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DREDGING AND DREDGED MATERIAL MANAGEMENT: A CASE STUDY OF MONGLA PORT

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ABSTRACT

Dredging is the relocation of earth which is mainly under or with water. This operation normally done to create or improve waterways and sometimes to improve the environment. There are several types of dredger such as cutter suction dredger, trailing suction hopper dredger, grab dredger, backhoe dredger, bucket dredger etc. Types of dredgers selected based on the location and soil properties. Dredged material normally disposed in open water or confined area. In some cases management of dredged material is a very complicated issue.

Mongla Port is situated on the left bank of Pussur River at about 130 km upstream of Bay of Bengal. At establishment time of the port depths of Pussur River at present location were satisfactory for average 8.5 m draft ships. But, since 1970 the depths in this area started to deteriorate rapidly. Since then, regular maintenance dredging has been required to provide sufficient depth alongside the berths and in the approaches to the berths. Till now Mongla Port has carried out 172.28 lac cu.m dredging which is about 4.30 lac cu.m/year. In the year 2019-20, Mongla Port is implementing the 117 lac cu.m dredging at outer bar and food silo area. In 2020-2022, Mongla Port is planning to dredge the approach channel upto 8.5 m CD and the quantity will be about 216 lac cu.m.

Mainly Cutter Suction Dredger and Trailing Suction Hopper Dredger used at Mongla Port dredging works. All the dredged material was dumped on land and all of the low land of port area has filled up. To keep the port operational in connection with the market demand, huge amount of dredging will be required in upcoming years. Dredged material management will be a serious issue in future. Now Mongla Port doesn’t have sufficient land for disposal of dredged material from any major dredging project. At this context disposal in water at suitable location could be an alternative. About 3,84,50,000.00 cu.m can be accommodated in shallow areas, deep pockets and deep channels.

But the present regulatory conditions of MPA as well as Bangladesh don’t allow open disposal. The government is now preparing “Dredging and dredged material management policy-2018”. The draft policy also recommended only confined disposal on land only. Considering the international practice in dredging field, open disposal need to permit in exceptional cases such as MPA. However the movement pattern of sediment and its effect on river need to assess through mathematical model and some case study.

Keywords: *Navigability, Pussur river, Dredging, Dumping, Mongla Port.*

1. INTRODUCTION

Mongla Port (MP) is situated on the left bank of Pussur River at about 130 km upstream of Bay of Bengal. The Pussur River forms part of a very big and complex river system. Numerous tributaries and channels connect the Pussur River with other rivers like Sibsa, the Ganges and Jamuna Rivers. Flow conditions in all these rivers determined the current and morphological condition in the Pussur River. At establishment time the depths of the Pussur River at present location were satisfactory for average 8.5 m draft ships. But, since 1970 the depths in this area started to deteriorate rapidly. When the construction of the berth was completed in 1978 the depths in the area had already been reduced significantly. Since then, regular maintenance dredging has been required to provide sufficient depth alongside the berths and in the approaches to the berths.

The navigation channel at the Pussur River entrance crosses a wide bar known as outer bar. The bar is relatively stable with sea bed elevation of -6.4 m Chart Datum (CD). This outer bar also needs to dredge up to 8.5 m CD at least. Till now MP has carried out 172.28 lac cu.m dredging which is about 4.30 lac cu.m/year. In the year 2019-20, MP is implementing the dredging at outer bar and food silo area. Quantity of those areas are 104 and 13 lacs respectively. In 2020-2022, MP is planning to dredge the approach channel upto 8.5 m CD and the quantity will be about 216 lac cu.m.

Mainly Cutter Suction Dredger (CSD) and Trailing Suction Hopper Dredger (TSHD) used at MP dredging works. All the dredged material was dumped on land and all of the low land of port area has filled up.The Port is well protected by the largest mangrove forest known as the Sundarbans, part of which has been declared as "World Heritage" in 1997 by UNESCO. Sundarban has covered about 100 km of bank of the channel and there is no scope of dumping on that 100 km bank.

