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International Association
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Editor
Marsha R. Cohen

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Front cover:
Dredging the world, from West to East: A cutter suction dredger was brought from Belgium to dredge the new Port Basin at Ennore, India (see page 3).

IADC
P.J.A. Hamburger, *Secretary General*
Duinweg 21
2585 JV The Hague, The Netherlands
Tel. 31 (70) 352 3334, Fax 31 (70) 351 2654
E-mail: info@iadc-dredging.com
http://www.iadc-dredging.com

International Association of Dredging Companies

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TERRA ET AQUA

Editorial

Many countries have their own state-owned dredging companies and, consequently, the private dredging industry is often less active in these lands. Fortunately these two groups do sometimes encounter each other – and with positive results.

For that reason we find it interesting to focus this issue on the recent work in India – in the first place at the Ennore Coal Port on the east coast, and secondly at Cochin, on the west coast.

Located 20 kilometres north of Chennai (formerly Madras), the newly created Ennore Coal Port has afforded IADC member companies an opportunity to demonstrate their abilities: Their expertise and technology. Their ingenuity when working far from their home harbours. At the Ennore Port, the private dredging industry has completed a cost-efficient project and delivered it on time.

In addition, the extensive environmental impact studies conducted at the Port of Cochin, the second largest port on the west coast of India, are an indication that dredging operations are being carefully monitored and executed in an environmentally conscious manner.

It is important to know that international standards, such as those established by the London Convention of 1972, are adhered to worldwide. More information about these regulations can be found in *Guide 2, Conventions, Codes and Conditions,* of the IADC/CEDA Environmental Aspects of Dredging series. IADC members are dedicated to performing according to these standards, wherever they are working.

Fair trade practices, open markets, environmental awareness – all these are IADC objectives. More than ever, IADC is also concentrating on education – on attracting the right person to the right dredging job. And equally important, on using our seminars (the next one is in Singapore in October) to inform port authorities and the public about dredging. The more people know about dredging, the better they understand that dredging contributes to the economic and ecological health of a nation.

Robert van Gelder
President, IADC Board of Directors

André Luypaert

Ennore Coal Port Project: Port Basin and Entrance Channel

Abstract

The Chennai Port on the eastern coast of India is the main port for the transshipment of coal for the nearby power plant. To limit the contamination from coal dust and to relieve the congestion of the Chennai harbour, plans for a new harbour at the small village of Ennore have been developed. The plans are sponsored by the Asian Development Bank. The ECPP/ C6 Contract for the dredging works of the Port Basin and Entrance Channel discussed here is one of several contracts awarded for this project. Within the framework of the same project are also the breakwater and the wharf construction. These contracts are to be executed by other contractors in the same time period.

André Luypaert received his degree as a Naval Construction Engineer from the University of Ghent, Belgium in 1968. Since 1972 he has worked for Jan De Nul N.V. on a variety of projects at home and abroad. He is presently Project Manager for the dredging of the port basin and entrance channel at the Ennore Coal Port project in India.

André Luypaert

Introduction

On July 31 1997 the Jan De Nul Group of Companies was awarded the contract for the Dredging of the Port Basin and Entrance Channel of the Ennore Coal Port Project, which is situated on the Coromandel Coast, 20 km north of Chennai, in the state of Tamil Nadu, India. The project was tendered in several contracts and this paper describes the tender known as Dredging Contract ECPP/ C6, which forms part of a general contract with the aim of developing a new port at Ennore.

The Ennore Port is planned as a multi-functional alternative to the Chennai Port (Figure 1). When completed, the project will be able to take vessels of up to 65,000 dwt, which would decongest the Chennai Port. The primary purpose of the new port is the import of coal for the North Madras Thermal Power Station (NMTPS) which is situated immediately south of the port.

For the time being, all coal shipments are off-loaded in Chennai Harbour and transported by train to the North Madras Thermal Power Station. The off-loading of the vessels must be done slowly because of a lack of efficient unloading facilities. This produces a great deal of dust and pollution for the harbour and the surrounding city. Future expansion of the port for mainly bulk cargo, LNG, oil products and chemicals is envisaged.

The Port itself consists of an Outer and Inner Port Basin with a coal wharf. This wharf is equipped with facilities to off-load two coal carriers at the same time.
Two rubble mound breakwaters protect the Port, e.g. the South Breakwater with a length of 1.0 km and the North Breakwater with a length of 3.5 km.
An Approach channel, which is orientated on the south-east, links the Port Basin to the open sea and enables the coal-carrying vessels to enter the port.

The ECPP/ C6 Contract for the dredging works was signed at Chennai on August 22 1997 and is being sponsored by the Asian Development Bank. Other main contracts awarded within the framework of the same project are the breakwater and the wharf construction. These contracts are to be executed by other contractors in the same time period (see page 9).

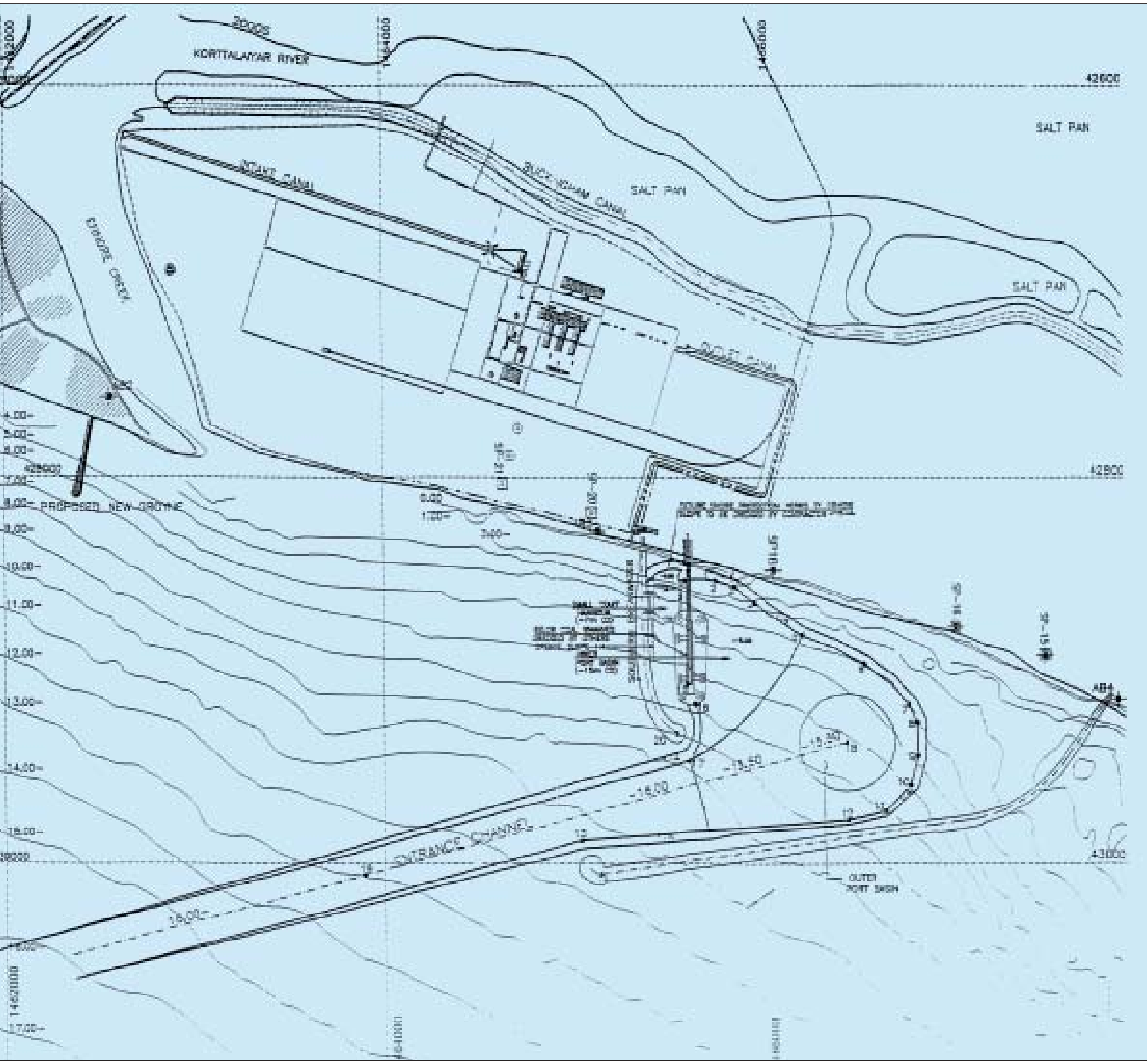


Figure 1. General lay-out plan of the Ennore Port project on the eastern coast of India.

Dredging Areas

For the ECPP/ C6 Dredging Contract, four dredging areas are specified:
– the Inner Port Basin;
– the Outer Port Basin;
– the Small Craft Harbour; and
– the Approach Channel to the Port Basin.

The 3,525 m long Approach Channel links the open sea to the Port Basin. The required dredging depth is –16.0 m CD with a bottom width of 250 m. At both sides a slope with a gradient of 1:8 is foreseen. The seaward limit is the –16.0 m CD level and the landward limit separates the Channel from the Port Basin (Figure 2).

The Port Basin, which is enclosed by the North and South Breakwaters, consists of two areas: the Outer and the Inner Port Basins. The Outer Port Basin has of a turning circle with a diameter of approx. 500 m. That area had to be dredged to a depth of –15.5 m CD with slopes not steeper than 1:4 or gentler than 1: 5.

The Coal Wharf is foreseen at the south side of the Port. In front of the wharf and in connection with the Outer Port Basin, the Inner Port Basin has to be dredged to –15.0 m CD with slopes at the sides of 1:4. The slope at the north of the Coal Wharf has to be protected over 200 m by a stone embankment. The boundary at the south side of this area is the centre line of the Coal Wharf.

South of this line, a Small Craft Harbour is placed with mooring facilities for small craft vessels which are to assist the larger vessels entering the future Port. A depth of –7.0 m CD has to be achieved for navigation of these small craft. Three small craft jetties are foreseen which are, currently under construction.

At the end of the Small Craft Harbour, a cooling water outlet was planned for the NMT Power Station. The dredging depth here would reach –5.0 m CD. But later on, the outlet was shifted to another location, just south of the Northern Breakwater and outside the harbour boundaries.

Quantities

A total volume of 14 million m^3 has to be dredged to create an Access Channel, a Small Craft Harbour, a Cool Water Outlet, and the Inner and Outer Port Basins. The sand material must be used for beach nourishment, land reclamation and stockpiling for future port construction. The main part of the dredged materials in the Port Basin consists of +/–7.2 million m^3 of sand (fine to silty clayey sand). The remaining parts are soft materials (+/–2.6 million m^3 of silt and clay).

The 4.2 million m^3 from the Approach Channel have almost the same composition as the materials in the Port Basin, and are to be disposed of at sea.

Soil Investigation

Borehole information was presented with the Tender. No additional soil investigation programme was conducted before carrying out the works.

In the Approach Channel, over the first 1,250 m from the Port Basin, a top layer of approx. 3.0 m of loose silty sand was present. Under this layer, soft to firm clay could be found down to the dredge level of –16.0 m CD. In the remaining length of the Approach Channel, the soft to firm clay was present over the entire dredging depth.

According to the borehole information supplied, the material to be dredged in the Port Basin consisted of a top layer of 2.0 to 3.0 m dense coarse sand with many shell fragments. Below this top layer, a layer of very loose to loose silty sand was present to a depth of –15.0 m. This layer became narrower at the –12.0 m water depth towards the Northern Breakwater under which soft to firm sandy silty clay was present down to the design dredge level. All this borehole information appeared to be quite reliable during execution. For the reclamation works however the content of fines, including the very fine sand composition up to +/–100, reached sometimes 85% of the samples, which made reclamation in the confined areas very difficult.
In the Beach Reclamation area, with an open sea disposal, this created no problems as the surplus of fines was easily washed away by the action of the sea.

Disposal / Reclamation of Dredged Material

Initially the dredged materials were to be disposed of via the following five locations:
– sea disposal;
– beach nourishment;
– sand stockpile;
– on-land sand reclamation; and
– on-land reclamation of soft materials (clay).

