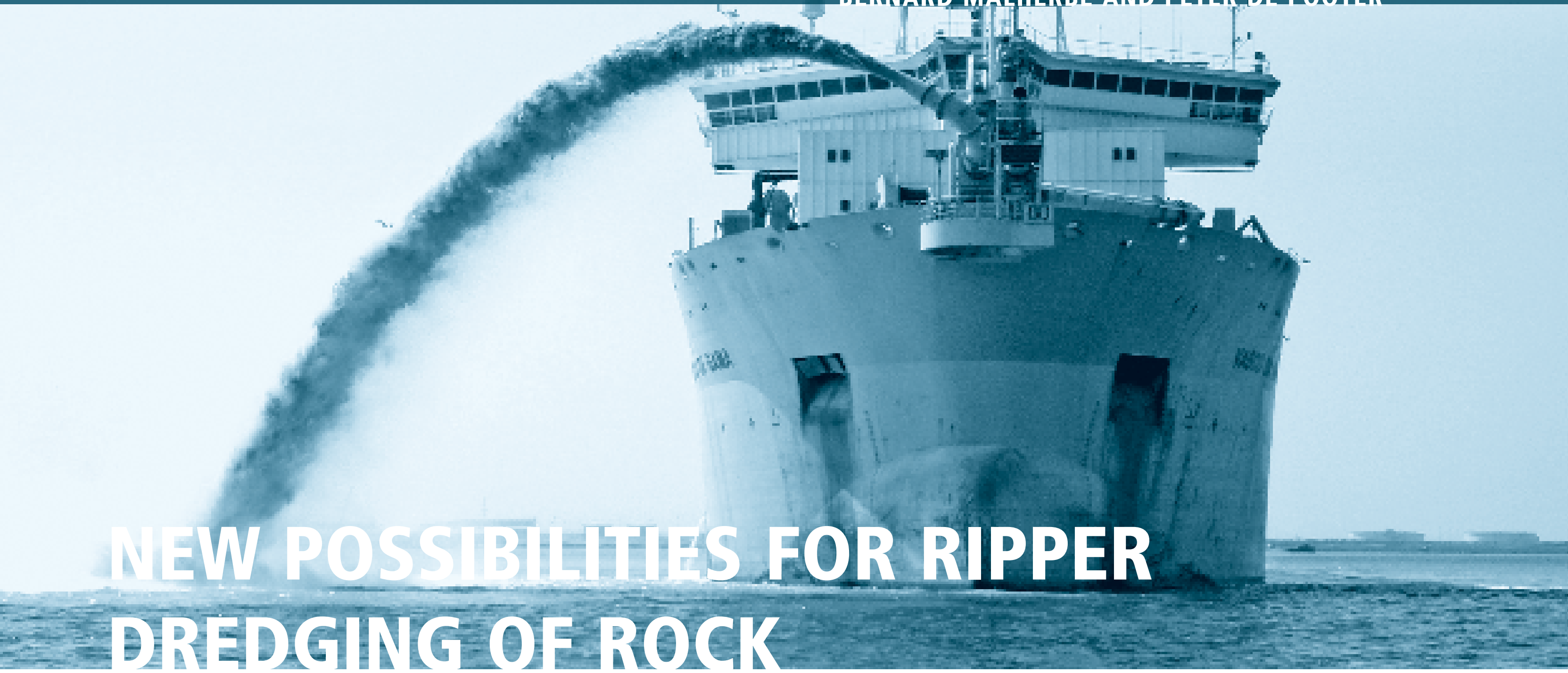
BERNARD MALHERBE AND PETER DE POOTER

NEW POSSIBILITIES FOR RIPPER DREDGING OF ROCK



Above, In order to ascertain the vessel's nautical safety above the coral reef, the TSHD *Vasco da Gama's* draught was kept below 8.6 m by rainbowing the dredged materials sidewards from the bow instead of loading inside the hopper.

ABSTRACT

Part of the Melut Basin Development Project at the Bashayer II Oil Export Terminal at Port Sudan – one of Sudan's most important ongoing economic development projects – was the dredging of a shore-approach trench trough in the coral-rich seabed at the Red Sea coast, for twin 36" oil export pipelines and 14" effluent pipeline.
The project was undertaken for the Petrodar Operating Company (JV CNPC, PCOSB/ Petronas, SUDAPET, AL-THANI) and the general EPC contractor was Peremba, INTEC, Sudan Pile Consortium (PISP).
The total length of 36" pipeline was twice 2,850 m and the length of 14" effluent pipeline was 1200 m. The trenching was CD – 0.5 m (at shore) to CD -49 m (at KP 0.980 m) of soil consisting of coral rock and coral debris with UCS between 2 and 12 MPa.

