

Bathymetric Survey in the Coastal Area of Bangladesh - A Challenging Experience for the Surveyors

1. Introduction

Bangladesh coast is located on the most active part of Ganges Delta. The area is very shallow and numerous numbers of rivers and channels are situated all along the coast. These rivers and channels carry huge amount of water from the upstream and fall into the Bay of Bengal throughout the year. The estuarine environment which is created along the coast is different from other parts of the world. The water is exceptionally laden with sediments mostly come from the Himalaya and every year almost 2.4 billion tons¹ of sediments are deposited in the Bay. This deposition over the years has created the Bay as one of the most dynamic area of world oceans.

The coastal area of Bangladesh has many notable facts such as monsoon, exceptionally high turbidity, large tidal range along with strong tidal stream, tropical revolving storm etc. Monsoon causes heavy rain fall in the upstream from June to September each year and those rain water falls in the Bay carrying large amount of sediment. As the number and capacity of channels vary, there are inhomogeneous mélange of saline and fresh water along the coast. Spatial variation of salinity and temperature is very prominent in the area. Various other characteristics that affect hydrographic surveying also differ from place to place.

Hydrography in the coastal waters of Bangladesh has never been an easy task for the surveyors. Due to those unusual characteristics of the coast, most of the hydrographic equipment does not function to it's optimum capacity. Sometimes, the degradation of performance is so prominent that the surveyors need extra time and effort to manage the survey work. Apart from the equipment performance, the prudence and professionalism of surveyors are always a critical factor to ensure the efficient progress of any survey work.

2. Description of the Coast

The extent of the coastal belt of Bangladesh is almost 710 km in East-West and North-South direction². The coastline which runs in the North-South direction is relatively stable. On the other hand, East-West coastline is very dynamic. Hundreds of small islands and Low Tide Elevations (LTE) are situated on this coast. The area is very shallow and mostly inaccessible by medium and deep draft vessels. Most of the rivers which form the Ganges Delta fall into the Bay of Bengal through this area.

1.J. M. Coleman, "The Sediment Field of Major Rivers of the World," *Water Resources Research*, Vol. 4, No. 4, 1968, pp. 26-59.

2. Md. GolamMahabubSarwar, "Impacts of Sea Level Rise on the Coastal Zone of Bangladesh" pp 4.

These rivers carry large amount of sediment from the upstream and deposit that sediment in the nearby Bay. The result of this deposition is number of new islands, LTE, shifting of navigational channels etc. Two of the major sea ports of Bangladesh i.e. Mongla and Payra are situated in this most dynamic part of the coast. These sea ports and their approaches require continuous survey to keep them accessible for the sea going vessels.

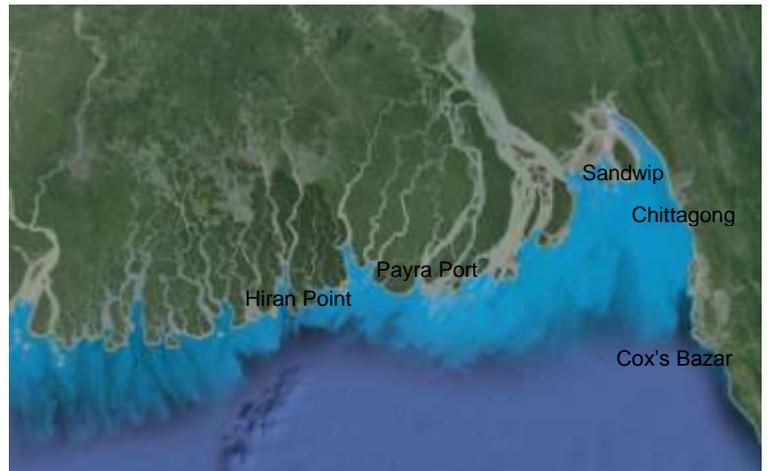


Figure 1. This Google Earth image shows the coastal area of Bangladesh. The presence of high turbidity is evident in the image. The area is highly unstable and numerous rivers and channels fall in the Bay of Bengal from inland area. The eastern coast is relatively stable.

