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EDITORIAL

Last year the Fédération Internationale des Ingénieurs-Conseils (FIDIC) developed a new form of contract for the engineering industry. Now, in collaboration with the International Association of Dredging Companies (IADC), they have prepared a form of contract specifically for dredging and reclamation works (see Publication form insert). Also last year, the Rotterdam Public Works Engineering Department issued a book in Dutch aimed at explaining the importance of construction and survey accuracies. Now, with the support of the IADC, this book in an English edition entitled *Construction and Survey Accuracies, for the execution of dredging and stone dumping works* (see page 26) has been made available to a wider international audience.

Both publications demonstrate the important role the IADC has assumed as a driving force in bringing professional information to the industry. IADC stresses its support of the publication of literature pertinent to dredging – and its cooperation with sister organisations in the dredging industry – as part of its mission and will continue to seek opportunities to realise this.

This issue of *Terra* emphasizes the innovative spirit of the dredging industry. To begin with, take the expanding fleet of so-called “jumbo” trailers (which in the future may soon emerge as “mega” trailers with cargo capacity of 38,000 tonnes). These giant vessels facilitate the winning and transporting of sand at great distances far out at sea. Then there is also the increasing use of geotextiles as a means of sustainable construction work. Developed by a Dutch company and used primarily in the United States, they are now being successfully implemented in other parts of the world.

Such technologies demonstrate the energy and ingenuity that the dredging industry and IADC companies put into R&D. It shows their long-term dedication to leading the way in the construction of sustainable infrastructures. From land reclamation projects in the Far East to offshore projects in Eastern Europe, the need for capital dredging has shown remarkable growth in the last decade and it is clearly continuing. IADC member companies remain at the forefront of this expanding industry, always seeking new, economically viable solutions.

Robert van Gelder
President, IADC Board of Directors
Abstract

Since 1994 the dredging industry has seen a major change — the introduction of the “trailer jumbo” as it has come to be called. In that year the first trailing suction hopper dredger (trailer) with a hopper capacity of 17,000 m³ was launched, marking a 40% increase in capacity with the next largest trailer. Since then eight more of these huge new trailing suction hopper dredgers have been built and the process is continuing. With these “trailer jumbos”, dredging companies are leading the way in making gigantic infrastructure projects economically feasible. If dredging in the 20th century can be divided into three epochs, the first would be the opening of the Panama Canal in the early part of the century; the second, the enlargement of the Suez Canal in the 1950s; and the third is the ongoing land reclamation projects in Southeast Asia, which have been made feasible by the introduction of the Trailer Jumbos. This paper concerns itself with this last phenomenon.

Introduction

Not even the most optimistic mind could have imagined what was to happen. It all began one day in 1994, when a trailing suction hopper dredger (a trailer) with a hopper capacity of 17,000 m³ was launched in the dredging industry. At the time the largest hopper held 12,200 m³. The new trailer’s equipment capacity was 40% greater (Figure 1).

It did not seem to be the most appropriate time for such a great increase in capacity. The demand for dredging work was on the decline. The boom in activity resulting from the works in Hong Kong appeared to have peaked. The construction of the emblematic Chek Lap Kok Airport, which included 238 million cubic metres of dredging, seemed like a dream that would be difficult to repeat in the future of the dredging industry.

But once again the initiative of the dredging companies emerged as the driving force of change and development. In the following six years, eight more of these huge trailing suction hopper dredgers have been built. All together they cost the dredging companies over 870 million euros. And the process does not seem to be stopping.

Meanwhile, the market responded positively to these brave initiatives. At the same time as these large trailers were incorporated into the dredging industry, gigantic fill projects have been started around the world, especially in Southeast Asia.

Approximately 300 million cubic metres of material are being dredged and used for fill in the first three
stages of the “Reclamation of Jurong Island & Tuas Extension” project in Singapore. The following stages 4.1 and 4.2 have already been awarded and involve 260 and 540 million cubic metres of material respectively. To date, the Jurong & Tuas Project represents four and a half times the volume dredged for the mythical Chek Lap Kok Project.

Dredging in Hong Kong has also recovered its level of activity. Important land reclamation jobs have been tendered and awarded such as the “New Hong Kong Disneyland at Penny’s Bay” project with 100 million cubic metres of dredging and fill and the Containers Terminal No. 9 project with similar volumes.

It is only with these new large sized trailing suction hopper dredgers, which are being called “Trailer Jumbos”, that these gigantic infrastructure projects can be taken on under economically feasible conditions. These units are giving the most satisfactory response to the requirements of these projects.

There have been three essential moments for the international dredging industry in the twentieth century. The first was at the beginning of the century with the opening of the Panama Canal. The second was the enlargement of the Suez Canal in the 50’s. And the third great moment is occurring today with the land reclamation projects in Southeast Asia. The economic growth rates foreseen for the next few years indicate that the moment will be a lasting one.

Without a doubt, the “trailer jumbos” are the great protagonists of this last essential moment in the dredging industry, and they are therefore certainly worthy of attention and analysis.

**Table I: Basic data of average Trailers.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Hopper Capacity (m³)</th>
<th>Length (m)</th>
<th>Breadth (m)</th>
<th>Depth (m)</th>
<th>Draft Dredging (m)</th>
<th>DWT (t)</th>
<th>Total Installed Power (HP)</th>
<th>Normal Dredging Depth (m)</th>
<th>Dredging Depth With Extended Pipe (m)</th>
<th>Group Maximum Dredging Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMALL</td>
<td>1,500</td>
<td>75</td>
<td>13</td>
<td>5.5</td>
<td>4.5</td>
<td>1700</td>
<td>4500</td>
<td>-20</td>
<td>-25</td>
<td>-45</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>6,000</td>
<td>100</td>
<td>19</td>
<td>9.5</td>
<td>8.0</td>
<td>9000</td>
<td>14700</td>
<td>-25</td>
<td>-35</td>
<td>-50</td>
</tr>
<tr>
<td>LARGE</td>
<td>10,000</td>
<td>135</td>
<td>23</td>
<td>10.5</td>
<td>9.0</td>
<td>16500</td>
<td>17200</td>
<td>-35</td>
<td>-50</td>
<td>-78</td>
</tr>
<tr>
<td>JUMBO</td>
<td>20,000</td>
<td>160</td>
<td>30</td>
<td>13.0</td>
<td>11.0</td>
<td>30000</td>
<td>35000</td>
<td>-60</td>
<td>-100</td>
<td>-131</td>
</tr>
</tbody>
</table>
THE ARRIVAL OF THE JUMBOS IN THE FLEET OF TRAILERS

The arrival of the Jumbos in the dredging fleet had an enormous multiplying impact on the total hopper volume available on the market, especially in the large trailers group. It is well known that this type of dredger is ideal for extensive land reclamation projects located far from where the material is dredged.

Actually, in 1993 there were 18 units in the large trailer group, that is, with hoppers over 8,000 m³. The total combined capacity of this group was 164,200 m³.

Both of these aspects are reflected in Figure 3, that indicates the number of trailers existing in 1993 in each size group.

Figure 4 shows the total hopper capacity of each group. The capacities have been calculated by adding the volume of the hoppers of all the dredgers within each group.

From that year to the end of 2000, 41 new units have been added to the dredging fleet. Figure 5 shows the distribution of the sizes built, four large trailers and nine trailer jumbos.

Figure 6 gives the total combined hopper volume of the new trailers that have been built. It will be noted that the Jumbos represent only 22% of the units built but provide 58% of the 333,100 m³ combined hopper volume incorporated on the market.
The configuration of the fleet of trailers in 2000 is shown in Figures 7 and 8 — the first representing the number of units existing in each group, and the second, their combined capacities.

The total combined hopper volume existing in 1993 increased by 333,100 m³, of which 191,900 m³ corresponds to the Jumbos. While the total number of trailers only grew by a bare 18% in the mentioned period, the total capacity of the Fleet is 48% greater, having increased from 699,300 m³ to 1,032,400 m³.

These aspects can also be seen in Figure 9 that compares the fleets of trailers in 1993 and 2000.

The fleet’s capacity for large reclamation projects, that is, the trailers with hopper capacities over 8,000 m³, has grown spectacularly during these last six years. In fact, the addition of 13 trailer units to the 18 that existed in 1993 has multiplied the total capacity by 2.4, that is, from 164,200 to 397,900 m³. And this tremendous jump in capacity was mainly a result of the appearance of the Jumbos.

Figure 10 shows the innovation in large trailers as a result of the trailer Jumbos. This graph considers the larger sized dredgers that includes large size trailers and Jumbos. The trailers under construction or with firm order have also been included. There is a column for each dredger, all of which are listed in the margin. The nominal hopper capacity of each dredger is established on the Y-axis.

A distinction is also made between the trailers built before and after 1994. It is amazing to observe several facts:

- The first is the spectacular increase in the hopper volume of the first Trailer Jumbo that was built in 1994, Dredger no. 11 in the graph, in relation to the largest one that existed at the time, no. 17 in the graph.
- The second is the abrupt change in the growth tendency curve for the hopper volume in 1994.
- The last is the new change that occurred in 2000 with the construction and commissioning of a 33,000 m³ trailer. It seems that the era of the “Mega Trailers” is coming into sight.