After unsuccessful trials by the EPC Contractor to open the trench in the steep slope of the coral reef with explosives, the decision was made to use trenching equipment. To achieve this, the backhoe dredger *Jerommeke* with rock bucket and the trailing suction hopper dredger *Vasco da Gama* with a new generation of ripper-draghead were brought into service.

INTRODUCTION

The joint company PETRODAR (PDOC) – a Joint Venture between China National Petroleum Company (CNPC), PETRONAS, SUDAPET and Al-Thani Corp. – awarded a general EPC (Engineering-Procurement-Construction) contract to PISP – a J.V. of PEREMBA SDN BMD (My) INTEC (US) and Sudan Pile (SU) – for the construction of the Bashayer II Oil Export Terminal at Port Sudan on the Red Sea Coast in Sudan (Figure 1). The Bashayer II OET is located approximately 40 km south of Port Sudan and is the terminal for the oil pipelines coming from the onshore Melut Basin Oil Field in southern Sudan. Both offshore pipelines with a total length of 2,850 m are connected to an offshore PLEM and SPM buoy for tanker loading; PLEM and SPM are anchored in water depths in excess of CD –50 m.

Very little soil information was available about the shore-approach seabed, and what scarce information there was showed the existence of a double-bump profile (see Figure 3). The first bump nearshore was documented by 3 boreholes as consisting of silty sand and clays at the very end of a coral reef. The drilling/corings at second bump further offshore at KP 0.650 to 0.950 indicated clay, soft clay, sand and coral debris [Ref 2].

The overall environment of the Red Sea coastline indicates a general presence of fringe-coral reefs. Jan De Nul therefore mentioned the likelihood of hidden coral reefs on both bump areas and a dedicated soil investigation was found necessary. According to the Operator and EPC Contractor [Ref 1], the coral-reefs, if any, were supposedly highly weathered and mainly loose. The EPC Contractor had already attempted to open the trench using explosives or a small cutter suction dredgers; both attempts were unsuccessful.

Because the project already suffered significant delays for various reasons, the Operator and the EPC Contractor decided to charter heavy-duty dredgers to open the pipeline-trench and to execute additional soil investigations just before the start of the works. There was no time left for additional geotechnical engineering and therefore, the

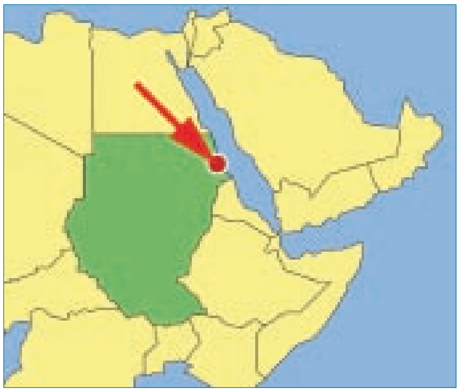


Figure 1. Location of Port Sudan situated on the Red Sea.

consortium PISP, represented by PEREMBA SDN BHD, decided to charter the 1.063 kW Backhoe Dredger (BHD) *Jerommeke* and the 37.060 kW Trailing Suction Hopper Dredger (TSHD) *Vasco da Gama* of Jan De Nul Dredging Ltd.

Because of the uncertainties about the exact soil conditions and characteristics before arrival of the vessel on site, Jan De Nul Dredging Ltd. strongly advised the EPC Contractor to adapt the design and dredge the deeper trench in the steep slope with a cut-&-fill profile instead with one of Jan De Nul Group's powerful seagoing rock cutter dredgers. However, the project team did not allow for any modifications in the design and the EPC Contractor, in the end, decided to attempt to dredge the trench with the *Vasco da Gama*.

Therefore Jan De Nul had to make a number of technical assumptions upon which the design of the rock-rippering draghead was to be based in order to maximise the chances of success. Assumptions were made about the strength of the coral, its homogeneity, the dynamic reaction forces, the wear and tear, the productivity, to

Figure 2. Coral blocks with size up to 2 m excavated by the backhoe dredger.

name a few. Furthermore the databases of previous works carried out in coral-dredging works were considered and several simulations were done.

