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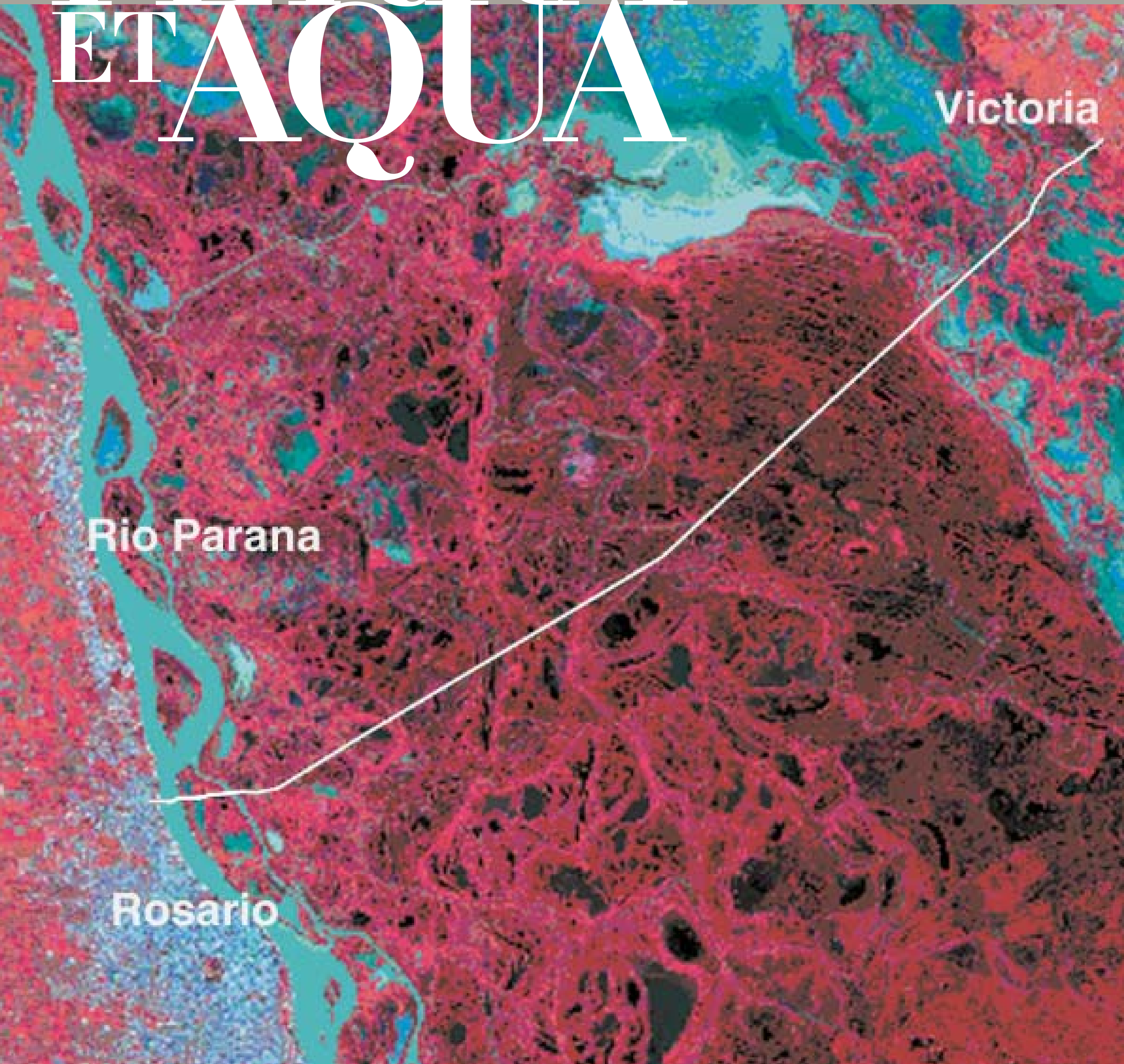
TERRA ET AQUA

International Association
of Dredging Companies



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Front cover:
An aerial satellite image of Argentina, showing the projected fixed link between Rosario and Victoria. The link will be a two-lane auto-railway, with 13 bridges and 13 embankments, covering almost 60 km (see page 3).

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International Association of Dredging Companies

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TERRA ET AQUA

Editorial

The first year of the new millennium is almost at a close. It has proven to be a year of significant expansion in the dredging industry.

In the Far East some mega-projects have been awarded to our IADC members, who will operate in joint ventures to get everything accomplished safely and on time. The high-tech equipment and well-educated staff of IADC members are clearly an essential advantage and have proven to be an absolute necessity in achieving the expected level of performance. Given the importance of the Far East, our International Seminar was again presented in Singapore and the participants were able to make site visits to some of these spectacular dredging works and view the new jumbo dredgers firsthand.

Also in other parts of the world, like South America, economic development is booming — as can be seen in our first article about the dramatic new Rosario-Victoria Fixed Link which will ease the way for an increase in local and international transportation. An outstanding aspect of this project has been the careful compliance to the ISO 14000 International Standards and the establishment of an Environmental Management System adhering to these standards.

Speaking of quality in the industry, we were happy to be able to officially present the IADC Student's Award to Judith Bosboom (see *Terra*, number 80). The IADC considers attracting young people to the profession – and recognising their contributions — as one of our important responsibilities.

Another responsibility is to make sure that the quality articles we publish in *Terra* reach the target audience. For this reason we are attempting to re-organise our mailing list and make sure that the Terra is actually arriving in the right mailboxes. Please take a moment and fill in the attached form with your correct address and details.

IADC is also in the process of launching its new logo. Though it has many links to the past (we're proud of our history), the new logo is a more dynamic symbol and we think better expresses the vital role IADC member companies play on the stage of world dredging.

Robert van Gelder
President, IADC Board of Directors

S. Dresken, M.A. Pool, E. Mumelter and F. Uelman

Rosario-Victoria Fixed Link: Dredging and Reclamation Works Across the Rio Paraná Fluvial Valley

Abstract

The Government of Argentina (through its Ministry of Economics and Public Works) together with the Provincial Governments of Santa Fé and Entre Rios (the client) developed a project, financed partly by a 25-year concession for a new link between both provinces, known as the Rosario-Victoria Fixed Link. The project is essential for local and international East-West road transport.

The fixed link is a two-lane auto-railway, consisting of 13 bridges connected by 13 embankments over a total length of 59 km, situated in the Rio Paraná fluvial delta. The Dutch Joint Venture, Boskalis International–Ballast Nedam Baggeren, as subcontractor of the Consortium Puentes del Litoral (main contractor), is responsible for the construction of the 47 km of road embankments.

The fixed link is completely located in the Paraná River delta. The geological record of the delta is characterised by a changing lithology, which in turn greatly influences the geotechnical parameters of the sub-soil. The knowledge of the geological record was provided by means of an extensive soil investigation. This was used for settlement and stability calculations, geometry and quality of the overburden as well as the underlying sand layer.

By contractual requirement, the dredging subcontractor has to comply with the ISO 14000 International Standards and the Environmental Management System (EMS) of the main contractor. For this project this compliance resulted in the setting up of an Environmental Management System (EMS) according to the International Standards, including an Environmental Management Plan (EMP) and a monitoring strategy as guideline during construction.

Figure 1. Location map showing project.

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Sander Dresken

Having studied both Geology (Leiden Univ.) and Geotechnical Engineering (TU Delft), Marinus A. Pool started with Boskalis in 1979, was a senior advisor for the European Commission for geotechnical and geohydrological missions to South America and is presently head of the on-site geotechnical department for the Rosario-Victoria fixed link project.

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Elena Mumelter

After receiving his MSc in Civil Engineering from TU Delft in 1978, Frans Uelman worked for Costain-Blankevoort as a research engineer. In 1987 he joined Boskalis Westminster in the soil group and at present is Senior Geotechnical Engineer at Hydronamic.

Frans Uelman

Introduction

The Government of Argentina (through its Ministry of Economics and Public Works) together with the provincial governments of Santa Fé and Entre Rios (the client) developed a project, financed partly by a 25-year concession for a new link between both provinces, known as the Rosario-Victoria Fixed Link. The location of the project is shown in Figure 1.
The fixed link is a two-lane auto-railway and consists of 13 bridges connected by 13 embankments over a total length of 59 km and situated in the Rio Paraná fluvial delta. This project is the largest of its kind in South America in terms of length and physical conditions.
The Paraná River is the second largest river in South America in terms of discharge (1 per 100 year discharge of 30,500 m^3/s through the main channel and 26,500 m^3/s through the fluvial valley; 5 m of yearly maximum water level fluctuation) after the Amazon River. An aerial satellite image with the projection of the fixed link is shown in Figure 2.

The project is essential for local and international road transports from East to West and back. The nearest two possible crossings now are 180 km upstream and downstream of Rosario. Local transport takes place amongst the provinces of Entre Rios, Corrientes, Misiones (situated East of the river) and the rest of the country. The international East-West transport takes place between the port of Rio Grande in the South of Brazil and the port of Valparaíso in the middle of the Chilean coast. This connection is called the Bioceanic Corridor and is essential for the region of the Mercosur — a commercial co-operation amongst several South American countries). As result of the construction of the Rosario-Victoria fixed link, the port of Rosario will be one of the most important distribution centres for the Mercosur. Furthermore, in the southern part of the province of Santa Fe increasing trade and industry is to be expected, as well as an increase of the tourism role of the small city of Victoria.

The concession has been awarded to the Consortium "Puentes del Litoral S.A." as main contractor, formed by five civil contractors: Impregilo, Iglys, Hochtief, Techint, Benito Roggio. This consortium has a Design, Finance, Build, Operate and Transfer contract with the Argentine government. The total value of the contract is $350 million of which $230 million will be paid directly to the consortium, and the outstanding $120 million by toll income over a period of 25 years. During this time the consortium is responsible for full maintenance. The project was awarded in 1998 and started immediately. Construction time will be approximately four years.

The Dutch Joint Venture Boskalis International–Ballast Nedam Baggeren as subcontractor of the Consortium Puentes del Litoral is responsible for the construction of the 47 km of road embankments. The total

subcontract price is $76 million and includes the following activities:
- dredging of overburden of the borrow pits;
- dredging of the sand itself and construction of the embankments;
- dredging of a 30 km lateral service channel for logistic purposes along the link; and
- dredging of the access channels from the service channel to the bridge location.

The project was awarded to the Joint Venture in December 1998 and started in February 1999. Construction time will be approximately 2.5 years.

Work Method

Long-term dredging equipment used has been the cutter suction dredgers/suction d*red*gers *Haarlem* and *Zuiderklip* (total installed power respectively 5,050 kW and 3,998 kW). Support vessels types Multicat are the *Candy* and the *Roomklopper* (total installed power respectively 800 kW and 538 kW). Temporary auxiliary dredging equipment has been locally contracted for the execution of small portions of the work.

The dredgers mechanically disrupt and loosen the soil and pump it straight into the disposal areas. In order to ensure the manoeuvrability of the dredgers in the dredging areas, a 450-m section of the pipeline consists of a floating line. Depending on the water level, an excavator or amphibious excavator is used to construct the first retaining wall or bund, at or below the water table to prevent the hydromixture from flowing back into the channel/borrow pit. The sand fill is placed directly on top of the existing topsoil. When this first layer reaches a certain height above the water table, a rigid onshore pipeline will be installed on top, to be connected to the floating pipeline. The main embankment body is constructed in phases, longitudinally in sections with contention bunds, and vertically in different layers.

The typical sequence of the filling of an embankment consists of:
- hydraulic placement of a first layer (to about 1 m above existing water level);
- hydraulic filling of several intermediate layers; and
- hydraulic and/or mechanical filling of last layers to the final level (design level + final evaluated settlement).

During construction of the embankment water outlet boxes are placed at the border of each section of the fill area to drain excess water after deposition of the sand.

Once a layer is finished, new retention bunds are built for the next layer on top and the water outlet boxes are elevated.

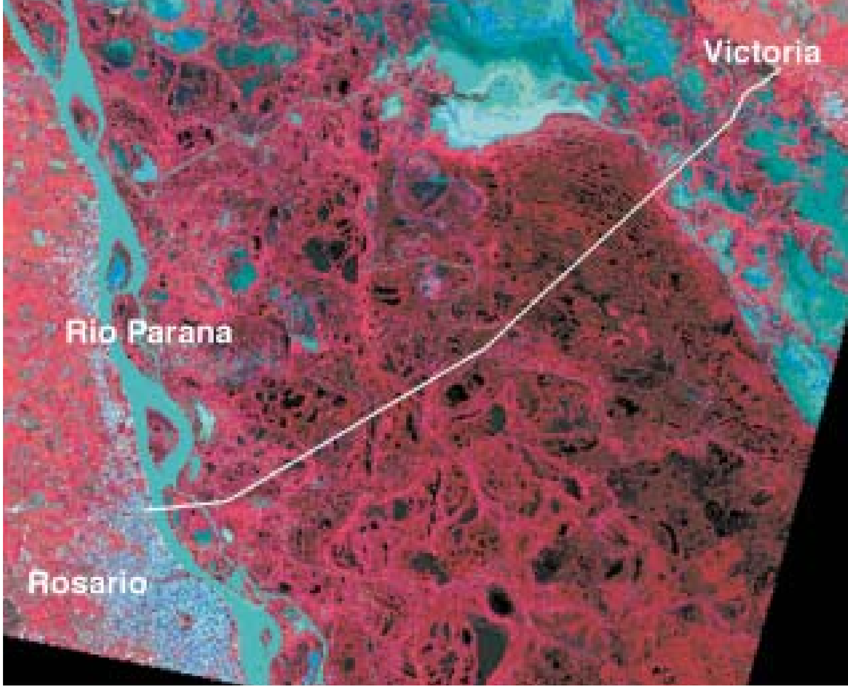


Figure 2. The fixed link, situated in the Rio Paraná fluvial delta, drawn over a satellite image.

The embankments have a crest width of 15 m and slopes of 1 to 4. The embankment height is about 7 to 8 metres up 10 to 11 metres (at the abutments near the bridges) with respect to the top of the natural terrain. An impression of the different construction phases is shown in Figures 3, 4, 5 and 6. Impressive views of the works are presented in Figures 7, 8 and 9.

Geological and Geotechnical Aspects of the Construction Area

The connection, by means of earth embankments and interconnecting bridges, is completely located in the Paraná River delta. The geological record of the delta is characterised by a changing lithology, which in turn greatly influences the geotechnical parameters of the sub-soil. The understanding of the geology forms the basis for the geotechnical knowledge of the subsoil, in which bridge foundations, borrow pits for dam construction; stability and settlement of the dams are the most important items.

The geology of the Paraná delta subsoil, at the location of Rosario, consists of a basal marine clay of Miocene age, which is overlain by Pleistocene sand. The topsoil or overburden consists of Holocene clays, sands and their mixtures. The geological development of the delta differs from Dutch sedimentary deltaic environment in the sense of type of and distance to the hinterland and e.g. climatic factors during its development. The transition between the Miocene clay (age: ± 30 million years) and the Pleistocene fluvial sand (1.5 million years before present) thus forms a discontinuity in time, in which the top of the marine clay represents an erosion surface.