The Fleet of Trailer Jumbos

Today, there are nine Jumbo trailers in operation. They are mentioned in Table II that also shows their most important general characteristics (Figures 11 and 12).
allows them perform the dredging and unloading activities quickly and to navigate at great speed, between 15.5 and 17.3 knots. These virtues make the Jumbos irreplaceable for jobs for which large amounts of material must be transported from an extraction point located at great distance from the final delivery site (between 30 and 100 miles).

2. The Jumbos have increased the possibilities of dredging in deep waters. In fact, they are all capable of dredging in depths of at least 60 metres. Most can work at 105 metres, the current limit.

Table III indicates the most significant specifications of the five trailers that are currently under construction or for which there is a firm order. It may very well be that when this article is published, some of them will have already been delivered (see Figures 13 and 14).

This data brings to light the three main characteristics that distinguish these units in dredging work:

1. The Jumbos have a tremendous load capacity, between 24,000 and 58,000 dwt. To this characteristic must be added the great engine power that allows them perform the dredging and unloading activities quickly and to navigate at great speed, between 15.5 and 17.3 knots. These virtues make the Jumbos irreplaceable for jobs for which large amounts of material must be transported from an extraction point located at great distance from the final delivery site (between 30 and 100 miles).

2. The Jumbos have increased the possibilities of dredging in deep waters. In fact, they are all capable of dredging in depths of at least 60 metres. Most can work at 105 metres, the current limit.
being 131 metres. This technical characteristic opens new horizons to the dredging world. Material can be extracted at great depths since this can be done in economically feasible conditions. It must also be pointed out that these dredgers that can work at greater depths cause a smaller impact on the environment than those that work in shallower waters.

3. Finally, the dimensions and ranges of these dredgers make them appropriate for working in the more severe wave, wind and current conditions than the largest of the dredgers of the previous generation. What’s more, the Jumbos have been progressively fit with other technical innovations over time that have made it possible to maintain the spirit of continuous improvement that prevails in the dredging industry.

**Innovations**

Noteworthy amongst these innovations are:

- The incorporation of new, powerful dredging pumps that are needed to dredge at great depths and pump at great distances in a minimum time.
- The improvements in the hopper’s overflow systems such as the flooded overflow installation that helps the dredged material to settle in the hopper.
- Direct reuse of the water from the overflow to feed the jet pumps of the draghead, improving the concentration of the dredged mix and reducing the loss from overflow.
- The improvement in the design of the dragheads, with the installation of high pressure jet systems of up to 6 kg/cm². These improvements make it possible to dredge more compact materials than the previous equipment could dredge with considerably more efficiency.
- As a result of the possibility of sand-dumping with the fall pipe, the material can be dumped at great depth in an exact spot only a short distance above the sea bed. This characteristic is very advantageous when, for example, marine outfall trenches must be covered or when material must be dumped on the bed without dispersing it or causing turbidity.
- The general improvements in the electronic, computer and communications systems in the

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**Table II. General characteristics of Jumbos.**

<table>
<thead>
<tr>
<th>Year built</th>
<th>Builder</th>
<th>Hopper capacity</th>
<th>Top coaming (cm)</th>
<th>Lightweight (tons)</th>
<th>dwt (tns)</th>
<th>Max.dredging Depth (m)</th>
<th>Length (m)</th>
<th>Breadth (m)</th>
<th>Draught loaded (m)</th>
<th>Speed loaded (knots)</th>
<th>Total installed Diesel capacity (kw)</th>
<th>Pump-room situation</th>
<th>Suction pipe diameter (mm)</th>
<th>Discharge pipe diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>stern</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearl</td>
<td>1994</td>
<td>17,000</td>
<td>10,112</td>
<td>24,746</td>
<td>60</td>
<td>144</td>
<td>75</td>
<td>28</td>
<td>10.4</td>
<td>16.0</td>
<td>19,061</td>
<td>stern</td>
<td>1,200</td>
<td>1,100</td>
</tr>
<tr>
<td>River</td>
<td>De Merwede</td>
<td>18,000</td>
<td>1,606</td>
<td>24,420</td>
<td>75</td>
<td>159</td>
<td>120</td>
<td>28</td>
<td>10.4</td>
<td>15.5</td>
<td>23,320</td>
<td>bow</td>
<td>1,100</td>
<td>1,000</td>
</tr>
<tr>
<td>WD Fairway</td>
<td>1997</td>
<td>23,347</td>
<td>15,950</td>
<td>32,068</td>
<td>112</td>
<td>172</td>
<td>120</td>
<td>32</td>
<td>11.5</td>
<td>16.8</td>
<td>27,567</td>
<td>bow</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Gerardus</td>
<td>Verolme</td>
<td>18,876</td>
<td>13,782</td>
<td>28,263</td>
<td>120</td>
<td>152</td>
<td>112</td>
<td>29</td>
<td>11.5</td>
<td>15.8</td>
<td>21,992</td>
<td>stern</td>
<td>1,200</td>
<td>1,100</td>
</tr>
<tr>
<td>Mercator</td>
<td>IHC</td>
<td>23,347</td>
<td>16,512</td>
<td>31,506</td>
<td>120</td>
<td>172</td>
<td>112</td>
<td>32</td>
<td>11.2</td>
<td>16.9</td>
<td>27,567</td>
<td>bow</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Queen of</td>
<td>Verolme</td>
<td>23,347</td>
<td>16,686</td>
<td>30,234</td>
<td>105</td>
<td>164</td>
<td>105</td>
<td>29</td>
<td>11.2</td>
<td>17.3</td>
<td>29,563</td>
<td>stern</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>the Netherlands</td>
<td>IHC</td>
<td>20,016</td>
<td>12,686</td>
<td>31,521</td>
<td>60</td>
<td>167</td>
<td>60</td>
<td>31</td>
<td>10.5</td>
<td>16.0</td>
<td>27,030</td>
<td>stern</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Terranova</td>
<td>IHC</td>
<td>20,000</td>
<td>10,700</td>
<td>24,250</td>
<td>110</td>
<td>144</td>
<td>110</td>
<td>28</td>
<td>10.4</td>
<td>16.0</td>
<td>21,116</td>
<td>stern</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Queen of</td>
<td>IHC</td>
<td>17,000</td>
<td>20,485</td>
<td>24,500</td>
<td>131</td>
<td>144</td>
<td>131</td>
<td>28</td>
<td>10.4</td>
<td>16.5</td>
<td>37,060</td>
<td>stern</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Penta-Ocean</td>
<td>IHC</td>
<td>34,350</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nile River</td>
<td>Krupp/Thyssen</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Vasco Gama</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>
automation of the dredgers and in monitoring the operations have given the dredging processes much greater precision and higher quality.
- The incorporation of the multibeam survey equipment on the suction pipe of the dredgers whereby the dredger itself does the control and follow-up soundings on the work at the same time as the dredging operations are being carried out.

**Design Characteristics**

When designing this type of ship, there are some design elements that have to be adjusted in accordance with the characteristics of the dredging work that the ship will have to carry out.

### Table III. General characteristics of Jumbos under construction

<table>
<thead>
<tr>
<th></th>
<th>HAM 318</th>
<th>Rotterdam</th>
<th>BN 320</th>
<th>BN 322</th>
<th>HAM 321</th>
</tr>
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<tbody>
<tr>
<td><strong>Year built</strong></td>
<td>2001</td>
<td>2001</td>
<td>2001</td>
<td>2002</td>
<td>2003</td>
</tr>
<tr>
<td><strong>Builder</strong></td>
<td>IHC</td>
<td>Van der Giessen</td>
<td>AESA</td>
<td>AESA</td>
<td>IHC</td>
</tr>
<tr>
<td><strong>Hopper capacity Top coaming (cm)</strong></td>
<td>23,700</td>
<td>21,500</td>
<td>16,500</td>
<td>16,500</td>
<td>23,700</td>
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<tr>
<td><strong>dwt (tns)</strong></td>
<td>36,450</td>
<td>38,000</td>
<td>25,900</td>
<td>25,900</td>
<td>36,450</td>
</tr>
<tr>
<td><strong>Max.dredging Depth (m)</strong></td>
<td>120</td>
<td>120</td>
<td>48</td>
<td>48</td>
<td>120</td>
</tr>
<tr>
<td><strong>Length (m)</strong></td>
<td>176</td>
<td>185</td>
<td>149</td>
<td>149</td>
<td>176</td>
</tr>
<tr>
<td><strong>Breadth (m)</strong></td>
<td>32</td>
<td>31</td>
<td>28</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td><strong>Draught loaded (m)</strong></td>
<td>12.0</td>
<td>11.3</td>
<td>11.0</td>
<td>11.0</td>
<td>12.0</td>
</tr>
<tr>
<td><strong>Speed loaded (knots)</strong></td>
<td>17.0</td>
<td>15.9</td>
<td>15.6</td>
<td>15.6</td>
<td>17.0</td>
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<tr>
<td><strong>Total installed Diesel capacity (kw)</strong></td>
<td>28,500</td>
<td>27,500</td>
<td>24,300</td>
<td>24,300</td>
<td>29,500</td>
</tr>
<tr>
<td><strong>Suction pipe diameter (mm)</strong></td>
<td>1,200</td>
<td>1,200</td>
<td>1,100</td>
<td>1,100</td>
<td>1,200</td>
</tr>
<tr>
<td><strong>Discharge pipe diameter (mm)</strong></td>
<td>1,200</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,200</td>
</tr>
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</table>

*Figure 11. Queen of the Netherlands (23,347 m³), launched in 1998, was part of the wave of jumbos built in the late 1990s. (Photo First)*

*Figure 12. Right, With a capacity of 34,350 m³, the Vasco da Gama is one of the largest and newest dredging vessels afloat.*
Hull design

Three aspects of the hull design were studied referring to the main body, the bow and the stern.