Sea disposal
All the dredged materials from the approach channel had to be dumped in the designated offshore disposal area in front of the port at a depth of minimum –23.0 m CD. The total estimated quantity was 4.2 million m^3.

Beach nourishment
At the north of the port, a Beach Nourishment area had to be constructed in order to alleviate future beach erosion which was expected to happen during and

Figure 2. Cutter suction dredger Vesalius, working in front of the North Madras Thermal Power Station.

after the development of the Port. Also, approx. 2.5 million m^3 of sand from the Outer Port Basin had to be placed in front of the existing beach.

Sand stockpile
Another area would consist of a sand stockpile with an original amount of 1,000,000 m^3.

On-land reclamation of sand and soft materials
Most of the layers above the –12.0 m CD of the Port Basin were suitable to be pumped into the Beach Nourishment and Sand Stockpile Area (Figure 3). The material originating from the rest of that layer and underneath that layer, were to be reclaimed to on-land clay and sand disposal areas.

During execution of the job, the original reclamation areas were modified. The original sand stockpile of 500,000 m^3 was shifted to another location and two additional stockpiles for sand were created, each containing respectively approx. 160,000 m^3 and 1,000,000 m^3. The sand from these stockpiles can be used for future port construction works.

The on-land sand and clay areas, which were foreseen on the western side of the Kortalaiyar River, shifted from their original location but remained at the same side of the river. Also the volume of these areas was reduced to 50%. Owing to the non-availibility of the clay area at the contractual date and the ongoing erosion of the beach north of the breakwater, a quite higher volume than figured at tender stage had to be reclaimed in the Beach Nourishment Area.

The sand for the Beach Nourishment, the sand stockpile and the on-land sand reclamation was tested according to BS 1377. All tests were carried out in a Soil Laboratory on site. For the Beach Nourishment, not more than 20% and 8% of the particle size by weight should be smaller than 0.063 mm and 0.002 mm respectively.

The specification demands for the dredged sand after placement at the stockpiles and at the on-land reclamation were much stricter, as the sand in these areas should not have more than 15% by weight of particles smaller than 0.063 mm and not more than 5% by weight particles smaller than 0.002 mm.

All the excess water of the reclamation areas had to be controlled on a regular basis in order to ensure its compliance with the Contractual Specifications. According to these specifications, any water discharged from confined reclamation areas to the neighbouring Buckingham Canal of the Kortalaiyar River must not contain more than 1.5 g/l of soil material.

During the execution of the reclamation works, these criteria could not be accomplished in the sand Stockpile and Clay Areas. Because of problems with the fines in the excess water, the reclamation in these areas was stopped before reaching the theoretical proposed volume. Samples taken from some materials involved, showed a silt content which was going up to almost 45%.

Work Programme

The work on site commenced on October 1998 with the clearing of the reclamation areas and the setting out of the works. In the meantime, temporary housing and offices for the Jan De Nul staff had been constructed on site by a local contractor.

The Vesalius

For carrying out the dredging works in the Port Basin, the cutter suction dredger *Vesalius* was mobilised from Belgium to Ennore. All equipment arrived on site in February 1999. The usual 500-m-long floating pipeline of the *Vesalius* could not cover the whole of the Port Basin, and extra submersible pipelines were required to connect the dredger and her floating pipeline to the shore pipeline (Figure 4).

Depending on the location of the cutter in the Port Basin, the length of these submersible pipelines varied from 350 m to 650 m. Occasionally they had to be repositioned and even connected to each other for a total length of 1000 m, in order to reach the outer limits of the Port Basin. Onshore, the pipelines were installed to each of the different reclamation areas. For the crossing of the river Kortalaiyar, a submersible pipeline was also used.

The dredging operation took place in horizontal layers in order to facilitate a separate disposal of the sand and the clay-type material.

Average pumping distances were dependent on the location of the various disposal areas. In general these distances varied from 1500 m for the nearest sand stockpile area to 5000 m for the clay disposal area, which is located at the greatest distance from the Port Basin.

Beach Nourishment Disposal Area

The Beach Nourishment Disposal Area was reclaimed directly at the seashore (open disposal) with only a bund at the landside, which was meant to prevent the inward land from flooding caused by the dredging waters.

In accordance with the stipulations, Beach Nourishment should be stopped after the dredging of 2,500,000 m^3 of suitable sand. But during execution, it appeared that owing to the continuous erosion at the seaside by the sometimes heavy swell and wave action, not even 50% of the expected volume for the

Figure 3. On-land discharge of the dredged materials.

Figure 4. Cutterhead of cutter suction dredger Vesalius during dredging operations.

Figure 5. The 9,000 m3 trailing suction hopper dredger Alexander von Humboldt, has been commissioned to the Ennore Port Project for dredging the 3,525-m-long Access Channel.

beach protection was in place. As a result, the original volume had to be doubled. An extra stockpile of suitable sand was even created on top of the first reclamation for future needs.

All the other on-land reclamation areas, which were confined disposal areas, were constructed with perimeter dykes and equipped with weir boxes for the discharge of the excess dredging waters. Prior to the filling operations in the sand reclamation areas, settlement poles were installed to monitor possible settlement or consolidation of the underlying ground. As these layers also consisted of sand, the measured settlement appeared to be negligible.

Fishing areas

Problems occurred quite regularly with the local fisherman. They were afraid that the execution of the Beach Nourishment scheme would spoil their fishing grounds. For the same reason, they were also protesting against the outlet of the sand stockpile to the Buckingham Canal. The Client succeeded in solving all these problems within a reasonable period of time through negotiations.

Currently, the 3,525-m-long Access Channel is being dredged to –16 m CD by the trailing suction hopper dredger *Alexander von Humboldt,* a recently built trailing suction hopper of 9,000 m^3. Her single 1.3 m-diameter suction pipe, incorporating a very wide draghead, makes her particularly suitable for these kinds of operations (Figure 5). All dredged material consisting of mud, soft clay and silty sand is being dumped in the offshore disposal area at a distance of approx. 4 km.

Conclusion

Completion dates of the project have been met as stipulated in the contracts, despite some unusual circumstances. The dredging works of the Small Craft Harbour were handed over on June 30 1999. According to the Contract, Port Basin and On-land Reclamation Area were to be handed over on February 28 2000. The Entrance Channel and Offshore Reclamation were to be handed over on the July 10 2000. However, all the dredging works to be executed by the CSD *Vesalius* were completed by mid-January 2000 and the TSHD *Alexander von Humboldt* completed her part by mid-February 2000. This resulted in the handing over of the whole dredging works at the end of February 2000, which was much earlier than the stipulated date in the contract.

The experience gained working in India, the capabilities of the dredging plant and expertise of the people involved greatly contributed to the success of this project, although circumstances were not always as easy as they seemed to be.

Hans Bijen

Ennore Breakwater Construction

Abstract

The eastern coast of India is subject to storms and cyclones during the monsoon, and the littoral drift creates a sand transport along the coast. Construction of a new harbour on this coast, known as the Ennore Coal Port, required the construction of two new breakwaters to protect the future coal harbour and incoming ships from waves and sedimentation problems. Because the soil there was determined to be insufficient to support such breakwaters, additional dredging and backfilling were needed and a new method of compaction was developed.

Hans Bijen has worked for more than 12 years at Van Oord ACZ. He was Works Manager for the Ennore, India project and is presently desk manager at VOACZ.

Hans Bijen

Introduction

As one of the world's fast emerging new economies, India plans to develop new infrastructure to open up its vast hinterland, so goods, commodities and produce can be transported from the coast to India's interior and vice versa. This implies that harbourage and harbour facilities have to be ameliorated, and the same applies to India's road system and railway infrastructure. India's rapid population growth (approximately 980 million inhabitants in 1998, expected to increase to over a thousand million before the end of the millennium) and expanding economy (approximately 6% in 1998) call for immediate action to ensure continuity and improvement of present and future living conditions for the Indian people.

Chennai – formerly known as Madras – is one of India's major harbours on the eastern coast of India, situated directly on the Gulf of Bengal, in the state of Tamil Nadu. Bulk vessels, loaded with coal, call at Chennai's harbour to deliver their tonnes of cargo. Coal is used as fuel for Chennai's electricity plants, that supply the city and its northern industrial hinterland with electric power. To protect the city from further contamination caused by the transshipment of coal and unburden the workload of the harbour facilities, the Chennai authorities decided to construct a satellite harbour at Ennore, a small village, situated 20 kilometres north of Chennai. This project is called the Ennore Coal Port Project (see article on page 3).

ECPP/C4 Breakwater Construction

As this part of the coast is subject to storms and cyclones during the monsoon and the littoral drift creates a sand transport along the coast, two breakwaters had to be constructed to protect the future coal harbour and incoming ships from waves and sedimentation problems.

The main features of the port consist of a Northern Breakwater with a length of approx. 3200 m and a Southern Breakwater with a length of approx. 1300 m, distanced approx. 2500 m, thus creating a harbour basin of approx. 2500 x 1500 m^2 to be dredged at a depth of –15.50 m, with an access channel to be dredged at –18.00 m (Figures 1 and 2).

Inside the harbour a Coal Wharf is under construction.

The Employer of the project is Chennai Port Trust. The Engineer for the project is a Joint Venture consisting of Haskoning of The Netherlands with Rites of India, responsible for the design and supervision of the works. Approximately 60% of the project is financed by the Asian Development Bank and the remaining part by the Chennai Port Trust.

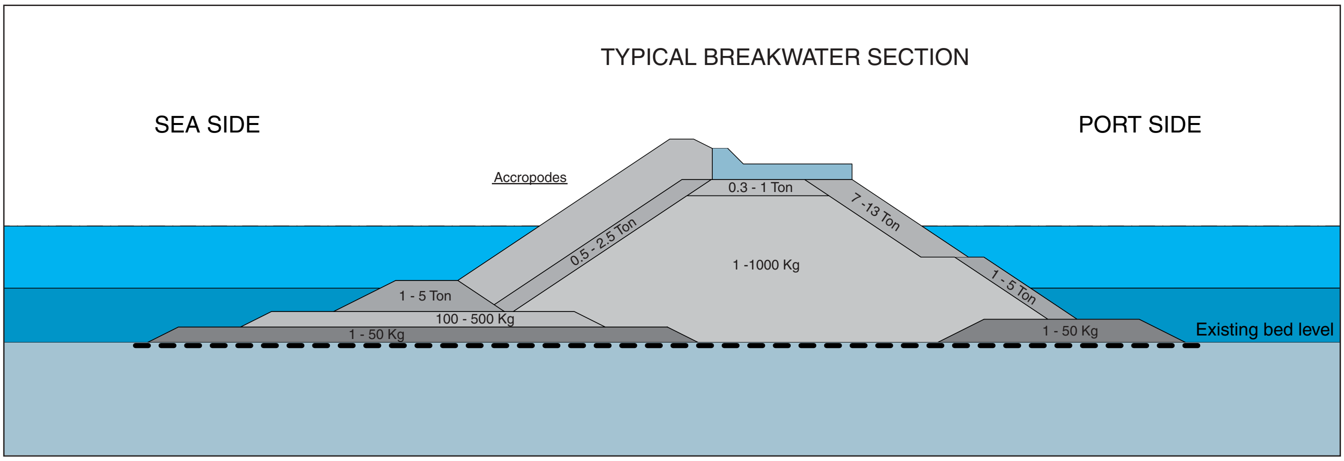


Figure 1. A cross-section of a typical breakwater.

The project was tendered in several separate contracts, which included the Contract ECPP/C4 Breakwater Construction. This contract was awarded to the Joint Venture, consisting of Hindustan Construction Company (HCC) of Mumbai/India and Van Oord ACZ (VOACZ) of The Netherlands, partaking for respectively 70%-30% in the construction works. HCC, the leading partner in the Joint Venture, and responsible for constructing the work harbour and the upper sections of the Northern and Southern Breakwaters on the foundations, constructed by their joint venture partner VOACZ, specialised in dredging and marine construction works.

The overall construction period was planned initially from 22nd August 1997 to 15th August 2000. In the course of the project an extension of time was granted, owing to extra works involving the realignment and extension of the Northern Breakwater. This resulted in the extension of the construction period to 1st September 2001.

