Republic of the Union of Myanmar
Myanma Port Authority

DATA COLLECTION SURVEY FOR SHIPS FOR NAVIGATION CHANNEL IMPROVEMENT

FINAL REPORT

September 2020

JAPAN INTERNATIONAL COOPERATION AGENCY

MYANMAR KOEI INTERNATIONAL LTD.

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FINAL REPORT

FOR

DATA COLLECTION SURVEY FOR SHIPS FOR NAVIGATION CHANNEL IMPROVEMENT

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1. GENERAL

1.1 Background of the Survey

Yangon Port consists of Yangon Main Port and Thilawa Port, which are respectively located about 30 km and about 15 km from the mouth of the Yangon River. The Yangon River is a tidal river, and its erosion and sedimentation are severe due to its high flow velocity, high turbidity and high sediment flow. In particular, the shallow water areas called the Inner Bar and Outer Bar spread around Monkey Point at the eastern end of Yangon Main Port and Elephant Point at the month of Yangon River, making the channel difficult for navigation. Regular dredging of the channel is essential to keep the position and maintain the water depth. In addition, it is necessary to move a marine navigation buoys according to a change in the position of the channel route.

Cargo throughput of Yangon Port is increasing year by year and various studies are examining ways to increase the handling capacity of Yangon Port after exceeding the cargo capacity of the Thilawa Port. However, maintenance dredging of channels and berths, bending points are drawbacks for the capacity of Yangon Port. Therefore, the marine services including dredging and channel safety work in Yangon River channel are critical works for the improvement of Yangon Port capacity.

The channel dredging of the Yangon River is under the jurisdiction of the Myanma Port Authority (hereinafter referred to as “MPA”) and is under implementation every year. Two dredging vessels owned by MPA are made in Germany (made in 1989) and other two dredgers are made in Japan (made in 1998). These dredgers are around 30 years and 20 years old, respectively, and are difficult to implement dredging work due to aging. Therefore, MPA has contracted out channel dredging to the private sector for five years from 2018. However, the contractor has not been able to adequately maintain and dredge to the specified water depth due to sedimentation more than originally expected, which has hindered entry and exit of ships.

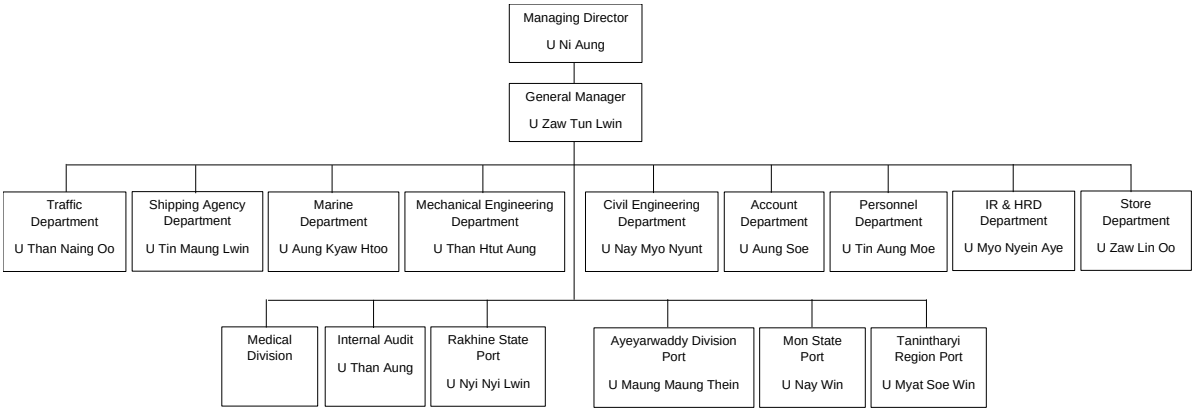
In addition, MPA owned two anchor vessels, medium and small, and used to move, retreat and install maritime navigation aids not only at Yangon Port but also at eight outports nationwide. On February 11, 2019, the medium-sized ship sank while working offshore in Rakhine State. Therefore, only with one small vessel, it could not maintain buoys along the river channel effectively, especially in rainy season. During the rainy season, about five buoys usually float out from their positions in Yangon River; thus, redeployment of a medium-sized anchor vessel is urgently needed.

1.2 Purpose of the Survey

The purpose of this Project is to collect information on the proper channel management system for the Yangon River channel, including the need for additional investment in dredgers and anchor vessels, and to propose a future channel maintenance plan.

1.3 Counterpart Organization

MPA is responsible for maintenance and management of inner port channel such as operation and maintenance of navigation aids and dredging works. For this Survey, Marine Department, Mechanical Engineering Department and the Survey Division and Dredging Division of Civil Engineering Department can be said counterpart departments. The organization of Myanma Port Authority (MPA) under Ministry of Transport and Communications, which will be the counterpart organization of the Survey is as follows.



Source: MPA

Figure 1-1 Organization of Counterpart

1.4 Scope of Work

The scope of the Consultant work includes:

1) Examination of the current state of dredging and channel maintenance and future policy proposals (including comparison of multiple means);
2) Collection and arrangement of information related to dredgers and anchor vessels;
3) Examination of the specifications of the dredger and anchor vessel; and
4) Calculation of estimated costs for dredger and anchor vessels and collection of information.

1.5 Consultant's Organization and Members

Myanmar Koei International Ltd. (MKI) in association with Nippon Koei (NK) and Japan Marine Science Inc. (JMS) formed a consultant team (hereinafter "the Consultant") and it is organized with the following international and local experts to fulfil the scope of consulting services.

Table 1-1 Consultant's Team Organization

International Experts
Team Leader/Navigation Channel Maintenance Planning
Co-Team Leader/Navigation Channel Maintenance Planning/Shipbuilding Planning
Procurement Planning/Cost Calculation
Ship Maintenance (1) & (2)
Organizational Planning for Navigation Maintenance (1) & (2)
Local Experts
Assistant Team Leader
Navigation Channel Expert
Cost Estimate Expert
Marine Civil Engineer
Mechanical Engineer (1) & (2)
Secretory/Translator (1) & (2)
CAD Operator

Source: the Consultant

2. REQUEST FROM MYANMAR GOVERNMENT

Channel maintenance work and channel safety work such as maintenance of navigation buoys and aids are the main responsibility of MPA. MPA is providing its best efforts for these services with its own four dredgers and two anchor vessels. However, due to the aging, recent capsize accident and capacity of the vessels, MPA is facing difficulties for performing channel dredging and maintenance works. In this regards, Myanmar Government requests assistants from JICA for the rehabilitation of capacity of MPA particularly in dredging and channel safety works, including rehabilitation of dredgers and anchor vessels.

2.1 Rehabilitation of Dredgers

MPA was carrying out the maintenance of Yangon River channel with four dredgers, namely Yadana Theinkha, Thiha-Dipa, Areindamar and Ramanya. Two dredging vessels are made in Germany (made in 1989) and other two dredgers are made in Japan (made in 1998). These dredgers are 30 years and 20 years old, respectively, and are difficult to maintain due to aging.

Starting from 2018, MPA outsourced the maintenance dredging work in Yangon River. MPA has contracted out channel dredging to the private sector for five years from 2018 to 2023. MPA contracted with a private dredging company, Star High Asia Pacific Pte Ltd. for the maintenance dredging work.

However, the contractor has not been able to adequately maintain and dredge to the specified water depth due to sedimentation which is more than originally expected, which has hindered entry and exit of ships. Given this situation, it is necessary to reconsider an appropriate maintenance dredging system after the expiration of the private consignment period. Moreover, restoration and rehabilitation of capacities of MPA, particularly for the dredging works in the Yangon River channel and the other navigation channels in the outports, are critical.

Source: Preparatory Survey for the Project for Expansion of Yangon Port in Thilawa Area, JICA

Photo 2-1 Photo of Dredger Owned by MPA (Ramanya)

2.2 Rehabilitation of Anchor Vessels

Yangon Port is a river port, and due to the nature of the river, there are many obstacles and limitations such as narrow and shallow areas, sand bars, sharp bends, high sedimentation rate, and strong current. Yangon River is unstable and navigation channel is changing depending on the seasonal change of river flow and sedimentation rate. Buoyage navigation system plays important role for safe navigation.

It is necessary to watch the channel by hydrographic survey and changes of the channel to the favorable waterways. Then the existing light-buoys have to be removed or replaced or laid down the new buoy in new

channel by the help of anchor vessel just in time. In addition, anchor vessels are regularly assigned to carry out inspection and renovation job for lighthouses and outport channels in the coastal area twice a year.

There were two anchor vessels in MPA: Sin Pyaung and Hsaddan for the whole country. On February 2019, one of the anchor vessels, Sin Pyaung vessel was capsized during her servicing duty in Rakhine coastal area. Therefore, now only one Hsaddan vessel remains for the service. Hsaddan is 34 years old and her size and power are less than Sin Pyaung and can only be used within Yangon Port area.

Source: MPA

Photo 2-2 Photo of Sunken Vessel Owned by MPA (Sin Pyaung)

MPA urgently needs anchor vessel which can be used within the Yangon Port limit as well as coastal area to carry out marine service and channel maintenance work for Myanmar.

3. CURRENT CONDITION OF DREDGING AND CHANNEL MANAGEMENT

3.1 Dredging and Channel Management by MPA

In Yangon River channel, dredging is mainly conducted around the Elephant Point near the Outer Bar and around the Monkey Point at the Inner Bar of the Yangon Port. Sometimes, the large vessels cannot enter and exit the port as the river is shallow and silted up. Furthermore, there is a concern over the possible breakdown of ships due to the propeller blockage resulted by underwater waste. There are many container vessels sailing along the Yangon River which add to the necessity of regular dredging and channel management. The extended river depth will not only allow for more vessels, but also allow for vessels with deeper draft to pass through. The proper channel management will also support the economic development of the country, as more ships will be able to enter and exit the port, increasing the size of business in the country.

Source: the Consultant

Figure 3-1 Location Map of Inner Bar and Outer Bar

The Marine Department of MPA is in charge for the channel maintenance dredging in the Yangon River in MPA's port limit as well as at the outports and the Dredging Division of Civil Engineering Department is in charge for the maintenance dredging in front of jetties and terminals. Due to the lack of proper dredgers of MPA, the channel maintenance work is outsourced to a private company with a five-year contract from 2018 to 2023. The details of the contract with the private company for channel maintenance dredging are summarized as follows:

Table 3-1 Contract Details of Five-Year Channel Maintenance Project

Contract Name	The 5 Year Channel Development Project for Yangon River
Contract Management	Marine Department of MPA
Contract Period	From 2018 to 2023 (for 5 years)
Component	1) Outer Bar channel improvement and maintenance works 2) Inner Bar channel improvement and maintenance works
Scope of Works	1) Outer Bar component Dredging area: within 3.0 nm along the recommended track Controlling depth: at least 5.0 m Channel width (straight line): at least 0.3 nm Channel width (turning point): at least 0.45 nm 2) Inner Bar component Dredging area: about 1.1 nm Controlling depth: at least 4.7 m Channel width (straight line): at least 0.05 nm Channel width (turning point): at least 0.075 nm
Disposal Area	Within 3 nautical miles of dredging in the river

Source: MPA

3.2 Dredging Operation by the Private Company

The bidding process for the five-year channel maintenance project took over one year and twenty-five contractors submitted proposals for the project. The tender evaluation was made according to the tender evaluation methodologies directed by the Myanmar President's Office Directive No: 1/2017 and the contract was awarded to Star High Asia Pacific Pte Ltd. in 2018. As the dredging contract was made based on the rules and regulations in Myanmar, there is no contractual issues between the parties. The channel maintenance is carried out with only one dredger by Starhigh due to the congestion of vessel traffic in the navigation channel. The detail specifications of the dredger used are collected as follows:

Table 3-2 Specifications of the Dredger Used by the Dredging Contractor

Ship Name	Reem Island
Type of Dredger	TSHD
Length (m)	107.5
Breadth (m)	18.3
Draft (m)	8.5
Built Year	1976
Country	HOLLAND
Gross Ton	5,601
Main Engine (PS)	3,000 HP × 2
Speed (knot)	11.9
Loading Capacity (m^3)	5,600

Source: Star High Asia Pacific Pte Ltd.

The dredging operation at Inner Bar is carried out once per week and the dredging work at Outer Bar is carried out according to the survey results of sounding data. The dredging operation is carried out 24 hours depending on the vessel traffic. The operation is carried out until the targeted depth.

Source: MPA

Photo 3-1 Dredger used by the Private Company (Reem Island)

The main difficulties for the operation are due to the priority of many inbound/outbound cargo vessels and it is also difficult to control the local cargo boats at inner bar and local fishing boats at outer bar. Additionally, the turning area is narrow at the Inner Bar around the dredging area due to the local cargo boats and fishing boats. The current flow at junction of the Inner Bar area causes the difficulties of maneuvering of the dredger. Although the contractor had noticed such kind of uncontrollable conditions, the contractor entered into the contract.

The sedimentation and river bed fluctuation in Yangon River are also the difficulties for channel maintenance. Due to the high sedimentation rate in Yangon River, MPA expected to carry out the channel maintenance work for anytime as needed in order to maintain the controlling depth. However, with the current Starhigh's dredger, the dredger is not perfectly suitable for operation in low tide condition while navigation of vessel is not frequently due to the large size.

By the Project for the Rehabilitation of Vessel Traffic Navigation Aid in Yangon River which will be implemented by Grant Aid, the safety of night time maneuvering will be improved and the vessel traffic congestion at day time is expected to reduce. Consequently, the duration of hindrance to dredging operation from passing of commercial navigation in the channel will be reduced and thereby increases in dredging working hour during day time. And one of the solutions for effective dredging is to operate with the best suited dredger which is highly efficient for both high tide and low tide.

3.3 Dredging Procedures and Guidelines by MPA

Normally, the Survey Division of Civil Engineering Department of MPA carries out the channel survey work and inform to the Marine Department for necessary dredging. The dredging work is carried out according to the instruction of Master Attendant of Marine Department. The dredging guidelines are also prepared and issued by MPA.

Table 3-3 Dredging Guidelines by MPA

No.	Location	Department in Charge	Target Depth (ft)	Frequency	Dredger Type
1	Monkey Point Channel	Marine Department	15.5 (4.7 m)	Everyday (Dry Season: Day and Night)	Trailing Suction Hopper Dredger
2	Yangon Main Port (Foreshore area)	Civil Engineering Department	5-12	Occasionally	Grab & Hopper Barge
3	Thilawa Port	Civil Engineering Department	>30	Occasionally	Grab & Hopper Barge
4	Middle Bank Channel	Marine Department	Nil	-	-
5	Western Channel (Elephant Point)	Marine Department	Nil (around 5 m)	-	-
6	Outer Bar	Marine Department	Nil (>15)	Occasionally	-

Source: MPA

3.4 Organization of MPA for Channel Management

For the channel management and dredging purpose, the Marine Department, the Survey Division of the Civil Engineering Department and the Mechanical Engineering Department can be said as the concerning departments for channel management works and the duties and tasks of each department are summarized as follows.

(1) Marine Department

Marine Department provides waterway channel maintenance including the dredging within the port limit area as well as pilotage service, aids to navigation service, mooring service, diving and salvage service, launch boat service, fresh water supply and 24-hr communication service. The other duties of the Marine Department are to carry out the marine services for vessels calling to or departure from the port limit, to issue the regulations

concerned with all vessels which are using port limit area to provide safety and to monitor them to abide by such regulations.

The main concern of Marine Department is the channel management and navigation facilities management. Currently for the five-year channel maintenance project, the Marine Department is the department in charge for management to the private contractor. The captains and pilots under the department have well-experience with the Yangon River channel and they only need the useful/operable vessels and equipment for more effective operation.

(2) Civil Engineering Department

a) Survey Division

Survey Division is responsible for hydrographic survey, land survey work within the port limit, and locating the navigation buoys.

The dredging near the Outer Bar channel is carried out according to the survey sounding data by the Survey Division. The Survey Division is also responsible for the positioning of the navigation buoys according to the channel condition. It can be said that the coordination between the Marine Department and Survey Division is important for future channel maintenance works.

b) Dredging Division

Dredging Division is responsible for management and operation work of grab dredger in front of the jetties and wharf areas and the dredging works carried out by the parties other than MPA.

