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Geomorphological Evolution and Vulnerability of Low-Lying Coasts in Bangladesh:

The Case Study of Sandwip Island

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DEDICATION

For my **beloved Mother** (Mohsena Khaatun), without whose love, blessings and care, I would not be where I am today.

For my **beloved Father** (Late Md Obaidul Hoque), who taught me "always keep busy working with something, even whe there's nothing to do".

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Finally, to **my respected mentor**, Professor Dr. Paolo Ciavola, without his help and continuous guidance, this would have never been possible.

ORIGINALITY STATEMENT

‘I hearby declare that this submission is my own work and to the best of my knowledge, it contains no materials previously published or written by another person for the award of any other degree at UNIFE or anyother educational institute, except where due acknowledgement is made in this thesis. Any contribution made to the research by others, with whome I have worked at UNIFE or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this work is the compilation of my own works, except to the extent that cooperate from others in the project design or in style, field works, presentation and linguistic expression is duly acknowledged.’

Signed **Date**

PREFACE

Most coastal areas are highly fragile, as they are constantly subjected to high physical energy imparted by varying degrees of wave, tide and current activities. Coastal areas like those in Bangladesh have been in more concern for their alarming huge and quick geomorphodynamic changes due to some more hydrometeorological effects like floods, cyclones and erosions etc. Increasing climate change induced vulnerability like Sea Level Rise (SLR) has been making the situation worse day by day. In order to properly interpret the hazardous mechanisms to set up a time demanding management and precautionary system towards reducing the vurnability to disasters, there is a need for a thorough understanding of the geomorphological evolution, hydro-meteorological setting, socio-economical and ecological status of the target area. Community perception and indigenous coping strategies are a well accepted approach worldwide for adaptation to climate induced disasters.

This particular study involves a comprehensive approach to understanding the situations making the erosion and storm surge prone Sandwip Island one of the most risky places to live.

The first chapter introduces the work structure, study background, objectives and motivation of the work while chapter two briefs on the study area geography, geo-morphology, socio-cultural and socio-ecological characteristics. A brief historical flash back and hydrodynamics around the island form part of this chapter.The materials and methods used in the research works are briefly described in chapter three.

In the chapters four and five, the results are summarized and the outcomes are discussed which ultimately aim at the objective of the project. Chapter four is composed of the results and discussion on the geomorphological, land use pattern changes and tidal variation status while the risk assessment by public perception and the copying strategies practices in the community are enclosed in chapter five. Finally, the conclusive remarks are outlined in the sixth chapter with useful recommendations for further use of the results.

The last chapter deals with the references of the extensive literature review on the studies, reports and documents which were found to be helpful to develop the project, to enrich the understanding of the works, to verify the results, to get useful information and also to follow the methods used during the mission.

In connection with the thesis, the following research papers have been published in the respective conference proceedings after presentation in international meetings:

Uddin, M.M. & Ciavola, P. 2012. Geomorphological Evaluation and Coastal Changes of Sandwip Island, Eastern GBM Delta, Bangladesh. Conference Proceedings: ITALY-CINA: AN ANCIENT CULTURAL HERITAGE AND THE CHALLENGE FOR FUTURE DEVELOPMENT, Bologna, Italy, 22 - 23 October 2012 (ISBN 978-88-6155-515-0), p181-188.

Uddin, M.M. & Ciavola, P. 2013. Sediment characteristics and Coastline Change of a Low-lying Island (Sandwip) in the Eastern GBM Delta, Bangladesh. Proceedings of ANDROID Residential Doctoral School Work Package III, Limassol, Cyprus, 23-24 October 2013 (ISBN 978-1-907842-52-8), p56-65.

Ciavola, P., **Uddin, M.M**., Duo, E., Lee, B. and Fakhruddin, S.H.M., 2015 (Accepted). Vulnerability of Bangladesh Coastline to Inundation under Cyclone Activity: Past Records and DRR Strategies at Sandwip Island. E-proceedings of the 36th IAHR World Congress, 28 June – 3 July, 2015, The Hague, the Netherlands.

ABSTRACT (ENGLISH)

Bangladesh is ranked as the "5th most at-risk country" in the world in terms of disasters with a world risk index of 20.22% in the World Risk Report 2012. Coast and island flooding induced by extreme storms and cyclones born in the Northern Indian Ocean passing through the funnel shaped shallow northern Bay of Bengal are the most dangerous natural hazards in the area. Additionally, remarkable geomorphological change of the lower GBM active delta and relative Sea Level Rise (SLR) have drawn special attention to the environmental scientists and respective managers for the alarming more intense and more frequent upcoming climate change vulnerabilities. The Lower Meghna River Estuary (LMRE) is an extremely dynamic estuarine system with dramatic geomorphological changes of the offshore islands. The erosion and accretion rates are remarkably high and the islands are reducing their original size. As populations flock to the coast and offshore islands at threat from erosions, storm inundation and sea level rise, intensive studies must be carried out on the vulnerability of these coastal regions.

Sandwip Island, located at the confluence of the Lower Meghna River Estuary, shaped and characterized by both tidal actions of the Bay of Bengal and river streams of the Meghna, was chosen as the only international case study site outside Europe in the framework of the Risc-KIT FP7 European project (http://www.risckit.eu/). The project aims to develop tools and methods to reduce risk and increase resilience of coastal areas. The toolkit will be implemented for each case study.

The present works aims to describe the state of the art of knowledge on the island covering geomorphology, sediment characteristics, hydrodynamics and socioeconomics. Community perceptions and indigenous coping strategies aspects of the island are included in a coastal vulnerability perspective to be useful in further research, development of effective preparedness, management and actions plan. To reach this goal, an attempt was taken to find out the answers to the following questions: 1) What is the status of geomorphological changes? 2) What are the sediment characteristics of the erosion-accretion prone shorelines? 3) What is the status of the sea level rise relative to the island 4) What is the total vulnerability/hazard ranking by local perceptions? 5) How much has the land use changed due to erosion and associated hazards ? and finally 6) What strategic changes should be taken?

The research questions were answered using topographic surveys, lab based sediment analysis, tide gauge data analysis, erosion-accretion mapping and development of high resolution DEM and TIN using Remote Sensing and GIS-based tools and techniques and questionnaire survey results interpreted with national disaster management plans.

The study found that the island is more physically prone to coastal erosion, coupling with storm surges and sea level rise making it more vulnerable in future. The erosion rate considering both shoreline and area changes is much more intense exceeding accretion in the silty clay sedimentary parts and the sea level rise trend is alarming in comparison with other nearby coastal areas in Bangladesh. Tidal data analysis for Sandwip shows semi-diurnal components higher in amplitude than Chittagong. Diurnal amplitudes are comparable and phases are generally higher for Sandwip with a 47 minute delay than Chittagong. The DEM demands more intensive bathymetric information that should be used for more accurate hydrometeorological models for the low elevated island, where as the island is almost flat with the average topography is only 5 meter above MSL and the north-western part is slightly higher than the south-western part as observed in the TIN justified by Topographic survey. The physical assets have been declining stressing on the socioeconomy of the community as found by the social survey as well as land use satellite mapping.

So, a relatively high earthen embankment encircling the island, a crossdam connecting north side of the island to mainland are immediately needed to protect the community from erosion as well as relative sea level rise and storm surge inundation hazards. A site specific hydrometeorological warning should be developed and announcement dissemination should be maintained in the local language. Development of roads and transportation system and the health training should be enhanced to make people more aware and adaptive with the associate disasters.

ABSTRACT (ITALIANO)

Il Bangladesh, classificato come quinto paese a rischio di disastri naturali, presenta un indice di rischio pari a 20.22% (World Risk Report 2012). I disastri più pericolosi dell'area risultano essere le inondazioni costiere causate da temporali e cicloni che si formano nell'Oceano Indiano e si dirigono verso la parte nord del Golfo del Bengala caratterizzata da acque poco profonde. Inoltre, scienziati e manager ambientali si stanno concentrando sull'area a causa dell'incremento della vulnerabilità dovuto al cambiamento climatico ed alla morfo-dinamica del basso delta GBM. L'estuario del basso fiume Meghna è un sistema estremamente dinamico con cambiamenti geomorfologici drammatici delle isole al largo. I tassi di erosione e deposito sono notevolmente alti e le isole si riducono in area. Poiché le popolazioni locali si riversano sulle coste e sulle isole minacciate dall'erosione, dalle inondazioni e dall'innalzamento del mare, sono necessari studi intensivi per la stima della vulnerabilità di queste zone.

Sandwip, isola situata alla confluenza del Meghna, modellata dall'azione della marea del Golfo del Bengala e dalle portate del fiume, è stata scelta come unico caso studio internazionale del progetto europeo FP7 Risc-KIT. L' obiettivo del progetto è sviluppare ed applicare ai casi studio una serie di metodi e strumenti per ridurre il rischio ed aumentare la capacità di ripresa delle zone costiere.

Questa Tesi di Dottorato ha come obiettivo di descrivere lo stato dell'arte delle conoscenze dell'isola in termini geomorfologici, sedimentari, idrodinamici e socio-economici. Nello studio sono incluse analisi della percezione del rischio da parte delle comunità e delle loro strategie di adattamento, in un'ottica di analisi di vulnerabilità per sviluppi futuri di ricerca, creazione di piani di management del rischio e di azione. Per raggiungere l'obiettivo, le domande di riferimento cui il Progetto di Dottorato ha cercato di rispondere sono: 1) qual è lo stato dei cambiamenti geomorfologici? 2) qual è lo stato sedimentologico della costa? 3) qual è lo stato dell'innalzamento del livello del mare? 4) qual è la percezione locale della vulnerabilità e del rischio? 5) quali cambiamenti dell'uso del suolo sono intervenuti a causa del rischio erosivo ed altri rischi associati? Ed infine, 6) quali cambiamenti strategici devono essere adottati?

Per rispondere a tali domande, sono state applicate svariate metodologie come rilievi topografici, analisi sedimentologiche di laboratorio, analisi dei dati ricavati da un mareografo, mappatura dell'erosione e del deposito, sviluppo di un DEM ed un TIN ad alta risoluzione tramite tecniche di telerilevamento e strumenti GIS, questionari per i residenti interpretati alla luce dei piani nazionali di gestione del rischio.

Lo studio ha dimostrato che l'isola è incline all'erosione che, in aggiunta all'innalzamento del mare dovuto ai cambiamenti climatici ed agli eventi atmosferici, aumenta notevolmente la vulnerabilità dell'isola. Il tasso erosivo, considerando le variazioni della linea di costa e dell'area dell'isola, è più intenso del tasso di deposito nella aree nord-ovest ed il trend dell'innalzamento del mare è allarmante a confronto con altre zone costiere in Bangladesh. L'analisi della marea di Sandwip ha evidenziato componenti semidiurne dominanti più ampie rispetto a Chittagong, mentre le componenti diurne risultano comparabili. Le fasi sono generalmente più alte dando luogo ad un generale ritardo dei valori estremi di 47 minuti rispetto a Chittagong. Il DEM, che evidenzia un'isola praticamente piatta con topografia media attorno a 5 m s.l.m., necessita di informazioni batimetriche più dettagliate per poter essere utilizzato come input di modelli idrometeorologici. Il TIN corretto con i rilievi topografici, d'altra parte, evidenzia che la zona nord-ovest è leggermente più alta della zona sud-ovest. L'asseto fisico dell'isola è peggiorato incidendo sugli aspetti socio-economici delle comunità, come evidenziato dai questionari e dalle immagini satellitari.

Di conseguenza, sono necessari un argine che circondi l'isola ed uno che connetta la parte nord dell'isola con la terraferma, per proteggere le comunità dell'isola dall'erosione, dall'innalzamento del mare e dal rischio di inondazione. Si deve sviluppare un sistema di allarme idrometeorologico locale migliorando anche i sistemi di disseminazione in lingua locale. Le infrastrutture, in particolare strade e trasporti, e la formazione sanitaria devono essere migliorate affinché la popolazione sia più consapevole e capace di adattarsi ai disastri naturali.

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1. INTRODUCTION

1.1 Background:

Bangladesh is geographically extended from 20° 45´N to 26° 40´N and from 88° 05´E to 92° 40´E situated in the area of the deltaic GBM (Ganges-Bhahmaputra- Meghna) system, having the Himalayas in the north and the Bay of Bengal in the south. The country is exposed to tropical cyclones originating in the northern Indian Ocean and moving along north-easterly tracks. The 710 km long coastline contains approximately 28% of the total population (15 million people). Due to its dense population, a wide and shallow continental shelf and a complex coastal configuration with a shallow bathymetry, the Bangladesh coast has suffered enormous storm-related casualties. Recorded storm surge flooding devastation due to tropical cyclones is the worst in the world. Coastal areas are struck by storm surge flooding which causes widespread damage to living communities and properties, along with pulses of coastal erosion and accretion of the mainland coasts and offshore islands. Moreover, the increasing migration trend of the population towards the coastal areas for livelihood opportunities and the increasing trends of tropical cyclones along with extreme erosion coupling with sea level rise phenomena are likely to increase vulnerability in the context of climate change.

Bangladesh is considered as one of the most vulnerable countries in the world to the impacts of climate change. The vulnerability to disasters especially for sea level rise and storm-surge inudation was revealed in several studies including Warrick and Ahmad 1996, Cruz et al. 2007, Nicholls et al. 2007, Sarwar and Khan 2007 and Karim and Mimura 2008. The Fifth Assessment Report (FAR) of IPCC (2014) indicates that the rate of sea-level rise since the mid-19th century has been larger than the mean rate during the last two millennia. It also publishes comments that there has been significant improvement in understanding and projection of sea-level change since the AR4 and the global mean sea-level rise will continue during the 21st century at a faster rate than observed from 1971 to 2010. The report considers four RCPs (Representative Concentration Pathways) scenarios for the period 2081-2100 relative to 1986-2005 that the rise will be in the ranges of 0.26 to 0.55 m for RCP 2.6, while 0.45 to 0.82 m for RCP 8.5. It also concluded that sea level will rise in more than about 95% of the ocean area by the end of the 21st century. The SAARC Meteorological Research Centre (SMRC) analysed sea level changes of 22 years historical tide data at three tide gauge locations in the coast of Bangladesh as mentioned in the paper of Mohal et al (2006) under WARPO project of IWM. The study revealed that the projected sea level rise might be 18 cm, 30 cm and 60 cm for the year 2030, 2050 and 2100 respectively which is many fold higher than the mean rate of global sea level rise over 100 years. A study by Ahmed and Alam (1998) mentioned 1 meter change of sea level by the middle of 21st century considering a 90 cm rise in sea level and about 10 cm local rise due to subsidence. A pilot study by the Department of Environment (DOE, 1993) mentioned a potential future sea level rise for Bangladesh of 30-50 cm by 2050. A recent study by Pethick and Orford (2013) on sea level rise in south west coast of Bangladesh presented evidence of relative sea level rise substantially in excess of the generally accepted rates from altimetry, as well as previous tide-gauge analyses. The study found rates of increase in RMSL (Relative Mean Sea Level) ranging from 2.8 mm/yr to 8.8 mm/yr whereas high water levels have been increasing at an average rate of 15.9 mm/yr and a maximum of 17.2 mm/yr. An increasing tendency in sea level rise from west to east along the coast has also been found (Singh et al., 2000).

Bangladesh was ranked as one of the world's most disaster-prone countries by World Bank (2005) with 97.1 percent of its total area and 97.7 per cent of the total population at risk of multiple hazards, including cyclones. About 178 severe cyclones of more than 87 km/h wind speed reported to be formed in the Bay of Bengal, causing huge destruction of life and property in between 1891 to 1898. There was devastation by 38 severe cyclones from 1970 to 1998 as reports published by BDKN (2013). Material damage of about USD 2.4 billion and human casualties numbered around 140,000 was inflicted by the supercyclone of 1991. A similar devestations caused in 1970 had claimed some 500,000 lives and uncountable properties loss (Choudhury, 1998). Furthermore, storm surge associated with a tropical cyclone originating in the Bay of Bengal, has also caused major devastation in the coastal region of Bangladesh (Islam, 1974; Alam, 2003). Cylone Sidr, the worst of its type since 1991, struck the coastal region of Bangladesh with winds of 250 km/h (155 mph) rising a five metre of surge, killing more than 3,300 people (Reuters News Agency, 2008). Approximately one million tonnes of rice was lost, and nearly 500,000 people were found still to be living in temporary accommodation, such as in tents made of polythene by January 2008. Study by IWM (2005) and Ali (2000) showed in details of the death numbers with surge heights from 1960 (Table 1.1) where it is also revealed that all high profile devastations covered Chittagong (highlighted in the table).

Figure 1.1 shows a compilation of track maps of the previous major 20 cyclones that made landfall between 1909 and 1991 found Chittagong as the most frequently hitted area by the cyclone hence more vulnerable than other areas (Rana et al 2011).

Table 1. 1: List of major cyclones with land fall area, wind speed, surge height and associated death casualties since 1960 (modified from Ali, 2000; IWM 2005).

Land Fall Date	Location of Land Fall	Max. Wind speed (km/h)	Max. Surge Height (m)	Death
30 Oct 1960	Chittagong-Cox's Bazar	208	6.1	5179
09 May 1961	Bhola, Noakhali	160	3.0	11468
28 May 1963	North of Chittagong	203	3.7	11520
11 May 1965	Barisal, Noakhali	162	4.0	19 279
15 Dec 1965	Cox's Bazar	210	3.7	873
23 Oct 1966	Noakhali, Chittagong	145	6.7	850
12 Nov 1970	Chittagong	222	10.6	300 000
25 May 1985	Chittagong	154	4.3	4264
29 Nov 1988	Khulna	160	4.4	1498
29 Apr 1991	Chittagong	225	6.1	138 000
02 May 1994	Cox's Bazar	215	3.3	188
19 May 1997	Chittagong	225	4.6	126
26 Sep 1997	Chittagong	150	3.0	155
16 May 1998	Chittagong-Cox's Bazar	165	2.5	12
15 Nov 2007	Barguna, Patuakhali	220-250	6	3500

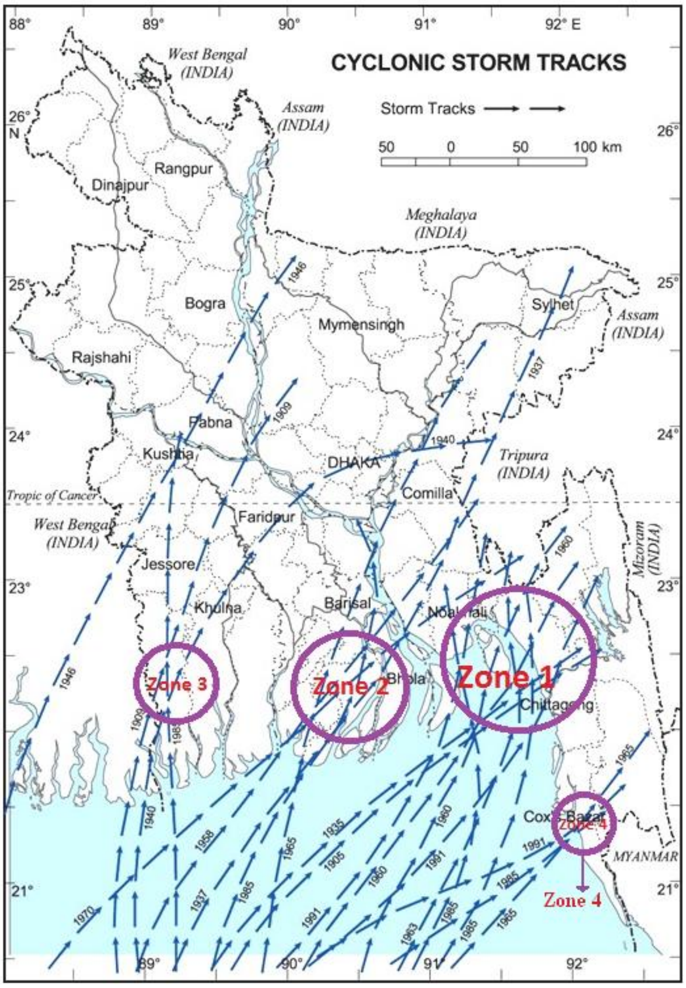

Figure 1. 1: Map of Bangladesh showing tracks of cyclones occurring from 1909 to 1991(Source Rana et al, 2011).

The relatively low number of deaths in the 2007 Sidr cyclone was considered the result of the cyclone early warning system, cyclone shelters and landfall location (Paul, 2009). So a more accurate and precise early warning system and high resolution risk map development should be given priority for the coastal zone of Bangladesh in order to reduce the casualties of climate vulnerability induced flooding. Good reviews of numerical storm surge modelling in the Bay of Bengal can be found in Murty et al. (1986) and Dube et al. (1997) describing the development of depth-averaged (2D) hydrodynamic models that solve the shallow-water equations. Many of these hydrodynamic models include wetting and drying, allowing a moveable coastal boundary that can represent storm surge generation and inundation simultaneously (Flather, 1994; Madsen and Jakobsen, 2004). Full shallow-water equation models may be overpredicted for many gradually varying flooding problems (Neal et al., 2012) and increasing model resolution may be a better way to improve predictive accuracy than including a more detailed physical process representation. Model resolution is particularly important for inundation modelling because channels and elevations need to be correctly resolved to allow storm tide penetration upstream and inland.

Inclusion of river flow also allows the simulation of backwater effects (Ali, 1995; Agnihotri et al., 2006) which can be important for an island like Sandwip located in the confluence of the Meghna River estuary. The nesting of numerical hydrodynamic models can improve in computational efficiency at resolution scales useful to flood risk managers (Madsen and Jakobsen, 2004); however, nationwide inundation models with a grid size of the order of kilometres are currently considered to be of high resolution in the region (Debsarma, 2009) but not that much effective for local forecasting. Development of the Bangladeshi Coastal Inundation Model that is built on the operational JMA-MRI storm surge forecasting model, incorporated with the components for tidal effects and waves is underway headed by WMO in the name of CIFDP-B (JCOMM, 2014).

In Bangladesh 62% of the coastal land has an elevation of up to 3 m whereas 86% only reaches heights of 5 m above MSL in the GBM delta (Mohal *et al.*, 2006; Ahmed, 2011; Talukder 2012). The active delta is characterized by low and flat deltaic islands such as Hatiya, Bhola, Sandwip, and many smaller ones. Typically the elevation of the most islands is less than 5 meter, and most commonly in between 2-3 meter (Pernetta, 1993). A map produced by global warming art shows the coastal elevation features of Bangladesh (Figure 1.2).

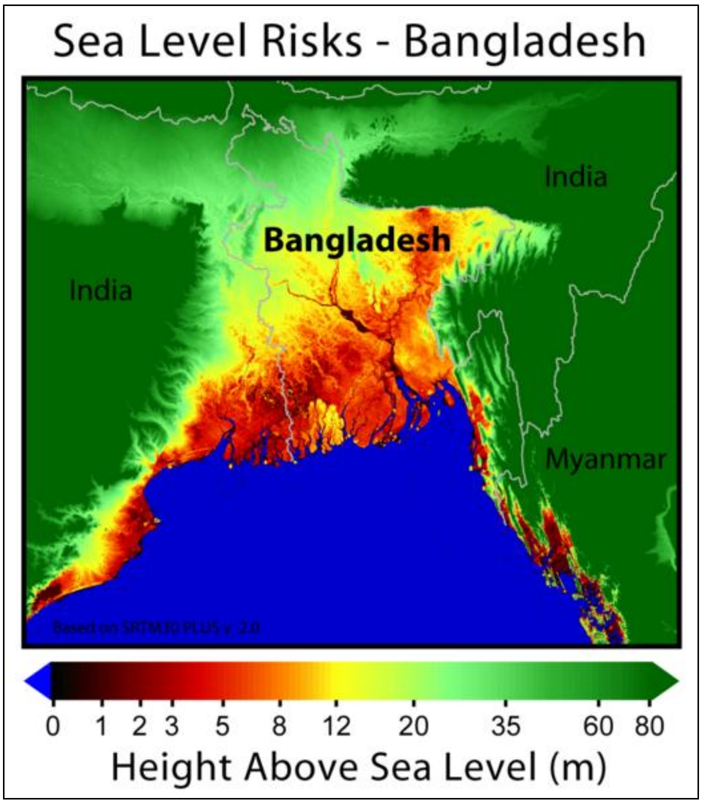

Figure 1. 2: Low elevation areas in coastal Bangladesh at risk of inundation fom climate change induced sea level rise

(Source: www.globalwarmingart..com/wiki/File:Bangladesh_Sea_Level_Risks_png)

The GBM delta front is strongly dominated by tidal processes: tides are semi-diurnal with a tidal range of up to 4 m, and generate shore-normal tidal currents of up to 0.3 m/sec (Barua et al., 1994). Barua (1990) notes that during periods of low river discharge, the eastern distributary channels (Hatiya and Sandwip Channels) serve as flood channels. The delta has been growing both upward and seaward since its creation and geological evidence shows an average progradation rate of about 80-100 m /year.

Additionally, the sediments of the islands are very soft, unconsolidated silts and clays offering low resistance to the erosive forces of waves during storm events. Early works by hydrolic engineers demonestrated correlation between particle sizes and the minimum water velocities to erode and transport of the sediments (Grabowski et al., 2011) where they found that boulders need stronger flow to erode than sand where as cohesive mud needs much more stronger to erode than silts and sands. Hjulstrom diagram (Figure 1.2) has become a standard reference tool to illustrate this relationship (Dade et al., 1992). Thus, the landforms of the active delta are extremely temporal and are easily changed by the river flood flow, tidal and wave action, river discharge and attack of cyclones. Most particularly, the islands in and around the mouth of the Meghna have been easily eroded by river flow and wave action (Pernetta, 1993; Umitsu, 1997).

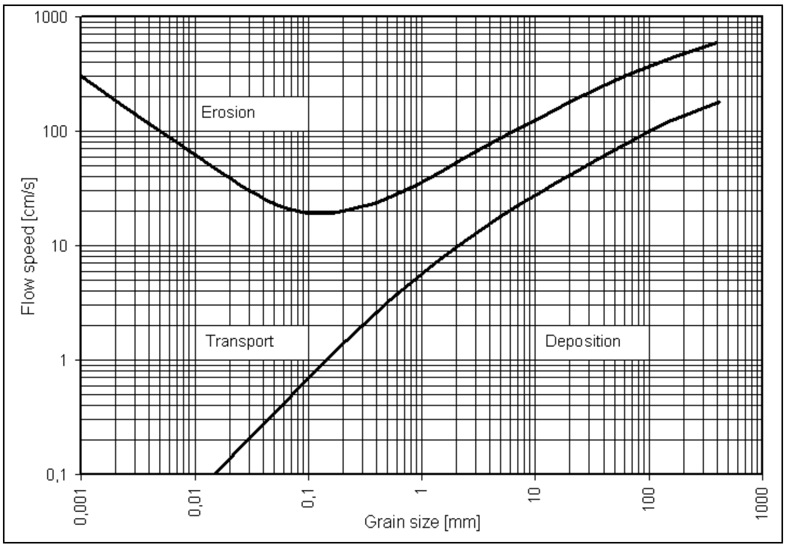

Figure 1. 3: The Hjulström curve (source: http://en.wikipedia.org/wiki/Hjulstrom)

There is however evidence that in the last two centuries the delta grew little towards the sea and faced severe erosion. The “backwater effect” is considered by the scientific community as one of the basic reasons for coastal erosion in the area. The backwater effect is generally referred to as the retardation of a river out flow by a rise in the level of water at its mouth (Ali, 1999). Due to rises in sea level, brackish water may even start flowing inland, in the reverse direction of natural flow. The backwater effect may happen for various reasons though. In the coastal region of Bangladesh the main causes can be pointed out as a strong southwest monsoon wind in the rainy season, high astronomical tides as well as high storm surges (Huq *et al*., 1999). Eventually these are the same reasons for coastal accretion as well. In addition, sea level rise is also considered as one of the most important factors having a long-term effect on coastal erosion in the area (Pramanik, 1983). As discussed by Pethik and Orford (2013), there is a further phenomenon causing an anomalous sea-level rise in particular the level of high tides. Analyzing data from estuarine tide gauges in Sudarban, they observed an increase in sea level rise which was largely a response to anthropogenic processes, principally estuary channel constriction by embankments, resulting in amplification of the tidal range along these channels.

But, before any management approach to be taken for a dynamic coast, a comprehensive understanding of geomorphological evolution is prerequisite. Coastline movement and area changes due to erosion and deposition has been a major concern for coastal zone managemnt. The coast line chanage rates determination is not scientifically important only for study the sediment budget and role of natural processes in the shoreline alterations but also necessary to determine safe constructions, settle property ownership dispute, study the effictiveness of shoreline protection structures and to make an effective land use strategies (Camfield and Morang, 1996). Very dynamic coastline such as south eastern Bangladesh coast, pose considerable hazards to human use and development which again coupling with climate change vulnerabilities make more people and properties prone to hazards. Accurate demarcation and monitoring of shorelines over the short and longterm is necessery for understanding dynamic coastal processes (Chowdhury and Tripathi, 2013). Remote sensing technology is widely accepted by the scietific community and engineers for assessing coastal environment and monitoring changes over time and space in the coastal zone (Green et al., 2000). Geographic Information Systems (GIS) have been found as succesful tools in analysing such changes over time and space by utilizing simple to complex analysing and modeling tools and its extensions (Chowdhury and Tripathi, 2013). So, the synoptic and repetitive capabilities of Remote Sensing Systems can be utilized to provide timely required spatial data for GIS, enables determination and monitoring of extent and rate of coastal movement (White and Asmar, 1999). Satellite imigeries have been using as one of the popular RS product for extarction of shorlines and GIS to over lay multipl temporal shorelines and maps to measure and visulaize the changes over time and space extensively.

1. INTRODUCTION

Land covers change analysis using satellite images have been used by risk managers, development policy makers and scientists since 70's. It enables monitoring the temporal changes in relation to many development concerns like natural hazards, land resource management etc. Bangladesh is a developing country and is prone to disasters of several types and frequencies . In the studies related to cyclone and storm surge, the aspect of land cover is generally ignored (Quader et al, 2014). The change of land cover is the result of the activities of the local inhabitants. Land cover change assessment may inform about natural resources and human assets exposed to the hazards over time. Some time people change the land cover to adapt to the impact of natural hazards. Settlement, forest, agricultural land and landscape of the coastal area changed over time with the regular hit of cyclones and tidal surges along the coast of Bangladesh (Quader et al, 2014). As the coasts and Islands in Bangladesh has been attacked by a lot of tropical cyclones and associated storm surges along with erosion, the evolution of the coastal land covers might be influenced by repetitive hazards along with many other factors of course.

From the brief discussion above about the effects of natural calamities in Bangladesh and dynamic geomorphological evidences, it is highly felt that we need a strategic model to predict the loss due to future natural disasters, especially for our coastal areas. We also badly needed more accuarate and precised timely cyclones and storm surges early warning systems depending on strategis geomorphic, hydrodynamic and hydrometeorological models to reduce the destructions. Strategic models can be constructed based upon a high resolution Digital Elevation Model (DEM) of Bangladesh coast. A detailed and integrated DEM can be useful not only for disaster prediction and risk assessment, but also for a wide variety of scientific, engineering and envieomental applications (FAP, 1995). For a comparison, the United States Geological Survey has conducted research and created digital elevation models of the whole coastal zone of the United States and major coastal cities. The resolution of the DEM varies from 1m to 10m (Foxgrover, *et al,* 2010). These sophisticated DEMs are now being used for various researches and long term planning purposes (Foxgrover, *et al,* 2010) as well as flood risk assessment studies. In 1993, Flood Action Plan-19 prepared several DEMs based on Bangladesh Water Development Board topographic data including DEM of North Central region, DEM of Tangail area and Bangladesh National DEM. But those DEMs include medium resolution regional DEM constructed from the original spot elevation points of BWDB maps and MPO's interpreted 1 km grid of elevation points. In October, 1994, FAP-19 produced a medium resolution or semi-detail DEM (500 m X 500 m) based on generalized BWDB spot elevation points. This generalization has been done manually by super imposing a transparent

500 m grid template on the source maps and recording the elevation point nearest each grid intersection. A detailed procedure is found in the FAP 19 Technical report (FAP, 1995). Finally the pixel size of the DEM was chosen as 300 m X 300 m where as the input data resolution was from the 500 m template grid.

Several studies (ISDR, 2002; World Bank, 2005; CRED, 2007) argued that the effects of natural hazards have been rising in terms of life and injuries in poorer or under developing countries including Bangladesh where institutional disaster reduction approaches should be adaptable to individual social and local livelihood experiences (ISDR, 2004; UNDP, 2004; DFID, 2005). The central consideration to the development of disaster research should have been vulnerability factors (Khan, 1974; Burton, Kates and White, 1993; Hewitt, 1997; Twigg and Bhatt, 1998; Weichselgartner, 2001, Wisner et al., 2004; IFRC, 2006) determined on spot (areas affected) of the effected locality and community. Understanding island processes, vulnerabilities and choosing proper implementing strategies for sustainable development becomes critical for island development (Teh, 2000).

Nonetheless, localized vulnerability factors in cyclone hazards arguably remain only partly considered or ignored, though a good progress made in cyclone preparedness, exemplified by the existing comprehensive disaster management policies of the Government of Bangladesh. Indigenous disaster response experiences could be more central to disaster interventions in Bangladesh. Enhanced local-level adaptation by community based copying strategy to natural hazards is crucial for resilience to any suspected increase in coastal climate hazards. This work explores the context of vulnerability profile and local coping strategies in relation to hazard response experiences in the study area. The analysis of the study is consistent with other works concerning vulnerability and disaster response in the country (Zaman, 1988; Haque and Zaman, 1994; Hutton and Haque, 2003, 2004; Edgeworth and Collins, 2006).

The current aim of the main disaster management government agency of Bangladesh, the Disaster Management Bureau of the Ministry of Food and Disaster Management (MoFDM), is to achieve a paradigm shift in disaster management: from conventional response and relief to a more comprehensive risk reduction culture. In doing so, it underscores capacity-building of affected people to create resilience to disasters (MoFDM, 2007). This reflects the adoption of the 'Hyogo Framework for Action 2005–2015' in national policies, emphasizing the need to reduce vulnerability and promote resilience (UNISDR, 2005). Yet, without in-depth understanding of the underlying vulnerabilities to natural hazards, the basis of local people's perceptions and behavior, and the goals that they set, disaster reduction strategies are considered unlikely to succeed (Khan, 1974; White, 1974; Burton et al, 1993; Blaikie et al., 1994). Any given risk or disaster event is distinguished by its geographic location and setting. These are important keys to the origins of danger, the forms of damage and whom they most affect. They are critical for the appropriateness and deployment of organized response (Hewitt, 1997).

Indeed most disaster commentators have implied, if not directly highlighted, that it is essential that planners, policymakers and development practitioners endeavour to understand local uses of the environment, local knowledge and local practices (White, 1974; Chambers, 1983; Sillitoe, 2001). Furthermore, the underlying causes of vulnerability to disasters more locally are often economic and societal, such as through landlessness, fragmentation of community cohesion, and lack of access to political representation.

Despite its renowned experience and ongoing progress for coping with disaster, Bangladesh still experiences a dearth of optimal coordination among physical, societal and technological systems in its most hazardous zones. Public adjustments occur, but less so with regard to people's perceptions or behaviour, these being cited as important factors responsible for the failure of past hazard mitigation strategies (Khan, 1974; Paul, 1984; Haque and Zaman, 1993; Hutton and Haque, 2004). Therefore, an analysis of the relationship between natural hazards and human behaviour in the coastal areas, using local-level and personalized accounts, appears to be an imperative for developing improved disaster reduction strategies. The rationale here is that understanding vulnerability and human responses in direct context leads to more applied application of the basic components frequently alluded to in disaster risk reduction frameworks (IFRC, 2002; ISDR, 2004; UNDP, 2004; DFID, 2005) along development of more accurate and precised warning system and risk mapping and comprehensive signal disseminations for a community.

1.2 Rationale of the Study

The island is located at a frequent passage of tropical cyclones and therefore extremely prone to storm induced floods and other associated natural hazards. Every year, people in the island face risks from cyclones and following storm surges threatening lives and households of the entire community. It is also exposed to a macro-tidal regime, with tidal variation in the range of 3 to 6m from neap to spring tides. Located in an active delta, the morphological evolution around the island is also very active due to the significant degree of hydrodynamic and sediment transport processes.

Coastal erosion is rapidly changing the living space for the community. The geographical position, the frequent occurrence of extreme hydro-meteorological events with the rapid changes in geomorphology and the socio-economic regime in Sandwip Island, badly needs an effective Disaster Risk Reduction (DRR) measure which is an extremely challenging task. A reliable and easy to understand early warnings and a community-based response framework can reduce significantly the loss of lives and properties. However, better understanding about the physical, hydro-meteorological, socio-economical, socio cultural and geomorphological characteristics along with community perception is prerequisite for a better management approach to be successfully implemented for the hazardous area.So, the study was attempted to review, collect, interpret and produce as much as information to characterize the erosion and storm surge prone Sandwip Island of Bangladesh

Thus, the work done during this project will provide the base and demonstrate the future directions towards those required actions.

1.3 Objectives

The most important hazards in the area as discussed earlier are caused by tropical cyclones and associated storm surges, resulting in massive flooding, that affected the entire Sandwip Island in most cases. Often these phenomena are combined with other hazards, such as strong winds and tidal inundation, resulting in intensified risk. The dense population and persistent poverty of the island resulted in recurrent casualties of immeasurable scales. In the years 1825, 1876, 1985 and 1991, Sandwip was affected by extreme meteorological events causing severe marine flooding and leading to immense destruction. During the most damaging storm that affected the island, in 1991, the estimated storm surge height was 6m and the human casualties were estimated at approximately 40,000 people, when 80% of the residential infrastructures were also destroyed. More specifically 25,000 human casualties occurred during the cyclone and 15,000 human casualties were caused bymalnutrition and diseases after the event.The rate of the erosion is very high and not compensated by deposition, despite its large rate. Several attempts as cited earlier to assess the erosion rate have been done considering the whole coast and lack of studies for the island evidencing the particular difficulties to develop scientific studies in this site.These devastating losses are becoming even more severe due to the loss of the agricultural crops and the associated scarcity of food, as well as due to the destruction of the majority of the traditional residences, roads and embankments.

So, the objective of this work is to improve the knowledge of the island including its coastal geomorphology, geomorphological evaluation, sediment characteristics, sea level variations and socioeconomics to community perceptions and indigenous coping strategicto disasters.The work aimed at producing a coastal vulnerability perspective to be used in further research, development of effective preparedness, management and actions plan.To reachthis goal, an attempt was taken to find out the answers to the following questions:

1) What is the status of geomorphological changes?
2) What are the sediment characteristics of the erosion-accretion prone shorelines?
3) What is the status of the sea level rise?
4) How to make a high resolution bathymetry (DEM) and topographic (TIN) map to be useful for further attempt like management or warning modeling for the island
5) What is the total vulnerability/hazard ranking by local perceptions?
6) What are the land use pattern changes due to erosion and associated hazards?
7) How do people cope with the disasters and think to be useful for further actions?

2. THE STUDY AREA

The study area is completely controlled and influenced by the Meghna Estuarine system where as the system itself is evaluated and influenced by the GBM delta. So, a brief description of the delta and the MES system followed by the island is given for a better understanding of the peculiar characteristics and scenarios relevant with the study area.

2.1 The GBM Delta

The Ganges and the Brahmaputra, two Himalayan mighty rivers together carry the largest sediment load of any river system via another small, non-Himalayan river, the Meghna which drains to the Bay of Bengal as a combined river system. Together these rivers have built the largest delta in the world, the GBM delta (Coleman, 1969; Milliman and Meade, 1983). The delta covers ~100,000 km^2, draining land from Bangladesh, Bhutan, China, India and Nepal. It includes most of Bangladesh and part of West Bengal, India, with many of the 147 million people (in 2000) living in the delta facing multiple challenges (http://delta.umn.edu/content/ganges-brahmaputra-meghna-gbm-delta, Figure 2.1).

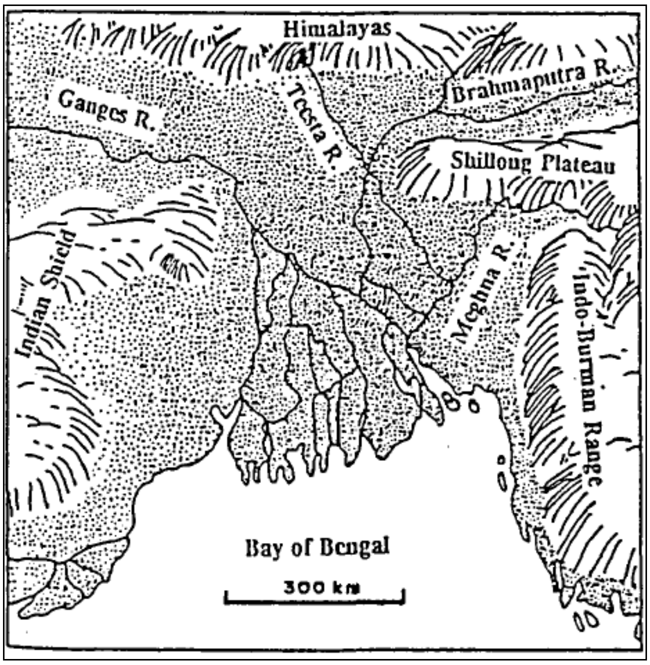

Figure 2. 1: The Bengal Delta (Source: Barua, 1997)

But the relative positions of the rivers along with the depocenter of the delta building processes changed in the course of time. For example, the Ganges River built several deltas those are no longer existing during its northeastward migration and finally settled at its present position.

Additionally, The Brahmaputra river built the early delta near Brahmaputra Mymensingh as proclaimed by Rennel's map and finally has got settled to its present straight southward course (Mojumdar, 1941; Niyogi, 1972; Morton & Khan, 1979; Umitsu, 1993). Almost 60% of the coastline formation of Bangladesh has been controlled by the delta forming activities of these rivers.

Two basic physiographic characteristics were identified throughout this deltaic coastline hence classified into two physiographic units: the inactive or the abandoned Ganges tidal plain which is relatively old and the active Meghna deltaic plain which is geologically very young (Barua, 1991a). The Meghna deltaic plain covers the areas from the Chittagong coast in the east to Tetulia Channel (Figure 2.2) which is highly dynamic, changing its plan form continuously (Eysink, 1983).

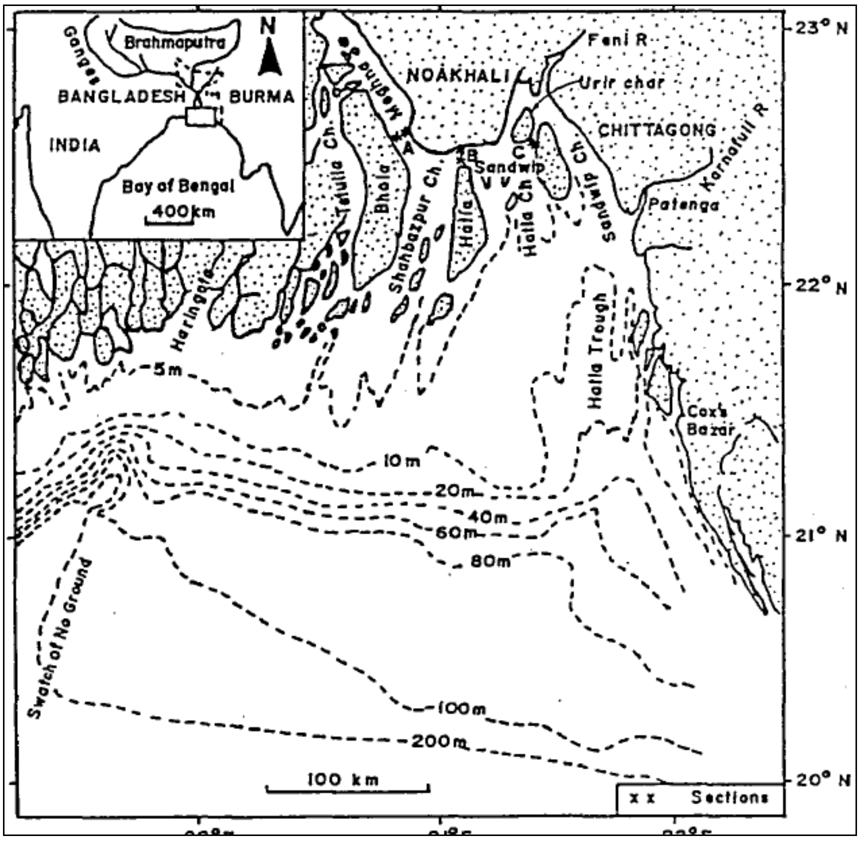

Figure 2. 2: Bangladesh coastline and the active Meghna Estuarine Delta (Source: Barua, 1997)

The climate of the GBM delta in Bangladesh part is fully controlled by the monsoon cycle. According to Brammer (1996) in Allison (1998), the Monsoon season extends from late May to September, when 80% of the rainfall occurs with winds blowing from the Indian Ocean (e.g. southeast to southwest). Annual rainfall in the delta ranges from 125 cm in western Bangladesh to more than 300 cm in the river mouth region, and more than 500 cm in the extreme northeast bordering the Himalayan plateau. Mean daily temperature ranges from about 18'C in the dry season of continental winds (December-February) to 30°C prior to the onset of monsoon in April-May. Temperature extremes of 4°C and 43°C have been recorded in the region, with a narrower range along the coast.Most of the sediment transported by the Ganges- Brahmaputra (80%) is silt and fine sand with little clay supplied by the young catchment area (Coleman, 1969). The whole catchment area and drainage basins is shown in the Figure 2.3.

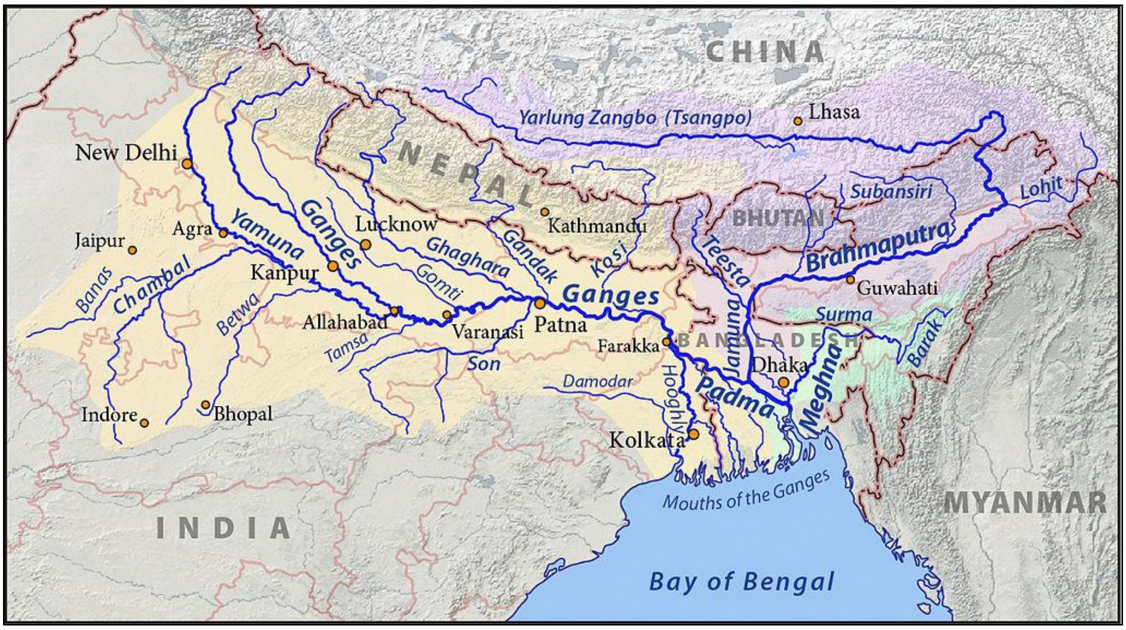

Figure 2. 3: Map of the combined drainage basins of the Ganges (orange), Brahmaputra (violet), and Meghna (green). Source: http://en.wikipedia.org/wiki/Ganges#mediaviewer/File:Ganges-Brahmaputra-Meghna_basins.jpg

2.2 The Meghna Estuarine System

The Meghna Estuary (Figure 2.4) of the active GBM deltaic plan is a very dynamic estuarine and coastal system which conveys the huge combined flows from three mighty rivers, i.e. the Ganges, Brahmaputra (known as Jamuna in Bangladesh part), and Meghna making the Lower Meghna River (100-200 km upstream of the Bay of Bengal) Estuary (LMRE) as one of the largest of this kind and finds its ultimate way to the Bay of Bengal. The sediment discharge through the Lower Meghna is the highest and the water discharges the third highest (after Amazon and Congo) considering all other system of similar kind in the world. This tremendous water and sediment load discharged by upstream and the tidal influence from the Bay of Bengal has characterized the estuary is an area of very active geo and hydro morphological system Producing high erosion and accretion rates (Sokolewicz, 2008). Furthermore, the area is very much prone to extreme cyclonic storms, coupled with tidal and storm surge inundation. The estuary is notably sensitive to climate change and sea level rise due to its geographical location and geomorphological settings (DHV, 2001). The low-lying land has developed within and surrounding the estuary which is home to over 4 million people. The local economy, livelihoods, and health are directly tied to the physical environment of the estuarine system (CEGIS, 2003).

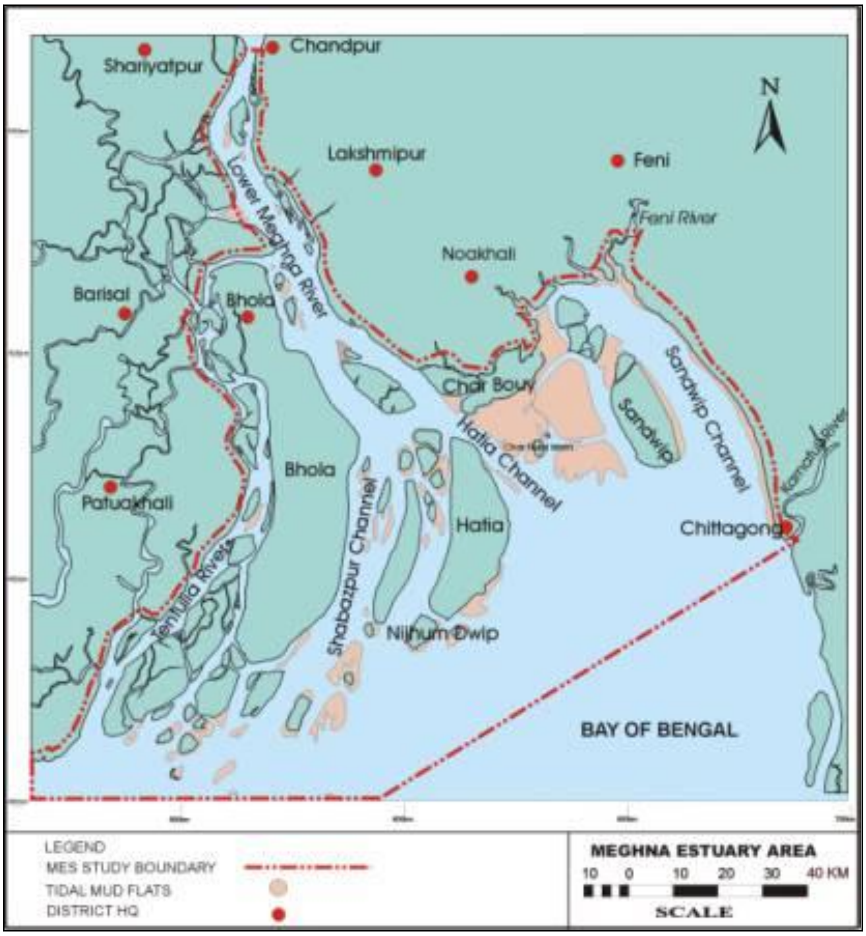

Figure 2. 4: The Active Meghna Estuarine Delta System. Source: http://www.warpo.gov.bd/rep/knowledge_port/KPED/Overview.htm

2.2.1 Hydrodynamics and geomorphology

The river discharge which is a combined discharge of the aforesaid three mighty rivers is strongly characterized by seasonal changes varying from 10,000m3/s during the dry season to 1000,000 m3/s during monsoon season approximately. The lower estuarine coastal area of the Meghna is heavily controlled by tides and freshwater flow, dominated by tidal influence in the eastern part whereas fresh water flow dominates in the mid and western part. The turbidity laden fresh water is conveyed to the bay of Bengal in the south eastern part. The eastern part is controlled mainly by tidal channel with a prominent counter clockwise residual circulation with a current velocities upto 4m/s following spring tides and monsoon flooding in the upper reach of lower Meghna (DHV, 2001, Sokolewicz, 2008). The eastern lower part is macrotidal with tidal variation of 3 to 6 meter following a mesotidal (2 to 4 meter) influence in the middle to micro tidal to further upstream of western Tetulia river (less than 2 meter) (Hayes, 1979; Sokolewicz, 2008). These studies also revealed that the salinity distribution is also strongly influenced by the freshwater discharge followed by salinity drops during monsoon and a strongly well mixed water column except distinct stratification only found in the eastern deep channel.

The geomorphological units of the Meghna Estuary are of fluvio-marine origin and flat in character. Silt and fine sand are the main bed materials with 70% is within the median grain size smaller than 75mm. The annual sediment load from the two largest rivers (the Ganges and Brahmaputra) is 1000-1200 Mtons of which 700 Mtons deposits to the lower Meghna estuary part of which forms new lands or vertical accreted lands (Goodbred and Kuehl, 1999). Sokolewicz et al (2008). In the study of DHV (2001) in its MES (2001) report showed that in the period of 1973 to 2000 the estuarine system has gained more than it has lost through erosion and accretion dynamics. The same trend was found from the sediment budget analysis of 1997 to 2000 data.

The net change for 1973 to 2000 shows an overall land gain for the Meghna Estuary system of about 50,800 hectares with an average annual gain for the entire study period was 1,880 hectares/year (Table 2.1).

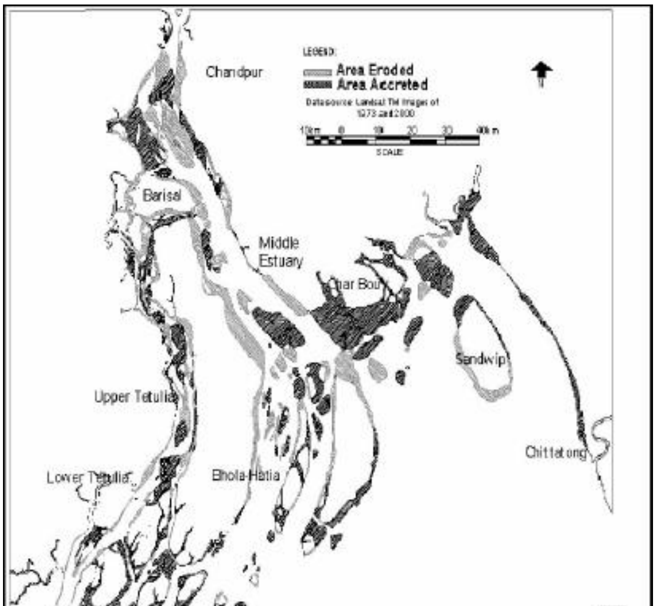

Figure 2. 5: Image of the Meghna estuary with bank line changes from 1973 to 2000 (MES, 2001)

Table 2. 1:. Summary of erosion and accretion scenerios in the Meghna Estuary of 1973–2000. (Source: MES, 2001)

Forms of Changes	Erosion and accretion in ha and ha/yr					
	1973–1979	1979–1984	1984–1990	1990–1996	1996–2000	1973–2000
Accretion for the period	50 175	45 550	33 505	56 520	23 850	137168
Erosion for the period	32 873	31 112	42 410	29 182	32 260	86366
Net change for the period	17 302	14 438	-8 905	27 338	-8 410	50 802
Annual rate of accretion	8 363	9 110	5 584	9 420	5 963	5 080
Annual rate of erosion	5 479	6 222	7 068	4 864	8 065	3 199
Annual rate of net change	2 884	2 888	-1 484	4 556	-2 103	1 882

2.3 Sandwip Island

2.3.1 A brief flash back on its history

It is often claimed that Sandwip Island has more than 3000 years of historical activity and uses. While this use was previously well documented, evidence of such use is no longer available.

Lying in the shadowy frontier area between the states of Bengal and Arakan, Sandwip was a contested area for local kings (delta *rajas/kings*), the sultans of Bengal, the Afghans and the Mughals, as well as the Portuguese, the Arakanese and the Burmese kings. Because of its location beyond the national frames it often changed hands of rulers, the history becomes very hard to recover. However, a summary of the history given here following Mukherjee, (2008); The Portuguese on the Bay of Bengal (http://www.colonialvoyage.com/portuguese-bay-bengal/), local websites on Sandwip Island and http://bn.wikipedia.org/wiki etc.

Sandwip is a lesser known salt trading island and port in the Bay of Bengal within the nexus of global trade and politics in the seventeenth century, now a part of Bangladesh. Previously it was successively part of the medieval kingdoms of Bengal, Tripura and Arakan by history. Sandwip was, briefly, held by the Portuguese and is referred to in Portuguese annals as a ‘minor’ settlement, part of their 'informal empire' in the Bay. The island is now a Sub-district (Upazilla-administrative unit) of Chittagong district in Bangladesh which in the sixteenth and seventeenth centuries was under the region comprised the southeastern part of the province of Bengal. The southeastern part of Bengal was the delta, known as *bhati* or lowlands, and local rulers, known as the delta *rajas* (delta king), ruled the delta from the ports of the kingdom of Chandecan (Sagor, south of present Kolkata), Sripur (near Dhaka), Bakla (Bakergunge, also near Dhaka) and sometimes Sandwip. Until the end of the sixteenth century, Bengal was an independent regional state ruled by the Husain Shahi sultans who were defeated by the Afghans under Sher Shah in 1538, and Sher Shah himself was defeated by the Mughals in 1576.So, at the turn of the seventeenth century southeastern Bengal was conquered, the delta *rajas* defeated, and the whole state made a province of the Mughal empire. But the Medieval Sandwip, called 'Sundiva', laid to the extreme east of the Bengal delta, in the area contiguous to the powerful medieval state of Arakan. That means, it was not under the control of either the Husain Shahis or the Mughals, on the contrary it was held by the kings (*rajas*) of the delta and frequently by Arakan. Arakan itself was absorbed into Burma (present Myanmar) in 1785.

Sandwip appears on the historical scene between 1521 and 1569. Travellers have left behind accounts of Sandwip, which lay on the route from Bengal to Pegu in Lower Burma. In 1569, Frederici (an Italian merchant) dropped by here for forty days on his way back from Pegu and found it a very pleasant place, well run by a Muslim governor as documented by Frederici Cesare of Venice (Hickock, 2004). Sandwip's Portuguese life started in 1590 but in a limited authority in some places and in 1602, the Mughals were defeated and Sandwip was brought under complete Portuguese control by Domingos Carvalho (Mukherjee, 2008). And according to Noakhali Gazette http://hdl.handle.net/10689/10182) due to huge salt business and nice but cheap shipbuilding industrial facilities the island was ruled by many rulers and succeddingly its present condition reached through British, Indian and Pakistan regime ended by independence of Bangladesh in 1971. The island was not only a river traffic station but also a source of many trade goods, such as rice, grain and cottons. Furthermore, Sandwip was the major source of salt for much of the Bay of Bengal, exporting two hundred boatloads of salt each year (Campos, 1919 in Mukherje, 2008).

Cartography gives us a clue to the importance and existence of Sandwip Island since hundreds of years back. It is marked in de Barros'Map of Bengal in *Quarta Decadas da Asia* (Lavanha edition of 1615) and shown but not named in both Gastaldi's 1561 *Map of Asia* and Linschoten's map of 1596. Additionally, Dutch and French cartographers continued to include it on their maps until 1747: Johann and Cornelius Blaeu in 1638 (Figure 2.6) and Johannes Jansson in 1639 as well as in subsequent editions throughout the 1640s and 1650s, Nicholas Visscher in 1660, 1670, Nicholas Defer around 1685, Sanson *fils* (Nicholas Sanson d'Abbeville) in 1705/1720, and Bellin in 1747 marked 'Sundiva (Figure 2.7) as documented with proper references by Mukherjee (2008). The Island was also included in the map of the delta of Ganges drawn as Sandeep by J. Rennell (1778) http://upload.wikimedia.org/wikipedia/commons/1/1a/The_delta_of_Ganges_by_J._Rennel.jpg) as shown in the Figure 2.8.

There are several theories to the origin of the name *Sandwip* among the locals. A folk etymology claims that it was derived from European word "sand heap" over time. Others say that 12 awlia (an Arabic word usually translated as friend, helper, supporter, patron or protector) from Baghdad travelling to Chittagong discovered this island in the middle of the ocean and found no people, so they defined it as "Shunno Dwip" means no man's land and which eventually became "Sandwip". And another group argues that "Sandwip" is named after Bakhorganj historian Mr. Beverage's "Shom Dwip".Some scholars have suggested that Portuguese people called it "Sandheep" (Hasan, 1999). Je the Baras marked it as "Sundiva" in his map (1550) (Figure 2.7). Candel Broke mentioned it as 'Sundiva' in his map (1660). Major Ranel mentioned it as 'Sundeep' in his map (http://en.wikipedia.org/wiki/Sandwip).

The historical background depicts the cyclone and natural disaster vulnerability of island from ancient time. It was mentioned by Frederici when he made landfall on the island after the cyclone that Sandwip is located in a tear drop shape just below this coast and as noted, the Meghna estuary is subject to cyclones and tidal surges from both the Sandwip and Hatia Channels. About 41 percent of cyclones travel through this funnel-shaped region each year presently, most hitting Sandwip. This environmental factor, coupled with the fact that rivers in Bengal are notorious for changing course almost overnight, ensured that historically few attempted control over this hostile land. The hostile environment also ensures that there are few vestiges left of the Portuguese presence in Sandwip (Mukherjee, 2008).

