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1. INTRODUCTION

Many decades of disposal of industrial wastes in the past have resulted in contamination of some seabed areas in the Hong Kong Harbour. Large amounts of copper, chromium and other metals associated with industrial processes such as electro-plating have accumulated in the upper layers of marine mud. Together with organic contaminants from large volumes of raw sewage, these pollutants have been mixed into the seabed materials by tidal currents, and ships propeller washing and anchoring, forming a superficial layer of contaminated mud overlying the seabed.

Dredging is essential to maintain navigation in ports, harbours and inland waterways and for the development of port facilities. Very often, soft seabed materials, which may be contaminated, need to be removed in capital works projects for infrastructure development and in maintenance dredging.

The objectives of this review are to summarise briefly the environmental effects of dredging contaminated mud, and to collect information on environmentally improved dredging plants/techniques being adopted in other countries, in order to explore their applicability to Hong Kong. The information collected in this review is based on a literature search and communication with some international dredging contractors.

2. ENVIRONMENTAL IMPACT OF CONVENTIONAL DREDGERS

2.1 General

Conventional dredgers often bring adverse effects to the environment during their operation. These effects are briefly described below:

(a) Over-dredging of contaminated material: Conventional dredgers have a low accuracy of level control on the excavated profile. This can result in an excessive volume of dredged material for treatment or storage. The volume can be large when dredging a layer of contaminated mud over a large area.

(b) Excessive suspended sediments: The creation of excessive suspended sediments by conventional dredgers in the vicinity of dredging and mud disposal areas may endanger sensitive local fauna and flora. If the suspended sediments are contaminated, this can result in the spread of contaminants into the water column.

(c) Creation of loose spill layers: The incomplete removal of the loosened layers by conventional dredgers may lead to large amounts of suspended solids later due to natural seabed erosion processes. These suspended solids can present risks if close to sensitive areas such as coral reefs or if the contaminants adsorbed on the sediment can be released and dispersed.

(d) Dilution of spoil: For fine-grained materials removed by conventional dredgers, when mixed with large quantities of water this can lead to an increase in the volume of dredged material to be stored or treated.

The influence of each of the above effects depends greatly on the nature of the materials to be dredged in individual projects and the type of dredging equipment/technique used.

Dredging involves the processes of breaking up the mass of a sediment, excavation, vertical and horizontal transports and relocation of dredged material (Rokosch, 1993). According to the working principles for these processes, dredgers may be categorised into three groups, viz. mechanical dredgers, hydraulic dredgers and mixed mechanical/hydraulic dredgers. The following sections describe generally the operations of some of the commonly used conventional dredgers and their impacts to the environment (IADC, 1998).

2.2 Mechanical Dredgers

Mechanical dredgers include all plants, which make use of mechanical excavation equipment for cutting and raising material. Dredgers under this category are grab dredgers, backhoe dredgers and bucket ladder dredgers.

2.2.1 Grab Dredger

A grab dredger is basically a conventional cable crane mounted on a pontoon (Figure 1). The seabed material is excavated by the bucket of the crane and raised by the hoisting movement of the cable. The material is dumped into a transport barge and then discharged at a disposal site through the bottom doors or split hull of the transport barge. The accuracy of dredging location is limited. The excavating bucket has to be repositioned at every cycle but the location control of conventional equipment is poor. For a conventional grab dredger with an open bucket, there will be loss of excavated material as suspended sediment is released during the raising of the material. During this raising movement, spillage from the grab can occur throughout the complete height of the water column. Sediment can also be lost from overflow of the barge or splashing during barge loading. Moreover, the anchorage requires a large working area, thus it could cause obstruction to marine traffic (Tang & Chalmers, 1995).

The output rate of a grab dredger is dependent on the water depth at the dredging location and is generally limited. Up to 1,000-2,000m^3/hr can be achieved with a few huge grab dredgers.

2.2.2 Backhoe Dredger

A backhoe dredger is basically a conventional hydraulic excavator mounted on a pontoon with a spud carriage system (Figure 2). The sediment is excavated by the backhoe's bucket which, in turn, is raised above water by the movement of the machine's arm. The excavated sediment is then placed into a transport barge.

The main disadvantages of the backhoe dredger are as follows:

(a) Its dredging location accuracy is low. The excavating bucket has to be repositioned at every cycle but the location control of conventional equipment is poor.

(b) Significant amounts of suspended sediment can be released during the raising of dredged material in an open bucket. During this raising movement, spillage can occur throughout the complete height of the water column.

The output rate of a backhoe dredger is highly dependent on the operator's skill. Up to 500m^3/hr can be achieved with the largest backhoe dredger.

2.2.3 Bucket Ladder Dredger

The bucket ladder dredger was first employed in Europe. It consists of a large pontoon with a central well in which a ladder, equipped with an endless chain of buckets, is mounted (Figure 3). The chain rotates along the ladder during dredging. The lowest bucket digs into the seabed and the cut material falls into the bucket. It is then carried upwards when the bucket chain rotates. At the upper end of the ladder, the bucket turns upside down and the excavated material falls into a chute which guides the material into a transport barge for further transportation.

A bucket ladder dredger has advantages over the grab dredger and backhoe dredger in that its dredging location accuracy is higher as long as the ladder remains in the same position. Also dilution of spoil by water is not significant. However, it has the following disadvantages (Tang & Chalmers, 1995):

(a) Significant amounts of suspended sediment can be released during the raising of the excavated material in an open bucket;

(b) operation cost may be higher compared with other types of dredger with similar productivity; and

(c) widely spaced anchors could cause obstruction to marine traffic.

The output rate of a bucket ladder dredger is low and up to 1,500 m^3/hr can be achieved.

2.3 Hydraulic Dredgers

Hydraulic dredgers include all dredging equipment which makes use of centrifugal pumps for the transport processes (raising and horizontal transport). Three main groups of hydraulic dredgers can be identified and they are: stationary suction dredgers, cutter suction dredgers and trailing suction hopper dredgers.