(3) Mechanical Engineering Department

The primary task of the Mechanical Engineering Department is to run port services regularly. The Mechanical Engineering Department carries out ships building and repair of vessels which have been used in various port services such as navigating, dredging, mooring, fresh water supply, towing, and fire-fighting. Moreover, the department also carries out the new construction and repair of navigation buoys and mooring buoys, maintenance and repair of container and general cargo handling equipment as well as maintenance and repair of vehicles and machineries, electrical and electronic apparatus of vessels, cargo handling equipment and port machinery. The department is also responsible for the installation, maintenance and repair of electrical appliances and electricity supply for port terminals, yards, warehouses and office buildings. The department also takes measure of afloat repair services on seagoing ships to and from the harbours. Furthermore, the department also carries out maintenance and repair of vessels machineries and electrical components used in outports, periodically surveys on non-propelled boats and cargo barges, and construction and repairing of vessels and buoys according to the orders given by government or other outside parties.

As mentioned before, the Mechanical Engineering Department is responsible for the repairing and maintenance of the dredgers and anchor vessels. The repairing and docking of the MPA vessels are carried out not only at the MPA's dockyards but also at the other dockyards. The Mechanical Engineering Department has three dockyards under MPA- Theinbyu, Angyi and Setsan dockyards but the dockyards are not modernized and equipped only with old equipment and facilities. Apart from MPA's dockyard, the vessels could also be repaired and docked at the other dockyards, for example: Myanma Shipyards-AMECC JV Dockyard and Dalla Dockyard.

3.5 Details of Existing Dredgers

MPA owns four dredgers for channel maintenance dredging but only three dredgers are still under operation. However, the dredgers do not have enough capacity to carry out the channel maintenance work. It is said that the current dredging vessels are old and the pump capacity is insufficient. As a result, because the dredging with MPA's dredgers is not effective, MPA could not maintain the planned water depth by its own. The dredging is simple and repetitive in operation however, dredging system in the dredgers are composed of different components such as drag head, suction arm, gantry, dredge pumps and part, dredge valve, sensors and transmitters, safety and firefighting equipment, hydraulic system parts, engine room systems, auxiliary pumps and parts. It is required to utilize each component to perform overall dredging works. The main problems for MPA's owned dredgers are in ship hull, dredging pump system and in propeller system due to their old service life without proper maintenance.

Table 3-4 Specifications of Dredgers Owned by MPA

Name	Type	Dimensions			Built Country and Year	Gross Tonnage	Main Engine (PS)	Speed (knots)
		Length (m)	Breadth (m)	Draft (m)				
Yadana Theinkha	TSHD	68.33	14	4.58	Japan 1998	1,669	3,000	10
Thiha-Dipa	TSHD	68.33	14	4.58	Japan 1998	1,669	3,000	10
Areindamar (not under operation)	TSHD	65.75	14.22	4.58	Germany 1989	1,532	1,475 × 2	10
Ramanya	TSHD	65.32	14	4.58	Germany 1989	1,532	1,085 × 2	10

Source: MPA
Note: the normal service life in general for a vessel is 30 years whereas the service life range from 25 to 40 years depending maintenance services. The current dredgers on MPA are now over 30 years and can be regarded as over the normal service life of vessel.

Source: MPA

Photo 3-1 Grab Dredger Owned by MPA

Source: Preparatory Survey for the Project for Expansion of Yangon Port in Thilawa Area, JICA

Photo 3-2 Trailing Suction Hopper Dredger Owned by MPA

3.6 Requirements for the Dredger by MPA

The Consultant discussed with MPA to confirm the major objective of dredging, method of transportation and other necessary information prior to consideration of dredger specifications. The purpose of the new dredger is to replace the existing old dredger for carrying out the channel maintenance dredging at Inner Bar and Outer Bar. If the new dredger is effectively useful for dredging at the Inner Bar and Outer Bar and if MPA could carry out the dredging operation by themselves in the future, the budget for hiring the contractor could be reduced. Dredgers with good pump capacity are requested by MPA. MPA's proposed size is a little bigger than current ones. Additionally, one-man-operated bridge dredgers is also requested for more convenient operation. As most of the captains and crews of MPA are currently using the old types of vessels, they are not familiar with the modernized types, and so, the trainings for operation shall be provided. MPA expects that MPA's budget for hiring the contractor could be reduced annually if MPA could carry out the dredging operation by themselves effectively with the procured new dredger at the Inner and Outer Bar.

3.7 Details of Existing Anchor Vessels

The buoy vessels are frequently used for checking of the buoy position, lifting and re-positioning of buoys along the length of the navigation channel. The area prone to damage are the main deck of buoy vessels, winches and crane and are regularly maintained and repaired. There were two buoys vessels owned by MPA in order to carry out the inspection and renovation job for lighthouses, navigation buoys and mooring buoys. However, one of the vessels, named Sin Pyaung was capsized during the inspection work at Man Aung, Rakhine State.

Table 3-5 Specifications of Anchor Vessels Owned by MPA

Name	Specifications					Ship Age as of 2019 (Years)
	LOA (ft)	Breath (ft)	Depth (ft)	Draft (ft)	Crane Capacity (Ton)	
Hsaddan	130	36.9	12.4	8.85	15	34
Sin Pyaung	174	37	16	12	15	60

Source: MPA

3.8 Requirements for the Anchor Vessel by MPA

Sea-going type anchor vessel is requested by MPA in order to carry out the inspection and maintenance of navigation facilities at the outports. A little bigger size with bigger safe working load capacity (15 tons to 20 tons) is also requested. Furthermore, one-man-bridge operated vessel is also requested. As most of the captains and crews of MPA are currently using the old types of vessels, they are not familiar with the modernized types, and so, the trainings for operation shall be provided. The Consultant considers the specifications of anchor vessel to be utilized as multipurpose vessel.

4. CANDIDATES OF VESSELS

4.1 Dredgers

4.1.1 General

Generally, the dredgers can be mainly classified into two categories as mechanical dredgers and hydraulic dredgers respectively based on method employed for transportation of dredged material from river bed to water surface. Bucket dredger, bucket ladder dredger, grab dredger and backhoe dredger can be regarded as mechanical dredger. Suction dredger, trailing suction hopper dredger and water injection dredger are classified as hydraulic dredgers.

There is a variety of dredgers and methods. Some have developed to meet a particular requirement, whilst others are more versatile. Some type of dredger may be quite unable to perform particular dredging tasks, or at best may only be able to perform that task at much reduced efficiency. With careful design and specification of dredging work, it may be possible to reduce the variety of dredger required, or to allow dredger to operate at greater efficiency. Therefore, selection of candidate dredgers plays a vital role in order to be in line with the navigational requirements of Yangon Port.

There are various types of dredgers equipped with various types of dredging equipment depending on the conditions of the dredging area and seabed, and it is important to fully understand the functions and characteristics of each type of dredger and to adopt the type that is suitable for the purpose and conditions of this Project.

Candidate dredgers are selected by taking into account of river bed material of Yangon River, weather and river condition, nature of disposal site, production rate and their maintenance system. The followings are some types dredgers widely used in the world for channel maintenance dredging.

4.1.1.1 Trailing Suction Hopper Dredger (TSHD)

The trailing suction hopper dredger is a ship suited to coastal or deep-sea navigation, which has the ability to load soil and water to a hopper provided within its structure by means of a centrifugal pump or pumps whilst the vessel is moving ahead. Most trailing suction dredgers have twin screw propulsion and a powerful bow thruster, which provide a high degree of maneuverability. Dredging takes place with the ship moving slowly ahead. Disposal method is normally by means of a bottom-discharge arrangement, or by pump discharge, in the latter case, usually to the shore.

Source: https://atozhub.weebly.com/mechanical-engineers/dredging

Photo 4-1 Trailing Suction Hopper Dredger

4.1.1.2 Cutter Suction Dredger

The cutter suction dredger has a pontoon hull structure without propulsion. However, some, usually large, may have a ship-form hull and be self-propelled. Dredging takes place with the dredger anchored. The dredger is most often used in works of land reclamation, or other hydraulic filling, but may be employed in a wide range of applications. The dredging process involves an initial powerful cutting action, followed by suction, and pumped discharge via a pipeline, or occasionally to barges.

Source: the Consultant

Photo 4-2 Cutter Suction Dredger

4.1.1.3 Backhoe Dredger

The backhoe dredger has evolved from the common land-based hydraulic backhoe excavator. Whereas the land-based machine is normally mounted on a tracked or wheeled undercarriage, the dedicated dredging machine usually is mounted on fabricated pedestal at one extremity of a spud-rigged pontoon. However, tracked machines are occasionally employed with tracks secured to the pontoon deck. The backhoe dredger evolves with the introduction of larger backhoe excavators which provide the greater digging depth and power required for many dredging applications.

Source: the Consultant

Photo 4-3 Backhoe Dredger

4.1.1.4 Grab Pontoon Dredger

The grab pontoon dredger consists of a lattice jib grabbing crane mounted on a simple pontoon. It has no hopper. Instead the dredger loads into independent hopper barges. Subject to an adequate supply of hopper barges, uninterrupted dredging is possible with the result that higher overall rates of production are possible than the grab hopper dredger. The grabbing crane is mounted towards one end of a pontoon which is usually approximately rectangular in plan, but may have a semi-circular or narrowed end projection on which the crane is mounted.

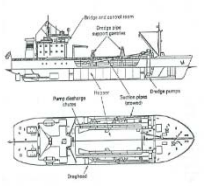
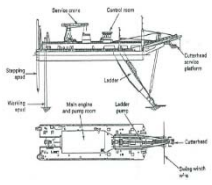
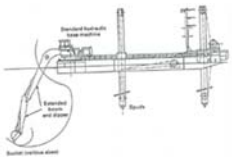
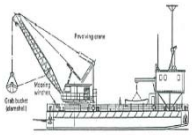
Source: the Consultant

Photo 4-4 Grab Pontoon Dredger

4.1.2 Comparison of Candidate Dredgers

The candidate dredgers are compared in term of their advantages, disadvantages, requirement of tug-boat assistance and material transferred barge, suitability of dredging material and necessity of maintenance.

Table 4-1 Comparison of Dredgers

Type of Dredger	Trailing Suction Hopper Dredger	Cutter Suction Dredger	Backhoe Dredger	Grab Pontoon Dredger
				
Merit	✓ Relative immunity to weather and sea conditions ✓ Independent operation ✓ Minimal effect on other shipping ✓ Able to transport dredged material over long distance ✓ Relatively high rate of production ✓ Simple and inexpensive mobilization procedure	✓ Able to dredge a wide range of material including rock ✓ Able to operate in shallow water ✓ High rate of production	✓ Able to dredge a wide range of materials including boulders, debris, stiff clays and weak rocks ✓ Able to be dredged by the larger dredgers providing excessive maximum required dredging depth ✓ Able to work in confined spaces ✓ Accurately control of position and depth ✓ The absence of anchors and associated wires ✓ The minimum disturbance and dilution of the material being dredged ✓ A faster cycle time than the equivalent size of grab dredger.	✓ Loaded dredged material with minimum disturbance ✓ The grab is well suited to the confined area such as alongside of quay, entrance of dock yard and jetty. ✓ The pontoon draught is normally quite small and thus can work in shallow water. ✓ Able to dredge narrow channel
Demerit	✓ Unable to dredge strong materials ✓ Sensitivity to concentration of debris ✓ Dilution of dredged materials during loading process	✓ Sensitive to sea condition ✓ Dilution of dredged material ✓ Limited dredged length ✓ High mobilization cost	✓ Low rate of production ✓ Difficulty in production accuracy and level bottom finish	✓ Low rate of production ✓ Difficulty in production accuracy and level bottom finish
Tug boat	✓ Not required for operation	✓ Not required for operation	✓ Not required for operation	✓ Required for operation
Split barge	✓ Not required	✓ Required for disposal	✓ Required for disposal	✓ Required for disposal
Dredging materials	✓ Fine grained materials	✓ Strong materials including rock	✓ Coarse sand, sand with medium gravel	✓ Coarse sand, sand with medium gravel
Maintenance	✓ Regular maintenance especially suction pipe, centrifugal pump and drag head is needed.	✓ Regular maintenance especially for cutter head is required.	✓ Regular maintenance will not be required	✓ Regular maintenance will not be required.
Evaluation	✓ Suitable for dredging and maintenance at navigation channel due to the minimum disturbance of operation and high rate of production.	✓ Suitable for land reclamation works and a wide range of materials including rock.	✓ Suitable for working from behind the face (the pontoon is located over the area to be dredged).	✓ Suitable for dredging at along quay, entrance of dockyard and shallow water area.

Source: Dredging Handbook for Engineers (Second Edition) by R N Bray, A D Bates & J M Land

4.1.3 Selection Criteria of Appropriate Dredger

4.1.3.1 Comparison of Dredging Methods

The selection of suitable dredging methods and equipment for appropriate dredging operation is be carried out taking into account the followings.

1) Characteristics of the dredging material/soil
2) Dredging area conditions
3) Soil dumping site

Firstly, some dredger types may be ruled out depending on whether the above three conditions for the dredging works in question are met by the operating limit for these dredgers. The remaining various dredgers are then compared based on their advantages, disadvantages and operating conditions to evaluate their productivity, operating costs and the unit cost of the dredging work. On that basis, the most economical choice is generally made. However, in some cases, when dredging work progress is mostly important, it may be chosen by maximum productivity.

4.1.3.2 Characteristics of Dredging Material/Soil

In general, the characteristics of the dredging material/soil are the most important factor in the selection of the dredging method. Therefore, the ground investigation to investigate the properties of the dredging material is an important preliminary investigation. In the case of very hard ground, gravelly ground, or ground containing foreign substances such as steel, grab dredgers and backhoe dredgers can be used. In other cases, cutter suction dredgers and TSHDs can be used to increase the dredging efficiency.

However, in the case of maintenance dredging, the soil properties of the dredging material are limited to the followings due to the fact that the dredging material is sediment that is deposited in a limited time in the channel and anchorage area.

- There is no case of dredging the rock.
- There is only fine-grained soil which is easy to move. (sandy, silty, viscous soil, etc.)
- When port facility is in planning phase, the soil properties of sediments are inferred through analysis of sediment sources and transport mechanisms, i.e., erosion, transportation and deposition, whereas in the maintenance phase, they can be confirmed by analysis of the sediment samples actually deposited.

The dredgers to be considered in this Project is continuous maintenance dredging. In the case of maintenance dredging, the sediment may not be condensed nor increased in strength. With this in mind, the dredge is not determined by the constraints imposed by the hardness of the dredging material. As far as no strong debris is found, dredging by TSHD is considered to be appropriate in terms of efficiency.

The selection criteria of the dredger by the dredging material is generally known as follow.

Table 4-2 Type of Soil and Applicable Dredgers

Soil/ Rock	Definition	Soil/Sand				Gravel mixed soil	
	N value and hardness	N value				N value	
		<10	10~20	20~30	>30	<30	>30
Dredger	Cutter Suction	○	○	○	○		
	TSH	○	○				
	Grab	○	○	○	○	○	

Source: the Consultant

4.1.3.3 Dredging Area Conditions

The following points should be considered as conditions for the dredging site.

- Access to the Dredging Area

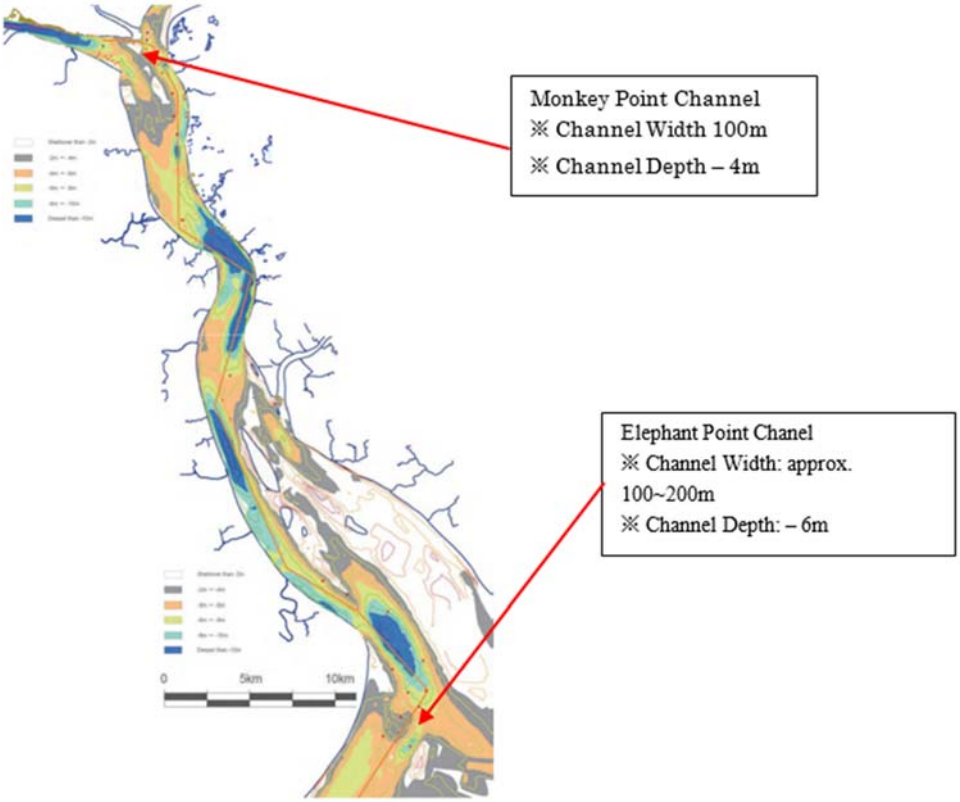
Some beaches and rivers are so shallow that access routes can only be secured during limited periods such as high tide and rainy season. Also, if there are narrow places such as rivers, accessibility of dredgers should be considered.

