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The effective development of offshore aggregates in south-east Asia – summary report

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The effective development of offshore aggregates in south-east Asia – summary report

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Front cover illustration: Pearl Estuary sand barged for use on Central Reclamation, Hong Kong (photo: Ian Selby)

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1 OFFSHORE AGGREGATES: EXECUTIVE SUMMARY

The recent and continuing growth of coastal cities in SE Asia has resulted in a major expansion in construction and strong demand for aggregates for building, roadstone and land reclamation. This demand has been met previously by land-based supplies, but in recent years offshore aggregates have made an increasingly important contribution. Primary aggregates in this report are defined as natural sands and gravels.

The growth of cities has increased pressure for development land that cannot be satisfied by the available stock because of conflicting demands, and or, because of the nature of the terrain. This pressure has forced developers to look offshore to produce new land by reclamation from the sea, or by raising low-lying ground. Offshore aggregates have usually provided the fill material for these type of developments.

Aims of Report

- Provide guidelines for planning and execution of offshore aggregate resource surveys
- Encourage adoption of long-term planning, surveying and monitoring methods
- Encourage environmentally sensitive and sustainable methods of offshore sand and gravel extraction

The main report (James and others, 1999) sets out the methodology, licencing and monitoring commonly adopted across NW Europe, Hong Kong and elsewhere for the location and extraction of offshore aggregate, and focuses on:

- the location and geological setting of aggregate deposits, with the aim of providing a better appreciation of the geometry of the deposits and effective and economic extraction plans
- the licencing and monitoring of aggregate extraction.

The status of marine aggregate extraction across SE Asia is outlined, with a brief examination of the geological setting of areas of major extraction. These include the tidal sand banks in the Yellow Sea, and off the west coast of Korea; the tidal incised channels between the islands south of Singapore; and the range of settings in Hong Kong waters. Offshore aggregate deposits are found within a well-defined range of marine environments. Channels cut during the lowstand in sea level some 18 000 years ago, and now infilled with sediment, are a common location for a resource body, but the geometry of the infilling sedimentary units may be complex. Sand banks and sheets laid down when sea level was rising some 10 000 to 5 000 years ago, and no longer mobile in the modern tidal regime (moribund deposits) are important sources in NW European waters. Sand sheets, sand waves and sand banks, active or mobile under modern conditions are also important sources. With the latter an appreciation of tidal sediment transport processes helps in understanding where such deposits may occur, and the possible effect of dredging such deposits on the surrounding region.

Aggregates have a range of uses, and each use has a defined aggregate specification (see appendices in main report), in terms of particle grain size and mineral composition. The fines and chloride content of "coarse aggregate" and concrete sand need to be low, and no minerals included should be likely to induce alkali silica reaction. Fill material is normally placed in large volumes and a major requirement is rapid draining and limited settlement after placement. The particle size specified for aggregate to be used for beach renourishment is tightly constrained, as the sediment is commonly required to be of the same gain size and appearance as the original beach.
Surveys for offshore aggregate resources begin with a desk study to assess the seabed morphology, local geology and possible offshore channels, and an appreciation of the modern tidal and wave regime of the region. This is followed by a reconnaissance survey using geophysical techniques, seismic reflection profiling, side-scan sonar, and echo sounder, and sampling, using grabs, vibrocoring and rotary drilling. The reconnaissance survey identifies possible resource areas, and would be followed by a prospecting survey collecting a greater density of data.

The geophysical and sampling data are used to create a geological model of the resource body, focussing on the physical form of the aggregate resource. An extraction plan is devised from this model taking into consideration factors such as, the volume of material to be extracted, the water depth at the site, the available dredgers, the location and facilities at the landing site, and any environmental restrictions. Most large modern dredgers are limited to working in depths of less than 50m (below sea surface) although some are currently being built to dredge at 120 m. Where large
volumes are being extracted, for use as fill material, large trailing suction hopper dredgers (TSHD) are preferred, and the specification of the dredged material may be relatively broad. However, where the aggregate is to be used as a construction material the required specification may be tighter, and greater care is needed in ensuring that the dredged material meets the specification.

Offshore dredging disrupts the sea bed and has the potential to affect the sea bed further afield from the dredging site and to change the regional hydrodynamic conditions. Because of these possible environmental impacts, offshore dredging is usually subject to control and licencing by national or local government. The licence terms and procedures vary in detail from country to country and a range of examples from around the world are included. In all cases a full description of the area to be dredged, volumes involved and possible environmental consequences need to be included in an environmental impact assessment (EIA) before a licence is issued. Such licences are commonly issued for a set time period with a stipulated volume of aggregate to be dredged. The report lists the factors to be considered when carrying out an EIA.

<table>
<thead>
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<th>Primary uses of offshore aggregate (sand and gravel)</th>
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<tr>
<td>• Building and concreting sand and gravel</td>
</tr>
<tr>
<td>• Base material and asphalt for road construction</td>
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</table>

Offshore dredging has the potential to change the hydrodynamic conditions at the adjacent coast. This is usually due to the excavation created by the dredging possibly leading to an increase and change in focus of wave energy impinging on the coast. Approaches to assess such effects are discussed, and in most cases if the dredging is in water depths in excess of 20m, and greater than a few kilometres from the coast, such effects are likely to be minimal.

