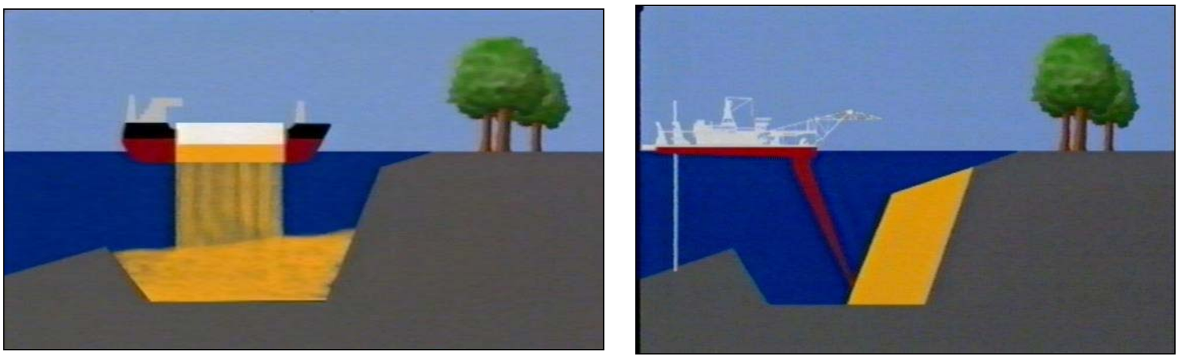
9.2.2.4 Bottom Dumping into Rehandling Pit

This method for discharging to a reclamation area where the required pumping distance is too great for the inbuilt capability of a trailer dredger is a variation of a trailer dredger pumping ashore. In this work method, the dredger bottom dumps into a prepared pit or area, from which the material is re-handled to the reclamation area by a cutter dredger or a suction dredger.



Schematic Sections Courtesy of WestHam Condreco Joint Venture

Figure 19 TSHD Bottom Dumping and CSD Pumping from a Rehandling Basin

9.3 Cutter Suction Dredger

Historically cutter suction dredgers, or cutter dredger, were primarily designed to dredge sands, soft clays and silts and discharge the material as slurry into a reclamation area near to the location of the dredging. In the reclamation area, the water is decanted, leaving the solid material in place.

Modern cutter dredgers can dredge a variety of materials ranging up to weak to moderate strength rocks, depending upon the power installed on the cutterhead and the weight and design of the ladder supporting the cutter head. Discharge distance capability is dependent upon the installed power on the dredge pumps. In large, modern cutter dredgers, typically the dredge pump power is provided by one submerged ladder pump and one or two inboard discharge pumps.

Cutter dredgers are very susceptible to sea state conditions and generally can only work in calm conditions.

9.3.1 Cutter Dredger Work Methods

The cutter dredger operates basically as a fixed vessel. The stern is held in position with a working spud, mounted in a movable carriage. The working spud is dropped, or lowered, into the seabed, thereby holding the stern in a fixed position. At the forward end of the dredger there are two powerful side anchor winches from which are connected two side anchors. These side anchors are positioned either side of the dredge cut. The side anchors winches reeve in and pay out in concert, thereby swinging the dredger from side to side across the full width of the dredge cut.

The dredger is swung from side to side across the cut, with each pass the ladder is lowered a pre-determined depth, or cut face height, until the required dredge depth is reached. Then (typically)

the ladder is raised so as the be clear of the seabed immediately in front of the cutterhead, and then the dredger is moved forward a controlled distance, or step, by means of a powerful hydraulic ram pushing on the spud carriage, in which the working spud in mounted. The cutting process then continues until again the desired dredge depth is reached and the stepping process is repeated.

The total travel forward when stepping ahead is limited by the travel of the spud carriage hydraulic ram or size of the spud carriage and spud carriage well. When the maximum travel distance is reached, the dredger is stopped from swinging and an auxiliary spud, also mounted at the stern of the dredger but to the side of the spud carriage, is then dropped into the seabed to hold the dredger in position. The working spud is then raised and the spud carriage ram retracted, the working spud lowered, the auxiliary spud raised and dredging then continues.

The cut face height and step length are varied to suit the properties of the materials being dredged at any given time.

The dredger breaks up the seabed material by the mechanical action of a rotating cutterhead, and pumps the dislodged material away as slurry from the work face by means of powerful dredge pumps positioned in the dredger and discharges it through a pipeline (typically) to a reclamation area.

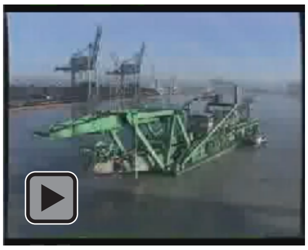
During this process, the seabed material is completely disturbed. Consolidated materials can break down into its constituent parts. The degree of breakdown will depend upon the in-situ physical properties of the material, the number of dredge pumps in the dredger and the pumping distance through the discharge pipeline.

When dredging clays, depending upon the physical nature of the clay, it is normal for it to form into clay balls, which “roll” along the bottom of the discharge pipe. Great care has to be taken by the operator to avoid blocking the pipeline when dredging this type of material.

The solids concentration of the slurry at any given time will vary greatly, ranging from zero to say 70%, depending upon the material type and a large number of operational variables. Typically, the average concentration will be in the range of 10% to 20% by volume for sands.

Photograph courtesy of Royal Boskalis Westminster

Figure 20 Heavy Duty CSD Phoenix



Video courtesy of DEME Group
Click to activate

Figure 21 CSD Operation Video

9.3.2 Cutter Dredger Discharging Methods

A cutter dredger can deliver the dredged material in the following manner:

1. by discharge to reclamation ashore via combinations of floating pipeline, submerged pipeline and shore pipeline;
2. by discharge into a hopper barge moored alongside the dredger (if so designed);
3. by crushing the material and leaving it on the seabed for subsequent removal by a trailer dredger;
6. by “rainbowing” from the stern of the dredger;
7. by discharging through a spreader pontoon for accurate underwater placement.

The method adopted depends on the project work requirements.

Photograph Courtesy of Jan De Nul Group

Figure 22 Mega CSD Leonardo da Vinci Loading Split Hopper Barges

Photograph Courtesy of Jan De Nul Group

Figure 23 Large Split Hopper Barge

9.4 Backhoe Dredger

A backhoe dredger typically comprises a large, "marinised" hydraulic excavator mounted on a spudded pontoon. The excavator is mounted on a turntable at one end of the pontoon, and loads the dredged material into a hopper barge moored alongside.

Typically, the excavators used on backhoe dredgers have been standard mining equipment, modified by having the tracks removed and then mounted on a turntable.

The pontoon onto which the excavator is mounted is fitted with three spuds, two “fixed” spuds forward and one “working” spud aft. The stern working spud is fitted into a spud carriage, which can travel along the centreline of the pontoon.

The reasons for this design are:

1. the pontoon is elevated by its spuds whilst dredging is taking place, thereby destroying its buoyancy. This enables the transfer of the large breakout forces generated by the excavator to the seabed, via the three spuds;
2. to position the excavator accurately during dredging;
3. to move the pontoon forward as dredging progresses;
4. to allow free access for the spoil barges or hoppers to come alongside and depart without greatly disrupting the dredging operations.

The backhoe dredger works in a similar manner to a land based excavator. The pontoon is held in position by its three spuds, dredging down to the design depth. It then steps ahead by first being lowered back down into the water until it is free floating, the excavator bucket placed onto the seabed on the dredge cut centreline, to hold the pontoon steady in position, and the two forward, fixed spuds, are raised clear of the seabed. Then the pontoon is pushed ahead a pre-determined step length, say 1 to 2 metres depending upon soil type, the size of the dredger and dredging depth, by the rear mounted spud carriage, the rear spud still being fixed into the seabed. The pontoon is then again lifted and the dredging continued.

This process continues until the spud carriage has reached its full travel capability, typically 6 metres to 10 metres, depending upon the size of the dredger, following which the pontoon is lowered and held in position by the two fixed spuds forward, the working spud raised and the spud carriage drawn back to its starting position, and so the dredging process then continues.

A backhoe dredger is not just a crane or an excavator on a barge. It is specifically designed for dredging hard materials and to be capable of operating in open water marine conditions.

In recent times a Dutch company has designed and constructed a number of backhoe dredgers, utilising a purpose designed excavator rather than a modified land excavator. These machines have all prime movers, hydraulic system, fuel supply etc. mounted below deck to greatly improve safety and to increase operating time. Also, the pontoon spud control system is mounted in the excavator control cabin instead of (typically) in the wheelhouse of the pontoon.

Photograph courtesy of Shipyard De Donge

Figure 24 Mega Backhoe (Backacter) Dredger

9.5 Grab Dredger

A grab dredger comprises a large crane mounted on a spudded, flat top barge or pontoon. Typically, the crane is mounted in the centre of the barge, but may also me mounted toward one end. The grab dredger loads the dredged material into a hopper barge moored alongside.

Whilst dredging, depending upon the water depth, the barge is held in position by the spuds. This allows the spoil barges or hoppers to come alongside and depart without greatly disrupting the dredging operations. If the water depth is too great to allow the use of spuds, the barge is also fitted with an anchor winch system to hold the dredger in position. Also in unfavourable sea state conditions the anchor winch system may be used instead of the spuds to increase the sea state working window, although this typically will only be a marginal increase.

Photograph Courtesy of Kojimagumi Co. Ltd.

Figure 25 Mega Grab Dredger Gosho

9.6 Rock Dredging

Rock dredging is costly and should be avoided whenever possible.

9.6.1 Rock Types

Broadly speaking the capability to dredge rock directly, without pre-treatment with explosives, is dependent upon both the inherent compressive strength of the rock and the physical characteristic of the rock. A rock may have a relatively high compressive strength, but if it is fissured or contains vugh holes, or is weathered, it may be able to be dredged without pre-treatment.