The tide of Yangon River is two high tides and low tides per day. At high tide, the water level is about 5.85 m and the current reverses and flows backwards from the estuary to the Yangon area. The velocity of the river current at ebb and flowing tide is about 4~6 knots. Waves near the mouth of the river are generally within 2 m and calm.

The width of the passage at the Monkey Point is approximately 100 m and the depth of the passage is -4 m. The passage from the Monkey Point downstream to the Thilawa area is deep in some areas, but the water depth is generally -6 m and the passage width is about 400 m in narrow areas. There is a point about 5 km upstream from Thilawa where the passage is narrows with depth of -6 m.

The passage from Thilawa to the Elephant Point is generally 6 m to 8 m deep, and the width of the passage is over 1,000 m in many places. There is a shallow water about 10 km downstream from Thilawa at a depth of about -5 m. There is also shallow water outside of the Elephant Point at a depth of about -5 m.

South of the Elephant Point to open sea can be said as very gentle slope where the location of -10m depth is 50 km away from the Elephant Point.



Source: the Consultant

Figure 4-1 Current Condition of Critical Channel

- Depth of Water

In general, the followings should be considered with respect to water depth.

- Maximum planned dredging depth
- Current water depth and draft of dredger
- Possibility to move/navigate the dredging vessel while dredging

For the channel dredging work, the planned channel depth is approximately -5 m for both the Inner Bar and Outer Bar, and the planned dredging depth is likely to be -6 m with an extra depth. In addition, the maximum tide difference between the two times a day is about 6 m, and it is necessary to take into account the maximum depth of over 10 m, which is quite deep for the backhoe dredger and it does not make the dredging efficiency very high. Therefore, a backhoe dredger would not be suitable except in areas where high dredging accuracy is required in the existing port facilities. Other dredging methods are within the limit of conditions for this Project.

- Length of the Dredging Area

In the case of TSHD, the dredging is more efficient as the distance within the dredging area is longer, because it dredges while moving forward. On the other hand, if the length of the dredging area is short, the work loss due to the interruption of the dredging operation when the vessel changes direction will be noticeable. Usually more than 1,000 m dredging length is considered economically acceptable. In the case of this Project, both the Inner Bar and the Outer Bar may be long enough to be suitable for the TSHD.

- Width of the Dredging Area

TSHD requires sufficient width to allow for a change of direction at the edge of the dredging area. A minimum of four times wider than the normal LOA is required. If THSD is equipped with a bow thruster, a minimum of 2.5 times is acceptable. Due to the shallow water depths outside the dredging area, consideration should be given to the rotation of TSHD and even other type of dredgers. In addition, dredging with anchors is not suitable for narrow routes.

- Wind

If the dredger is facing the wind from the side during operation, the wind pressure against the dredger will cause the dredger to drift. Depending on the type of dredger such as with spuds, anchors, etc., must be able to counter this external force. TSHD also drifts when it catches wind from the side, but since it has no spuds or anchors, it is more flexible in operation. Since strong winds are rare in this Project site except for cyclones, wind condition does not need to be taken into account.

- Waves

In the case of dredging at the Outer Bar channel, the effect of waves is not negligible. Waves can be a constraint depending on how the dredger is positioned. In the case of a dredger fixed by spuds, the spuds and spud holders must be able to withstand the external forces to the hull generated by the waves. In case of backhoe dredger with damper barge, it is not possible to moor the barge on the side of the vessel due to high waves.

TSHD and the grab dredger are the most resistant to waves due to their hull shape and design for open sea, and is more resistant to waves due to swell compensation system of drag head against wave action.

In accordance with the Technical Note of The Port and Harbour Research Institute, MLIT, Japan, the limit conditions of marine construction works including dredging are summarized as follows.

Table 4-3 Working Limit of Marine Construction Works

	Working Limit	Evacuation Limit
Wind speed (m/sec)	<10.0	<15.0
Wave Height (m1/3)	<1.0	<2.0
Visibility (m)	<1000	<500

Source: the Consultant

However, the working limit of the wind and wave by the type and size of dredgers excluding TSHD is generally explained as reference as shown in the table below. Working limit shall be considered and set taking into consideration of the actual design of the dredger by the operator.

Table 4-4 Working Limit by Type of Dredger

Work	**Specifications**		**Wind speed (m/s)**	**Wave (m)**
Dredger	Cutter Suction	<1,000 ps	5	0.3
		2,000 ps	10	0.4
		3,000 ps	10	0.5
	Grab	<100 ps	5	0.3
		200 ps	10	0.4
	Backhoe	<350 ps	5	0.3
		1,000 ps	10	0.4

Source: the Consultant

➢ Navigation of the Other Vessels

In the case of maintenance dredging, it is necessary to pay attention to the other vessels because of different influences on the navigation by the other vessels depending on the positioning method of the dredger. In case of grab dredger using anchors, the anchor wires interfere with navigation of the other vessels in the vicinity of the dredger. If a vessel approaches, the grab dredger shall be required to loosen the anchor wire to maintain sufficient depth of wire and the dredging operation will be suspended. TSHD does not require anchors and therefore has the least impact on the navigation of ships in nearby.

In a cutter suction dredger, the sand discharge pipe may block the route. In this case, it is necessary to install a sand discharge pipe at the bottom of the sea, but the time and effort of moving the sand discharge pipe becomes large.

4.1.3.4 Soil Dumping Site

Soil dumping site can be on land or at sea. Either way, there are cases where reclamation for future use is carried out in conjunction with dredging, and there are cases where dredging is the purpose of a project and only the dumping of soil is carried out. There are three methods of transporting the dredged material to the dumping site.

- Pumping
- Loading into the hopper of the ship
- Loading into the hopper of dumping barge

In case of loading into the hopper, there are two ways to dispose the soil at the dumping site: by opening the bottom of the hopper or by arranging another dredger to discharge the soil. In particular, when a TSHD is used to dump soil near the shore, a pressurized spray (called "rainbow") can be used with the nozzles on board the ship.

Source: the Consultant

Figure 4-2 A Dredger on the way to Dumping Site in Yangon River

If there is a dumping area near the site, pumping with a discharge pipe is the most efficient and therefore economical method of transportation. In case of dumping area being farther away, the more economical way is to transport by hopper dredger or another dumping barge such as TSHD or grab hopper dredge. In the case of this Project, the soil dumping would be approximately one mile at the Inner Bar and the open sea at the Outer Bar, and reclamation would not be considered. Due to the long distance to the dumping site and vessel traffic condition, it is considered that the pumping system is not suitable.

4.2 Anchor Vessels

Anchor vessels can be generally known as buoy laying vessel that are designed to facilitate the handling and maintenance of navigational aids in river, coastal and offshore waters. All ports under MPA are river ports and channel instability occur not only in Yangon Region but also in coastal area where outports exist. To overcome these problems, buoyage navigation system and anchor vessels play key role for channel safety. Anchor vessels are a type of supply vessel that supply tow and anchor to not just to navigational aid also to cargo-carrying barges. At present, MPA utilizes the anchor vessel for removing, replacing or laying down the light-buoys. In addition, it is used to inspect and renovate the lighthouse in coastal area and outport channels. The vessel shall provide the proper space for crews, appropriate crane capacity subjected to targeted handling object and equipped with other facilities such as firefighting.

In accordance with the examination and analysis results of collected information, and interview with related departments of MPA, it is observed that similar type of anchor vessel is preferable due to simple handling and operation system. Therefore, the candidates anchor vessel type shall be similar to anchor vessels which is familiar to MPA with respect to basic function, propulsion and maintenance system. However, MPA prefers a little bit bigger size of vessel and crane capacity. Therefore, selection of the candidate anchor vessel shall satisfy the requirement of MPA if it is of similar type but bigger size and capacity. The followings are the minimum requirements of candidate anchor vessel. Anchor vessels shall be:

1. bigger size of existing Hsaddan Vessel
2. safe working load being more than 15 ton
3. sea-going vessel type for inspection at outports of Myanmar
4. vessel with one-man-operated bridge so that one operator could control the operation
5. equipped with other suitable facilities

As an alternative, crane barge with tug boat assistance can be considered for buoy laying and handling of navigational aid. In this case, strong engine power of tug boat assistance is prerequisite against strong flow of river current with high velocity so that buoy can be laid the preferable location.

Anchor Vessel Owned by MPA (Hsaddan)

Source: MPA

Crane Barge & Tug Boat

Source: the Consultant

Photo 4-5 Types of Anchor Vessels

Table 4-5 Comparison for Types of Anchor Vessels

No.	Condition	Crane Barge & Tug Boat	Anchor Vessel
1)	Versality	○	○
2)	Ship Building Period	○	○
3)	Capital Cost	○	△
4)	Maintenance	△	△
5)	Ease of Operation	○	○
Recommendation		○	○

○: Good, △:Average, ×:not good

Source: the Consultant

4.3 Proposed Dredger and Anchor Vessel for Yangon River

4.3.1 Dredging Plan

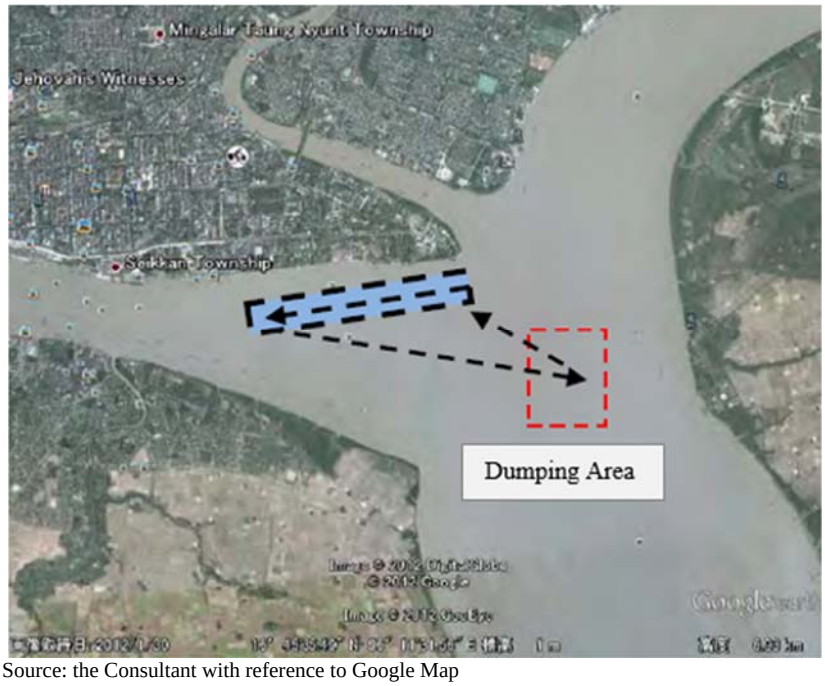
To make proposal of most appropriate type of dredger and anchor vessel for Yangon River, the following conditions are required to be considered.

4.3.1.1 Current Dredging Operation

(1) Dredging Area

MPA has been conducting Inner Bar surveys weekly and based on the results, dredging is carried out by a self-propelled Trailing Suction Hopper Dredger (TSHD). The dredging route of the Inner Bar has been divided by survey into five lines and dredging of each line has been carried out. Dredging starts at low tide and the dredging direction is from East to West with a depth of approximately CD +5.6 m. The distance of one line is 1.6 miles, and the dredging speed during dredging is approximately 2.0-3.0 knots. The dredging time of one line is approximately 30 minutes and the 850-1,000 m^3 capacity of hopper become full of seawater and soil. After dredging one line, the hopper is split and disposed at the dumping site (12 m depth) approximately one mile away from the Inner Bar. The dredging cycle from dredging one line to dumping of the soil is approximately one hour and this cycle is repeated five times during low tide and takes approximately five hours to complete.

Dredging at the Inner Bar is carried out by a single dredger during the rainy season from June to December and by two to three vessels during the dry season from January to May due to the high tide which causes more sand. Figure 4-3 shows the dredging area and dredge work at the Monkey Point of Inner Bar.



Source: the Consultant with reference to Google Map

Figure 4-3 Dredging Work Area at Monkey Point

(2) Dredging Volume

In the current Yangon Port route, dredging is being carried out at two sandbars, Monkey Point (Inner Bar) and Elephant Point (Outer Bar), in order to maintain the route. Annual maintenance dredging amount of soil of each site according to MPA's internal record is shown in table below.

Table 4-6 Past Record of Dredging Volume

Site	Volume of Maintenance Dredging (Million m^3/year)
Monkey Point (Inner Bar)	1.0～2.0
Elephant Point (Outer Bar)	0.2~0.4

Source: MPA

Scope of work is to dredge and maintain channel depth up to CD -5.0 m in Outer Bar channel and CD -4.7 m in Inner Bar.

Table 4-7 Dredging Guideline of MPA

No.	Location	Target Depth	Frequency	Dredger Type
1	Monkey Point Channel	15.5 ft (4.7 m)	Everyday (Dry Season: Day and Night)	Training Suction Hopper Dredger
2	Yangon Main Port (Foreshore area)	5 -12 ft (1.5-3.7 m)	Occasionally	Grab & Hopper Barge
3	Thilawa Port	>30 ft (>9.1 m)	Occasionally	Grab & Hopper Barge
4	Middle Bank Channel	Nil.	-	-
5	Western Channel (Elephant Point)	Nil.	-	-
6	Outer Bar	Nil >15 ft (>4.6 m)	Occasionally (1~2 years interval)	-

Source: MPA

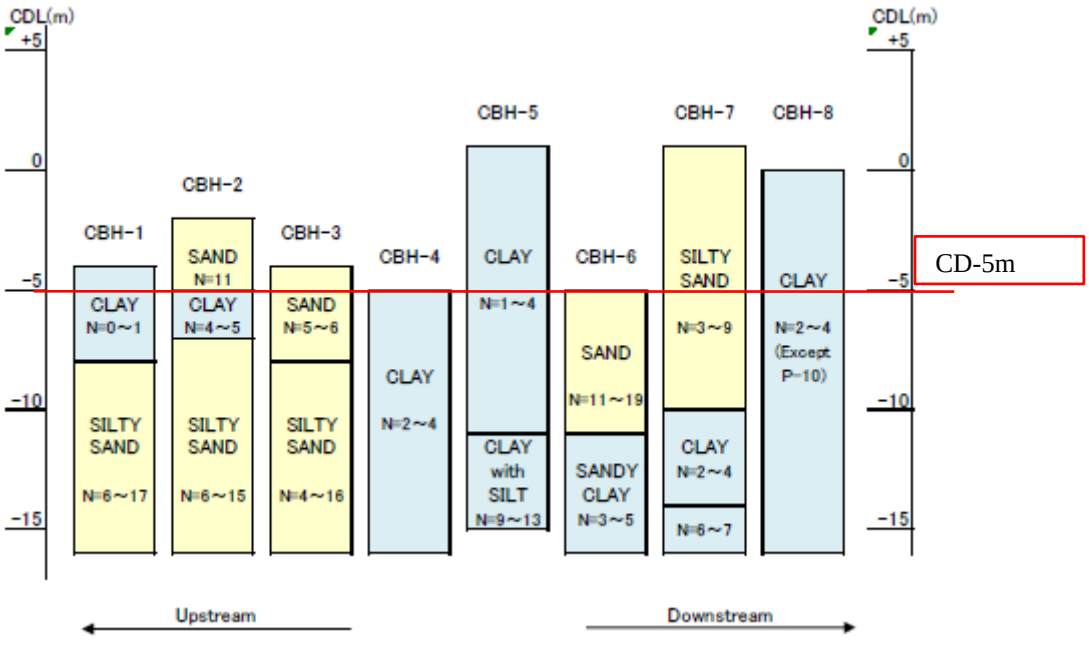
4.3.1.2 Dredging Material

Based on the results of the geological survey carried out by JICA for the development of Thilawa port, the ground configuration of the navigation channel is surveyed as figure below.