Many gullies were cut into the marine clay surface with the increase of the fluvial environment. In fact it can be concluded from the geological profile that a sudden "catastrophic" change took place at the start of the

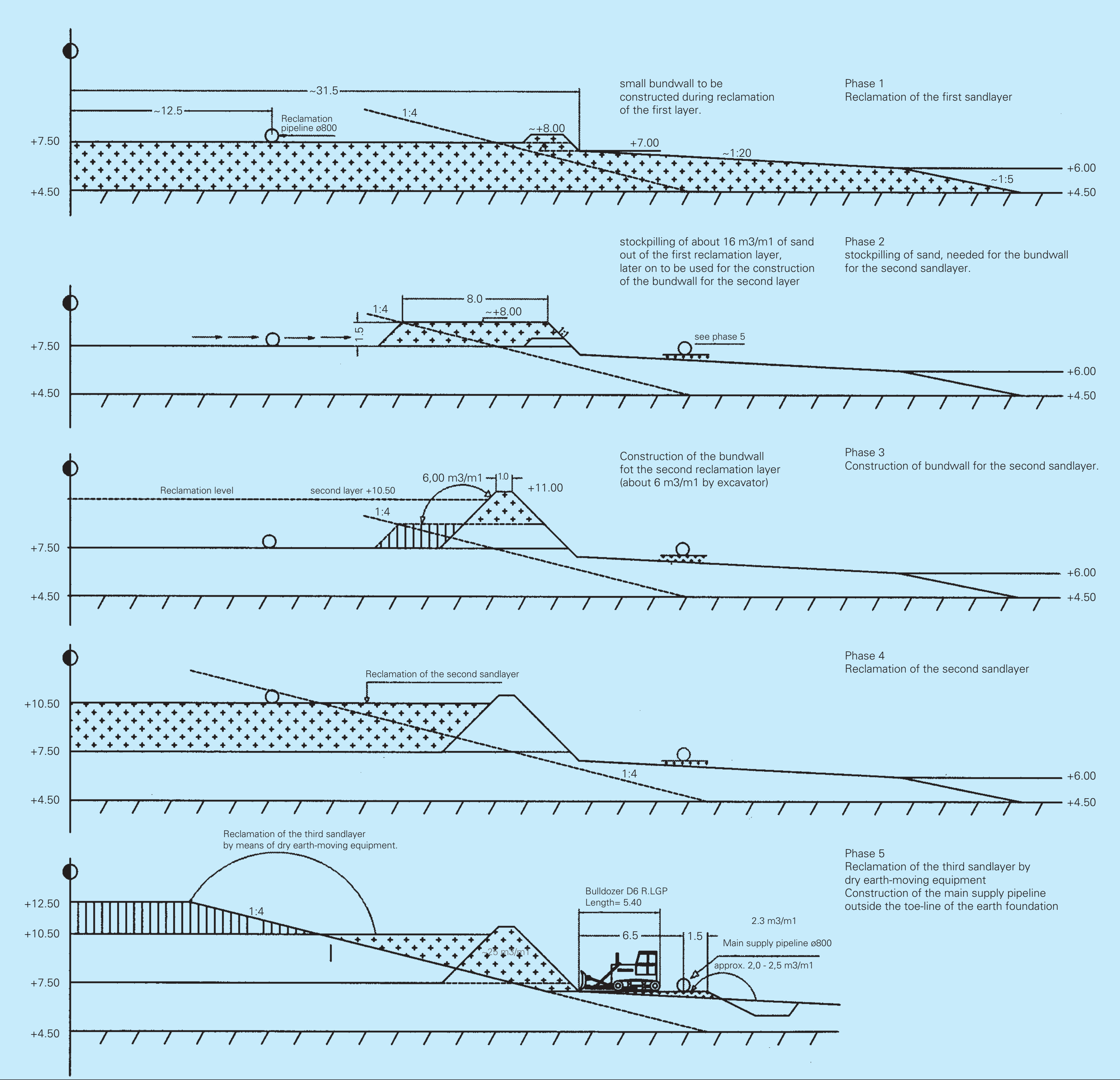


Figure 3. Cross-sections of the construction in 5 phases.

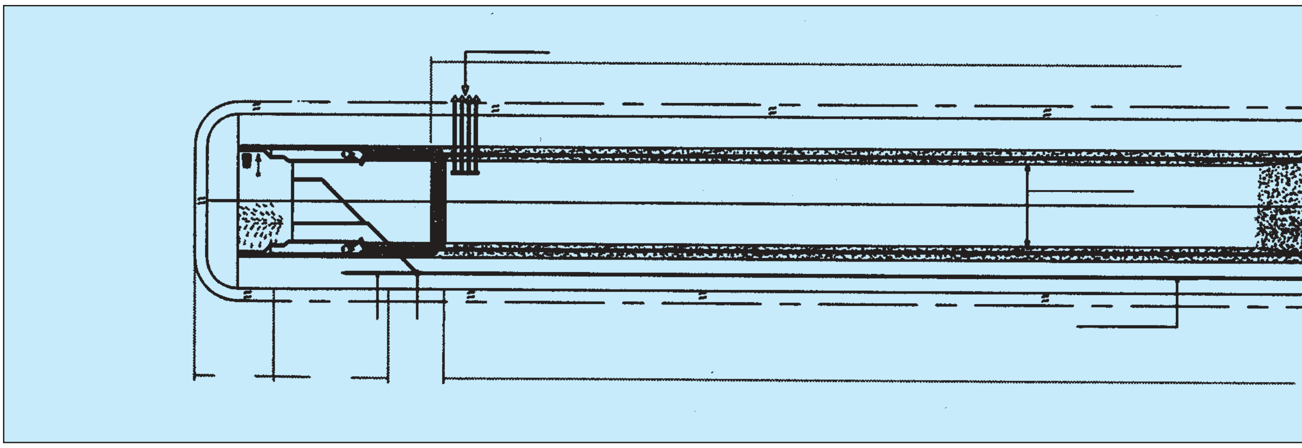


Figure 5. Cutter suction dredger Zuiderklip dredging sand in a borrow pit and filling an intermediate layer of an embankment – view from Victoria (East) with respect to the Connection.

Pleistocene. The main trigger of the change in lithology is of course the climate change, inducing a sea-level change and a changing environment in the source area of the sediments (the hinterland). In Holland it is observed that Pleistocene glaciations resulted in less fluviatile transport and lower sea levels. In the Paraná delta the conclusion can be drawn that at sea level low-stand was combined by an increase of fluviatile transport from the source area. This resulted in a huge transport of mainly sand from the hinterland (with source areas in south Brazil, Paraguay and the north of Argentina).

A schematic geometry of the erosion and deposition by the Paraná River is presented in Figure 10.

The width of the delta, and thus the length of the fixed connection to be made, is nowadays around 59 kilometres. At the time that the first sands were transported this width was small, increasing with time. This means that the early Paraná River basin was relatively narrow, without a delta at the Rosario-Victoria location but increased gradually in width. The Paraná River started to erode the very stiff clays and marls at the Victoria side in Early Pleistocene times, cutting its own channel to a depth of more than 25 m into the Tertiary marine sediments, filling it up and shifting itself in time, whilst cutting in and filling up towards the Rosario side, where it presently runs.

During the Holocene period, around seven thousand years ago, the sea level started to rise quickly. The outlet of the Paraná River came closer towards Rosario, the sedimentary flux changed and the whole delta could now be inundated during river high stands. The Paraná River could deposit a more clayey deposit on top of the whole Pleistocene sand layer. This resulted in the present configuration of a topsoil cover, with clayey inundation areas, separated by more sandy levees.

Figure 4. Helicopter view of the construction.

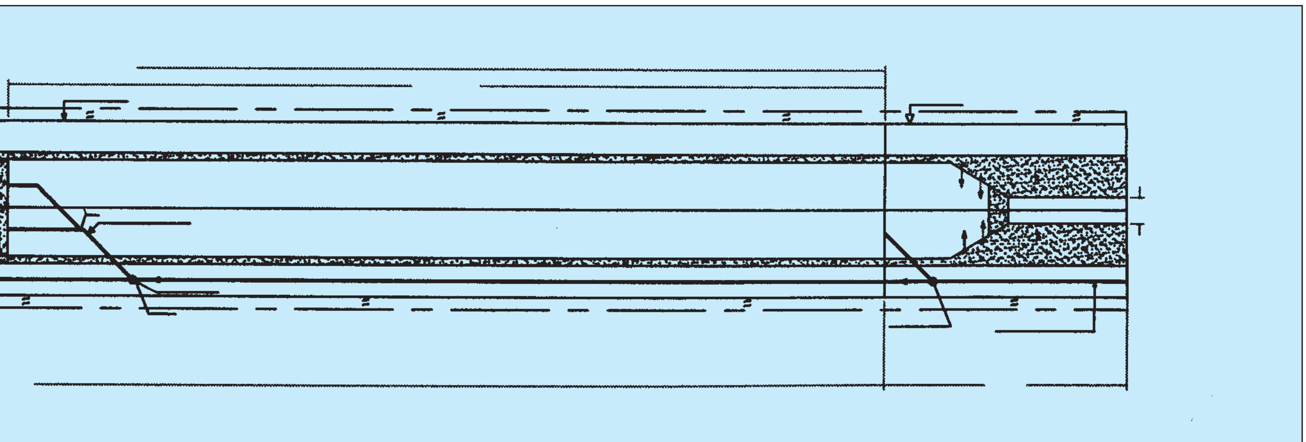


Figure 6. Bulldozers at work.

Geotechnical Aspects of the Paraná Delta Deposits

The knowledge of the geological record was provided by means of an extensive soil investigation for a number of reasons:

- to retrieve samples for consolidation tests, in order to predict the final heights of the dams, compensating for settlement;
- to verify the thickness and quality of the overburden for stability reasons during and after construction of the dams;
- to gather information about the geometry and quality of the sand layer for the borrow areas, especially when a deep suction method of dredging is applied; and
- to gain insight on the thickness and quality of the clayey topsoil (overburden) for the borrow pits, which has to be removed prior to starting dredging.

Soil investigation

For this project a Cone Penetration Test apparatus (CPT Hyson, 200 kN penetration force, manufactured by A.P. v.d. Berg, The Netherlands) was bought. This apparatus is well known in The Netherlands but quite uncommon in Argentina, where most soil investigations are done with rotary, Shelby or SPT methods. The equipment was mounted on a floating platform with anchoring for counterweight, or on an amphibious excavator, to ensure that the investigations could continue, even during floods and dry periods.

The CPT equipment was also equipped with a sampling device (65 mm wide and 40 cm long for consolidation and triaxial tests for cohesive material and 35-mm width samples for sand or silt material), called Mostap, which can sample at even rather great depths. The advantage of this equipment is its velocity in penetration and the achievement of relatively undisturbed samples for laboratory testing.

In total 210 boreholes were made along the 59-km-long stretch, each with an average length of 10 to 30 m. The accessibility of the area is very difficult, and thus it took a great deal of time to finish the campaign. Samples of the overburden were taken to the fully equipped Boskalis-Ballast laboratory for consolidation and triaxial tests, granulometry and Atterberg limits. Samples of the underlying sand were tested on densities and granulometry.

Figure 7. First completed embankments at the start of the connection in Victoria.

Figure 8. Aerial photo of the bridge and completed embankment from Northeast with respect to the Connection.

A geological profile from Rosario to Victoria based on the CPT and SPT borings and all relevant data available has been prepared for the project. These are shown in Figure 11.

Determination of geotechnical parameters for construction purposes

All necessary parameters were calculated from the laboratory results as for the input for different geotechnical calculations. The most important are listed below:

- intermediate (by multistage construction) and final settlement and consolidation time of the subsoil;
- stability evaluation during multistage construction, using slip circle analysis; and
- grain size analysis of sandy topsoil and the main underlying sand layer for quality of the dam itself.

Intermediate parameter

The final settlements were calculated from the consolidation tests according to both Buisman-Koppejan and NEN 6744 methods. From these determinations a prediction of final construction heights was made.

The subcontractor wants to be assured that enough sand is dredged and available at the dam itself to compensate for extra settlements of the dams. Once the dredger moves to another borrow pit, located many kilometres away, a return for extra sand owing to unexpected settlements is too costly. During construction and 6 months after the subcontractor monitors the settlements, by means of settlement beacons and measured with a DGPS system.
This means that the contractor and client have to arrive at a consensus on the final settlements, even when the hydrodynamic period is not ended (or the T_{95} has not been reached). This involves a back analysis of the measured settlement and implementation of the parameters gained from this back analysis.

Figure 9. SD Zuiderklip dredging the Main Service Channel beyond a small creek towards Rosario.

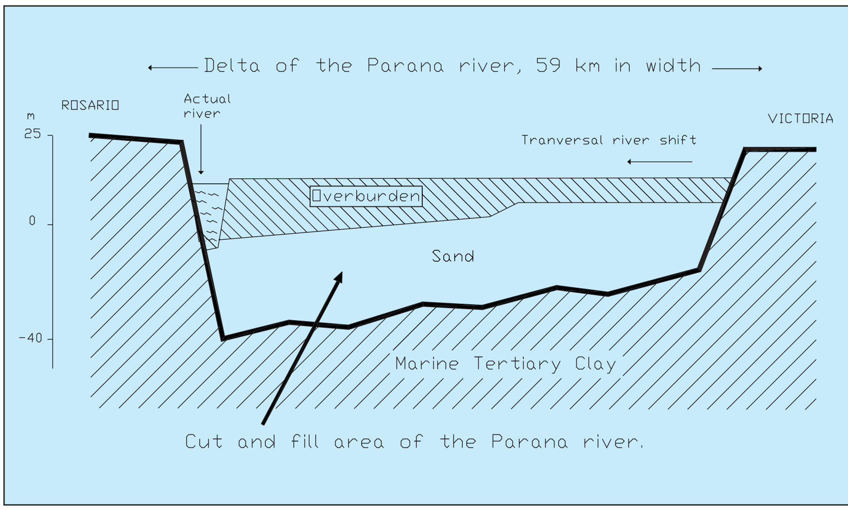


Figure 10. Schematic drawing showing the geometry of the erosion and deposition by the Paraná River.

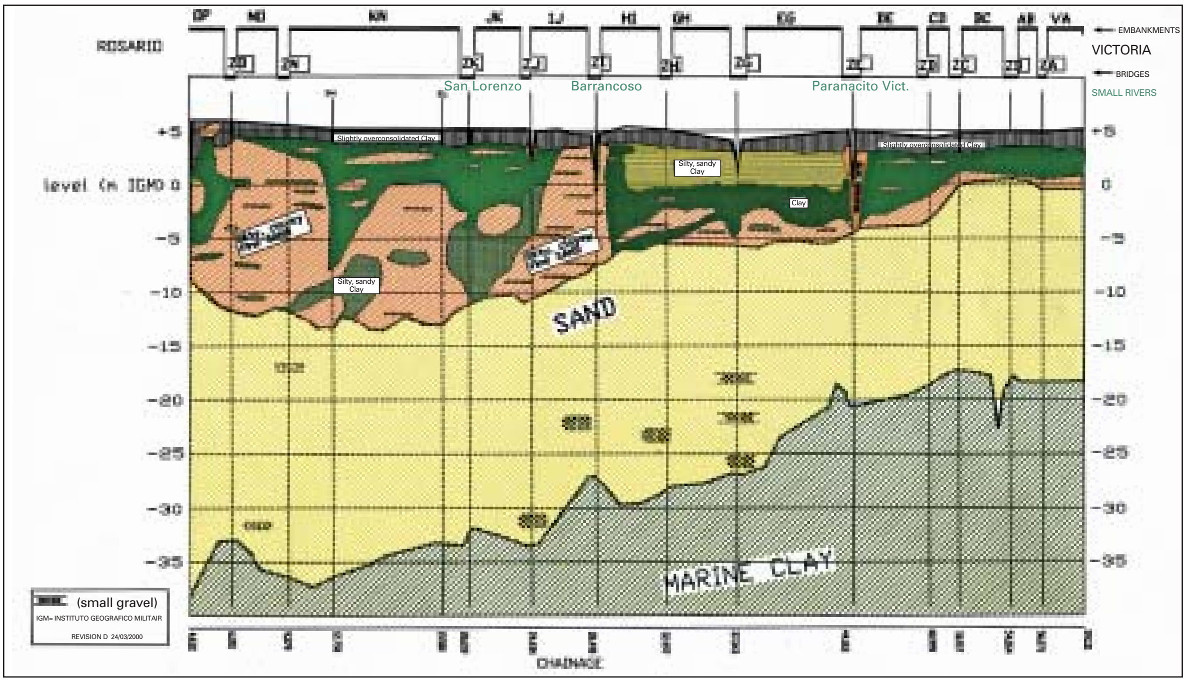


Figure 11. General geological profile of the subsoil along the Rosario-Victoria fixed link.

The client did not accept a decrease of the consolidation time by drains because of financial reasons. Predicted settlements match reasonably well with the ones measured in the field, varying from 0.3 m to about 1 m, based on an average of 7 m superimposed embankment. Nevertheless the actual hydrodynamic periods of most compressible subsoil is less than the calculated ones, because of the presence of sandy intercalations.