To keep the port operational in connection with the market demand, about 320 lac cu.m to be dredged in next 05 years and after that yearly 30-40 lac cu.m dredging will be required. Since the financial capability of Bangladesh in increasing day by day, financing for dredging may not be a problem but dredged material management will be a serious issue in future.

2. DREDGING

Dredging is the activity to remove material from one part of the water body and replacing it to another. In most of situations the excavation is undertaken by a specialist floating plant, known as a dredger. Dredging is carried out in many different locations and for many different purposes, but the main objectives are usually to recover material that has some value or use, or to create a greater depth of water.

2.1 Types of dredging equipment

Dredging equipment can be divided in Mechanical Dredgers and Hydraulic Dredgers. The differences between these two types are the way that the soil is excavated, either mechanical or hydraulic (Emermanand & White, 2017).

2.1.1 Mechanical Dredgers

Mechanical dredgers work by mechanically digging or gathering sediment from the bottom surface of a body of water, typically through use of a bucket. Mechanical dredging takes place at the shoreline or working off of a barge. The most common types of mechanical dredgers are:

2.1.1.1 Bucket Dredger

Bucket Dredger is a stationary dredger, fixed on anchors and moved while dredging along semi-arcs by winches. The bucket dredger is one of the oldest types of dredging equipment. It has an endless chain of buckets that fill while scraping over the bottom. The buckets are turned upside down and empty moving over the tumbler at the top. The dredged material is loaded in barges.

2.1.1.2 Grab Dredger

Grab Dredger is a stationary dredger, moored on anchors or on spud-poles. A spud is a large pole that can anchor a ship while allowing a rotating movement around the point of anchorage. The dredging tool is a grab normally consisting of two half-shells operated by wires or hydraulically. The grab can be mounted on a dragline or on a hydraulic excavator of the backhoe type. Many modifications of grabs have been constructed like open grab, closed grabs and watertight grabs. The dredged material is loaded in barges.

2.1.1.3 Backhoe Dredger

Backhoe Dredger is a stationary dredger, moored on anchors or on spud-poles. A spud is a large pole that can anchor a ship while allowing a rotating movement around the point of anchorage. Small backhoe dredgers can be track mounted and work from the banks of ditches. A backhoe dredger is a hydraulic excavator equipped with a half open shell. This shell is filled moving towards the machine. Usually the dredged material is loaded in barges. This machine is mainly used in harbors and other shallow waters.

2.1.2 Hydraulic Dredger

Hydraulic dredgers work by sucking up a mixture of sediment and water from the bottom surface and then transferring the mixture through a pipeline to another location. This dredger acts like a giant floating vacuum, removing sediment.

2.1.2.1 Suction Dredger

Suction Dredger is a stationary dredger used to mine for sand. The suction pipe is pushed vertically into a sand deposit. If necessary, water jets help to bring the sand up. It is loaded into barges or pumped via pipeline directly to the reclamation area.

2.1.2.2 Cutter Suction Dredger

Cutter Suction Dredger is a stationary dredger which makes use of a cutter head to loosen the material to be dredged. It pumps the dredged material via a pipeline ashore or into barges. While dredging, the cutter head swing around the spud-pole powered by winches. The cutter head can be replaced by several kinds of suction heads for special purposes, such as environmental dredging.

2.1.2.3 Trailing Suction Hopper Dredger

Trailing Suction Hopper Dredger is a self-propelled ship which fills its hold or hopper during dredging, while following a pre-set track. The hopper can be emptied by opening bottom doors or valves or by pumping its load off ashore. This kind of dredger is mainly used in open water such as rivers, canals, estuaries and the open sea.