In general, all igneous and metamorphic rocks will require pre-treatment to be able to be economically dredged.

9.6.2 Suitable Dredgers

The dredgers which are capable of dredging weaker strength rock without the aid of pre-treatment are:

1. heavy duty and mega cutter dredgers;
2. large and mega backhoe dredgers;
3. large bucket dredger (weak rock only);
4. large grab dredger fitted with a heavy rock bucket (very weak rock only).

The dredgers that are capable of dredging pre-treated rock are:

1. medium, large and mega backhoe dredgers;

2. large bucket dredger;
3. large grab dredger fitted with a heavy rock bucket (bucket weight >30 tf);
4. heavy duty and mega cutter dredgers, in some circumstances, and typically very small volumes only.

Other equipment such as vibro-hammers mounted on a backhoe dredger, or needle piles have been used, with varying degrees of success in certain circumstances. However, the economic success of these methods is very dependent upon the type of rock, the layer thickness to be removed, the total volume to removed and a large number of other site variables such as sea state conditions, marine traffic, tidal currents and the like.

9.6.3 Marine Drilling and Blasting

Marine drilling blasting is a precise science, and can be used to great effect to prepare rock for dredging.

Ground vibrations can be very well controlled with the use of delayed detonation. With marine drilling and blasting the majority of the explosive's energy is dissipated into the rock and not into the water column. Notwithstanding some fish kill will occur within the immediate location of the blasting.

Initiation of the explosive is effected using non-electrical, down hole systems, and air blast is eliminated.

Again, marine drilling and blasting is expensive, and should be avoided if at all possible.

For rock dredging to be successful, the control of fragmentation of the rock is critical. The largest components of the fragmented rock will control the production rate of the dredger. In some situations, depending upon the type of dredger being deployed, it will also control whether dredging can take place at all, following the blasting. Once an area of rock has been blasted, if the fragmentation is not correct, it is virtually impossible to go back and re-drill and re-blast the area.

Not all types of rock can be suitably fragmented with explosives to allow effective dredging. Calcareous type rock and rock like materials are very difficult to fragment successfully, as are thin layers of harder rock, where blasting is likely to result in large slabs being created.

Boulders are notoriously difficult to blast and are better removed by other dredging or removal work methods.

9.6.4 Marine Drilling and Blasting Barge

Successful fragmentation of rock in the marine environment is heavily reliant upon very accurate positioning of the drill holes. The best means to achieve this is to deploy a Self-Elevating Platform (SEP) drill barge.

Photograph: Baggerman Collection

Figure 26 Self Elevation Platform Drill Barge

10 RECLAMATION

Reclamation work is typically associated with hydraulic dredging work methods. However, it may also be formed using mechanical work methods and land fill methods.

This section is devoted to the hydraulic dredging work method.

10.1 Filling

10.1.1 Working with Sand

In creating reclamation using a hydraulic work method the dredged materials will be placed directly from the discharge pipe of the cutter dredger into the reclamation area.

The hydraulic action of this process means that the density of the placed material is usually sufficient for general land use. However, this is very dependent upon the nature of the material being dredged and the ultimate use to which the land will be put.

The manner and sequence it is placed is completely dependent upon the nature of the material being dredged, and to a lesser extent the size of the dredger.

With competent, non-cohesive materials being dredged, earth moving equipment can be deployed directly on the area as it is being filled to control the discharge of the material and the final placement level.

Photograph: Baggerman Collection

Figure 27 Typical Sand Reclamation

Photograph: Baggerman Collection

Figure 28 Typical Sand Reclamation

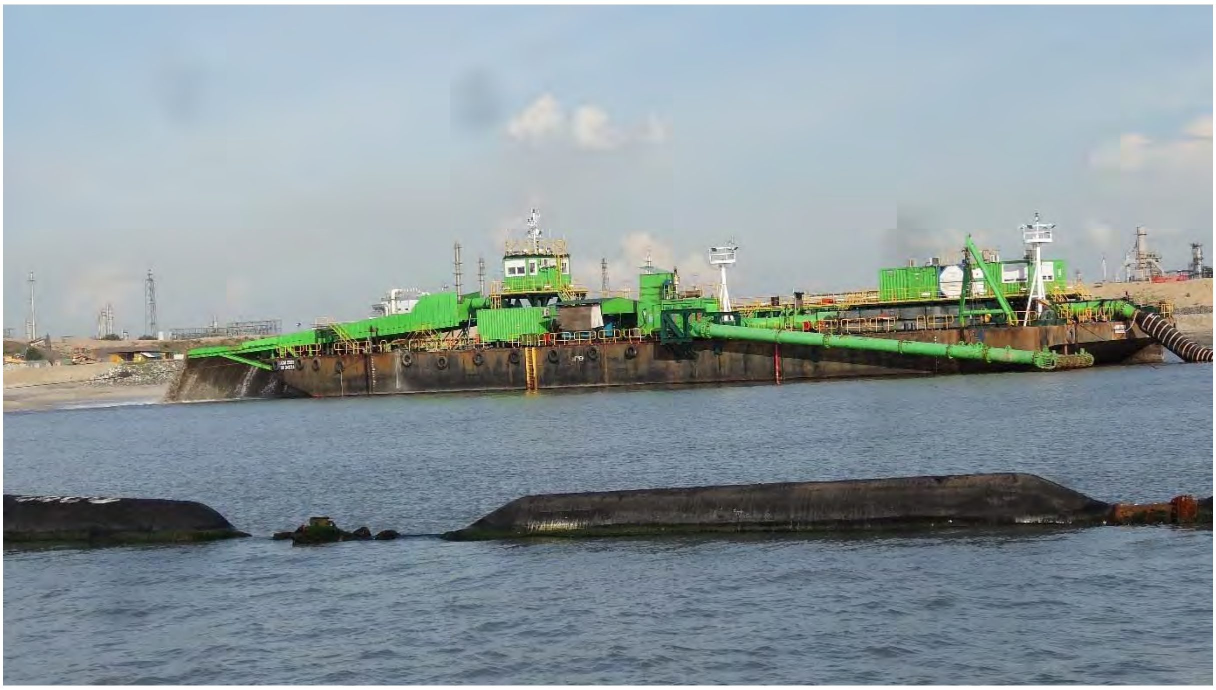
10.1.2 Under Water Placement

Sand can also be placed under water in a controlled manner, or spread, using a purpose-built Spreader Pontoon.

It is difficult to control the accuracy of the finished level, as the pontoon has to be moved in unison with fluctuation in the incoming solids concentration of the supply slurry. The spreader pontoon may be fed by either a trailer dredger (pumping out) or by a cutter dredger.

The accuracy of placement is controlled by having velocity and concentration metres on the spreader pontoon, a data link to the production monitoring system of the supply dredger, and an automated winch system.

Typical best vertical accuracy achieved is in the order of ± 50cm.



Photograph: Baggerman Collection

Figure 29 Spreader Pontoon

10.1.3 Working with Silt and Clay

When clay is being dredged the constructability of a reclamation area is completely changed when compared to working with non-cohesive material.

As the dredged material is transported through the discharge pipeline of the cutter dredger, some of the clay material will form into clay balls, and some will breakdown down into its constituent parts generating HMCM.

The degree of disintegration is related to the distance the material travels through the discharge pipeline, and the volume of the HMCM generated can typically be in the order of four to five times greater than its initial in-situ volume.

Typically, as the placement of the dredged material using a cutter suction dredger progresses, the heavier material falls at the end of the discharge pipeline, which pushes the HMCM, generated in the pipeline, in front of it.

The deposited solid material, comprising clay chunks and clay balls, does not spread as is the case when dredging non-cohesive material, so the discharge pipeline has to be extended at much more frequent intervals.

Working on the newly deposited material with earth moving equipment is much more difficult, the degree of success depending upon the nature of the clay.

Notwithstanding this is a proven work method, provided pockets of the HMCM do not become isolated and entrapped, thereby creating pockets of very unstable material which will subsequently erupt to the surface as the weight of the overburden materials, and or working loads, increase.

Photograph: Baggerman Collection

Figure 30 Typical Clay Reclamation Discharged by Cutter Dredger

10.2 Build-up of HMCM in Reclamation Area

10.2.1 Dredging Silty Sand

Fines will settle out and typically build up in front of the reclamation fan of the more rapidly settling coarser materials. The degree of build-up will depend upon the fines content of the materials being dredged, the flow being discharged from the dredger (that is the size of dredger being deployed) and the free water depth within the reclamation area.

When dredging sand the fines will generally form at a very flat gradient, typically in the range of 1 vertical to 200 to 500 horizontally. Initially the progressing fan of reclaimed coarser materials will "push" the built up unsuitable materials in front of it as it progresses. However, there is considerable risk that a point will be reached when the internal shear strength of the mass of the built up unsuitable material will be such that it will no longer be pushed ahead of the main body of the fill and the coarser materials will subsequently flow over the top of it and create a large pocket of unstable high moisture content material.

Further, as the reclamation area is progressively filled, the HMCM will also build up in front of the sluice boxes, therefore creating pockets of unstable material at those locations.

10.2.2 Dredging Silt and Clay

When dredging silt and clay, great care must be given to the prevention of the build-up of mud waves and or pockets of unsuitable materials within the reclamation area.

This is managed by visual inspection as the work proceeds, by sampling as the work proceeds, and by the control of the water flow running from the end of the dredge discharge pipe.

10.2.3 High Moisture Content Material Removal

A common work method to remove the unsuitable material is to deploy a very small cutter dredger within the reclamation area itself, and dredge away this HMCM material and pump it into a storage area. This storage area will itself require a settlement pond and a sluice box to ensure the supernatant water discharged during this work also meets water quality requirements. With a very controlled work method high solids concentration of the re-dredged slurry can be consistently achieved.