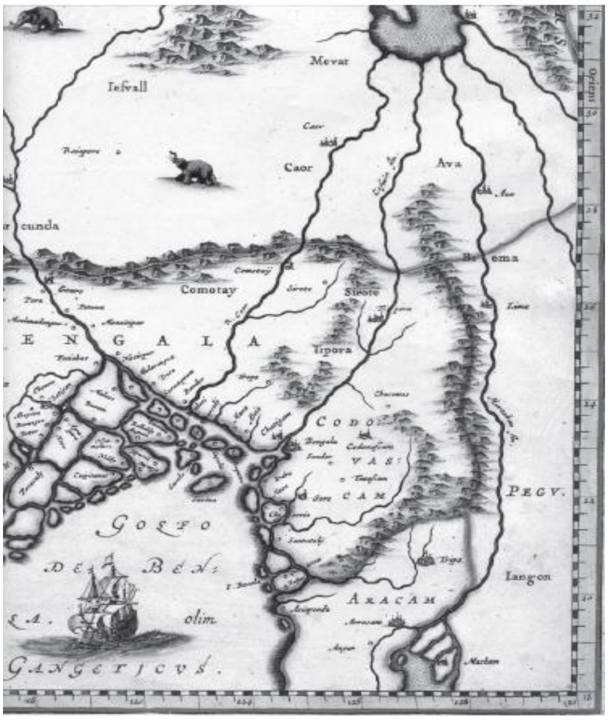

Figure 2. 6: Map of‘Sundiva’ in Johann and Cornelius Blaeu, 1638 AD, ‘Magni Mogolis Imperium’ (in Mukherjee, 2008)

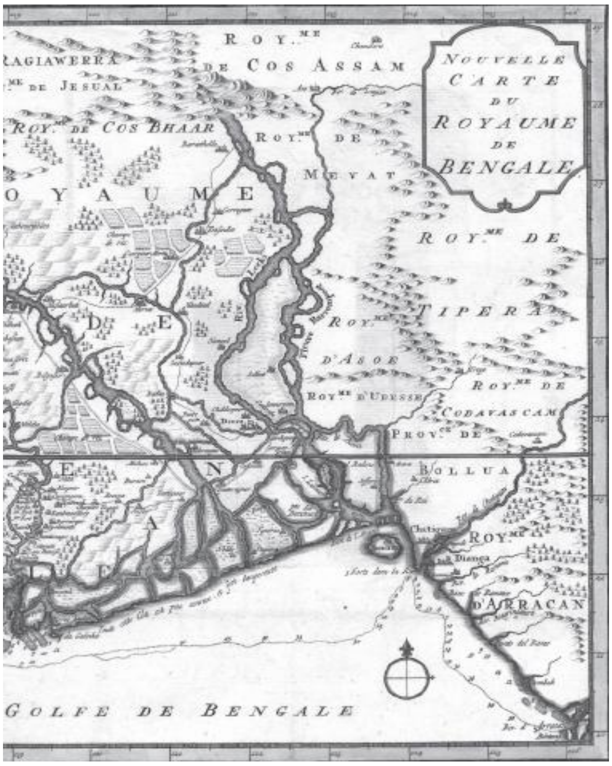

Figure 2. 7: Map of ‘Sundiva’ in Jacques Nicholas Bellin, 1747 AD, ‘Nouvelle Carte du Royaume de Bengale’ (in Mukherjee, 2008.)

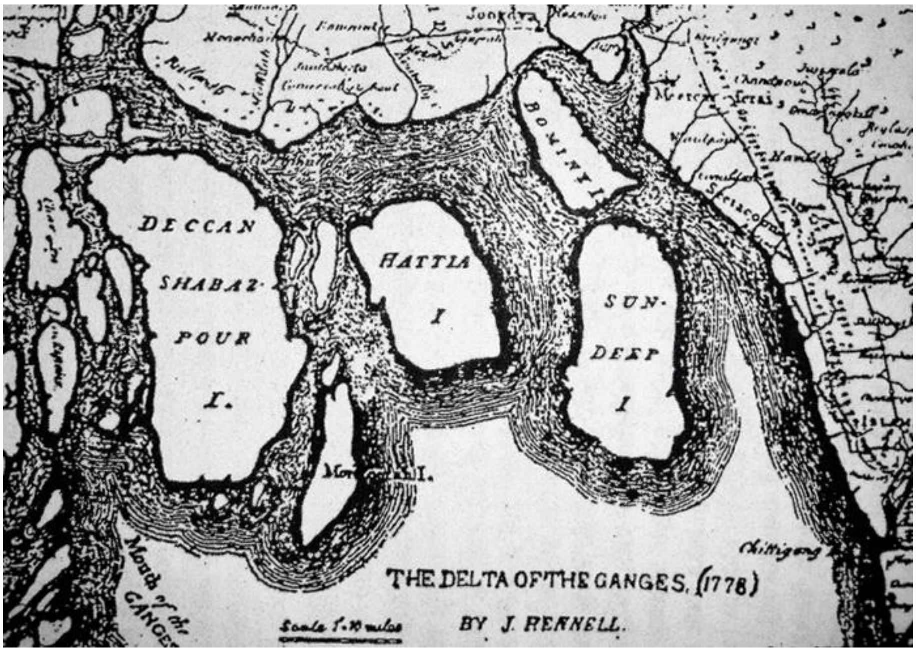

Figure 2. 8: Map of Surveyor J. Rennell **-** Screenshot from the book History of Sandwip by Shri Rajmohon Chakrabarti and Shri Ongomoho Das (published 1924)

2.3.2 Geographical setting

The main study site, Sandwip Island is situated at the confluence of the eastern Lower Meghna River Estuary (LMRE), the most dynamic estuarine and coastal system of the Eastern active part of the GBM delta. The island (Subdistrict) belongs to the Chittagong district of Bangladesh known as Sandwip Upazilla and is located at 22°22'-22°34'N and 91°26'- 91°34'E. The entire island is 50 kilometers long and 5-15 kilometers wide. It is naturally bounded by the Bamni river to the north, the Meghna river and Hatiya island to the west, Sandwip channel and Sitakundo upazilla (sub district) to the east and the Bay of Bengal to the South (Fig 1). In another way, it is surrounded by the tide dominated East Hatiya Channel, the Sandwip Channel, and the link channel between Hatiya and Sandwip Channel (Barua, 1997).

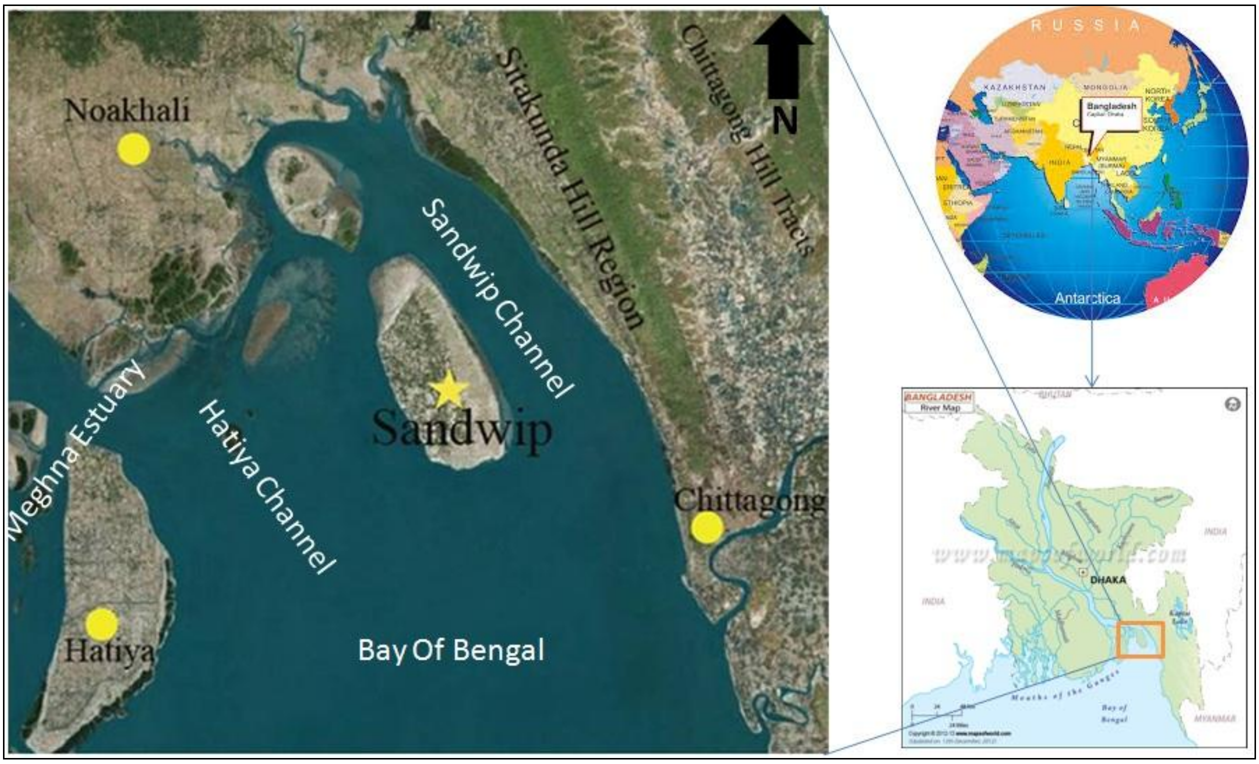

Figure 2. 9: Study area location Map

2.3.3 Hydrodynamics and geomorphological characteristics

The information on hydrodynamics around the island is all described in section 2.2.1 available so far. The surficial sediments consist mainly of admixture of clay, silt and very fine to fine sand for most of the offshore island situated in the Lower Meghna River estuary is the only information found study done by Habib et al.(2011). Most of the study on the sediment is confined to either whole coast or the Meghna estuarine system as described in section 2.2.1.

Even if during the last two centuries, the Ganges-Brahmaputra delta did not grow significantly towards the sea, the Meghna estuarine delta has changed significantly during this period. Considerable changes occurred mainly on the islands of Sandwip (and adjacent islands), Hatiya, Bhola and on the coastline of the Noakhali mainland. Some accretion happened in its northern part due to closure dame (Muhuri Project, an irrigation project) on the Feni River. Earlier Sandwip Channel was nearly isolated from the distributaries but is now tide-dominated, allowing net import of fine sediment. Available data shows that in between 1896 to 1979 Sandwip Island has been reduced about 50 per cent of its original size due to considerable erosion in the northwestern part. Map comparisons show that erosion accelerated after 1963 and it grew from 3 km^2 in 1963 to 46 km^2 in 1981 (Hoque, 2006). Erosion in Sandwip Island of the Ganges delta has assumed serious proportions. From 1913 to 1988 (i.e. 75 years), the island has been reduced further to about 50% of its previous size. The rate of erosion was 200m/year between 1913 and 1960 and about 350 meter/year between 1963 and 1984 (Barua, 1997). The causes of erosion were attributed to strong wave action due to strong southwest monsoon winds, high astronomical tides, frequent and extreme storm surges in the Bay of Bengal (BOB) (Hegde, 2010). Comparing the size variations adopted from various survey map and satellite images (1779-1979) Pramanik (1983) made a comparison table for Sandwip and Hatiya Island (Table 2.2).

Accretion has been coupled with erosion of the island for the last few decades. The island's shape and area has been dramatically changing with erosion in the south western part and accretion in the north western part. This has led to a number of questions if the island, where about 400000 people currently live, will exist in the near future? Furthermore, due to erosion effected people have been relocating to further inland intensifying settlement and declining agricultural land and other facilities. The island community has been in severe pressure of natural capital as well as social capital crises.

Allison (1997), on the basis of the comparison between historical maps of 1840 and a Landsat scene of the 1980s, clearly identified dominant erosion of the north-western part of Sandwip, whereas accretion was dominating the south-eastern part. The morphological evolution of the LMRE was enormous during the 20th century due to the hydrodynamic and sediment transport rates at stake. Wide mudflats have emerged in the northwest and southeast of the island. A general trend of southward island migration was clearly observed by Barua (1997). Figure 2.10 shows the bank line comparison of Sandwip Island carried out by Barua (1997) for the period 1913-1916 and 1988 where as Figure 2.11 shows the morphological changes of the island from 1925 to 1984 by Umitsu (1997).

Table 2. 2: Land Area of Hatiya and Sandwip Island measured from 1779 to 1979 (km^2), (Source: Pramanik, 1983)

Year	Map Source	Hatiya (km^2)	Sandwip (km^2)
1779	Delta of Ganges (Rennel)	370	579
1896	Survey of India	469	502
1945	Survey of India	1070	500
1959	Aerial Photograph	1030	391
1973	Landsat-1	399	290
1976	Landsat-2	399	269
1979	Landsat-3	370	290

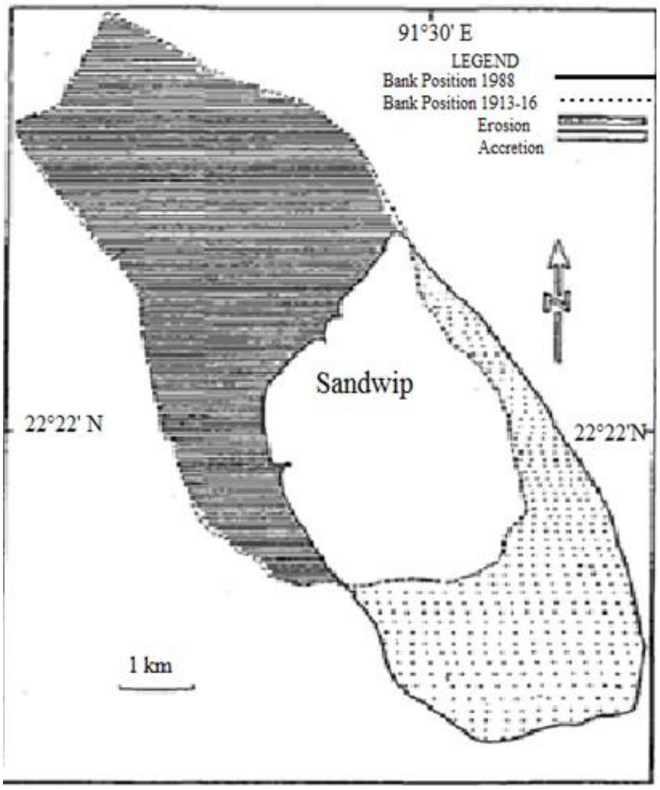

Figure 2. 10: Development of Sandwip Island in between 1913-1916 and1988 (Barua, 1997)

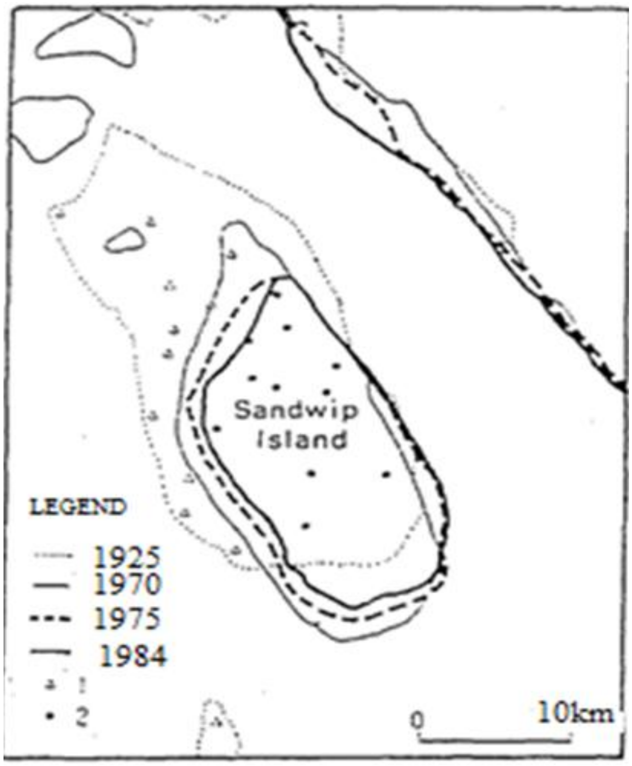

Figure 2. 11: Change of coastlines around Sandwip Island (Umitsu,1997)**.**

2.3.4 Demography, literacy and occupations

Sandwip is a densely populated island with current population size around 4,00,000. Males constitute 49.68% of the population, and females 50.32%, where Muslim religion covers the largest 87.91%, Hindus 11.51% and others 0.58%. Sandwip Upzila consists of 15 union Parishads(the smallest government unit), 31 mouzas and 34 villages. There are 265 Mosques, most noted of which are Shahabanu Mosque, Sandwip Town Jami Mosque and Abdul Gani Chowdhury Mosque along with temple 72 in numbers (Upazilla office).

Data collected from the upazilla office during our field survey shows that Sandwip has an average literacy rate of 35% (7+ years) which is better than most of the other parts of the country and of which male 40.8% and female 29.5%. Notable Educational institutions are 1 Government College, five private colleges, Secondary high schools 26, Madrasa 14, government primary school 103, non-government primary school 47.Regarding occupations of the people, Agricultural labor 22.98%, service 20.32%, agriculture 17.23%, business 10.36%, wage labour 5.48%, fishing 2.65%, renting house 2.45%, transport 2.11%, and others 16.42%. Nowadays many people are working as good professionals such as doctor, engineers, lawyer, teacher and Banker etc. Considerable foreign Remittance by family members working in abroad (EU, USA, Middle East etc) is earned every year. Main economic drivers in the island is shown in Figure 2.12.

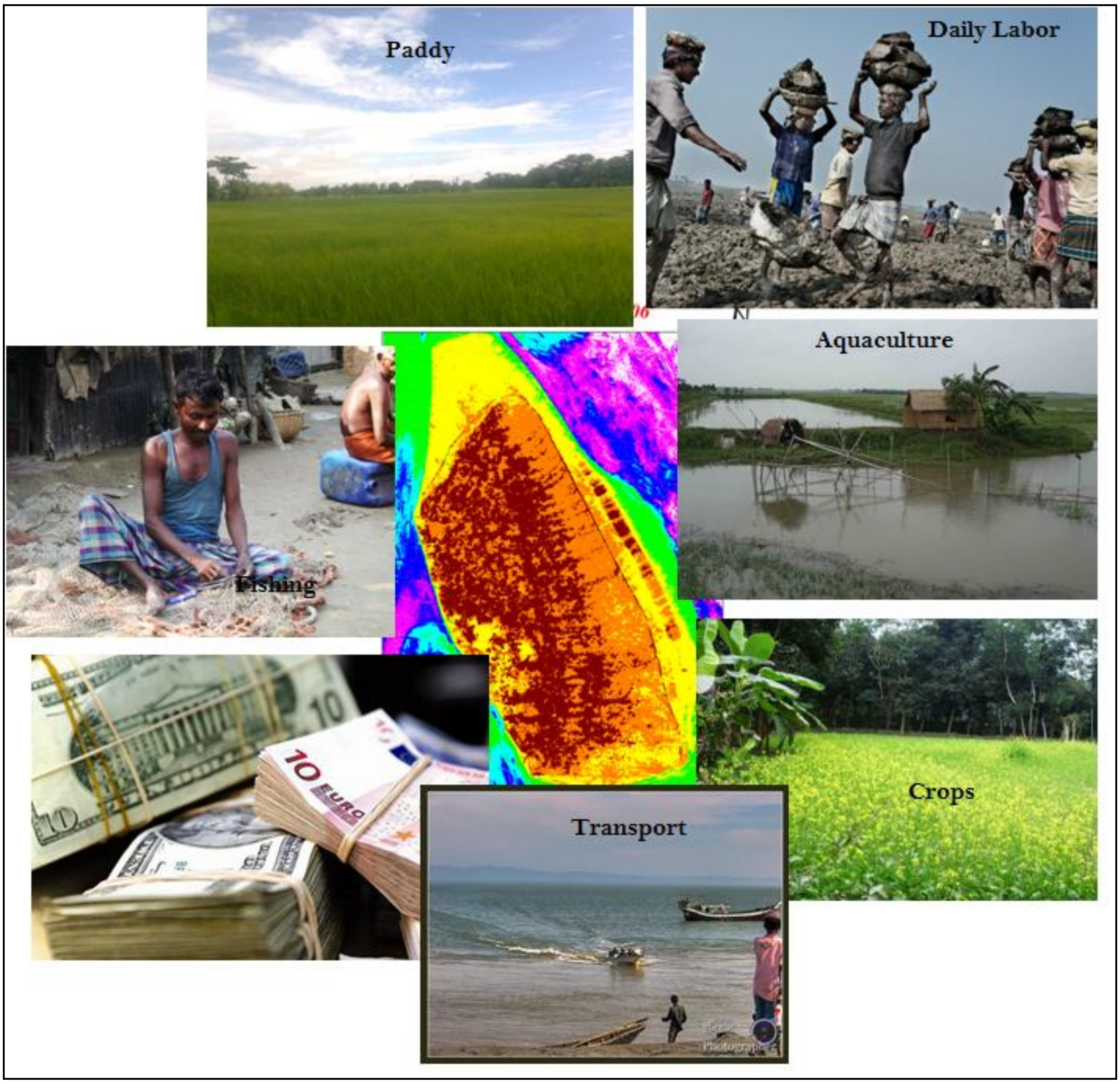

Figure 2. 12: Main economic drivers in the Island

2.3.5 Land use

Local agriculture office provided that total cultivable land of the island is15120.60 hectares and fallen land 8469.04 hectares of which single crop is cultivable 35%, double crops 45% and triple crops land 20%. Cultivable land under irrigation is 85% of total cultivable lands. Among the farmers, 58.96% is landless, 24.04% small scale and 17% intermediate level. The market value of the land of the first grade is approximately Tk 7500 per 0.01 hectare. Paddy, jute, potato, aborigine, patal, betel leaf, betel nut, coconut, peanut, palm, vegetables, and sugarcane are the main products. The whole Island is agribased and according to the island agricultural office agricultural land use account is shown in the table below (Table 2.3): Main Land use and land cover status in the island is depicted in the figure 2.13.

Table 2. 3: Agricultural land use statistics in the island (Source: Upazila Agriculture Office)

Particulars	Amount (Hectare) 38800 (total)
Single Croped Area	10500
Doubled cropped area	8000
Trippled cropped area	3200
Net Cropped area	21700
Total Cultivable land	27900
Total Cropped area	36100
Marsh land	1850
Medium High land	15227 (65%)
Hilly area and High land	No
Medium low land	7027 (30%)
Low land	1171 (5%)
Cultivable fallen Land	540
Permanent Fallen land	155
Flood area	920
Drought area	560
Saline soil	21780

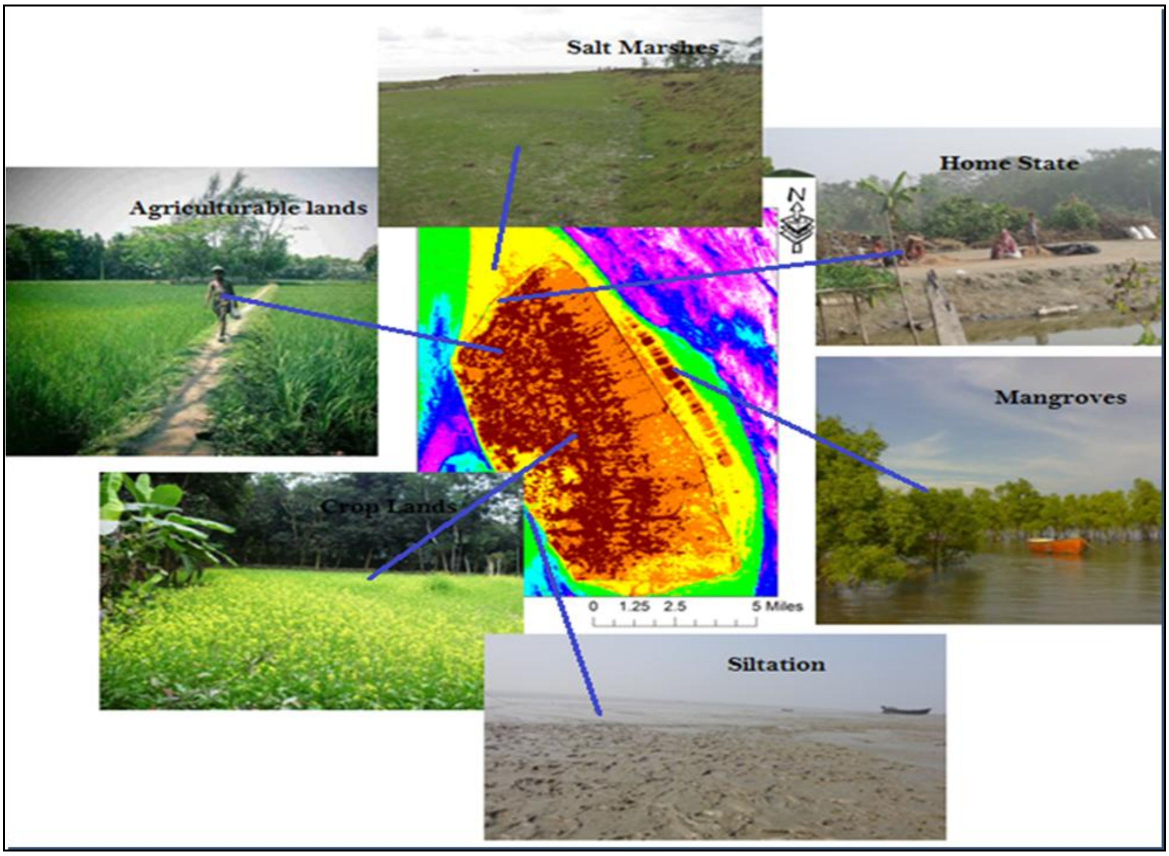

Figure 2. 13: Main land use and land cover picture in Sandwip Island

3. MATERIALS AND METHODS

Numerous tools and procedures have been applied to achieve a better comprehension of the study area in the perspective of its dynamic geomorphological changes in the face of devastating natural hazards induced by climate change vulnerability and finally to recommend some effective management strategies keeping priorities of the local community perception and practices. The field work and data analysis were developed in cooperation with CFR Italy and WMO (Geneva, Switzerland) under RISCKIT Project of EU (http://www.risckit.eu/). Field activities were implemented in the study site, Sandwip Island while data analysis was performed in Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh and Department of Physics and Earth Sciences, University of Ferrara, Italy. The materials and methods are briefly described.

3.1. Field Work

The field mission to the island in Bangladesh took place in several events starting from February 2013 to October 2014 in order to start up preparation, collaboration with local institutes and people, collection of available data of the study area through literature inventory, official documents and questionnaire survey to the local people, to install a tide gauge along the coast of the island and to do a repeated topographic survey on some cross sections on the west coast of the island.

3.1.1 Tide gauge installation and data acquisition

It is notable here that tidal measurement and data analysis was done in collaboration with Mr Enrico Duo, a master's student of University of Ferrara, Italy who has already submitted his master's thesis (Duo, 2014).

The aim was to install a tide gauge on any artificial platform on the west coast of Sandwip, but finding no such suitable platform in the target site, attempts were taken to install in the jetty on the eastern coast also known as Sandwip Eastern Coast Terminal which was partly damaged during cyclones season in previous year. The idea was the correction of the collected data with the Chittagong port area data collected automatically and the data of the BIWTA collected to the western side of the island manually. The most important challenge was to find a suitable location in the jetty to install the instrument in a proper way in order to be easily reachable for data downloading and, on the other hand, to save it from stealing and vandalism as well as heavy tidal current. The first attempt to install the instrument after a period of analysis of the opportunities, designing of the installation and building of the housing structure was completed on a temporary basis (Figure 3.1) but it failed because of the coincidence of different particular circumstances, specially due to the dangerous location, lack of proper facilities and technologies, difficulties in the management and planning of the steps of the whole activity.

As no other suitable structures were available in the island and all the island is affected by the high tidal range of 4-6 m and consequently by the high massive flow, the decision to temporary install the instrument with a low technology structure was taken in the western offshore area of the island (Figure 3.2). The chosen location was close to the manual tide gauge operated by BIWTA. The proximity with the manual tide gauge allows the assumption of the same level for the pressure transducer. On 6^{th} March 2014 a simple bamboo structure was installed with some local facilities consisting of a main long and strong enough (6 meter) pole collected from the island inserted in the mud, fixed with four smallest poles as anchors connected with ropes strongly tightened (Figure 3.3). A stainless steel pole with the instrument is fixed to the main pole with ropes.

A similar structure was built nearby in order to fix a red flag as visible signal during low and high tide to escape it from damage by vessels. The pressure sensor was fixed with the lower part of the steel rod, just 15 cm above the mud bed and its position was corrected and leveled comparing with the local manual gauge position and leveling. The installation was completed on 6^{th} March 2014 (Figure 3.3).

Figure 3. 1: Photo of 1st attempt to install the tide gauge on the eastern coast jetty

Figure 3. 2: Final installation point of tide gauge in western offshore of the Island

Figure 3. 3: Photo of installation of tide gauge in western offshore, 6th March 2014

The installed instrument was the absolute pressure gauge STS DLN70 (www.sts-sensors.com). It was a stainless steel and titanium cylinder of 24 mm diameter and 291 mm long. The pressure sensor was located in the bottom. It measures absolute pressure (time referenced) in the range 0.1÷25 bar with accuracy of 0.1÷0.25 mbar. Measurements time step can be set from 0.5 s to 24 h. It stores up to 500,000 values in its proper memory. The lithium battery is able to power the instrument for years, depending on the frequency set for measurements. No automatic data transmission system was implemented and download was made manually connecting the instrument to a laptop (Figure 3.3) through a RS485 interface cable at every spring tide until it suddenly became out of order for an unknown accident occured in the last week of June 2014.

Figure 3. 4: Tidal data downloading

The pressure gauge was set to measure the (absolute) pressure in mH2O every minute and store the average of 5 measurements (every 5 min). At the moment no corrections of atmospheric pressure were implemented because of lack of available data. The scheme of the measurements is shown in the Figure 3.5 below. To refer the measurements WL_m to the CDBM (WL_0) it is necessary to add to the water level measured, the difference between the Mean Sea Level referred to the datum (MSL_0), given from the BIWTA manual tide gauge, and MSL_m calculated on measures (Figure 3.5).

$$WL_0 = WL_m + MSL_0 - MSL_m \quad (1)$$

However, at the moment of installation MSL_0 was unknown. Further analyses has been set to be implemented on the signal deducted of the average on the period of observations.

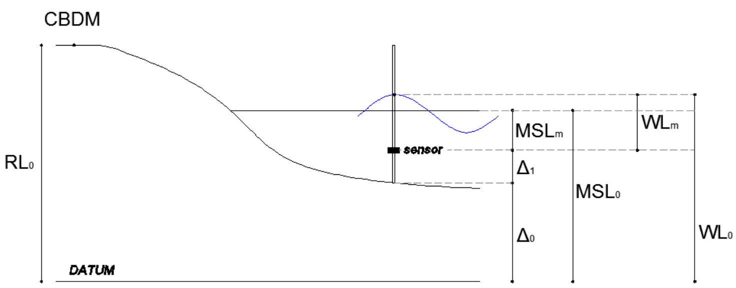

Figure 3. 5: Datum reference and water level measurements scheme.

The measurements began on 6th March 2014 at 12:36:50 (UTC+6, Bangladesh) and last downloaded measurements refers to the 15th June 2014 at 10:18:16. Several download missions were made and in Table 3.1 are summarized the last measurement before and the first one after the downloading before it became out of work.

Table 3. 1: Data downloading summary.

ID dwnl	Last Record (UTC+6, BD)		First Record (UTC+6, BD)	
1	07-mar-14	12:31:50	07-mar-14	12:37:38
2	10-mar-14	14:12:38	10-mar-14	15:06:23
3	19-mar-14	11:11:23	19-mar-14	11:18:33
4	19-mar-14	12:03:33	20-mar-14	09:33:58
5	29-mar-14	08:08:58	29-mar-14	08:16:02
6	18-apr-14	08:51:02	18-apr-14	08:59:44
7	13-May-14	06:54:44	13-May-14	07:03:04
8	31-May-14	09:33:04	31-May-14	09:38:04
9	15-Jun-14	10:18:16	15-Jun-14	-

3.1.2 Datum correction for the tide gauge

The tide gauge was installed close to the BIWTA manual tide gauge in the west coast of Sandwip Island. Assuming that the instrument sensor is located at 15 cm above the sea bed and that the sea bed is at the same level of the BIWTA manual tide gauge the leveling is defined. The reference of the BIWTA Manual Tide Gauge is the Chart Datum Bench Mark (CDBM) in Sandwip, located at (UTM/WGS84 Zone 46 Northern Hemisphere):

- X= 339104.00 m LON(E)= 91.436009 deg
- Y= 2487354.78 m LAT(N)=22.485032 deg

The water level is referred to its elevation referred to the Minimum Spring Tide calculated on 18 years of observations by BIWTA which is 7.19 m. The datum for the new tide gauge is considered the same as the BIWTA manual tide gauge. Alternatively, a first assessment of the tide gauge reference was implemented. The sensor is located at 10 cm above the Minimum Spring Tide in 18 years of observation.

3.1.3 Topographic survey

A digital shore line survey (Figure 3.6) of the erosion and accretion prone south-west, south and north-west part of the island was done usinga total station (*KOLIDA-442RC),* prisms & GPS Garmin-62s), scale and leveling. Accuracy of the instrument was fuse angle (1” To 5”), distance 5-Km (5mm,). The coordinate system was used as UTM with datum and ellipsoid WGS 84.

Figure 3. 6: Survey works in the field

The survey was topographically calibrated using the CDBM (Chart Datum Bench Mark) RL point of the BIWTA (Bangladesh Inland Water Transport Authority) established for its manual tide gauge measurement established on a culvert at the western ship Ghat (Ship Terminal) of Sandwip referred to as BM (Bench Mark) as shown in the figure 3.7.

Additionally, 4 more TBMs (Temporary Bench Mark); 2 north of BM (TBM1N is to the north of BM and TBM2N is to further north) and 2 south of BM (TBM1S is to the south of BM and TBM2S is to the further south) were established (Figure 3.7, 3.8) on some permanent structures available nearby considering the morphological changes noticed. Table 3.2 describes the geographical location, name of the TBM and BM and description of the platform established on used.

Finally, 5 cross section profile of the shore line starting from the established TBMs and BM was carried out upto watermark to produce a topographic survey map of all elevation from south to north of the western coastline, following top of the mud cliff break to lowest water mark of the western Sandwip coast which was used as ground truthing for satellite image analysis as well as DEM and TIN. All coordinates, angles, slopes and distances were recorded for the detail map preparation. The survey was 1st time conducted on the last week of March 2013 and repeated on the last week of February 2014 for change analysis.

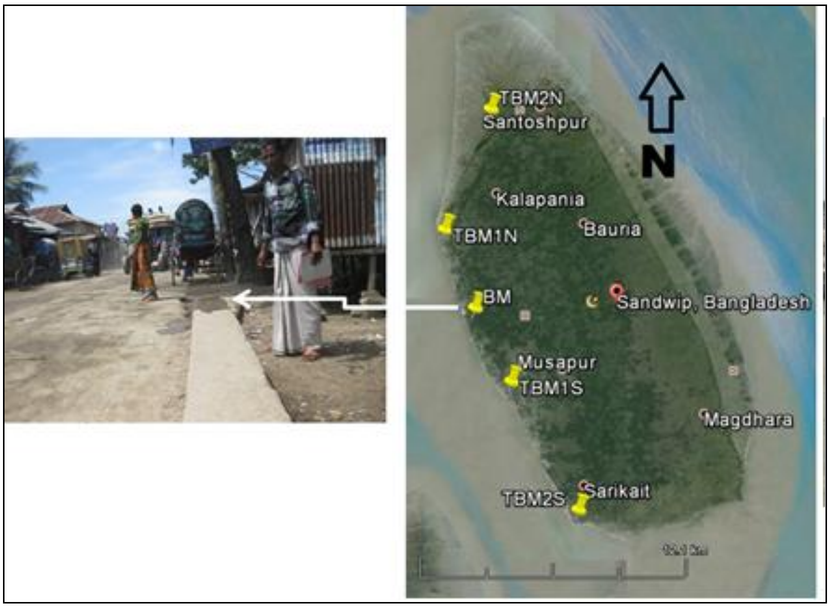

Figure 3. 7: Photo showing BM position and temporary benchmarks, Google Earth 2014

Figure 3. 8: Photo of TBM established structure location in Sandwip by total station

Table 3. 2: Position, ID of the TBM and BM with description of the platform established on

Position ID	Position Y	Position X	Platform escription
CDBM/BM	2487354.78N	339104.00 E	Old culvert
TBM1N	2490165.94N	338629.41E	Newly built bridge over canal
TBM2N	2496143.39N	340015.93E	Deep Tube well base
TBM1S	2483901.23N	341125.26E	Damaged floor a Mosque
TBM2S	2478683.10N	344056.85E	A small culvert beside the road

3.1.4 Sediment sampling

Sediment samples were collected from all cross section profiles starting from the mud cliff top to base (Figure 3.9) up to the water mark and referred as BM1, BM2, BM3 and BM4 (4 samples) for CDBM cross section; BM1N1, BM1N2 and BM1N3 (3 samples) for BM1N cross section; TBM2N1, TBM2N2 and TBM2N3 (3 samples) for TBM2N cross section; TBM1S1, TBM1S2, TBM1S3, TBM1S4 and TBM1S5 (5 Samples) for TBM1S cross section and TBM2S1, TBM2S2, TBM2S3 and TBM2S4 for TBM2S cross section. All samples were carried to the Laboratory (IMSFCU, Bangladesh and Unife, Italy) for further analysis of sediments characteristics, texture and qualitative minerals.

Figure 3. 9: Sediment sampling scheme and picture of sampling and crosssections

3.1.5 Questionnaire survey on local perception of coastal hazards

Questionnaire survey has been conducted in two separate schemes: For socio-cultural, socio-ecological, socio-economic and physical data under the RISCKIT project as per the requirement of the WP1, considering all sector of stakeholders relevant to the hydrometeorological events sufferers as well as planners, managers and researchers; 50 individuals were identified of which 43 (Table

3.3) were found to be contacted for personal interviews as well as consultation meetings (Figure 3.10) following the RISCKIT format (ANNEX 4A, 4B) of the interviewed people.

Table 3. 3:. Professional and social positions of the interviewed people

Category/profession	Description of the catagory	number
Upazilla Chairman (Political Leader elected)	Sandwip Island is an Upazilla (Sub District of Chittagong district, and there are 64 district in Bangladesh) and a chairman is elected for 5 yrs by the voting right of the citizen as per the constitution.	1
UNO (Upazilla Nirbahi Officer)	UNO is the Chief executive Officer for the whole Sandwip appointed by the Government	1
UPIO (Upazilla Planning and Implementation Officer)	UPIO is responsible for any development or new project including disaster and management etc. Who implem,ent and regulate all projects consulting with Upazilla Chairman, UNO and all relevant section officer in the island	1
Other Government Officer	Upazilla fisheries, Agriculture, weather officer	3
Union Parishad Chairman	Small unit of local government operated by 1 elected Chairman through general election of the Union parishad voted by the adult citizen of the Union. Whole Sandwip Island has 15 Union parishad.	5
Union Parishad Member	Each union parished has 9 Union parishad member elected through general election like chairman of the Union Parishad.	5
NGO officer +Worker	SDI (Social Development Initiative)	3
Teacher	Teaches in School, Madrasha and College	5
Civil Society leader	Anwar Trust, Sandwip Unique Society (club)	2
Journalist	Daily Shamokal	1
Religious Leader	Who teaches religious education and prayers	2
Farmer	Engaged with agricultural activities professionally	2
Fisherman/ Boatman	Engaged with fishing activities professionally	4
Business/Shopkeeper	Small business or traders professionally	2
Village doctor	Not MBBS but medical trained known as LM F	1
General People)	(Household/ Take care of family and properties	4
	Total	**43**

Figure 3. 10: Consultation meeting and interview to the RISCKIT respondents

The second scheme of the study was based on a questionnaire interview, participatory observation and focus group discussion (FGD) as shown in Figure 3.12. A total number of 150 HH (House Hold) heads were selected for interview from three unions covering all western coastlines (One from south west coast-Sarikait, one from middle west coast -Rahmatpur and another from north west coast- Santospur) (Figure 3.11) .Selected union positions in the island are shown in the Figure 4.10. People livings on the exposed coast or at a small distance from the coast were interviewed randomly selected. The interview focused on climate change vulnerability, its impact and indigenous coping strategies against climate change disasters. The interview also focused on socio-economic variables, social and environmental problem and impacts of previous events on livelihood of the community.

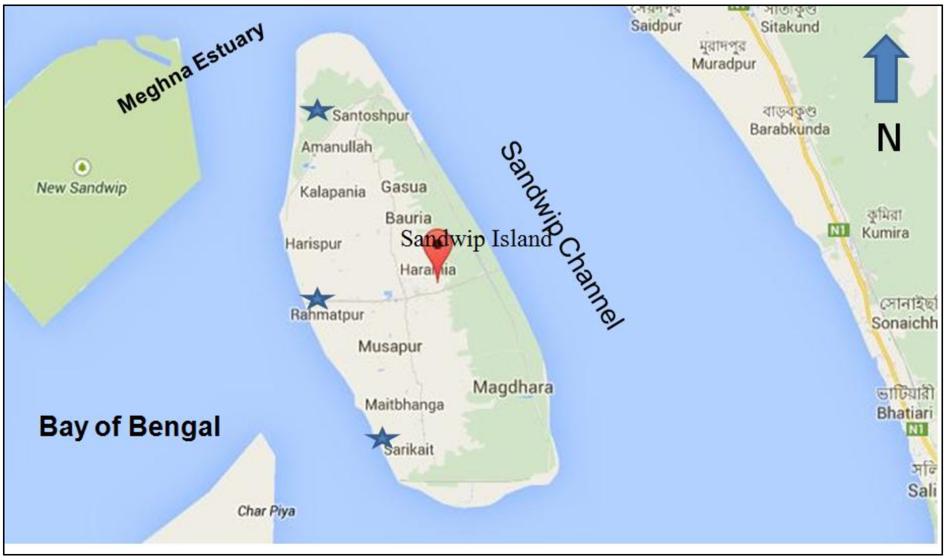

Figure 3. 11: Selected 3 unions (*) in the island for questionnaire survey and focus group discussion

The questionnaire pretest enabled to understand better the adaptation processes and their costs, and to realize the effectiveness of the adaption option. In this study both qualitative and quantitative data were collected. Data collection also included other variables like- gender, age, education level, occupation, income and studying member etc. Government assistance and migration data also were collected from their response as well as documents. Secondary data collected from Sandwip Upazila as well as respective Union Parishad office. The work plan of the survey is shown in the flow chart (Figure 3.13).

Figure 3. 12: Questionnaire interview, participatory observation and focus group discussion

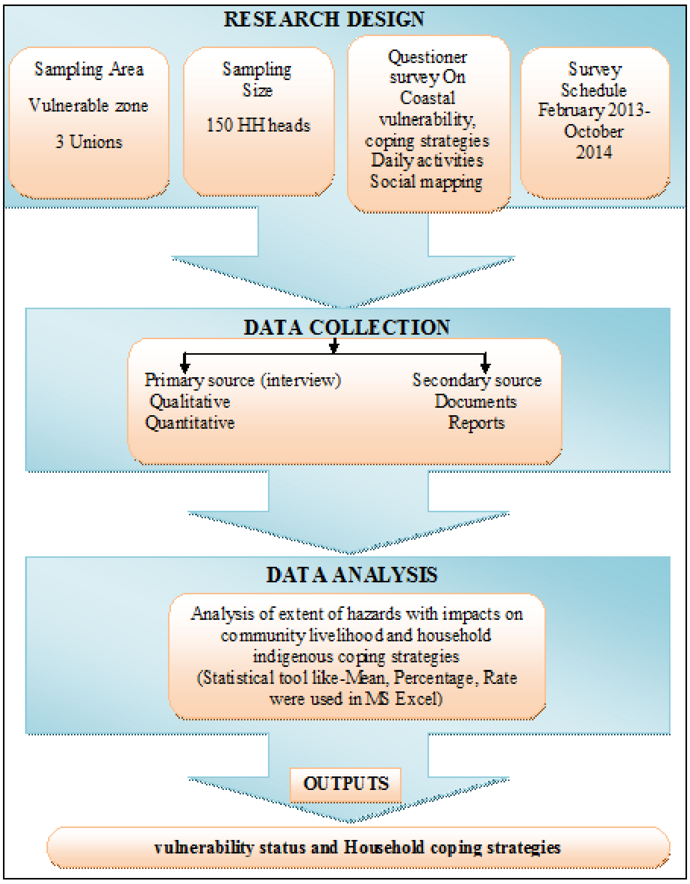

Figure 3. 13: Work plan by questionnaire survey

3.2 Field Data Analysis

3.2.1 Tide gauge data analysis

The tide data set was previously analyzed by Duo (2014) applying general procedures following international guidelines and manuals (GLOSS, 2011; IOC, 2002; IOC-CEC, 1993; ISPRA 2012). Duo (2014) extracted hourly data for harmonic data analysis through t_tide (Pawlowicz et al., 2002). This tool was used to get amplitude and phase for analyzed components for each monitoring station water level signal. The author's chosen period of analysis was between 22nd March 2014 and 14th June 2014. Those parameters were used to calculate a prediction of the astronomical tide.

Finally, Duo (2014) compared the tidal amplitude and tidal delay in between the observed data and a tidal time series data downloaded from the Chittagong Tide Gauge, belongings to Global Sea Level Observing System (GLOSS), through the Intergovernmental Oceanographic Commission (IOC) Sea Level Station Monitoring Facility (www.ioc-sealevelmonitoring.org). The tide gauge is located in the Chittagong Port Harbour at Latitude 22.3333 deg and Longitude 91.825 deg and is managed by Hydrographic Department of Bangladesh Navy (BN). The location is completely different from the Sandwip Island one, as it is located in a harbor and upstream to the Karnaphuli River mouth (Figure 3.14). A visual comparison was made overlapped the Sandwip signal to the signals in Chittagong.

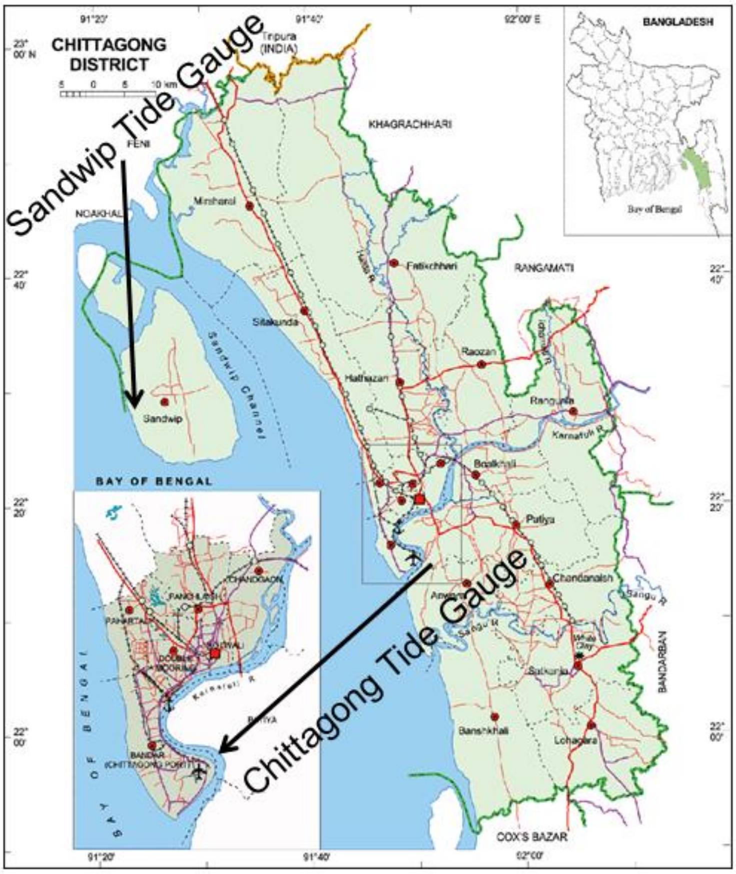

Figure 3. 14: Position map of Chittagong Tide Gauge station to Sandwip

3.2.2 Historical tidal data analysis collected from BIWTA and CPA

Yearly average values for higher water level (CD) were filtered for all nine operating tide gauge to the southeastern coast of Bangladesh for last 30 years covering the manual tide gauge in Sandwip collected from Bangladesh Inland Water Transport Authority Record book. The figure shows the position of the tide gauges selected for the water level recorded (Figure 3.15).

Additionally, yearly highest water level were filtered for four tidal stations (Kalurghat, Sadarghat, Kahl no 10 and Khal no. 18) at the Karnafully river of Chittagong (Figure 3.16) collected from the Chittagong Port Authority record who are responsible to maintain those tide gauges for port hydrography management purposes. And finally a simple graph and table comparison exercise was followed to find the status of the sea water level dynamics near by the island in comparison with other areas.

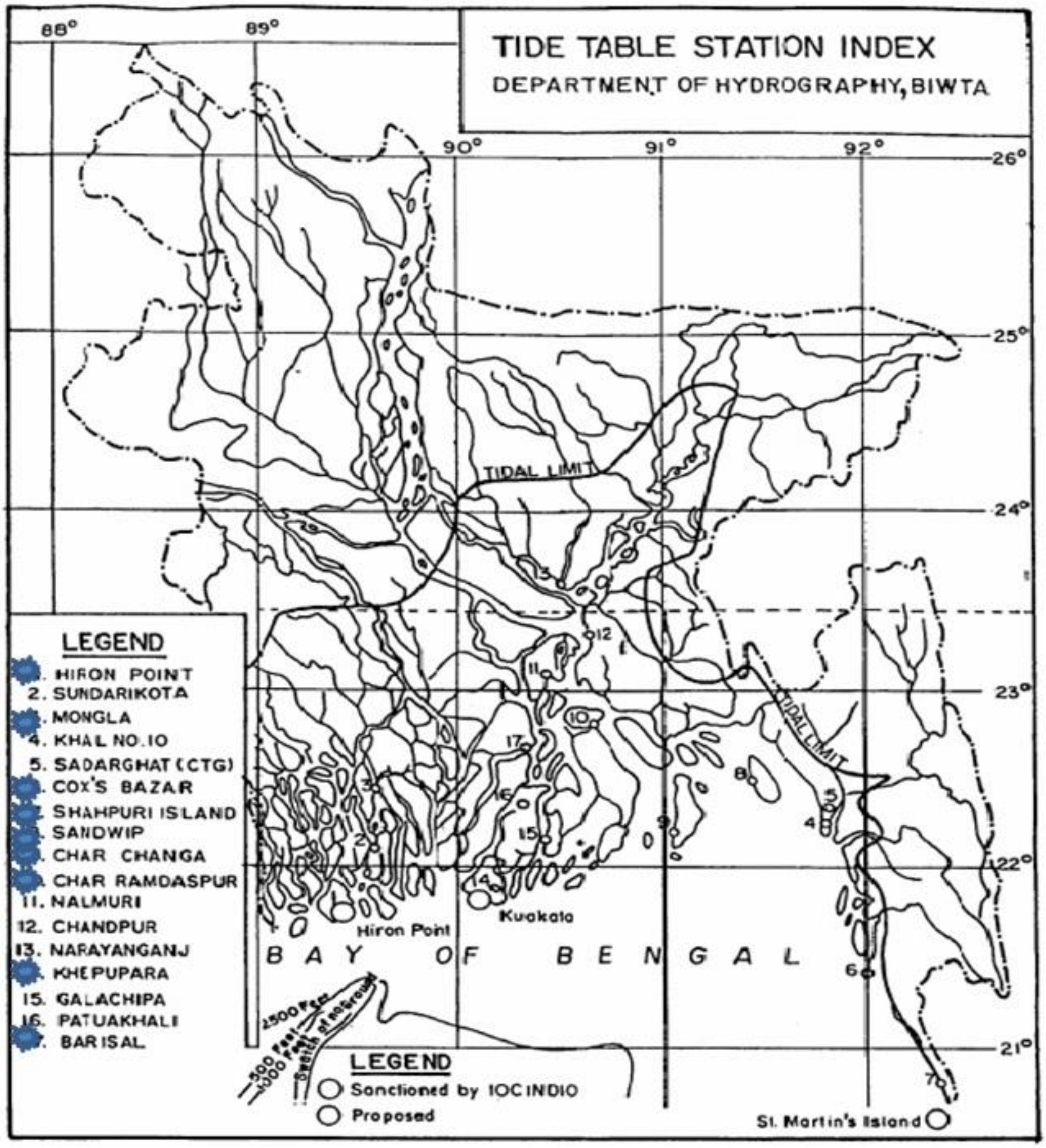

Figure 3. 15: Tidal stations in coastal zone of Bangladesh ( )

A line curve was also plotted using a 5 yrs running meane of the highest water level_for the 4 tidal gauges in the karnafully river, Chittagong to make a better understanding of the trends.

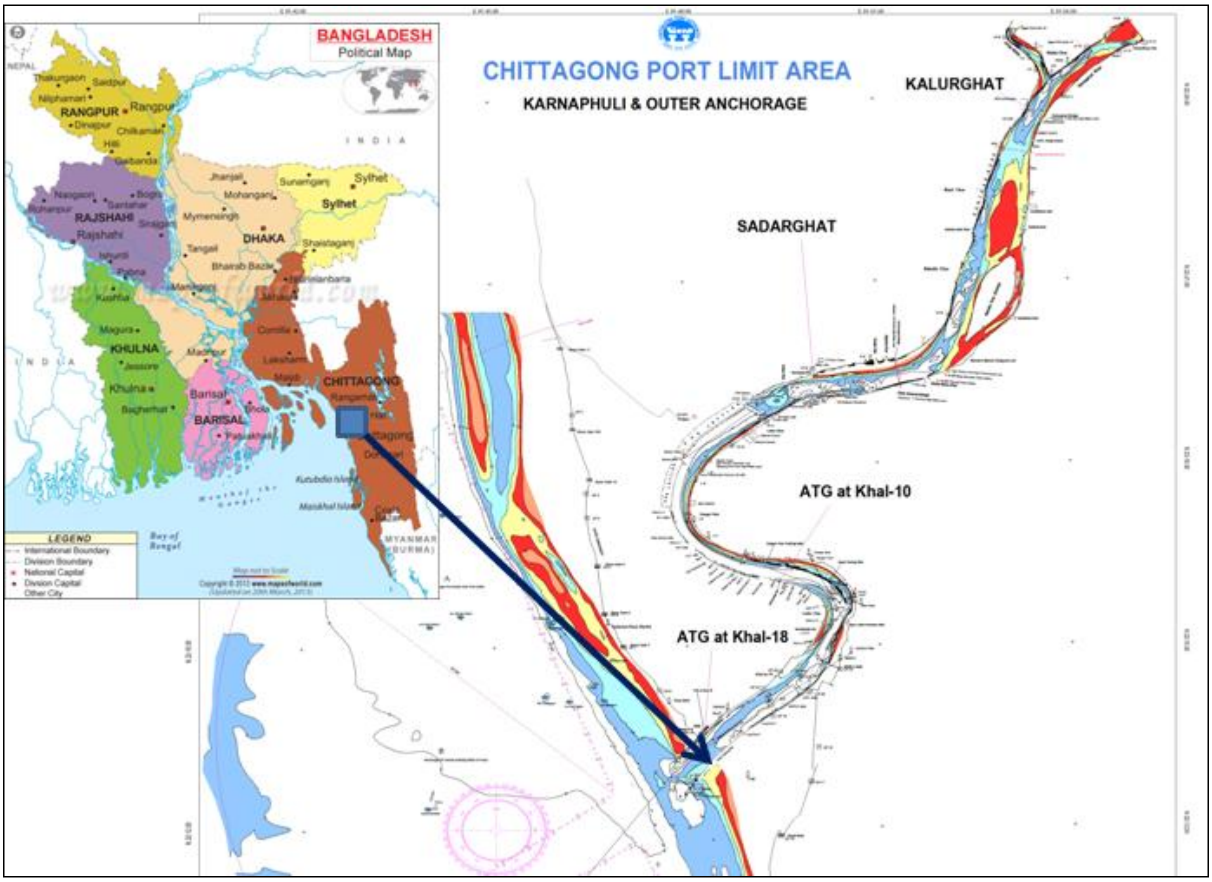

Figure 3. 16: Map of Tidal Stations in Karnafully River, Chittagong

3.2.3 Sediment characteristics

In the lab of the Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, wet sieving through a 0.63mm mesh separated the sand like fractions and mud fractions (Figure 3.17). Sediment moisture percentage was determined by loss of weight drying at 65° C. Furthermore, Sediment Organic Matter (SOM) was determined after drying the samples at 105°C and using Loss On Ignition (LOI) at 500°C for 6 hours. The loss in dry weight was measured and organic matter content was expressed as a percentage (Parsons et al., 1989). But major portion of the of fine sediment samples were processed as dried and brought to UNIFE sedimentological laboratory for further analysis for sediment size and mineralogy.

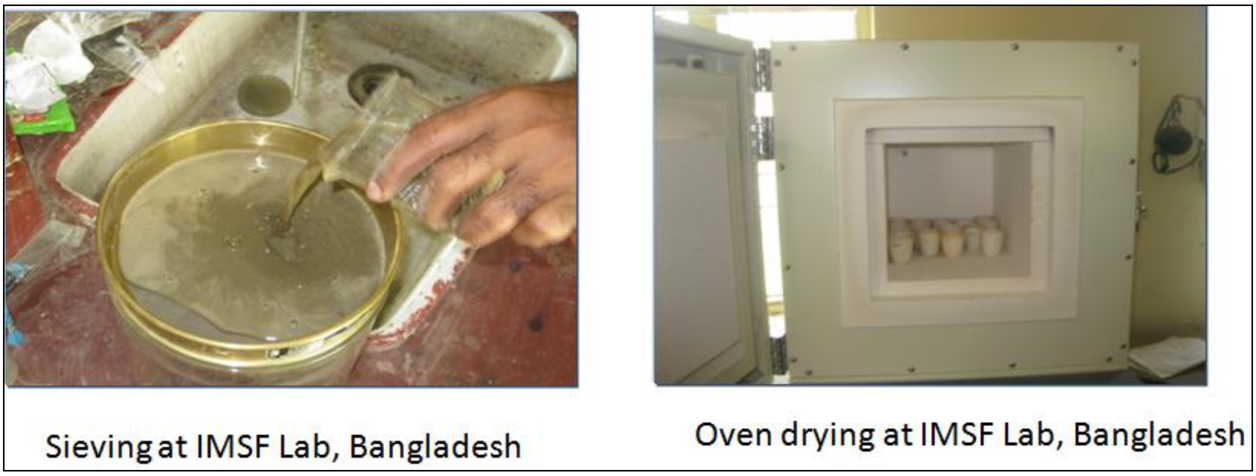

Figure 3. 17: Lab works in IMSF Lab, Chittagong University, Bangladesh

3.2.3.1 Sediment grain size analysis

The X-ray Sedimentation technique for determining the relative mass distribution of a sample by particle size is based on two physical principles: sedimentation theory and the absorption of X-radiation. These two theories are embedded in an analytical instrument called the SediGraph 5100 produced by Micromeritics. Inthe sedimentation theory which is based on Stokes' Law, a particle settling in a liquid will achieve a terminal velocity when the gravitational force balances the buoyancy and drag forces on the particle and is dependent on the size and the density of the particle, and the density and viscosity of the liquid. The process can be translated as if all other variables are held constant, settling velocity is proportional to particle size. Additionally, in absorption of X-radiation which is based on Beer-Lambert Law, a beam of photons (X-rays, in this case) passing through a medium is attenuated in proportion to the path length through the medium, its concentration, and the extinction coefficient of the medium (Figure 3.18). The process can be translated as if all other variables are held constant; X-ray attenuation is proportional to mass concentration.

Total procedure from sample preparation to graph production is described in the following work flow chart (Figure 3.19).