In the first place, the increase in the block coefficients of the hull of the Jumbo in relation to those of the trailers of the previous generation of dredgers should be mentioned. The main characteristic sought when first conceiving the trailer Jumbo was to increase the profitability of transporting material. This objective implied combining, on the one hand, a large load capacity and, on the other, a high operating speed both for extraction and unloading and for navigation. This second requirement made it necessary to fit the Jumbo dredgers with high powered engines in machinery, equipment and services. Consequently, the large load capacity and the weighty installed machinery implied an increase in the ship’s total displacement. But at the same time, the ship’s design required the least possible draught to allow dredging and above all dumping and pumping in shallow waters as this is necessary for land reclamation work.

Therefore, the significant increase in the ship’s total weight had to be made compatible with a shallow draught.

As an excessive increase in the length and beam was not advisable in order to be able to work in confined areas, the final design of the Jumbo dredger has resulted in hulls with a high block coefficient. These requirements also produced certain problems in the hull’s hydrodynamic design, especially in the ship’s stern. In fact, the low draught requirement made it necessary to define a propulsion unit based on propellers with relatively small diameters in relation to the ship’s displacement. Otherwise, hydrodynamic vibrations would be produced in the ship’s hull and cavitations in the propellers and nozzles. There would also be risk of the nozzles or rudders being damaged or breaking down. The solution of all of these problems has led to a hull design with a twin gondola escutcheon stern and without propeller shaft struts in the most recent Jumbos (Figure 15).

Finally, with respect to the bow, it was necessary to satisfy the need for a short length with respect to displacement. This requirement is based on the need to work in areas where the space for maneuvering is limited such as ports, marine basins, and so on. The result is the bulbous bow that most of the Jumbos have but which was not very usual in dredgers built before they appeared.

The bulbous bow improves the hull’s hydrodynamic behavior as well as the ship’s overall maneuverability.

Location of the pump room

The location of the pump room is an aspect that has affected the design of the dredger. As mentioned above, it was necessary to balance the need to take advantage of space to increase the volume of the hopper while maintaining the draught relatively low.

This led to considering the convenience of installing the pump room in the ship’s bow in order to optimise and increase the dead weight/length and dead weight/draught ratios.
than the fully diesel ones which means that they consume more fuel per power unit. This is a very important economic factor at this time when the cost of fuel is so high. But it has the advantage that they have a lower initial cost and less maintenance than a diesel drive.

As can be seen in Table II, neither of the two alternatives has prevailed although the individual dredging companies and ship designers seem to prefer one system or the other depending on what they are accustomed to working with.

To install the pump room in the bow required a diesel-electric drive for the pumps on board since the engine room was located in the stern. This drive has certain advantages such as a more progressive speed control for the pumps.

When the pump room is located in the stern of the dredger, the drive for the pumps is totally diesel in which case the need to use a gear-box makes it necessary to have only 2 or 3 operating speeds. The electric-diesel installations have lower efficiency than the fully diesel ones which means that they consume more fuel per power unit. This is a very important economic factor at this time when the cost of fuel is so high. But it has the advantage that they have a lower initial cost and less maintenance than a diesel drive.

As can be seen in Table II, neither of the two alternatives has prevailed although the individual dredging companies and ship designers seem to prefer one system or the other depending on what they are accustomed to working with.
The installed power
It is worth mentioning the great power installed to run the complex and numerous equipment of the trailer when compared with most other types of conventional ships with similar tonnage. To illustrate this fact, for comparative purposes only, let’s consider the conventional ship that is most like a trailer. Because of the type of load it transports, the bulkcarrier has been chosen.

Table IV reflects the average characteristics of a Jumbo with 30,000 dwt and the same characteristics of a bulkcarrier with the same dead weight.

Table IV also contains the characteristics of the Jumbo that currently has a greater dead weight. They are compared with those of a bulkcarrier of the same weight.

With respect to the total installed power, the difference is enormous: 29,563 Kw in the 30,000 dwt Jumbo and 8,000 Kw in the bulkcarrier of the same weight. The power/dwt ratio is 0.985 for the Jumbo and 0.267 for the bulkcarrier. These ratios demonstrate the importance of the equipment and machinery installed on the Jumbo in comparison with those of a conventional ship.

Conclusion: The Future of the Jumbos
To this point the impact of the trailer Jumbos on the dredging industry and its repercussion on the demand of infrastructure projects has been demonstrated. But what does the future hold for this type of dredger?

The forecast for the future seems to be optimistic. The contracts already awarded to dredging companies guarantee that these dredgers will be fully occupied for the next five years.

The importance of world trade continues to grow. In areas like Singapore, Hong Kong and South Korea, the economic growth in 2000 was over 8%, and long term projections continue to be positive.

Economic growth is often reflected in the movement of merchandise. And as long as marine traffic is the least expensive and most ecological means of transport – the latter being an aspect that is often forgotten – more wharves and deeper navigation channels will be required.

It will also be necessary to respond to the industrial development that will be produced by the economic growth. New locations in other less industrialised parts of the world will have to be found where the chemical and oil industries can be developed, such as is happening now in Jurong.

The possibility of moving airports from the cities out into the sea, as was done in Hong Kong, is being considered for other locations such as Amsterdam, Buenos Aires, Lisbon, Barcelona, to name a few, and some will certainly be realised.

The dredging industry is alert to all these phenomena. The five Jumbos currently under construction or firmly on order will undoubtedly be followed by others to meet the expectations for the future. Existing dredgers are presently being transformed to lengthen and increase the capacity of their hoppers. And so the era of the Mega Jumbo is about to dawn.

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Table IV. Comparison Jumbos/Bulkcarriers.

<table>
<thead>
<tr>
<th></th>
<th>Dwt tons</th>
<th>Length (Lm)</th>
<th>Width (Bm)</th>
<th>Depth (Dm)</th>
<th>Draught dredging mark (Tm)</th>
<th>Draught summer loan line (Ts m)</th>
<th>Total installed power (P Kw)</th>
<th>Propulsion free sailing (Ps Kw)</th>
<th>Speed loaded (V Knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulkcarrier 30,000</td>
<td>30,000</td>
<td>172.5</td>
<td>26.0</td>
<td>14.7</td>
<td>10.0</td>
<td>8,000</td>
<td>6,200</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Jumbo 30,000</td>
<td>30,000</td>
<td>162.0</td>
<td>29.0</td>
<td>12.8</td>
<td>11.2</td>
<td>9.6</td>
<td>29,563</td>
<td>22,680</td>
<td>17</td>
</tr>
<tr>
<td>Bulkcarrier 58,000</td>
<td>58,000</td>
<td>200.0</td>
<td>32.0</td>
<td>17.5</td>
<td>12.4</td>
<td>12.0</td>
<td>12,000</td>
<td>9,900</td>
<td>16</td>
</tr>
<tr>
<td>Jumbo 58,000</td>
<td>58,000</td>
<td>200.0</td>
<td>36.2</td>
<td>19.0</td>
<td>14.0</td>
<td>13.5</td>
<td>37,060</td>
<td>29,400</td>
<td>17</td>
</tr>
</tbody>
</table>
Gerardo M. E. Perillo, Jorge O. Pierini, Daniel E. Pérez and Eduardo A. Gómez

Suspended Sediment Circulation in Semi-enclosed Docks, Puerto Galván, Argentina

Abstract

The circulation pattern of two docks at Puerto Galván (Bahía Blanca Estuary, Argentina) have been studied in relation to dredging operations. Even though both docks have different designs, the study shows that they are prone to import material. During the measurements, a fluid mud layer at the docks and in the Canal Principal was first detected in the estuary.

The authors wish to thank the authorities of the Consorcio de Gestión del Puerto de Bahía Blanca (CGPBB) for the authorisation to use their data for the present article as well to its personnel for their support during the cruises and pre- and postprocessing of the information. Thanks go also to Mr Jurgen Nieuwenhoven and HAM Dredging for logistic support during the study.

Introduction

Puerto Galván (Figure 1) is one of the five harbours that form the Bahía Blanca Harbour System, the largest and deepest of Argentina. The harbours are all located along the Canal Principal of the Bahía Blanca Estuary, a mesotidal, coastal plain environment (Perillo, 1995) formed by a series of major NW-SE trending major channels separating extensive tidal flats, low salt marshes and islands. The geomorphology and physical characteristics of the estuary are described in detail elsewhere (Perillo and Piccolo, 1999) including a recent review of its major environmental features (Perillo et al., 2000).

Although the main economic activity of the harbour system is related to the export of agriculture products, especially grains, in recent years there has been a marked increase in the export of oil, gas and especially petrochemical derivatives. In 1989-90 a major dredging operation moved the nominal depth for the navigation channel and harbour sites to 13.8 m (45 ft), which stimulated an immediate increase in the economic activity of the harbours as larger vessels were allowed to enter into the system.