The soil by layer is classified as follows.

- Sand
- Clay
- Clay with silt
- Silty sand

As shown in the figure, there is a difference in ground height of about 5 m between the upstream and downstream sides, and the formation is extremely complex and not uniform. The trend is that the upstream side is dominated by sandy strata from relatively shallow depths, while the downstream side is dominated by clay strata.



Source: the Consultant

Figure 4-4 Schematic Diagram of the Navigation Area

It is also understood by the other JICA survey that the grain size distribution in the upper reaches of Yangon Port, Monkey Point and Thilawa area was similar; most of them was consisted of sand and was less than 4.75 mm in size and the representative grain size was about 0.3 mm. The particle size distributions of the

Pazundaung Channel and the Bago River were also similar, with most of them was composed of silt and clay, with a representative particle size of about 0.02 mm.

Since the dredging plan at Inner Bar and Outer Bar is up to CD -5.0 m plus additional dredge, it can be said dredging material will be sand, clay or silty sand with the maximum N value of less than 19.

4.3.2 Proposed Type of Dredger

There are various types of dredgers equipped with various types of dredging equipment depending on the conditions of the dredging area and seabed, and it is important to fully understand the functions and characteristics of each type of dredger and to adopt the type that is suitable for the purpose and conditions of this Project.

Taking into account the premises of the dredging work required to maintain the planned depth at Monkey Point (Inner Bar) and Elephant Point (Outer Bar), the results of the evaluation are summarized as shown below.

Table 4-8 Comparison for Types of Dredger

No.	Conditions		Type of Dredger			
			TSHD	Cutter	Grab	Backhoe
1)	Characteristics of the dredging material/soil	Sand, Clay or Silty Sand N value < 19	○	○	○	○
2)	Dredging site conditions	Access to the dredging area				
		Inner Bar Limited width of channel, Tidal difference, Less wave	○	×*1	○	○
		Outer Bar Tidal difference, Wave is >1.0 m	○	△	△	△
		Depth of water				
		Depth CD -5 to -10 m (HWL)	○	○	○	△
		Navigable during dredging	○	×	△*2	△
		Length of dredging area > 1,000 m	○	○	○	○
		Width of dredging area > 4 × LOA	△*3	○	○	○
		Wind < 10 m/sec	○	○	△	○
		Navigation of the other vessels	○	×	△*2	×
3)	Soil dumping area		○	△	△	△
RECOMMENDATION			○	△	○	△

○: Good, △:Average, ×:not good

Note: *1 Cutter Suction Dredger is required the discharge piping and this cannot easily access the site.
*2 If it is self-propelled hopper grab type, navigable during the dredging work.
*3 If TSHD has thruster, width of dreading area become not issue.

Source: the Consultant

4.3.3 Suitability of Proposed Dredger

Since the dredging area in Yangon Port is relatively small and many vessels are sailing and mooring every day, it is necessary to select a form of dredging that does not interfere with the movement of the dredger itself during the dredging process, and does not require floating bodies such as discharge pipes.

In addition, it is not assumed that there will be a soil dumping site in the vicinity of the land, and dredged material will need to be dumped in designated area in the water.

Furthermore, the soils of the passage are primarily clay, sand and silt, and there is no need to consider hard gravels or bedrock.

As noted in the above sea and weather conditions, at the harbor mouth of the Outer Bar and outside the harbor, a dredger of a type that does not require spuds for positioning during dredging is required due to the high frequency of significant wave heights exceeding the acceptable limits for the use of spuds.

As for the type of new dredger, MPA requested to use the same type of TSHD dredger as existing dredgers due to the familiarity of operation and maintenance and the compatibility of equipment and parts. Its suitability of the proposed dredger is reviewed as below.

4.3.3.1 Required Capacity of Dredger

As shown in the Table 3-4, MPA currently has four trailing suction hopper dredgers, with a total of approximately 2,400,000 m^3/year of dredging in the Inner and Outer Bars.

(1) Capacity of Hopper

Current TSHDs have average dredging volume of 600,000 m^3/year per vessel (2.4 Mil/ 4 TSHD). Assuming the annual operating days of the dredging vessel (hopper capacity 1,000 m^3) to be 330 days and 5 cycles per day, and assuming a hopper loading factor (silt, sand) of approximately 0.3-0.35, the dredging volume per vessel would be approximately 495,000-578,000 m^3/year, which is close to the actual average value. The hopper capacity of route maintenance dredger from Outer Bar to Thilawa Port is 400,000 m3/year, and the dredging route around Elephant Point is one line with 1.6 miles and speed at 2-3 knots. For the Monkey Point dredging, if two suction pumps with the capacity of 3,000-3,300 m3 is used, the hopper can be filled in about 30 minutes, which is the same duration as current operation. Therefore, the same type of hopper capacity (1,000 m3) as the existing vessel can be used.

(2) Deployment Plan of the Dredger

The channel maintenance dredging volume at the Outer Bar is 200,000-400,000 m3 which can be carried out by the same type of the dredger currently owned by MPA (hopper capacity 1,000 m3).

The existing four dredgers are dredging 2,400,000 m^3/year at Monkey Point and Elephant Point, while the route to the Thilawa Port requires dredging volume of 400,000 m3 for maintenance purposes.

In order to fulfill dredging requirement with existing dredgers, repair and maintenance of the four dredges are essential to ensure the smooth running of these operations.

In addition, two of the existing four vessels are very old (32 years old) and it is necessary to introduce a new dredger as urgent matter.

4.3.3.2 Preliminary Design of the Dredger

(1) Type of the Dredger

Dredgers are required to have high maneuverability to perform dredging work while ensuring the safety of its own vessel to avoid marine accidents such as collision with incoming and outgoing vessels. In terms of satisfying these features and performance, volume of dredging material and the conditions of dredging operation system, the same type of the existing dredger (trailing suction hopper dredger) is optimal. The positive effects of introducing the same type of dredger include the following are expected.

- A crew familiar with the main equipment and systems will be able to start operating the new dredge without problems.
- Skilled crew members can train newly recruited seafarers on the job.
- It is expected to reduce the cost of maintenance and management by sharing the spare parts of major equipment and marine parts.

(2) Specifications of the Dredger

For the new dredger, MPA requested slightly larger capacity/size from existing TSHD. The existing TSHDs has 1,000 m^3 capacity of hopper and has been operating 5 cycles/5 hours for 330 days and as the result, about 600,000 m^3 / vessel is dredged in a year.

Provided that, hopper capacity is fixed to 1,000 m^3, and the Table 4-9 shows the estimation of the working time for one cycle by the different capacity of the suction pump. Table 4-10 shows the estimation of the annual dredging volume of TSHD by the different capacity of the suction pump calculated based on the result of Table 5-7 and same running hours of 5 hr/day and 330 days/year.

As the result of the estimation, with the 2,000 m^3/hr suction pump and 1,000 m^3 hopper capacity will result in about 503,000 m^3 /year. Therefore, the record of dredging volume can be said close to the actual dredging volume.

Table 4-9 and Table 4-10 show that the capacity of the dredger to maintain a water depth of -5 m, which is the same as the current one, is possible with the TSHD of 1,000 m^3 hopper capacity with different pump capacities,

and if four vessels can be operated, it is also possible to dredge 2.4 million m^3 per year in the Inner Bar and Outer Bar.

Table 4-9 Estimation of Working Time of TSHD by Different Capacity of Suction Pump

	Pump Capacity	Hopper Capacity	Residual Water	Suction Process		Working time					
			20%	S.W. Inlet Volume	Dredging time	Dredging time	Dumping time	Vessel Speed	Distance to Dump site	Required time/1 cycle	Working hr/day
	m^3/hr	m^3	m^3	m^3	min	min	min	kt	nm	min	hr
1	2,000	1,000	200	800	24.0	24.0	10	8.0	1.6	59	5
2	3,000	1,000	200	800	16.0	16.0	10	8.0	1.6	51	5
3	4,000	1,000	200	800	12.0	12.0	10	8.0	1.6	47	5

Source: the Consultant

Table 4-10 Estimation of the Annual Dredging Volume by Different Capacity of Suction Pump

			Existing	Future Plan	
	Pump Capacity	m^3/hr	4,000	3,000	2,000
Hc	Hopper Capacity	m^3	1,000	1000	1,000
H	Working Hour/day	hr/d	5	5	5
T	Dredging Time/1 cycle	hr	0.98	0.85	0.78
γ	Soil Contents		0.3	0.3	0.3
W	Working Day/year	d/y	330	330	330
Q	Annual Dredging Vol.	m^3	503,049	582,353	631,378
	(Q=Hc x H/T x γ x W)				

Source: the Consultant

The basic specifications of the trailing suction hopper dredger with a hopper capacity of 1,000 m^3 are explained as follows.

The new dredger is a TSHD for the maintenance dredging of the route to Yangon Port. The vessel is designed to dredge the seabed consisting of fine-grained soil/clay, fine sand and silty sand.

The hull section is made of steel and two propulsion systems are installed in the engine room at the rear of the ship. The propulsion system is a double shafting consisting of two marine diesel main engine and two Controllable Pitch Propeller (CPP) system. It also has two rudders.

The bow pump room will be equipped with a single dredging pump driven by a dedicated diesel engine. Sediment dredged and stored in the hopper is discharged through a door at the bottom of the hopper to the outside of the vessel. The ship's bow, stern, and bridge (including accommodation) are arranged, and a 1,000 m^3 hopper is located in the center of the hull. One drag arm is fitted to starboard.

a) General & Hull Part

Currently, small size dredgers are used for dredging operation in inland waterway channel maintenance in Chindwin and Ayeyarwaddy rivers. However, small size dredgers are not suitable for operation in Yangon River. Dredgers which satisfy with below conditions are suitable for dredging in Yangon river.

Detail of specification for hull, dredging part and engine part are as follows:

Port of Registry : Yangon, Myanmar

Classification : Class NK

NS* (Hopper Dredger, Coastal Service), MNS*

Length Over All (LOA) : about 70 m

Length between Perpendicular : about 65 m

Breadth (Mold) : about 14 m

Depth (Mold)	: about 4.7 m
Draft (Mold)	: about 4.0 m
Dead Weight	: about 1,800 tons
Hopper Capacity	: about 1,000 m^3
Ship Speed	: about 10 knots
Complement	: 28 persons
Senior Officer	: 6 persons
Junior Officer	: 5 persons
Ratings	: 17 persons
Bow Thruster	: about 200 kW × 1set

b) Dredging Part

Side drag (Starboard Side)	
Maximum Dredging Depth	: 17.5 m
Dredging Pump	: about 4,000 m^3/hr × 20 m TH × 1set
Swell Compensator	: Hydro Pneumatic type/Max stroke 1.8 m × 1set
Hopper Door	
Remote control from Bridge	: Pump speed, Dredging Valve, Drag Arm, Hopper door

c) Engine Part

Main Engine	: about 1,200 PS × 2 sets
Shafting	: Controllable Pitch Propeller × 2 sets

4.3.4 Operation Team

(1) Consideration to MLC Convention

The working hours of seafarers are stipulated in the Maritime Labour Convention (MLC) 2006, along with enforceable seafarer's rights, and are determined by the ship's flag state on the basis of the following.

The MLC Convention applies to essentially all ships, except for small ships.

Working Hours and Break Hours

- The normal working hours shall be eight hours per day, with one day of break per week as a rule.
- The maximum limit for working hours and the minimum limit for resting time may be determined by the Flag State.

Maximum Working Time Limits

- Seafarers shall not work for more than 14 hours in any 24-hour period.
- Seafarers shall not work for more than 72 hours in any seven-day period.

Minimum Resting Time.

- Seafarers must take at least 10 hours of break every 24 hours.
- Seafarers must take at least 77 hours of break every seven days.

The break time shall not be divided into more than two installments, one of which shall be at least six hours. In addition, they shall not work continuously for more than 14 hours without taking a break. However, in the event of an emergency, such as when the vessel or crew is in danger, or when rescuing another vessel or people in distress, the master may suspend the work plan until the emergency is lifted.

(2) Work Time Plan and Personnel Deployment Plan

The dredging time plan is based on the same dredging time as the current situation, based on discussions with the MPA, with a crew of 28 people bound for 8 hours per day for 5 days for Monday through Friday. In the case of dredging the Inner Bar, with approximately 5 hours of dredging operation is planned as basis.

The maximum is 24 hours of restraint and can be divided into two teams to work in two shifts. The principle is that each team will work six hours and take six-hour breaks in a row.

The maximum operation case will be expected as 24 hours and the operation can be divided into two teams to work in two shifts. The principle is that each team will work six hours and take six-hour breaks in a row.

However, the effective time actually available for dredging work is assumed to be 19.2 hours per day in total, assuming 80% of the working time, taking into account the time to go to the dredging area, the time to return to port after work, and the time to take off from the shore.

In addition, equipment inspections and repairs will be performed on Saturdays, and Sunday will be a holiday. Each team will be replaced after two consecutive weeks on the ship, and one team will be replaced each week. In other words, one team shall be always waiting on land, so a crew of 42 people/3 teams is needed.

Dredging operations will be conducted 47 weeks per year, with the remaining 5 weeks of the year as days of stoppage for repairs, replacement of supplies and maintenance, and days of no work due to bad weather, etc. In addition, periodic inspections are to be conducted once every five years. In that year, 44 weeks of operation per year, four weeks of periodical inspection work at the dock, and a total of four weeks of unworkable days due to repairs, replacement of consumables, maintenance, bad weather, etc. at the dock.

The table below is the ideal staffing to be onboard the dredger for the continuous operation

Table 4-11 Ideal Manning Schedule of the Proposed Dredger

	Category	Task	Team 1	Team 2	Total
1	1st Deck Officer	Captain	1	1	2
2	1st Deck Officer	1st Mate	1	1	2
3	2nd Deck Officer	2nd Mate	1	1	2
4	3rd Deck Officer	3rd Mate	1	1	2
5	Dredge Master	Master	1	1	2
6	1st Seaman	Helmsman	1	1	2
7	1st Seaman	Pipe Operator	1	1	2
8	1st Seaman	Helmsman	1	1	2
9	Seaman	Cook	1	1	2
10	1st Engine officer	Chief Engineer	1	1	2
11	1st Engine Officer	1st Engineer	1	1	2
12	2nd Engine Officer	2nd Engineer	1	1	2
13	3rd Engine Officer	3rd Engineer	1	1	2
14	1st Seaman	Engineer	1	1	2
	Total		14	14	28

Source: the Consultant

4.3.5 Proposed Anchor Vessel

4.3.5.1 Navigational Aid Rehabilitation Plan

From the previous JICA survey of “Preparatory Survey for the Project for Rehabilitation of Vessel Traffic Navigation Aid in Yangon River”, it was confirmed that there are currently 26 lighted buoys on the Yangon River. Some of the buoy bodies are in a relatively good condition, and there is a high possibility to continue using them through repairs. However, most of the paint conditions are either unpainted or only anti-rust paint, and the top coat (red and green) is thin and in need of repair.

The MPA's standard floating light buoys (3 m in diameter) have a cage mounted on the top to prevent theft and to keep out bird droppings, and the lighters and solar cells are installed inside. However, many of them are in poor condition, such as those without their cage, those without locks on their doors, and those that are damaged. The most common damages of navigation aid are low battery voltage, followed by electrical system failure, theft, and ship collision.

Under the Project, the following new buoys and light houses are expected to be repaired or newly installed.