2.1.2.4 Reclamation Dredger

Reclamation Dredger is a stationary dredger used to empty hopper barges. A suction pipe is lowered into the barge. Extra water can be added by water by water jets to facilitate the suction process. The dredged material is pumped by pipeline ashore, to a reclamation area, or to a storage depot.

2.1.2.5 Barge unloading dredgers

Barge unloading dredgers are used to transfer material from hopper barges to shore, usually for reclamation. A barge unloader is basically a pontoon supporting a suction pump for the unloading, and a high-pressure water pump used to fluidize the barge contents by jetting. The mixture is then pumped through a pipeline to the point of reclamation or relocation.

2.2 Locations and Quantities for Dredging

When dredging projects are planned, the locations and quantities of material are the most important considerations that need to be addressed. The biggest problem is usually the disposal of the dredged material, which means that long-term projections are essential. Before the project commences, hydrographic surveys carried out to determine the existing depths as well as the depths that will be attained after the dredging operation. The process requires the use of proper equipment and both vertical and horizontal controls to ensure accurate calculations.

2.2.1 Physical Properties of Sediments

If there is a specialized problem with the dredging operations, then field testing is required to determine the quantities, characteristics, and location of the material that needs to be removed. Sediment samples normally collected down to the depth that will be targeted. At the same time, a pre-dredge survey carried out. Once the characteristics are well known based on multiple samples, then a smaller number of samples can be used for future work. When soft materials are present, then grab sampler (using a bucket or scoop) or push tube sampler (using an open-ended tube that is thrust vertically into the sediment) are used for sample collection.

2.2.2 Sampling for new Project

When samples are taken for new work, then conventional boring techniques are usually used. These samples obtained in the major work zones for a full representation of site samples. These samples go through laboratory testing to determine the proper dredge plant, disposal alternatives, the design of retention dikes and channel slopes, and the estimation of long-term storage capacity when the disposal areas are confined. These sample tests normally include:

- Natural Water Content Test
- Plasticity Analysis
- Specific Gravity Test
- In Situ Density
- Grain size distribution

2.2.3 Selection of Dredging Equipment

Sometimes limitations are placed on equipment depending on the circumstances. Avoid of specifications whenever possible is helpful to avoid restriction to the competitive bidding process. The goal of equipment selection is to reduce the environmental impact that occurs due to the operation. This protection is an adequate justification for managing the selection and control of the dredging equipment.

2.3 Disposal of Dredged Material

Before selecting any dredging equipment, it is important to consider the options for disposal alternative, especially from technical and environmental point of view. Three common disposal alternatives might be used:

- Open-water disposal
- Confined disposal
- Beneficial Use

The operation for dredging and dredged material disposal needs to cover both short-term and long-term management goals. Typically, short-term focus is on the channels that are needed for existing navigation, but it doesn’t necessarily need to be based on the project dimensions. Ideally, the dredging process done using the best technical options that are both economically feasible and environmentally compatible. On the other hand, long-term goals are focused on the operation and management of the disposal areas. Preliminary data collection for a dredging and dredged material disposal project includes:

- Assessing the location as well as the amount that needs to be dredged.
- Determining the chemical and physical characteristics of the sediments.
- Identifying potential alternatives for the disposal.
- Considering the applicable environmental, social, and institutional factors.
- Evaluating the dredge plant requirements.

2.3.1 Open water Disposal

Open water disposal can be in the ocean, estuarine waters, lakes and rivers, all of which are highly regulated. Although open-water disposal may be inexpensive, it gives the least amount of control over hydrodynamic and environmental aspects. The suitability of the open-water option normally carefully determined by taking sediment samples which are then evaluated for chemical and biological composition. Both the dredged material itself and the placement area evaluated for compatibility. In sensitive open-water environments, for instance, where there are coral reefs and other marine flora and fauna, placement of sediment, even if it is clean and compatible, may be deemed unsuitable.

