Appendix A2

APPENDIX A2

DESCRIPTION OF THE DREDGING TECHNIQUES AND EQUIPMENT

CONTENTS

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1. INTRODUCTION

There are numerous types of dredger, the performance and suitability of which are affected, to varying degrees, by the detailed nature of the sediments and by site characteristics such as water depth, sea conditions, currents and size of area to be dredged.

In this appendix several of the more common types of dredger and dredged material transport methods are outlined in terms of their method of operation and operational and environmental constraints.

Most dredgers can be divided into two broad groups depending on the method by which they excavate and transport the dredged material to the surface:

- **Hydraulic dredgers**: these dredgers rely on powerful centrifugal pumps to loosen the mud and raise it to the surface in the form of a slurry; and

- **Mechanical dredgers**: these excavate the marine mud directly using grabs or buckets achieving greater dilution than is the case with hydraulic dredgers.

The dredgers reviewed are restricted to the types which are most likely to be considered for use by contractors during the LAPH development.

Transport of dredged material to the reclamation or disposal area is usually achieved by one or a combination of the following three methods:

- hydraulic transport through pipelines;
- hopper transport within the hold, or hopper, of the dredger; and
- barge transport in dumb or self-propelled barges.

Placement of dredged fill materials can be achieved by the following methods:

- simple bottom-dumping from barges or trailer dredgers;
- hydraulic filling, involving the pumping of the fill in the form of a slurry to the placement area; and
- 'rainbowing': spraying directly into the filling area through a nozzle mounted at the bow of a trailing suction hopper dredger.

2. THE TRAILING SUCTION HOPPER DREDGER

2.1. General Description.

The trailing suction hopper dredger, or 'trailer', is one of the most common types of dredger and has frequently been used in Hong Kong, including Container Terminals 6 and 7, West Kowloon Reclamation and for removal of overburden from the Marine Borrow Area allocated to the Tin Shui Wai Land Formation Project. It is a sea-going vessel which incorporates a large hopper for the storage and transport of dredged material and a hydraulic dredging system, comprising a suction pipe, draghead and pumps, for lifting material from the sea bed and placing it in the hopper. A typical trailing suction hopper dredger is illustrated in Figure A2.1.

2.2. Method of Operation.

On arrival at the dredging site the suction pipe is lowered and the draghead, which is attached to the lower end of the suction pipe, is positioned on the sediments to be dredged. Centrifugal dredge pumps in the hull, and sometimes additionally in the dredging arm, draw a mixture of marine mud and water through the draghead and dredging arm and thence to the hopper. To ensure a continuous supply of material to the draghead the vessel moves slowly in a straight line across the dredging site.

Except in some very low density soft muds, the dredger usually has to dredge a mixture of mud and water. Because of this, it is sometimes desirable to overflow the hopper to the surrounding sea, thereby making room for the storage of more dredged material, or mixtures of higher density, which tend to sink to the bottom of the hopper. The economic importance of ensuring as full a load as possible, and thus dredging with extended overflow times, becomes greater as transport distances increase.

Another method of improving the production rate of trailer dredgers is the 'Automatic Light Mixture OverBoard'(ALMOB) system. The ALMOB system measures the density of the dredged material being drawn up the suction pipe and, when it drops below a pre-set level, discharges it straight back to the sea until the density increases.

Modern trailers are also often fitted with de-gassing systems for working in marine muds which have a high biogenic gas content. De-gassing is essential for maximum pump efficiency, which is required to ensure dredging at high density. Although some of the Hong Kong marine muds (including some within the present Study Area) are known to contain biogenic gas, it is understood that the concentrations which have so far been encountered have not necessitated the use of de-gassing systems.

3. THE DEEP SUCTION DREDGER

3.1. General Description.

The deep suction dredger is usually a pontoon-mounted suction system designed to work in granular materials at depths of 40 metres or more. The suction system comprises an articulated suction pipe which is raised and lowered by winches and a forward-projecting gantry. The dredger remains stationary during operation and discharges the dredged material into barges for transport or pumps it directly to the fill area through a pipeline. Some trailing suction hopper dredgers have the capability of operating in deep suction mode but, in this case, they transport the material in their own hopper.

