ভূগোল ও পরিবেশ বিভাগ
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CERTIFICATE OF VALIDATION

I have the pleasure to certify that Mahmudun Nabi (Ph. D. researcher, Registration No. and session 5/2009-2010), Department of Geography and Environment has completed his Ph. D. Dissertation titled "**CHANGE DETECTION OF SELECTED TOPO-FEATURES USING GEOGRAPHIC INFORMATION SYSTEM (GIS): AN INVESTIGATION INTO THE TOPOGRAPHIC MAP MAKING PROCESS IN BANGLADESH**." under my supervision. I also certify that the document represents his original research work and has not been submitted anywhere else before.

Professor Dr. A.M.M. Amanat Ullah Khan
Department of Geography and Environment
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Mahmudun Nabi

Abstract

Topographic maps are fundamental units of information for many types of field studies including geosciences and archeology that present a wide range of information, making them useful to both professional and recreational map users. The topographic mapping technologies in Bangladesh have seen two major transitions, the analogue mapping techniques of the British-Indian/Pakistan/Bangladesh Period (up to the 1980s) and the Bangladesh Period digital mapping techniques since the 1990s to the present times. The author had access to the topographic maps of SOB of both the period and therefore availed this unique opportunity to research the technology used for mapping in both the period and detect changes that had taken place on selected important features (river, forest and shore) of this country over last 60 years using GIS.

Traditional mapping technology was studied by collecting internal documents of Survey department at various times; the publications/hand books about mapmaking in the British Indian Subcontinent and key persons and selected number of very experienced SOB Surveyors were Interview. Study of old instruments of SOB archive was also helpful in this aspect. It was found that the traditional method was very much laborious, methodical, time consuming, labor intensive and confined within the government domain. Modern mapping technology was studied by implementing various recent projects at SOB and exposure to mapping technology of various countries by the author. Modern method is more cost effective, quicker, precise and digital technology dependent. It is spreading quickly to the private and enterprise domain.

Various data Sources both primary and secondary were used for change detection. Primary data used was topo- maps of SOB. Secondary data were collected from other organizations and sattelite image from web sites. All these data were processed, harmonized and desired features extracted into vector format using GIS. Then algorithm was developed to make GIS model for data analysis to detect changes.

Three major rivers- Padma, Meghna and Jamuna were selected for change detection. Division wise changes are detected first where it was found that Barisal and Chittagong divisions are subjected to major changes by the Meghna river. Then the results are compared with similar studies done before by other organizations like WARPO and JICA to validate the findings. No such study involving entire Bangladesh territory has been carried out so far because of the unavailability and cost of map and satellite data at this scale. However, few studies are available that involves part of our river system. Padma river was found to retreat more than 6 kms most probably between 1940 to 1967 and flowing through a completely new channel. Jamuna river was found to be braided from 8 to 11.5km in last six decades. Its getting more wider and uniform. On average, most erosions are taking place at upstream and deposition at downstream near estuaries. Over all net changes in entire country is only 100 km sq erosion which is negligible in 60 years although commoners apparently think about huge erosion and loss of lands.

In forest change detection it was found that both deforestation as well as afforestation has taken place over the ages. Most of the deforestation is found in Dhaka division. A big chunk of forest has

altogether been deforested at Haluaghat. Rest of the deforestation is found in Gazipur and Modhupur forest. Some afforestation is found around the same area which is done mainly under "Community Afforestation" scheme taken by the government. A good amount of afforestation is noticeable along coastal belt of Noakhali, Vola, Potuakhali and Borguna districts. This is done mainly under the projects of Coastal belt protection schemes.

It was found in the shore change detection that land mass of Kamalnagar, Ramgati and Subarnachar which was an island before but has become part of mainland now due to major shift of the Meghna River towards west. In other words, the Meghna River had two main channels into the Bay of Bengal keeping those islands in between the channels thus separating the islands from mainland. Now, the west channel is the only channel and the east channel has totally disappeared. Hatia and Sandwip islands have been eroded heavily in the north and deposited lightly on the south. Monpura has been elongated southward by deposition with some more islands deposition further down the channel. Bhola is also eroded in the north east and deposited southward and connected up to Char Fassion and beyond. A big island has also deposited in between Char Fassion and Golachipa. Some erosion is also observed at Mohesh Khali.

Over all net changes in entire country is only 100 km sq erosion in sixty years which is negligible. It means that bank erosion and growth of land/char goes parallel due to meandering nature of the rivers. Erosion takes place mostly at mid and upstream of the river channels where as deposition takes place mostly at the lower part of river channels specially at the estuaries.

ACRONYMS

APIs	application programming interfaces
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BIWTA	Bangladesh Inland Water Transport Authority
BTM	Bangladesh Transverse Mercator
BUTM	Bangladesh Universal Transverse Mercator
CEGIS	Center for Environment and Geographic Information Services
CORS	Continuously Operating Reference Station
DBMS	Database Management System
DEMs	Digital Elevation Models
DORIS	Doppler Orbitography and Radio-positioning Integrated by Satellite
EDMI	Electro-optical Distance Measuring Instrument
EDM	Electronic Distance Meter
GCP	Ground Control Point
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
IERS	International Earth Rotation and Reference Systems Service
ITRF	International Terrestrial Reference Frame
LCC	Lambert Conformal Conic
LGED	Local Government Engineering Department
MADTRAN	Mapping Datum Transformation
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIF	Near Infra-red

NSDI	National Spatial Database Infrastructure
OGC	Open Geospatial Consortium
RTK	Real Time Kinematic
SDE	Spatial Data Exchange
SOB	Survey of Bangladesh
SQL	Structured Quarry Language
USGS	US Geological Survey
WGS	World Geodetic System
WARPO	Water Resources and Planning Organization

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Chapter 1

Introduction

1.1 Background of the study

Bangladesh, occupies the major portion of the Ganges Delta in the northern apex of the Bay of Bengal. Substantial parts in the east of the country incorporate some tertiary hills and the middle north and north is occupied by elevated tracts known as the Pleistocene terraces. The process of delta formation here started billions of years ago with the mountain building movement that created the Himalayan mountain systems. In fact much of the northern Indian alluvial plain occupied by Ganga-Brahmaputra catchment area – the states of Uttar Pradesh, Bihar, West Bengal of India and Bangladesh has been created by the filling up of the Gangetic Geo-syncline over millions of years that have resulted from the Himalayan Orogeny. Delta building processes near the confluence of Ganges, Brahmaputra and Meghna have still been continuing. Each year, large areas of land are formed by alluvial deposition in the Meghna estuary and along the active floodplains of the rivers Jamuna, Ganges and lower Meghna. This whole milieu of the highest mountain systems, largest river systems, the vast flood plain system worked on by the elements of the changing climatic systems have modified the life and livelihood of the population of the region. People designed their life and livelihood adapting to the dictates of the physical nature and the physiography of the country.

Study of this struggle for adapting to the challenges of physiography is expressed in the changing topographic features of the region. Each of the feature's present profile is the result of the long term interaction between the components of the milieu that has been referred to above – the mountains, the shore lines, the rivers, the flood plains and the people make the region's topography. This research in its attempt to understand the human adaptation process focuses attention to the changes in topography of the region. The topographic changes of various times are recorded in the topographic maps produced by the country's main map-making agency the 'Survey of Bangladesh' (SOB). This research takes up a map study based approach for comparing the topographic changes over time. In doing so the research concentrates on the topographic maps and the map making processes followed in this country. A review of the activities of the Survey of Bangladesh over the last half century, thus becomes imperative. In doing so the research concentrates on the validity and reliability of the topographic maps and making processes followed in this country by studying the activities of the Survey of Bangladesh over the last half century.

1.2. Characteristics of Topographic Maps

A topographic map is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines but, historically, using a variety of methods. Traditional definitions require a topographic map to show both natural and man-made features. A topographic map is typically published as a map series, made up of two or more map sheets that combine to form the whole map. A contour line represent elevation on a topographic map and is a combination of two line segments that connect but do not intersect. Topographic maps along with other maps of different demographic and cultural information provide the context of the human livelihood. It provides the visual evidence of how humans manipulate the natural resources that the earth provides them to make his living. By providing contextualization of data and information, specifically for locating socio-demographic information in relation to the locale over the surface of the earth that it occupies maps become essential for understanding earth - human spatial relationships. These earth - human spatial relationships are critical to any study as human development geography.

Topographic maps are a summary of the landscape and show important physical (natural and man-made) features in an area. Characteristics of topographic maps include: a) representation of i) physical relief features including elevations through the use of contour lines; ii) human settlement features (roads, cities, buildings etc) through the use of symbols; iii) other thematic information such as vegetation or the boundaries of national parks; b) they are typically i) produced by government agencies – these are often specialist mapping agencies and may have either a civilian or defense purpose and have ii) well defined standards (called specifications) which are strictly adhered to – these vary between mapping agencies and the scale of the map iii) have very good location reference systems – including latitude and longitude, but may also have grid lines vi) often have additional information such as an arrow pointing to Magnetic North as well as True North. Topographic maps are usually part of a series of maps, but may be one-off/stand-alone maps. An example of topo-map is shown at Figure 1.1 below.

Figure 1.1 : Example of Topo-Map

Source : Survey of Bangladesh

In Bangladesh modern topographic mapping technologies have been introduced by the British in the mid 18th century as part of the effort to map the whole of the interior of the empire under the auspices of the organization the Survey of India. Topographic survey activities in Bangladesh up to 1947 remained under the Survey of India. Bengal at that time was geographically much larger and all survey activities in the British eastern provinces of India were coordinated from Bengal. After 1947, Bangladesh as the eastern province of Pakistan became part of Survey of Pakistan. The Survey of Bangladesh came into existence in 1971 with the emergence of independent Bangladesh. The topographic mapping technologies in Bangladesh have thus seen two major transitions, the analogue mapping techniques of the British-Indian/Pakistan/Bangladesh Period (up to the 1980s) and the Bangladesh Period digital mapping techniques since the 1990s to the present times.

The following section presents a very brief account of the antecedent history of the Survey of Bangladesh tracing its, British and Indian roots. The narrative is mainly based on a volume of Historical Records of the Survey of India by Phillimore, R. H. (1945), and a review of activities of Survey of India by Roy, R.D (1986).

1.3 Antecedents of Survey of Bangladesh

Topographic mapping through actual land survey was started by the British in Bengal in 1760. The first opportunity for any regular survey came however in Bengal where as a result of the victory at Plassey, the English Company obtained the grant of the 24 – Paraganas and a close alliance with Nawab of Bengal; and then in 1760 they obtained from the Nawab the further grant of the province of Chittagong, Burdwan and Midnapore , practically the whole of the lower Bengal.

Knowledge of the geography of Bengal was at this period practically confined to the banks of the Ganges and Hoogly rivers. Surveys of the new possessions were ordered by the local council, and encouraged from London. The first thought was to ascertain the extent of cultivated lands and the value of their revenues; then there was the safety and regularity of communication, both by sea and through rivers and then the defense of the passes of the western frontiers.

Plaisted was put on to survey the coasts of Chittagong and the sundarbans, and Hugh Cameron to survey "the New Lands" of 24 paraganas. On Cameron's death in 1764, James Rennell was appointed surveyor in his place, but deputed to survey of the Ganges River and search for a waterway for up-country traffic from Calcutta that should be navigable throughout the year. Early in 1765 De Gloss was appointed to survey the Burdwan district and then as the defence of the western passess became an urgent matter, one surveyor after another was appointed, either by the Council at Fort Williams of by the commander of the forces on the frontier.

In 1765 Clive returned to Bengal for his second term of office and having been specially asked by Robert Orme, the historian to make him "a vast map of Bengal", commissioned Rennell to carry out this task.

Rennell set about his work with so much enthusiasm and ability, showing a positive genius for putting maps together, that Clive and his council made him Surveyor General from the beginning of 1767, and placed all available surveyors under his orders. Some of these were engineer officers and a few were infantry officers, who had a taste for the work; amongst the latter was the Frenchman Claud Martin, who became famous in after years as the founder of the "La Martiniere" schools.

The necessity for a proper marine survey of the coasts and islands was not overlooked and Ritchie was appointed marine surveyor after Plaisted's death and made a complete survey of the coasts from the south of Chittagong, round through the Sundarbans and down the east coast as far as Madras.

By 1773 Rennell and his surveyors had completed the survey of the Company's possessions in Bangal and Bihar which now extended to the frontiers of Oudh and Allahabad on the west and to the southern jungles of Chota Nagpur and the forests of Orrissa on the south. To the north-east Rennell had himself surveyed the Brahmaputra River as far as the Assam frontier near Goalpara in 1765 and the survey now extended to the foot of the Garo and Khasi Hills and embraced the whole of Sylhet and Chittagong.

By early in 1774 he submitted to the Government a complete set of provincial maps on the scale of 5 miles to an inch, together with general maps on smaller scales. Thanks to the strong start given to him by Clive and also to his own clear view of what could be done with the available men, instruments and time Rennell succeeded in giving Bengal and Bihar inside the comparatively short period of 12 years, a continuous and uniform set of maps. The survey was far from Complete or accurate in detail, but showed the general geography of the whole country and the more important features with sufficient accuracy for the needs of the time.

The British rulers in India came to understand that they should conduct extensive surveys of various types over the territories which they acquired either by conquer or by cession. It was essential for them to have a complete geographical knowledge of the country for their revenue and administrative purposes. Three main branches of land surveys conducted by the East India Company in India were (a) revenue surveys, (b) topographical surveys and (c) trigonometrical surveys which threw voluminous information about the land and the people of the country.

In the south of India, after the fall of Seringapatam in 1799 Lord Wellesley felt the necessity of exploring and collecting information of the newly conquered vast territories. Three streams of surveys started almost concurrently. Francis Buchanan started a general agricultural survey of Mysore and Malabar. Topographical and trigonometrical surveys were led respectively by Colin Mackenzie and William Lambton.

William Lambton, a geographer as well as a geodesist correctly understood that accurate maps of a large country could be obtained only through geodetic surveys. William Lambton submitted his plan for a Geographical and mathematical Survey in 1799 and started working in 1802. By 1815 Lambton was able to measure a large number of baselines with a network of triangles covering the country up to 18 degree latitude. The total area surveyed by Lambton was 165,342 square miles.

George Everest joined the trigonometrical survey in 1818. After the death of Colonel Lambton in 1823 he became the Superintendent of the Great Trigonometrical Survey. He measured the Beder base line to connect Bombay and Great Arc from Cape Comorin to the Himalayan Mountains. He improved the methodology of surveying by introducing the use of luminous signals at night instead of flags and beacons by day and also the gridiron system which replaced Lambton's laborious method of throwing a network of triangles. He became the Surveyor General of India in 1830 and was succeeded by Andrew Waugh in 1843. Triangulation of a vast region between the Great Arc and Calcutta was completed by Waugh. He also measured the north-eastern Himalayan series and determined the heights of 79 Himalayan peaks and the names the 15th peak as Mount Everest.

1.4. Research Objectives:

Given the discussions above on the importance of topographic features on life and livelihood of the people the present research intends to investigate the changing pattern of selected large scale topographic features of the country over the last hundred years since the field survey based topographic map making started in this region under the auspices of the British. The main objective of this research is to:

a) detect the changes in selected topographic features over time using the topographic mapping technologies of the two different times;

b) is to trace the evolution of the Topographic Map- making technology in Bangladesh during the two distinct period identified above; and

c) is to design a methodology to merge the topographic map making technology of the two periods and to use the same to study the topographic changes in selected topographic features.

Specifically the following objectives will be pursued:

1. review the topographic map making process in analog era of British Indian/Pakistan/Bangladesh period and generate topographic profile of river network, natural forest distribution and the shorelines;

2. review the topographic map making process in digital era in Bangladesh and generate topographic profile of river network, natural forest distribution and the shorelines;

iii) detect and measure the amount of changes in the river network, the natural forest distribution and the shorelines from the earlier to the latter period.

1.5 Methodology

The research on the evolution of the Topographic Map- making and Map-making Technology in Bangladesh was accomplished, following an elaborate data collection procedure that included both primary and secondary data collection procedures. The historical data for reconstructing the story of the evolution of topographic map making in this country mainly came from the various sources:

1. internal documents of Survey department at various times (see below);

2. the publications/hand books about mapmaking in the British Indian Subcontinent (Philmore , 1945; Ahmed, 1984; Hunter, 1911; SOI, 1911, 1935, 1947; Dev, 1986);

3. key person Interview of selected number of very experienced SOB Surveyors; About a dozen of experienced Surveyors and Drafts men were interviewed both serving and retired who have practical experience working on ground. They came up with old manuals, pamphlets, handouts and personal notes that they preserved at their individual archives. The key informants persons were from various discipline of SOB like Geodetic section, Photogrammetric section, GIS section, Cartographic section as well as field surveyors. They have on ground experience of both analog and digital map making technique in their

individual subjects. They were thoroughly interviewed in order to fill up the gaps that were experienced in the theories as well as the customization that were practiced at SOB in making topographic maps.

4. Valuable information also obtained from the study of old survey instruments. The study of survey instrument, yielded significant information about the map making culture that evolved in the region starting from the earliest days of map making.

5. The selected topographic features, the river network, the natural forest distribution and the shoreline profile of the two periods were prepared from the individual topo-sheets of respective periods following methods described below.

Data Sources: The couple of choices have been considered as published sources of collecting geospatial data of Bangladesh and they are:

Government data authorities:

Survey of Bangladesh (SOB)
Water Resources and Planning Organization (WARPO)
Center for Environment and Geographic Information Services (CEGIS)
Local Government Engineering Department (LGED)
Department of Forest etc.

International Geospatial data portals:

NASA (http://edcdaac.usgs.gov/main.html)
USGS (http ://usgs.gov)
ASTER (http://www.gdem.aster.ersdac.or.jp/)
Landsat (http://www.landsat.org/)
MODIS () etc.

Data Collection: The study uses data from various secondary sources as well as satellite images from different sensors. The details of the collected data are given below:

Topographic Map: Series of topographic maps has been used in the research.

1: 10000 scale topographic map (1961-1975). Total number of sheet used are approximately 1400.
1: 15840 scale topographic map (1998-2000). Total number of sheet used are approximately .
1: 50000 scale topographic map (2000-2010). Total number of sheet used are 267.
250,000 scaled topographic maps of recent decades [2000 to 2011].
250,000 scaled topographic maps of 1940s.
500,000 scaled topographic maps of recent decades [2000 to 2011].
500,000 scaled topographic maps of 1940s.

Aerial Photo:

50 cm resolution colored aerial photo of 2010/11 of SOB has been used to delineate shore line of Bangladesh which is used as calibration data to compare with the 250k shore line data used for this study.

Details of collected data from Survey of Bangladesh: Following maps are used as shown at Table 1.1 below:

Table 1: 1:250000 Maps used in this Research

Series	Publishing Year	
	New Map	Old Map
78B	2000	1944
78C	1975	1942
78D	1995	1946
78F	1993	1943
78G	1993	1946
78H	2002	1946
78K	2001	1955
78L	2001	1944
78O	2001	1954
78P	2001	1955
79A	2001	1927
79B	2000	1944
79E	2000	1956
79F	2001	1941

Series	Publishing Year	
	New Map	Old Map
79G	2000	1941
79I	2002	1958
79J	2001	1955
79K	2001	1946
79M	2000	1955
79N	2000	1944
79O	2002	1943
83C	2001	1933
83D	2002	1943
84A	2001	1956
84B	2002	1958
84C	2000	1959
84D	2000	1956

Source : Self Prepared

According to the above table, the average of the old map series year is 1948, for this reason I mentioned in this thesis 40/50s years map, similarly for new map series mentioned 1990-2000 because of average value.

Collection of Satellite Images:

Two types of satellite image are considered in this study.

MODIS satellite (Terra sensor) images: MODIS (or Moderate Resolution Imaging Spectro-radiometer) instrument has been designed and developed since the Engineering Model (EM) was completed in mid-1995. Terra MODIS is viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands. These data helps to understand of global and regional dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

Specification of MODIS Satellite:

Orbit:	705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular
Scan Rate:	20.3 rpm, cross track
Swath Dimensions:	2330 km (cross track) by 10 km (along track at nadir)
Telescope:	17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop
Size:	1.0 x 1.6 x 1.0 m
Weight:	228.7 kg
Power:	162.5 W (single orbit average)
Data Rate:	10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
Quantization:	12 bits
Spatial Resolution:	*250 m (bands 1-2)* *500 m (bands 3-7)* *1000 m (bands 8-36)*

The study considered all the images of 2001 and 2011 of this satellite. Calculating NDVI of this image forest changes can be compared.

Landsat satellite (Sensor TM4, TM5 and ETM+) images

The Landsat program is the longest running enterprise for acquisition of satellite imagery of Earth. These satellites have taken specialized digital photographs of Earth’s continents and surrounding coastal regions for over three decades, enabling people to study many aspects of our planet and to evaluate the dynamic changes caused by both natural processes and human practices.

The following years images are considered for the study

Year	Sensor	Bands	Resolution
1977-78	Landsat MSS	4	60m
1990-91	Landsat TM4 and TM5	6	30m
2000-01	Landsat ETM+	7	30m
2010-11	Landsat TM5	7	30m

Data Collection Workflow:

The key part of data collection is *planning* that includes establishing research requirements, garnering resources, and developing a research plan. According to the research objective, the main idea of the study is to use geo-information technology and in this regards, the study considered to collect geospatial data in the form of hardcopy maps and softcopy digital data.

From the government sources, data has been collected either hardcopy or soft copy and in some cases both. To make digital version of data, hardcopy of maps are scanned for *geo-reference* and *digitization*.

There are many cases of the collected data involves *redrafting* poor-quality map sources, *editing* scanned map images, removing noise, setting up appropriate GIS hardware and software systems to accept data.

Data format:

One of the biggest problems with data obtained from external sources is that they can be encoded in many different formats. Though many tools have been developed to move data between systems and to reuse data through open application programming interfaces (APIs).

OGC (Open Geospatial Consortium) is a group of vendors, academics, and users interested in the interoperability of geographic systems and they ensures data translation software that must address both syntactic and semantic translation issues.

In Bangladesh most of the geospatial data considered customized Transverse Mercator (e.g. BTM, BUTM), UTM (Zone 45 and 46), Lambert Conformal Conic (LCC) using ellipsoid Everest 1830 and WGS 1984 and storing format is shapefile (ESRI owned), Coverage (ESRI owned), DXF, DWG (CAD file). However, in this research, shapefile and file-geodatabase (gdb) are considered storing format of vector data and for raster data storing format considered tif and img.

Raster Data Capture:

Remote sensing is a technique used to derive information about the physical, chemical, and biological properties of objects without direct physical contact. One of the main objective of the study is to identify changes of land morphologies and this is why remote sensing technique is used in this research. Using this technique, information is derived from measurements of the amount of electromagnetic radiation reflected, emitted, or scattered from objects.

Remote sensing data often called raster data can easily compare and show the spatial and temporal characteristics however, in this research the kind of data are not directly considered to process and analysis for finding.

Vector Data Capture:

Since, there is no temporal vector (digital) data available from any government and private sources, so it is required to make vector data for my study. According to my research objective, here I considered 250K maps to convert vector maps. This research did not consider all topographic features. The following features created for the study:

Major Rivers of the country
Approximate Forest area
Coastal Line
Char and Islands
After geo-reference of topographic and other maps, only selected (target object) objects are captured as vector data through digitization process. Apart from this, raster data are converted to vector data, like major rivers and vegetation data are converted to vector data to compare and analysis.

Data Harmonization

The collected data from different sources consist different *storing formats*, used different *coordinate systems*, used different *schema* etc. Harmonization of these data is one of the main challenges of the study. Digitizing and *transfer* to target format and storage are the stages where the majority of the effort is expended. Editing and improvement covers many techniques designed to *validate* the data, as well as to correct *errors* and improve *quality*.

Customized Universal Transverse Mercator (UTM) projection system which is established by Survey of Bangladesh recently has been considered in this research. The parameters are given below:

Projection Name: Bangladesh Universal Transverse Mercator (BUTM)

Projection System: Transverse Mercator
Scale Factor: 0.9996
False Easting: 500000
False Northing: 0
Center of Meridian: 90.0000 E
Center of Origin: 0.0000
Datum: WGS 1984

Topographic Map Geo-referencing:

ArcGIS Desktop has been used to georeference all scanned maps through using ‘Georefenencing Tools’. In the following snapshot how the collected maps are referenced that depicted the procedures like control points creation, RMS error (in 250,000 map 12 meter RMS error is definitely well acceptable), etc.

Figure 1.2 : Georeferencing Tool in ArcGIS

Source : ArcGIS 10.1

The collected topographic maps were Everest 1830 datum based, there for all the maps firstly scanned in good resolution then projected into its original projection system. After that all the maps required to mosaic and finally re-projected using datum transfer values into the above mentioned coordinate system. The above process helps to minimize the projection error for the study. In this georeference process, datum translation place important issue to edge match, comparison to other projection data etc.

Justification for choosing the selected satellite data:

In this research, the AOI considered country level mapping which in fact refers small scale map analysis (50,000 to 250,000 map-scales). This is the reason the research does not require high resolution images. The research needs to analyze change detection based on past data as possible. The high resolution images are not available in free of cost and also not cover whole Bangladesh database in past.

Geo-rectification Process of Satellite Image:

The collected (free downloaded) images are pre-projected in UTM system with WGS 1984 datum. It only required re-projection or transformation to target projection system as shown at Figure 1.3 below.

Figure 1.3: Projection Parameters in ArcGIS

Source : ArcGIS 10.1

The properties of one Landsat TM5 satellite image shows its default projection values. In my research I have considered customized Transverse Mercator means where only central meridian was needed to change (93 to 90 or 87 to 90 degree) and rest of the values will remain same.

Mosaicing of Satellite Image:

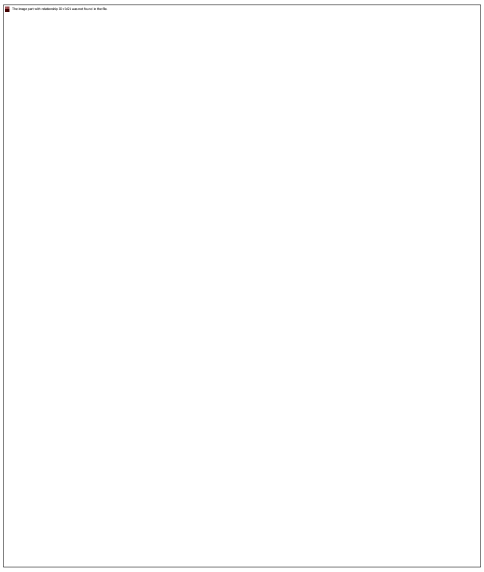
Mosaic pro of ERDAS Imagine module has been used to mosaic all the scenes required to make full country image which is shown at Figure 1.4 and Figure 1.5 below .

Figure 1.4: Moasic in ERDAS Imagine

The image part with relationship ID rId20 was not found in the file.

Source : Moasic Pro in ERDAS Imagine

Figure 1.5: Image Moasic covering Bangladesh



Source : Self Prepared

Training data collection/Signature creation:

After visualization of satellite image, manually digitize the target object as an AOI (Area of Interest) which has been shown at Figure 1.6 below.

Figure 1.6: Digitizing Area of Interest

Source : ERDAS Imagine

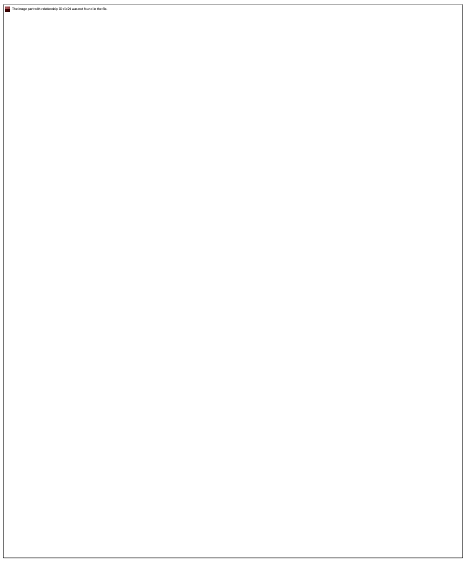
Feature Space is also used to create signature. To extract water features from Landsat TM image band 2 and band 5 combination gives excellent output considering the lowest values of the bands. The following picture at Figure 1.7 below shows the result of the process I considered.

Figure 1.7: Feature Space use to Extract water

Source : ERDAS Imagine

Using the feature space signature the following picture at Figure 1.8 below shows the result of extracting water bodies.

Figure 1.8: Result of Extracted Water

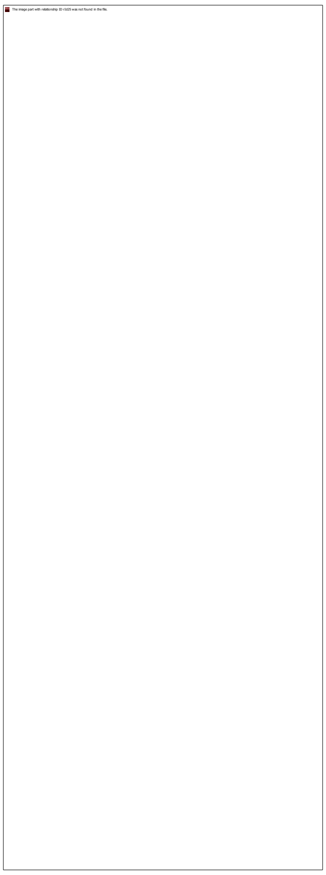


Source : Self Prepared

Data Process:

On screen digitization, editing, edge matching, topological correction, polygon generation etc. are the key data processing steps for vector data extraction. On the other hand signature creation, supervise classification, accuracy assessment, raster clumping, raster to vector conversion, smoothing and generalization steps are important steps for raster data process. These are described below at Figure 1.9 up to Figure 1.13 graphically in the form of flow charts.

Figure 1.9: Raster Data Processing



Source : Self Prepared

Figure 1.10: Conceptual Overview Of Methodology Chart

The image part with relationship ID rId26 was not found in the file.

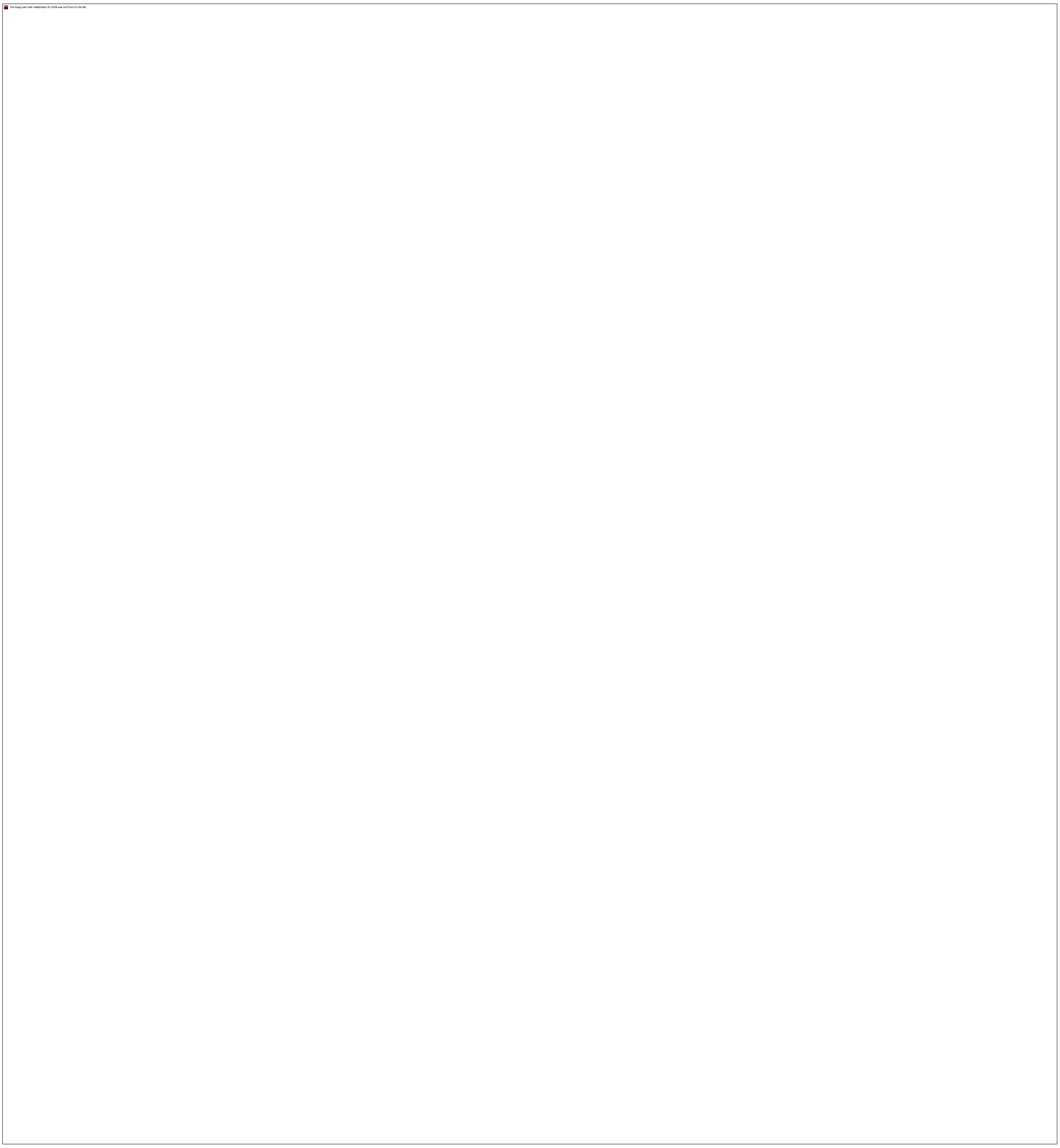
Source : Self Prepared

Figure 1.11: Data Collection Chart

The image part with relationship ID rId27 was not found in the file.

Source : Self Prepared

Figure 1.12: Data Processing Chart



Source : Self Prepared

Figure 1.13: Data Analysis Chart

Source : Self Prepared

After creation of temporal vector data using all mentioned steps above finally geoprocessing steps will generate comparison maps and tables to represent and results for further analysis.

One of the key geoprocessing function IDENTITY I have used number of times that computes geometric intersection of the input features and identity features. The input features or portions thereof that overlap identity features will get the attributes of those identity features.

Pivot table analysis provides the results of identity database created from geoprocessing operations. The picture below at Figure 14 shows how the data has been summarized.

Figure 1.14: Pivot Table Analysis

Source : Self Prepared

Calibration: The selected three features i.e. river, forest and shore areas have been digitized/extracted manually from two periods of 250k maps. Any kind of error either random or systematic in the entire process will have great impact in analyzing data for change detection. In order to detect major mistake in manual process if any, the extracted data has been verified comparing with other available data as described below:

a. River layer of 250k map has been verified against river layer extracted from Land sat TM5.

b. Forest layer of 250k map has been verified against forest layer extracted from Land sat TM5.

c. Shore area of 250k map has been verified against shore area extracted from latest orthophoto (2010/11) of SOB, 10k and 15k maps.

