Analysis of Sediment Accumulation and Decumulation Pattern by Means of Bathymetric Surveys: A Case Study in Beruwala Fishery Harbour

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Abstract – Hydrography is one of the main branches of surveying. In the modern world, the hydrography field plays a major role in safe navigation purposes and seafloor mapping. Bathymetry survey is the science of identifying and preparing charts about the behaviour of the ocean's floor. Also, bathymetric data provides an important foundation for the process of generating profiles of the seafloor, charts for safe navigation, coastal area erosion/accretion, sea-level variations, and so on. Due to the waves and currents, the sediments are transporting along the seabed and the seafloor may differ continuously. Therefore, hydrographers should collect hydrographic data for safe navigation purposes and other oceanographic requirements. The present study mainly focused on sediment accumulation and decumulation patterns utilizing bathymetric surveys in the Beruwala fishery harbour. The bathymetric data were collected by using a single beam echo-sounder in February 2012, September 2013, August 2017, and February 2019. Further, sand volumes were calculated by time series of bathymetric data using ArcGIS software with several tools (IDW, etc.) and results shows that sand accumulation is evident in February 2012 and February 2019. Further, sand decumulation is obvious in September 2013 and August 2017. Based on the obtained results, sand accumulation inside the harbour is evident during the northeast monsoon season and sand decumulation is evident during southwest monsoon season. So, this information is important for the maintenance of the harbour basin.

Keywords: *bathymetry, hydrography, monsoon, single beam echo sounder*

I. INTRODUCTION

Sri Lanka is an island in South Asia, located in the Indian Ocean to the southwest of the Bay of Bengal and to the southeast of the Arabian Sea. The nation has a total area of 65,610 km^2 and it belongs 64,740 km^2 of land area and 870 km^2 of water bodies. As an Island, it has a beautiful coastline around the country and its length is 1,340 km (830 mi).

The ocean provides an important act towards the growth of the economy of the nation. Moreover, it provides transportation around the ocean, helping to bind the various nations with import and export business, awareness of bathymetry as the primary basis for introducing practices related to structures in marine areas such as pipeline laying, infrastructure, oil drilling, port structures, dredging, aquaculture, management, fishing, etc. The determination of seafloor structural behaviour changes in sediments and planning of navigational bathymetric behaviour secure transport maps are also important and underwater depth information carries a similar significance.

Maintenance dredging to widen or retain navigable waterways or channels that owing to sedimented sand and mud, are threatened to become silted over time, likely making them too shallow for navigation. This is also done with a hopper dredge for cutter suction. Dredging land reclamation from the seabed to mine sand, clay or rock and using it to create new land elsewhere. Beach nutrition: underwater sand extraction and positioning on a beach to replace sand which are eroded by storms or wave action. This is done to strengthen the function of the beaches for leisure and safety, which can be destroyed by human activities or storms. Sediment volumes can be estimated to determine the level of sediment accumulation in a navigation channel, given multiple sets of bathymetric survey data and the modelling of seafloor levels.

According to El-Hattab (2014), many ports and harbors have dredged channels, berths and anchorages, which suffer from siltation, thus reducing the depth of water usable for shipping. Ports work with a minimum under keel clearance that must be retained by a ship transiting to a port. Routine maintenance dredging refers to the excavation from channel beds of accumulated sediments to preserve the design depths of current public-use structures. The thickness of the layers that will be removed during maintenance dredging is fairly thin. According to El-Hattab (2014), accurate determination and modelling of the seafloor levels are essential to avoid unnecessary over-dredging and extra costs. Therefore, with a view to providing some of these kinds of facilities Ceylon fishery harbor was established. For conducting these types of facilities, the bathymetric survey should be conducted for an all over the country. That can materialize inside the harbor or navigational channel etc.

II. BACKGROUND OF THE PROBLEM

It is a well-known fact that Sri Lanka has a four different monsoon seasons during a year. Due to different types of monsoon seasons, the behavior of nearshore and offshore areas of the ocean is continuously changing those completely affecting to the country's' ocean related activities such as fisheries, transportation, recreation, tourism, etc.