3.2. Method of Operation.

Deep suction dredgers have a method of operation which is quite different from that of all other dredgers and one which is very heavily reliant on marine mud conditions. The dredger is positioned and the suction pipe is lowered into the seabed. As the suction mouth penetrates the seabed, it creates a relatively small circular pit from which dredged material is removed. With increasing penetration, failure of the upper part of the pit is initiated and a steep mud face begins to move away from the suction pipe forming a larger circular pit with a shallow bottom slope and a steep side slope. Marine mud from the side slope flows as a density current towards the centre of the pit where it passes into the suction system.

The upper pit continues to enlarge until it eventually stabilises, by which time the suction pipe will already have been lowered further to initiate a second failure at a deeper level. The process continues in this manner until the maximum depth capability of the dredger has been reached or all of the available material has been removed.

Deep suction dredgers can either deliver the dredged material into barges or pump it through a pipeline, if the distance to the filling area is not too great. In both cases, poor sea conditions are likely to result in damage and/or delays. Being pontoon-mounted, they are suited to working in shallow water.

4. THE DUSTPAN DREDGER

4.1 General Description.

The dustpan dredger is another hydraulic dredger which uses centrifugal pumps to lift and pump dredged mud/water mixtures through a pipeline to a barge or disposal site. The dredger is pontoon-mounted and has a dredging arm, or ladder, which can be raised or lowered, to the end of which is attached a wide suction head. This dustpan head may have a suction entrance width of 10 metres or more. The head is normally fitted with water jets to assist in dislodging and fluidising the marine muds to be dredged. A dustpan dredger is illustrated in Figure A2.2 together with a typical suction head.

In principle, dustpan dredgers are only suited to working in non-cohesive materials, but they can dredge very soft clays and silts which are capable of being fluidised by the water jets. They would not normally be used, however, for overburden removal. They are capable of working in granular materials containing thin cemented bands and clay layers but efficiency will be impaired and production will fall away rapidly as the layers become thicker.

4.2 Method of Operation.

The dredger is positioned at the dredging site and the dredging ladder is lowered to the dredging depth. The hydraulic dredging and water jet systems are activated and the dredger is then hauled forwards by its head wire across the dredging site. This process is repeated in parallel strips across the site until the whole dredging area has been covered.

5. THE GRAB DREDGER

5.1 General Description.

The grab dredger is essentially the same as the grab crane used in many construction activities on land. In most cases the grab crane is mounted on a pontoon for dredging but some grab dredgers are sea-going vessels containing their own hoppers similar to the trailer dredger described above. A pontoon-mounted dredger is illustrated in Figure A2.1. Grab dredgers are common in Hong Kong and can dredge a variety of marine mud types but are most frequently used for dredging muds and silts.

5.2 Method of Operation.

The dredger is positioned by means of a four-point anchor spread. The wire-operated grab bucket is lowered to the sea bed in the open position. When the bucket has reached the sea bed, or a pre-determined point just above it depending on the closing mechanism of the bucket, the crane operator activiates the bucket closure wire. This wire draws the two halves of the bucket towards one another until the bucket is closed with the dredged material inside. If a piece of rock or debris gets between the jaws of the bucket it may be prevented from totally closing.

The bucket is then raised to the surface and lifted into the air to a sufficient height for it to be swung round to one side of the pontoon by the crane until it is positioned over a hopper barge moored alongside. The bucket is then opened, releasing the dredged material to the hopper, and the whole cycle is repeated. When the hopper barge has been filled with dredged material it is taken or, in the case of self-propelled barges, sailed to the disposal ground to be emptied.

6. THE BUCKET DREDGER

6.1 General Description

Bucket dredgers are purpose-built vessels, usually of the pontoon type, which have a central well through which an endless chain of buckets passes, carrying marine muds from the seabed to a point high up in the superstructure of the dredger. Figure A2.2 illustrates the general arrangement of this type of dredger. The bucket chain is supported on a hinged ladder which can be raised or lowered to adjust the depth of dredging.