A critical part of this control is to obtain very accurate data of the layer thickness of the unsuitable materials and the profile of the underlying material.

An alternative work method is to deploy a large submersible pump suspended from a pontoon. This work method it more difficult to control the accurate removal of the unsuitable material and also more difficult to maintain the maximum possible concentration of the material as it is being removed.

Photograph: Baggerman Collection

Figure 31 Very Small Cutter Dredger

10.3 Settlement of Suspended Fines

Suspended fines in the supernatant water will settle out in the reclamation area and in the settlement ponds prior to the water being discharged back into the sea via sluice boxes.

The degree of settlement that will take place in the reclamation area is dependent upon the size of the reclamation area, depth of the free water at any given location and the retention time within the reclamation area, and also the degree of disturbance being created during the discharge of the slurry from the dredger's discharge pipeline.

This is a constantly changing process due to the fact the reclamation area's effective containment volume gets smaller as it is being filled.

It is crucial that the supernatant water has adequate retention time to travel within the reclamation area to allow sufficient of the suspended sediment to settle out, so that the water being discharged will meet water quality requirements.

Depending upon the area of land available the physical size of the reclamation area may not be sufficient to meet these criteria. In such a situation, separate settlement ponds would need to be constructed as part of or as close as possible to the main reclamation area to fulfil this function.

10.4 Run Off Water Sluice Boxes

One or more sluice boxes with adjustable discharge level will be required to allow the supernatant water to be first discharged from the reclamation area into the settlement pond area, and then from the settlement pond back into the environment.

Photographs: Baggerman Collection

Figure 32 Reclamation Sluice Boxes

The size of the sluice boxes, their positioning and number of discharge pipes required is dependent upon the nature of the material being dredged, environmental management requirements for the quality of the run-off water and the size of the dredger being deployed.

10.5 Bund Walls

The internal surface of the perimeter bund walls may need to be protected with a geotextile fabric or HDPE in order to avoid either erosion of the internal bund surfaces and or to prevent material leakage through the external perimeter wall or both.

Photograph: Baggerman Collection

Figure 33 Geotextile Protected Bund Wall

10.6 Reclamation Area Levelling and Compaction

Typically, the material is placed as close as possible to final level as the works proceed, or the level specified.

The volume of material placed into the reclamation area must be accurately measured to ensure there is sufficient volume of material available to provide the finished level, and compaction of the material must also be taken into account.
The accuracy achievable when dredging non-cohesive materials can be in the order of ± 30 cm. If a closer tolerance is required, then levelling by earthmoving equipment will be required after dredging is completed.

When dredging clay typical the final surface may be very rough, depending upon the nature of the clay and the ability of the earthmoving equipment to work on it at any given time.

When dredging sand, if the land is going to be used for general purposes then typically the density of the hydraulically placed material may provide the required bearing strength with mechanical compaction.

However, this is very dependent upon the type and nature of the dredged material, and final surface design loadings. Additional compaction may be required.

For container port operations, it can be expected that post-dredging consolidation of specific areas will be required.

When dredging clay, it can be expected that post-dredging land improvement will always be required.

10.7 Reclamation Area Surface Run-off

Provision must be made for the control and dissipation of rainfall during the construction and subsequent management of the reclamation area.

10.8 Wind Blown Particles

Provision must be made for the control of windblown materials during the construction and subsequent management of the reclamation area.

10.9 Safety

Any reclamation area may contain dangerous pockets or areas of very soft, quick sand like material.

Access to reclamation areas must be controlled.

11 PROJECT SPECIFIC RECLAMATION REQUIREMENTS

The principal prerequisites for the reclamation area's functional performance typically are described as following.

11.1 Land Use

The port land functional requirements will comprise the following:

1. wharf structures and supporting operational areas;
2. container stacking;
3. container handing;
4. terminal roads;
5. rail access corridors;
6. ancillary port structures and facilities.

All land is required to have the following surface characteristics:

1. a maximum transverse gradient of 1%;
2. a maximum cross fall of 0.5%.

11.2 Reclamation Area User Specification

A typical specification for the quality of the reclamation area fill material, is as follows.

Example requirements for container handling and storage at this time are:

1. less than 50 mm total settlement in 2 years;
2. less than 300 mm total settlement in 20 years;
3. differential settlement less than 1:200;
4. container exchange area maximum gradient 1% longitudinal and 0.5% transverse.

11.3 Dredged Materials Qualities

Given the nature of the greater portion of the material to be dredged for this project is clay, the dredging work method selected will have widely varying end results pertaining to the physical properties of the material, once it is dredged.

If it is placed into reclamation its subsequent physical condition will be difficult to manage effectively in order to achievement of the necessary load bearing strength required for port road and rail traffic, and container handling operation.

Consequently, considerable ground improvement treatment will be required following completion of dredging to make it fit for purpose.

12 GENERIC WORK METHODS AND RESULTANT MATERIAL BEHAVIOR

The following is a brief overview of the various dredging work methods possible for this project, the resulting impact on the physical properties of the materials as it is dredged, and the environmental management consideration necessary to minimise the potential resultant impacts upon the environment.

	Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
			Dredging	Reclamation	Dredging	Reclamation
Type 1	Very soft to firm Clay and Silt	1. TSHD to offshore DMG.	• Loads easily if very soft; • Fines do not settle in hopper; • Easily discharged from hopper; • Material becomes very disturbed during dredging process, very little of the mass retained in the hopper; • Firm clays become less economical to dredge due to in-situ ridging.	Not Applicable.	• High levels of water turbidity can be generated unless hopper overflowing is restricted. • High levels of water turbidity can be generated by propeller wash.	Not Applicable
		2. TSHD pumping ashore.	• Loads easily if very soft; • Fines do not settle in hopper; • Not easily pumped out unless very soft; • Material becomes very disturbed during dredging process, very little of the mass retained in the hopper; • Firm clays become less economical to dredge due to in situ ridging;	• Large volume of High Moisture Content Material (HMCM) generated; • Requires a large tract of land to manage HMCM and dredging run-off water. This land will be quarantined for a very long time; • Requires very long time to dehydrate after placement, unless placed in thin layers;	• High levels of water turbidity can be generated unless hopper overflowing is restricted; • High levels of water turbidity can be generated by propeller wash.	• Large area of land required to contain HMCM generated by hydraulic dredging process; • Large area of settlement ponds required to control suspended solids content of discharge water;

Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
		Dredging	Reclamation	Dredging	Reclamation
		• Selective dredging of material not possible (typical).	• Poor engineering qualities. Comprehensive ground treatment required.		• Security fencing required; • potential interaction with subterranean water; • management of returning run-off water back into Western Port.
	3. CSD to reclamation.	• Easily dredged; • Material becomes very disturbed during dredging process; • Selective dredging of material not possible (typical).	• Dredged material will form clay balls in the discharge pipeline; • Material breaks down into constituent parts during slurry transport process in dredger's discharge pipeline; • Large volume of High Moisture Content Fines (HMCM) generated; • Requires a large tract of land to manage HMCM and dredging run-off water. This land will be quarantined for a very long time; • Requires very long time to dehydrate after placement, unless placed in thin layers; • Poor engineering qualities. Comprehensive ground treatment required.	• Water turbidity localised to near cutter head; • Discharge pipeline creates local navigation hazard; • Lights onboard dredger at night may attract birds etc.;	• Large area of land required to contain HMCM generated by hydraulic dredging process; • Large area of settlement ponds required to control suspended solids content of discharge water; • Security fencing required; • potential interaction with subterranean water; • management of returning run-off water back into Western Port.

Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
		Dredging	Reclamation	Dredging	Reclamation
	4. CSD loading hoppers to offshore DMG.	• Easily dredged; • Material becomes disturbed during dredging process; • Selective dredging of material not possible (typical).	Not Applicable.	• Water turbidity localised to near cutter head; • Overflow from hoppers will generate water turbidity; • Lights onboard dredger at night may attract birds etc.	Not Applicable
	5. BHD loading barges, rehandle to onshore.	• Easily dredged; • Selective dredging of materials possible; • Material remains near or at its in-situ constitution.	• Material remains near or at its in-situ constitution; • Work method requires double or triple handling; • Requires a long time to dehydrate after placement, unless placed in thin layers; • No run-off water from dredging process, therefore bund walls not required; • Placement of material into final location difficult, may require construction of considerable number of temporary access roadways; • Poor engineering qualities. Comprehensive ground treatment required.	• Water turbidity restricted to near dredger; • greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.	• Considerable amount of earthmoving equipment and trucks required for the re-handling; • Twenty-four hours per day, seven days per week operation required.
	6. BHD loading barges to offshore DMG.	• Easily dredged; • Selective dredging of material possible.	Not Applicable.	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	Not Applicable

	Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
			Dredging	Reclamation	Dredging	Reclamation
Type 2	Sand (very fine clayey sand, silty sand)	1. TSHD to offshore DMG	• Loads easily; • Fines do not settle in hopper; • Easily discharged from hopper; • Selective dredging of material not possible (typical).	Not Applicable.	• High levels of water turbidity generated by hopper overflowing, draghead agitation and propeller wash.	Not Applicable
		2. TSHD pumping ashore.	• Loads easily; • Fines do not settle in hopper; • Easily pumped out but pumping distance is limited, dependent upon median grain size of material; • Selective dredging of material not possible (typical).	• Large volume of High Moisture Content Material (HMCM) generated; • Requires a large tract of land to manage HMCM and dredging run-off water. This land will be quarantined for a very long time; • Requires very long time to dehydrate after placement, unless placed in thin layers; • Poor engineering qualities. Comprehensive ground treatment required.	• High levels of water turbidity generated by hopper overflowing, draghead agitation and propeller wash.	• Large area of land required to contain HMCM generated by hydraulic dredging process; • Large area of settlement ponds required to control suspended solids content of discharge water; • Security fencing required; • potential interaction with subterranean water; • management of returning run-off water back into Western Port.
		3. CSD to reclamation.	• Easily dredged; • Selective dredging of material not possible (typical).	• Material breaks down into constituent parts during slurry transport process in dredger's discharge pipeline;	• Water turbidity localised to near cutter head; • Discharge pipeline creates local navigation hazard;	• Large area of land required to contain HMCM generated by hydraulic dredging process;

Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
		Dredging	Reclamation	Dredging	Reclamation
			• Large volume of High Moisture Content Fines (HMCM) generated; • Requires a large tract of land to manage HMCM and dredging run-off water. This land will be quarantined for a very long time; • Requires very long time to dehydrate after placement, unless placed in thin layers; • Poor engineering qualities. Comprehensive ground treatment required.	• Lights onboard dredger at night may attract birds etc.; •	• Large area of settlement ponds required to control suspended solids content of discharge water; • Security fencing required; • potential interaction with subterranean water; • management of returning run-off water back into Western Port.
	4. CSD loading hoppers to offshore DMG.	• Easily dredged; • Material becomes disturbed during dredging process; • Selective dredging of material not possible (typical).	Not Applicable.	• Water turbidity localised to near cutter head; • Overflow from hoppers will generate water turbidity; • Lights onboard dredger at night may attract birds etc.	Not Applicable
	5. BHD loading barges, rehandle onshore.	• Easily dredged; • Selective dredging of materials possible; • Material remains near or at its in-situ constitution.	• Material remains near or at its in-situ constitution; • Work method requires double or triple handling; • Requires a long time to dehydrate after placement, unless placed in thin layers; • No run-off water from dredging process, therefore bund walls not required;	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	• Considerable amount of earthmoving equipment and trucks required for the re-handling; • Twenty-four hours per day, seven days per week operation required.

	Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
			Dredging	Reclamation	Dredging	Reclamation
				• Placement of material into final location difficult, may require construction of considerable number of temporary access roadways; • Poor engineering qualities. Comprehensive ground treatment required.		
		6. BHD loading barges to offshore DMG.	• Easily dredged; • Selective dredging of material possible.	Not Applicable.	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	Not Applicable
Type 3	Stiff to Hard Clay (sandy clay and silty clay)	1. CSD to reclamation.	• Easily dredged; • Material becomes very disturbed during dredging process; • Selective dredging of material not possible (typical).	• Dredged material may form clay balls in the discharge pipeline; • Material breaks down into constituent parts during slurry transport process in dredger's discharge pipeline; • Large volume of High Moisture Content Fines (HMCM) generated;	• Water turbidity localised to near cutter head; • Discharge pipeline creates local navigation hazard; • Lights onboard dredger at night may attract birds etc.;	• Large area of land required to contain HMCM generated by hydraulic dredging process; • Large area of settlement ponds required to control suspended solids content of discharge water;

Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
		Dredging	Reclamation	Dredging	Reclamation
			• Requires a large tract of land to manage HMCM and dredging run-off water. This land will be quarantined for a very long time; • Requires very long time to dehydrate after placement, unless placed in thin layers; • Poor engineering qualities. Comprehensive ground treatment required.		• Security fencing required; • potential interaction with subterranean water; • management of returning run-off water back into Western Port.
	2. CSD loading barges to offshore DMG.	• Easily dredged; • Material becomes disturbed during dredging process; • Selective dredging of material not possible (typical).	Not Applicable.	• Water turbidity localised to near cutter head; • Overflow from hoppers will generate water turbidity; • Lights onboard dredger at night may attract birds etc.	Not Applicable
	3. BHD loading barges rehandle onshore.	• Easily dredged; • Selective dredging of materials possible; • Material remains near or at its in-situ constitution.	• Material remains near or at its in-situ constitution; • Work method requires double or triple handling; • Requires a long time to dehydrate after placement, unless placed in thin layers; • No run-off water from dredging process, therefore bund walls not required; • Placement of material into final location difficult, may require construction of	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	• Considerable amount of earthmoving equipment and trucks required for the re-handling; • Twenty-four hours per day, seven days per week operation required.

	Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
			Dredging	Reclamation	Dredging	Reclamation
				considerable number of temporary access roadways; • Poor engineering qualities. Comprehensive ground treatment required.		
		4. BHD loading barges to offshore DMG.	• Easily dredged; • Selective dredging of materials possible; • Material remains near or at its in-situ constitution.	Not Applicable.	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	Not Applicable
Type 4	Stiff to hard Silt (sandy silt and clayey silt)	1. CSD to reclamation.	• Easily dredged; • Material becomes very disturbed during dredging process; • Selective dredging of material not possible (typical).	• Material breaks down into constituent parts during slurry transport process in dredger's discharge pipeline; • Large volume of High Moisture Content Fines (HMCM) generated; • Requires a large tract of land to manage HMCM and dredging run-off water. This land will be quarantined for a very long time;	• Water turbidity localised to near cutter head; • Discharge pipeline creates local navigation hazard; • Lights onboard dredger at night may attract birds etc.;	• Large area of land required to contain HMCM generated by hydraulic dredging process; • Large area of settlement ponds required to control suspended solids content of discharge water; • Security fencing required;

Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
		Dredging	Reclamation	Dredging	Reclamation
			• Requires very long time to dehydrate after placement, unless placed in thin layers; • Poor engineering qualities. Comprehensive ground treatment required.		• potential interaction with subterranean water; • Management of returning run-off water back into Western Port.
	2. CSD loading barges to offshore DMG.	• Easily dredged; • Material becomes disturbed during dredging process; • Selective dredging of material not possible (typical).	Not Applicable.	• Water turbidity localised to near cutter head; • Overflow from hoppers will generate water turbidity; • Lights onboard dredger at night may attract birds etc.	Not Applicable
	3. BHD loading barges rehandle onshore.	• Easily dredged; • Selective dredging of materials possible; • Material remains near or at its in-situ constitution.	• Material remains near or at its in-situ constitution; • Work method requires double or triple handling; • Requires a long time to dehydrate after placement, unless placed in thin layers; • No run-off water from dredging process, therefore bund walls not required; • Placement of material into final location difficult, may require construction of considerable number of temporary access roadways; • Poor engineering qualities. Comprehensive ground treatment required.	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	• Considerable amount of earthmoving equipment and trucks required for the re-handling; • Twenty-four hours per day, seven days per week operation required.

	Material Description	Applicable Work Method	Typical Physical Behavioural Characteristics of Materials (During and After Dredging)		Environmental Considerations	
			Dredging	Reclamation	Dredging	Reclamation
		4. BHD loading barges to offshore DMG.	• Easily dredged; • Selective dredging of materials possible; • Material remains near or at its in-situ constitution.	Not Applicable.	• Water turbidity limited and restricted to near dredger; • Greater number of dredgers required; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger.	Not Applicable
Type 5	Weathered Rock (overlain by sand, gravel and clay)	1. Marine drilling & blasting pre-treatment. BHD loading barges to offshore DMG.	• Hard to dredge, low output; • Rock fragmented, overburden should remain near its in-situ consistency.	Not Applicable.	• Water turbidity limited and restricted to near dredger; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger; • Potential of blasting to impact on marine fauna.	Not Applicable
		2. Marine drilling & blasting pre-treatment. BHD loading barges rehandle to onshore.	• Difficult to dredge, low output; • Rock fragmented, overburden should remain near its in-situ consistency.	• Hard to rehandle, low output; • Rock fragmented, overburden should remain near its in-situ consistency.	• Water turbidity limited and restricted to near dredger; • Lights onboard dredger at night may attract birds etc.; • Risk of hydrocarbon spills from in-water hydraulic equipment of dredger; • Potential of blasting to impact on marine fauna.	

Table 3 Typical Dredged Material Behaviour

13 VIABLE WORK METHODS

The following are the work methods that are considered to be viable for the Bay West port project, either as a stand-alone work method or in combination with other listed work methods.

Also included are Rough Order of Magnitude cost assessment of these dredging and reclamation work methods, and the likely execution time based upon the cut and fill volumes developed by others to this time.

The following work methods are recommended to be suitable methods to be considered for this project. The viable work methods are grouped according to the destination of the dredged material.

13.1 Basis for Work Method Acceptability

This assessment is primarily based upon the technical merits of each work method. No assessment has been made of the relativities of any potential environmental sensitivities between the short-listed work methods or to the acceptability of any work method in this regard.

The long-term fate of any materials placed into an offshore DMG has not been considered in this preliminary work method assessment.

The following dredging and reclamation work methods are technically viable and are recommended to be evaluated further, giving due consideration to:

1. the nature of the material to be dredged;
2. the necessity to craft beneficial use of the material dredged whenever practically possible;
3. the need to provide land for the development of the port land of suitable quality within an acceptable timeframe.

13.2 R.O.M. Cost Details

The level of detail considered in the preparation of the R.O.M. costs for each work method includes but may not be limited to the following elements, as appropriate for each type of dredge spread and or work method.

13.2.1 Mobilisations

13.2.1.1 Self-propelled Vessels Arriving from Overseas

a) Drydocking (typically) in Singapore for AQIS hull inspection and inspection by specialist marine biologist;
b) Crew change-over and union inspections (typically) in Singapore;
c) Crew safety training;
d) Department of Environment inspections upon arrival;
e) Sailing time (nominal), customs and immigration clearances.

13.2.1.2 Self-propelled Vessels Arriving from Interstate

a) Crew safety training;
b) Department of Transport (Marine Safety) inspections and compliance;
c) Department of Environment and Primary Industries inspections upon arrival;
d) Sailing time (nominal).