1. Justification of the Study

Survey of Bangladesh (SOB) is the only topographic map making national organization in Bangladesh. Only this organization possess map of different scale covering entire country. Due to security reason access to these maps are limited. Although the restrictions are relaxed recently, it is yet to be widely circulated as such hardly known to the public and researchers. Emergence of google as a favorite web site played significant role behind relaxing the restrictions.

The writer of this research paper had access to these data and found it to be an excellent opportunity to compare between old and new maps in order to detect changes on major features that had taken place through ages. This would be certainly a new research that could not be undertaken by any other researchers due to accessibility problem. The writer has also got adequate knowledge and experience of whole range of mapping for last 15 years serving in SOB. The experience covers both analog and digital surveying and mapping.

SOB has recently introduced WGS84 as its map datum with UTM projection called BUTM2010 and its geodetic reference system as ITRF called ITRF08. This will enable the surveying and map making process faster and cost effective by directly acquiring GPS data as mapping and surveying input. This will also make our map data compatible with regional and global data and data exchange will be easier for various purposes like disaster management, crime prevention, counter terrorism, etc. Previous datum of old maps was in Everest1830 datum with LCC projection. In this research, all data has been converted to WGS84 datum with BUTM2010 projection so that it work as a common platform for other researchers to use these data for further researches and input can be given directly from GPS in this GPS era.

250k maps have been selected for comparison in this research. Reason is that whole set of maps covering entire country were available covering both the periods that have been chosen for this research. Features like river, shore area and forest needed to be extracted in vector format by digitizing in GIS software for data processing and analysis purpose. This manual digitizing is a tedious and time consuming process and would not be possible to perform within research period, hence a larger scale map been selected. As an example, SOB took 15 years' time digitizing 50k maps of entire country employing 30 operators. However, SOB digitized all features where I digitized three features. 250k map is more generalized than larger scale maps and thus suitable for comparison of features covering entire country using GIS as selected for this research. Authentication of this map is also cross checked by overlaying on satellite image and seemed reasonably accurate for this research. The old maps of 1940s could not be cross checked due to nonexistence of any satellite image of that period, however, we may presume that those were the most authentic map of that time since prepared by only national mapping agency of the time.

Chapter 2

British Indian/Pakistan/Bangladesh Period Analogue Topographic Mapping in Bangladesh

2.1 Introduction

This chapter presents a review of the topographic mapping activities in Bangladesh during the analogue period of the Survey of Bangladesh. In order to accomplish this chapter first provides a very brief introduction to the countrywide survey activities that were undertaken during early part of Survey of Bangladesh's history. Then it reviews the topographic survey technology that has evolved over the years since its emergence from its roots within the Survey of India. The review of the analogue survey technology begins with the early efforts in setting up of an elaborate cadastral survey network that includes the establishment of the first Geodetic Control Network of the country, the details of the Triangulation methods followed, the introduction of the Theodolite traversing methods, the introduction of Air Survey Photogrammetry techniques, the Plane Tabling methods and finally the procedure for fair drawing of the survey output Topographic Maps follows with some discussion on spheroids an projections used at that time. Then it highlights on the significant achievements made by SOB in its analog era. Finally, three composite maps of the three study topographic features, the river networks, the forest distribution and the country shore lines are generated.

2.2 Countrywide Analogue Survey and Mapping

Since the 1767, through this century, all cartographic works in this country had basically been carried out by the Survey of Bangladesh (SOB). The government survey department started its journey as "Bengal Survey" in 1767 in British India and conducted surveying and mapping activities till 1947. After the partition of the sub-continent on 14th August 1947, `Survey of Pakistan' was created and established its Deputy Surveyor General (DSG) office at Dhaka. This DSG's office was transformed into `Survey of Bangladesh' when Bangladesh emerged as an independent state in 1971.

The importance of mapping in the subcontinent came into focus first at the time of Sultan Sher Shah (1540-45). He introduced measurement of lands and a regular system of assessment and collection of revenue. But the first real step towards accurate assessment based on a comprehensive survey of land and the establishment of one uniform standard of measurement was, however, achieved by Emperor Akbar's revenue and finance Minister, Todar Mall (1571-82). Because of his assessment policy, the land revenue representing of the Suba (province) of Bengal, Bihar and Orissa increased substantially.

Todar Mall's system of assessment was in practice until 1765 when the English East India Company assumed control of the revenues of Bengal. No change was made in the existing system till 1769, when supervisors were appointed to monitor the collection of revenue by the Bengali officers of the former regime. In 1772, the former supervisors were converted into collector of revenue in districts.

When Warren Hastings took over as Governor General of India, he introduced a system in which the estates were offered to farmers making the highest bid for five years. In 1784, Pitt's India act was passed in British Parliament. The Act required the government of India to enquire into the condition of landlords and establish permanent rules for collection of revenue founded on local laws and usages of the country.

In 1786, Lord Cornwallis came to India with a letter from the East India Company directors, recommending 'a permanent settlement of a reasonable and fair revenue to be the best, for the payment of which the hereditary tenure of the possession is to be the only necessary security'. At first, a decennial settlement was made for ten years in 1789-90 with the actual collectors of rent of all denominations, viz Zamindars, independent Talukdars, and other lessees. However, in 1793, the terms of the decennial settlement were made permanent by Regulation 1 of 1793, which were unalterable and fixed forever. The permanently settled areas were about 91% of the total area (56,977 sq mile) of present day Bangladesh. As the cultivation expanded, rents were collected by Zamindars for lands, which were often not actually covered by the permanent settlement. Then the theme of Parganas came and later several surveys were conducted as shown below (BANGLAPEDIA, National encyclopedia of Bangladesh).

The Major Survey Operations in Bangladesh: The major survey operations conducted in the Bangladesh territory so far are the:

1. Thakbast Survey (1845-1877);
2. Revenue Survey (1846-1878);
3. Khasra operations (1841-1854) and
4. Diara Surveys (1862-1883). The following provides a brief summary of each of these surveys:

1. **Thakbast Surveys** were conducted in 1845-1877 for demarcating the MOUZA (also loosely called village) boundaries and ascertaining the rural resources of Bengal. *Thak* is a Persian word meaning boundary pillar. Bengal *mouza*s had no precise legal boundaries until this survey. Mouza boundaries were hitherto defined nationally in terms of natural marks like *nalas* or creeks, old trees, rivers, marshes, jungles, roads, other mouzas and so on. Such a system worked well in the past when population was scarce and the man-land ratio was in favor of man. But in the late 19th century, when pressure on land increased significantly, such a system became the cause of frequent boundary disputes and litigation. Besides, hitherto, rents were assessed on the basis of custom and past records only. Never was any survey made for ascertaining the actual resources of estates. Getting to know the village resources more accurately on the part of the colonial state was, therefore, a necessity both from administrative and revenue considerations.

The success of the *Thakbast* surveys in the Northwestern Provinces had inspired the authorities to undertake them in Bengal districts also. The operation was begun in 1845 and completed in 1877. The object of the operations was to demarcate mouza boundaries, estate boundaries within the mouza, assess landed and other resources, identify various types of landed interests, chart out geographical and topographical features by scientific mapping of all mouzas, parganas and districts. A mouza was the unit of the Thak survey. A sketch map, in some districts scaled, was compiled for every village showing the estates, households, fields, crops grown, population and physical features. Every village was given a Thak number as a reference. Based on the findings of Thak surveys revenue surveys were conducted subsequently.

2. **Revenue Survey** (1846-1878) The revenue surveyor commenced his work with the data available from the preceding thak survey and the marks on the ground. The objectives of the revenue survey were to make accurate maps of the village boundaries and, sometimes, of the estate boundaries, showing topographical details, compiling certain statistical data for general

administrative purposes, and making maps (usual scale: 4 inches = 1 mile and 1 inch = 1 mile) of each village and pargana. The details of a village were shown and the origin upon which the whole work was based was, theoretically, a station of the Great Trigonometrical Survey (1840-1865). The details of the survey may be viewed under two heads: (a) boundaries and (b) topographical details. The interior details may be considered as accurately surveyed, because the traverse stations gave ample points and bases, from which details could be mapped. This is because the most correct work in revenue survey was the traverse work. It is only the traverse points, which should be accepted for relaying work, but only if they can be located. The revenue survey measured the whole surface of the country and allotted all lands to one village or another under a specific number. The results of the revenue survey were normally used for preparation of 1inch =1 mile pargana maps. These maps were used later by the surveyor general for making 1 inch to 1 mile-maps of a district and for compiling the atlas of India on the scale of 4 inches to 1 mile.

3. **Khasra operations** (1841-1854) It was customary for khasra operations to be carried out in temporarily settled tracts, and also in those permanently settled lands in which interests were so interfaced as to make it impossible or unduly expensive to show field details upon the thak maps or thakbast papers. The common scale used was 16 inches to 1 mile. The details collected were generally field (plot) number, tauzi number in the collector's rent-roll, name of the estate, proprietor's name, cultivator's name, plot details and areas, crops grown, etc. Khasra maps were not often made and, where made, these were mostly inaccurate and incomplete. From a khasra survey, it was but a short step to the modern cadastral maps. The existing cadastral system was first employed in large scale in the seventies of the last century in the United Provinces (now Uttar Pradesh of India); then it spread to Bengal including Eastern Bengal (now Bangladesh). The system was first introduced in Bengal by Col JR Sandeman. The system employed in Eastern Bengal surveys was substantially that used by him as the first director of Bengal surveys, modified to existing conditions by Lt Col RT Critchton, who was director of surveys in West Bengal, Bihar and Orissa.

4. **Diara surveys** (1862-1883) Under the provisions of Act IX of 1847, diara surveys on the scale of 4 inch to 1 mile were carried on in the beds of the Ganges and other large rivers of the province. These surveys were carried out to provide a basis of assessment of land, which had formed since the decennial settlement of 1789. The results of diara surveys are helpful in making accurate comparative maps, which can be made to show revenue, diara and modern boundaries geographically. The importance of this work cannot be overrated, because it is very often the true

basis of settlement of riverbed disputes. As far as Bengal is concerned, the whole of the Ganges and some other rivers in northwest Bihar were surveyed professionally in 1862-65.

2.3 Establishing Modern Cadastral Survey Infrastructure

Establishment of Survey Control Points: The control points in Bangladesh were originally established by the Survey of India at the beginning of the nineteenth century. Because of the triangulation chains adopted for the control point surveying, the control points were not evenly distributed throughout the country. Consequently, a large blank area where no control points were installed was found especially in the northeast region and in the northwest region as well and the same blank area was also left in the southwest region. The national geodetic control network created by the Survey of India in the 18th century lacked geodetic datum, vertical datum and tidal stations necessary for determining the national geodetic plane. It was also observed that because the control points have been poorly and insufficiently maintained, they have been left exposed to natural or artificial damages and most of them have been lost or missing. Even what have been surveyed has shown a marked functional deterioration in terms of accuracy. The bench marks were found to have been far more seriously damaged than the control points in terms of accuracy with the passage of time as well as in the number of what have been lost or ruined.

Establishment of National Geodetic Control Network: The partition of India-Pakistan in 1947 caused the horizontal datum station as well as the vertical datum stations that were later set up by Survey of India, to have been left behind in India. For that reason Bangladesh have never had an opportunity of having datum stations of its own since then. From 1947 till 1990, Survey of Bangladesh continued its survey and mapping activities with those remnant geodetic control points. The number of surviving horizontal control points were about 70 and the number of vertical control points about 100 in 1990.

The production of topographical maps and various kinds of civil engineering and construction projects encountered a great deal of difficulties in Bangladesh for the above reasons. Therefore greatest and the most urgent issue for Bangladesh was to reestablish its geodetic network. The Survey of Bangladesh regarded the reconstruction of the devastated geodetic system as the greatest and the most urgent issue for Bangladesh and had started a project in the year 1990 aimed to reestablish the geodetic system in Bangladesh on a scientific basis, including the determination of a horizontal datum station, a vertical datum station and mean sea level and the installation of control points and setting up bench marks throughout the country. Funds and expertise was received from the Japanese government.

Geodetic network consists of horizontal and vertical network. Horizontal network consist of latitude longitude (X,Y) coordinates on nationwide spread monuments called GPS monuments, also known as ground control points(GCP). In analog era these used to be observed by triangulation method. Triangulation points used to be observed by constructing towers (60-90 feet high) of bricks called 'Buruz' or prefabricated iron angles called 'Bilbi' tower. Base length used to be measured using survey chains. Later on, theodolite traversing was introduced where baseline distance used to be measured by electro-optical distance measuring instrument (EDMI) called Tellurometer, Tellumate,etc using 'Helio', a kind of sun light reflector at day and Hazack light at night placed on the other tower. 20 to 25 km was possible to be measured in this way if the line of sight was clear. Angle used to be measured by theodolite, Wild T3 by SOB. Later on, Total Stations were introduced which can measure both angle and distance up to 5 km. For measuring more than five km distance, electronic distance meter (EDM) is still the answer.

Survey Instruments: A significant no of analogue instruments are still preserved at SOB archive revealing history of those days map making. Only some pictures with name and brief description are give below for a curser idea which will be more clear at the latter stage.

Figure 2.1: Wild Theodolite

Source: Survey of Bangladesh archive

Name of equipment: Analogue Theodolite

Brand : Wild

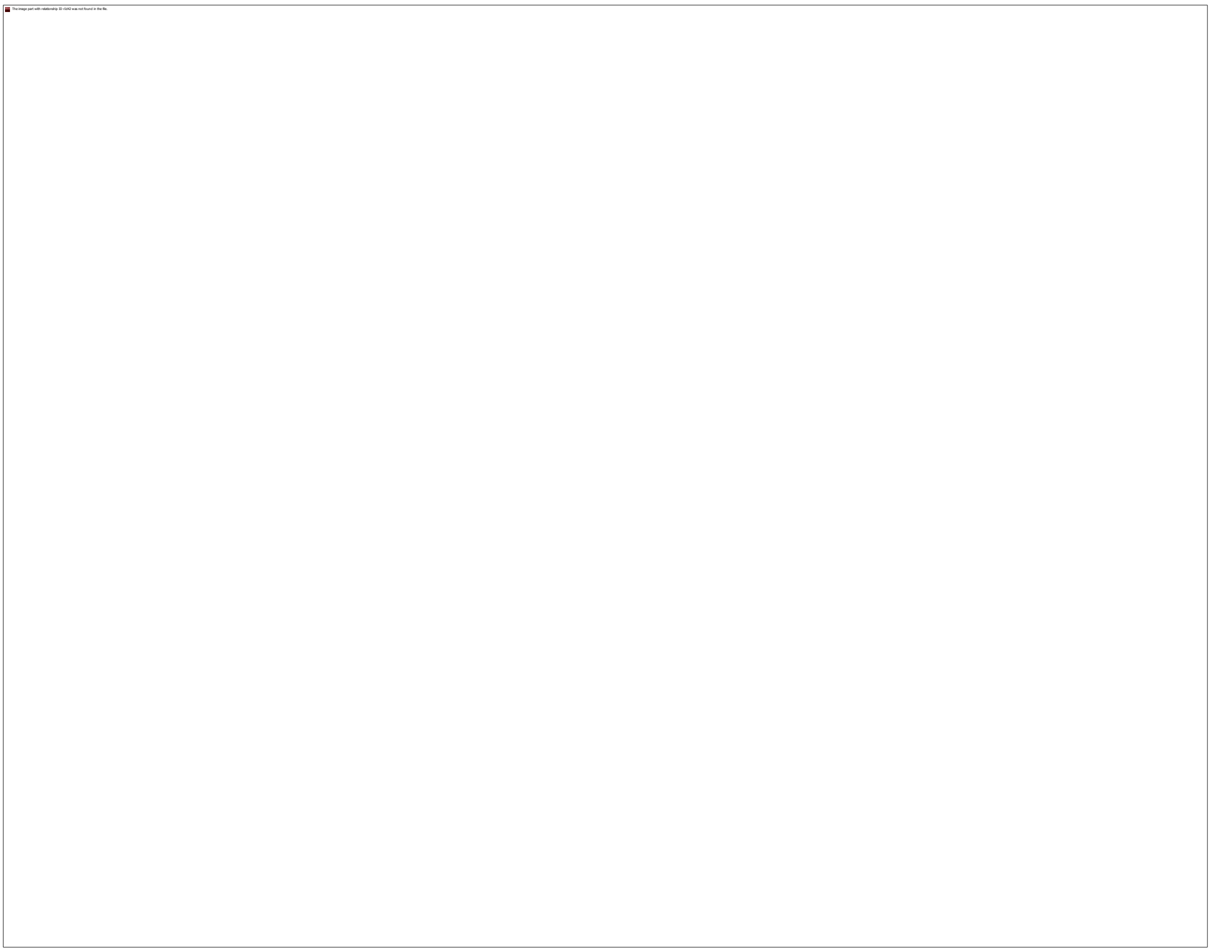
Model : T2

Made in: Switzerland

Uses : Used for measuring angle of Traverse and Triangulation survey.

Period of use: Before 1998.

Figure 2.2: Analog Level Machine



Source: Survey of Bangladesh archive

Name of equipment: Analogue Level

Brand : Wild

Made in: Switzerland

Uses : Used for measuring height difference between consecutive benchmarks by precise leveling. Also used for river cross leveling.

Period of use: Before 1980.

Figure 2.3: Film Pricker (Point Transfer Machine)

Source: Survey of Bangladesh archive

Name of equipment: Film Pricker (Point Transfer Machine)

Brand : Wild

Model : PUG4-4328

Made in: Switzerland

Uses : Used for transfer control points from one film positive to another.

Period of use: Before 1998

Figure 2.4: Plotting Machine

Source: Survey of Bangladesh archive

Name of equipment: Plotting Machine

Brand : Wild

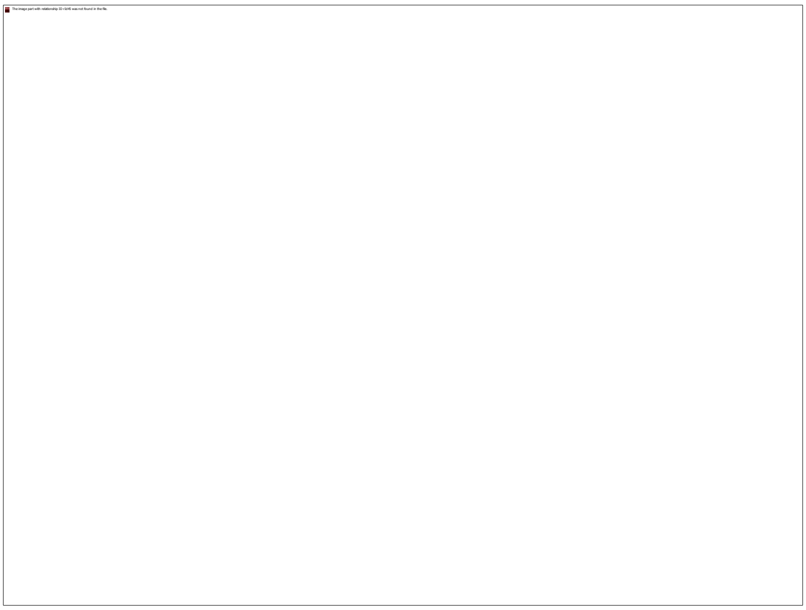
Model : B8

Made in: Switzerland

Uses : Used for details drawing from 3D view of film positive of aerial photograph.

Period of use: Before 2000

Figure 2.5: Radial Schator



Source : Survey of Bangladesh Archive

Name of equipment: Radial Schator

Brand : Zeiss

Model : Aerotopo 52120

Made in: Switzerland

Uses : To determine coordinate (XY) of unknown point with the help of four or more known coordinates on template which is called ‘Slotter Template Combination’.

Period of use: Before 1998

Establishment of a National Coordinate System: Bangladesh’s longitude is from about 88 degree East to about 92 degree East. As UTM uses 60 bands on longitude to divide the earth into zones, Bangladesh falls into two different UTM zones: zone 45 (East of 90 degree) and zone 46 (west of 90 degree). However, the parameter values that characterize a UTM zone varies with zones. Therefore, problem arises in terms of projection accuracy when someone goes for mapping the area of Bangladesh that falls in both of the UTM zones.

The Universal Transverse Mercator system of projections deals with this by defining 60 different standard projections, each one of which is a different Transverse Mercator projection that is slightly rotated to use a different meridian as the central line of tangency. Each different centerline defines a UTM Zone. The "UTM Zone" is a shorthand way of naming a specific, different projection that consists of a Transverse Mercator projection using a different meridian as the centerline. By rotating the cylinder in 60 steps (six degrees per step) UTM assures that all spots on the Earth will be within 3 degrees of the centerline of one of the 60 cylindrical projections. The accuracy of any Transverse Mercator projection quickly decreases from the central meridian. Therefore, it is strongly recommended to restrict the longitudinal extent of the projected region when using Universal Transverse Mercator projections to +/- 6 degrees from the central meridian.

WGS 84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. WGS 84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields. WGS 84 is the standard U.S. Department of Defense definition of a global reference system for geospatial information and is the reference system for the Global Positioning System (GPS). It is compatible with the International Terrestrial Reference System (ITRS). The accuracy of WGS 84 coordinates directly determined in WGS 84 by GPS Satellite Point Positioning, their respective precise ephemerides and ground-based satellite tracking data acquired in static mode, in terms of geodetic latitude. The errors incorporate not only the observational error but the errors associated with placing the origin of the WGS 84 coordinate system at the earth’s centre of mass and determining the correct scale. Historically, at the time of establishing WGS 84, only Satellite Doppler measurements with corresponding accuracy were available to determine the ground control segment of WGS 84. The WGS 84 coordinates of a non-satellite derived local geodetic network station will be less accurate than the WGS 84 coordinates of a GPS station due to the distortions and surveying errors.

For Bangladesh several GCS are taken viz. Gulshan, WGS 84, and Everest 1830. There exists some deviation along the seam line for choosing different Datum. If we want precise measurement then we have to care about it. Almost map of Bangladesh use WGS84 and Everest 1830.There may be the research problem to construct the error estimate for datum transformation for Bangladesh aspect. This may be done by Mapping Datum Transformation (MADTRAN) or other software.

Establishment of Cartographic Standards: The purpose of a topographic survey is to gather survey data about the natural and man-made features of the land, as well as its elevations.

From this information a three-dimensional map may be prepared. You may prepare the topographic map in the office after collecting the field data or prepare it right away in the field by plane table. The work usually consists of the following:

1. Establishing horizontal and vertical control that will serve as the framework of the survey

2. Determining enough horizontal location and elevation (usually called side shots) of ground points to provide enough data for plotting when the map is prepared.

3. Locating natural and man-made features that may be required by the purpose of the survey.

4. Computing distances, angles, and elevations.

5. Drawing the topographic map.

6. Topographic surveys are commonly identified with horizontal and/or vertical control of third-and lower-order accuracies.

However, the first stage the problem of receiving on the basis of original cartographic information (aerospace photographs, disjointed original and colored drawing map's prints) vector digital model of a map - the base of a digital topographic map is solved. This problem is solved in the following ways:

1. by means of digitizing original cartographic information on the map-case (digitizer) in the way of tracking object's contours, preparing and bringing in semantics, structure of digital information;

2. by means of scanning original cartographic information with subsequent automatic or interactive vectorization and recognition of raster representation on the display, input of required semantics and structuring of digital information.

At the same time for automation recognition and vectorization of raster representation very efficient is to use mechanism of cartographic expert system for tuning and training software at given parameters of locality and maps recognizable elements and objects. Present scanner technologies of automatic raster digital information getting provide automation of recognition 90% on relief, 50-60% in hydrography and growth by using published map originals. Approximate efficiency - 70-100 hours for one nomenclative list.

In the second stage following problems are solved:

1. symbolization of vector model;

2. creation of a digital topographic map according to the degree of load;

3. control and editing of symbolized digital topographic maps;

4. receiving of archival graphical symbolized copy of a digital topographic map.

The notion of symbolization process is in appropriation to each object the code (N) corresponding to a conventional sign from the library of conventional signs in accordance with classified code, object's characteristics and its meaning. This process is carried out automatically depending on the scale and the type of a digital map. At the same time unified library of conventional sings and types is formed. Each conventional sign has its own digital description - vector or (and) raster. Besides for following visualization a group of deduction sequence of cartographic representation is prepared.

The creation of a digital topographic map according to the degree of load is realized on the display in interactive mode in the windows, beginning with the most little window, within which all objects are read, with the following window upsizing through the method "quadrotree". At the same time load coordination and objects' brief between windows is provided within one nomenclative list or between adjacent nomenclative lists for each degree of load. For solving this problem it is efficient to use mechanism of cartographic expert system for taking decisions about objects' selection optimization in the degree of load taking into account a number of factors. This solving requires mechanism of establishment space-logical connections.

When forming digital topographic maps due to the degree of load, program and visual control and information editing is carried out, which, basically, comes to the placement of objects' names. The process of map creation ends with receiving symbolized graphical copy in series for each degree of load, beginning with the first (with more important objects).

Digital map creation is carried out in universal data structure, that provide an opportunity of vector information recording in consecutive as well as in chain-nodal representation, in raster view, supplemental information and also creation of the section of present users. The technology is realized through the complex of automatized work places, united in local network.

Methods and technologies of maps creation

1. Dataware technologies of digital maps creation include:

2. classification and coding system of cartographic information;

3. rules of digital description of cartographic information;

4. system (of library) of conventional signs of digital maps;
5. data format of digital maps.

To the main methods of map creation belong:

1. methods of automatic recognition of images (raster depictions, got while scanning);
2. methods of cartographic generalization with the use of graph theory and logical-procedural approach, mechanism of expert system;
3. methods of multimedia software;
4. methods of expert systems;
5. methods of space-logical connections' establishment.

All main qualities and advantages of digital topographic maps manifest while using them. Therefore together with digital maps a user may be given a digital map database control system, which carries out following main tasks:

1. creation and running digital map database;
2. work with cartographic representation:
3. display, ranging, cartographic representation movement in arbitrary direction;
4. control of dynamic window and the degree of visual depiction load;
5. receiving information about objects;
6. depiction editing;
7. managing of classifier and library of conventional signs;
8. creation, storage, mapping a user layer and its editing on digital maps;
9. managing of user's classifiers of conventional signs library (for example, library of special conventional signs);
10. depicting of cartographic representation on plotter or other devices;
11. connection with standard database;

12. user's interface, which is used to solve applied informative and calculated tasks.

It must be noted, that the creation technology of digital maps and user's system of database control is realized on one and the same program module, which allows unifying software and data ware on the whole.

2.4 Survey of Bangladesh Triangulation methods

Establishment of a unified geodetic network is one of the priority activities for mapping. The accuracy of a survey depended ultimately on the accuracy of its framework or basis. The basis of a survey consisted of points fixed by one, or a combination of the following methods:

1. Triangulation.
2. Traverse.
3. Astronomical determinations.

Of these, soundest method for topographical operations is beyond all questions a system of accurate triangulation, whereby undue accumulation of error is precluded in the extension of the work, and at the same time limits is set to the intrusion of error in the internal details. Triangulation may be divided into two classes (i) Geodetic, (ii) Minor. The Indian Survey established two geodetic networks (horizontal and vertical networks) in the country as early as the 1700s. Therefore, the densification of networks continued over the years. The reference geodetic system was officially called Indian Datum, and the associated ellipsoid was Everest 1830. By 1971, when the country became independent, the whole country was reasonably covered by horizontal and vertical networks. But the network was not maintained for a long time, and the pillars marking the network points were destroyed one by one, and only a few points survived.

The vertical network suffered also. Vertical and horizontal network points sited along railway lines and major road highways have been destroyed during reconstruction works. However, from 1991, with help from Japan, large GPS exercises were carried out in the 1990's and early 2000's, allowing to establish a new geodetic reference system (based on WGS84), a new vertical datum (based on a tidal station built for that purpose) and a new network of geodetic points in Bangladesh, even though they have not been calculated in the latest modern, global reference system called ITRF2008. For purposes of topographical survey all geodetic data and that of the Great Trigonometric Survey must be considered errorless, except heights and that relating to ''intersected points'', which latter should only be considered errorless when observations have been taken to a helio or an opaque signal defining the point.

The triangulation known as G.T. minor is not geodetic and cannot necessarily be considered as errorless. Some is of geodetic quality, and some is equivalent to rough exploratory triangulation. It was not to be used as a basis for topographical triangulation without reference to the Director of the Geodetic Branch, who would advise on the quality of the work in any particular case. Although the heights derived from modern geodetic triangulation are quite accurate enough for topographical purposes, too much reliance was not placed on those of the older work, which were not of the same standard of accuracy, owing to the uncertainty of atmospheric refraction.

Data necessary for commencing a triangulation: The initial data required for commencing minor triangulation in an area of which a detail survey is contemplated, are a base of known length, an azimuth, and the latitude, longitude and height above mean sea-level of one station. The base length and azimuth would normally be obtained by a Hunter Short Base* and astronomical azimuth, and in India the geographical position and height of one station could usually be obtained from previous triangulation in the vicinity of the proposed survey. Scale and azimuth deduced from a geodetic series might be used if convenient, but that deduced from other existing triangulation would not be used; further connections were served as a check on geographical positions only.

When the survey of a new area was about to be begun, the officer in charge of the party must had to obtain the triangulation pamphlets and charts covering the region, or if they were not yet published, applied through the Director of his Circle, to the Director of the Geodetic Branch for the data of any triangulation which might serve as a basis for the minor triangulation that would be required. The remainder of the minor triangulation was based on this and was computed in the manner described in manual. Minor triangulation, used to consist of a number of main series, running from one series of geodetic triangulation to another. These main series was generally be about 30 miles apart, i.e., so close that subsidiary triangles thrown out from each would provide bases from which intersected points could be observed throughout the intervening area. The main series was inter-connected by branch or cross-series at about every 30 miles, to ensure that there would be no accumulation of serious relative error.

When considering his triangulation programs the officer in charge of the party had to decide of the general lines along which these main minor series should run, with a view to breaking up the intervals between geodetic series in the best way. He had to also decide where cross-connections were necessary. If the distance between adjacent geodetic series was great, he should consider whether minor triangulation of ordinary quality is good enough to cross from one series to the other without serious error, or whether he should makes a point of carrying triangulation right across the area before plane-tabling based on it, in order to adjust its closing errors first. It might even be necessary to run a special series of better quality across the middle of any exceptionally large area, although this should seldom happen. In an ordinary minor series it will be a little over half the average triangular error, or about 5 feet in the case of a vernier theodolite. After 50 mils, such a series will be liable to an error of about 15 feet in latitude or longitude. After 100 mils the possible error will be about 40 feet. If a series can be adjusted on to geodetic triangulation at its far end, its liability to error will be more than halved. It was desirable that the stations of minor triangulation should be correctly fixed within at most 20 feet, so that from the point of view of fixing positions the desirability of adjusting before plane-tabling, or of undertaking special triangulation, calls for consideration if minor triangulation is likely to proceed more than 50 miles from a geodetic series.

The possible error in height must also be considered. It accumulates less rapidly than error of position, but a smaller margin was permissible, especially in Flat County. The officer in charge must had to consider what value of P is likely to occur, and apply the formula given in manual. Thus, if P is expected to be 2, the possible error in height after 50 miles will be 4 feet, and after 100 miles 6 feet, so that 50 miles would again be about the limit to which minor triangulation could proceed without adjustment or control. When estimating the probable value of P it must be remembered that it depends more on the lengths of sides and on the nature of the country than on the quality of the theodolite. Long sides or grazing rays make for large values of P. Values as high as 3 have occurred in geodetic series, but the short sides of minor triangulation would generally result in smaller values. Under ordinary circumstances 2 was probably a safe value, but the records of work previously done under similar conditions used to be referred to.

Errors in triangulation.—(i) *Measure of error.*—Owing to imperfection in observation, errors are developed in all triangulation. As it was essential that every piece of triangulation should be sufficiently accurate for the purpose for which it was intended, it was desirable to think out beforehand what magnitude of error, even if exceptional, could not be accepted without embarrassment, and thus decide on the standard and quality of the work that would be necessary. The best measure of this permissible error was the error of position or height that might be accumulated in a certain triangulated distance.

Subsidiary triangulation.—In addition to the main series of minor triangulation it was generally be necessary to observe a number of subsidiary stations inside and on the flanks of the main series, to provide bases for the observation of interacted points.

Trigonometrical stations and intersected points.— Trigonometrical points were either `stations of observation ' where a theologize was set up or ' intersected points ' which, unvisited by the observer, were fixed by three or more rays from stations of observation. Size of triangles and number of points.—The sides of the triangles of minor triangulation was usually from 5 to 20 miles in length. In order to cover the ground as quickly as possible and shorten the computations the triangles were Large, provided that a sufficient number of points were obtained for the plane-tabler; this depended on the scale of survey, the nature of the country, and the state of the atmosphere at different times of the year.

Triangulation programs: under the past organization of the survey of India, each party was allotted a certain area to survey. This area, in most cases, was of such extent as to employ the party for several years. Having received instructions, from the Director of the Circle, as to the order in which the degree sheets covering the area were to be surveyed, the officer in charge of the party had to take such steps as would ensure his minor triangulation programs being kept at least one year in advance of his detail survey program. At the commencement of any field season there would then be sufficient points fixed to employ plane-tables for the whole season. In parts of W & East Pakistan, the haze, which occurred at the beginning of the hot season, was frequently so dense as to stop triangulation entirely. Officers in charge of parties working in country where haze occurs in this way used to start their triangulations as to the approximate date by which it might be expected to occur and limit their area to that which could probably be completed by that date.

Connection of work of different observers.—When one series of triangulation was joined to another it was necessary to check scale, azimuth, position, and height. For this purpose two adjacent stations must be common to the two series. It was essential that both triangulators should use identical stations, and that the mark-stones should be found and used.

Construction and preservation of stations: Selection and building of stations.—In order to get the best results from a theodolite it was indispensable that it should be placed on a perfectly stable foundation; for this reason, whenever possible, stations used to be placed on rock in situ and so arranged that the legs of the theodolite rest on the rock itself. Where rock was available, the mark consisted of a hole drilled into the rock about one inch deep with a circle engraved round it.

Where rock was not available, a large stone, used to be embedded about 3 feet underground, with a circle and dot cut on it, with a second mark-stone, similarly treated, and having its dot vertically above the dot of the lower mark, placed flush with the top surface of the platform. Or, if the triangulate can obtain some old one-inch piping, a four-feet length should be driven vertically into the ground, the centre of this being taken as the actual mark. It was very important that every triangulator should left a mark that had every prospect of lasting permanently, and which was easy to identify. In localities, where marks were liable to destruction by jungle growth, wild animals or human interference, and also in areas of military importance the triangulator should have, whenever practicable, laid down at least three subsidiary marks from which the original mark might be re-laid.