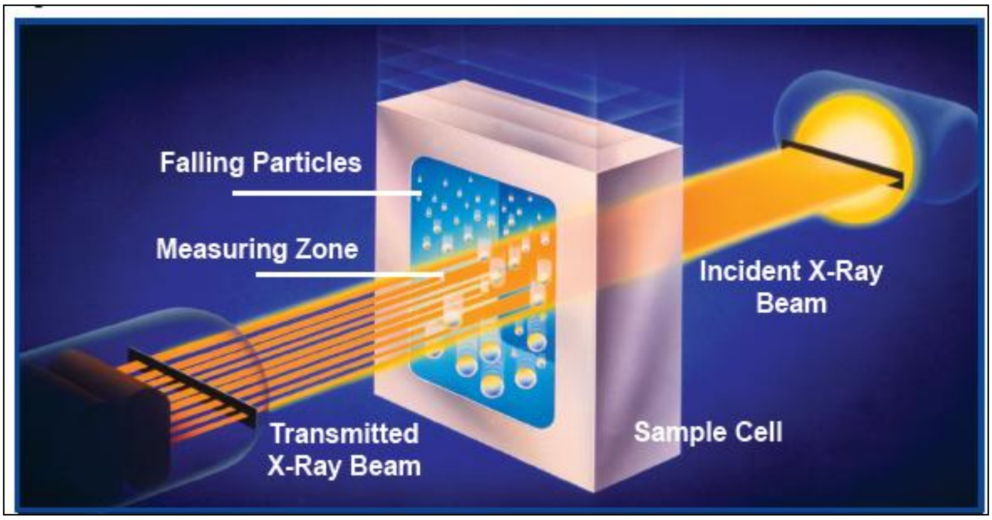

Figure 3. 18: Pictorial Sedigraph working process

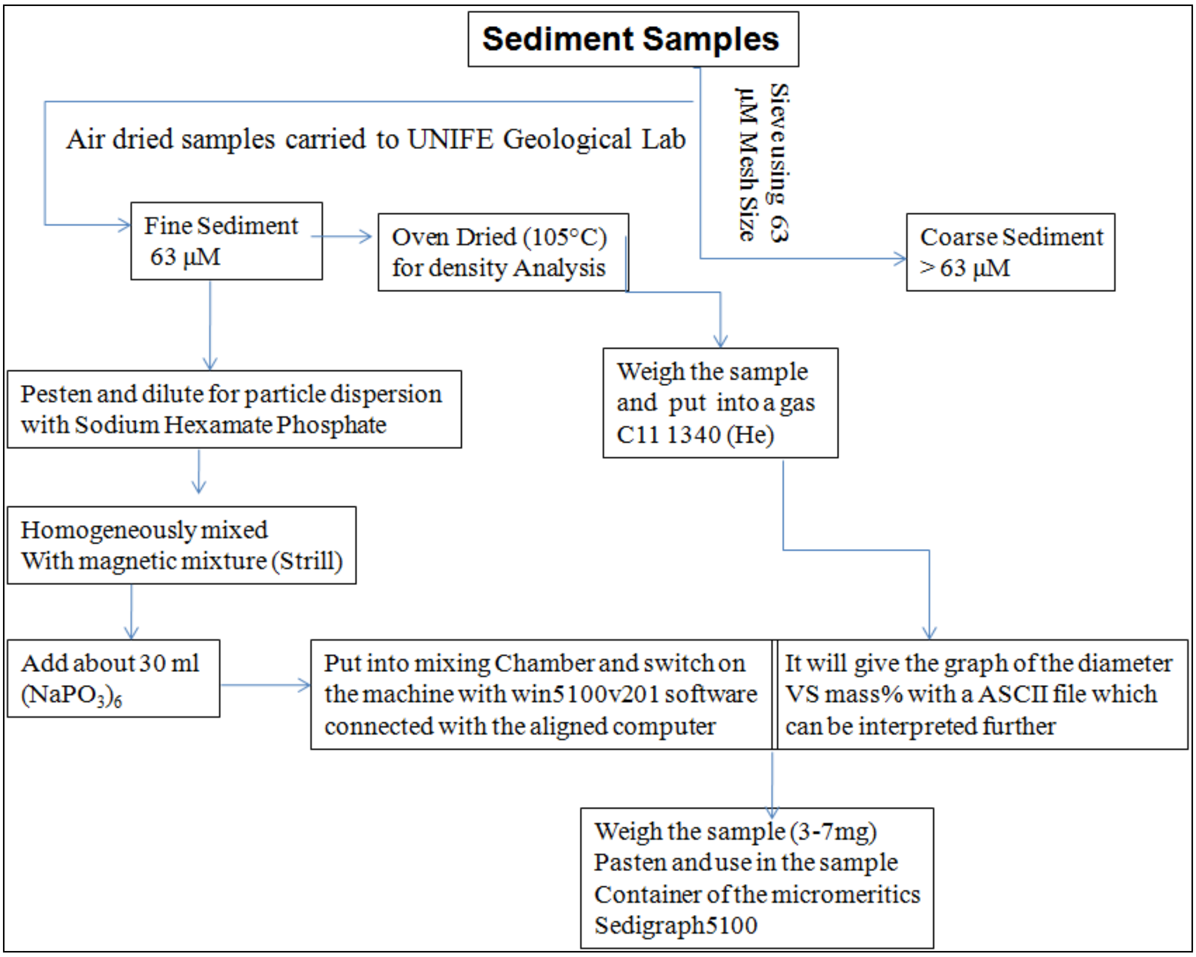

Figure 3. 19: Work flow for sediment grain size analysis

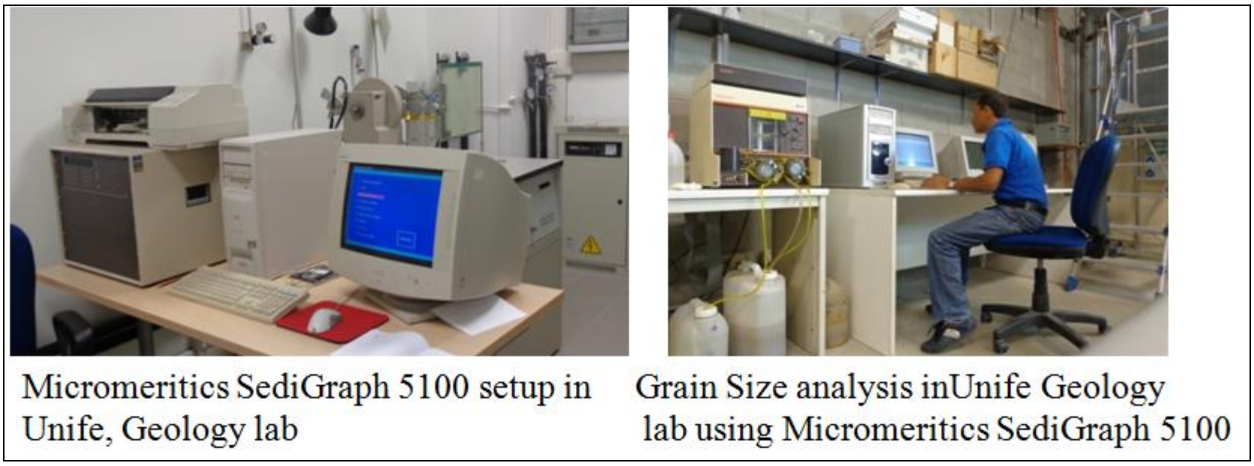

Figure 3. 20 :Lab works in sedimentological laboratory, University of Ferrara, Italy

3.2.3.2 Sediment Mineralogy

The qualitative mineralogical composition (< 63µm) fractions were determined. The oriented samples on ceramic plates were scanned with a Philips 1830 X-ray diffractometer (XRD) with Ni filtered Cu- Kα radiation (at 40 kV, 25 mA) at a scanning speed of 0.02°/sec (2 hrs 10 minute for each sample) from 5° to 75° 2θ with 2 sec per step (Figure 3.21). The identification of minerals was generally based on International Center for Diffraction Data (http://www.icdd.com).

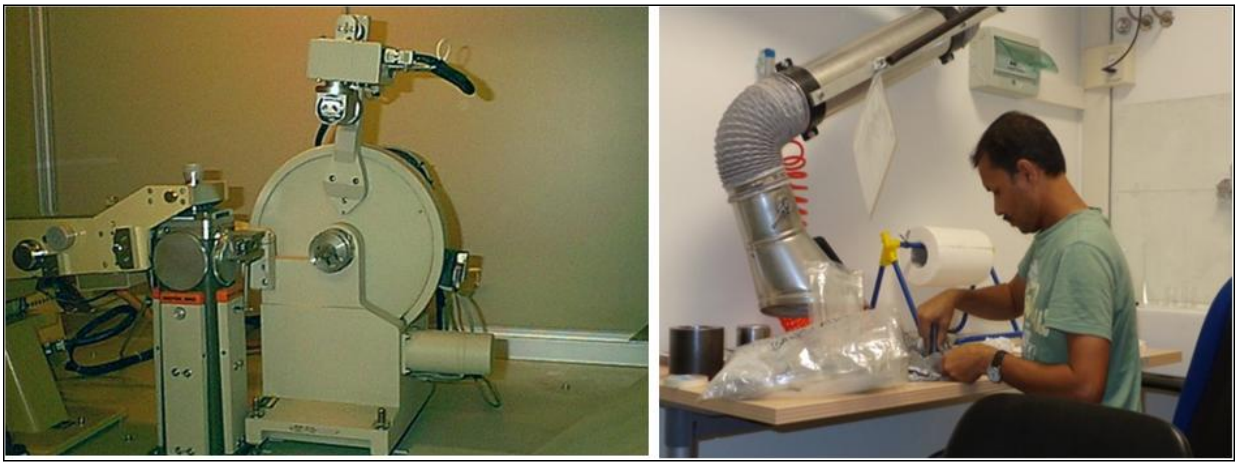

Figure 3. 21: Mineral determination using XRD method in Unife Mineralogy lab, Italy

3.2.4 Questionnaire survey data

Collected data from questionnaire interview were entered in to the computer software like Microsoft Excel and Microsoft word. Multiple responses were calculated to measure extent of hazards, its impact on livelihood of island community and household coping strategies. Livelihood framework tool (Figure 3.22) was used to understand the livelihood status of the disaster prone people where as livelihoods framework is a tool to improve our understanding of livelihoods, particularly the livelihoods of the poor. It was developed over a period of several months by the Sustainable Rural Livelihoods Advisory Committee (DFID, 1999) Adapted from Chambers, R. and G. Conway (1992) Sustainable rural livelihoods: Practical concepts for the 21st century. 5 forms of capitals with 5 types of assets affected in the community by the hazards for each forms were analyzed to get the results.

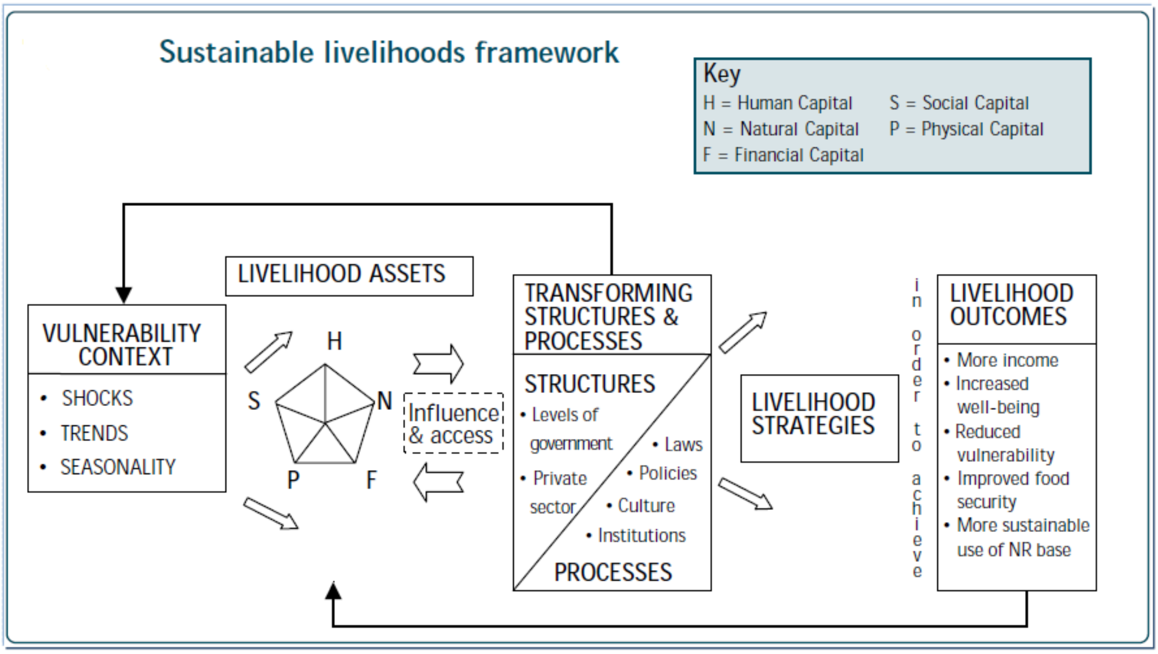

Figure 3. 22: Sustainable Livelihood Framework for vulnerability analysis

3.3 Remote Sensing and GIS Analysis

3.3.1 Shoreline change

Almost all of the near and middle infrared (0.74-3.0 μm) radiation enters deep water and is absorbed with negligible amount of scattering (Jensen, 2000). Due to this absorption characteristic of water infrared bands, satellite imageries can be used successfully to extract land water boundaries with sufficient accuracies. Band 5 (1.55-1.75 μm) of Landsat TM and ETM+ and band 3 (0.7-0.8 μm) of Landsat MSS were used to extract the shorelines. In Landsat TM and ETM any of bands 4, 5 and 7 can be used for coastline extraction, however band 5 is reported to yield better results (Frazier and Page, 2000).

Multi Spectral Scanner (MSS) of 1978, Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) of 2001 and 2006 Landsat scenes covering the target island were downloaded from the Global Land Cover Facility (http://glcf.umiacs.umd.edu/) (Table 3.4).

Table 3. 4: Basic information of the Satellite images used for shoreline change mapping

Image	Date of Acquisition	Resolution	Path/Row	Image Transf. Method	RMSE (Pixel)	RMSE (Meter)
Landsat, MSS,1978	4/15/1978	60	146/044	Polynomial	0.723	43.38
Landsat, ETM+,2001	2/7/2001	30	136/044	Polynomial	0.461	13.83
Landsat, ETM+,2006	12/6/2006	30	136/044	Polynomial	0.432	12.96

These images are available already orthorectified in UTM zone 46N and WGS84 datum. ILWIS, the free user-friendly raster and vector GIS software (v3.7) was used to digitize on screen the shorelines (land-water boundary) using the scale of 1:24000 as a primary attempt to get an idea of the status and extends of shoreline changes for the island. Then the changes were measured using ILWIS onscreen measuring tools from multilayerd shorelines overlayed (Figure 3.23).

Figure 3. 23: Onscreen short Shoreline degitization using ILWIS (Academic virsion)

A comparatively detailed shoreline change mapping was done usin the DSAS (Digital Shoreline Analysis System), an extension of ArcGIS developed by the US Geological Survey allows calculate the rate of change (backward / forward) between the lines to shore for each transect. Setting a base line, the DSAS automatically generates lines perpendicular and equidistant (transects) (Figure 3.23) that intersects the various shorelines (Thieler et al., 2009). The Digital Shoreline Analysis System (DSAS) enables users to calculate shoreline rate-of-change statistics from a time series of multiple shoreline positions in a GIS Environment. The extension was designed to aid in historic shoreline change analysis which is also useful for datasets that use poly lines as a representation of a feature's position at a specific point in time, such as the forward limit of a glacier; river channel boundaries, land use and land cover maps etc. DSAS works by generating orthogonal transects at a user-defined separation and then calculates rates-of-change and associated statistics that are reported in an attribute table (Theiler, et al, 2003). Several statistical methods are used to calculate the shoreline change extends and rates with the most commonly used been are end-point rate (EPR), net shoreline movement (NSM) and shoreline change envelop (SCE) .The end point rate calculations are done by dividing the distance of shoreline movement by the time gap between the oldest and youngest shoreline in the data set. The major advantage of this method is ease of computation and calculations can be done on minimum two shorelines only. The EPR method is only good for short term shoreline change analysis as it only consider latest and oldest shoreline position and suppresses all in other in long term analysis. The net shoreline movement (NSM) reports distance not rate. It reports the distance between the oldest and youngest shoreline for each transect where as SCE is distance (not rate) between the shoreline farthest from and closest to the baseline of each Transect. It represents the total change in shoreline movement for all available shoreline positions regardless their dates.The inputs required for this tool are shoreline in the vector format, date of each shoreline, and transect distance(Thieler et al., 2009).

For the present study, a total of four (1978, 1989, 2001 and 2006) multi temporal and multispectral landsat satellite images were collected from Glovis (glovis.usgs.gov), (Table 3.5) were used to extract and digitize vector shoreline data. a baseline parallel to the general orientation of the shoreline is generated inshore. The longitudinal extent of the studied shoreline was approximately 52 kilometers (the baseline polyline length) all around the island. Arc GIS 10.1 was used for digitization and generalization of extracted shorelines. Shorelines were digitized on-screen in ArcMap follwing visula cliff top line as shoreline all around the island. All shorelines with the same georeferences and using required attribute fields were used following the USGS users guidelines for

DASA 4.0 (Thieler et al., 2009) to appened in a a sigle feature class and creating a baselines in the personal geodatabase. A transect interval of 100 meters was selected which in effect divided into 525 discrete transect locations (Figure 3.24), at which DSAS estimated the landward and seaward changes of the shoreline in elapsed period.

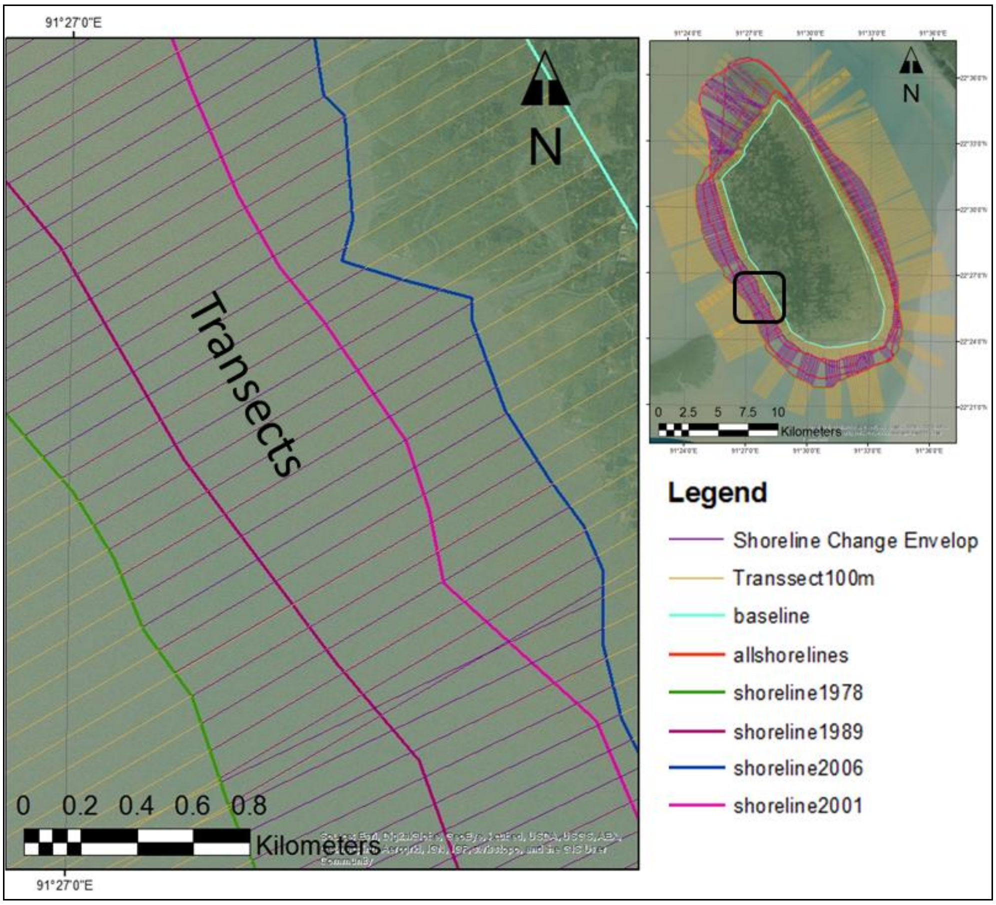

Figure 3. 24: Transescts (100 meter apart) generated by DSAS extensions.

Table 3. 5: Basic information of the Satellite images used for shoreline change mapping

Image	Date of Acquisition	Resolution	Path/Row	Image Transf. Method	RMSE (Pixel)	RMSE (Meter)
Landsat, MSS,1978	4/15/1978	60	146/044	Polynomial	0.723	43.38
Landsat, TM,1989	2/22/1989	30	136/044	Polynomial	0.441	13.23
Landsat, ETM+,2001	2/7/2001	30	136/044	Polynomial	0.461	13.83
Landsat, ETM+,2006	12/6/2006	30	136/044	Polynomial	0.432	12.96

The whole coast has been divided into 4 zones according to geomorpgological differences in their dynamics processes as justified from the field visit for a better description (Figure 3.25). They are the north zone covering transects 4 to 86, the east zone covering transecets from 87 to 283, the south zone covering transept is from 284 to 384 and the west zone covering transects from 385 to 525 and 1 to 3. And finally, the statisticale tables of all automatically calculated data in DASA for whole transect and seperatly for transsects of all 4 zones have been extracted into Excell for numerical and graphical comparison of the study.

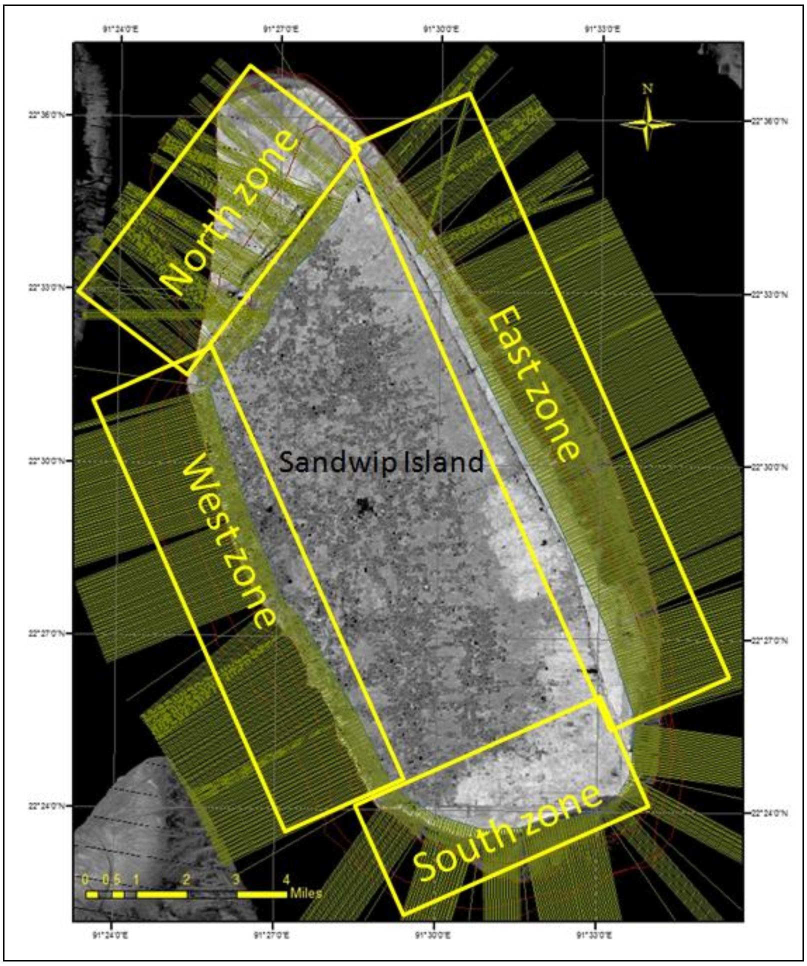

Figure 3. 25: Four sectional zones divided of the transsects

3.3.2 Erosion-Accretion area map

The erosion-accretion assessment was conducted using Landsat satellite imagery. The horizontal datum used to create the shoreline change maps was WGS 84. The data processing and evaluation and shoreline assembly and assessment are described in the following subsections.

3.3.2.2 Data collection

All the datasets are satellite imagery datasets of landsat images from different versions of landsat satellites. All the datasets were collected from glovis.usgs.gov. The datasets were all geo-referenced satellite images with resolution of 30m (Table 3.6).

Table 3. 6: Basic information of the Satellite images used for erosion accretion maping

Image	Date of Acquisition	Resolution	Path/Row	Image Transf. Method	RMSE (Pixel)	RMSE (Meter)
Landsat, MSS,1978	4/15/1978	60	146/044	Polynomial	0.723	43.38
Landsat, TM,1989	2/22/1989	30	136/044	Polynomial	0.441	13.23
Landsat, ETM+,2001	2/7/2001	30	136/044	Polynomial	0.461	13.83
Landsat, ETM+,2006	12/6/2006	30	136/044	Polynomial	0.432	12.96
Landsat, ETM+, 2014	4/24/2014	30	136/044	Polynomial	0.463	13.87

3.3.2.3 Data processing

The acquired imagery datasets were processed manually using arcmap 10.1. The area of the island was first cut manually using polygon shapefiles of the island of different years. Then shoreline was drawn using line shapefiles. Then using overlapping method, the erosion and accretion were determined. Then using measurement tool, total eroded and total accreted areas were determined.

3.3.2.4 Data validation

The processed data were verified using google earth, arc basemap and ground truthing. The Whole process is described briefly in the following work flow chart (Figure 3.26).

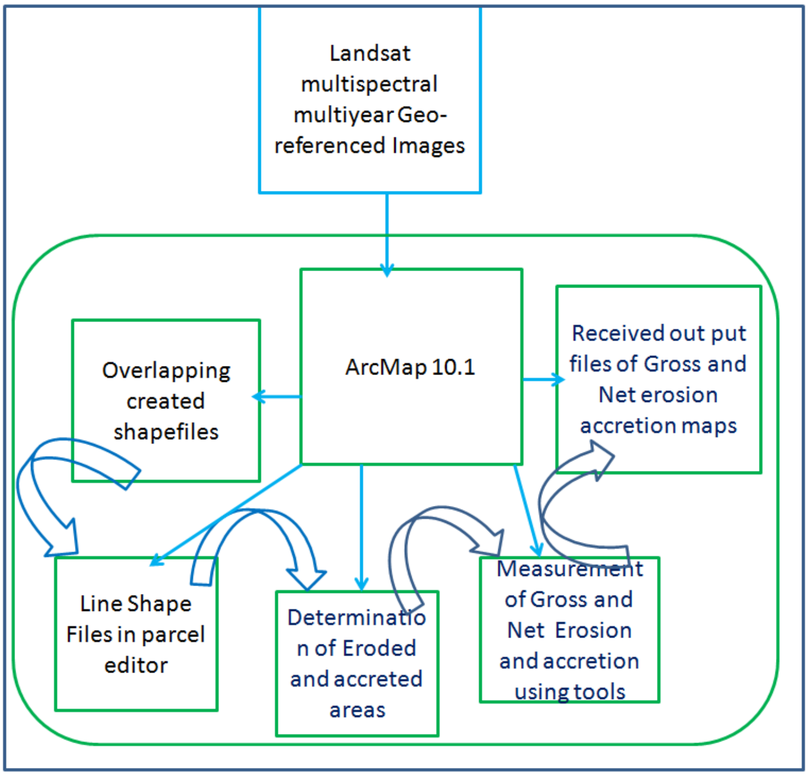

Figure 3. 26 :Work flow chart for erosion accretion mapping

3.3.3 Land use and land cover change

There are mainly three ways of landuse/landcover mapping namely 1) Ground surveying, 2) Supervised classification of satellite image and 3) Unsupervised classification of satellite image. Ground surveying is the hardest and most laborious one. Supervised classification can be done when the resolution of acquired satellite image is high (i.e. <30m/pixel) and unsupervised classification is the way to make landcover maps when the resolution of acquired satellite image is low (i.e. >=30m.pixel). As the resolution of our satellite images were 30m, so unsupervised classification is preferred to determine the change in land cover of the island.

The land cover change maps were done using landsat satellite imagery of multiyaers and mul;tispectral. The horizontal datum used to create the change maps was WGS 84. The data processing and evaluation and shoreline assembly and assessment are described in the following subsections.

3.3.3.1 Data collection

All the datasets are satellite imagery datasets of landsat images (Table 3.7) from different versions of landsat satellites (Figure 3.6). All the datasets were collected from glovis.usgs.gov. The datasets were all geo-referenced satellite images with resolution of 30m.

3.3.3.2 Data processing

The acquired imagery datasets were processed manually using arcmap 10.1. using image classification tools following unsupervised classification.The whole process is described briefly in the following work flow chart (Figure 3.27).

Table 3. 7: Basic information of the Satellite images used for land cover changes maping

Image	Date of Acquisition	Resolution	Path/Row	Image Transf. Method	RMSE (Pixel)	RMSE (Meter)
Landsat, TM,1989	2/22/1989	30	136/044	Polynomial	0.441	13.23
Landsat, ETM+,2001	2/7/2001	30	136/044	Polynomial	0.461	13.83
Landsat, ETM+, 2014	4/24/2014	30	136/044	Polynomial	0.463	13.87

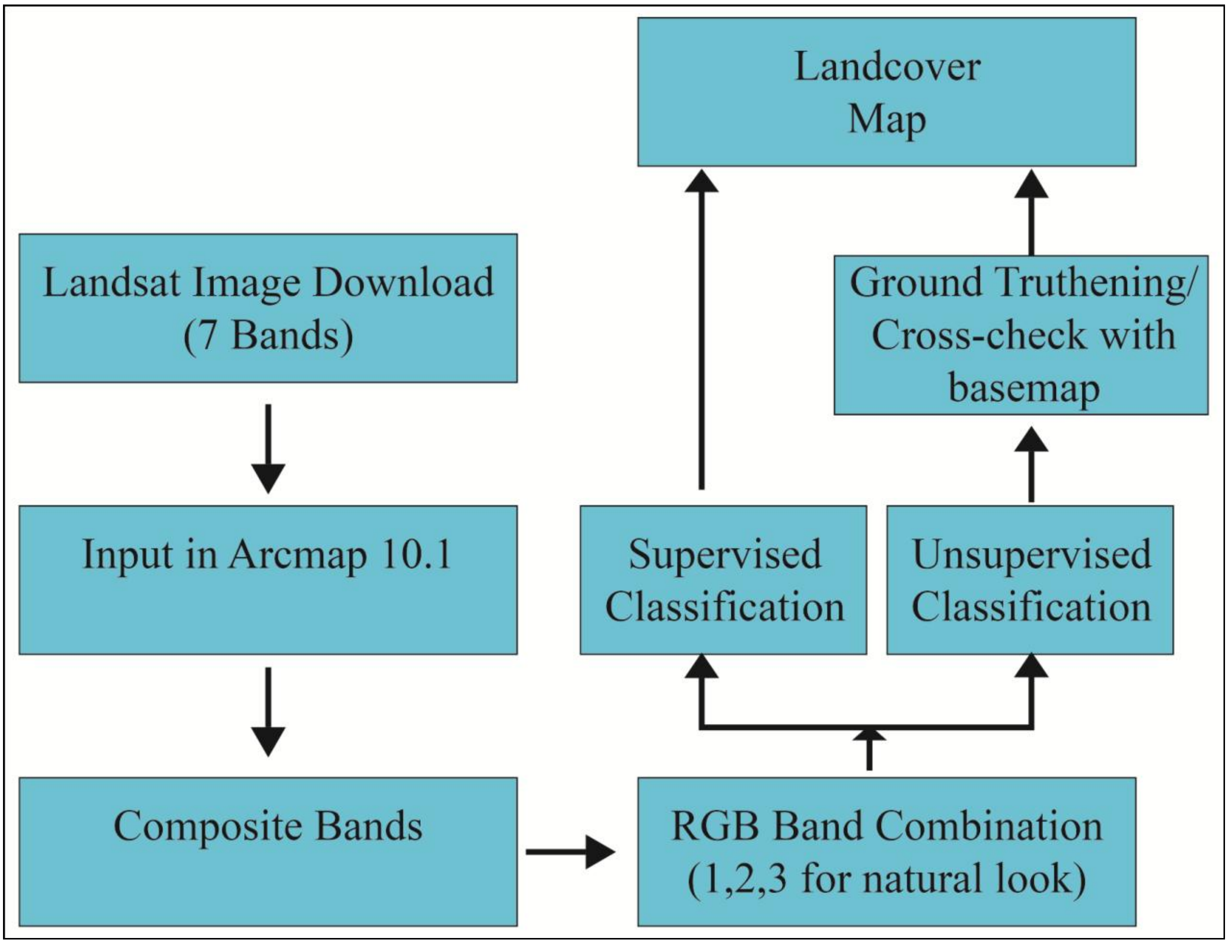

Figure 3. 27: Workflow of land cover change mapping

3.3.4 DEM (Digital Elevation Model)

The DEM of Sandwip was created using bathymetric survey data from BIWTA, topographic satellite data from ASTER satellite and shoreline datasets from GEBCO to merge the bathymetric and topographic data. The horizontal datum used to create the DEM is WGS 84. Data processing and evaluation and DEM assembly and assessment are described in the following subsections. The data collection process is described elaborately below (Table 3.8):

Table 3. 8: Specifications of Sandwip Island DEM

Grid Area	Sandwip, Chittagong, Bangladesh
Coordinate System	Geographic Decimal Degree
Horizontal Datum	World Geodetic System of 1984 (WGS 84)
Vertical Datum	Mean Sea Level
Vertical Units	Meters
Cell Size	1 arc second
Grid Format	ESRI Arc ASCII Grid

3.3.4.1 Data collection

Topographic data sets of ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) were collected from the Earth Explorer website. ASTER is a Japanese sensor which is one of fivere mote sensory devices on board the Terra satellite launched into Earth orbit by NASA in 1999. ASTER provides high-resolution images of the planet Earth in 14 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light. The ground resolution of images ranges between 15 to 90 meters. ASTER satellite image data contributes to a wide array of global change-related application areas including vegetation and ecosystem dynamics, hazardmonitoring, geology andsoils, land surface climatology, hydrology, land cover change, and the generation of digital elevation models (DEMs).

The data format is *geotiff* and the acquisition date of the data was 17/10/2011. The data is free of cost and is the latest 30m pixel resolution data of the study area, which could be acquired without any cost. To download data from the Earth Explorer website, one must open an account to the website and then he/she can download imagery data sets for various purposes. Both cost free and paid data sets are available for use in the website.

Bathymetric data sets from their latest bathymetric survey covering 2008 to 2012 were collected from BIWTA (Bangladesh Inland Water Transport Authority) regional office of Chittagong, CPA (Chittagongt Port Authority) and BN (Bangladesh Navy) conducted around Sandwip Island.. BIWTA, CPA and BN conduct survey to that coastal region because of its importance as an water transport and port facilities

Shoreline data sets were collected from the global shoreline website of NOAA which is Self-consistent Hierarchical High-resolution Shorelines (GSHHS). The gridded shoreline datasets used here were produced and released in February, 2013.

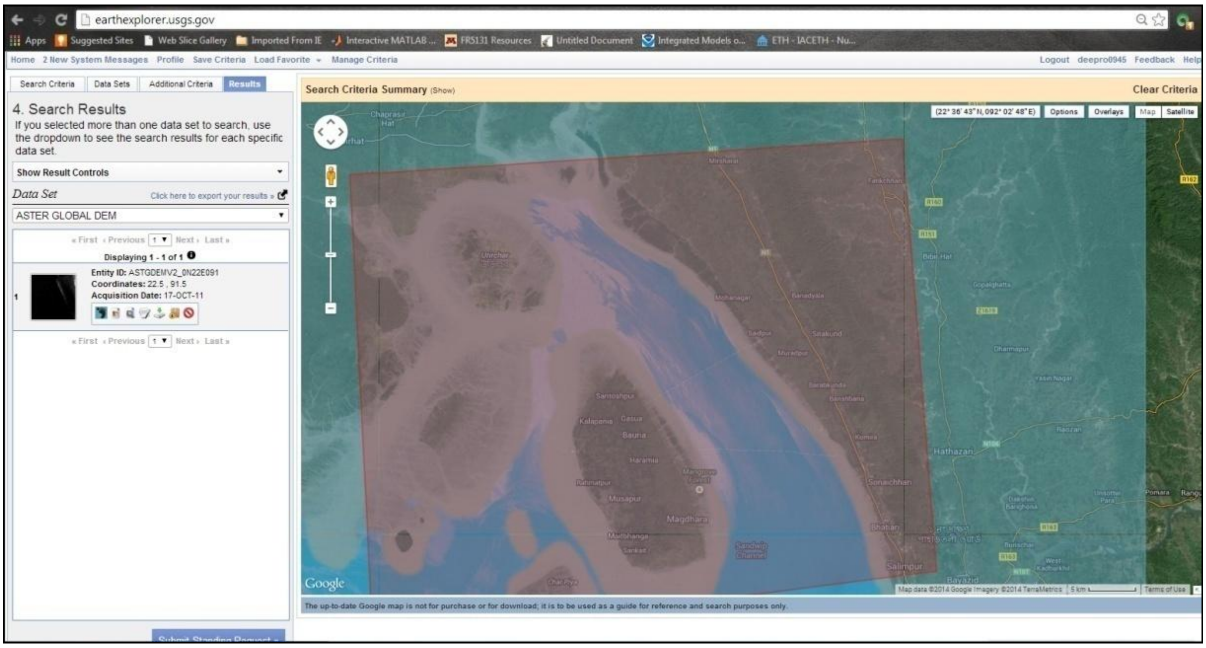

Figure 3. 28: Topographic data view collected from Earth Explorer

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3.3.4.2 Data processing

A variety of softwareswere used to process the collected data setsincluding MS Excel convert the bathymetric data sets of *.xls* format to *.csv* format and ArcGIS 10.1 to create a 2D DEM of the study area mainlymerging and processing all data sets required.

The formatted bathymetric datasets collected, the topographic datasets and coastline datasets downloaded were the processed (brought in the same folder of the workspace-connected the folder of the data setss to the workspace- allinged-merged-converted vector to raster data-interpolated and mosaic etc) in the GIS environment of the arc tools follwing step by step roles bringing under a same folder to work in arcmap to produce the final product, 2D model of the expected DEM. The whole process is given as a flowchart below (Figure 3.29).

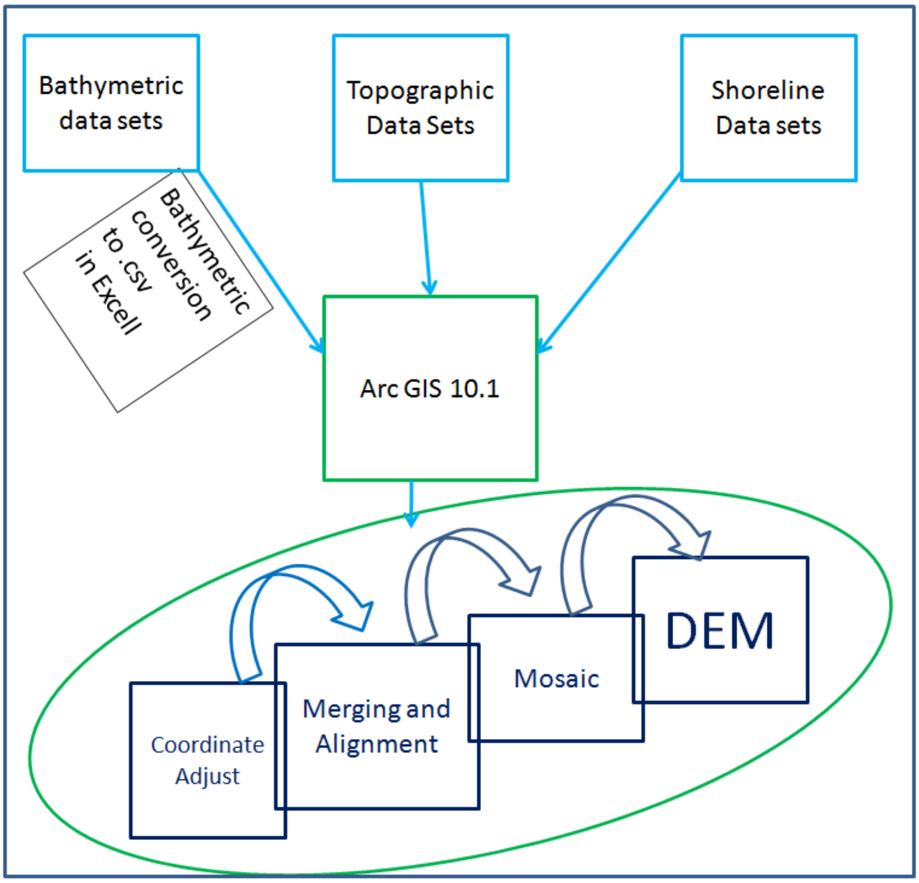


Figure 3. 29: Flow chart DEM creation process

3.3.5 TIN (Triangulated Irregular Network)

Trianguated Irregular Network (TIN) is important to understand the real time elevation of any area. TINs can be derived from any satellite developed Digital Elevation Models i.e. SRTM/ASTER. The TIN was produced using DEM dataset of ASTER collected Earth Explorer (from earthexplorer.usgs.gov). The data is free of cost and is the latest 30m data of the study area, which could be acquired without any cost. To download data from the Earth Explorer website, one must open an account to the website and then he/she can download imagery data sets for various purposes. Both cost free and paid data sets are available for use in the website. Data processing, evaluation and TIN assessment are described in the following subsections.

Table 3. 9: Specifications of Chittagong-Noakhali coast DEM

Grid Area	Sandwip, Chittagong, Bangladesh
hCoordinate System	Geographic Decimal Degree
Horizontal Datum	World Geodetic System of 1984 (WGS 84)
Vertical Datum	Mean Sea Level
Vertical Units	Meters
Cell Size	1 arc second
Grid Format	ESRI Arc ASCII Grid

3.3.5.1 Data collection

Topographic data sets of ASTER were collected from the Earth Explorer website. The data format is *geotiff* format and the acquisition date of the data was 17/10/2011.

3.3.5.2 Data Processing

Aster data downloaded for the target area of study was open in arc map (Figure 3.30), desired area was cut using shapefile as a mask (Spatial analyst tool) ((Figure 3.31, 3.32) and using symbology property of the layer elevation was clasified (Figure 3.33, 3.34). Finally, using 3d analyst tool (Figure 3.35) the raster was converted to TIN (Figure 3.36).

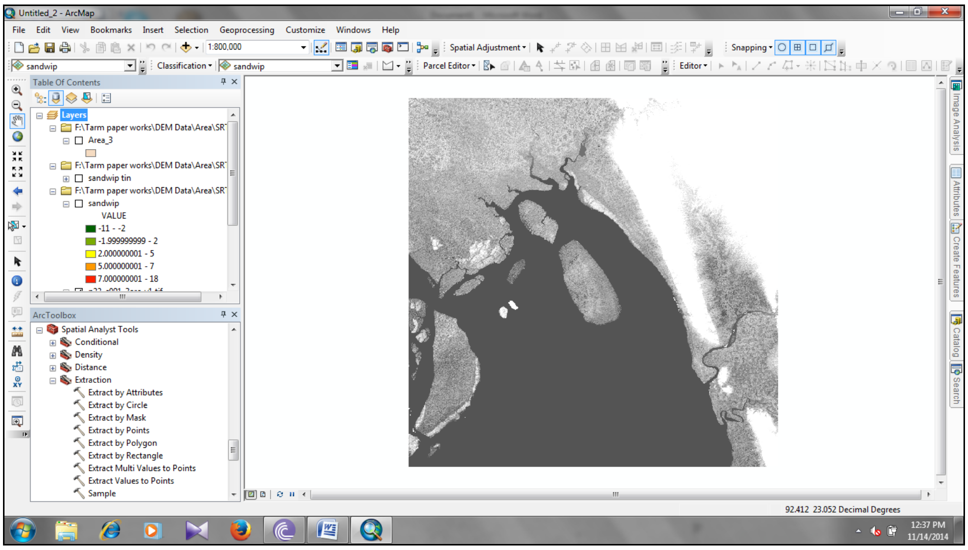


Figure 3. 30: Opening the data in arc Map

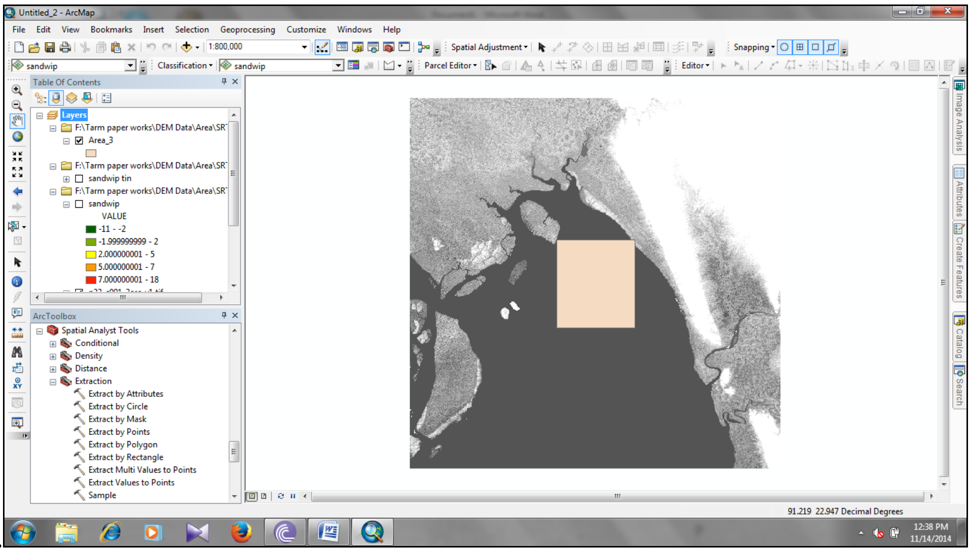


Figure 3. 31: Cutting the desired area using a shapefile

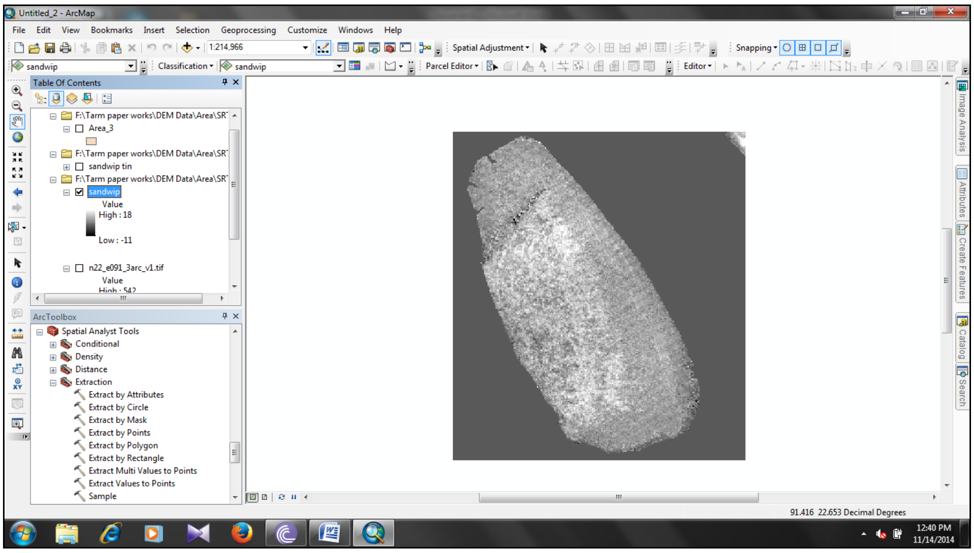


Figure 3. 32: Desired area in arcMap

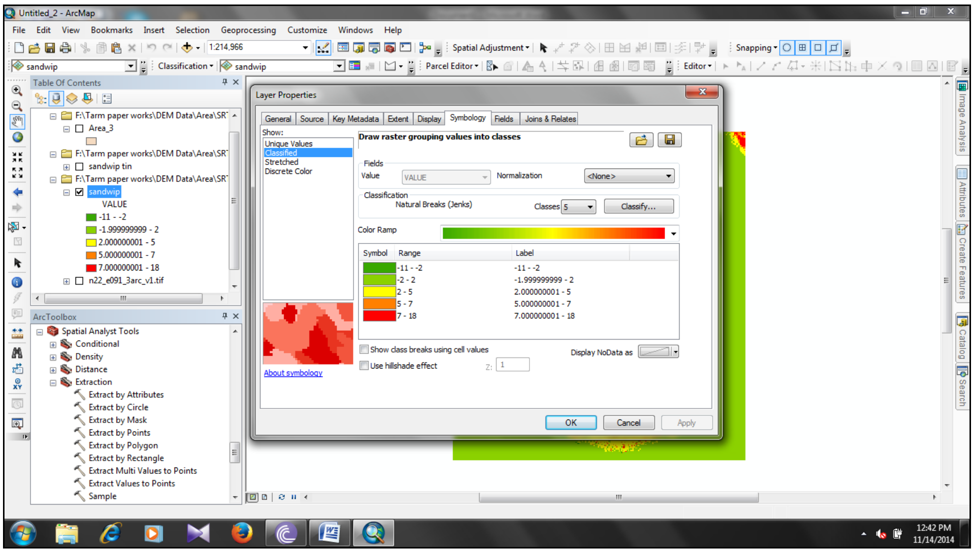


Figure 3. 33: Elevation classification using symbology property

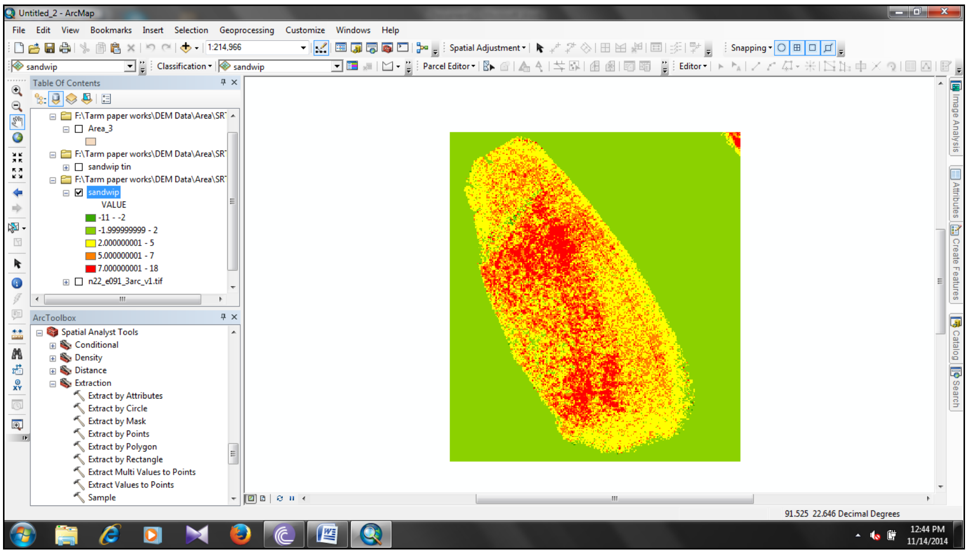


Figure 3. 34: Elevation by color scale

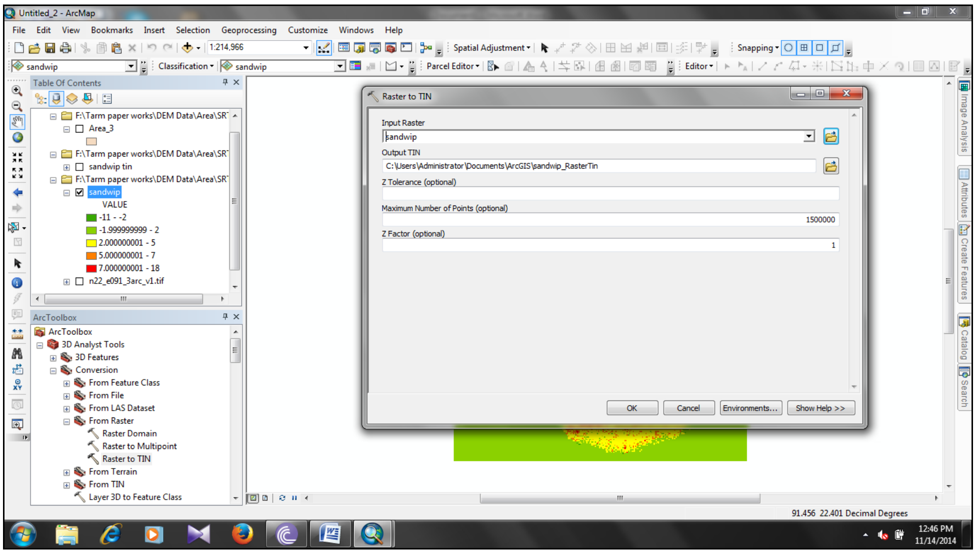


Figure 3. 35: Use of 3D Analyst tool

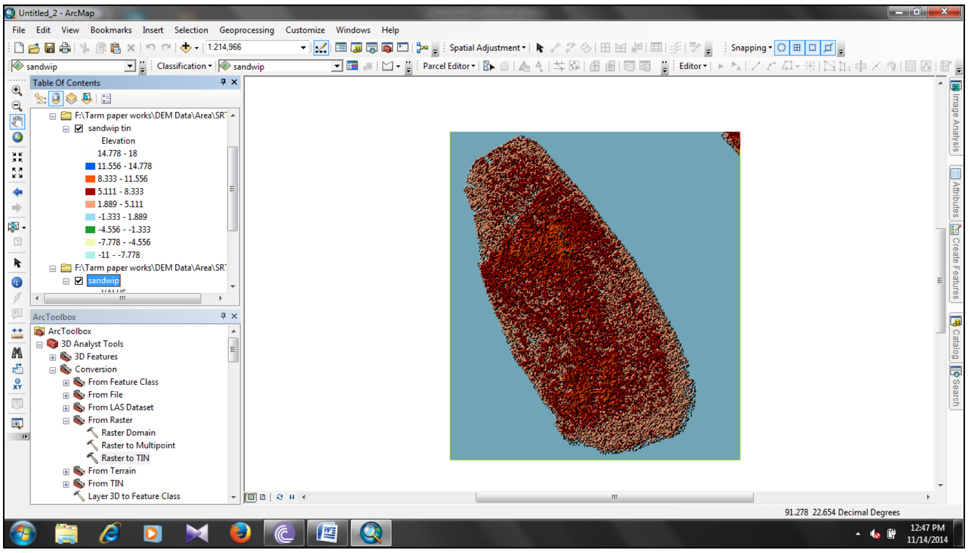


Figure 3. 36: Elevation by color scale

3.3.6: Contouring for inundation assessment

Topographic maps show the elevation of a region above some datum level, which is usually mean sel level. Mean Seal Level (MSL) is the average level of water in the oceans, which is set as the zero points for elevations on topographic maps. Elevation data are three dimensional points of land surface features that scientists can use to create Digital Elevation Model (DEMs) or surfaces that can then be shown on maps as simple contour lines, which are lines connecting all points that have the same elevations above mean sea level. Along with the use of topographic maps by contour lines in numerious perspectives, hydrograpgers, hydrologistas and meteorologists use it to find the area susceptible to inundation due to floods or storm surges along with so many different uses. There are mainly two available data sets for height measurement, ASTER and SRTM both of which are algorithm images. However, ASTER is comparatively better than SRTM in case of height and coordinates measurements etc (Li et al., 2013).

So, using ASTER digital elevation model of the study area of 2011 image, contours were drawn using “contouring” tool from ‘spatial analysis’ with an interval of 3 meters starting from ‘-3m’ to ‘+12m’ in compare with the datum of MSL in ArcMap 10.1. Then individually 3 meter and 6 meter elevations were chosen to show the areas of expected inundation. An interval of 3 meters is set to show the height of 0 to 3 meter and 6 meter to be high lightened. Then a polygon including all the areas following upto 3 meter and 6 meter height were drawn. The small fractions were neglected could be estimated from available satellite imagery. The area covered by the polygon was measured using measurement tool, subtract the measurment from total area and the reslut is the remaining area after certain level of inundation.

The whole process can be shown in the flow chart below (Figure 3.37) :

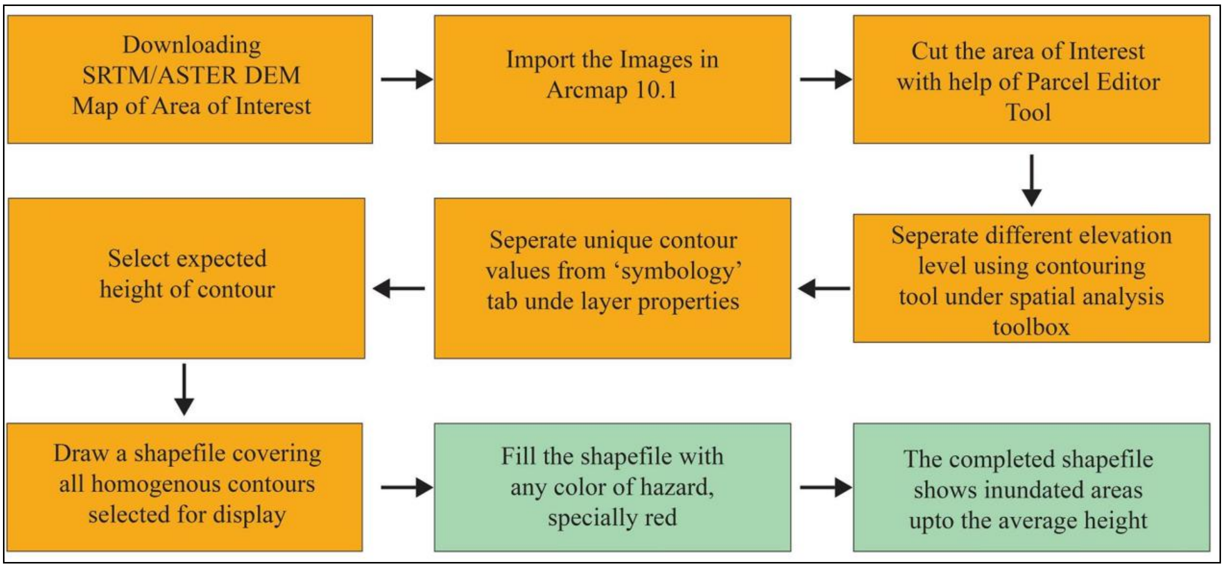


Figure 3. 37: Flow chart showing contour line and inundation polygon creating for 3 and 6 meter storm surges

4. RESULTS AND DISCUSSION: TIDAL REGIME, GEOMORPHOLOGY AND LAND COVER

4.1 Tidal Data

4.1.1 Observed tidal data and comparison with Chittagong station

The data analysis revealed that Sandwip signal has a higher tidal range and it is delayed in time compared to Chittagong more possibly due to the distance of the island to the north and irregular shallower bathymetry. Moreover, Sandwip Island signal evidences an asymmetry for low tide levels too. A visual comparison is shown in Figure 4.1. The general delay found during calculation was 47.5 minute. For further details the reader is suggested to consult Duo (2014).

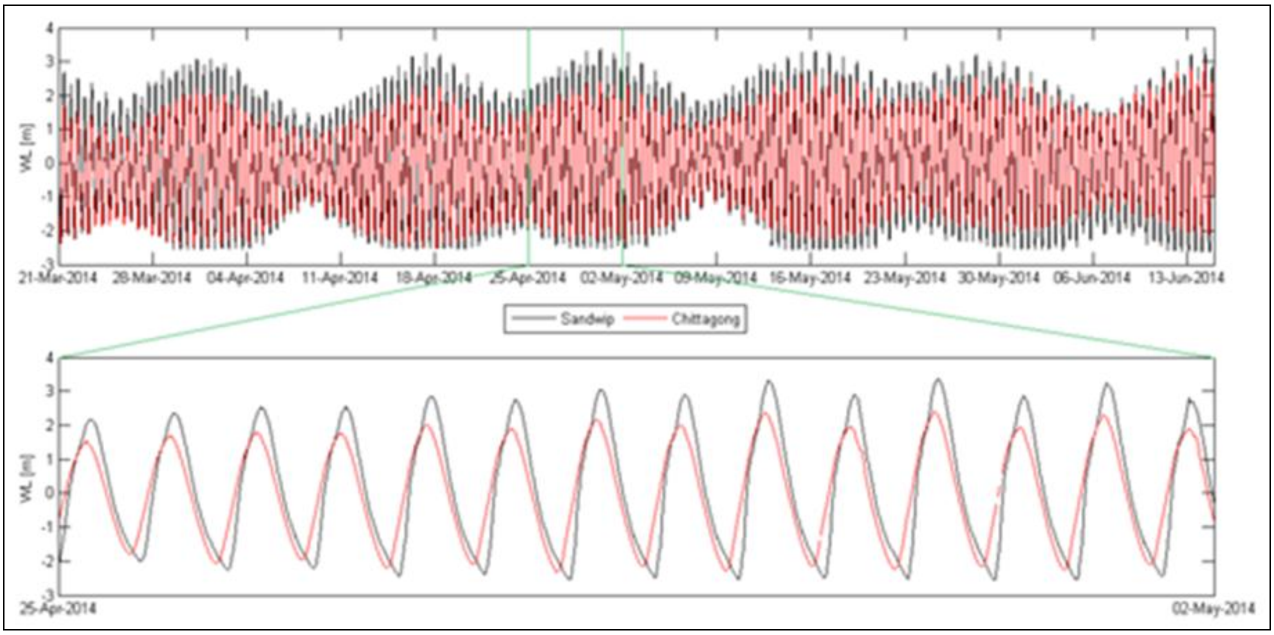


Figure 4. 1: Visual comparisons between Sandwip Island and Chittagong signals

4.1.2 Historical tidal data analysis

Analysis of the 29 years tidal data collected from nine different stations of south eastern coast of Bangladesh observed by BIWTA shows that maximum 0.68 meter increase of the sea level which is in Sandwip area situated in the lower Meghna river estuary and minimum is 0.20 meter which is in Cox's Bazar situated in the southeastern tip of Bangladesh open to the open ocean (Table 4.1).

4. RESULTS AND DISCUSSION: TIDAL REGIME, GEOMORPHOLOGY AND LAND COVER

Table 4. 1: Yearly average high water spring tidal records in the south eastern coast of Bangladesh (Note: BIWTA Tide Table Record)

Year	Hiron Point	Mongla	Cox's Bazar	Shahpuri Island	Sandwip	Char Changa	Khepupara	Char Ramdaspur	Barisal
1985	3.32	3.51	4.10	3.80	6.42	4.10	3.09	4.02	2.42
1986	3.38	3.49	4.06	3.82	6.26	4.12	3.12	4.12	2.52
1987	3.45	3.43	4.08	3.76	6.35	4.25	3.29	4.16	2.59
1988	3.52	3.56	4.12	3.92	6.52	4.30	3.31	4.19	2.49
1989	3.70	3.58	4.20	3.95	6.70	4.32	3.16	4.20	2.58
1990	3.80	3.61	3.90	3.98	6.60	4.41	3.21	4.20	2.75
1991	3.50	3.57	3.90	3.87	6.80	4.38	3.10	4.10	2.79
1992	3.43	3.53	3.99	3.85	6.90	4.34	3.07	4.58	2.86
1993	3.42	3.55	4.02	3.88	7.03	4.34	3.11	4.61	2.76
1994	3.45	3.51	4.03	3.82	6.94	4.32	3.07	4.55	2.82
1995	3.42	3.54	4.08	3.87	7.05	4.40	3.09	4.64	2.79
1996	3.48	3.54	4.04	3.83	7.12	4.37	4.67	4.64	2.74
1997	3.42	3.50	3.97	3.75	6.87	4.24	4.55	4.39	2.72
1998	3.37	3.96	4.08	3.88	7.12	4.42	4.37	4.67	2.77
1999	3.38	3.93	3.98	3.89	6.97	4.30	4.26	4.59	2.73
2000	3.41	3.87	3.97	3.92	6.78	4.28	4.15	4.45	2.81
2001	3.42	3.87	4.07	3.95	6.93	4.39	4.25	4.58	2.84
2002	3.42	3.85	3.94	3.93	6.93	4.31	4.25	4.62	2.71
2003	3.49	3.82	4.02	3.89	6.78	4.17	4.12	4.41	2.78
2004	3.51	3.85	4.04	3.93	6.69	4.27	4.17	4.50	2.80
2005	3.48	3.90	3.98	3.97	6.95	4.34	4.30	4.58	2.78
2006	3.43	3.91	4.02	3.96	7.03	4.36	4.30	4.64	2.76
2007	3.41	3.92	4.07	3.98	7.05	4.25	4.32	4.52	2.73
2008	3.44	3.95	4.10	4.02	6.95	4.21	4.35	4.53	2.75
2009	3.45	3.97	4.15	4.06	6.98	4.34	4.29	4.57	2.75
2010	3.49	3.92	4.20	4.08	6.99	4.35	4.39	4.59	2.76
2011	3.52	3.93	4.24	405	7.03	4.50	4.38	4.58	2.79
2012	3.56	3.96	4.26	4.12	7.08	4.59	4.42	4.61	2.77
2013	3.62	3.99	4.30	4.15	7.10	4.65	4.47	4.64	2.85

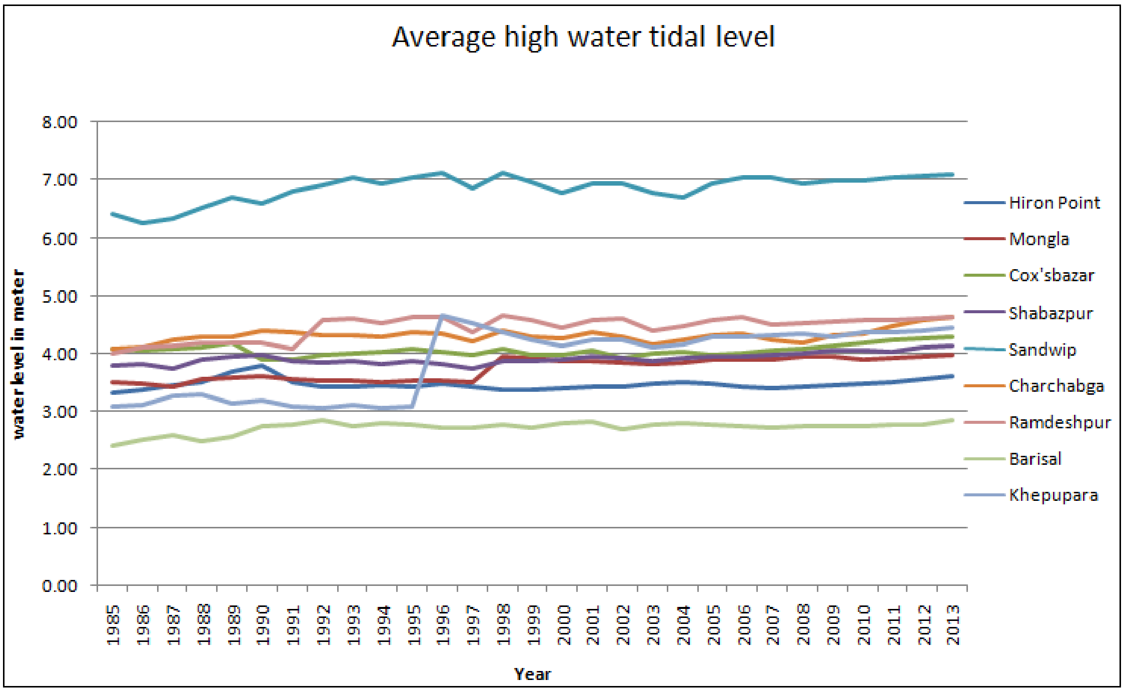


Figure 4. 2: A plot of average yearly maximum high water level of different tidal stations in Bangladesh Coast

It is also notable here that the trend of high water increasing is remarkable for almost all stations except an unexpected irregular trend for khepupara (may be for datum change) and the increasing trend is more in Sandwip Station (Figure 4.2).