Even with all the uncertainties mentioned above, the EPC Contractor declared that the execution of this work could not bear any further delays, that there was no time left to wait for results of the soil investigations (which were also delayed). The order was given to mobilise both dredgers and attempt to open the pipeline-trench by any and all means.

TRENCH DREDGING IN CORAL REEF 1 WITH A BACKHOE DREDGER

The BHD *Jerommeke* was transported from Dubai to Port Sudan on board the submersible barge DN 116, together with its assistance tug, a KRUPP 4000 hydraulic breakhammer, spare rock-buckets, and sufficient spare parts.

The trench bottom width was 12 m with side slope designed at 1 vertical and 3 horizontal. The average trench depth with respect to the adjacent seabed was 4 m. The natural seabed consisted of hard coral with an Unconfined Compressive Strength (UCS) between 2 and 4 MPa, coral debris and silty sand.

The trench-dredging of the Coral Reef 1, between KP 0.048 (at the shore) and KP 0.480 (water depth CD –18 m) was successfully executed with the 740 kW BHD *Jerommeke*. The dredged material was deposited to each side of the trench. The work was executed between August and October 2006.

During dredging, coral blocks of up to 2 m diameter were excavated (Figure 2). The trench was surveyed at regular intervals during execution in order to monitor the progress. These surveys indicated that the backhoe dredger achieved a constant and high productivity.

TRENCH DREDGING IN CORAL REEF 2 WITH A TRAILING SUCTION HOPPER DREDGER

The Coral Reef 2 was located between KP 0.610 (CD –19 m) and KP 0.980 (CD –49 m). The seabed consisted of a hard coral formation with coral blocks of more than 2 m in diameter and with UCS values between 8 and 12 MPa. The designed trench had a bottom width of 12 m, side slopes of 1 vertical and 3 horizontal and a trench depth (BOT) between 1 m and 17 m below original seabed as shown on the longitudinal profile in Figure 3. The target BOT depths of max CD –49 m excluded the use of a rock cutter suction dredger; the EPC Contractor therefore decided to have the trench dredged by a large trailing suction hopper dredger and, in that respect, selected the world's most powerful trailer.

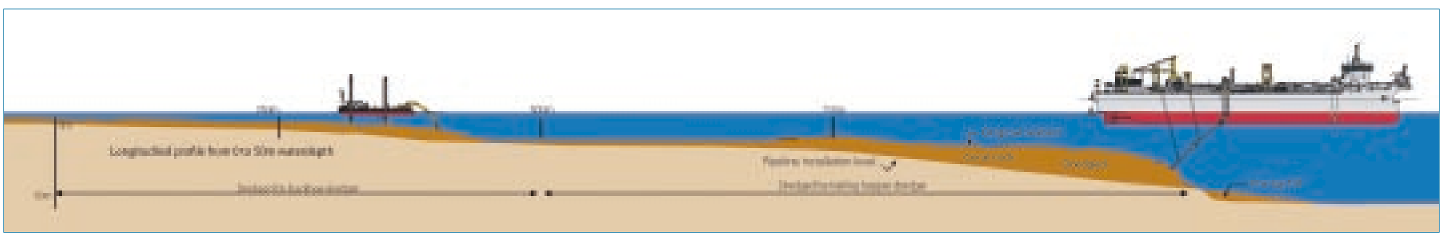


Figure 3. Longitudinal profile of the shore-approach trench (brown sections indicate the dredged section).

BERNARD MALHERBE
graduated in 1976 with a MSc in Geology at the University of Leuven (Belgium). In 1980 he completed his studies as a Master of Engineering Science in Geological Engineering at the École Nationale Supérieure de Géologie (France). He worked in the dredging industry for more than 20 years – for a contractor joint venture and as an engineering consultant – before joining the Jan De Nul Group in 2004. Since then he has been employed as Area Manager on many offshore projects. Presently he is Engineering Manager for project development.

PETER DE POOTER
graduated in 1990 with a MSc in Civil Engineering at the University of Ghent (Belgium). He worked in the engineering and construction industry for more than 10 years before joining the Jan De Nul Group in 2003. Since then he has been employed as Engineering Manager on the offshore project Sakhalin II in Sakhalin (Russia) and as Project Manager on several offshore projects. Presently he is working as Project Manager of the Manifa Field Causeway and Island Construction Project in Saudi Arabia.