Surrounding the mark, a platform used to be built of earth and stones at least one foot high and from 8 to 10 feet square. The sides of the platform should be revetted with big stones or gently sloped. Wood should on no account be used in the construction of the platform. The tripod legs of the theodolite should be well pressed into the soil of the platform: or wooden pegs, driven firmly into the ground, might be used for the feet of the theodolite to rest on. The centers of these pegs should be about four feet nine inches from each other, and two feet nine inches from the mark.

Raised stations.—In flat country, where there was much low jungle and where stones were available, the station platform was raised to such a height that the necessity of much cutting and clearing was obviated.

Observing tripods.—Another method of overcoming this difficulty was to carry a portable braced on which the stand of the theodolite was placed. The tripod was surrounded by a detached outer tripod which carried a platform for the observer. If these tripods were well constructed, there was no difficulty in raising the telescope of the theodolite to a height of 15 feet above the ground.

Selection of ''pakka'' stations.—All the stations of minor triangulation cannot be preserved, but in every degree sheet, in which there were no Great Trigonometrical Stations, four or five of these minor triangulation stations were made ''pakka'', ''Pakka'' statior were selected by the triangulator during his reconnaissance, preference being given to rock sites, they were selected in pairs, each pair forming a side of triangles of the network of minor triangulation. The fact that any station was a ''pakka'' one was clearly noted in the description of it in the angle book.

Construction of ''pakka'' station.—The lower mark of ''pakka'' statior was made as described in para 10. Over this mark a solid masonry pillar not less than one foot high was built. A mark-stone, with ʘ deeply engraved on it, were built into the pillar flush with the top and with its dot vertically over the centre of the lower mark. Whenever possible the triangulator personally supervised the placing of the upper mark; at the same time he trained his recorder so that, if necessary, the latter could be deputed to supervise the work.

Preservation of G.T. stations.—The triangulator must, when making use of G.T. Stations, be careful to leave them properly protected according to the rules given below:

1. hollow towers of "pakka" masonry.—Stop all cracks; close the trap-door; block up the windows and the doors in the basement; and should the roof have fallen in, shape the debris in the form of a comer on the basement floor.
2. Solid towers of "pakka" masonry with central "pakka" solid pillar.—Cover over summit of structure with a large pile of mud sloped away to carry off the rainfall.
3. Solid towers of "kachcha" masonry with central "pakka" perforated pillar.—Protect summit of structure as in (b) ; and close the passages to the basement floor with earth and stones.
4. Low platform of "kachcha" materials with "pakka" solid cylindrical pillars about 40 inches in diameter.—Repair platform if necessary; and pile up a pyramid of earth and stones over pillar and platform.
5. "pakka" perforated pillars without platforms.—Close the passages to the basement floor; and prevent water lodging round about the pillar.
6. pakka" pyramidal pillars.—Cover over with earth and stones as in (d).

2.5 Theodolite Traversing

Purposes of theodolite traversing: In a topographical party, theodolite traverses were required for the following purposes:

1. to fix points for plane-tables in area unsuitable for triangulation;
2. to fix the course of a road, river, or boundary with accuracy greater than can be done by plane-table;
3. to fix the relative positions of boundary pillars in numerical terms that can be recorded for their future identification.

Traversing is a more laborious and at the same time a less accurate method of fixing points than triangulation, and therefore except for reasons under (b) and (c), would only be resorted to in flat ground where buildings, trees, high grass or haze prevent distant vision. In such country traversing supplements or replaces minor triangulation. In exceptional cases traverses may replace secondary triangulation, but the traversing must then be of a specially high class.

Definition: A traverse is the course taken when measuring a connected series of straight lines, each joining two points on the earth's surface. These points are called traverse stations. A traverse which follows a circuitous route and returns to its initial station, thus enclosing an area, is called a traverse circuit. A traverse circuit may be broken into sub-circuits and one station may be connected to another by a tie-line.

Thus a traverse commencing at station A and passing through B C D E F, and returning to A, is a traverse, circuit, which is said to close on station A. A line traversed from B to E would be called a tie-line. Whilst figures A B E F A and B C D E B might be computed as sub circuits. The initial or starting station of a traverse is the station of an old traverse line, or the new station, fixed direct from triangulation or old traverse work, at which a traverse starts observing.

3.4 Air survey and Photogrammetry:

Air Survey- Means the art of drawing maps from aerial Photographs. Photogrammetry means measurement of distance on the photographs. In Survey, this term was used for the preparation of topographical map by means of aerial photographs. This technique was being used in Survey since 1930 and in particular during and after the World War II. Photography and air survey are basically the same thing. This technique was considered more economical, expeditions and adequately accurate in the production of topo maps. The whole method of air survey was based on an analogy to the method of topographical Survey on the ground. The air photography was considered merely as bringing the country into office. Vertical or near vertical photographs and Oblique or high oblique photographs used to be taken.

The strip of photographs used to be taken in a fairly straight line from a nearly constant height so that each photograph includes in its view the points of detail representing the centre of the photographs immediately preceding and following it and so that two points where positions are known on the ground are included and can be identified on photographs in the strip. The effect of combined tilt and height used to be largely reduced by carefully selecting minor control points nearly in the same horizontal plane. Planimetric ground control and height control used to be provided by :-

1. Triangulation by theodolite.
2. Traverse by theodolite.
3. Astronomical observations.
4. Leveling by spirit – level machine.

Ground controls were fixed up either before or after photography. Control fixed before photography was known as prepointing and control fixed after photography was known as post-pointing. Each method had its own advantages and disadvantages. Before photography a plan of the area was prepared showing the direction of the strips and areas to be covered. This was prepared on the existing map and was known as " Lay out of photography ". Actual photography, the scale of photographs was to be decided first, because scale is dependent on the height of the air craft over the ground. Scale of photograph should be equal to the scale. The photography is taken in strips. Flying strips were run parallel to one side of the area of with 60 percent overlaps fore-and-apt and sufficient over lap (10 to 30) percent laterally between strips to avoid gaps. After photography a detail index of photograph was prepared on the existing maps showing PPs of photographs, direction of strips and overlaps etc.

Scale of the photograph = $\frac{1}{D} = \frac{f}{H}$ =(in any unit)

where f = Focal length of the lens.

H = Height of the air craft.

D = Distance on the ground (corresponding to the unit distance on the photograph).

If the contents were not known, the scale used to be found by comparing the length of two points in the photograph against the same on the ground.

Method of Compilation by graphical or radial line method from vertical air photograph :

Better results were obtained:-

1. Where the ground is reasonably flat.
2. Scales of the photographs are sufficiently close to the map scale.
3. Ground relief is less than 2 (two) percent of the flying heights.
4. Camera tilt do not exceed 3 (three) degrees.
5. Photographs are in true angle at the principal point.

Method of combination by radical line method :

Two photographs were placed at an arbitrary distance apart and two points well out on each side of the principal point were intersected. The principal point of the next photograph was fixed on the arbitrary scaled plot by a graphical resection from the previous principal point and the two intersected point. Two more points were intersected from the second and third photograph and the principal point of the 4th was respected and so on. While selecting intersection points in the mountainous country, these used to be selected at about the same height as principal points.

Accuracy of the map depended on the accuracy of control and extensive use was made on extending control by slotted templates triangulation for mapping of plain areas and normal aero-triangulation control for providing control in the hilly areas. The ground detail was then traced out from the aerial photographs in appropriate topo symbol. These were known as plot sheets. Tracing of details from rectified air photograph-by this method, field control in the 4 corners of each photograph was provided first with the help of these control points, photographs were rectified in SEG machines and grids super imposed. Details were then traced on to some transparent medium directly. This practice was applicable for tracing of details in the flat areas only. The plot sheets did not include features which were not recognizable in the photography as well as features developed since date of photography. A Surveyor did this job by plane table instrument.

2.7 Plane Table Methods:

A blue print of the sheet surveyed by air survey method used to be given over to the surveyor for field verification by plane table method. He verified the surveyed detail and picked up new detail. He also collected names, boundaries, and classifies roads. He also picked up relative height, types of vegetation, water information's, location of places of worship, graves, hospitals DBs, POs, P.T.Os, Telephone lines, Power lies, market days wells, springs etc and other doubtful details. He also surveyed any new detail with the help of existing detail of the blue print. Survey of contours by the help of aerial photographs required special training in the photo-interpretation and stereoscopic fusion. Contours were surveyed in the office and the error corrected in the field. The blue print was completely inked up in the field. The inked up blue print served as a color guide also. An average surveyor could give an output of 100 sq. miles per month on 1 : 50,000 scale in the plain area.

General Principles. - The plane-table needed to be leveled, this was especially important in hilly ground and in large scale surveys. When some of the fixed points ware above the observer, and some on the same level, or below, a slight dislevelment of the plane-table would throw out the position of the fixing very considerably. It used to be roughly ascertained whether a plane-table was level or not by dropping a pencil on the board a few times and noting the direction in which it tends to roll; the spirit level attached to the clinometers was also used to level the plane-table.

In soft and marshy ground, a firm footing used to be obtained for the plane-table by driving in stout wooden pegs flush with the surface of the ground for the legs to rest; in loose sand, a certain amount of stability used to be effected by inserting each leg of the plane-table stand into a block of wood with a hole drilled through it. The pencil used was a hard one, and kept very sharply pointed, as fineness of line was absolutely essential to accurate intersection and “clean” sketching of detail; a small piece of fine grained sandpaper was useful for renewing the point of the pencil.

When making a fixing or intersection, rays were drawn through the centre of the fixed point, and not tangentially to it. The blunt end of the pencil (with a little of the lead removed, so as to prevent smudging) was used as a pivot for the sigh-rule; a pin was not used, as pin holes photograph, and ware also apt to cause blots when the section was inked up. When taking a ray, the pencil was held as upright as possible, and at the same angle throughout, the point being kept pressed close to the edge of the sight-rule. If the sight-rule was at all bowed, special care was taken to prevent the pencil running under its edge, and so deviating from the straight line. After checking with the pencil point that the sight-rule was directly over the pivoting point, a short ray used to be drawn at the estimated position of the object aligned, which was marked lightly with a small circle or with the appropriate symbol; it was sometimes also convenient to draw a third line at or near the edge of the board; at this third line, a note of the object, or a slight sketch of it, was entered.

Cleanliness.- In order that the plane-table section remained clean, the following precautions were taken:-

(a) A clean piece of white paper were pasted on the bottom of the sight-rule and magnetic compass box.

(b) All pencil line were rubbed out as soon as they ware finished with. It was, however, useful to leave pencil rays to intersected points, etc., which fall outside the surveyed area.

(c) When not in use, the board were covered with a piece of white muslin or cloth.

(d) The plane-tablers made sure that their hands and arms ware clean and dry before commencing work at each fixing.

(e) Protected the board from drippings, etc., when working under a tree.

(f) When inking in, kept the board covered, leaving exposed only the area actually being worked on.

(g) Lifted the sight-rule clear of the board, when moving it.

Work at first Station.- When commencing work, the surveyor used to set up his plane-table on a prominent hill station, or well-fixed trigonometrically point situated in as commanding a position as possible, placing it level, and nearly over the station mark. He then truly oriented his board, by placing his ruler so that its edge passes through the point at which he was standing and the most distant visible point plotted on his board, and turning the table bodily round in azimuth until the true distant point is intersected by the sigh-rule. The was commonly called as “setting” the plane-table. He then tested the accuracy of all the trigonometrically points on his board by laying his sight-rule in succession; if any ware found to be wrong, the plotting of them were examined and corrected, if necessary, by reference to the data in his note book.

2.8 Fair Mapping

In a properly constituted topographical party the area surveyed each field season used to be fair mapped during the following recess, the fair sheets being finally examined and submitted to the circle office before the party again took the field. Every fair sheet had a separate file the title of which was the number of the sheet, or, in the case of special maps, the name of the map. All officers and subordinates were trained in fair drawing, and a certain number in typing and hand-printing. For convenience of supervision and control, survey parties were, during recess, divided into sections. All section officers and draftsmen used to be provided with magnifying glasses, and the former also with minifying glasses with rests of the proper length to suit the proportion which the published sheet bears to the fair sheet. The best available hand-made drawing paper used to be used for fair mapping. Paper with a highly glazed surface was objectionable on account of its gloss, which tends to interfere with the photographic operations; such paper does not stand scratching or erasing well, and, moreover, owing to its want of “bite”, causes the lines to thicken. The necessity for keeping fair sheets clean throughout their preparation were strongly insisted on; applied to not only to the face but also to the back of the sheet.

The use of black pencils on a fair sheet was strictly prohibited; only light blue pencils or cobalt were used. Fair sheets were either drawn with a mapping pen, or crow-quill, or with a ruling or swivel pen. In order to get the best results from heliozincography, it was essential that the line work should have been black, unbroken, and sharp. When straight roads, railways, canals, etc, were drawn, a ruler was invariably used. A fine stylographic pen was useful for dotting purposes. It was important that the Indian ink, which was used for fair drawing, was of the best quality. Erasures were avoided as far as possible, and never made except under the orders of the officer in charge of the mapping; they were best carried out with a very sharp pen-knife, the portion to be erased being placed over a thick sheet of smooth glass, and care being taken to remove the ink with as kittle of smooth glass, and care being taken to remove the ink with as little damage to the surface of the paper as possible. The "Ariel" electric erasing machine, made by B. J. Hall & Co Ltd., was also useful for erasing large areas, headings, etc. There were no pasting on any fair sheet except with the specific sanction of the then Director. All one-inch, half-inch and quarter-inch sheets in the neighborhood of the frontier were completed to edge, even when it was necessary to use old small scale surveys for the purpose.

Fair sheets intended for dispatch by post or rail used to be carefully rolled and packed in a tin tube which, for further protection, was enclosed in a stout wooden case. Large consignments and all shaded drawings used to be sent packed flat in tin-lined cases. All consignments of fair sheets of plane-table sections, whether dispatched by post or rail used to be insured. The one-inch and half-inch sheets were published in black and colors.

2.9 Spheroids & Projections

Spheroids : The Surveyor measures the distance between points in feet or metes, while the geographical positions of the points he fixes are normally expressed in latitude and longitude. To enable latitudes and longitudes to be computed, it is consequently necessary to know how many feet are comprised in a second of latitude or longitude. If the earth was a perfect spheroid whose dimensions were known, the number of feet in a second of latitude or longitude in different parts of the earth could be calculated. Actually the earth is only approximately a spheroid, and spheroids of varying dimensions have been adopted as a basis of calculation in different countries.

Sometimes, at different periods of its history, a country has used different spheroids in the same area. It is then very necessary to distinguish between latitudes and longitudes computed on the two different spheroids. The number of seconds of latitude corresponding to a given linear distance may vary by as much as 1 part in 7000, according to the spheroid used, and in a country covering (Say) 10 degrees of latitude discrepancies of 5 seconds may consequently result.

Projections: A projection is any orderly system by which the meridians and parallel of the spheroid may be represented on a plane map. Since a curved surface such as the spherical earth cannot be flattened out without tearing, stretching or wrinkling, all projections must involve some imperfections. The important projections are :-

1. **Simple conical** –The parallels are represented by circles and the meridians by converging straight lines. The projection is not orthomorphic. This projection has in the past been used for maps of India on a scale smaller than 1/M. but has later superseded by the Lambert.

2. **Conical Orthomorphic, or Lambert, projection-**This is an excellent projection for countries with a somewhat limited extent from North to South. If the origin of a Lambert projection is on the equator, it becomes the well-known Mercator projection.

3. **The Transverse Mercator projection:-** This has the properties of a Lambert (or Mercator) projection, turned through a right angle. It has unlimited extent from north to south, but involves scale error to the east and west of the origin. It is orthomorphic. While it is an excellent projection for countries of limited extent from east to West, the calculations involved in its use are not quite so simple as those of the Lambert.

4. **The simple polyclone projection: -** This projection is suited to great extension in latitude and small extension in longitude. It has been used in some regions for geographical and also topographical maps extending over considerable ranges of longitude. In India, however, it has been used only for topographical maps, with the longitude limited to the sheet width: so that the distortions involved are ordinarily unpalatable and the maps are perfect.

5. **The Cassini Projection: -** This projection has been much used for countries of limited extent from east to West.

Different types of Projecrions used by Survey of Bangladesh maps

1.	1/2M – Map of Pakistan	Lambert conical orthomorphic
2.	50 mile Map of Pakistan	Mortified secant conical
3.	1/M Carte International series	International (Polyclone)
4.	1: 500, serial	Lambert Conformal Conic projection
5.	1:250,000, 1:50,000 and larger scale Maps	Platonic Projection on Everest Spheroid

Grid System: All maps, regardless of type, have a common characteristic, in that they should show relative location of objects. For reference purposes, maps locate objects spearing thereon by various methods. During the First World War it was found that reference to locations and directions was too complex in the usual system of latitudes and longitudes recorded in degree, minute and second. For this reason, the French over printed a net work of squares upon their maps. The military then employed this system of net work of squares formed by straight, approximately north – south and East – West lines superimposed on military maps. This system of net work of lining is known as grid.

Need for grid: The grid on maps provides a system of squares which simplify the location of points and the computation of azimuths and distances. The distance between lines on a map represents a distance on the ground in yards or meters. By using a system of simple grid co-ordinates, one locates points or objects on a map and then communicated their positions to anyone possessing a copy of the same map.

The grid is named after the name of the projection and the origin of the projection is the "True origin" of the grid.

1. **Lambert Grids:** These have the advantage of Lambert Projection and have been much used in the Survey of India maps since 1929. If the extent is 8° from North to South, the scale error is limited to about 1:800.

2. **Cassini Grids:** Since this projection is not orthomorphic, grid angles do not equal to observed angles and computations can only be carried out in grid term by using complicated formula. They may be done in spherical, or in superposed Lambert grid and afterwards converted to Cassini.

3. **Transverse Mercator Grids:** These are good grid with all the advantages of Lambert, but neither Survey of India nor Survey of Pakistan is acquainted with this system.

4. **Simple Polyclone Grids:** These may be met through but they are uncommon. The projection is not orthomorphic. Simple polyclone grids could be defined by true squares on topo maps but a separate grid would be required for each longitude strip, corresponding to simple map width.

During the 1st World War different countries used their own grids and the many overlapping grid systems caused endless confusion. The Cartographers then introduced the following two systems.

1. **Universeed Transverse Mercator Grid:** Since it is a conformal grid all computations are simpler. The world is divided in 6° n – S belts reaching from 80°N to 80°S; Zones begin at 180° numbered eastwards. The origin of the central meridian of each zone is at the equator. False origin is 500,000 miles west of the equator (for the southern hemisphere 10,000,000 miles south) Twenty five miles of overlapping is provided but never used for reference.

2. **The World Polyconic Grid system:** The maps of Asia, Africa and Australia were girded by the British. The world Polyconic grid system covers all the areas not covered by the British. It can be applied to any part of the world except the polar region north and south of 72° latitude.

System of grid lettering: Every grid has a point where its north-south and east-west lines coincide with true north & south and east & west. This point is known as the "True Origin" of the grid. Whether it be the only point at which grid lines correspond with True North – South etc. lines depends on the properties of the projection to which the grid is applied.

Detailed system of grid lettering: The area covered by each grid is divided into squares of 500,000 unit sides. Each of these 500,000 unit squares is again divided into twenty five 100,000 unit sides.

Both sizes of squares are lettered from west to East from 'A' in the north – west to 'Z' in the south-east omitting the letter 'I'. The system of 500,000 unit squares is so placed, that the south – west corner of square 'V' is it the false origin of the grid and its grid easting and northing are zero. A reference to the diagram will show that the north - west corner of 500,000unit square 'A' is 2,500,000 units north of false origin while the south west corner of square 'Z' is 2,500,000 units of it. North and east of these two points respectively, the system repeats itself so that identical references on the same grid recur at intervals of 2,500,000 units or about 1500 mils on a yard grid 100,000 unit squares are similarly laid up.

Grid references: Where full grid reference is necessary, the band, zone and hemisphere have to be given. Thus a full reference may read 111 BNI, 329,200-,625,400, on large scale maps, however, where the approximate location is known 292-254 would be enough to locate the point with 100 yards.

A grid reference normally consists of two letters followed by a group containing an even number of figure. The first letter is that of 500,000 square and is followed by that of 100,000 squares. The former is smaller in type on the face of the map. It will be apparent from the previous para that the two letters at once indicate the distance of the point east and north of false origin to within 100,000 units. The first half of the group of figures indicates the easting of the point from the western edge of the 100,000 unit square in which it falls; the second half indicates the northing of the point from the southern edge of this square. The first figure of the easting of the reference represents 10, 00 units, the second figure represents 100 units and the third 100 units and so on. Thus, to describe the position of a point accurately to one unit, two letters and a group of ten figures is required, Except for Survey work such precision is seldom necessary and for ordinary references, group of 8, 6 or even 4 are all that are required.

Intermediate grid lines_have one or more figures according to the size of the squares on the maps. 10,000 unit squares on 1:250,000 maps have only one figure, while the 1000 unit squares of 1:50,000 and larger scale have two figures.

2.10 Activities and Achievements in Analog mapping by SOB:

After the partition of India-Pakistan, routine job was to update the topo maps inherited from British India. These were 1million scale, 500k scale, 250k scale and 50k scale topo maps. These used to be carried out through Revision survey. Surveyors used to go to the field with blue prints and update collected in the dry season by the method of Plane table survey. Then come back to the office and draw the maps for final printing by Fair mappig method as mentioned in this chapter above. Every map used to be updated in 5-10 years' time except military maps some of which used to be updated on need to basis.

Additionally, some extra-departmental map mapping projects were also undertaken by the request of other government organizations. One such undertaking is the creation 1:15840 scale topo map prepared as East Pakistan Water Development Maps where heights are measured spirit leveling method in every 100m apart for contour drawing. These sheets has been compiled from 4-inch enlargements of air photographs on 1-6 inches to a mile scale taken by Messer Air Survey Company Ltd. London in February 1952 and verified on the ground during project tenure. All heights appearing on this sheet are in terms of the Survey of Pakistan datum. To bring these heights in terms of the East Pakistan P.W.D. datum add 1.509 feet. Contours have been shown by interpolation between spirit leveled spot heights. The Contouring has not been done on the ground and is approximate.

There were about 2400 map sheets covering almost the entire country. Almost one eighths of the maps are of larger scale by four times i.e. 1:7920 scale. This was a huge undertaking by the then government which continued throughout 1950/1960/1970s. This project reveals the capability and state of art of the survey organization of that time. This is an excellent asset for Bangladesh. Using modern technology, these can be georeferenced and digitized into a seamless GIS database of the country on a fairly medium scale and archive the same for various references. Since it has spot heights at 100m interval covering the entire country, it is possible to get a precise topography of that time by creating DEM in GIS software. It would be an excellent asset for researchers, academia and the government itself. One example of map sheet with blow up and the index sheet of those maps are shown at Figure 2.6, Figure 2.7 and Figure2. 8 below.

Figure 2.6 : 1:15840 Scale Topo Map

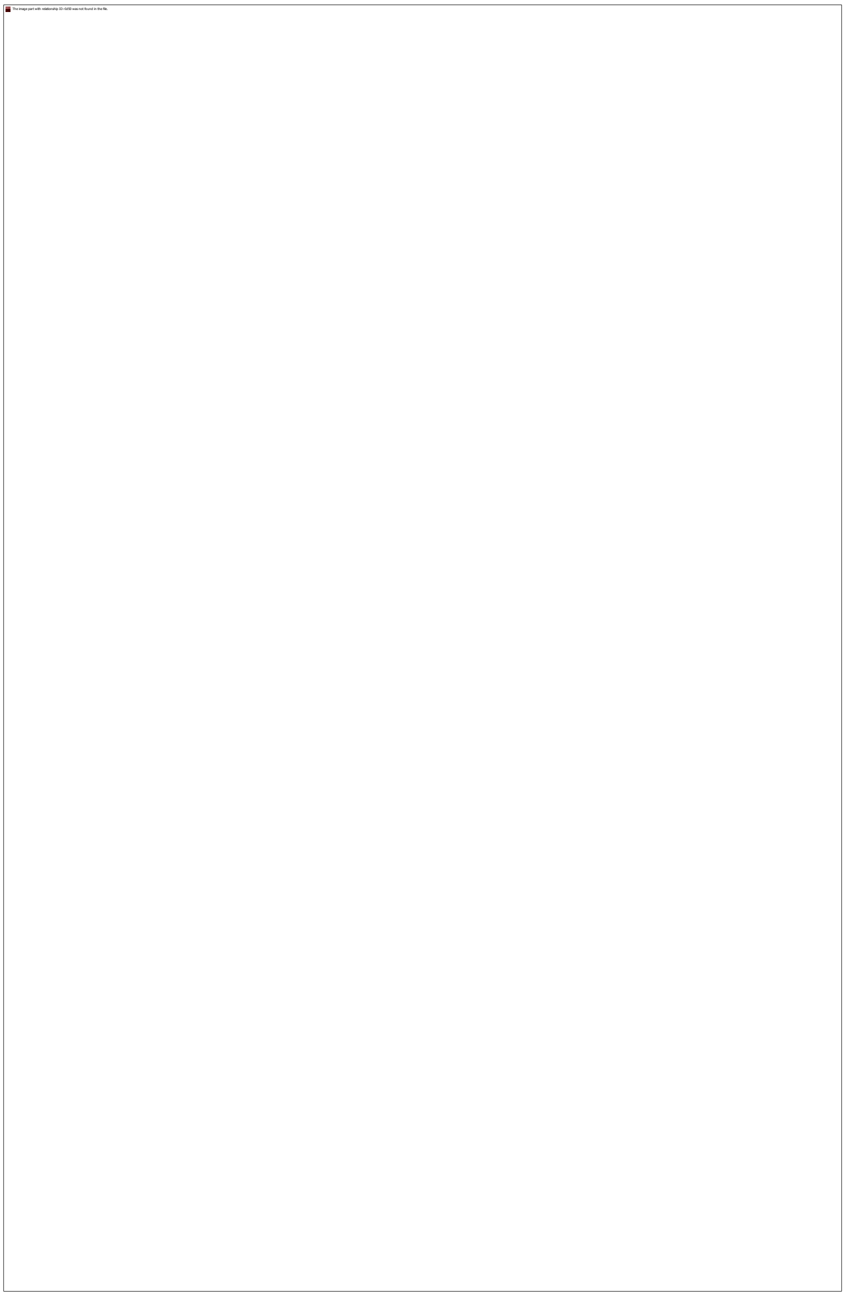
The image part with relationship ID rId48 was not found in the file.

Source: Survey of Bangladesh

Figure 15: Blow Up of 1:15840 Scale Topo Map

Source: Survey of Bangladesh

Figure 2.8 : Index Sheet of 1:15840 Maps



Source: Survey of Bangladesh

Another project was undertaken in 1970s to create 1:1200 scale map of the then Dacca city. The map was compiled for Bangladesh Power Development Board from enlargements of air photographs on scale 1:5,000 taken by Bangladesh Air Force in Jan 1977 and verified on the ground during 1978. One sample map with blow up shown below. It was the largest scale map production ever undertaken by SOB so far for the capital city consisting about 1200 sheets. Although the map is not a gridded one, it is an excellent product for planning and decision making. One example is that the government is unable to recover the much needed grabbed canals in Dhaka city due to unavailability of information of that time. This map could be an excellent document to decide the original extent of the canals in 1970s and recover the same provided the government has the good will to do so. Even it is possible to georeference the maps into a seamless GIS data base of old Dhaka city using modern technology and archive the same as historical document for the capital city. An example of this map with blow up is shown at Figure 2.9 and Figure 2.10 below.

Figure 2.9 : 1:1200 Scale Map

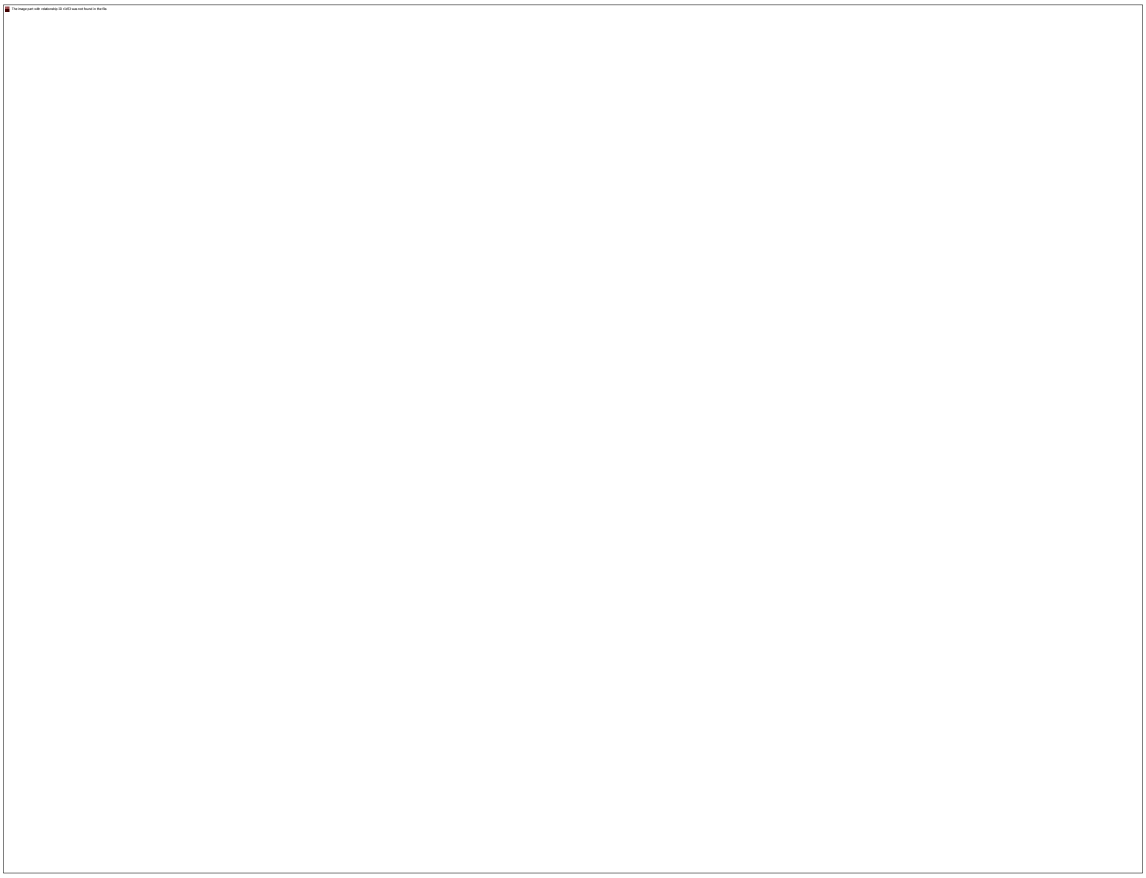
Source: Survey of Bangladesh

Figure 2.10 : Blow Up of 1:1200 Scale Map

Source: Survey of Bangladesh

Another project undertaken to produce 10k map of coastal belt.in 1990s. Maps were Compiled from aerial photographs taken in 1990 by FINNMAP Oy and updated from aerial Photographs taken in 1998 by FM International Oy. Field identification and compilation was done till 1999. This map was produced for Bangladesh Inland Water Transport Authority (BIWTA) in cooperation with FINNIDA (Finland) and the Commission of the European Community. These map sheets effectively covers the entire coastal belt consisting approximately 1400 map sheets. Coastal belt being the most vulnerable to natural disaster, these maps are valuable asset for disaster management and other coastal planning. This map has got spot heights at every 150m to 300m interval which can be converted into DEM using GIS software. This could be a good DEM of recent decades (1990s) for the coastal belt of Bangladesh. This DEM can also be compared with DEM of 1:15840 scale maps discussed above for change detection of coastal belt between 1970s and 1990s and extrapolate for future likely changes. This kind of analysis would certainly help in more precise planning and decision making regarding coastal area rather than the present trend of planning in isolation. An example of the map with blow up and the index sheet is shown at Figure 2.11, Figure 2.12 and Figure 2.13 below.

Figure 2.11 : 1:10000 Scale Map



Source: Survey of Bangladesh

Figure 2.12 : Blow Up of 1:10000 Scale Map

Source: Survey of Bangladesh

Figure 2.13: Index Sheet of 1:10000 Scale Map

Source: Survey of Bangladesh

2.11 Output of this study from Old Maps:

It was discussed in Chapter1 under methodology that 1:2,50,000 scale maps of 1940/50s were selected for extracting the selected features like rivers, forests and coastal belt. There are total 28 sheets covering the entire country and these sheets are prepared following the methods and instruments described in this chapter. The Sheet Nos with index are shown at Figure 2.14 below.

Figure 2 .14: Index Sheet of 1:250000 Scale Map

The image part with relationship ID r1d56 was not found in the file.

Source: Survey of Bangladesh

So the sheet nos are 78B, 78C, 78D, 78F, 78G, 78H, 78K, 78L, 78O, 78P, 79A, 79B, 79E, 79F, 79G, 79I, 79J, 79K, 79M, 79N, 79O, 83C, 83D, 83C, 84A, 84B, 83C and 84D, as evident from figure above. It may be noted that although the map sheets are printed in 1940/50s, survey was conducted as early as 1840s to 1920s as shown in figures below. So the topo features depict its state of those times of survey. Examples are shown at Figure 2.15 and Figure 2.16 below.

Figure 2.15: 1:2500000 Map Showing Surveyed Period

Source: Survey of Bangladesh

Figure 2.16: 1:2500000 Map Showing Surveyed Period and Other Information

Source: Survey of Bangladesh

In order to prepare the data for this study, the 28 map sheets are scanned in precise scanner and then georeferenced in its original coordinate system i.e. Everest 1830 ellipsoid and LCC projection using Arc GIS software. Then sheets are cropped along neat line so that they can be mosaicked to a seamless map of entire country. Now the map was ready for topo feature extraction in vector format from raster. Before feature extraction, the mosaicked map datum is converted to WGS84 Ellipsoid and BUTM10 projection from Everest 1830 ellipsoid and LCC projection. The parameters used for the datum conversion are shown below.

Ellipsoid:

DX= +283.729m

DY= +735.942

DZ= +261,143

Da= +860.655

Df= +0.28361368

BUTM10 Projection:

Latitude of Origin= 0 degree North

Longitude of Origin= 90 degree East

False Easting= 5,00,000m

False Northing= 0m

Scale Factor= 0.9996

Accordingly, the features were digitized in vector format (geodatabbase). Then it needed to be edited for topological correction in order to be able to utilize the data for GIS analysis. For satellite data, supervised classification was performed in order to separate the water and forest area. Then data conversion was performed to create vector data. These vector data were then generalized so as to be compatible to the 250k map scale. In fact, this data is mainly prepared for checking the validity of the data prepared from 250k maps not for change detection.