6.2 Method of Operation.

The dredger is anchored at the dredging site with pairs of wires on either side and a very long 'headwire' forward. After the bucket chain has been set in motion the side wires are hauled in on one side of the dredger and let out on the other, in such a way as to move the vessel laterally across the dredging site. This has the effect of excavating a strip of the seabed down to the desired depth. The dredger is then hauled forwards on its head wire and the lateral movement is recommenced, travelling in the opposite direction.

Marine muds excavated by this method are carried to the top of the bucket chain at which point the bucket passes over a tumbler and discharges into a chute. Chutes are mounted on either side of the superstructure and the dredged material is directed to one side of the dredger, where it falls into a hopper barge moored alongside. When the barge is full the chute arrangement is altered to discharge down the other side of the dredger into another barge, whilst the full barge is taken to the disposal site.

7. THE CUTTER SUCTION DREDGER

7.1 General Description

Cutter suction dredgers, or 'cutter' dredgers, are one of the most common types of dredger and are capable of excavating a wide range of marine muds. Very heavy and powerful versions are available which are capable of dredging hard rock material. The cutter dredger (Figure A2.1), comprises a pontoon with a hinged 'ladder' which supports a suction pipe. A rotating cutterhead at the lower end of the ladder excavates the marine mud which is drawn up the suction pipe, through a centrifugal pump, from whence it is discharged through a pipeline.

The pipeline may lead to one or more diffusers mounted on the pontoon which load the mixture into a barge for transport to a disposal ground or, more commonly, it leads to a long floating or submerged pipeline which delivers the material directly to the disposal or reclamation site. Pipeline distances of 500 to 1000 metres are common and distances of 5 to 8 Km are possible with the largest dredgers working in fine materials.

7.2 Method of Operation

The method of operation of the cutter dredger is similar in some respects to the bucket dredger in that it cuts a face laterally across the site. However in the case of the cutter dredger the whole vessel pivots about a positioning spud pole located at the stern of the dredger. The rotating cutterhead is lowered on the end of the dredging ladder to a position within the upper layers of the sea bed and the dredger is then swung across the dredging area by means of anchor wires attached to each side of the ladder. At the end of each swing the cutterhead is lowered further until the required dredging depth is reached. At this point the dredging ladder is raised, the dredger advances into the face and the process is repeated.

8. TRANSPORT OF DREDGED MATERIALS

8.1 Hydraulic Transport

Hydraulic transport through pipelines is the normal method of transporting material dredged by anchored suction dredgers of various types. Dredgers which do not include a suction system cannot utilise, directly, hydraulic transport methods. The ease with which material is transported hydraulically depends on a number of factors, including the diameter of the pipelines, grain size etc.

The pumping of marine muds through pipelines is thus an operation which can take maximum advantage of the pumping power available. However, even with these advantageous conditions, the distances achievable are limited to 5 to 8 Km, depending on mixture density and pumping power. In the case of sands, maximum pumping distances are typically up to about 2.5km. If very long pumping distances are required, booster pumps can be placed in the line at appropriate intervals.

8.2 Transport in the Hopper

A number of dredgers, notably the trailing suction hopper dredger, carry their dredged load to the disposal site in their own hoppers. All hoppers have to discharge at the disposal site and must have a method of opening to allow the dredged material to drop to the sea floor (bottom-dumping). A number of methods of achieving this have been used, such as bottom valves, sliding doors, hinged doors and split hoppers where the whole vessel splits in half.

After material has been bottom-dumped a large amount of water remains in the hopper, often as much as 20% of the hopper volume. This water, termed "rest water", is usually pumped overboard as the dredger returns to the dredging site. However, when dredging sand it is often advantageous to retain the rest water in order to keep the pumps as low as possible and thus increase their efficiency. Many modern trailer dredgers are fitted with self discharging mechanisms which enable them to pump material ashore through a pipeline or to place material by spraying ('rainbowing'), through a nozzle at the bows of the vessel. In most cases, this requires the addition of water to mobilise the hopper contents and thus increase the volume of material for disposal or treatment.