Stability parameter

A safety analysis (stability) during multistage construction of the dams was carried out using Bishop calculating methods. The consolidation of the subsoil results in an increase in shear strength of the foundation soil.

A required overall factor of safety determined by a degree of consolidation was calculated for each construction layer. The derived safety factor was mostly above 1.4, but sometimes also near 1.0, meaning almost instability. This was mainly a result of the presence of highly plastic soft clays. As drains were not allowed, a significant increase in shear strength because of consolidation, given a relative short period of construction, could not be expected. Moreover, back-analysis from the field data showed a much faster adaptation of the compressible layer to the applied load than that obtained from the laboratory results. Thus in most cases the faster consolidation between the construction stages ensured the stability of the dam.

Grain sizes

Grain sizes influence production during the dredging process. Losses of dredged material during the deposition of the hydromixture are to a large extent dependent of the grain size itself. The geology of the area ensures an increase of grain size of the sand with depth from 110 micron up to 400 micron. Again the geological knowledge, and more specifically the sedimentological history of the area, explains the increase in grain size with depth. The closer to the source area (provoked by a low sea-level stand), the coarser the material. This is confirmed by the presence of gravel at the base of the sand layer at some locations.

Quality specifications of the dam

Contractually, the construction material should comply with the SM-SP characteristics (USCS). The construction itself should have a relative density, varying with depth from 40 to 70 percent. The top of the dam should have a CBR of 20. Quality control includes grain-size analysis, in-situ density measurements by volume-meter and the determination of maximum and minimum densities in the laboratory. After completion of every layer of the dam, extra SPT tests are made to determine the densities of the whole dam body.

Environmental Aspect of the Project

The 1-km-wide and approximately 59-km-long project area between Rosario and Victoria covers only a very small strip of the Paraná River and the river floodplain. When travelling from Rosario to Victoria the plain is crossed by the main 2-km-wide river channel, directly next to Rosario, numerous minor watercourses separated by marshlands and islands of various sizes, and a relatively open-water area near Victoria.
The width of the watercourses, their flow discharges and the surface areas of the islands vary depending on the water level of the river.

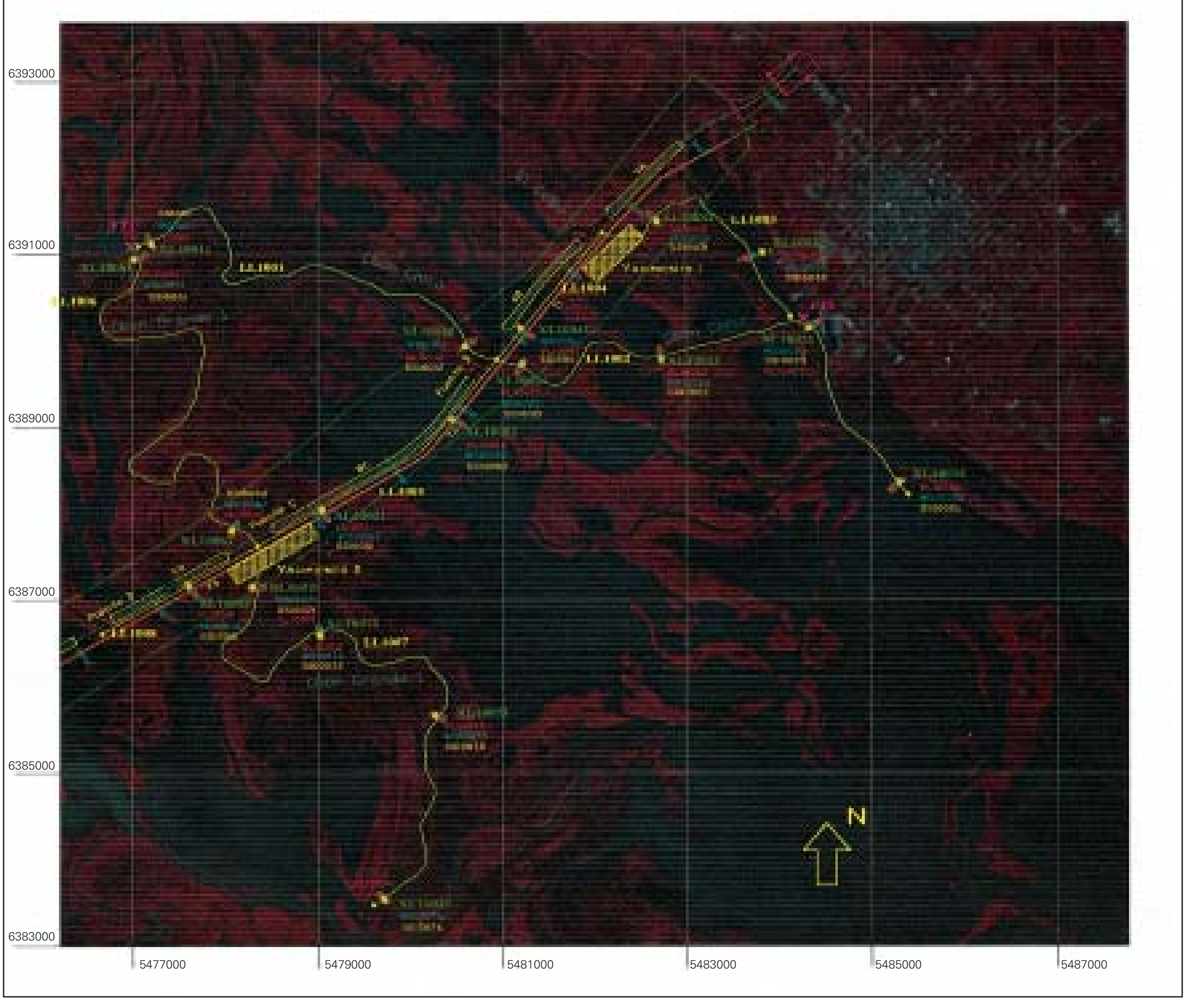


Figure 12. Monitoring map for the first three months of the works, in front of Victoria.

General commitment of the subcontractor was to execute the works whilst minimising the (eventual) damage to the environment. The environmental impact analysis considers both human environment (eventual disturbance to fishers who live on the islands and to navigation, recreation, atrophic pastures) and natural environment (eventual damage to air, water and soil quality, to aquatic life, birds and animals in the river valley and the floodplain). Special attention was focussed on the water intake of Victoria, which provides the city with drinking water from the river, located just outside the harbour, downstream of the road connection. This is a very sensitive point with respect to the increase in turbidity and requires continuous monitoring of water quality.

Environmental Management System

By contractual requirement compliance exists between the ISO 14000 International Standards and the Environmental Management System (EMS) of the main contractor. For this project this compliance results in the setting up of an Environmental Management System (EMS) according to the International Standards, including an Environmental Management Plan (EMP) and a monitoring strategy as guideline during construction.

The EMS provides the basic concepts and objectives related to environment and social protection and control for the dredging activities within the project. It identifies the legal, operational, and procedural requirements to execute the dredging works. It also includes:

- the identification and evaluation of the environmental effects of the dredging activities;
- the definition of the mitigating plan;
- the definition, explanation and periodicity of the monitoring plan for the outlined effects and mitigating measures; and
- the procedures for preparing environmental quarterly reports, for environmental protection, emergency response, waste disposal, bunkering, clearance of floating vegetation and environmental audits.

Figure 13. Setting up of the fixed multi-sensor sonde at the water intake of Victoria.

Most relevant environmental effects of the dredging activities have been identified as temporarily damaging to water quality. Consequently, some water quality parameters (turbidity, dissolved oxygen, pH, temperature, water level and conductivity) have been selected to be monitored as potentially affected by the dredging activities. The monitoring strategy is to continuously control the conditions both upstream as well as downstream of the dredging works, and to periodically monitor the same parameters all over the area influenced by the dredging activities along selected pathways. This has been achieved by means of two fixed stand-alone monitoring stations (one upstream and one downstream) and a mobile one (on survey boat): since the works will proceed from one edge of the road connection to the other, the selected strategy will allow the following of the works as they proceed by shifting the whole system (of mobile and fixed stations).

In view of the selected parameters, three multi-parameter stand-alone sondes (Endeco YSI 6600) have been acquired and their location opportunely planned.

Water samples by pump sampling have been forecasted and executed at selected locations in order to measure Chemical and Biological water Oxygen Demand (COD, BOD_5), grain size of suspended sediments and especially suspended sediments concentration, in order to properly characterise the turbidity plume eventually caused by the dredging works and to correlate suspended sediments with turbidity.

As a result of the variety of natural scenarios along the Rio Paraná fluvial valley and of the dredging activities, the periodicity of the monitoring plans has been set to a three-monthly period. Figure 12 shows the planned monitoring pathways and locations for the period April-June 1999 in the Victoria area. Figure 13 shows one of the YSI sonde in its steel structure prepared to be placed in water at the location of the water intake of Victoria.

Environmental reporting

As a continuous activity during the whole length of the project, the following tasks can be mentioned:

- the redaction of Quarterly Environmental Monitoring Programmes (EMOP), defining the parameters to be monitored, the locations of the fixed stations, the longitudinal, transversal and vertical lines to be monitored with the mobile equipment, the location of the water samples, the frequency and modality of all the monitoring activities for the subsequent three months. In particular, since the beginning of the works, on the Victoria side, the downstream stand-alone fixed station has been located at the water intake of Victoria;
- the preparation of Environmental Management (System) Quarterly Reports (EMQR), which present and evaluate all the environmental aspects of the dredging works and the results of the environmental monitoring activities undertaken during the previous three-monthly periods;
- the preparation of Environmental Management (System) Yearly Reports (EMYR), which represent a yearly summary of the environmental aspects of the dredging works and of the monitoring results; and
- the preparation of Environmental Monthly Memorandums (EMMR) for prompt information of the Consortium of the monitoring results when particular situations arise.

Preliminary Conclusions

The Environmental Management System has already been audited several times, internally (by the Argentine Consortium) and externally (by the Governmental Control Body), and has proved to comply with prevention, control and mitigation of eventual disturbances of the environment.

In general, expected negative effects so far have been minimal. So far no relevant discomfort to local island inhabitants in the area or relevant hindrance to small-scale navigation has been detected.

No water contamination by oil/lubricant spill has occurred and no relevant occurrence of stagnant water has been revealed. As expected, the risk of stagnant water occurrence has been reduced by the presence of the channel, and no permanent impairment of small watercourses has been recorded. With the exception of the borrow pits areas, no relevant changes in channel morphology nor in the morphology of the disposal areas have been detected: the disposed material was found to fit within the surrounding environment and to provide new surfaces for vegetation growth and pasture. No relevant loss of vegetable species has been detected, and new vegetation has rapidly grown on the disposal areas. Besides, a high density of fishes/birds has been observed, respectively, close to the dredging areas and on the disposal areas because of higher food availability.

Up to now, water quality has been only slightly and temporarily affected by local increases in turbidity. Besides the Fixed Link related dredging works, local non-related dredging activities proved to have produced high turbidity clouds, even close to such a sensitive point as the water intake of Victoria. In general, no damage has been encountered so far to the local fauna. As is common in such a dynamic system, the environment has reacted promptly and apparently adapted itself to the presence of the works.

Alwin Albar

Effect of Various Terminal Velocity Equations on the Result of Friction Loss Calculation

Abstract

Several equations for calculating terminal velocity of sediment particles are presented. Each formula is then used to determine friction loss in slurry pipelines. The study evaluates the effect of each equation on the value of friction loss. Results are presented first as a function of slurry velocity, and then as a function of particle diameter. They are later compared with experimental data available in literature. It is found that there is a considerable difference between friction loss values yielded by those terminal velocity equations. This paper also discusses the advantages and disadvantages of applying these equations for friction loss calculation.

Introduction

Determining the terminal velocity is commonly used to calculate friction loss in a pipeline system. Previous researchers developed independently different methods to define the terminal velocity equation, mostly empirically. This resulted in various methods with their own characteristics and they claim their methods as satisfactory. The claims may be true for a particular case, however, it is not necessarily suitable for a particular friction loss calculation. This study will try to examine some methods that are commonly used for friction loss calculation in a pipeline.

In evaluating the various terminal velocity equations, this paper limits the discussion on Wilson's friction loss model only. The Wilson model (1992) has gained wide acceptance in the hydraulic transport industry. Matousek (1997) confirmed that the modelling approach by Wilson *et al.* (1992) recognises different slurry flow behaviour in flows with a different degree of flow stratification.

The Wilson friction loss model does not explicitly contain terminal velocity relations. The only parameter in the Wilson model that includes the terminal velocity is the particle-associated velocity (w). According to Wilson (1997), when the particle size becomes progressively finer, the value of the particle terminal velocity does not tend toward zero, as well as the value of w.

It would seem that the terminal velocity values would not influence the friction loss value very much, but it turns out that it does, considerably. Although there is no recommendation to use Wilson's method in calculating terminal velocity, it is possible that using it instead of others might be best.

Objective

The objective of this study is to observe the effect of the terminal velocity as evaluated from various terminal velocity equations on the result of Wilson friction loss calculations. Results of this observation will be used to help choose a suitable method of terminal velocity equation in friction loss calculation developed by Wilson *et al.* (1997), based on experimental data.

Terminal Velocity Equations

It is known that terminal velocity of the sediment particles plays a significant role in slurry transport. The most important factors generally considered are particle size, density and shape and ambient fluid properties. Various investigators have collected extensive data pertaining to terminal velocity of such particles and they have developed empirical equations to evaluate the terminal velocity. The following equations presented here were selected because of common use, simplicity and their recent development.

Equation developed by Schiller (1992)
Schiller (1992) developed an empirical relationship

Nomenclature

a	= maximum dimension of particle [m]
$A_{particle}$	= projected particle area for any particle [m^2]
A_{sphere}	= projected particle area for spherical particle [m^2]
Ar	= Archimedes number
b	= intermediate dimension of particle [m]
c	= minimum dimension of particle [m]
d_{50}	= median particle diameter [m]
d_{85}	= particle diameter for which 85% of the particles are finer [m]
d_n	= nominal particle diameter [m]
d_*	= dimensionless particle diameter (Cheng, 1997)
d^*	= dimensionless particle diameter (Wilson, 1997)
f	= fluid-pipeline friction coefficient
g	= gravitational force [m/s^2]
M	= non-dimensional exponent coefficient
Re	= Reynolds number
SG_f	= specific gravity of fluid
SG_m	= specific gravity of mixture
SG_s	= specific gravity of particle
V_{sm}	= critical value of V_m at limit deposition
V_t	= particle terminal velocity [m/s]
V_{tf}	= dimensionless parameter
$V_{t(Sc)}$	= terminal velocity [mm/s]
w	= parameter of particle associated velocity
w_*	= non-dimensional fall velocity
β	= Corey shape factor
Δ	= $(\rho_s - \rho_f)/\rho_f$, dimensionless parameter
μ_f	= fluid dynamic viscosity [Ns/m^2]
μ_s	= mechanical friction coefficient of solids against pipewall
υ	= fluid kinematic viscosity [m^2/s]
υ_*	= non-dimensional kinematic viscosity
ρ_f	= fluid density [kg/m^3]
ρ_s	= sediment particle density [kg/m^3]
ψ	= particle sphericity, shape factor

using regression techniques based on data from Graf *et al.* (1966) and the result is:

$$V_{t(Sc)} = 134.14\left(d_{50} - 0.039\right)^{0.972} \qquad (1)$$

This equation is widely used because of its simplicity. It requires only the knowledge of the median grain size (d_{50}) in millimeters.

Equation developed by Swamee and Ojha (1991)

Swamee and Ojha derived the empirical equation for terminal velocity of non spherical particles based on the experimental data of Schulz *et al.* (1954). The proposed expression for terminal velocity is:

$$w_* = \left[\frac{44.84\,\upsilon_*^{0.667}}{\left(1+4.5\beta^{0.35}\right)^{0.833}} + \frac{0.794}{\left(\beta^{4} + 20\,\beta^{20} + \upsilon_*^{2.4}\exp\left(18.6\,\beta^{0.4}\right)\right)^{0.125}}\right]^{-1} \qquad (2)$$

with non dimensional parameters:

$$w_* = \frac{V_t}{\sqrt{(SG_s - 1)gd_n}} \qquad (3)$$

$$\upsilon_* = \frac{\upsilon}{d_n\sqrt{(SG_s - 1)gd_n}} \qquad (4)$$

to remove the implicitness and avoid iteration process.