An increasingly important aspect of the dredging operation is the monitoring of activity as it proceeds, with in some conditions a stipulation for such monitoring to continue for a number of years after dredging has ceased. Such monitoring would check, for example, whether the dredging remained within the licencing conditions by checking that the dredging depth limits were not exceeded, whether the suspended sediment plume generated by the dredging was not larger than predicted. In the UK the position of dredging vessels is monitored continuously while actively dredging.

The report uses a number of examples taken from NW Europe and Hong Kong to demonstrate the geological settings at a number of licenced areas. Sand banks off the UK are given as examples of dredging in shallow water very close to the coast which have raised environmental concerns. Extensive monitoring is taking place to identify possible changes in bank form or increased erosion along the adjacent coast that might be due to dredging. Dredged infilled channels are described from east of the Isle of Wight and sand and gravel sheets from off East Anglia. In most cases in the UK offshore aggregate is used for construction or beach recharge. Hong Kong borrow areas include infilled channels, sand banks and sand sheets and most this material has been used as reclamation fill. The examples identified in Hong Kong are typical of environments found across SE Asia, especially in areas of strong tidal currents and a hinterland of quartz rich rocks.

The report provides the reader with a description of the issues involved in the dredging of offshore aggregates, with a focus on the location, reserve estimation, licencing and monitoring aspects. It is hoped that this will provide an effective background to assist planners and dredging companies to develop a licencing and extraction policy which leads to the required supply of aggregate to the cities and at the same time limits the damage to the local offshore environment.
2 OFFSHORE AGGREGATES: STATUS IN SOUTH-EAST ASIA

Information published or publicly available on the status of the marine aggregates sector in south-east Asia is generally limited. However, the status of the offshore aggregate is described in eleven countries and regions in south-east Asia:

Korea Peoples' Republic of China Hong Kong Special Administrative Region
Vietnam Cambodia Hong Kong
Malaysia Singapore Thailand
Brunei Philippines Indonesia

There is a wide variability in the maturity of the industry in these countries. Some are in their infancy with little or no regulatory framework whilst Hong Kong, for example, has sophisticated and strictly controlled methods of investigation and extraction to meet demand and supply. The box below outlines the main conclusions drawn from this review of the industry's status in south-east Asia:

CONCLUSIONS

- Extraction of marine aggregates is likely to increase substantially in the years ahead as pressure increases to build at or near coastal locations and land based aggregate supplies become scarce.

- National or state licencing authorities need to locate, assess and quantify marine aggregate resources to formulate and administer long term sustainable extraction policies. Hong Kong is a successful example of a well planned regulatory system.

- Legislative frameworks need to be adopted to control indiscriminate extraction of marine sand and gravel and destruction of coral reefs for aggregate.

- Comprehensive site investigations and geological interpretations are essential in understanding the form and geometry of potential deposits of marine aggregates.

- Environmental issues can only be addressed with a regional understanding of sea bed habitats, sedimentary environments and hydrographic conditions.

- A focus on non-coral sources of marine aggregate and use of such material will help to relieve the pressure on coral reefs as a source of aggregate.

3 OFFSHORE AGGREGATES: CLASSIFICATION & SPECIFICATION

The term 'aggregate' describes a wide variety of materials although primarily they are natural sands and gravels or crushed rock. No single classification based on the grain size specification of aggregates exists, but it is important when describing aggregates to use an appropriate Standard (e.g. British Standard (BS) or American Standard (ASTM)), and to make clear which is being used. Aggregate specifications for various end uses are described in the report.

The grain size and sorting of aggregate used in concrete varies with the type of concrete. The proportion of fines (mud grade sediment) needs to be generally below 4% and the particles should not
show a predominantly “flakey” shape. The shell content of the sediment should be less than 20% for material in the 5 to 10mm size range. Particle strength and abrasion need to be within set limits, and reactive silica minerals such as opal, trydimite or volcanic glass need to be low to limit possible Alkali Silica Reaction (ASR). The chloride content of the concrete needs to be low to prevent corrosion in steel, and this is achieved for offshore aggregate by careful quality control and if necessary, washing in fresh water.

For building sand (mortar) the sand grains need to be hard, durable, clean and free from coatings or clay pellets. Most specifications set out a particle size distribution, with different limits for bricklaying and plastering or rendering sands.

For fill material used in reclamations the main requirement is that the sediment is free-draining. Any granular, well-graded (well sorted) sediment is adequate and the material should have a low organic content. The requirements for fill material are normally not stringent as for other uses.

The choice of material to use in beach renourishment schemes depends on the stability required of the final beach, the durability of the sediment, and recreational and environmental suitability of the sediment. Usually the sediment to be placed on beach should have the same or slightly coarser grading as that of the original beach, though this may not always be practical either technically or economically. In addition the sediment should be free of contaminants, and the clasts rounded. The specification of aggregate for a beach renourishment scheme may therefore be very tight and difficult for the dredging contractor to maintain.