2.3.1 Suction Dredger

The suction dredger is the simplest type of hydraulic dredger. The operation procedures are that, from the floating pontoon, the suction pipe is lowered into the sea bottom and by suction action of the dredge pump which is often mounted on the suction ladder, seabed material is sucked up (Figure 4). After raising the material through the suction pipe, the material is either hydraulically discharged through a floating pipeline to shore, or more often, loaded into a barge (IADC, 1998).

The suction dredger has the disadvantages that the accuracy of dredging location is low and that considerable spill is possible due to relatively uncontrolled process of applying suction. Water is added to the excavated material for transportation purpose. Thus, dilution of excavated material is significant.

Depending on the size of the suction dredger and the characteristics of the excavated material, the output rate can vary widely, from 50 to 5,000 m^3/hr.

2.3.2 Cutter Suction Dredger

The cutter suction dredger is usually not self-propelled and it dislodges the seabed material with a rotating cutter equipped with cutting teeth. The loosened material is sucked into the suction mouth located in the cutter head by means of a centrifugal pump installed on the pontoon or ladder of the dredger (Figure 5). The dredged material can be pumped into a transport barge for further transport. Good dredging location accuracy can be obtained because the movement of the dredging head is controlled from a fixed point (the working spud). Owing to the disturbance of the seabed around the rotating cutter, there is a high risk of creating significant amounts of suspended sediment at the dredging site. As water together with the dredged material are sucked into the suction pipe, dilution of the dredged material is significant.

Like the suction dredger, the output rate depends on the size of the cutter suction dredger and the characteristics of excavated material. It can vary widely, from 50 to 5,000 m^3/hr.

2.3.3 Trailing Suction Hopper Dredger

The trailing suction hopper dredger (TSHD) is a sea-going ship equipped with a suction ladder. At the end of the ladder is a draghead, which can be lowered onto the seabed while the TSHD navigates at a reduced speed (Figure 6). During the forward movement of the TSHD, the draghead agitates a thin layer of the seabed. The loosened material, together with some water, is sucked into the suction pipe by means of a centrifugal pump, which is installed in the vessel's hull. The material is then pumped into the vessel's hopper until it is completely filled. During this loading phase, excess water may flow overboard together with some of the finer material, while the coarser fraction accumulates in the hopper. While overflow is an essential requirement for the efficient and economic operation of the TSHD when working for sand dredging, this process is critically important when assessing environmental effects, especially in the dredging of contaminated mud. Moreover, spill and turbidity will occur during the trailing of the suction mouth over the sediment. The accuracy of the dredging is low compared with the cutter suction dredger. A vertical level accuracy of 15 to 25 cm approximately can be obtained with the provision of sophisticated monitoring and steering equipment.

Depending on the size of the THSD, the productivity rate can vary widely, ranging from 200 to 10,000 m^3/hr.

2.3.4 Dustpan Dredger

The dustpan dredger (Figure 7) is a stationary suction dredger that is usually moved longitudinally by means of anchor wires. It has a wide flat suction mouth which is suitable for the removal of thin layers of sediment (up to a few centimetres) (Rokosch, 1993). Water jet is used at the suction head to fluidize and dislodge the sediment during dredging. The dustpan dredger is normally used for maintaining navigation channels by making a series of parallel cuts through the shoal areas until the required widths and depths are achieved (US Army Corps of Engineers, 1983). Sediment re-suspension is mainly caused by disturbance of the seabed due to the action of the water jets. When used for shoal dispersion, which has been a common application of dustpan dredger, particular in the USA, sediment re-suspension has occurred on a massive scale (Bray, Bates & Land, 1997).

2.4 Mixed Mechanical/Hydraulic Dredgers

Mixed mechanical/hydraulic dredgers have the characteristics that the mass of the sediment to be dredged is broken by mechanical means, the excavation is either mechanical or hydraulic and the vertical transport is by hydraulic means (Rokosch, 1993). This type of dredgers is normally designed by making use of the advantages of the mechanical and hydraulic techniques. Hence, mixed mechanical/hydraulic dredgers are more environmentally friendly than mechanical dredgers and hydraulic dredgers. The disc bottom cutter dredger is a type of mixed mechanical/hydraulic dredger. This type of dredger will be discussed in detail in Section 3.4 below.

3. ENVIRONMENTALLY IMPROVED AND OTHER INNOVATIVE DREDGING TECHNIQUES

3.1 General

Over the last thirty years, the environment has become an increasingly important consideration in capital works projects and in maintenance dredging involving contaminated mud. Environmentally acceptable and economically affordable techniques are one of the major considerations in almost all modern dredging projects. During the last decade, many dredgers and dredge heads have been designed, usually for specific projects, aiming to remove contaminated dredged mud (CDM) in an environmentally friendly way (Volbeda, 1993). Desirable characteristics of these environmental dredgers are:

(a) to take layers of CDM with a high dredging location accuracy, avoiding over-dredging and mixing of CDM with uncontaminated material;

(b) to dredge the CDM with minimum turbidity generation and dispersion of contaminated sediment into the surrounding water; and

(c) to dredge as close to the in-situ density of the seabed material as possible by minimising dilution during the dredging process.

Minimising the turbidity being generated during dredging is certainly important to reduce adverse impact to the environment. A high accuracy in dredging location will lead to less volume to be transported, stored or treated, and more efficient removal of contaminated sediment. A high density of dredged material achieved by minimising dilution during the dredging process will reduce the volume to be stored or treated.

The following sections briefly describe some improved environmental dredgers, conventional dredgers with suitable modifications and new dredging technologies being used in other countries to improve environmental friendliness.