3. Characteristics of the Coast

The coast of Bangladesh has got some unique characteristic and phenomenon that makes the hydrographic surveying task more challenging and different from other parts of the world. Some of those are described below:

3.1 Tide

Accurate measurement of tide is always very important for all hydrographic survey. Tides in Bangladesh coast are mainly semi-diurnal with small diurnal inequality. Tidal range can reach more than 7 m near Sandwip channel, whereas, it is only 2-3 m on the western side near Hiran Point³. Tide is much affected by the local conditions like geomorphology, configuration and orientation of the coast, upstream flow of rivers, number of openings in the coast etc. As the coastal area is gently shelving and tidal range is more, consecutive installation of tide gauges are needed to measure the tide. Again, offshore tidal range is more than onshore range in the central part of the coast which is a deviation from the normal phenomenon. The incoming tidal waters from south are obstructed on the land features during flooding and the sea level rises very quickly. Time for rise and fall of tides also differs considerably in this region. So, in any hydrographic survey much time is dedicated for tide measurement. The prudence of surveyors is always very important for accurate tide measurement in this area.

3. Bangladesh Tide Tables 2015, BIWTA, pp 1-6 and 43-48.

3.2 Tidal Stream

Tidal stream in the coastal area of Bangladesh is very strong. In some area it can reach up to 5.5 knots⁴ which makes the surveyor's task very difficult. Strong tidal stream affects the speed of advance of survey motor boats and it is extremely difficult for the boat Coxswain to steer the boat on the planned lines. Strong tidal stream also adversely affect the deployment of various equipment like Side Scan Sonar, Current Profiler, Auto Tide Gauge etc. Again, some channels having multiple opening to sea have peculiar tidal stream characteristics. In those channels, direction of tidal stream is quite opposite within the same channel during same tidal condition.

3.3 Salinity

Salinity in the coastal area varies from place to place with strong gradients. There is fresh water influx into the sea from upstream. This mixing of fresh water varies with the number of channels present in the area as well as on season of the year. During monsoon fresh water influx is much more than dry season. Saline water of the sea is heavier than that fresh water and it remains close to the bottom. Fresh water coming from upstream remains above that saline water. So, there is inhomogeneous mixing of water layers around the coast. The surface salinity in the open part of the Bay oscillates from 32 to 34.5 ppt and in the coastal area it varies from 10 to 25 ppt. But at the river mouths, the salinity decreases to 5 ppt or even less. Along the coast salinity increases up to 15 to 20 ppt in winter⁵. So, if the surveyor is not careful enough, the error budget will grow bigger and it will be very difficult for him to meet the standard specified in SP 44 in terms of depth uncertainty.

3.4 Temperature

Temperature profile in the coastal area of Bangladesh is not homogeneous. Due to the influx of fresh water, the spatial variation of temperature is quite prominent. Number of channels and their discharge rate varies from place to place. This creates an inhomogeneous mixing of fresh water in the coastal area. So, the surveyor has to be very careful while using sensors which work on acoustic principles.

3.5 Turbidity

The coastal water of Bangladesh is heavily laden with suspended sediment. The cloudiness of this water specially during monsoon is so high that it is impossible to

4. BN Chart 25002, Edition No 2, date 08 Oct 2015.

⁵Lt Cdr S Firoz Ahmed, "Surveying in Ganges Delta Region" a dissertation for M Sc in Hydrographic Surveying, Goa University, India, September 2007, p-13.

see through it even for few centimeters. This extremely high turbidity degrades equipment performance. Sometimes, the attenuation is so high that sound energy is mostly absorbed and the equipment is unable to perform as designed. Surveyor's experience is very crucial factor to get satisfactory result out of those equipment.

3.6 Monsoon

The Bay of Bengal is much affected by the monsoon. Heavy rain fall occurs in the region during monsoon and those waters are mostly drained in to the Bay of Bengal through various river systems of Bangladesh. During monsoon turbidity around Bangladesh coast increases and salinity decreases remarkably. Sea also remains quite rough during monsoon which possesses greater risk for smaller vessels operating in the area. Survey vessels cannot operate during monsoon considering safety of survey motor boats and crew fatigue. This factor shortens survey operations time in the Bay of Bengal. The ideal survey season around Bangladesh coast is during post monsoon from November to March only.

3.7 Shallow and Indented Coast

The coastal area of Bangladesh is very shallow and indented in nature. Most of the places are inaccessible by survey vessel due to the presence of LTE and shallow patches. So, the survey vessel has to remain at anchor and send her boats for survey works at distant places. It becomes very difficult to manage those boats and the progress of work is hampered. Again, sometimes sudden change of sea conditions makes survey boats difficult to return mother ships.