4 OFFSHORE AGGREGATES: ENVIRONMENTS OF DEPOSITION

An understanding of the geometric form, composition and environment of deposition of an aggregate sediment body are essential for the determination of a cost effective approach to its extraction. The pre-dredging seismic and sampling survey provides the bulk of this information. However, for the interpretation of this survey data to provide accurate estimates for aggregate resource assessment it must be placed within a geological framework.

Sediments are laid down in discrete bodies commonly stacked on top of each other or in lateral succession, and such bodies may be identified from both the seismic and sample evidence. Sandy and gravelly deposits may be laid down in a range of natural environments, and the deposits within each setting have a distinctive geometry and lithological range. Alluvial, coastal and marine deposits are considered and described in the report.

From a geological perspective potential aggregate resource deposits may be modern and actively forming at present on the sea bed such as sand banks and sand wave fields; or much older, laid down thousands of years ago when sea level was lower and environments were different, e.g. alluvial deposition within filled river channels.

These are important criteria to understand when planning the exploitation of an aggregate resource. For example, modern deposits can reform during and after dredging as long as the sediment supply, driven by tides and waves, is adequate to replace the dredged sediment.

In contrast older deposits formed under conditions which no longer exist will not be replenished after dredging. However, the dredge site may infill with modern deposits, although these may be lithologically very different from the original dredged deposits. Any evaluation of the impact of dredging on the sea bed needs to take account of whether modern or older deposits are being dredged.

A third type of deposit is classed as “moribund”. These are usually sand banks or sand waves which were formed in conditions which no longer exist such as when sea level was lower than at present, and tidal currents were stronger than they are now and formed these moribund features. Examples of moribund sand banks are found in the deeper waters of the East China Sea.
5 OFFSHORE AGGREGATES: SURVEY AND SAMPLING

Locating and evaluating resources and reserves of offshore aggregate requires a programme of research, survey and sampling to undertaken. This can be divided into at least three stages:

1 Desk study  2 Reconnaissance marine survey  3 Prospecting /reserve evaluation marine survey

The desk study identifies the areas where reconnaissance surveys should be concentrated.

The reconnaissance survey investigates the general area to target its potential resources. The prospecting survey focuses on specific resource targets, the scale of which would be determined by the volume of material being sought. A well planned and executed resource/reserve evaluation survey leading to a detailed 3-D model of the dredged deposit is essential to ensure that the dredging itself is carried out with the minimum production and quality problems (Selby and Ooms, 1996).

An aggregate resource/reserve survey can be divided into seismic and sampling components and for these, common datums for recording depths and position should be specified.

1 SEISMIC SURVEY

- Equipment deployed should include echo-sounder and seismic reflection system; side-scan sonar may also be used in areas where the resource is at the sea bed.
- A navigation system with an accuracy of at least ±2 m should be specified.
- All navigation and seismic data should be recorded digitally in a computer.
- During survey all printed records should be marked up rigorously with relevant data such as fix and line numbers, sweep speed and firing rate. A daily survey log should be kept.
- The planned seismic grid should be drawn as two sets of parallel lines at right angles. This rectilinear grid should run normal and parallel to bathymetric features such as sand banks and the presumed "grain" of resource deposits.
- The size and spacing of the seismic grid will depend on the scope of the survey e.g. a reconnaissance survey could be at a 1 to 5 km grid, a borrow area survey grid would be tighter at <50 m to 200 m.
- Charts produced from the survey data should include corrected bathymetric values and seismic track lines with line and fix numbers.
- A common scale and size should be specified for all charts and maps produced.

2 SAMPLING SURVEY

It is recommended to complete the seismic survey and initially interpret the seismic data before embarking on a major sampling survey programme.

- Sample sites should be identified from seismic interpretation and predictions made of results expected from sampling.
- Sample sites identified from seismic interpretation should explore a range of options and not assume the seismic interpretation is totally correct.
- The sampling equipment to be used depends on available funds and requirements. Shallow (<1m thick) seabed sedimentary units may be sampled using a seabed grab, deeper units need a vibrocorer or drill rig.
- Logging descriptions should be to a standard agreed format including geological and geotechnical data.
- Sub-samples should be taken for grain size analysis from sand and gravel horizons.
The data collected should be checked and validated and held in an information management system. The final report should integrate the interpretation of the seismic and sampling surveys and evaluate the aggregate resources. The planning and execution of borrow area surveys should be detailed enough to produce volumes for sand and gravel reserves.

6 OFFSHORE AGGREGATES: DREDGING

Dredging is the process of excavating sediments from below the water surface. The two commonly used dredging techniques offshore are:

hydraulic dredging
mechanical dredging

Hydraulic dredging is by far the most commonly used technique for offshore aggregate extraction with the trailing suction hopper dredger (TSHD) the primary hydraulic dredger in use. Various types of mechanical and hydraulic dredgers are described including TSHDs. A general guide to the selection of dredgers for various sites depending specific conditions is given in Table 1.