3.2 Environmental Grab

The environmental grab is a specially designed grab with the following features to minimise over-dredging and prevent spillage from the grab bucket:

(a) during the opening and closing of the grab, the cutting edge remains at the same horizontal plane (Figure 8);

(b) the opening and closing of the grab is undertaken hydraulically, or mechanically with a special rigging of cables (Figure 9);

(c) all openings are sealed to minimise spill when the grab is closed; and

(d) the crane is equipped with a positioning system on top of the crane boom to accurately measure the position of the turning point of the cable. An encoder is used to measure the paid-out cable length to identify precisely the depth of the grab during the dredging process.

The environmental grab can be installed either on a grab dredger (cable crane) or on a backhoe dredger. The accuracy of position control of the grab hanged on a cable crane is high (Figure 8). In addition, the environmental grab is generally used in combination with other protective measures such as silt curtains. As regard to the productivity rate of the environmental grab, it is mainly determined by the size of the grab bucket and is generally limited to a few hundred cubic metres per hour.

3.3 Environmental Auger Dredger

Auger dredgers have been used in European countries for many years, mainly in lake clean-up projects. Combining their working principles with some specific environmental features as listed below, the environment auger dredger (Figure 10) is specially designed for the removal of thin layers of contaminated sediment.

(a) the dredged material is pumped up by a suction head, thus the sludge can be compacted to a high density;

(b) the dredging process takes place within an enclosed space; and

(c) a flexible silt screen is installed around the auger to ensure that any turbidity is contained inside the protective flap.

Comparing with conventional dredgers with respect to the environmental criteria, the environmental auger dredger has a number of improvements, including:

(a) it is essentially a stationary dredger with a spud system. Coupled with precise positioning of the cutting head and the automatic steering and control system, it can work to tolerances within 5 cm;

(b) the auger is closed off from the environment by a skirt, thus resulting in little suspension of sediment around the cutting device;

(c) the auger cuts and conveys material towards the suction mouth of the dredger. Combining good control of the pumping process with this feature, the spill layer can be eliminated to a minimal; and

(d) with a good monitoring and control system on the water fed in for transporting the dredged material, the amount of water needed can be reduced to a minimum.

As regard to the productivity rate of the environmental augur dredger, it is determined by the size of the auger and can be up to 500 m^3/ hr.

3.4 Disc Bottom Dredger

The disc bottom dredger is a mixed mechanical/hydraulic type dredger. It is a stationary dredger equipped with a cylindrical-shaped cutter with a flat, closed bottom and a vertical rotation axis (Figure 11). The suction mouth for removal of the cut material is situated inside the cutter to avoid spillage. A shield over the soil to be cut prevents both the cut material from entering the surroundings as well as the intake of excessive volume of water. High precision can be achieved in dredging location control with the disc bottom dredger as the cutting edge can be positioned within centimetres of the target depth. The completely closed shield around the cutter of the disc bottom cutting device is designed to avoid spreading of the cut material. The creation of suspended sediment is therefore minimised and limited to the close proximity of the cutter device (IADC, 1998).

3.5 Scoop Dredger

Scoop dredger is an upgraded cutter suction dredger specially adapted for dredging contaminated material. A two-sided functional draghead (Figure 12) is mounted to allow dredging in two opposite swing directions. This is achieved in practice by using a turning blade that scrapes the material from the water into the suction head of the dredger. At the end of the swing, the blade turns in the opposite direction and the dredger moves forward (1.5 to 2.5m) and the draghead continues scraping in the opposite direction (Vandycke & Lefever, 1997). The scoophead has no rotating cutting devices, so turbidity and the addition of transport water is minimised. At the same time, no rotating part means very low interference with debris in the dredging area. The outer casing prevents dilution with water and the creation of turbidity in the surrounding water. The presence of gas bubbles in the dredged material would provoke cavitation of the ladder pump and reduce the performance of the ladder and delivery pumps. As such, a specially designed degasification system has been added to the basic scoop dredger which draws off gas and some silt from the dredged material before it reaches the ladder pump.

3.6 Improvement to the Overflowing System of Trailing Suction Hopper Dredger

In the last decade, the TSHD has emerged as one of the most important tools of the dredging industry. One of the major environmental constraints of the TSHD is the suspended sediment generated by the overflow of excessive transport water with a high fines content. New technologies have been developed to overcome this, such as:

(a) use of the low-density trailers that have a relatively large hopper well, with special features to increase the rates of settlement of the dredged material in the hopper;

(b) controlled overflow is provided. This reduces the loss of excessive suspended sediment;

(c) controlled overflow, using a special guiding system along the suction pipe, to discharge the excess water to the lower water layers. This system directs the overflow water to the seabed and reduces the discharge of suspended sediment to the upper water layers. Using such system, the spread of suspended sediment into the surroundings can be considerably reduced; and

(d) de-gassing of the gas-entrained sediment/water mixture (e.g. when dredging silty seabeds with high organic content) to minimise air bubbles in the overflow water such that suspended sediment will not be raised to the water surface by the gas bubbles.

3.7 Hopper Dredge Recirculation System

Dredging companies in the European Economic countries have developed a system to recirculate hopper dredge overflow water to the draghead in a closed system to increase production efficiency and reduce surface turbidity plumes resulting from conventional hopper overflows. Instead of allowing the overflow (composed of fine organic material and transport water) to go directly back into the water, the new system pumps the overflow along the dragarm to the draghead to assist in the suction operations. Reusing overflow water in this manner maintains a closed system so that only a minimal turbidity plume is produced and potential contaminated sediment is not discharged (McLellan & Hopman, 2000).

The basic technology of the system involves reuse of transport water overflow as both pressure water and transport water in the suction head of a closed cycle system. This new technique has three main benefits:

(a) minimization of sediment/turbidity clouds on surface water by avoiding overflow and the possible related water pollution problems;

(b) increased material flow in relation to transport water, which in turn increases dredge efficiency by reducing loading time; and

(c) decreased pressure drop inside the draghead, which reduces dredge pulling force. Thus, it reduces energy needed for propulsion and lowers fuel consumption.