Furthermore, the waves those are converts to currents after the breaker zone and those currents can be categorised as longshore currents and cross-shore currents. Mainly, the longshore currents are caused to sediment transport to inside the harbor basins. That is a huge problem of harbors in Sri Lanka.

For the efficient harbour operations, it wants to maintain a required constant depth (e.g., 2.5m–3.0m) in harbour basin mainly to safe docking purposes of ships and boats. That constant depth maintains by using dredging procedures with the help of bathymetric surveys. The bathymetric data of the harbour basin that can be used to calculate the sand volume by using existing volume calculation methods (using manual method and software like ArcGIS, Surfer etc.) Beruwala fishery harbour is located in southwest coast of Sri Lanka and the seasonal sand accumulation into the harbour basin experienced there can be identified as a main problem.

Moreover, this research mainly focuses on analyzing and calculating sand volume inside the harbour basin using existing bathymetric data and give recommendations to reduce accumulation of sand into Beruwala fishery harbour.

III. PROBLEM STATEMENT

Temporal sand accumulation and decumulation of fisheries harbors have severely affected to harbor operations and that has increased the cost of maintenance.

IV. LITERATURE REVIEW

Principle of Acoustic Depth Measurement

According to El-Hattab (2014), Depths are usually measured by echo sounders using either single-beam (SBES) or multi-beam (MBES). SBES is now the most common instrument used in port and port surveys and when used properly in a well-designed and conducted survey, will continue to provide accurate results.

According to Stephenson (1970), it is very important to realize than an echo sounder does not, and cannot, measure depth. For that echo sounders measure time taken for a pulse of sound to travel from a transmitter to the seabed and back this time interval is then converted to depth by multiplying it by the velocity of sound on water, thus

- Depth = ½ *v*t

D = Measured depth is between the transducer and some point on the acoustically reflective bottom.

v = Mean velocity of sound in water

t = time taken for pulse to travel to the seabed and back

Depth corrected to referenced water surface

- $d = \frac{1}{2}(v*t) + k + dr$

If the velocity of sound propagation in the water column is known, along with the distance between the transducer and the reference water surface, the corrected depth (d) can be computed by the measured travel time of the pulse.

where:

d = corrected depth from reference water surface

v = average velocity of sound in the water column

t = measured elapsed time from transducer to bottom and back to transducer

k = system index constant

dr = distance from reference water surface to transducer (draft)

The parameters v, t, and dr cannot be perfectly determined during the echo sounding process, and k must be determined from periodic calibration of the equipment. The elapsed time, t, is dependent on the reflectivity of the bottom and related signal processing methods used to discern a valid return.

According to Bouwmeester and Heemink (1993), purpose of conducting a hydrographic survey is to obtain a predefined accurate insight of the characteristics of the sea bottom. Also, these activities fully depend on the information about the seabed. Those activities are Nautical charting, Maintenance and control of harbor approaches of deep draft shipping routes, Optimization of dredging operations, Scientific marine research etc. Not only that, from hydrographic data we can analyze and identify sediments volume that accumulated inside the harbor basin, sediments volume that decumulate from the harbor basin, monthly sediment transport rate along the coastal belt, etc.

Two fishery harbors, namely Beruwala and Hikkaduwa are located in southwestern coast of Sri Lanka. According to Samaranayake (2019), thirty-six sediment samples were collected systematically using a grab from Beruwala harbor for analysing grain size. The mean grain size of the Beruwala harbor varied from 1.83mm to 4.19mm and the average was 3.08 in phi scale indicating that most of them belonged to the fine to very fine sand range.

These sediments travel moving to the offshore due to the energetic cross shore currents. Normally during north-eastern monsoon period most of sediments come from offshore due to the calm weather condition. Also, during that period, the wave consists of low energy. Sediments around Beruwala harbor vary fine to very fine sand range. The mean grain size is varying from 1.83 mm to 4.19 mm. Therefore, the sand inside the Beruwala fishery harbor is traveling most recently from inside and outside of the harbor basin.