13.2.1.3 Reclamation Spread

a. Equipment operator's safety training;
b. Mobilisation of equipment to site and readiness for work;
c. Mobilisation of floating, sunken and shore pipelines including shore connections.

13.2.2 Site Installation

a. Management staff;
b. Hydrographic survey spread;
c. Site office facilities and services;
d. Workshop facilities;
e. Pre-dredge surveys;
f. Vessel readiness for work;
g. Temporary moorings;
h. Personnel transfer dock including engineering and certification;
i. Pump ashore mooring and or discharge ashore infrastructure;
j. Assembly and installation of floating, sunken and shore pipelines, including construction of shore connections;
k. Construction of bund walls, sluice boxes, settlement ponds, run-off water management infrastructure;
l. Supply and installation of reclamation area perimeter floating silt curtain:

13.2.3 Execution

a. Site Management;
b. Unpaid over-dredging;
c. Bulking factors of dredged materials;
d. Routine repair and maintenance including soil touching parts;
e. Bunkering waste disposal and crew changes;
f. Provision for shipping, sea state and weather delays as appropriate;
g. Progress surveys (hydrographic and topographic);
h. Post-dredge / Clearance surveys;
i. Reclamation crew and earthmoving equipment;
j. Reclamation run-off water monitoring system;
k. Reclamation safety / security fencing;
l. Dust and traffic control;
m. Spreader pontoon crew.

13.2.4 Demobilisation

13.2.4.1 Self-propelled Vessels

a. Preparation for departure;
b. Crew change-over (typically) in Singapore for vessels returning overseas;

c. Sailing time (nominal).

13.2.4.2 Reclamation Spread

a. Demobilisation of equipment from site;
b. Disassembly and demobilisation of floating, sunken and shore pipelines, including shore connections.

13.2.5 Site Clearance

a. Management staff;
b. Hydrographic survey spread;
c. Site office facilities and services;
d. Workshop facilities;
e. Temporary moorings;
f. Pump ashore mooring;
g. Personnel transfer dock;
h. Pump ashore and or discharge ashore infrastructure;
i. Removal and demobilisation of floating, sunken and shore pipelines including shore connections;
j. Removal of sluice boxes and decommissioning of run-off water management infrastructure;
k. Removal and disposal of perimeter silt curtain.

13.2.6 Fuel

R.O.M. costs estimates are based upon the cost of fuel as at December 2016 at AUD 1.10 per litre.

13.2.7 Exchange Rates

Typically, the operating cost of the dredgers and the split hopper barges have a significant European Euro cost component.
The R.O.M. costs estimates are based upon the following exchange rate as at the 14th November 2016:

EUR 1.0 = AUD 1.44.

13.2.8 Rounding

Mobilisation and demobilisation and site installation costs are typically rounded to the nearest $0.01 million.

Execution unit rates are typically rounded to the nearest $0.05 per cubic metre.

*

13.3 Work Methods Considered Viable for Bay West

The following dredging work methods are considered viable to consider:

A. Small shallow draught trailer dredger removing the soft silty sand, and delivering it to an offshore DMG;
B. Mega backhoe dredgers or grab dredgers removing all clay, placing into box barges. Box barges then unloaded by floating Barge Unloader for subsequent placement by cantilevered conveyor arm into onshore reclamation;
C. Mega backhoe dredgers or grab dredgers removing all clay, placing into split hopper barges. Split hopper barges then delivering to offshore VRCA DMG;
D. Jumbo TSHD dredging engineering quality sand from South Channel and or offshore winning area in Bass Strait, delivering direct into construction of an underwater bund for berth construction purposes;
E. Jumbo TSHD dredging engineering quality sand from South Channel and or offshore winning area in Bass Strait, delivering direct into reclamation for permanent works and surcharge of clay;
F. Jumbo TSHD fitted with a ripper draghead dredging sedimentary rock to widen the Great Shipping Channel in The Rip. The dredged material to be placed into a nominated DMG.

13.4 Dredge Material Type Targeting

It must be noted that in the following work method descriptions the material types described for a particular work method are meant to be used as an overall guideline and may not necessarily be prescriptive for that work method, and other material types may be dredged at the same time.

Apart for the backhoe dredger work methods, selective dredging of a particular material type generally may not be possible.

13.5 Method A: Mid-size TSHD Removing Very Loose Surface Material

It could be considered to deploy a mid-size shallow draught trailer dredger to strip off surface layer of very silty sands and recent marine deposits, if they can be identified. The dredged material could then be carried to an offshore DMG, or bottom dumped into the reclamation area.

Advantages

This work method offers the following advantage:

1. may enhance beneficial use of materials to be dredged.

Disadvantages

This work method has the following draw backs:

1. can only dredge unconsolidated, softer materials;
2. potential for large amount of turbidity to be generated by propeller wash during dredging and manoeuvring in and near the dredge area;
3. draught restriction will apply in the area considered for dredging therefore not all of the very loose material will be able to be dredged using this work method;
4. dredging cost of selected materials will be high;
5. additional mobilisation and demobilisation costs.

ACTIVITY	A mid-size, shallow draught trailer dredger selectively removes any recent marine deposits material and takes them to an offshore DMG. Hopper overflowing restrictions may be applied.		
Nominal Net In-situ Volume			T.B.A.
Dredge Material	Very soft and soft clays and silts, sand, loose clayey sand, loose silty sand.		
Dredging Spread	Trailer dredger (Draught limitations apply in dredge area) a) Hydrographic survey b) Crew boat c) Site Management		
Environmental Sensitivities	a) Control of water turbidity in the dredge area and nearby environs. b) Spread of dredged material from the DMG once placed. c) Large amount of this type of material will be put into suspension mainly by propeller wash from the TSHD. Estimated approximately 40% of in-situ volume will go to the DMG. d) Marine mammals and cetaceans.		
Human Resources	Offshore	28	Includes expatriates.
	Onshore	2	
	Site Management	9	Includes expatriates.
Mobilisation & Demobilisation Costs		$10.5 million	

Dredging Unit Rate	Measured in-situ in dredge area.	$15.40 / m3 $12.65 / m3	NIL hopper overflowing. 20 min. hopper overflowing / load.
Execution Times	Mobilisation Dredging (Hopper measure) Demobilisation	6 to 8 weeks 66,240 m3 / week 58,400 m3 / week 3 to 6 weeks	 Nil overflowing. 20 min. overflowing.
Variables	1) Does not include environmental monitoring activities. 2) This size dredger unable to economically dredge stiff and harder clay. 3) Assumes material put into suspension in water column does not settle within dredging footprint. 4) No allowance for clean-up of settled material adjacent to dredging footprint. 5) Production estimates include provisional allowances for propeller wash, draghead turbulence suspension and the like. 6) Production estimates subject to size of dredge area, trail length and the like. 7) Assumes bulk dredging only. Does not allow for any unpaid over dredging. 8) Based upon a one-way haul distance of 13.5 km to a DMG. 9) Based upon operating 7 days per week, 24 hours per day. 10) Based upon fuel and labour costs as at December 2016.		
Technical Risk	1) Strength and physical nature of clay.		

Table 4 Work Method A – Mid-Size TSHD — Material to DMG

13.6 Method B: Backhoe Dredgers Loading Box Barges for Rehandling into Reclamation

All material is dredged by a number of mega backhoe dredgers and or mega grab dredgers with the material being placed into large box barges. The dredged material is then subsequently removed from the box barges by a floating barge unloader using large, long reach excavators. Material is then distributed cantilevered conveyor arm into the reclamation area, up to approx. LWL.

Advantages

This work method offers the following advantages:

1. material when placed ashore will be near its natural in-situ moisture content, making it comparably somewhat more suitable as engineering fill;
2. selective dredging of material can be planned, based upon geotechnical information;
3. lowest water turbidity generation in Port Phillip waters;
4. no land required for settling ponds as is required for a cutter dredger work method.

Disadvantages

This work method has the following draw backs:

1. higher cost;
2. slowest programme;
3. higher technical risk (schedule);
4. material is not suitable for immediate development of port land;
5. high cost to undertake ground improvement in order to provide useable land to develop the port;
6. material to be dredged is not suitable to construct reclamation bund walls;
7. work method completely dependent upon the capability of effectively unloading the box barges with high capacity, long reach excavators and conveyor system.

ACTIVITY	Mega backhoe dredgers and or mega grab dredgers removing all material, placing into box barges. Box barges then unloaded by floating barge unloader by long arm excavators for subsequent placement via cantilevered conveyor arm into reclamation.	
Nominal Net In-situ Volume		19.0 million m3
Dredge Material	Very soft to hard clay and silts, sand, clayey sand, silty sand.	
Dredging Spread	Mega Backhoe dredger	Fitted with 40m3 or 25m3 bucket
	a) Box barges	6 off
	b) Barge Unloader	2 off
	c) Multicat	
	d) Work boat	
	e) Hydrographic survey spread	
	f) Crew boat	
	g) Site Management	
Environmental Sensitivities	a) Hydrocarbon spills from BHDs.	
	b) Water turbidity around reclamation area	

Human Resources	Offshore	TBA	Includes expatriates.
	Onshore	TBA	
	Site Management	TBA	Includes expatriates
Mobilisation & Demobilisation Costs		$81.75 million	
Dredging Unit Rate	Soft to Firm clay	$31.5 / m3	Measured in situ
	Firm to V. Stiff clay	$56.40 / m3	
Execution Times	Mobilisation	6 to 10 weeks	
	Dredging / BHD	132,000 m3 / week	Soft to Firm
	Dredging / BHD	68,000 m3 / week	Firm to V. Stiff
	Demobilisation	4 to 6 weeks	
Variables	1) Based upon above volume. 2) Does not include environmental monitoring activities. 3) Volume refers to cut in-situ volume placed into reclamation area. Does not account for bulking or post-placement consolidation following ground improvement. 4) Clay placed to LWL (approx.). 5) Mob / demob cost estimate includes supply, installation, removal and disposal of floating, tethered silt curtain surrounding entire reclamation area. 6) Based upon operating 7 days per week, 24 hours per day. 7) Based upon fuel and labour costs as at December 2016. 8) No ground improvement costs included.			
Technical Risk	1) Operational availability of BHDs. 2) Operational effectiveness of Barge Unloaders.			