Setting Up Camp

After a long period of contract negotiations, the contract for the ECPP/C4 Breakwater Construction was awarded in July 1997. Establishing offices and housing facilities for the staff were the first challenges.

Work had to start immediately, so the majority of the VOACZ staff were based in Chennai where temporary offices were set up in a hotel, because camp site facilities were still under construction by HCC. However, excessive traffic and traffic jams on the roads between the site at Ennore and the Chennai hotel cost too much valuable time, better spent on preparing the actual dredging and rock dumping activities.

The decision was made to move the team to the site for housing and offices at Ennore while the surrounding infrastructure works and final completion of the camp site facilities were still in progress.

By the beginning of 1998, Van Oord ACZ staff had moved to these facilities. The camp was fully equipped for food and lodging of the, in the majority, European staff and a well had to be bored to provide fresh water. The necessary precautions were taken to provide medical care in this rather remote area, including contracting a helicopter service to evacuate employees to the leading Chennai hospital in case of an emergency.

Cone Penetration Tests and Soil Boring

Additional engineering studies, based on the future use of the Ennore Coal Port, had shown that the Northern Breakwater had to be realigned and extended with 400 m. To determine the extent of the additional dredging and backfill works, a soil investigation campaign had to be conducted. These works were subcontracted to Fugro, a Dutch company specialised in soil research.

The Indian branch of Fugro mobilised a self-elevating platform to the site and started taking boreholes in the specified zone. The researchers soon found out that the bearing capacity of the sea bottom was so low that the poles of the platform got stuck in the mud and clay.

Owing to this constraint and the bad sea conditions, only a limited number of borings could be taken. During this process it was decided to execute further cone penetration tests (CPT) that could then be compared to the limited number number of boreholes, which were possible to execute. The results of these tests were then compared with previous test results and extrapolated over the whole area. The conclusion was reached that substantial additional dredging and backfilling were necessary. All these extra works had to be executed in the same non-monsoon period.

Dredging and Backfill

Previous surveys and soil investigations, particularly within the breakwater alignment, had shown that the bearing capacity of the soil was insufficient to support the weight and to ensure the stability of the breakwaters. Therefore, in future breakwater locations large quantities of soil had to be removed to a level of –15.00 m. and backfilled with suitable sand. This had to be accomplished in the short time frame during the non-monsoon period. Additional soil investigation, which was executed as a result of the realignment of the Northern Breakwater, resulted in a further increase in depth and length of the trench to be backfilled by suitable sand from the offshore borrow area.

The unsuitable materials were dredged with hopper dredgers and dumped at sea in a designated area at water depths of at least 20 m. Suitable sand was dredged in an offshore borrow area, located approximately 6 km from the tip of the Northern Breakwater. In May the first two trailing suction hopper dredgers *Orwell* and *Volvox Hansa* arrived at Ennore to start the dredging activities. Bringing in two trailing suction hopper dredgers was necessary, because of the available time frame and the limited water depths of the working locations where dredging and infill were required.

The *Volvox Hansa* with an unloaded draught of approximately 6 m started dredging in the deeper trenches of the Southern and Northern Breakwater in water depths varying from 11.5 to 8 m. and also worked with reduced loads in shallower areas. The *Orwell,* on the other hand, concentrated on the Coal Wharf Trench as her loaded draught was more suitable to manoeuvre in shallower water depths. This trench had to be dredged on the future location of the coal unloading jetty, to be constructed as part of the overall construction scheme.

Taking into account the fairly small manoeuvring space for this type of ship in combination with the shallow water depths and a tight schedule of working in the non-monsoon season, the planning and coördination of the dredging activities was a complicated process.

After an initial in-survey, the dredging operations could start. During the dredging operations interim surveys were carried out to monitor the progress of the works. When sections of the dredged trench were completed and the final survey was approved, backfill could start with the dumping of suitable sand. Backfill materials have to be placed in successive layers.

Because of the shallow water depths in and surrounding the trenches, especially close to the shore, the *Volvox Hansa* could work in these areas only with reduced loads. Dredging and dumping had to be carried out with utmost care according to a strict dumping sequence. To ensure safe operations, the overflow system of the *Hansa* was modified to allow maximum access in shallow waters. The final result of the backfilling/dumping process was that final levels were achieved within the contractual tolerances.

An Innovative Method of Compaction

The contract specified the following criteria for the specific density, qc, to be obtained for the underwater fill underneath the breakwaters:

Figure 2. A three-dimensional model of the North Breakwater at Ennore.

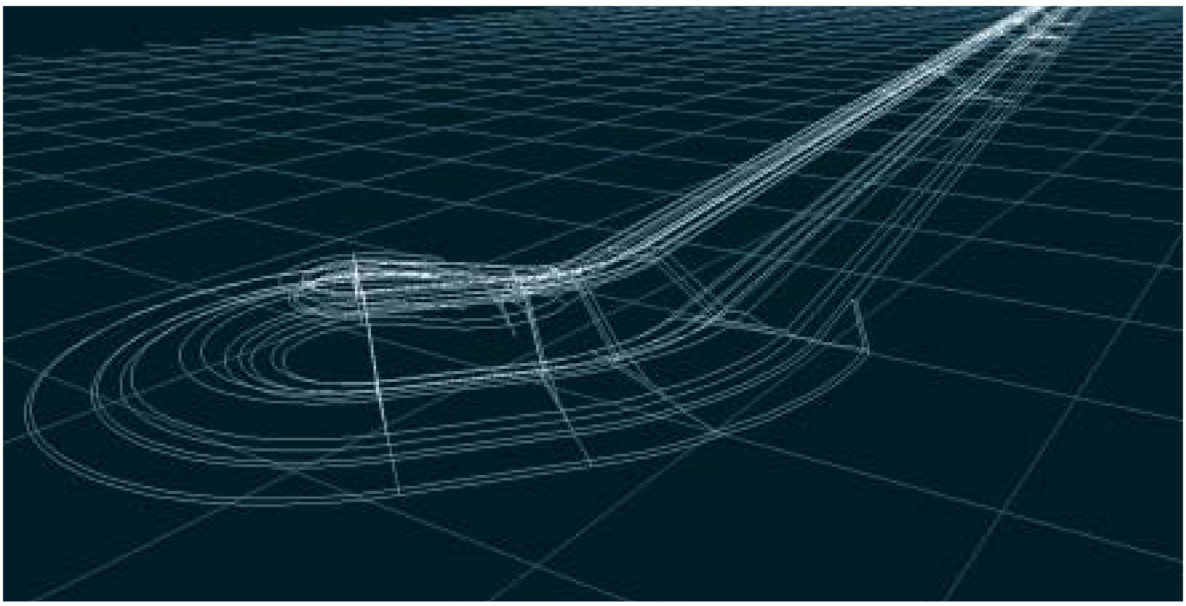


Figure 3. The side stone dumping vessel Frans being loaded at the temporary work harbour.

1 m below top of the fill : qc ≥ 6 mpa
2 m ,, ,, ,, ,, ,, : qc ≥ 10 mpa
3 m ,, ,, ,, ,, ,, : qc ≥ 12 mpa

To meet with these criteria, the contract also specified that underwater compaction of the fill had to be undertaken, according to a method to be proposed by the contractor. Cone penetration tests (CPTs) had to be executed to verify the correct density in the upper 3 m. of the fill.

To make sure that the compaction of the sand met with these requirements, a special dumping method was adopted for the backfill operations. Based on laboratory tests and tests undertaken in the borrow area, the contractors came to the conclusion that the borrow area contained sufficient quantities of good quality coarse sand with phi-values of 34˚ and 35˚. These phi-values were such that, in combination with the adopted dumping method, good stability and compaction of the fill could be expected in accordance with the contractual requirements. VOACZ carried out a number of additonal laboratory tests and studies of the sand to verify the relation of the CPT and the phi-value for this type and gradation of sand.

During the course of the mobilisation period of the secondary compaction equipment, it was decided that 100% compaction of the backfill area would be carried out, based on the results of a pilot test. This pilot test was executed over an area of 100 x 100 m2, within the alignment of the Southern Breakwater. After compaction tests had been carried out, the engineer would then decide whether additional compaction was still necessary over the remaining area.

A vibro-compaction method, especially developed by VOACZ for this project was chosen for the compaction. After being refitted with special equipment for this operation, the multipurpose, stone-dumping vessel *Jan Steen* was mobilised from Singapore and brought to the site. The *Jan Steen* disposes of a dynamic position system and has a I 3/3 Special Service Deep Sea classification. Given the rough sea conditions on the site, it was necessary to develop a technique whereby the ship and vibration unit could operate independently.

Therefore on the rear side of the ship a 200-tonne crane was mounted to lift a special frame (rig) with a weight of 20 tonnes from the ship to and from the sea bottom. This frame was specially developed for this project, designed in The Netherlands and built in Batam, Indonesia. Its purpose was to manoeuvre the vibration needle, mounted in the frame, underwater into the fill. The frame was designed in such a way that it could absorb the underwater sea movements and the forces resulting from the vibrator block and needle. The vibration unit consisted of a vibrator block and specially designed needles, 1.2 m wide at the needle's point. This equipment was shipped in from The Netherlands. With this equipment it was possible to achieve the compaction criteria for the upper 3 m of the fill.

After the *Jan Steen* had been mobilised and the frame erected, the multipurpose vessel was brought into position above the test location (100 x 100 m2) and the frame with vibration blocks and needle was lowered down by crane and winches. Steered by remote control, the needle penetrated into the soil until the lowest point was reached. Then, in one unanimous movement, the needle was pulled up, vibrating at the same time, to compact the sand.

These penetrations were executed according to a predetermined depth/time sequence and according to a grid agreed with the Engineer.

Figure 4. The fully loaded SSDV Frans leaving the workharbour.

After completion of the vibro-compaction in this area, several cone penetration tests were executed and soil samples were taken by borings and tested in the laboratory. Based on the test results it was decided that the required angle of internal friction and thus the required density of the fill had been achieved. So further improvement by means of compaction resulting from the vibro-vibration was not required and the *Jan Steen* and compaction equipment were demobilised from the site.

Rock Dumping Operation

After the trenches of the Northern and Southern Breakwaters had been filled in and compacted, the rock-dumping operation was carried out by VOACZ up to 4 m below sealevel with the side stone dumping vessel *Frans* (Figures 3, 4 and 5). Approximately 1,250,000 tons of rock had to be placed by this method. Above the – 4.00 m CD level, HCC then took over the rock dumping with land-based equipment by back tipping method, for which they used 40 tonne dumpers (Figure 6). By this method, HCC completed the breakwaters by dumping the remaining core and placing the armour layers, accropodes and concrete capping. In total over 2,500,000 tons of rock had to be placed.

While the *Jan Steen* was still working on the compaction trial of the backfill of the Southern Breakwater, the dynamic positioned side stone dumping vessel *Frans* was already dumping rock on the areas where no soil improvement was required for both the Southern and the Northern Breakwaters. With the *Frans,* first rock grade G- (1-50 kg) and F-filters (50-500 kg) on both seaside and portside had to be dumped, prior to dumping the quarry run (1 to 1000 kg) for the core of the breakwaters. Then different grades of rock, varying between 300 kg and 2.5 tonne were used for the underwater slopes of the Southern and Northern Breakwaters, according to the design of the construction.

The northeast monsoon

The northeast monsoon started while the *Frans* was still working on the rock- dumping operations. If weather conditions became unsafe because of a cyclone, the vessels would not be able to seek shelter in the harbour of Chennai as all ships are evacuated from this harbour when a cyclone is expected. The vessels would therefore have to sail to Colombo, in Sri Lanka, four days sailing from Ennore.

Luckily the weather stayed good enough to continue working off the coast of Ennore. Only once did the ships have to seek refuge in the harbour of Chennai because of high waves, and only once did she have to anchor offshore. In general, weather conditions were

Figure 5. Close up of the Frans sailing to the South Breakwater.

Figure 6. Stone dumpers discharging rock class G at the work harbour.

better than expected and weekly productions of sometimes above 50,000 tonnes a week were able to be achieved.