However, there are a series of sites both along the channel and at the harbours that require periodic maintenance. In particular, both Ingeniero White and Puerto Galván harbours have sites that are semi-enclosed and act as sediment traps. There is an estimate of 500,000 m³ of fine silt and clay that must removed annually from these sites by harbour authorities. Traditionally this operation is being done by hopper dredgers that then carry the material to different sites in the estuary for disposal.
During the year 2000, the company having the contract for the system maintenance suggested to the harbour authorities, Consorcio de Gestión del Puerto de Bahía Blanca (CGPBB), the use of a new dredging procedure for the semi-enclosed sites. This procedure is based on water injection into the bed sediments. As the sediments become fluidised, they move along a slope towards the deeper portions of the Canal Principal where, hopefully, the strong tidal currents may disperse them within a relatively short period of time.

Before any agreement could be reached for the change in operational procedure, the CGPBB decided to evaluate the operation of the dredger as well to assess a preliminary environmental impact that the dredger may produce into the estuarine environment. The tests were performed at two sites of Puerto Galván where 50,000 m³ of sediments were dredged in May 2000.

During the evaluation studies a series of interesting features of the circulation of suspended sediments and the presence of fluid mud, never before described for the estuary, were discovered. Therefore, the aim of the present article is to describe these processes and how they may induce an increased sedimentation within the sites independently of the dredging mechanism employed. No attempt will be made here to analyse the characteristics of the quality of the dredger used or the dredging operation.

Characteristics of the Study Area

Puerto Galván is located on the northern margin of the Canal Principal of the estuary (Figure 1). It comprises two docks (5 and 2/3) located to the east and west, respectively, of a wharf. All harbour operations are made along the wharf and the docks have maximum operational depths along it.

Dock 5 (to the east of the wharf) is closed for three sides and open only to the Canal Principal. It is approximately 600 m in length and 120 m wide at the mouth with maximum dredged depths of the order of 9 m. The operative maximum width, however, is about 80 m. The eastern shore of the dock was originally a tidal flat that was reclaimed during the 1989-90 dredging. Two major petrochemical plants are being built there but they have no access to the dock facility. Although no detailed study of the siltation rate of this dock was made, the values are quite large and require at least one or two maintenance dredgings per year. Bed sediments are silty clays with no traces of sand.

Dock 2/3 is also about 600 m in length and 120 m wide at the mouth, it continues further inland in the Galván tidal channel. Maximum dredged depths at this site are 12 m. The western border is formed by a low tidal flat that is fully covered by at least 0.5 m of...
currents (as well as depth of the instrument) were determined using an FSY 2D acoustic current meter with data gathered at 1 s interval while the equipment was slowly lowered and hoisted from the surface to the bottom and back. Simultaneously vertical profiles of conductivity, temperature and NTU were obtained in a similar way using an InterOcean MiniCTD fitted with a D&A optical backscatter sensor (OBS). The latter was calibrated in the laboratory using water samples collected during the cruises to obtain the suspended sediment concentration $C$. The conversion was linear and the correlation coefficient was 0.99. In all cases a complete profile took less than 5 minutes to complete even to the maximum depths of 17 m; therefore, all values were considered as they were taken simultaneously at time $t$.

Each station was occupied sequentially following the general methodology designed by Perillo and Piccolo (1993, 1998) to study residual circulation in estuarine cross-sections having only one set of instruments.

An average of 16 profiles per station was determined on each study period. Data was post processed and calibrated in the office by standard procedures to obtain vertical profiles of the different variables interpolated to non dimensional depths $z$ referred to the total depth of the station at the moment the profile was measured. For the present case, the discussion is only about the distributions of suspended sediment concentration...
C and fluxes ($F$) calculated by

$$F(z,t) = u(z,t) C(z,t)$$

where $u$ is the longitudinal component of the velocity estimated normal to the cross-section of the site. In most cases the transversal component ($v$) was relatively small and it will not be considered further.

**Results and Discussion**

Predredging conditions were evaluated by sampling three stations (Figure 2) on May 18, 2000. Tidal range during the study period was 3.68 m at the Ing. White tidal station which is about the mean tidal range for this part of the estuary. Current velocities at station 3 reached peak velocities of 0.66 m/s. Also, two side scan sonar profiles were made along the Canal Principal close to the entrance to the docks. A ribbon parallel to the channel 50-75 m wide of fluid mud (Figure 3a) is observed superimposed to the typical hard bottom of the channel. During this survey, there was no dual frequency echosounder to estimate the thickness of the layer. Although from the vertical profiles, done soon afterwards, the thickness was always less than 50 cm.

Suspended sediment concentration at Station 1 (Dock 5) during the tidal cycle and in almost all the water column was below 50 mg/l (Figure 4a) except for a resuspension event that occurred at the end of the ebb and beginning of the flood that increased the concentration to 400 mg/l. Some resuspension also occurred at max flood, but maximum concentrations were below 90 mg/l. Current velocities in this dock were always quite small (less than 0.25 m/s) which resulted in fluxes of suspended sediment in the same proportion. Although there are large periods of outward fluxes (Figure 4b), even during flood conditions, the net flux indicates that the dock is importing sediment and acts as a trap (Table I).

At Station 2 (Dock 2/3) concentrations were much smaller than the previous case (Figure 4c). Maximum SSC was 140 mg/l at high water slack at the beginning of the measurements and from then on, it was always below 50 mg/l. However, when the fluxes are analysed, they show a behaviour completely different to the one expected. As will be presented further on, the same circulation was observed in all three cruises, clearly indicating that this is the common behaviour at this dock. During the ebbing tide, the circulation and the resulting SS flux pattern was directed towards the inner dock, whereas during the flood stage, the circulation was reversed. The net flux is practically balanced (Table I).
During the first cruise (18/05/00) samples from only one station in the main channel (Figure 2) were taken. The concentration of SS for the area was typical for the estuary. In most of the tidal cycle and the water column, the SS was less than 30 mg/l with maximum of 65 mg/l (Figure 4e). Some resuspension events were observed, especially during flood. The net flux is also typical for the estuary which has a strong ebb-dominance (Perillo and Piccolo, 1999), especially on the northern part of the Canal Principal.

Measurements to control the dredger were made two days after the operations were initiated. By the start of these observations, the dredger had just finished the dredging the Dock 2/3 and started on Dock 5. Therefore, these data correspond to the two extremes of the operation as well as during the dredging. However, the study here covers only the circulation of SS and does not provide any analysis on the way it performed or the quality of the dredging. Due to the continuous operation of the dredger, no bathymetry nor side scan sonar surveys were made during this part of the study.

Figure 5 shows the location of the four stations employed in the study made on 26/05/00 as well as in the third cruise on 21/06/00. The same stations sampled at the Docks 5, 2/3 and the Canal Principal were repeated in the three occasions. For the last two cruises Station 4 on southern part of the Canal Principal was added to cover the conditions for the whole channel.

In Station 1 SS concentration increased at least tenfold in the water column and close to the bottom, maximum values reached 5200 mg/l during max flood (Figure 6a). Although it was expected owing to the dredging procedure, a fluid mud layer developed at the station after the dredger started its operation in the dock between 1 and 2 m thick. The data consider the maximum depth to normalise the information based on the depth at which SS concentration was greater than 7 gm/l. Current velocities were smaller than 0.37 m/s during this cruise at Station 1.

When analysing the SS fluxes for this station (Figure 6b) positive (exportation) values occur over 60% of the time, however, the import values are larger in magnitude. Thus the resulting condition for the dock, even though it was being dredged, shows a net flux inward even larger than in the first cruise.

At Station 2 max SS concentrations are observed just at the end of the dredging with values of 1400 mg/l (Figure 6c), about 10 times those from the previous

Table I. Tidal-integrated net suspended sediment flux (mg/cm² s) for each station and cruise. Positive values indicate a mouthward flux and vice versa.

<table>
<thead>
<tr>
<th>Station</th>
<th>Draga I 18/05/00</th>
<th>Draga II 26/05/00</th>
<th>Draga III 21/06/00</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dock 5</td>
<td>−662.01</td>
<td>−1232.03</td>
<td>7177.65</td>
</tr>
<tr>
<td>2 Dock 2/3</td>
<td>−30.44</td>
<td>9874.92</td>
<td>2484.74</td>
</tr>
<tr>
<td>3 C. Ppal. Norte</td>
<td>1872.30</td>
<td>−13051.30</td>
<td>257.36</td>
</tr>
<tr>
<td>4 C. Ppal. Sur</td>
<td>—</td>
<td>−13213.20</td>
<td>−2979.50</td>
</tr>
</tbody>
</table>
measurement. Although during ebb and at low water slack concentrations are minimal, during the flood concentrations reach above 1000 mg/l close to the surface.

It is evident that the dynamic processes in this dock are quite complex. Again the circulation pattern is reversed from the expected directions (Figure 6d). During ebb fluxes are negative (importing material) which may indicate that the sediment in the Canal Principal is forced into the dock at a larger velocities than the outflow. This may be owing to the effect of barrier produced by the wharf. From mid-ebb the SS flux becomes positive reaching maximum values in mid-flood. Although data gathered at one station alone do not allow a definite confirmation, the flow divergence at the tip of the wharf may induce flow separation and the formation of an eddy. If this is true, the eddy could produce an inverse flow that may explain the differences in the fluxes. Anyway, the net flux at this station is positive (Table I).