3.8 Shifting of Channel

Out of the 03 major sea ports of Bangladesh, Mongla and Payra ports are situated well inside the coast. So, any vessel coming to these ports, need to traverse long distance in the inland waters. These navigational channels are very dynamic and change almost every year. Surveyors remain very active throughout the year to keep these channels safe for the navigators.

3.9 Cyclone

During the pre and post monsoon period Tropical Revolving Storm is very common in the Bay of Bengal. Every year number of these cyclones hit the coast of Bangladesh. Sometimes, bathymetry of the coastal area also changes due to the cyclone and new islands/LTEs emerge in the area. South Talpatti was one such island emerged after the cyclone of 1970 which again disappeared due to

the cyclone of 1985⁶. This island was emerged at the mouth of Hariabhanga River near India-Bangladesh border area and had an area of 2,500 sq m in 1974 as per the satellite data released by USA. In the coastal area of Bangladesh, there are many such islands/LTEs which are created due to the devastating effect of some cyclones occurred in the past. To accommodate these changes, frequent updating of nautical charts is essential in the Bay.

3.10 Presence of Fishing Fleet

The coastal area of Bangladesh is very rich for some species of fish. A vast majority of the coastal population lives on fishing. Apart from the licensed fishing fleet there are many conventional/traditional fishing activities all around the coast. Fishermen lay bamboo, different types of net and other gears in the sea which cause significant problem for navigation in the area. This also hamper the survey operations in the area as many of the surveying instrument like Side Scan Sonar, Sub-bottom Profiler, portable echo sounder etc. cannot be used for safety concern.

3.11 Inaccessibility to the Coastal Area

The coastal area of Bangladesh specially on the western side is mostly inaccessible. Shoreline and landform also change very rapidly in these places. The low gradient of the coast makes the intertidal zone quite large. In some places there are marine growths as well as mangroves. So, it is almost impossible to walk along the coast. As a result, coast lining during hydrographic survey is a daunting task in the area.

4. Effect on Hydrographic Survey Operations

The unique characteristics of Bangladesh coast described above affects the hydrographic surveying operations in many ways. Hydrographic sensors do not function as designed. The progress of the survey work is affected by the inferior quality of data acquired using various equipment. Again, frequent re-survey/check survey needs to be undertaken in some of the area considering the changes occur within short span of time. Some of the facts that affect the hydrographic survey operations in the area are described below:

⁶ Arbitration under annex VII of the United Nations Convention on the law of the Sea, People's Republic of Bangladesh V Republic of India, Reply of Bangladesh, Volume I dated 31 Jan 2013.

4.1 Equipment Performance

Various factors described above affect the performance of hydrographic equipment while deployed in the coastal area of Bangladesh. The sensors which are mostly affected by the local conditions are as follows:

4.1.1 Single Beam Echo Sounder (SBES)

SBES is widely used for bathymetric data collection during hydrographic survey. Transducers of SBES can either be fixed on the ship's hull or have portable arrangement on boats/ survey crafts. In the coastal area of Bangladesh portable arrangement of transducer is widely used on board survey motor boats as the area is generally shallow. Performance of these Echo Sounders depends on many factors such as turbidity, tidal stream, turbulence of water, bottom configuration, prevailing environmental condition etc. Sometimes, Echo Sounders are unable to provide depth information due strong tidal stream, turbulence and other local factors prevail in the area. Surveyors need to be very cautious all the time to understand the situation and tune his Echo Sounder as appropriate. Sometimes, it is very difficult to determine the actual bottom due to the presence of a column of soft mud near the sea bed. Dual frequency Echo Sounder helps in this situation to determine the actual bottom. Again, high turbidity in the water degrades the quality of data. It can be mentioned here that during ebb tide, turbidity is more as suspended sediments comes from upstream. So, during the 3rd/4th hour of ebb tide when the tidal stream is also more, the performance of Echo Souder is highly affected. Sometimes the surveyor is forced to stop the data acquisition and wait for favorable condition.