Table 4-12 List of Installed Equipment

Item Number		Name	Units	Quantity
1.		Navigation Buoy		
	1-1	3 miles type Navigation Aid Light Buoy with synchronizer	sets	10
	1-2	5 miles type Navigation Buoy (including Monitoring)	sets	12
	1-3	5 miles type Navigation Buoy	sets	2
2.		Navigation Buoy repair		
	2-1	3 miles type Navigation Buoy	sets	1
	2-2	3 miles type Navigation Aid Light Buoy with synchronizer	sets	2
	2-3	5 miles type Navigation Buoy (including Monitoring)	sets	4
3.		Light Tower		
	3-1	Sector Light Monkey Point	sets	1
	3-2	Transit Light (Front) Thanlyin Point	sets	1
	3-3	Transit Light (Back) Thanlyin Point	sets	1

Source: Preparatory Survey for the Project for Rehabilitation of Vessel Traffic Navigation Aid in Yangon River (JICA)

Navigation Buoy
Center Spit (Thilawa Area)
(November 2018)

Navigation Buoy
Center Middle Bank (Thilawa Area)
(November 2018)

Navigation Buoy
Hmawun Lumps
(November 2018)

Source: the Consultant (The Preparatory Survey for the Project for Rehabilitation of Vessel Traffic Navigation Aid in Yangon River - JICA)

Photo 4-6 Navigation Buoys at Yangon River

The specifications of the new buoy will be according to IALA standards and MPA requirement. The specifications are as follows.

Table 4-13 Specifications of Buoys

Diameter	3.0 m and 5.0 m
Lighting apparatus	Light source: LED Light color: IALA Power Source: Solar battery
Buoy body	Steel of Fiber

Source: Preparatory Survey for the Project for Rehabilitation of Vessel Traffic Navigation Aid in Yangon River (JICA)

4.3.5.2 Anchor Vessel

(1) Anchor Vessel of MPA

There are two anchor vessels of middle size and small size owned by MPA. Before the accident of anchor vessel sinking in 2019, MPA did the maintenance of Navigation Buoys by two anchor vessels owned by MPA.

Table 4-14 Anchor vessels owned by MPA

	Specifications					Age	Others
	LOA	Breath	Depth	Draft	Crane Capacity		
Hsaddan	130 ft	36.9 ft	12.4 ft	8.85 ft	15 ton	34 years	Tow Fire Fighting and Supply
Sin Pyaung (capsized in 2019)	174 ft	37 ft	16 ft	12 ft	15 ton	60 years	Tow Fire Fighting and Supply

Source: MPA

There was no major docking and maintenance for anchor vessels annually since last five years and some minor maintenance, eg: electric system, steering and radar, and engine control repair was carried out as floating repair.

The middle size anchor vessel named Sin Pyaung is a very old (60 years) vessel and it sunk on 11 February 2019 in Rakhine State vessel. It is noted that the main cause except deterioration of capsize of Sin Pyaung is due to the severe weather condition of coastal area. Due to the swells, the sea water interred from port holes located under the main deck and made the vessel careen to the port side. Subsequently, the cargo moved to the port side and speed-up the capsizing. The last docking of the vessel was in 2017 at Myanma Shipyard and the accident occurred about two years after the docking.

Therefore, MPA has only one vessel remaining now and this vessel could not provide sufficient maintenance service to the navigation facilities. MPA sometimes requests support from some private companies if needed to collect the buoy and maintenance of the buoys.

(2) Required Anchor Vessel by MPA

Since only one old Anchor vessel is in operation but not fully operable, at least one new anchor vessel is required as outport operation and urgent matter. As the existing Hsaddan vessel is appropriate for operation in Yangon area only, the new vessel shall be appropriate for operation in elephant point around Outer Bar and coastal area. It is expected that both existing and new anchor vessels will be the urgent requirement of MPA for navigation channel management.

Buoys needed to be look after in Yangon River is 39 in total as follows.

- Yangon River Channel- 25 buoys
- Sittwe Channel- 3 buoys
- Mawlamyaing Channel- 2 buoys
- Pathein Channel- 6 buoys
- Dawei Channel- 3 buoys

Under the urgent necessity of procurement of an anchor vessel, MPA is desirous to have the following functions and specifications.

Table 4-15 Required Function and Specifications of the Anchor Vessel

1.	Specifications	• A little bigger size than existing • LOA to be about 120 ft (36.5 m). • Draft to be about 12 ft (3.5 m) • Safe working load to be greater than 15 ton • Remaining Hsaddan vessel is the river type vessel, and so MPA prefers to get a sea-going one to carry out the operation at the outports. • One-man-operating bridge is preferred.
2.	Buoy Handling Crane Capacity	The weight of mooring buoys without chain weight is 8 tons. 15 tons to 20 tons crane capacity is better. Local divers are used for positioning of mooring buoys currently.
3.	Crane position for anchor vessel	MPA's captains and operators are not familiar with the cranes at the back side or modernized design. Thus, front side is preferred. Trainings shall be provided for operation.
4.	Normal Working Hour of Anchor Vessel	The anchor vessels work only when the operation is needed. They can work 24 hours during operation period.

Source: Interview Results with MPA

The vessel shall be designed as a twin-screw vessel driven by twin diesel engines through two controllable pitch propellers in the fixed nozzle at the stem for operation in unrestricted waters and for multipurpose roles such as:

- ✓ To retrieve & launch marine navigation buoys
- ✓ To provide repair and maintenance to marine navigational buoy
- ✓ To transport marine navigational buoys and/or spare parts
- ✓ To transport general cargoes

(3) Technical Feature Generally Required of the Anchor Vessel

The main duty of the ship called anchor vessel is anchor vessel is a ship whose main duty is to set up and collect lighted buoys among navigation aids. By utilizing a derrick or a crane at the front of the bridge to lift buoys and lower parts such as chains and sinkers (anchors and other heavy objects) to fix the light buoy to the main body of the light buoy, and connect the parts to each other to install and retrieve the light buoy. In order to set up the light buoy at the correct position, GPS-based positioning device is used and, while fine-tuning the ship's position with the Controllable Pitch Propeller (CPP) and bow thrusters.

The photos show the anchor vessel of Japan Coast Guard, Kaio, 619 GT, LOA 55.0m


Light Buoy


Bridge and Derrick Boom


View from Bow Side


Side View

Source: http://www.vspg.net/jcg/

Photo 4-7 Buoy Handling by Anchor vessel in Japan

The anchor vessel accommodates buoy pick-up, maintenance and installation on its forecastle. It has been built with special design features, making for greater work efficiency, the utilization of information technology, the detailed are described below, and precautions against piracy.

a) Efficiency Enhancement

The efficiency of buoy positioning is enhanced by a Differential Global Positioning System (DGPS) and an Electronic Nautical Display and Information System (ECDIS). The boom is equipped with two hooks for greater efficiency in picking up buoys and heaving chains, and an anti-pendulum system is used to prevent the buoys from swinging when they are raised. For onboard adjustment and repair of buoys, the vessel has been equipped with many types of maintenance equipment, including a workshop and a sand blaster. The vessel is further provided with a high-performance rudder and a bow thruster to facilitate navigation in the Straits of Malacca.

b) IT Utilization

The main and auxiliary engines are equipped with a monitoring system, which uses a computer screen to display the revolutions, exhaust temperatures and intra-cylinder pressures of the engines.

Additionally, it shows data trends, thus making possible the early detection of any abnormality in the main or auxiliary engine. Thus, maintenance can be properly timed. The handling manuals for the main equipment items are digitized. There is an online help system that enables the operator, simply by clicking an item on the drawing of machines and instruments, to display the manual for that item. LAN cables link the wheelhouse, office and individual cabins with a view to the future installation of an on-board computer network.

(4) Proposed Type of Anchor Vessel

The specifications below is the sample for anchor vessels designed as ocean going vessel for about two weeks endurance. These vessels are currently operating at Malaca Strait and Indonesian water. These are designed as ocean going vessel for about two weeks endurance. However, for the anchor vessel/ in Yangon River and Outer Bar, not long endurance nor many of the crew is required. So, taking into consideration of the size of the buoys with 3.0 m diameter, etc., to be newly installed as per IALA design guidelines, it is recommended to have the same size anchor vessel as existed one to handle the buoys on the deck of the vessel.

Table 4-16 Sample Type of Anchor Vessel

Specifications	Case No.1 Foc'sl deck operation with Derick Boom	Case No.2 Foc'sl deck operation with Deck Crane
	 Source: Consultant	 Source: Consultant
Ship Owner	Government of Indonesia	Government of Indonesia
Built	2002	
Navigation Area	Coastal	
Length Over All (LOA)	58.02 m	51.95 m
Breadth (Mold)	11.00 m	10.2 m
Depth (Mold)	4.50 m	4.35
Draft (Mold)	3.50 m	3.00
Gross Tonnage	858 T	
Dead Weight Ton	(design) abt .645 t (summer) 649.03 t	335 t (summer)
Ship Speed	Max. 12.94 kn 10.5 kn	11.5 kn
Main Engine	(MCR) 735 kW × 390 min - 1 ×1 (NSR) 625 kW × 370 min - 1×1	
Propeller	4 Blades FPP×1	
Compliment	Captain 1 Chief Engineer 1 Officers 8 Crew 33 MSC 1 Owner 1 Total 45	Total 51
Bow Thruster	163 kw FPP Nominal thrust: 24.5 kN (2.5 tf)	150 kw, FPP
Cargo Winch	No.1 abt. 44 kN × 1 No.2 abt. 44 kN × 1	
Topping Winch	abt. 73.5 kN (7.5 tf)	
Slewing winch	abt. 39.2 kN (4.0 tf)	
Derrick boom Deck Crane	Derick Boom Two topping lifts, single derrick, with two hoisting hooks lifting cap 147.1 kN (15.0 tf) each Hoisting speed abt. 6 m/min SWL 294.2 kN (30.0 tf) × outreach 2.8 m	Deck Crane 1 × Electric-hydraulic. 10 t at 7.5 m (Sea State 2-4)

Source: the Consultant

4.4 Dredging Operation in Japan

4.4.1 Dredgers Deployed in Japan

In Japan, port managing offices (Municipal or local governments) are responsible for the maintenance and management of ports and navigation channels based on the Port Regulations Law. Therefore, private companies do not control the navigation channels and ports. The maintenance dredging of the navigation channel is also carried out by the port managing office in accordance with the port's management plan.

In addition, depending on the size of the river, the government (Ministry of Land, Infrastructure, Transport and Tourism) or local governments are responsible for the maintenance and management of the river routes. For the development of rivers, river development plans are drawn up in accordance with the River Law and the River Law Enforcement Order. There are not many rivers in Japan that can be navigated by large ships, and the main focus is on flood control and water resource management, but there are some river ports close to the sea.

For the dredging work related to the construction of ports, there are five types of dredging works: 1) Hydraulic/Pump dredging, 2) Grab dredging, 3) Hard soil dredging, 4) Rock dredging, and 5) Backhoe dredging are classified according to the estimation standard for port and harbour civil engineering work issued by Japan Ports and Harbors Association, and these dredging methods and types of dredgers are selected according to the conditions such as soil quality and construction depth.

As mentioned above, the development and maintenance of the port is carried out by the local government, which is in charge of managing the port, but the dredgers, sediment carriers, etc. required to carry out dredging are owned and operated by the private companies, which are contracted according to the construction work.

In addition, in order to dredge the navigation channel of a certain distance, width and depth of the channel or anchorage area, pump dredging and grab dredging of a certain size are mainly employed. In Japan, three trailing suction hopper dredgers are owned by the Regional Development Bureau, MLIT in Hokuriku, Chubu and Kyushu district and provide navigational channel maintenance services as required. Only three dredgers are owned by the government and one is owned by the Tokyo Metropolitan Government. The characteristics of Japanese trailing hopper suction dredgers are not only dredging, but also responding to oil spills at sea, equipped with cyclone type oil recovery equipment and designed to store the oil and water recovered in holds.

The type of the dredger mainly deployed are as follows.

Table 4-17 Type of Major Dredgers Classified in Japan

Category	Type of Dredger	Purpose/Features	Dredging Material
Hydraulic Dredger	Trailing Suction Hopper Dredger	Navigation channel, Anchorage area. Self-propelled.	loam, sand, silt, clay
	Cutter Suction Dredger (Pump Dredger)	Port construction (reclamation), Navigation channel, Anchorage area. Small type is used for river, water way. Self-propelled, Non self-propelled	Rock, Gravel, loam, sand, silt, clay
	Cutterless Suction Dredger (jet water)	Port construction, Navigation Channel. Safe dredging is possible in the remaining mine/unexploded ordnance area.	loam, sand, silt, clay
	Micro Pump dredger	River, water way, beach	loam, sand, silt, clay
Mechanical Dredger	Grab Dredger	Navigation channel, Anchorage area, Port construction. Dredger with/without hold.	loam, sand, silt, clay, gravel
	Bucket Dredger	Navigation channel, Anchorage area, Port construction. Damping barge required. (not available in Japan)	loam, sand, silt, clay, gravel
	Backhoe Dredger	Small volume. Good for hard bedrock. High accuracy of work.	Rock, Gravel, loam, sand, silt, clay

Source: the Consultant

Among of those dredgers, trailing suction hopper dredger, grab dredger and bucket dredger are commonly used for the navigational channel dredging with large volume.

Table 4-18 Typical Dredgers Deployed in Japan

Dredgers for Navigation Channel Maintenance in Japan	Ship Name/Particulars
Trailing Suction Hopper Dredger  Source: Japan Workvessel Association	Hakusan (MLIT, Hokuriku Regional Development Bereau) LOA: 93.9 m, B: 17 m, D: 7.5 m, d: 5.4 m GT: 4,185 t M/E: 2,350 kW×2 sets, M/Gen: 2,200 kW × 2 sets Side Dragging Dredging pump: 3,300 m^3/h × 2 sets Hopper: 1,380 m^3
Cutter Suction Dredger  Source: Japan Workvessel Association	Dai San Toa Maru (Toa Construction Co., Ltd.) Total output: 7,720 kW Nominal capacity: 1,200 m^3/hr Dredging Depth -5 to -30m
Grab Dredger  Source: http://www.pa.thr.mlit.go.jp/akita/index.html	Dai 11 Heisei (Aoki gumi) LOA: 56 m, B: 23 m, D4.2m Grab bucket capacity: 30 m^3 Dredging Max depth 50m Engine 2,500ps
Backhoe Dredger  Source: Japan Workvessel Association	BHC-2401 LOA: 50 m, B: 21.6 m, d:3.45 m, Dredging depth：-24 m Backhoe: Komatsu PC2000-8

Source: the Consultant

5. COST ESTIMATION

5.1 Cost Estimation for Dredgers

The primary cost estimate for candidate dredgers is shown in the below table. The cost is only for ship building not including transportation fee, tax, consultant fee, etc.

Table 5-1 Cost Estimate of Candidates Dredgers

Name	Specification			Built Country and Year	Main Engine (PS)	Speed (knots)	Cost (million JPY)	Building duration (Years)	Remarks
	Length (m)	Breadth (m)	Draft (m)						
Trailing Suction Hopper Dredger	more than 68	14.5	more than 4.5 m	Japan/ New	Pump Engine 3000 ps	10	4,530	3	Hopper Capacity is 1,000 m^3
Grab Dredger	more than 68	20	more than 4.5 m	Japan/ New	2,000 × 2	10	2,500	3	Grab capacity is 8 m^3
Back hoe Dredger	more than 68	18	more than 4.5 m	Japan/ New	2,000 × 2	10	2,000	3	
Cutter Suction Dredger	106.65	18.57	3.3	Unknown/ 2009	-	-	1,400	N/A	Tug boat with 3000 PS and Sand barge is needed. Need to change nationality.

Source: the Consultant

5.2 Cost Estimation for Anchor Vessel

The primary cost estimate for candidate anchor vessels is shown in the below table. The cost is only for ship building not including transportation fee, tax, consultant fee, etc.