2.3.2 Confined Disposal

Confined disposal takes place in a structure which isolates the dredged material from the surroundings, e.g., within a diked area either in water or on land. When the dredged material is contaminated and cannot be cleaned, then placing it in a confined disposal area, be it on land or at sea, is the only choice. In water or underwater confined disposal can be complex. Space is not an issue but ensuring complete control over the isolation of the materials may not be possible. Confined disposal options can be controlled better but options are limited by the space available.

2.3.3 Beneficial Use

Also, the benefits of disposal area reuse shouldn’t be overlooked. When the dewatered fine-grained material and coarse-grained material are removed from the site, then partial or total reuse of the disposal area is available. This strategy basically turns the disposal area into a transfer station, where the dredged materials are collected, processed, and then moved to another location for inland disposal or productive use. Examples of productive use include:

- Construction or landfill material
- Low land reclamation
- Material for sanitary landfill cover
- Enhancement of agricultural land

3. DREDGING OF MONGLA PORT

3.1 Dredging Activity

Mongla Port was designed for berthing ships having 8.50 m draft. Up to 1980 there was not any siltation problem either in Jetty front or Channel area. But after 1980 siltation started in Jetty front Area (Rahman and Ali, 2018). From that time regular maintenance dredging was performed in jetty front area. In the meantime, it was seen that siltation has started in Harbor Area (About 13 Km downstream from Port Jetty). Due to this siltation, 04 times capital dredging project has implemented in the year of 1994 - 1995, 2004 - 2005, 2013-2014& 2017-2019. For regular maintenance dredging, Mongla Port Authority has 02 nos 18” dia Cutter Suction Dredger. Moreover, MPA carried out maintenance dredging every year at different location of the channel. Table 1.1 presented a brief dredging history of Mongla Port Authority.

Table 1.1: Dredging History of MPA

Dredging period	**Dredger Authority**	**Dredging Area**	**Dredging Quantity (Lac cu.m)**	**Total expenditure (CroreTaka)**	**Dredger Type**
1979-1981	Water Dev. Board	Jetty front(J5-J9)	3.25	0.896	CSD
1983-1987	BIWTA	Jetty front(J5-J9)	6.95	3.094	CSD
1988-1990	Water Dev. Board	Jetty front(J5-J9) & Confluence	5.23	2.856	CSD
1991-1992	China Harbour Engineering Company, China	Harbour Area	35.51	30.88	CSD
1993-1996	Khanak dredger of Ctg. Port. (Trailing Suction Hopper Dredger)	Southern Anchorage confluence & Sabur Beacon	2.26	2.989	TSHD
1994-2001	Water Dev. Board	Jetty front (J5-J9)	8.13	9.714	CSD
2000-2004	PT. Rukindo- Basic Dredging Partnership	Harbour Area	27.9	45.480	CSD & TSHD
2003-2004	Water Dev. Board	Jetty no- 8 & 9	0.69	0.805	CSD
2004-2005	Basic dredging Co.	Jetty no- 8 & 9	0.54	0.724	CSD
2005-2006	Water Dev. Board	Jetty no- 8 & 9	0.69	0.905	CSD
2007-2008	Water Dev. Board	Jetty no- 8 & 9	1.08	1.941	CSD
2009-2010	Water Dev. Board	Jetty no- 8 & 9	0.71	1.576	CSD
2012-2013	MPA’s own Dredger	Jetty no- 8 & 9	0.17	-	CSD
2013-2014	China Harbour Engineering Company, China	Harbour Area	34.06	111.85	CSD
2015-2016	AZ dredging Company Ltd	Approach and Pontoon front of Nil Komol	1.55	3.197	CSD
2017-2018	Banga Dredgers Ltd	Jetty Front	1.40	3.560	CSD
	Dredging Corporation of India	Mongla Port to Rampal Power Plant	4.10	11.90	CSD
	Bangladesh Navy	Approach to Nil Komol	0.38	1.20	CSD
2018-2019	Banga Dredgers Ltd	Jetty Front	1.25	3.240	CSD
	Dredging Corporation of India	Mongla Port to Rampal Power Plant	34.7	107.10	CSD & TSHD
	Bangladesh Navy	Approach to Nil Komol	0.48	1.70	CSD
	Asian Dredgers Ltd.	Food Silo Area	1.25	2.80	CSD
Total			**172.28**	**348.407**	