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<tr>
<th>Site conditions</th>
<th>Standard trailer</th>
<th>Light trailer</th>
<th>Cutter suction</th>
<th>Bucket wheel</th>
<th>Bucket hopper</th>
<th>Grab pontoon</th>
<th>Grab bucket</th>
<th>Back-hoe</th>
<th>Dipper</th>
<th>Barge unloader</th>
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<tbody>
<tr>
<td>Bed material</td>
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<tr>
<td>Fine sand</td>
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<td>1</td>
<td>N</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Medium sand</td>
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<td>1</td>
<td>1</td>
<td>N</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
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<tr>
<td>Coarse sand</td>
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<td>1</td>
<td>N</td>
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<td>1</td>
<td>1</td>
<td>3</td>
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<tr>
<td>Gravel</td>
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<td>1</td>
<td>N</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
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<td>2</td>
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<td>2</td>
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<td>Very weak rock</td>
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<td>Enclosed waters</td>
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<td>1</td>
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<td>Sheltered waters</td>
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<tr>
<td>Exposed waters</td>
<td>1</td>
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<td>3</td>
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<td>N</td>
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<tr>
<td>Placing by</td>
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<td>Direct dumping</td>
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<td>2</td>
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<td>1</td>
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<tr>
<td>Direct pumping</td>
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<td>1</td>
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<tr>
<td>Transport and pump</td>
<td>1</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>N</td>
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<tr>
<td>Dump and pump</td>
<td>1</td>
<td>1</td>
<td>N</td>
<td>N</td>
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<td>Quantities</td>
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<td>&lt; 100 000 m$^3$</td>
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<td>1</td>
<td>N</td>
<td>1</td>
<td>2</td>
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<tr>
<td>&lt; 250 000 m$^3$</td>
<td>1</td>
<td>2</td>
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<td>1</td>
<td>N</td>
<td>2</td>
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<td>&lt; 500 000 m$^3$</td>
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<td>&gt; 500 000 m$^3$</td>
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<td>2</td>
<td>2</td>
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<tr>
<td>Heavy traffic</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>N</td>
<td>2</td>
<td>3</td>
<td>2</td>
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<td>2</td>
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<tr>
<td>Confined working</td>
<td>N</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>N</td>
<td>1</td>
<td>3</td>
<td>2</td>
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</tr>
</tbody>
</table>

Key: 1 = Suitable  2 = Acceptable  3 = Marginal  N = Not usually suitable
Note: Other factors not referred to may influence the choice of dredger.
The table provides only a preliminary engineering guide

Table 1 General guide to dredger selection,
Source: Table 16, British Standards, BS 6349 Part 5, 1991
The techniques involved in the process of dredging and transporting sediment, as well as constraints, are also covered. Developments in the dredging industry have been rapid since the release of the BS6349 in 1991 (Table 2) giving guidance on the current and wave conditions under which plant can operate. A number of subsequent large projects have demanded an extension to the capabilities of dredgers beyond the limitations presented in Table 2. Trailing suction hopper dredgers (TSHD) have been build and are under construction with dredging depths up to 120m, and the maximum hopper capacity of new TSHDs has doubled over the last two years.

<table>
<thead>
<tr>
<th>Operational parameters</th>
<th>Unit</th>
<th>Trailer suction</th>
<th>Suction</th>
<th>Cutter wheel</th>
<th>Bucket wheel</th>
<th>Stationary</th>
<th>Gravel hoper</th>
<th>Gravel portion</th>
<th>Gravel chain</th>
<th>Hydraulic backhoe</th>
<th>Hopper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min depth of water</td>
<td>m</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1.5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Max depth of water</td>
<td>m</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>20</td>
<td>85</td>
<td>45</td>
<td>80</td>
<td>35</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Max wave height</td>
<td>m</td>
<td>2</td>
<td>1</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Max swell height</td>
<td>m</td>
<td>2</td>
<td>1</td>
<td>0.6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max cross-current</td>
<td>m</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Min cut width</td>
<td>m</td>
<td>NA</td>
<td>NA</td>
<td>5</td>
<td>5</td>
<td>NA</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Max cut width (single pass)</td>
<td>m</td>
<td>NA</td>
<td>NA</td>
<td>175</td>
<td>105</td>
<td>NA</td>
<td>15</td>
<td>70</td>
<td>200</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Min turning circle</td>
<td>m</td>
<td>75</td>
<td>75</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>75</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Min water consumption</td>
<td>m³/h</td>
<td>NA</td>
<td>NA</td>
<td>300</td>
<td>350</td>
<td>450</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Max particle size</td>
<td>mm</td>
<td>500</td>
<td>200</td>
<td>500</td>
<td>450</td>
<td>150</td>
<td>450</td>
<td>3500</td>
<td>2500</td>
<td>3000</td>
<td>2500</td>
</tr>
<tr>
<td>Max soil shear strength</td>
<td>kN/m²</td>
<td>75</td>
<td>NA</td>
<td>500</td>
<td>400</td>
<td>NA</td>
<td>100</td>
<td>300</td>
<td>350</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>Max rock crushing strength</td>
<td>kN/m²</td>
<td>100</td>
<td>NA</td>
<td>30000</td>
<td>10000</td>
<td>NA</td>
<td>500</td>
<td>1000</td>
<td>3000</td>
<td>10000</td>
<td>5000</td>
</tr>
</tbody>
</table>

NA - Not usually applicable

Note 1 The maximum rock crushing strength is very dependent on rock quality.

