two Sections: Section I for Inland Navigation and Section II for Maritime Navigation.

For further information contact:
PIANC General Secretariat
Graaf de Ferraris building - 11th floor
Blvd. du Roi Albert II, 20 - Box 3
B-1000 Brussels (Belgium)
Tel: +32 2 553 71 61, Fax: +32 2 553 71 55
Email: meetings@pianc-aipcn.org

WEDA XXVI and TAMU 38
MARRIOTT MISSION VALLEY HOTEL,
SAN DIEGO, CALIFORNIA, USA
JUNE 24-27, 2006

The Twenty-sixth Western Dredging Association (WEDA XXVI) and the Thirty-eighth Texas A&M Dredging Seminar (TAMU 38) will be held at the Marriott Mission Valley Hotel in San Diego, California. The theme of the conference "Dredging: Creating a Strong Economy” will provide a unique forum between the various dredging contractors, port and harbor authorities, academicians to discuss the positive impact that dredging has on the world economy. The three-day technical programme will include the following topics of interest: economic benefits of dredging, dredging and navigation, beneficial uses of dredged material, wetland creation and restoration, dredging systems and techniques, new dredging equipment, channel deepening projects, rivers and inland dredging, geotechnical aspects, dredging for beach nourishment, automation in dredging, contaminated sediments, and project case studies.

For further information contact:
Larry Patella, Executive Director
Western Dredging Association
P.O. Box 5797, Vancouver, WA 98668
Tel: +1 360 750 0209
Email: weda@comcast.net

ICCE 2006
MANCHESTER GRAND HYATT HOTEL
SAN DIEGO, CALIFORNIA USA
SEPTEMBER 3-8 2006

The Local Organising Committee of ICCE and Coasts, Oceans, and Rivers Institute (COPRI) of the American Society of Civil Engineers are planning the 30th International Conference on Coastal Engineering in San Diego. The conference brings together coastal engineers from around the world to discuss the coastal engineering related research, design and case studies experienced by the attendees.

In addition, five one-day technical short courses will be offered over the two days immediately prior to the conference. Professional Development Hours (PDF) will be offered for attendance at these courses. The registration fee for each course is $150.

For further information contact:
ICCE 2006 Secretariat
P.O. Box 4219
Santa Barbara, CA 93140-4219 USA
Tel: +1 805 965 6210, Fax: +1 805 965 6230
Email: info@icce2006.com

Hydro 06
PROVINCIAL HOUSE, ANTWERP, BELGIUM
NOVEMBER 6-9, 2006

The theme of the International Hydrographic Conference 2006, known as Hydro 06, is “Evolutions in Hydrography”. It is organised and hosted by The Hydrographic Society Benelux on behalf of International Federation of Hydrographic Societies. Papers are welcome on all topics related to hydrography such as oceanography, shallow water, inland surveying, charting, dredging support, tides, sediment transport, multibeam, side-scan sonar, positioning, remote sensing, subbottom profiling, and so on.

For further information contact:
Hydro 06 c/o Technologisch Instituut vzw
Desguinlei 214, BE-2018 Antwerp, Belgium
Tel: +32 3 260 0840, Fax: +32 3 216 0689
Email: info@hydro06.com
www.hydro06.com
MEMBERSHIP LIST IADC 2006

Through their regional branches or through representatives, members of IADC operate directly at all locations worldwide.

AFRICA
Boskalis South Africa, Pretoria, South Africa
Dredging and Reclamation (Jan De Nul) Ltd., Lagos, Nigeria
Dredging International - Tunisia Branch, Tunis, Tunisia
Dredging International Services Nigeria Ltd., Ikoyi Lagos, Nigeria
Nigerian Westminster Dredging and Marine Contractors Ltd., Lagos, Nigeria
Van Oord Nigeria Ltd, Ikeja-Lagos, Nigeria

ASIA
Ballast Ham Dredging (Malaysia Sdn Bhd, Johor Darul Takzim, Malaysia
Ballast Ham Dredging India Private Ltd., Mumbai, India
Boskalis Dredging India Pvt Ltd., Mumbai, India
Boskalis International Pte Ltd., Singapore
Boskalis Westminster International Bv Korea Branch, Seoul, South Korea
Boskalis Westminster International bv, Beijing, P.R. China
Boskalis Westminster International bv, Kowloon, Hong Kong, P.R. China
Boskalis Westminster International bv, Kuala Lumpur, Malaysia
Dredging International Asia Pacific (Pte) Ltd., Singapore
Far East Dredging (Taiwan) Ltd, Taipei, Taiwan ROC
Far East Dredging Ltd Hong Kong, P. R. China
Hyundai Engineering & Construction Co. Ltd., Seoul, Korea
Jan De Nul (Singapore) Pte. Ltd., Singapore
P.T. Boskalis International Indonesia, Jakarta, Indonesia
PT Penconindo LLC, Jakarta, Indonesia
Penta-Ocean Construction (Hong Kong) Ltd., Hong Kong, P.R. China
Penta-Ocean Construction (Malaysia) Sdn. Bhd., Malaysia
Penta-Ocean Construction Co. Ltd., Tokyo, Japan
Siam Goyo Co. Ltd., Bangkok, Thailand
Tideway DI Sdn Bhd, Kuala Lumpur, Malaysia
Toa Corporation, Tokyo, Japan
Van Oord (Malaysia) Sdn Bhd, Selangor, Malaysia
Van Oord ACZ India Pte Ltd, New Delhi, India
Van Oord ACZ Marine Contractors bv Hong Kong Branch, Hong Kong, P.R. China
Van Oord ACZ Marine Contractors bv Shanghai Branch, Shanghai, P.R. China
Van Oord Dredging and Marine Contractors bv Korea Branch, Busan, Republic of Korea
Van Oord Dredging and Marine Contractors bv Philippines Branch, Manila, Philippines
Van Oord Dredging and Marine Contractors bv Singapore Branch, Singapore