The stations at the Canal Principal show maximum concentrations of 500 to 900 mg/l during the dredging (Figures 6e and 6g). These values are between 10 and 15 times those observed in the first cruise. It is interesting to observe that the concentration stays approximately stable along the whole tidal cycle within the lower third of the water column which may be associated to the determinations of fluid mud detected during the measurements. During this stage, a fluid mud layer was expected as this material was produced by the dredger at the docks and driven into the deeper parts of the Canal by gravitational flow and helped by the currents.

When the fluxes at both stations are analysed (Figures 6f and 6h) the exportation (positive) and importation (negative) fluxes are clearly related to the ebb and flood parts of the tide, respectively. However, the magnitudes in both stations are also clearly different. Nevertheless, they both result in a net import flux of the order of ~13,000 mg/cm² s (Table I).

Figure 7 corresponds to the measurements made on June 21, 2000 at the same four stations described in the previous cruise. The hypothesis was that after about one month, the material deposited by the dredging operation at the Canal Principal should have been distributed along the estuary. One month was considered an adequate time separation based on preliminary unpublished calculations of the residence time for this part of the estuary that may be around 28 days. Because of the effects of the tidal flats that prevents the use of continuity, it is impossible to calculate precisely the residence times for most of the Bahia Blanca Estuary.

SS concentration at Station 1 (Figure 7a) appeared much higher than those observed during the first cruise and even during the dredging. Largest concentrations occur near the bottom and specially during high and low-water slack, although certain resuspension is detected, also close to the bottom, during flood. Combining the data gathered with a dual frequency echosounder while on station and the turbidity sensor, a fluid mud layer developed at the dock. Even though most thickness values were on the order of 1 m, in certain occasions up to 3 m of this layer was detected.

Flow velocities measured along the tidal cycle at Dock 5 were very low, rarely were they over 0.10 m/s, and occasionally reached 0.30 m/s. Therefore, the SS fluxes (Figure 7b) mostly reflect the distribution of SS with peak values coincident with the concentration peaks. The net flux appears, contrary to the previous cruises, exporting material (Table I). However, it is clear from Figure 7b that the largest exportation occurs very close to the bottom at the end of ebb which may indicate the flowing of the mud layer along the deeper portion of the dock towards the Canal Principal.

Dock 2/3 data shows homogeneous conditions (Figure 7c) with values below 50 mg/l in almost all the tidal cycle. There is only one exception of a resuspension event that occurred about 2 hours before high tide when the concentration reached over 3500 mg/l near the bottom associated to the only moment in which a 0.50 m thick layer of fluid mud was detected. Evidently, for this site, the presence of fluid mud may be restricted to small pools since it was detected only twice. Also with such low concentrations of SS, fluxes were also very low although the directions maintained the inversion described previously (Figure 7d). As in all previous measurements, the net flux was positive (Table I).
SS concentrations for Station 3 (Figure 7e) returned practically to the ones observed during the first cruise, with a peak value of 94 mg/l owing to a resuspension event related to the max ebb velocities. With respect to the fluxes of SS (Figure 7f), even though the peak values were registered near both high-water slack, this was owing to the higher SS concentrations in the water column. During the highest velocities, the larger fluxes occurred near the bottom. The net flux was very small and positive (Table I).

As a result of vessel traffic during the measurements period, Station 4 was located further south than the same station in the previous cruise. That may have implied that an indentation of the tidal flats may have induced a reduction on the velocities obtained at the station in comparison with those occurring on the middle of the channel. Nevertheless, this allowed the observation that this sector acts as a trap for the sediment. During this survey a much higher frequency in fluid mud data was detected (in 8 out of 12 profiles) with a thickness of the order of 1 m or less. Previous data from the same area (i.e., Piccolo and Perillo, 1990; Pérez and Perillo, 1998, Gómez et al., 1997) did not report fluid mud occurrences.

During the sampling, and considering only the water column above the fluid mud layer, maximum concentration occurred at high water slack (Figure 7g) with over 550 mg/l. The rest of the time up to the second high water slack, concentrations were lower than 50 mg/l. SS fluxes have peculiar characteristics owing to the fact that the station was located closer to the southern border of the channel and the effect of the indentation (Figure 7h). This is evident because the positive fluxes are limited to only one part of the ebb and particularly to the upper water column. Even a negative peak flux near the bottom at the beginning of ebb may indicate the possible development of a vortex due to flow separation. The net flux resulted in this case negative with almost –3,000 mg/cm² s.

**Conclusions**

The study included three cruises covering the conditions prior to, during and post-dredging of the harbour facilities. The results indicate, as was expected by the characteristics of the dredger, an increase from ten- to twenty-fold of the SS concentration from the initial values. However, after one month, the concentration returned to values approximately similar to normal for the area, although somewhat higher. The analysis of the SS fluxes show that both docks have circulation conditions that favour sediment deposition. In both cases, most of the net fluxes indicate sediment importation.

During the dredging and post-dredging stages, a fluid mud layer was detected in both docks and in the Canal Principal. This layer is much more developed in Dock 5 where it reached up to 3 m thick, although in most cases it was below 1 m. The presence of the fluid mud layer further favours sedimentation as turbulence is reduced as well as the capacity for the currents to resuspend the material available. Lack of or strongly reduced turbulence helps deposition of particles suspended near the bottom increasing the sedimentation rate in comparison with a bottom free of a fluid mud layer.
Figure 7. Depth vs time plots of SS concentration (a,c,e,g) and fluxes (b,d,f,h) of Draga III. I tidal curve during the measurements.

References


Geotubes as the Core of Guide Dams for Naviduct at Enkhuizen, The Netherlands

Abstract

Geotubes are being used in the construction of guide dams for the Naviduct at Enkhuizen in The Netherlands. These sausage-shaped sacks are made from geotextiles that are hydraulically filled with sand. They form the core of the dams and are then covered over with a layer of quarry stone. The system, developed by a Dutch company, was first used in the United States as a coastal defence. Compacting the sand into these geotubes enables the use of locally occurring sand that would otherwise be too fine. This makes a considerable contribution to sustainable construction work and constitutes a step forward in the use of innovative techniques in hydraulic engineering.

Introduction

The Krabbersgat Lock at Enkhuizen is an important bottleneck in the main network of waterways in The Netherlands. Owing to the increase in recreational shipping, waiting times at the locks can reach up to 3 hours in the peak season. Since the bridge needs to be raised for most vessels, long waiting times ensue for road traffic also. In the future, traffic on both water and road is expected to become even busier.

In order to deal with this bottleneck, the Department of Public Works for the IJsselmeer area has developed three solutions:

- the construction of an additional lock chamber alongside the existing Krabbersgat Lock;
- an aqueduct with a resistance channel on either side and with an underpass for traffic;
- the construction known as a “Naviduct”.

The last, the Naviduct, is a combination between an aqueduct and a lock whereby road traffic is diverted under the lock chamber via a tunnel. The Naviduct seemed to be the most favourable solution because the lock capacity was tripled as a result of it and traffic obstruction was reduced to a minimum. The new lock has two lock chambers while the former lock also remains in use for vessels that can pass beneath the bridge. The difference in height from the dike to the Naviduct is 17 metres for road traffic and approximately 15 metres for cyclists. The construction of the Naviduct makes soil available that can be used both for the construction of the guide dams and for the construction of peninsulas. These protect the Naviduct from drifting ice and are laid out as pre-shore zones with conservation areas.

After receiving his degree in civil engineering at the Technical University in Arnhem, Koos Spelt started at Baggermij Boskalis b.v., becoming chief surveyor and superintendent on several sandfill and dry-earth moving jobs near Rotterdam. He has worked in Nigeria (Port Harcourt), in Singapore, and was project manager in Kota Bahru, Malaysia. In 1992 he became project manager on several riverbed protection projects in Germany. In 1994 he was project manager on a pilot project to do environmental dredging with backhoes within 10 cm accuracy to clean up sand out of polluted sludge, using new dredging techniques with the environmental dredger Vecht on the highly polluted Ketelmeer. At the moment he is project manager on the Naviduct project in Enkhuizen, The Netherlands.

Koos Spelt
In designing the Naviduct (Figure 1), attempts have been made to make use as much as possible of the materials that are released. This contributes towards the principles of “sustainable construction work” as it lessens the need to transport building materials from elsewhere, and also provides savings in construction costs. The sand on site is not suitable for the raising of the guide dams, because it is of uniform grain size and too fine to withstand the wash of the Markermeer. For this reason, it was decided to use geosystems so that the sand, which becomes available can be utilised, even though it is too fine.

There is limited experience in The Netherlands in using these techniques. Experience has been gained in various projects using submerged components, such as geocontainers and relatively small “sand sausages”. Tests were also carried out on an experimental scale in the 1980s on filling some “sand sausages”. However, various large-scale projects have been carried out in the United States and the Far East.