Apart from cross-currents, minimum figures apply to smallest types of plant and maximum to the largest.
None of the figures are absolute limits, but operation outside these parameters is unusual and may be difficult.

Table 2 Guidance on the use of dredging plant
Source: Table 10 British Standards, BS 6349 Part 5, 1991

7 OFFSHORE AGGREGATES: BORROW AREA ASSESSMENT

The ultimate purpose of a borrow area assessment is to recommend whether the area is an economic reserve and can be exploited. To make such a recommendation the assessment will:

- outline the extent of the aggregate reserve.
- describe its quality.
- calculate its volume.
- describe physical and environmental constraints.
- outline dredging methods.
- produce an extraction plan.

It is clear that a considerable amount of data from a large number of sources has to be gathered together to enable a comprehensive assessment to be undertaken. It requires a multi-disciplinary approach with contributions from specialists in geology, geophysics, civil engineering, dredging, marine science, hydrology and surveying. The data produced is best managed and assessed within an information management system. Such data would include:

- bathymetric survey, seismic survey track and interpretation data.
- Cone Penetration Test (CPT) and Standard Penetration Test (SPT) data.
borehole logs and Particle Size Analysis (PSA) data.
- distribution of utilities (oil and gas pipelines and telephone cables etc).
- coastline of adjacent land and islands.
- navigation channels and marine traffic constraints.

The key to the success of such a system is the uniformity in data entry and integration of data. All borehole and sample descriptions should follow the same style and terminology. Data should be consistent e.g. borehole descriptions should agree with particle size analysis carried out on the core. Similarly the seismic interpretations may need modifying after drilling to ensure that the chosen reflectors agree with the main lithological boundaries in the boreholes and CPTs.

With an integrated information management system planning of the reserve may commence. The system can be used to integrate a number of sediment layers, and produce an average particle size for a single layer. This may be important where thin layers of unsuitable specification may be dredged with the main resource body. Alternatively the system may be used to determine the base and overburden thickness of a resource across a possible borrow area.

The next step is the creation of a ground model which can be used to calculate the geometry of the extraction site and likely volumes recovered. One approach is to grid the reserve and generate data for each of the small grid squares which can be integrated to produce solutions for part or the whole area. Issues to be addressed include the need to leave a certain thickness of reserve at the bottom of the borrow area, thus not utilising its total thickness; the slope on the sides of any deep borrow pit; and the stripping ratio (overburden to be removed against reserve underneath).

These issues form the borrow pit assessment, and allow a start to be made on calculating the economics involved in dredging the pit. Other factors to be taken into consideration are the required volumes and rate of delivery of dredged material onto the site, the specification of the material required, and the transport arrangements and costs. Each of these issues differ from site to site even within a small area and each borrow area needs to be considered separately.

Examples of borrow areas which have been exploited are described from the United Kingdom, The Netherlands and Hong Kong.

### 8 OFFSHORE AGGREGATES: LICENSING AND LEGISLATION

In most countries dredging within territorial waters can only be carried out with the permission of the owner of the affected sea bed, foreshore or river. In the majority of countries the mineral rights are owned by the state but in some countries (e.g. the UK and the Netherlands) the rights are owned by the Crown. The owner usually licences operators to dredge minerals from the sea bed over a specified area in return for royalties on the volume of material landed. The licencing is usually controlled by Government and involves prior consultation with the interested parties which may be affected by the proposed dredging.

Licencing arrangements vary from country to country and the local system reflects the history, development and maturity of the national dredging industry. Licences are usually limited in time though there is a great range from a maximum of 2 years in the Netherlands to 25 years in the UK. An outline of the arrangements in a range of European countries are given in Table 3.

Japan is the world’s largest producer of marine aggregates and the licences are issued by the local (prefectural) government based on national laws governing a wide range of maritime and environmental issues. The requirements vary between prefectures and any application is valid only for a year. For coastal protection purposes offshore dredging is prohibited within a kilometre (3km in some prefectures) of the coast, and the government generally prohibits dredging in water depths of less than 30m.
In the United States offshore aggregate extraction is the responsibility of the Minerals Management Service (MMS) of the Department of the Interior, and the Minerals Management Program (MMP) provides policy directives and guidance for the development of marine minerals resources. The regulatory process is based on a three-tiered programme covering prospecting, leasing and operating regulations designed to ensure environmental protection, and to encourage safe exploration and development of the resources.