V. EXPERIMENTAL DESIGN

Study Area

The study area of research project is focused on Beruwala fishery harbor situated in the western province in Kalutara district, bordering to the Southern end of the western province. Entering position is given by 142089.2 N & 112124.9 E (National Grid Coordinates). Beruwala fishery harbor consists of 4.6 Ha of land area and the 11.99 Ha of the basin area. Also, this harbor maintains a constant depth like 2.5 m – 3.0 m for docking their boats.

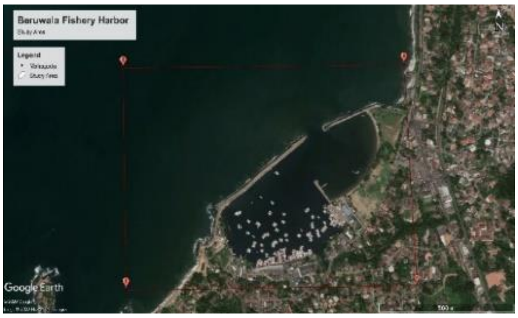

Figure 1. Study Area

VI. METHODOLOGY

Table 1. Calculated sand volumes above the reference plane (-4.27)

Data Set	Calculated Sand Volume above the reference Plane	Sand Accumulate or Decumulate
February 2012	172150 m^3	Accumulated
September 2013	171234 m^3	Decumulated
August 2017	147589 m^3	Decumulated
February 2019	182885 m^3	Accumulated

Main objective for this research is assessing sand accumulation and decumulation pattern in Beruwala fishery harbor by means of existing bathymetric data. For that, author used four different bathymetry data sets which are collected in different monsoon time periods using single beam echo sounder. These four different data sets were collected according to February 2012, September 2013, August 2017, February 2019 respectively. In order to gain an understanding of the accumulation and decumulation pattern in fishery harbor, data were processed by using Arc GIS software.

Therefore, by using Arc GIS software create a unique polygon for all the data sets. Now all the data points are covered by that unique polygon. If not, the study area is going to change with different data sets. Because bathymetry data were not collected for a unique area. By using IDW tool we can convert those points into one raster image. Likewise, four different rasters were created four different data set.

Volumes were calculated with one reference plane. That reference plane is the plane that travels through the deepest point (-4.27) of all the data sets.

By using IDW tool in ArcGIS software and from that a raster surface may be interpolated from points.

For a raster, triangulated irregular network (TIN), or terrain dataset surface, we may generate contour lines. In here, contours created by using raster image and contour interval is 0.2 m. After running the surface volume tool, it measures the volume between a surface and reference plane. By analysing amount of sand volumes with different datasets, we can calculate monthly rate of sediment transport.

VII. RESULTS

The calculated sand volumes above the reference plane (-4.27 m) are as follows,

We can identify those sediments accumulated inside the harbor premises during February 2012 and February 2019. Also, sediments decumulated from the harbor basin during September 2013 and August 2017. With respective to February 2012 September 2013 provide that it was evident -916 m^3 sediment decumulate from the harbor basin. Furthermore, comparing with August 2017 gives -24,561 m^3 sediment decumulated from the harbor basin. Those data have been collected during the southwest monsoon period.

Finally, February 2019 data set provide 10,735 m^3 sediment accumulated into the harbor and belongs to the northeastern monsoon period.

Table 2. Monthly volume transport rates with respect to 2019

Data Set	Number of months between two datasets	Sand Volume (m^3)	Volume Transport rates with respect to 2019 (m3/month)
February 2019		182885	
	18		1960.889
August 2017		147589	
	47		179.246
September 2013		171234	
	19		127.798
February 2012		172150	

Above Table 2 shows, monthly volume of sediment transport rates during February 2019 to February 2012.

Above monthly volume transport rates calculated by difference between volumes with respective two data sets divided total number of months between those two data sets.