Many difficulties were faced during the entire process of data collection and preparation. Age old map papers got wrinkled and decayed, took much time to sift better ones from unattended and dusty map depot. Modern scanners often got jammed due to age old papers. Georeferencing had to be done very carefully due to obscure neat lines. Mistakes in parameter entry for georeferencing made the mosaicking into seamless map difficult. Many trial and error had to be performed to prepare the data at various stages. Digitizing was a very tedious and tiring undertaking since the data were huge covering entire country. Computer often got hanged due to huge data memory. Sometimes losing the data of entire day effort due to wrong button press was not very rare. Hopefully, the laborious job will pay dividend during data analysis. Output of three layers mentioned above are displayed at Figure 2.17, Figure 2.18 and Figure 2.19 below.

Figure 2.17: River Layer from 1:250000 Old Map

The image part with relationship ID rId59 was not found in the file.

Source: Self Prepared

Figure 2.18: Forest Layer from 1:250000 Old Map

The image part with relationship ID rId60 was not found in the file.

Source: Self Prepared

Figure 2.19: Shore Layer from 1:250000 Old Map

Source: Self Prepared

Chapter 3

Modern Digital Topographical Mapping in Bangladesh

3.1 Introduction

Digital mapping has taken over analog mapping all over the world because it is more precise, quick, cost effective and possible to process and analyze in computer and can be used as decision making tools. Survey of Bangladesh has embraced the technology during the 1990s. Survey of Bangladesh has engaged itself to create topographic maps covering entire country. Areal survey and ground truthing as well as final topographic map production has been going on since 1970s. It now possess and distributes maps of various series like 1: 1000000 scale, 1: 500000 scale, 1: 250000 scale and 1: 50000 scale.

Till now, 1: 50000 scale analog topographic map is considered to be the official base map for Bangladesh. However, Now, SOB has undertaken a project (2007-2016) to produce 1:25000 scale digital map covering entire Bangladesh. It will also produce 1: 5000 scale digital map of all divisional towns. This 1:25000 scale digital map will be the base map or foundation for future Digital Bangladesh. It will also serve as foundation for national spatial database infrastructure (NSDI) in future. The SOB's digital map making process is studied below as an example of digital mapping and surveying process.

3.2 Digital Mapping at the Survey of Bangladesh:

Digital map production-line consists of six distinct disciplines closely integrated together. These are Geodesy, Photogrammetry and Imagery, Field Completion, GIS, Cartography and Printing. Geodesy is the infrastructure for mapping which provides control points for mapping and surveying. Photogrammetry and Imagery provides Aerial Photo and Satellite Image for mapping from where map features are extracted including relief. GIS does the topological correction to the map feature data and create database by attaching the attribute of each feature. Cartography generalizes the map feature data and prepare the map in final shape for printing by adding legend, neat line, graticules and marginal information. Printing deals with colour seperation in order to get desired print of hard copy of maps.

This chapter briefly describes about the modern geodetic control network, collection of geographic data from space, Field verification, Spatial data preparation and Final map creation in digital era then highlights the mapping activities and achievements in digital mapping by SOB and displays the outputs from recent maps of SOB.

3.3 Establishment of Modern Digital Geodetic Control Network in Bangladesh:

In digital era these are observed by GPS which is more precise and less arduous and time consuming. GPS receives frequencies from different global positioning satellite constellations to calculate its own coordinates or positions. Global positioning System (GPS) of USA is the main positioning satellite so far. It was originally created for military purposes and later was made available for civil navigation and other purposes. The positional error (about 100 m) imposed on civil use called Selective Authority (SA) was withdrawn in 2001 thus allowing better precision in navigation. Russia has its own constellation called Global Navigation Satellite System (GLONASS) (**expand!).** In order to get rid of the GPS dependence, EU and China has created their own constellation called Galillio and Compass respectively.

GNSS CORS and VLBI are added in digital era that makes mapping and surveying quicker, precise and also can monitor tectonic plate movement. A permanent GPS station is made up of a receiver that continuously records GPS data (in general at an interval of 1 second). It is designated by the acronym CORS (Continuously Operating Reference Station). An active GPS station is a permanent station combined with a telecommunication outfit that allows the user to determine his position in real time using radio transmitted corrections. In Bangladesh, these stations are sometimes referred to as beacons. Now, correction messages are broadcast (in this case we will call it an active GPS station) so as to allow real time kinematic (RTK) surveys. Even though real time GPS requires high-cost equipment and that the ranges are limited to 5 to 10 kilometers in urban areas, the possibility to upgrade a permanent station should always be kept in mind. The existence of permanent stations may entice professionals to equip themselves with GPS technology. But the main advantage of the stations is to provide easy access to the new geodetic reference system

The ITRF was established and is maintained by the terrestrial reference frame section of the IERS Central Bureau. The construction of the ITRF is based on the combination of sets of IGS station coordinates and velocities derived from observations of space geodetic techniques such as Very Long Base Interferometry, satellite laser ranging, lunar laser ranging and Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS), by various analysis centers. The IERS CB computes the annual ITRF solutions. The first was published in 1988. Some sites host two or more collocation techniques. Being the most precise reference system available, ITRF must reflect time evolutions. The coordinates of sites on the earth's surface slowly change (by up to 10 centimeters per year!) due to the motion of tectonic plates (a component of which is familiarly known as continental drift). Consequently, velocities are associated to the sites used in ITRF calculations. Even transformation parameters relating the most recent ITRF to previous frames have an associated rate.

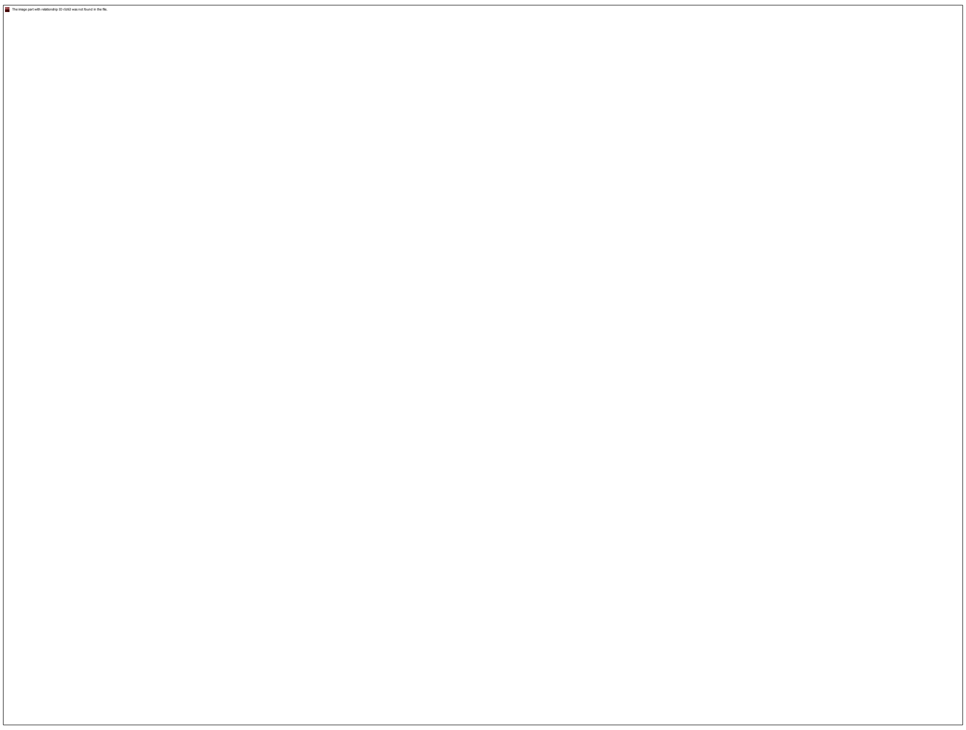
Vertical control network consist of elevation above mean sea level on nationwide spread monuments called bench mark (BM) monuments, also known as ground control points (GCP). This is observed by manual leveling from a point where sea level is measured by an established tide gauge called 'Tidal Station' like the one at Rangadia, Chittagong for Bangladesh. Manual leveling is laborious and time consuming, more difficult in hilly areas. Precise measurement of MSL needs observation of 18.6 years data, a full lunar cycle. In digital era these BM elevation can be obtained instantly but less precisely by GPS if geoid model of the area is available. Geoid model is the model of the earth represented by the equipotential surface of the sea. Surface of sea is not smooth as presumed/perceived but undulated due to varying gravitational force across the earth due to its varying mass, lunar gravity, etc. Geoid model of Bangladesh has 20 cm accuracy which will be upgraded soon with better accuracy. GCPs are vital for georeferencing any map. Modern geodetic achievements of SOB are shown below.

Table 3.1 : Geodetic Control Points of Bangladesh

(As on June 2014)

Ser	Geodetic Control Points	Nos
1	1st Order Horizontal Control Points by GPS Observation	267
2	2nd Order Horizontal Control Points by GPS Observation	756
3	1st Order Vertical Control Points by Levelling	665
4	2nd Order Vertical Control Points by Levelling	1300
5	3D Control Points	629
6	Total Number of Control Points	2988

Figure 3.1: Horizontal Datum at Gulshan

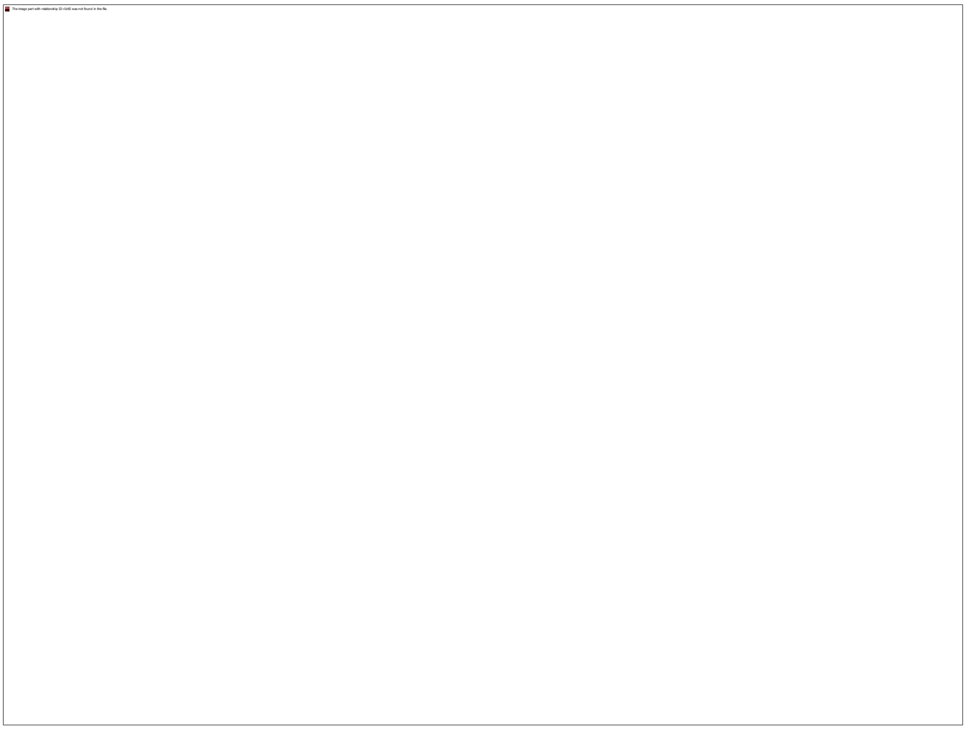


Source: Survey of Bangladesh

Figure 3.2: Vertical Datum at Gulshan

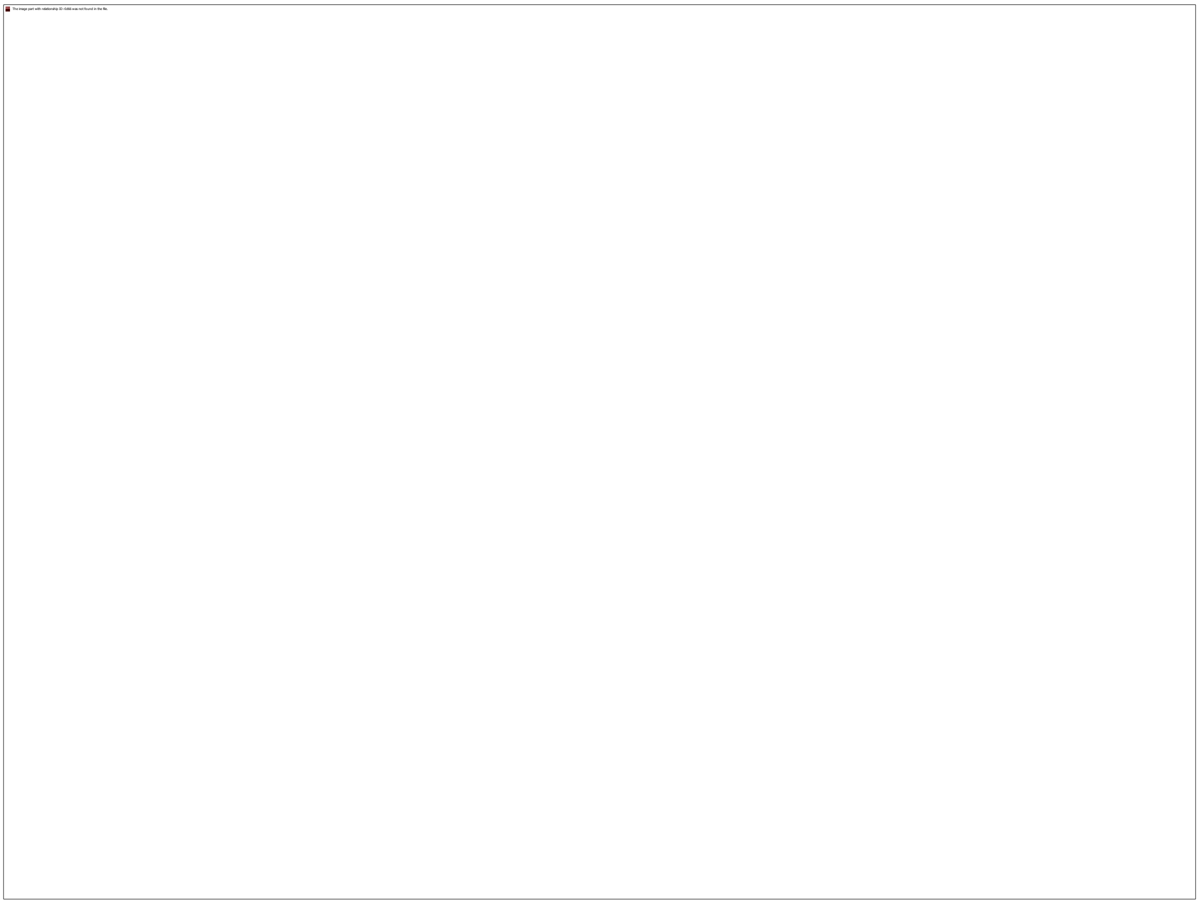
Source: Survey of Bangladesh

Figure 3.3: Tidal Station at Chittagong



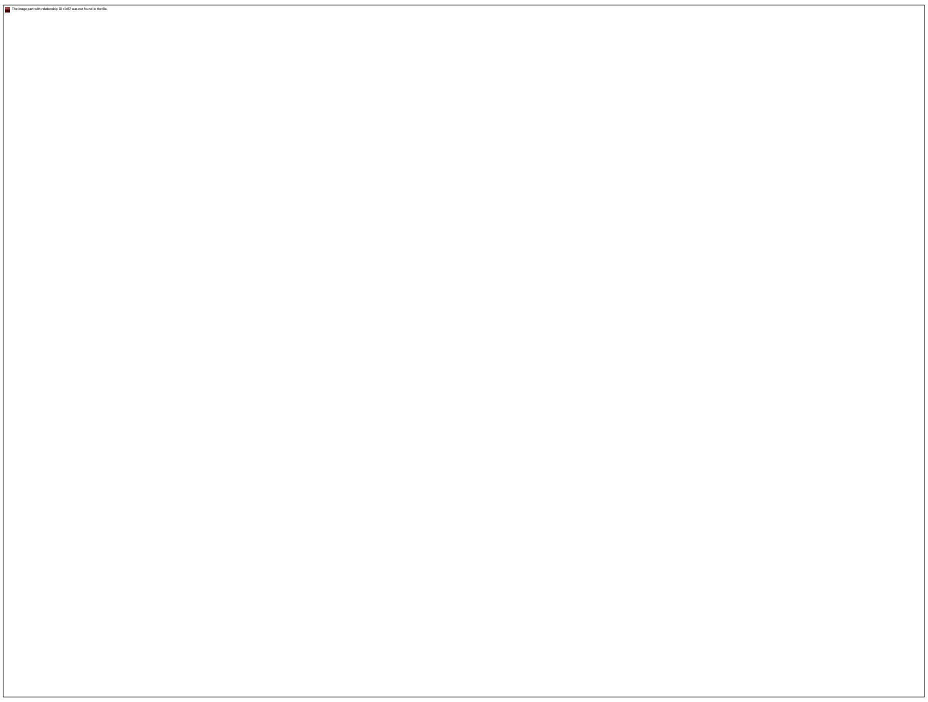
Source: Survey of Bangladesh

Figure 3.4: Horizontal Control Points in Bangladesh



Source: Survey of Bangladesh

Figure 3.5: Geoid Map of Bangladesh

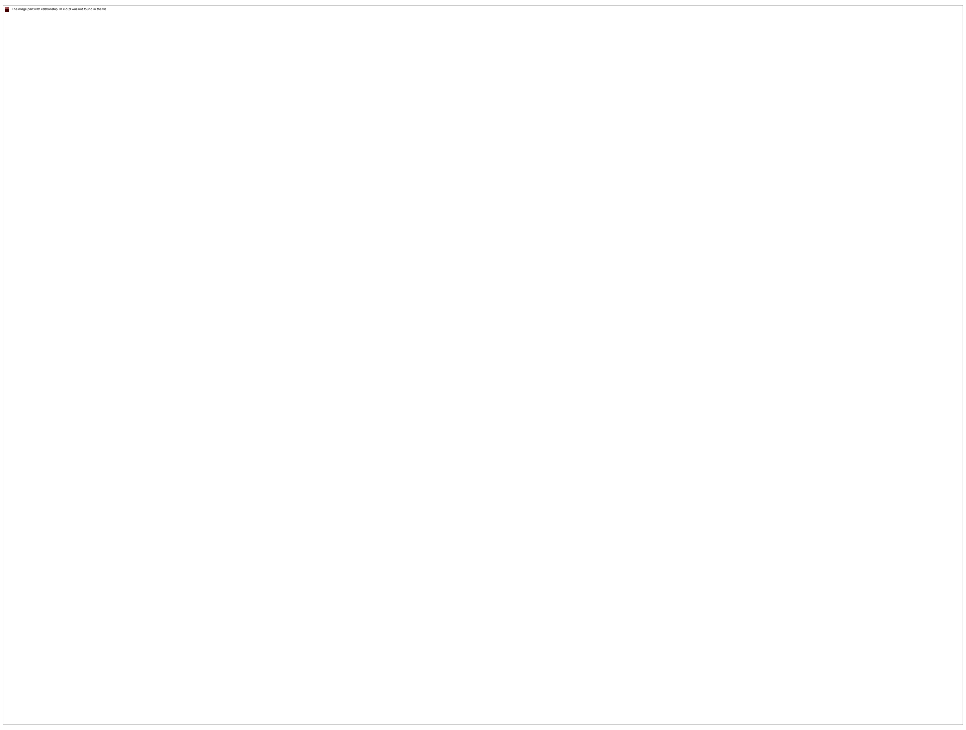


Source: Survey of Bangladesh

Figure 3.6: GNSS CORS at Dhaka

Source: Survey of Bangladesh

Figure 3.7: GNSS CORS Network in Bangladesh



Source: Survey of Bangladesh

3.4 Collection of Geographic data from Space:

High resolution digital camara is used to capture the terrain data to produce colour and near infra-red aerial photo. These aerial photos are processed in digital photogrammetry to extract topographic features. Digital Photogrammetry uses a combination of manual as well as automation method to extract topo-features. Automation is one of the main goal of digital photogrammetry. The human is capable of fast, precise, reliable measurement and cognitive reasoning for orientations and feature extraction but limited to human speeds and resilience. Again the computer is very fast and resilient but it has limitations of reasoning. Automation includes the photogrammetric processes like 'Interior Orientation', 'Relative Orientation', 'Absolute Orientation', Aerial Triangulation' and Automatic Feature Extraction'. It also involves Orthophoto and DEM generation. Interior orientation involves reliable automatic localization of fiducial marks, positional orientation and transformation.

Automation performs the job in generic manner, with fully automation, robustness and reliability, fast and precisely. Relative orientation (RO) involves reliable automatic localization of conjugate, well distributed and estimation of RO parameters. Absolute orientation(AO) involves reliable localization of ground control features and estimation of AO parameters. AO can be area or feature based (image to image), feature based (3D model to image features) and relational matching (model description to image description). Aerial triangulation involves preparation means control point identification, tie point selection, point marking, point transfer and point numbering, measurement means fiducials, image coordinates, data reduction like interior, etc and block adjustment. Present system is almost fully automatic except human interaction for GCP.

Feature extraction is the most time consuming task in photogrammetry. Fully automatic acquisition of roads, buildings, cartographic features from aerial imagery, ect appears to be difficult to model and to implement in computer algorithms. Rather, human operators appear to be indispensible for a reliable interpretation of aerial images. So called semi automatic procedure therefore combines the interpretation skills of the operator with the measurement speed of a computer. To obtain a higher degree of automation for interpretation of the aerial image by computer algorithms, much more knowledge is to be modelled and full automation is still a long way to go. Manual DEM creation is highly tedious and time consuming, few times more than feature extraction. Automatic DEM gives high economic efficiency and it has particular application to orthophoto production. Problem can occur due to terrain and image texture. In certain circumstances manual techniques can be more efficient.

3. 5 Spatial Data Preparation:

GIS has given a new dimension to the digital mapping. It has the capability to capture, store, manipulate, edit, attach attribute to features, display, manage and analyze digital map data both at raster and vector format. It has come to the forefront of IT and given individuals the capability to deal with map data which was mainly a government domain before. The attributes of map features are stored and managed in Relational DBMS or Object Oriented DBMS which enables the users to analyze data by structured query language (SQL). GIS middleware called spatial data exchange (SDE) maintains the relation between graphic data and DBMS. Now it also allows Server GIS through middleware called Arc SDE applicable for ESRI that allows to store and manage huge amount of spatial data as applicable for national mapping organizations. Open GIS (e.g. QGIS) getting more favorite to the users since proprietary GIS is expensive and open GIS getting more functional capability day by day.

Many different geographic phenomena are displayed and analyzed as surfaces. Some are among the most concrete that Geographic Information Systems (GIS) are designed to work with, while others are among the most abstract. The surfaces concerned are completely different in type, but they all have one thing in common: a surface representation is appropriate under any circumstances where the phenomena being modeled can be thought of as varying *continuously* across space. Indeed, the vector polygon model is a special case of a surface in which the changes in value across space happen abruptly at polygon boundaries. The most tangible surface is the land, the ground under our feet, measured as an elevation above a particular datum, commonly mean sea level, which is conceptualized as a horizontal surface.

The more abstract surfaces conceived by geographers include, for example, population density surfaces, soil pH, and atmospheric air pressure. Conventional conceptualizations of geographic objects make a distinction between point, line, area, and surface types. The continuous nature of surfaces means that, strictly, they do not embody any topology, although our inability to create truly continuous data structures means that surfaces are represented by various approximations that may include topological information. These include the use of SDE, digital elevation models (DEMs), and isolines/ contours, each of which can be handled by GIS. We conventionally refer to the variable of interest, represented as the height of the surface as the Z variable (and associated Z values), to distinguish it from the familiar X and Y variables of two-dimensional cartographic space. More importantly, GIS allows the users to unify data from various sources by bringing it to a same platform through change of datum and projection. But without the knowledge on geodesy, this conversion may create more trouble than solution.

3.6 Field Verification:

Field Completion: After the digitizing from images, a stage of field completion is necessary. The vision of field reality is partial and submitted to interpretation on aerial images. The stage of field completion allows to verify digitizing exhaustiveness, missing entities, objects geometry, correct codification etc.

The proportion of corrections by field completion depends on field characteristics and over all vegetation coverage. This stage is carried out by a surveyor team. The team leader manages, organize, help and control data of surveyor work. The modus operandi has of field completion in digital era. It has become quicker and faster. GPS is used to collect data on field. Mobile mapper and many other versions of GPS allows to capture field data directly to the laptops. GNSS CORS gives corrections to these GPSs to make the data collection more precise and quick. Integrated Survey (IS) is also favorite now using both GPS and Total Stations together where Total Stations are used in places without satellite cover and integrate the data direct to the computer with data acquired by GPS with satellite cover. 3D mobile mapper is a vehicle fitted 360 degree moveable camera fitted with GPS which takes photos in 360 degrees as it ply through road. This data is then integrated with other map data which expedite the field completion time considerably.

3.7 Final Map Creation:

This section discuss about importance of group of cartographic techniques associated with the 25k and 5k digital mapping in SOB.

Legend: The Legend cannot follow old standard which were established when all the survey was carried out on the field. Thus, the legend could not be as accurate as it was otherwise the field survey would cost a lot, and at least the whole of the mapping process without true and objective benefit. A compromise should always be found between a reasonable fieldwork and a map legend close to the old one. On the other hand, we should integrate in the new legend some features, which can be useful for end-users, and easy to capture from images. A modern legend should integrate land-user concept and is coming from a collaborative work between SOB and other users (public and private). However, the tradition and cultural aspect should be kept into consideration. The legend keys are defined in parallel with the Conceptual Data Model of the Data Base, because the maps are generated from this base, so all the required information must be in the Data Base.

The sheet line system: The actual sheet line system is based on geographic coordinates related to the official geodetic system. It follows standards in term of size of maps, i.e 1/25,000 is 7'5 by 7,5' and 1/50,000 is 15' by 15'. The projection associated with the old India Datum (Everest 1830) is a

Lambert projection. The projection associated with WGS84 is BUTM (Bangladesh Transverse Mercator). Because of the offset between those 2 systems, (roughly 250m), the maps will present this same offset. It means that 2 hardcopies of contiguous maps in those both systems cannot be adjusted properly and there will be a gap on one side and a lack on the other side. Considering this situation, the new 1/25,000 maps sheet lines were designed according to the modern Bangladesh Geodetic system (based on WGS84) and his linked projection. Thus, there will be some problems on the 1/50,000 between old maps and new maps but this new sheet line system is a good opportunity before starting a new map series at 1/25,000.

The generalization issue: As the database describes the features as they were seen on aerial images (50cm resolution), we can expect that the internal accuracy will not be so far to one meter. Taking account minimum size of building on maps (0.4mm x 0.4mm) in order to make their identification clear (universal cartographic rule), and taking account the size of houses in the countryside in Bangladesh, average 5mx7m, it leads to that the minimum scale for mapping the houses just considering the scale effect should be 1/12,500. On the other hand, it means that mapping houses in 1/25,000 maps cannot be done without generalization process. We could resume this by: It was impossible to map Bangladesh at 1/25,000 keeping original location of features just reduced to this scale. The situation became more complex for mapping the country at 1/50,000 using the topographic database as well. Generalization process could not be done automatically even if recent results from research laboratories let hope that we are not so far from acceptable results. However, these tools are still very expensive and complex to set up. So a compromise was found between manual process and full automatic process by scripting in Python software.

Automated Generalization: Many of the generalization decisions are simultaneous rather than sequential. Therefore such programs are difficult to model and implement it by computer algorithm. Some theoretical or conceptual models and workflows have been developed. But the implementation of such systems have not been successfully accomplished the major difficulties being the lack of full understanding of map generalization and associated cartographer rules. The need for automated generalization has increased in recent years and there is a big growth in the fully digital production of maps and Internet has increased the requirement for on demand mapping. Automated generalization has some benefits like less manpower cost, more speed, reduce manual errors and quick production to suit market need. In order to automate generalization it is necessary to break the process in smaller stops called ''operators''. These operators are:

a. **Selection/Classification** : Selection is the process of deciding which classes of features will be necessary to serve the maps purpose. The goal of classification is to express the salient character of a distribution. It groups similar phenomena in order to gain relative simplicity. Example of selection is to portray roads or not to portray roads, to show or not to show towns with a population less than 2000.

b. **Elimination**: It is done by the elimination of point line and area features. It eliminates minor object of the same class refair the major objects, therefore reduces excessive clutter caused by changes in scale and symbol overlap. Before elimination three factors should be considered. These are importance of feature, degree of isolation e.g. retain all houses that are 500m from any other habitation; density of information typification aide elimination by reducing feature density and the level of detail while maintaining the representative distribution, pattern and visual impression of the original feature group. It helps reducing the amount of information, increase legibility but retaining the essence of the are this is very difficult to automate because very subjective with decisions based on a knowledge of the area.

c. **Simplification:** Is reducing the quantity of detail in a point line or area feature. This is done by removing unnecessary dibit such as extraneous bends and fluctuations from al line or area boundary without destroying its essential shape. It element unwanted details, reduce amount of information, increase legibility retain essence of a feature. Recent algorithm developed such as the Douglas pucker attempt to keep critical points (point elimination) weeding out redundant points. There critical points are relevant to the physical character of the line as well those related to perceived points of importance such as a city on a river.

d. **Exaggeration:** Is to increase the spatial extent of a feature's representation for the purpose of emphasis and legibility. Exaggeration will prevent important features becoming lost amongst the map clutter. But exaggeration will loose scale, enlarge some features relative to others and produce topological errors, eg enlarging the size of an island of navigational importance which is otherwise small enough to be removed without exaggeration, it is not possible retain features like roads, streams, buildings etc in large scale maps.

e. **Collapse:** Is reducing an area feature to a linear point feature or a linear feature to a point feature. Collapse reduces the amount of represented detail to avoid clutter on the map face e.g. tour that cannot be represented by as a polygon due to insufficient space and has to be represented as a point feature instead.

f. **Aggregation**: Is merging originally distinct objects into a single representative object. It is done by combining features in close proximity or adjacent features into a new area features. Methods of aggregation area boundary removal and related neighbors. Purpose is to omit small spaces and simplify general outline. Aggregation must be logical e.g. amalgamating building on different sides of a major road is not logical.

g. **Symbolization:** Symbolization may also require generalization because the cartographer may change a feature dimensionally. Road exaggerated to make it stand out as an important feature, however, it is now misinterpreted. Now appears wider and may overlap to obscure other features.

h. **Displacement:** Is to prevent overlap between objects caused by a reduction in scale or other generalization processes. Displacement is a major task within the map making process. The problem is that this will not necessarily follow a pattern or be consistent throughout a map sheet and is very difficult to automate is only a small part of a selected feature needs to be moved. For example when the scale is a road and a river in one area of he map may merge or overlap in a different area they may not totally be dependent on the nature of the ground.

j. **Enhancement:** It removes jagged edges from computer generated line and area features, particularly when curved. Enhancement is used to smooth the effects of simplification caused by poor use of thresholds or sampling. Generally applied after simplification, Methods used are moving average operator and adding points. Additional points are added remove the spiky appearance of the generalized line which is done by fitting a spline curve.

k. **Aesthetic Refinement:** Other examples where it may be necessary as a result of other generalization process to adjust the geometry or zymology of a feature to improve its visual impression eg squaring building, aligning buildings to a road.

3.8 Activities and Achievements in Digital mapping by SOB:

The first initiative for digital surveying and mapping was taken in 1992 by establishing 1st order geodetic network for Bangladesh. Survey of Bangladesh established horizontal datum at Gulshan by 7 days GPS observation and process the data with respect to four other GPS stations around the globe. Then 140 horizontal control points are established with respect to datum by GPS observation. A tidal station was established at Rangadia, Chittagong. Tentative mean sea level was observed taking the data of two years observation with the proposition that MSL will be finally decided after one lunar cyle of observation i.e. 18.6 years. Leveling was performed along Dhaka-Chittagong road by level machines and vertical datum was established at Gulshan. A total of 453 nos 1st order vertical control points were established in Bangladesh. This geodetic network replaced the old inaccurate network inherited from British India and form the foundation for quick and precise digital mapping and surveying. The height reference system is the existing one, that is the Gulshan datum. The type of altitudes is orthometric and the linear unit is the meter. The origin of altitudes is presently a mean value of the sea level taken at Rangadia, in Chitagoong, over a period of two years between 1992 and 1994, but now the full luner cycle data for 18.6 years are available and computed where less than 3 mm variation is found which is insignificant to declare the change of altitude at Gulshan datum.

Now, the National mapping organization has improved the geodetic networks of the country, as a support to the cartographic activity, and express it in the most precise world-wide geodetic reference system ITRF2008, while at the same time maintaining links to the fragments of the old geodetic network and leveling networks. Later on, SOB densified its geodetic network over the time.

The second initiative for digital mapping was taken in 1995. A project was undertaken to digitize the analog 50k paper maps (267 sheets) with the assistance of France Government. There are two ways of making digital map. One by digitizing the existing paper map which is less accurate, less expensive, comparatively less skill required but more quick. The other one by photogrammetric method which is more accurate, more expensive, high skill required and time consuming but much faster and less exhaustive than analog mapping. The former method was chosen because SOB did not have any digitally skilled manpower and foreign aid was limited. Accordingly, production line up set up with requisite number of hardware and software. The softwares were of French origin called

"GeoConcept", a kind of semi GIS cum Cad software. A considerable amount of operators were trained at home and abroad and then the digitization began with trial and error. It took around 15 years to digitize 267 sheets. Irony was that, at the end of the project it was understood that these data could not be used in formal GIS software like ArcGIS neither possible to make seamless map of Bangladesh since the data format can not be converted to common GIS format like shape format. So the use of the digitized map remained limited to that of the analog maps for years together. Ultimately, after a lot of trial and error by professional consultant and with the advent of modern software it was possible to convert the data into GIS database in 2013, although not an ideal one. Now SOB possess a seamless digital map data of Bangladesh. An example with such map with blow up is shown at Figure 3.8 and Figure 3.9 below.

Figure 3.8: Blow Up of Topographic Map of SOB

Source: Survey of Bangladesh

Figure 3.9: Topo Map of SOB

The image part with relationship ID rId71 was not found in the file.

Source: Survey of Bangladesh

Another initiative was taken to prepare medium scale (1:5000) digital map of Dhaka city in 2002. It was assisted by JICA. This time photogrammetric method was followed. This was jointly prepared by JICA and SOB. Aerial photo was taken in early 2003. Field verification was done in late 2003. Map was prepared and printed in 2004. At the same time seamless GIS database, ortho photo and DEM of Dhaka city is also prepared. A sample map with blow up is shown at Figure 3.10 and Figure 3.11 below.