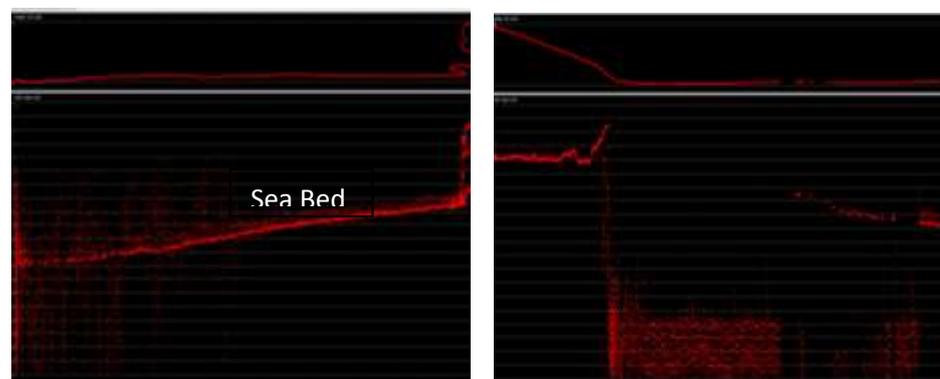


Figure 2. These two echograms were taken from a SBES profile near Sandwip Island where turbidity was very high and the tidal stream was very strong. First echogram indicates the presence of noise which needs to be cleaned during processing. Second echogram indicates that bottom was lost and Echo Sounder was unable to provide sounding. These are very common phenomenon in the area.

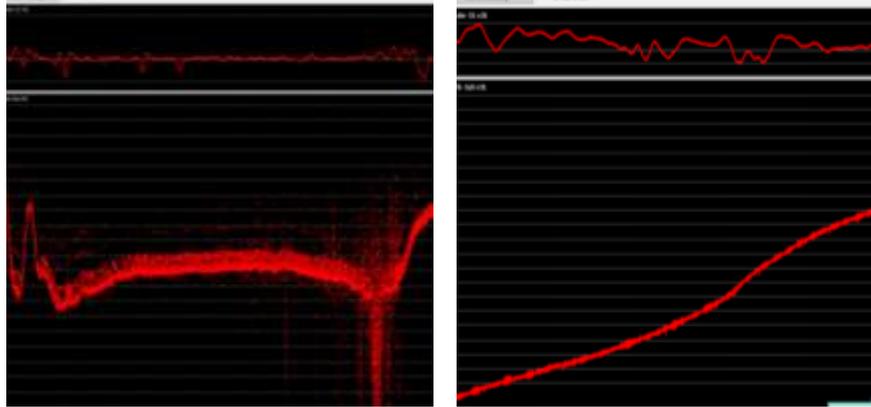


Figure 3. First echogram was taken in Meghna Estuary where the sea bottom composed of soft mud. The image of the sea bottom is almost 2m wide. So, it is very difficult to find the actual bottom here. In this echogram there are lots of noises also due to the presence of high turbidity. Second echogram was taken down Cox's Bazar area where water is clean. The clean image of the echoaram also confirms that there was no turbidity in the area.

4.1.2 Multi-Beam Echo Sounder (MBES)

Now-a-days, MBES is extensively used in hydrographic survey operations. It gives detail information of the sea bed and many hydrographic offices prefer to use this equipment at least for some important places of their waters like port & harbor area, their approaches etc. Performance of this equipment in the coastal area of Bangladesh is highly affected by the local conditions. Due to the inhomogeneous mixing of fresh and salt waters, sound velocity profile is unusual which affects the performance of this equipment significantly. Again, due to turbidity, optimum swath coverage is not attainable as the beams are concentrated towards the center. Quality of data is not also good and it requires extensive cleaning during processing. Like SBES, MBES also gives better performance during flooding when turbidity is comparatively less in the area.

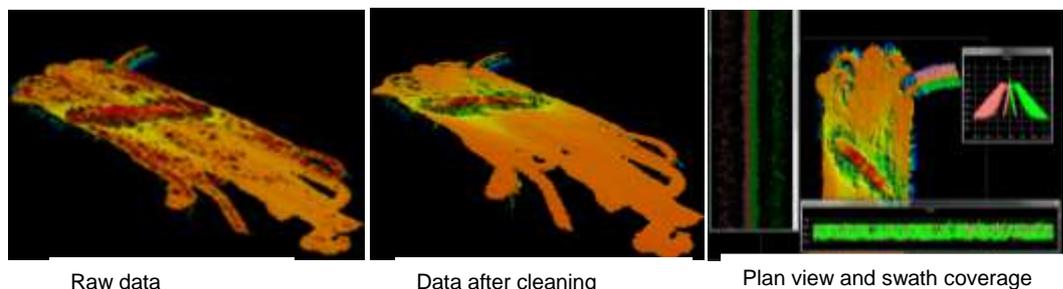


Figure 4. This MBES data was collected from Chittagong Port anchorage area at a depth of 9m during ebb tide in the month of April when the upstream discharge was quite high. Due to the presence of high turbidity and unusual salinity profile, the raw data has got lot of noise. Even after extensive cleaning the image of the wreck is not smooth enough. In the plan view, it is evident that beams are also concentrated towards the center and swath coverage is 12m only. As per the equipment specification, the optimum swath coverage at 9m depth should be 90m.