Table 5-2 Cost Estimate of Candidates Anchor Vessel

Name		Specifications				Built Country and Year	Main Engine (PS)	Speed (knots)	Cost (million JPY)	Building duration (Years)	Remarks
		Length (m)	Breadth (m)	Draft (m)	Crane Capacity						
Anchor Vessel		36	40	3.6	more than 15 Ton	Japan/ New	3000	10	2,500	2	
Crane Barge + Tug Boat	Crane Barge	26.2	15.0	3.0	15 Ton	Japan/ New	-	-	1,400	2	
	Tug Boat	40.5	9.5	4.5	-	Japan/ New	1,500 × 2	10			
Anchor Vessel		23.9	9.0	2.7	30	Japan/ 1992	500 × 2	Unknown	38	-	Only ship price without repairing (for reference)
Crane Barge + Tug Boat	Crane Barge	50.0	14.0	3.5	19	Japan/ 1988	-	-	65	-	Only ship price without repairing (for reference)
	Tug Boat				-		850	8		-	

Source: the Consultant

5.3 Second-hand Market of Dredgers

The second-hand dredgers information is available on the internet site but not through the individual ship broker or shipbuilders, since the dredgers are built by the specific demand such as for a project for marine construction, or navigational channel/port development project. Thus second-hand market exists, not like international cargo ships, with Q & A basis through the specific ship brokers. However, some specific international brokers are dealing with the second-hand dredgers on website.

The following second-hand dredgers are cited from the Dredge Brokers; http://www.dredgebrokers.com/ as reference, taking the size of dredger and their age that shall not be over 40 years in general. The price is just the reference and the actual price shall be fixed including transportation, refurbishment if required by Classifications and/or owner, payment terms, etc.

(1) Trailing Suction Hopper Dredger (TSHD)

There is no particular trend in the correlation between its size and price of used TSHDs, and the market price is almost at scrap value plus even if the vessel is 40 years old. It is also hard to find the younger age of TSHD. If the ship is 40 years old, the pumps and other parts of the ship are often refurbished after some years of operation.

When considering the actual purchase, consideration should be given not only to the condition of the hull, main engine and dredging equipment, but also to the possibility of procuring parts.

Table 5-3 Second-hand Trailing Suction Hopper Dredger (TSHD)

	Hopper (m^3)	Year Built	Age (years)a	Built in	USD	JPY (1$=108JPY)
1	1,365	1980	40	Croatia	2,500,000	270,000,000
2	7,208	1979	41	Japan	2,200,000	237,600,000
3	850	1997	23	India	1,820,000	196,560,000
4	7,000	2018	2	China	30,300,000	3,272,400,000
5	1,700	1980	40	-	8,000,000	864,000,000
6	1500	1975	45	Netherland	Price on Request	
7	2400	1991	29	Netherland	Price on Request	
8	2690	1981	39	Germany	2,670,000	288,360,000
9	1100	1973	47	Belgium	2,966,667	320,400,036
10	2743	1987	33	-	Price on Request	
11	650	1972	48	-	1,555,556	168,000,048
Information of Selected Dredger						
	1,365 m^3 Trailing Suction Hopper Dredger w/ Rainbowing This Trailing Suction Hopper Dredger has 2 × 460 kW IHC HOLLAND, electric dredge pumps each with a suction diameter of 600 mm (24-inch). The hopper can hold a max of 1365 m^3 and can unload via hydraulically operated bottom doors, pump ashore installation or rainbow installation capable 45° ± 35 m ashore. Built in 1980 in Croatia, the dredger was rebuilt in 2014. It has a class notation of Russian Maritime Register of Shipping. Location: Turkey					USD 2,500,000
	850 m^3 Trailing Suction Hopper Dredger Trailer Suction Hopper Dredger (TSHD) 850 m^3 hopper capacity with 12 hydraulically operated bottom doors with 2 cranes mounted at the forward and aft having grab capacity of 3 m^3 each. The vessel has forward Bow Thruster. The dredger was built in 1997 and is due for dry-docking in January, 2020. The price includes the dry docking of the vessel in which everything from the rubber seals of the bottom doors to the deck, electronics etc. will be updated and fully refurbished. Price includes dry-docking and fresh classification certificates. Location: West Coast India					USD 1,820,000

Source: the Consultant

(2) Grab Dredger

There are a few numbers of second-hand grab dredger in the market and no particular trend in the correlation between its size and price. The market price is varied depending on the specifications i.e. with/without hopper, etc.

When considering the actual purchase, consideration should be given not only to the condition of the hull, main engine and dredging equipment, but also to the possibility of procuring parts and also the necessity of dumping barges as extra.

Table 5-4 Second-hand Grab Dredger

	Hopper (m^3)	Year Built	Age (years)	Grab Capacity (m^3)	Built in	Crane Capacity (ton)	USD	JPY (1$=108JPY)
1	3000	2016	4	4	Italy	300	16,444,444	1,775,999,952
2	500	2002	18	5.6		80	1,711,111	184,799,988
3	-	1996	24	18	Japan	160	3,844,711	415,228,788
4		1995	25	20			4,440,000	479,520,000
5	1200	1972	48	5	Portugal	45/75	1,422,222	153,599,976
6	-	1987	33	13	Japan	160	1,444,111	155,963,988
7	Clamshell	1984	36	8			3,000,000	324,000,000
	Harbor Tug	1961	59	-	USA	1650hp		
8	Clamshell	1992	28	8	China	20	3,810,000	411,480,000
	Hopper 900	1991	29					
	Towing Tug	1981	39			1000hp		
9	-	2001	19	2.25		55	688,889	74,400,012
10	-	1973	47	26			1,444,444	155,999,952
Information of Selected Dredger								
	18 m^3 Grab Dredger This grab dredger includes 2 bucket – 18 m^3 (45 tons) and 8 m^3 (16 tons) - and a 45-ton rock breaking rod. The crane has a max lifting capacity of 160 tons and is powered by a 2000 hp Mitsubishi engine. The dredger has 1 tilting spud and 2 fixed spuds each 34 m (98-feet) in length. The dredger was built in 1996 in Japan. Location: Japan							JPY 410,000,000 (USD 3,844,711)
	3,000 m^3 Grab Loading Bottom Dumping Hopper Dredger Built in 2016 in Italy, the dredger has a Class Notation of C Hopper Dredge AUT-UMS. The vessel has a load capacity of 4,300 tons. The load compartment is equipped on the bottom with horizontal openable hatches to unload material. The crane is a 300-ton capacity Liebherr HS 8,300 with a 20 m^3 hydraulic clamshell. The vessel is also geared for the installation of different dredging technologies. Accommodations for 12 persons is included.							EUR 14,800,000 Price in Your Preferred Currency: USD 16,444,444

Source: the Consultant

(3) Backhoe Dredger

Backhoe dredger is common in the second-hand market. There is a market ranging from new one to over 30 years, and no particular trend in the correlation between its size and price. The market price is varied depending on the backhoe specifications, etc.

When considering the actual purchase, consideration should be given to backhoe itself, spud system, etc.

Table 5-5 Second-hand Backhoe Dredger

	Bucket capacity (m^3)	Year Built	Age (years)	L (m)	B (m)	Dredge Depth (m)	USD	JPY (1$=108JPY)
1	3.5-5.0	2018	2	44	1.4	15	4,444,444	479,999,952
2	6	1998	22	48.2	11.2	18	5,105,556	551,400,048
3	6	1997	23	55.2	15.2	15	6,238,889	673,800,012

4	8	1983	37	50.5	11.4	18.5	2,844,444	307,199,952
5	7	2000	20	50	18	10	1,230,000	132,840,000
6	1.5	1996	24	40	9	10	6,444,444	695,999,952
7	5.6	1988	32	22	7.5	-	346,667	37,440,036
8	8	1983	37	50.5	11.4	-	4,500,000	486,000,000
9	2.25	2001	19	34	16	-	688,889	74,400,012
Information of Selected Dredger								
	6 m^3 Hitachi EX 1200-5 Excavator Dredger. Recently fully refurbished Hitachi EX 1200 Excavator, currently working in Spain. Under full Bureau Veritas class well maintained by owners. Excavator has two buckets 4 m^3 & 6 m^3 and a maximum dredging depth of 18 m (59-feet). The dredger is 48.15 m (158-feet) in length and has 4 stabilizing spuds. Deck load capacity is 10 t/m^2. Location: Spain							EUR 4,595,000 (USD 5,105,556)
	7 m^3 Excavator Dredge w/ 500 m^3 Deck Cargo Area This listing is for a 7 m^3 excavator dredge with a 500 m^3 deck cargo area was built in Japan in 2000. Location: Far East of Russia							USD 1,230,000

Source: the Consultant

(4) Cutter Suction Dredger

There is a number of second-hand cutter suction dredger available from small to gigantic and no particular trend in the correlation between its size and price. The second-hand cutter suction is selected its pipe size of over 20 inches. The market price is varied depending on the specifications etc.

As the cutter suction dredger requires the discharge pipes and dredging material is clay, sand, for the Yangon river dredging, it is not recommendable. However, when considering the actual purchase, consideration should be given to the condition of the hull, pump, cutter, etc.

Table 5-6 Second-hand Cutter Suction Dredger

	Pipe size (inch)	Year Built	Age (years)	L (m)	B (m)	Dredge depth (m)	USD	JPY (1$=108JPY)
1	26	1984	36	66.2	11.9	15	2,100,000	226,800,000
2	20	2016	4	43.4	10	16.8	730,000	78,840,000
3	24	2007	13	40.6	9	15	5,040,872	544,414,176
4	22	1989	31	59	9.5	10	1,590,000	171,720,000
5	20	2006	14	33.2	8	14	2,383,333	257,399,964
6	20	2005	15	41	9	16	1,711,111	184,799,988
7	28	2010	10	60.7	12.4	20	2,055,556	222,000,048
8	20	2010	10	36.5	8.4	17	2,000,000	216,000,000
Information of Selected Dredger								
	26-inch Cutter Suction Dredge (CSD) Dredge is in class lay-up and the maintenance lay-up program is strictly followed. Condition of the vessel is reported to be good. Location: Middle East							USD 2,100,000
	500 mm (20-inch) Cutter Suction Dredger (CSD) This listing is for a 500 mm (20-inch) Cutter Suction Dredger built in 2016. It has a maximum dredging depth of 16.8 m (55-feet) and a swing width dredging depth of 40 m (131-feet). Location: Vietnam							USD 730,000

Source: the Consultant

5.3.1.2 Second-hand Anchor Vessel

Since the anchor vessel are owned and operated by the government agencies, such as National Coast Guard, the second-hand vessel is seldom sold in the market.

The following list is found in the website; however not many of detail information with price is given on the site including the price.

Table 5-7 Second-hand Anchor Vessel

	GT	Year Built	Age (years)	L (m)	B (m)	Crane Capacity (ton)	USD	JPY (1$=108JPY)
1	80	1980	40	21.3	6	9.1	599,000	64,692,000
2	235	1991	29	28.3	9.5	10	on request	
3	526	1974	46	412.8	10		on request	

Source: the Consultant

5.4 Operation Cost

(1) General Concerns Interviewed

The followings are the major concern on the current situation surrounding work vessels interviewed from five Japanese construction companies that are mainly engaged in marine civil engineering and own work vessels.

- There is a sense of crisis about the aging of the work vessels, especially the aging of the pump dredgers/cutter suction dredgers.
- Aging work vessels cost more to maintain and manage them and it becomes difficult to procure replacement parts, which may lead to serious accidents due to lack of safety.
- There is no inspection by the Transportation Bureau on non-self-propelled vessels without propulsion engines. It is left to the owners to decide whether to carry out repairs or not, except for those that have individual inspections of cranes, boilers, etc.

a) Opinions from Shipyards

If the ballast tanks in work vessels are severely corroded, the ship will often be sold or scrapped because of the large repair costs.

b) Opinions of workboat crews

- The dredging pipes may need to be replaced after 10 years.
- After 10 years, manufacturers' inventories of replacement parts for electrical equipment such as inverters begin to run out. If not in stock, a major replacement of the assembly may be required.
- The checklist is used as a reference for preparing a plan that describes the time of repair and replacement for each equipment such as a propeller, power generator and dredging pipe by preparing a checklist to control the operating time, frequency of use and measurement of wall thickness of the pipe and to perform maintenance.
- Since the navigation, dredging and oil recovery work of the ship are all performed by the automatic control system, the software for the control system needs to be updated every few years.
- The dragging head used for dredging is 10 years old, but it has not been replaced, so it will need major repair in the future.

(2) Operation and Maintenance Cost of the Vessel

a) Operation Cost

Operating expenses of ship is generally classified as 1) Operation cost, which requires the cost for ship operation such as fuel oil, fresh water, port charge, etc., and 2) ship cost, which is the running cost including fixed cost such as crew expenses, maintenance fee, insurance, office costs, etc., as follows.

Table 5-8 Breakdown Items for Ship and Operation Cost

Ship Cost	Operation Cost
Crew Expense Lubricating Oil Docking Fee Maintenance Fee Spare Parts (fast moving) Insurance Office Cost Others (administration)	Fuel Oil Fresh Water Port Charge

Source: the Consultant

For example, if same operation plan as proposed in the Section 4.3 for 1200 PS TSHD, the fuel oil required for main engine only will be different as follows.

The assumption is made with the 50% of main engine output for 5 hr/day and 330 days operation.

As the result, it is estimated that the new ship can save 68.5 MT of fuel oil. For other consumables, lubricating oil cost is far less than used ship.

Table 5-9 Assumption of Fuel Oil Consumption

Main Engine	Main Engine Output	FOC of New M/E	FOC of Old M/E
	1200 ps × 2 sets (882 kW)	190 g/kW-h	230 g/kW-h
Operation day/year	330	325.5 MT/year	393.9 MT/year
Operation hr/day	5		

Source: the Consultant

6. CONCLUSION AND RECOMMENDATION

6.1 Dredger

Riverbed along the navigation channel of Yangon Port is mostly composed of sand, clay or silty sand with maximum N value of 19. In the case of maintenance dredging, the sediment may not be condensed nor increased in strength. Therefore, Trailer Suction Hopper Dredger (TSHD) is suitable in terms of efficiency as far as no strong debris is found along the channel dredging route. In addition, TSHD is the most appropriate dredger for channel maintenance dredging because it can dredge while moving forward along the channel where the length of dredging area is longer.

Due to the restriction of navigation channel and congestion of cargo vessel along the channel, high production rate of dredging operation is genuinely demanded. Moreover, dredger shall be robust enough for rough river condition because Yangon River is a tidal river and current is very strong. To cope with these challenges, it is recommendable to select the Trailer Suction Hopper Dredger (TSHD) which has relative immunity to rough weather and river condition, minimal impact on vessel going along the navigation channel due to unnecessity of anchors and relatively high rate of production.

In addition, MPA dredging personnel are totally familiar with the TSHD operation and it should be noted that similar type of TSHD shall be more practicable for the end user. However, it is not recommendable that too modernized TSHD because there is no inspection and maintenance technician in Myanmar and all personnel have to be brought from oversea if some problem encounter. As a result, the maintenance cost and technician fees will be relatively high.

6.2 Anchor Vessel

At present time, MPA is using small size anchor vessel (Hsaddan) to move, retreat and install navigational buoys not only at Yangon Port and also at eight outports. However, Hsaddan is a river-going type vessel and her design is not perfectly suitable to carry out the operation in outports. Therefore, sea-going anchor vessel type is highly recommendable for suitability of operation. Moreover, this sea-going type vessel shall be bigger in size and safe working load than existing anchor vessel (Hsadden) so that it can be utilized not only for buoy handling which weight is small and also other multipurpose. Crane barge with tug boat is also recommendable from the view point of economic and versality as substitution of anchor vessel. In considering not only buoy handling and also necessary operation at outports, anchor vessel will be the best solution for long term fulfillment of navigational operation by MPA.

6.3 General Recommendation to MPA

6.3.1 General

Channel maintenance is one of the most important tasks of MPA. In 2017 alone, 2,267 ships passed the channel from abroad to Yangon Port. Therefore, along with the economic development of Myanmar, ship calling numbers and ship size are expanding. On the other hand, because of the difficulty of channel maintenance in Yangon River, the channel will have a bottle neck risk of port activity soon.

6.3.2 Condition of Channel Maintenance

Before 2017, MPA did the maintenance dredging by himself. The annual maintenance dredging volume was 200,000 m^3 for Inner Bar and 20,000 m^3 for Outer Bar. In 2018, MPA made agreement with private company for the dredging work. Unfortunately, it could not satisfy the dredging to planned water depth of both MPA and the company due to not enough productivity mainly caused by the difficulties described under Section 3.2.

MPA has four dredgers but they are old and need fully maintenance to use stably and efficiently. Maintenance fee cannot be collected easily and smoothly, because maintenance dredging cannot make profit directly. Therefore, new vessel is suitable for MPA considered with MPA's budged.