Figure 3.10: 1:5000 Scale Digital Map of Dhaka city

The image part with relationship ID rId72 was not found in the file.

Source: Survey of Bangladesh

Figure 3.11: Blow Up of 1:5000 Scale digital map

Source: Survey of Bangladesh

The fourth initiative of digital mapping by SOB is considered as a big leap forward for a country like Bangladesh. This is 25k digital mapping of entire Bangladesh and 1:5000 scale for Divisional cities. Outputs are about 1100 digital map sheets, GIS database, Orthophoto, DEM of entire country and establishment of 6 GNSS CORS stations spreading over Bangladesh. It is a JICA funded project and duration is from 2007-2016. It is a very challenging project for any country due to requirement of highly skilled technicians' in various discipline of mapping and surveying subjects, Knowledge and capability at mid-level management and above all vision at decision making level. Vigorous training was imparted to operators both at home and abroad. Motivation played a vital role in encouraging operators to acquire difficult and tedious skills. Best equipment and software were procured and production line up was installed. Aerial photo of entire country except international border area was acquired in 2010 and 2011. Aerial photos are digital, colour and near infra-red (NIF) with 50cm resolution and 25cm resolution for Divisional cities. SPOT colour imagery of 2.5m resolution for the border and Sudarban area along with DEM is also procured. Then features are extracted by photogrammetric method in 3D, sent for field verification, edited and topology correction given as well as features are attributed to create GIS database and then cartographers produce final maps for printing by compilation, symbolization, generalization and attaching marginal information. Orthophoto and DEM are created by Photogrammetry section. Digital map creation process is shown at Figure 3.12 below.

Figure 3.12: Digital Map Creation Process

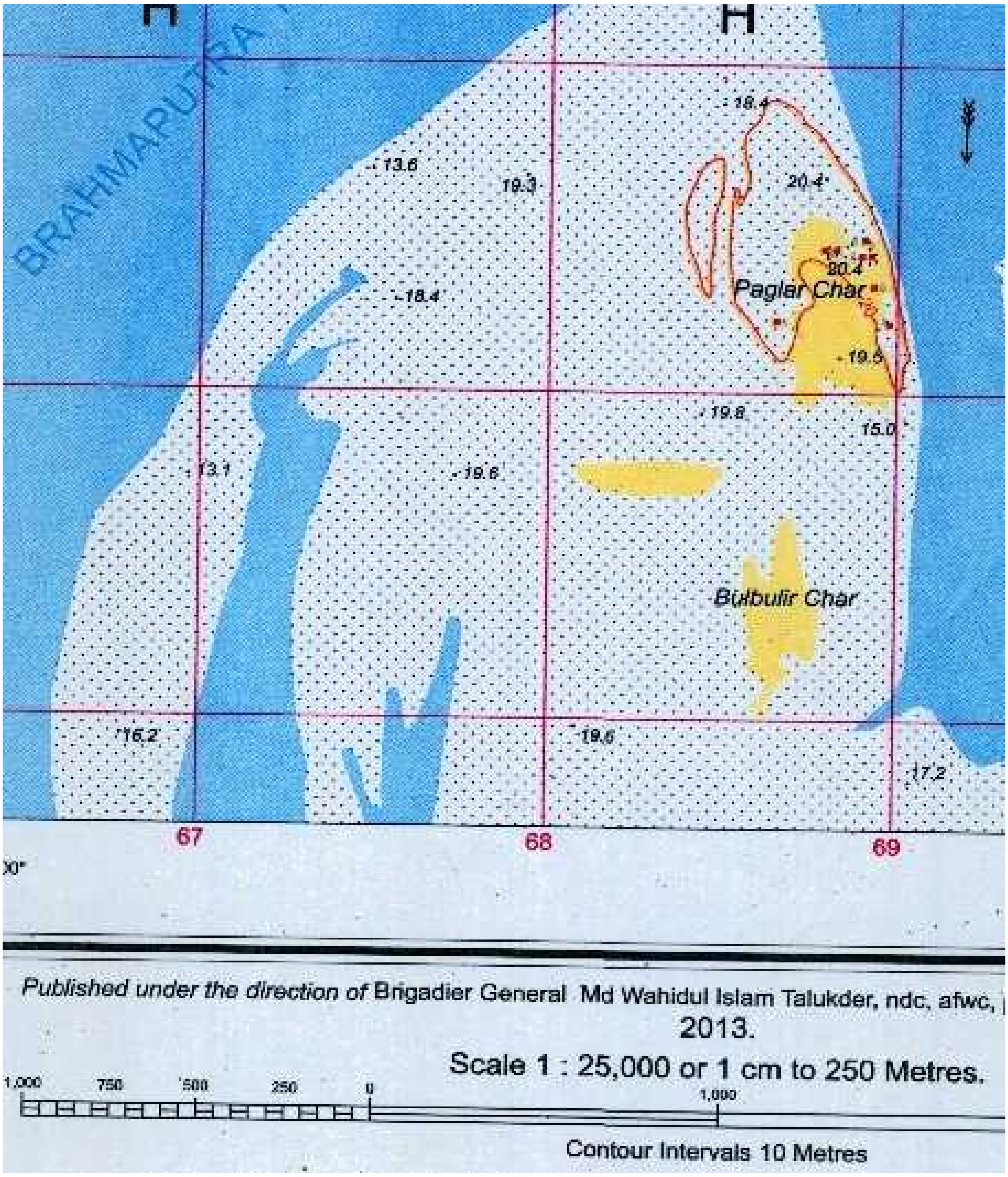
Source: Survey of Bangladesh

The project is being implemented very efficiently and hopefully be completed in time. It will certainly uplift Bangladesh to a new height of technology and prestige. These data will be the foundation data for future NSDI of Bangladesh. An example of map with blow up is shown at Figure 3.13 and Figure 3.14 below.

Figure 3.13: 1:25000 Scale Digital Map of Bangladesh

Source: Survey of Bangladesh

Figure 3.14: Blow Up of 1:25000 Scale Digital Map

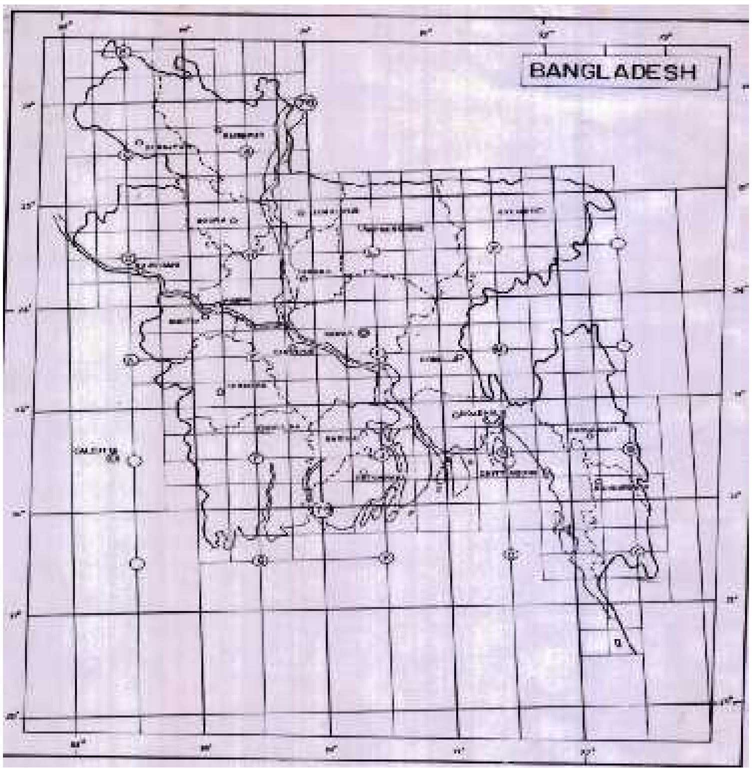


Source: Survey of Bangladesh

3.9 Output of this study from Recent Maps:

It was discussed in Chapter2 under methodology that 1:2,50,000 scale maps of 2000 onward were selected for extracting the selected features like rivers, forests and coastal belt. There are total 28 sheets covering the entire country and these sheets are prepared following the repeated revision surveys in the field from those maps of 1940/1950s. Updates are also compiled from 50k series time to time. However, these sheets are not made digital with the idea that once the 50k maps are made digital then 250k maps would be compiled from there. In fact, that is how smaller scale maps are normally compiled from larger scale maps by generalization. The Sheet Nos with index are shown at Figure 3.15 below.

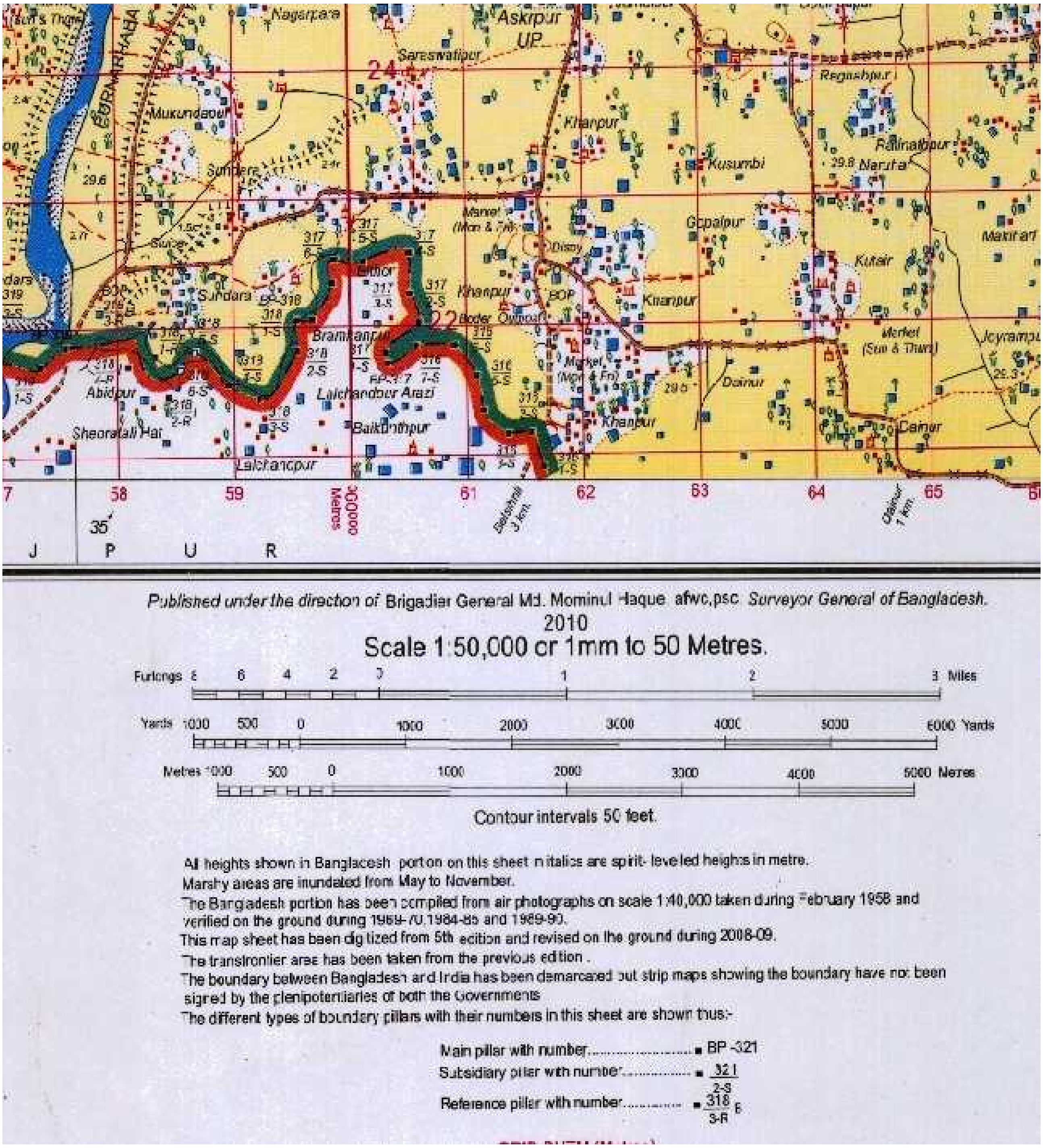
Figure 3.15: Index Sheet of 1:250000 Scale Maps



Source: Survey of Bangladesh

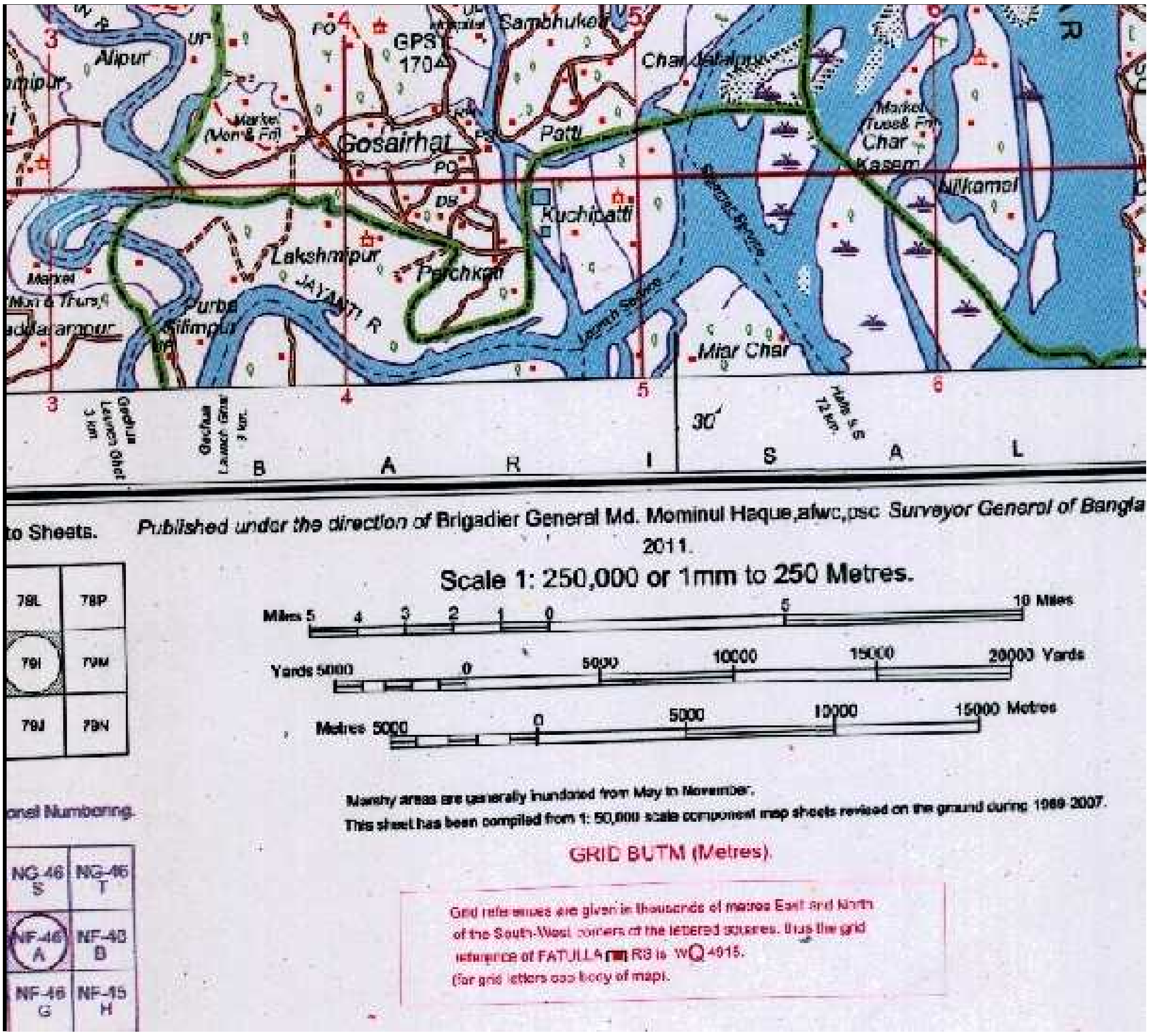
So the sheet nos are 78B, 78C, 78D, 78F, 78G, 78H, 78K, 78L, 78O, 78P, 79A, 79B, 79E, 79F, 79G, 79I, 79J, 79K, 79M, 79N, 79O, 83C, 83D, 83C, 84A, 84B, 83C and 84D, as evident from figure above. It may be noted that although the map sheets are printed in 1990/2000s, field verification was conducted 5-10 years before as shown at Figure 3.16 and Figure 3.17 below. So the topo features depict its state of those times of survey.

Figure 3.16: 1:250000 Map Showing Field Verification Time



Source: Survey of Bangladesh

Figure 3.17: 1:250000 Map Showing Field Verification Time



Source: Survey of Bangladesh

In order to prepare the data for this study, the 28 map sheets are scanned in precise scanner and then georeferenced in its original coordinate system i.e. Everest 1830 ellipsoid and BUTM projection using Arc GIS software. Then sheets are cropped along neat line so that they can be mosaicked to a seamless map of entire country. Now the map was ready for topo feature extraction in vector format from raster. Before feature extraction, the mosaicked map datum is converted to WGS84 Ellipsoid and BUTM10 projection from Everest 1830 ellipsoid and BUTM projection. The reason for bringing the datum to WGS84 and BUTM10 projection is that the 50k and satellite data are available in this datum which is used for validity check of the data produced for this study. The parameters used for the datum conversion are shown below.

Ellipsoid:

DX= +283.729m

DY= +735.942

DZ= +261,143

Da= +860.655

Df= +0.28361368

BUTM10 Projection:

Latitude of Origin= 0 degree North

Longitude of Origin= 90 degree East

False Easting= 5,00,000m

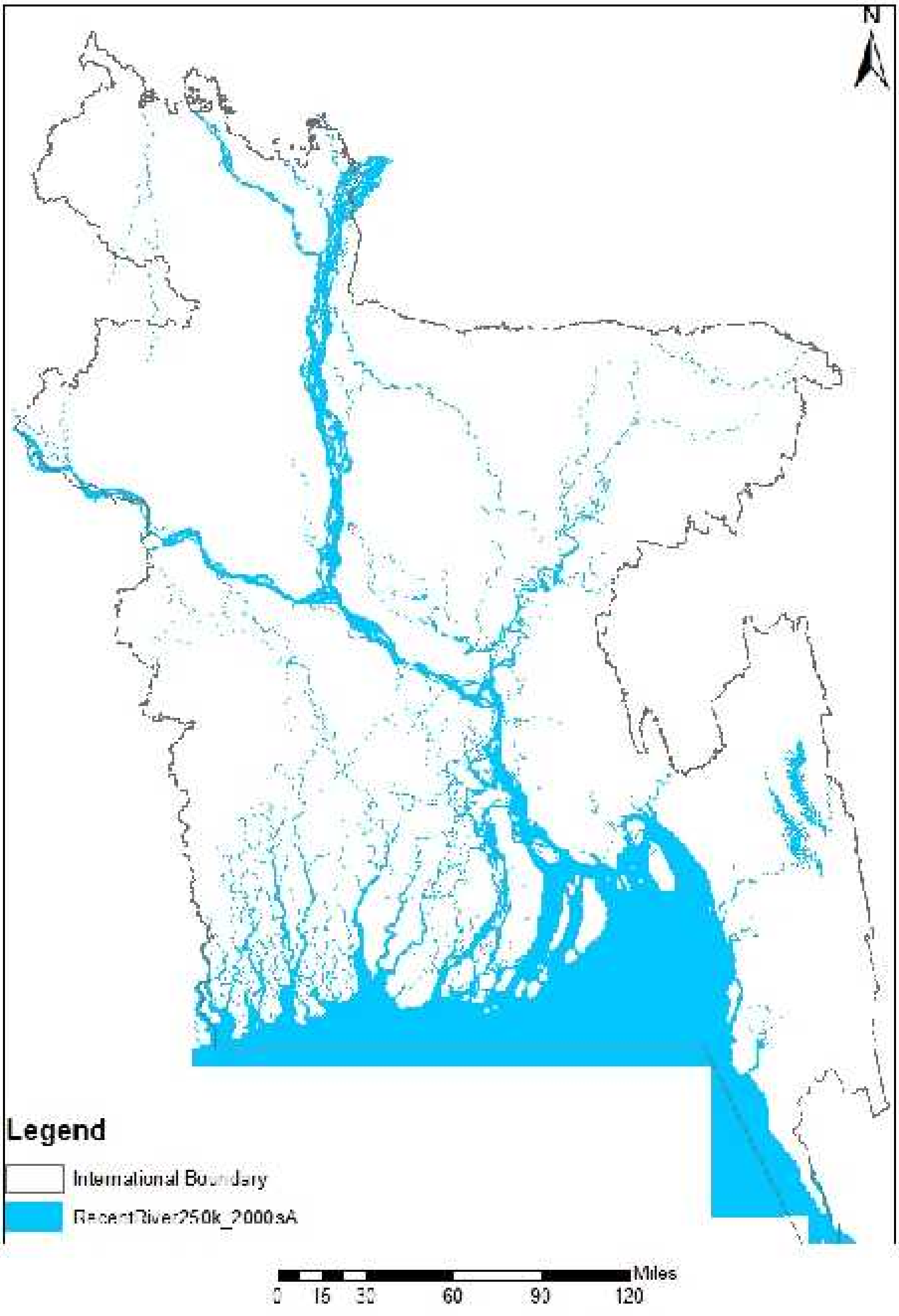
False Northing= 0m

Scale Factor= 0.9996

Accordingly, the features were digitized in vector format (shape/geodatabbase). Then it needed to be edited for topological correction in order to be able to utilize the data for GIS analysis. For satellite data, supervised classification was performed in order to separate the water and forest area. Then data conversion was performed to create vector data. These vector data were then generalized so as to be compatible to the 250k map scale. However, this data is mainly prepared for checking the validity of the data prepared from 250k maps not for change detection.

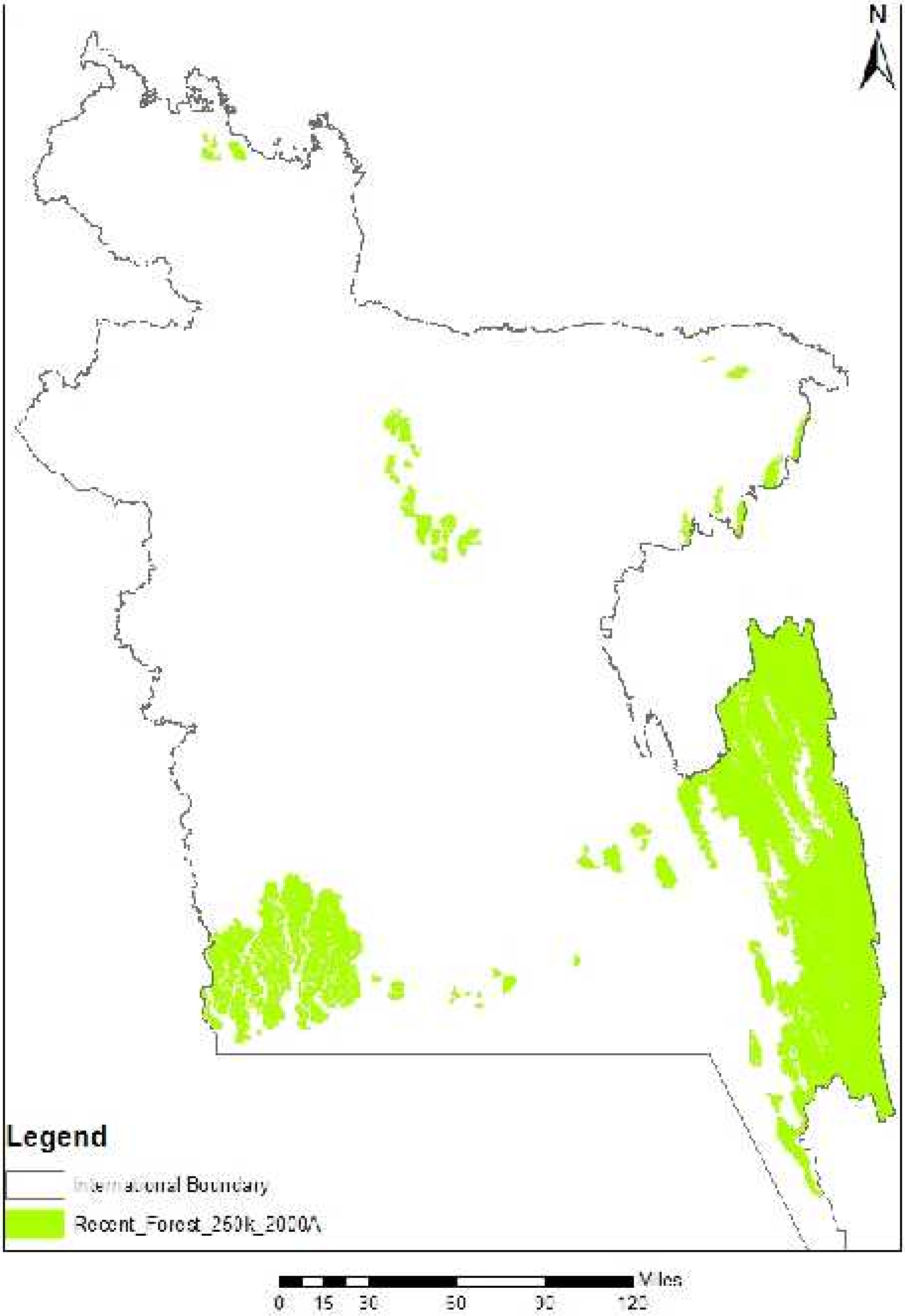
Many trial and error had to be performed to prepare the data at various stages. Digitizing was a very tedious and tiring undertaking since the data were huge covering entire country. Computer often got hanged due to huge data memory. Sometimes losing the data of entire day effort due to wrong button press was not very rare. Hopefully, the layers prepared will pay dividend during data analysis in Chapter 5. Output data of the three layers mentioned above are displayed at Figure 3.18, Figure 3.19 and Figure 3.20 below.

Figure 3.18: River Network Extracted from New Digital Maps



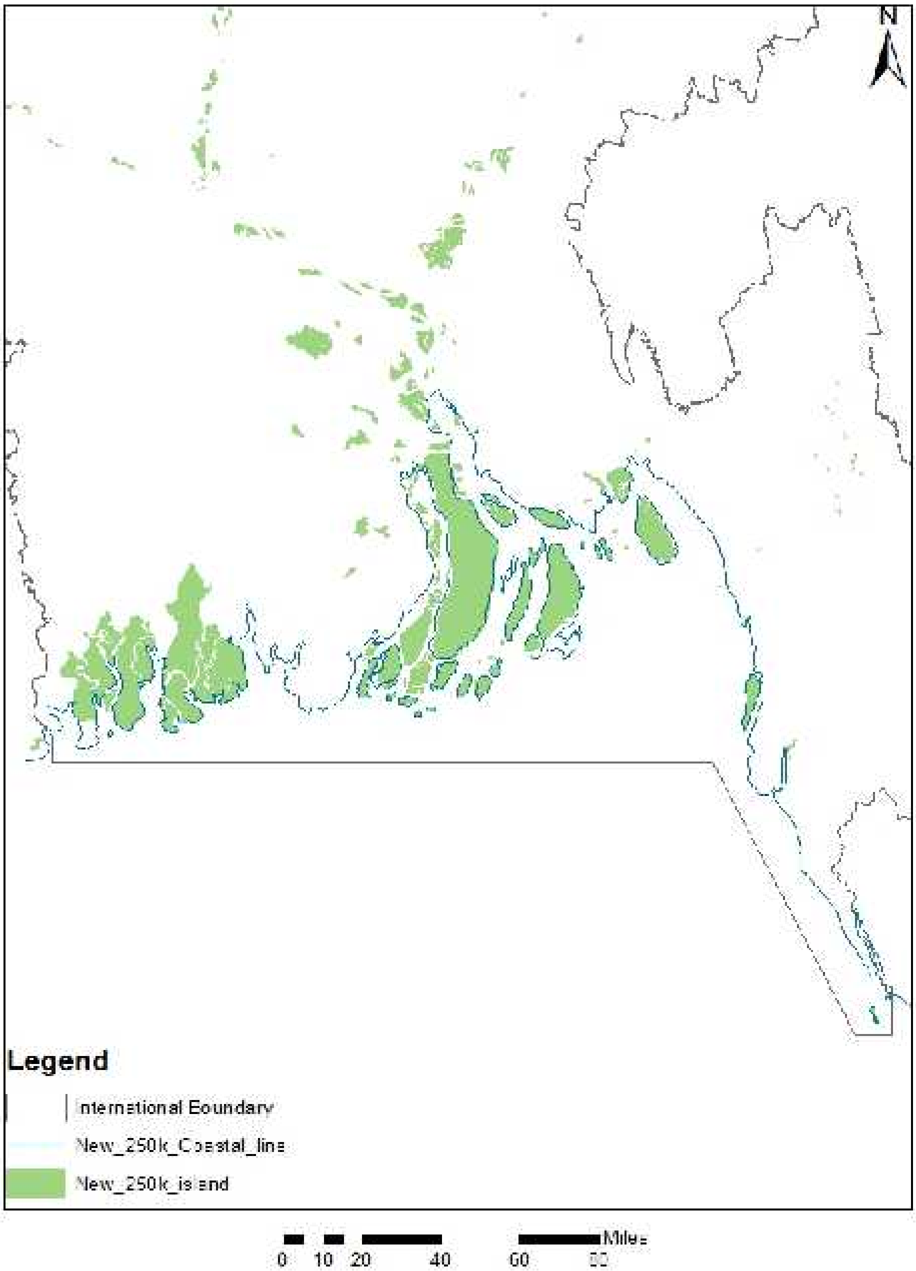
Source: Self Prepared

Figure 3.19: Forest Layer Extracted from New Digital Maps



Source: Self Prepared

Figure 3.20: Shore Layer Extracted from New Digital Maps



Source: Self Prepared

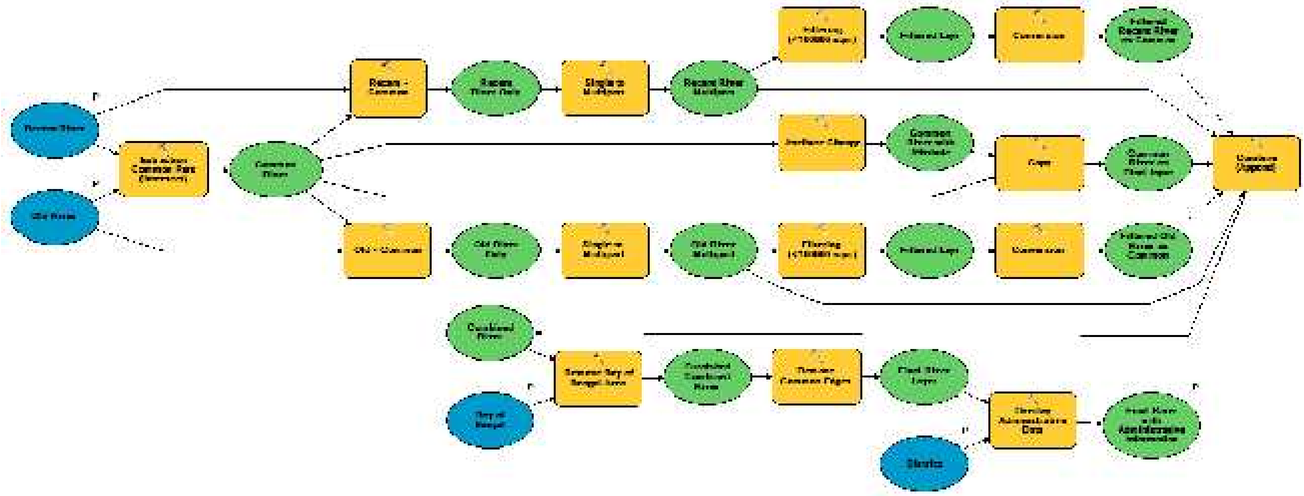
Chapter 4

Extracting River Topo-Features data and Detect Changes for the two periods

4.1 River Change Detection:

This data processing aims at detecting/identifying the changes that has taken place between the rivers of 1940s verses 2000s. This is achieved by processing and analyzing the vector data of rivers in GIS using the existing functions/tools to create a Model for analysis in order to get the desired output in the from of statistics. So the output data of previous two chapters has been used as input data to detect the changes between 1940s and 2000s. As we know, direction of the river Jamuna got sudden change in the year of 1762 due to a big earthquake as a result of tectonic uplift of the Modhupur tract. Such changes are not expected within the period covered in this research. However, Bangladesh being the greatest delta in the world huge natural changes does take place due to river erosion, river meandering nature, construction of dams, etc which will be well detected in this research. This chapter describes about GIS model for data processing, detect division wise river changes and validate the results comparing with similar studies on the river. The data model prepared in GIS is shown at Figure 4.1 below.

Figure 4.1: Data Model for River Analysis



Source: Self Prepared

4.1.1 Extracting common part of old and Recent Rivers:

All the rivers have changed their courses over the time. We need to identify the portion of the rivers of both the period that is common means remained as part of flowing rivers. The function ''Intersection'' is used to extract common part of old and new river called common river in the model. This common river indicates the portion of both rivers which is not affected by the changes means it exists throughout the time of comparison. Graphically this is represented by deep blue colour.

4.1.2 Identify Newly Developed River:

After the common river is identified, it is now possible to identify newly developed river. The function 'Erase' is used to identify newly developed part of river called 'Recent River only' in the model which is achieved by subtracting common river from recent river. 'Recent River only' indicates that this part is converted to river from land. Graphically this is represented by deep maroon colour.

4.1.3 Identify Dead part of old River:

Similarly the dead part of old river can be identified. The function 'Erase' is again used to identify the part of the old river that is converted into land/char called ''Old River only'' in the model. This is achieved similarly by subtracting common river from old River. Graphically this is represented by deep gray colour.