For other sets of 34 years highest yearly water tidal data collected from 04 different stations of Karnaphuli River in Chittagong, Bangladesh observed by Chittagong Port Authority shows that maximum 0.70 meter increase of the sea level which is in Khal no-18 (only about 30 km, not far from Sandwip) on the river mouth of Karnaphuli river is meeting on Bay of Bengal and minimum is 0.23 meter which is in Sadarghat tidal station of Chittagong Port Authority, 18 km upstream from Khal no-18 (Table 4.2). The yearly highest water plot also shows that the highest tidal water rapidly increasing here in all these stations (Figure 4.3).

Table 4. 2: Yearly highest water level in meter (ISLWL) Note (Note: Chittagong Port Authority Tide Book Record)

Year	Kalurghat	Sadarghat	Khal No.10	Khal No.18
1980	4.24	5.02	5.46	5.55
1981	4.26	5.03	5.57	5.79
1982	4.11	4.88	5.13	5.91
1983	4.49	5.11	5.23	5.95
1984	4.26	4.90	5.60	6.60
1985	4.75	5.00	5.95	5.96
1986	4.17	4.99	5.00	5.98

1987	5.25	5.13	5.70	6.00
1988	4.30	4.99	5.30	5.88
1989	4.20	5.03	5.41	6.10
1990	4.25	5.05	5.53	5.77
1991	4.50	6.30	5.32	5.74
1992	4.20	4.87	5.29	5.75
1993	4.76	5.28	5.75	6.37
1994	4.28	4.77	5.25	5.60
1995	4.73	5.25	5.96	5.80
1996	4.48	5.10	5.82	5.86
1997	4.64	5.15	5.48	5.90
1998	4.45	5.08	5.68	6.05
1999	4.72	5.15	5.45	5.82
2000	4.76	5.29	5.78	6.10
2001	4.27	5.06	5.56	5.90
2002	4.90	5.35	5.79	6.00
2003	4.48	5.05	5.62	5.90
2004	4.76	5.10	5.50	5.97
2005	4.65	5.32	5.78	6.00
2006	4.58	4.97	5.8	5.90
2007	4.78	5.25	5.78	6.15
2008	4.60	5.85	5.6	6.05
2009	4.64	5.26	5.68	6.25
2010	4.94	5.35	5.99	6.50
2011	5.56	5.08	5.54	6.13
2012	4.64	5.14	5.57	6.11
2013	4.68	5.25	5.75	6.25

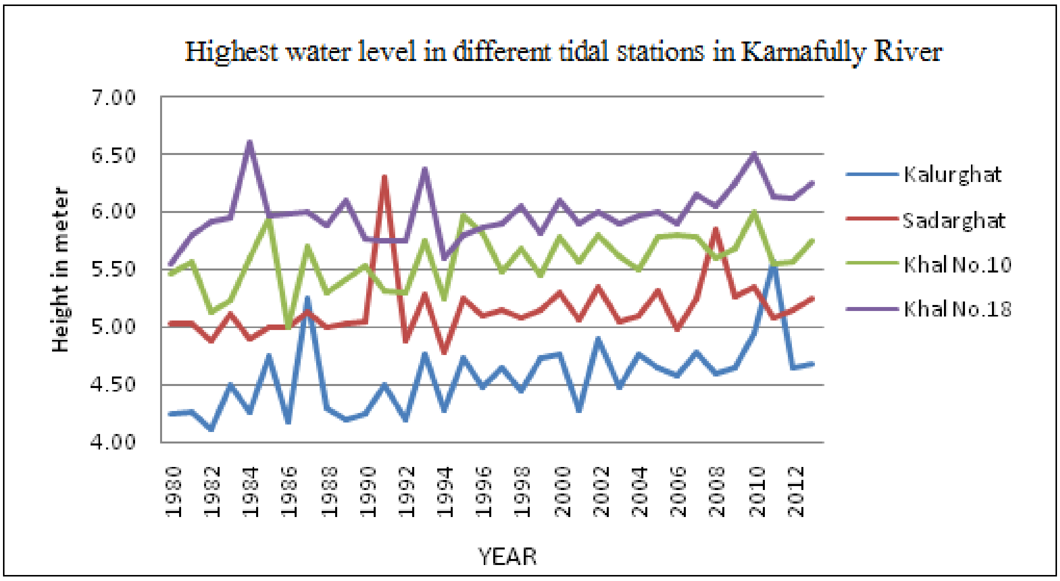


Figure 4. 3:: Plot of early highest tidal water Curve in 4 different stations of Karnaphuli River

To find the lineraity of the increasing water height, attempt was taken to fit a regression line doing a scatter plot using those data of Karnafully river but found very poorly correlated and relatively good regression coefficint was found in Kalurghat (0.283) which is situated in upper stram of the estuary (Figure 4.4).

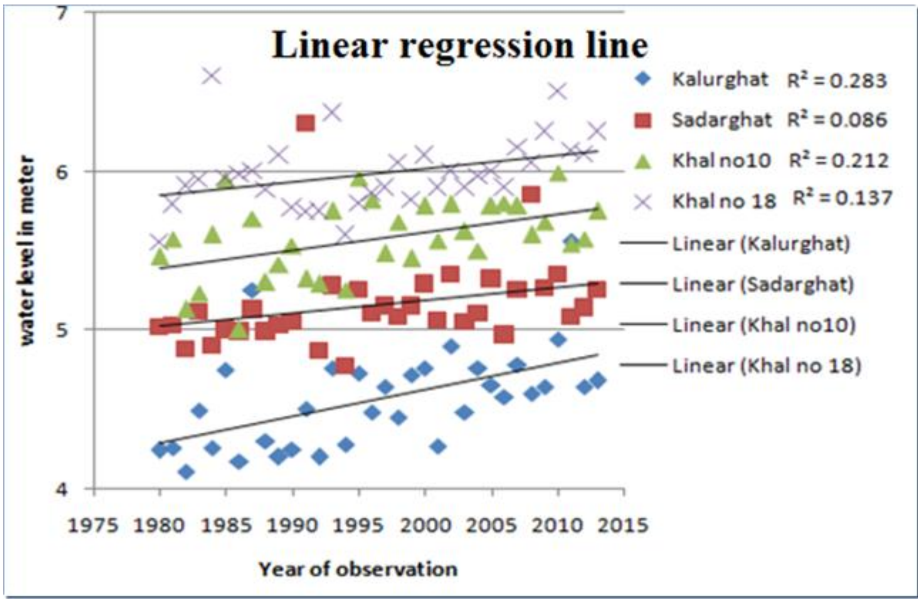


Figure 4. 4: Correlation regression of yearly highest water levels in different stations of Karnafully River

Further attempt of 5 years running mean of yearly highest water plot for those stations showed very significant increasing trends of highest water level for two of the stations (Figure 4.5).

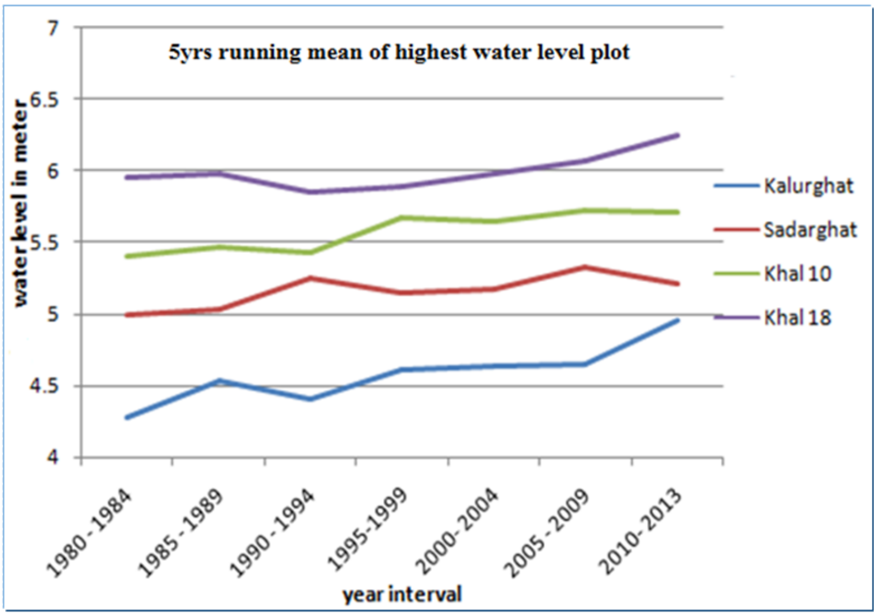


Figure 4. 5: Plot of five year running mean of highest water level in different tidal stations in Karnafully river

So, analyzing the above two scenarios, it can be predicted that sea level will be increased 1(one) meter within the coastal area of Bangladesh by 2030 which must be taken in account when making any modeling and management strategies. So, the results are supportive with the projection of Ahmed and Alam (1998) and comment by the SAARC Meteorological Research Centre (SMRC) with its 22 yrs tidal data analysis (Singh et al., 2000). An increasing tendency in sea level rise from west to east along the coast has also been found by Singh et al.(2000) which has proved by present tide level analysis in the eastern coast.

4.2 Cross Sections Profiling

The topographic survey found that the accreted coast of the north western side is very gently sloping (2N in Figure 4.4) whereas it is extremely steep sloping for eroding (1N, 1S and 2S in the Figure 4.6) south western coast showing highest steepness in the 1N profile. Furthermore, the island’s western coast at the southern eroding profile was found only about 5.4 meter higher while the northern accreting side has an elevation of 7.4 meters as corrected with the local CDBM.

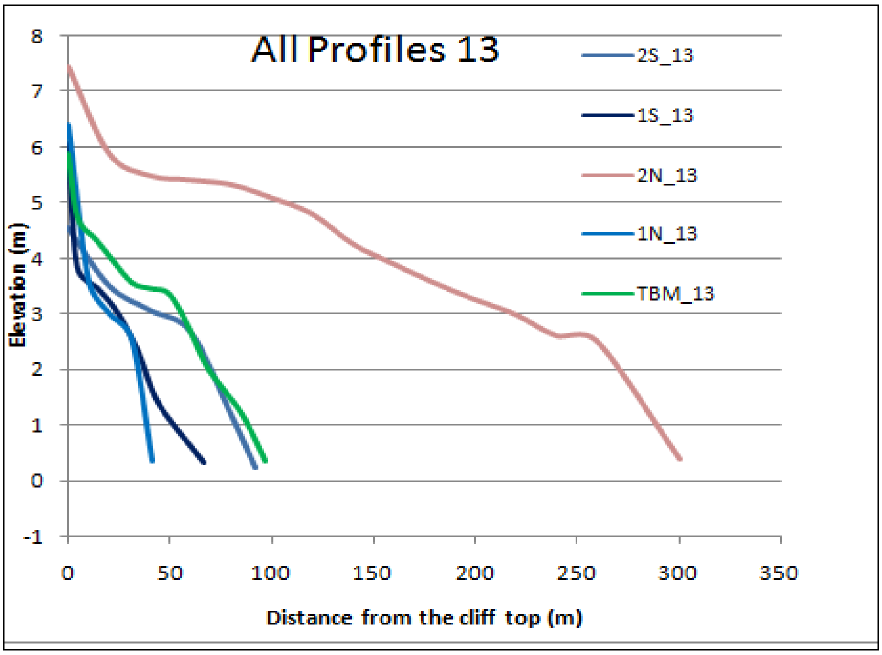


Figure 4. 6: Comparison of elevation in 5 different profiles in March 2013

The length of shore profiles (from the cliff top to water mark) varies following the type of changes in the respective profiles (Figure 4.6). The accreting northern most profile extends more than 310 meter where as the eroding profiles extend not more than 120 meter and the most eroding steeper

1N profile extends only 40 meter showing further retreat will take immediately.The shore profiles at the eroding site was found to be steep, probably because of the role of wave and tidal action retreats further inland causing erosion and shorting the extent. On the other hand, at the accreting site the coastal profile was found to be gently sloping and longer because of the continuous sedimentation due to the huge supply of fine sediments from upstream of the GBM estuary and tidal counteraction of the river flow in the area as suggested by Umitsu (1997). A pictorial view of the eroding and accreting shores is shown in the Figure 4.7.

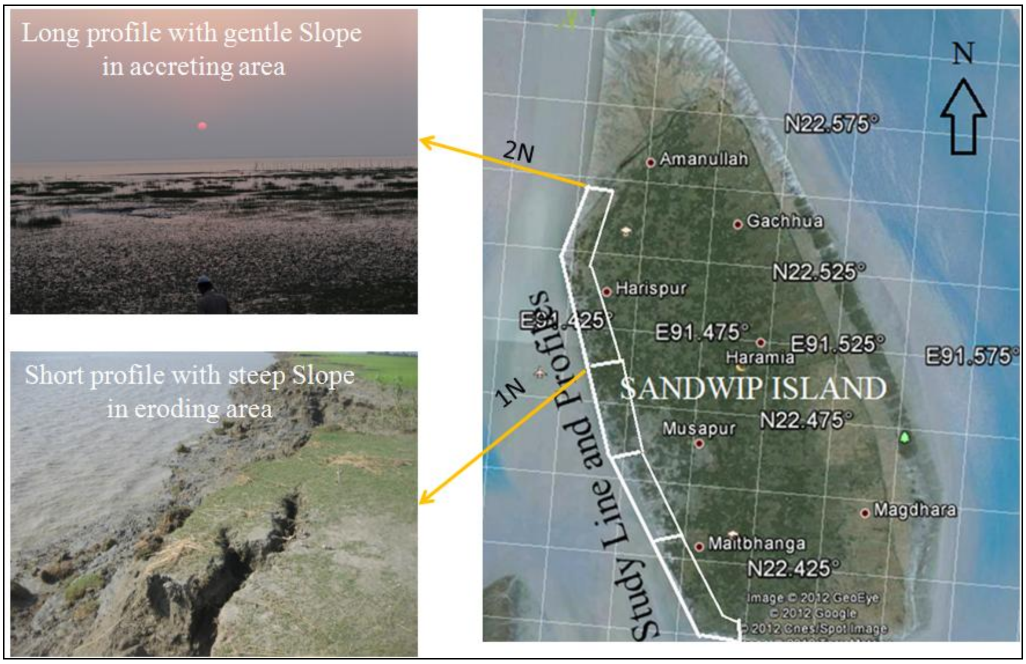


Figure 4. 7: Shore profile variation in two different scenarios

After comparison with the repeated cross section profiles survey in the following year, it was found that the profiles shows lot of changes in their elevation and extents, revealed the extreme geomorphdynamics. The north part (2N) shows notable erosion and subsidence pattern making a bit steeper and shorten of the profile. The Middle Western coast (TBM) shows an increases in length and elevation of the profile following. The south western profile (2S) shows increasing the profile length with no change of elevation but the rest two were found almost unchanged by the last 1 year (Figure 4.8). All cross section profiles with their position in the island and their changing forms are shown in figure 4.9 for a comprehensive understanding of the changes at a glance.

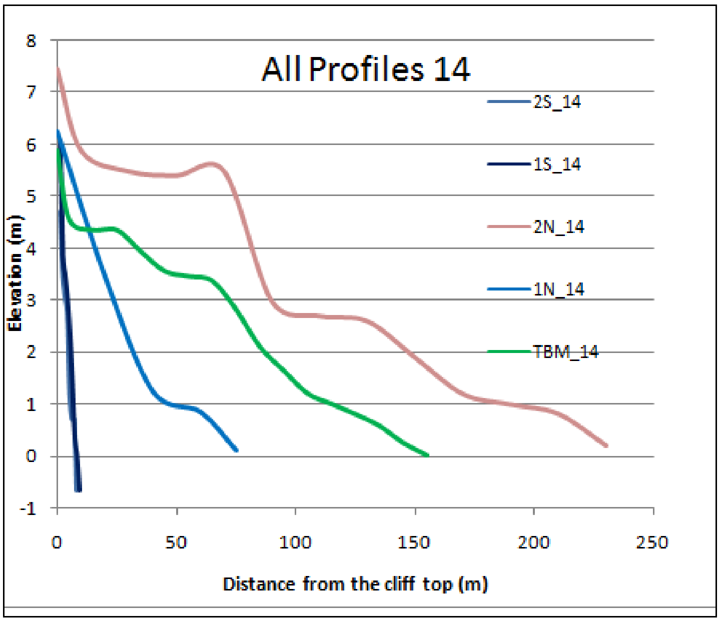


Figure 4. 8: Comparison of elevation in 5 different profiles in March 2013

Figure 4.8:

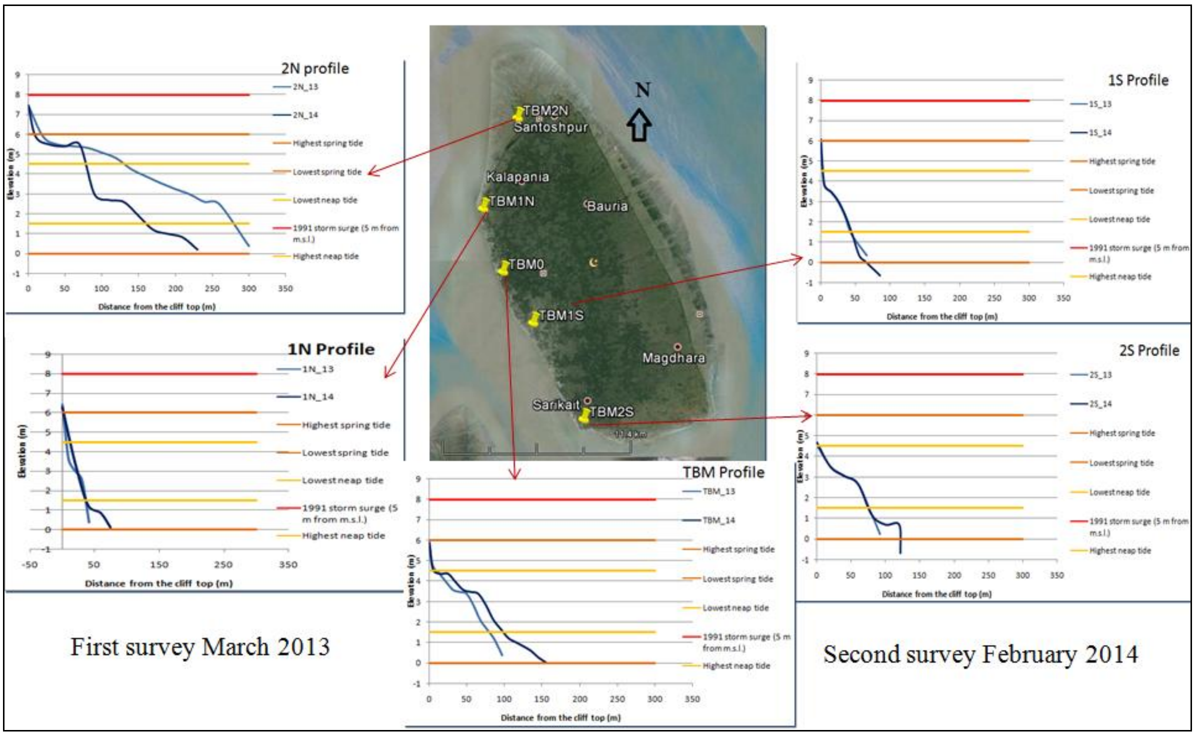


Figure 4. 9: Cross section profiles comparison between 2013 and 2014

It is also evidenced that most of the western and south western coast inundates even by the spring tide and the whole island was under water by the last storm as shown by overlapping general tidal ranges and last heavy storm surges height of 1991 (Figure 4.10 a & b) on the surveyed topo profiles. So, the increasing high profile low frequency storms and the sea level rise are predicted to be more sever for the island in future. And the inundation scenario is much more than the national ongoing and predicted scenario as documented and described by Warrick and Ahmad (1996), World Bank (2005), Cruz et al. (2007), Nicholls et al. (2007), Sarwar and Khan (2007) and Karim & Mimura (2008). The overlapping figure shows that the south-western Sandwip is comparatively more vulnerable in comparison with the northern side and the situation is more vulnerable due to no existence of protection embankment in the south and western coast of Sandwip.

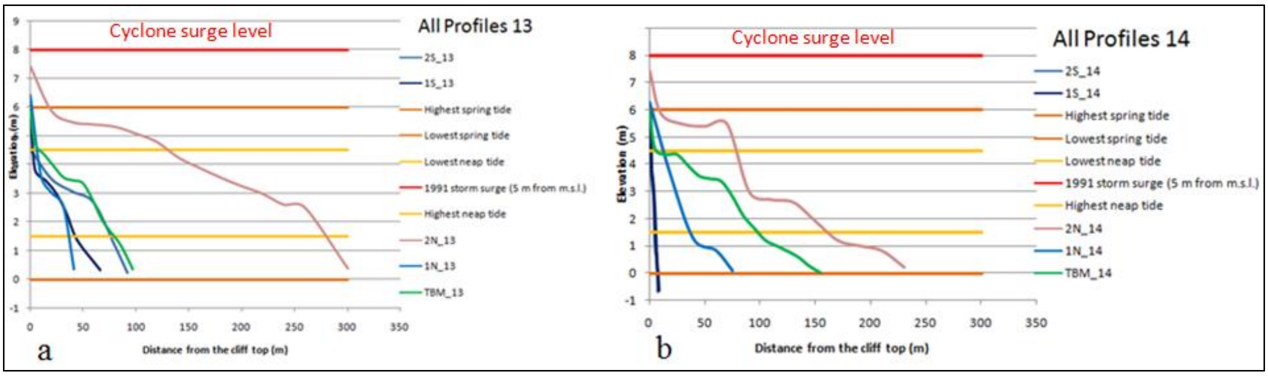


Figure 4. 10: Comparison of all profiles in two consecutive years with tidal height and 1991 storm surge

4.3 Sediment Characteristics

Sediment moisture analysis (Figure 4.11 and Table 4.3) showed that the percentage of moisture has been increasing from the shore cliff top towards the water mark making sense with some irregular variation resulted for TBM1N and BM. Highest moisture content was found in the south western (TBM1S) profile section where huge loose and fine sediments were loaded followed by northern accreted profile (TBM2N). Organic matter content was also distinctly characterized by increasing trend available in the accreted northern section due to huge agricultural activities in the new lands in comparison with very irregular and in most cases decreasing trend in the eroding and stable profile sections starting from cliff tops to water mark. The sieve based grain size analysis by the present investigation found almost negligible amount of course materials (>0.63mm) in almost all sections and highest proportion (98%) of fine (<0.63mm) sediment in the accreted newly formed northern profile section (Table 4.3) which also agreed with the findings of Umitsu (1997), Coleman (1969), Goodbred and Kuehl (1999) for LMRE and Hussain et al (2013) for Urir Char island nearby.

A correlation between moisture content and fine sediments curve shows negative linear relation Figure 4.12).

Table 4. 3: Sediment analysis data collected from different elevation of the section profiles

Sample Identity	Fine Sediment (< 63nm)gm	Coarse Sediment (> 63nm) gm	Moisture gm	Organic matter (%)
TBM1N1	74.701	1.892	23.407	4.486
TBM1N2	63.38	3.464	33.156	3.857
TBM1N3	72.633	2.061	25.306	2.757
TBM2N1	72.631	0.171	27.198	3.179
TBM2N2	68.787	0.597	30.616	4.006
TBM2N3	66.21	0.035	33.755	5.429
BM1	78.078	0.249	21.673	3.886
BM2	76.785	0.189	23.026	3.480
BM3	66.565	4.484	28.951	3.635
BM4	63.321	3.634	33.045	4.132
TBM1S1	71.672	2.122	26.206	5.970
TBM1S2	78.059	0.315	21.626	3.683
TBM1S3	72.837	0.629	26.534	2.950
TBM1S4	62.657	0.95	36.393	3.818
TBM1S5	72.546	0.302	27.152	2.798
TBM2S1	72.505	1.427	26.068	4.227
TBM2S2	70.523	1.567	27.91	3.351
TBM2S3	70.136	0.418	29.446	4.714
TBM2S4	66.111	2.195	31.694	5.744

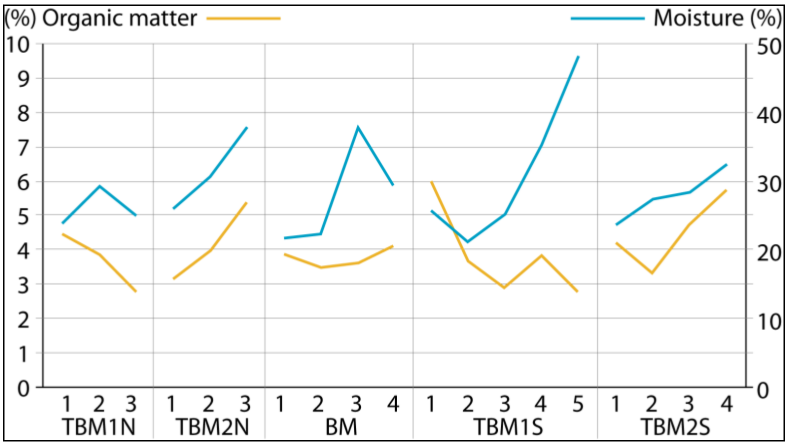


Figure 4. 11: Organic matter and moisture content in sediments of 5 Profiles.

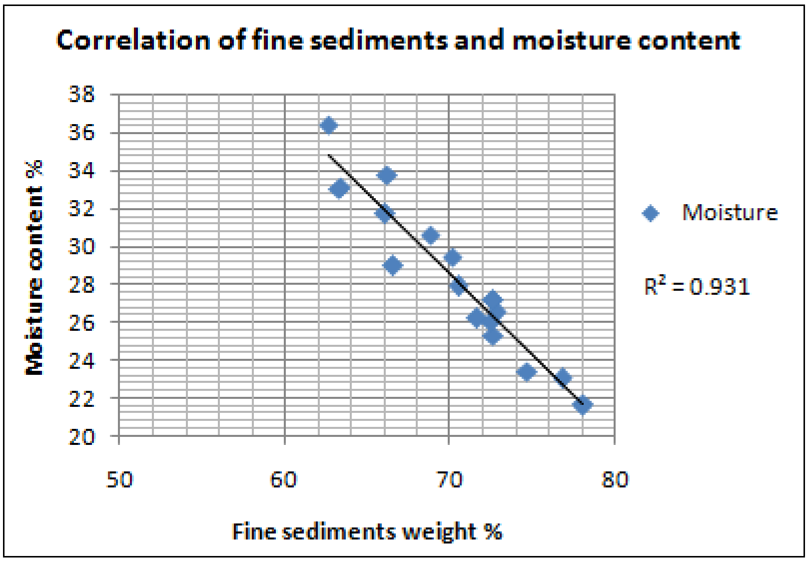


Figure 4. 12: Correlation curve in between moisture content and find sediment for all sections

Further grain size analysis (Sedigraph) of the fine sediments showed dominance of silt materials around the coast. More than 60 to 70% of the sediments are silt while rest of them are clay particles. A combined Sedigraph for all samples from all cross sections are shown in the Figure 4.13 which shows that the diameter varies from 4.5 to 11 phi value only. More sedigraphs for sediment samples ((a) cliff top and (b) cliff base of each profile) are available in ANNEX 2. More silt (86%) were found in the lower profile of eroding south western coast while more silts (92%) where found in the upper profile of the accreted north-western area of the island. A mean grain size analysis among all 5 sections shows limited range of variations (Figure 4.14) in all sections of the profiles. The grain size is decreasing from cliff top to watermark in northern accreted profile but for all other profile it was opposite except irregular trend found in the southern most profile.

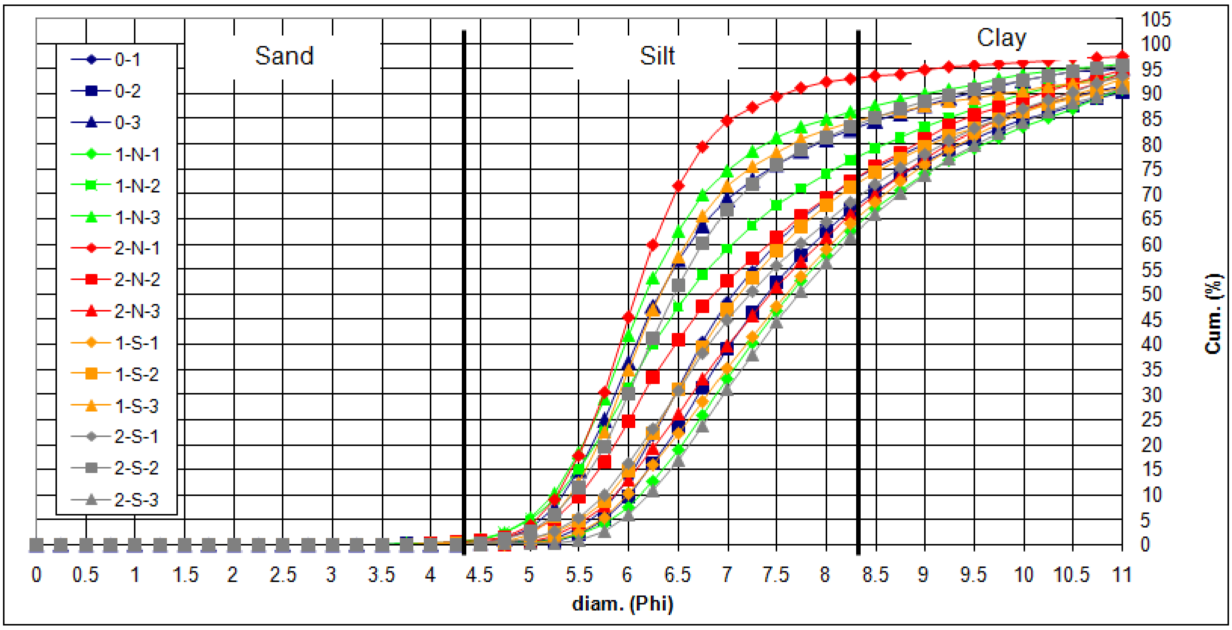


Figure 4. 13: Sedigraph for 3 samples in each of the cross section's sediments

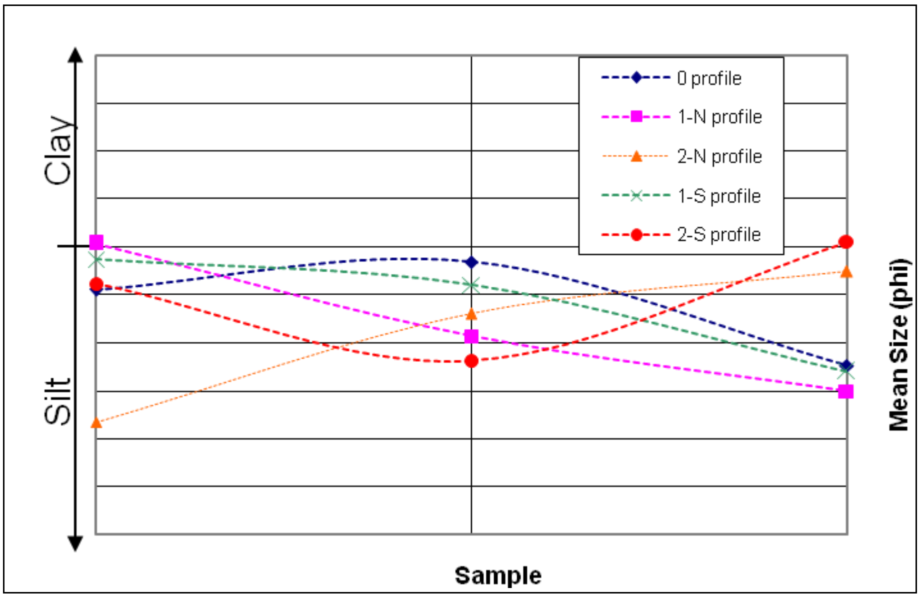


Figure 4. 14: Mean grain size (phi) 3 points (cliff, base and water mark) for all profiles

A qualitative mineralogical analysis of the fine sediment revealed that all the sediments are almost silty minerals containing quartz - calcite - iron oxide – muscovite while no clay minerals were depicted. Figure 4.15 is used as a representative for all similar graphs and all other graphs are added in ANNEX 3 for more information.The mineralogical results studied by Hussain et al (2013) in nearby Urir char Island which was once part of Sandwip Island shows the similarity with the present study. Kuhel et al (2005) and Allison et al (2003) found the sediments in the upper Meghna estuary composed of silts and clay mainly and major minerals are illite, kaolinite and Chlorite etc.

The studies revealed the original sources for sediments are the same for the lower to higher extent of the GBM delta. Brahmaputra sediment is characterized by higher relative abundances of Illite (63% vs. 41%), Kaolinite (29% vs. 17%), and Chlorite (2–3% vs. < 1%), whereas Ganges sediment contains significantly higher Smectite (39% vs.3%) according to the study by Heroy et al. (2003) and Huizing (1971).

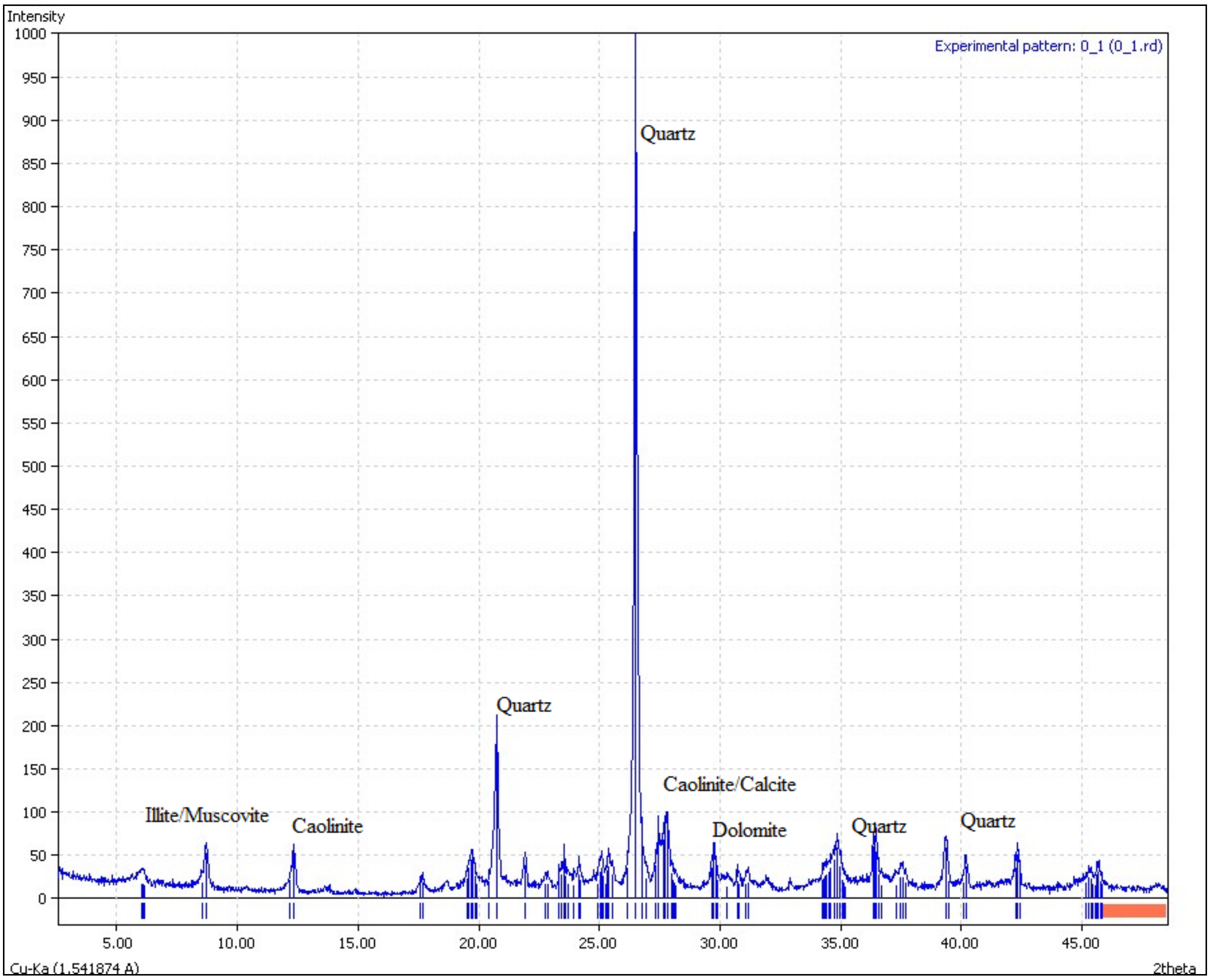


Figure 4. 15: X-ray diffractogram of sediment samples from cross-section profiles in Sandwip

4.4. Erosion Accretion Assessment

4.4.1. Coastlines change and change rate calculation:

According to our preliminary analysis of satellite images using ILWIS, the northern and north-western coastlines of the island have been growing by about 3.8 km (maximum) and 0.7 km in the eastern protected part from 1978 to 2001 (Figure 4.16a). Shoreline analysis also shows that the south and south-eastern cliffs had been eroded from 1.8 km and more than 2.6 km respectively during this 23 year (1978 to 2001) period (Figure 4.16a). The comparison of coastlines from the images of 1978 and 2006 show that the erosion is migrating towards the southern and south-eastern parts of the island by the course of time. By this time (from 1978 to 2006) the south-western part has already lost about 4 km whereas the northern and north-western parts continue to accrete (Figure 4.16b).

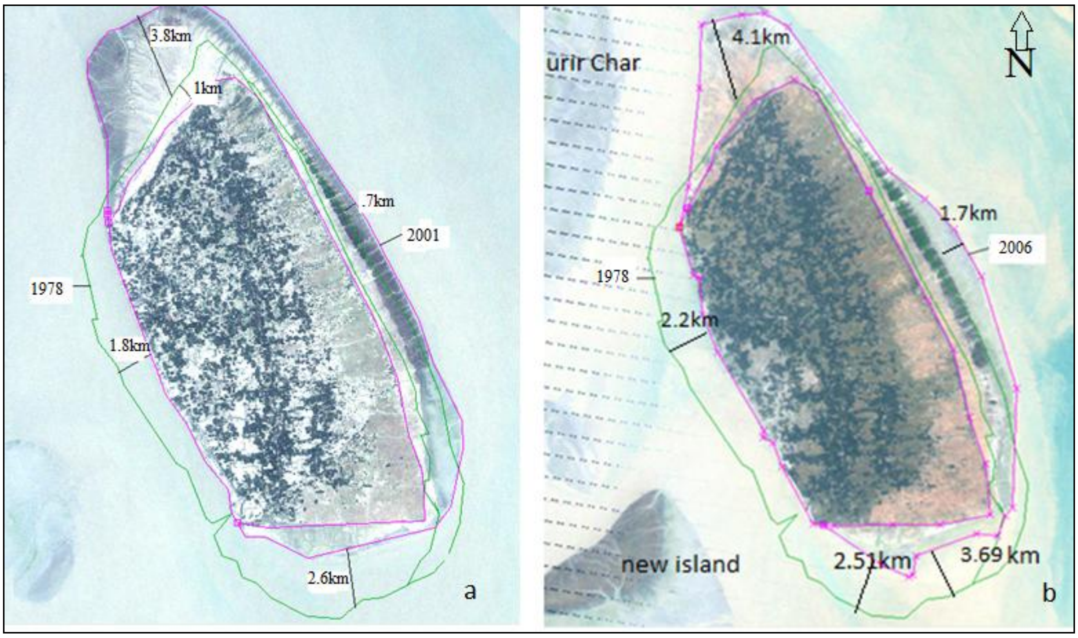


Figure 4. 16: a), Shoreline overlay of 1978 and 2001, b) Shoreline overlay of 1978 and 2006

A detailed signature of the shoreline movement at every 100 meter interval all along the Island coast done by DSAS is shown in Figure 4.17. Clear trends of erosion-accretion are captured in longer time intervals (1978 and 2006) over about two decades where generally eroding south-western and accreting north-eastern shorelines can be recognized. DSAS analyses of shorelines data reveals a complicated scenario of localized and periodic erosion and accretion along Sandwip coast, as summarized in Statistical data are shown in Table 4.4, 4.5 and 4.6 calculated for EPR, NCE and NSM respectively for the whole as well as for the divided zonal transects. Movement of shoreline was spatially and temporally variable as revealed by the study. EPR for the entire shoreline shows that only 48% transects (252 in totals out of 525) fall at the north and eastern side records advancing shoreline where as 52% (273 in totals out of 525) transects lines fall at the south and western side experience retreating shoreline during the time span of 1978 to 2006. Additionally, maximum change rate was found as accretion of 107.59 m/yr at transect no 71 located at northern coast where as maximum erosion was found as 82.28 m/yr at transect no 355 located at southern coast with an average change rate of 8.61 erosion considering all 525 transects. In SCE method shows a maximum of more than 5 km shoreline change to the north with an average of 1.732 km change during the time span. Furthermore, NSM method finds on an average of 246.74 meter erosion with maximum 2356.69 meter erosion at transect no 355 located in the southern coast.

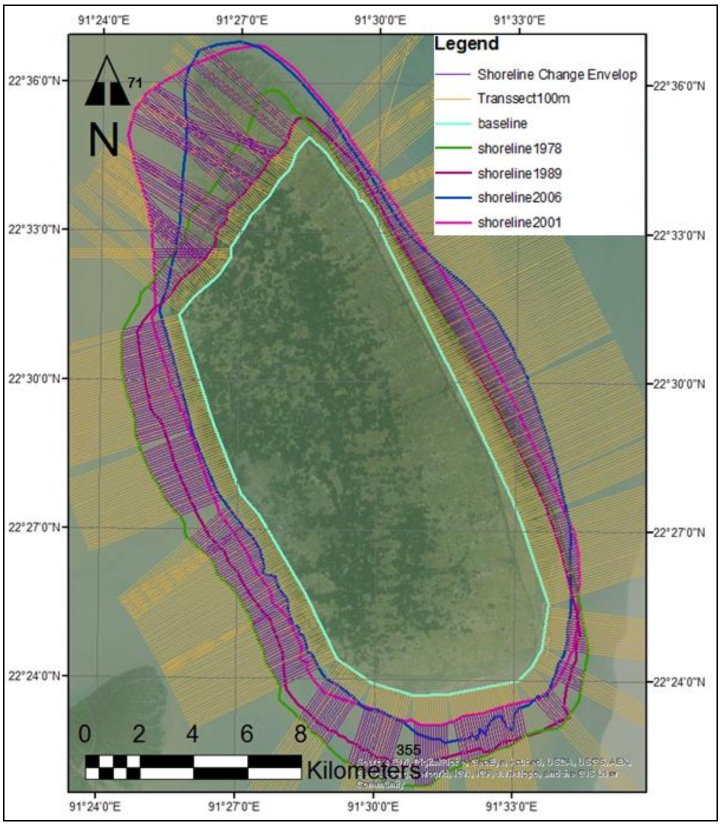


Figure 4. 17: Shorelines positions (1978, 1989, 2001 & 2006), Baseline, Transects and SCE for whole Islands

The Baseline and Shorelines positions for 1978, 1989, 2001 & 2006, all transects and SCE for whole Islands are shown in the Figure 4.17. Figure 4.18 (a) shows transect wise shoreline change rate and Figure 4.18 (b) shows net shoreline changes between 1978 and 2006.

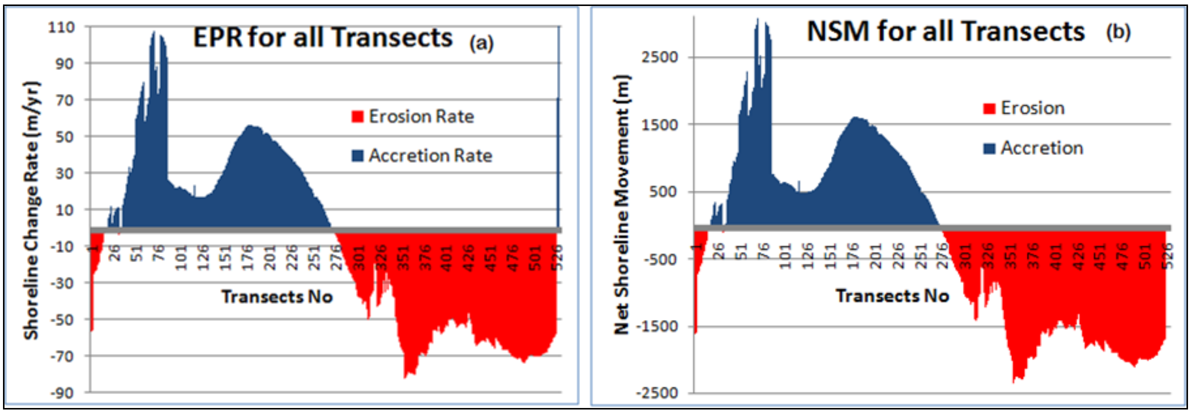


Figure 4. 18: Graph of a. End Point Chnage Rate (EPR) and b. Net Shoreline Movement (NSM) for all transects

Table 4. 4: Summary of DSAS statistical calculation for EPR

EPR (1978 -2006)	**Whole coastline**		**North Zone**		**East Zone**		**South Zone**		**West Zone**	
		Transect No		Transect No		Transect No		Transect No		Transect No
Max Accretion/Min. erosion rate (m/yr)	107.59	71	107.59	71	56.20	178	-13.72	284	-46.15	428
Max Erosion/Min Accretion Rate (m/yr)	-82.28	355	-25.24	4	-9.75	283	-82.28	355	-73.877	490
Avg. Change Rate (m/yr)	-8.61	525	39.55	83	29.92		-47.5	101	-61.82	
Accreting transects (%)	48	252 (Subtotal)	78.57	66 (sub total)	94.42	186 (total)	0	0	0	0 (subtotal)
Eroding transects (%)	52	273 (subtotal)	20.23	17 (sub total)	5.58	11 (subtotal)	100	101 (subtotal	100	144 (subtotal)
Total Transects		**525**		**83**		197		**101**		**144**

Table 4. 5: Summary of DSAS statistical calculation for SCE

SCE (1978-2006)	**Whole coastline**		**North Zone**		**East Zone**		**South Zone**		**West Zone**	
	Meter	Transects No	Meter	Transect No	Meter	Transects No	Meter	Transects No	Meter	Transects No
Max. Change	5208.79	66	5208.79	66	1627.38	192	2418.54	355	2115.98	490
Min. Change	325.52	283	830.63	4	325.52	283	392.88	284	1321.85	428
Average Change	1732.15	525 (total)	3552.84	83 (total)	1013.029	197 (total)	1582.79	101 (total)	1770.77	144 (total)

Table 4. 6: Summary of DSAS statistical calculation for NSM

NSM (1978 and 2006)	**Whole coastline**		**North Zone**		**East Zone**		**South Zone**		**West Zone**	
	Meter	Transects No	Meter	Transects No	Meter	Transects No	Meter	Transects No	Meter	Transects No
Max. Accretion/ Min. Erosion	3081.62	71	3081.62	71	1609.85	178	-392.88	284	-1321.85	428
Max. Erosion/ Min. Accretion	-2356.69	355	-723.02	4	-279.39	283	-2356.69	355	-2115.98	490
Average Change	-246.74	525 (total)	1132.9	83 (total)	857.01	197 (total)	-1360.49	101 (total)	-1770.77	144 (total)

EPR for the northern zone shows 78.57% transects (66 intotal out of 83) records advancing where as only 20.23% (17 intotal out of 83) transect lines experience retreating during the time span of 1978 to 2006. Maximum erosion rate was found as 25.24 m/yr at transect no 4 where as the maximum accretion rate was the same as found for the whole transects. Additionally, an average change rate of 39.55 m/yr accretions was found considering all 83 transects. An average of 3.552 km change during the time span was recorded in the north zone in SCE method with the maximum as 5.21 km at transect line 66 while the minimum as 830.63 meter change at transect no 4 was found. Furthermore, NSM method calculates an average of 1.133 km accretion for all transects with maximum 3.082 km accretion at transect no 71 and maximum erosion of 723.02 meter at transect no 4for the north zone. The Baseline and Shorelines positions, all transects and SCE for whole north zone are shown in the Figure 4.19. Figure 4.20 (a) shows transect wise shoreline change rate and Figure 4.20 (b) shows net shoreline chnages between 1978 and 2006 transect wise for northern area.

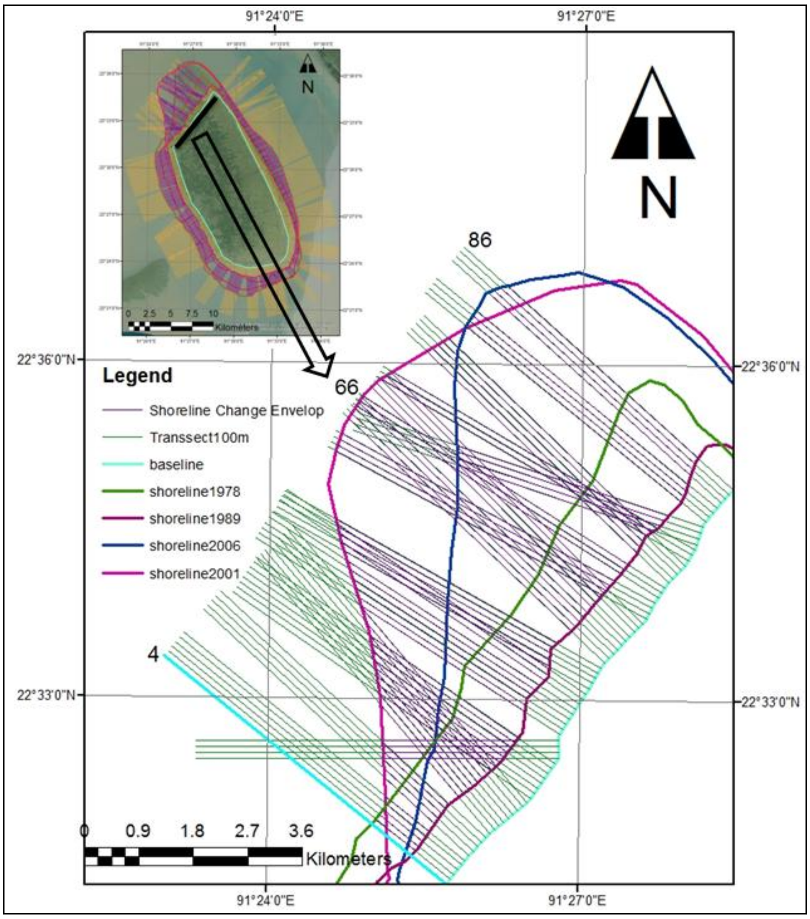


Figure 4. 19: Shorelines positions (1978, 1989, 2001 & 2006), Baseline, Transects and SCE for North Zone

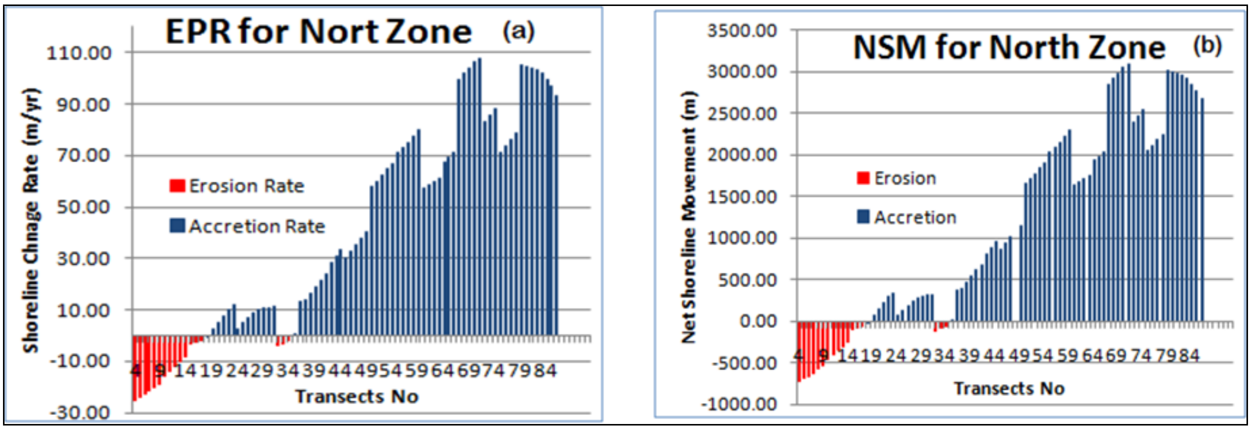


Figure 4. 20: Transect wise graph of a. End Point Chnage Rate (EPR) and b. Net Shoreline Movement (NSM) for North Zone

94.42% transects (186 intotal out of 197) records advancing shoreline where as only 5.58% (11 intotal out of 197) transects lines experience retreating shoreline during the time span of 1978 to 2006 in EPR calculation for the eastern zone. Maximum erosion rate was found as 9.72 m/yr at transect no 283 where as the maximum accretion rate was found as 56.20 m/yr at the transect line 178 for this zone. Additionally, an average change rate of 29.92 m/yr accretions was found considering all 178 transects. An average change of 1.01 km accretion considering all 197 transects with maximum change of 1.63 km at transect line 192 while minimum change of 325.52 meter accretion was recorded during the time span in SCE methodd for the eastern zone. Additionally, NSM method calculates an average of 857.01m accretion with maximum 1.61 km accretion at transect no 178 and maximum erosion of 279.39 meter at transect line 283 for the eastern zone. The Baseline and Shorelines positions, all transects and SCE for whole east zone is shown in the Figure 4.21. Figure 4.22 (a) shows transectwise shoreline change rate and Figure 4.22 (b) shows net shoreline chnages between 1978 and 2006 transect wise for eastern zone.

From the EPR calculation statistics for the southern zone, it was found that all transect (101 transects in total) lines experience retreating during the time span of 1978 to 2006. Maximum erosion rate was found as 82.28 m/yr at transect no 355 where as the minimum erosion rate was 13.71 m/yr at the transect line 284 with an average erosion rate of 47.5 m/yr considering all 101 transects in this zone. An average change of 1.58km considering all 101transects with maximum chnage of 2.42 km at transect line 355 while minimum change of 392.88 meter at transect line 284 was recorded during the time span in SCE method for the southern zone. Additionally, NSM method calculates an average of 1.36 km with maximum 2.36 km at transect no 355 and minimum of 392.88 meter erosion at transect line 284 for the southern coast of the island.

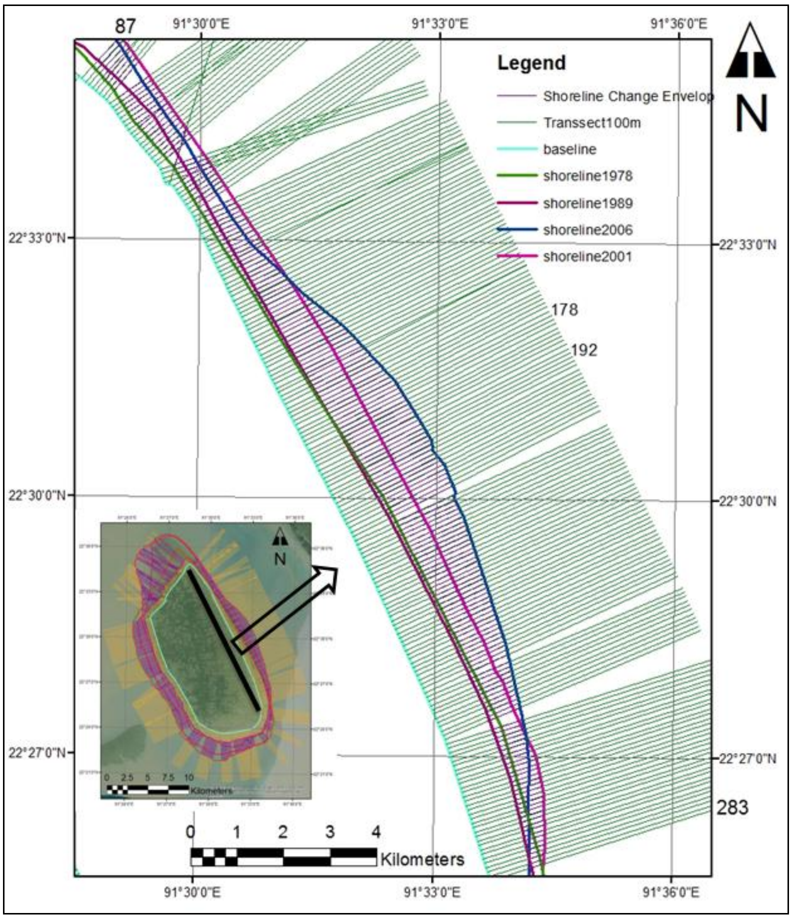


Figure 4. 21: Shorelines positions (1978, 1989, 2001 & 2006), Baseline, Transects and SCE for East Zone

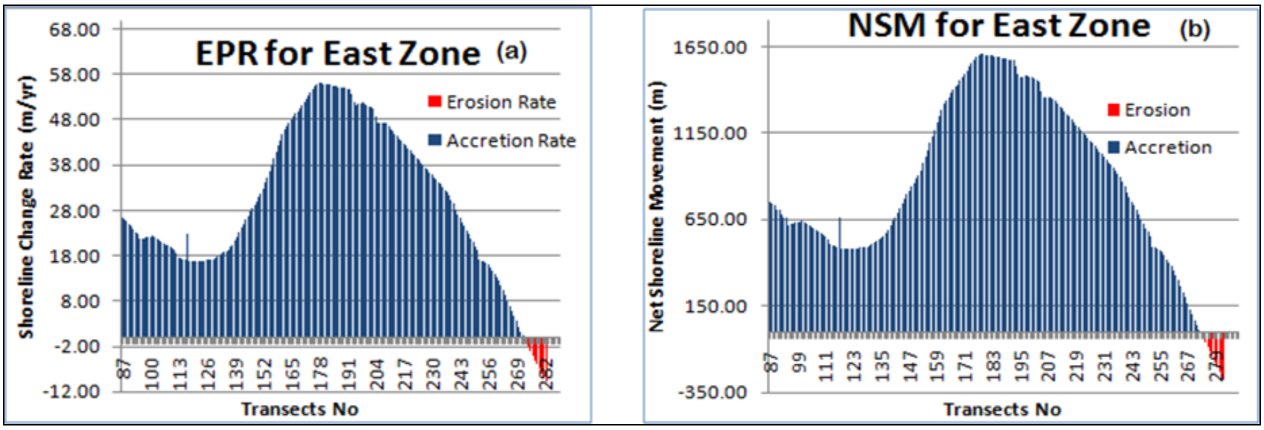


Figure 4. 22: Transect wise graph of a. End Point Chnage Rate (EPR) and b. Net Shoreline Movement (NSM) for East Zone

The baseline and all horeline positions, all transects and SCE for whole south zone of the study area is shown in the Figure 4.23. Figure 4.24 (a) shows transectwise shoreline change rate and Figure 4.24 (b) shows net shoreline chnages between 1978 and 2006 transect wise for this zone.