Among the above 29 lac cu.m was dredged by TSHD and 143 lac cu.m by CSD. In 2019-2020, another two dredging projects will be completed at outer bar and food silo area. Approximate quantity of those projects is 117 lac cu.m, among them 104 lac cu.m will be dredged by TSHD and 13 lac cu.m will be dredged by CSD.

Upto 2017-18, average dredging at MP is 4.3 lac cu.m/year which will be 7.05 lac cu.m/ year at the end of 2010-2020. MP is also planning a long-term dredging project to handle 9 m draft vessel in first phase and 11 m draft vessel at second phase. That project includes capital dredging, river training and maintenance dredging. Approximate quantity of capital dredging will be 216 lac cu.m in 1st phase, 1470 lac cu.m in 2nd phase and yearly maintenance dredging will be at least 150 lac cu.m.

3.2 Sediment Characteristics

DHI (1993) has collected a large quantity of data on this river, based on which the governing physical processes and the nature of the sediment transport processes in the Pussur River can be understood.

From the suspended samples analysis, DHI concluded that the main part of the suspended sediment material consists of silt which is only represented in the bed material by approximately 5 percent. Consequently, the suspended sediment picked up in the measurements for the main part consists of wash load. Silt is generally not found in the bed along the main flow of Pussur River indicates that suspended silt contributes in any significant way to the erosion/deposition processes along the river. The bed material along the main flow areas of the bigger rivers is fine sand. Closer to the banks it is often mainly silt. The suspended fine material does not contribute significantly to erosion/sedimentation processes in the main flow regions of the bigger rivers including the navigation channel of Mongla Port.

3.2.1 Bed Load Characteristics

To know the characteristics of river bed material near the Mongla Port area, 4 (four) bed samples were collected and analyzed. Sieve analysis of the bed material shows that the Fineness Modulus (FM) of the collected samples are 0.30, 0.60, 0.48 and 0.49, i.e. the bed material is mostly sandy. Figure 1 shows the average grain size distribution of bed material, where d_{50} is found as 0.052 mm.