Table 5 Work Method B – Mega BHD into Box Barges — Material to Reclamation

13.7 Method C: Backhoe Dredgers Loading Split Hopper Barges for Placement into VRCA DMG

All material is dredged by a number of mega backhoe dredgers and or mega grab dredgers with the material being placed into split hopper barges. The dredged material is then subsequently placed into the existing VRCA DMG to facilitate construction of additional underwater containment bunds.

Advantages

This work method offers the following advantages:

1. material when placed ashore will be near its natural in-situ moisture content, minimising environmental risk;
2. selective dredging of material can be planned, based upon geotechnical information;
3. low water turbidity generation in Port Phillip waters;

Disadvantages

This work method has the following draw backs:

1. higher cost;
2. slowest programme;
3. higher technical risk (schedule);

ACTIVITY	Mega Backhoe Dredgers and or mega grab dredgers removing all materials, placing into split hopper barges and delivering to offshore VRCA DMG in Port Phillip.		
Nominal Net In-situ Volume			19.0 Mm3
Dredge Material	Very soft to hard clay and silts, sand, clayey sand, silty sand.		
Dredging Spread	2 x Backhoes a) Split hopper barges. up to 6 off b) Work Boat c) Multicat d) Hydrographic survey spread e) Crew Boat f) Site Management		Fitted with 40m3 and 20m3 bucket See Variables notes.
Environmental Sensitivities	a) Hydrocarbon spills. b) Spread of dredged material from the DMG once placed. c) Marine traffic.		
Human Resources	Offshore Onshore Site Management	TBA TBA TBA	Includes expatriates. Includes expatriates

Mobilisation & Demobilisation Costs		$50.9 million	(6 hoppers)
Dredging Unit Rate	Soft to Firm clay	$37.55 / m3	Measured in situ
	Firm to V. Stiff clay	$60.60 / m3	
Execution Times	Mobilisation	6 to 10 weeks	
	Dredging / BHD	100,000 m3 / week	Soft to Firm
	Dredging / BHD	56,600 m3 / week	Firm to V. Stiff
	Demobilisation	4 to 6 weeks	
Variables	1) Based upon above volume. 2) Does not include environmental monitoring activities. 3) No environmental clean-up of dredging footprint. 4) Based upon a one-way haul distance of 13.5 km to VRCA DMG. 5) Based upon operating 7 days per week, 24 hours per day. 6) Based upon fuel and labour costs as at December 2016.		
Technical Risk	1) Offshore sea state conditions for split hopper barges. 2) Operational availability of BHDs.		

Table 6 Work Method C – Mega BHDs into Split Hopper Barges — Material to DMG

13.8 Method D: Jumbo TSHD Winning Sand for Placement into Underwater Bund Construction

A jumbo trailer dredger is very cost effective to haul sand over significant distances. It could be used to win sand from inert seabed locations in deep water in Bass Strait, or from the South Channel where routine maintenance dredging is required, or capital deepening or widening may be required for the Bay West port development.

The sand can be placed in a controlled manner using a spreader pontoon to construct an underwater bund wall as part of the construction requirements for the quay wall.

Advantages

This work method offers the following advantage:

1. cost effective;
2. rapid production rate;
3. quality of sand delivered will be free from silt.

Disadvantages

This work method has the following draw backs:

1. safety management as it requires transiting through The Rip if winning sand in Bass Straight;
2. environmental risk management for marine mammals, cetaceans;
3. draught restriction will apply in the Bay West location when under development;

ACTIVITY	Jumbo TSHD dredging engineering quality sand from an offshore winning area, and delivering direct into underwater bund construction.		
Nominal Net Volume			0.9 million m3
Dredge Material	Sand	Medium grain size sand (assumed)	
Dredging Spread	Trailer dredger a) Floating Pipeline b) Spreader Pontoon c) Multicat d) Hydrographic survey spread e) Crew boat f) Site Management	Draught limitations may apply near project site.	 600 metres
Environmental Sensitivities	a) Water turbidity in winning area. b) Marine mammals and cetaceans.		
Human Resources	Offshore Onshore Site Management	TBA TBA TBA	Includes expatriates. Includes expatriates
Mobilisation & Demobilisation Costs		$28.03 million	See Variables notes.
Dredging Unit Rate	TSHD hopper.	$22.85 / m3 $15.70 / m3	From Bass Strait From South Channel

Execution Times	Mobilisation Dredging Demobilisation	3 to 5 weeks 227,000 m3 / week 330,000 m3 / week 3 to 6 weeks	 From Bass Strait From South Channel
Variables	1) Based upon above volume. 2) Does not include environmental monitoring activities. 3) Allows for economical hopper overflowing each load. 4) Based upon a one-way haul distance of 128 km from the winning area in Bass Strait. 5) Cost differential for varying one way haul distance ± $0.11 / m3 / km. 6) Based upon operating 7 days per week, 24 hours per day. 7) Based upon fuel and labour costs as at December 2016. 8)		
Technical Risk	1) Severe offshore sea state conditions.		

Table 7 Work Method D – Jumbo TSHD Winning Sand — Material to Underwater Bund

13.9 Method E: Jumbo TSHD Winning Sand for Placement into Reclamation Area

A jumbo trailer dredger can be used to win sand from inert seabed locations in deep water in Bass Strait, or from the South Channel where routine maintenance dredging is required, or capital deepening or widening may be required for the Bay West port development.

The sand can be placed in a controlled manner into the reclamation area to cap the clay already placed, and also to supply additional sand for surcharging the clay.

Advantages

This work method offers the following advantage:

1. cost effective;
2. rapid production rate;
3. quality of sand delivered will be free from silt.

Disadvantages

This work method has the following draw backs:

1. safety management as it requires transiting through The Rip if winning sand in Bass Straight;
2. environmental risk management for marine mammals, cetaceans;
3. draught restriction will apply in the Bay West location when under development;

ACTIVITY	Jumbo TSHD dredging engineering quality sand from an offshore winning area, and delivering direct into reclamation permanent works.		
Nominal Net Volume			8.3 million m3
Dredge Material	Sand	Medium grain size sand (assumed)	
Dredging Spread	Trailer dredger	Draught limitations may apply near project site.	
	a) Floating Pipeline		600 metres
	b) Reclamation pipeline		3,000 metres
	c) Multicat		
	d) Hydrographic survey spread		
	e) Crew boat		
	f) Reclamation Spread		
	g) Typical LGP earth moving equipment, labour, lighting etc.		
	h) Site Management		
Environmental Sensitivities	a) Control of run-off water from placement site b) Water turbidity in winning area. c) Marine mammals and cetaceans.		
Human Resources	Offshore	TBA	Includes expatriates.
	Onshore	TBA	Excludes plant operators

	Site Management	TBA	Includes expatriates
Mobilisation & Demobilisation Costs		$26.0 million	See Variables notes.
Dredging Unit Rate	TSHD hopper.	$22.25 / m3	From Bass Strait
		$17.10 / m3	From South Channel
Execution Times	Mobilisation	6 to 8 weeks	
	Dredging	227,000 m3 / week	From Bass Strait
		330,000 m3 / week	From South Channel
	Demobilisation	3 to 6 weeks	
Variables	1) Based upon above volume. 2) Does not include environmental monitoring activities. 3) Allows for economical hopper overflowing each load. 4) Based upon a one-way haul distance of 128 km from Bass Strait winning area. 5) Cost differential for varying one way haul distance ± $0.11 / m3 / km approx. 6) Mobilisation and demobilisation costs allow for runoff water management. 7) Based upon operating 7 days per week, 24 hours per day. 8) Based upon fuel and labour costs as at December 2016. 9)		
Technical Risk	1) Severe offshore sea state conditions. 2)		

Table 8 Work Method E – Jumbo TSHD Winning Sand — Material to Reclamation

13.10 Method F: Jumbo TSHD Widening the Great Shipping Channel in The Rip

The following work method for the widening of the Great Shipping Channel through "The Rip" is based upon the experienced gained during the Channel Deepening Project (CDP).

13.10.1 Safety

The Rip is one of the most dangerous stretches of water in the world, and is notorious for currents and swell.

It is important to note that for a TSHD tidal currents up to 6 knots will be from different directions at different locations. That is when crossing The Rip, currents will come from one side at one moment and then from the opposite side a few moments later. This means it is very difficult for a TSHD to dredge consistently into the current. Given all of this any TSHD planned to be deployed in The Rip needs to be large and powerful.

During the CDP, a vector system was installed onboard the TSHD so that the bridge crew always knew simultaneously from which directions the currents were attacking the dredger, both at the stern and bow.

Having a boat alongside the dredger for crew change and victualling etc. was only possible inside of The Rip. During the CDP, this often impacted on dredging and the dredging cycle.

13.10.2 Material to be Dredged

The compressive strength of materials dredged during the CDP ranged from 1 to 27 MPa. This was the approximate maximum hardness possible for the powerful dredger "Queen of the Netherlands", which was fitted with especially designed dragheads and associated safety systems.

13.10.3 Environmental Risk Management

A deep canyon runs diagonally across The Rip. This canyon is environmentally very sensitive and an EMP requirement during the work was to avoid any dredged material being spilt into the canyon. Therefore, dredging was always positioned at locations such that the tidal currents were running are away from the canyon. This placed critical limitations on the dredging work method.