AUSTRALIA
Boskalis Australia Pty. Ltd., Sydney, Australia
Dredeco Pty. Ltd., Brisbane, QLD, Australia
NZ Dredging & General Works Ltd., Maungatani, New Zealand
Van Oord Australia Pty Ltd., Brisbane, QLD, Australia
WA Shell Sands Pty Ltd, Perth, Australia

EUROPE
Aannemingsbedrijf L. Paans & Zonen, Gorinchem, Netherlands
Atlantique Dragage S.A., Nanterre, France
Atlantique Dragage Sarl, Paris, France
Baggemaatschappij Boskalis B.V., Papendrecht, Netherlands
Baggerwerken Decloedt en Zoon NV, St. Petersburg, Russia
Ballast Ham Dredging, St. Petersburg, Russia
Ballast Nedam Baggeren bv, Rotterdam, Netherlands
Baltic Marine Contractors SIA, Riga, Latvia
Boskalis B.V., Rotterdam, Netherlands
Boskalis International B.V, Papendrecht, Netherlands
Boskalis Italia, Rome, Italy
Boskalis Offshore bv, Papendrecht, Netherlands
Boskalis Sweden AB, Gothenburg, Sweden
Boskalis Westminster Dredging & Contracting Ltd., Cyprus
Brewba Wasserbaugesellschaft Bremen mbH, Bremen, Germany
DEME Building Materials NV (DBM), Zwijndrecht, Belgium
DRACE, Madrid, Spain
Dragapor Dragagens de Portugal S.A., Alcochete, Portugal
Dravo SA, Italia, Amelia (TR), Italy
Dravo SA, Lisbon, Portugal
Dravo SA, Madrid, Spain
Dredging and Contracting Rotterdam B.V, Bergen op Zoom, Netherlands
Dredging International N.V., Zwijndrecht, Belgium
Dredging International (UK) Ltd., Weybridge, UK
European Dredging Company S.A, Steinfort, Luxembourg
Ham Dredging Contractors bv, Rotterdam, Netherlands
Heinrich Hirdes G.m.b.H., Hamburg, Germany
International Seaport Private Ltd, Zwickriedt, Belgium
Irish Dredging Company, Cork, Ireland
Jan De Nul Dredging nv, Aalst, Belgium
Jan De Nul (U.K.) Ltd., Ascot, UK
Jan De Nul B.V., Eindhoven, Netherlands
Jan De Nul Nederland bv, Gorinchem, Netherlands
Jan De Nul nv, Rotterdam, Netherlands
Jan De Nul Offshore bv, Gorinchem, Netherlands
Jan De Nul Overseas bv, Gorinchem, Netherlands
Jan De Nul Sweden ab, Göteborg, Sweden
Van Oord UK Ltd., Newbury, UK
Water Injection Dredging bv, Rotterdam, Netherlands
Westminster Dredging Co. Ltd., Fareham, UK

MIDDLE EAST
Boskalis Westminster (Oman) LLC, Muscat, Oman
Boskalis Westminster Al Rashid Co. Ltd., Al Khobar, Saudi Arabia
Boskalis Westminster M.E. Ltd., Abu Dhabi, UAE
Boskalis Westminster Middle East Ltd., Manama, Bahrain
Boskalis Westminster Middle East, Doha, Qatar
Gulf Cobla (Limited Liability Company), Dubai, UAE
HAM Saudi Arabia Company Ltd, Damman, Saudi Arabia
Jan De Nul Dredging Ltd. (Dubai Branch), Dubai, UAE
Jan De Nul Dredging, Abu Dhabi, UAE
Van Oord Gulf FZE, Dubai, UAE

THE AMERICAS
Ballast Ham Dredging do Brazil Ltda, Rio de Janeiro, Brazil
Boskalis International Uruguay S.A., Montevideo, Uruguay
Coral and Inland Marine Services Inc., Bethania, Panama
Compania Sud Americana de Dragados S.A, Capital Federal, Argentina
Dragemex SA de CV, Coatzacoalcos, Mexico
Dravensa C.A., Caracas, Venezuela
Dredging International Mexico SA de CV, Veracruz, Mexico
Dredging International NV - Sucursal Venezuela, Caracas, Venezuela
Mexicana de Dragados SA de CV, Col. Polanco, Mexico
Stuyvesant Dredging Company, Louisville, USA
Van Oord ACZ Marine Contractors by Argentina Branch, Buenos Aires, Argentina
Van Oord Curaçao nv, Willemstad, Curaçao

Terra et Aqua is published quarterly by the IADC, The International Association of Dredging Companies. The journal is available on request to individuals or organisations with a professional interest in dredging and maritime infrastructure projects including the development of ports and waterways, coastal protection, land reclamation, offshore works, environmental remediation and habitat restoration. The name Terra et Aqua is a registered trademark.

© 2006 IADC, The Netherlands
All rights reserved. Electronic storage, reprinting or abstracting of the contents is allowed for non-commercial purposes with permission of the publisher.

ISSN 0376-6411