4.1.4 Generalization of Insignificant Part of Rivers:

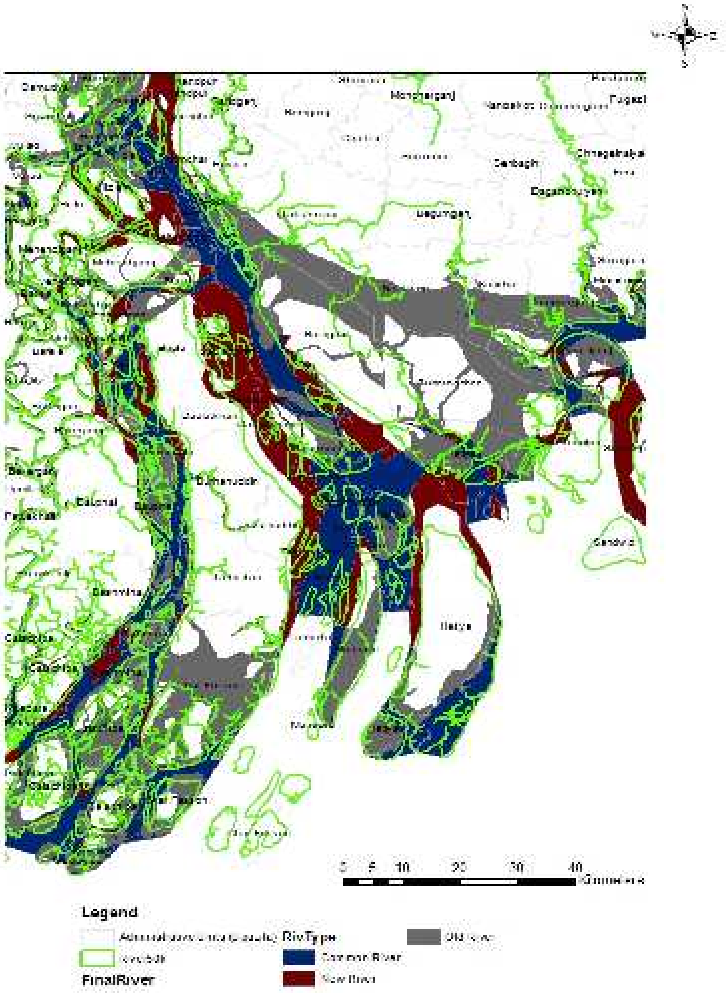
The river data are digitized from 1:2,50,000 scale maps after scanning. There lies some errors from natural digitization error, resolution of image, human eye constraint, georeferencing, projection transformation, etc. In this research work an irregular area of the rivers (both old and recent) upto 1,00,000 sqm has been considered to be generalized and merged with the common river. In fact, this value has been decided after number of trial-and-error of visual checking. To identify the insignificant parts of rivers generated because of mentioned digitization error the model used SQL based filtering function and changed attributes of the rivers to 'Common River', so that those parts can be merged later. This has been achieved by using the functions called ''Make Feature Layer'' and ''Field calculate'' to filler out irregular areas less then 1,00,000 sqm from both old and recent rivers those are respectively called ''Filtered old river as common river'' and ''Filtered recent river as common river'' in the model.

4.1.5. Finalization of Both River Data:

In order to prepare the river data for statistical analysis we need to create a combined River layer consisting of attributes of common river, Recent River only and old river only, This is achieved by the no of functions ''Field calculate'', 'Append' and 'Dissolve' from generated features called 'New Rivers Only', 'Old Rivers Only' and 'Common River' to Final River data. This data, however, consists of three types of data and those are 'Common River', 'New River' and 'Old River'. Finally we made 'identity-overlay' function to bring administrative information (Division name and District Name) for zonal analysis in the" Final River" data. Now this is the layer to generate different statistical data using GIS model.

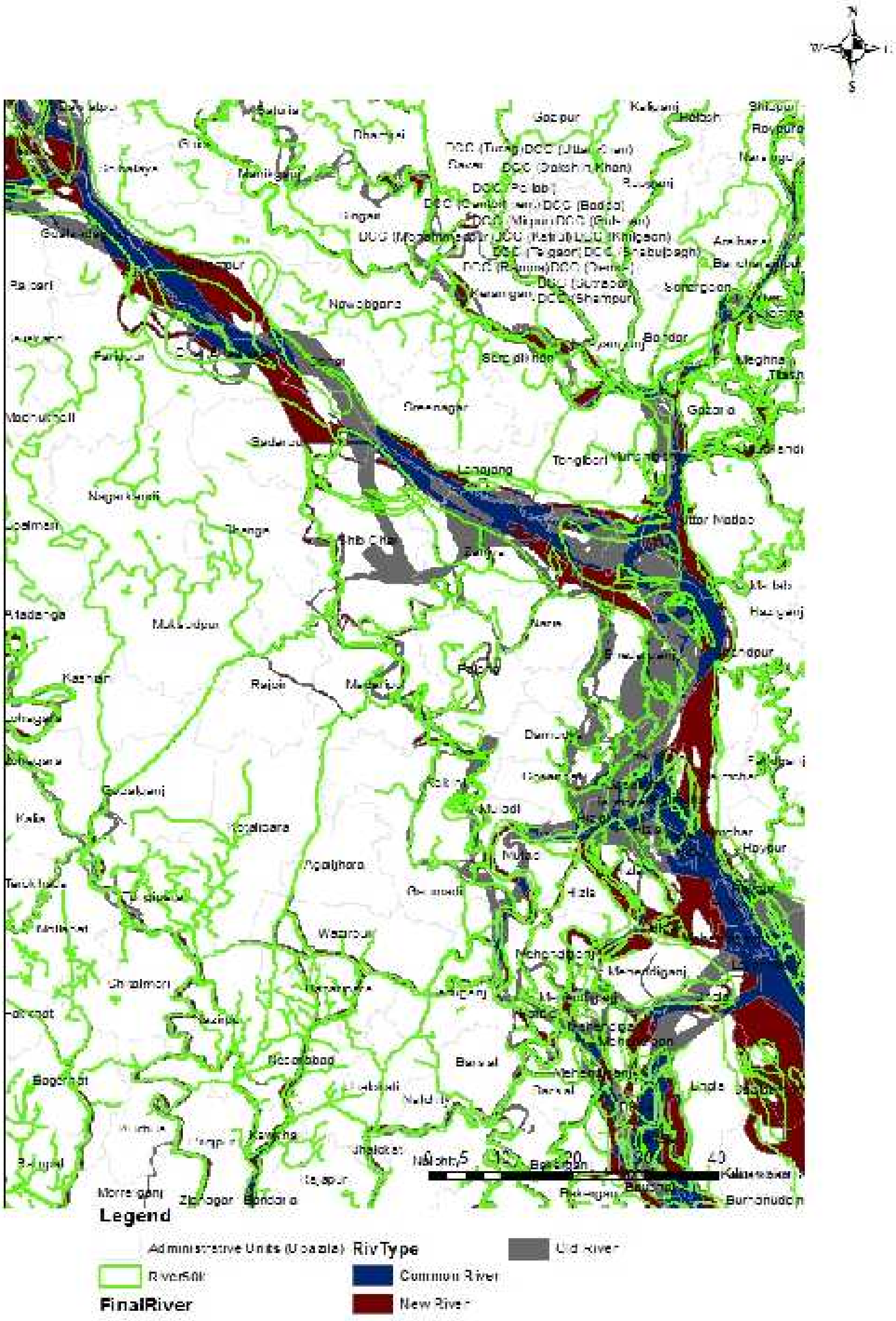
4.1.6 Validation of Created Data: The river data created in this research must be validated against some authenticated data. Accordingly, river data created by SOB from 1:50000 scale map very recently was collected and overlaid on 'Final River' data. 1:50000 scale data is more up to date than 1:250000 scale new data although both data created within 2000 to 2012. However, this overlay gives us a reasonable idea about the validity of the produced data in this research. 1:50000 scale river flow and islands data are represented by green outlines only. Three segments of the overlaid data are displayed at Figure 4.2, Figure 4.3 and Figure 4.4 below for comparison. The new 1:250000 scale rivers are represented by blue and maroon colour.

Figure 4.2: Comparison of Meghna River



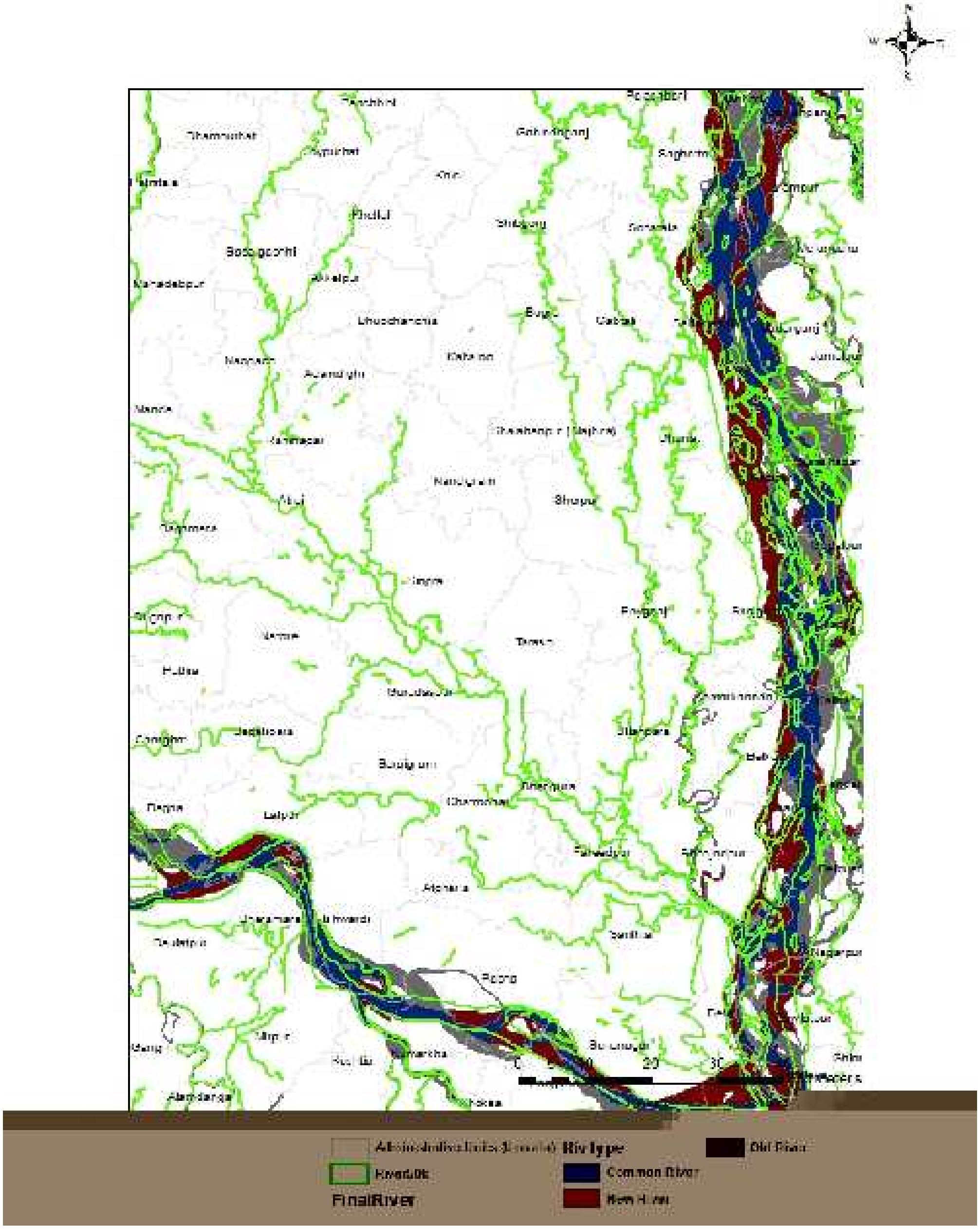
Source: Self Prepared

Figure 4.3 : Comparison of Padma River



Source: Self Prepared

Figure 4.4: Comparison of Jamuna River



Source: Self Prepared

From the above, we can see that the 50k river coincides more with blue and maroon colour of 250k river than blue and gray colour. Blue and maroon colour represents the flow of river from recent 250k maps rather than old 250k river represented by gray and blue colour. Slide variation is due to the difference in scale of maps and different updating period of maps. It may be noted that all maps of entire Bangladesh are not updated in one season rather it takes 5 to 10 years to cover the entire country. As such different parts of river represents the layout of different years within a span of 5 to 10 years. Major deviation courses between 50k and 250k maps are attributed to these reasons where river changes are quite fast due to soil condition and lack of river protection in this country.

4.2 Statistical Analysis from the Developed Data:

GIS can generate various statistics from the attributes of digital map data. Now that we have district and divisional attribute in our processed digital map data we may get following answers:

1. How much changes has occurred in each district by river changes?
1. Which are the most vulnerable districts?
1. Is the total river area increasing or decreasing?
1. Changes are taking place in which direction and pattern?
1. River erosion's direction?
1. Etc.

Similarly, if we overlay population, industry, educational institutes, health facilities, irrigation, terrain analysis for defense potentiality etc., data on this Final River data, it is possible to address many relevant questions. Division and district wise river changes are shown in Table 4.1 below.

Table 4.1: Division and District wise River Changes in Bangladesh

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Barisal Div	1,437.08	1,182.03	1,269.91	3,889.03	2,706.99	2,619.12
Barguna	FALSE	79.45	54.69	310.53	54.69	79.45
Barisal	145.75	304.97	187.96	638.68	333.71	450.72
Bhola	523.30	467.47	584.87	1,575.63	1,108.16	990.77
Jhalokati	15.05	32.54	6.68	54.27	21.73	47.59

Patuakhali	487.07	237.07	406.40	1,130.54	893.47	724.15
Pirojpur	89.53	60.53	29.32	179.37	118.84	150.06
Chittagong Div	1,023.63	1,349.99	1,563.37	3,936.99	2,587.01	2,373.62
Bandarban	0.22	0.10	0.01	0.33	0.23	0.32
Brahamanbaria	72.47	63.71	52.87	189.05	125.34	136.18
Chandpur	155.49	178.26	53.39	387.13	208.87	333.75
Chittagong	121.01	178.16	157.95	457.12	278.95	299.17
Comilla	24.20	40.23	16.35	80.78	40.55	64.43
Cox'S Bazar	85.78	26.62	185.49	297.89	271.26	112.40
Feni	19.50	16.14	31.06	66.71	50.56	35.64
Khagrachhari	-	6.35	-	6.35	-	6.35
Lakshmipur	214.84	112.94	301.47	629.25	516.32	327.78
Noakhali	318.00	183.72	761.54	1,263.26	1,079.54	501.71
Rangamati	12.12	543.77	3.25	559.14	15.37	555.89
Dhaka Div	863.45	1,072.49	1,277.20	3,213.14	2,140.65	1,935.94
Dhaka	20.70	65.72	78.58	165.01	99.29	86.42

Faridpur	61.32	118.65	54.79	234.76	116.11	179.97
Gazipur	6.58	9.38	6.50	22.46	13.08	15.96
Gopalganj	8.78	21.54	24.60	54.92	33.38	30.32
Jamalpur	122.39	130.71	211.88	464.98	334.27	253.10
Kishoreganj	65.71	80.01	32.16	177.87	97.86	145.72
Madaripur	30.73	44.75	107.80	183.28	138.53	75.48
Manikganj	85.21	155.57	74.51	315.29	159.72	240.78
Munshiganj	68.57	74.22	61.03	203.81	129.60	142.78
Mymensingh	14.59	35.66	26.34	76.60	40.94	50.26
Narayanganj	35.13	40.81	34.42	110.36	69.55	75.94
Narsingdi	48.01	91.79	25.34	165.14	73.35	139.80
Netrakona	5.61	9.02	3.83	18.45	9.44	14.63
Rajbari	85.39	40.02	61.12	186.54	146.52	125.41
Shariatpur	127.02	93.14	319.18	539.33	446.20	220.16
Sherpur	4.10	5.64	6.08	15.81	10.18	9.74
Tangail	73.62	55.86	149.04	278.52	222.66	129.48

Khulna Div	1,159.61	554.15	555.49	2,269.25	1,715.10	1,713.76
Bagerhat	295.58	143.93	166.31	605.83	461.89	439.51
Chuadanga	14.44	1.57	7.08	23.09	21.52	16.01
Jessore	0.98	3.21	2.60	6.78	3.57	4.18
Jhenaidah	15.86	1.42	2.62	19.89	18.47	17.28
Khulna	367.15	214.71	177.18	759.04	544.33	581.86
Kushtia	104.02	43.36	90.11	237.50	194.14	147.38
Magura	17.56	10.38	9.11	37.05	26.67	27.94
Meherpur	3.45	-	1.83	5.27	5.27	3.45
Narail	11.38	20.15	13.76	45.29	25.14	31.54
Satkhira	329.19	115.42	84.90	529.51	414.09	444.61
Rajshahi Div	687.61	699.90	436.34	1,823.86	1,123.95	1,387.51
Bogra	118.14	118.66	34.24	271.04	152.38	236.80
Naogaon	1.43	4.35	2.70	8.48	4.13	5.78
Natore	25.58	29.28	8.28	63.14	33.86	54.86
Nawabganj	59.71	76.67	118.36	254.75	178.07	136.39

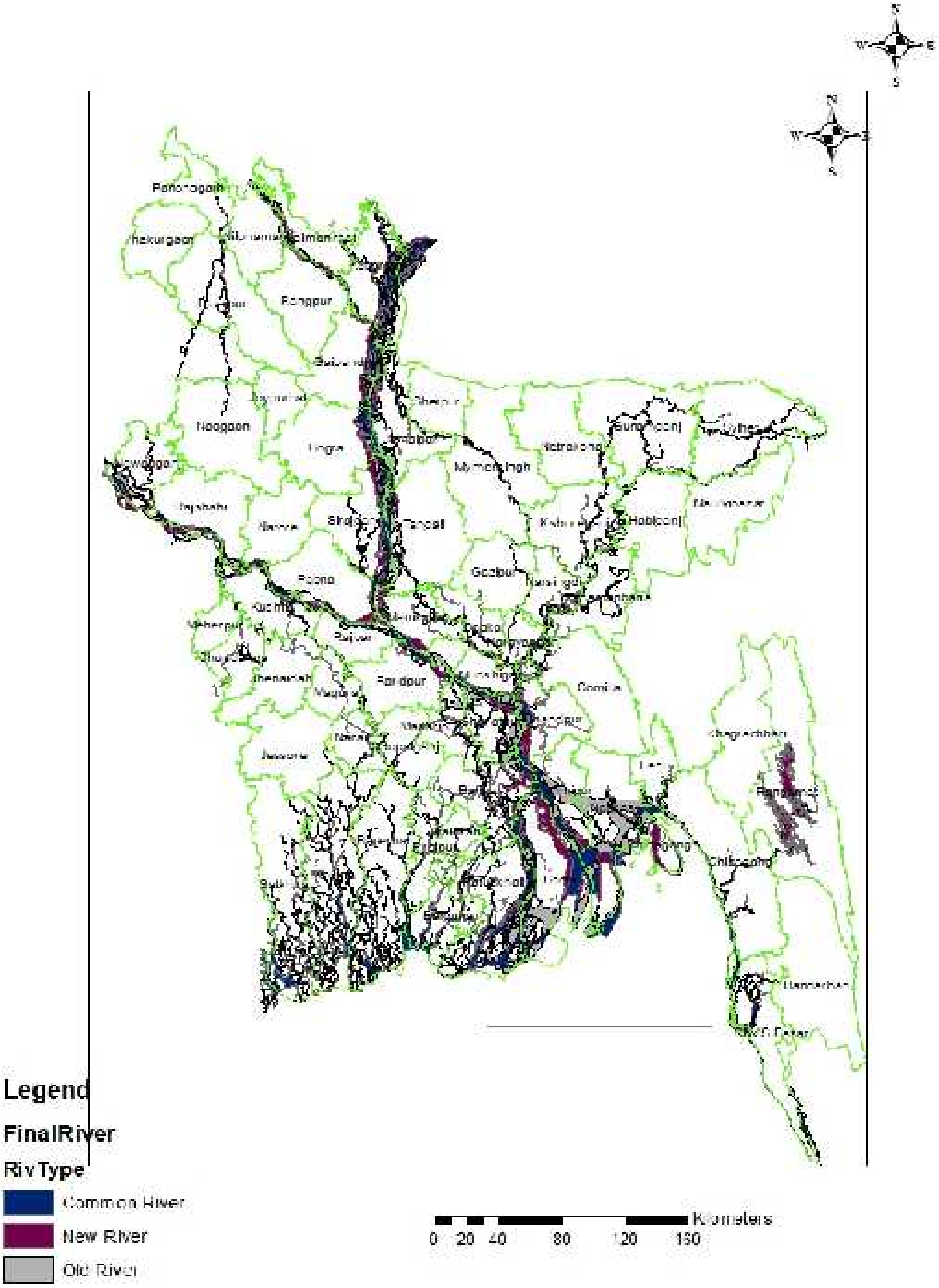
Pabna	142.38	139.45	52.77	334.60	195.15	281.83
Rajshahi	64.31	69.58	58.81	192.71	123.13	133.90
Sirajganj	276.06	261.90	161.18	699.15	437.24	537.96
Rangpur Div	507.92	612.04	397.22	1,517.18	905.14	1,119.96
Dinajpur	6.02	31.91	19.57	57.50	25.58	37.93
Gaibandha	163.07	178.44	91.09	432.61	254.17	341.52
Kurigram	291.93	247.53	223.14	762.61	515.08	539.46
Lalmonirhat	19.84	85.57	35.66	141.06	55.49	105.40
Nilphamari	8.74	22.21	15.45	46.40	24.19	30.95
Panchagarh	8.94	4.33	3.37	16.65	12.32	13.27
Rangpur	9.38	42.05	8.94	60.37	18.32	51.43
Sylhet DIV	53.47	101.95	89.84	245.26	143.31	155.42
Habiganj	13.05	18.23	11.20	42.48	24.24	31.28
Maulvibazar	2.24	3.99	2.07	8.30	4.31	6.23
Sunamganj	17.86	43.15	37.35	98.35	55.21	61.01
Sylhet	20.32	36.58	39.23	96.13	59.55	56.90

(blank)	751.96	322.80	407.53	1,482.29	1,159.48	1,074.76
(blank)	751.96	322.80	407.53	1,482.29	1,159.48	1,074.76
Grand Total	**6,484.74**	**5,895.36**	**5,996.90**	**18,377.00**	**12,481.64**	**12,380.09**

Source: Self Prepared from GIS Model Statistics

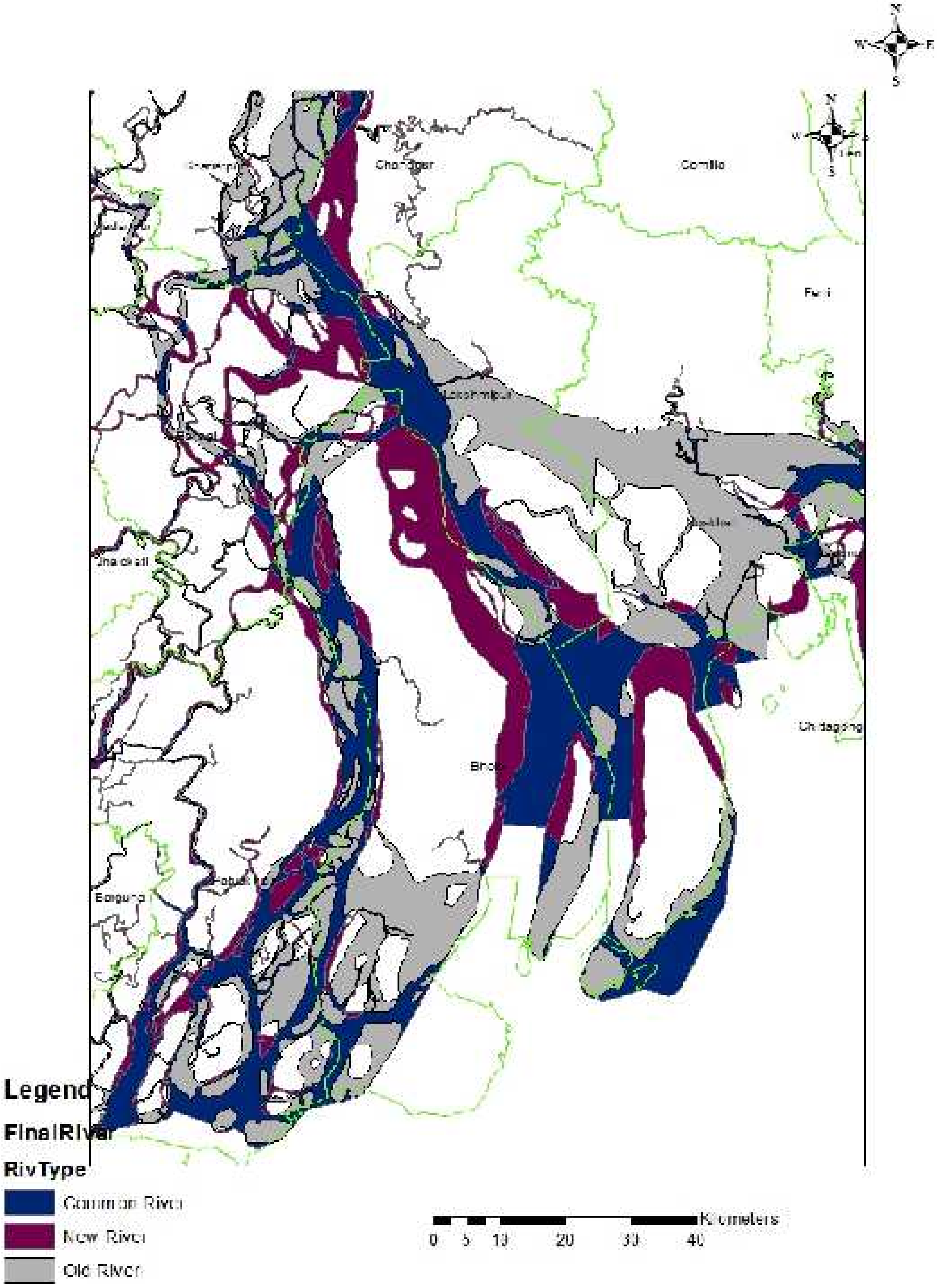
Graphical representation of the table are displayed below in various segments. Gray colour represents accretion means dead river called old river, deep maroon colour represents erosion means new river and deep blue colour represents flowing part of river of both the period called common river. River changes in Bangladesh are shown at Figure 4.5 up to Figure 4.12 below.