For the Naviduct, the geotubes or “sand sausages” (cylindrically shaped geotextile bags) are filled with sand and are later covered with a surface layer of quarry stone. The materials resulting from the excavation of the lock chambers and the navigation access channels are used in the peninsulas, according to the principle of making local use of material. Class 2 material is placed on the bed and is covered with class 0 material.

The work was contracted out on 15 May 1998. Following negotiations, the Krabbersgat Lock Combination Naviduct (“Combinatie Naviduct Krabbersgatsluis”, CNK, was selected from thirteen tenderers). This combination makes use of the years of experience in geosystems of the subcontractor Van den Herik in Sliedrecht, as well as being the offer with the best price-quality ratio (Table I).

An extensive preparatory investigation was carried out by CNK, in the summer of 1999 because of the scale of the work and the innovative character of employing geosystems on this scale. As well as materials research, practice tests were undertaken on filling sand-sausage prototypes. It appeared from these that changes to the shape of the filling holes and the hydraulic properties of the geotextile were necessary. The geotextile became clogged as a result of congestion and natural filtrate build-up, bringing the filling of the sand sausage to a standstill. Instead of the prescribed pore size (O90) of 100 µm, a geotextile was used with an O90 of 250 µm. Experiments were also carried out using different types of stitched seams to make reliable joins.

A geotube or sand sausage is made from woven geotextiles. These are produced on looms in widths of 5 m to 5.20 m. The properties depend on the type of mater-
from the end of the tube. The geotextile properties depend on the sand used. As a rule of thumb \( O_{90} = 2 \times D_{50} \) of the sand. For sand sausages with a diameter of 3.92 m (circumference 12.30 m) and 105 m long, the geotextile’s tensile strength must be 100 kN/m.

**Execution**

Soil mechanics research was carried out in the preparatory phase. Seabed protection was incorporated subsequently. A new installation technique was employed instead of using traditional Dutch mattresses (Figures 2 and 3).

This technique involves the geotextile being put in place from a special pontoon using a roller system. The location is closely monitored to an accuracy of 10 cm using the Digital Global Position System (DGPS).

---

**Table I. Project data.**

<table>
<thead>
<tr>
<th>Project</th>
<th>Construction of the Enkhuizen Naviduct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Department of Public Works of the IJsselmeer area</td>
</tr>
<tr>
<td>Management</td>
<td>Construction Service of the Department of Public Works</td>
</tr>
<tr>
<td>Client</td>
<td>Krabbersgat Naviduct Combination (“Combinatie Naviduct Krabbersgat”)</td>
</tr>
<tr>
<td>composed of</td>
<td>VBK Hoorn bv, Van Laere nv (B) and Boskalis bv.</td>
</tr>
<tr>
<td>Start</td>
<td>1 April 1999</td>
</tr>
<tr>
<td>Completion</td>
<td>1 April 2003</td>
</tr>
</tbody>
</table>

Flexible, cylindrical filling hoses are attached to the top of the tube, with oval connectors for the correct distribution of the forces. The filling holes are fixed in a straight line on the top of the tube to prevent the tube from rolling during filling. The end of the tube is stitched up to close it. The first filling hole is at 7.5 m from the end of the tube. The geotextile properties depend on the sand used. As a rule of thumb \( O_{90} = 2 \times D_{50} \) of the sand. For sand sausages with a diameter of 3.92 m (circumference 12.30 m) and 105 m long, the geotextile’s tensile strength must be 100 kN/m.
During positioning, the 15 m wide geotextile is kept firmly on the bed by mechanical means using a pressure roller. Two crane ships sailing along together place a 10-60 kg layer of quarry stone on either side of the geotextile. Approximately 4000 m² of seabed protection is put in place daily in this way.

The pre-assembled folded packages have a length of 105 metres. No overlapping is necessary because the pieces of geotextile are sewn together on the pontoon.

To fix the geotubes, steel tubes are pushed into the soil in the longitudinal axis of the soil protection 5 metres apart. The geotubes are attached on the left and right to the steel tube using specially affixed loops. A settlement beacon is positioned every 105 metres to allow settlement of the subsoil to be monitored. The geotubes have a length of 105 m and diameter of 3.92 m. The filling holes are placed at intervals of 15 m. Filling is done using a light water-sand mixture of 2-5%.

When the geotube is under pressure the concentration is increased to 15%. The sand sausage is filled first to approximately 80 to 90% from one side and then from the other end. A number of filling holes are open during filling and the filling tube has a pressure relief valve to prevent pressure in the geotube from becoming too great and causing damage. A relatively open geotextile has been used for the geotubes in order to limit residual settlement. As a result of this, the finest fraction is washed away during filling to an extent of approximately 20%.

A geotextile is placed over the geotubes to give them additional protection from damage and UV radiation. A “catamaran” has been developed for this, consisting of two flat-bottomed barges joined together.

An unrolling mechanism is in place on top of this with which the geotextile is pulled over the geotubes. Immediately behind this, the geotextile is covered with quarry stone (gradation 10-60 kg) originating from Belgium. In the second phase, after settlement, the dam is given a final load of quarry stone (40-200 kg) originating from Belgium and Germany. Between 20 and 25 tonnes of quarry stone is used per running metre of guide dam (Table II).

**By-product Reclamation Work**

The material brought up from the trench and the access channels is sprayed into the pre-shore areas. In doing this, the contractor has laid out this area with a great degree of freedom. Experience was gained in the construction of pre-shore areas during the construction of the Ketelmeer depot. A temporary partition dam has been raised to enable work to progress quickly.
subdued, enabling the innermost dam to be constructed under good conditions as well. Since experience has been acquired in other projects on the construction of geotubes with much larger dimensions, this technique has perspectives to offer for future hydraulic engineering projects in The Netherlands. Working on the seabed in deep water can be made possible, irrespective of the weather conditions, through the development of special equipment and the construction of structures using geotubes. Furthermore, research into manufacturing techniques for continuous geotubes with greater dimensions may increase the efficiency and usability of these systems in large-scale (coastal) hydraulic engineering projects.

Table II. Material type, quantities, properties and origin.

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Properties</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/peat</td>
<td>900,000 m³</td>
<td></td>
<td>Houtribdijk</td>
</tr>
<tr>
<td>Geotextile (bed protection)</td>
<td>79,000 m²</td>
<td>Tensile strength</td>
<td>Amoco Fabrics, Gronau (G)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand density</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porosity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porosity</td>
<td>Ten Cate Nicolon</td>
</tr>
<tr>
<td>Geotextile (geotubes)</td>
<td>93,000 m²</td>
<td>Tensile strength</td>
<td>Amoco Fabrics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand density</td>
<td>Gronau (G)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porosity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porosity</td>
<td></td>
</tr>
<tr>
<td>Geotextile (sand-sausage protection)</td>
<td>60,253 m²</td>
<td>Tensile strength</td>
<td>Ten Cate Nicolon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand density</td>
<td>Amoco Fabrics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porosity</td>
<td>Gronau (G)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Porosity</td>
<td></td>
</tr>
<tr>
<td>Quarry stone 10-60 kg Bed protection + protection of the sand sausages</td>
<td>18,000 tonnes</td>
<td>Density 2,650 kg/m³</td>
<td>Sprimont, Galex, Cimescaut (B)</td>
</tr>
<tr>
<td>Quarry stone 40-200 kg Surface layer for guide dams</td>
<td>74,000 tonnes</td>
<td>Density 2,650 kg/m³</td>
<td>Cimescaut, Sprimont, Dulière, Marche le Dames (B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Density 2,700 kg/m³</td>
<td>Ochtendung (G)</td>
</tr>
</tbody>
</table>

Furthermore, the area has been artistically laid out, with flowing height variations and a series of artificial inlets. It is important that stagnant water does not occur and that the pools are connected to the water from the Markermeer. It is expected that seeds brought in by the water and the wind will germinate in the course of the summer and that the first pioneer vegetation will be visible at the end of summer.

Conclusions: Experience and Future Possibilities

From the experience gained from installing geotubes for the Naviduct, it would appear that these systems could be put to good use in The Netherlands. As so often happens with innovative techniques, experience was gained that had not been predicted in studies or in earlier projects. A geotube was filled on the construction site by way of a test to obtain a clear insight into the filling process of the geotubes. Behaviour will be researched and reported on the basis of video footage and an extensive measurements programme.

The construction process is less manageable, particularly in shallow water with large fetches. This has been solved in the Enkhuizen project by working in the lee of the floating equipment and by constructing the outermost dam first. The results were that the waves were subdued, enabling the innermost dam to be constructed under good conditions as well.

Since experience has been acquired in other projects on the construction of geotubes with much larger dimensions, this technique has perspectives to offer for future hydraulic engineering projects in The Netherlands. Working on the seabed in deep water can be made possible, irrespective of the weather conditions, through the development of special equipment and the construction of structures using geotubes. Furthermore, research into manufacturing techniques for continuous geotubes with greater dimensions may increase the efficiency and usability of these systems in large-scale (coastal) hydraulic engineering projects.
Management of River Basins and Dams: The Zambezi River Basin

M. J. Tumbare, Editor

This intriguing publication is a compendium of 37 technical papers; all relating to the Zambezi River Basin located in or adjacent to the African nations of Zambia, Zimbabwe, Botswana, Angola and Mozambique. The papers cover a very wide range of subjects, from dam safety, the Zambezi River Authority, hydroelectric schemes, environmental impacts, social impacts, bank stabilisation, water quality, hydrology, seismic activities, drought and food production, and multiple-use strategies. A review of the authors reveals that almost exclusive African technical expertise is presented. The papers are very well written, quite readable, and provide a wealth of information on the area and the river basin.