6.3.3 Maintenance of Navigation Buoy

There are over 20 navigation buoys and some light towers. The navigation buoys are mainly located at Inner Bar and Outer Bar. Yangon River has heavy sedimentation and erosion. Moreover, the buoys are re-located every year along the change of navigation channel. The buoys are picked up for the repairing at the dockyard and re-set up after repairing. The anchor vessels are important for the maintenance of the navigation buoy. As only one anchor vessel owned by MPA is remaining for the navigation facility maintenance and management, MPA needs an additional anchor vessel urgently in order to carry out sufficient services. As MPA does not have sufficient budget for inspection and maintenance, old vessel which costs much maintenance fees is not suitable for MPA.

6.3.4 Surveying and Monitoring

For the efficient channel maintenance, to understand the mechanism of sedimentation and erosion is important. The biggest challenges of maintenance dredging for Yangon River channel are the mechanism of sedimentation and erosion is unknown, and the annual dredging volume, sedimentation area and sedimentation time are not stable. If MPA could get new hopper dredgers and carry out the maintenance dredging by himself, the channel maintenance will be improved. The continuous bathymetric survey and river conditions observation as tide, water current, salinity, wave, turbidity, and wind are important. Tide station with weather condition survey device will also be installed at Elephant Point and Monkey Point by JICA ODA Project. The observation data will be useful not only the daily channel navigation but also the future development analysis.

6.3.5 Organization of Channel Maintenance

Marine Department manages the pilotage, dredging and ship navigation. Mechanical Engineering Department manages the repairing of ships and buoys. Civil Engineering Department manages the bathymetric survey and tide observation. Because of the lack of budget, equipment, man-power and technology, the channel maintenance has not been enough. Furthermore, enhancement of organization of MPA will also be needed.

In generally and globally, public institutions conduct channel maintenance from the viewpoint of cost and sustainability because estimation of dredging cost which considered with directly invisible profit is difficult. Therefore, MPA should conduct channel maintenance by himself. Privatization of dredging work would relief some workload from MPA but in view of cost and sustainability of the business of MPA for long terms, private outsourcing for dredging is not recommended.

6.3.6 Recommendation for Future Channel Maintenance

It is difficult to meet the urgent needs from the viewpoint of cost and construction period. The countermeasures until providing new dredger and anchor vessel is mentioned below.

- Dredger

  MPA keeps outsourcing with higher contract amount after current contract is completed

- Anchor vessel

  MPA keeps utilizing the existing anchor vessel for Yangon River Channel and gets support from some private companies if necessary, for the maintenance of the navigation buoys.

6.4 Future Channel Maintenance Guidelines

6.4.1 General Guidelines for Vessel Inspection

Depending on the size of the ship and the cargo to be loaded, the structure of the hull, fire protection and lifesaving facilities, etc., are determined. An inspection of a ship is to check whether the structure and equipment of the ship meet the specified conditions so that the ship can navigate safely and the lives of the crew can be protected in the event of distress.

Generally, MPA follows the guidelines from the vessel's operation and maintenance manual. However, there is no regular maintenance for MPA's vessel due to budget problem.

For the international commercial ships, the International Convention on the Safety of Life at Sea (SOLAS), established by the International Maritime Organization (IMO), sets global standards for the inspection.

In the case of cargo ships, when the ship is built, it is inspected, and if it passes the inspection, a "ship inspection certificate" valid for five years is issued by the Classification Society i.e. Class NK, Lloyd's Register of Shipping, etc. Thereafter, a detailed inspection will be carried out every five years at the end of the Certificate's validity period (periodic inspection). In addition, during the 5-year validity period of the Certificate, a simple inspection (interim inspection) will be carried out once a year and another inspection (within three years of the issuance of the Certificate) will be carried out.

Also, passenger ships are subject to more detailed inspections because of the large number of passengers and crew on board.

In case of the trailing suction hopper dredger, the inspection requirement is generally according to those of cargo ship, however, the classification sets the special requirements for the dredgers. Therefore, these regulatory requirements shall be followed.

6.4.1.1 Class Maintenance Surveys

Ships including steel barges, submersibles, mobile offshore drilling units etc., and floating offshore facilities for crude oil/petroleum gas production, storage and offloading classed with the Classification society are to be subjected to Class Maintenance Surveys by the surveyor in accordance with the requirements.

Class Maintenance Surveys consist of Periodical Surveys, Planned Machinery Surveys, Occasional Surveys and Unscheduled Surveys, which are as specified in the followings. At each of these surveys, inspections, tests or examinations are to be carried out to verify that all necessary items are in good order.

1) Periodical Surveys

- Annual Surveys
  The surveys consist of general examinations of hull, machinery, equipment, fire-fighting equipment, etc. Annual Surveys are to be carried out within three months before or after each anniversary date.

- Intermediate Surveys
  The surveys consist of general examinations of hull, machinery, equipment, fire-fighting equipment, etc. Intermediate Surveys are to be carried out at the time of the second or the third Annual Survey after the Classification Survey during Construction or a Special Survey. Annual Surveys are not required to be carried out when an Intermediate Survey is carried out.

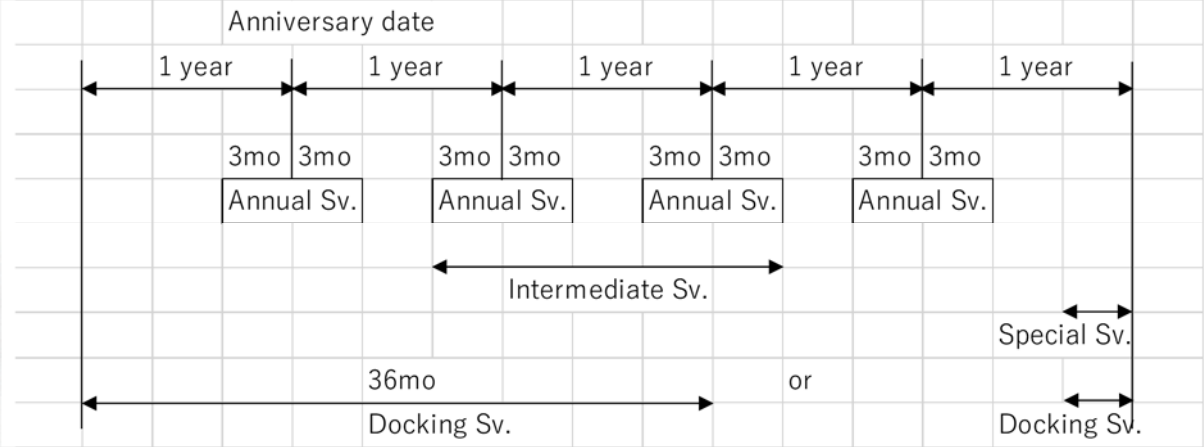
- Special Surveys
  The surveys consist of detailed examinations of hull, machinery, equipment, fire-fighting equipment, etc. Special Surveys are to be carried out within 3 months before the date of expiry of the Certificate of Classification

- Docking Surveys
  The surveys consist of bottom inspections normally carried out in a drydock or on a slip-way.
  Docking Surveys are to be carried out as prescribed in (a) and (b) below.
  (a) Concurrently with Special Surveys
  (b) Within 36 months from the date of completion of the Classification Survey or the previous Docking Survey

- Boiler Surveys
  The surveys consist of open-up examinations and performance tests of boilers.

- Propeller Shaft and Stern Tube Shaft Surveys
  The surveys consist of open-up examinations of propeller shafts and the stern tube shafts.

The type of the survey and its interval are illustrated as below.



Source: the Consultant

Figure 6-1 Survey Requirement by Classification

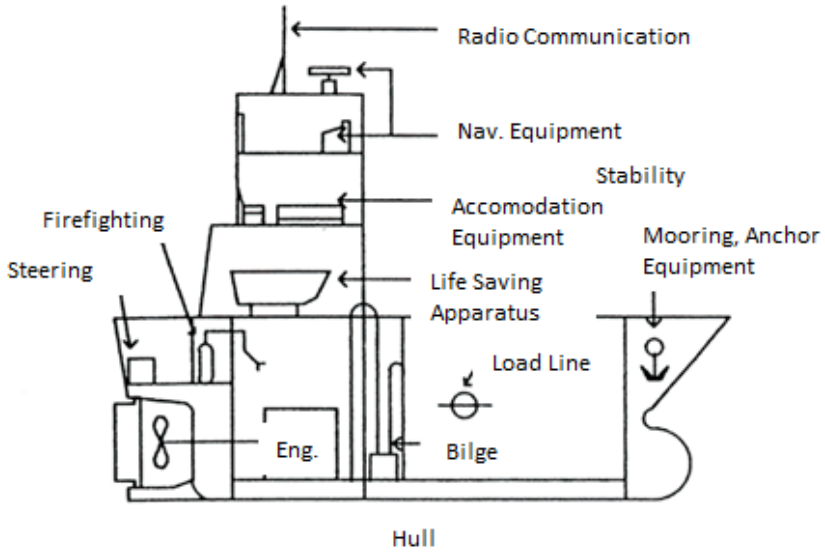
Although, the dredgers to be owned by MPA, the Government of Myanmar, are not commercial vessels and not necessarily required to maintain the Classification, it is only required to follow the Classification requirement for the periodical inspection of the ships' condition to keep the government properties to be in good condition and thus enable to sustain the unstoppable dredging requirement.

Required periodical inspection point of the ship is as shown on the table and figure below. On top, dredging equipment are required to check like the major equipment.

Table 6-1 Required Inspection Item for Periodical Inspection

Inspection Type / Inspection Item	Special Inspection	Intermediate Inspection
Hull	Dry up Visual Inspection Inner Inspection	Dry up Visual Inspection
Engine	Open Visual Inspection Inner Inspection Operation Test	Open Visual Inspection Inner Inspection Operation Test
Bilge	Open Visual Inspection Inner Inspection Operation Test	Open Visual Inspection Inner Inspection Operation Test
Steering Equipment	Pressure Test Operation Test	Operation Test
Mooring, Anchor Equipment	Pressure Test Operation Test	Operation Test
Lifesaving Apparatus	Current Status Check Operation Test	Current Status Check Operation Test
Firefighting Apparatus	Current Status Check Operation Test	Current Status Check Operation Test
Accommodation Equipment	Current Status Check	Current Status Check
Navigation Equipment	Current Status Check Operation Test	Current Status Check Operation Test
Stability	Document Check Sea Trial	Document Check
Loadline	Current Status Check	Current Status Check
Radio Communication Equip.	Current Status Check	Current Status Check

Source: the Consultant



Source: the Consultant

Figure 6-2 Items to be Inspected Periodically

6.4.1.2 Important Parts of Vessel which to be Paid Great Attention during Operation

There are several methods for maintaining the dredging fleet in a normal and economical condition to achieve the planned dredging schedule. Maintenance of dredging fleet would be remarkably improved by executing the following recommendations.

- Regular Inspection

The first step toward improvement is to establish a system of regular preventative inspection. Otherwise, it will take more time and money to rectify damage by acting after problems happen. Items of equipment to be inspected, inspection interval and the crew in charge, etc. should be decided for each dredger.

As inspection items and intervals are generally recommended by the manufacturer of engine or equipment, inspection works should follow these instructions.

General inspection items are shown below for reference.

i) Quantity, pressure and temperature of lubricating oil
ii) Quantity, pressure and temperature of cooling water
iii) Quantity of fuel oil
iv) Exhaust gas temperature
v) Leakage of oil or water
vi) Filter
vii) Abnormal vibration or noise

An example of a typical list of regular inspection items is provide by the previous JICA study as shown in the following table. This list may not coincide with the equipment and machinery of MPA's dredgers since dredging part is mainly for cutter suction dredger with spud, however, the fundamental points of maintenance can be envisaged for such equipment. For doing the inspection at least once a year, the inspection items shown here can be utilized as a guideline.

Table 6-2 Typical List of Regular Inspection Item of Dredger

I) Internal Combustion Engine			
Item	**Content**	**Inspection method**	**Criteria**
General	Starting	Operation	Normal starting
	Rpm, pressure, temperature	Measurement	Normal rpm & pressure, no abnormal high temperature
	Noise and vibration	Sound, touch, visual check	No abnormal noise and vibration
	Exhaust gas	Visual check	No dark smoke or no remarkable blue smoke

	Leakage	Visual check	No water leakage, no oil leakage No air leakage
	Oil supply	Visual check	Sufficient quantity of oil supply
	Indicator	Visual check	Normal indication and operation
Lubricating oil	Purity	Visual check	No mixture of foreign matters nor water
	Quantity	Visual check	To maintain the proper amount
	Viscosity	Measurement	Within the range of standard
II) Cooling Water and Lubricating Oil System			
Item	**Content**	**Inspection method**	**Criteria**
General	Movement	Operation	Normal movement
	Pressure, temperature	Measurement	Normal pressure, no abnormal high temperature
	Noise, vibration	Sound, touch, visual check	No abnormal noise and vibration
	Leakage	Visual check	No water leakage, no oil leakage
Piping	Damage, corrosion	Visual check, test hammer	No damage, no bad corrosion
	Leakage	Visual check	No water leakage
Filter	Clogging	Visual check	No clogging
Cooler	Temperature of cooling water	Visual check	Proper temperature
	Leakage	Visual check	No leakage
III) Hydraulic System			
Item	**Content**	**Inspection method**	**Criteria**
Hydraulic pump, motor, cylinder	Movement	Operation	Normal movement
	Pressure, temperature	Measurement, touch	Normal pressure, no abnormal high temperature
	Noise, vibration	Sound, touch, visual check	No abnormal noise and vibration
	Damage, leakage	Visual check	No damage, no oil leakage
Piping: pipe	Damage, corrosion, leakage	Visual check	No damage, no remarkable corrosion, no leakage
hoses	Damage, aging, deformation, leakage	Visual check	No damage, no aging, no deformation, no oil leakage
valve	Movement Leakage	Operation Visual check	Smooth movement, reliable open/ shut No oil leakage
joint	Fitting, leakage	Visual check	No looseness, no oil leakage
Hydraulic oil	Cleanliness	Visual check	No foreign matters, no water mixture
	Quantity	Visual check	Normal oil level
	Viscosity	Measurement	Within the range of standard
Filter	Clogging	Visual check	No clogging
Cooler	Temperature of cooling water	Visual check	Proper temperature
	Leakage	Visual check	No leakage
IV) Gauge, Indicator			
Item	**Content**	**Inspection method**	**Criteria**
General	Movement	Visual check	Normal movement, normal indication
Sensor, indicator	Damage, corrosion, deformation	Visual check	No damage, no remarkable corrosion, no deformation
	Fitting	Visual check	No looseness, no loss of fitting bolt, etc
V) Dredge Pump			
Item	**Content**	**Inspection method**	**Criteria**
General	Noise, vibration	Sound, touch, visual check	No noise, no abnormal vibration
	Temperature	Touch	No abnormal high temperature
	Lubrication	Visual check	Good lubricating condition

	Fitting	Visual check, wrench	No looseness, no loss of fitting bolt
	Leakage	Visual check	No water leakage
Impeller	Damage, wear	Touch, visual check	No damage, no remarkable wear
Casing liner	Damage, wear	Touch, visual check	No damage, no remarkable wear
Mouth ring, suction mouth	Damage, wear	Touch, visual check	No damage, no remarkable wear
Shaft, shaft bearing	Wear, adjustment	Touch, visual check	No remarkable wear, good adjustment
VI) Ladder			
Item	**Content**	**Inspection method**	**Criteria**
General	Noise, vibration	Sound, visual check	No noise, no abnormal vibration
	Lubrication	Visual check	Good lubricating condition
Trunnion shaft	Wear	Visual check	No remarkable wear
Cap tightening bolt	Fitting	Visual check, wrench	No looseness, no loss of bolt
Suction head	Wear	Visual check	No remarkable wear
VII) Cutter			
Item	**Content**	**Inspection method**	**Criteria**
General	Noise, vibration	Sound, visual check	No noise, no abnormal vibration
	Lubrication	Visual check	Good lubricating condition
	Fitting	Visual check, wrench	No looseness, no loss of fitting bolt
Coupling	Damage, wear	Visual check	No damage, no remarkable wear
	Aging	Visual check	No remarkable aging at flexible coupling
	Non-alignment of shaft	Visual check	Proper alignment of shaft center
Cutter head, blade, tip	Damage, wear	Visual check	No damage, no crack, no remarkable wear

Source: the Consultant

- Sample Maintenance Schedule

The maintenance schedule for the vessel is recommended as follow:

Table 6-3 Sample Maintenance Schedule

Sample Maintenance Schedule	
Hull	Interval
Regularly check that all watertight closures will keep water out. • Verify that closure devices – doors, hatches, windows, port lights, etc. – can be closed easily and completely. Check for warping, that gaskets are in good shape and that a complete seal is maintained. Lubricate mechanisms –latches, dogs – as necessary. • Check that water does not enter the vessel by spraying water directly onto closure devices using a hose.	Monthly At least annually
• Inspect and renew as needed - Anti-fouling bottom paint / topside cleaning / waxing	At the end of dredging operation
• Inspect all through-hull fittings and attachments for leaks.	Weekly
• Check all through-hull fittings can be moved to closed position	
• Check all above-deck watertight and through-deck fittings, including cleats, stanchion mounts, hatches, ports, doors, antenna mounts, and the hull to deck seal.	