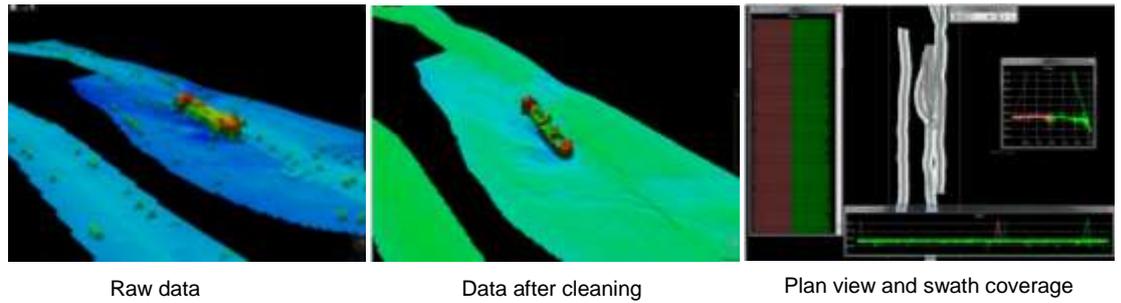
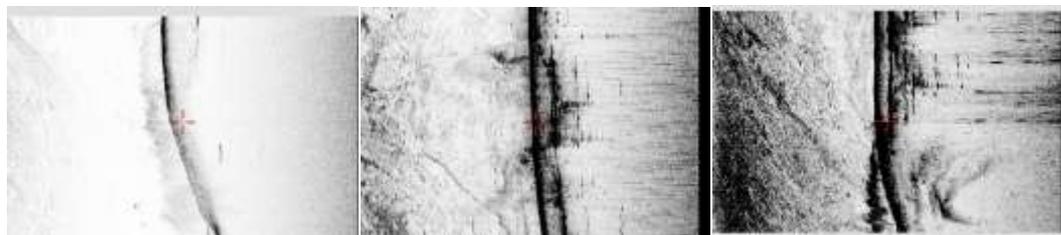


Figure 5. This MBES data was collected near Cox's Bazar at a depth of 9m during flooding in the month of February when the upstream discharge was less. During this time turbidity was less in the area. The raw data has got less noise and the image of the wreck is quite smooth after cleaning. Here the swath coverage is almost 46m which is far better than the previous case.

4.1.3 Side Scan Sonar (SSS)

To comply SP-44 special order and order 1(a) survey full sea floor search is required during bathymetric survey. SSS plays very important role for under water search and detection of wrecks, obstructions etc. The performance of this equipment is also dependent on the environmental conditions. Image of SSS is not clear enough if the turbidity is very high. Operating range of the equipment also reduces remarkable in such cases. Moreover, due to the presence of fishing gear all around the coastal area, it is not safe to operate the equipment in shallow waters. To overcome these limitations low upstream discharge period is selected for SSS search and the area is cleaned before lowering a towfish in the water.



Edge Tech 4125 (400-900 KHz)
Range 43.8 m to Stbd

Edge Tech 4200 (300-600 KHz)
Range 57.3 m to Stbd

Edge Tech 4200 (100-400 KHz)
Range 73.8 m to Stbd

Figure 6. The above SSS images were taken at Chittagong outer anchorage on a known wreck where turbidity is exceptionally high. In ideal condition, the definition of an image collected using higher frequency would be better. Here the third image which is collected using lower frequency is better visible than other two. Transmitted energy is much absorbed by turbid water for higher frequency. For that reason, even the first image is taken from a closer distance, is not clear enough. Sometime, the performance of high frequency equipment degrade so much that the image is not visible at all.

4.1.4 Current Profiler

In most of the hydrographic survey Current Profiler is deployed for measuring tidal stream to show it on nautical charts. Sometimes, the quality of data is affected due to the local conditions and noise to signal ratio is much more than the normal level. Again, it is very difficult to deploy the equipment as the tidal stream is exceptionally strong in some places of the coast. Sometimes, the equipment is also swept away by fishing gear. So extra precaution is always needed while deploying this equipment.