13.10.4 Work Method

During the CDP, the TSHD "Queen of the Netherlands" was deployed to dredge in The Rip. This is a powerful dredger, and was fitted with purposed designed "ripper" draghead and associated safety systems. For this dredger, the maximum strength of materials encountered was at its working limit.

During the CDP, the most effective work method was achieved by shunting. That is dredging in one direction, then backing up to commence the next dredging run.

Production rates were extremely low, but this is the only type of dredger that may be safely deployed in The Rip.

Given the strength of the material to be dredged, and the extreme hydrodynamic forces to be contented with by the dredger in The Rip only one suction pipe was deployed.

Photograph Courtesy of Royal Boskalis Westminster

Figure 34 The "Queen of the Netherlands"

13.10.5 Alternative Equipment

Other dredger types, namely jumbo and mega cutter dredgers and mega backhoe dredgers can dredge this strength materials, however their safe sea state workability in The Rip can be considered to be approaching Nil.

13.10.6 Dredge Volume

Given that the dredging in The Rip is widening, it is expected that it will consist of mainly removing high spots and pinnacles, that is continual "high spot hunting". Therefore, as with the CDP dredging undertaken in The Rip, the over dredging ratio will be very high.

13.10.7 Cost Estimate

Two scenarios have been considered, namely:

1. dredging undertaken in concert with other required capital dredging;
2. dredging undertaken as a "stand alone" component.

Given the environmental risk management considerations noted above the base cost estimate is based upon dredging only taking place on the ebb tide (Item 1), and therefore at other times the dredger is gainfully engaged upon other capital dredging for the project.

A subsidiary estimate (Item 2) is based upon dredging also being undertaken on the flood tide.

Spoil disposal is assumed to be into the existing spoil ground(s) in Capel Sound. Note that draught limitations may now apply for jumbo trailer dredgers in this area.

Given the nature of the work method in dredging in The Rip, and the environmental and safety risk management requirements the cost estimated are based upon lump sums, not unit rates.

The cost estimates are based upon a net volume of 100,000 m3, and a swept area of 110,000 m2.

The cost adopted in these estimates are based upon a greatly reduced cost for developing and trialling the ripper dragheads that will be required, given that it has been proven during the CDP that this work method is effective.

13.10.7.1 Base Cost Estimate

For this cost estimate the mobilisation, site installation and demobilisation cost are picked up by other capital dredging components. The cost of developing, constructing and trialling ripper dragheads for the dredging in The Rip are included.

Execution Cost:	$150,000,000
Mobilisation:	$ 9,300,000
Total	$159,300,000

13.10.7.2 Subsidiary Cost Estimate

For this cost estimate the mobilisation, site installation and demobilisation cost are included but only for the spread necessary for The Rip dredging. It does not include any reclamation or pipeline or pump ashore requirements that will be necessary for other dredging components of the project.

The cost of developing, constructing and trialling ripper dragheads for the dredging in The Rip are (also) included.

This estimate is based upon unrestricted trailing, that is dredging at any stage of the tide, ebb or flood.

Execution Cost:	$64,000,000
Mobilisation:	$30,200,000
Total	$94,200,000

ACTIVITY	Jumbo TSHD dredging sedimentary rock from the Great Shipping Channel in The Rip. Dredged material to be placed into a nominated DMG	
Nominal Net Volume		100,000 m3
Dredge Material	Sedimentary rock	Strength ranging from 1 to 27 MPA (UCS)
Dredging Spread	Trailer dredger a) Multicat b) Hydrographic survey spread c) Crew boat d) Site Management	Draught limitations may apply for DMG
Environmental Sensitivities	a) Dredging near the Canyon b) Marine mammals and cetaceans.	

Human Resources	Offshore	TBA	Includes expatriates.
	Onshore	TBA	Excludes plant operators
	Site Management	TBA	Includes expatriates
Ripper dragheads: develop and supply		$9.3 million	See Variables notes.
Dredging Cost		$150.0 million	
Execution Times	Mobilisation	Included in other activities	
	Dredging	In the order of 30 weeks, carried out in conjunction with other dredging tasks.	
	Demobilisation	Included in other activities	
Variables	1) Based upon environmental risk management profile developed for the Channel Deepening Project. 2) Based upon above volume. 3) Does not include environmental monitoring activities. 4) Assumes mobilisation and demobilisation costs are covered by other required dredging activities 5) Allows for unrestricted hopper overflowing each load. 6) Based upon a one-way haul distance from The Rip to the DMG of 25 km. 7) Based upon operating 7 days per week, 24 hours per day, on ebbing tide only. 8) Based upon fuel and labour costs as at December 2016.		
Technical Risk	1) Severe offshore sea state and tidal current conditions. 2) Vessel to vessel transfers not possible in dredging area.		

Table 9 Work Method F – Jumbo TSHD Widening Great Shipping Channel

14 WORK METHOD ENDORSEMENTS

The following summarises what is considered to be the most appropriate work methods for both port development options, independent of other construction activities, based upon their environmental risk management profile and engineering technical requirements.

These work method considerations need to be developed in conjunction with the port construction planning.

14.1 Port of Hastings

The most appropriate work methods are considered to be as follows.

a. Small trailer dredger removes soft overlaying sand and sediments
b. Small trailer dredger places the dredged material either into offshore DMG, or into wetlands
c. Heavy duty or mega cutter dredger dredges and loads clay into large split hopper barges
d. Split hoppers place dredged material into offshore DMG
e. Jumbo trailer dredger delivers sand for required reclamation

14.2 Bay West

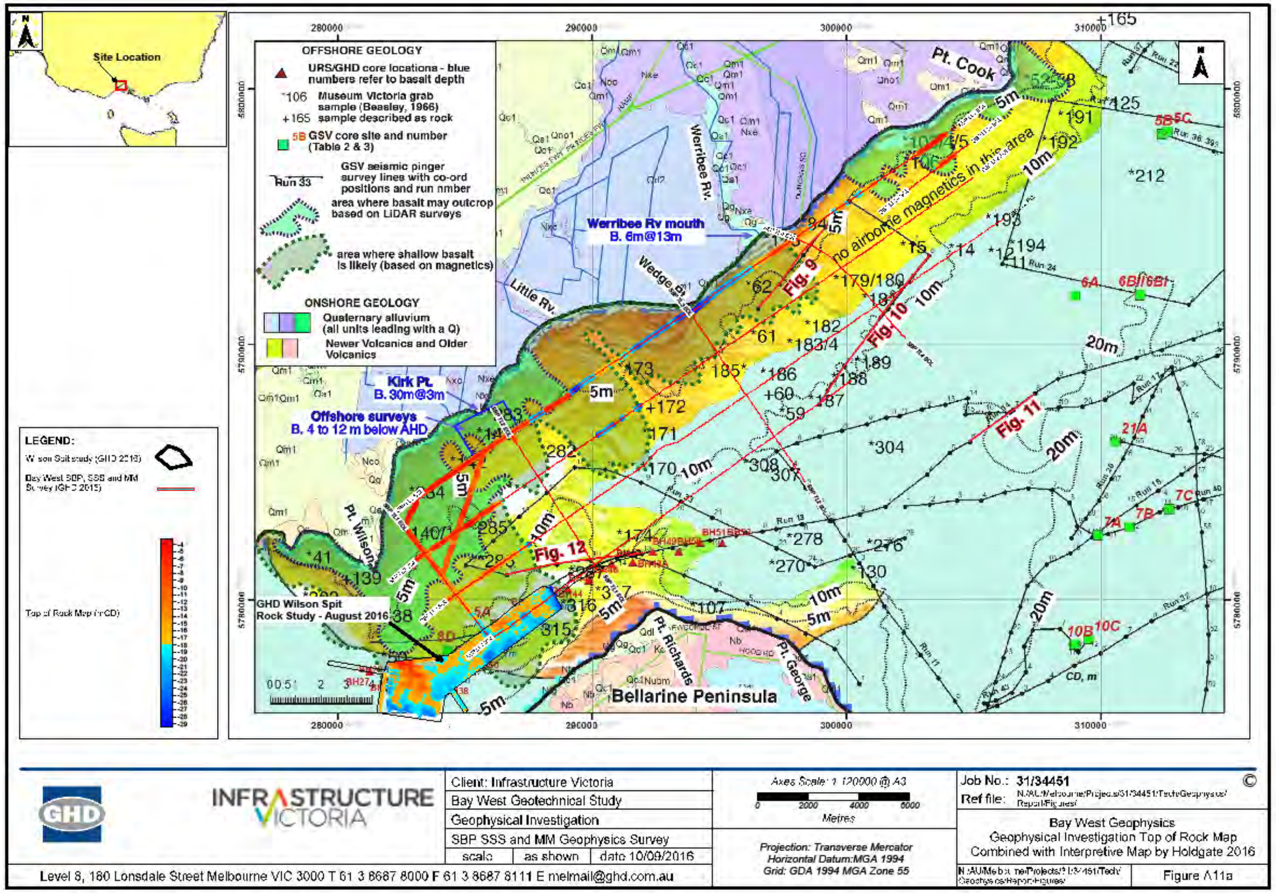
The most appropriate work methods, assuming the assumptions concerning the materials to be dredged are reasonably correct, are:

a. Mega backhoe dredgers and or mega grab dredgers loading box barges
b. Box barges emptied using unloader barges
c. Unloader barges distribute the clay over the reclamation area up to MLW (approx.)
d. Jumbo trailer dredger builds quay wall bund using sand via a spreader pontoon up to MLW (approx.)
e. Jumbo trailer dredger delivers sand for surcharging the clay in the reclamation, and to complete the quay wall bund to full height.