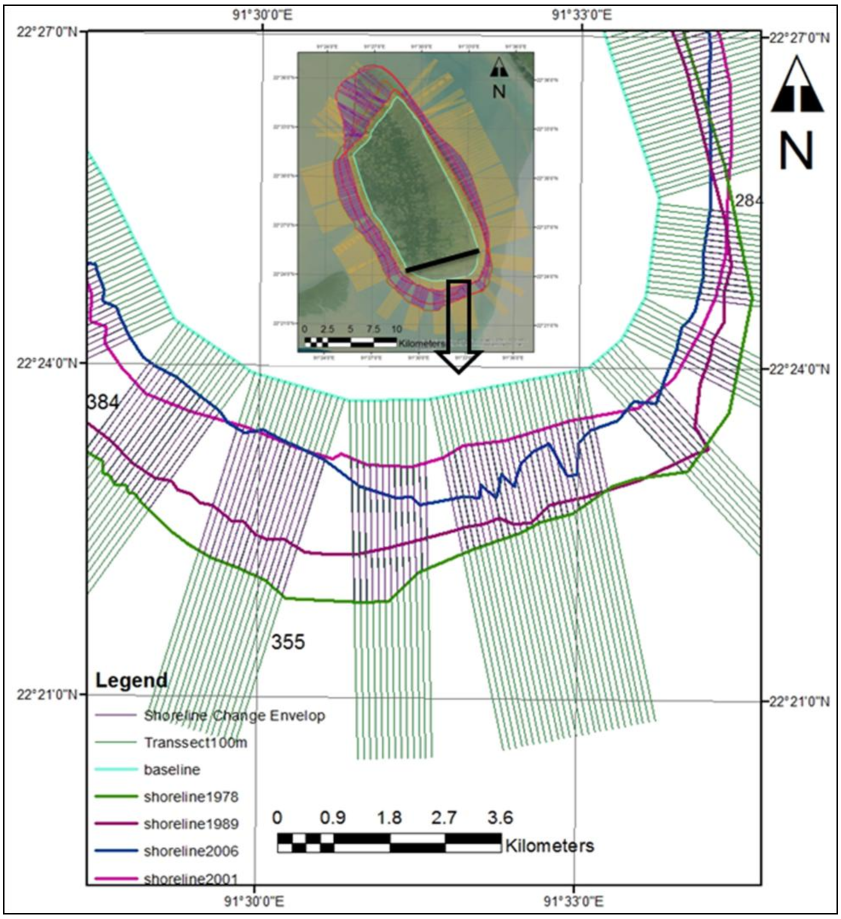


Figure 4. 23: Shorelines positions (1978, 1989, 2001 & 2006), Baseline, Transects and SCE for South Zone

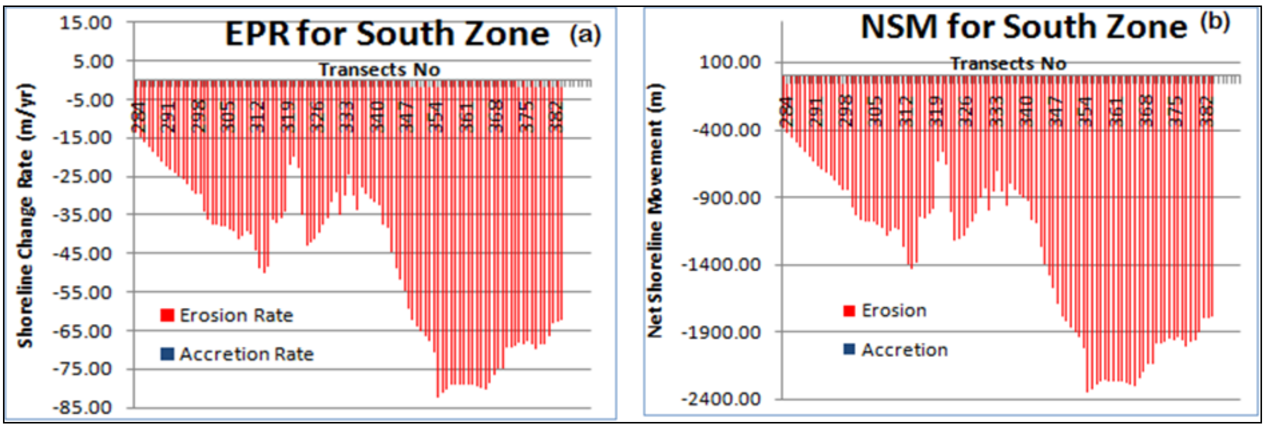


Figure 4. 24: Transect wise graph of a. End Point Chnage Rate (EPR) and b. Net Shoreline Movement (NSM) for South Zone

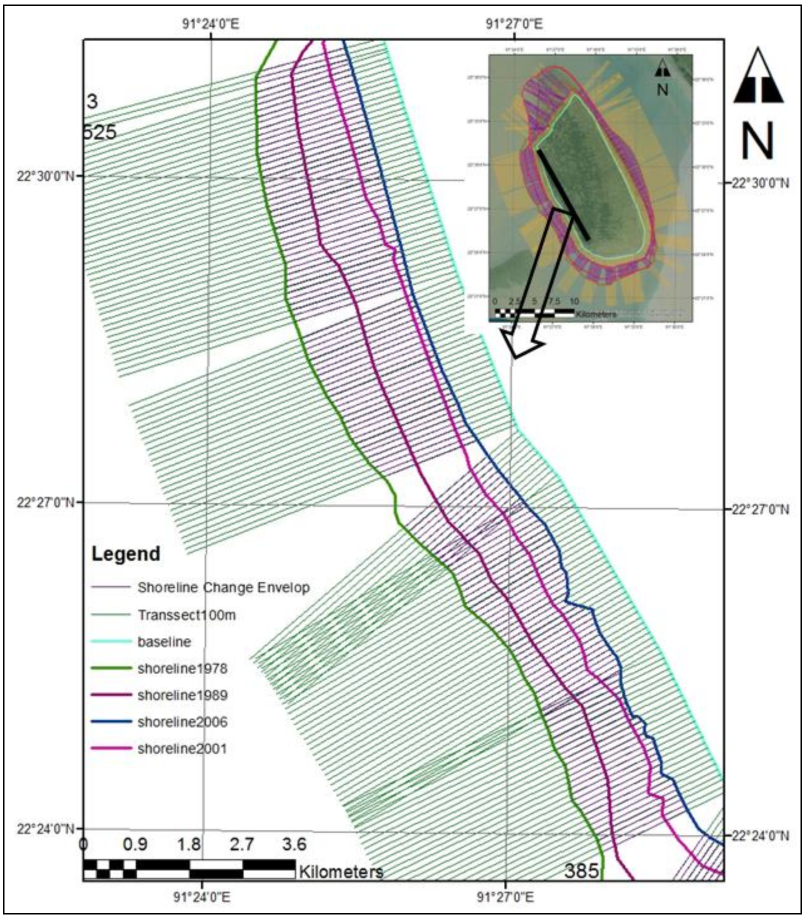


Figure 4. 25: Shorelines positions (1978, 1989, 2001 & 2006), Baseline, Transects and SCE for West Zone

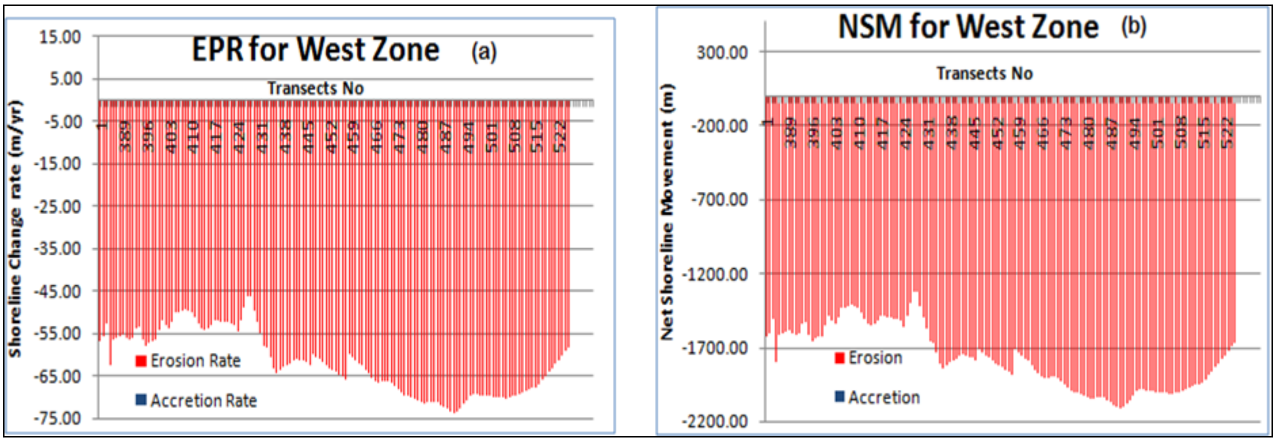


Figure 4. 26: Transect wise graph of a. End Point Chnage Rate (EPR) and b. Net Shoreline Movement (NSM) for West Zone

EPR calculation statistics for the western zone finds no transsect line (out of 144 transects in total) shows accretion like the eastern zone during the time span of 1978 to 2006. Maximum erosion rate was found as 73.88 m/yr at transect no 490 where as the minimum erosion rate was as 46.15 m/yr at the transect line 428 with an average erosion rate of 61.82 m/yr considering all 144 transects in this zone. An average change of 1.77 km considering all 144 transects with maximum change of 2.12 km at transect line 490 while minimum change of 1.32 km at transect line 428 was recorded during the time span in SCE method for the western zone. Furthermore, NSM method calculates an average of 1.77 km with maximum 2.12 km at transect no 490 and minimum of 1.32 km erosion at transect line 428 for the western coast of the island. All Shorelines positions, all transects, base line and SCE for whole west zone of the study area is shown in the Figure 4.25. Figure 4.26 (a) shows transectwise shoreline change rate and Figure 4.26 (b) shows net shoreline chnages between 1978 and 2006 transect wise for west zone.

So, the visual examination as well as the statistical data analysis in DSAS whole as well as of the 4 sections revealed that the coast can be classified in to the following accretion-erosion patterns, namely, (a) severely eroding southern side, (b) moderately eroding western side, (c) moderately accreting eastern side and (d) rapidly accreting northern side. The substantial load of the sediments transferred by estuarine system from the upper Meghna leads to advancement of the shorelines by accretion in the north and eastern sides where as the south and western side is affected by longshore drift current associated with wave action coupled with huge incoming water fore from the upper Meghna pushed the shoreline back from its earlier position leading to retreating of shorelines. The findings here are supported by the comment of Sarwar and Woodroffe (2013) as the island was found geomorphologically dynamic affected by rapid erosion and accretion trend of shorelines. However, the length of eroding and accreting shorelines are not balanced and retreating is much more than accretion.

4.4.1. Net area change calculation for erosion and accretion:

Net erosion and accretion volume and rates calculated for the Island using ArcGIS 10.1, for the same boundaries between the zones for 1978, 1989, 2001, 2006 and 2014 satellite images shows that erosion of the island has always been exceeding accretion except the year between 1989 and 2001 starting just after the devastating super cyclone of 1991 (Table 4.7 and Table 4.8). The erosion rate continuously increasing since the last two decades and it argued that the erosion rate almost 5 km^2 calculated from 2006 and 2014 images where as it was 3 km^2 from 1978 to 1989.

Table 4. 7:. Area of Island in different years between 1978 and 2014 as measured by polygons of shorlines

Year	Area (Km^2)
1978	305.4
1989	272.9
2001	299.3
2006	287.3
2014	250.9

Table 4. 8: Erosion and Accretion data in between 1978 to 2014

Year	Difference(Km^2)	Erosion (Km^2)	Erosion Rate (km^2/yr)	Accretion (Km^2)	Accretion Rate (km^2/yr)
1978-1989	-32.510	34.500	3.128	1.907	.173
1989-2001	+ 26.379	30.916	2.576	57.322	4.776
2001-2006	-11.955	23.133	4.626	11.286	2.257
2006-2014	-36.460	39.572	4.946	3.036	0.379
1978-2006	-18.086	57.009	2.036	38.937	1.391

And the long term erosion rate (1978 to 2006) also shows unpredictable and it is 2.036 km^2 where as the rate of accretion is only 1.391 km^2. This high rate of erosion of >2 km^2/yr is much higher than the estimate by Allison (1998b) who observed an erosion of 1.9 km^2/yr in the western part over the period 1792 – 1984, implying an acceleration of erosion along the southwest coast. A predictable curve using the areas for all those 5 years shows a more erosion in the coming years if the trend exists (Figure 4.27). The overlapping shorelines in figure 4.28 shows the extreme unpredictable dynamicity of the shorelines especially to the northwestern coast which degraded in between 1978 and 1989 where as extended remarkably later on (1989-2001) but again started to erode after 2001 (Figure 4.29-4.31). During the ground truthing visit to the accreted area, it was found that the accretion started after 1991 (after the disaster of 29 April 1991 of category 5 which washed out about 13000 people of the island) and it has already extended about 3 km to the north-western part. Present observation is in opposition to the trend of coastal change observed in previous works that studied coastal change up to the 1990s. For example Barua (1997) and Allison (1997) identified the extreme erosion of the north-western part of the island from 1884 to 1988.

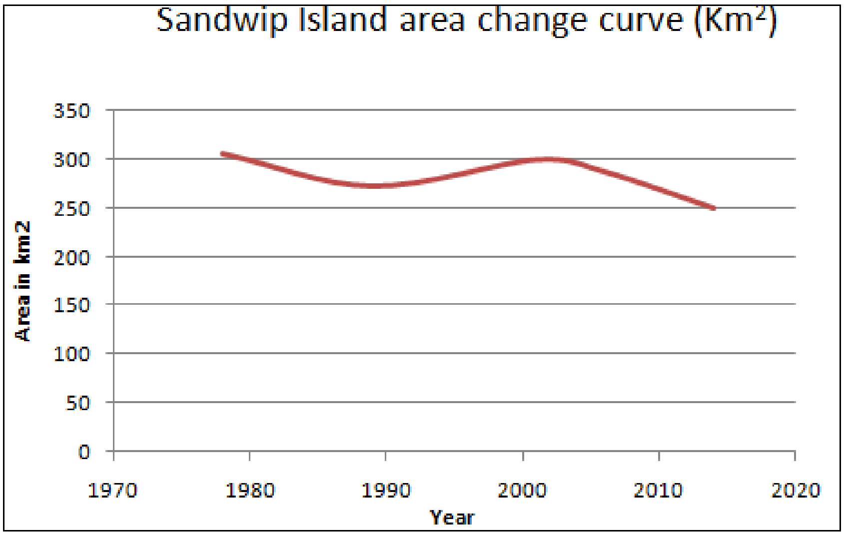


Figure 4. 27: Area change curve of Sandwip Island due to erosion-accretion

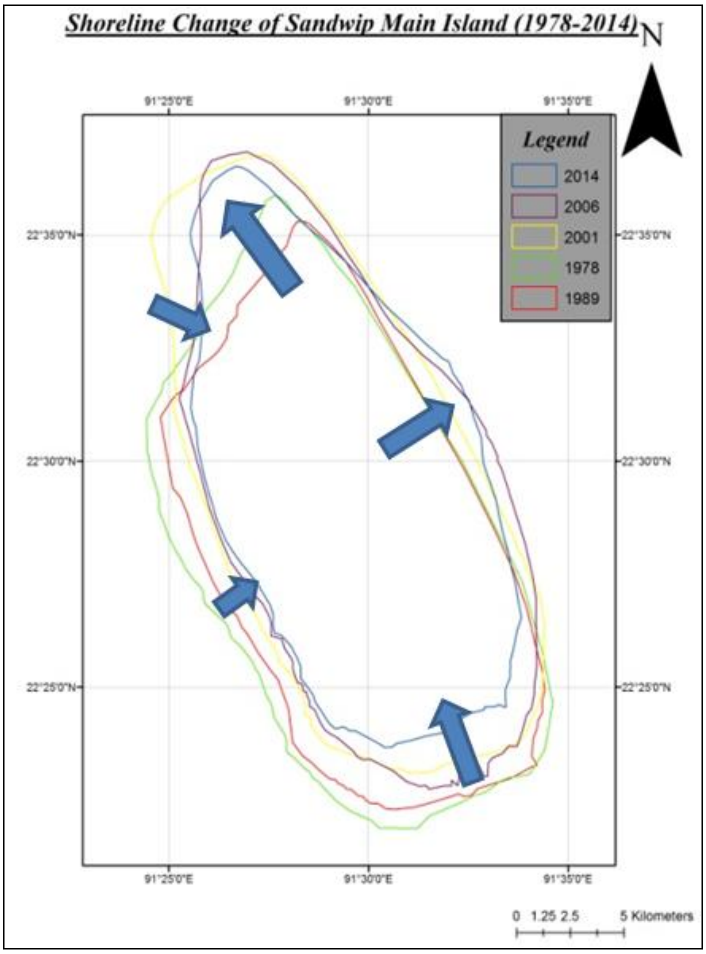


Figure 4. 28: Overlapping of multiyear digitized coastline of Sandwip Island

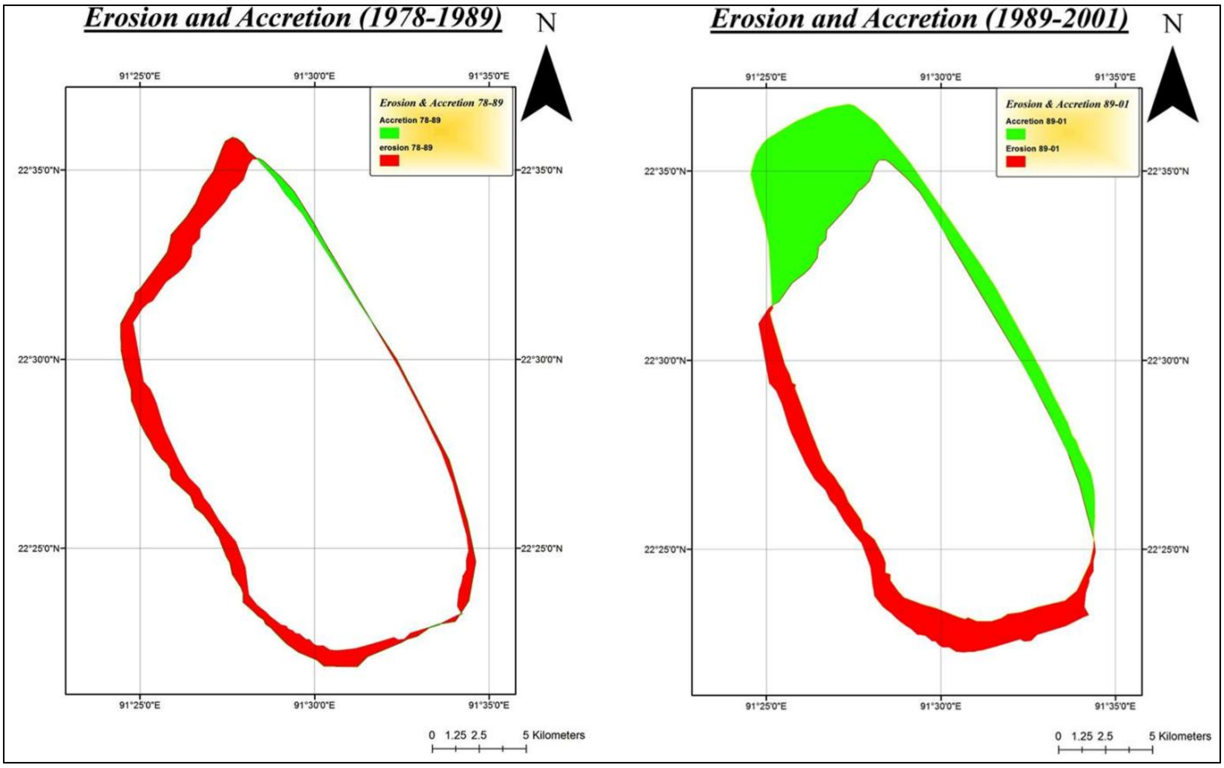


Figure 4. 29: Area of erosion and accretion in Sandwip Island in between 1978-1989 and 1989-2001

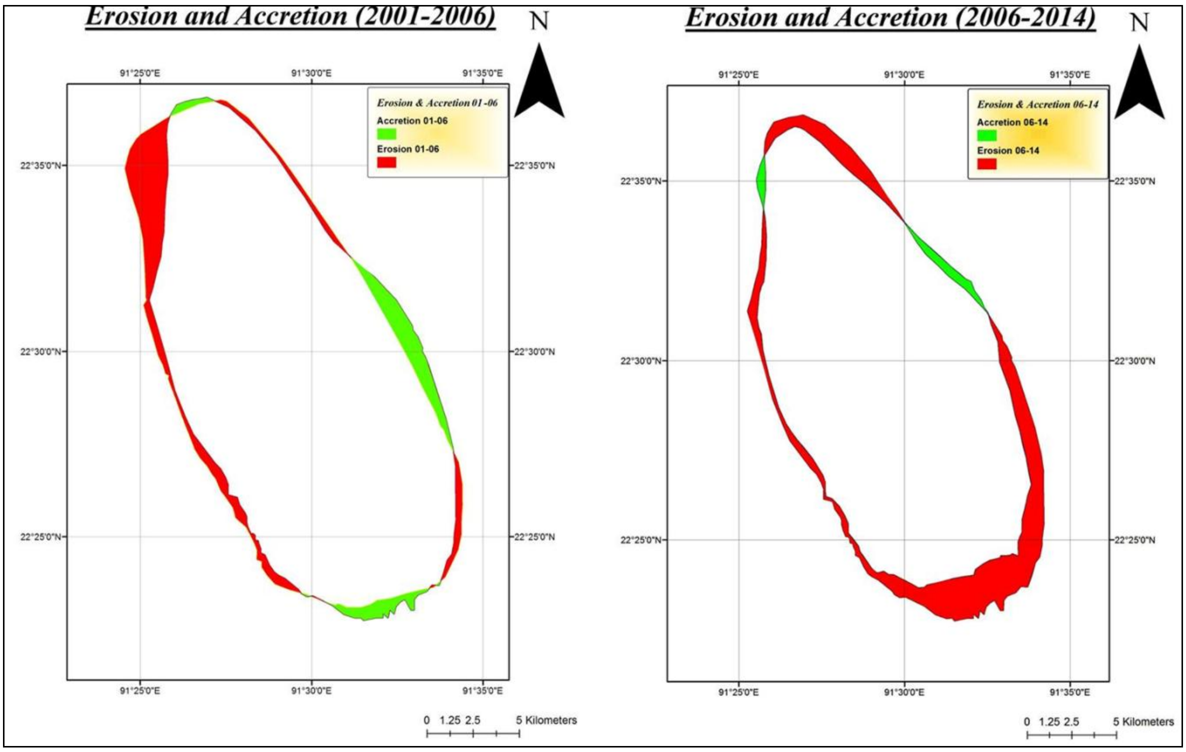


Figure 4. 30: Area of erosion and accretion in Sandwip Island in between 2001-2006 and 2006-2014

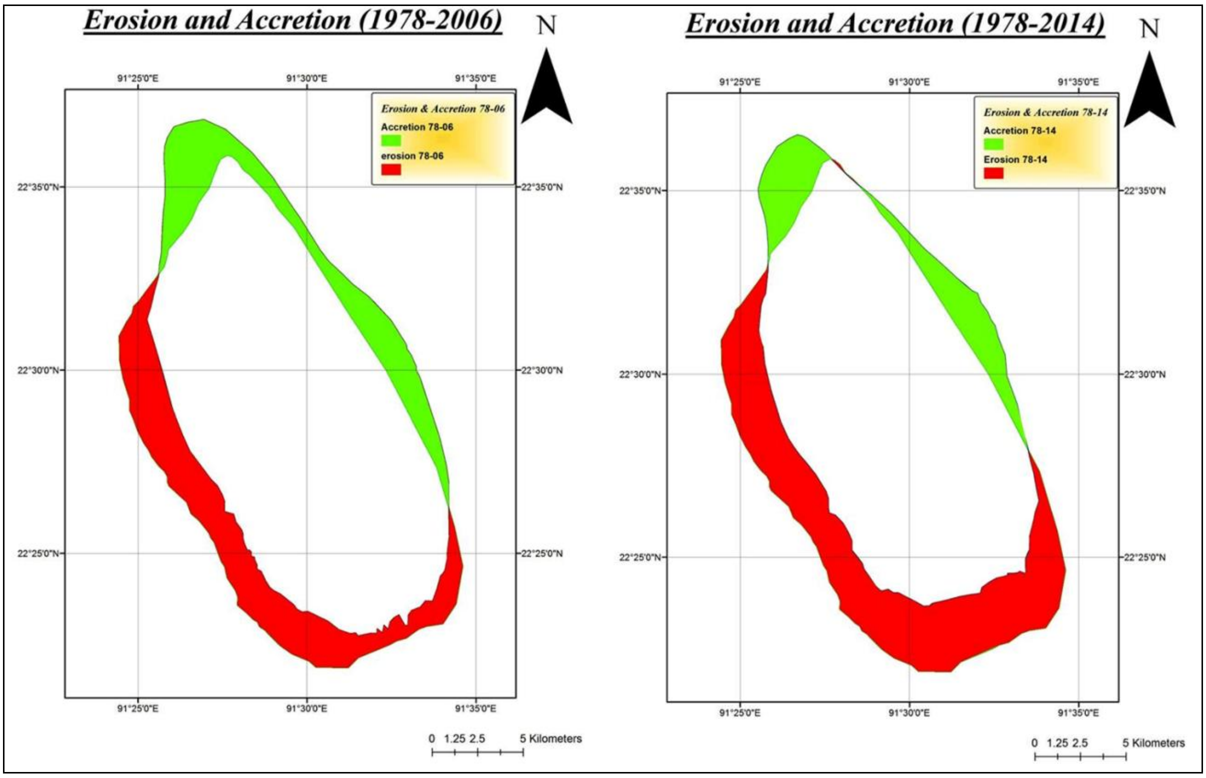


Figure 4. 31: Area of erosion and accretion in Sandwip Island in between 1978-2006 and 178-2014

This erosion caused inundation of villages on several occasions, generating a deterioration of the environment by washed out sediment and salinity intrusion. The comparison between the digitized images outlines an intense transformation of the coastline. A reason for this can be due to the interaction between tidal energy and fluvial discharge due to circulation driven by the coriolis effect. Barua (1990) indicated an anticlockwise sediment motion in the area resulting primarily from the net export of sediments through ebb channels and net import of sediments through flood channels. The finer fraction of sediments is thus recycled back into the estuary.

The generation of an erosive trends in the southern and south-eastern part of the island is assumed to be due changes in the river discharge flow pattern, together with changes in the tidal current regime, after the development of the Muhuri Project on the Feni river in 1985-86. The Sandwip channel has become isolated from the Meghna river estuarine discharge, which was feeding sedimentation in the southeastern part of the island. On the other hand, the sediment carried by the lower Meghna river to the Bay of Bengal could now been trapped by the tidal influence and precipitate in the northeastern part and eastern part of the Hatiya channel.

4.5 Land Use and Land Cover Change

The resources vulnerable to natural hazards in the area are land, settlements, livelihood, homestead forest, mangroves, argi and fisheries activities along with domestic animals etc. Getting a better understanding from the results of the questionnaire survey on livelihoods and coastal resources five major land cover classes are identified in the 1989, 2001 and 2014 satellite images covering Sandwip Island (Figure 4.22). Great change in the amount of agricultural land, human settlement, homestead forest and mudflats followed by mangrove forest is observed from 1989 to 2014. Settlement increased while agriculturable decreased remarkably due to erosion and relocated people rehabilated further inside the island. Homestead forest, new mudflats and mangrove vegetation increased notably after 1991 cyclone induced storms with huge new land accretion. But after 2001 onwards all most all resources have been decreasing but human settlement. Conversion of fallen and agricultural land to settlement and homestead forest suggests rapid growth of population in the Island area although huge people have been migrating over the last 24 years of study which is supported by the national census statistics of whole country that population was doubled over this time (BBS, 2011).

Figure 4.32 shows the Middle Eastern part of the island has been intensified with settlement growing from 7% (1989) to 26% (2001) to 37% (2014) of the total area in those three years. The agricultureal lands reduced dramatically from 64% in 1989 to 23% in 2001 due to conversion of huge agrilands into settlement and home state forest after the devastation of 1991 but increased to 32% with most of the accreted land has been converted into agricultural lands specially in the north-western coast of the island now a day’s which goes inverse for the mudflats. Mangrove vegetation in the eastern coast has been increasingwith some reduction for erosion in the last 5 years.

Figure 4.33 shows remarkable changes of land cover in terms of percentage of cell number converted to total rea of the island in the respective years. It shows continuous increasing of home settlement in the island.

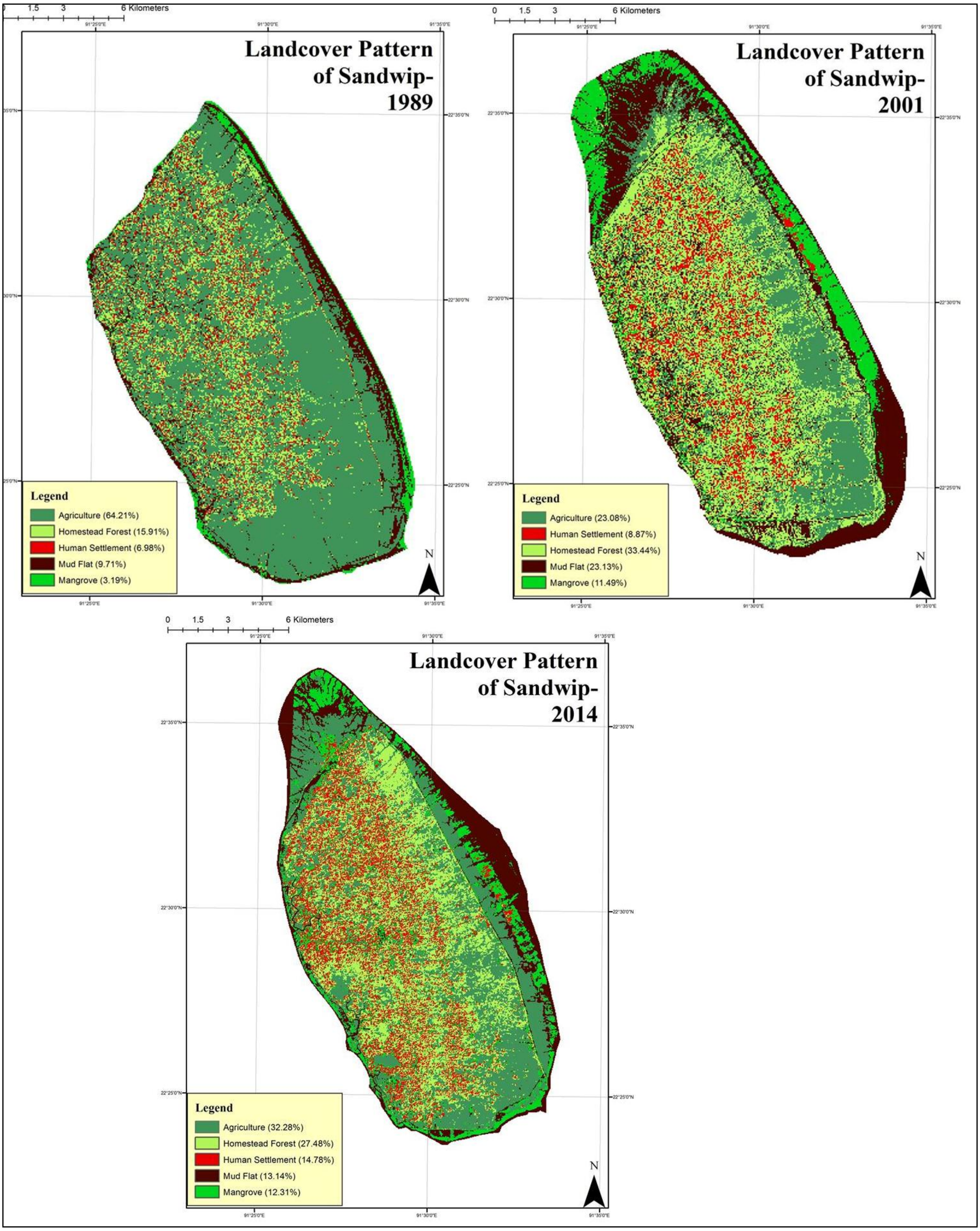


Figure 4. 32: Land cover map of Sandwip Island in1989 and 2001 and 2014

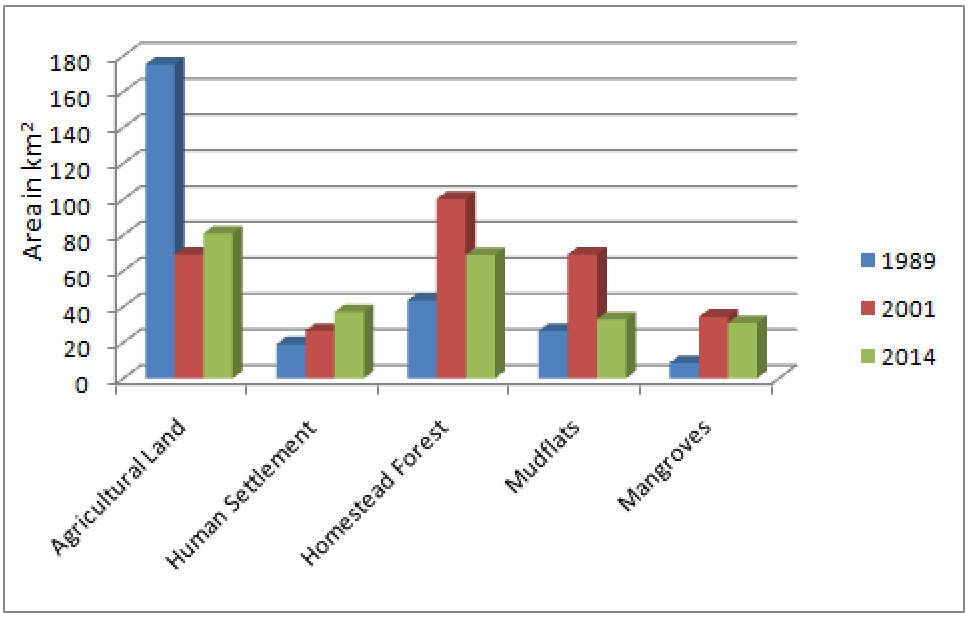


Figure 4. 33: Changes of land covers in terms of area.

4.6 DEM (Digital Elevation Model)

Bathymetric map (Figure 4.34) of the study area produced with BIWTA survey datasets shows highest point as 0 m (mean sea level) and the lowest point or bottom topography is as -13 m nearby Sandwip Island. The site is a very turbid zone due to a huge mixing of fluvial sediments from the Meghna river flow and refraction flow with tidal water making sense of some north-western zones is so shallow that, survey could not be conducted (Figure 4.35).

The Bathymetric map confirms the bottom irregular shape in almost full southwestern to northwestern Hatiya channel with number of sediment deposition forms (Char area) but comparatively deeper south eastern Sandwip Channel to shallower north eastern Sandwip Channel (Figure 4.34-4.36).

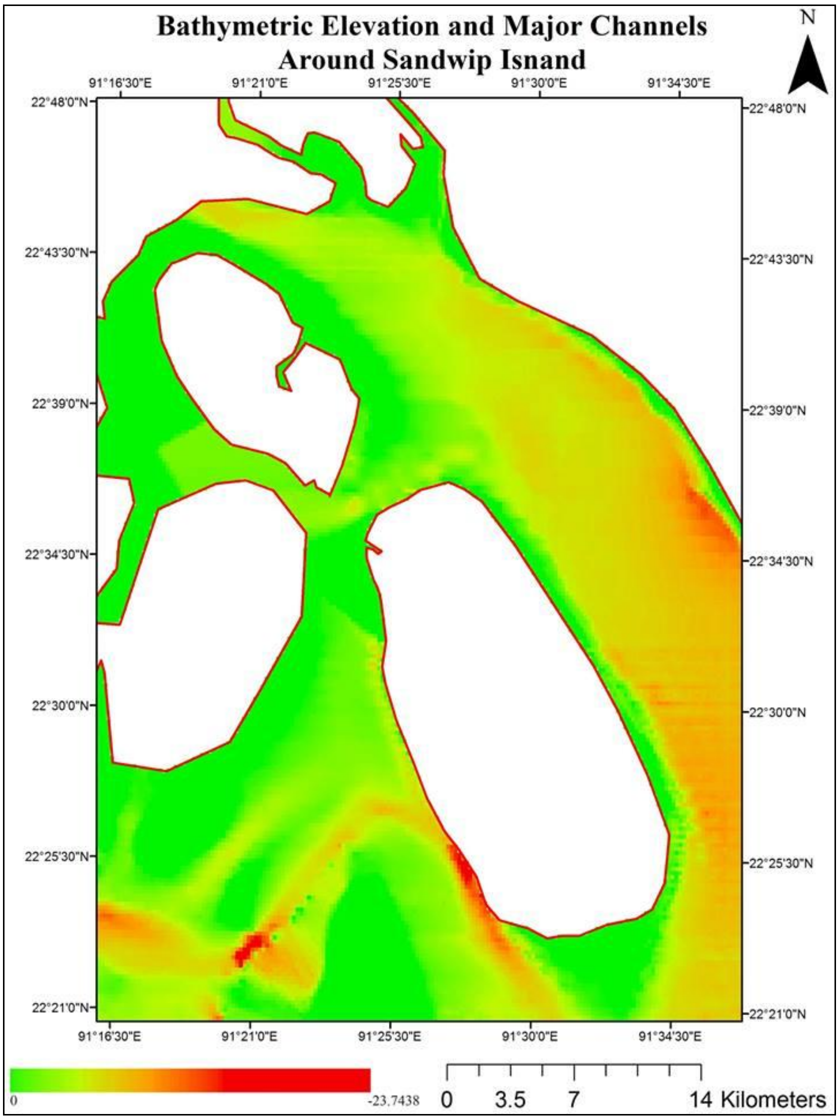


Figure 4. 34: Bathymetric Map of Sandwip Island using BIWTA soundings data

All the Digital Elevation Model prepared previously in our country, starting from the national elevation grid of 1980 to European Council funded DEM for accessing Tsunami and Storm surge risk of 2009 with almost no bathymetric datasets. According to the Digital Elevation Model producing method developed by National Oceanographic and Atmospheric Administration (NOAA) in 2010, to model the elevation of any area, all the water body data should be collected precisely to predict the risk of water borne natural disasters like storm surge, tsunami and flood. So the present DEM will definitely be helpful the authors believe. According to NOAA, all the elevation models should be produced from high resolution datasets which starts from 30 m resolution. But all the previous DEMs are developed with 500m resolution datasets with a huge area, where precise DEMs with small selected and important areas are totally absent.

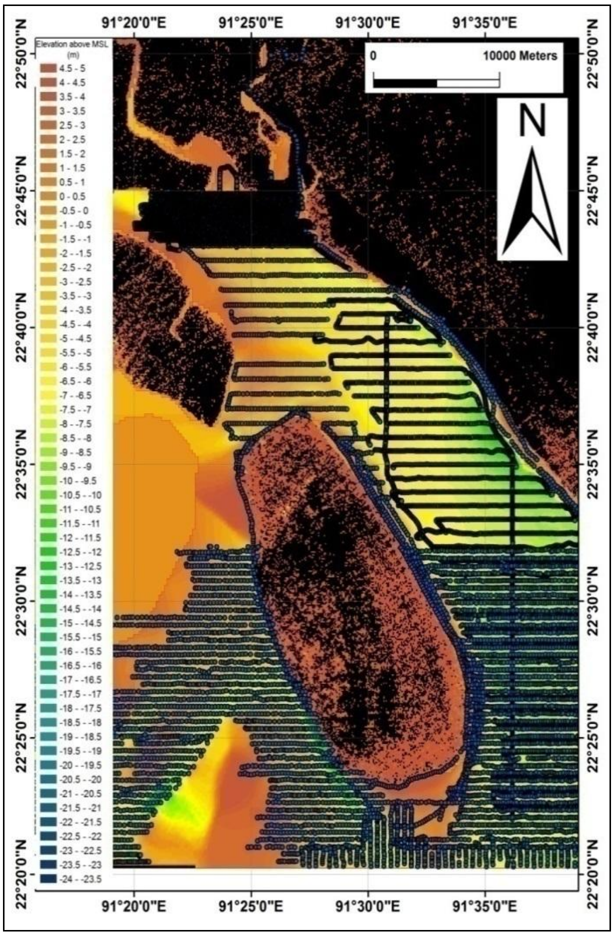


Figure 4. 35: Bathymetric soundings used for the DEM shows some data gap

The DEM shows (Figure 4.36) the elevation of the area starting from the lowest point under water cover of the area to the highest point of the island (higher than 5 meter is black). Off course the TIN will clear our understanding about the land elevation of the Island. The study area of the present DEM contains the vital socio-economic importance due to presence of the densely populated island in the mouth of Meghna river estuary, which is the main flow of Ganges-Brahmaputra-Meghna (GBM) river system that carries a huge amount of fluvial sediment every year to produce a very fertile land coupling with losing huge area by erosion.

So, by understanding the water flow pattern using DEM produced and its proportion with the land elevation, the areas vulnerable for storm surges can be determined more precisely along with prediction of the amount caused by a storm surge. Secondly, the procedure of DEM production developed by NOAA is adaptive to all datasets. The DEM produced by following the procedure above, is a high resolution DEM of 30 m resolution and can easily be used as a tool for disaster management, urban planning and even predicting and assessing sea level rise.

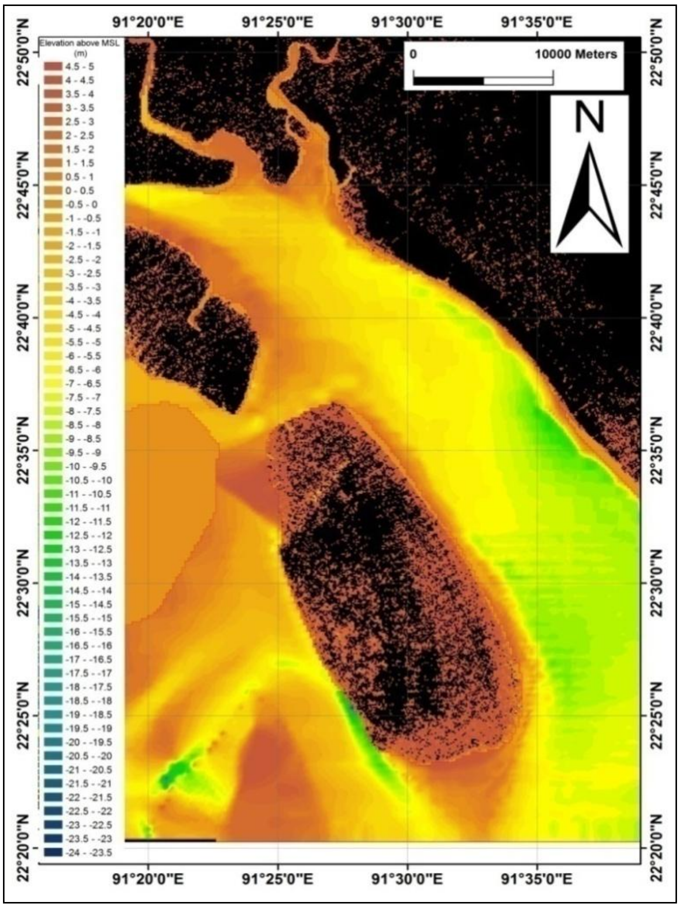


Figure 4. 36: DEM merging Bathymetry, Topography and Shoreline

4.7 TIN (Triangulated Irregular Network)

The development of methods for interpolation and filtering of DEM data continues to be a central area of digital terrain analysis. DEM interpolation methods based on triangulations have been seen as attractive because they can be adapted to various terrain structures and to varying data densities. Surface-specific point elevations, including high and low points, saddle points, and points on streams and ridges make up the skeleton of terrain (Clarke 1990). The created TIN (figure 4.37) shows the Island is almost flat and most of the part is below 5 meter from MSL. It also shows that the north-eastern part is higher than south-western part which was verified with topographic survey in the field during cross section profilings. The eastern coast seems lower elevated as well but protected by the encircling embankment, so most of this area could avoid the hazards.

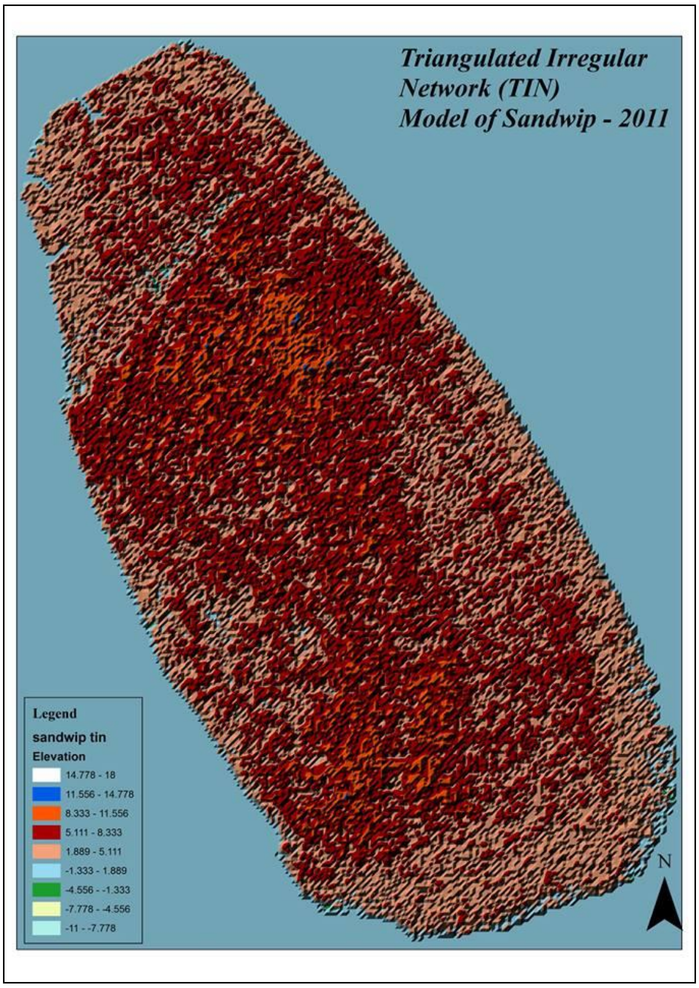


Figure 4. 37: Triangulated Irregular Network (TIN) Model of Sandwip Island

4.7 Countoring for Inundation Assessment

Highlighted contour lines (Figure 4.38a) for 3 meter elevation in the island image shows that most part of the north, west and southern coastal areas are equal or lower than 3 meter above MSL. Additionally, a 6 meter contour line (Figure 4.38b) shows most of the area of the island covers within the elevation less than 6 meter. So, a surge height of 6 meter would hardly save any area, people or their properties from inundation. Polygon area calculation reveals that almost two third of the island (the area of the polygon is 91km^2) are very susciptable to inundation if only 3 meter storm surges is produced from cyclone born or any other sources (Figure 4.39a) wheras, the susceptible area of inundation for a 6 meter height of surge was found as 171 km^2 of the island (Figure 4.39a).

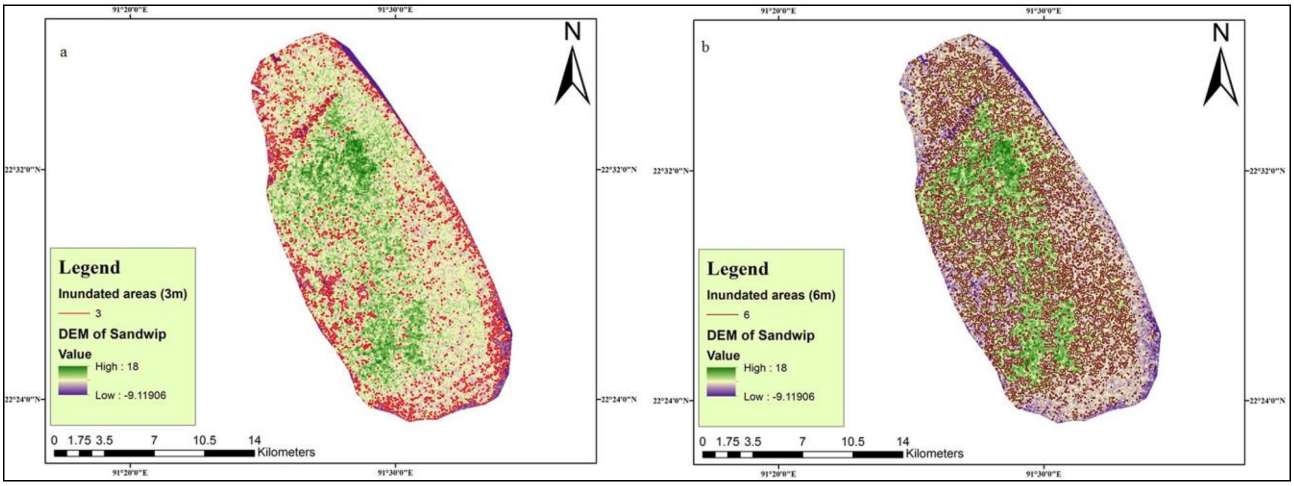


Figure 4. 38: Contour line highlitned (a) 3 meter and (b) 6 meter Topo map of the island

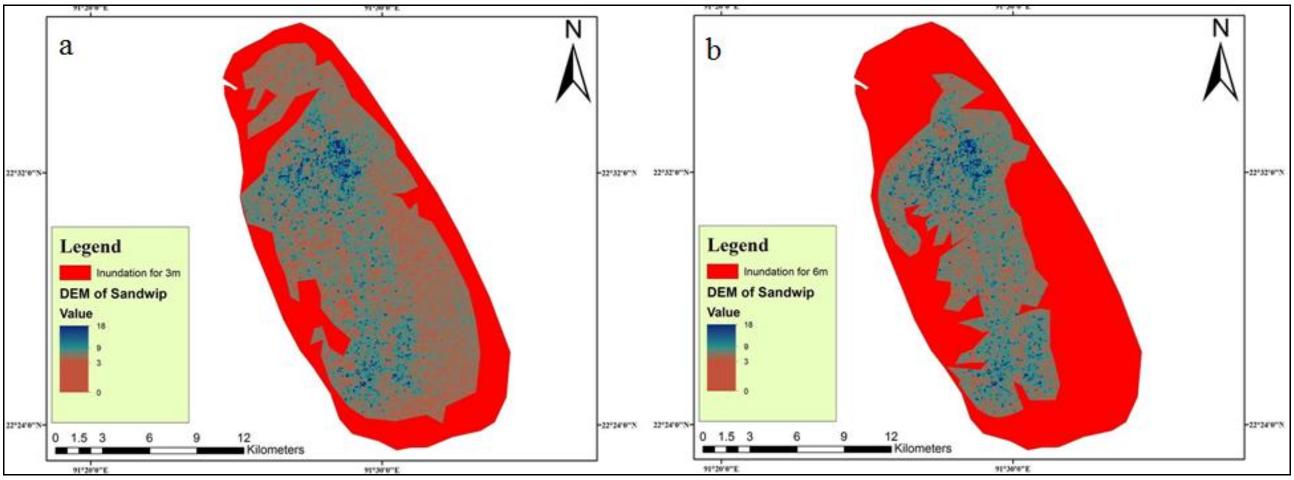


Figure 4. 39: Susceptible inundation for (a) 3 meter and (b) 6 meter storm surges

5. RESULTS AND DISCUSSION: COMMUNITY RISK ASSESSMENT & COPYING STRATEGIES

5.1: Questionnaire Survey

5.1.1 Community Socio-economical Status

The questionnaire survey conducted through personal interview, group discussion, consultation meeting and field visit brought out the social picture, traditional and cultural practices, educational status and financial conditions of the community, their daily routine activities including seasonal calendar of the island. As the respondents were selected randomly and likely found almost all kinds of professionals and ages after 20 yrs among the respondents, their life styles, assets etc reflects the features of whole community of the island. Tables 5.1 to 5.3 are the summarized information of community and their capacities.

5.1.1.1 Socio economic profile

Majority of the respondents were house hold heads dominating male in the age range of 20 to 65. Majority were farmers (23%) followed by businessmen (mainly shop keeper), Labor and Fishermen. A complete summarized information about their socio-economy and socio-educational condition is presented in Table 5.1 & Table 5.2 below.

Table 5. 1: General information of the respondents at Sandwip Island

Profile Type		Minimum	Maximum	Mean
Age		20	65	42.5
Household member		2	7	4.5
Household income	monthly	3000	8000	5500
	Yearly	36000	96000	49500
Members in Study		0	3	1.5
Members living outside of Sandwip		0	4	2
Members living abroad		0	3	1.5

Table 5. 2: Professional, Educational and Economical profile of the respondents at Island

Profile Type		Frequency	Percentage
Occupation			
Farmer		35	23.3
Business		20	13.3
Labor		30	20
Fishing		25	16.6
Official Service		15	10
House hold		10	6.6
Others		15	10
Total		**150**	**100**
Education			
Primary (5th grad)		75	50
Junior Secondary School		40	26
Secondary School Certificate		20	13.3
Higher than SSC		07	4.7
Uneducated/Under Primary		8	5.3
Total		**150**	**~100**
Assets type			
House	Building/ concrete	10	6.7
	Traditional	80	53.3
Land		30	20
Shop		20	13.3
Net		05	3.3
Boat		05	3.3
Total		150	~100

5.1.1.2 Daily Activities

Generally men work from 6 am till 12 am and then do their lunch either at home or at working place and continue to further work for the day while they almost every day visit market (local Bazar) at evening, where they gossip, buy household requirements as well as meeting with friends and relatives (Figure 5.1). On the other hand women are responsible for cooking, collecting water, fuel, housework, children care etc. Night is blessed for their happy sleep which starts at 8 to pm (Figure 5.2).

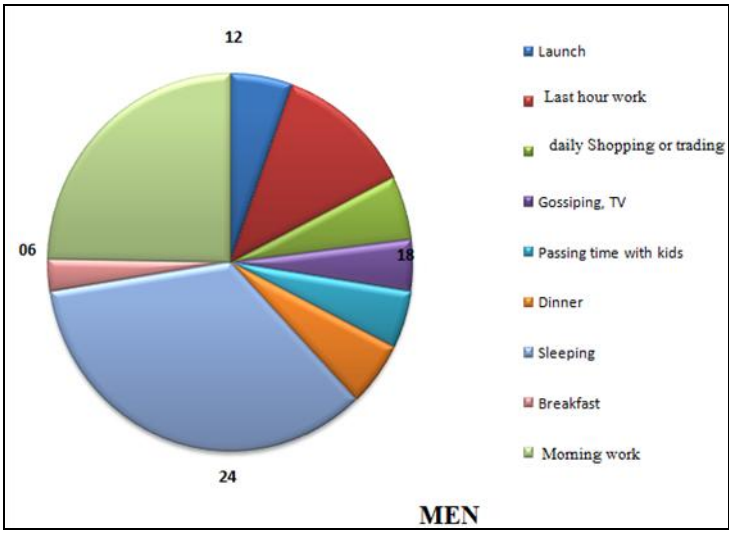


Figure 5. 1: Daily in general activity of men in Sandwip Island

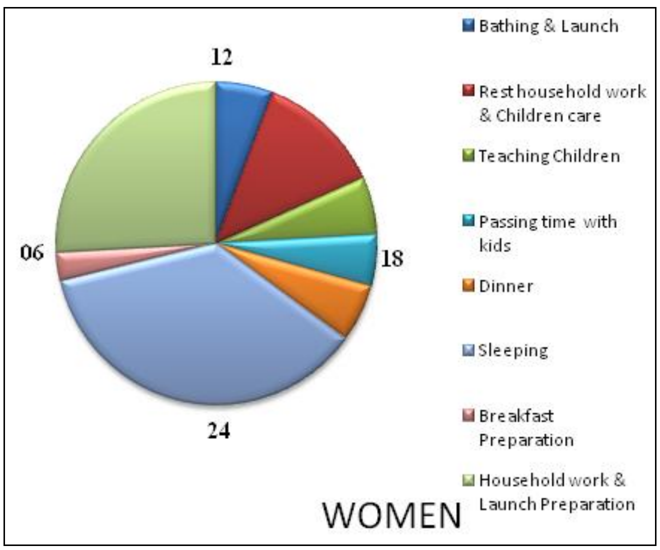


Figure 5. 2: Daily in general activity of women in Sandwip Island

5.1.1.3 Seasonal Calendar

A seasonal calendar is helpful for documenting significant events and activities happening during a year and influences the life of the community which provides a general picture of important environmental and socio-economic changes during the year. The outcomes finally is shown in Table 5.3 as a seasonal calenderer.

Table 5. 3: Seasonal Calendar of the respondents in the Sandwip Island

Activities	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fishing												
Paddy												
Vegetables												
Shrimp fry collection												
Net sewing												
Handicraft												
Concrete collection												
Fire wood collection												
Poultry rearing												
Daily labour												
Service												
Rainfall												
Cyclone												
Boat making												
Boat repairing												

5.1.2 Livelihood assets assessment

"A livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base''- DFID (1991).

Using the pentagon livelihood framework (PLF) as proposed in the Sustainable livelihoods guidance sheets of DFID (1991), Livelihood assets of the island community were analyzed. These assets are the basically of livelihoods combinations of different assets work to cope against different climate change vulnerabilities.

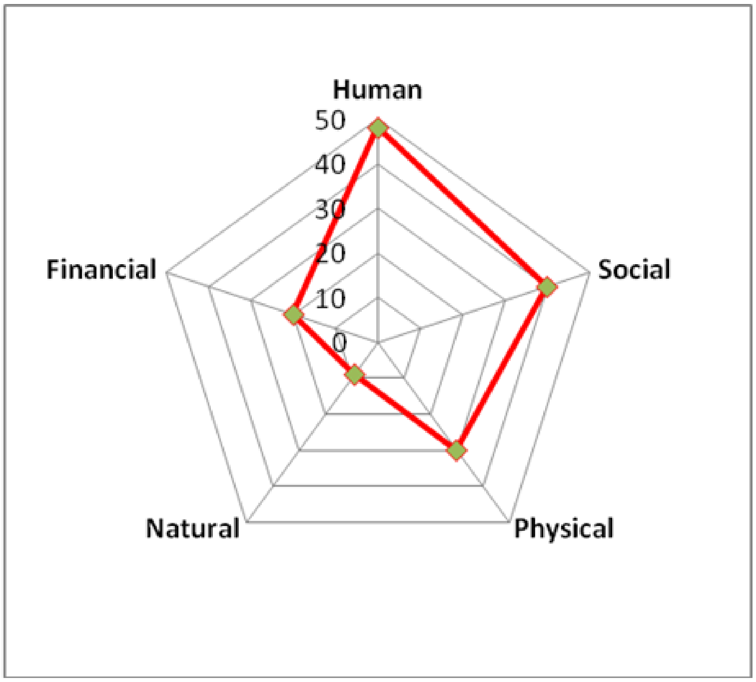


Figure 5. 3: Capital Assets Pentagon of the Island

They are basically for the development of coping strategies. Present study identified 25 types' components under human, natural, financial, physical and social capital on which livelihood depends. Combination of 25 components is shown in Figure 5.3 which are the outcomes from the following 5 types of capital assets where it is clear that the people are stressing by financial, natural and physical assets due to continuous loss by past hazards like storms and erosions and they are still thriving there only with Human and social assets . So, the natural resources should be restored and the physical assets should be recovered.

5.1.2.1 Human Capital

Skill, knowledge, ability to labor and good health etc are worked as important factors for human capital to purse livelihood activities. In this research five types of components were identified under human capital which shows (Figure 5.4) about 24% respondents engaged with farming activities, 20% labor, 17% fishing, 13% business, 10% official while 17 % involves with households and other activities.

5.1.2.2 Natural capital

Natural resources like land, water, fisheries etc are considered as natural capital. Over population and frequently occurring climate change disaster causes depletion of natural capital. The findings of this study showed (Figure 5.4) that 35% have fisheries, 25% paddy land, 15% crop land, 10% grass land and rest 10% ponds.People are becoming landless more and more as the intensity of coastal erosion are increased and also decrease the area of crop and grass land.

5.1.2.3 Financial capital

Savings, supplies of credit, regular remittances and pensions, social security payments or insurance served as financial resources and provide livelihood option for community. The study showed that (Figure 5.4) 41% has credit and only 3% have shop. Most of the people engaged themselves in day laboring, rickshaw pulling and other work for cash income.

5.1.2.4 Physical capital

Physical resources like House, land, water, Shops etc are considered as natural capital. Over population and frequently occurring climate change disaster causes depletion of natural capital. The finding of this study showed that (Figure 5.4) 60% has house made of concrete or traditional, 20% land, 13% shop, 3% net and boat only 3%. People are becoming landless more and more as the intensity of coastal erosion are increased and also decrease the area of crop and paddy land.

5.1.2.5 Social capital

Social capital is getting more prominence as an instrument is designing development policy. Membership of group and organization, relationship of trust contact networks those are taken to purse a livelihood option refers the social capital. Coastal communities get advantages from social capital that has affected the livelihood. The study shows that about 50% involved Different Trade associations, 30% involves labour association and 30% take credit from bank (Figure 5.4). Recently various NGOs have been starting facilities to help the coastal people but it is very rare case.

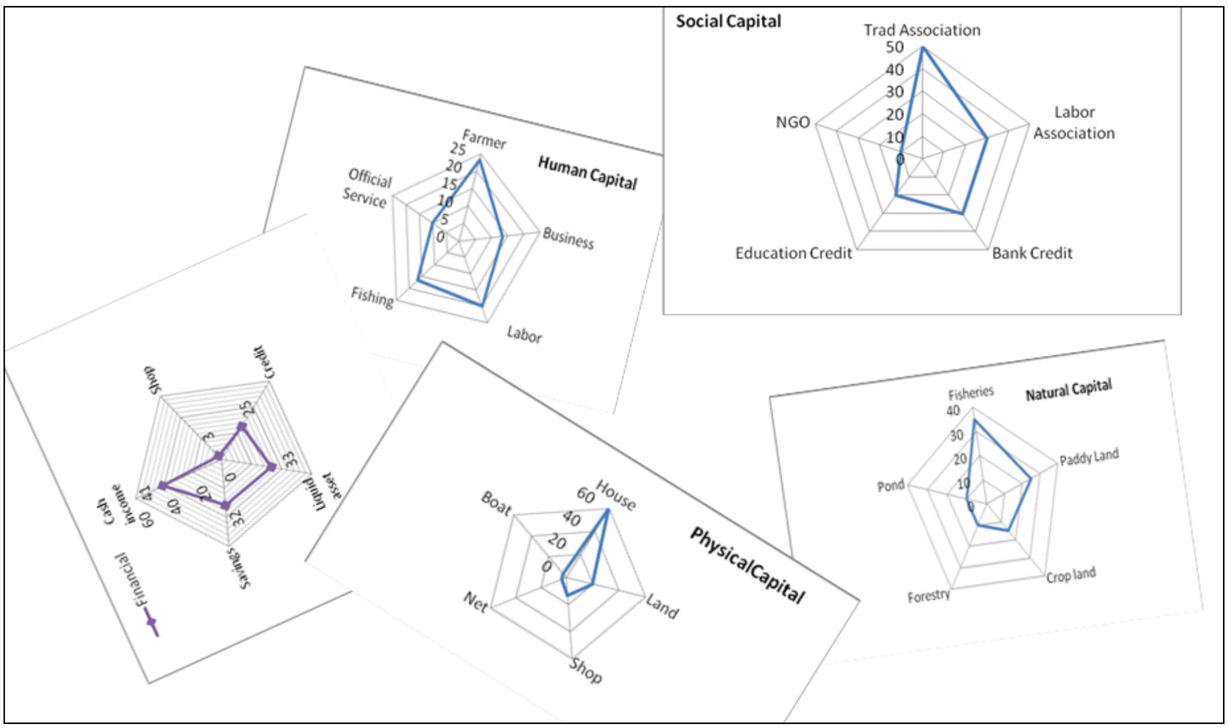


Figure 5. 4: Multiple capital assets (Human, financial, social, natural and physical) pentagon

5.1.3 Vulnerability profile

Both categories of the respondents identified erosion as their most affected hazards while they have different opinions for 2nd ranking of the vulnerability. The selected people who are believed to be most concern (RISCKIT identified) selected cyclone & storm Surges as their second dangerous hazards followed by tidal inundation as third while the local but randomly selected people ranked tidal inundation as second and cyclone induced storm surges as third. Of course there were some of the people told many more miseries for communication and water logging problem. People's response are summarized in the tables below (Table 5.4& Table 5.5)

Table 5. 4: Response on coastal Vulnerability Profile by People selected by RISCKIT guidelines

Vulnerable Hazards	Problem Ranking 1st Choice	Risk Level	Total %
Coastal Erosion	17	****	39.53
Cyclone & Storm Surges	13	****	30.23
Tidal Inundation	7	***	16.28
Water Logging	5	**	11.63
Communication	2	*	4.65
Total	43		100

NB: (* = Low Vulnerability, ** = Medium Vulnerability, *** = High Vulnerability, **** = Critical Vulnerability)

Table 5. 5: Randomly selected People's response on coastal Vulnerability Profile of the Island

Vulnerable Hazards	1st ranking by people	Causes Identified	Frequency	%	Risk Level	What are the risks	Total %
Coastal Erosion	60	Tidal Action	17	28.3	*****	>Land & properties	40
		Wave Action	15	25			
		Meghna Flow	15	25		>Household family	
		Poor Dam	13	21.6			
			Total= 60	100		>Village infra-structure	
Tidal inundation of land	50	Erosion	16	32	****	> Greater extent of the Village	33.3
		Sea Level Rise	15	30		> Fresh water body	
		Poor Dam	12	24		> Severe damage on crops, properties and lives.	
		Geographic location	7	14			
			Total= 50	100			
Cyclone/ Storm surge	40	Erosion	12	30	***	>Household structure	26.6
		Low elevation	10	25		> Young, old and women	
		Warning response	8	20		>Domestic animal	
		Sea-level rise	5	12.5		> All of tangible assets	
		Communication	5	12.5			
			Total=40	100			
Total	150						100

NB: (* = Low Vulnerability, ** = Medium Vulnerability, *** = High Vulnerability, **** = Critical Vulnerability)

In the face of climate change induced sea level rise, the erosion of these islands should become a national concern and island systems will be completely eroded if the situation is not addressed immediately, the respondents claimed. The bottom topography of the Bay of Bengal near Bangladesh is shallow which helps amplification of waves like storm surges and tides. For this reason island like Sandwip face destructive erosion, tidal inundation, cyclone etc. Some forms of scenarios in high vulnerable events on the islands are shown in the following pictures (Figure 5.5-5.8: An accounts eroded assests scenerios is listed (Table 5.6) from the union office (an union which is striggling in the face of erosion for the last 20 years) to make an idea of hoew much the whole island has been loosing every year.