Transport by hopper is technically not limited by distance. However, since the dredger cannot dredge whilst travelling to the disposal ground and back, it is preferable to use other methods, if possible, when very long transport distances are involved.

8.3 Transport by Barge

Barge transport is one of the commonest methods of transporting dredged material. Barges may be self-propelled or dumb (i.e. without propulsion), in which case they are pushed or towed to the disposal ground by tug. Barges discharge their load by bottom dumping through doors or by splitting in half ('split barges').

Barge transport suffers from few constraints, the most important being the sea state and the maximum swell or wave height in which barges can safely operate. In particular, operations involving loading into barges are prone to delays caused by the relative movement between the barge and the dredger.

The majority of barges which are available in Hong Kong have capacities of between 750 and 1,200m^3. When being loaded by hydraulic dredgers they overflow quickly and, in fine granular materials, losses can be considerable. The magnitude of the loss can be reduced, for a given rate of delivery from the dredger, by increasing the barge size. It is expected that Japanese, Korean and U.S.A. contractors will import very large barges to H.K. with capacities in the range 3- 5,000m^3 in the near future.

9. WATER QUALITY CONSIDERATIONS

Environmental constraints associated with dredging activities generally relate to water quality considerations.

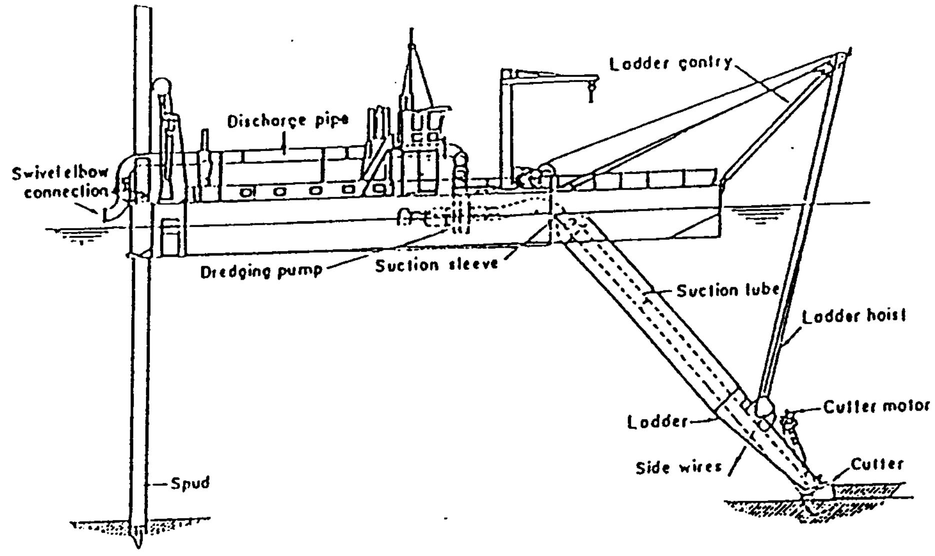
Inevitably, all dredging activities cause a localised increase in water turbidity, and the dispersal and settlement of resuspended sediments. This can potentially cause the release of toxic substances contained in the marine muds, and also the smothering of marine bottom dwelling biota. The increase in turbidity can restrict the availability of sunlight, limiting plant growth and therefore reducing oxygen availability. Also organic matter in the suspended material can deplete available oxygen from the surrounding waters creating a stressed environment for marine life.