Littoral tide effects

A setback was caused by the littoral tide and strong waves, before and during the northeast monsoon in 1997. When the *Orwell* and *Volvox Hansa* started working on the Southern Breakwater in accordance with the contractual programme, the waves and littoral tide caused great problems. Outside the northeast monsoon, the littoral drift causes erosion of the coast line in a south to north direction. During the northeast monsoon the wind direction changes and the erosion of the coast line is reversed: from north to south.

Before the monsoon, as the Southern Breakwater was being constructed, the coastal line north of Chennai to the Ennore shoals reclined for approximately 120 m inland as a result of the breakwater's obstruction. That year, the coastal recline was so grave that the coastal road, along which sand for the infill of the breakwater trenches was transported to the site, came under threat of being undermined.

At the same time the whole area south of the Southern Breakwater was transformed into an enormous shoal, while sand sedimentation also threatened to block the harbour entrance and therefore the entrance to the work harbour VOACZ needed for their operations. Meanwhile the alignment of the Northern Breakwater suffered from severe erosion on the seaside.

The location of the work harbour had to be adjusted and additional maintenance dredging had to be executed. When the northeastern monsoon started and the littoral tide reversed, the recline of the coastline and the erosion of the Northern Breakwater were back to normal within four weeks.

Quarry, Stockpile, Work Harbour and Concrete Plant

To construct the Ennore breakwaters, 3 million tonnes of rock were needed for the rock-dumping operations (Figure 7). The Employer and the Engineer had appointed an area at Karikal, situated approximately 80 km inland east of Chennai, for the development and exploitation of the rock quarry. Former investigation tests had established that the specific gravity of the rock (SG 2.6) in that area complied with the contract criteria.

Under a separate contract, the ECPP/C1-contract, it was the task of HCC, who were awarded this contract as well, to develop and exploit the Karikal quarry. The quarry had to produce different grades of rock: over 1.7 million tonnes of quarry run and over 1.3 million tonnes of rock grading between 50 kilograms up to a quantity of 173,000 tonnes ranging between 2.5 and 12 tonnes.

Transport of the rock was provided by trucks from the quarry to a nearby railway station over a distance of 10 km and from there by train up to the site at Ennore. The existing railway was extended to the Ennore site, where the stockpile was situated. Also special skips were constructed for the transport of the rock.
The skips were loaded in the quarry on trucks and, at the railway station, lifted from the trucks and placed by portal cranes into the railroad carriages. Another set of portal cranes at the Ennore site lifted the skips off the train into awaiting trucks. The trucks then drove to the selected stock pile area on site, where the rocks would be dumped in specially assigned areas for the different grades of rock.

According to contract, rock-dumping operations could only be started after 1 million tonnes of rock had been put in the stockpile. Before starting the rock-dumping operations with the *Frans,* a work harbour had to be constructed. On this location the rocks, loaded on

Figure 7. The placing of in situ concrete slab and wave wall at the South Breakwater under construction.

trucks at the stockpile area, were unloaded with cranes on board the *Frans.* This work harbour was located at the existing seashore, halfway between the two future breakwaters, and had to be built in an area not yet protected by the breakwaters.

A causeway with a length of approximately 200 m was built from the beach into the sea, with rock taken from the stockpile to reach a water depth of –3.00 m. At this point the harbour was built, consisting of a platform made of quarry-run, a quay wall made of concrete blocks for the mooring of the *Frans* and other vessels, and a harbour basin dredged by a small dredger.
A temporary breakwater protected the harbour.
All these works were executed by HCC. As indicated earlier, the changing littoral drift caused problems for the maintenance of the required depth of the harbour.

For the ECPP/C-4 contract HCC built a complete concrete plant at the Ennore site for the production of the accropodes and concrete capping slabs, necessary for the top layer of both breakwaters. Over 8500 accropodes were fabricated with weights of 9.6, 12 and 15 tonnes each. Also over 65,000 m^3 of concrete had to be produced for the construction of the concrete slab on the breakwaters and the blocks of the work harbour. Furthermore a well-equipped laboratory was built to test concrete, sand, soil and rock samples.

Conclusion

Although VOACZ's part of the works is completed by now, the final completion of the breakwaters by HCC and the dredging of the harbour basin, some of the construction of the coal jetty and other building and road works by other contractors is still in progress.

The execution of this project was a challenge to develop and apply new techniques and solutions for a project that was executed under sometimes difficult circumstances.

Thanks to solid foundations, the new port will provide a safe shelter for all ships when the port becomes operational in the year 2001.

A.N. Balchand and K. Rasheed

Assessment of Short Term Environmental Impacts on Dredging in a Tropical Estuary

Abstract

Dredging, while earlier an art, is at present a scientific subject that successfully reflects human skills. This artificial process attempts to win material for beach nourishment, for making roads and railways or for removing settled sediments to facilitate marine transportation. The process, of course, brings about environmental problems in short and long time scales in marine and estuarine environments. This study mainly looks at the short-term impacts of dredging in the estuarine environment of Cochin harbour, India.

As expected, the results indicate only transient changes, mainly during the time of dredging. On the other hand, precipitating or long-acting perpetual fluctuations are time bound reversible and are environmentally acceptable. The estuary being variant in hydrographic features, adds significance to this study in regulating the short-term impacts.

Introduction

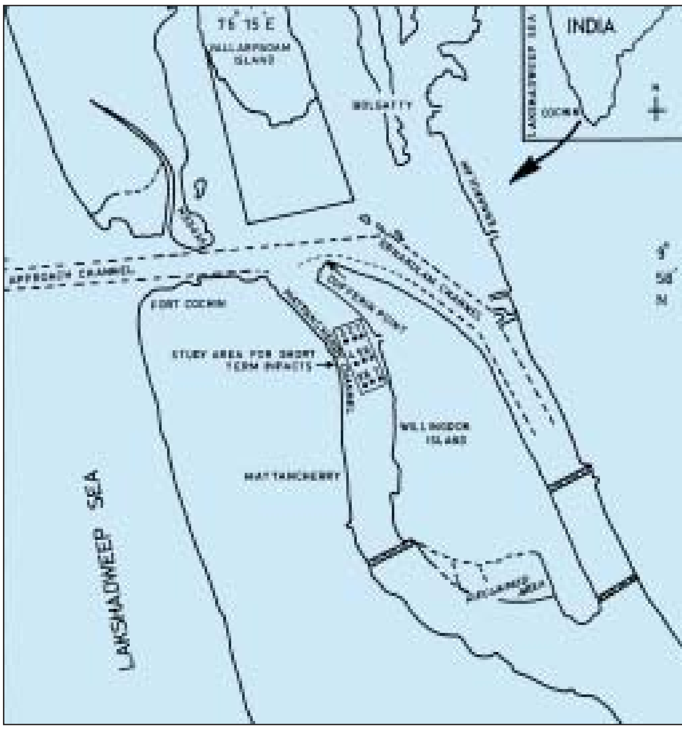
Cochin is the second largest port along the west coast of India. Historically, this area is known for trade, commerce and cultural activities with other countries especially Arabia, Portugal and Holland.
This harbour and neighbourhood environment is quite natural (Bristow 1967) with a free permanent connection (Cochin gut–tidal inlet) with the sea, allowing land drainage derived from terrestrial sources. It has three dredged channels:

- the approach channel oriented along the east-west direction of around 10 km length and 500 m width; and
- two inner channels located on either side of the Willingdon Island, i.e. Ernakulum channel of around 5 km length with a width of around 250-500 m and Mattancherry channel of 3 km long with a width of 170-250 m.

All the three dredged channels are maintained at a depth of 10-13 m. The tropical estuarine environment shows multitudinal features (Rasheed 1997) and is likely to face critical environmental issues related to of inter-tidal land reclamation, pollution discharges and proposed numerous water resources management schemes (Ajith and Balchand 1997).

Though extensive studies have been carried out in Cochin estuary especially on physical, chemical and biological aspects, issues dealing with environmental impacts of dredging were never addressed.

Figure 1. Location map: Study area for short-term impacts.



A detailed picture of the dredging techniques and the sedimentation features are available in reports published by Mathew and Chandramohan (1993), Rasheed and Balchand (1995). The main objective of this study was to investigate the short-term impact assessment of dredging which would also reflect on environmental responses and cures in a short time scale.

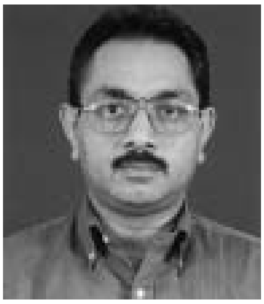
For the above purpose, nine stations were selected within the Mattancherry channel of Cochin estuary and eight parameters were thoroughly monitored before, during and after dredging (see Figure 1). The dredging operations were held at station 5 and its very immediate vicinity.

This site was chosen taking into consideration the fact that dredging operations were not held at or in the larger vicinity for more than three weeks fitting in with the scope of this study. The parameters monitored were:

- current speed and direction (at 2 m interval in the vertical);
- salinity (surface, middle and bottom);
- turbidity (at 2 m interval in the vertical);
- transparency;
- bottom sediment textural characteristics;
- nutrient content (surface and bottom);
- abundance of chlorophyll *a,b,c* (surface and bottom); and
- bottom fauna.

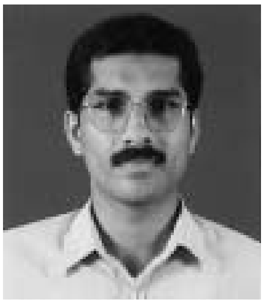
The results of monitoring these parameters and a discussion follow (Figure 2).

Dr. A.N. Balchand obtained his postgraduate degree (1980) as well as doctorate (1984) from Cochin University of Science and Technology (CUSAT), India, in Oceanography. His doctoral work was in the area Environmental oceanography – Dynamics and pollution aspects of coastal aquatic waters. In 1985 he proceeded on a commonwealth fellowship to PML, Plymouth, UK. He joined the Faculty of Marine Sciences in 1990 and currently serves as Professor at the Department of Physical Oceanography of CUSAT. The work presented here is part of a project supported by DST (India).



Dr. A.N. Balchand

Dr. K. Rasheed received his postgraduate degree in Oceanography (1990) and M.Tech in Atmospheric Sciences (1993) from Cochin University of Science and Technology, CUSAT, India. He secured his doctorate degree from the same University in 1998 on the topic, "Impact Assessment of Harbour Desilting", financially supported by UGC (India). Currently he is serving the National Institute of Oceanography as a research associate.



Dr. K. Rasheed

Currents

The short-term impact of dredging was studied during the ebb phase of the tide. The observed current vectors during the study period indicated surface currents to be higher compared to the bottom values at almost all the stations prior to the commencement of dredging (09/01/96). The near bottom current speeds were lower at all stations (< 20 cm/s) which points out to the penetration of the tide into the estuary along the bottom while flow at the surface was directed seaward. The current vectors are multidirectional when viewed from surface to bottom owing to the inward and outward flow of estuarine waters.

During the time of dredging (on 10/01/96), the tide phase was the same as that of the previous day.

The current vectors indicated more or less similar features compared to that of the observations made before dredging (the previous day). Almost at all the depths, low (1 to 20 cm/s) and intermediate current vectors (21 to 60 cm/s) were observed. Along the bottom, the range of current speed was minimum almost at all the stations (<15 cm/s) compared to the higher surface values. After the dredging operations, observations were made on 11/01/1996, when the tidal conditions were once again very nearly similar to the prior two days. The surface current vectors showed a slight increase in values, but at all other depths, current speeds gradually decreased with increase in depth. The direction of vectors was again multidirectional owing to the prevailing ebb tide conditions.

Figure 2. DCI Dredge VIII cruising out of the Port of Cochin toward the discharge area offshore.

Salinity

Salinity, also measured along with currents before (09/01/96), during (10/01/96) and after (11/01/96) the dredging operations, indicated changes of very limited magnitude in the context of dredging operations. Before the commencement of dredging operations, the surface salinity at all the stations showed high values (>27.0) except at station 7 where it was 21.0.

The mid-depth salinity values gradually increased (31.5 to 34.0) except at station 7 (27.0). Along the bottom layer, salinity gradually increased from 31.0 to 34.0. At the time of dredging, the observations made at the ebb phase of the tide indicated no appreciable changes in salinity values. The day after dredging, the observations on salinity showed no conspicuous changes – the salinity distribution maintained the same pattern as the days before and during dredging. At this estuarine harbour, salinity fluctuations are the resultant of tidal-freshwater interactions, season-wise.