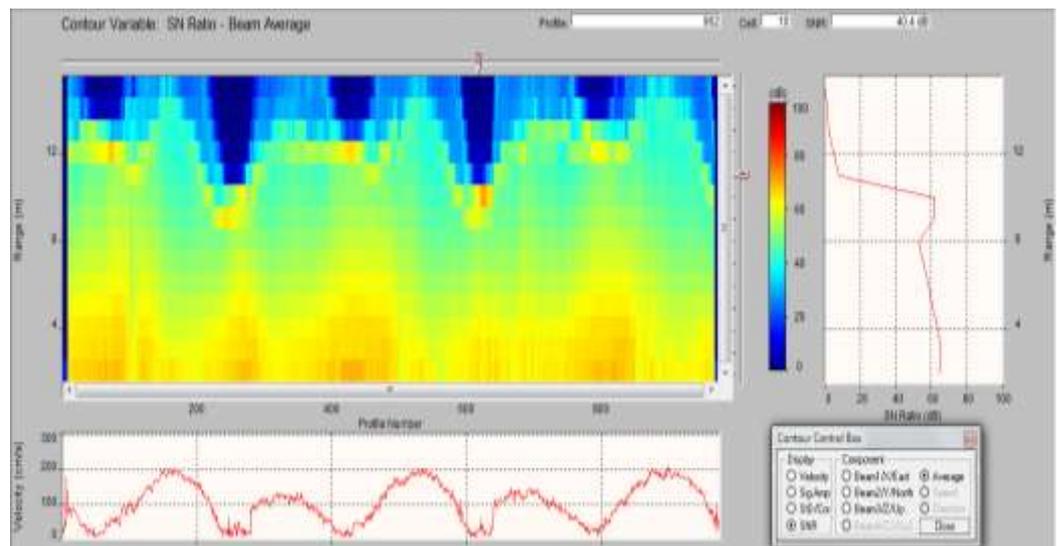


Figure 7. The above profile is taken by Sontek Current Profiler (500 KHz) near to the coast of Bangladesh. In that image current velocity and Signal to Noise ratio (SNR) is visible. Maximum profiling range of this equipment is 120 m in ideal condition. Data less than 3dB cannot be used as it determines the maximum profiling range of the equipment. Here we can see that SNR is close to 0 dB beyond 10m-12m depth. Again, during slag water, the cut off line for 3dB extends beyond due to the presence of high turbidity in the water columns.

4.2 Re-survey/Check Survey

As the area is very dynamic, frequent check/re-survey is very common in the coastal area of Bangladesh. The area has high risk of grounding if the mariners do not follow the latest charts available by the national hydrographic office. Sometimes, even the main shipping channels are also shifted within a very short span of time. So, it becomes very difficult for the national hydrographic office to manage the area with limited resources. Moreover, time available for survey operations is also very short due to monsoon and other local factors mentioned before. Hydrographic office always remains busy to plan the survey activities of the area in the most effective way to keep it safe for the mariners.



Extract of INT 7426 (Edition 2) published in 2015



Extract of INT 7426 (Edition 1) published in 2011

Figure 8. The extract of INT 7426 is showing the approaches of Mongla Port. Marked change of bathymetry is visible in the two images. These changes took place within a time span of 3-4 years only. Number of grounding also reported in the area in last few years only for not following updated charts.



Extract of BA 859 (2002)



Extract of BN 40001 (2009)

Figure 9. The area represents the main shipping route for Chittagong port. On 28 March 2010, MV St Kiril was grounded in position $21^{\circ}35.4' N, 091^{\circ}44.8' E$ where BA 859 chart is showing a depth of 14m. However, bathymetry in that area changed remarkably over the period and the recent edition chart published by BN indicates lesser depth in the same position. The vessel grounded for not following the most updated chart available for the area.

4.3 Unsuitability of Modern Surveying Techniques

Hydrographic survey is a very costly affair. Surveyors remain in the survey ground day after day with their vessels and work day and night to get data for producing nautical charts. Presently, there are some modern techniques like LIDAR, Satellite

Derived Bathymetry etc. available which has eased some of the survey operations. These techniques have the inherent advantages of collecting data with less cost and time. However, these techniques are not suitable for Bangladesh coast due unclear water heavily loaded with sediment.