There is no preface or introduction that serves to give the reader a purpose or rationale for the publication. But a read of the papers leads one to believe that the papers are a result of a technical conference on the Zambezi River Basin. Almost all authors give acknowledgement to the Zambezi River Authority. Also lacking is the affiliation of the authors that would give some sense of their diversity and backgrounds. Nonetheless, the book does give the reader a wide appreciation for the geography, hydrology, political structures, and technical issues facing this rich developing region.

The Zambezi River Authority came into existence in 1987 as a successor to the Central African Power Corporation under the bi-national agreements of Zambia and Zimbabwe. The Authority provides engineering and maintenance of all works associated with Lake Kariba the Kariba Dam and other potential training works or dams along the Zambezi River. The Zambezi River originates at an elevation of 1400 metres in Zambia and flows for 2700 kilometres and enters the Indian Ocean in Mozambique. The watershed of the Zambezi River incorporates 1.3 million square kilometres and eight countries, seven of which claim riparian rights to the river. It is the fourth largest river in Africa and the largest in South Africa. One of the notable features along the river is the Victoria Falls.

The River Authority and its successful management and development of the waterway are evidence of the potential that collaborative efforts, which overcome nationalistic goals, can attain. Any consultancy, government or contractor that may wish to become involved in the waterways of Africa will find this book very useful and valuable.

No matter where the readers call home, they will likely find the paper, "The importance of politicians in water-related development programs," relevant to their own locales and situations.

This publication may be obtained from:
A.A. Balkema
PO Box 1675
3000 BR Rotterdam
The Netherlands or
A.A. Balkema Publishers
Old Post Road
Brookfield, Vermont 05036-9704 USA

Construction and Survey Accuracies, for the execution of dredging and stone dumping works
Rotterdam Public Works Engineering Dept., Port of Rotterdam, VBKO, IADC. Softbound. 47 pp. Illustrated. NLG 42.

CROW (Dredging, Shore and Bank Protection Works) Working Group, editors

Dredging, coastal and embankment protection works need to be carried out within certain accuracies and these requirements are usually specified in a contract.
The book covers the areas of:
- Construction accuracies for underwater excavations and for stone dumping;
- Survey accuracies during monitoring of underwater excavations and during monitoring of dumped stone;
- Possible consequences of construction and survey inaccuracies including:
  - functional failure of structures; and
  - contractual risks for contractors and principals.

The premise of this book is that specifications for these activities must remain realistic, and all parties must be aware of them. Systems for attaining a maximum degree of accuracy are offered and explained. For instance, “natural roughness” and “added roughness” are considered and linked with the type of dredging equipment used. The discharge behaviour of a side dumping vessel is analysed. The practical achievable vertical accuracies of various dredging equipment under various working circumstances are compared, as are the vertical accuracies for dumping stone with differing methods. Monitoring and surveying with single- and multi-beam systems are also discussed.

The conclusion is reached, and experience has shown, that uncertainties exist and errors will occur. The effects of these inaccuracies can be far reaching and disagreeable, and so it is important to consider these uncertainties in a reasoned and reasonable way. The central purpose of this publication is to present a balanced picture of dredging and stone dumping works and to help participants avoid unpleasant confrontations. It seeks to establish a code of conduct for drafting fair contract conditions for dredging and stone dumping works in an effort to avoid unnecessary controversy. For this reason, it is an invaluable tool for principals, contractors and specifications writers.

At the end of the book is a list of terms, definitions and abbreviations, and a “Selection table of sounding systems by survey area and nature of the survey”, as used by the Port of Rotterdam in June 1998. An extensive Bibliography (primarily, though not exclusively, Dutch references) concludes the book.

This publication can be ordered from the IADC Secretariat in The Hague.
Seminars/Conferences/Events

WEFA and Texas A&M University
33rd Annual Dredging Seminar & Exhibition
Wyndham Greenspoint Hotel, Houston, Texas, USA
June 24-28 2001

The conference is an opportunity for an exchange of thoughts by dredging contractors, ports, engineering services, environmentalists and environmental consultants, US Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), Fish and Wildlife Services and members of academia. It provides an opportunity to keep up with the changing Technology and Regulatory issues facing the dredging industry.

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

For further information please contact:
Larry Patella
WEDA Executive Offices
tel. +1 360 750 0209
e-mail: WEDA@juno.com

Coastal Zone 01
Cleveland, Ohio USA
July 15-19 2001

Cleveland is a Great Lakes coastal city and the conference will notably address coastal and ocean management concerns. It will feature important lessons learned by coastal managers around the world and models of successful partnerships such as that established in the Great Lakes, where two sovereign nations jointly manage water and living resources of this great “inland sea”.

The overriding theme will be to examine creative urban planning strategies, fiscal incentives, innovative policies and other techniques to hinder urban sprawl along ocean and inland coasts and to achieve instead “smart growth” in coastal communities.

For further information please contact:
Seas and Oceans Congress Secretariat
att: 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
www.wsm.szczecin.pl

1st International Congress of Seas and Oceans
Szczecin Maritime University
Szczecin and Międzyzdroje, 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 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. In addition, an exhibition will be organised for national and international suppliers, contractors and consultants.

For further information contact:
Jan Kucklick, NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, South Carolina 29405 USA
tel. +1 843 740 1279, fax +1 843 740 1313
email: Jan.Kucklick@noaa.gov
Indian International Maritime Expo
(INMEX) 2001
Mumbai (Bombay), India
October 10-13 2001

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

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

For further information contact:
INMEX Secretariat
Pradeep Deviah & Associates
Nor. 35, Gover Road, Cox Town,
Bangalore 560 005, India
tel. +91 80 54 84 155/ 54 84 389
fax +91 80 54 85 214
email: pda@blr.vsnl.net.in
Web: www.inmexindia.com

Ghent Environmental Geotechnics
University of Ghent, Belgium
October 29-31 2001

In cooperation with ISSMGE Technical Committee 5, Laboratory of Soil Mechanics, this specialty conference GEG 2001 will focus on underwater geoenvironmental issues. It aims to bridge the gap between current technological and engineering skills in underwater geoenvironmental issues and their corresponding academic and research state of knowledge.

The conference topics include: environmental dredging and related technologies, underwater ground improvements; in situ and off situ remediation of dredged material; (bio)chemical phenomena related to soft soil mechanics; land reclamation problems, waste ponds/tailings dams designs and case histories.

There will be a technical visit to observe the most advanced underwater geoenvironmental technologies used in the Antwerp area as well as some soil remediation facilities.
International Conference on Port and Maritime R&D and Technology

The Maritime and Port Authority of Singapore (MPA), the National University of Singapore (NUS), Nanyang Technological University (NTU) and Singapore Maritime Academy (SMA) have organised a conference to bring together researchers in the academic and research institutes, consultants and practitioners in the port and maritime industries.

The conference will cover port development, management and operations; coastal engineering; marine environment; innovative ship designs; and navigation and maritime training in the digital era. An exhibition featuring the latest R&D and technological products, systems and services will be held concurrently.

For further information please contact:
Ms Hui-Sian Jong, Conference Secretariat
c/o Professional Activities Centre,
National University of Singapore, 9 Engineering Drive
1 Blk EA#04-10, Singapore 117576
tel. +65 874 5113, fax +65 874 5113
email: icpmrdt@n7us.edu.sg
Web: www.mpa.gov.sg

Sea-Port 2001

This is Korea’s primary exhibition of international port, logistics and environmental technology, simultaneously held with KOMARINE and Naval & Defence under the umbrella of Marine Week 2001. The show is authorised by the Ministry of Commerce, Industry and Energy and the Ministry of Maritime Affairs and Fisheries. Top quality port-related industry products, logistics technology and environmental protection systems will be exhibited.

For further information please contact:
Sea-Port 2001 Show Management OfficeRm. 501,
Kumsan Bld., 17-1 Yoido-dong
Yongdeungpo-ku, Seoul 150-010, Korea
tel. +82 2 785 4771, fax +82 2 785 6117/8
email: kyungyon@netsgo.com

Europort 2001

The Europort Exhibition is one of the largest trade shows for the international marine industry and is held every two years in Amsterdam. Exhibitors include all branches of the maritime industry from shipbuilding, to suppliers of technical and safety equipment, port authorities, port management and development, offshore and dredging industries. Visitors come from all over the world and encompass a broad range of people in related industries, science, research, government and academia.

For further information please contact:
Mr Farouk Nefzi, Project Manager, Europort 200
Amsterdam RAI, PO Box 77777
Amsterdam, The Netherlands
tel. +31 20 549 1212, fax +33 1 20 546 44 69
email: europort@rai.nl
Web: www.europort.nl

CEDA Dredging Day 2001

"Dredging Seen; Perspectives, from the Outside Looking In" is the theme of this year’s Dredging Day which will be held during the Europort Exhibition. How do people and organisations from outside the dredging world look at dredging? Do they know what dredging is? And if they are aware, does it provide the services required? To explore these questions CEDA has invited notable speakers from outside the world of dredging to offer their perspectives.