Figure 5. 5: Pictures of shopping (Bazar), Household structures, and sluice gate erosions in the Island

Figure 5. 6: Have become part of history (govt College Building, the Court building and the cyclone shelter

Table 5. 6: Eroded resources of an Union (Rahmatpur) in the last 20 years (union chairman office)

Physical Resources		No of resources			**Brief description**
	Total	1990-2000	2000-2005	2005-2009-	
Primary School Structure	5	3	2	0	Eroded 5 times, 3 rebuilt and 2replaced other union.
High School	2	1	1	0	Eroded 2, no rebuilt, 1 replaced.
College	1	1	0	0	Eroded 1, replaced
Madrasha	4	2	1	1	Eroded 4 rebuilt 4.
Moktob	15	6	5	4	Eroded 15 times, rebuilt 15.
Mosque	14	7	4	3	Eroded14 times,rebuilt14.
House	18610	10510	4900	3200	Migrated
Shop	11445	5035	3010	3400	Eroded
Cyclone center	5	3	2	0	Eroded 5 times, no rebuilt.
Post Office	1	0	1	0	Eroded1, rebuilt.
Health Care center	3	1	1	1	Eroded 3, rebuilt 3
Tube well	683	275	250	158	Eroded 683.
Deep- Tube well	83	45	20	18	Eroded 83.
Concrete Road (km)	27	18	5	4	Eroded 27
Raw Road 75 (km)	64	35	17	12	Eroded 64 km
Breeze / Calvert	37	20	11	6	Eroded 37
Power House	1	1	0	0	Eroded 1 rebuilt in others union.

Figure 5. 7: Photos of Life and properties destruction by Storm in Sandwip Island

Figure 5. 8: Photos of Water logging disrupt the communication and Salt water intrusion destroy the crops in Sandwip Island

5.1.4 Impact of climate change vulnerability

5.1.4.1 On livelihood

An impact study is most helpful when focusing on a single stressor, in this case climate change vulnerability is not just a function of geography or dependence on natural resources, it also has social, economical and political dimension which influence how climate change affects different groups. Rapid increased population in coastal area and limited alternative employment opportunities has made the lives difficult. Coastal area is very hazardous from April to August due to severe weather condition. Impacts of climate change (Figure 5.9) alter the function, diversity and productivity of ecosystem and livelihood. The life and livelihood of Islands people are more vulnerable than any other non coastal area, because they are facing continuously natural calamities especially erosion, Cyclone, tidal inundation, water logging etc.

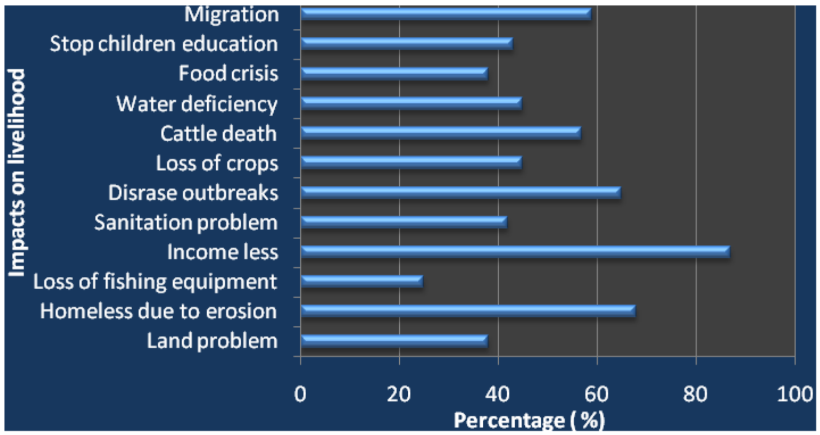


Figure 5. 9: Impacts of the top ranked vulnerabilities on livelihood

Present study reveals that 87% people become income less due to climate change hazard, which is more serious constrain of the study area. Loss of cattle lives due to flood and cyclone is also reported as a major vulnerability by respondents which are an income source of community. Due to coastal erosion people become homeless, which makes miserable coastal community lives. Salinity intrusion is also result in low cash income of the coastal community. Most of the respondents reported that their families could not have three meals a day. Some gets twice and some only once in a day. Even some become starve when they didn’t able to earn. People send their children in supplementary activities for additional income although primary education is compulsory in Bangladesh.

5.1.4.2 On Navigation and transportation

Coastal erosion and water logging due to storm surge or tidal flood affect navigation and transportation. Goods that typically are transported via this coast, waterways and internal roads will be delayed and postponed from getting to their destination. This will create a cost for the depending on these commodities or, more typically, it will cause a price increase for these commodities. This price increase leads to a reduction in household income for persons using these commodities. This reduction in household income reverberates throughout the Sandwip and local economies.. Table: 5.7 shows that, last 10 years 54 km concrete road, 182 km muddy road and 208 Calverts were damaged due to climate change vulnerabilities. Peoples are not getting proper treatment even if they sometimes die because of getting delay to medical. The hradles of trasnporation after any disasters is shown in figure 5.10.

Figure 5. 10: Navigation and Transportation problem (No permanent jetty)

Table 5. 7: Last 10 years destruction of communication structure (Source: Sandwip upazila, 2010)

Types of vehicle road	**Years**			**Remarks**
	2000	2005	2010	
Concrete road (Km)	22	17	15	Total 54km road
Raw road (km)	78	56	48	Total 182 km road
Breeze/ Calvert	87	76	45	Total 208 Calvert/Breeze

5.1.4.3 Impacts on Migration

Continued erosion, hazardous transportation system, lack of modern utility services like power, healthcare, safe drinking water and telephone have turned into miserable life of coastal community at Sandwip Island. Erosion, in particular in coastal areas, aggravates this situation, leading to deteriorating socio-economic phenomena such as migration. At least 22 percent out of about 400000 lace people of the island were forced to migrate (Figure 5.5.13) to safer places in Chittagong city, Sitakunda, Mirsharai, Noakhali, Hatiya and other parts of the country as their homesteads were destroyed following unabated erosion. Each year many families were forcedto leave their homesteads either to safer places in the island or other parts of the city saying goodbye to their beloved ancestral homes**.**There are instances that a family had to shift their home four to five times in last 50 years due to ferocity of nature. Many affluent families became poorer as they lost their assets and traditional means of subsistence following erosion. Major portion of the embankment surrounding Island either damaged completely or partially incapacitating it to protect the land and its inhabitants from tidal surge or inundation during the rainy season. For this reason community are bounded to migrate.

5.1.5 Coping strategies

The residents of Sandwip Island have been trying to protect themselves since people started to live here. The survey results revealed that most adaptation strategies of the households were autonomous. It also found that households have individually trying to adopt applying very traditional and manual methods. However, the households also acted as a group, led by the social leader, in requesting government assistance so that they could cope with the climate change vulnerabilities. Their action may be considered as one type of collective adaptation.

5.1.5.1 Coping strategies for erosion

Adaptive capacityis dependent on several factors: economic wealth, technology, information and skills, institutions and equity. Efforts have been made to stop the processes of erosion; all the households have applied at least one option in this regard. In terms of the protective strategies, It was found during the survey that most households frequently complained that they might not survive very long if government agencies would not do anything for them.The choice of household adaption may be classified into three types of autonomous adaption.

Protection

Some households have applied hard structures in parallel with the coast in order to protect their house/ land. Examples of such structure like:

- Heightening of dike
- Bamboo revetment
- Concrete-pole breakwater

The function of such construction is to lessen the impact of waves and storms. The individual options cannot substitute others but rather support other options. Among these, heightening of dike is the most popular adaptation option. Almost 50% people adopt it to cope with erosion (Figure 5.11) and bamboo revetments takes only 13% people (Figure 5.11). But concrete-pole breakwater is most affective.

Figure 5. 11: Picture showing Bamboo revetment (left) and Heightening of dike (right)

However, the construction of a concrete-pole breakwater involves some physical constraints. Sometimes it is impossible to carry from other place to build the breakwater. For this reason only 13% people adopt it to cope with erosion.

Re-Built

Re-built which is also called relocation (Figure 5.12) involves moving of infrastructures, properties and human settlements to other areas. Such strategy will likely have social and psychological impacts as well, as it entails uprooting people from their communities. Re-built is adopted only that time, when individual households are completely triumph over by sever climate change vulnerability. Only 13% respondents adopt it to cope with erosion.

Figure 5. 12: Picture showing Re-built house (left) and Shifting house materials (right)

Plantation

Some households also try to protect themselves by planting various plant species. It is not very much popular option because it takes huge time. Sometimes household didn't cut (Figure 5.13) existing trees on the coast line, although such trees has economic value. They wait untill the uprooting (Figure 5.13) of those plants by erosion.

Figure 5. 13: Picture showing Existing Trees (left) and Trees uprotted (right)

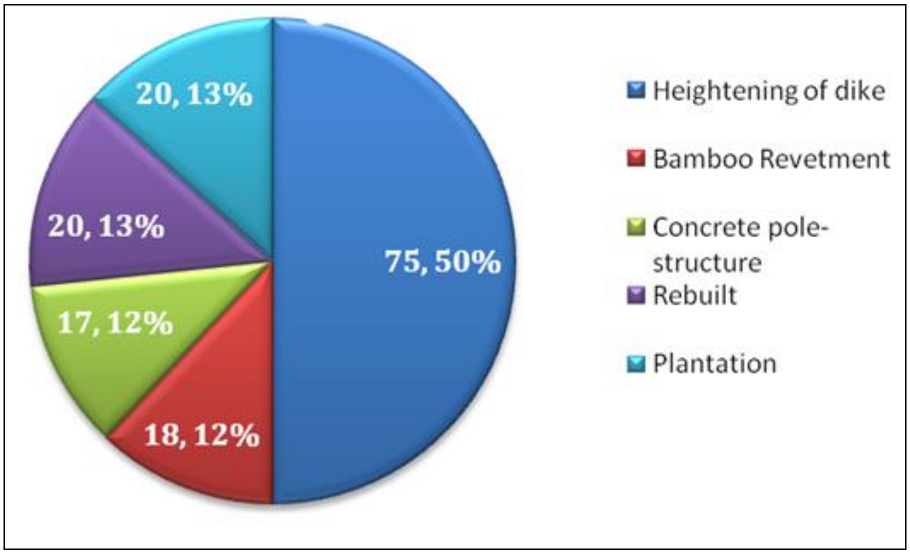


Figure 5. 14: Number of Households Applying Each Adaptation Option

Assessing effective and popular indigenouscoping strategies

Although Relocation and Concrete Pole-structure is quite effective but it's highly costly for these reason poor communities hardly do this. Among the adaption option heightening of dike is widely (Figure 5.15) used because of minimum coast and they can do it by their own labour.

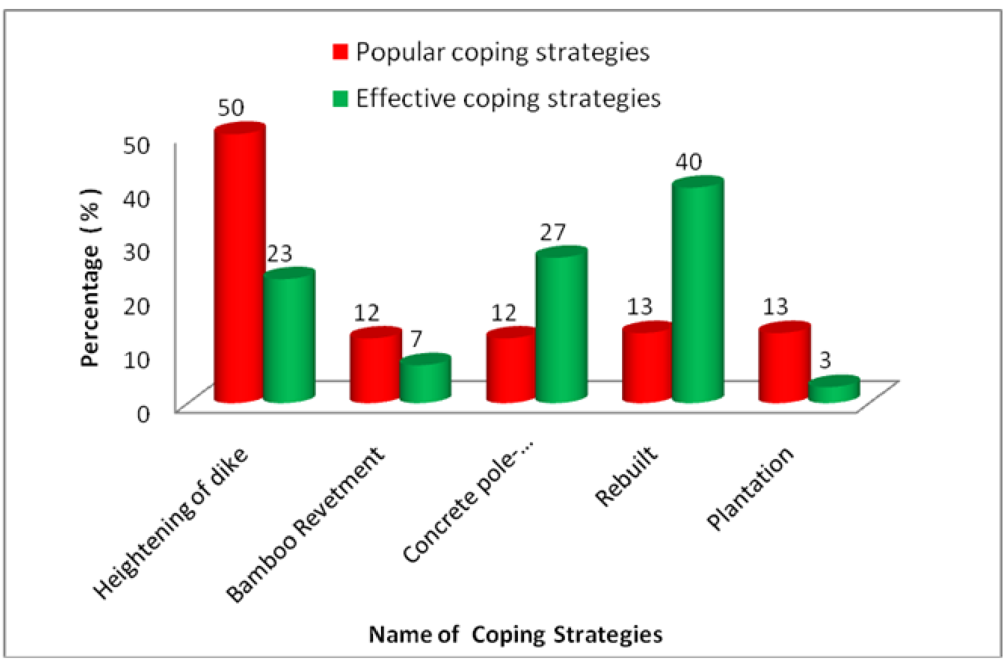


Figure 5. 15: Assessing effective coping strategies

Government assistance to protect erosion

There is not so much work going on to stop the erosion in the Bay of Bengal, island of Sandwip. In the end of the seventies an economic and social feasibility study was taken of construction of a 22 km "cross-dam" (barrage) across a part of the Bay of Bengal, linking the island of Sandwip with the mainland of Bangladesh, in order to promote land reclamation and to create new land for agriculture but there but no advance has yet been done. Government built an earthen protection embankment after the major cyclone in 1991 encircling the island financed by world bank continue maintenance every year in association under Water Development Board in order to protect the coastal but most of its western and southern part has been eroded..In 2004, Water Development Board built 200 kilometers of embankment to protect Sandwip coast from erosion, among this 25 km is completely and 48 km is partially damaged.

5.1.5.2 Coping Strategies for Tidal inundation

The major adaptation measure against flooding in the coastal region of Bangladesh is the construction ofearthen embankments along the rivers as well as parallel to coastline. Theembankments are designed primarily to prevent flooding during highastronomical tides and are found useful during cyclone-generated stormsurge too. Even if, the effectiveness of embankments is being questioned inseveral occasions, the Government of Bangladesh is currently implementingcoastal embankment rehabilitation project considering its primary benefits toagricultural productions as well as flood protection. In most cases, heights arebeing increased under current rehabilitation works to coop with SLR. The embankments are being strengthening by planting trees along its sloping faces. However, all the adaptation measures are summarized in the following figure (Figure 5.16).

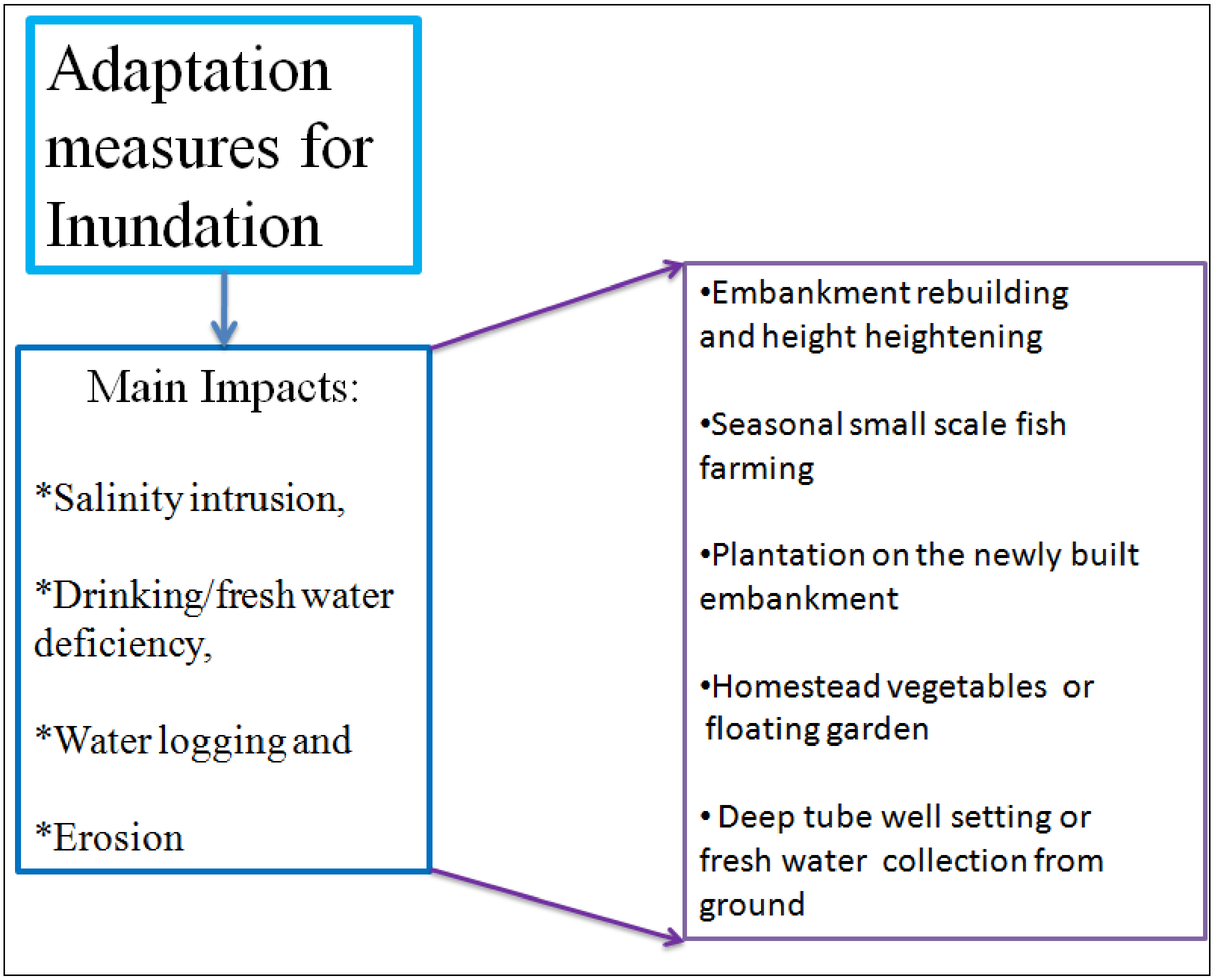


Figure 5. 16: Coping strategies of different problems of tidal inundation

5.1.5.3 Coping Strategies for Cyclone

A majority of respondents reported that, prior to a cyclone; they take several steps to reduce their losses and to save their belongings. Their preparation depends on the presence of local signs (indigenous early warning) and the cyclone signals. Some coastal and island people hide their food, valuables and money inside the earth, while others send their valuable materials to their relatives who arem living in comparitively safer areas. Some habitants of the near coastal area also take shelter in their relative's homes located in the inner areas. Several attempts are taken by households to protect houses including tie their houses with the big trees and poles using ropes, because most of those are not made of bricks. They also put new poles around the house, boring them into the earth. Most of the farmers consider the safety of domestic animals likwise their family members. If the warning signal number hoisted is nine or more, they set domestic animals free from sheds. They also try to send domestic animals to highland areas. The questionnaire surveys and participant observations revealed that farmers also try to collect agricultural crops from the field beforehand of cyclone hazard. The most applicable coping strategies for cyclone were found to construct of new cyclone shelters, heighteing of embankment and plinth, and coastal afforestation etc**.**

An important and widely acceptable cyclonic adaptation option in Bangladesh is the construction of shelters commonly known as 'Cyclone-Shelter' (5.18) which have been built since 1960s. Analyzing of survey data reveal that 82% people go cyclone shelter during cyclone at least after bad experience of 1991 big cyclone, washed out thousands of people and properties of millions of dollars .

Embankments help to protect the entry of water in to the island and even if the surge over tops them, the wave energy reduces to a considerable extent. So that almost 22% people adopt this adaptation as a prepreparation**.** In the recent years, plantations in the coastal areaas well as along the embankments are being extensively practiced to enhance flood mitigation measures in the coastal zone by the Department of Forest and Environment (DoFE).

A strong demand of the following attempts were voiced by the people to the goverenment in the reply of the question: What is your proposal to the government to reduce the risk and losses?

- Building Crossdam
- Island Circling Embankment
- Warning System accuracy and Timely dissemination
- Risk relevant education & Adaptation training
- Transport, health and communication development

The overall coping strategies of Island community for cyclone are given below (Figure 5.17).

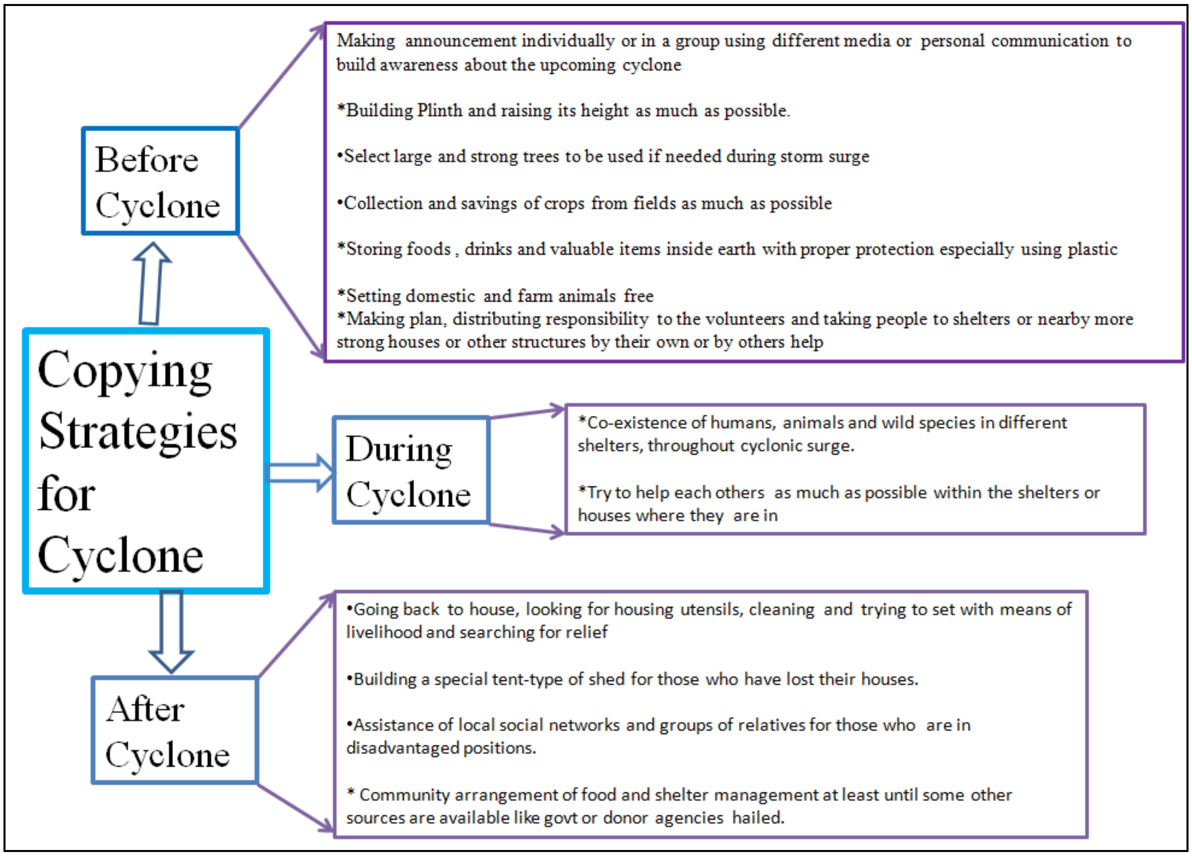


Figure 5. 17: Different coping strategies of cyclone

So, questionnaire survey results are most indicative and informative for all about the community, their life styles and properties, their capacities and their indigenous coping strategies to climate hazards along with the gaps they think government should make access. They are mainly engaged in agriculture, daily labor or fishing activities followed by small business and some official activities with an average income of 5500 bdtk (about 53 Euro) per month having excellent social networking to share and cooperate each other in copping climate change induced disasters. But protection actions against the most devastating hazards, the erosion according to them is beyond their capacity, they have been keeping their try to make several though. They have identified erosion as their main hazards making sense that due to erosion enormous number of families become hopeless, landless, properties less and livelihood less and finally become refugees living here and there. The community who were relatively safe from storms or tidal inundation due to far distance from the sea, are not safe now as the sea already before them just after 5 years because of intense erosion of the coasts. The relocated people are somehow have to be rehabilitated in the inner side, on the coastal bank or other side of the island making further pressure on declining the agricultural land areas or other properties with daily necessities. The pentagon analysis of the selected 25 factors shows minimum natural and physical assets followed by financial capacities with they have been living in the climate induced vulnerabilities like erosion, storm surges and tidal inundation. The poor education, health and communication system makes their life more disastrous day by day hindering preparedness, rescues and after events management.

Government initiatives like training for preparedness, awareness building activities or extracurricular activities are not community involved or community friendly in most cases, according to the people's comments. The government should take major steps for the erosion protection like Crossed dam, more cyclone shelter with a strong island encircling embankment with enough sluice gates. The coastal managers should take necessary steps considering tradition, culture and people used to manners in the island. The forecasting system should be developed local base and the dissemination of the signaling should be in local language or in the form of local people's understanding. Financial supports is sought to rebuilt their structures for housing and livelihood.

These findings also reflect some of the wider comments from disaster- and development-related studies that increasingly emphasize the long standing awareness that strategies must be community-based. A variety of authors are currently making this point including Hilhorst and Bankoff (2004) note how vulnerability is also about people, their perceptions, ideas about risk, and practices. Questions surround the nature of resilient societies following its promotion through the Hyogo Accord of 2005 (Paton and Johnston, 2006;Birkmann, 2006). Collins (2009b) provides a version of disaster and development studies that synthesises much of the people centered perspectives flagged here.

Some management actions including Mangrove plantation, Island Encircling Embankment for Flood protection and rehabilitation, Cyclone shelter building, Sluice gate building, Cyclone and Flood Preparedness training, Agricultural rehabilitation etc are shown in figure 5.21**.**

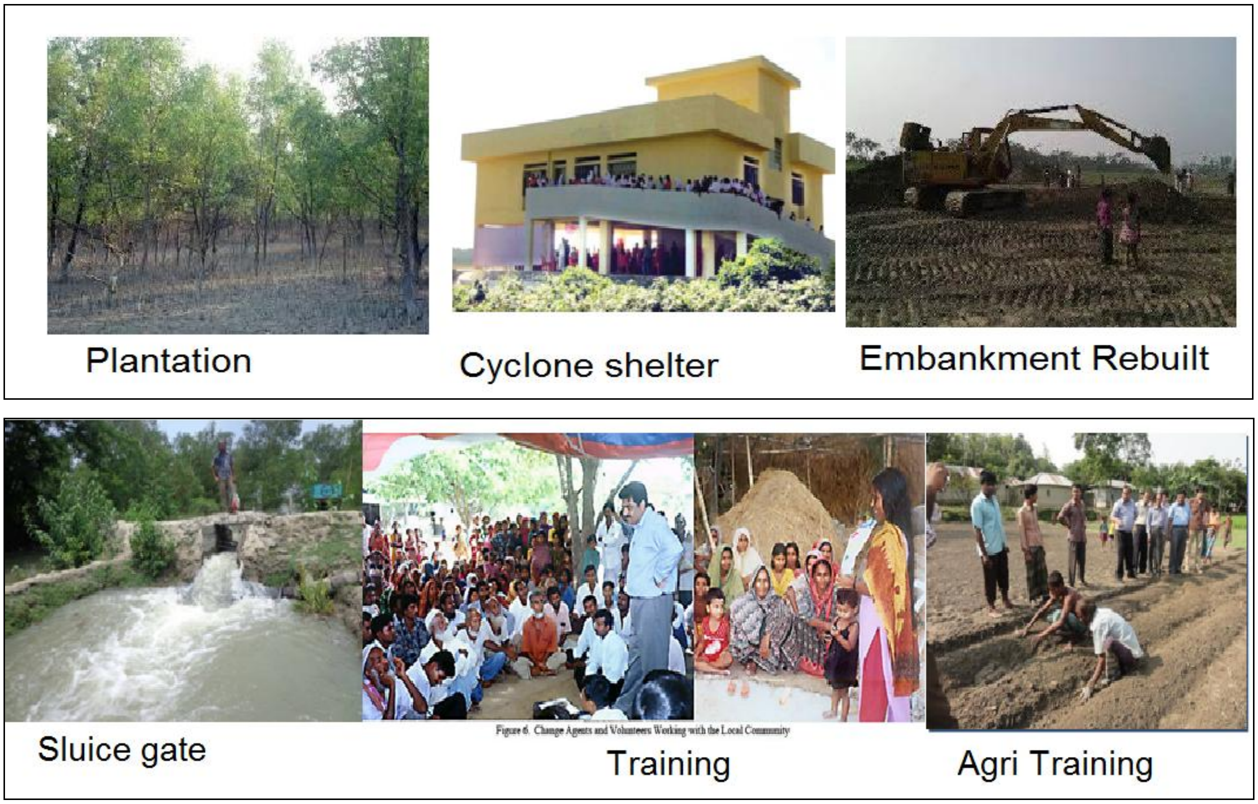


Figure 5. 18: Pictures of some management action so far taken in the Island

6. CONCLUSION AND RECOMMENDATIONS

Field work and data analysis on Sandwip Island evidenced the difficulties in implementing field activities in this location. The topographic survey revelaled that the northern accreted coast is almost 1 meter higher and the cross section extent (distance between clip top to water mark) is longer than the southern eroded coast. It evidenced notable erosion occured during the last year as found by comparison of repeated surveys. Grain size analysis found a negligible amount of coarse materials (>0.63mm) for all sections and highest proportion (98%) of fine (<0.63mm) sediment in the newly formed northern area while further grain size analysis (Sedigraph) of the fine sediments found that more than 60 to 70% of the sediments are composed of silt while the rest of them are clay particles. Furthermore, the mineralogical analysis of the fine sediment revealed that all the sediments are composed of silty minerals containing quartz - calcite - iron oxide – muscovite while no clay minerals identified.

It was measured a high tidal range from 5 to 6 m. The tidal delay between the GLOSS tide gaguge at Chittagong and that at Sandwip is of 47 minute, while the amplitude at Sandwip is 25% higher than Chittagong. The island has been more vulnerable than the predicted global Sea Level Rise scenario as historical tidal analysis found increasing trend of higher tidal water here.

The multi shorelines analysis and automatic change calculation statistics in GIS enviroment revealed that the shoreline change rate and net shoreline movement is much more than that observed by any other study for the whole Bangladesh coast including previous work on Sandwip Island. The erosion-accretion mapping showed dramatical geomorphological changes reducing the island size (from 305.4 Km^2 in 1978 to 250.9 Km^2 in 2014) with a highest rate of erosion observed in the last 10 years (2.72 Km^2/year calculated from 2001 to 2014) regarding erosion patterns, the north eastern coast is accreting whereas the south western coast is critically eroding. The land use change mapping and the interviews with the local residents revealed the reduction of physical and natural properties and livelihoods alarmingly. Bathymetry analysis show that the bottom topography around the island is very much irregular with zones of sediment deposition in the south western and south eastern offshore areas. The topographic survey and the TIN revealed that the island elevation is very close to MSL being comparatively more elevated from north to south. Further nanalysis of ASTER topography for the island creating contour lines

(3 and 6 meter) showd that the island people, structures and resources are extremly vulnerable to any kind of inudation like it happend in the 1991 super cyclone with storm surge of 6 meter above MSL.

Local people have been surviving following a very strong social networking but the communication and the health system is inefficient. The geomorphological changes due to erosion and accretion and previous devastating and increasing vulnerability demands the development of a high resolution early warning system for the island. The predective capability of national warning systems has not enough resolution to actually resolve detailed flooding of the island and the warning dissemination system is no more comprehensive to be usable for the community.

From the analyses, it is clear that accelerated coastal geomorphological change, cyclone induced storm surges and Sea Level Rise (SLR) are threatening Sandwip Island, Bangladesh coast. Human fatalities and property losses will probably increase under the current scenario of climate change.

The following topics are recommended to be considered for further research and better management approaches for the island:

1. A locally based storm surge early-warning system considering geomorphological change should be developed because in the ongoing national warning system local phenomena are almost ignored.

2. A detailed DEM using improved and recent bathymetry is immensely needed to be incorporated in the hydrodynamic model for warning system because of the speed of coastal change and new land formation in and nearby offshore area.

3. Continuous monitoring of the accelerated geomorphological changes is necessary and this should be considered in all management and development actions.

4. A permanent digital water level, water flow and wave monitoring station needs to be established for hydrodynamic understanding of the high tidal range and the controversial sea-river interacting estuarine system around the island

5. The storm warning message should be disseminated via more comprehensive terms and language to be understood by the local people for effective preparedness by the time allowed.

6. People's ability to adapt, prepare and cope with the ongoing hazards needs to be upheld through direct financial as well as training and education by government as well as donor and cooperative agencies.

7. An island encircling protection embankment with enough sluice gate outlets is need to be rebuilt following a better topographic survey and hydro-meteorological modeling considering geomorphological changes. More cyclone shelter should be built in the most risky areas.

8. The development of communication and health systems in and with the island can lessen the devastation of the hazards by a notable fraction.

9. To protect the island and people from erosion, the proposed cross dam structure with the northern Sandwip to Companiganj of Noakhali can be justified by the government after an integrated Environmental Impact Assessment study in geomorphological, hydrodynamical and sustainable perspective.

10. Soft eco-engineering attempts by developing any ecological habitats or ecosystem to support the unconsolidated loss sediments to be grown can be an alternative initiatives to protect the land erosion like the ECOBAS project (Eco-engineering in Bangladesh), is being implemented in another offshore island of Bangladesh in co-operation with Netherlands (http://edepot.wur.nl/315009).

7. REFERENCES

7.1 Literatures

Agnihotri N, Chittibabu P, Jain I, Sinha PC, Rao AD, Dube SK. 2006. Abay–river coupled model for storm surge prediction along the Andhracoast of India. Natural Hazards 39: p83–101.

Ahmed A. 2011. Some of the major environmental problems relating to land usechanges in the coastal areas of Bangladesh: a review, Journal of Geography andRegional Planning 4(1), p1-8.

Ahmed AU and Alam A. 1998. Global circulation modelling and development of futureclimate scenarios. Vulnerability and Adaptation to Climate Change for Bangladesh, ed:S. Huq, Z. Karim, M. Assaduzzaman and F. Mahtab, Kluwer Academic Publishers,Dordrecht, The Netherlands, p13-20.

Alam ME. 2003. 'Post cyclone adjustment process: basic needs perspective'. Oriental Geographer. 47(2): p 47–60.

Ali A. 1995. Numerical investigation into the retardation of flood wateroutflow through the Meghna river in Bangladesh due to SW monsoonwind. Estuarine Coastal Shelf Sci., 41: p689–704.

Ali A. 1999. Climate change impacts and adaptation assessments in Bangladesh, Climate Research, 12: p109-116.

Allison MA. 1998. Geologic Framework and Environmantal Status of the Ganges-Brahmaputra Delta. Journal of Coastal Research, 14(3):p826-836.

Allison MA, Khan SR, Goodbred SL, and Kuhel SA. 2003. Stratigraphic evolution of the late Holocene Ganges–Brahmaputra lower delta plain: Sedimentary Geology, 155: p317–342.

Ascoli FD. 1912. Changes in the Ganges delta: The Geographical Journal (London), 39: p611–612.

BBS. 2011.Household Income and Expenditure Survey 2011, Dhaka, Bangladesh.

Blaikie P, Cannon T, Davis I, and Wisner B. 2003.At Risk: Natural Hazards, People's Vulnerability and Disasters, 2nd edition, Routledge, London, 417p.

Burton I, Kates RW and White GF. 1993. The Environment as Hazard. Second edition.The Guilford Press, New York, NY, 290p.

Barua DK. 1990. Suspended sediment movement in the estuary of the GangesBrahmaputra-Meghna river system. Mar. Geol. 91: p 243-253.

Barua DK. 1991a. The coastline of Bangladesh—An overview of processes and forms. Proc. 7th Symp. on Coastal and Ocean Management, Am. Soc. Civil Eng.,p 2284-2301.

Barua DK. 1997. The active delta of the Ganges-Brahmaputra Rivers: Dynamicsof its presentformations, Marine Geodesy, 20 (1): p.1-12.

Barua DK, Kuehl SA, Miller RL, and Moore WS. 1994. Suspended sedimentdistribution and residual transport in the coastal ocean off the Ganges-Brahmaputrariver mouth. Marine Geology, 120: p 41-61.

Brammer HB. 1996. The Geography of the Soils of Bangladesh. University Press Limited, Dhaka, Bangladesh, 287p

Campos JJA. 1919.History of the Portuguese in Bengal, Janaki Prakashan, Patna and Calcutta

CEGIS. 2003. Integrated Coastal Zone Management Plan Project: Knowledge Portal on Estuary Development (KPED) Working Paper WP017, Prepared for: Program Development Office Sponsored by the Government of the Netherlands and the United Kingdom Executed by ARCADIS Euroconsult, the Netherlands. Dhaka, Bangladesh, 111p.

Chambers R. 1983.Rural Development: Putting the Last First. Longman, London, 235p.

Chambers R. and Conway G. 1992**.** Sustainable rural livelihoods: Practical concepts for the 21st century. IDS Discussion Paper 296. Brighton: IDS.29pp

Choudhury AM. 1998. ‘Disaster monitoring in Bangladesh’. Paper presented at the UnitedNations/International Astronautical Federation Workshop on ‘Expanding the User Communityof Space Technology Application in Developing Countries’, Melbourne, Australia, 24–27, September.

Clarke KC. 1990. Analytical and computer cartography. Englewood Cliffs, Prentice-Hall

Coleman JM. 1969. Brahmaputra river. Channel processes and sedimentation. Sed. Geol.,3:p 129- 239.

Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C and Ninh NH. 2007. Asia. In Parry ML, Canziani OF, Palutikof JP, Linden P.Jvd., HansonCE. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution ofWorking Group II to the Fourth Assessment Report of the Intergovernmental Panel onClimate Change, Cambridge University Press, Cambridge, UK, p469-506.

Dade WB, Nowell ARM and Jumra PA. 1992. Predicting erosion resistance of muds, Marine Geology, 105(1-4): p285-297.

Debsarma SK. 2009. Simulations of storm surges in the Bay of Bengal, Marine Geodesy 32:p 178–198.

DHV. 2001. Hydro-morphological dynamics of the Meghna Estuary, Meghna Estuary Study, Submitted to Ministry of Water Resources, Bangladesh Water Development Board, by DHV Consultant BV and Associates.

DOE. 1993. Assessment of vulnerability of coastal areas to sea level rise and other effects ofglobal climate change. Pilot Study for Bangladesh, Report prepared by Department ofEnvironment, Government of Bangladesh, Dhaka.

Dube SK, Rao AD, Sinha PC, Murty TS, Bahulayan N. 1997. Storm surgein the Bay of Bengal and Arabian Sea: the problem and its prediction.Mausam, 48: p 283–304.

Duo, E. 2014. Development of a Delft3D tidal model of the Bay of Bengal and tide measurements along Sandwip Island (Bangladesh), masters thesis, University of Ferrara, Italy.200p.

Camfield FE and Morang A. 1996. Defining and interpreting shoreline changes, Coastal Managemnt, 32(3): p129-151.

Chowdhury SR and Tripathi NK. 2013. Coastal erosion and accretion in Pak Phanang, Thailand by GIS analysis of maps and satellite imagery, Songklanakarin J. Sci. Technol., 35(6): p739-748.

CRED (Centre for Research in the Epidemiology of Disasters). 2007. 'EM-DAT 2007: TheOFDA/CRED International Disaster Database'. Université Catholique de Louvain, Brussels.

DFID (Department for International Development). 2005.Disaster Risk Reduction: A Development Concern. Policy Briefing Paper, DFID, London.

Edgeworth R and Collins AE. 2006. ‘Self-care as a response to diarrhoea in ruralBangladesh: Empowered choice or enforced adoption?’ Social Science and Medicine, 63(10): p 2686–2697.

Eysink WD. 1983. Basic considerations on the morphology and land accretion potentials in the estuary of the lower Meghna River. Land Reclamation Project, Dhaka, Bangladesh, Tech. Rep. 15.

FAP (Flood Action Plan) 19. 1995. National digital elevation model: A 500 meter resolution land surface model of Bangladesh, Dhaka: Flood PlanCoordination Organisation, Ministry of Irrigation, Water Development and Flood Control.(Rexrt prepared by ISPAN).

Flather RA. 1994. A storm surge prediction model for the northern Bayof Bengal withapplication to the cyclone disaster in April 1991. J.Phys. Oceanogr., 24: p172–190.

Frazier PS and Page KJ. 2000. Waterbody detection and delineation with Landsat TM data. Photogrammetric Engineering and Remote Sensing, 66(12): p1461-1467.

Foxgrover AC. 2010. 2010 Bathymetric survey and digital elevation model of Corte Madera Bay, California; Open-File Report 2011-1217.

Green EP, Mumby PJ, Edwards AJ and Clark CD. 2000. Remote Sensing Handbook for Tropical Coastal Management, AJ, Edwards, editor, Coastal Management Sourcebook 3,UNESCO, Paris, France, 316p.

GLOSS. 2011. Manual on Quality Control of Sea Level Observations, Version 1.0, 38p.

Grabowski RC, Droppo IG and Wharton G. 2011. Erodibility of Cohesive sediment: the importance of sediment properties, Earth Science Reviews, 105(3-4):p101-120.

Habib MA, Ahsan K and Alam MF. 2011. Characteristics of Estuarine Sediments with Special Emphasis to Bhola and Adjoining Islands, Presented in Bangladesh National Seminar on Bangladesh Coast: Geology, Hazards and Resources Dhaka, Bangladesh, 29-30 May 201.

Hickock T. 2004. 'Account Of Pegu', Translated from the Italian by Master ThomasHickock, SOAS Bulletin of Burma Research,2(2), Autumn: p130-159.

Haque CE and Zaman MQ. 1993. 'Human responses to riverine hazards in Bangladesh:a proposal for sustainable floodplain development',World Development. 21(2): p93–107.

Haque CE. and Zaman MQ. 1994. 'Vulnerability and response to riverine hazards inBangladesh: a critique of flood control and mitigation processes', In A. Varley (ed.) Disaster, Development and Environment. John Wiley & Sons, London. p65–80.

Hedge AV. 2010. Coastal Erosion and mitigation methods – Global state of art,Indian Journal of Geomarine Sciences, 39(4): p521-530.

Heroy DC, Kuehl SA, and Goodbred SL. 2003. Mineralogy of the Ganges and Brahmaputra Rivers: implications for river switching and Late Quaternary climate change: Sedimentary Geology, 155: p343–359.

Hewitt K. 1997.Regions of Risk: A Geographical Introduction to Disasters. Longman,Harlow.

Hayes MO. 1979. Barrier island morphology as a function of tidal and wave regime. In S.P. Leatherman(ed.), Symposium on Barrier Islands,New York: Academic Press, p1-28.

Hoque MN. 2006. The Legal and Scientific Assessment of Bangladesh's Baselinein the Context of Article 76 of the United Nations Convention on the Law of the Sea,United Nations – The Nippon Foundation, National University of Ireland GalwayRepublic of Ireland, 107p.

Huizing HGJ. 1971. A Reconnaissance study of the mineralogy of sand fractions from East Pakistan sediments and soils: Geoderma, 6: p109–133.

Hussain MS, Khan ZH, and Ibrahim H.2013. Minerological composition of soils from UrirChar- A tiny offshore Island of Bangladesh. J. Asiat. Soc. Bangladesh, Sci., 39(1): p 95-104.

Hutton D and HaqueCE. 2003. 'Pattern of coping and adaptation among erosion-induceddisplacees in Bangladesh: implications for hazard analysis and mitigation'. Natural Hazards. 29(3): p405–421.

Hutton D and Haque CE. 2004. 'Human vulnerability, dislocation and resettlement:adaptation processes of river-bank erosion-induced displaces in Bangladesh'. Disasters,28(1): p41–62.

Huq S, Karim Z, Asaduzzaman M & Mahtab F. 1999. Vulnerability and Adaptationto Climate Change for Bangladesh, Kluwer Academic Publishers, The Netherlands.

IFRC. 2006.World Disaster Report 2006: Focus on Neglected Crisis. IFRC, Geneva.

IOC. 2002. Manual on sea-level measurement and interpretation. Volume III: Reappraisals and Recommendations as of the year 2000, IOC Manuals and Guides No. 14, UNESCO.

IOC-CEC. 1993. Manual of Quality Control Procedures for Validation of Oceanographic Data,Manuals and Guides No.26, UNESCO.

IPCC. 2014. Climate Change 2014:Synthesis Report, Summary for Policymakers to the IPCC Fifth Assessment Synthesis Report, edited by Pachauri RK and Meyer L, 396p.

ISDR (International Strategy for Disaster Reduction). 2002.Disaster Risk and Sustainable Development: Understanding the Links between Development, Environment and Natural Hazards Leading to Disasters,Background document for the World Summit on Sustainable Development. ISDR, Geneva.

ISDR. 2004.Living with Risk: A Global Review of Disaster Risk Reduction Initiatives, ISDR, Geneva.

ISPRA. 2012. Manuale di mareografia e line guida per I processi di validazione dei dati areografici, Manuali e line guida 77/2012, and Istituto Superiore per la Protezione e la Ricerca Ambientale, Rome

Islam MA. 1974.Human Adjustment to Cyclone Hazards: A Case Study of Char Jabbar. The Natural Hazards Research Working Paper Series. No. 18. Natural Hazards Centre, Boulder, CO.

IWM. 2005. Impact assessment of climate change on the coastal zone ofBangladesh. Final Report, Institute of Water Modelling, Dhaka, Bangladesh,37p.

JCOMM. 2014. Final Report on the Meeting of the National Coordination Team for the Coastal Inundation Forecasting Demonstration Project for Bangladesh (CIFDP-B-NCT),Dhaka, Bangladesh, JCOMM Meeting Report No. 113, 16-18 February 2014.

Jensen JR. 2000. Remote Sensing of the Environment: An Earth Resource Perspective, Princeton Hall, New Jersey, USA, 544p.

Karim MFand Mimura N. 2008. Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh, Glob Environ Chang, 18: p490-500.

Kamrul MA., Kervyn M and Khan AU.2014. Land Cover Changes of the Coast of Bangladesh in Relation to Cyclones and StormSurges: International ConferenceAnalysis and Management of Changing Risks for Natural Hazards, 18-19 November 2014, l Padua, Italy.

Khan AA. 1974. ‘Perception of cyclone hazard and community response in the Chittagongcoastal area’. Oriental Geographer., 18(2): p1-7.

Kuehl, HA, Allison MA, Goodbreed SL, and Kudrass H. 2005. The Ganges-Brahmaputra Delta.SEPM Special Publication No. 83, River Deltas—Concepts, Models, and Examples, p413–434.

Li P, Shi C, Li Z, Muller J-P, Drumond J, Li X, Li Y and Liu J. 2013. Evaluation of ASTER GDEM using GPS benchmarks and SRTM in China, Inmternational Journal of Remopte Sensing, 34(4): p1744-1771.

Madsen H, Jakobsen F. 2004. Cyclone induced storm surge and floodforecasting in the northern Bay of Bengal. Coastal Eng., 51: p277–296

Milliman JD, and Meade RH. 1983. World-wide delivery of river sediment to the oceans. J. Geol.,91: p 1-21.

MoFDM (Ministry of Food and Disaster Management).*2007.*Comprehensive Disaster Management programme,A disaster management programme of the Government ofBangladesh in collaboration with the Department for International Development and theUnited Nations Development Programme.

Mohal N, Khan ZH and Rahman N. 2006. Impact of Sea level Rise on Coastal Rivers of Bangladesh, conference-proceedings of 9th International Conference on River Symposium and Environmental Flows, Brisbane, 4-7 September. 66p.

Mojumdar SC. 1941. Rivers of the Bengal Delta. Alipore, Bengal: Bengal Government Press.

Morton WH, and Khan Q. 1979. Groundwater in the coastal zone and offshore islands of Bangladesh, UNDP/UNDCTD, GWC.

Mukherjee R. 2008.The struggle for the Bay: The life and times of Sandwip, analmost nknown Portuguese port in the Bay of Bengal in theSixteenth and Seventeenth Centuries, Revista da Faculdada de Letras Historia, Porto, III Serie, 9: p67-88.

Murty TS, Flather RA, Henry RF. 1986. The storm surge problem in theBay of Bengal. Prog. Oceanogr., 16: p 195–233.

Neal J, Villanueva I, Wright N, Willis T, Fewtrell T, Bates P. 2012.How much physical complexity is needed to model flood inundation?Hydrol. Proc., 26: p2264–2282

Nicholls RJ, Wong PP, Burkett VR, Codignotto JO, Hay JE, McLean RF, Ragoonaden S, Woodroffe CD. 2007. Coastal systems and low-lying areas. In Parry ML, CanzianiOF, Palutikof JP, Linden PJvd, Hanson CE. Climate Change 2007: Impacts,Adaptation and Vulnerability, Contribution of Working Group II to the FourthAssessment Report of the Intergovernmental Panel on Climate Change, CambridgeUniversity Press, Cambridge, UK, p315-356.

Niyogi D. 1972. Quartemary mapping in plains of West Bengal. Proc. Sem. on Geomorphology, Geohydrology and Geotechnics of the lower Ganga Basin, Indian Institute of Technology.

Parsons TM, Maita Y and Lalli CM. 1989. A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford: Pergamon Press. 173p.

Pernetta JC (Ed). 1993. Marine Protected Area Needs in the South Asian Seas Region. Volume 1: Bangladesh. A Marine Conservation and Development Report, IUCN, Gland, Switzerland, 42p.

Pethick, J & Orford, J. 2013. 'Rapid rise in Effective Sea-Level in southwest Bangladesh: Its causes and contemporary rates'*Global and Planetary Change*, 111:p 237–245.

Paul BK.1984. ‘Perception of and adjustment to floods in Jamuna Floodplain,Bangladesh.’ Human Ecology.,1(12): p3–19.

Paul BK. 2009. Why relatively fewer people died? The case of Bangladesh’scyclone Sidr. natural Hazards 50: p289–304.

Parnetta, JC (ed.). 1993. Marine protected area needs in the south asian seas region, volume 1: Bangladesh, IUCN, Gland, Switzerland.

Pawlowicz R, Beardsley B, and LentzS. 2002. Classical Tidal Harmonic Analysis IncludingError Estimates in MATLAB using T_TIDE, Computers and Geosciences, Issue 8, 28: p929–937.

Pramanik, MAH. 1983. Remote sensing applications to coastal morphologicalinvestigations in Bangladesh, Ph D Thesis, Jahangirnagar University, Savar, Dhaka.

Pugh DT.1996. Tides, surges and mean sea-level (reprinted with corrections), Chichester, UK, John Wiley & Sons Ltd, 486p.

Quader MA, Kervyn M and Khan AU. 2014. Land Cover Changes of the Coast of Bangladesh in Relation to Cyclones and StormSurges, International Conference on "Analysis and Management of Changing Risks for Natural Hazards ", 18-19 November 2014, Padua, Italy.

Rana SMM, Kamruzzaman M, Rajib MA and Rahman M. 2011. Changes in Cyclone Pattern with Climate Change Perspective in the Coastal Regions of Bangladesh, in Environmental Research, Engineering and Management, 2(56): p20-27.

Sarwar GM and Khan MH. 2007. Sea Level Rise: A Threat to the Coast of Bangladesh.Internationales Asien Forum. Int Q Asian Stud 38: p 375-397.

Sarware M and Woodroffe CD. 2013. Rates of Shoreline change along the coast of Bangladesh, Journal of Coastal Conservation, 17(3): p515-526.

SADKN. 2013. Bangladesh Disaster Knowledge Network, Hazard Profiles, http://www.saarc-sadkn.org/countries/bangladesh/hazard_profile.aspx.

Sillitoe P. 2001. 'What know natives?: local knowledge in development',Grassroots Voice. 4(1): p1-27.

Singh OP, Khan TMA, and Rahman MS. 2000. The vulnerability assessment of theSAARC coastal region due to sea level rise: Bangladesh case. SMRC-No.3, SMRCPublication.

Sokolewicz M, Zhang G and Louter T. 2008. Plan form development of the Meghna estuary in Bangladesh, River, Coastal and Estuarine Morphodynamics: RCEM 2007- Dohmen-Janssen & Hulscher (eds), Taylor and Francis Group , London, p 129-135.

Talukder B. 2012. 'Sustainability of Changing Agricultural Systems in the CoastalZone of Bangladesh' Master's thesis, Queen's University, Canada

Teh TS. 2000. Sustainable development and environmental management of Malaysian islands (Chapter 18). Islands of Malaysia: Issues and Challenges, ed. T.S. Teh, R&D 0237: Kuala Lumpur, p319-340.

Thieler ER, Himelstoss EA, Zichichi JL and Ergul A. 2009. Digital Shoreline Analysis System (DSAS) version 4.0- An ArcGIS extension for calculating shoreline changes, US Geological Survey Open File Report 2008-1278, 79p.

Twigg J and Bhatt M. 1998.Understanding Vulnerability: South Asian Perspective. Intermediate Technology Publications, London.

Umitsu M. 1993. Late Quartemary sedimentary environments and landforms in the Ganges Delta. Sed. Geol.,83:p177-186.

Umitsu M. 1997. Landforms and floods in the Ganges delta and coastal lowland ofBangladesh, Marine Geodesy, 1(20): p77-87.

UNDP (United Nations Development Programme). 2004. Reducing Disaster Risk: A Challenge for Development. Bureau of Crisis Prevention and Recovery, UNDP, New York, NY. , 146p.

UNISDR (United Nations International Strategy for Disaster Reduction). 2005.The Hyogo Declaration,World Conference on Disaster Reduction, Kobe, Hyogo, Japan, 18–22 January.

Warrick RA, Ahmad QK (ed). 1996. The implications of climate and sea level change for Bangladesh, Kluwer Academic Publishers, Dordrecht, The Netherlands

Weichselgartner J. 2001. 'Disaster mitigation: the concept of vulnerability revisited'. Disaster Prevention and Management,10 (2): p85–94.

White, G.F (ed.). 1974. Natural Hazards: Local, National, Global. Oxford University Press, New York, NY.

White, Kevin and Asmar, HMEI. 1999. Monitoring Changing positions of coastlines using thematic mapper imagry, an example from the Nile Delta, Geomorphology, 29 (1-2):p93-105.

Wisner B, Blaikie P, Cannon T and Davis I. 2004.At Risk: Natural Hazards, People's Vulnerability and Disasters. Second edition. Routledge, London.

World Bank. 2005.Natural Disaster Hotspots: A Global Risk Analysis. Disaster Risk Management Series. No. 5. World Bank, Washington, DC.

Zaman MQ. 1988.The Socioeconomic and Political Dynamics of Adjustment to Riverbank Erosion Hazard and Population Resettlement in the Brahmaputra Jamuna Floodplain. PhD dissertation, University of Manitoba, Winnipeg, MB.