Turbidity

The most commonly observed changes in water quality during dredging are the rapid increase in turbidity. This aspect is very important in tropical estuarine and coastal waters as these estuaries receive and store large amounts of suspended load from perennial rivers.

Likewise, Cochin estuary also receives large amounts of river inputs from Periyar on north and Muvattupuzha on south and also additionally from Pamba, Manimala, Meenachil, and Achankovil on a seasonal basis, which leads to siltation at the harbour region. Previous studies had indicated that the natural turbidity in the surface waters of this harbour was less than 30 mg/l (Gopinathan and Qasim 1971). Of course, in monsoon, i.e. during the rainy season from June to September, the load content may go up to values like 100-120 mg/l or more.

In the study of the short-term impact on turbidity caused by dredging the following occurred:

– Observations at station 1 before the commencement of dredging showed that turbidity does increase with an increase in depth (surface < 5 mg/l; middle 20-30 mg/l and bottom 30-40 mg/l). But during the time of dredging, the turbidity showed a sharp increase which is clearly observed in Figure 3. The turbidity values at certain depths were more than 100 mg/l, which is generally detrimental to the aquatic organisms. After the stoppage of dredging, the turbidity values showed a decrease to normal values.
– At station 2, similar features but at a higher range of values were observed – even higher values like 300 mg/l at the time of dredging.
– At station 3, during dredging, the surface turbidities increased to more than 120 mg/l; however on the bottom, a decrease of turbidity was observed during the same time.
– At station 4, during dredging, turbidity increased towards the bottom with peak values at certain sub-surface layers.
– At stations 5 and 6, turbidity sharply increased with depth during the time of dredging and most of the values were above 60 mg/l.
– Interestingly, station 7, located upstream of the dredging site, did not show an increase in turbidity during the time of dredging.
– At station 8 an increase of turbidity up to 4 m was noted during the time of dredging but no change was noted for greater depths.
– An increase of turbidity was noted at all depths except at the surface during the dredging time at station 9.

Figure 3. Reading from bottom to top, turbidity values at stations 1–9, before , during and after dredging.

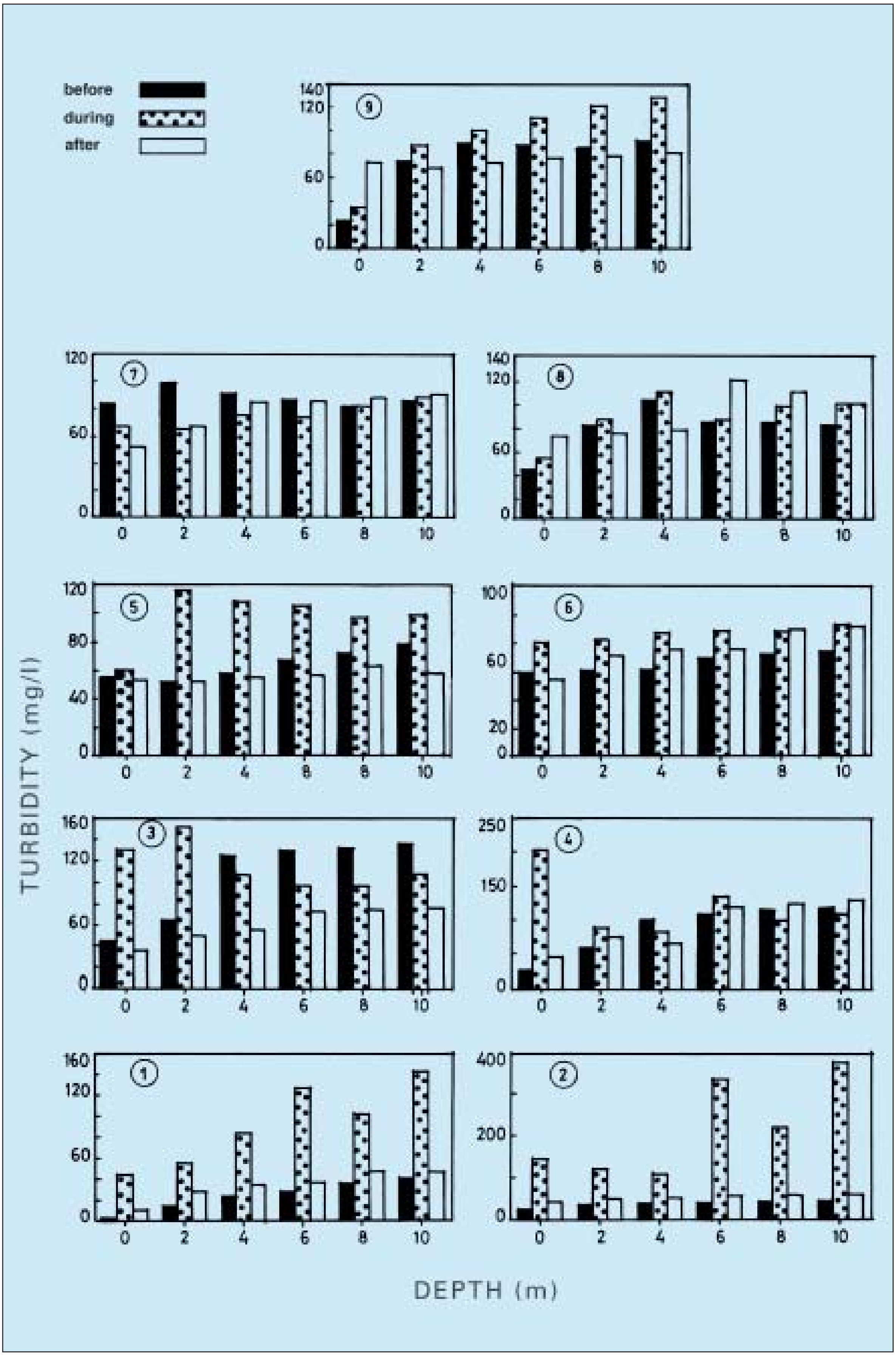


Table I. Extinction Coefficient before, during and after dredging.

Stations	1	2	3	4	5	6	7	8	9
09/01/96 (Before)	2.26	2.62	2.62	2.27	1.57	1.55	3.54	1.78	1.60
10/01/96 (During)	1.89	6.80	1.70	11.30	1.78	2.00	1.89	1.72	1.65
11/01/96 (After)	1.89	2.00	1.85	2.00	1.89	1.65	1.55	1.54	1.60

The facts indicate that upstream stations (7 to 9) are not being affected for the given stage of tide, i.e. ebb phase.

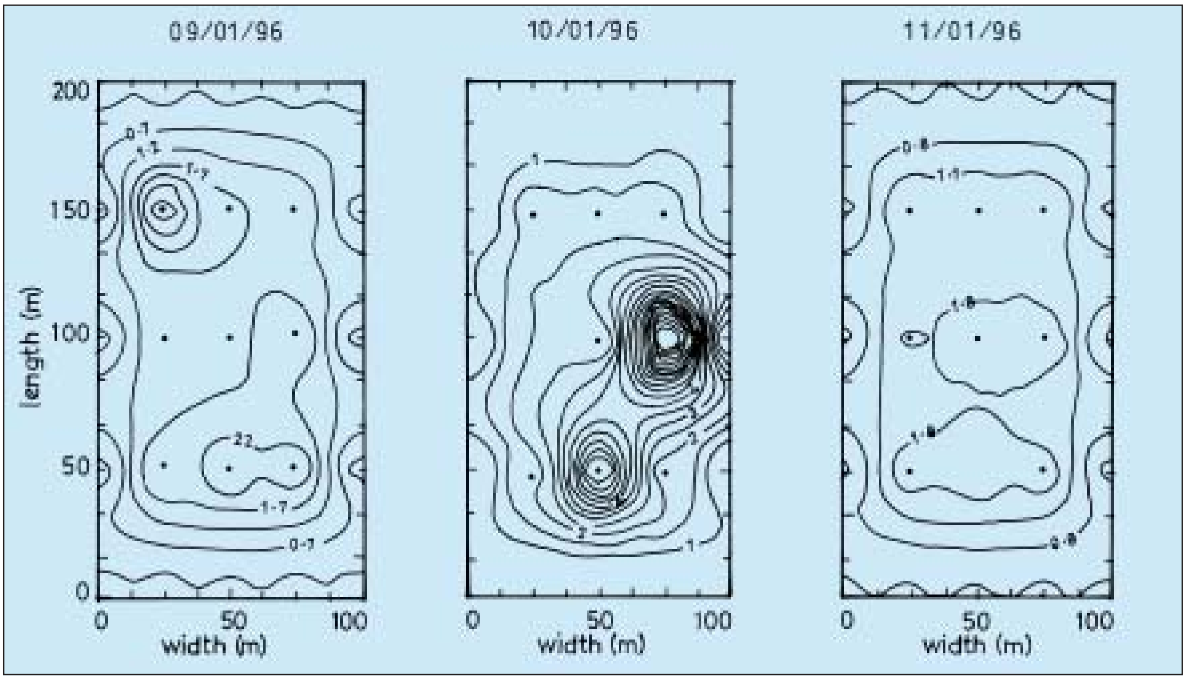
From the above results, it is ascertained that change of water quality owing to dredging will not leave a permanent impression. The turbidity change was transient and localised. But the main concern will be to know how it affects the biota. Certain earlier studies have revealed that some of the estuarine and coastal organisms (may have) adapted to a small change of turbidity but rapid changes of above nature in a particular range may have highly detrimental effects to the propagation of organisms, especially on growth and reproduction (Sherk 1971). Increased turbidity will also adversely affect the production of phytoplankton as it interferes with photosynthesis by limiting light penetration. (Bray 1979; Johnston Jr. 1981). The benthic algae are particularly susceptible to inhibition resulting from decreased light intensity (Windom 1976), and the increase of turbidity probably will affect fish gills by its clogging action and can also clog the membranes of filter feeding organisms (Bray 1979).

Transparency

The short-term impact on the transparency/extinction coefficient at the dredging site was also assessed for three days, i.e. before (09/01/96), during (10/01/96) and after (11/01/96) dredging operations. The variation of the extinction coefficient is shown in Figure 4 as 2D plots made at 0.5 intervals. The values are also provided in Table I. Just prior to dredging, the transparency was high, giving low values of the extinction coefficient (1.55 to 2.62) which indicates the presence of clear waters before the dredging operations. The exception was the high extinction coefficient value (3.54) observed at station 7 indicating the presence of turbid waters owing to some probable local action.

During the time of dredging, the extinction coefficient was very high (11.3) at station 4, followed by 6.8 at station 2, indicating the presence of high turbidity in the surface waters. The 2D plot showed two pools of high extinction coefficients at stations 2 and 4. Observations made in the aftermath of dredging operations indicated high transparency with low extinction coefficients.

Figure 4. 2D plot of extinction coefficient on the three days.



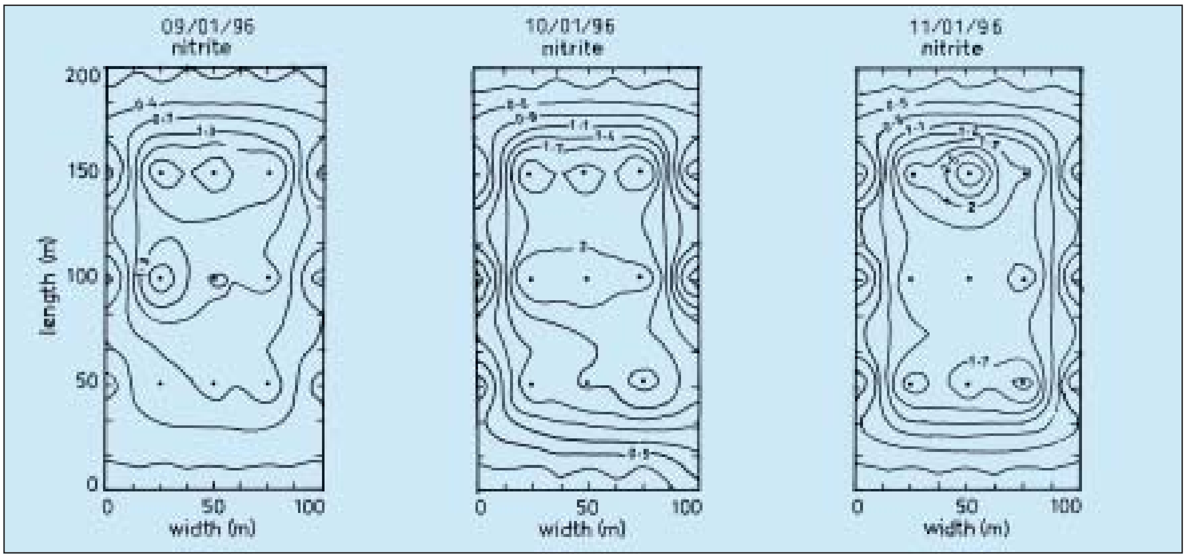


Figure 5a. 2D plot of nitrite at surface during the three days of the investigation.