3.8 DOP Submersible Dredge Pumps

De Groot Nijkerk of Nijerk, the Netherlands, has developed a series of submersible dredge pumps called DOP pumps (McLellan & Hopman, 2000). The DOP pump has many advantages:

(a) it facilitates accurate dredging; and

(b) it has a large production capacity of about 2,000 m^3/hr due to the high mixture concentration that can be handled.

The DOP pump is based on proven dredge pump design. By applying a mechanical seal in shaft sealing instead of the conventional gland, gland water and grease are superfluous. The impeller is clamped to the pump shaft by means of a tension set. The DOP pump is driven by a hydraulic or electric motor placed directly on the pump. The DOP can be outfitted with various suction mouths such as a cutter unit, dustpan, or auger. The unit cost per cubic metre of material pumped compares favourably to conventional pumping costs (McLellan & Hopman, 2000).

3.9 Low-Turbidity Dredge Head

The low turbidity dredge head (LTDH) or called sweephead (Figure 13) has been developed by Jan de Nul, Belgium. The LTDH has been installed on the cutter suction dredger “Dirk Martens”. LTDH has the following characteristics (McLellan & Hopman, 2000):

(a) it can remove thin layers of sediment with high accuracy;

(b) the dredged material is close to in-situ density;

(c) it can work in shallow waters; and

(d) it helps to minimise the mechanical disturbance to the soil mass to reduce turbidity generation and mobilization of contaminants.

The LTDH has two inlets and works without any additional mechanical movement. A hydraulic valve in the head opens the inlets towards the dredging direction.

4. REVIEW ON SUITABILITY OF NEW TECHNIQUES FOR USE IN HONG KONG

4.1 Dredging in Hong Kong

For safe and efficient port operations in Hong Kong, regular maintenance, including maintenance dredging, of port facilities is particularly important. Maintenance dredging is aimed at the restoration of the original seabed or riverbed levels by means of dredging or desilting (CEO, 2000). Maintenance dredging usually involves removal of recently deposited materials, which are mostly fine materials of low strength and may have a high contamination level.

Capital works dredging involves the creation of new or improved facilities such as areas of reclaimed land for housing and infrastructure development and container terminals, and deepening of navigation channels. It usually requires the removal of undisturbed materials. Some of these materials may be hard, and consequently, the dredging plants for capital works may need to be stronger and more powerful than those which work only on maintenance dredging.

The annual volumes of dredged contaminated mud arising from maintenance dredging and capital works dredging in Hong Kong are shown in Figure 14. Over the last 3 years, the volume generated from maintenance dredging and capital works dredging is 1-2 Mm^3 and 2-5Mm^3 per year respectively.

In selecting suitable types of dredging plants for a particular project, the following major factors should be considered:

(a) Dimension factors - These include water depth, size of the dredging site, and thickness of the material to be dredged and the overburden. Water must be deep enough to allow the passage of dredging plant. Adequate space should be available at the dredging site for operating a particular dredger. For example, for THSD, normally a site with a length longer than 1,000m is preferred for effective operation (Tang & Chalmers, 1995). The thickness of material to be dredged in maintenance dredging in Hong Kong is usually about 1 to 2m over a small area. For capital works dredging, removal of contaminated mud up to 5m over a large area has not been uncommon.

(b) Physical factors – These include, but not limited to, weather conditions and properties of materials to be dredged. Strong wind conditions will affect manoeuvring and positioning of the dredging plant. Materials to be dredged in maintenance dredging are usually weak and contain much fines in the more exposed areas in Hong Kong. Capital works dredging for reclamation projects in Hong Kong is often in nearshore areas which are sheltered.

(c) Operational factors – These usually relate to constraints due to marine traffic and limited working areas such as dredging adjacent to edges of marine structures. Maintenance dredging in a busy fairway can be difficult to carry out due to the need to maintain marine traffic. Capital works dredging is generally less affected by marine traffic.

(d) Environmental factors – These relate to environmental impacts of dredging and disposal operations on the water quality and the marine ecology, especially those operations connected with disposal of contaminated mud.

> Maintenance dredging in Hong Kong has generally been of a small scale and of short duration. Environmental factors need to be considered but have not been a major issue. Capital works dredging, on the other hand, is often close to sensitive receivers and the construction period may be up to few years for sizeable projects, thus environmental factors would be one of the key concerns.

Among the above factors, the size of the dredging site and the operational factors are usually prevailing on the selection of suitable types of dredging plants for maintenance dredging. Large stationary dredgers, although they may perform well environmentally, may have difficulties for maintenance dredging, particularly at busy fairways. In general, capital works dredging projects, often of larger scale in comparison with maintenance dredging and with less operational constraints, may have flexibility in adopting the improved environmentally dredgers and innovative techniques mentioned above.

4.2 Suitability of New Equipment/Techniques

The potential merits and shortcomings of employing the plants/techniques described in Section 3 in Hong Kong are discussed below:

4.2.1 Environmental Grab

The environmental grab dredger is small in size. Therefore, it is suitable for sites that are difficult to reach and for relatively small sites. The cost of mobilisation and installation of an environmental grab to a grab dredger is relatively low. However, it needs well-trained operators for manoeuvring the grab in order to achieve a high positional accuracy and minimisation of turbidity during dredging of contaminated mud. As the environmental grab dredger is a stationary piece of plant, it may not be suitable for dredging at busy fairways.

4.2.2 Environmental Auger Dredger

The environmental auger dredger can achieve a high positional accuracy in dredging (with tolerances of less than 5cm). Therefore, it is suitable for maintenance dredging where the thickness of material being dredged is thin (about 1-2m thick). It is also favourable for dredging large amounts of contaminated mud and over an extensive area so that over-dredging can be minimised. On the other hand, the environmental auger dredger is a stationary type dredger with a length of about 60m. Hence it is not quite suitable for operation at busy fairways. Moreover, this type of dredger is operating mainly in Europe, and hence needs to be mobilised from Europe. The mobilisation cost would be substantial due to the necessity of transportation by a submersible dock vessel. Depending on the design, the dredge depth is usually less than 15m. The operation cost may also be expensive because of the sophistication of the equipment and lack of skilful operators in Hong Kong.