7.2 Websites

http://delta.umn.edu/content/ganges-brahmaputra-meghna-gbm-delta

http://en.wikipedia.org/wiki/Ganges#mediaviewer/File:Ganges-Brahmaputra-Meghna_basins.jpg

http://www.warpo.gov.bd/rep/knowledge_port/KPED/Overview.htm

http://upload.wikimedia.org/wikipedia/commons/1/1a/The_delta_of_Ganges_by_J._Rennel.jpg

http://bn.wikipedia.org/wiki

http://hdl.handle.net/10689/10182

http://www.colonialvoyage.com/portuguese-bay-bengal

http://earthexplorer.usgs.gov

(http://glcf.umiacs.umd.edu/

www.ioc-sealevelmonitoring.org

http://www.eos.ubc.ca/~rich/#T_Tide

http://www.icdd.com

http://edepot.wur.nl/315009

ANNEXES

Annex1A: Cross section profiles in February 2014

Annex1B: Cross section profiles in March 2013

Annex 2**:** Sedigraph for sediment samples cliff top (a) and cliff base (b) of each profile

Annex 3: X-ray diffractogram of sediment samples for 3 profiles 2N, CDBM and 2S ($_1$ for top, $_2$ for base and $_3$ for water mark position)

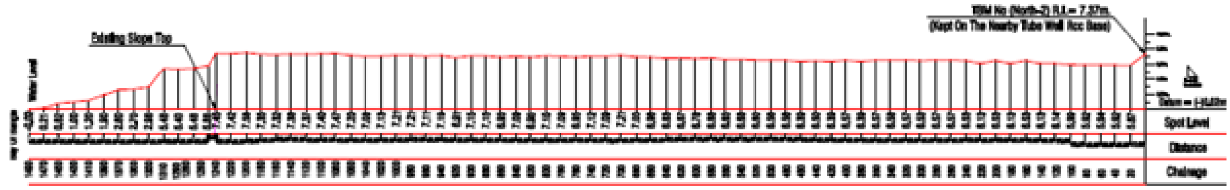
Annex 4a: Interviewee list

Annex 4b an example of RISCKIT Questionnaire

Anex 5: Transect wise Statistical calculation for the whole shorelines

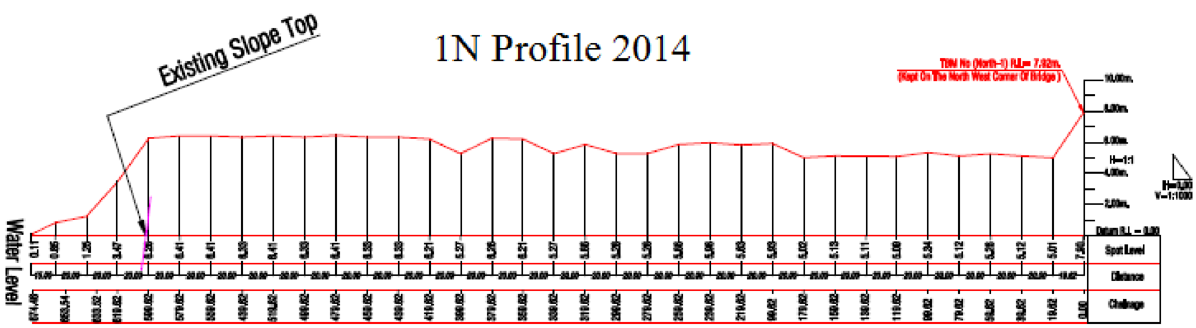
Annex1a: Cross section profiles in February 2014

2N Profile 2014



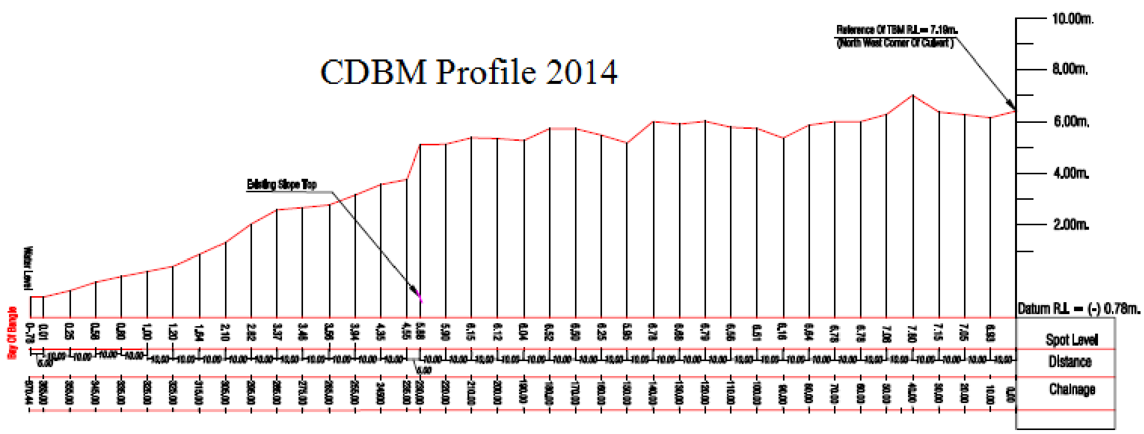
TBM No (North-2) R.L= 7.37m.
(Kept On The Nearby Tube Well Rcc Base)

1N Profile 2014



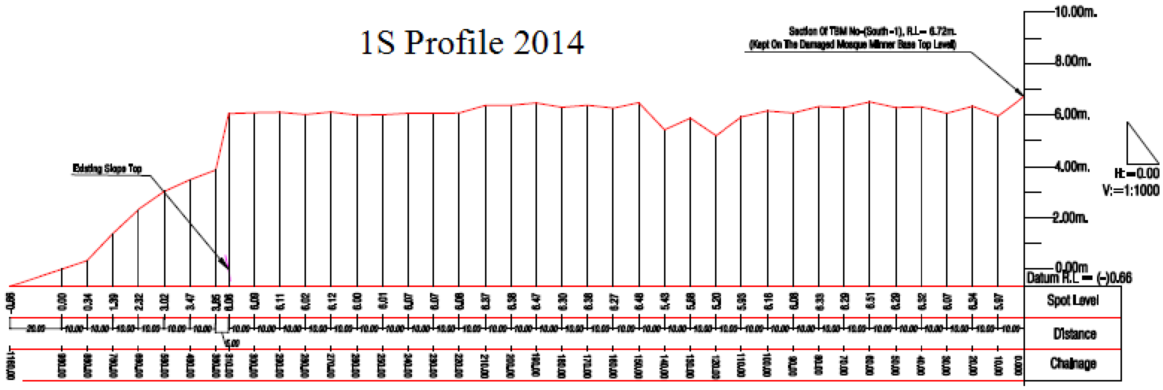
Section Of TBM No (North-1) R.L= 7.92m.
(Kept On The North West Corner Of Bridge)

CDBM Profile 2014



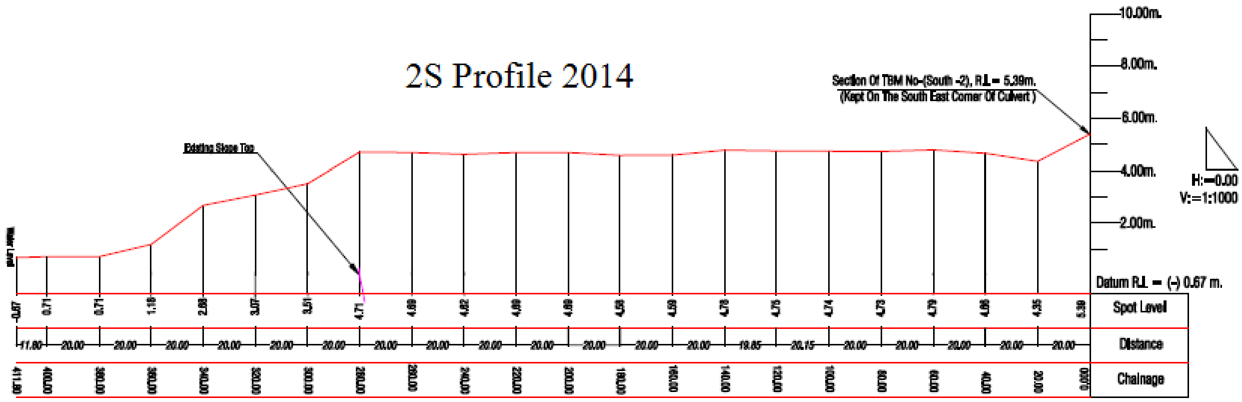
Reference Of TBM R.L= 7.19m.
(North West Corner Of Dalalpara Culvert)

1S Profile 2014



Section Of TBM No-(South -1), R.L= 6.72m.
(Kept On The Damaged Mosque Minner Base Top Level)

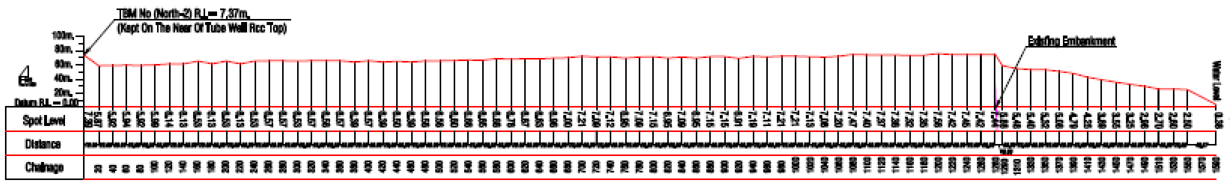
2S Profile 2014



Section Of TBM No-(South -2), R.L= 5.39m.
(Kept On The South East Corner Of Culvert)

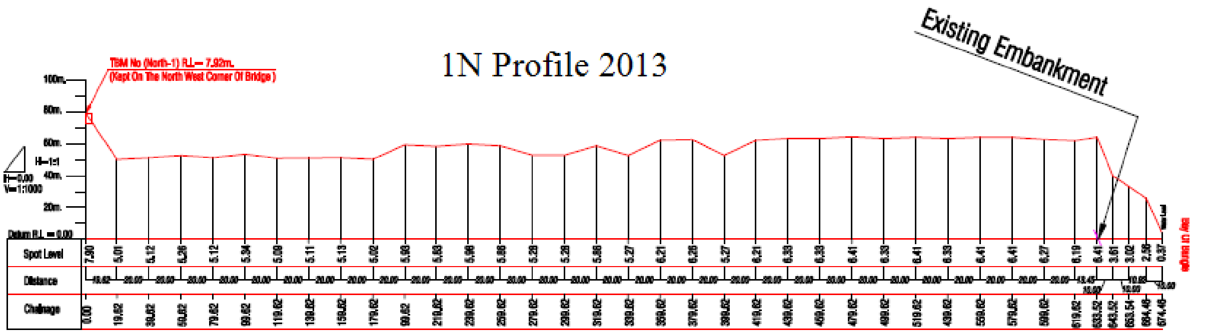
Annex1b: Cross section profiles in March 2013

2N Profile 2013



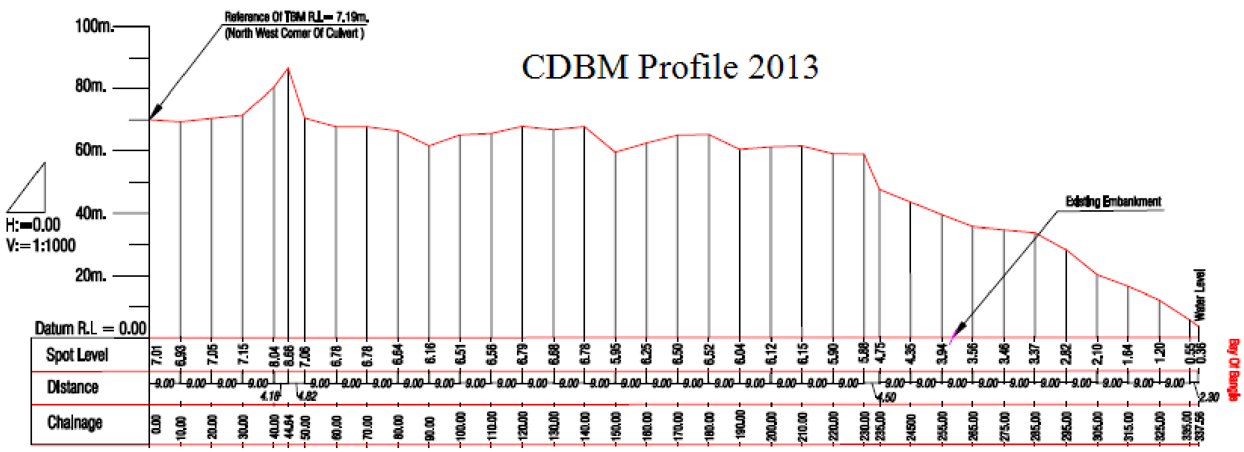
Section Of TBM No (North-2) R.L= 7.37m.
(Kept On The Near Of Tube Well Rcc Top)

1N Profile 2013

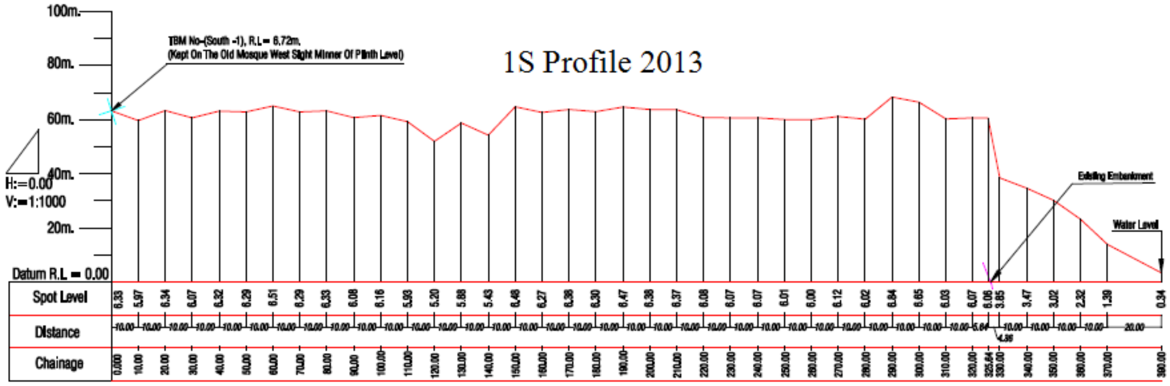


Section Of TBM No (North-1) R.L= 7.92m.
(Kept On The North West Corner Of Bridge)

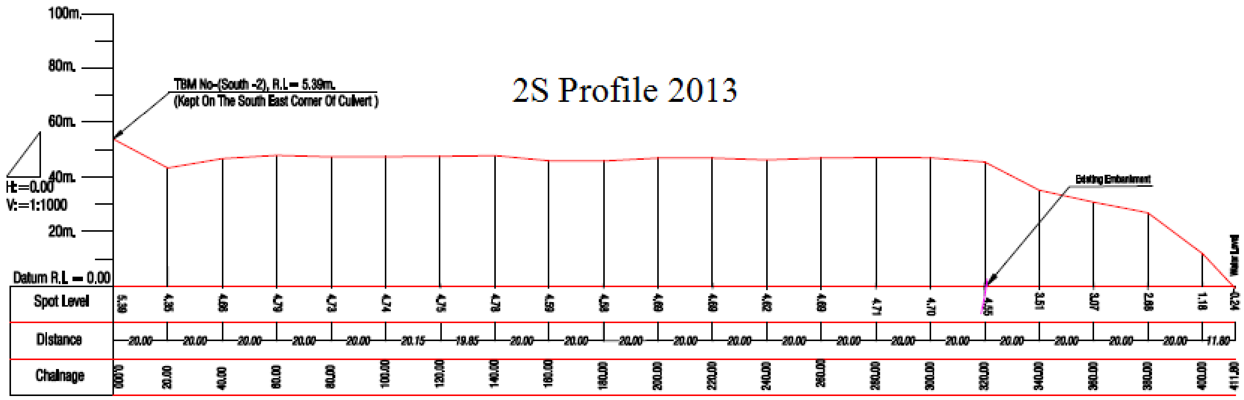
CDBM Profile 2013



Section Of Reference Of TBM R.L= 7.19m.
(North West Corner Of Culvert)



Section Of TBM No-(South -1), R.L= 6.72m.
(Kept On The Old Mosque West Sight Minner Of Plinth Level)



Section Of TBM No-(South -2), R.L= 5.39m.
(Kept On The South East Corner Of Culvert)

Annex 2: Sedigraph for sediment samples cliff top (a) and cliff base (b) of each profile

2N TBM Profile

a)

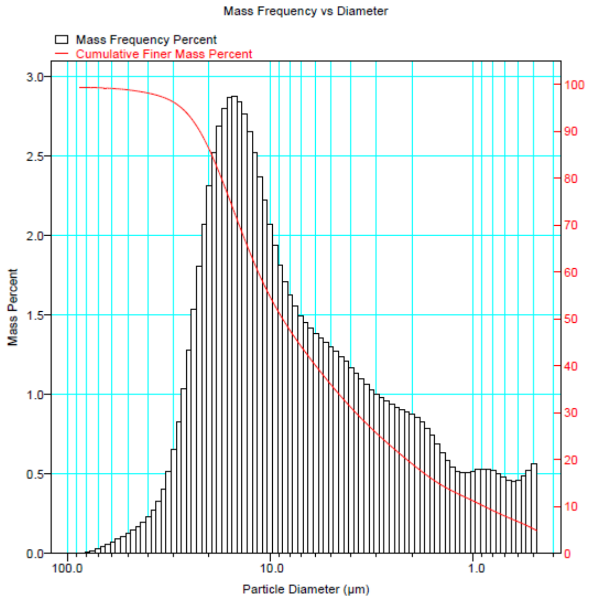
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 2_N_2
File Name: C:\WIN5100\DATA\MUNNA\2_N_2.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 13.38.28
Reported: 10/09/13 09.55.31
Liquid Visc: 0.7235 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.754 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 55 KCnts/s



quarto

WIN5100 V2.01 Unit 1 S/N 498 Page

Sample: 2_N_2
File Name: C:\WIN5100\DATA\MUNNA\2_N_2.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 13.38.28
Reported: 10/09/13 09.55.31
Liquid Visc: 0.7235 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.754 g/cm
Liquid Density: 0.9941 g/c
Base/Full Scale: 104 / 55 KC

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.3	0.0	0.0
88.40	74.30	81.04	99.3	0.0	0.0
74.30	62.50	68.15	99.2	0.1	0.0
62.50	52.60	57.34	98.9	0.3	0.0
52.60	44.20	48.22	98.5	0.4	0.0
44.20	37.20	40.55	97.8	0.7	0.0
37.20	31.30	34.12	96.7	1.2	0.0
31.30	26.30	28.69	94.3	2.4	0.0
26.30	22.10	24.11	89.9	4.4	0.0
22.10	18.60	20.27	83.2	6.7	0.0
18.60	15.60	17.03	74.7	8.4	0.0
15.60	13.10	14.30	66.1	8.6	0.0
13.10	11.00	12.00	58.4	7.7	0.0
11.00	9.300	10.11	52.3	6.1	0.0
9.300	7.800	8.517	46.9	5.3	0.0
7.800	6.600	7.175	42.5	4.4	0.0
6.600	5.500	6.025	38.1	4.4	0.0
5.500	4.500	4.975	33.6	4.5	0.0
4.500	3.900	4.189	30.6	3.0	0.0
3.900	3.300	3.587	27.4	3.2	0.0
3.300	2.800	3.040	24.5	2.9	0.0
2.800	2.300	2.538	21.3	3.2	0.0
2.300	2.000	2.145	19.1	2.2	0.0
2.000	1.600	1.789	16.0	3.2	0.0
1.600	1.400	1.497	14.4	1.6	0.0
1.400	1.200	1.296	12.8	1.5	0.0
1.200	1.000	1.095	11.2	1.6	0.0
1.000	0.820	0.906	9.4	1.8	0.0
0.820	0.690	0.752	7.9	1.5	0.0
0.690	0.580	0.633	6.5	1.4	0.0
0.580	0.490	0.533	4.9	1.6	0.0

b)

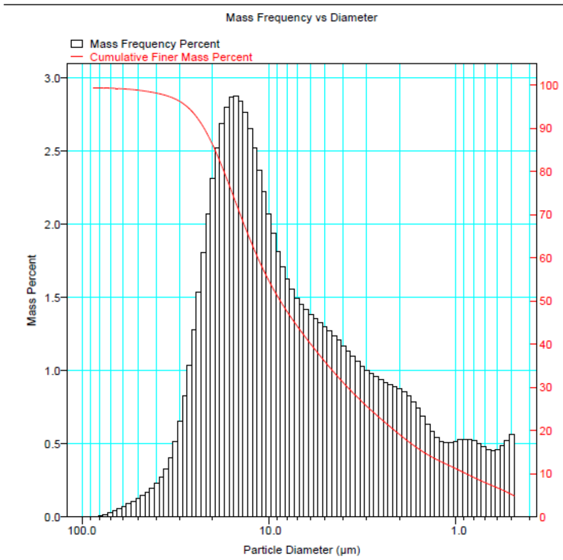
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 2_N_2
File Name: C:\WIN5100\DATA\MUNNA\2_N_2.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 13.38.28
Reported: 10/09/13 09.55.31
Liquid Visc: 0.7235 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.754 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 55 KCnts/s



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WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 2_N_2
File Name: C:\WIN5100\DATA\MUNNA\2_N_2.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 13.38.28
Reported: 10/09/13 09.55.31
Liquid Visc: 0.7235 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.754 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 55 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.3	0.0	0.0
88.40	74.30	81.04	99.3	0.0	0.0
74.30	62.50	68.15	99.2	0.1	0.0
62.50	52.60	57.34	98.9	0.3	0.0
52.60	44.20	48.22	98.5	0.4	0.0
44.20	37.20	40.55	97.8	0.7	0.0
37.20	31.30	34.12	96.7	1.2	0.0
31.30	26.30	28.69	94.3	2.4	0.0
26.30	22.10	24.11	89.9	4.4	0.0
22.10	18.60	20.27	83.2	6.7	0.0
18.60	15.60	17.03	74.7	8.4	0.0
15.60	13.10	14.30	66.1	8.6	0.0
13.10	11.00	12.00	58.4	7.7	0.0
11.00	9.300	10.11	52.3	6.1	0.0
9.300	7.800	8.517	46.9	5.3	0.0
7.800	6.600	7.175	42.5	4.4	0.0
6.600	5.500	6.025	38.1	4.4	0.0
5.500	4.500	4.975	33.6	4.5	0.0
4.500	3.900	4.189	30.6	3.0	0.0
3.900	3.300	3.587	27.4	3.2	0.0
3.300	2.800	3.040	24.5	2.9	0.0
2.800	2.300	2.538	21.3	3.2	0.0
2.300	2.000	2.145	19.1	2.2	0.0
2.000	1.600	1.789	16.0	3.2	0.0
1.600	1.400	1.497	14.4	1.6	0.0
1.400	1.200	1.296	12.8	1.5	0.0
1.200	1.000	1.095	11.2	1.6	0.0
1.000	0.820	0.906	9.4	1.8	0.0
0.820	0.690	0.752	7.9	1.5	0.0
0.690	0.580	0.633	6.5	1.4	0.0
0.580	0.490	0.533	4.9	1.6	0.0

1N TBM Profile

a)

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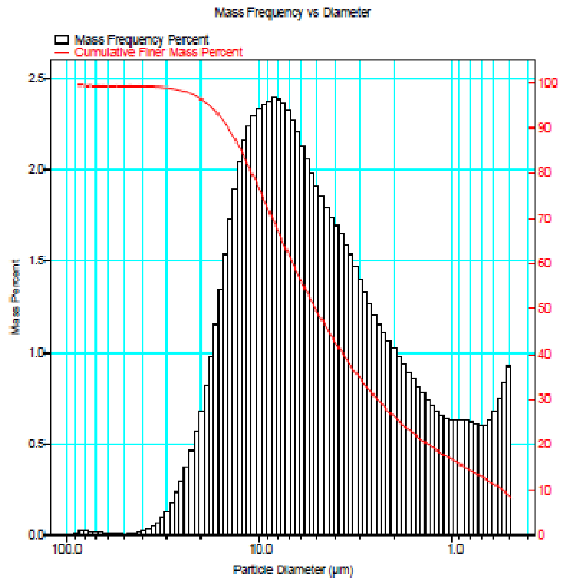
IN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 1_N_1
File Name: C:\WIN5100\DATA\MUNNA\1_N_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 11.41.54
Reported: 10/09/13 09.53.07
Liquid Visc: 0.7242 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.796 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 53 KCnts/s



quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 1_N_1
File Name: C:\WIN5100\DATA\MUNNA\1_N_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 11.41.54
Reported: 10/09/13 09.53.07
Liquid Visc: 0.7242 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.796 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 53 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.4	0.0	0.0
88.40	74.30	81.04	99.3	0.1	0.0
74.30	62.50	68.15	99.3	0.1	0.0
62.50	52.60	57.34	99.2	0.0	0.0
52.60	44.20	48.22	99.2	0.0	0.0
44.20	37.20	40.55	99.1	0.1	0.0
37.20	31.30	34.12	99.0	0.2	0.0
31.30	26.30	28.69	98.5	0.5	0.0
26.30	22.10	24.11	97.4	1.1	0.0
22.10	18.60	20.27	95.4	2.0	0.0
18.60	15.60	17.03	92.0	3.4	0.0
15.60	13.10	14.30	86.9	5.1	0.0
13.10	11.00	12.00	80.4	6.5	0.0
11.00	9.300	10.11	73.7	6.8	0.0
9.300	7.800	8.517	66.4	7.3	0.0
7.800	6.600	7.175	59.6	6.8	0.0
6.600	5.500	6.025	52.8	6.8	0.0
5.500	4.500	4.975	46.2	6.7	0.0
4.500	3.900	4.189	41.8	4.3	0.0
3.900	3.300	3.587	37.2	4.7	0.0
3.300	2.800	3.040	33.1	4.1	0.0
2.800	2.300	2.538	29.0	4.2	0.0
2.300	2.000	2.145	26.4	2.6	0.0
2.000	1.600	1.789	22.7	3.6	0.0
1.600	1.400	1.497	20.8	1.9	0.0
1.400	1.200	1.296	18.9	1.9	0.0
1.200	1.000	1.095	16.8	2.1	0.0
1.000	0.820	0.906	14.7	2.2	0.0
0.820	0.690	0.752	12.8	1.8	0.0
0.690	0.580	0.633	10.9	1.9	0.0
0.580	0.490	0.533	8.4	2.5	0.0

b)

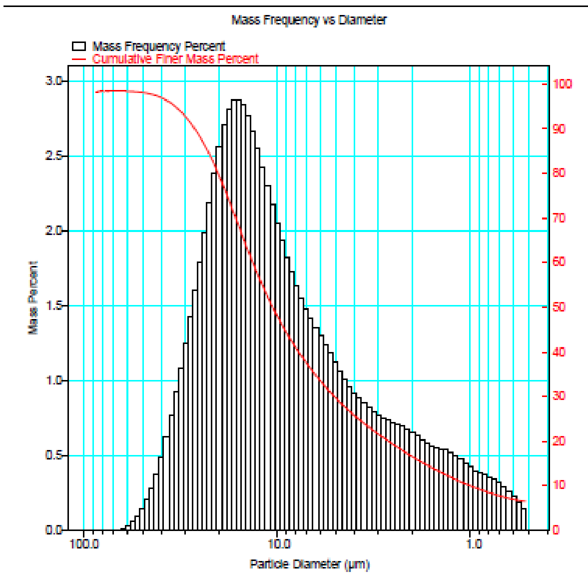
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 1_N_2
File Name: C:\WIN5100\DATA\MUNNA\1_N_2.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 12.13.41
Reported: 10/09/13 09.53.28
Liquid Visc: 0.7239 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.796 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 55 KCnts/s



quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 1_N_2
File Name: C:\WIN5100\DATA\MUNNA\1_N_2.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 12.13.41
Reported: 10/09/13 09.53.28
Liquid Visc: 0.7239 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.796 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 55 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	98.4	0.0	0.0
88.40	74.30	81.04	98.4	-0.1	0.0
74.30	62.50	68.15	98.4	0.0	0.0
62.50	52.60	57.34	98.3	0.2	0.0
52.60	44.20	48.22	97.7	0.6	0.0
44.20	37.20	40.55	96.3	1.4	0.0
37.20	31.30	34.12	93.7	2.6	0.0
31.30	26.30	28.69	89.5	4.1	0.0
26.30	22.10	24.11	83.7	5.8	0.0
22.10	18.60	20.27	76.2	7.5	0.0
18.60	15.60	17.03	67.5	8.7	0.0
15.60	13.10	14.30	59.1	8.4	0.0
13.10	11.00	12.00	51.6	7.4	0.0
11.00	9.300	10.11	45.6	6.1	0.0
9.300	7.800	8.517	40.2	5.3	0.0
7.800	6.600	7.175	35.9	4.3	0.0
6.600	5.500	6.025	31.7	4.1	0.0
5.500	4.500	4.975	27.8	3.9	0.0
4.500	3.900	4.189	25.4	2.4	0.0
3.900	3.300	3.587	23.0	2.5	0.0
3.300	2.800	3.040	20.7	2.2	0.0
2.800	2.300	2.538	18.3	2.5	0.0
2.300	2.000	2.145	16.6	1.7	0.0
2.000	1.600	1.789	14.2	2.4	0.0
1.600	1.400	1.497	12.9	1.3	0.0
1.400	1.200	1.296	11.5	1.4	0.0
1.200	1.000	1.095	10.0	1.5	0.0
1.000	0.820	0.906	8.7	1.3	0.0
0.820	0.690	0.752	7.7	1.0	0.0
0.690	0.580	0.633	6.9	0.8	0.0

CDBM Profile

a)

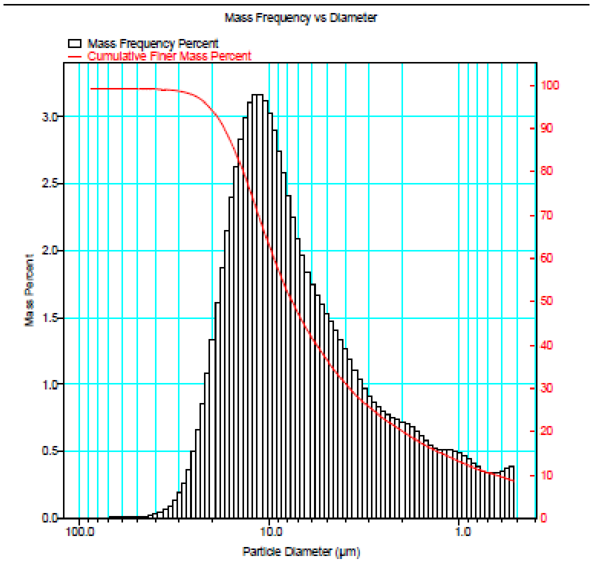
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 0_1
File Name: C:\WIN5100\DATA\MUNNA\0_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 09.39.14
Reported: 10/09/13 09.44.43
Liquid Visc: 0.7251 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.733 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 56 KCnts/s



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WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 0_1
File Name: C:\WIN5100\DATA\MUNNA\0_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 09.39.14
Reported: 10/09/13 09.44.43
Liquid Visc: 0.7251 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.733 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 56 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.1	0.0	0.0
88.40	74.30	81.04	99.2	0.0	0.0
74.30	62.50	68.15	99.2	0.0	0.0
62.50	52.60	57.34	99.1	0.0	0.0
52.60	44.20	48.22	99.1	0.0	0.0
44.20	37.20	40.55	99.0	0.1	0.0
37.20	31.30	34.12	98.7	0.3	0.0
31.30	26.30	28.69	98.0	0.8	0.0
26.30	22.10	24.11	96.1	1.9	0.0
22.10	18.60	20.27	92.3	3.8	0.0
18.60	15.60	17.03	85.9	6.3	0.0
15.60	13.10	14.30	77.5	8.4	0.0
13.10	11.00	12.00	68.0	9.5	0.0
11.00	9.300	10.11	59.1	8.9	0.0
9.300	7.800	8.517	51.1	8.0	0.0
7.800	6.600	7.175	44.9	6.2	0.0
6.600	5.500	6.025	39.3	5.6	0.0
5.500	4.500	4.975	34.0	5.3	0.0
4.500	3.900	4.189	30.7	3.3	0.0
3.900	3.300	3.587	27.4	3.3	0.0
3.300	2.800	3.040	24.7	2.7	0.0
2.800	2.300	2.538	22.0	2.8	0.0
2.300	2.000	2.145	20.2	1.8	0.0
2.000	1.600	1.789	17.5	2.6	0.0
1.600	1.400	1.497	16.2	1.4	0.0
1.400	1.200	1.296	14.8	1.4	0.0
1.200	1.000	1.095	13.1	1.6	0.0
1.000	0.820	0.906	11.6	1.6	0.0
0.820	0.690	0.752	10.5	1.1	0.0
0.690	0.580	0.633	9.4	1.1	0.0

b)

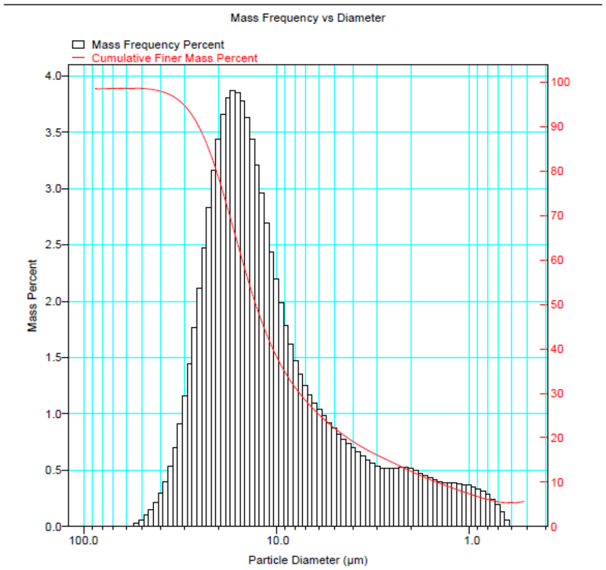
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 0_3
File Name: C:\WIN5100\DATA\MUNNA\0_3.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 10.45.53
Reported: 10/09/13 09.52.18
Liquid Visc: 0.7250 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.733 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 56 KCnts/s



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WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 0_3
File Name: C:\WIN5100\DATA\MUNNA\0_3.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 09/09/13 10.45.53
Reported: 10/09/13 09.52.18
Liquid Visc: 0.7250 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.733 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 56 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	98.5	0.0	0.0
88.40	74.30	81.04	98.6	-0.1	0.0
74.30	62.50	68.15	98.7	-0.1	0.0
62.50	52.60	57.34	98.7	0.0	0.0
52.60	44.20	48.22	98.4	0.3	0.0
44.20	37.20	40.55	97.6	0.8	0.0
37.20	31.30	34.12	95.6	2.0	0.0
31.30	26.30	28.69	91.5	4.1	0.0
26.30	22.10	24.11	84.3	7.2	0.0
22.10	18.60	20.27	74.3	10.0	0.0
18.60	15.60	17.03	62.6	11.7	0.0
15.60	13.10	14.30	51.5	11.1	0.0
13.10	11.00	12.00	42.4	9.1	0.0
11.00	9.300	10.11	35.8	6.6	0.0
9.300	7.800	8.517	30.8	5.1	0.0
7.800	6.600	7.175	27.1	3.7	0.0
6.600	5.500	6.025	23.7	3.3	0.0
5.500	4.500	4.975	20.7	3.0	0.0
4.500	3.900	4.189	18.9	1.8	0.0
3.900	3.300	3.587	17.1	1.8	0.0
3.300	2.800	3.040	15.5	1.5	0.0
2.800	2.300	2.538	13.7	1.8	0.0
2.300	2.000	2.145	12.5	1.3	0.0
2.000	1.600	1.789	10.6	1.8	0.0
1.600	1.400	1.497	9.7	1.0	0.0
1.400	1.200	1.296	8.6	1.0	0.0
1.200	1.000	1.095	7.4	1.2	0.0
1.000	0.820	0.906	6.3	1.2	0.0
0.820	0.690	0.752	5.5	0.7	0.0
0.690	0.580	0.633	5.3	0.2	0.0

1S TBM Profile

a)

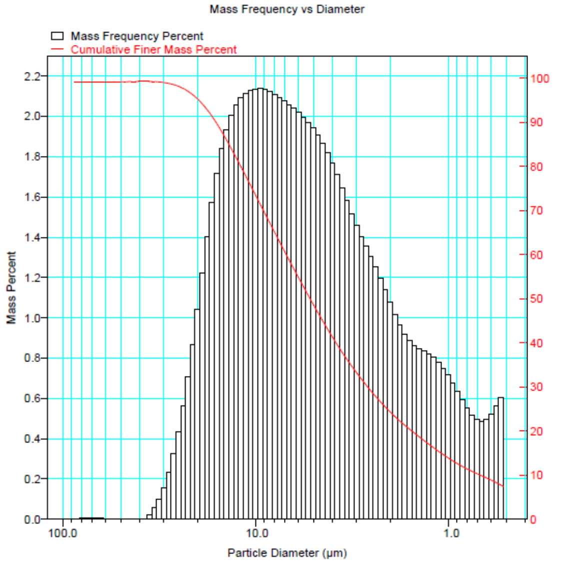
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 1_S_1
File Name: C:\WIN5100\DATA\MUNNA\1_S_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 09.53.04
Reported: 10/09/13 10.08.37
Liquid Visc: 0.7252 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:11 hrs:min
Sample Density: 2.738 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 54 KCnts/s



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WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 1_S_1
File Name: C:\WIN5100\DATA\MUNNA\1_S_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 09.53.04
Reported: 10/09/13 10.08.37
Liquid Visc: 0.7252 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:11 hrs:min
Sample Density: 2.738 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 54 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.1	0.0	0.0
88.40	74.30	81.04	99.1	0.0	0.0
74.30	62.50	68.15	99.1	0.0	0.0
62.50	52.60	57.34	99.1	0.0	0.0
52.60	44.20	48.22	99.2	-0.1	0.0
44.20	37.20	40.55	99.2	0.0	0.0
37.20	31.30	34.12	99.1	0.1	0.0
31.30	26.30	28.69	98.5	0.6	0.0
26.30	22.10	24.11	96.9	1.6	0.0
22.10	18.60	20.27	93.9	3.0	0.0
18.60	15.60	17.03	89.2	4.7	0.0
15.60	13.10	14.30	83.4	5.8	0.0
13.10	11.00	12.00	77.1	6.3	0.0
11.00	9.300	10.11	70.9	6.2	0.0
9.300	7.800	8.517	64.4	6.5	0.0
7.800	6.600	7.175	58.3	6.0	0.0
6.600	5.500	6.025	51.9	6.4	0.0
5.500	4.500	4.975	45.2	6.8	0.0
4.500	3.900	4.189	40.7	4.5	0.0
3.900	3.300	3.587	35.9	4.8	0.0
3.300	2.800	3.040	31.6	4.2	0.0
2.800	2.300	2.538	27.2	4.5	0.0
2.300	2.000	2.145	24.4	2.8	0.0
2.000	1.600	1.789	20.6	3.8	0.0
1.600	1.400	1.497	18.6	2.0	0.0
1.400	1.200	1.296	16.4	2.2	0.0
1.200	1.000	1.095	13.9	2.4	0.0
1.000	0.820	0.906	11.7	2.2	0.0
0.820	0.690	0.752	10.1	1.6	0.0
0.690	0.580	0.633	8.6	1.5	0.0

b)

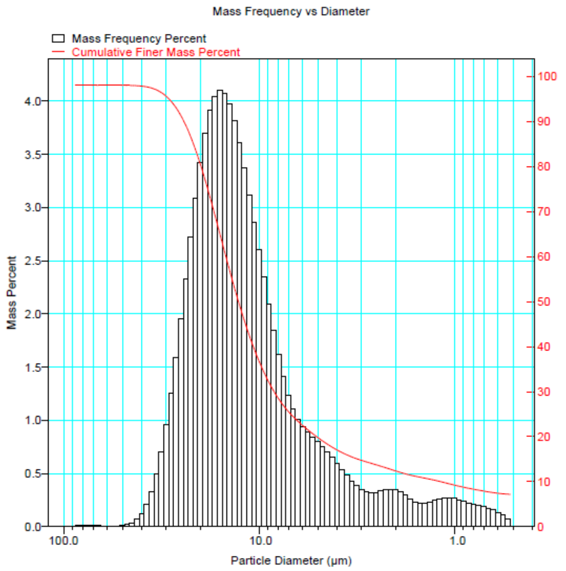
quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 1_S_3
File Name: C:\WIN5100\DATA\MUNNA\1_S_3.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 10.50.03
Reported: 10/09/13 11.05.27
Liquid Visc: 0.7247 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:11 hrs:min
Sample Density: 2.738 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 56 KCnts/s



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WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 1_S_3
File Name: C:\WIN5100\DATA\MUNNA\1_S_3.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 10.50.03
Reported: 10/09/13 11.05.27
Liquid Visc: 0.7247 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:11 hrs:min
Sample Density: 2.738 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 56 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	98.2	0.0	0.0
88.40	74.30	81.04	98.1	0.0	0.0
74.30	62.50	68.15	98.1	0.0	0.0
62.50	52.60	57.34	98.1	0.0	0.0
52.60	44.20	48.22	98.0	0.1	0.0
44.20	37.20	40.55	97.7	0.3	0.0
37.20	31.30	34.12	96.4	1.4	0.0
31.30	26.30	28.69	92.8	3.5	0.0
26.30	22.10	24.11	86.1	6.7	0.0
22.10	18.60	20.27	76.2	9.9	0.0
18.60	15.60	17.03	64.0	12.2	0.0
15.60	13.10	14.30	51.9	12.1	0.0
13.10	11.00	12.00	41.5	10.3	0.0
11.00	9.300	10.11	33.8	7.7	0.0
9.300	7.800	8.517	28.0	5.8	0.0
7.800	6.600	7.175	24.2	3.7	0.0
6.600	5.500	6.025	21.2	3.0	0.0
5.500	4.500	4.975	18.4	2.8	0.0
4.500	3.900	4.189	16.8	1.6	0.0
3.900	3.300	3.587	15.4	1.4	0.0
3.300	2.800	3.040	14.4	1.0	0.0
2.800	2.300	2.538	13.2	1.1	0.0
2.300	2.000	2.145	12.4	0.8	0.0
2.000	1.600	1.789	11.2	1.2	0.0
1.600	1.400	1.497	10.7	0.5	0.0
1.400	1.200	1.296	10.1	0.6	0.0
1.200	1.000	1.095	9.2	0.9	0.0
1.000	0.820	0.906	8.4	0.8	0.0
0.820	0.690	0.752	7.8	0.6	0.0
0.690	0.580	0.633	7.4	0.5	0.0

2S TBM Profile

a)

quarto

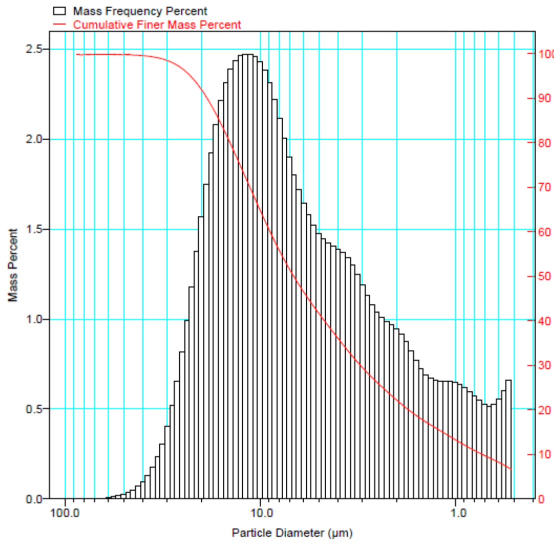
WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 2_S_1
File Name: C:\WIN5100\DATA\MUNNA\2_S_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 12.36.28
Reported: 10/09/13 12.51.56
Liquid Visc: 0.7250 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.732 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 55 KCnts/

Mass Frequency vs Diameter



quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 2_S_1
File Name: C:\WIN5100\DATA\MUNNA\2_S_1.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 12.36.28
Reported: 10/09/13 12.51.56
Liquid Visc: 0.7250 cp
Analysis Temp: 34.8 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.732 g/cm³
Liquid Density: 0.9942 g/cm³
Base/Full Scale: 104 / 55 KCnts/s

Report by Size Table

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.7	0.0	0.0
88.40	74.30	81.04	99.8	-0.1	0.0
74.30	62.50	68.15	99.8	0.0	0.0
62.50	52.60	57.34	99.7	0.0	0.0
52.60	44.20	48.22	99.6	0.1	0.0
44.20	37.20	40.55	99.4	0.3	0.0
37.20	31.30	34.12	98.7	0.7	0.0
31.30	26.30	28.69	97.3	1.5	0.0
26.30	22.10	24.11	94.4	2.9	0.0
22.10	18.60	20.27	89.9	4.5	0.0
18.60	15.60	17.03	83.7	6.2	0.0
15.60	13.10	14.30	76.5	7.2	0.0
13.10	11.00	12.00	69.0	7.5	0.0
11.00	9.300	10.11	61.9	7.1	0.0
9.300	7.800	8.517	55.1	6.8	0.0
7.800	6.600	7.175	49.5	5.6	0.0
6.600	5.500	6.025	44.2	5.3	0.0
5.500	4.500	4.975	39.1	5.2	0.0
4.500	3.900	4.189	35.6	3.5	0.0
3.900	3.300	3.587	31.7	3.9	0.0
3.300	2.800	3.040	28.2	3.4	0.0
2.800	2.300	2.538	24.6	3.6	0.0
2.300	2.000	2.145	22.3	2.4	0.0
2.000	1.600	1.789	18.9	3.4	0.0
1.600	1.400	1.497	17.2	1.7	0.0
1.400	1.200	1.296	15.4	1.8	0.0
1.200	1.000	1.095	13.3	2.1	0.0
1.000	0.820	0.906	11.2	2.1	0.0
0.820	0.690	0.752	9.5	1.6	0.0
0.690	0.580	0.633	7.9	1.6	0.0

b)

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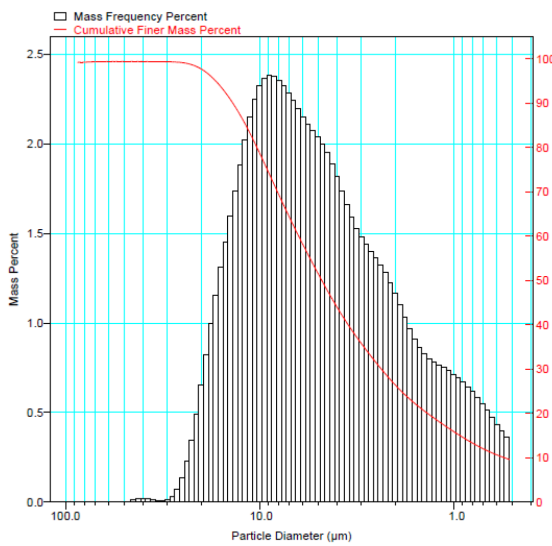
WIN5100 V2.01 Unit 1 S/N 498 Page 2

Sample: 2_S_3
File Name: C:\WIN5100\DATA\MUNNA\2_S_3.SMP
Material/Liquid: sabbia/Water

Test Number: Average
Analyzed: 10/09/13 13.34.39
Reported: 10/09/13 13.51.43
Liquid Visc: 0.7242 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.732 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 53 KCnts/s

Mass Frequency vs Diameter



quarto

WIN5100 V2.01 Unit 1 S/N 498 Page 1

Sample: 2_S_3
File Name: C:\WIN5100\DATA\MUNNA\2_S_3.SMP
Material/Liquid: sabbia/Water

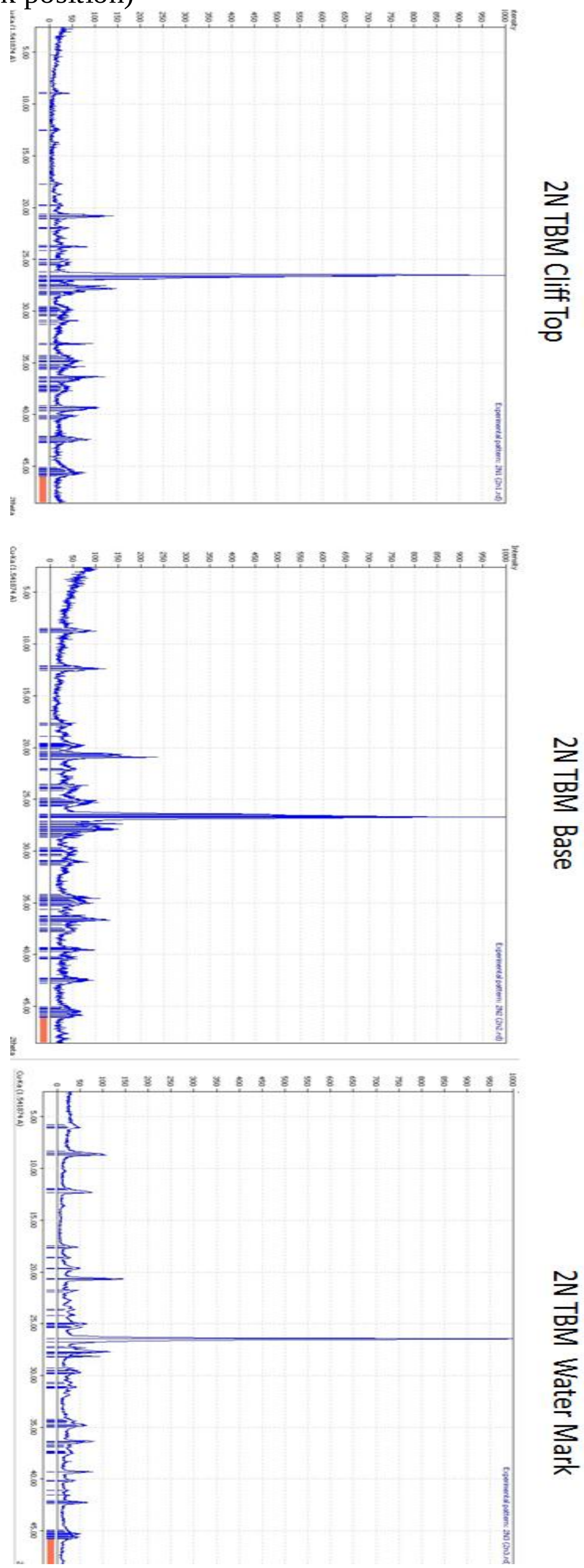
Test Number: Average
Analyzed: 10/09/13 13.34.39
Reported: 10/09/13 13.51.43
Liquid Visc: 0.7242 cp
Analysis Temp: 34.9 °C
Full Scale Mass: 100.0%

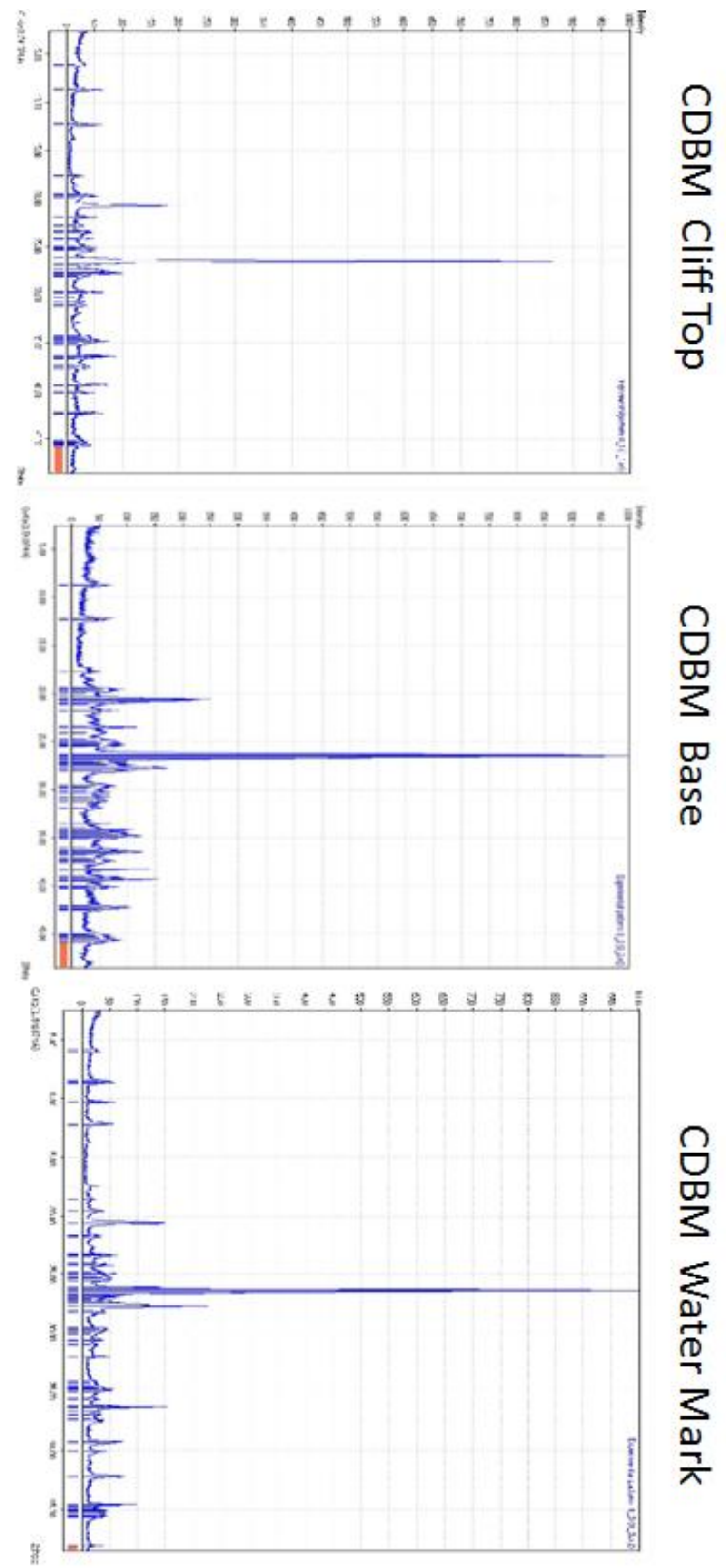
Analysis Type: Standard
Run Time: 0:10 hrs:min
Sample Density: 2.732 g/cm³
Liquid Density: 0.9941 g/cm³
Base/Full Scale: 104 / 53 KCnts/s

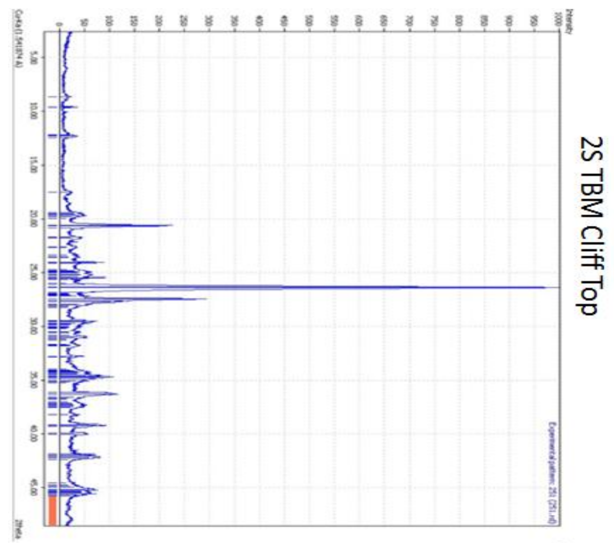
Report by Size Table

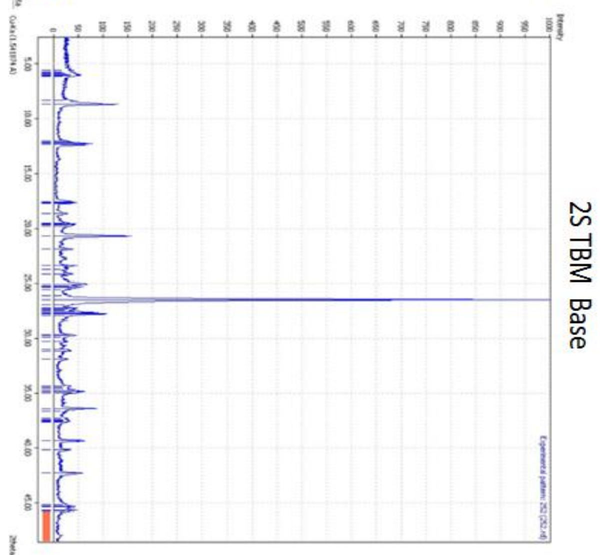
High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Mass Finer (Percent)	Mass Frequency (Percent)	Cum. Mass Standard Deviation (1 tests)
105.1	88.40	96.39	99.2	0.0	0.0
88.40	74.30	81.04	99.3	-0.1	0.0
74.30	62.50	68.15	99.3	-0.1	0.0
62.50	52.60	57.34	99.4	-0.1	0.0
52.60	44.20	48.22	99.4	0.0	0.0
44.20	37.20	40.55	99.3	0.1	0.0
37.20	31.30	34.12	99.3	0.0	0.0
31.30	26.30	28.69	99.2	0.1	0.0
26.30	22.10	24.11	98.6	0.6	0.0
22.10	18.60	20.27	96.8	1.8	0.0
18.60	15.60	17.03	93.4	3.4	0.0
15.60	13.10	14.30	88.6	4.8	0.0
13.10	11.00	12.00	82.5	6.1	0.0
11.00	9.300	10.11	75.8	6.7	0.0
9.300	7.800	8.517	68.6	7.3	0.0
7.800	6.600	7.175	61.9	6.7	0.0
6.600	5.500	6.025	55.1	6.8	0.0
5.500	4.500	4.975	48.0	7.1	0.0
4.500	3.900	4.189	43.3	4.7	0.0
3.900	3.300	3.587	38.4	4.9	0.0
3.300	2.800	3.040	34.2	4.3	0.0
2.800	2.300	2.538	29.5	4.7	0.0
2.300	2.000	2.145	26.5	3.0	0.0
2.000	1.600	1.789	22.4	4.0	0.0
1.600	1.400	1.497	20.4	2.0	0.0
1.400	1.200	1.296	18.3	2.1	0.0
1.200	1.000	1.095	16.0	2.4	0.0
1.000	0.820	0.906	13.6	2.3	0.0
0.820	0.690	0.752	11.9	1.8	0.0
0.690	0.580	0.633	10.4	1.4	0.0

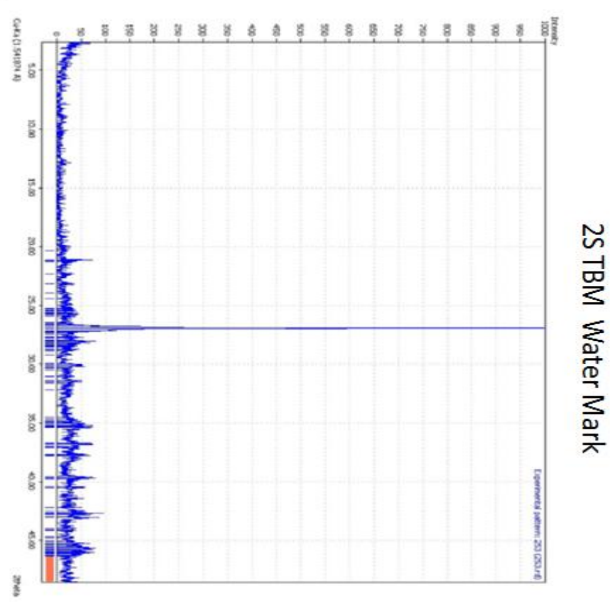
Annex 3: X-ray diffractogram of sediment samples for 3 profiles 2N, CDBM and 2S (Cliff top, base and for water mark position)




CDBM Cliff Top
CDBM Base
CDBM Water Mark


2S TBM Cliff Top


2S TBM Base


2S TBM Water Mark

Annex 4A. List of Interviewee at Sandwip case study site Regarding WP1 data collection for RISCKIT Project

Name	Profession	Current Position	Address
1.Md. Shahjahan BA	Business and Teaching	Upazilla Chairman	Bauria, Sandwip +88 01819108344
2. Noor E Khaja Alamin	Govt Officer	UNO, Sandwip	Upazilla Complex, Sandwip, +88 01771572787
3. Maksudur Rahman Fulmia	Business and family property	Union Parishad Chairman	Santoshpur, Sandwip +88 01717160596
4. Abdul Malek Ledu	Land lord	Union Parishad Chairman	Sarikait, Sandwip +88 01917700352
5. Kazi Arif Fuad	Business	Union Parishad Chairman (Panel)	Harishpur, Sandwip +88 0171831383
6. Delwar Hossen Fulmia	Business	Union Parishad Chairman	Dirgapar, Sandwip +88 01753500497
7. Mrinal Kanti	Business	Union Parishad Chairman (Panel)	Azimpur, Sandwip +88 01836418029
8. Elias Kamal Babu	Journalism	Senior reporter, Dainik Shomokal	Badamtali, Rahmatpur, Sandwip +88 01816802697

9. Ashraf Hossen	Private service	Senior Project Coordinator	SDI, Upazilla Complex, Sandwip +88 01712809826
10. Md Abdur Rahim	Teaching	Assistant Professor	, Govt Haji AB College, Musapur, Sandwip, +88 01815501773
11. Md. Zafar Iqbal	Teaching	Senior Assistant Teacher	Boshiria Kamil Madrasha, Rahmatpur, Sandwip, +88 01816446015
12.Azizur Rahman	Teaching	Head Master	Govt. A.K. Primary School, Gachua, Sandwip, +88 01748978835
13. Omar Kaiser	Teaching	Assistant Teacher	Middle Sontoshpur High School, Sontoshpur, Sandwip +88 01721018830
14. Md Saiful Islam	Teaching	Assistant Teacher	Govt Primary School, Azimpur, Sandwip, +88 01816826824
15. Md. Shah Alam	Govt Service	Upazilla Agri. Officer	Upazilla Complex, Sandwip, +88 01811848126

16. Abul Monsur	Govt Service	Assistant Met Officer	Weather station Building, Senerhat, Sandwip,
17. Bashir Ahmed Sumon	Govt Service	BIWTA Gauge Reader incharge	Bauria, Sandwip, +88 01724804598
18. Md Kamrul Hossen	Govt Service	Upazilla Project Implemenation Officer	Upazilla Complex, Haramia, Sandwip, +88 01746341920
19. Mohammad Ayub	Business/household	Union Parishad member	Harishpur, Sandwip, +88 01718254574
20. Md Rezaul Karim	Business	Union Parishad member	Sarikait, Sandwip,
21. Akter Hossen Shibli	Private job	Union Parishad member	Sarikait, Sandwip,
22. Md Belal Uddin	Farmer	Union Parishad member	Dirgapar, Sandwip
23. Abdul Mannan	Fisherman	Ex Union Parishad member	Sontoshpur, Sandwip, +88 01720404072
24. Tafura Begum Chinu	Nonthing specific	Union Parishad member	Sontoshpur, Sandwip, +88 01828574375

25. Mowlana Younus	Teaching/Religious Leader	Head Mouluvi	A.K. Academy High School, Gachua, Sandwip, ++88 01836711010
26. Mowlana S. I. Feroz	Teaching/Religious Leader	Head Mouluvi	South East Sandwip High School, Moghdhara, Sandwip, +88 01712835845
27. Anwar Absar	Lawer	Planning secretary, Anwar Trust	Santoshpur, Sandwip, +88 01819365396
28. Kaji Mezba	Varsity Student	President, Sandwip Unique Society	Sarikait, Sandwip, +88 01762621804
29. Jesmin Akter	NGO worker	Secretary, CBO, SDI	Musapur, Sandwip, +88 01843570854
30. Aktara Begum	NGO worker	CBO, SDI	Rahmatpur, Sandwip, +88 01820190254
31. Abdussalam	Farmer	General people	Sontoshpur, Sandwip,
32. Humayon Kabir	Farmer	General People	Harishpur, Sandwip,
33. Md. Shahedur	Local govt employee	Village police	Harishpur, Sandwip,

Rahman			+88 01815366031
34. Md. Abul Bashar	Business	General People	Rahmatpur, Sandwip, +88 01814177347
35. Md Shipon	Nothing specific	General People	Rahmatpur, Sandwip, +88 0182223447
36. Shahidullah	Nothing specific	General People	Rahmatpur, Sandwip, + 88 01837703598
37. Akber Hossen	House hold	General People	Santoshpur, Sandwip +88 01710205743
38. Md Ayub	Shop Keeper	General People	Rahmatpur, Sandwip
39. Saiful Islam	Boatman/Fisherman	General People	Santoshpur, Sandwip
40. Kamal	Boatman	General People	Bauria, Sandwip
41. Mohammad Zafar	Boatman/Fisherman	General People	Rahmatpur, Sandwip, +88 01857257339
42 ABM Siddiqur Rahman.	Contractor/business (Retired)	General People	Upazilla Complex, Sandwip, +88 01816127377
43. Abdul Baten	Physician	Village Doctor	Azimpur, Sandwip, +88 01812893669

Annex 4b) An example of RISCKIT Questionnaire:

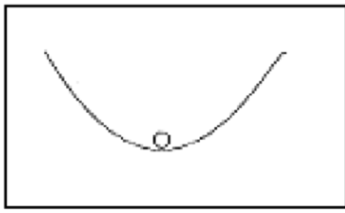
Name: Akbar Hossain

Age:42 yrs, **Profession**: Household, Position**:** , **Address:** Ator Ali Munshir Bari, Santoshpur, Sandwip, Chittagong, Email & Cell phone: +8801710205743

This annex provides an overview of questionnaires for use in field data collection in Phase 2 (Steps 6 and 7)

Socio-cultural information – to be (1) used as overall frame in which investigations are embedded and (2) to identify DRR solutions that are acceptable to local perceptions and social, political and economic circumstances especially for task 4.1. and 4.2.
A) Information on values and, traditions in the municipality/community in relation to risk reduction planning 1. How long have you lived in Sandwip? ■ Since my birth 2. Is there any particular reason why you decided to move here/stay here? ■ All of my family members and relatives have been here for generations except for a certain duration for job or education. 3. How would you describe Sandwip to someone who has never been here? ■ Full of natural resources in and around 4. What do you think is truly special about Sandwip, and what do you treasure most of all about living here? ■ People's unity which has been generated due to almost fully dependence of nature regarding the natural calamities. 5. Are there any physical or non-physical heritage sites in your region? (e.g. buidlings, artifacts, monuments –at the coast, in the water or soil). If yes, what meanings do they represent to the local people? ■ Palace of the king Dilal with bamboo 6. Please take a look at the following sketches and read the accompanying descripti Then select the description that is closest to your understanding of nature and circle corresponding number. Could you also explain what you mean by the image of y choice.

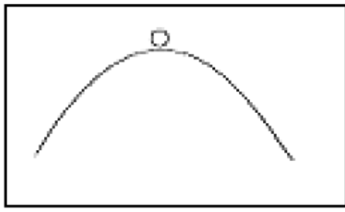
1



"Nature is benign"

Basically, nature will always regain its balance. No matter what man does, the ball will always return to the original position

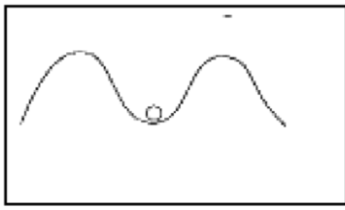
2



"Nature is ephemeral"

Nature is very sensitive to any type of intervention. Even very small interventions can make the ball get out of control

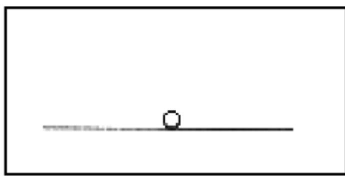
3



"Nature is tolerant"

Nature is tolerant to a certain degree of intervention. Only when a certain threshold is crossed does the ball

4



"Nature is capricious"

When intervening in nature, one can never be sure whether this will have positive or negative consequences.

7. Are there any aspects of local culture (such as traditions, local rituals) which are only found in Sandwip and which are meaningful to the peoples live with the coast and the ocean here? Why are these important?
   - Palagan (chorus)Tradition during weeding, celebration of new crops cutting by traditional food, songs and dance , riding on Palki during wedding etc
8. What values (personal, social, cultural) would you say are particularly important in Sandwip? Do you identify with these values?
   - Social (obedient to parent)
9. Do you think that historical events or past change have altered Sandwip? What changes have taken place? Did these changes influence the attitudes or values of the people living here? Do you think these changes were positive or negative?
   - No
10. What do you think the future holds for Sandwip? What aspects about life in Sandwip should definitely not change, and what aspects should change or will change anyway in your view?
    - Agriculture is in crises due to climate change which ultimately impact our livelihood
11. Do the people living here engage with environmental issues? Do they take an active

role in preserving the environment? Do you think that the people living here spend more time thinking about the environment than people living elsewhere, and if so, why?

- Not really active but occasionally they are concern about disaster and erosion

B) Information on perceived levels of threat with relevance to risk reduction planning

12. In your view, what are the biggest problems Sandwip is facing right now?
    - The ring embankment is disrupted/damaged in many points letting the tidal and surge water enter to the island
13. Just thinking about the coastal environment, which issues should be given priority in Sandwip and why?
    - Agricultural adaptation as well as risk adaptation should be given priority
14. Do you think that the people in this region should be concerned about storms, flooding, inundation and coastal erosion, and if so, why?
    - Yes they must be concerned to speed up the measures by the govt and themselves
15. How have past environmental hazards and disasters affected your thinking about your region?
    - Yes they are
16. Would you say you live in a region which is
    a. √ at risk

       You stated that there is a considerable risk of flooding in your area. Do you use the lower stories of your house accordingly?