The nominal diameter (d_n) and Corey shape factor (β) were used in the formulation (Swamee and Ojha 1991). The nominal diameter is the diameter of a sphere of the same volume as the given particle, and defined as:

Table I. Correlation for dimensionless terminal velocity (V_{ts}*) as a function of dimensionless diameter (d*), after Grace (1986).

Range			Correlation
d*	V_{ts}*	Re_p	
≤ 3.8	≤ 0.624	≤ 2.37	$V_{ts}^* = (d^*)^2/18 - 3.1234\times10^{-4}(d^*)^5 + 1.6415\times10^{-6}(d^*)^8 - 7.278\times10^{-10}(d^*)^{11}$
3.8 to 7.58	0.624 to 1.63	2.37 to 12.4	$x = -1.5446 + 2.9162w - 1.0432w^2$
7.58 to 227	1.63 to 28	12.4 to 6370	$x = -1.64758 + 2.94786w - 1.09703w^2 + 0.17129w^3$
227 to 3500	28 to 93	6370 to 326000	$x = 5.1837 - 4.51034w - 1.687w^2 - 0.189135w^3$
			with: $w = \log_{10} d^*$; $x = \log_{10} V_{ts}^*$

$$d_n = \left(\frac{6V}{\pi}\right)^{1/3} \quad (5)$$

The Corey shape factor (*β*) is defined as:

$$ß = \frac{c}{\sqrt{ab}} \quad (6)$$

which was developed by considering the fact that the particles orienting themselves in the fluid presents the greatest resistance to the passing fluid. The Corey shape factor (*β*) is a logical dimensionless shape factor expressing the relative flatness of the particle where *ab* represents the particle projected area and *c* corresponds to the particle thickness.

Equation developed by Wilson et al. (1992)

Wilson (1992) calculates the settling velocity for a sphere falling in water and then corrects for the particle shape and subsequently considers hindered settling. For a sand particle that is assumed to be a sphere the terminal velocity is determined using the relationship tabulated in Table I. The following parameters (d^* and V_{tf}) are essential for calculating terminal velocity:

$$d^* = d_{50}\left[\frac{\rho_f(\rho_s - \rho_f)g}{\mu^2}\right]^{1/3} \quad (7)$$

$$V_{tf} = \left[\frac{\rho_f^2}{(\rho_s - \rho_f)\cdot g\cdot \mu}\right]^{1/3} \quad (8)$$

Once the value of V_{ts}^* is determined, the sphere terminal velocity V_{ts} can be calculated:

$$V_{ts} = \frac{V_{ts}^*}{V_{tf}} \quad (9)$$

In order to calculate non-spherical particle terminal velocity, the velocity ratio ξ must be obtained from the following chart after determining the correct volumetric shape factor k from Table II :

The actual terminal velocity can then be obtained by correcting V_{ts} using the following equation.

$$V_t = \xi \cdot V_{ts} \quad (10)$$

Equation developed by Hartman et al. (1994)

Hartman *et al.* (1994) conducted experiments on limestone and combined their results with data of Pettyjohn and Christiansen (1948). The materials were selected so that the particles had approximately equal axes at right angle to each other. More than 400 experimental data points were fitted by minimising the standard deviation between the experimental values and the values estimated from the proposed relationship.

Alwin Albar (center) recipient of the IADC Award is seen here with Mr Peter Hamburger (left), Secretary General of the IADC, and Dr Robert Randall, Director of the Center for Dredging Studies at Texas A&M University.

IADC Award 2000

Presented at the WEDA XX and 32nd Texas A&M University Dredging Seminar, Warwick, Rhode Island, USA June 25-28 2000

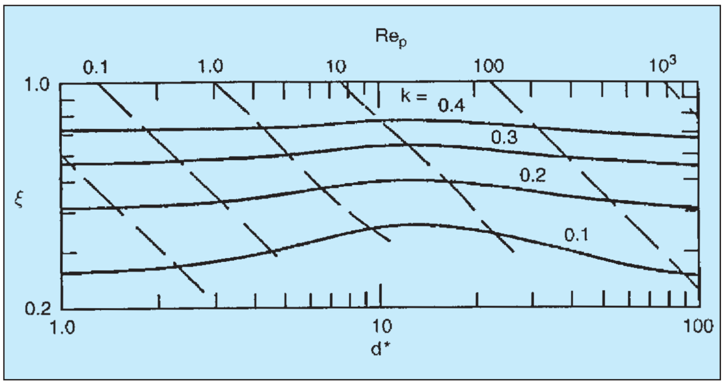
At the Twentieth Western Dredging Association Annual Meeting and Conference, held in late June this year, Alwin Albar was presented with the annual IADC Award for young authors. Mr Albar received his BSc in Mechanical Engineering from Bandung Institute of Technology, Indonesia, in October 1992. He proceeded with his study, earning a MSc in Mechanical Engineering from the University of Wisconsin at Madison in May 1995. In 1996 he was recruited by PT Timah Tbk, an Indonesian tin-mining company, and then received a full scholarship to pursue a PhD in Ocean Engineering at Texas A&M University, College Station, Texas where he is presently enrolled in the Ocean Engineering Programme of the Civil Engineering Department.

Each year at a selected conference, the International Association of Dredging Companies grants an award to a paper written by an author younger than 35 years of age. The Paper Committee of the conference is asked to recommend a prize-winner whose paper makes a significant contribution to the literature on dredging and related fields. The purpose of the award is "to stimulate the promotion of new ideas and encourage younger men and women in the dredging industry". The IADC Award consists of US$ 1000, a certificate of recognition and publication in *Terra et Aqua*.

Table II. Volumetric shape factors for isometric and mineral particles (Wilson 1997).

Isometric Particles	k	Mineral Particles	k
Sphere	0.524	Sand	0.26
Cube	0.696	Silliminate	0.23
Tetrahedron	0.328	Bituminuos Coal	0.23
Rounded	0.54	Blast furnace slag	0.19
Sub-angular (partly rounded)	0.51	Limestone, talc, plumbago	0.16
Sub-angular (tending to caboodle)	0.47	Gypsum	0.13
Sub-angular (tending to tetrahedral)	0.38	Flake graphite	0.023
		Mica	0.003

Figure 1. Ratio of the terminal velocity of a non-spherical particle to the value for a spherical particle, ξ, as a function of dimensionless diameter, d (Wilson 1997).*



Hartman used the sieve diameter and sphericity shape factor (ψ) in the calculation (Hartman et al. 1994).
The sphericity shape factor (ψ) is defined as:

$$\psi = \frac{A_{sphere}}{A_{particle}} \qquad (11)$$

The more ratio departs from unity, the lower the value of sphericity ($\psi = 1$ corresponds to a sphere). It is difficult to determine ψ directly in the case of irregular particles.

The proposed relationship for Reynolds number for any given particle dimension that implicitly include the terminal velocity (V_t) is:

$$\log \mathrm{Re}(A_r, \psi) = \log \mathrm{Re}(A_r, 1) + P(A_r, \psi) \qquad (12)$$

where:

$$V_t = \frac{\nu \cdot d_{50}}{\mathrm{Re}} \qquad (13)$$

$$\log \mathrm{Re}(A_r, 1) = -1.2738 + 1.04185 \log A_r$$
$$- 0.060409(\log A_r)^2 + 0.0020226(\log A_r)^3 \qquad (14)$$

and:

$$P(A_r, \psi) = -0.071876(1-\psi)\log A_r$$
$$- 0.023093(1-\psi)(\log A_r)^2 + 0.0011615(1-\psi)(\log A_r)^3$$
$$+ 0.075772(1-\psi)(\log A_r)^4 \qquad (15)$$

$$A_r = d_{50}^{\ 3}\, g \frac{\rho_f(\rho_s - \rho_f)}{\mu_f^{\ 2}} \qquad (16)$$

Equation developed by Cheng (1997)

Cheng (1997) proposed a recent empirical relationship for terminal velocity of non spherical particles.
A simplified explicit formula was evaluated based on experimental data of Schiller and Naumann (1933) and US Inter Agency Committee (1957). Cheng limited his formulation to natural sediment only and did not clearly stated the dimension definition used in the calculation, although the paper implicitly stated that the shape factor used is the Corey shape factor (β=0.7) and the diameter used in the calculation is the sieve diameter (Cheng 1997). The proposed formula for terminal velocity is:

$$\frac{V_t \cdot d_{50}}{\upsilon} = \left(\sqrt{25 + 1.2 d_*^{\ 2}} - 5\right)^{1.5} \qquad (17)$$

with:

$$\Delta = \frac{(\rho_s - \rho_f)}{\rho_f} \qquad (18)$$

$$d_* = d_{50} \cdot \left(\frac{\Delta g}{\upsilon^2}\right)^{1/3} \qquad (19)$$

Friction Loss Calculation

There are many approaches to calculate slurry flow friction loss such as empirical, microscopic and macroscopic approaches. The first predictive tools were empirical approaches developed in the 1950s, which predicted basic slurry pipeline characteristics. The next was a microscopic approach, which defined the laws governing slurry flow for an infinitesimal control volume of slurry, developed in the 1980s. A macroscopic approach offers good compromise between the other two. This approach applies the balance (conservation) equation to a larger control volume of slurry.
An example of such a control volume is a unit length of pipe length containing an approximately uniform concentration of solids.

Wilson (1970) introduced the concept based on the principle of force balances in the two-layer pattern of mixture flow stratified into a bed load and a suspended load. Furthermore, Wilson (1992) developed a new semi-empirical model for heterogeneous flow in slurry pipelines, which was calibrated by using experimental data. This model is based on considering heterogeneous flow as a transition between two extreme flows governed by a different mechanism for support of a solid particle in the stream of the carrier liquid which are fully stratified flow and fully suspended flow. Resistance in fully stratified flow is predominantly a result of mechanical friction between solid particles and the pipeline wall. The frictional head loss is predicted by using a two-layer model.

Wilson *et al*. (1992) introduced the parameter V_{50} that expresses the mean slurry velocity at which one half of the transported solid particles contribute to a suspended load and half by contact with other particles.
This equation expresses the influence of suspension mechanisms for the carrier fluid turbulent diffusion and the hydrodynamic lift acting on particles larger than the sub-layer thickness in the near wall region.
The V_{50} can be estimated by equation:

$$V_{50} = w\sqrt{\frac{8}{f}}\cosh\left(\frac{60 \cdot d}{D}\right) \quad (20)$$

where:

$$w = 0.9v_t + 2.7\left[\frac{(\rho_s - \rho_f)g\mu}{\rho_f^{\,2}}\right]^{1/3} \quad (21)$$

The relationship between the relative solids effect and mean slurry velocity is given as:

$$\frac{I_m - I_f}{SG_m - 1} = 0.22\left(\frac{V_m}{V_{50}}\right)^{-M} \quad (22)$$

The exponent M is given by the expression

$$M = \left[\ln\left(\frac{d_{85}}{d_{50}}\right)\right]^{-1} \quad (23)$$

The value of M should not exceed 1.7, the value of narrow-graded solids, or fall below 0.25. In practice the value of M is considered to be equal to 1.7.

The Wilson model gives a scale-up relationship for friction loss in slurry pipelines of different sizes transporting solids of different sizes at different concentrations. It is based on the assumption that there is a power relationship between the relative solid effect and the mean slurry velocity that is valid in all slurry flow conditions. The exponent M of this relationship is assumed to be dependent on the particle size distribution only.

Wilson (1992) also proposed a particular relation for calculating the deposition-limit velocity (V_{sm}), which is a minimum value of flow velocity to enable sediment to be transported. The relation is:

$$V_{sm} = \frac{8.8\left(\frac{\mu_s(SG_s - SG_f)}{0.66}\right)^{0.55} D^{0.7} d_{50}^{\,1.75}}{d_{50}^{\,2} + 0.11D^{0.7}} \quad (24)$$

Case Study

The objective of the first case study is to compare the friction loss values using all terminal velocity models and experimental data (Potnis 1997). Each model is plotted as a function of flow velocity for a particular pipe size, specific gravity and particle size. To make them comparable, values used in the calculation are the same with values used in the experiment.
Potnis (1997) measured the experimental data of sand (SG_s = 2.65) for 10.16 cm (4 in.), 15.24 cm (6 in.) and 20.32 cm (8 in.) pipes with particle diameter 0.3 mm.

It can be seen from the graphs (Figure 2) of the first case study that the Wilson method gives the closest result to the experimental data. Based on this fact, the next case study is meant to compare other models with the Wilson method. In other words, the Wilson method is used as a reference for others because of its best results. With this in mind, graphs in this next case study (Figures 3 and 4) showing differences with the Wilson model, are expected to give an overview of the other models performance. The performance is expressed by percent difference (results of each model subtracted by the results of reference model, divided by the results of reference model).

The graphs shown here are samples for a particular

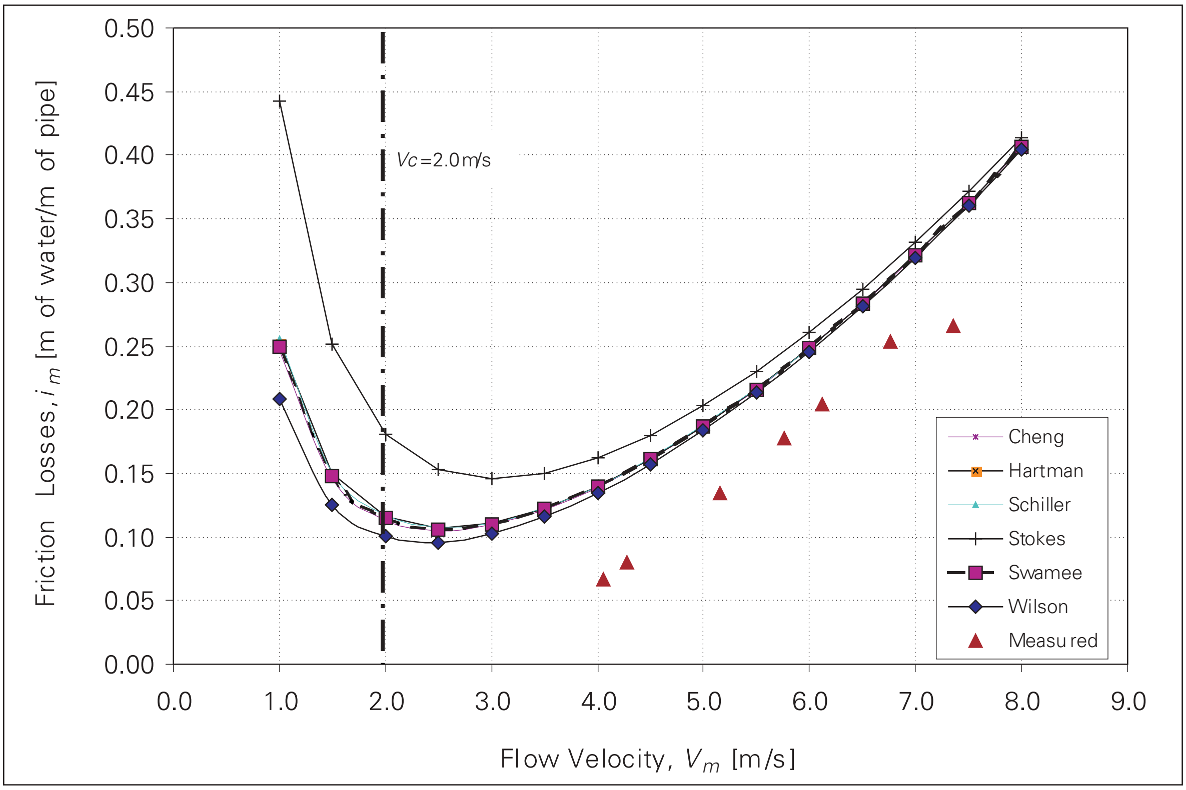


Figure 2. Variation of friction loss with flow velocity, pipe size 4 in., particle size = 0.3 mm.