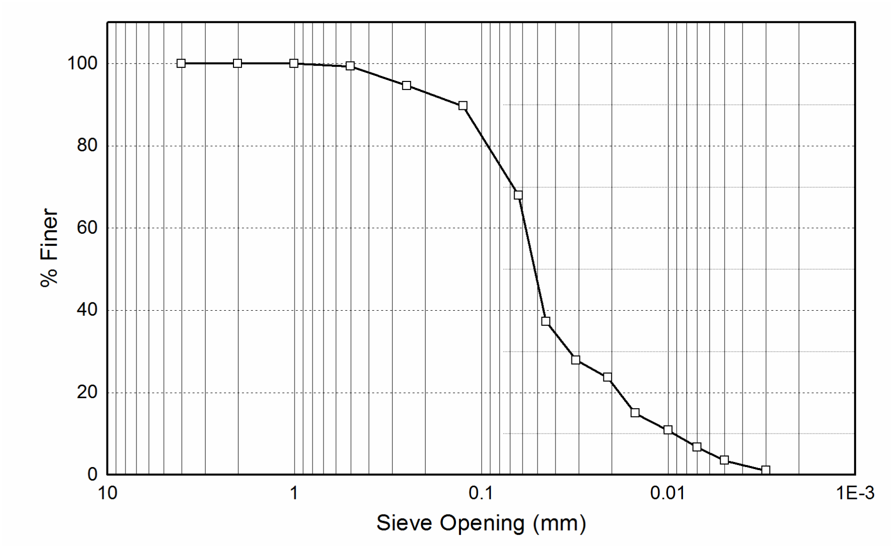

Figure 1: Average grain size distribution of bed material

3.3 Disposal of MP Dredged Material

Initially, the land area of MP was 2068 acre. Within this land EPZ, BEZA, and Navy was established later on. Most of this 2068-acre land was low land, which has developed by the dredged material of MP. Some industries in Mongla area, Road construction project of Rampal power plant, partial development of Block-B of Rampal power plant has also done by dredging material. Now all of MP land has developed and private upcoming industries along the river side already developed their land. Due to Sundarban, DoE is not giving permission for any industrialization at south side of Mongla River up to Joymonirgol and this reach of Pussur River is mainly siltation prone area which require huge dredging.

MP is not getting any land for dumping the dredge material at south side of Mongla River upto Joymonirgol because all the land is mainly using for fish pond. In 2014-15, MP has filled about 250-acre private lands at Chilla and Joymonirgol area. Till now, there is no use of those land, neither agriculture nor fishing. Due to the saline content of dredged material, even any plantation is not possible there upto certain years. To implement the dredging project at Joymonirgol area, MP is now thinking to get some private land by giving compensation. Present dredging project is small quantity of only 13 lac cu.m and compensation may not be a problem. But in future, if MP implement project to handle higher draft vessel then the dumping area for 1686 lac cu.m from capital dredging and yearly 150 lac cu.m from maintenance dredging will be the main challenge of MP. Only the capital dredging material will need 10,000-acre land and maintenance dredging may need 900 acre/year. This amount of land is totally impossible and alternative solution should be found out before planning any of this project.

3.4 Alternatives of Disposal Area

Considering the future dredging demand of MP, alternative disposal method should be considered. In most of the worldwide sea ports, open discharge in deep pockets of channel is very common. Most of the seaports in the world are near to sea and disposal of dredged material in sea is economical and easiest solution there. But the ports like MP which are very far from sea, carrying the material to sea is not economical. In these cases, deep pocket in channel and very shallow area could be an alternative. Length of Pussur Channel is 130 km from sea, within which only 22 km from port to Harbaria and 11 km at the entrance of channel requires dredging. Dredged material from entrance channel which is known as outer bar, can be dumped either in sea or land. Sea is about 15 km and nearest islands such as Dubla Island, Bangabondhu Island is within 10 km of dredging area. Channel between Harbaria to outer bar has sufficient depth more than 10 m which never requires dredging. For disposal of dredged material of port to Harbaria, following areas can be considered:

- Shallow area at west side of port
- Shallow area at downstream of Mongla river
- Deep water pocket at danger khal area
- Deep water pocket at Joymonirgol
- Deep channel at downstream of Joymonirgol
- Deep channel at upstream of monkey point
- Deep water pocket at monkey point

The possible disposal areas have indicated in figure 2. The shallow areas are mainly situated on the convex end and deep pockets are on concave side. The details of these areas are stated in following articles.

3.4.1 Shallow area at west side of port

The width of river near port area is about 1000 m, within which only 200 – 300 m at east side is used as navigation channel. The velocity of flow is strong in this portion only. Depth at remain 700-800 m varies between 1-4 m. Length of shallow area between Digraj to Mongla river is 7000 m. If half of the shallow area i.e 400 m is considered then the area will be 28,00,000.00 sq.m. This area can accommodate about 70,00,000.00 cu.m at a filling height of 2.5 m which is also below the water level. Material of maintenance dredging from port area can be dumped in this shallow area.

3.4.2 Shallow area at downstream of Mongla river

The width of river at downstream of Mongla is about 1500 m, within which only 200 – 300 m at west side is used as navigation channel. The velocity of flow is strong in this portion only. Depth at remain 1200-1300 m varies between 1-4 m. Length of shallow area at downstream of Mongla River is 7000 m. If half of the shallow area i.e 650 m is considered then the area will be 45,50,000.00 sq.m. This area can accommodate about 1,13,75,000.00 cu.m at a filling height of 2.5 m which is also below the water level. Material of maintenance dredging from inner bar area can be dumped in this shallow area.