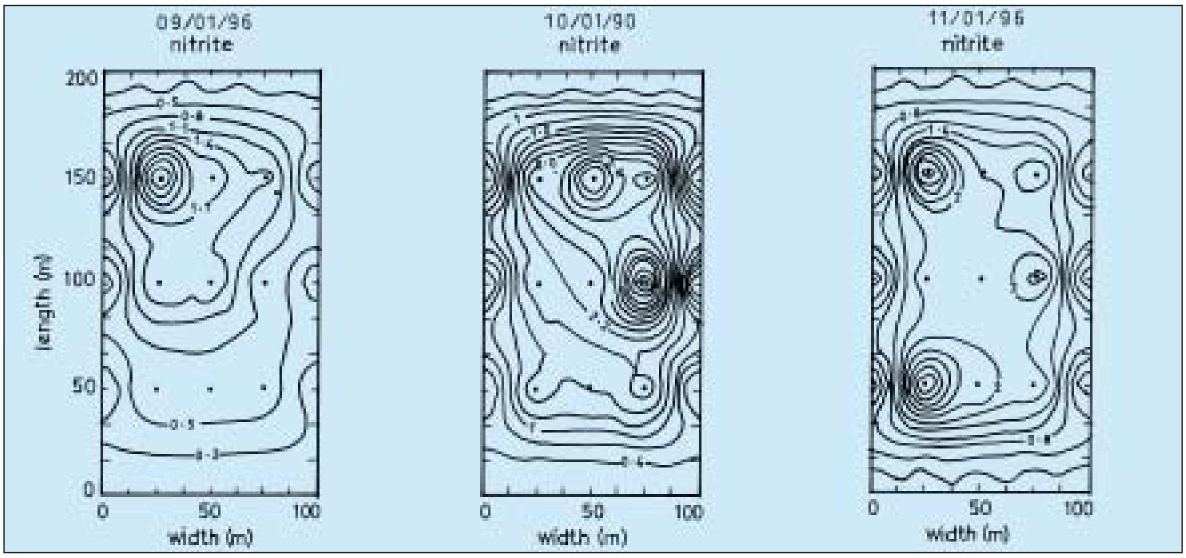


Figure 5b. 2D plot of nitrite at bottom during the three days of investigation.

No closed isolines were observed at any of the stations, which indicates a trend in the turbidity to gradually attain normalcy in the estuarine regions soon after stoppage of dredging.

Sediment Textural Characteristics

The analyses of samples collected the day *before dredging* at stations 5 and 6 indicated that fine silt played a dominant role. Coarse silt was very low compared to clay fractions and at station 5, the values on standard deviation, skewness and kurtosis showed that the sediment was poorly sorted, very finely skewed and very leptokurtic but the sediments at station 6 showed very poorly sorted, coarse skewness and platykurtic.

The analysis of sediments collected *during dredging* showed that very fine silt mixed with the clay fractions were of higher percentage when compared to the observations of the previous day. At station 5, the sediments were poorly sorted, nearly symmetrical and mesokurtic. At station 6, the sediments were poorly sorted, finely skewed and mesokurtic.

After the stoppage of dredging, the next day, very fine silt fractions dominated the sediment texture in the study area. The sediments at station 5 were poorly sorted, nearly symmetrical and mesokurtic.
At station 6, sediments were poorly sorted, finely skewed and very leptokurtic. Also there was an increase in the percentage amounts of very fine silt and clay size sediments when compared to the dredging time samples. At station 6, very fine silt

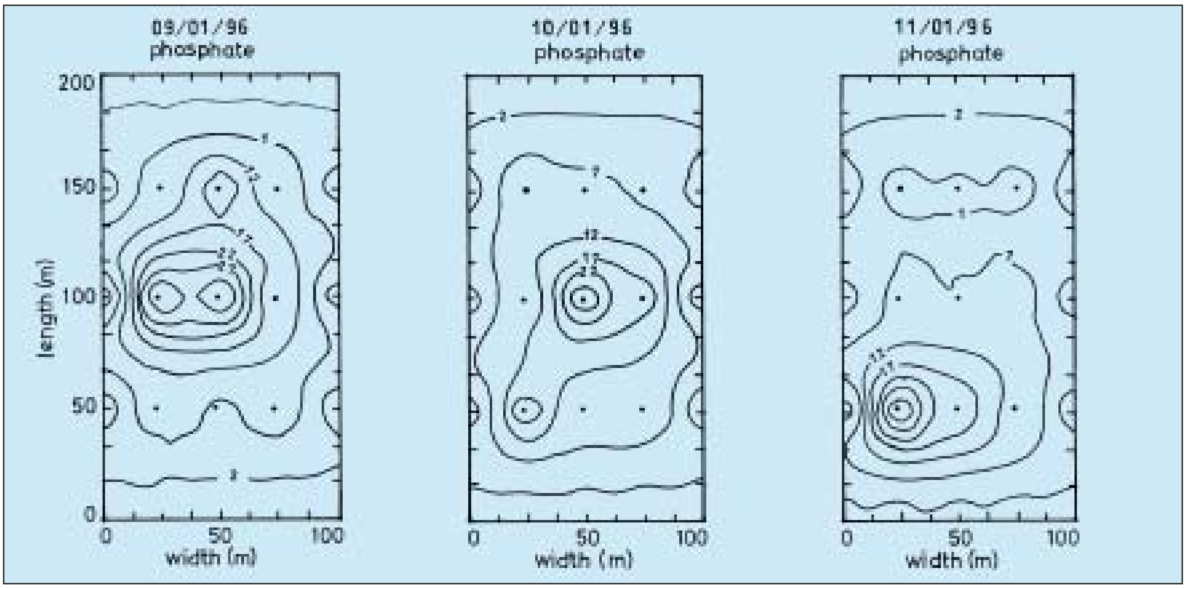


Figure 6a. 2D plot of phosphate at surface during the three days of investigation.

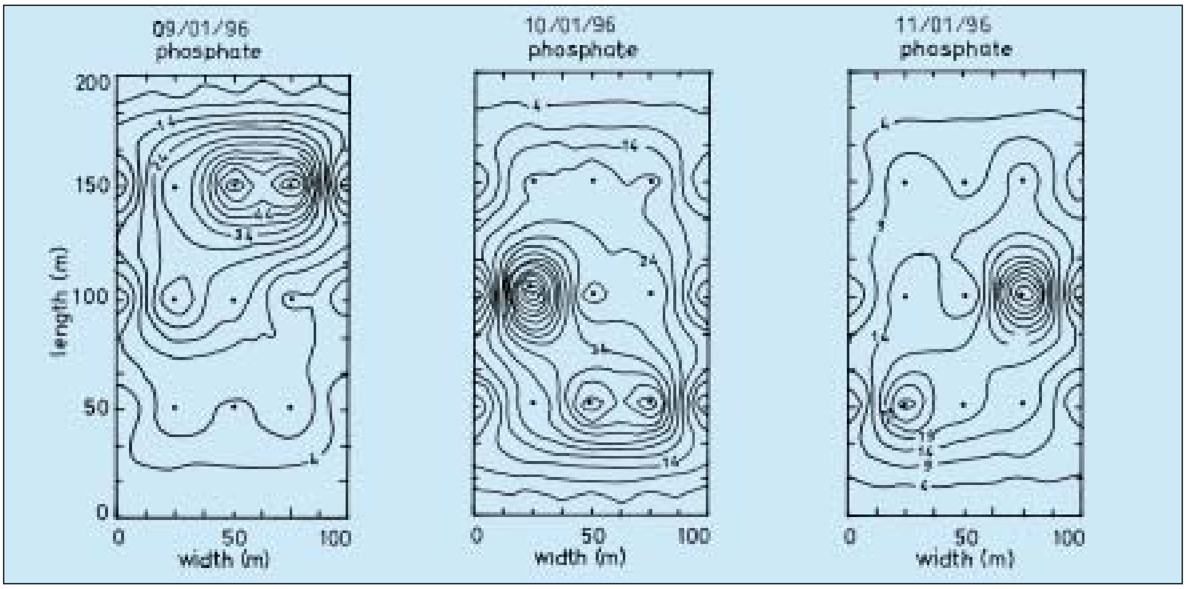


Figure 6b. 2D plot of phosphate at bottom during the three days of investigation.

increased from 27 to 37 percent whereas clay fractions increased from 14 to 18 percent.

Nutrients

The nutrients carried to the sea by rivers are the principal agents for maintaining the fertility of the oceans. Within estuaries, the continued inflow of nutrients via the rivers must frequently be assessed for their importance in maintaining productivity especially since most rivers carry some amounts of polluted loads in addition to elements leached from the land sites. Recent studies have thrown better light on nutrient transformation in coastal water bodies (Matsukawa and Sasaki 1986; Matsukawa 1989; Gopinathan *et al.* 1994; Gouda and Panigrahy 1995) and on recycling within estuaries (Thornton *et.al.* 1995; Kronkomp *et al.* 1995).

a) Nitrite

According to Windom (1976) both polluted and unpolluted fine grain sediments of coastal and estuarine areas contain high concentrations of soluble nutrients (phosphorous and nitrogen). This may be a result of the accumulation of organic detritus, which decompose to regenerate and recycle the nutrients. The study conducted by Windom (1975) in Intracoastal Waterway maintenance dredging analysis showed that no increase of nutrients (ammonia, nitrite and phosphate) were noticeable. May (1973) also reports similar results for phosphorous in Mobile Bay. However, in some instances, nutrient release mechanisms do not favour increase of nitrite or phosphate on dredging.

To study the short-term impact of dredging on dissolved nutrient content, observations were made before, during and after the dredging operations.

The results indicated in Figure 5a point out that the analysis before the start of dredging at surface showed maximum concentration of nitrite as 1.87 µgat/l at station 6 followed by 1.83 µgat/l at station 7. The minimum value was observed at station 1 as 0.71 µgat/l.

During dredging, the sediments (rich in nutrients), on resuspension to the surface waters, released nutrients in the dissolved form and their presence was noted as an increase in the content in the water column. The maximum value was 2.37 µgat/l at station 6 followed by 2.35 µgat/l at station 9. A day after the dredging, the observations showed that the nitrite content persisted slightly enhanced at station 8 (2.95 µgat/l), which indicates the continued release of nitrite to the upper water column. At most of the other stations, values showed a gradual decline.

In bottom waters, prior to dredging, nitrite content showed a higher value at station 7 (3.3 µgat/l) and the minimum was at station 4 (0.66 µgat/l) (see Figure 5b).

Comparing these values to that of surface, the nitrite content at bottom was more or less enriched in concentration. During the dredging time, the substrata are totally disturbed and release of nutrients to the bottom waters enhanced the content of nitrite. The values of nitrite showed a sharp increase at all stations; the maximum value was observed at station 4 (5.4 µgat/l) followed by 4.4 µgat/l at station 9. Two close sets of isoline patterns are quite evident at station 4 and station 8 in Figure 5b as presence of enriched resources.