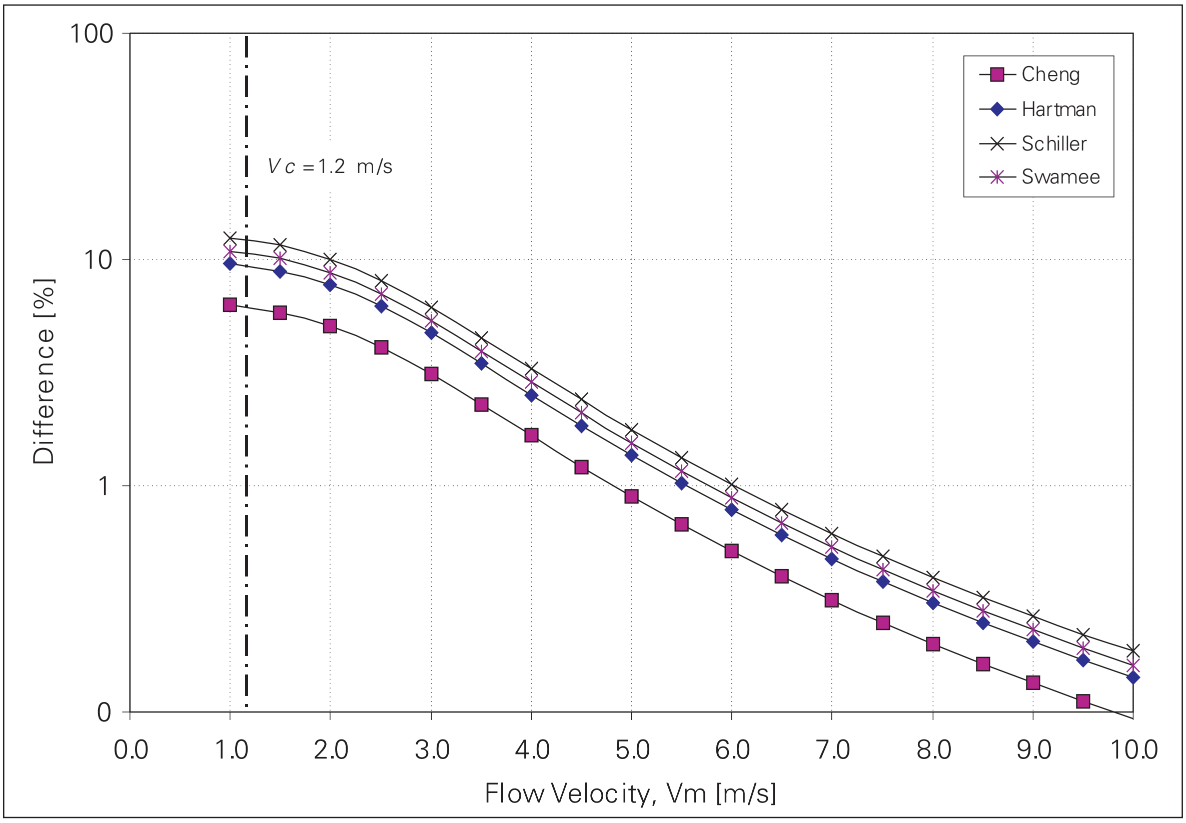


Figure 3. Percent difference of friction loss compared to Wilson model pipe size D=8 in., particle size d = 0.1 mm.

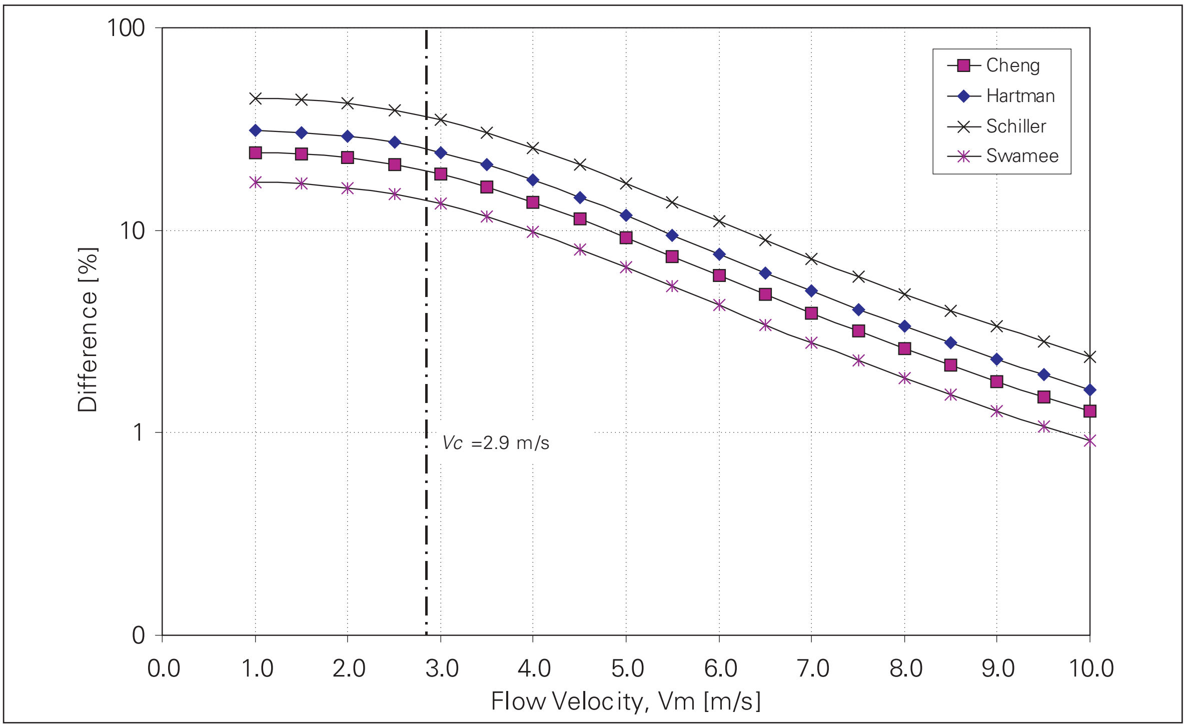


Figure 4. Percent difference of friction loss compared to Wilson model pipe size D=8 in., particle size d = 1.0 mm.

pipe size. Results for other pipe sizes, although not shown here, exhibit similar behaviour. Figures from the second case study show that each model gives different performance as the particle size changes. This leads to the last case study, where the behaviour of each model as a function of parameters is studied extensively by varying simultaneously the particle size and flow velocity. Figure 5 shows the behavior of the Wilson model itself. The other figures (Figures 6 through 9) present the percent difference of the other models with the plot of Figure 5.

Discussion

Five equations for evaluating the particle settling (terminal) velocity have been reviewed and the following observations about the different methods are made:

- The Swamee equation (Eq. 3) is valid for any range of particle grain size and for any specific gravity. Although not very simple, it is relatively easy to use in the sense that no iteration is needed.
- The Schiller model is a very simple equation, however its simple form results in some limitations. The grain size is limited to 2 mm maximum, and valid only for materials that have a specific gravity equal to sand.
- The Wilson equation is the most complicated of all the equations presented here. It is valid for any range of grain size and for any specific gravity. The complexity is increased by certain conditions for different ranges of dimensionless particle diameters, which make it difficult to calculate. Moreover, the particle shape factor used in the Wilson equation is not commonly used.
- The Hartman particle shape factor is not easy to calculate. Although not as complex as the Wilson equation, it is still a long and complex equation. One advantage is that it is valid for any range of grain size and for any specific gravity.
- The Cheng equation is the simplest and is limited to natural sand only. It is valid for only one particle shape factor.

The Wilson friction loss calculation is a function of many parameters. Amongst these parameters are parameters affecting both terminal velocity and the friction loss directly, for example particle diameter (d) and particle specific gravity (SG_S). On the other hand, there are parameters affecting the values of friction loss only, such as pipe diameter (D) and flow velocity (V_m). However, there is also the particle shape factor (*PSF*), which affects terminal velocity only.

To show how the terminal velocity affects the friction loss values, this study chooses particle diameter as the varied parameter owing to the consideration that it gives the greatest influence on the values of terminal velocity. At this time, the study is limited for a single material, which has certain values of particle shape factor (*PSF*) and SG_S. Other parameters varied to observe their influence on the friction loss are D and V_m.

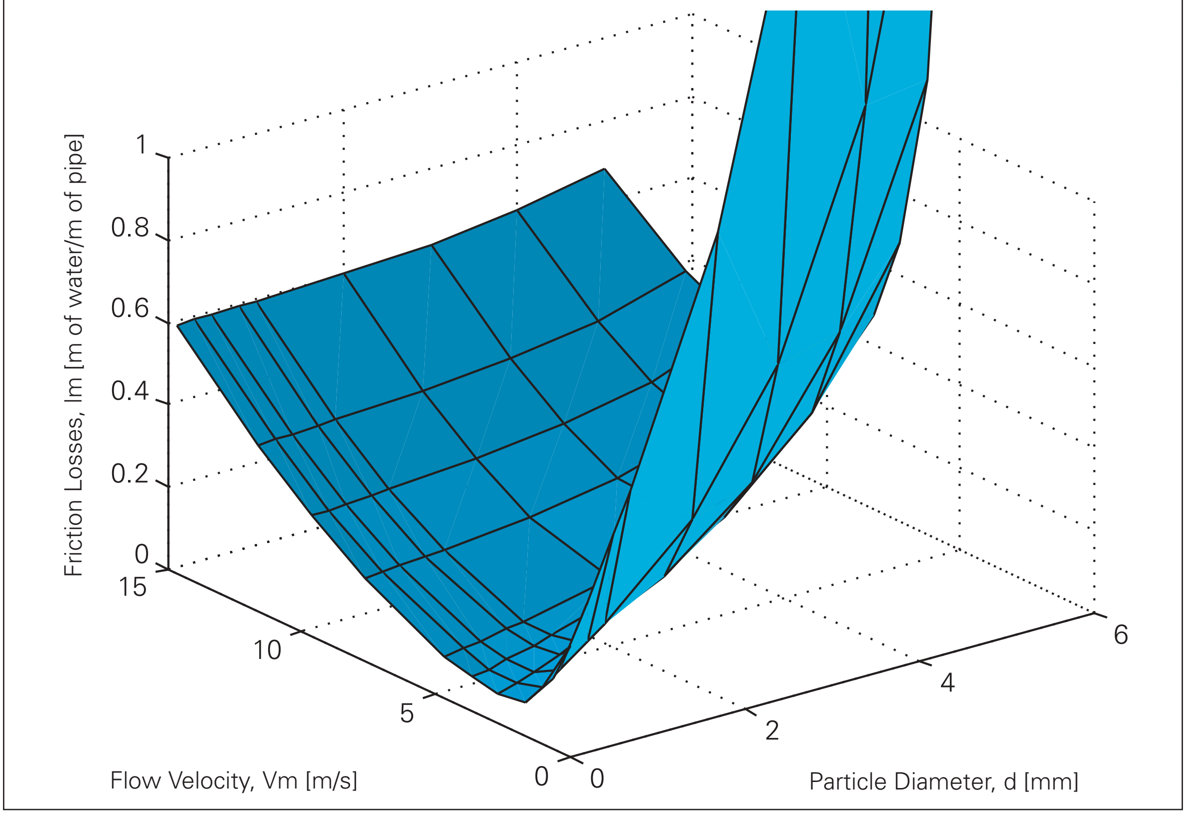


Figure 5. Variation of friction loss with various flow velocity and particle diameter pipe size D = 8 in.

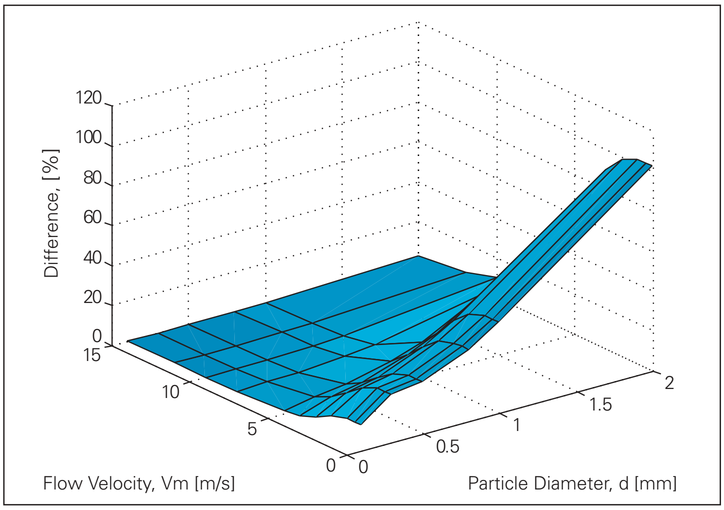


Figure 6. Percent difference of friction losses using Cheng equation compared to Wilson model pipe size D = 8 in.

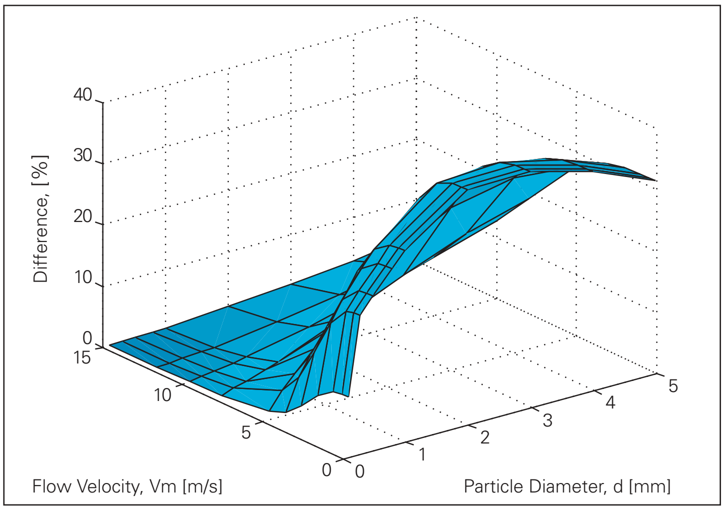


Figure 7. Percent difference of friction losses using Hartman equation compared to Wilson model pipe size D = 8 in.

The first case study (Figure 2) shows that every equation presented in this study exhibits a similar trend in calculating the friction loss as a function of V_m.

As mentioned before, the Wilson method is used as a reference because it has the closest results to all experimental data. This study shows that pipe size affects only the values of friction loss but not the trend of each model. This makes the graphs shown here reflect the trend (not value) of friction loss for all pipe sizes.

Results from the second and third case studies show that other equations always have a positive difference compared to Wilson method. These results also show that each terminal velocity equation has its own characteristic. The following is a summary of these characteristics for an 8-inch pipe diameter:

– The Swamee equation gives consistent results in all ranges of particle size and flow velocity (Figure 9), meaning that the percent difference is almost constant for those ranges. The difference peaks at 21% at V_m= 0.1 m/s and d = 0.5 mm. An interesting characteristic of this equation is that the peak difference occurs at particle sizes below 1 mm.
– At smaller ranges of particle size, the Schiller equation agrees well (Figure 8). However, as grain size increases, the percent difference rises drastically. The peak difference is the highest amongst the models presented in this paper (102% at V_m=0.1 m/s and d= 2 mm).
– The Hartman equation gives the maximum difference 38% at V_m=0.1 m/s and d= 3 mm (Figure 7). Similar to the Swamee equation, the peak difference does not occur at large particle sizes.
– Amongst models, Cheng gives best results for particle sizes up to 0.5 mm. However, the

difference grows rapidly as particle size increases (Figure 6). Maximum difference = 32% is found at the highest particle size from the data set (d = 5 mm) and V_m = 0.1 m/s.

Overall, the most consistent results are given by the Swamee equation. For smaller particle sizes the Cheng equation gives the best results amongst others. Its performance degrades as particle size increases. For example, above d = 0.5 mm, the Swamee equation outperforms the Cheng equation in terms of percent difference. The other two equations always have larger differences than the Swamee and Cheng equations.

Conclusions

This study addresses the issue of the friction loss calculation affected by various terminal velocity equations. It is observed that the largest influence of terminal velocity is in low flow velocity and coarser particle grain size. The first case study showed that using the Wilson method in calculating terminal velocity gives the closest results to measurements. The second and third case studies gave an overview of the characteristics of each equation on friction loss calculation. It is hoped that these results can give some insight on the differences of incorporating various terminal velocity equations into the friction loss calculation.