Figure 4.5 : River Changes in Bangladesh



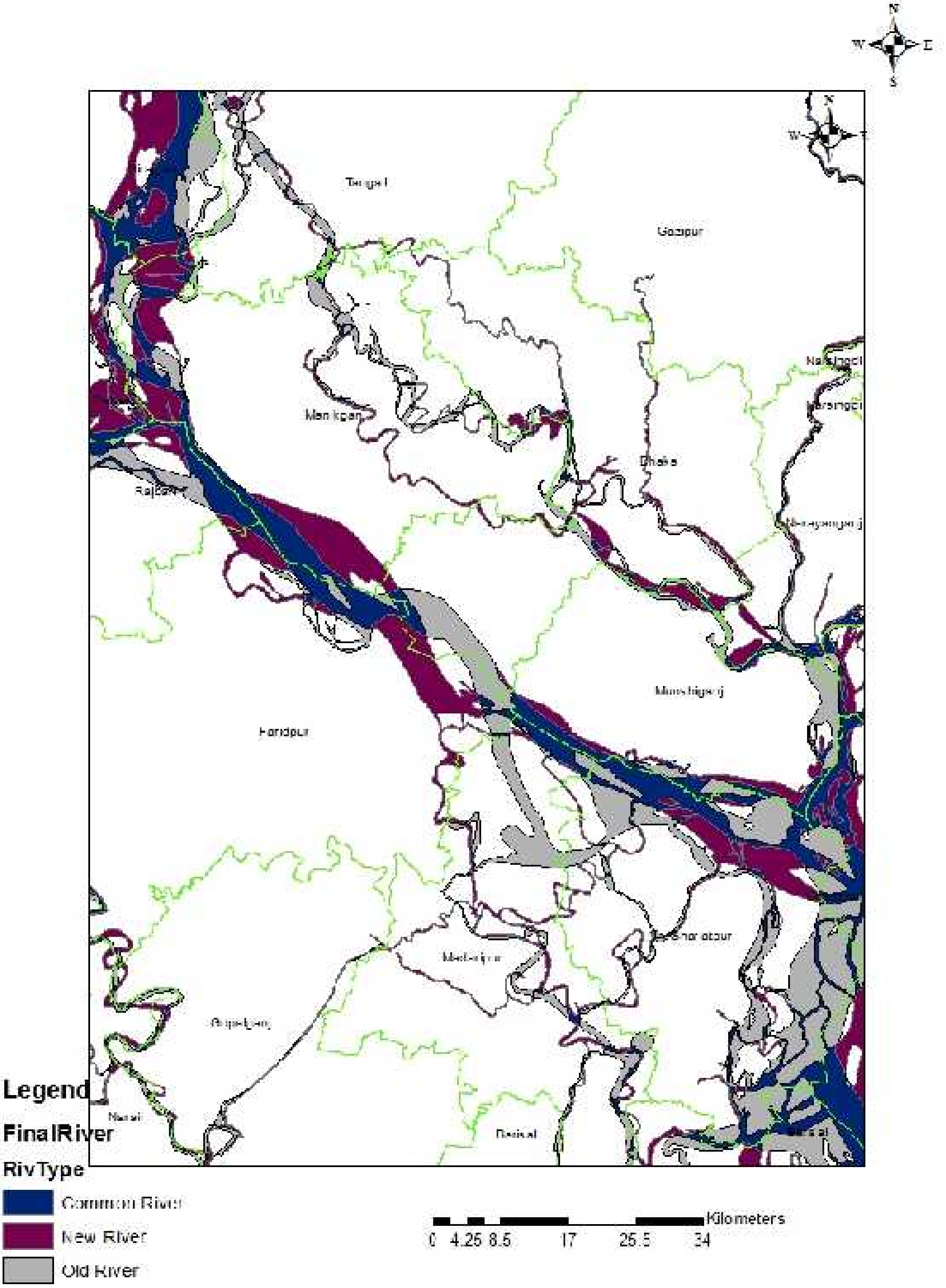
Source: Self Prepared

Figure 4.6 : Lower Part of River Meghna



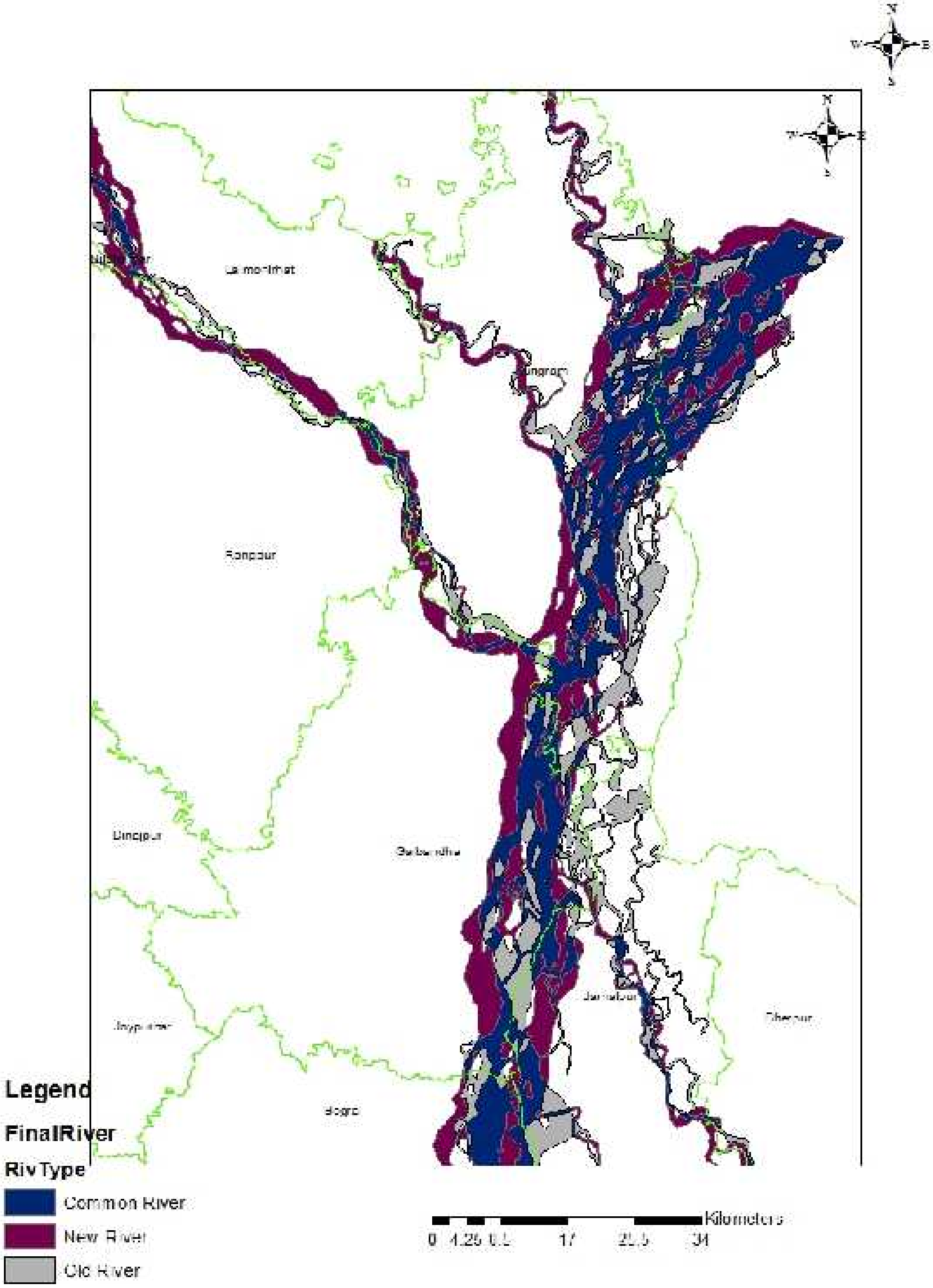
Source: Self Prepared

Figure 4.7 : River Padma



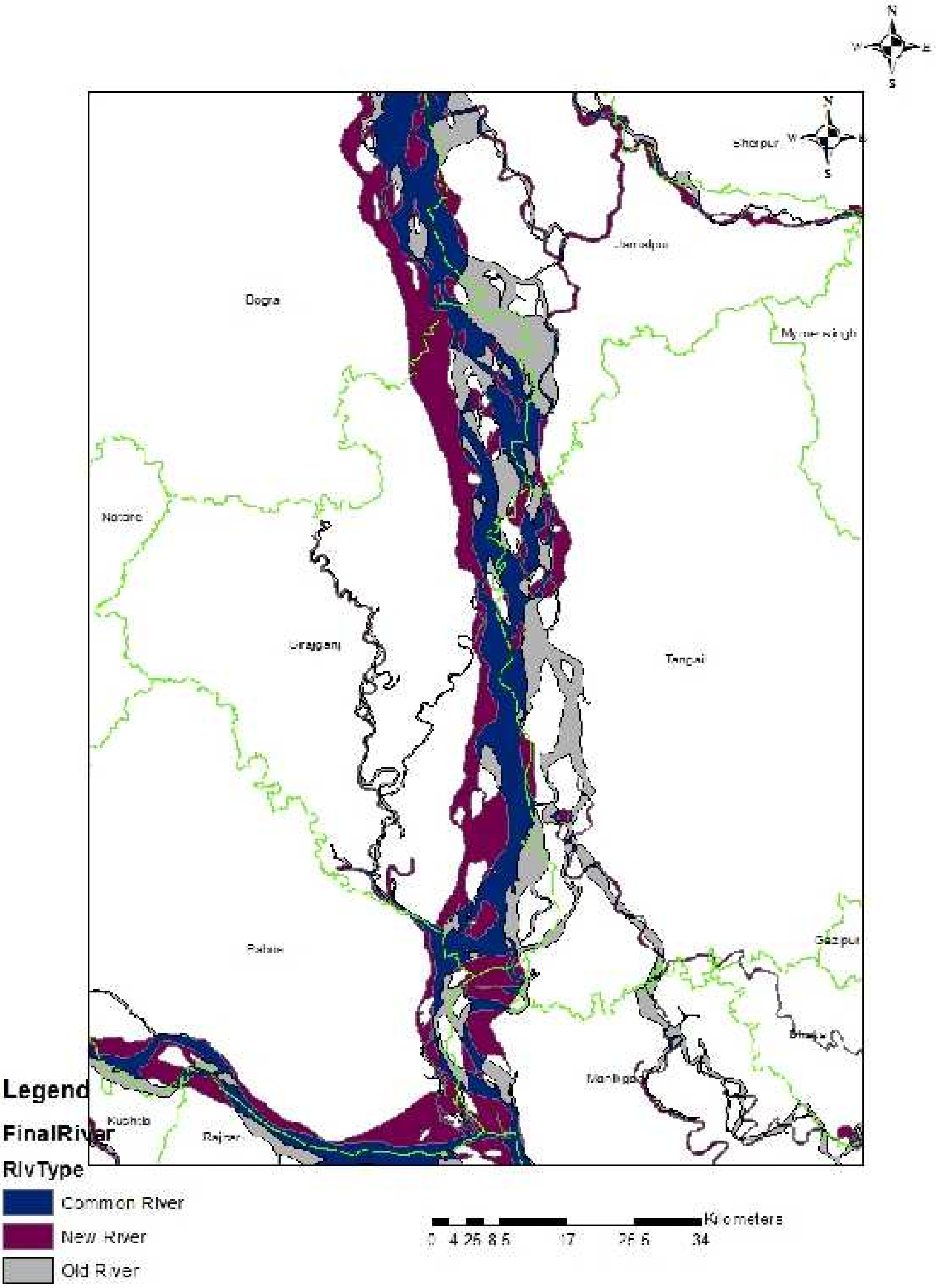
Source: Self Prepared

Figure 4.8 : Upper Part of River Jamuna



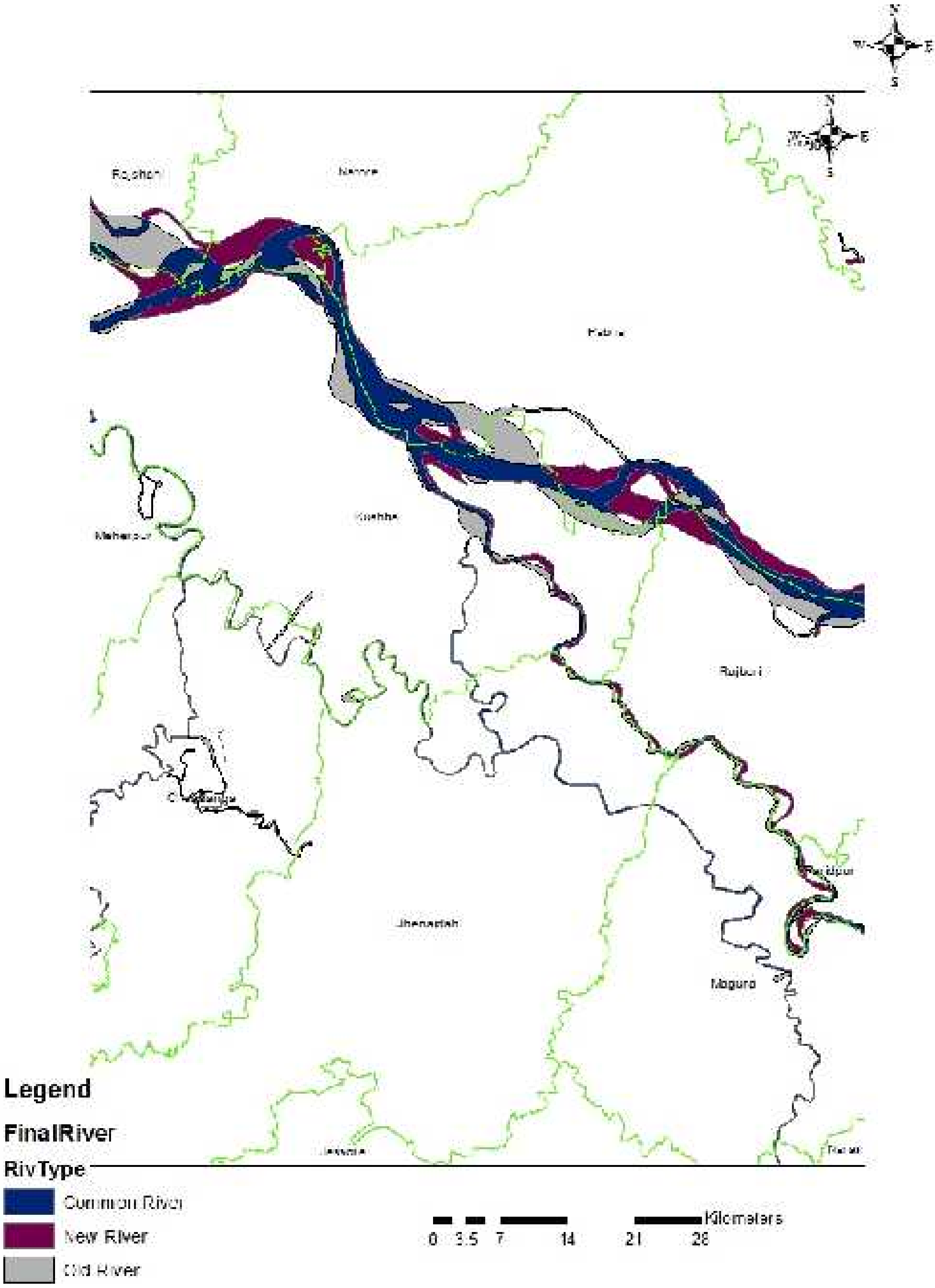
Source: Self Prepared

Figure 4.9 : Lower Part of River Jamuna



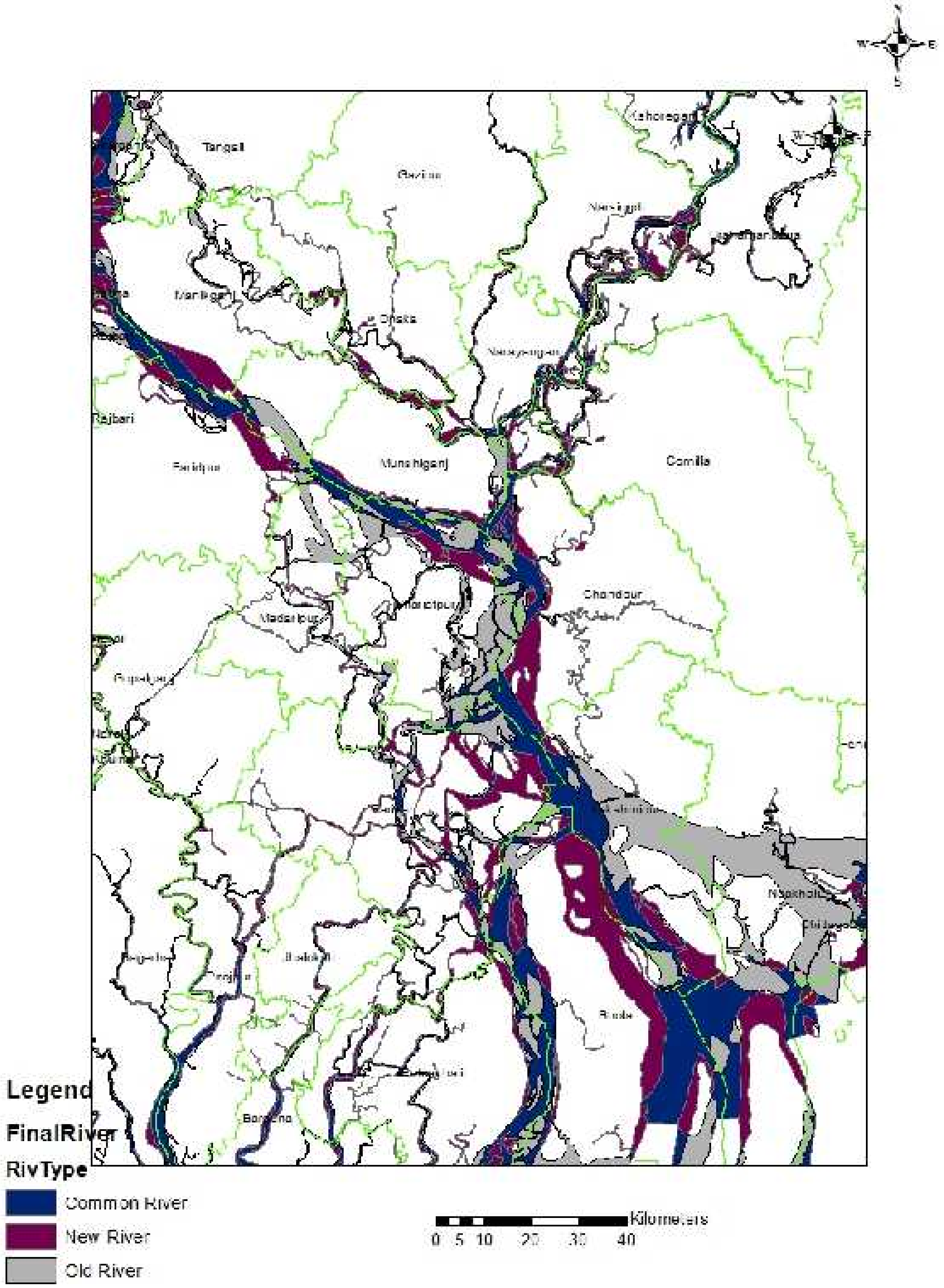
Source: Self Prepared

Figure 4.10 : Lower part of river Ganges



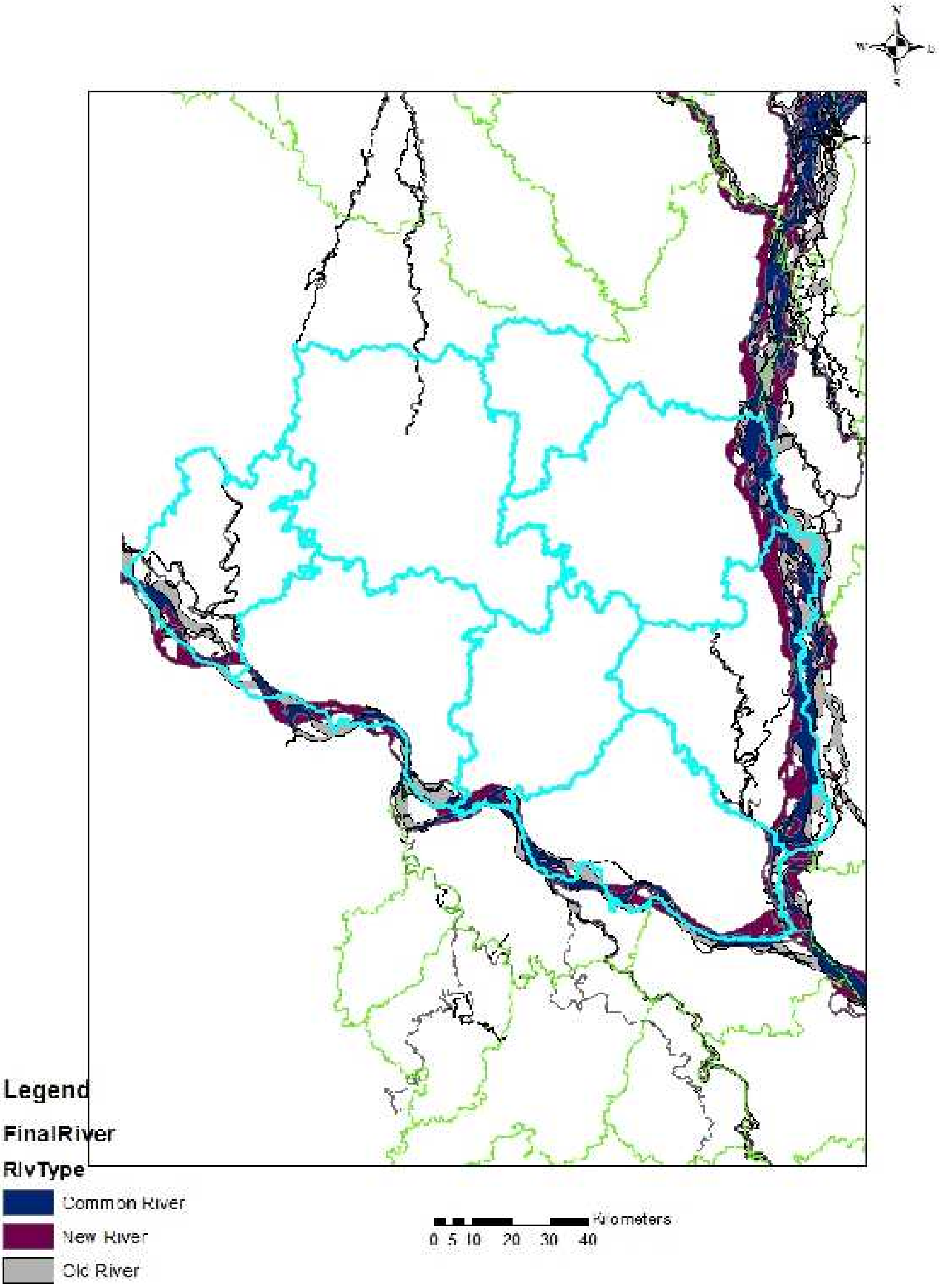
Source: Self Prepared

Figure 4.11 : River Padma Meghna joins at Chadpur



Source: Self Prepared

Figure 4.12 : River Ganges Jamuna mixes at Goalondo



Source: Self Prepared

Division wise River Change Analysis are described below.

4.2.1 River Changes in Barisal Division: River Changes in Barisal Division are shown statistically at Table 4.2 and graphically at Figure 4.13 below.

Table 4.2 : River Changes in Barisal Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Barisal Div	1,437.08	1,182.03	1,269.91	3,889.03	2,706.99	2,619.12
Barguna	FALSE	79.45	54.69	310.53	54.69	79.45
Barisal	145.75	304.97	187.96	638.68	333.71	450.72
Bhola	523.30	467.47	584.87	1,575.63	1,108.16	990.77
Jhalokati	15.05	32.54	6.68	54.27	21.73	47.59
Patuakhali	487.07	237.07	406.40	1,130.54	893.47	724.15
Pirojpur	89.53	60.53	29.32	179.37	118.84	150.06

Source: Self Prepared

Figure 4.13 : River Changes in Barisal Division

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Source: Self Prepared

Both the statistics and maps are displayed above in order to analyze the results easily. We can see that Bhola and Potuakhali are the most affected by the Meghna river changes since these two districts are located at the Meghna Estuaries to the Bay of Bengal. Mximum erosion and deposition had taken place here within the Division. Resultant growth of land/char is more than 100 km sq in Bhola district and more than 150 km sq in Potuakhali district between 1940s and 20000s. This is quite understandable because the entire sediment of Padma-Brahmaputra basin is going down the Meghna channel to the Bay of Bengal resulting into deposition at the estuaries. In other four districts, erosion or loss of land has taken place. Barisal is the worst affected district where resultant loss of land is more than 120 km sq. This is due to lateral shift of main course of river Meghna from east to west direction near Lakshmipur. Resultant growth of land/char in Barisal Division is near about 100 km sq.

4.2.2 River Changes in Chittagong Division: River Changes in Chittagong Division are shown statistically at Table 4.3 and graphically at Figure 4.14 below.

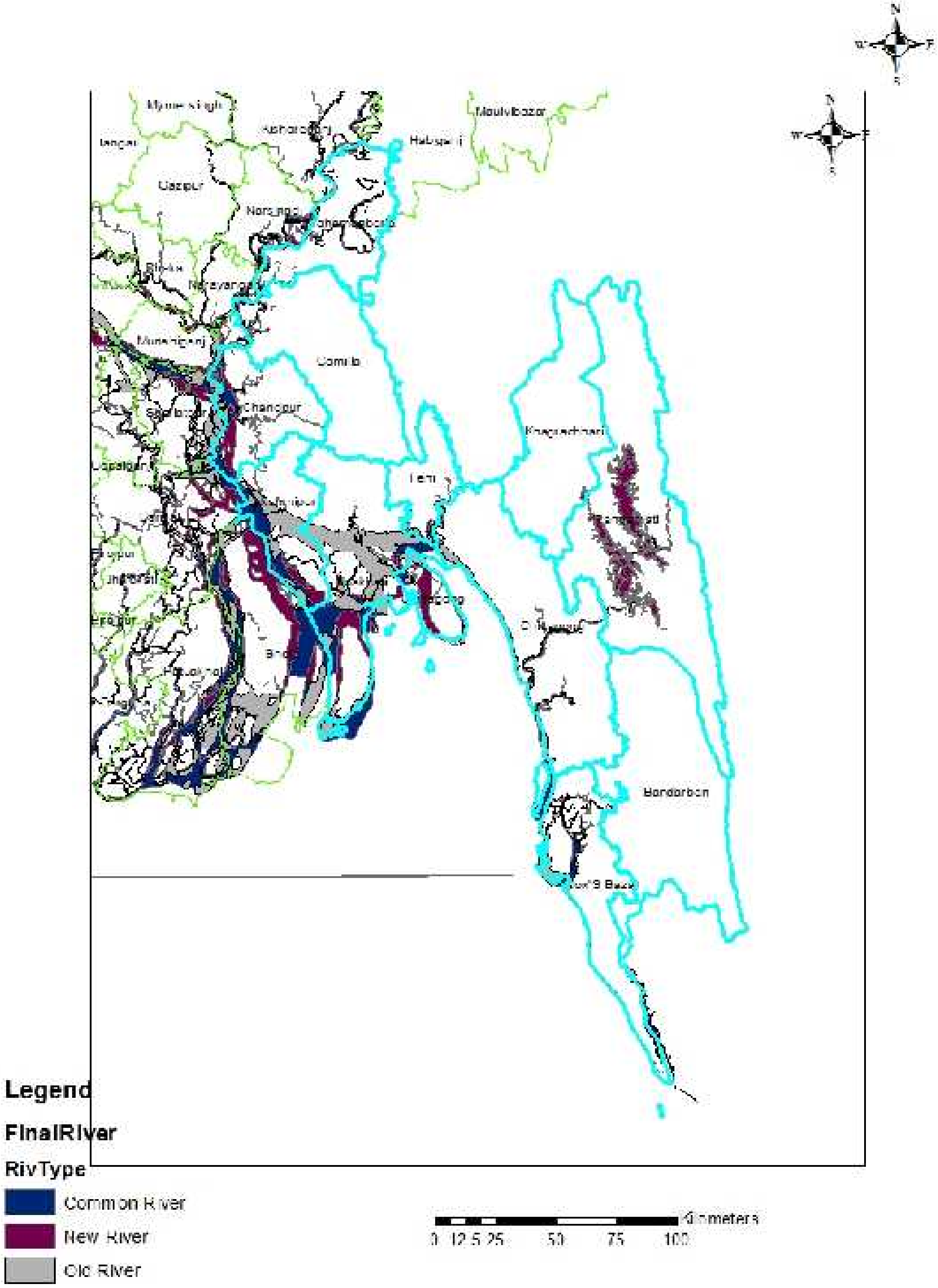
Table 4.3 : River Changes in Chittagong Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Chittagong Div	1,023.63	1,349.99	1,563.37	3,936.99	2,587.01	2,373.62
Bandarban	0.22	0.10	0.01	0.33	0.23	0.32
Brahamanbaria	72.47	63.71	52.87	189.05	125.34	136.18
Chandpur	155.49	178.26	53.39	387.13	208.87	333.75
Chittagong	121.01	178.16	157.95	457.12	278.95	299.17
Comilla	24.20	40.23	16.35	80.78	40.55	64.43
Cox'S Bazar	85.78	26.62	185.49	297.89	271.26	112.40

Feni	19.50	16.14	31.06	66.71	50.56	35.64
Khagrachhari	-	6.35	-	6.35	-	6.35
Lakshmipur	214.84	112.94	301.47	629.25	516.32	327.78
Noakhali	318.00	183.72	761.54	1,263.26	1,079.54	501.71
Rangamati	12.12	543.77	3.25	559.14	15.37	555.89

Source : Self Prepared

Figure 4.14 : River Changes in Chittagong Division



Source: Self Prepared

Chittagong division has a great impact due to changes in Meghna river. Noakhali district has a growth of land/ char of more than 550 km sq. This is a phenomenal change that had taken place within last 60 years. Meghna had two main channels 60 years before, one through Lakshmipur-Noakhali and other through Lakshmipur-Bhola. Over the time, the entire Lakshmipur-Noakhali channenl had died down leaving a big chunk of land/char and Lakshmipur-Bhola is the main channel now with a subsidiary channel through Bhola-Potuakhali border which is likely to develop as one of the main channels. Swandip was created by the deposition from Lakshmipur-Noakhali channenl and Hatia was created from Lakshmipur-Bhola channel. Now, erosion is taking place in both the islands due the impact of main channel from north-west to east direction. That's why the north of Hatia and west of Swandip has significant erosion as visible in the map above.

Lakshmipur and chadpur districts has also got significant changes due to river changes. Lakshmipur has been increased by almost 200 km sq. Similar phenomena like Noakhali is applicable here due to death of Lakshmipur-Noakhali channel. On the other hand, Chandpur district has eroded by more than 100 km sq. this is due to the natural shift of Meghna channel from west to east at lower part of the district. The shift is about 220 meter per year. Chadpur Sadar is the worst affected due to the erosion.

Significant change is also visible in Cox Bazar district. More than 150 km sq growth of land/char is found here. This is due to growth of deposition around Moheshkhali and Kutubdia island specially on the west bank of kutubdia. This is probably by the fine sediments carried by the Meghna channel which is passing in between Hatia and Swandip isands and rolling down the Chittagong-CoxesBazar coast line.

Significant change is also found in Rangamati district. There is a loss of land of more than 500 km sq. This is not due to the effect of river change rather due to the creation of catchment of Kaptai dam created during Pakistan period in 1956-1962 that created Kaptai lake.

The resultant growth of land/char is about 700 km sq without taking the Kaptai lake into consideration. This is understandable because Chittagong division is located at the maximum siltation zone of Padma- Brahmaputra basin.

4.2.3 River Changes in Dhaka Division: River Changes in Dhaka Division are shown statistically at Table 4.4 and graphically at Figure 4.15 below.

Table 4.4: River Changes in Dhaka Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Dhaka Div	863.45	1,072.49	1,277.20	3,213.14	2,140.65	1,935.94
Dhaka	20.70	65.72	78.58	165.01	99.29	86.42
Faridpur	61.32	118.65	54.79	234.76	116.11	179.97
Gazipur	6.58	9.38	6.50	22.46	13.08	15.96
Gopalganj	8.78	21.54	24.60	54.92	33.38	30.32
Jamalpur	122.39	130.71	211.88	464.98	334.27	253.10
Kishoreganj	65.71	80.01	32.16	177.87	97.86	145.72
Madaripur	30.73	44.75	107.80	183.28	138.53	75.48
Manikganj	85.21	155.57	74.51	315.29	159.72	240.78
Munshiganj	68.57	74.22	61.03	203.81	129.60	142.78
Mymensingh	14.59	35.66	26.34	76.60	40.94	50.26
Narayanganj	35.13	40.81	34.42	110.36	69.55	75.94
Narsingdi	48.01	91.79	25.34	165.14	73.35	139.80

Netrakona	5.61	9.02	3.83	18.45	9.44	14.63
Rajbari	85.39	40.02	61.12	186.54	146.52	125.41
Shariatpur	127.02	93.14	319.18	539.33	446.20	220.16
Sherpur	4.10	5.64	6.08	15.81	10.18	9.74
Tangail	73.62	55.86	149.04	278.52	222.66	129.48

Source: Self Prepared

Figure 4.15 : River Changes in Dhaka Division

Source: Self Prepared

Within Dhaka division, most changes are observed in Shariatpur district. There is a growth of land/char of more than 200 km sq. This is due to the shift of Meghna channel from west to east. This being the neighbor district of Chadpur, yearly shift is about 220 meter per year as discussed before. As a result the entire channel has gone out of the district to the neighboring Chadpur district now where as the entire channel used to flow through this district before.

Similar phenomena is observed in Tangail where the Jamuna channel has shifted from east to west resulting growth of land/char of almost 100 km sq.

Jamalpur and Madaripur have some growth of land/char near 70 km sq where as Faridpur and Manikganj has eroded from 50-90 km sq. These occurred due to natural shift and erosion of Padma river. Norshindhi has also lost land due to expansion of upper Meghna channel. Rest of the districts in Dhaka division does not have any significant change since rivers within these districts did not change much.

The resultant growth of land/char in Dhaka division is about 200 km sq.

4.2.4 River Changes in Khulna Division: River Changes in Khulna Division are shown statistically at Table 4.5 and graphically at Figure 4.16 below.

Table 4.5 : River Changes in Khulna Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Khulna Div	1,159.61	554.15	555.49	2,269.25	1,715.10	1,713.76
Bagerhat	295.58	143.93	166.31	605.83	461.89	439.51
Chuadanga	14.44	1.57	7.08	23.09	21.52	16.01
Jessore	0.98	3.21	2.60	6.78	3.57	4.18
Jhenaidah	15.86	1.42	2.62	19.89	18.47	17.28
Khulna	367.15	214.71	177.18	759.04	544.33	581.86
Kushtia	104.02	43.36	90.11	237.50	194.14	147.38
Magura	17.56	10.38	9.11	37.05	26.67	27.94

Meherpur	3.45	-	1.83	5.27	5.27	3.45
Narail	11.38	20.15	13.76	45.29	25.14	31.54
Satkhira	329.19	115.42	84.90	529.51	414.09	444.61

Source: Self Prepared

Figure 4.16 : River Changes in Khulna Division

Source: Self Prepared

No major river passes through Khulna division except Kushtia district which contains some part of Padma river. The growth of land/char in Kushtia district is about 50 km sq due to the effect of Farakka dam in the upstream. Rest of the districts does not have any significant change. However, some erosion/inundation is observed at the southern tip of Khulna and Bagerhat district i.e. at the tip of Sundarban which is about 40 to 20 km sq.

4.2.5 River Changes in Rajshahi Division: River Changes in Rajshahi Division are shown statistically at Table 4.6 and graphically at Figure 4.17 below.

Table 4.6 : River Changes in Rajshahi Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Rajshahi Div	687.61	699.90	436.34	1,823.86	1,123.95	1,387.51
Bogra	118.14	118.66	34.24	271.04	152.38	236.80
Naogaon	1.43	4.35	2.70	8.48	4.13	5.78
Natore	25.58	29.28	8.28	63.14	33.86	54.86
Nawabganj	59.71	76.67	118.36	254.75	178.07	136.39
Pabna	142.38	139.45	52.77	334.60	195.15	281.83
Rajshahi	64.31	69.58	58.81	192.71	123.13	133.90
Sirajganj	276.06	261.90	161.18	699.15	437.24	537.96

Source: Self Prepared

Figure 4.17 : River Changes in Rajshahi Division

Source: Self Prepared

Changes in Rajshahi division is due to the changes of both rivers, i. e. Padma and Jamuna river. Rajshahi is eroded by 100 km sq due to the effect of Farakka dam. Worst affected district is the

Shirajganj district. It is eroded by 100 km sq due to the erosion of Jamuna channel. Shirajganj sadar comes under threat almost every year. Bogura district is also affected by Jamuna erosion. It has eroded by almost 80 km sq in last sixty years. Over all loss of land or erosion in this division is about 250 km sq.

4.2.6 River Changes in Rangpur Division: River Changes in Rangpur Division are shown statistically at Table 4.7 and graphically at Figure 4.18 below.

Table 4.7: River Changes in Rangpur Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Rangpur Div	507.92	612.04	397.22	1,517.18	905.14	1,119.96
Dinajpur	6.02	31.91	19.57	57.50	25.58	37.93
Gaibandha	163.07	178.44	91.09	432.61	254.17	341.52
Kurigram	291.93	247.53	223.14	762.61	515.08	539.46
Lalmonirhat	19.84	85.57	35.66	141.06	55.49	105.40
Nilphamari	8.74	22.21	15.45	46.40	24.19	30.95
Panchagarh	8.94	4.33	3.37	16.65	12.32	13.27
Rangpur	9.38	42.05	8.94	60.37	18.32	51.43

Source: Self Prepared

Figure 4.18: River Changes in Rangpur Division

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Source: Self Prepared

In Rangpur division there are erosion in Gaibandha, Lalmonirhat and Rangpur district by 90, 50 and 30 km sq respectively. Gaibandha district is eroded by Jamuna and other two districts by the river

Teesta. Kurigram also eroded by about 30 km sq by the river Jamuna. Over all erosion in this division about 200 km sq.

4.2.7 River Changes in Sylhet Division: River Changes in Sylhet Division are shown statistically at Table 4.8 and graphically at Figure 4.19 below.

Table 4.8 : River Changes in Sylhet Division

Row Labels	Common River (Sqkm)	New River(sqkm)	Old River(sqkm)	Grand Total	Old+Com	New+Com
Sylhet DIV	53.47	101.95	89.84	245.26	143.31	155.42
Habiganj	13.05	18.23	11.20	42.48	24.24	31.28
Maulvibazar	2.24	3.99	2.07	8.30	4.31	6.23
Sunamganj	17.86	43.15	37.35	98.35	55.21	61.01
Sylhet	20.32	36.58	39.23	96.13	59.55	56.90
(blank)	751.96	322.80	407.53	1,482.29	1,159.48	1,074.76
(blank)	751.96	322.80	407.53	1,482.29	1,159.48	1,074.76
Grand Total	**6,484.74**	**5,895.36**	**5,996.90**	**18,377.00**	12,481.64	12,380.09

Source: Self Prepared

Figure 4.19: River Changes in Sylhet Division

Source: Self Prepared

Sylhet division does not have any significant effect by the river changes since no major river exist in this division.

Over all net changes in entire country is only 100 km sq which is negligible. It means that bank erosion and growth of land/char goes parallel due to meandering nature of the rivers. Erosion takes place mostly at mid and upstream of the river channels where as deposition takes place mostly at the lower part of river channels specially at the estuaries.

4.3 Comparison with Similar Studies:

No such study involving entire Bangladesh territory has been carried out so far because of the unavailability and cost of map and satellite data at this scale. However, few studies are available that involves part of our river system.

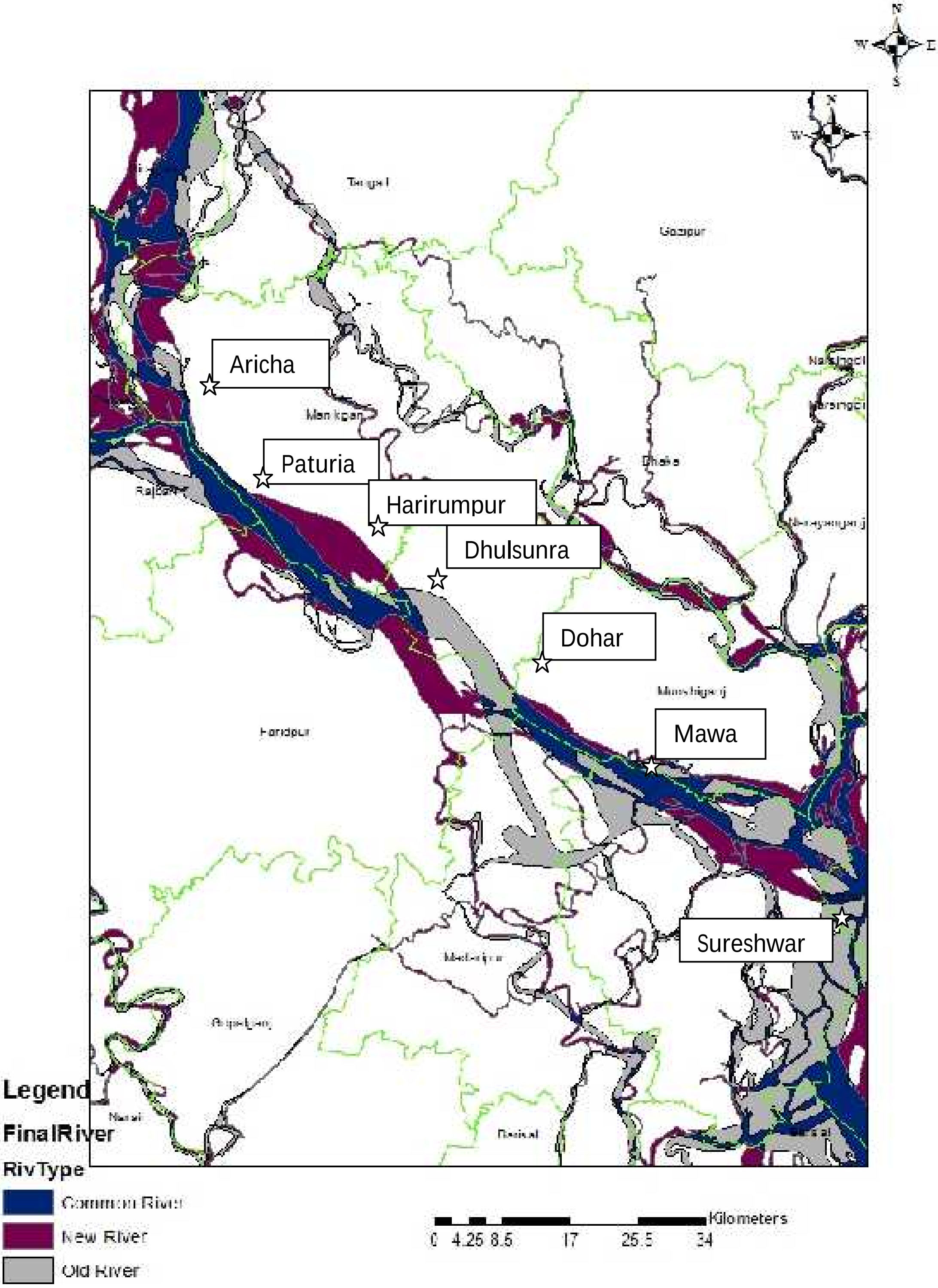
4.3.1 Comparison on the Padma River:

One such study called "Identification of the different types of bank materials along the Padma River" was carried out in 2004 as a part of Morphologic study applying remote sensing for the feasibility study of Padma Bridge for submission to JICA study team. It was prepared by CEGIS. We call it JICA study in this research. They used time series satellite images (1973-2003), historical maps including Rannels map (1765), field investigation data and bore hole data. The accuracy level of those maps varies from 100 to 2000 meters. Relevant part of Padma River of JICA study as well as this research are displayed below for comparison at Figure 4.20 and Figure 4.21 respectively.