4.2.3 Disc Bottom Dredger

The merits of disc bottom dredger are similar to that of the environment auger dredger. As a large stationary dredger, it is not feasible to be used at busy fairways. This type of dredger is currently not available in Hong Kong. Therefore, mobilisation cost is one of the factors that need to be considered.

4.2.4 Scoop Dredger

Scoop dredger, which is a modified cutter suction dredger, is suitable for dredging hard soils. Depending on the design, the length of this dredger may be of the order of 100m. Additionally, this dredger is a stationary dredger and the movement of the dredge head is controlled from a working spud. Hence, this type of dredger is not practical for working at busy fairways or dredging sites with limited space. Like the disc bottom dredger, this dredger is currently not available in Hong Kong, and mobilisation cost is one of the factors that need to be considered.

4.2.5 Improvement to the Overflowing System of Trailing Suction Hopper Dredger

Although there are many advancements in the overflowing system of the TSHD in recent years, the dredging of mud in Hong Kong cannot currently benefit from them as overflow is generally prohibited during dredging of mud.

4.2.6 Hopper Dredge Recirculation System

The hopper dredge recirculation has been successfully affixed to new TSHDs such as the Nautilus, the WD Fairway and Queen of the Netherlands (McLellan & Hopman, 2000). However, the investment cost for retrofitting this system to existing THSDs is very high, and can be in the order of one million US dollars.

Nevertheless, small size THSDs with the provision of a hopper dredger recirculation system can be considered for maintenance dredging of contaminated mud at busy fairways.

4.2.7 DOP Submersible Dredge Pump and Low-Turbidity Dredge Head

As discussed in Section 3, the DOP submersible dredge pump and the low-turbidity dredge head are mainly fitted to and installed on cutter suction dredgers to improve their performance on positional accuracy, minimise the turbidity and to achieve a close to in-situ density for the dredged mud. Therefore, the application of these components is highly dependent on the availability of cutter suction dredger in Hong Kong. The mobilisation cost will be high when cutter suction dredgers are not available in Hong Kong.

5. CONCLUSION

The environmentally improved dredger/innovative dredging techniques discussed above have been used in many countries, particularly those in Europe, and have been found to be successful. As most of these dredgers/techniques are not available in Hong Kong, the mobilisation cost or the initial cost for purposely-built environmental dredger/dredging equipment will be one of major factors to be considered in the selection of techniques to be used. For maintenance dredging in Hong Kong, the thickness of material to be dredged is, under most circumstances, less than 2m. As such, high accuracy dredging plant such as an environmental grab dredger is worth considering, in particular if such plant is mobilised to Hong Kong by other projects. For capital works projects where dredging will generate a large volume of contaminated mud, the constraints due to high mobilisation cost of the dredger and site conditions would become less important. It is worth exploring the adoption of various environmental improved techniques to enhance the environmental friendliness of the project.

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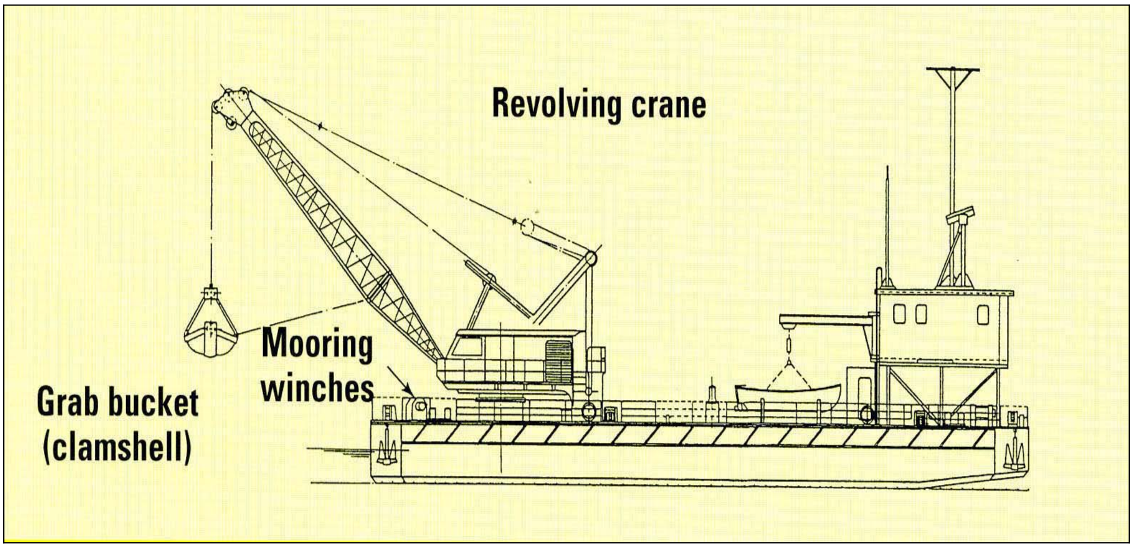
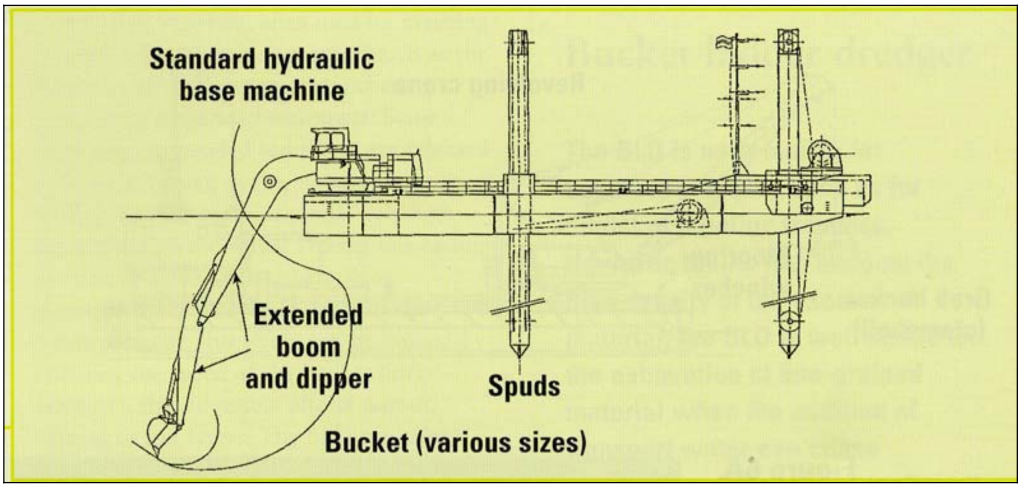