The increase in turbidity is dependant on the type and duration of the dredging operation:

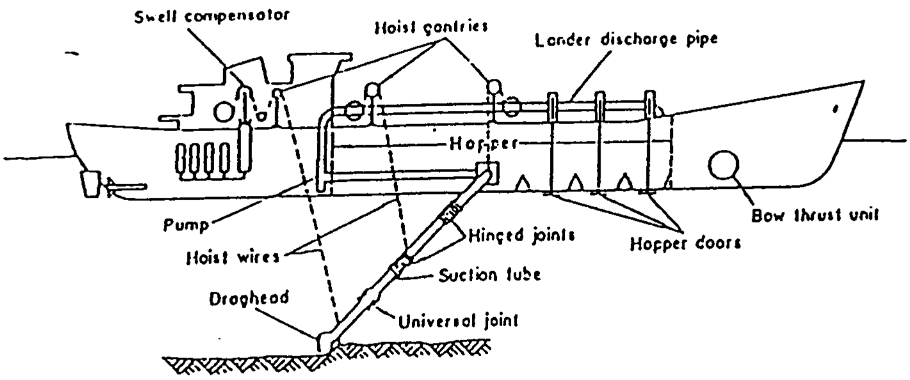
Dredging by use of a grab or bucket mechanical dredger is likely to increase turbidity more significantly than suction/hydraulic pump action dredging. This is a result of the increased disturbance of the seabed, and the loss of material from the grab/bucket which is dispersed throughout the water column. Thus as a general principle the use of suction/hydraulic dredgers, where possible, would be preferred on environmental grounds. Where mechanical dredges are required, the grab/bucket should close completely minimising the dispersion of sediments in the water column.

The use of the "Automatic Light Mixture Overboard" (ALMOB) system and degassing systems also contribute to increased turbidity levels. The gas levels detected so far in Hong Kong marine muds do not necessitate the use of de-gassing systems, use of the ALMOB system should be avoided where possible.

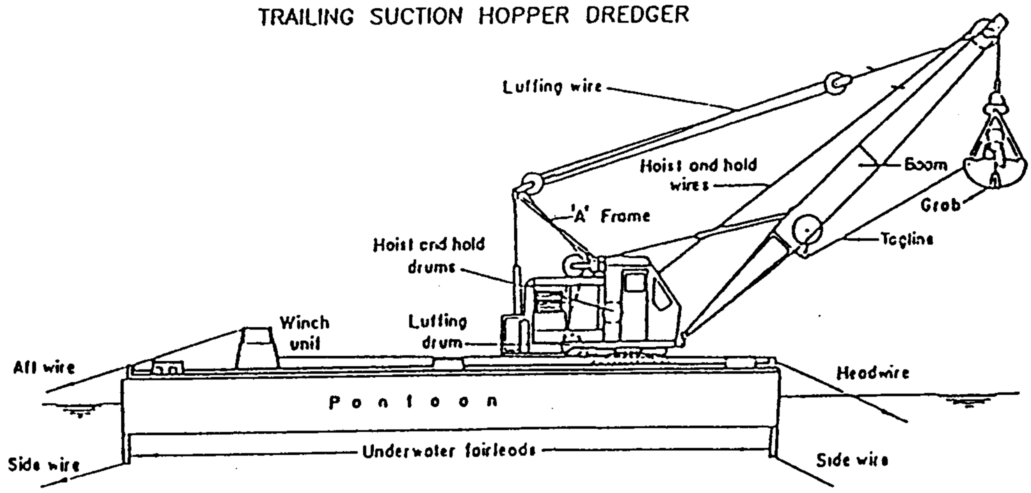
A further source of turbidity is through overflow , the loss of fine dredged material overboard when filling the barge. The impact of the overflow can be minimized to some extent by increasing the barge size. Alternatively, other methods of transporting the dredged material can be adopted such as hydraulic pumping or transportation in the hopper.