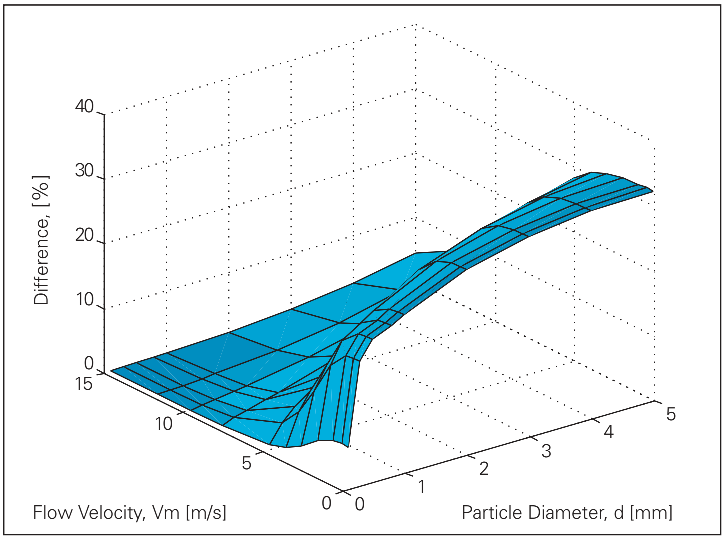


Figure 8. Percent difference of friction losses using Schiller equation compared to Wilson model pipe size D = 8 in.

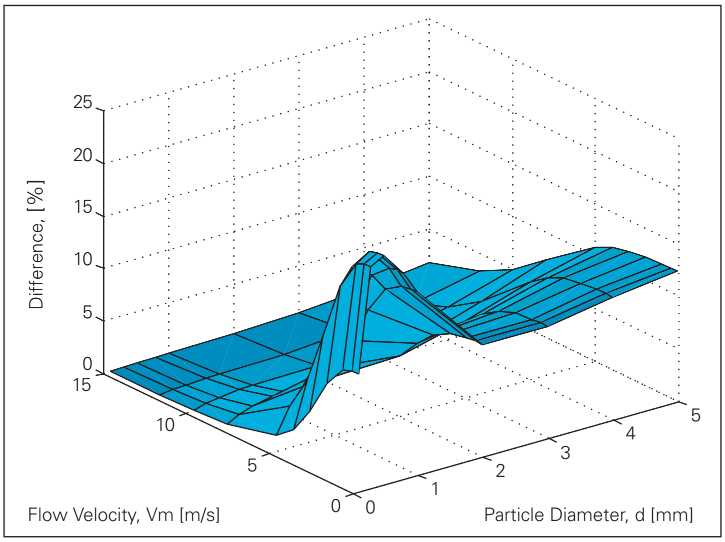


Figure 9. Percent difference of friction losses using Swamee equation compared to Wilson model pipe size D = 8 in.

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C.A. Angevaren, A.H. Boezeman, W. van den Bos and W.J. Vlasblom

Structural and Dynamic Analysis of Sub-sea Diamond Miner MK II

Abstract

The Namibian Minerals Corporation (Namco) has had a sub-sea diamond miner operational for a number of years. Recently a second machine called the "sub-sea diamond miner MK II" was designed. This machine is to be operated from a ship that is currently being adapted for this purpose. For practical reasons the construction of a real prototype is not an option.
A *virtual* prototype was constructed by Delft University of Technology at the section of Dredging and Transport Technology (The Netherlands). With the help of Computer Aided Engineering (CAE) both the dynamic behaviour and the structural aspects were researched. Some problems in the design have been solved before the machine was actually constructed.

Introduction

The Namibian Minerals Corporation (Namco) has had a sub-sea diamond miner operational for a number of years. Recently a second machine called the "sub-sea diamond miner MK II" was designed.

This machine is to be operated from a ship that is currently being adapted for this purpose. The miner is also under construction. It will be equipped with a 1800 kW dredging pump that is connected to a 600 mm diameter discharge hose that in turn is connected with a processing plant on the ship. The machine is 18 metres long and weighs in at 160 tonnes.

Critical activities in the miner's operation cycle are the launch and recovery. During launch the machine is hoisted from the back of a ship by a synthetic cable. The ships motion and the water-induced forces working on the machine introduce large dynamic loads in the system.

Owing to the specific nature of the machine it is difficult to determine its characteristics. However, it is necessary to understand the working conditions of the machine in an early stage of the design phase in order to ensure correct operation. The behaviour of the new machine cannot be predicted directly from the existing one as the dimensions are considerably larger and dynamics were supposed to be more significant.

For practical reasons the construction of a real prototype is not an option. Namco decided that a *virtual* prototype had to be constructed by Delft University of Technology at the section of Dredging and Transport technology (The Netherlands). With the help of Computer Aided Engineering (CAE) both the dynamic behaviour and the structural aspects were researched.

The work was executed in close co-operation with Namco and their South African engineering counterpart Ingenio. As a result of this method of engineering some problems in the design have been solved before the machine was actually constructed.

Process of Virtual Prototyping

A virtual prototype is a computer model that represents the mechanical properties of a real system.
This enables the research of the machines behaviour in various operating circumstances.

In addition to the fact that building a virtual prototype is a time- and money-saving operation compared to constructing a real prototype, this approach has other advantages:
– It is possible to look at very extreme conditions, without endangering a costly machine or personnel.
– It would be very difficult to reflect the working conditions of a submerged machine in a normal prototyping phase.

The starting point was a 3D-CAD model that was deduced from the original 2D drawings. A 3D model gives good insight in the space frame structure of the diamond miner and was used to check the interference of geometry of the beam structures. From this model, both a Finite Element model (FEM) and a Multi-Body model have been derived, as illustrated in Figure 1.

Besides obvious influences such as applied forces and moments in the FEM analysis, the effects of water pressure and buoyancy have been accounted for.
A set of load cases was introduced to reflect mining conditions and the process of launching. These load cases were used to compare the results of the parties involved. By using two different modelling techniques (by TU Delft and Ingenio) this provided a means of validation of the models.

In the FEM model small deformations of the structure were the subject of attention (strength and stiffness). In the Multi-Body model the focus was on large motions with respect to the dimensions of the system (dynamic behaviour of the machine). In order to represent the mechanical properties and external effects the following elements have been introduced in the Multi-Body model:

- water-related forces acting on the machine and discharge hose: viscous drag of the water, buoyancy and added mass as a result of machine movements;
- a hoisting system that consists of a cable, winch and wave compensator; and
- prescribed ship heave and pitch motion.

Some peculiarities in the cable force characteristics during the launching procedure have been communicated back to Namco. Load cell measurements on the existing machine under similar circumstances proved to display a similar trend. This gave a validation of the simulation results on the one hand, and cleared up some phenomena of the existing machine on the other.

Results

The three different models used for the study of the MK II have all led to improvements in the initial design.

3D-CAD
In the main frame the welding of several pipes would be difficult or even impossible. This was primarily the result of the large number of connecting pipes in some nodes and the complexity of the space structure.
In two-dimensional drawings it was not possible to perform these checks.

The machine was also researched for interference of elements as a result of the relative motion of the constituent parts. The main frame and inner yoke would have intersected at approximately 30 degrees swing angle (Figure 2). Both discoveries led to the redesign of the frame.

FEM
In addition to design changes in the main frame, which were mainly a result of high cable forces, some modifications on the boom were suggested.

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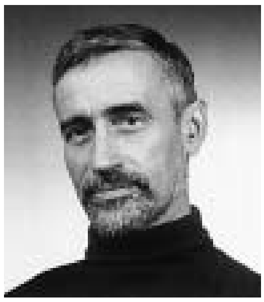
W. van den Bos

Professor W.J. Vlasblom graduated with a degree in Civil Engineering from Delft University of Technology in 1968. From 1968-1992 he worked for several international dredging companies. In 1992 he became Head, Production and Planning Department, Airport Platform Marine Contractors JV in Hong Kong. In 1994 he was appointed Professor at Delft University and is presently Chair of the Dredging Technology Department.



W.J. Vlasblom

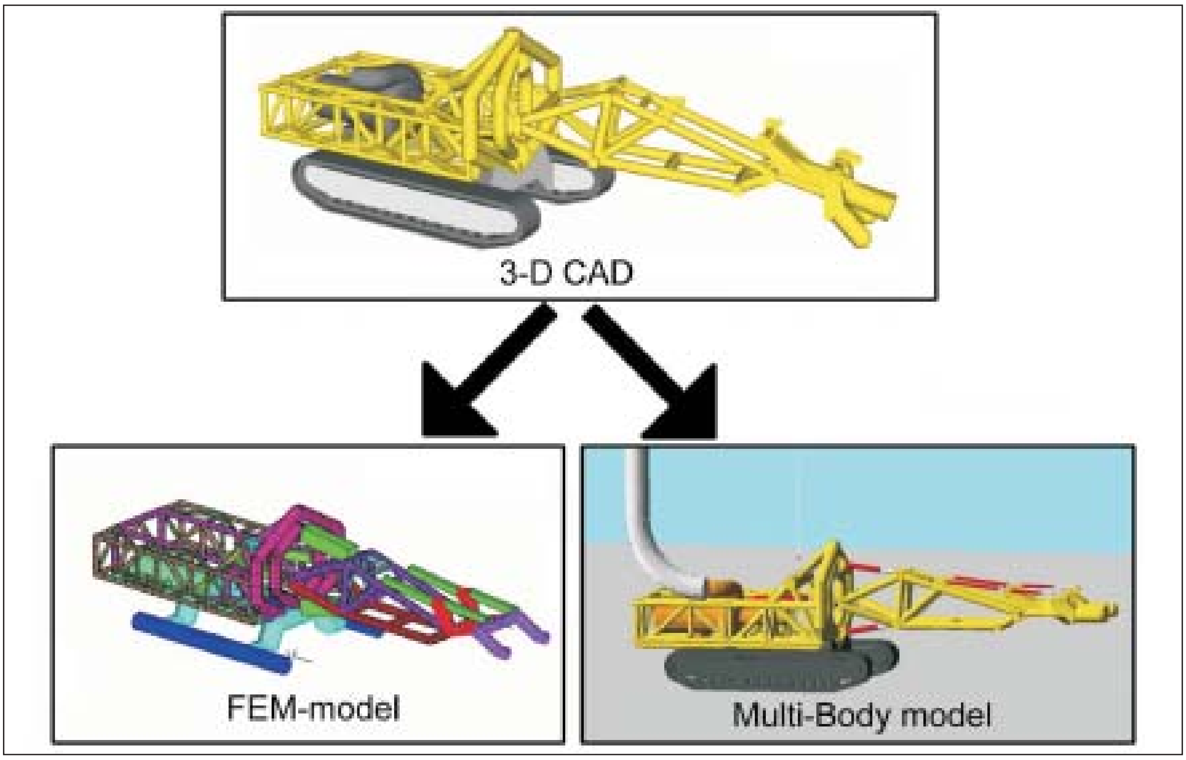
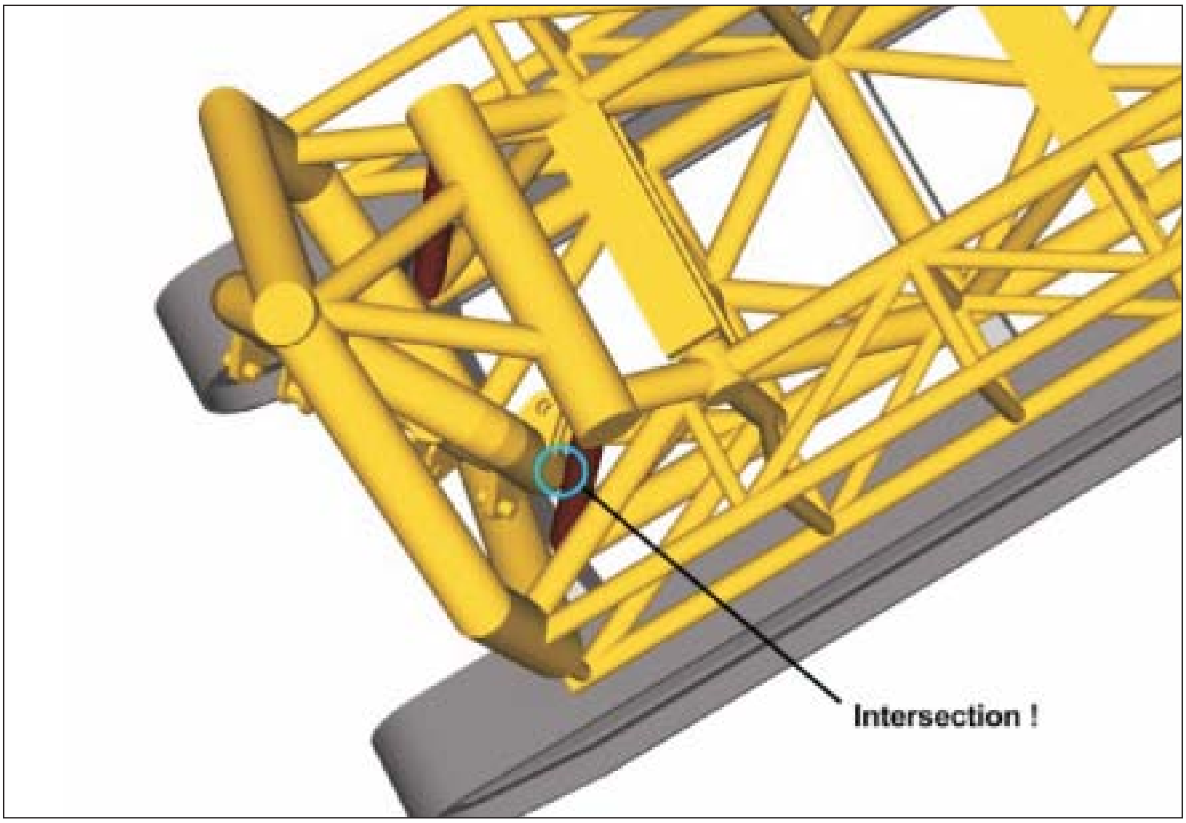


Figure 1. Conversion from 3D CAD-model to FEM and Multi-Body models.

Figure 2. Intersection of inner yoke and main frame at approx. 30 degree swing angle.



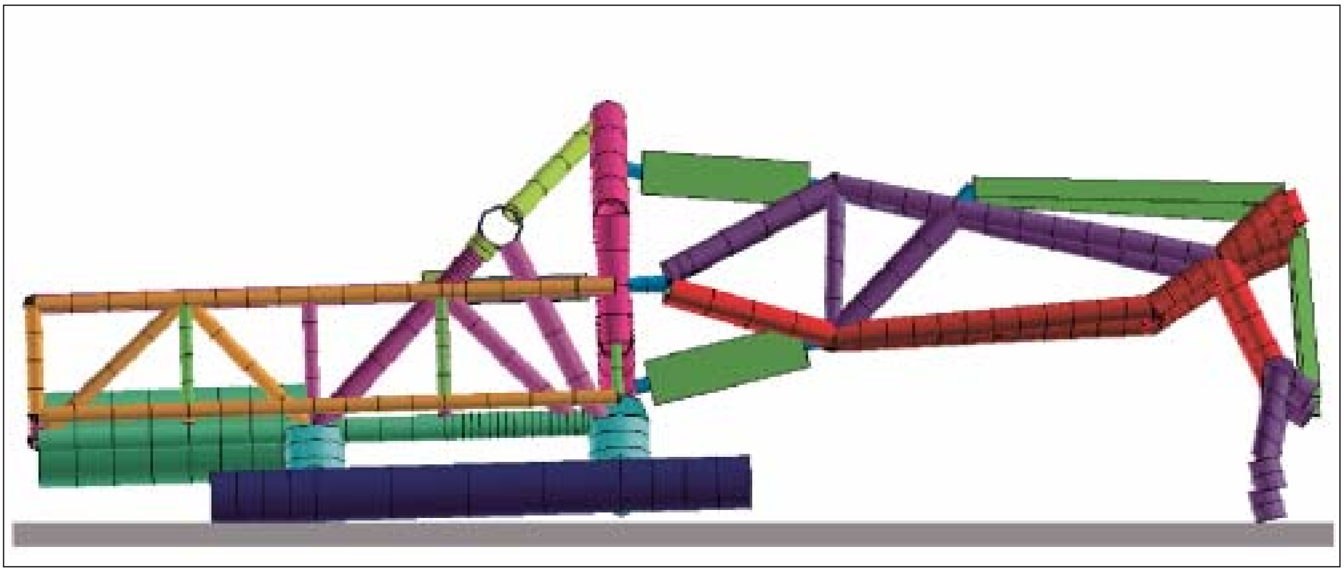


Figure 3. Machine "push up" with the boom.