APPENDICES

APPENDIX A

Bay West Geophysics

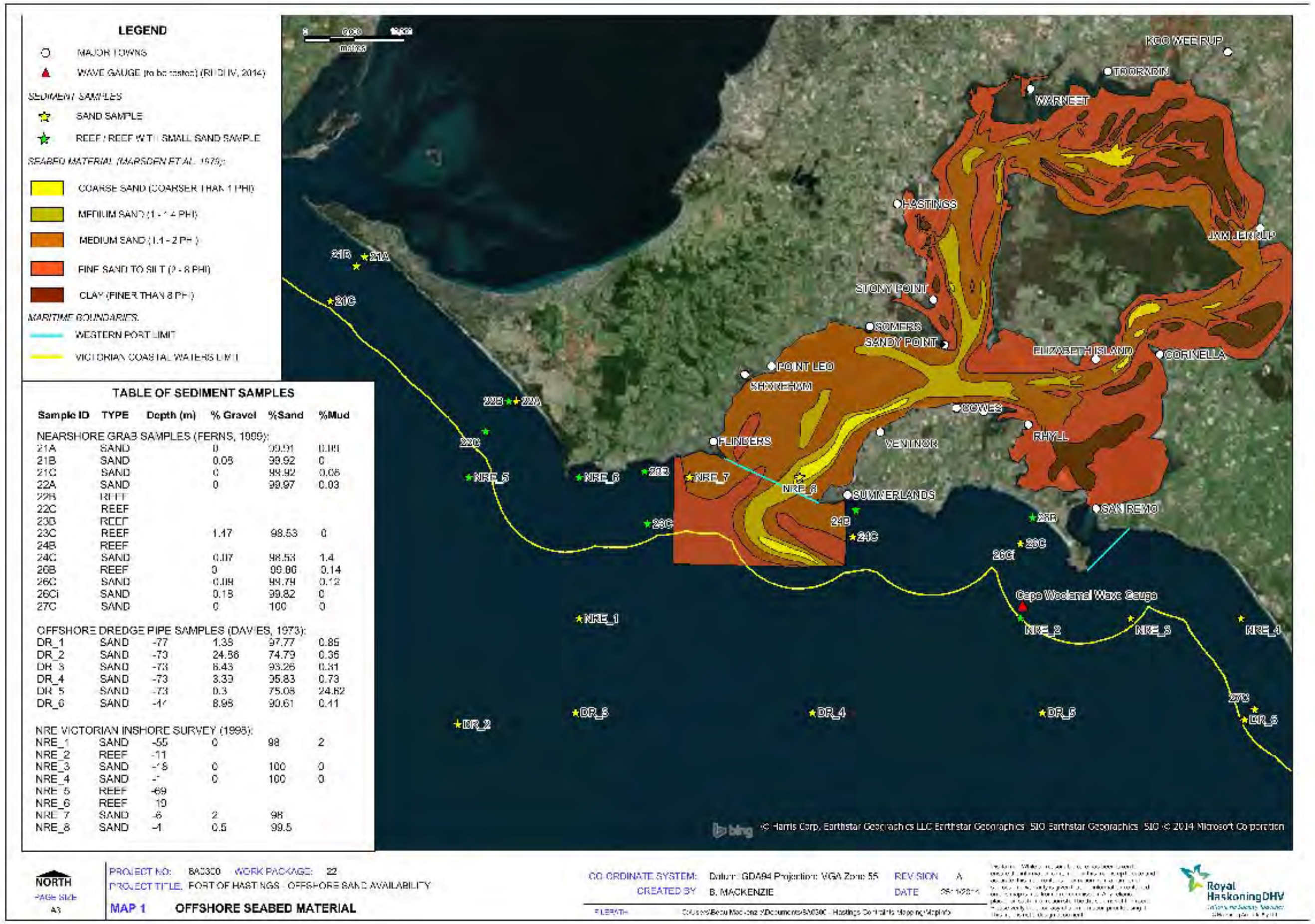


Sketch courtesy of GHD

Bay West Location Geophysics

APPENDIX B

Bass Straight Offshore Seabed Material Map



Sample ID	TYPE	Depth (m)	% Gravel	%Sand	%Mud
NEARSHORE GRAB SAMPLES (FERNS, 1999):					
21A	SAND		0	99.91	0.09
21B	SAND		0.08	99.92	0
21C	SAND		0	99.92	0.08
22A	SAND		0	99.97	0.03
22B	REEF				
22C	REEF				
23B	REEF				
23C	REEF		1.47	98.53	0
24B	REEF				
24C	SAND		0.07	98.53	1.4
26B	REEF		0	99.86	0.14
26C	SAND		0.09	99.79	0.12
26Ci	SAND		0.18	99.82	0
27C	SAND		0	100	0
OFFSHORE DREDGE PIPE SAMPLES (DAVIES, 1973):					
DR_1	SAND	-77	1.38	97.77	0.85
DR_2	SAND	-73	24.86	74.79	0.35
DR_3	SAND	-73	6.43	93.26	0.31
DR_4	SAND	-73	3.33	95.83	0.73
DR_5	SAND	-73	0.3	75.08	24.62
DR_6	SAND	-47	8.98	90.61	0.41
NRE VICTORIAN INSHORE SURVEY (1995):					
NRE_1	SAND	-55	0	98	2
NRE_2	REEF	-11			
NRE_3	SAND	-18	0	100	0
NRE_4	SAND	-1	0	100	0
NRE_5	REEF	-69			
NRE_6	REEF	-10			
NRE_7	SAND	-6	2	98	
NRE_8	SAND	-4	0.5	99.5	

Sketch courtesy of Royal HaskoningDHV

Offshore Seabed Material Map

APPENDIX C

Port Phillip Marine Geology Report

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Marine geology of Port Phillip, Victoria

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The marine geology of Port Phillip is described in detail, based on data from seismic profiling, vibrocoring and grab sampling. Three major unconsolidated facies can be distinguished: sands and muddy sands peripheral to the present coastline, muds covering the major central region, and channel fills of muds and sands. The first two facies units result from an increase in wave sorting towards the coast, reworking of Tertiary and Quaternary sandstone outcrops around the coast, and a dominant mud supply from river sources into the central area. The distribution and thicknesses of the unconsolidated facies have been augmented by a shallow-seismic program that reveals the thicknesses of the modern sediments overlying an older surface comprised of consolidated clays and sandy clays of Pleistocene or older age. In central Port Phillip, muds and sands up to 27 m-thick have infilled Pleistocene channels cut into underlying consolidated units. Sediments immediately above the channel bases show characteristic seismic patterns of fluvial deposition. The presence of peat deposits together with gas phenomena in the water column suggest organic breakdown of channel-fill deposits is releasing methane into the bay waters. Outside the channel areas, carbon-14 dating indicates that the unconsolidated sediments largely post-date the last glaciation sea-level rise (<6500 a BP), with an early Holocene period of rapid deposition, similar to other Australian estuaries. Stratigraphic and depositional considerations suggest that the undated channel-fill sequences correlate with the formation of cemented quartz-carbonate aeolianite and barrier sands on the Nepean Peninsula at the southern end of Port Phillip. Previous thermoluminescence dating of the aeolianites suggests that channel-fill sequences B, C and D may have been deposited as fluvial and estuarine infills over the period between 57 and 8 ka. The eroded surface on the underlying consolidated sediments is probably the same 118 ka age as a disconformity within the Nepean aeolianites. Further estuarine and aeolianite facies extend below the disconformity to 60 m below sea-level, and may extend the Quaternary depositional record to *ca* 810 ka. Pliocene and older Tertiary units progressively subcrop below the Quaternary northwards up the bay.

KEY WORDS: marine geology, Port Phillip, Quaternary, sediments, seismic profiles.

INTRODUCTION

This study aims to delineate the spatial distribution and 3-D architecture of the unconsolidated sediment facies outlined by the seabed sampling programs of the National Museum of Victoria (Beasley 1966), the Ministry of Conservation (Seedsman & Marsden 1980), and the Marine and Freshwater Resources Institute (Greilach *et al.* 1996). An earlier paper (Holdgate *et al.* 1981) was produced on the Late Pleistocene channels that were identified seismically in the central part of Port Phillip, but the complete study of Port Phillip has only now been finalised. This paper therefore completes the results of these surveys and further augments the studies of nearshore sand deposits undertaken by the Ports and Harbours Division of the Board of Works up until the late 1980s (Buckley & Clark 1987). To our knowledge, little subsequent stratigraphic work has been carried out on the Port Phillip subsurface marine geology, except for the shallow (400 mm) coring of Greilach *et al.* (1996). Environmental impacts of future developments along the Port Phillip coastline may impinge on the waters and bottom sediments of Port Phillip Bay, and this study should provide a basis for evaluating unconsolidated sediment thicknesses as potential pollutant repositories.

GEOGRAPHICAL AND GEOLOGICAL SETTING

Port Phillip Bay is located centrally on the southern coastline of Victoria. It includes an area of 1167 km² of almost land-locked water with a maximum length in the north to south direction of 50 km, and a maximum width in the east to west direction of 32 km (Figure 1). On the western side it includes an embayment 25 km wide known as the Outer Geelong Harbour and Corio Bay, and in the north is the embayment of Hobsons Bay (Figure 2). Water depths in Port Phillip generally range from 9.1 to 23.7 m (referred to lowest astronomical tide), except in the south where a large <5.0 m deep area of sand shoals known as the Nepean Bay Bar occurs (Keble 1946) (Figures 2, 3). The sandbars form a veneer of variable thickness resting on indurated Pleistocene aeolianites. They almost close across the entrance to Port Phillip except at The Rip where a narrow 3.2 km-wide opening maintains oceanic exchange between Port Phillip and Bass Strait. In The Rip water depths exceed 60 m locally.

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Note: Facing page only presented in this report.