M.V.T.R =(Volume of 2019 – Sand volume of another dataset) (Number of months between two datasets)

Table 3. Volume transport rates with respect to 2012

Data Set	Number of months between two datasets	Sand Volume (m^3)	Volume Transport rates with respect to 2019 (m3/month)
February 2012		172150	
	19		48.210
September 2013		171234	
	47		372.136
August 2017		147589	

The Table 3 shows, monthly volume of sediment transport rates during February 2012 to August 2017. We are moving from February 2012 to September 2013 the monthly sediment transport rate is 0.48×10^2 m^3 per month. The sediment transport rate is given for 19 months. When we move from February 2012 to August 2017 the monthly sediment transport rate is 3.72×10^2 m^3 per month. This amount of sediment transport rate is given during 66 months of time period.

According to Chandramohan et al., (1990),Longshore transportation along the west coast of Sri Lanka occupies the south from January to March and the north May to December. The annual gross transport rate is lower all over the Sri Lankan coast and the southern portion of the coast is estimated to be lower.

VIII. DISCUSSION

A, Different monsoon changes around the coastal belt.

During southwest monsoon period the sea around western part of Sri Lanka is going to be rough. The currents and waves happen very frequently. Therefore, during this time there is no sediments deposition around coastal belt due to energetic waves and currents. All the sediments travel to the offshore area. But during Northeast monsoon we can see a calm sea around western part of Sri Lanka. During this time period sediments travel from deep sea to coastal areas with the help of waves and currents. During that time period sediments can be deposited and accumulated inside to the harbor.

B. Sediments accumulate from the Beiray river straightly to the harbor basin.

The small drainage river called Beiray river is situated in Beruwala Area. This is a type of drainage river which goes to the Beruwala fishery harbor. During Southwest monsoon time period, the average rainfall is high in Beruwala area. Therefore, sediment moves to the offshore due to the energetic waves. When the rain falls, the sediments come from the land and most of them move to the offshore due to energetic cross shore currents. Normally, low rainfall occurs during Northeastern monsoon time period. So, less amount of sediment come from the land side. But most of sediments come from offshore due to calm weather condition. Due to the low energetic wave's sediments coming from the offshore to the harbor basin. The sediments came from the land area also traveling through this process too. Therefore, sediments get accumulated during northeastern monsoon period.

C, Sediment characteristics of Beruwala fishery harbor.

According to Samaranayake (2019), the mean grain size of the Beruwala fishery harbor varied from 1.83 mm to 4.19 mm and the average was 3.08 in phi scale indicating that most of them belongs to the fine to very fine sand range. Sediments around Beruwala harbor can usually be transported by currents. Because those sediments are not very coarse or coarse. Depending different type of monsoon periods, the travelling process of sediments is going to change.

D. Due to waves, currents and tides.

Waves, currents and tides contribute greatly to the redistribution of the sediments supplied to the depositional inside to the harbor basin according to Saravanan & Chandrasekar (2010). Waves are found to provide the necessary energy for the movement of water and sediments within the nearshore zone. Depending on the energy of waves, currents and tides the sediment can be easily accumulated and decumulated from the harbor basin. During north east monsoon time period the Beruwala area consists of a calm sea weather condition. Therefore, sediments accumulate inside to the harbor premises during that period. During southwest monsoon time period, the energy of waves and currents is high in Beruwala area. Therefore, most of beach sediments are traveling to offshore by energetic currents and waves.

IX. CONCLUSION

Mainly, there are four types of reasons for sand accumulation and decumulation in Beruwala fishery harbour. Those are; (i) Different monsoon changes around the coastal belt, (ii) sediments accumulate from the Beiray river straight to the harbor basin, (iii) sediment characteristics of Beruwala fishery harbor and (iv) due to waves, currents and tides.

To prevent sand accumulation inside to the harbor we can suggest some engineering plans for harbors. One of them is preparation of suitable break water. From that we can protect harbor from storm waves. Prepare some artificial harbor. From that harbor having no natural protection but artificial arrangement is made to protect the harbor from storm and wind. sand accumulation and decumulation of fisheries harbors and harbors have severely affected to harbor operations and that is increased the cost of maintenance. From these kind of construction projects, we can minimize sand accumulation and decumulation inside to the harbor. Accordingly, we can minimize the cost of maintenance of the harbors.

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