After dredging operations, the next day, the peak values had shifted to stations 1 and 7 as 3.58 and 3.47 µgat/l in concentration. Two close sets of isolines appear around these stations. The results indicated that normal values of nitrite are not attainable after one day of dredging and the mechanism of nitrite uptake and release may be a slow process.

b) Phosphate

The variation of phosphate in surface waters before, during and after dredging is shown Figure 6a. In the surface waters, before commencement of dredging, considerable content of phosphate was observed which revealed that this nutrient element in estuarine region may act as a sink or source. The concentrations observed at stations 5 and 6 are at the upper extent of range, 37.5m gat/l as indicated by rapidly closing isolines of proximity at these locations. The content showed a decrease at other stations.

During dredging time, the surface values drastically reduced; the highest value was noted at station 5 as 31.05 mgat/l. One day after the dredging (11/01/96), no consistent increase or decrease could be observed except at station 5, where the value drastically reduced. The highest value was observed at station 1 as 36.00 mgat/l.

The change of phosphate content in the bottom waters during the three days of study is shown in Figure 6b.

The results before dredging showed that higher values occurred at all the stations compared to surface values. The highest value was observed at station 9 (63.05 mgat/l) which is evidenced by the pattern of isolines around that station. During the time of dredging, still higher values were observed at station 6 (79.50 mgat/l). After the stoppage of dredging, no drastic changes were noted but the values gradually reduced compared to those observed during dredging.

This aspect may indicate the adsorption/absorption of phosphate onto the resuspended particulates and the extent of geochemical control which would play an important role in the distribution of nutrients. Unlike nitrite, absolute values of phosphate do not significantly indicate release mechanisms but the change in content (increase/decrease) play a dominant bio-environmental role.

Chlorophyll

a) Chlorophyll a

Analysis of chlorophyll *a* before, during and after dredging showed that higher values were observed in bottom waters compared to the surface waters. Before dredging, the surface samples contained <10 mg/m^3, but bottom values at four stations (stations 4, 5, 7, 8) showed >10 mg/m^3. Investigation continued during dredging on 10/01/96 gave surface values higher than 10 mg/m^3 only at stations 1, 2 and 3. With regard to bottom waters all stations except station 7, 8 and 9 gave values higher than 20 mg/m^3 and peaked around the main dredging site (stations 4, 5, 6). Study conducted after dredging indicated that the surface waters regained the original status on the very next day (11/01/96). The bottom waters also showed similar tendency as that of surface waters except at station 2.

b) Chlorophyll b

Before dredging, in surface waters, the values of chlorophyll *b* was below detectable limits at some locations. In bottom waters it was around 5 mg/m^3.

During dredging, surface waters showed <10 mg/m^3 except at stations 2 and 4. In bottom waters, the content showed > 20 mg/m^3 except at stations 7, 8 and 9.

Table II. Number of organism per 0.05 m^2 before, during and after dredging.

	Before (09/01/96)									During (10/01/96)									After (11/01/96)								
Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Species																											
A. Polychaeta																											
Nephthys sp	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Neries sp	1	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Prionospio sp	45	–	1	–	–	–	–	–	–	–	4	–	–	2	–	–	–	–	1	–	–	–	–	1	4	3	–
Lumbriconeries sp	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	1	–	–	–	–	–	–	–	–
B. Crustaceans																											
Amphipod	1	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–
C. Nematodes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Total	47	–	1	–	–	1	–	–	–	–	4	5	–	4	–	–	–	–	2	–	–	1	–	1	6	4	–

Table III. Species diversity before, during and after dredging.

Stations	Before (09/01/96)	During (10/01/96)	After (11/01/96)
1	0.2	–	0.6
2	–	–	–
3	–	0.6	–
4	–	–	–
5	–	0.6	–
6	–	–	–
7	–	–	0.6
8	–	–	0.5
9	–	–	–

Both in surface and bottom waters, chlorophyll *b* gave peak values at station 2. After completion of dredging operations, the surface waters readily regained the conditions prior to dredging while bottom waters, particularly at stations 1 and 2, did not reach the ambient conditions prior to dredging.

c) Chlorophyll c

Chlorophyll *c* also showed a nearly similar tendency as that of chlorophyll *a*, but the values were found to be a little on the higher side than that of chlorophyll *b*. Before dredging on 09/01/96 the values generally showed the surface and bottom waters to contain <10 mg/m^3. During dredging, on 10/01/96, chlorophyll *c* in the surface waters, gradually increased and a peak was observed at station 2; but in bottom waters, values were above 30 mg/m^3 except at stations 8 and 9, followed by higher values at stations 2 and 5 (>120 mg/m^3). The observation after dredging indicated a decrease in values towards the riverine side.
The surface values were below detection limits except at stations 1 and 2. Bottom values showed content greater than >10 mg/m^3 except at stations 7, 8 and 9. The maximum value was observed at station 1.

The higher values of chlorophyll *a, b* and *c* in bottom waters may be a result of the introduction of benthic flora into those particular locations by the churning up action caused by dredging. The higher values in the surface waters may be a result of the influence of bottom waters moving towards the surface during dredging.

The increase of chlorophyll *a* supported by changes in nutrients may bring about higher productivity but this will not likely happen in reality owing to a decrease of light penetration caused by an increase in turbidity.

The other two types of pigments, namely chlorophyll *b* and *c*, exhibited increases during dredging time as compared to values prior to start and after stoppage. Established relationships between primary production and chlorophyll *a, b* and *c* are well documented elsewhere (Uye *et al.* 1987).

Bottom Fauna

The short-term impact on benthic fauna reveals that before dredging, polychaete was the dominant group (Tables II and III) especially at station 1 (45 Prionospio Sp was observed). At stations 3 and 6, single specimens of polychaete were noted. A total of 49 organisms were observed and the species diversity at station 1 was 0.21. At stations 2, 4, 5, 7, 8 and 9, no organisms

Figure 7. DCI Dredge V III at work in Cochin Port.

were observed. During dredging, the polychaete was the dominant group but much fewer organisms were detected; crustaceans ranked second.

No organisms were observed at stations 1, 4, 6, 7, 8 and 9 of the dredging locations. The species diversity was 0.69 at station 5 and 0.67 at station 3. The observations made on the next day of dredging (11/1/96) showed that polychaetes ranked first, followed by crustaceans and nematodes.

A higher number of organisms were observed at station 7 of the dredging site. A few more organisms also appeared at stations 1, 4, 6 and 8 of the study area. At other stations, no organisms were observed. The species diversity showed a higher value at station 1 followed by station 7 (0.64) and station 8 (0.56).

Conclusions

1. Based on the information presented in this article short-term dredging impacts indicate that immediately after dredging there is a likelihood of inhibition or reduction of bottom fauna. The abundance of bottom fauna otherwise is also controlled by many other biological factors and is species-selective as well. A drastic reduction of organisms belonging to the species Prionospio was observed. Another interesting result associated with aftermath of dredging was that the species diversity index increased compared to timings prior to and after desilting operations.

2. The other salient features relate to transient localised changes in turbidity, transparency and sediment textural characteristics. As regards nutrient content, certain forms of the life-supporting elements rapidly change whereas others are dominant. Of major significant are changes in the chlorophyll *a, b* and *c* contents which have a predominant influence on productivity in coastal estuarine water bodies – an increase of pigments supported by changes in nutrients may set forth a tendency for higher productivity, but this is counteracted by the decrease of light penetration caused by an increase in turbidity.

3. The positive aspects of studies of short-term impacts relate to the conductive excavation activities afforded maintenance forms of dredging at Cochin harbour. The short-term impacts also rule out the development of acute toxicity when dredged soil was excavated from within the harbour region.

4. Furthermore, the operations have been aesthetically clean, low noise and do not interfere with historical or archeological areas which are numbered but significant in Cochin.

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Charles W. Hummer, Jr.

Books/ Periodicals Reviewed

National Symposium of Contaminated Sediments: Coupling Risk Reduction with Sustainable Management and Reuse. Conference Proceedings 19. National Academy Press, Washington DC. 1999. Paperback, 144 pp, Appendices.

Transportation Research Board and National Research Council

These proceedings are an outgrowth of earlier studies and reports by the National Research Council on the issues, technologies and strategies to address contaminated sediments in the waters of the United States. The National Research Council is an arm of the National Academy of Sciences that is mandated to advise the US government on scientific and technical matters.

The first report in this field, *Dredging of Coastal Ports: An Assessment of the Issues,* was published in 1985. This was followed by other reports, such as *Contaminated Marine Sediments: Assessment and Remediation* (1989). Each study, symposium and report builds on the conclusions and recommendations of the previous studies. The NRC report, *Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies,* was published in March 1997 (see review in *Terra et Aqua,* nr. 73, December 1998) and the present report continues the discussions raised in that report.

The stated goal of the symposium which took place from May 27-29, 1998 was: "to engage stakeholders in a productive exchange of ideas and to foster a partnership for cooperative problem solving".

The symposium organised itself into a structure based upon the 1997 National Resource Council report cited above that focused on the following tasks:

- review, evaluation and ranking of sediment remediation technologies in terms of implementability, effectiveness, practicality and costs;
- aspects of project implementation, including source control, cost sharing, and beneficial uses of contaminated sediments; and
- use of a risk-based approach for improving decision-making, including the availability of decision-analysis.

The continuing deliberations of the National Research Council's Committee on Contaminated Marine Sediments formed the basis for this symposium and the committee's mandate was to:

- assess best management practices and emerging technologies for reducing adverse environmental impacts;
- appraise interim control measures for use at contaminated sediment sites;
- address ways to use and communicate information about risks, costs, and benefits to guide decision-making; and
- assess current knowledge and identify research needs for enhancing contaminated sediment remediation technology.

The symposium and the proceedings are organised to present the basis, discussion and recommendations emanating from the symposium. The Introduction covers a summary on the 1997 study report, followed by and overview of the report and the primary stakeholders response to the study report.

The next section addresses technologies and research and development beginning with case studies and summaries of break-out sessions. This section is followed by a discussion of decision-making which again uses case studies as a basis followed by a round-table discussion. A section entitled "Perspectives on Project Implementation" uses a panelist approach to present diverse issues, such as:

- beneficial uses of processed sediments;
- mining industry issues;
- environmental dredging;
- developing techniques for source control; and
- long-term monitoring.

The final section entitled, "Summation and Next Steps" is a synthesis of responses by the represented

stakeholders participating in this ambitious symposium.
It includes interesting responses from:
– Coastal Ocean Ports Perspective,
– Chemical Manufacturers Perspective,
– Forest Products Industry Perspective,
– Mining Perspective,
– Inland Waterways and Lakes Perspective, and
– Industry Response.

This final section is really a synthesis of the various stakeholders and their views of the problem, the impact of the National Research Council activities and the future actions that should be undertaken in this regard. It is valuable to see both the congruency and differences of these stakeholders.

The proceedings also include four Appendices:
– A: Conference Poster Displays and Exhibits
– B: Committee Member Biographical Information
– C: List of Conference Participants
– D: Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies – Executive Summary.

The report covers a wide variety of contemporary issues from the perspective of the major players. The fact that there remains a progressive participation of experts and stakeholders seeking solutions to the problems involving contaminated sediments is encouraging. The report serves as an excellent summary of the state-of-the-art and thinking of the key players in the United States and as such should be of interest on a global basis where the problem of contaminated sediments is ubiquitous.

The publication may be obtained from:
Transportation Research Board Business Office
National Research Council
2101 Constitution Avenue
Washington, D.C. 20418
Telephone: (212)-334-3214
Fax: (202)-334-2519
Email: TRBSales@nas.edu

Proceedings of the Western Dredging Association XIX Technical Conference and 31st Texas A&M Dredging Seminar, May 15-18, 1999, Louisville, Kentucky.
Published by Center for Dredging Studies, Ocean Engineering Program, Civil Engineering Department, Texas A&M University, College Station, Texas, USA. 1999. Paperback, 598 pp, illustrated.
Edited by Robert E. Randall, Ph.D., P.E.

The voluminous proceedings contain the technical papers presented at the WEDA XIX and 31st Texas A&M Seminar that are held in combination annually. The first eleven papers constitute the Texas A&M Seminar and the next twenty-eight papers comprise the WEDA Technical Conference portion of the proceedings.

The table of contents shows the papers in both sections of the proceedings with no further separation or distinction by subject matter. While it is fairly easy to browse the table of contents to determine the subject of each paper, it would have facilitated the use of the proceedings if they were organised by distinct subjects – as was the programme of the conferences. Papers relating to geotechnical, environmental, operational, management, beneficial uses, sediment characterisation and remediation are dispersed throughout the proceedings.