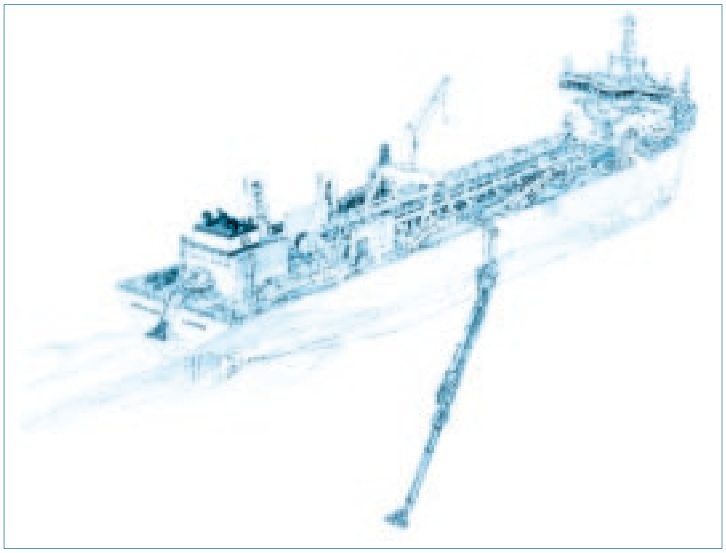


Figure 4. Artist's rendering of the *Vasco Da Gama* which has a maximum dredging depth of 135 m.

Consequently, the *Vasco da Gama* was selected and fitted with a specially modified draghead equipped with an adaptable number of ripper-teeth (Figure 4).
During this work, this heavy and solid rock-rippering draghead would prove its unique efficiency and flexibility. The extreme installed propulsion power of the *Vasco da Gama* (29,400 kW of a total installed 37,000 kW) ascertained a continuous and efficient operation and production, despite the fact that each dredging track commenced inshore with a ground-speed of 0 knots, because the ship is in fact going backwards. Moreover, the vessel was equipped with an onboard multibeam echo-sounder in its central moon-pool for continuous online monitoring the dredged profile by

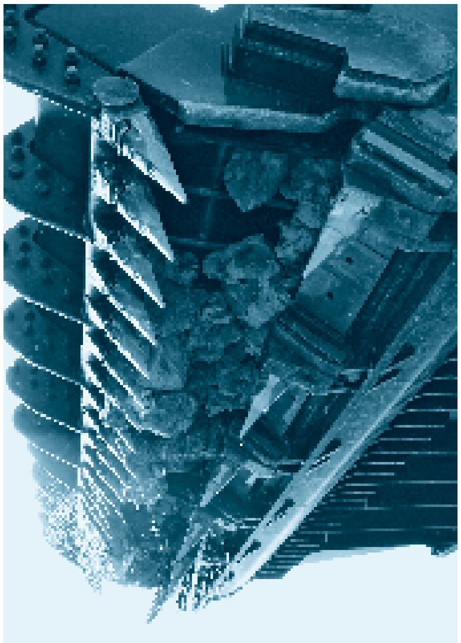


Figure 5. Ripper draghead with 1 m long ripper teeth.

the client and project team on board without having to wait for survey results. The ultimate generation of rock-rippering dragheads, developed by Jan De Nul for the *Vasco da Gama* weighs 60 tonnes, is 8 m wide and is fitted with 7 ripping-teeth (1 metre long) on the draghead's heel and 20 pick points on the draghead's visor (Figures 5 and 6). For security reasons in case of excessive ripping forces, a security-flange system with breaking bolts was installed at the draghead/suction-tube flange.

By the time the ship arrived on site in September 2006, new geotechnical investigations had been done and the cores indicated heterogeneous coral reef rocks over the full thickness of the reef: Unconfined Compressive Strength (UCS) values of up to 12 MPa of the coral rock

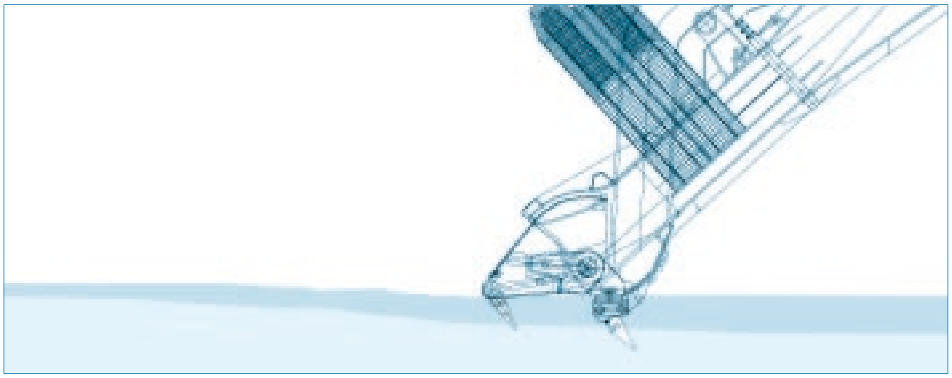


Figure 6. Drawing of draghead with ripper teeth on seabed.