The most critical load case for the boom results from a rescue type of operation. When the tracks lose grip, the machine can do a "push up" with the boom. Balancing on the back of the tracks and the suction nozzle, the boom is forced in a rotation so that the machine can correct course (Figure 3).

In order reduce the bending moments in the longitudinals in this situation additional elements have been proposed (Figure 4).

Multi-Body

As a result of the buoyancy force of the discharge hose acting on the machine the static pitch angle is dependent of the water depth. The effect of this is demonstrated in Figure 5, where 100 m and 200 m *static* angles of the machine are displayed.

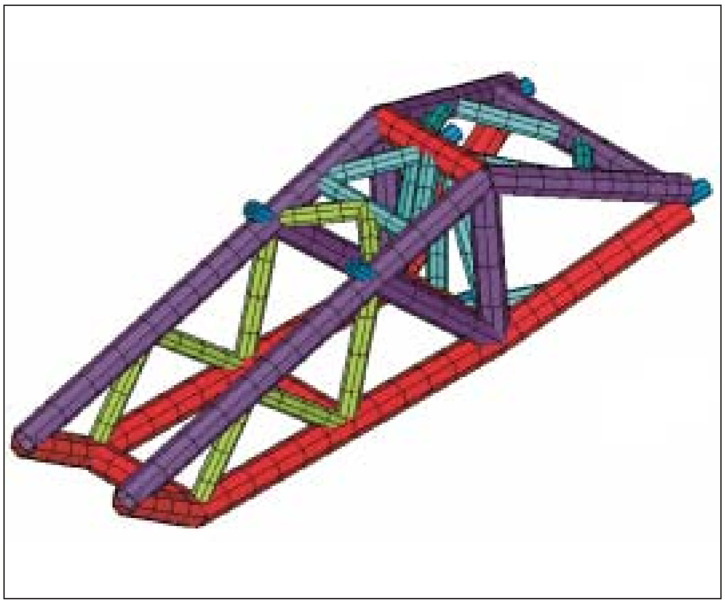
Because of the ship's motion the machine will have an additional dynamic rotation.

The motion of the machine influenced by the ship's heave and pitch during heavy sea conditions is depicted in Figure 6. Four snapshots covering 8 seconds out of the 9- second cycle time are presented here.

The *dynamic* rotation is mainly the result of:
- inertia effects of the discharge hose: the mass of the discharge hose resists acceleration; and
- a "wind vane" effect: in contrast to the main frame, the boom has a relatively large area with respect to the mass.

The position of the hoisting point on the machine has been modified in order to reduce the machine's static and dynamic pitch angle.

Figure 4. The boom with additional elements in green.



Conclusions

Computer Aided Engineering or virtual prototyping has given insight in the behaviour of the submerged machine lifted by a cable. This has enabled several improvements to the design and the detection of flaws before construction of the machine. The virtual prototype has been used to determine the systems-operating window.

The availability of a virtual prototype facilitates research into best improvement in case of undesired system behaviour in a very short time span. Because of the possibility to keep repeating an undesirable situation, a virtual prototype is a useful tool in failure analyses.

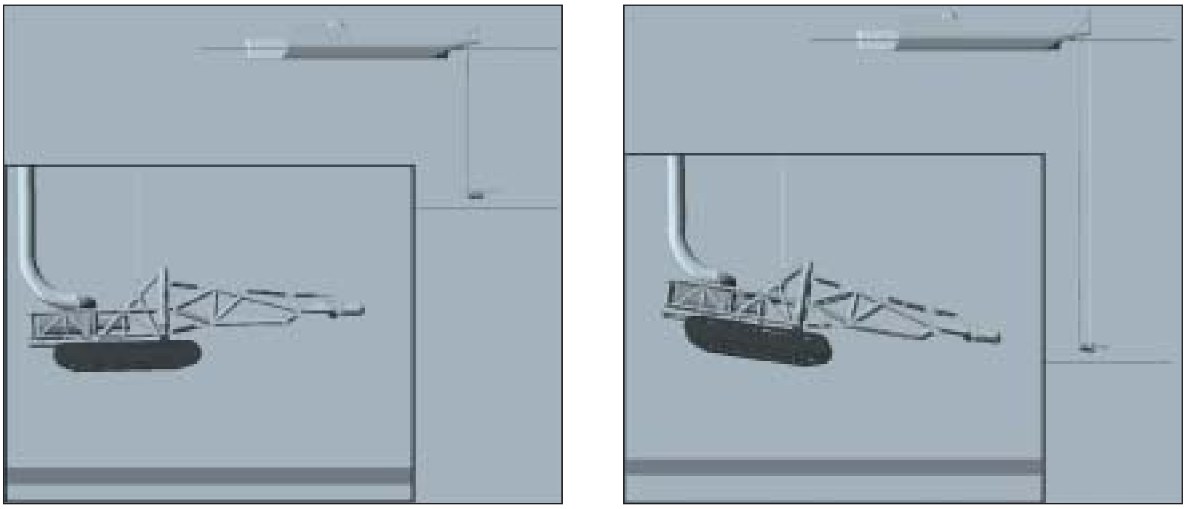


Figure 5. Static angle as a result of the buoyancy of the discharge hose (left 100 m, right 200 m) prior to modification of the hoisting point.

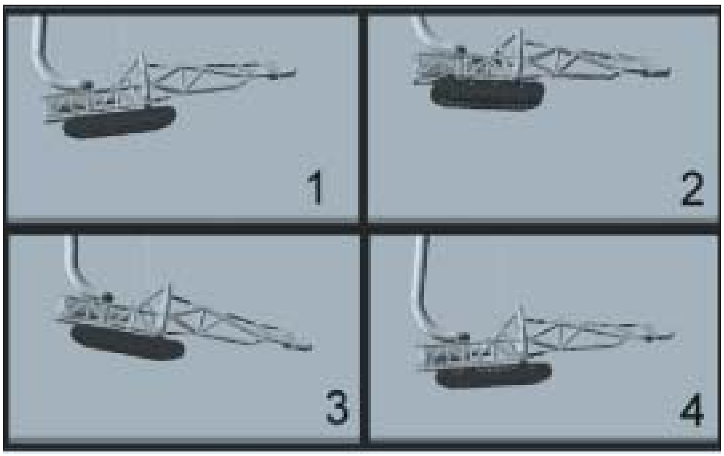


Figure 6. Machine pitch owing to heavy ship motion and water-related forces prior to modification of the hoisting point.

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Vlasblom, W.J., Angevaren, C.A., Boezeman, A.H. and Bos, W. van den (1999).
Structural and dynamic analysis of sub-sea diamond miner MK II. Delft University of Technology, Faculty of Mechanical Engineering and Marine Technology, Delft, The Netherlands.

Charles W. Hummer, Jr.

Books/ Periodicals Reviewed

Handbook of Coastal Engineering
McGraw-Hill, New York 1999. Hardbound, 1132 pp., illustrated, indexes US$ 125.00.
John B. Herbich, Editor

Dr. Herbich once again provides the literature with a timely and relevant compilation of papers on coastal engineering. He published his first *Handbook on Coastal and Ocean Engineering* in 1990 and followed that by two additional volumes in 1991 and 1992. Dr. Herbich also edited a fine volume entitled, *Handbook of Dredging Engineering*, in 1992. The latter two volumes on coastal engineering and the *Handbook on Dredging Engineering* were all reviewed in this journal (*Terra et Aqua*, *No. 50*, January 1993 and *No. 51*, May 1993, respectively).

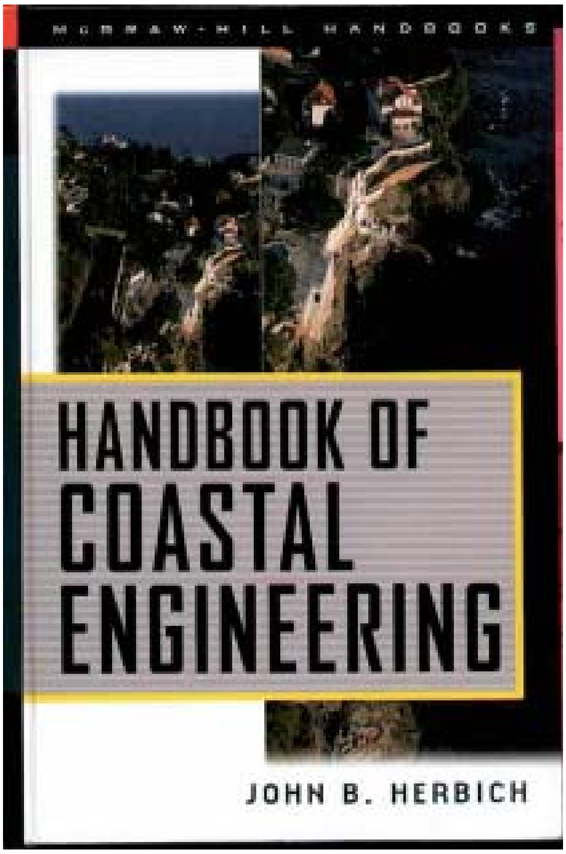
This "handbook" incorporates new research as well as information from the biannual International Coastal Engineering Conferences. The stated purpose of the editor is "to collect all available relevant material [on coastal engineering] under one cover". From a review of the table of contents and the handbook itself, one must conclude that the editor has successfully accomplished his purpose.

The handbook represents the efforts of twenty-seven experts from around the world. Contributors are from Australia, China (PRC), United Kingdom, Japan, New Zealand, South Africa, The Netherlands and the United States. Each of the chapters was peer reviewed, which adds to the value and credibility of the handbook. In summary, the volume is a compendium of expert information on contemporary coastal engineering theory and practice: This book is directed to civil engineers who have not taken courses in coastal engineering; senior coastal engineering students and graduate students; graduates from non-coastal engineering curricula who may be asked to design coastal and offshore structures; and consulting engineers. It also serves as a valuable reference work for civil engineers engaged in coastal engineering and dredging activities.

It is always helpful for the potential purchaser of a technical volume to have a sense of the contents. Therefore, an outline of the volume follows:

Wave Equations
– Numerical Solution of Coastal Water Wave Equations
Design of Revetments, Dikes and Breakwaters
– Revetment Protection for Coastal and Shoreline Structures Exposed to Wave Attack
– Design of Dikes and Revetments, Dutch Practice
– Wave Forces on Vertical and Composite Walls
– Offshore (Detached) Breakwaters
– Wave Overtopping of Coastal and Shoreline Structures
Beach Erosion and Protection
– Sediment Transport and Beach Profile Change Due to Random Waves
– Coastal Protection Methods
– Shoreline Protection Methods-Japanese Experience
– Beach Nourishment Design
Navigational Channels
– Navigation Channels- Design and Operation
– Maintenance Dredging of Channels and Harbors
Dredging and Handling of Contaminated Sediments
– Subaqueous Capping of Contaminated Sediment
– Modeling the Physical and Chemical Stability of Underwater Caps in Rivers and Harbors
– The USACE (US Army Corps of Engineers) Dredging Operations and Environmental Research (DOER) Program
– Numerical Models for Predicting the Fate of Dredged Material Placed in Open Water
– Removal of Contaminated Sediment by Dredging
– Marine Aggregate Dredging
Coastal Hazard Zones and Setbacks
– Methodology for Delineation of Coastal Hazard Zones and Development Setback for Open Duned Coasts

Appendix A- Automated Coastal Engineering System (ACES)
Appendix B- Tables
Indexes, Author and Subject



Each of the chapters is followed by a superb list of references, which will allow the reader to delve deeper into any one of the subject matters. A review of the references reveals the inclusion of current literature sources which underlies the value of this volume in maintaining currency in the field of Coastal Engineering and Dredging Engineering over that found in the earlier handbooks. Also the volume contains both subject and author indices which makes it particularly useful in finding information in the handbook.

Appendix A, which runs 144 pages, covers the Automated Coastal Engineering System (ACES) developed by the Coastal Engineering Research Center of the US Army Corps of Engineers. In and of itself, this appendix is extremely valuable to the intended users of the handbook.

It is proper to repeat the description of Dr. Herbich that appeared when we first reviewed his *Handbook on Coastal and Ocean Engineering* in *Terra et Aqua, No. 50* in January 1993, for it remains as true today as it did nearly ten years ago:

> "A few words about the editor are appropriate…. Dr. Herbich enjoys a rare place in the field of dredging because of his many contributions and leadership in the research, academic and technology fields over a long time. He founded the Center for Dredging Studies at Texas A&M, has produced a bibliography of dredging-related technical papers which is unique in the field, and has conducted the annual dredging seminars sponsored by the Center for Dredging Studies for 25 years. Few have made a greater contribution to the education and technical literature related to all phases of dredging technology. His latest contributions to the literature mark again a unique milestone".

This publication may be obtained from:
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Proceedings of the Western Dredging Association Twentieth Technical Conference and Thirty-Second Annual Texas A& M Dredging Seminar, June 25-28, 2000, Warwick, Rhode Island, USA.
Center for Dredging Studies, Texas A&M University, USA. Softcover, 482 pp., 215 mm x 275 mm, illustrated.
Robert E. Randall, Ph.D., P. E., Editor

The proceedings consist of 17 technical papers presented at the Texas A&M University Dredging Seminar and 23 papers presented at the Twentieth Annual Technical Conference of the Western Dredging Association (WEDA). For a number of years these two mainstream technical groups have combined their programmes into a single venue. This has allowed a greater participation by all segments of the dredging industry to participate and concentrates the technical presentations into a single location and time period. The authors represent a spectrum of academia, consultancies, research organisations and practitioners of dredging contracting and related fields in the US and worldwide. The subjects presented are likewise diverse and relevant to a broad audience interested or involved in dredging activities. There does not seem to be central theme that distinguishes one programme from the other with both having a good representation of relevant subject matter.

A listing of the papers presented at the Texas A&M Dredging Seminar follows:
– Innovations in Dredging Technology: Equipment, Operations and Management
– Numerical Study on the Vane Overlap for Dredge Pump Impellers
– Experiences With Cutter Suction Dredge Simulator Training
– The Modeling of the Swing Winches of a Cutter Dredge in Relations with Simulators

- Laboratory Study of Hydraulic Dredging with a Siphon
- On the Economy of the Transportation of Highly Concentrated Broadly Graded Sand-Water Slurries: Results of Laboratory Tests
- The Effect of High Concentrated Sand-Water Mixtures on the Characteristics of a Slurry Pump
- Effect of Various Terminal Velocity Equations on the Result of Friction Loss Calculation (see page XXX)
- Prediction of Downtime of Dredges Operations in the Open Sea
- Assessment of Sediment Release during Dredging: A New Initiative Called TASS
- Verification and Modification of TSS Source Strength Models for Hydraulic Cutter Dredging Operations
- Describing the Position of Backhoe Dredge Buckets
- Piper Channel Geotube Jetty System: A Case History
- Dewatering Highly Organic Fine Grained Dredged Material Using Geotextile Tubes
- Dynamic Modeling of Turbidity Plumes from Bucket Dredge Operations
- The Use of Dredged Material for Shoreline Erosion Control Methods
- Innovative Dredging Methodology

Papers presented at the WEDA Twentieth Annual Technical Conference are as follows:

- US Army Corps of Engineers Dredging of Channels and Waterways
- Expanding of the Port of New York and New Jersey for the 21st Century
- Maintenance of Arthur Kill Reach of New York and New Jersey Channels Federal Navigation Project
- Evaluation of Dredged Material Proposed for Placement in Upland Sites
- A Review of Construction Techniques for Poplar Island Habitat Restoration Project, Phase I
- Deepening and Seismic Rehabilitation of the Terminal 5 Wharf, Port of Seattle
- The Boston Harbor Navigation Improvement Project CAD Cells: Recommendations for Future Projects Based on Field Experience Monitoring and
- Geotechnical Evaluation of Sediment Data Collected in Boston Harbor Confined Aquatic Disposal Cells
- Dredging for the I-90 Crossing of Fort Point Channel in Boston, Massachusetts
- Evaluation of Closed Buckets for East Waterway Deepening
- The Cable Arm Clamshell: Development and Track Record for Environmental Dredging
- Near-Field Turbidity Observations During Boston Harbor Bucket Comparison Study
- The Diagnostic Modeling System-DMS: A New Tool for Evaluating the Causes of Channel Shoaling
- The DMS Data Manager- An Overview
- Application of Diagnostic Modeling System Methodologies to Channel Shoaling at East Pass, Florida
- DMSART- Current Status and Implementation at Mobile District
- Monitoring Dredged Material Placement at the Historic Area Remediation Site with the Automated Disposal Surveillance System, High Resolution Bathymetry and Side-Scan Sonar
- Ongoing Investigation of Tons Dry Solids (TDS) Measurement as a Payment Basis
- ediment Capping Demonstration Project on the Ottaw River: an Impacted Lake Erie Tributary
- Summary of Constructed CDF Containment Features for Contaminated Sediments
- Upland Disposal of Contaminated Sediments: A Case Study
- The Foss Waterway Remediation: Design Status Report
- Dredge Guidance Technologies- Environmental Dredging Projects: Two Case Studies

The technical papers contained in these proceedings cover a wide range of topics and aspects of dredging. The WEDA portion seems to be more project-oriented and the Texas A&M portion more properly academic, although there is a good symbiotic overlap.
The programme demonstrates a good representation of international expertise and several of the papers cover some innovative initiatives of particular note.