As is typical of the annual proceedings, the papers represent a wide spectrum of subjects, technical sophistication and emphasis. From a global point of view, the participation of presenters from outside the US increases the value of both the conference and the proceedings. Interestingly, papers from Delft University scientists dominated the Texas A&M portion of the proceedings.

Depending on the what is of interest to the reader, there are some excellent presentations. Most, but not all, of the papers include author-generated key words, that should make these proceedings more useful in terms of searching their inclusion in searchable databases. Although selecting one or two papers for specific reviews is not appropriate, suffice it to say that there are some excellent presentations on aspects related to beneficial uses, including clean and contaminated sediments.

These conferences resulted in the assembly of the first major literature in the dredging field over thirty years ago, and no technical library should be without a full collection of the proceedings from this annual conference series.

The proceedings may be obtained from:
Executive Director
Western Dredging Association
PO Box 5797
Vancouver, Washington 98668-5797 USA
tel.: +1 360 750 0209
email: WEDA@juno.com
or
Civil Engineering Department
Texas A&M University
College Station, TX 77843-3136
tel.: +1 409 845 4516
fax: +1 409 862 8162

Seminars/ Conferences/ Events

River Trans China 2000

Central China International Fair Center,
Wuhan, PR China
June 13-16 2000

The 2nd China Wuhan International River Transportation, Port & Shipbuilding Technology and Equipment Expo is being organised by the Chang Jiang River Transportation Administrative Bureau, an agency of the Ministry of Communication. The Chang Jiang (formerly Yangtze) river is the number one river in China and now ranks as the second largest economic region after the southeast coastal area. A plan from 1995-2010 for future development of the Chang Jiang area has been approved by the Wuhan Government. Its aim is to construct ports and channels, strengthen the support and maintenance systems as well as renew modern cargo ships in order to meet the needs of the national economy and social development.

The first exhibition was held in 1998 and was well attended by many European and Asian exhibitors.
This year's exhibits will include ports and channels engineering; ports communication systems; harbour and dock equipment; marine managment and engineering; and other related exhibits.

For more information please contact:
Ms Carmen Yeung, Managing Director
or Ms Michelle Lee
Units A&B, 14/F, Guangdong Tours Centre
18 Pennington St., Causeway Bay, Hong Kong
tel. +852 2881 5889, fax +852 2890 2657
email: tgrexpo@netvigator.com
http://www.together-expo.com

WEDA XX & TAMU 32

Crowne Plaza Hotel,
Warwick, Rhode Island, USA
June 25-28 2000

The Twentieth Western Dredging Association Annual Meeting and Conference and the Thirty-second Texas A&M University Dredging Seminar will be held simultaneously in June 2000 in Rhode Island. The theme of the conference is "Dredging Technology for the Millennium" and will be a forum amongst port and harbour authorities, agencies, users, dredging companies, environmentalists, consultants and academicians in this field.

A technical paper committee will review and select all submitted papers. In addition, "a student call for papers" has been issued to selected academic institutions asking students to submit abstracts. Four student papers will be selected, included in the conference papers and given a monetary reward.
An exhibition will also accompany the conference, and space is presently available.

For further information please contact:
Executive Director, WEDA, PO Box 5797,
Vancouver, WA 98668-5797 USA
tel. +1 360 750 0209, fax +1 360 750 1445
email: weda@juno.com

Sea: The Environment

Stadthalle Bremerhaven, Germany
July 6-9 2000

An international congress and Exhibition for maritime environmental protection entitled "Sea: The Environment" will be held in the Civic Centre in Bremerhaven. The main focus will be: ocean, ship and harbour technologies, non-polluting protective coatings, water and sewage technology, hazardous substances, air quality and emissions, waste managment, contaminated sediments, environmental analysis and management systems, logistics, renewable energies, and more.

For further information contact:
Prof. Dr Ing. Wilfried Schütz
Head of Institute of Environmental Technology
Umweltinstitut Silke Wiechmann
An der Karlstadt 6
D-27568 Bremerhaven, Germany
tel. +49 471 94 48 701
fax +49 471 94 48 722

BaltExpo-2000

Olivia Hall, Gdansk, Poland
September 5-8 2000

This 10th International Maritime Exhibition BaltExpo-2000 has established itself amongst Europe's leading exhibition in the maritime sector and has created a forum for Polish and foreign suppliers and end-user. The exhibit is sponsored the Polish President, Prime Minister and Minister of Transportation and Maritime Economy. Exhibits will include shipbuilding, repairs and conversion; euipment, manchiner and engines; communication, navigation and position; ports, services and terminals; cargo handling; offshore; pollution control and much more.

For further information please contact:
Agpol Promotion Ltd.
17, Śniadeckich Str.,
00-654 Warsaw, Poland
tel. +48 22 628 7295 or 628 7296
fax +48 22 625 23 98
email: agpol@pol.pl

Biuro Reklamy SA
9, Flory Str.,
00-586 Warsaw, Poland
tel. +48 22 849 6081 or 849 6006
fax +48 22 849 3584
email: BRSA@pol.pl

4th PIANC-PCDC Seminar

Buenos Aires, Argentina
November 20-24 2000

Camara Argentina de Consultores with the support of the Subsecretaria de Puertos y Vias Navegables and in cooperation with the Spanish National Section of PIANC is organising this seminar in Buenos Aires. Papers will be presented on inland waterways and shipping; capital and maintenance dredging; maritime ports and shipping, including port and channel planning, container and dry bulk terminals, and environmental and safety aspects; multi-modal transport, fishing ports and coastal zone managment. The seminar will be conducted in Spanish with simultaneous translation into English and vice versa.

For further information please contact:
PIANC Secretariat,
Graaf de Ferraris, 11éme ètage,
Boïte 3 Bld. Emile Jacqmain 156,
B-1000 Brussels, Belgium
tel. +32 2 553 7159 or 7160,
fax +32 2 553 71 55
email: navigation-aipcn-pianc@tornado.be
http://www.tornado.be/~navigation-aipcn-pianc

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 set 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 transport 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

For other countries:
Jane Blinkenberg, OI Americas
PGI/Spearhead, Spearhead Exhibitions Ltd,
Ocean House, 50 Kingston Road,
New Malden, Surrey KT3 3LZ, United Kingdom
tel. +44 181 949 9813 or 949 9222,
fax +44 181 949 8186
email: oiamericas@spearhead.co.uk
http://www.oiamericas.com

India International Maritime Expo (INMEX) 2001

Mumbai, India
October 10-13 2001

INMEX will provide an opportunity for overeas 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 present facilities the MoST has launched an ambitious plans for infrastructure development in the port sector, the shipbuilding industry and inland water transport, and private investments are being encouraged.

For further information contact:
INMEX Secretariat
Pradeep Deviah & Associates
Nor. 35, Gover Road, Cox Town,
Bangalore, India 560 005
tel. +91 80 548 4155/ 548 43898
fax +91 80 548 5214
email: pda@blr.vsnl.net.in

Call for Papers

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.

Prospective authors are requested to contact either the EADA or CEDA Secretariats. The deadline for the submission of draft manuscripts is September 1 and the final submission is February 1, 2001.

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

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

Dr. Ram K. Mohan (WEDA)
Gahagan & Bryant Associates, Inc.
9008-0 Yellow Brick Road
Baltimore, MD 21237 USA
tel. +1410 682 5595
fax +1410 682 2175
email: rkmohan@gba-inc.com

1st International Congress of Seas and Oceans

Szczecin Maritime University
Szczecin and Miedzyzdroje, Poland
September 18-23 2001

On behalf of the West Pomeranian University Rectors Conference this congress is being organised to exchange ideas and experiences in the field of sustainable use of maritime resources for the development of humanity.

The conference will take place in Szczecin, a port city on the river Odra, and important for the shipyard industry, and also in Miedzyzdroje, a seaside resort.

The following topics are within the scope of the congress:
– research of seas and oceans (waves, currents, chemical, biological and lithodynamic processes);
– oceans and seas as sources of food and energy;
– mineral resources under sea (including crude oil and natural gas);
– sea transport including waterways, ships, ports and port management;
– protection of the sea environment;
– seas and oceans for recreation and sports; and
– maritime policy of coastal states (legal aspects, organisation of maritime administration and rescue).

The congress is open to all interested parties. Parallel to the congress, an exhibition will be organised for national and international suppliers, contractors and consultants.

All enquiries about submission of papers or exhibition space should be addresssed to Seas and Oceans Congress Secretariat:
Dr inż. Jarosław Guziewicz
Wyższa Szkoła Morska
Ul. Wały Chrobrego 1/2
70 – 500 Szczecin, Poland
tel. +48 91 434 42 26, ext. 329
tel./fax +48 91 489 4003
email: icso@wsm.szczecin.pl
http://www.wsm.szczecin.pl

International Seminar on Dredging and Reclamation

Place: **Singapore**
Date: **October 9-13, 2000**

In cooperation with the National University of Singapore (NUS) and the Applied Research Corporation (ARC), International Association of Dredging Companies is pleased to organise, for the fifth time, an intensive, one-week seminar on dredging and reclamation.

The last course, held in February 1998, met with such enthusiastic response, that IADC, building on this success, has decided to present this seminar again in 2000. The costs are US$ 2950, which include six nights accommodation at the conference hotel, breakfast and lunch daily, one special participants dinner, and a general insurance for the week.

The seminar includes workshops and a site visit to a dredging project. Highlights of the programme are:

Day 1: **Why Dredging?**
The Need for Dredging/Project Phasing
Day 2: **What is Dredging?**
Dredging Equipment/Survey Systems (includes a Site Visit)
Day 3: **How Dredging?**
Dredging Projects
Day 4: **Preparation of Dredging Contract**
Day 5: **Cost/Pricing and Contracts**

Representatives of port authorities, companies, and individuals interested in attending are requested to complete the preliminary registration form below as soon as possible and prior to August 31, 2000, and return to:
IADC Secretariat, Duinweg 21,
2585 JV The Hague, The Netherlands
tel. +31 70 352 3334, fax +31 70 351 2654
e-mail: info@iadc-dredging.com

(please print)

Name ....
Title ....
Company ....
Address ....
....
Tel. .... Fax ....
E-mail ....

Please send this form and your deposit by cheque or credit card for US$ 500 in order to guarantee your place at the seminar. Upon receipt of this form and your deposit your place in the seminar is confirmed. We will then send you further detailed information, final registration forms, and an invoice for the correct amount.

Without your deposit we cannot guarantee your place and accommodations at the seminar.

- ☐ A Cheque is enclosed.
- ☐ Please charge my credit card:
- ☐ American Express ☐ Eurocard/Master Card ☐ VISA ☐ Diners Club

Account no.: | | | | | | | | | | | | | | | | | | |

Expiry date: | | | | | | |

Signature .... Date ....

Membership List IADC 2000

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

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Dredging International N.V., Singapore
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HAM East Asia Pacific Branch, Taipei, Taiwan
HAM Hong Kong Office, Wanchai, Hong Kong
HAM Philippines, Metro Manila, Philippines
HAM Singapore Branch, Singapore
HAM Thai Ltd., Bangkok, Thailand
Jan De Nul Singapore Pte. Ltd., Singapore
Mumbai Project Office, Mumbai, India
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Tideway DI Sdn. Bhd., Selangor, Malaysia
Van Oord ACZ B.V., Dhaka, Bangladesh
Van Oord ACZ B.V., Hong Kong
Van Oord ACZ B.V., Singapore
Van Oord ACZ Overseas B.V., Karachi, Pakistan
Zinkcon Marine Malaysia Sdn. Bhd., Kuala Lumpur, Malaysia
Zinkcon Marine Singapore Pte. Ltd., Singapore

Middle East
Boskalis Westminster Al Rushaid Ltd., Dhahran, Saudi Arabia
Boskalis Westminster M.E. Ltd., Abu Dhabi, UAE
Dredging International N.V., Middle East, Dubai
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
Van Oord ACZ Overseas BV., Abu Dhabi, UAE

Australia
Condreco Pty. Ltd., Milton, QLD., Australia
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
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

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