CEDA is also holding a substantive programme, "The Academic Hour", in which university and college students and young faculty are asked to present their research on any matter related to dredging. In addition, CEDA has issued a “Call for a Dredging Song”. It is meant to be informative, evocative humourous or emotional, all in the spirit of good fun.

For further information please contact:
CEDA Secretariat, Anna Csiti
PO Box 488, 2600 AL Delft, The Netherlands
tel. +31 15 278 3145, fax +31 15 278 7104
email: ceda@dredging.org
Oceanology International 2002
ExCel, London, UK
March 5-8 2002

This is one of the largest and busiest international events in the global marine science and ocean technology fields. It has some 600 exhibitors and will attract thousands of trade visitors including policy makers, industrialists, government representatives, researchers, managers and manufacturers involved in all aspects of marine science.


For further information please contact:
PGI Spearhead Ltd.
Coombe Hill House, Beverley Way,
Raynes Park, London SW20 0AR, UK
tel. +44 208 949 9222
fax +44 2089 949 8186
www.oceanspace.net

30th PIANC Navigation Congress
Sydney, Australia
September 22-26 2002

The Organising Committee, under the auspices of PIANC and the Institution of Engineers, Australia, and with support from government, industry and academia, is presenting a conference which will focus on the following topics:

- How to guarantee sustainable navigation;
- Environmental issues, such as habitats, management of world heritage areas and stakeholder consensus;
- Policy issues, such as the role of public and private sectors in port development;
- Inland waterways transport including assessment of needs and technical and economic problems;
- Port issues, such as revitalisation and port planning and operations; and
- Issues related to ships and fairways.

For further information please visit the Australian Organising Committee homepage:
or contact:
PIANC, General Secretariat
Graaf de Ferrairis - 11th Flr.
20, Boulevard du Roi Albert II,
1000 Brussels, Belgium
tel. +32 2 553 7160, +32 2 553 7155
e-mail: info@pianc-aipcn.org
Web: www.pianc-aipcn.org

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Call for Papers

Oceanology International 2001
Singapole Expo,
December 4-6 2001

OI Pacific Rim 2001 provides a unique place to network with industry, academia, the R&D community and governments in Southeast Asia. Disciplines such as marine environmental sciences, survey and engineering, navigation and remote sensing, marine pollution monitoring and control, hydrography, dredging and coastal engineering, renewable energy and more are represented at the exhibition.

The exhibition is supported by an important conference with the theme "Science and Technology for Surveying, Evaluating and Protecting Marine Resources and the Environment". The National University of Singapore's Tropical Marine Science Institute will help coordinate the conference and keynote speakers.

The topics include:
– coastal oceanography
– marine information systems
– ballast water management
– coastal marine resource management

Abstracts of 200 words are invited for online submission at www.oceanologyinternational.com through Friday, June 29 2001. Topics outlined above are intended as a guide and are not exclusive. Acceptance notices will be issued at the beginning of August 2001.

For further information about the conference contact:
Angela Pederzolli
tel. +44 20 8949 98339
fax +44 20 8949 8186
email: angela.pederzolli@spearhead.co.uk
www.oceanologyinternational.com

COPRI Dredging ’02
Rosen Plaza Hotel,
Orlando, Florida USA
May 5-8 2002

Dredging ’02 organised by Coastal, Oceans, Ports, and Rivers Institute (COPRI) of the American Society of Civil Engineers, will focus on "Key Technologies for Global Prosperity". The economic impacts of dredging will be emphasised, in subjects such as:
– increasing costs of dredged material disposal;
– the necessity for deepening projects to maintain port viability; and
– benefit and cost considerations of dredging as a large-scale environmental remediation tool.

A wide range of other general topics, such as, beneficial uses of dredged materials, treatment of contaminated sediments, specialty dredging equipment, case studies of special dredging projects and so on are also of interest.

Abstracts should be no more than 400 words or two typed, double-spaced pages, and should be submitted electronically to: www.asce.org/conferences/dredging02.

Abstracts will be accepted through July 1, 2001 and will be considered for oral presentation or for display at a poster session. Authors will be notified of acceptance by September 1, 2001 with papers due by December 1, 2001.

In addition, the conference will feature an Exposition of the newestest technologies and services for dredging professionals.

For further information about technical programme and abstracts contact:
Stephen Garbaciak, Jr., P.E.
Technical Programme Chair
BBL, Inc., 200 S. Wacker Dr, Suite 3100
Chicago, IL 60606-5802
tel. +1 312 674 4937
dg@bbl-inc.com

For general information contact:
COPRI/ASCE Headquarters
Conference Department
1801 Alexander Bell Drive
Reston, VA 20191-4400
tel. +1 800 548 2723
fax +1 703 295 6144
d@asce.org
Membership List IADC 2001

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

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Boskalis South Africa (Pty.) Ltd., Cape Town, South Africa
Boskalis Toyo Sarl., Leuven, Tokyo
Boskalis Westminster Cameroun Sarl., Douala, Cameroon
Dredging International Services Nigeria Ltd., Lagos, Nigeria
HAM Dredging (Nigeria) Ltd., Lagos, Nigeria
Nigerian Westminster Dredging and Marine Ltd., Lagos, Nigeria

The Americas
ACZ Marine Contractors Ltd., Brampton, Ont., Canada
Beaver Dredging Company Ltd., Calgary, Alta., Canada
Draagmen S.A. de CV, Coatzacoalco, Mexico
Gulf Coast Trailing Company, New Orleans, LA, USA
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HAM Dredging Canaré, Caraguati, NA
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Stuyvesant Dredging Company, Metairie, LA, USA
Usco, Wilmington, DE, USA

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Ballast Nedam Dredging, Hong Kong Branch, Hong Kong
Boskalis International BV., Hong Kong
Boskalis International Far East, Singapore
Boskalis Taiwan Ltd., Hualien, Taiwan
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Dredging International N.V., Singapore
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HAM Singapore Branch, Singapore
HAM Thai Ltd., Bangkok, Thailand
Jan De Nul S.A.P.T. Ltd., Singapore
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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 Rushaih Ltd., Dhuhran, Saudi Arabia
Boskalis Westminster M.E. Ltd., Abu Dhabi, UAE
Dredging International N.V., Middle East, Dubai
Dredging International N.V., Teheran Branch, Teheran, Iran
Gulf Cobia (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 B.V., 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 Ingenieur & Entrepreneurs A/S, Copenhagen, Denmark
Anglo-Dutch Dredging Company Ltd., Beaconsfield, United Kingdom
HAM A/S Jebens ACZ, Bergen, Norway
Atlantique Dragage S.A., Nantes, France
Baggermaatschappij Boskalis B.V., Papendrecht, Netherlands
Baggermaatschappij Bremenbocht B.V., Rotterdam, Netherlands
Ballast Nedam Bau- und Bugger GmbH, Hamburg, Germany
Ballast Nedam Dredging, Zeist, Netherlands
Ballast Nedam Dragage, Paris, France
Boskalis Dolfm B.V., Dordrecht, Netherlands
Boskalis International B.V., Papendrecht, Netherlands
Boskalis B.V., Rotterdam, Netherlands
Boskalis Westminster Annecy, France
Boskalis Westminster Dredging B.V., Papendrecht, Netherlands
Boskalis Westminster Dredging & Contracting Ltd., Cyprus
Boskalis Zinkcon B.V., Papendrecht, Netherlands
Brewa Waterbedrijfsscheepen Bremen mbH, Bremen, Germany
CEI Construcciones N.V., Afdeling Bagger- en Grondwerken, Zele, Belgium
Delta G.m.b.h., Bremen, Germany
Dragflumar SA., Neiveille Les Dieppe, France
Dragados y Construcciones S.A., Madrid, Spain
Draavo S.A., Madrid, Spain
Dredging International N.V., Madrid, Spain
Dredging International N.V., Zwijndrecht, Belgium
Dredging International Scandinavia AB, Copenhagen, Denmark
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 Niederlagen und Tiefbaus GmbH, Wilhelmshaven, Germany
N.V. Baggerwerken Decloud & Zoon, Brussels, Belgium
S.A. Oversees Declouet & Fils, Brussels, Belgium
Sider-Almagià S.p.A., Rome, Italy
Skanska Dredging AB, Gothenborg, Sweden
Sociedade Portuguesa de Dragagens Ltda., Lisbon, Portugal
Sociedad Española de Dragados SA., Madrid, Spain
Società Italiana Dragaggi SPA “SIDRA”, Rome, Italy
Société de Dragage International “S.D.I.” S.A., Marly le Roi, France
Sodranord SARL, Paris, France
Terramare Oy, Helsinki, Finland
Tideway B.V., Breda, Netherlands
Van Oord ACZ B.V., Gorumchem, Netherlands
Van Oord ACZ Ltd., Newbury, United Kingdom
Wasserauffahrt AG, Bremen, Germany
Westminster Dredging Co. Ltd., Fareham, United Kingdom
Zasun Verstoept B.V., Papendrecht, Netherlands
Zinkcon Contractors Ltd., Fareham, United Kingdom
Zinkcon Dekker B.V., Rotterdam, Netherlands
Zinkcon Dekker Waterbedrijf B.V., Bremen, Germany