3.4.3 Deep water pocket at danger khal area

The confluence of Pussur river and danger khal is very deep due to scouring effect of water. The length of deep area is 500 m and width 200 m. Depth at this area varies between 12 ~ 18 m. The navigation channel is adjacent to this deep area. Dredged material is possible to dispose in this deep area during slag tide. This area can accommodate at least 4,00,000.00 cu.m.

3.4.4 Deep water pocket at Joymonirgol

The confluence of Pussur River and shella river is very deep due to scouring effect of water. The length of deep area is 1200 m and width 400 m. Depth at this area varies between 15 ~ 30 m. The navigation channel is adjacent to this deep area. Dredged material is possible to dispose in this deep area during slag tide. This area can accommodate at least 38,00,000.00 cu.m.

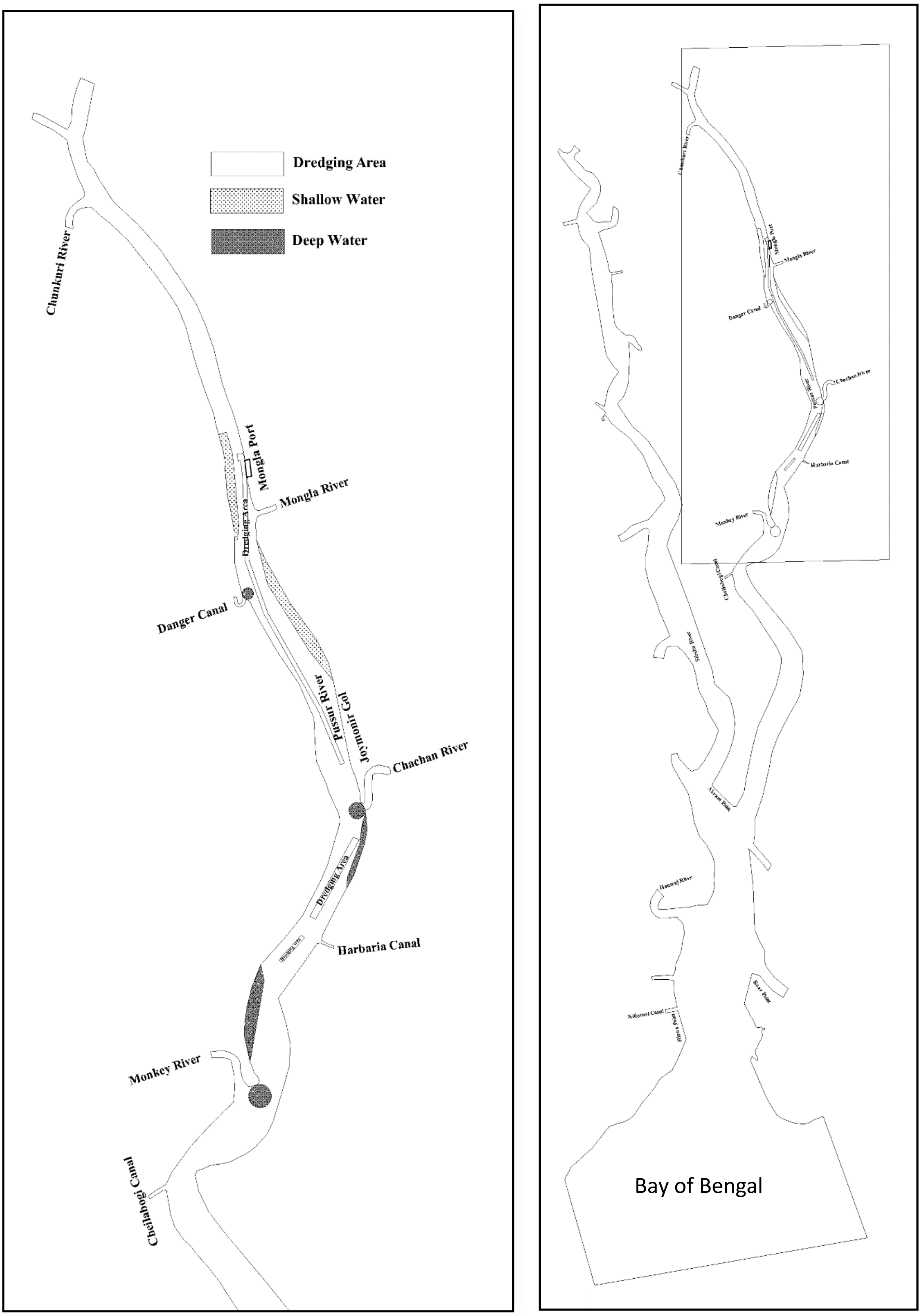

Figure 2: Disposal options of dredged material

3.4.5 Deep channel at downstream of Joymonirgol

The navigation channel at downstream of Joymonirgol is 10-14 m deep. If MP wants to maintain the channel at a minimum depth of 8 m CD then this area also can be considered as disposal area like a lot of sea ports in the world. The length of this deep channel portion is about 5000 m. This area can accommodate about 40,00,000.00 cu.m which have possibilities to spread in the deeper channels at further downstream.

3.4.5 Deep channel at upstream of monkey point

The navigation channel at upstream of monkey point is 10-14 m deep. If MP wants to maintain the channel at a minimum depth of 8 m CD then this area also can be considered as disposal area. The length of this deep channel portion is about 6000 m. This area can accommodate about 50,00,000.00 cu.m which have possibilities to spread in the deeper channels at further downstream.

3.4.6 Deep water pocket at monkey point