5. Approach to the Problems

As discussed above, it is evident that the hydrographic survey is not an easy task to perform in the coastal area of Bangladesh. However, as a signatory of the SOLAS convention, Bangladesh is committed to provide updated information to the mariners as per the standard specified in SP 44. Following aspects are always considered both by national hydrographic office and the surveyors while surveying in this dynamic environment:

- To ensure quality of bathymetric data extra efforts are provided for measuring sound velocity profile, tide and tidal stream in the area. Sound velocity profiles are collected at short distances to minimize the error. Much time is also dedicated to measure the tide and tidal stream.
- Frequent check survey/re-survey is undertaken to identify changes so that the mariners feel safe while navigating in the area.
- The whole year is not suitable for survey operations for various factors prevail in the area. To overcome this fact, increased numbers of survey platforms are being used during the suitable time of the year. Mentionable here that BN uses 05 survey ships/crafts to cover a small area of her jurisdiction. In ideal condition, the same resources could be used for much bigger area in other parts of the world.
- Most of the equipment does not function to their optimum capacity in the area. To overcome this limitation, only quality equipment is used. Best results are achieved once this quality equipment is used with a blend of dedication, commitment and experience of surveyors.
- BN puts extra effort for training activities. Most of the time of the year is dedicated for training which makes the surveyors confident and fit for this dynamic environment.

6. Conclusions

Being situated in the deltaic region, coastal area of Bangladesh is very dynamic. Siltation, shifting of channels, emergence of new islands/LTE etc. are very common phenomenon in the area. Apart from few common deltaic conditions, there are many local conditions which are peculiar to this area only. The coastal water is exceptionally laden with sediments coming from upstream and thereby, turbidity is extremely high. Monsoon in the region causes extra rain fall which makes the situation more complex. Seasonal cyclone adds another dimension to the complexity of the area.

Salinity in the area is not homogeneous. Temperature profile also varies from place to place. It is very difficult to quantify the changes of these two parameters in the coastal area of Bangladesh. High turbidity degrades the performance of survey equipment. Even the most sophisticated state of the art hydrographic equipment does not function as designed. Measurement of tide and tidal stream is another difficult task in the area. Deployment of various survey equipment like Current Profiler, Auto Tide Gauge, SSS etc. is very difficult and safety of these equipment is a major concern for the surveyors. All these factors put extra difficulty to the surveyors while conducting hydrographic survey in the area.

As a signatory to the SOLAS convention, Bangladesh is committed to provide up to date information to the mariners. Frequent re-survey/ check survey are conducted to delineate the changes. Extra efforts are provided for measuring sound velocity and temperature profile while conducting hydrographic survey. Additional resources are used for comparatively smaller area. Extensive training activities are conducted to keep the surveyors at par with the situation. Above all, the prudence, professionalism and dedication of the surveyors are the most important factors for the successful hydrographic management of the area.

Biography of the Writer



Commander Sheikh Firoz Ahmed, (H1), psc, BN joined Bangladesh Navy on 01 Jul 1992. He received gold medal for his outstanding performance during naval officers basic training. He completed his Cat B hydrographic course from 'Ecole des Hydrographes', EPSHOM, France. He also completed his Cat A Hydrographic course from National Institute of Hydrography, India. He obtained his Masters in 'Hydrographic Surveying' from Goa University, India with distinction. He is a graduate of Defence Services Command & Staff College, Mirpur, Dhaka.

Commander Firoz commanded number of BN Hydrographic ships including BNS DARSHAK, BNS TALLASHI, BNS AGRADOOT and BNS SHAIBAL. During his tenure on board BNS TALLASHI and BNS AGRADOOT, he conducted bathymetric surveys in the western area of Bangladesh coast near Sundarban mangrove forest. As the commanding officer of BNS SHAIBAL, he conducted number of shallow water hydrographic surveys in the central and east coast of Bangladesh. He was involved in the survey of newly built Payra port approaches which is a very dynamic area of Bangladesh coast. Cdr Firoz also served at Naval Headquarters as the Deputy Director of Hydrography. There he was involved in the planning of hydrographic activities as well as the management of BN hydrographic resources. He was a United Nations peace keeper in DR Congo. Presently, he is serving as the Commanding Officer of BNS ANUSHANDHAN (Ex-HMS ROEBUCK), a purpose built Hydrographic Survey vessel of Bangladesh Navy.