were found. These values are extreme and never before in the history of trailing suction hopper dredging have such hard rocks been dredged; despite this, the EPC Contractor decided to proceed with the planned work-execution with the *Vasco da Gama*.

In order to ascertain the vessel's nautical safety above the coral reef, the dredger's draught was kept below 8.6 m by rain-bowing the dredged materials sidewards from the bow instead of loading inside the hopper. Trenching started at the end of September 2006 and was completed by mid November 2006. The trenching operation was executed by having the vessel navigated with stern towards shore, lowering the suction tube and trailing to the offshore end whilst dredging and ripping. At the end of each dredging track, the suction tube was hoisted and a new dredging cycle was executed. Dredging/ripping productivities ranged from 2,000 to 4,000 m³/day and a total of 140,000 m³ of soil was excavated and moved to achieve a cut-&-fill profile as shown on the longitudinal profile; approximately 75% of the excavated soil was dredged and side-casted. The other 25% were bull-dozed downhill the slope of the Reef 2.

This material consisted of coral blocks fragmented by the ripper teeth (Figure 7) and trailed toward the end of the slope. It showed to be stable rockfill for the pipeline foundation. The bearing capacity was tested by load test with the draghead compensation system. Ultimately, the EPC Contractor accepted the cut-&-fill trench profile executed based on the bearing capacity assessment, the free-span analysis and the pipeline stress-strain analysis.

Figure 7. Coral blocks removed from the ripper draghead.

MONITORING OF TRENCH PROFILE AND FREE-SPAN ANALYSIS

During the whole trenching operation, the trench and stockpile areas were monitored daily with multibeam echo-sounding surveys (Figure 8). This allowed both the dredging operators and the Client's representative to monitor the trenching operation.

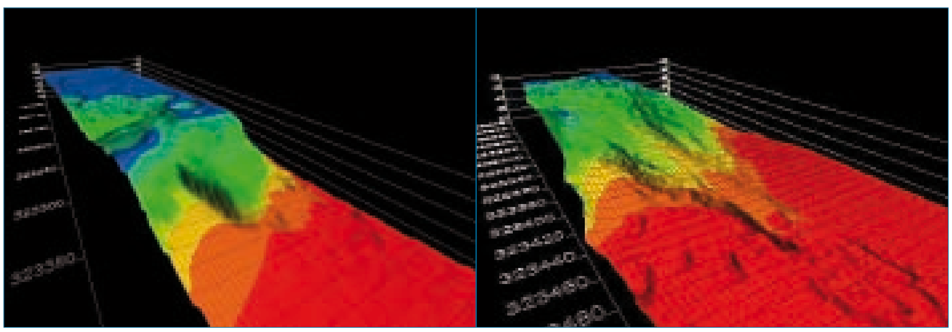


Figure 8. 3D view of the trench made through the coral reef survey result (Left: in-survey; Right: out-survey).

CONCLUSIONS

Too often insufficient attention is paid to geotechnics in engineering dredging works. In the Melut Basin Bashayer II project this was clearly the case. Despite this, the con-trolled dredging of an acceptable seabed profile in water depths up to 50 m and in hard coral rock was successfully completed.

The *Vasco da Gama*, equipped with a special modified ripper-teeth draghead has proven to be able to meet this challenge and pushed the limits of trailing suction dredger ever further. Coral rock in massive reef and blockformations with UCS values between 8 and 12 MPa was excavated successfully, thanks to a combination of the vessel's extremely high-installed power and this new generation of ripping drag-head. The work was executed in over less than half the time originally estimated for the Client.

REFERENCES

1. PISP report. *"Sudan Melut Basin Oil Terminal Development Project -EPC- Trenching and Dredging Specifications"* (ref MTF-PLN-SPN-0019 Rev A 24 Nov 2004).

2. FUGRO report for PISP. *"Geotechnical Investigations for the Melut Basin Oil Development Project"* (MTF-PLN-SP-0003, dd 4/03/2005).