The confluence of Pussur River and Monkey River is very deep due to scouring effect of water. The length of deep area is 2700 m and width 500 m. Depth at this area varies between 15 ~ 30 m. The navigation channel is adjacent to this deep area. Dredged material is possible to dispose in this deep area during slag tide. This area can accommodate at least 70,00,000.00 cu.m of dredged material.

3.4.7 Summary of disposal options

The shallow and deep areas adjacent to the dredging sections in Pussur channel can accommodate at least 3,84,50,000 cu.m dredged material. But the present regulatory conditions of MPA as well as Bangladesh don't allow open disposal. The government is now preparing "Dredging and dredged material management policy-2018". The draft policy also recommended only confined disposal on land only. Considering the international practice in dredging field, open disposal needs to permit in exceptional cases such as MPA.

4. CONCLUSIONS

Pussur River requires huge amount of dredging to meet up the future demand. Proper management of dredged material will be the main challenge for implementing the dredging projects. Now MPA and the government must have to consider the open disposal options. If government allows open disposal, then may be a sustainable solution of dredged material management. However, the movement pattern of sediment and its effect on river need to assess through mathematical model and some case study.

REFERENCES

Emerman, D., and White, J. 2017. "Sustainable solutions for dredged material management in Ohio." Western Dredge Association – Midwest Chapter, Omaha, Nebraska

Rahman, M.M. and Ali, M.S. 2018. "Hydrological Characteristics of Pussur River and its Navigability." Proceedings of the 4th International Conference on Civil Engineering for Sustainable Development, Khulna, Bangladesh

Rahman, M.M. and Ali, M.S. 2018. "Potential causes of navigation problem in Pussur River and interventions for navigation enhancement." Proceedings of the 4th International Conference on Civil Engineering for Sustainable Development, Khulna, Bangladesh

US Army Corps of Engineers, 2015. "Dredging and Dredged Material Management, Engineering and Design", EM 1110-2-5025