<table>
<thead>
<tr>
<th>Country</th>
<th>Administrator</th>
<th>Area of application</th>
<th>Annual tonnage dredged (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Ministry of Economic Affairs, Dept of Quality &amp; Safety</td>
<td>Continental Shelf, including territorial waters</td>
<td>2.3</td>
</tr>
<tr>
<td>Denmark</td>
<td>Ministry of the Environment National Forest and Nature Agency</td>
<td>Danish Exclusive Economic Zone</td>
<td>10.2</td>
</tr>
<tr>
<td>France</td>
<td>Ministry of Industry</td>
<td>All continental and territorial waters</td>
<td>3.9</td>
</tr>
<tr>
<td>Germany</td>
<td>Inside territorial waters: Mining authorities of the Federal States. Outside territorial waters: Chief Mining Board</td>
<td>Continental shelf, territorial waters</td>
<td>2.1</td>
</tr>
<tr>
<td>Ireland</td>
<td>Department of the Marine</td>
<td>Up to 12 miles from the foreshore, up to 30 feet below the sea bed</td>
<td>---</td>
</tr>
<tr>
<td>Italy</td>
<td>Ministry of Mercantile and Shipping Activities</td>
<td>Sea bed up to territorial limit</td>
<td>---</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Ministry of Transport and Public Works</td>
<td>Beyond the 20m isobath, or beyond 20km from the coast, up to 2m below the seabed (up to 5m in harbour approach channels)</td>
<td>37.1</td>
</tr>
<tr>
<td>Norway</td>
<td>Dept of Industry and Energy</td>
<td>All national waters</td>
<td>0.1</td>
</tr>
<tr>
<td>Poland</td>
<td>Ministry of Environmental Protection</td>
<td>Polish EEZ beyond coastal protection zone</td>
<td>0.5</td>
</tr>
<tr>
<td>Spain</td>
<td>Directorate General of Coasts</td>
<td>Foreshores, beaches, territorial seas, EEZ and Continental Shelf</td>
<td>---</td>
</tr>
<tr>
<td>Sweden</td>
<td>Geological Survey of Sweden</td>
<td>Swedish EEG</td>
<td>---</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Department of the Environment, Transport and the Regions</td>
<td>UK continental shelf (landward to where there is no danger of coastal erosion)</td>
<td>26.6</td>
</tr>
</tbody>
</table>

Table 3 Licensing for marine sand and gravel extraction in Europe – (1996)

The administration of sand dredging off Malaysia is the responsibility of the Federal government out to three miles from the coast and the State government out to the shelf edge. Dredging is generally restricted within 1.5km of the coast or in water depths of less than 10m, whichever is further from shore. Environmental Impact Assessments are required for any dredging covering an area greater than 50 hectares and such assessments must include details on the body being dredged.

In Hong Kong a multi-disciplinary inter-departmental government committee was set up in 1989 called the Fill Management Committee (FMC). The Committee became a forum where planners and engineers involved in forming reclamation in Hong Kong got together with environmental, maritime and other regulators to plan and co-ordinate the dredging and placement of marine sand (Whiteside, 1991). The FMC also planned and managed the majority of the geological and geotechnical investigations which identified the reserves of marine sand and this was supplemented by work carried out by consultants and contractors engaged on the various reclamation. The FMC was responsible for allocating sand from marine borrow areas to individual reclamation contracts. This ensured that the limited sand reserves were fully utilised from each borrow area prior to any necessary backfilling with mud. The disposal of dredged mud was also a planning function of the FMC.
Although Hong Kong is an exceptional case with large-scale marine sand operations, it does show the value of planning in the exploration and extraction of marine sand with comprehensive site investigation allied to thorough geological interpretations. The approach illustrates cost effective principles and procedures which are equally applicable elsewhere in south-east Asia. The FMC estimated that all the planning, site investigation, environmental and regulatory work undertaken by them, their consultants and contractors added only three US cents to the cost of each cubic metre of marine fill (Whiteside, Massey & Lam, 1998).

9 OFFSHORE AGGREGATES: ENVIRONMENTAL ASSESSMENT

It is now almost universal practice to require an Environmental Impact Assessment (EIA) or Statement before a major offshore aggregate extraction operation is approved by the appropriate body. The World Bank and European Union have issued guidelines on the appropriate contents and details of the EIAs for different type of projects, and these are usually modified by thresholds or criteria put in place by the appropriate state or national bodies. EIAs aim to enable the organisations responsible for licencing offshore aggregate extraction to establish whether dredging will have any significant impact on adjacent coasts or fisheries, either local or regional, and areas of marine conservation.

One of the main emphases within an EIA is early and full consultation by the developer with all bodies with an interest in the likely effects of the proposal. These bodies would include the licencing authority, national, regional and local government, environmental protection and conservation agencies, and fishing and maritime interests. The EIA should be set within an administrative, legal, and regulatory framework governing offshore dredging, and the contractor carrying out the work should fully understand these regulations.

The EIA should describe aspects of the borrow area and dredging including:
- location and size of the proposed borrow area
- the volume and type of material to be extracted
- the method of dredging
- the timing, rate and zoning of production
- vessel numbers and movements
- the operational controls on the dredging
- the bodies to be notified and consulted during dredging
- onshore destination and landing area
- possible sources of alternative material

The physical and biological aspects, and human environment of the potential borrow area and its surrounds should also be described in sufficient detail to enable a subsequent assessment to be made of the proposed dredging activity.