Figure 1 – Schematic Drawing of Pontoon-mount Grab Dredger (IADC, 1998)



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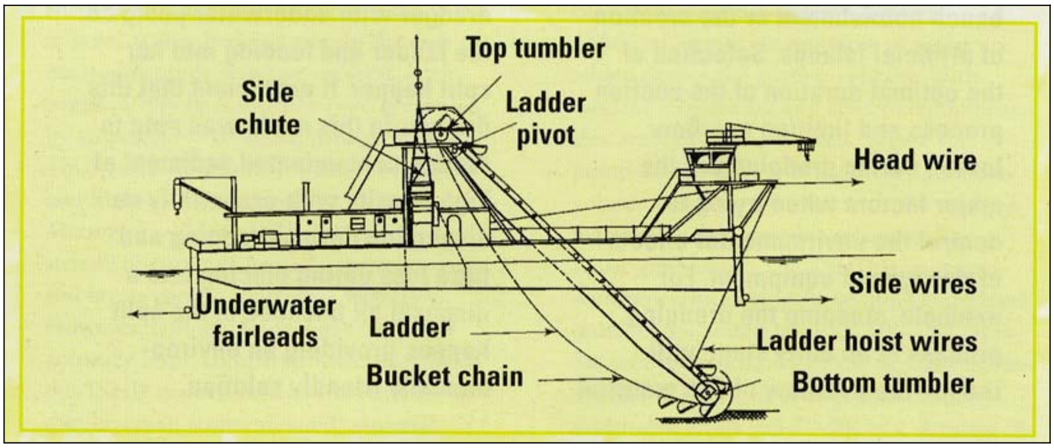

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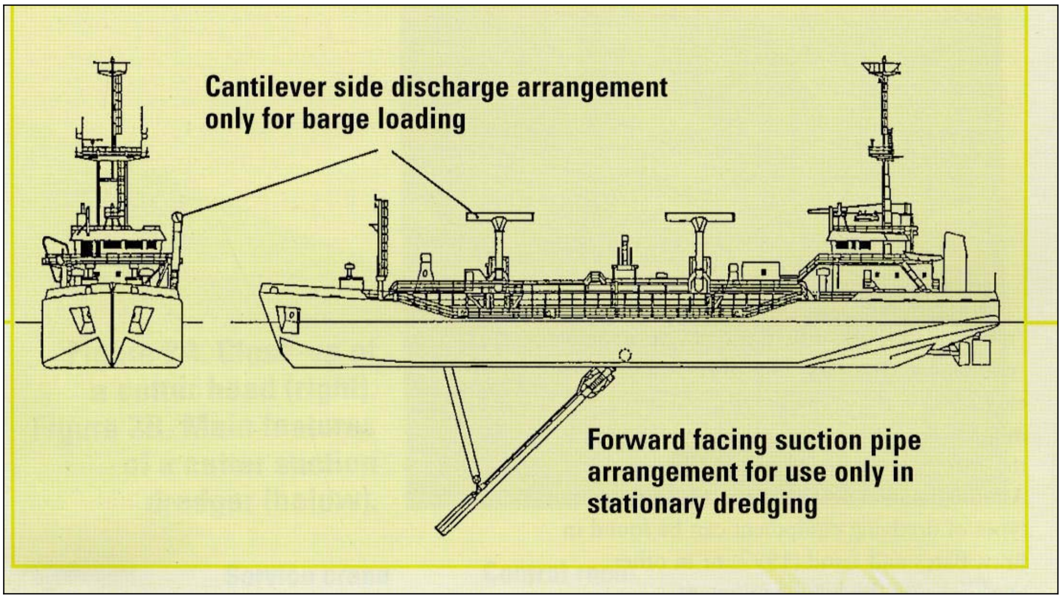

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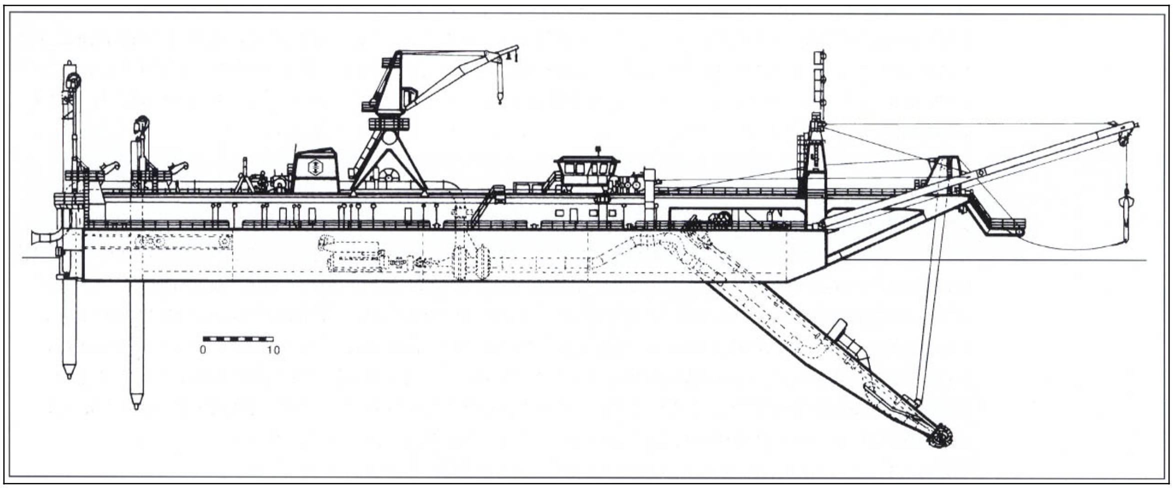