CONVENTIONAL CUTTER SECTION DREDGER



TRAILING SUCTION HOPPER DREDGER



GRAB DREDGER

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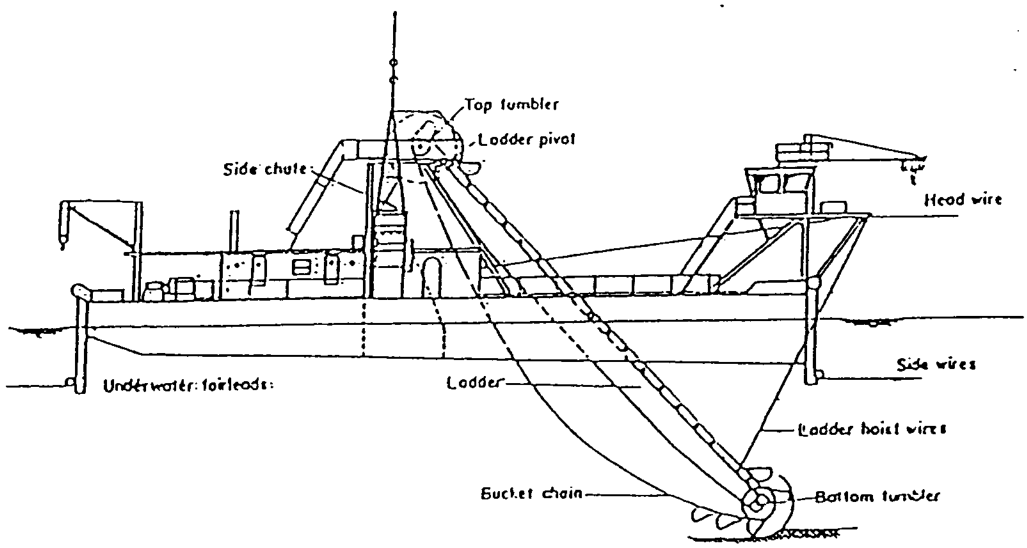
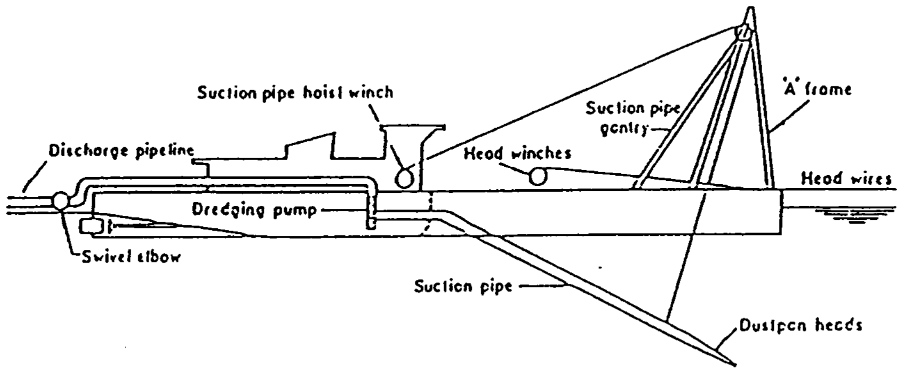
FIGURE A2.1

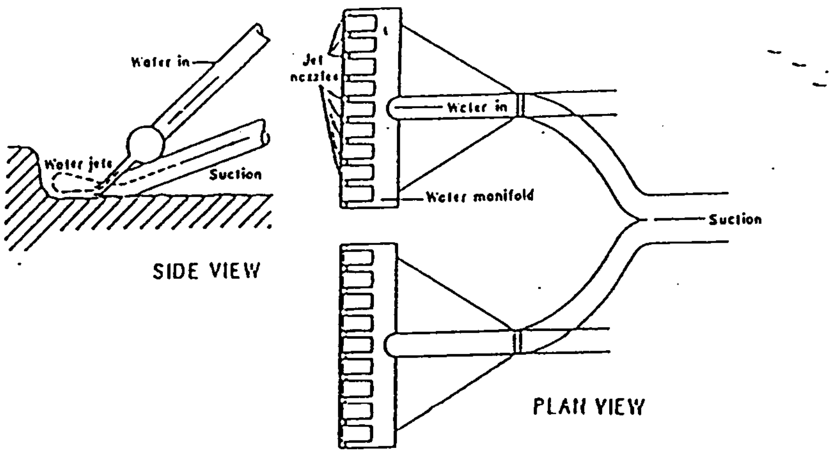
DREDGING PLANT (SHEET 1)



BUCKET DREDGER



DUSTPAN DREDGER



DETAILS OF DUSTPAN DREDGER HEADS

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FIGURE A2.2

DREDGING PLANT (SHEET 2)