When evaluating the overall impact, it is necessary to identify and quantify the environmental consequences of the proposal, and this should be summarised as an impact hypothesis. The assessment of some of the potential impacts requires predictive techniques, and it may be necessary to use appropriate mathematical models.

The EIA should include consideration of the practical steps that might be taken to mitigate the effects of the dredging. These steps might include:-
- modifying the dredging to limit changes to the sediment transport regime of the region
- minimising the interference with shipping and navigation routes
- zoning the area to be licenced with seasonal restrictions to protect sensitive fisheries
- placing a safety exclusion zone around archeological sites
- consultation with bodies with a conservation interest
Aggregate extraction by its very nature causes disturbance to the marine environment. Some of these effects are predictable but others are not. Monitoring of dredging operations is an important criteria in assessing its impact and controlling compliance with licence conditions and regulations.

Monitoring may be used to address a number of issues. Compliance monitoring records the position of the dredger to ensure no out of area operations. In the UK all dredgers carry Electronic Monitoring Devices which record the position of the dredger on a 24 hour basis and whether the dredging equipment is operational.

Physical environmental monitoring involves bathymetric, side-scan sonar and seismic surveys to ensure that the terms of the licence are being adhered to in relation to dredging depth and the form and depth of the sea bed after the completion of dredging. Repeat bathymetric surveys allow estimation of volume change to sand banks over time. Beach surveys identify possible changes which may be related to the dredging offshore. This data must be used with care for seasonal changes in beach levels are normal, as are long term changes measured over decades. Plume monitoring is another important factor to ensure that the sediment carried in the plume of overflow water is as predicted and does no major harm to the regional sea bed habitats.

Benthos monitoring involves measuring the effects of dredging on the organisms living above, on or within the sediment. Ideally such monitoring should be conducted for a number of years prior to dredging in order to establish the natural population dynamics but such data are rarely available. Benthic communities have been known to change suddenly in response to changed rates of organic input or abnormal winter temperatures. It may be necessary to monitor such sensitive communities over the lifetime of the dredging activity to determine any impact. As the dredging activity will more or less remove the substrate from the worked parts of the licence area it may be more appropriate to concentrate monitoring activities in peripheral areas which may be vulnerable to indirect effects. It is appropriate to continue monitoring after dredging has ceased to assess the rate and success of recolonisation of marine organisms. Such data provides a good indication of the long-term effects of dredging and ultimately will provide a better understanding of processes applicable for assessing the consequences of future dredging proposals.

Dredging changes the form of the sea bed and therefore the hydrodynamic processes in and around the extraction area. The geographic extent of such changes need to be predictable so that they do not lead to damage on adjoining coasts or to offshore installations. Brampton and others (1998) indicate that the possible effects of such changes are:

- Damage to beaches caused by draw-down of sediment into the dredged area
- Change to waves at the coast by changed refraction behavior over the dredged areas
- Reduction in shelter to a coast provided by offshore banks that become smaller or change orientation after dredging
- Changes in tidal currents, particularly if such changes extend close to a coastline
- Disruption in sediment supply to the coast, either locally or at a distance from the dredged area

These changes could be investigated as part of a coastal impact study before the awarding of a dredging licence.

## 10 OFFSHORE AGGREGATES: GEOLOGICAL ENVIRONMENTS IN SOUTH-EAST ASIA

This section in the main report (James and others, 1999) describes aspects of the marine geology of the continental shelf off south-east Asia which are relevant to the exploration and assessment of aggregate resources. It includes examples of areas in which reserves of sand and gravel have been discovered and dredged, and those in which sand and gravel deposits may occur and therefore be targets for resource surveys. The descriptions concentrate on areas which lie within water depths of
less than 100m: 50m is the present maximum working depth of most trailer hopper suction dredgers although a few can work to a depth of 120m.

The descriptions are based almost exclusively on published data, and are divided into the individual countries or offshore areas bordered by more than one country listed below. They do not represent definitive or complete descriptions of likely resources within each country or area, and some important worked or potential aggregate resource areas may have been omitted.

Korea
Peoples' Republic of China
Hong Kong Special Administrative Region
Vietnam
Gulf of Thailand
Straits of Malacca and Singapore
Sabah and Sarawak

11 OFFSHORE AGGREGATES: CHECKLIST FOR DEVELOPMENT

1 First principles

☐ Where is the aggregate required?
☐ What type of aggregate is required?
☐ How much aggregate is required?

2 Desk study

☐ Delineate area of search; both local and regional.
☐ Acquire geological maps, reports and papers; published and unpublished.
☐ Acquire Admiralty and Hydrographic Charts, and bathymetric data.
☐ Acquire available seismic, sampling and core data.
☐ Acquire tide, current, wave and water quality data.
☐ Acquire data on meteorological conditions; wind, temperature, typhoons, monsoons.
☐ Acquire data on fisheries, coral reefs and sea bed habitats.
☐ Acquire data on sea bed pipelines, cables, anchorages, shipping lanes.
☐ Acquire data on local coasts; beaches, sediment sources, drift, wave climate.
☐ Archive and hold data within a data management system.
  - Include paper, analog and digital data.
  - Set up common formats for holding record and survey data.
  - Define co-ordinate system e.g. National Grid or Lat/Long.
  - Define datum for depth measurement.