       Do you have technical measures at home in case your area is affected by a flood (e.g. a pump or an power generator)?

    b. Somewhat at risk
    c. Not at risk at all
17. How often do you experience hazards and disasters? (If the interviewee thinks that the region in 'at risk' or 'somewhat at risk' the next question is applicable):
    - Repeatedly all most every year in monsoon
18. What types of actions have been taken/are planned to prepare/ adapt to this risks (e.g. ecosystem based approaches, technical solutions, social solutions)?
    - Nothing almost in my knowledge
19. Is any type preferred, and why? Please explain.
    - N/A
20. How successful was the approach?
    - ………………….
21. Was there a participatory process in your community and who was involved?
    - no

22. Who should take responsibility for formulating and implementing risk reduction measures?
    - Government offices, NGOs
23. Should further risk reduction measures/ management plans be implemented?
    - A strong and durable coastal embankment should be implemented
24. How realistic is such implementation (e.g. finances, cooperation, political dynamics amongst decision makers and interest etc)?
    - Not realistic

C) Risk reduction knowledge / transfer of knowledge

25. Do you think that other communities have had similar risk experiences? Have similar strategies been developed to cope with change? Are there similar cultures of participation and dialogue, and are there similar perspectives for the future?
    - Hatiya
26. What sources of information do you use to inform yourself about coastal risk in your region?
    - Radio, Television and Red crescent's announcement
27. What do you consider the best examples of successful risk management here in your region?
    - Cyclone shelter
28. How could information on this be shared between similar communities/towns/regions?
    Very rarely shared
29. What factors/circumstances have so far prevented cooperation?
    - Nothing

Is there anything else you would like to tell us?

For statistical purposes, we would like to know some basic information about you: Please tell us your age, profession, education and family status. We will treat this information confidentially.

Anex 5: Transect wise Statistical calculation for the whole shorelines

TransId	TCD	EPR	ECI	SCE	NSM	ShorelineI	Distance	IntersectX	IntersectY
1	0.00	-56.88	0.025	1629.34	-1629.34	04/15/1978	2289.655	336189.900	2490636.939
2	100.00	-55.88	0.025	1600.68	-1600.68	04/15/1978	2276.836	336189.229	2490688.552
3	200.00	-52.71	0.025	1509.81	-1509.81	04/15/1978	2264.017	336188.559	2490740.165
4	300.00	-25.24	0.025	830.63	-723.02	04/15/1978	2224.178	336213.972	2490798.827
5	400.00	-24.05	0.025	836.63	-688.84	04/15/1978	2176.179	336247.263	2490859.619
6	500.00	-22.77	0.025	840.02	-652.13	04/15/1978	1578.408	337151.010	2492460.858
7	600.00	-21.44	0.025	835.07	-614.11	04/15/1978	1573.041	337186.669	2492496.315
8	700.00	-20.11	0.025	849.37	-576.08	04/15/1978	1574.161	337217.290	2492535.858
9	800.00	-18.66	0.025	926.80	-534.54	04/15/1978	1575.281	337247.910	2492575.401
10	900.00	-15.67	0.025	1127.25	-448.98	04/15/1978	1576.400	337278.530	2492614.944
11	1000.00	-13.90	0.025	1217.46	-398.17	04/15/1978	1577.520	337309.150	2492654.488
12	1100.00	-12.13	0.025	1307.67	-347.35	04/15/1978	1578.640	337339.770	2492694.031
13	1200.00	-10.28	0.025	1397.87	-294.36	04/15/1978	1579.760	337370.391	2492733.574
14	1300.00	-8.38	0.025	1496.83	-240.03	04/15/1978	1580.880	337401.011	2492773.117
15	1400.00	-3.24	0.025	1997.49	-92.94	04/15/1978	1582.000	337431.631	2492812.660
16	1500.00	-2.72	0.025	2146.20	-77.96	04/15/1978	1583.120	337462.251	2492852.203
17	1600.00	-2.26	0.025	2323.28	-64.65	04/15/1978	1584.240	337492.872	2492891.746
18	1700.00	0.11	0.025	2500.35	3.13	04/15/1978	1592.685	337590.131	2493017.348
19	1800.00	2.67	0.025	2671.72	76.36	04/15/1978	1597.392	337620.757	2493057.150
20	1900.00	5.22	0.025	2840.30	149.59	04/15/1978	1602.106	337651.378	2493096.957
21	2000.00	7.78	0.025	3008.88	222.82	04/15/1978	1606.820	337681.998	2493136.764
22	2100.00	10.31	0.025	3226.47	295.40	04/15/1978	1611.534	337712.619	2493176.571
23	2200.00	11.81	0.025	3461.75	338.19	04/15/1978	1616.248	337743.240	2493216.378
24	2300.00	2.66	0.025	2245.80	76.16	04/15/1978	1620.962	337773.861	2493256.185
25	2400.00	4.70	0.025	2369.22	134.65	04/15/1978	1625.676	337804.481	2493295.992
26	2500.00	6.74	0.025	2492.16	193.15	04/15/1978	1630.390	337835.102	2493335.799
27	2600.00	8.79	0.025	2591.65	251.65	04/15/1978	1635.104	337865.723	2493375.606
28	2700.00	10.04	0.025	2691.14	287.48	04/15/1978	1639.818	337896.344	2493415.413
29	2800.00	10.49	0.025	2790.64	300.60	04/15/1978	1680.216	338048.777	2493613.576
30	2900.00	10.95	0.025	2890.13	313.74	04/15/1978	1691.022	338079.966	2493654.122
31	3000.00	11.41	0.025	2989.64	326.87	04/15/1978	1702.442	338110.759	2493695.138
32	3100.00	-3.74	0.025	1981.63	-107.24	04/15/1978	1714.388	338141.212	2493736.554
33	3200.00	-3.03	0.025	2058.37	-86.75	04/15/1978	1726.333	338171.665	2493777.970
34	3300.00	-1.76	0.025	2135.12	-50.34	04/15/1978	1738.279	338202.118	2493819.386
35	3400.00	0.47	0.025	2211.86	13.39	04/15/1978	1750.225	338232.571	2493860.803
36	3500.00	12.92	0.025	3231.32	370.05	04/15/1978	1762.170	338263.024	2493902.219
37	3600.00	13.56	0.025	3303.06	388.42	04/15/1978	1774.116	338293.477	2493943.635
38	3700.00	16.15	0.025	3384.08	462.60	04/15/1978	1786.061	338323.931	2493985.051

39	3800.00	18.74	0.025	3530.53	536.78	04/15/1978	1798.007	338354.384	2494026.468
40	3900.00	21.33	0.025	3676.57	610.95	04/15/1978	1809.953	338384.837	2494067.884
41	4000.00	23.92	0.025	3812.36	685.13	04/15/1978	1821.898	338415.290	2494109.300
42	4100.00	28.09	0.025	4089.53	804.72	04/15/1978	1833.844	338445.743	2494150.716
43	4200.00	30.71	0.025	4204.64	879.73	04/15/1978	1845.790	338476.196	2494192.133
44	4300.00	33.26	0.025	4255.06	952.81	04/15/1978	1857.735	338506.649	2494233.549
45	4400.00	30.25	0.025	3905.87	866.33	04/15/1978	1885.691	338526.761	2494287.187
46	4500.00	32.77	0.025	3966.43	938.61	04/15/1978	1918.242	338543.904	2494344.333
47	4600.00	35.17	0.025	4010.73	1007.53	04/15/1978	1831.604	338307.119	2493962.188
48	4700.00	37.58	0.025	4090.71	1076.45	04/15/1978	1830.180	338336.751	2494002.487
49	4800.00	39.99	0.025	4213.25	1145.37	04/15/1978	1828.756	338366.382	2494042.786
50	4900.00	57.86	0.025	5096.52	1657.44	04/15/1978	1827.331	338396.014	2494083.084
51	5000.00	59.86	0.025	5123.23	1714.59	04/15/1978	1825.907	338425.645	2494123.383
52	5100.00	61.97	0.025	5135.02	1775.12	04/15/1978	1824.483	338455.277	2494163.682
53	5200.00	64.61	0.025	5144.33	1850.59	04/15/1978	1823.059	338484.908	2494203.981
54	5300.00	66.60	0.025	5153.64	1907.71	04/15/1978	1822.290	338514.000	2494244.653
55	5400.00	70.89	0.025	5143.62	2030.56	04/15/1978	1838.532	338529.107	2494295.008
56	5500.00	72.91	0.025	5130.12	2088.25	04/15/1978	1854.774	338544.213	2494345.363
57	5600.00	74.96	0.025	5115.23	2147.10	04/15/1978	1871.017	338559.320	2494395.718
58	5700.00	77.42	0.025	5086.52	2217.50	04/15/1978	1887.259	338574.426	2494446.072
59	5800.00	79.87	0.025	5057.82	2287.89	04/15/1978	1903.501	338589.533	2494496.427
60	5900.00	57.19	0.025	5006.60	1638.12	04/15/1978	1919.743	338604.639	2494546.782
61	6000.00	58.26	0.025	5052.60	1668.72	04/15/1978	1935.985	338619.745	2494597.137
62	6100.00	59.57	0.025	5096.68	1706.38	04/15/1978	1952.227	338634.852	2494647.491
63	6200.00	61.10	0.025	5140.76	1750.05	04/15/1978	2243.950	338021.615	2493578.265
64	6300.00	67.39	0.025	5191.76	1930.34	04/15/1978	2205.489	338060.076	2493628.265
65	6400.00	68.99	0.025	5201.43	1976.17	04/15/1978	2167.212	338098.353	2493678.265
66	6500.00	71.07	0.025	5208.79	2035.57	04/15/1978	2130.448	338135.117	2493728.265
67	6600.00	99.33	0.025	4817.23	2845.09	04/15/1978	2093.683	338171.882	2493778.265
68	6700.00	101.64	0.025	4757.33	2911.32	04/15/1978	2056.918	338208.647	2493828.265
69	6800.00	103.95	0.025	4697.44	2977.55	04/15/1978	2020.153	338245.411	2493878.265
70	6900.00	106.26	0.025	4638.32	3043.77	04/15/1978	1983.389	338282.176	2493928.265
71	7000.00	107.59	0.025	4641.64	3081.62	04/15/1978	1887.749	338700.642	2494999.990
72	7100.00	83.13	0.025	5087.66	2381.06	04/15/1978	1910.894	338708.434	2495054.534
73	7200.00	85.74	0.025	5091.70	2455.99	04/15/1978	1927.573	338721.651	2495105.558
74	7300.00	88.36	0.025	5095.34	2530.92	04/15/1978	1919.582	338755.564	2495143.158
75	7400.00	71.38	0.025	3431.72	2044.55	04/15/1978	1911.592	338789.478	2495180.757
76	7500.00	73.59	0.025	3525.40	2107.81	04/15/1978	1903.601	338823.391	2495218.357
77	7600.00	75.98	0.025	3598.99	2176.26	04/15/1978	1895.610	338857.305	2495255.956
78	7700.00	78.43	0.025	3676.85	2246.43	04/15/1978	1887.620	338891.218	2495293.556
79	7800.00	105.25	0.025	4594.07	3014.59	04/15/1978	1879.629	338925.131	2495331.156
80	7900.00	104.48	0.025	4579.34	2992.66	04/15/1978	1871.638	338959.045	2495368.755

81	8000.00	103.71	0.025	4558.32	2970.71	04/15/1978	1863.648	338992.958	2495406.355
82	8100.00	102.95	0.025	4529.10	2948.77	04/15/1978	1848.970	339057.751	2495478.191
83	8200.00	102.03	0.025	4519.42	2922.46	04/15/1978	1842.238	339091.542	2495515.654
84	8300.00	99.39	0.025	4427.86	2846.93	04/15/1978	1835.505	339125.333	2495553.118
85	8400.00	96.65	0.025	4333.23	2768.33	04/15/1978	1828.772	339159.123	2495590.582
86	8500.00	93.24	0.025	4236.56	2670.78	04/15/1978	1822.040	339192.914	2495628.045
87	8600.00	26.33	0.025	883.30	754.10	04/15/1978	1815.307	339226.705	2495665.509
88	8700.00	26.07	0.025	878.57	746.68	04/15/1978	1808.575	339260.495	2495702.972
89	8800.00	25.51	0.025	873.86	730.56	04/15/1978	1826.329	339186.108	2495620.499
90	8900.00	24.81	0.025	866.05	710.53	04/15/1978	1815.069	339220.435	2495658.557
91	9000.00	24.51	0.025	863.04	702.09	04/15/1978	1803.809	339254.762	2495696.616
92	9100.00	23.80	0.025	849.31	681.70	04/15/1978	1792.548	339289.089	2495734.674
93	9200.00	23.09	0.025	835.59	661.31	04/15/1978	1781.288	339323.416	2495772.732
94	9300.00	22.95	0.025	838.38	657.44	04/15/1978	1770.028	339357.743	2495810.791
95	9400.00	21.62	0.025	814.73	619.38	04/15/1978	1758.768	339392.070	2495848.849
96	9500.00	21.71	0.025	817.90	621.81	04/15/1978	1747.508	339426.398	2495886.907
97	9600.00	21.85	0.025	821.07	625.84	04/15/1978	1736.248	339460.725	2495924.966
98	9700.00	21.99	0.025	824.24	629.87	04/15/1978	1748.882	339736.475	2496324.155
99	9800.00	22.13	0.025	827.42	633.90	04/15/1978	1757.418	339764.854	2496366.197
100	9900.00	22.27	0.025	830.59	637.94	04/15/1978	1765.954	339793.232	2496408.239
101	10000.00	22.39	0.025	833.06	641.26	04/15/1978	1774.491	339821.611	2496450.281
102	10100.00	22.05	0.025	822.62	631.69	04/15/1978	1783.027	339849.989	2496492.323
103	10200.00	21.86	0.025	817.81	626.25	04/15/1978	1791.563	339878.367	2496534.365
104	10300.00	21.53	0.025	807.40	616.70	04/15/1978	1800.100	339906.746	2496576.407
105	10400.00	21.20	0.025	796.98	607.16	04/15/1978	1808.636	339935.124	2496618.449
106	10500.00	20.86	0.025	786.56	597.60	04/15/1978	1825.794	339957.270	2496666.449
107	10600.00	20.53	0.025	776.15	588.05	04/15/1978	1844.070	339978.608	2496715.221
108	10700.00	20.21	0.025	765.73	579.02	04/15/1978	1878.603	340018.024	2496805.313
109	10800.00	19.90	0.025	755.32	570.13	04/15/1978	1898.168	340039.544	2496854.503
110	10900.00	19.59	0.025	744.90	561.24	04/15/1978	1917.733	340061.065	2496903.693
111	11000.00	19.28	0.025	734.49	552.34	04/15/1978	1937.299	340082.585	2496952.883
112	11100.00	18.74	0.025	724.08	536.69	04/15/1978	1956.864	340104.106	2497002.073
113	11200.00	17.62	0.025	730.53	504.65	04/15/1978	1976.429	340125.627	2497051.263
114	11300.00	17.39	0.025	732.21	498.12	04/15/1978	1995.994	340147.147	2497100.453
115	11400.00	17.30	0.025	735.11	495.62	04/15/1978	2015.559	340168.668	2497149.643
116	11500.00	17.22	0.025	737.33	493.12	04/15/1978	2035.125	340190.189	2497198.833
117	11600.00	22.99	0.025	888.53	658.38	04/15/1978	2054.690	340211.709	2497248.024
118	11700.00	16.83	0.025	715.17	481.93	04/15/1978	1936.230	339995.600	2496754.059
119	11800.00	16.76	0.025	717.26	479.98	04/15/1978	1940.441	340015.712	2496800.029
120	11900.00	16.77	0.025	719.34	480.41	04/15/1978	1944.651	340035.823	2496845.999
121	12000.00	16.79	0.025	721.43	480.83	04/15/1978	1948.862	340055.935	2496891.969
122	12100.00	16.80	0.025	723.53	481.27	04/15/1978	1953.072	340076.047	2496937.939

123	12200.00	16.82	0.025	725.62	481.70	04/15/1978	1957.283	340096.159	2496983.909
124	12300.00	16.83	0.025	727.71	482.13	04/15/1978	1961.493	340116.271	2497029.879
125	12400.00	16.85	0.025	729.80	482.57	04/15/1978	1965.704	340136.383	2497075.849
126	12500.00	17.01	0.025	740.64	487.17	04/15/1978	1989.885	340212.675	2497250.232
127	12600.00	17.05	0.025	743.65	488.49	04/15/1978	1997.663	340232.957	2497296.591
128	12700.00	17.10	0.025	746.66	489.81	04/15/1978	2005.441	340253.239	2497342.949
129	12800.00	17.15	0.025	749.67	491.13	04/15/1978	2013.218	340273.521	2497389.308
130	12900.00	17.39	0.025	752.69	497.97	04/15/1978	2019.184	340295.332	2497434.694
131	13000.00	17.73	0.025	755.70	507.92	04/15/1978	2016.077	340324.797	2497475.209
132	13100.00	18.08	0.025	759.94	517.87	04/15/1978	2028.252	340589.668	2497839.406
133	13200.00	18.43	0.025	766.36	527.82	04/15/1978	2035.105	340619.352	2497880.221
134	13300.00	18.77	0.025	772.78	537.77	04/15/1978	2041.957	340649.035	2497921.036
135	13400.00	19.07	0.025	777.77	546.29	04/15/1978	2048.809	340678.719	2497961.851
136	13500.00	19.30	0.025	780.76	552.81	04/15/1978	2055.661	340708.402	2498002.665
137	13600.00	19.89	0.025	783.76	569.86	04/15/1978	2062.514	340738.086	2498043.480
138	13700.00	20.49	0.025	782.73	587.01	04/15/1978	2069.366	340767.769	2498084.295
139	13800.00	21.40	0.025	785.71	613.02	04/15/1978	2076.218	340797.453	2498125.110
140	13900.00	22.31	0.025	788.68	639.02	04/15/1978	2083.193	340827.048	2498166.009
141	14000.00	23.22	0.025	791.65	665.04	04/15/1978	2104.028	340846.644	2498216.508
142	14100.00	24.13	0.025	794.63	691.05	04/15/1978	2076.717	340603.205	2497858.019
143	14200.00	25.03	0.025	797.60	717.06	04/15/1978	2071.948	340632.747	2497898.639
144	14300.00	25.94	0.025	800.57	743.07	04/15/1978	2067.179	340662.289	2497939.260
145	14400.00	26.85	0.025	803.54	769.07	04/15/1978	2062.411	340691.831	2497979.880
146	14500.00	27.72	0.025	806.52	793.95	04/15/1978	2057.642	340721.373	2498020.500
147	14600.00	28.44	0.025	814.66	814.66	04/15/1978	2052.873	340750.915	2498061.121
148	14700.00	29.26	0.025	838.23	838.23	04/15/1978	2137.716	340514.673	2497736.288
149	14800.00	30.09	0.025	861.79	861.79	04/15/1978	2121.862	340545.524	2497778.708
150	14900.00	30.91	0.025	885.36	885.36	04/15/1978	2106.008	340576.376	2497821.129
151	15000.00	31.73	0.025	908.92	908.92	04/15/1978	2090.155	340607.227	2497863.550
152	15100.00	32.68	0.025	935.95	935.95	04/15/1978	2074.301	340638.079	2497905.971
153	15200.00	34.04	0.025	974.97	974.97	04/15/1978	2058.447	340668.930	2497948.392
154	15300.00	35.40	0.025	1013.98	1013.98	04/15/1978	2042.594	340699.782	2497990.812
155	15400.00	36.76	0.025	1052.98	1052.98	04/15/1978	2026.740	340730.633	2498033.233
156	15500.00	38.12	0.025	1091.99	1091.99	04/15/1978	2010.886	340761.485	2498075.654
157	15600.00	39.49	0.025	1131.01	1131.01	04/15/1978	2094.377	341075.774	2498806.957
158	15700.00	40.85	0.025	1170.02	1170.02	04/15/1978	2110.700	341094.802	2498855.992
159	15800.00	42.20	0.025	1208.71	1208.71	04/15/1978	2127.024	341113.830	2498905.026
160	15900.00	43.52	0.025	1246.62	1246.62	04/15/1978	2143.347	341132.859	2498954.060
161	16000.00	44.85	0.025	1284.53	1284.53	04/15/1978	2159.671	341151.887	2499003.095
162	16100.00	46.05	0.025	1318.99	1318.99	04/15/1978	2175.994	341170.915	2499052.129
163	16200.00	46.75	0.025	1339.22	1339.22	04/15/1978	2192.317	341189.943	2499101.164
164	16300.00	47.46	0.025	1359.43	1359.43	04/15/1978	2248.435	341251.485	2499259.752

165	16400.00	48.17	0.025	1379.66	1379.66	04/15/1978	2265.384	341272.462	2499308.200
166	16500.00	48.87	0.025	1399.88	1399.88	04/15/1978	2279.318	341295.675	2499354.626
167	16600.00	49.58	0.025	1420.11	1420.11	04/15/1978	2293.253	341318.888	2499401.051
168	16700.00	49.98	0.025	1431.60	1431.60	04/15/1978	2307.187	341342.101	2499447.477
169	16800.00	50.68	0.025	1451.70	1451.70	04/15/1978	2321.121	341365.314	2499493.903
170	16900.00	51.38	0.025	1471.81	1471.81	04/15/1978	2335.056	341388.526	2499540.328
171	17000.00	52.09	0.025	1491.91	1491.91	04/15/1978	2348.990	341411.739	2499586.754
172	17100.00	52.79	0.025	1512.01	1512.01	04/15/1978	351.038	343426.295	2498255.635
173	17200.00	53.49	0.025	1532.11	1532.11	04/15/1978	346.517	343460.171	2498218.583
174	17300.00	54.14	0.025	1550.74	1550.74	04/15/1978	341.996	343494.047	2498181.531
175	17400.00	54.76	0.025	1568.54	1568.54	04/15/1978	337.475	343527.923	2498144.479
176	17500.00	55.38	0.025	1586.33	1586.33	04/15/1978	332.955	343561.799	2498107.427
177	17600.00	56.00	0.025	1604.12	1604.12	04/15/1978	328.434	343595.675	2498070.375
178	17700.00	56.20	0.025	1609.85	1609.85	04/15/1978	323.913	343629.552	2498033.323
179	17800.00	56.10	0.025	1606.98	1606.98	04/15/1978	319.392	343663.428	2497996.271
180	17900.00	56.00	0.025	1604.49	1604.11	04/15/1978	315.315	343688.466	2497968.886
181	18000.00	55.90	0.025	1606.10	1601.25	04/15/1978	308.703	343722.498	2497931.663
182	18100.00	55.80	0.025	1607.71	1598.39	04/15/1978	302.091	343756.530	2497894.440
183	18200.00	55.70	0.025	1609.32	1595.53	04/15/1978	295.478	343790.563	2497857.217
184	18300.00	55.60	0.025	1611.02	1592.66	04/15/1978	288.866	343824.595	2497819.995
185	18400.00	55.50	0.025	1613.00	1589.80	04/15/1978	282.253	343858.627	2497782.772
186	18500.00	55.40	0.025	1614.97	1586.93	04/15/1978	267.703	343887.554	2497739.471
187	18600.00	55.31	0.025	1617.02	1584.14	04/15/1978	252.513	343916.069	2497695.680
188	18700.00	55.21	0.025	1619.10	1581.38	04/15/1978	237.323	343944.584	2497651.889
189	18800.00	55.11	0.025	1621.17	1578.62	04/15/1978	223.753	344005.862	2497557.784
190	18900.00	55.02	0.025	1623.23	1575.85	04/15/1978	222.335	344033.156	2497515.867
191	19000.00	54.92	0.025	1625.31	1573.09	04/15/1978	220.917	344060.451	2497473.950
192	19100.00	54.82	0.025	1627.38	1570.32	04/15/1978	219.499	344087.746	2497432.033
193	19200.00	53.59	0.025	1596.92	1535.02	04/15/1978	218.081	344115.040	2497390.117
194	19300.00	51.92	0.025	1553.93	1487.19	04/15/1978	216.663	344142.335	2497348.200
195	19400.00	51.33	0.025	1543.57	1470.19	04/15/1978	215.245	344169.629	2497306.283
196	19500.00	51.49	0.025	1554.98	1474.80	04/15/1978	213.827	344196.924	2497264.366
197	19600.00	51.65	0.025	1566.39	1479.41	04/15/1978	212.409	344224.219	2497222.450
198	19700.00	51.81	0.025	1577.79	1484.02	04/15/1978	210.991	344251.513	2497180.533
199	19800.00	51.59	0.025	1572.06	1477.62	04/15/1978	209.573	344278.808	2497138.616
200	19900.00	51.31	0.025	1558.59	1469.77	04/15/1978	208.155	344306.103	2497096.699
201	20000.00	51.04	0.025	1545.11	1461.92	04/15/1978	207.444	344333.979	2497055.185
202	20100.00	50.76	0.025	1531.63	1454.07	04/15/1978	212.828	344366.865	2497017.140
203	20200.00	50.49	0.025	1518.15	1446.21	04/15/1978	218.211	344399.752	2496979.095
204	20300.00	48.68	0.025	1466.29	1394.28	04/15/1978	223.595	344432.639	2496941.049
205	20400.00	47.20	0.025	1424.19	1352.09	04/15/1978	227.143	344451.434	2496919.306
206	20500.00	47.21	0.025	1424.55	1352.35	04/15/1978	227.789	344484.134	2496881.476

207	20600.00	47.22	0.025	1424.90	1352.60	04/15/1978	228.434	344516.835	2496843.646
208	20700.00	47.23	0.025	1425.24	1352.85	04/15/1978	229.079	344549.535	2496805.816
209	20800.00	47.17	0.025	1423.47	1350.98	04/15/1978	229.725	344582.236	2496767.986
210	20900.00	46.63	0.025	1408.21	1335.63	04/15/1978	230.370	344614.936	2496730.156
211	21000.00	46.09	0.025	1392.96	1320.27	04/15/1978	231.015	344647.636	2496692.326
212	21100.00	45.56	0.025	1377.70	1304.92	04/15/1978	231.661	344680.337	2496654.496
213	21200.00	45.02	0.025	1362.44	1289.57	04/15/1978	232.306	344713.037	2496616.667
214	21300.00	44.49	0.025	1347.19	1274.22	04/15/1978	232.951	344745.738	2496578.837
215	21400.00	43.95	0.025	1331.92	1258.85	04/15/1978	233.597	344778.438	2496541.007
216	21500.00	43.41	0.025	1316.66	1243.50	04/15/1978	234.242	344811.138	2496503.177
217	21600.00	42.88	0.025	1301.41	1228.15	04/15/1978	234.887	344843.839	2496465.347
218	21700.00	42.34	0.025	1286.15	1212.80	04/15/1978	235.533	344876.539	2496427.517
219	21800.00	41.81	0.025	1270.89	1197.44	04/15/1978	236.178	344909.240	2496389.687
220	21900.00	41.27	0.025	1255.64	1182.09	04/15/1978	236.823	344941.940	2496351.857
221	22000.00	40.73	0.025	1240.38	1166.74	04/15/1978	237.469	344974.640	2496314.028
222	22100.00	40.20	0.025	1225.13	1151.39	04/15/1978	238.114	345007.341	2496276.198
223	22200.00	39.66	0.025	1209.87	1136.03	04/15/1978	238.759	345040.041	2496238.368
224	22300.00	39.13	0.025	1194.61	1120.68	04/15/1978	239.405	345072.742	2496200.538
225	22400.00	38.59	0.025	1179.36	1105.33	04/15/1978	267.553	345169.125	2496089.035
226	22500.00	38.05	0.025	1164.09	1089.97	04/15/1978	283.496	345200.062	2496046.643
227	22600.00	37.52	0.025	1148.83	1074.62	04/15/1978	295.401	345227.167	2496002.973
228	22700.00	36.97	0.025	1133.41	1059.09	04/15/1978	307.306	345254.272	2495959.304
229	22800.00	36.42	0.025	1117.73	1043.32	04/15/1978	319.210	345281.377	2495915.634
230	22900.00	35.87	0.025	1102.05	1027.55	04/15/1978	331.115	345308.483	2495871.965
231	23000.00	35.32	0.025	1086.38	1011.78	04/15/1978	343.020	345335.588	2495828.295
232	23100.00	34.77	0.025	1071.91	996.00	04/15/1978	411.370	345169.483	2496088.621
233	23200.00	34.22	0.025	1059.40	980.24	04/15/1978	372.896	345205.958	2496037.144
234	23300.00	33.67	0.025	1046.87	964.47	04/15/1978	329.325	345240.933	2495980.795
235	23400.00	33.12	0.025	1034.34	948.70	04/15/1978	218.894	345370.194	2495772.540
236	23500.00	32.57	0.025	1021.82	932.92	04/15/1978	216.553	345396.591	2495730.011
237	23600.00	32.02	0.025	1009.30	917.16	04/15/1978	214.211	345422.988	2495687.483
238	23700.00	31.35	0.025	993.47	898.08	04/15/1978	211.870	345449.386	2495644.954
239	23800.00	30.45	0.025	970.76	872.13	04/15/1978	209.529	345475.783	2495602.426
240	23900.00	29.54	0.025	948.06	846.18	04/15/1978	207.187	345502.180	2495559.897
241	24000.00	28.18	0.025	913.44	807.19	04/15/1978	204.846	345528.577	2495517.369
242	24100.00	27.28	0.025	890.85	781.35	04/15/1978	202.504	345554.974	2495474.840
243	24200.00	26.38	0.025	868.26	755.51	04/15/1978	200.163	345581.371	2495432.312
244	24300.00	25.47	0.025	845.68	729.67	04/15/1978	197.822	345607.768	2495389.783
245	24400.00	24.57	0.025	823.10	703.84	04/15/1978	195.480	345634.165	2495347.254
246	24500.00	23.67	0.025	800.51	677.99	04/15/1978	193.139	345660.562	2495304.726
247	24600.00	22.77	0.025	777.93	652.16	04/15/1978	190.797	345686.959	2495262.197
248	24700.00	21.87	0.025	755.34	626.31	04/15/1978	188.456	345713.356	2495219.669

249	24800.00	20.96	0.025	742.49	600.48	04/15/1978	186.115	345739.753	2495177.140
250	24900.00	20.11	0.025	731.03	575.98	04/15/1978	183.773	345766.150	2495134.612
251	25000.00	19.26	0.025	719.71	551.63	04/15/1978	188.381	345809.110	2495064.760
252	25100.00	17.22	0.025	689.26	493.27	04/15/1978	194.280	345835.288	2495021.754
253	25200.00	16.97	0.025	678.07	485.95	04/15/1978	200.179	345861.466	2494978.748
254	25300.00	16.77	0.025	666.90	480.48	04/15/1978	206.078	345887.643	2494935.742
255	25400.00	16.58	0.025	655.71	475.01	04/15/1978	211.978	345913.821	2494892.735
256	25500.00	16.08	0.025	653.16	460.70	04/15/1978	217.877	345939.999	2494849.729
257	25600.00	15.37	0.025	665.19	440.24	04/15/1978	223.776	345966.176	2494806.723
258	25700.00	14.66	0.025	677.21	419.78	04/15/1978	229.675	345992.354	2494763.717
259	25800.00	13.94	0.025	689.23	399.33	04/15/1978	235.574	346018.532	2494720.711
260	25900.00	13.23	0.025	701.26	378.88	04/15/1978	241.474	346044.709	2494677.705
261	26000.00	12.51	0.025	693.55	358.42	04/15/1978	247.373	346070.887	2494634.698
262	26100.00	11.53	0.025	678.14	330.16	04/15/1978	253.272	346097.065	2494591.692
263	26200.00	10.38	0.025	662.75	297.34	04/15/1978	259.171	346123.242	2494548.686
264	26300.00	9.23	0.025	653.07	264.52	04/15/1978	265.070	346149.420	2494505.680
265	26400.00	8.09	0.025	648.35	231.70	04/15/1978	270.970	346175.598	2494462.674
266	26500.00	6.94	0.025	643.62	198.88	04/15/1978	276.869	346201.775	2494419.667
267	26600.00	5.80	0.025	638.89	166.06	04/15/1978	282.768	346227.953	2494376.661
268	26700.00	4.65	0.025	634.16	133.24	04/15/1978	288.667	346254.131	2494333.655
269	26800.00	3.51	0.025	622.05	100.42	04/15/1978	295.997	346281.609	2494291.245
270	26900.00	2.36	0.025	599.83	67.60	04/15/1978	303.608	346309.343	2494248.951
271	27000.00	1.37	0.025	577.63	39.17	04/15/1978	311.218	346337.077	2494206.657
272	27100.00	0.52	0.025	555.42	14.95	04/15/1978	318.829	346364.810	2494164.363
273	27200.00	-0.32	0.025	533.21	-9.27	04/15/1978	326.439	346392.544	2494122.069
274	27300.00	-1.17	0.025	511.00	-33.48	04/15/1978	334.050	346420.277	2494079.776
275	27400.00	-2.01	0.025	488.79	-57.70	04/15/1978	339.558	346442.651	2494045.656
276	27500.00	-2.96	0.025	466.59	-84.78	04/15/1978	345.720	346470.277	2494003.527
277	27600.00	-4.00	0.025	444.38	-114.55	04/15/1978	351.882	346497.902	2493961.398
278	27700.00	-5.04	0.025	422.17	-144.33	04/15/1978	358.044	346525.527	2493919.270
279	27800.00	-6.08	0.025	399.96	-174.10	04/15/1978	364.206	346553.152	2493877.141
280	27900.00	-7.12	0.025	367.82	-203.88	04/15/1978	370.368	346580.778	2493835.013
281	28000.00	-8.16	0.025	346.64	-233.65	04/15/1978	376.529	346608.403	2493792.884
282	28100.00	-9.03	0.025	336.08	-258.68	04/15/1978	382.691	346636.028	2493750.756
283	28200.00	-9.75	0.025	325.52	-279.39	04/15/1978	388.853	346663.653	2493708.627
284	28300.00	-13.72	0.025	392.88	-392.88	04/15/1978	395.015	346691.279	2493666.499
285	28400.00	-14.94	0.025	428.03	-428.03	04/15/1978	401.177	346718.904	2493624.370
286	28500.00	-16.17	0.025	463.17	-463.17	04/15/1978	407.339	346746.529	2493582.242
287	28600.00	-17.40	0.025	498.31	-498.31	04/15/1978	413.501	346774.155	2493540.113
288	28700.00	-18.62	0.025	533.46	-533.46	04/15/1978	419.663	346801.780	2493497.984
289	28800.00	-19.85	0.025	568.60	-568.60	04/15/1978	425.825	346829.405	2493455.856
290	28900.00	-21.08	0.025	603.75	-603.75	04/15/1978	431.987	346857.030	2493413.727

291	29000.00	-22.30	0.025	638.89	-638.89	04/15/1978	438.149	346884.656	2493371.599
292	29100.00	-23.28	0.025	666.70	-666.70	04/15/1978	444.311	346912.281	2493329.470
293	29200.00	-24.12	0.025	690.96	-690.96	04/15/1978	449.770	346939.276	2493287.031
294	29300.00	-24.97	0.025	715.21	-715.21	04/15/1978	454.154	346965.306	2493244.117
295	29400.00	-25.82	0.025	739.47	-739.47	04/15/1978	458.538	346991.336	2493201.202
296	29500.00	-27.10	0.025	776.24	-776.24	04/15/1978	462.921	347017.366	2493158.288
297	29600.00	-28.55	0.025	817.84	-817.84	04/15/1978	467.305	347043.396	2493115.373
298	29700.00	-29.70	0.025	850.68	-850.68	04/15/1978	471.689	347069.426	2493072.459
299	29800.00	-29.77	0.025	852.78	-852.78	04/15/1978	476.072	347095.456	2493029.544
300	29900.00	-34.04	0.025	974.97	-974.97	04/15/1978	480.456	347121.486	2492986.630
301	30000.00	-36.18	0.025	1036.29	-1036.29	04/15/1978	484.840	347147.516	2492943.715
302	30100.00	-37.61	0.025	1077.14	-1077.14	04/15/1978	489.224	347173.546	2492900.801
303	30200.00	-37.73	0.025	1080.78	-1080.78	04/15/1978	493.607	347199.576	2492857.886
304	30300.00	-37.86	0.025	1084.43	-1084.43	04/15/1978	497.991	347225.607	2492814.972
305	30400.00	-37.99	0.025	1088.07	-1088.07	04/15/1978	502.375	347251.637	2492772.057
306	30500.00	-38.60	0.025	1105.55	-1105.55	04/15/1978	506.758	347277.667	2492729.143
307	30600.00	-39.30	0.025	1125.55	-1125.55	04/15/1978	511.142	347303.697	2492686.228
308	30700.00	-41.46	0.025	1187.64	-1187.64	04/15/1978	515.526	347329.727	2492643.314
309	30800.00	-40.41	0.025	1180.75	-1157.44	04/15/1978	519.909	347355.757	2492600.400
310	30900.00	-39.35	0.025	1247.41	-1127.24	04/15/1978	524.293	347381.787	2492557.485
311	31000.00	-39.97	0.025	1238.95	-1144.93	04/15/1978	528.677	347407.817	2492514.571
312	31100.00	-44.43	0.025	1272.63	-1272.63	04/15/1978	533.060	347433.847	2492471.656
313	31200.00	-48.89	0.025	1400.32	-1400.32	04/15/1978	537.444	347459.877	2492428.742
314	31300.00	-50.09	0.025	1434.73	-1434.73	04/15/1978	541.828	347485.907	2492385.827
315	31400.00	-48.60	0.025	1392.05	-1392.05	04/15/1978	546.212	347511.937	2492342.913
316	31500.00	-36.42	0.025	1248.73	-1043.26	04/15/1978	550.595	347537.968	2492299.998
317	31600.00	-37.12	0.025	1291.89	-1063.31	04/15/1978	555.291	347564.278	2492257.222
318	31700.00	-35.75	0.025	1335.50	-1023.97	04/15/1978	560.227	347590.803	2492214.551
319	31800.00	-34.38	0.025	1379.10	-984.62	04/15/1978	565.162	347617.328	2492171.881
320	31900.00	-22.11	0.025	1417.60	-633.42	04/15/1978	570.098	347643.853	2492129.210
321	32000.00	-19.74	0.025	1450.73	-565.28	04/15/1978	575.033	347670.378	2492086.539
322	32100.00	-22.93	0.025	1483.87	-656.82	04/15/1978	579.968	347696.903	2492043.869
323	32200.00	-35.23	0.025	1496.98	-1009.15	04/15/1978	584.904	347723.428	2492001.198
324	32300.00	-42.90	0.025	1493.41	-1228.88	04/15/1978	589.839	347749.953	2491958.527
325	32400.00	-42.18	0.025	1489.85	-1208.27	04/15/1978	594.775	347776.478	2491915.857
326	32500.00	-41.46	0.025	1486.28	-1187.66	04/15/1978	599.710	347803.003	2491873.186
327	32600.00	-39.59	0.025	1482.72	-1133.86	04/15/1978	604.646	347829.528	2491830.516
328	32700.00	-37.74	0.025	1490.77	-1081.02	04/15/1978	609.581	347856.053	2491787.845
329	32800.00	-35.66	0.025	1511.09	-1021.48	04/15/1978	614.516	347882.578	2491745.174
330	32900.00	-31.49	0.025	1531.42	-902.04	04/15/1978	619.452	347909.103	2491702.504
331	33000.00	-29.00	0.025	1557.81	-830.72	04/15/1978	624.387	347935.628	2491659.833
332	33100.00	-34.91	0.025	1585.13	-999.99	04/15/1978	629.323	347962.153	2491617.162

333	33200.00	-29.95	0.025	1608.70	-857.98	04/15/1978	634.258	347988.678	2491574.492
334	33300.00	-24.63	0.025	1632.28	-705.36	04/15/1978	639.193	348015.203	2491531.821
335	33400.00	-29.82	0.025	1655.85	-854.22	04/15/1978	643.140	348036.302	2491497.880
336	33500.00	-33.59	0.025	1679.42	-962.09	04/15/1978	647.274	348062.788	2491455.270
337	33600.00	-28.07	0.025	1703.00	-804.07	04/15/1978	651.408	348089.275	2491412.661
338	33700.00	-29.58	0.025	1700.90	-847.14	04/15/1978	655.541	348115.762	2491370.052
339	33800.00	-30.89	0.025	1678.65	-884.79	04/15/1978	659.675	348142.249	2491327.443
340	33900.00	-31.71	0.025	1658.59	-908.35	04/15/1978	663.809	348168.735	2491284.834
341	34000.00	-32.42	0.025	1643.42	-928.60	04/15/1978	667.942	348195.222	2491242.225
342	34100.00	-37.45	0.025	1764.89	-1072.64	04/15/1978	672.076	348221.709	2491199.616
343	34200.00	-38.29	0.025	1775.99	-1096.67	04/15/1978	676.210	348248.196	2491157.007
344	34300.00	-44.56	0.025	1816.00	-1276.33	04/15/1978	680.343	348274.682	2491114.397
345	34400.00	-48.88	0.025	1906.15	-1400.01	04/15/1978	684.477	348301.169	2491071.788
346	34500.00	-51.88	0.025	2005.31	-1485.95	04/15/1978	688.927	348327.938	2491029.324
347	34600.00	-54.88	0.025	2104.48	-1571.90	04/15/1978	694.216	348355.453	2490987.242
348	34700.00	-59.31	0.025	2203.64	-1698.96	04/15/1978	699.506	348382.968	2490945.160
349	34800.00	-62.50	0.025	2264.34	-1790.31	04/15/1978	704.795	348410.483	2490903.078
350	34900.00	-63.81	0.025	2271.18	-1827.79	04/15/1978	710.084	348437.998	2490860.996
351	35000.00	-65.12	0.025	2278.01	-1865.27	04/15/1978	715.373	348465.513	2490818.914
352	35100.00	-66.43	0.025	2309.40	-1902.74	04/15/1978	720.663	348493.029	2490776.832
353	35200.00	-67.94	0.025	2355.34	-1946.14	04/15/1978	725.952	348520.544	2490734.750
354	35300.00	-70.58	0.025	2395.16	-2021.71	04/15/1978	731.241	348548.059	2490692.668
355	35400.00	-82.28	0.025	2418.54	-2356.69	04/15/1978	736.531	348575.574	2490650.586
356	35500.00	-81.26	0.025	2371.62	-2327.51	04/15/1978	741.820	348603.089	2490608.504
357	35600.00	-80.22	0.025	2324.70	-2297.72	04/15/1978	747.109	348630.604	2490566.422
358	35700.00	-79.18	0.025	2277.78	-2267.95	04/15/1978	752.398	348658.119	2490524.340
359	35800.00	-79.04	0.025	2263.95	-2263.95	04/15/1978	757.688	348685.635	2490482.258
360	35900.00	-79.13	0.025	2266.52	-2266.52	04/15/1978	762.977	348713.150	2490440.176
361	36000.00	-79.16	0.025	2267.31	-2267.31	04/15/1978	768.266	348740.665	2490398.094
362	36100.00	-79.18	0.025	2268.12	-2268.12	04/15/1978	773.556	348768.180	2490356.012
363	36200.00	-79.26	0.025	2270.20	-2270.20	04/15/1978	778.845	348795.695	2490313.930
364	36300.00	-79.65	0.025	2281.57	-2281.57	04/15/1978	784.134	348823.210	2490271.848
365	36400.00	-80.05	0.025	2292.93	-2292.93	04/15/1978	789.423	348850.725	2490229.766
366	36500.00	-80.42	0.025	2303.40	-2303.40	04/15/1978	794.713	348878.241	2490187.684
367	36600.00	-78.55	0.025	2250.36	-2249.85	04/15/1978	800.002	348905.756	2490145.602
368	36700.00	-76.65	0.025	2252.58	-2195.46	04/15/1978	805.291	348933.271	2490103.520
369	36800.00	-74.91	0.025	2234.36	-2145.67	04/15/1978	810.580	348960.786	2490061.438
370	36900.00	-74.74	0.025	2205.28	-2140.85	04/15/1978	815.870	348988.301	2490019.356
371	37000.00	-69.56	0.025	1992.41	-1992.41	04/15/1978	821.159	349015.816	2489977.274
372	37100.00	-69.26	0.025	1983.80	-1983.80	04/15/1978	826.448	349043.331	2489935.192
373	37200.00	-68.87	0.025	1972.78	-1972.78	04/15/1978	831.738	349070.847	2489893.110

374	37300.00	-68.03	0.025	1948.69	-1948.69	04/15/1978	837.027	349098.362	2489851.028
375	37400.00	-68.54	0.025	1963.09	-1963.09	04/15/1978	842.316	349125.877	2489808.946
376	37500.00	-67.63	0.025	1937.15	-1937.15	04/15/1978	847.605	349153.392	2489766.864
377	37600.00	-68.53	0.025	1962.86	-1962.86	04/15/1978	852.895	349180.907	2489724.782
378	37700.00	-70.05	0.025	2006.59	-2006.59	04/15/1978	858.184	349208.422	2489682.700
379	37800.00	-68.80	0.025	1970.80	-1970.80	04/15/1978	863.473	349235.937	2489640.618
380	37900.00	-68.59	0.025	1964.73	-1964.73	04/15/1978	868.762	349263.453	2489598.536
381	38000.00	-66.56	0.025	1906.53	-1906.53	04/15/1978	874.052	349290.968	2489556.454
382	38100.00	-62.99	0.025	1804.12	-1804.12	04/15/1978	879.341	349318.483	2489514.372
383	38200.00	-62.85	0.025	1800.12	-1800.12	04/15/1978	884.630	349345.998	2489472.290
384	38300.00	-62.52	0.025	1790.86	-1790.86	04/15/1978	889.920	349373.513	2489430.208
385	38400.00	-62.70	0.025	1796.04	-1796.04	04/15/1978	895.209	349401.028	2489388.126
386	38500.00	-56.39	0.025	1615.25	-1615.25	04/15/1978	900.498	349428.543	2489346.044
387	38600.00	-55.96	0.025	1602.81	-1602.81	04/15/1978	905.787	349456.059	2489303.962
388	38700.00	-55.61	0.025	1592.89	-1592.89	04/15/1978	911.904	349484.310	2489262.258
389	38800.00	-55.46	0.025	1588.70	-1588.70	04/15/1978	918.173	349512.697	2489220.623
390	38900.00	-55.94	0.025	1602.22	-1602.22	04/15/1978	924.443	349541.085	2489178.988
391	39000.00	-56.46	0.025	1617.23	-1617.23	04/15/1978	930.712	349569.472	2489137.353
392	39100.00	-56.13	0.025	1607.78	-1607.78	04/15/1978	936.982	349597.859	2489095.718
393	39200.00	-53.75	0.025	1539.71	-1539.71	04/15/1978	943.251	349626.247	2489054.083
394	39300.00	-53.62	0.025	1535.81	-1535.81	04/15/1978	949.521	349654.634	2489012.448
395	39400.00	-56.32	0.025	1613.19	-1613.19	04/15/1978	955.790	349683.022	2488970.814
396	39500.00	-57.82	0.025	1656.10	-1656.10	04/15/1978	962.060	349711.409	2488929.179
397	39600.00	-57.32	0.025	1641.81	-1641.81	04/15/1978	962.205	349734.346	2488884.750
398	39700.00	-56.68	0.025	1623.42	-1623.42	04/15/1978	962.261	349757.205	2488840.281
399	39800.00	-56.65	0.025	1622.63	-1622.63	04/15/1978	962.317	349780.063	2488795.812
400	39900.00	-54.37	0.025	1557.29	-1557.29	04/15/1978	962.374	349802.922	2488751.343
401	40000.00	-52.05	0.025	1490.86	-1490.86	04/15/1978	962.430	349825.780	2488706.874
402	40100.00	-52.97	0.025	1517.31	-1517.31	04/15/1978	962.487	349848.639	2488662.405
403	40200.00	-53.71	0.025	1538.40	-1538.40	04/15/1978	962.543	349871.497	2488617.936
404	40300.00	-52.18	0.025	1494.47	-1494.47	04/15/1978	962.600	349894.356	2488573.467
405	40400.00	-50.14	0.025	1436.09	-1436.09	04/15/1978	962.656	349917.214	2488528.998
406	40500.00	-49.92	0.025	1429.98	-1429.98	04/15/1978	964.254	349958.474	2488448.731
407	40600.00	-49.50	0.025	1417.84	-1417.84	04/15/1978	966.400	349981.353	2488404.221
408	40700.00	-49.13	0.025	1407.16	-1407.16	04/15/1978	968.546	350004.233	2488359.712
409	40800.00	-49.66	0.025	1422.40	-1422.40	04/15/1978	970.692	350027.112	2488315.202
410	40900.00	-50.19	0.025	1437.67	-1437.67	04/15/1978	972.839	350049.992	2488270.692
411	41000.00	-51.20	0.025	1466.45	-1466.45	04/15/1978	974.985	350072.871	2488226.182
412	41100.00	-52.55	0.025	1505.08	-1505.08	04/15/1978	977.131	350095.751	2488181.672
413	41200.00	-53.69	0.025	1537.81	-1537.81	04/15/1978	979.277	350118.630	2488137.162
414	41300.00	-54.26	0.025	1554.10	-1554.10	04/15/1978	981.423	350141.510	2488092.652
415	41400.00	-53.99	0.025	1546.57	-1546.57	04/15/1978	983.569	350164.389	2488048.142

416	41500.00	-53.02	0.025	1518.65	-1518.65	04/15/1978	985.716	350187.269	2488003.632
417	41600.00	-51.91	0.025	1487.01	-1487.01	04/15/1978	987.862	350210.148	2487959.122
418	41700.00	-52.09	0.025	1491.99	-1491.99	04/15/1978	990.008	350233.028	2487914.612
419	41800.00	-52.31	0.025	1498.23	-1498.23	04/15/1978	992.154	350255.907	2487870.102
420	41900.00	-52.44	0.025	1502.08	-1502.08	04/15/1978	994.300	350278.787	2487825.592
421	42000.00	-52.49	0.025	1503.52	-1503.52	04/15/1978	996.447	350301.666	2487781.082
422	42100.00	-52.63	0.025	1507.59	-1507.59	04/15/1978	998.593	350324.546	2487736.572
423	42200.00	-52.99	0.025	1517.72	-1517.72	04/15/1978	1000.739	350347.425	2487692.063
424	42300.00	-54.42	0.025	1558.84	-1558.84	04/15/1978	1002.885	350370.305	2487647.553
425	42400.00	-51.86	0.025	1485.37	-1485.37	04/15/1978	1005.031	350393.184	2487603.043
426	42500.00	-48.79	0.025	1397.65	-1397.65	04/15/1978	1007.178	350416.064	2487558.533
427	42600.00	-46.25	0.025	1324.87	-1324.87	04/15/1978	1009.324	350438.943	2487514.023
428	42700.00	-46.15	0.025	1321.85	-1321.85	04/15/1978	1011.470	350461.823	2487469.513
429	42800.00	-49.78	0.025	1425.95	-1425.95	04/15/1978	1013.616	350484.702	2487425.003
430	42900.00	-52.14	0.025	1493.41	-1493.41	04/15/1978	1015.762	350507.582	2487380.493
431	43000.00	-54.84	0.025	1570.69	-1570.69	04/15/1978	1017.909	350530.461	2487335.983
432	43100.00	-57.80	0.025	1655.70	-1655.70	04/15/1978	1020.055	350553.341	2487291.473
433	43200.00	-58.19	0.025	1666.73	-1666.73	04/15/1978	1022.201	350576.220	2487246.963
434	43300.00	-60.58	0.025	1735.35	-1735.35	04/15/1978	1024.347	350599.100	2487202.453
435	43400.00	-63.23	0.025	1811.04	-1811.04	04/15/1978	1026.493	350621.980	2487157.943
436	43500.00	-64.37	0.025	1843.86	-1843.86	04/15/1978	1028.639	350644.859	2487113.433
437	43600.00	-63.67	0.025	1823.81	-1823.81	04/15/1978	1030.786	350667.739	2487068.923
438	43700.00	-62.97	0.025	1803.76	-1803.76	04/15/1978	1032.932	350690.618	2487024.414
439	43800.00	-62.54	0.025	1791.33	-1791.33	04/15/1978	1035.078	350713.498	2486979.904
440	43900.00	-62.18	0.025	1781.17	-1781.17	04/15/1978	1037.224	350736.377	2486935.394
441	44000.00	-61.44	0.025	1759.77	-1759.77	04/15/1978	1039.370	350759.257	2486890.884
442	44100.00	-60.84	0.025	1742.54	-1742.54	04/15/1978	1041.517	350782.136	2486846.374
443	44200.00	-61.23	0.025	1753.96	-1753.96	04/15/1978	1043.663	350805.016	2486801.864
444	44300.00	-61.53	0.025	1762.49	-1762.49	04/15/1978	1045.809	350827.895	2486757.354
445	44400.00	-61.87	0.025	1772.31	-1772.31	04/15/1978	1047.955	350850.775	2486712.844
446	44500.00	-62.59	0.025	1792.70	-1792.70	04/15/1978	1050.101	350873.654	2486668.334
447	44600.00	-59.80	0.025	1712.85	-1712.85	04/15/1978	1052.248	350896.534	2486623.824
448	44700.00	-60.48	0.025	1732.24	-1732.24	04/15/1978	1054.394	350919.413	2486579.314
449	44800.00	-61.15	0.025	1751.62	-1751.62	04/15/1978	1056.540	350942.293	2486534.804
450	44900.00	-61.83	0.025	1771.01	-1771.01	04/15/1978	1058.686	350965.172	2486490.294
451	45000.00	-62.51	0.025	1790.39	-1790.39	04/15/1978	1060.832	350988.052	2486445.784
452	45100.00	-63.18	0.025	1809.77	-1809.77	04/15/1978	1062.979	351010.931	2486401.274
453	45200.00	-63.68	0.025	1824.03	-1824.03	04/15/1978	1065.125	351033.811	2486356.765
454	45300.00	-64.13	0.025	1836.80	-1836.80	04/15/1978	1067.271	351056.690	2486312.255
455	45400.00	-64.67	0.025	1852.26	-1852.26	04/15/1978	1069.417	351079.570	2486267.745
456	45500.00	-65.21	0.025	1867.72	-1867.72	04/15/1978	1071.563	351102.449	2486223.235
457	45600.00	-65.75	0.025	1883.18	-1883.18	04/15/1978	1073.710	351125.329	2486178.725

458	45700.00	-59.87	0.025	1714.83	-1714.83	04/15/1978	1075.856	351148.208	2486134.215
459	45800.00	-60.70	0.025	1738.61	-1738.61	04/15/1978	1078.002	351171.088	2486089.705
460	45900.00	-61.53	0.025	1762.38	-1762.38	04/15/1978	1080.148	351193.967	2486045.195
461	46000.00	-62.08	0.025	1778.07	-1778.07	04/15/1978	1082.294	351216.847	2486000.685
462	46100.00	-62.63	0.025	1793.97	-1793.97	04/15/1978	1084.440	351239.726	2485956.175
463	46200.00	-63.59	0.025	1821.52	-1821.52	04/15/1978	1086.587	351262.606	2485911.665
464	46300.00	-64.55	0.025	1849.07	-1849.07	04/15/1978	1088.733	351285.485	2485867.155
465	46400.00	-65.52	0.025	1876.63	-1876.63	04/15/1978	1090.879	351308.365	2485822.645
466	46500.00	-66.27	0.025	1898.30	-1898.30	04/15/1978	1093.025	351331.244	2485778.135
467	46600.00	-66.52	0.025	1905.24	-1905.24	04/15/1978	1095.171	351354.124	2485733.625
468	46700.00	-66.46	0.025	1903.55	-1903.55	02/07/2001	1614.193	351846.413	2485905.484
469	46800.00	-66.40	0.025	1901.87	-1901.87	04/15/1978	1099.464	351399.883	2485644.606
470	46900.00	-66.34	0.025	1900.18	-1900.18	04/15/1978	1101.610	351422.762	2485600.096
471	47000.00	-66.67	0.025	1909.55	-1909.55	04/15/1978	1103.756	351445.642	2485555.586
472	47100.00	-67.44	0.025	1931.68	-1931.68	04/15/1978	1105.902	351468.521	2485511.076
473	47200.00	-68.21	0.025	1953.82	-1953.82	04/15/1978	1108.049	351491.401	2485466.566
474	47300.00	-68.98	0.025	1975.96	-1975.96	04/15/1978	1110.195	351514.280	2485422.056
475	47400.00	-69.51	0.025	1991.04	-1991.04	04/15/1978	1112.341	351537.160	2485377.546
476	47500.00	-69.84	0.025	2000.45	-2000.45	04/15/1978	1114.487	351560.039	2485333.036
477	47600.00	-70.17	0.025	2009.85	-2009.85	04/15/1978	1116.633	351582.919	2485288.526
478	47700.00	-70.50	0.025	2019.24	-2019.24	04/15/1978	1118.780	351605.798	2485244.016
479	47800.00	-70.82	0.025	2028.64	-2028.64	04/15/1978	1120.926	351628.678	2485199.506
480	47900.00	-71.15	0.025	2038.04	-2038.04	04/15/1978	1123.072	351651.557	2485154.996
481	48000.00	-71.48	0.025	2047.43	-2047.43	04/15/1978	1128.112	351689.208	2485081.751
482	48100.00	-71.38	0.025	2044.56	-2044.56	04/15/1978	1131.695	351712.125	2485037.168
483	48200.00	-71.24	0.025	2040.68	-2040.68	04/15/1978	1135.277	351735.042	2484992.585
484	48300.00	-71.11	0.025	2036.79	-2036.79	04/15/1978	1138.860	351757.959	2484948.002
485	48400.00	-71.06	0.025	2035.35	-2035.35	04/15/1978	1142.442	351780.876	2484903.419
486	48500.00	-71.80	0.025	2056.46	-2056.46	04/15/1978	1146.025	351803.793	2484858.836
487	48600.00	-72.31	0.025	2071.34	-2071.34	04/15/1978	1149.607	351826.710	2484814.253
488	48700.00	-72.83	0.025	2086.22	-2086.22	04/15/1978	1153.190	351849.627	2484769.670
489	48800.00	-73.35	0.025	2101.10	-2101.10	04/15/1978	1156.772	351872.544	2484725.087
490	48900.00	-73.87	0.025	2115.98	-2115.98	04/15/1978	1160.355	351895.461	2484680.505
491	49000.00	-73.47	0.025	2104.33	-2104.33	04/15/1978	1163.937	351918.378	2484635.922
492	49100.00	-72.60	0.025	2079.63	-2079.63	04/15/1978	1167.520	351941.295	2484591.339
493	49200.00	-71.70	0.025	2053.87	-2053.87	04/15/1978	1171.103	351964.212	2484546.756
494	49300.00	-70.74	0.025	2026.12	-2026.12	04/15/1978	1174.685	351987.129	2484502.173
495	49400.00	-69.77	0.025	1998.38	-1998.38	04/15/1978	1178.268	352010.047	2484457.590
496	49500.00	-69.30	0.025	1984.91	-1984.91	04/15/1978	1181.850	352032.964	2484413.007
497	49600.00	-69.40	0.025	1987.99	-1987.99	04/15/1978	1185.433	352055.881	2484368.424
498	49700.00	-69.51	0.025	1991.06	-1991.06	04/15/1978	1189.015	352078.798	2484323.841
499	49800.00	-69.62	0.025	1994.15	-1994.15	04/15/1978	1192.598	352101.715	2484279.258

500	49900.00	-69.73	0.025	1997.22	-1997.22	04/15/1978	1196.180	352124.632	2484234.675
501	50000.00	-69.83	0.025	2000.10	-2000.10	04/15/1978	1199.763	352147.549	2484190.092
502	50100.00	-69.93	0.025	2002.99	-2002.99	04/15/1978	1217.787	352223.222	2484042.876
503	50200.00	-70.03	0.025	2005.87	-2005.87	04/15/1978	1226.175	352246.400	2483997.786
504	50300.00	-70.13	0.025	2008.75	-2008.75	04/15/1978	1226.969	352262.342	2483950.389
505	50400.00	-70.23	0.025	2011.63	-2011.63	04/15/1978	1225.918	352276.527	2483902.432
506	50500.00	-70.33	0.025	2014.52	-2014.52	04/15/1978	1224.867	352290.711	2483854.474
507	50600.00	-70.14	0.025	2008.95	-2008.95	04/15/1978	1223.816	352304.896	2483806.517
508	50700.00	-69.84	0.025	2000.43	-2000.43	04/15/1978	1222.765	352319.081	2483758.560
509	50800.00	-69.53	0.025	1991.54	-1991.54	04/15/1978	1221.714	352333.265	2483710.602
510	50900.00	-69.22	0.025	1982.61	-1982.61	04/15/1978	1220.663	352347.450	2483662.645
511	51000.00	-68.90	0.025	1973.67	-1973.67	04/15/1978	1219.612	352361.634	2483614.688
512	51100.00	-68.59	0.025	1964.72	-1964.72	04/15/1978	1218.561	352375.819	2483566.730
513	51200.00	-68.28	0.025	1955.79	-1955.79	04/15/1978	1217.510	352390.003	2483518.773
514	51300.00	-67.97	0.025	1946.84	-1946.84	04/15/1978	1216.459	352404.188	2483470.816
515	51400.00	-67.66	0.025	1937.90	-1937.90	04/15/1978	1215.407	352418.372	2483422.858
516	51500.00	-66.89	0.025	1916.05	-1916.05	04/15/1978	1214.356	352432.557	2483374.901
517	51600.00	-65.95	0.025	1888.98	-1888.98	04/15/1978	1213.305	352446.742	2483326.944
518	51700.00	-65.01	0.025	1862.24	-1862.24	04/15/1978	1212.254	352460.926	2483278.987
519	51800.00	-64.08	0.025	1835.49	-1835.49	04/15/1978	1211.203	352475.111	2483231.029
520	51900.00	-63.15	0.025	1808.75	-1808.75	04/15/1978	1210.152	352489.295	2483183.072
521	52000.00	-62.21	0.025	1782.01	-1782.01	04/15/1978	1209.101	352503.480	2483135.115
522	52100.00	-61.27	0.025	1754.98	-1754.98	04/15/1978	1208.050	352517.664	2483087.157
523	52200.00	-60.26	0.025	1726.00	-1726.00	04/15/1978	1206.999	352531.849	2483039.200
524	52300.00	-59.25	0.025	1697.03	-1697.03	04/15/1978	1205.948	352546.033	2482991.243
525	52400.00	-58.24	0.025	1668.06	-1668.06	04/15/1978	1204.897	352560.218	2482943.285

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