The Diagnostic Modeling System, which is the subject of four papers in the WEDA portion of the programme, should be of interest to a number of readers.
The continued investigation and verification of the "Tons Dry System" for payment in the US is also notable since this is a practise commonly used in The Netherlands. Finally, the reports on aquatic confined disposal of contaminated dredged material should have wide interest and potential application.

As is generally been the case, these proceedings are a valuable addition to all dredgers technical libraries.

These proceedings (and a limited number of proceedings from other conferences) can be ordered from:
WEDA Executive Office
PO Box 5797
Vancouver, Washington 98668-5797 USA
WEDA@juno.com
Tel. +1 360 750 0209
Fax +1 360 750 1445

Seminars/ Conferences/ Events

Thirtieth Dredging Engineering Short Course

Texas A&M University,
College Station, Texas
January 8-12 2001

This short dredging course is sponsored by the Center for Dredging Studies, Ocean Engineering Program of the Civil Engineering Department of Texas A&M University. It takes place in four full-day programmes which include a mixture of lectures, laboratories and discussions. The costs are US$1250.00 which includes two textbooks and course notes on all lecture material, an ice breaker, banquet and local transportation.
A certificate and Continuing Education Units are earned by attending the course.

For further information please contact:
Center for Dredging Studies, Texas A&M University,
College Station, Texas 77843- 3136
fax +1 979 862 8162
http://edge.tamu.edu/dredging/intex.html
Dr. R.E. Randall, Director, tel. +1 979 845 4568
email: r-randall@tamu.edu
Ms Christa Keiper, tel. +1 979 845 4515
email: ckeiper@civilmail.tamu.edu
Ms Nell Bowden, tel. +979 845 4516
email: n-bowden@tamu.edu

Marine Indonesia

Jakarta Internatinal Exhibition
Centre Kemayoran, Indoenesia
February 21-24 2001

This 10th international marine, shipping, port equipment and cargo handling exhibition will take place in Jakarta, Indonesia. It will also include warehousing and logistics, offshore technology, shipbuilding, ship repair and conversion, fishing, aquaculture, engines, boats, refrigeration, navigation, satellite and communication systems and environmental technology.

For further information please contact:
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11 Manchester Square, London, WIU 3 PL, UK
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email: marineindo@montnet.com

International Expo Management Pte Ltd
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email: carolyn@montnet.com

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Deutsche Bank Bldg., Jl Imam Bonjol 80
Jakarta 10310, Indonesia
tel. +62 21 316 2001, fax +62 21 316 1981/2
email: pamindo@rad.net.id

WODCON XVI and Exhibition

Hotel Shangri-la,
Kuala Lumpur, Malaysia
April 2-5 2001

The Sixteenth World Dredging Congress and Exhibition will be entitled "Dredging for Prosperity; Achieving Social and Economic Benefits". New ways of dredging and handling dredged materials are continually being found. These need to be promoted in order to achieve social and economic benefits. Papers showing the benefit/cost relationship of dredging works are especially encouraged, including new forms of dredging, developments in education and training, case studies and other developments in the industry.
An international exhibition will be held in conjunction with the conference. In addition, a technical visit to Paya Indah, Malaysia's prestigious wetland sanctuary will be featured. For up-to-date and detailed information visit the WODA website at http://www.woda.org.

For further information, please contact:
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Expo Age International (M) Sdn Bhd, Wisma Pico,
19-20 Jalan Tembaga SD5/2, Bandar Sri Damansara
52200 Kuala Lumpur, Malaysia
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email: expoagei@mol.com.my

EADA Secretariat, John Dobson
GPO Box 388, Hamilton Central,
Qld 4007, Australia
tel/fax +61 7 3262 3834
email: dobsoncj@hotmail.com, or

CEDA Secretariat, Anna Csiti
PO Box 488, 2600 AL Delft, The Netherlands
tel. +31 15 278 3145, fax +31 15 278 7104
email: ceda@dredging.org

Oceanology International 2001 Americas

Miami Beach Convention Center,
Miami Beach, Florida, USA
April 3-5 2001

The first OI Americas exhibition and conference will be held in April 2001 and will be held biennially thereafter. It is et to become a joint ocean forum bringing together all sides of industry, science, research,government and academia, with a natural focus on the opportunities facing the Americas.
As a transportation hub handling 60 percent of airline traffic between the Americas, Miami has been chosen for ease of travel for the global ocean community as well as for the concentrations of ocean science and technology institutions in Florida.

For further information please contact:
In the Americas:
Kari Jacobson, OI Americas
PGI/Spearhead, PGI Inc,
2200 Wilson Boulevard, Ste. 200
Arlington, VA 22201-3324, USA
tel. +1 703 312 9129, fax +1 703 528 1724

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tel. +44 181 949 9813 or 949 9222, fax +44 181 949 8186
email: oiamericas@spearhead.co.uk
http://www.oiamericas.com

22nd IAPH World Ports Conference

Queen Elizabeth Hotel,
Montreal, Canada
May 19-26 2001

This first IAPH conference of the new millenium will highlight the renewed and revitalised maritime industry. Organised in cooperation with the Montreal Port Authority, the conference will focus on the future of the maritime sector. The conference will include a trade show which will also be held at the conference site.

For more information please contact:
Lafleur Communication Marketing Inc.
500 Place d’Armes, Suite 2110
Montreal, Quebec, Canad H2Y 2W2
fax: +1 514 288 2601
email: eric.lafleur@lcm.ca

or the following websites:
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Governmennt of Quebec: www.gouv.qc.ca
City of Montreal: www.ville.montreal.qc.ca
IAPH: www.iaph.or.jp
Montreal Port Authority: www.port-montreal.com

Coastal Zone 01

Cleveland, Ohio USA
July 15-19 2001

Cleveland is a Great Lakes coastal city and the conference will notably address coastal and ocean management concerns. It will feature important lessons learned by coastal managers around the world and models of successful partnerships such as that established in the Great Lakes, where two sovereign nations jointly manage water and living resources of this great “inland sea”. The overriding theme will be to examine creative urban planning strategies, fiscal incentives, innovative policies and other techniques to hinder urban sprawl along ocean and inland coasts and to achieve instead “smart growth” in coastal communities.

For further information contact:
Jan Kucklick, NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, Soth Carolina 29405 USA
tel. +1 843 740 1279
fax +1 843 740 1313
Jan.Kucklick@noaa.gov

India International Maritime Expo (INMEX) 2001

Mumbai (Bombay), India
October 10-13 2001

The second India International Maritime Expo (INMEX) will provide an opportunity for overseas companies to enter the maritime market in India and to meet with representatives from government such as the Ministries of Surface Transport (MoST) and Defence, and the Coast Guard.The MoST is responsible for policies for the development of modes of transport including the maritime sector.

In order to decongest the present major port facilities the MoST has launched an ambitious plans for infrastructure development in the port sector, the shipbuilding industry and inland water transport. Private investments are being encouraged for port development as well as ship building and repair.

For further information contact:
INMEX Secretariat
Pradeep Deviah & Associates
Nor. 35, Gover Road, Cox Town,
Bangalore 560 005, India

tel. +91 80 54 84 155/ 54 84 389
fax +91 80 54 85 214
email: pda@blr.vsnl.net.in
www.inmexindia.com

Port China & Marintec China

Intex Shanghai, China
December 4-7 2001

China's premier maritime conference and exhibition, Marintec China, will now include Port China. Currently China has over 2000 ports and 128 ports which are open to foreign vessels. Many ports are already being upgraded and increased trade is expected to come form China's entry into the WTO. The port authorities of Shanghai and Rotterdam have signed a letter of intent to cooperate on technology interchange. Port China will address the demand for better and more expedient ort facilities and services and will benefit from running concurrently with Marintec China. High level seminars and the Senior Maritime Forum will allow policy makers and industry leaders a chance to exchange views.

For further information please contact:
Ms Ginnie Koay in Hong Kong,
email: ginniekoay@mfasia.com.hk

Madam Wang Lingzhi in Shanghai,
email: ssname@uninet.com.cn

Mr Richard Johnson,
email: rjohnson@seatrade-global.com

Mr Michael Kazakoff, Miller Freeman
email: mkazakoff@compuserve.com

Call for Papers

WEDA and Texas A&M University 33rd Annual Dredging Seminar and Exhibition

Wyndham Greenspoint Hotel,
Houston, Texas
June 24-28 2001

The conference is an opportunity for an exchange of thoughts by dredging contractors, ports, engineering services, environmentalists and environmental consultants, US Corps of Engineers, Environmental Protection Agency, Fish and Wild Life Services and members of academia. It provides an opportunity to keep up with the changing Technology and Regulatory issues facing the dredging industry.
In addition a special "Call for Student Papers" is being issued. WEDA will wave the conference registration fee for student paper presenters and provide them a $500 reimbursement toward expenses.
For consideration the paper should be solely written by a student with no co-authors.

Deadline for one page abstract is December 15, 2000.

To accommodate the PIANC session, the conference has been extended a half day, and on the last day, there will be a post-convention tour to the Houston Channel ship channel deepening project.

For further information please contact:
WEDA Executive Offices
tel. +1 360 750 0209
email: WEDA@juno.com

International Conference on Port and Maritime R&D and Technology

Singapore
October 29-31 2001

This inaugural international conference being held in Singapore has the theme "R&D and Technology for Port and Maritime Excellence". The aim of the conference is to bring researchers in academia and at institutes in contact with consultants and practitioners in the port and maritime industries to share new developments, concepts and practices and exchange views and experiences. The conference is jointly organised by the Maritime and Port Authority of Singapore, National University of Singapore, Nanyang Techological University and the Singapore Maritime Academy. In conjunction with the conference, an exhibition of the latest R&D and technological products, systems and services in the port and maritime industries as well as several workshops will be organised.

Subjects to be included are :
- port development, management and operations;
- coastal engineering;
- concern for the marine environment;
- innovative ship designs; and
- navigation and maritime training in the digital era.

Abstracts of 200 words should be sent together with the registration form by January 15 2001 to the Conference Secretariat. For the paper to be accepted at least one author must register and present the paper.

For further information please contact:
Ms Hui-Sian Jong, Conference Secretariat
c/o Professional Activities Centre, Faculty of Engineering
National University of Singapore, 9 Engineering Drive 1,
Blk EA #04-10, Singapore 117576
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Dredging International N.V., Tehran Branch, Tehran, Iran
Gulf Cobla (Limited Liability Company), Dubai, UAE
HAM Dredging Company, Abu Dhabi, UAE
HAM Saudi Arabia Ltd., Damman, Saudi Arabia
Jan De Nul Dredging, Abu Dhabi, UAE
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Dredeco Pty. Ltd., Brisbane, QLD., Australia
New Zealand Dredging & General Works Ltd., Wellington
Van Oord ACZ B.V., Victoria, Australia
WestHam Dredging Co. Pty. Ltd., Sydney, NSW, Australia

Europe

ACZ Ingeniører & Entreprenører A/S, Copenhagen, Denmark
Anglo-Dutch Dredging Company Ltd., Beaconsfield, United Kingdom
A/S Jebsens ACZ, Bergen, Norway
Atlantique Dragage S.A., Nanterre, France
Baggermaatschappij Boskalis B.V., Papendrecht, Netherlands
Baggermaatschappij Breejenbout B.V., Rotterdam, Netherlands
Ballast Nedam Bau- und Bagger GmbH, Hamburg, Germany
Ballast Nedam Dredging, Zeist, Netherlands
Ballast Nedam Dragage, Paris, France
Boskalis Dolman B.V., Dordrecht, Netherlands
Boskalis International B.V., Papendrecht, Netherlands
Boskalis B.V., Rotterdam, Netherlands
Boskalis Westminster Aannemers N.V., Antwerp, Belgium
Boskalis Westminster Dredging B.V., Papendrecht, Netherlands
Boskalis Westminster Dredging & Contracting Ltd., Cyprus
Boskalis Zinkcon B.V., Papendrecht, Netherlands
Brewaba Wasserbaugesellschaft Bremen mbH, Bremen, Germany
CEI Construct NV, Afdeling Bagger- en Grondwerken, Zele, Belgium
Delta G.m.b.H., Bremen, Germany
Draflumar SA., Neuville Les Dieppe, France
Dragados y Construcciones S.A., Madrid, Spain
Dravo S.A., Madrid, Spain
Dredging International N.V., Madrid, Spain
Dredging International N.V., Zwijndrecht, Belgium
Dredging International Scandinavia NS, Copenhagen, Denmark
Dredging International (UK), Ltd., Weybridge, United Kingdom
Enka-Boskalis, Istanbul, Turkey
Espadraga, Los Alcázares (Murcia), Spain
HAM Dredging Ltd., Camberley, United Kingdom
HAM, dredging and marine contractors, Capelle a/d IJssel, Netherlands
HAM-Van Oord Werkendam B.V., Werkendam, Netherlands
Heinrich Hirdes G.m.b.H., Hamburg, Germany
Holland Dredging Company, Papendrecht, Netherlands
Jan De Nul N.V., Aalst, Belgium
Jan De Nul Dredging N.V., Aalst, Belgium
Jan De Nul (U.K.) Ltd., Ascot, United Kingdom
Nordsee Nassbagger- und Tiefbau GmbH, Wilhelmshaven,Germany
N.V. Baggerwerken Decloedt & Zoon, Brussels, Belgium
S.A. Overseas Decloedt & Fils, Brussels, Belgium
Sider-Almagià S.p.A., Rome, Italy
Skanska Dredging AB, Gothenborg, Sweden
Sociedade Portuguesa de Dragagens Lda., Lisbon, Portugal
Sociedad Española de Dragados SA., Madrid, Spain
Società Italiana Dragaggi SpA. "SIDRA", Rome, Italy
Société de Dragage International "S.D.I." S.A., Marly le Roi, France
Sodranord SARL, Paris, France
Terramare Oy, Helsinki, Finland
Tideway B.V., Breda, Netherlands
Van Oord ACZ B.V., Gorinchem, Netherlands
Van Oord ACZ Ltd., Newbury, United Kingdom
Wasserbau ACZ GmbH, Bremen, Germany
Westminster Dredging Co. Ltd., Fareham, United Kingdom
Zanen Verstoep B.V., Papendrecht, Netherlands
Zinkcon Contractors Ltd., Fareham, United Kingdom
Zinkcon Dekker B.V., Rotterdam, Netherlands
Zinkcon Dekker Wasserbau GmbH, Bremen, Germany

International Association
of Dredging Companies