3 Determine geological environment and areas of survey

☐ Are there any major rivers or estuaries entering the area?
☐ Do the rivers flow through areas of coarse-grained rock and sediment?
These are likely to transport sand and gravel offshore.

Do the rivers flow through areas of fine-grained rock and sediment?

These are likely to transport mud offshore not sand and gravel.

Is there any evidence of rivers transporting sand and gravel into the sea?

Are there any tidal sand ridges or sand bars visible on bathymetric charts?

Are there areas of strong currents and tides?

Sand and gravel are likely to be associated with areas of strong currents.

Sand bars, ridges and sand wave fields occur in strong current conditions.

Strong currents are commonly associated with islands, channels and shoals.

Areas of high tidal range may also be associated with strong currents.

Admiralty charts indicate the occurrence of bars and tidal ridges.

Admiralty charts include descriptions of sampled sediment on the sea bed.

Currents tend to decrease in velocity with depth offshore on open shelves.

Rivers may have incised channels and deposited sand and gravel offshore when they flowed across marine shelves during periods of lower sea levels.

Old river channels may be traced offshore from the mouths of modern rivers.

Are there any areas offshore where moribund and relict sediments may have accumulated?

Coasts with barrier beach and dune systems may have similar systems submerged offshore.

Sand and gravel eroded from cliffs may be deposited offshore.

4 Recommend areas of survey

Interpret all available data and produce desk study report, include preliminary environmental assessment.

Recommend areas for reconnaissance aggregate survey.

Give reasons for choosing recommended areas.

Produce track plan for seismic survey of recommended areas.

Spacing of seismic track plan grid will depend on a number of factors including:

- Extent of the area to be surveyed.
- The scale and number of target features

The reconnaissance seismic grid may vary from a kilometre spacing to over 5 km.

- The grid should generally be two sets of parallel lines at right angles.
- One set parallel to features, such as the coast, a sand ridge or channel.
- Other set at right angles across the feature.

Produce specification for seismic survey, recording and navigation systems.

Produce specification for data deliverables from survey including:

- Co-ordinates, datum, charts, digital files, seismic records.
5 Reconnaissance and target area survey and assessment

- Complete reconnaissance seismic survey.
- Undertake an initial interpretation of the seismic records.
- Locate and define target areas for aggregate assessment.
- Recommend sites for coring and sampling of target areas.
  - Sites should always be located on seismic tracks to aid interpretation.
- Re-interpret seismics with aid of coring and sampling data.
- Re-assess target areas and recommend areas suitable for borrow area survey.
- Place all data in information management system.

6 Borrow area survey and assessment

- Undertake further seismic survey across recommended borrow area.
- Survey at narrower seismic grid with spacings of <50 m to 200 m.
- Undertake further coring and sampling.
- Include cone penetrometer tests if available.
- Analyse samples for particle size, carbonate content, mineralogy.

- Undertake aggregate reserve assessment.
- Re-interpret seismics with aid of coring, test and sample data.
- Delineate areas of sand and gravel reserve.
- Calculate volume of overburden, where present, lying on aggregate reserve.
- Calculate volume of waste material e.g. mud within aggregate reserve.
- Produce report with estimate of extent, quality and volume of aggregate reserve.

- Undertake dredging assessment.
- Consider site conditions for dredging, e.g. bathymetry, tides and currents.
- Calculate volume to be dredged and rate of delivery.
- Produce borrow area dredging plan.
- Produce plan for disposal of unsuitable material.

- Undertake environmental impact assessment (EIA).
- Assess effects of dredging on fisheries and local coast.
- Undertake sampling and survey as appropriate, before and after dredging.
- Produce EIA report with recommendations and mitigation and monitoring plans.

12 REFERENCES


Whiteside, P.G.D. 1991. Management of Hong Kong’s marine fill resources. 33-47 in *Reclamation - Important current issues*. Blacker, P. (Editor). (Hong Kong: Hong Kong Institution of Engineers.)

Whiteside, P.G.D., Massey, J.B. and Lam, B.M.T. 1998. Marine Fill - the key to Hong Kong’s Airport Core Projects. 97-108 in *Geotechnical aspects of the Airport Core Projects*. (Hong Kong: Hong Kong Institution of Engineers.)

**WEB SITES AND SOURCES OF INFORMATION**

www.bgs.ac.uk – British Geological Survey  
www.cefas.co.uk - CEFAS  
www.unescap.org/enrm/mrs/mrshome.htm – UN ESCAP, Bangkok  
www.uneprg.org – UN Environment Programme  
www-esd.worldbank.org – World Bank  
www-tt.wbmt.tudelft.ni/ceda – Central Dredging Association

DEBBY is a dredging and environmental bibliography developed to run on IBM-compatible PCs. It is available through IADC  
2508 GM The Hague  
The Netherlands

*Terra et Aqua* is published quarterly by the IADC, the International Association of Dredging Companies and contains articles on topics related to dredging, including aggregates and environmental issues.

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