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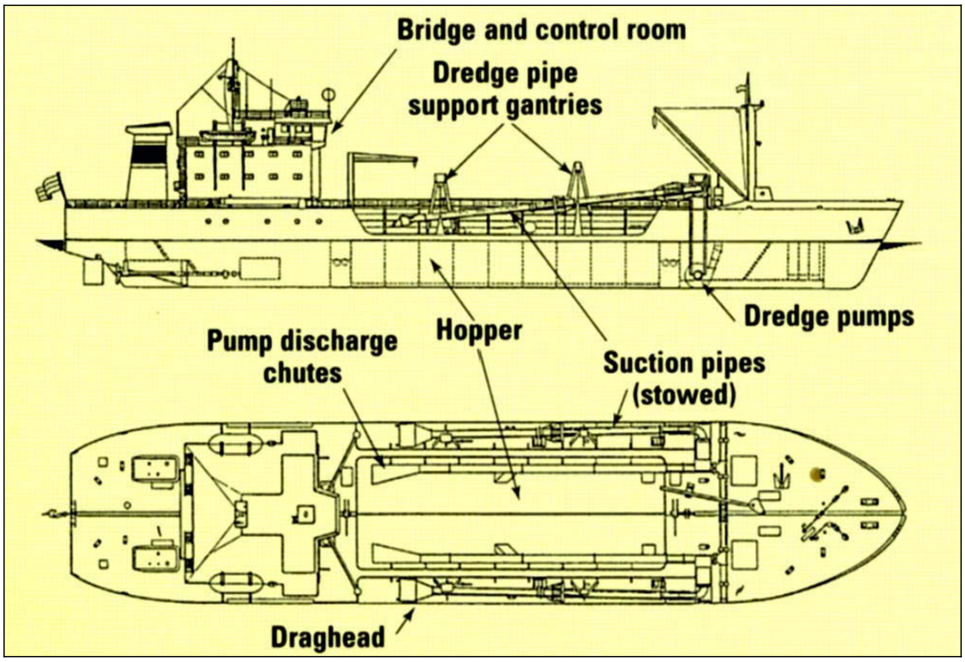

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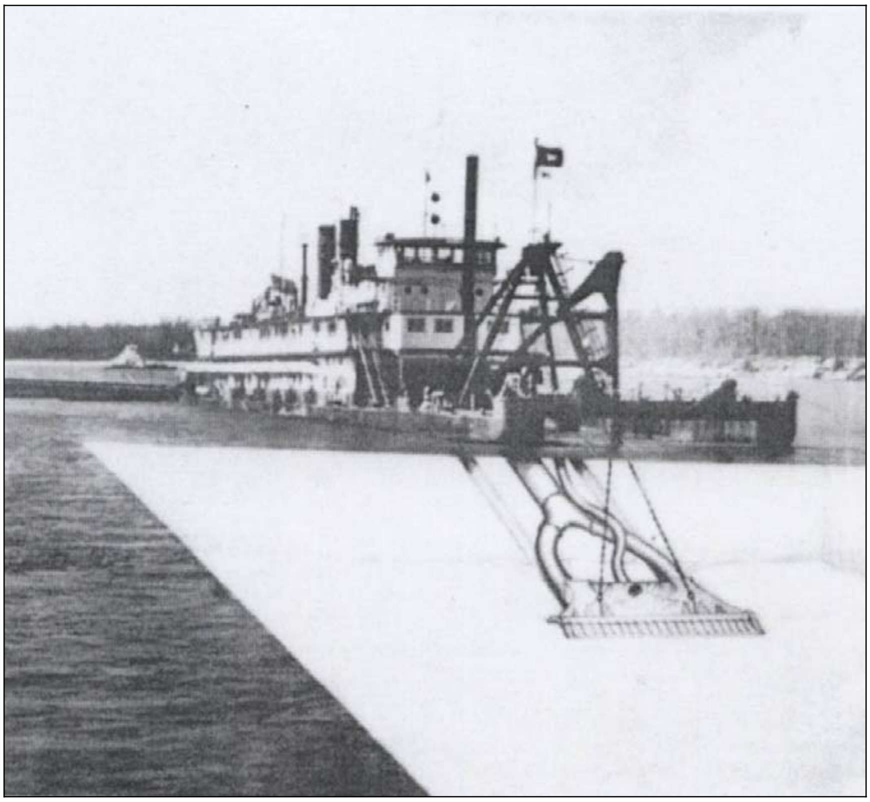

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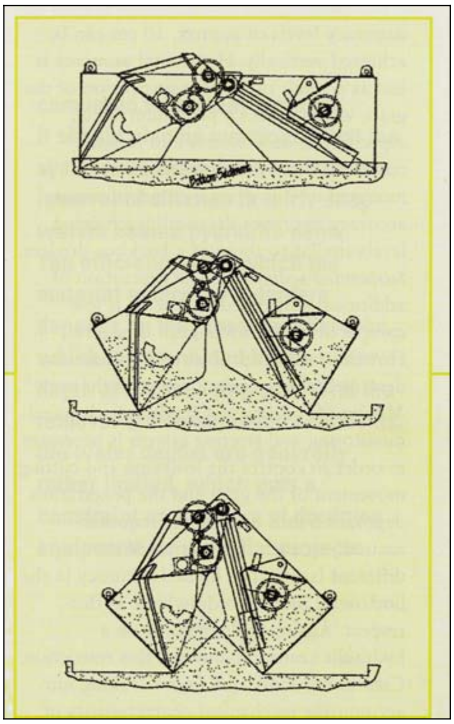