• Check the cabin interior for water and stains, which could signal a leak and weak materials.	
Machinery	
• Change main engine and auxiliary generator oil and filter at the hours of operation interval recommended by the manufacturer or once a year, whichever comes first.	Insert manufacturers recommended intervals, e.g. “Every 300 hours”
• Check fluid levels. oil, water, engine coolant	Daily
• Check the engine(s) for oil or fuel leaks.	
• Tune up gasoline engines every year and replace electrical parts, such as spark plugs, as needed.	
• Inspect and tighten all hoses and drive belts often. Replace them when they are worn or cracked.	
• Inspect the starter motor and alternator.	
• Check that bilge alarms and pumps sound or turn on when activated.	Weekly
• Taking care not to pollute, verify that the bilge pumping system or bilge pump(s) clear water from the bilges.	At least annually.
• Maintain painted surfaces and apply a light coating of oil every year to reduce corrosion	
• Inspect and service transmissions and outdrive units according to manufacturer’s recommendations.	Insert manufacturers recommended intervals
• Pressure check outdrive units.	
• Check transmission fluids and gear oil for water.	
• Change transmission fluids and gear oil.	Insert manufacturers recommended intervals and next due date.
• Grease universal joint, gimbal bearing, propeller spline, and unit fittings.	
• Check bellows and water seals and replace, if needed.	
• Check and replace the sacrificial zinc anodes on shafts, props, tabs, and other underwater gear, as well as engine-mounted zincs on the underside of exhaust elbows or risers and on the end caps of heat exchangers to guard against corrosion.	
• Clean and service outdrive unit.	
• Verify that the steering gear has its full range of motion and that the gear moves easily, without being loose.	Annually or as recommended by manufacturer.
• Check anchor and cable/ rope/ chain for wear.	At the beginning of dredging operation.
Electrical System	
• Test all circuits for proper operation.	At the beginning of dredging operation.
• Inspect all exposed wiring, fuse/ breaker panels and electrical equipment. Wire insulation should be intact. Contacts and connectors should be secure and clean.	
• Replace defective parts.	
• Secure loose wiring.	
• Inspect and test batteries. Batteries should be in approved boxes or trays, well ventilated and securely fastened.	
Safety Systems	
• Check lifejackets for deterioration.	At the beginning of dredging operation
• Send liferaft for servicing at a station accredited by the manufacturer.	As required by regulation – insert date.
• Check liferaft hydrostatic release unit expiry date.	At the beginning of dredging operation
• Check first aid kit and re-stock as necessary.	Monthly
• Check fire/smoke detectors. (replace battery)	At the beginning of dredging operation
• Check fire hoses in place and equipment operational (nozzle).	

• Have fire extinguishers inspected by technician.	At recommended intervals – see documentation and insert next due date and the interval.
• Check EPIRB battery validity.	At the beginning of dredging operation
Other Systems	
• Inspect and service the fuel tank, filter, fitting, and lines on a regular basis. Keep tanks free of scale, dirt, and water.	At the beginning of dredging operation
• Flush and chlorinate the fresh water system.	
• Check all fresh water lines and connections for tightness. Repair and/or replace as needed.	
• Check, clean and lubricate mechanical parts of all systems as needed for proper operation. These systems include hydraulic trim systems, air systems, anchoring systems, and bilge and sanitation systems.	
• Check safety equipment: lifejackets, flares, fire extinguishers, liferafts, life buoys, bilge pumps, oars, anchors, etc.	
• Check radio equipment, antennas, batteries, and backup systems.	
• Inspect, and clean covers and upholstery.	
• Replace any outdated or damaged equipment.	

Source: Government of Canada (https://www.tc.gc.ca/eng/marinesafety/debs-small-vessels-procedures-maintenance-3005.htm)

6.4.2 General Guideline for Environmental Consideration

6.4.2.1 General Environmental Guideline

As the international norm regarding the damping control of the dredged material, "the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention: LC) and its 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Protocol: LP) is the regulatory norm.

The London Protocol was adopted in London in November 1996 and entered into force in March 2006. The Protocol prohibits, in principle, the dumping and incineration of wastes at sea, and enumerates the items that can be considered for dumping at sea, such as dredged materials and sewage sludge as exceptions, and even if these items can be dumped at sea, they are permitted only under strict conditions.

In order to further strengthen the measures to prevent marine pollution under the London Convention, this Protocol prohibits in principle the dumping of wastes, etc., from ships in the ocean, and permits them under strict conditions, even in exceptional cases where dumping is permitted. In addition, in line with the obligation to comply with the Protocol, it has become necessary for the parties to develop a mechanism for predicting and assessing the impact of each waste dumping at sea on the marine environment and for the regulatory authorities to issue permits based on this assessment.

The key regulatory matters are as follows.

i) A ban on dumping waste and other materials (excluding those specified in Annex I) at sea from vessels. Note: Suspended solids, sewage sludge, fish residue, ships and platforms, inert geological and inorganic materials, organic materials of natural origin, etc.
ii) The dumping of waste and other materials listed in Annex I requires permission under Annex II (referred to as the Waste Assessment Framework).
iii) The incineration of waste and other materials in the ocean is prohibited.
iv) Require that measures be taken for the application of the provisions of the Protocol in inland waters or for effective permitting and regulation in inland waters.
v) Provides for the application of precautionary measures and the promotion of the polluter pays principle.

In case of the river, it is the inland and territorial water of each country and thus there is no international uniformed guidelines for the dredging activities. However, if the dredging work may cause the contamination of the water, river bank or others, it shall be carefully provided the protection measures and contingency plan to mitigate any risks expected to the environment.

In Japan, “the Law Relating to the Prevention of Marine Pollution and Maritime Disaster” was enacted in 2003, with respect to sediment in the water containing dioxins followed by the "Cabinet Order for Partial Revision of the Enforcement" was promulgated to prohibit discharges from ships in the sea area that exceed the standards set forth in the Ordinance of the Ministry of the Environment from being discharged to places other than landfill sites that meet certain requirements, and to prohibit the disposal of such discharges to the ocean.

The environmental standards for sediment contaminated by dioxins based on the Act on Special Measures against Dioxins 1999 have been revised to focus on measures for sediment contaminated by dioxins in addition to mercury and PCBs, and have been newly compiled into the Guidelines for the Treatment and Disposal of Sediment.

The main changes are the addition of the application of simplified analysis method to the investigation for monitoring and the addition of detoxification as a construction method in addition to dredging, excavation and containment.

At the removal of sediment by dredging, etc., sufficient attention shall be paid to the operation that takes into account the characteristics of the subject sediment, topography of the water area, sea conditions, current conditions, fishing season, fishing conditions, and other regional characteristics so as not to cause secondary pollution.

The specific measures for dredging work are "Environmental Preservation Technology Manual for Port Construction (Doctor of the Sea) " published by Japan Landfill Dredging Association.

This manual introduces the effects of port and harbor construction on the surrounding natural and living environments and the measures to reduce or prevent them, and provides a comprehensive explanation, based on environment-related laws and regulations, including items to be considered at the construction stage.

This manual summarizes the environmental impacts of port and harbor construction in eight categories: water quality, sediment, soil, noise and vibration, odor, biological environment, waste and recycling, and air quality, while incorporating the latest laws and standards. Although this manual mainly covers port and harbor construction, it can also be applied to fishing ports, coasts, marine and offshore airports, and water area construction, including lakes and rivers.

As the other guideline, Environment Agency, Government of UK, has established the “Dredging and the removal of silt and sand from main rivers is regulated under the Environmental Permitting Regulations 2010.”

This note sets out what must be done when dredging on main rivers. Individuals, businesses and public bodies must meet the requirements to comply with the regulations. This will ensure you maintain your watercourses in an environmentally sensitive way.

6.4.2.2 General Notes

General notes on responses to hazardous materials during dredging and removal are shown below.

Table 6-4 Handling of Hazardous Substances during Dredging and Removal

	Correspondence	Abstract
During Dredging	Use of closed-grab dredging method	The sealed grab dredging method is adopted to prevent the diffusion of heavy metals, etc., as it is possible to dredge efficiently with low pollution diffusion and high mud content.
	Use of anti-pollution frame or anti-pollution membrane	As an environmental conservation measure to reduce the effect of turbidity (SS) caused by the work, use of a turbidity control frame or a turbidity control membrane during excavation and dredging to prevent the diffusion of turbidity.
	Countermeasure with anti-diffusion sheet	The area around the dredging site will be enclosed with a sheet to prevent the diffusion of heavy metals and other harmful substances.
During Transport and Dumping	Examples of measures to prevent scattering during marine transportation	• By covering the dredged material with a sheet, the scattering of soil containing heavy metals, etc. is prevented. In addition, it is possible to suppress the increase in the water content in rainy weather. • By using an enclosed dumping barge, it is possible to transport the cargo while it is shielded from the external environment.

Source: the Consultant

6.4.3 Guideline for Dredging

6.4.3.1 International Guideline for Dredging

The seagoing dredgers are subject to compliance with a large number of general and dedicated regulations. The key international regulations and guidelines applicable to dredgers are listed in the table below:

Table 6-5 Key International Regulations and Guidelines Applicable to Dredgers

International Safety of Life At Sea (SOLAS) Convention, 1974 (self-propelled ships > 500 gt)
International Convention on Load Lines (ICLL), 1966 (L >24 m)
International Convention for the Prevention of Pollution from Ships (MARPOL), 1973
Guidelines for the Assignment of Reduced Freeboards for Dredgers (DR-68), 2010 Developed by DR-67 Joint Working Group, 3 February 2010
Code of Safety for Special Purpose Ships (SPS Code), 2008 IMO Res. MSC.266(84), adopted 13 May 2008 Previously IMO Res. A.534(13), adopted 17 November 1983
Ballast Water Management Convention, 2004
Maritime Labour Convention, 2006
Standards of Training, Certification & Watchkeeping (STCW), 2005

Source: the Consultant

Seagoing hopper dredgers engaged on international voyages are generally compliant with international regulations as well as the rules and regulations of a classification society. In general, International Classification Society provides rules for the Survey and Construction of Steel Ship and as its part requirements on Working Ships including dredgers are provided.

6.4.3.2 Specific Requirement of Bureau Veritas (France)

In some International Classification Society i.e., Bureau Veritas (B.V) has provided more detailed and specific requirements.

Bureau Veritas Rules for the Classification of Steel Ships contains a special chapter for ships for dredging activity, which is applicable to ships with the following service notations (Bureau Veritas, 2010):

- **dredger**, for ships specially equipped only for dredging activities (excluding carrying dredged material);
- **hopper dredger,** for ships specially equipped for dredging activities and carrying spoils or dredged material;
- **hopper unit**, for ships specially equipped for carrying spoils or dredged material;
- **split hopper unit**, for ships specially equipped for carrying spoils or dredged material and which open longitudinally, around hinges;
- **split hopper dredger**, for ships specially equipped for dredging and for carrying spoils or dredged material and which open longitudinally, around hinges.

Under these service notations, Trailing Suction Hopper Dredgers (TSHDs) are assigned as the service notation hopper dredger, Cutter Suction Dredgers (CSDs) the service notation dredger. Backhoe dredgers and stone dumping vessels are assigned the service notation special service, followed by an additional service feature (short description of the function of the vessel). Typical examples are given as follows:

- **special service - backhoe dredger;**
- **special service - side stone dumping vessel;**
- **special service - fall pipe vessel.**

Dredgers are likely to operate at sea within specific limits which are related to practical operational issues, such as water depth and capacity of the heave compensation system for the suction tube. Within Bureau Veritas rules, such dredgers may be granted an operating area notation, which express the specified area in which the dredgers are likely to operate at sea within specific restrictions which are different from normal navigation conditions.

The following operating area notations may be assigned (Bureau Veritas, 2010):

- **dredging within 8 miles from shore;**
- **dredging within 15 miles from shore or within 20 miles from port;**
- **dredging over 15 miles from shore.**

6.4.3.3 Ship Safety Law of Japan

Dredgers, either ship type dredger or non-ship type dredger, constructed in Japan fall under the Ship Safety Laws or related Laws and regulations. The applicable laws and regulations in Japan are briefly explained below.

Hull section

i) Non-self-propelled ships

A non-self-propelled vessel is not considered as a ship under the Ship Safety Law of Japan, so each equipment or machinery is subject to the relevant laws and regulations, i.e. heavy equipment, etc.

- Related to the Ship Safety Law
  Trailing suction hopper Dredger is a ship and the Class Regulations such as Class NK or Lloyd's Register of Shipping will be applied. Also, in Japan, Ship Safety Law will be applied.
  Even if the Ship Safety Law does not apply to some type of dredgers, there are no laws and regulations that apply to the required equipment in the hull section, except for the following:

- Radio Law
  Under the Ordinance for Enforcement of the Ship Safety Law, the Radio Law exempts wireless telegraphy and other facilities on ships, so non-self-propelled ships do not need to consider the Radio Law.
- Convention on the International Regulations for Preventing Collisions at Sea (COLREG)
  Under COLREG, a non-navigational crane ship is defined as a ship with limited maneuverability and has a priority relationship in terms of navigation.
  Non-self-propelled crane ships shall display lights and figures in accordance with COLREG.

- Law Relating to the Prevention of Marine Pollution and Maritime Disaster
  The Law regulates the discharge of oil, hazardous liquid substances and waste from ships into the ocean, and provides that ships must be equipped with bilge and other discharge prevention equipment.

- Fire Service Act
  The Fire Service Act applies to non-self-propelled vessels that are not subject to the Ship Safety Law, but since there are no specific regulations, non-self-propelled vessels are referred to the Ship Equipment Regulations.

- Electrical Equipment
  The Electricity Business Act applies to electrical installations for non-self-propelled vessels to which the Ship Safety Law does not apply.
  A crane ship with power generation and demand facilities is treated as a power plant and demand facility under the Electricity Business Act.
  According to the amendment in 1995, internal combustion power plants and demand facilities are required to be notified in the installation of 1,000 kW or more, but not in the case of less than 1,000 kW.

a) Self-propelled ship

Self-propelled ships, like general ships are covered by maritime laws and regulations, mainly the Maritime Safety Law, in terms of hull structure and equipment in general. The following rules and regulations related to the Ship Safety Law are applied to the facilities required for self-propelled ships.

Vessel Structure Rules - Vessel Engine Rules - Vessel Compartment Rules

Vessel Equipment Regulations - Vessel Lifesaving Equipment Regulations - Vessel Fire Fighting Equipment Regulations

b) Lifting Equipment

- Non-self-propelled ship
  Since the Ship Safety Law does not apply to non-self-propelled vessels, the rules and regulations related to the hoists of non-self-propelled ship are applicable to the Occupational Health and Safety Law.

- Occupational Health and Safety Law
  The Law stipulates that if a mobile crane with a lifting load of 3 tons or more is manufactured, it is necessary to obtain a permit from the director of the Prefectural Labor Standards Bureau.

- Mobile Crane Construction Standards
  The mobile crane structure standard specifies the stability of the floating crane. The Construction Standard specifies the combination of load, diameter of drum, etc., and relaxation of wire rope for the lifting load of 200 tons or more for the lifting crane.

- Self-propelled ship
  Mobile cranes under the Order for Enforcement of the Industrial Safety and Health Act, shall be treated as not including those installed on ships to which the Ship Safety Act applies. However, self-propelled floating cranes with a gross tonnage of less than 300 tons shall be inspected in accordance with the Industrial Safety and Health Law.

For cranes installed on a ship to which the Ship Safety Law applies, Chapter 1 of Equipment for Cargo Handling and Other Operations, Part 5 of the Marine Equipment Regulations shall apply.