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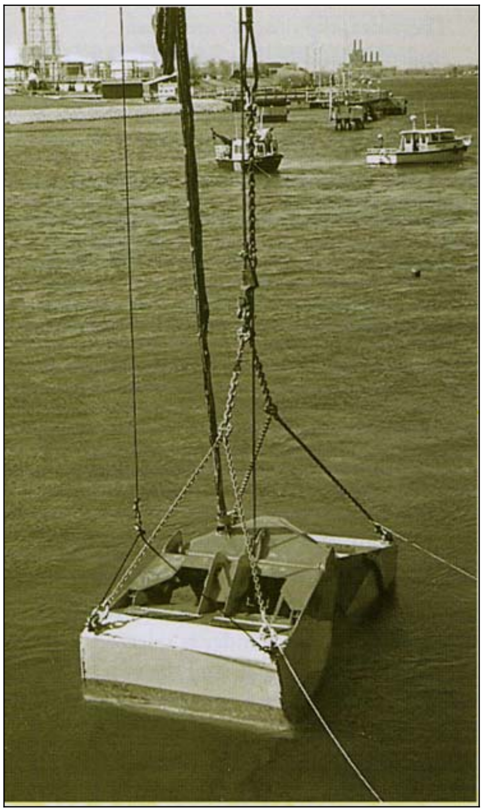

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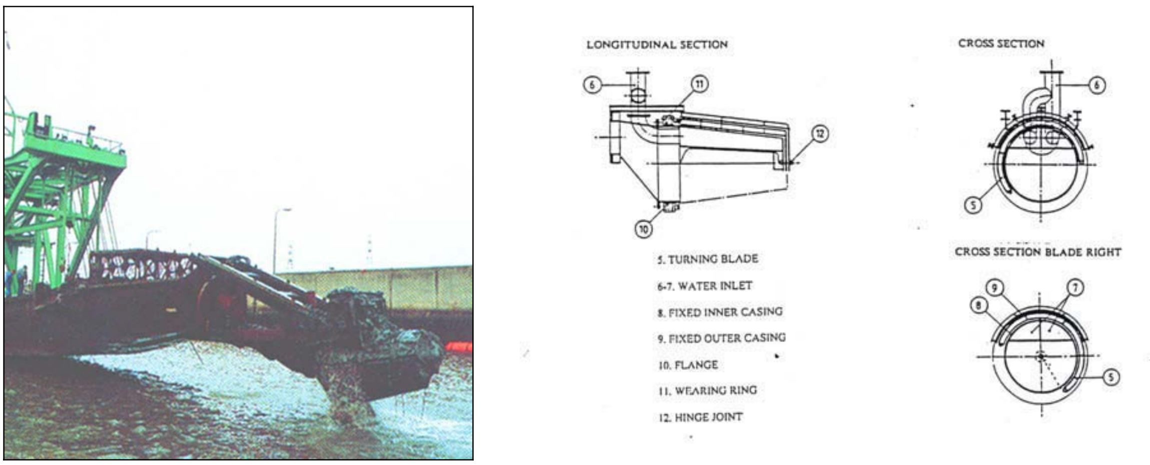

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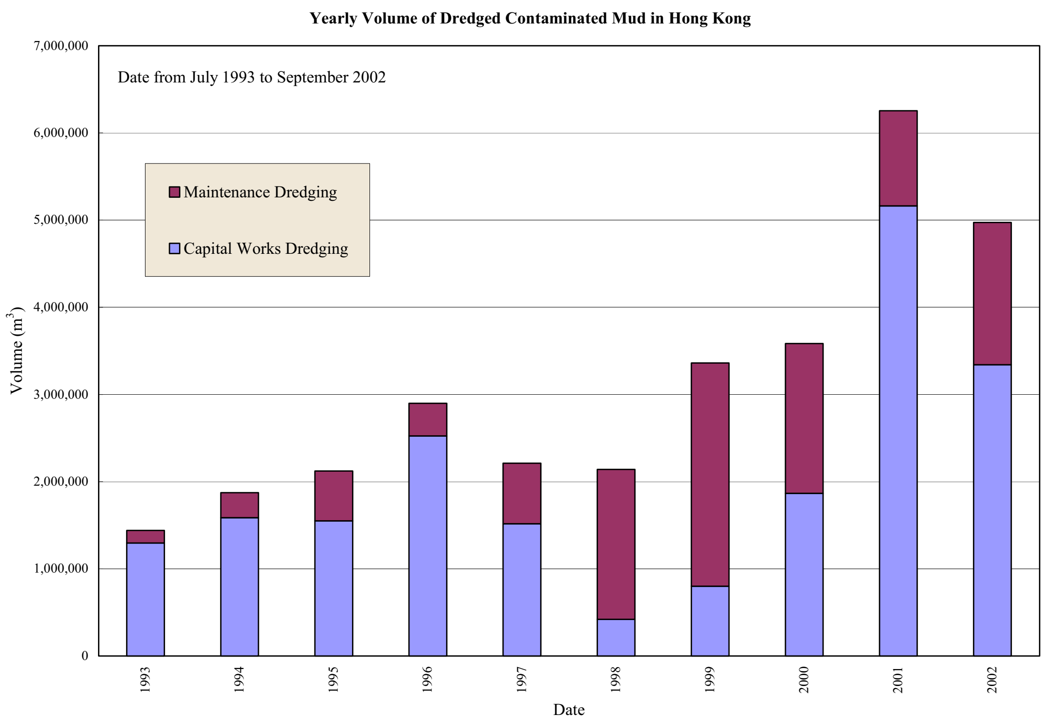

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