Figure 4.20: JICA Study on Padma River

Source: feasibility study of Padma Bridge in 2004 prepared by CEGIS

Figure 4.21: Result of this research on Padma River



Source: Self Prepared

Whereas, the map used in this research has an accuracy of 100 meters all through. It appears from this research that the Padma River has more erosion along left bank than right bank except near Faridpur on the left and Harirumpur on the right where the river expanded in both direction. JICA study had similar findings where they mentioned that the bank materials of the Padma river along the left bank are highly susceptible to erosion because they consist of sand and contain little silt. When the main flow of the river attacks bank, they found the erosion rate becomes several hundred meters per year. This research found around 100 meter per year analyzing six decades data where they used three decades data.

This research found an exception along left bank in Sureshwar where the river looks stable within last sixty years. JICA study had similar findings where they concluded that the relatively older floodplains of Sureshwar consisting of clay has a very insignifican erosion to a few meters when the flow attacks.

From Aricha to Paturia, no significant change has been found on the right bank in this research. JICA study also found that the presence of relatively erosion resistant bank material in this area has resisted the erosion. The floodplains along right bank are mostly composed of "Atri- gur" and "Tippera Surface" sediment the ages of which are probably several hundred to several thousand years, JICA study observed. These sediments are composed of clay and silt, and relatively consolidated sediment thus more resistant to erosion.

From Paturia to Dhukshanra, the erosion rate was found very high, nearly 100 meter per year. JICA study found that the floodplains in Harirumpur, which was formed recently and where the bank erosion rate is very high – several hundred meters per year considering their three decades data.

From Dhulsunra to Mawa the river has shifted more than 6 km towards south west near Dohar as observed in this research. JICA study found that erosion resistant bank material are available along this bank but they did not mention anything about the big retreat of river Padma at this stretch. This is because the JICA study considered three decades data starting from 1967. Since the right bank is more consolidated composed of Tippera surface and the left bank is less consolidated and erosion prone, The Padma river has made a big retreat towards left within a short span of time. This is one very significant change in Padma river in last six decades that the river had retreated more than 6 kms most probably between 1940 to 1967 and flowing through a completely new channel. JICA study did not mention also about the moderate erosion along about 14 km upstream of Mawa including Mawa that has been observed in my research which is about 16 to 20 m/year. However, Mawa Ferry Ghat seems to be the least susceptible to erosion. Most probably, this has also happened within 1940 to 1967 if we compare the two study.

There is some moderate erosion found down-stream of Mawa in my study. JICA study found that although the floodplains at the downstream of Mawa appear to be composed of "Tippera Surface", they are found susceptible to erosion. The average rate of bank erosion has been 20 to 40m/years during last three decades, which is between the observed erosion rates in the recently formed and older flood plains at the upstream of Mawa. In my research, this is found to be 16 to 20m/year in last six decades.

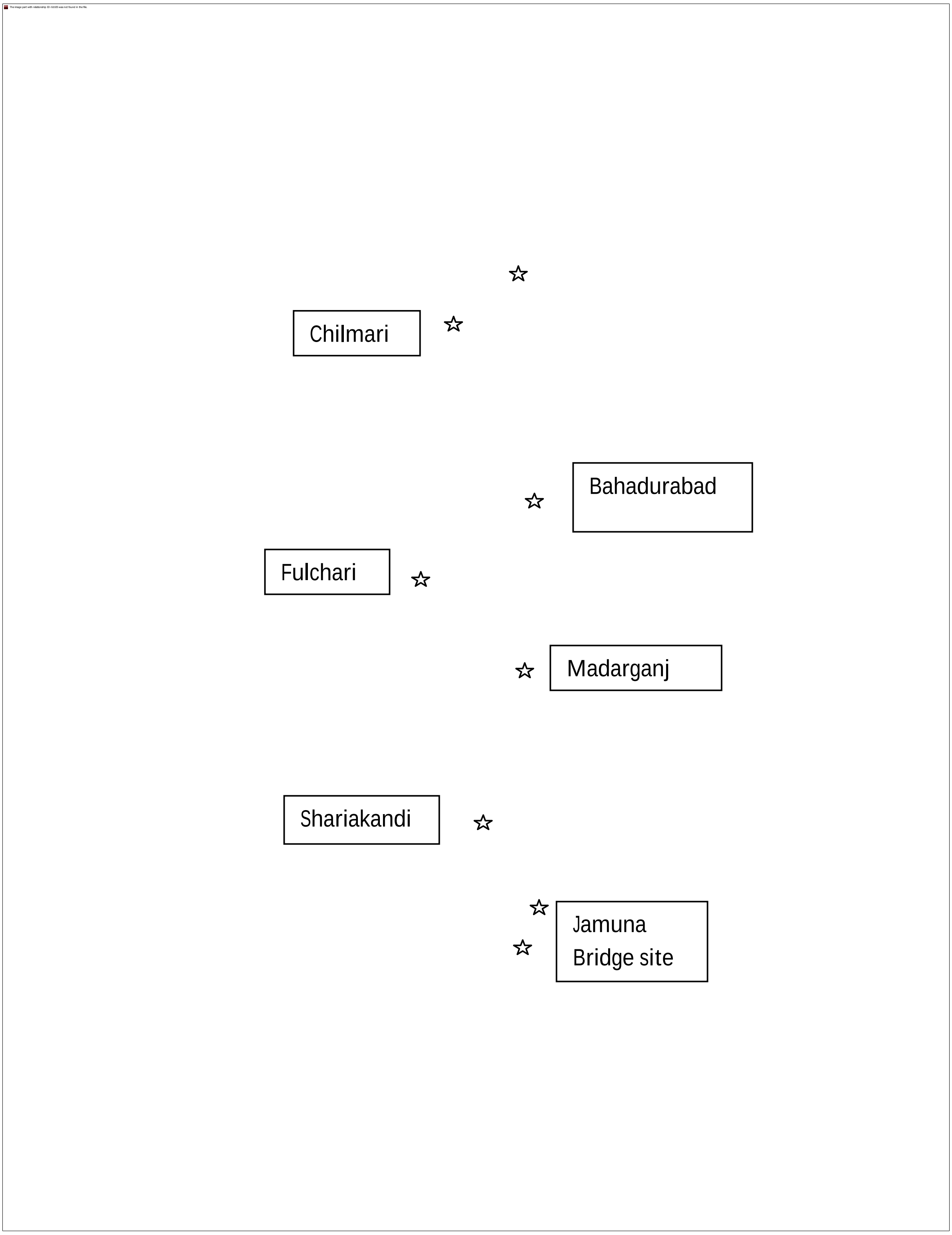
JICA study concluded that all bank material of the Padma River are divided into three catagiries: highly erodible, moderately erodible and relatively erosion resisestant. It implies that when a main channel of the Padma river attacks the bank, the erosion rate would be more than a hundred meters per year along the highly erodible bank, 20 to 50m/year along the moderately erodible bank and 0 to 15m/year along the relatively erosion resistant bank. In my research, similar is the erosion pattern with slightly less erosion rate since my study covers six decades data as opposed to three decades data of JICA study.

4.3.2 Comparison on Brahmaputra-Jamuna River: A study called 'Morphological Dynamics of the Brahmaputra-Jamuna River' was carried out by Water Resources Planning Organization (WARPO), Ministry of Water Resources, Government of Bangladesh in 1997. It was prepared by the then Environment and GIS (EGIS) and sponsored by Royal Netherlands Government. We call it WARPO study in this paper. Relevant part of Jamuna River of WARPO study as well as this research are displayed below for comparison at Figure 4.22 and Figure 4.23 respectively.

Figure 4.22: WARPO Study on Jamuna River

Source: A study called 'Morphological Dynamics of the Brahmaputra-Jamuna River' was carried out by Water Resources Planning Organization (WARPO), Ministry of Water Resources, Government of Bangladesh in 1997.

Figure 4.23: Result of this Research on Jamuna River



Source: Self Prepared

A River Morphology and Resource Information System (RMRIS) was developed by WARPO with a spatial database and analysis capability for storing and analyzing satellite images, historical maps, topographic and hydrometric data, river morphology and other information about the major rivers of Bangladesh. In this project RMRIS was used to study the morphology of the Brahmaputra-Jamuna, a braided river system characterized by rapid and substantial changes in platform, with particular emphasis on bank line and width changes, channel braiding characteristics and char development. The databases and analysis tools of the RMRIS were designed to meet the requirements of a number of Development projects, including the Jamuna Bridge, the River Bank protection project and several programs related to the Flood Action plan, and for general planning for the river chars and adjacent floodplain areas. The database took years to develop and has, in addition to the results obtained in this study, much potential for related analysis including predictive modeling of the future morpho-dynamic behavior and morphological evolution of the river.

A substantial portion of the spatial database was derived from a time series of satellite images consisting of 26 Landsat image frames, acquired between 1973 and 1996. The study area covers the entire Brahmaputra-Jamuna River in Bangladesh form the northern border with India to the confluence of the Ganges, a distance of 240 km. The data were geo-referenced to a common map projection, classified by computer image processing, and interpreted and analyzed using a geographic information system (GIS). The satellite image time series was supplemented with hydrometric data, including water levels and discharge for the period of study, historic maps and results of other studies.

A number of key findings, observations and predictions were presented by WARPO study. These are derived from the direct factual information and analysis of this study, along with results and findings of other studies, field study and the experience of the authors of the report.

River Width

The river is becoming wider through retreat of both right and left banks.

1. WARPO study found that the average width of the river has increased about 130m per year since 1973. This research found an average increase of about 70 meter per year for last six decades. It means that the widening is faster in recent decades
2. WARPO study found that recent widening has occurred through retreat of both left and right banks. The average width of the river has increased from about 8 km to 11 km since 1973, an increase of 3 km or nearly 40 percent. My research shows similar result where the river has increased from 8 to 11.5 km in six decades.
3. Relative to the mean width increase, the minimum width is increasing faster and the maximum width is increasing slower. Thus, the overall river is becoming wider and more uniform. Widening of the river is likely to continue. Same trend has been observed in my research

1. WARPO study observed that since adopting its present course sometime before 1830, the river has been widening. It seems to be creating an active corridor 16 kilometers across, a width sufficient to co ntain its braiding channels, bars and chars.
2. WARPO study found that based on historical and current trends, widening will continue of at least another two decades and possibly three or more.

WARPO study has shown four comparisons of river braiding in the Figure 18 above. Amongst the four, the third one covering 1953-1996 matches most near to my study period i.e. 1940s-2000s.

Bank Erosion

Both river banks are retreating and eroding floodplain land.

1. Bank erosion is twice as likely to occur as bank accretion at any place along the river in any two to three year period as observed by WARPO study. Similar trend is also found in this research where deep maroon colour represents erosion and gray colour represents accretion in Figure 19 above.
2. The left bank has retreated to the west by an average of 1.5 km since 1973, at an average rate of about 65 meters per year. In my study it is found around 50 meters per year over six decades.
3. Westward migration of the left bank has been particularly severe between Fulchari and Sirajganj as observed by both WARPO as well as my study.
4. The right bank has also retreated since 1973, but not at all locations. Eastward retreat is worse in the northern and southern thirds of the river. In the middle third, between the Old Brahmaputra offtake and Bhuapur, retreat through bank erosion and advance through bank accretion are almost matched. This observation is common for both the study as evident from Figure 18 and Figure 19 above.

Based on the above observations, WARPO Study concluded the following:

Erosion risks are high for dwelling along the river banks.

1. On average, bank erosion has occurred in two out of three years for most reaches of the river.
2. The rate and extent of erosion may be very severe, with about a one in ten chance annually that more than 400 meters of retreat will occur.

River bank erosion will continue unabated without additional river bank protection and river training.

1. Unless bank protection currently under construction at Mathurapare and Sariakandi are complated, a breakthrough of the Jamuna to the Bangali River is inevitable, probably before the end of the century.
2. In the longer-term, other locations will be threatened with river breakthrough requiring consideration of further bank protection works.

The cost for bank protection and river training will increase.

1. The river's tendency to widen, particularly through retreat of the right bank, will continue. This means direct attack on existing and future bank protection and training structures, and accompanying maintenance costs.
2. As river banks continue to crode up and downstream of river training and protection structures, the threat to those structures will become more acute. Further works will be required, in part to protect the existing structures.

River Braiding

Some investigators have suggested that the river may be changing in form from braided to meandering.

There is no evidence to support this; in fact, braiding is increasing.

1. The average number of low flow channels, between which low flow season discharges are divided, has increased by 40 percent since 1973 and their average length has increased by 30 percent.
2. The intensity of the river's braiding has particularly increased in the last decade and is now at the highest level during the study period (1973-96).

The increase in braiding will likely continue increasing in the future.

1. The intensity of braiding observed in some reaches suggests that the maximum braiding intensity for the river has not yet been reached and that a further increase of about 25 percent is possible for those reaches.

The river form is different for the reaches above and below Sirajganj, but there is no reason to expect a single channel to form below Sirajganj and the Jamuna Bridge site.

2. Upstream of Sirajganj the river is weakly anatomized. Major left and right bank anabranches have semi-independent planforms that alternate between braided and meandering.
3. For much of the 1980s, the river downstream of Sirajganj followed a meandering path with wide point bars and multiple chute and back channels, but recently it has developed more braiding tendencies.
4. The rapid widening of the river at the Jamuna Bridge site is part of a general shift from meandering to braiding in the 1990s.

Increased braiding will continue to have impacts on navigation.

5. Increased braiding helps explain why navigation conditions during the low flow season have become more difficult despite best efforts to maintain ferry and shipping routes. These conditions are likely to continue to deteriorate.

Floodplain Destruction and Charland Growth

River bank retreat and widening is eroding floodplain land.

6. The river has consumed over 70,000ha of mainland floodplain since 1973 and created only about 11,000ha of land through accretion along its banks.

7. Large monsoon floods have especially harsh impacts on the floodplain. For example, between 1987 and 1989 the rate of mainland floodplain erosion rose to over 8,000 ha per year.
Expansion of the river is taking place primarily through destruction of mainland floodplain and creation of short-lived charland.

1. Much of the lost flooplain land is going into the creation of new charland. On average, 2,000 hectares of charland appeared in the braided course of the river each year since 1973. The new char areas are typically less productive than the eroded mainland and are under constant threat of flooding and loss due to river erosion.

2. With exception of the 10 percent of stable char land more than 20 years old, chars are frequently destroyed at one location and created at another. The average age of a given area of charland is only four years. This means that the homesteads, lands and infrastructure of most char dwellers are destroyed by erosion every few years.

Other serious erosion events may be attributed to local factors and to the methods used to define the backlines in this study (see Section 2.4). For example, the large area of the left bank, opposite the Teesta confluence, that was removed from the floodplain during 1987-89 actually remained intact but became separated form the floodplain by capture of a khal, to become an island-char. Knight on and Nanson (1993) refer to land removed from the floodplain by this process as being ''excised'' rather than ''eroded'' Conversely, the large area eroded form the left bank upstream of the Ganges confluence during 1987-89 was destroyed by incremental bank erosion due to meander bend growth and migration in a large anabranch channel. To differentiate between these processes of bankline shifting in the Brahmaputra-Jamuna, it is recommended that term ''excised'' be used to describe the isoation of an intact area of floodplain by khal enlargement, and the term ''eroded'' be used to describe destruction of floodplain by bank erosion.

Cumulative floodplain loss through backline shifting may thus occur by:

(a) Erosion: bank erosion that destroys floodplain land and carries it away to another location, and/or.

(b) Excision: capture and/or enlargement of a floodplain channel or khal that isolates an area of floodplain from the mainland, incorporates it into the braid without destroying it, and so converts floodplain land into charland.

The highest rates of bank line shifting tend to be associated with the second process

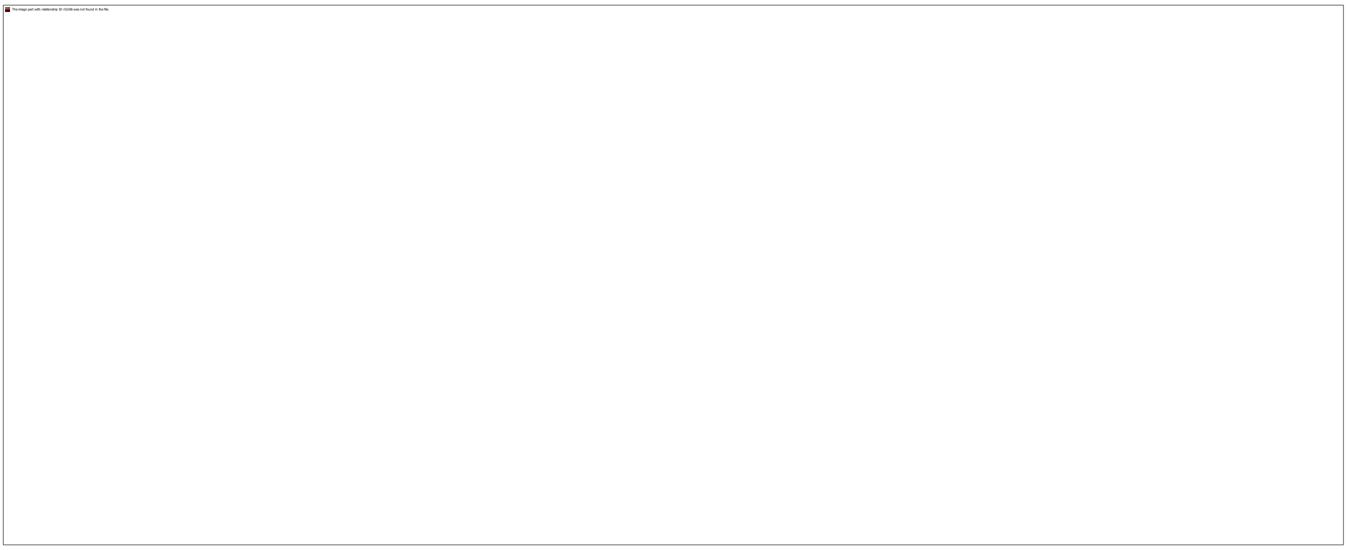
Chapter 5

Extracting Forest Topo-Features data and Detect Changes for the two periods

1. Forest Change Detection:

This data processing aims at detecting/identifying the changes that has taken place between the forests of 1940s verses 2000s. This is achieved by processing and analyzing the vector data of forests in GIS using the existing functions/tools to create a Model for analysis in order to get the desired output in the form of statistics. So the output data of previous two chapters has been used as input data to detect the changes between 1940s and 2000s. Data processing steps are shown at Figure 5.1 and described below.

Figure 5.1: Data Model for Forest Analysis



Source : Self Prepared

5.1.1 Extracting Common Part of Old and Recent Forest:

All the forests have been affected over the time due to human intervention although some afforestation has also taken place. We need to identify the portion of the forests of both the period that is common means remained throughout. The function ''Intersection'' is used to extract common part of old and new forests called common forests in the model. This common forests indicates the portion of both forests which is not affected by the changes means it exists throughout the time of comparison. Graphically this is represented by light green colour.

5.1.2 Identify Newly Developed Forest:

After the common forests are identified, it is now possible to identify newly developed forests. The function 'Erase' is used to identify newly developed part of forests called 'Recent forests only' in the model which is achieved by subtracting common forests from recent forests. 'Recent forests only' indicates that this part is converted to forests from bare land. Graphically this is represented by magenta colour.

5.1.3 Identify Dead part of old Forest:

Similarly the dead part of old forests can be identified. The function 'Erase' is again used to identify the part of the old forests that is converted into encroached land called ''Old forests only'' in the model. This is achieved similarly by subtracting common forests from forests. Graphically this is represented by red colour.

5.1.4 Generalization of Insignificant Part of Forest:

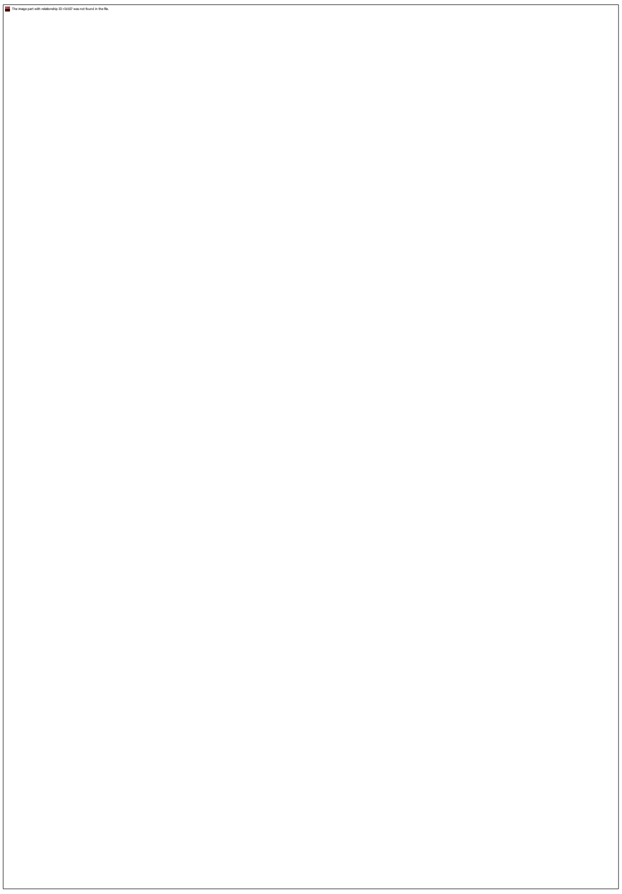
The forests data are digitized from 1:2,50,000 scale maps after scanning. There lie some errors from natural digitization error, resolution of image, human eye constraint, georeferencing, projection transformation, etc. In this research work an irregular area of the forests (both old and recent) upto 1,00,000 sqm has been considered to be generalized and merged with the common river. In fact, this value has been decided after number of trial-and-error of visual checking. To identify the insignificant parts of forests generated because of mentioned digitization error the model used SQL based filtering function and changed attributes of the forests to 'Common forests', so that those parts can be merged later. This has been achieved by using the functions called ''Make Feature Layer'' and ''Field calculate'' to filler out irregular areas less then 1,00,000 sqm from both old and recent rivers those are respectively called ''Filtered old forests as common river'' and ''Filtered recent forests as common forests'' in the model.

5.1.5 Finalization of Both Forest Data:

In order to prepare the forests data for statistical analysis we need to create a combined forests layer consisting of attributes of common forests, Recent forests only and old forests only, This is achieved by the no of functions ''Field calculate'', 'Append' and 'Dissolve' from generated features called 'New forests Only', 'Old forests Only' and 'Common forests' to Final Forests data. This data, however, consists of three types of data and those are 'Common forests', 'New forests' and 'Old forests'. Finally we made 'identity-overlay' function to bring administrative information (Division name and District Name) for zonal analysis in the" Final forests" data. Now this is the layer to generate different statistical data using GIS model.

5.1.6 Validation of Created Data: The forests data created in this research must be validated against some authenticated data. Accordingly, forests data created from satellite imagery was collected and overlaid on 'Final forests' data. This satellite data is more up to date than 1:250000 scale new data although both data falls within 2000 to 2012. However, this overlay gives us a reasonable idea about the validity of the produced data in this research. Satellite forests data are represented by red outlines only. Chittagong segments of the overlaid data are displayed below for comparison. The new 1:250000 scale forests are represented by light green colour. It can be observed that red outlines almost matches the green in figure 5.2 below meaning the forest data created in this research is reasonably accurate.

Figure 5.2: Comparison of Forest in Chittagong



Source : Self Prepared

5.2 Statistical Analysis from the Developed Data: Division wise statistics of forest data are shown in Table 5.1 below.

Table 5.1: Division wise Statistics of Forest area

Division	**Common Forest (SQM)**	**New Forest (SQM)**	**Old Forest (SQM)**
Barisal		194.69	76.16
Barguna		85.19	76.16
Bhola		59.61	
Patuakhali		49.90	
Chittagong	13,183.97	1,176.02	727.02

Bandarban	4,472.16	7.44	90.67
Chittagong	981.22	112.93	270.46
Cox'S Bazar	544.07	130.17	178.17
Khagrachhari	2,294.85	412.19	60.76
Noakhali		185.14	
Rangamati	4,891.66	328.15	126.97
Dhaka	389.15	322.47	794.80
Gazipur	133.85	145.47	141.15
Jamalpur			2.63
Mymensingh	12.98	10.70	457.02
Netrakona			0.60
Sherpur			0.76
Tangail	242.32	166.30	192.64
Khulna	3,769.52	296.94	397.55
Bagerhat	1,421.21	118.57	106.74
Khulna	1,335.29	115.31	141.26
Satkhira	1,013.03	63.06	149.55
Rangpur	73.32	67.64	46.95
Lalmonirhat	0.01	66.90	5.36
Nilphamari	69.17	0.74	41.59
Panchagarh	4.14		
Sylhet	121.24	293.80	65.09
Habiganj	41.45	3.42	6.80
Maulvibazar	79.79	220.48	28.02
Sunamganj			9.98
Sylhet	0.00	69.90	20.28

Grand Total	**17,537.20**	**2,351.55**	**2,107.57**

Source : Self Prepared

Changes of forest between two periods in Bangladesh are shown at Figure 5.3 below.

Figure 5.3: Changes of forest between two periods

Source : Self Prepared

We can see from the above map that both deforestation as well as afforestation has taken place over the ages where red colour represents deforestation and magenta represents afforestation. Region wise comparison is done below.

5.2.1 Forest Changes in Dhaka Division: Forest Changes in Dhaka division is displayed at Figure 5.4 below.

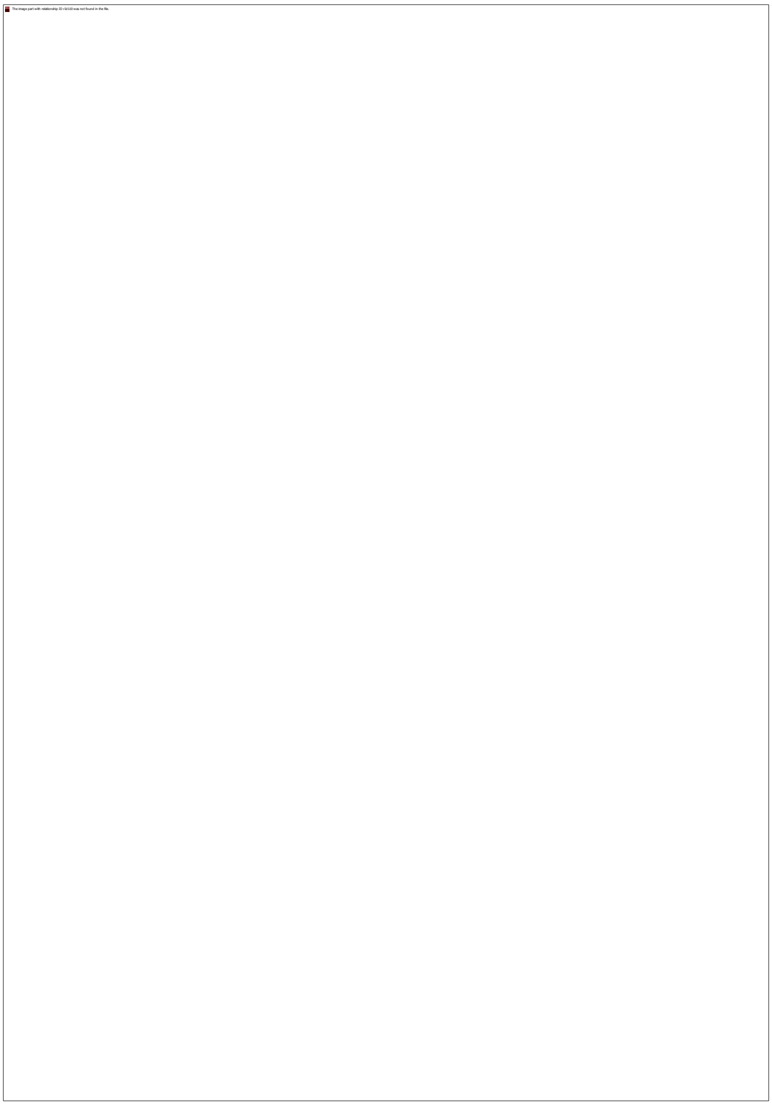
Figure 5.4: Forest Changes in Dhaka Division

Source : Self Prepared

Most of the deforestation is found in Dhaka Division which is approximately 795 sq km in size. A big chunk of forest has altogether been deforested which started from 1970s by providing govt permits to collect timber. Later on, a port for coal import has been established and it turned into a busy area to aggravate the situation further. Rest of the deforestation is found in Gazipur and Modhupur forest which is due to the unholy collaboration between forest officials and business peoples. Of course some afforestation of approximately 323 sq km is found around the same area which is done mainly under "Community Afforestation" scheme taken by the government.

5.2.2 Forest Changes in Chittagong Division : Forest Changes in Chittagong division is displayed at Figure 5.5 below.

Figure 5.5 : Forest Changes in Chittagong Division



Source : Self Prepared

In Chittagong division, an area of approximately 727 sq km has been deforested mainly from Chittagong, Khagrachari, Bandarban and Coxesbazer city neighborhood area. On the other hand, an area of approximately 1176 sq km has been afforested mainly in Khagrachari area and some in Rangamati and Coxesbazar.

5.2.3 Forest Changes in Coastal Belt: Forest Changes in coastal belt is displayed at Figure 5.6 below.

Figure 5.6 : Forest Changes in Coastal Belt

Source : Self Prepared

A good amount of afforestation is noticeable along coastal belt of Noakhali, Vola, Potuakhali and Borguna districts. This is done mainly under the projects of Coastal belt protection schemes.

5.2.4. Forest Changes in Sundarban: Forest Changes in mangrove Sundarban is displayed at Figure 5.7 below.

Figure 5.7 : Forest Changes in Sundarban

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Source : Self Prepared

In Sundarban mangroove forest, deforestation has mostly taken place in Barguna and Satkhira districts due to expanding human habitation near Sundarban. Rest of the deforestation is visible along the banks of the khals and rivers flowing through Sundarban. A similar study called " Mangrove Cover Changes in the Bangladesh Sundarbans from 1989-2000: A Remote Sensing Approach" was done in USA Landsat Thematic Mapper satellite imagery. Their finding was that most of the deforestation had taken place in the southeastern and western edge of Sundarban which is similar to the findings of this study. The southeastern corner is adjacent to an area that is not part of the reserved forest; it has almost no remaining mangrove forest and has a substantial permanent human population. The area is also adjacent to the Baleswar River, which is fed directly from the Ganges. While there are several possible explanations for deforestation in this area, further research is necessary to determine the exact reasons. One possible explanation is that it is the most accessible part of the *Sundarbans* to the permanent population living in close proximity.

There is a road leading from the adjacent area to populous areas to the north, including Khulna, which is the third largest city in Bangladesh. Ismail (1990) reported that this region of the *Sundarbans* supplies raw materials to newsprint mills, match factories, and packing box industries in Khulna and surrounding cities; thus, it is a major entry point for people involved in forest extraction industries. Another possible reason for deforestation in this area is that since the mid-1970s, it has experienced substantial ecological change because of the commissioning of the Farraka Barrage. Diversion of dry season water from the Ganges might have resulted in higher soil salinities; at this time, however, there are no data to verify this. The other main area of deforestation, along the western edge of the study area, is near the Indian border. The northern part of this border area is adjacent to a region that has experienced dramatic growth in shrimp farming. Wikramanayake *et al*. (2001) reported that immature shrimp are being collected from the *Sundarbans* at unsustainable levels and that mangrove forests are being cleared to build shrimp farms leading to habitat loss. Iftekhar and Islam (2004) suggest that the *Sundarbans* ecosystem is not well understood, the forest management system is inadequate, and that too many people are economically dependent on the forest.

5.2.5 Forest Changes in Sylhet Division: Forest Changes in Sylhet division is displayed at Figure 5.8 below.

Figure 5.8 :Forest Changes in Sylhet Division

Source : Self Prepared

Afforestation is more than deforestation in Sylhet division which is respectively 294 and 64 km sq. The afforested areas are found along border area Moulovibazar district and near Sylhet sadar.

5.2.6 Forest Changes in Rajshahi Division: Forest Changes in Rajshahi division is displayed at Figure 5.9 below.

Figure 5.9: Forest Changes in Rajshahi Division

Source : Self Prepared

Some afforestation has taken place in Lalmonirhat district and almost equal deforestation has taken place in Nilphamari district of our north bengal region.

5.3 Cumulative Change and Comparison with Similar Study:

In cumulative measurement it is found that total afforestation area is about 2352 km sq and the deforestation area is about 2108 km sq. Total forest in our country is about 20,000 km sq which is about 13.8% of our land mass. 30% is considered as ideal one.

A study called "**ASIA-PACIFIC FORESTRY SECTOR OUTLOOK STUDY II"** on Bangladesh forestry outlook study was carried out by FAO in 2011. This study reported that the Forest department manages about 15,300 sq km but most of this area does not carry good tree cover. The tree cover on these lands is declining. A general understanding is that about 50% of the FD managed lands is almost denuded. There are about 0.7 million hectares of USF. About 80% of these USF lands are without tree cover. There are some tree covered areas of about 22.6 000 hectares in the tea garden area. There are about 0.3 million hectares under homesteads. The homestead areas have a fairly good tree growth. With the increase of the total population of the country there is very little scope for Government managed forest area to expand, but there is enough scope for bringing many of the degraded Government forest land under good tree cover. But this will depend on the availability of funding and launching of forestry projects.

Under the globally declining trend of natural resources, there is no reason to believe that the forests in Bangladesh will be increasing. To date the Government is the sole authority to look after the forests. It is however a fact that the major wood demand of the nation is met not from the Government forests but from the homesteads. The forests in Bangladesh are declining and in the near future nothing will happen that will drastically change the situation as a whole. The trend of depletion in the Government managed forests may slow down slightly provided some serious efforts are taken. With enhanced tree planting adopted by the public in recent past, homestead gardens may become richer in tree resources.

The key driving forces affecting forests and forestry in Bangladesh are:

1. Land hunger, poverty and population boom.

2. Very high demand for wood resulting in illicit felling from government forest land.

3. Socio economics, especially more recreational demand on forests.

4. Enhanced importance of surface water.

5. Climate change.

6. Lack of awareness of the general public.

7. Importance, or lack of it, attached to forestry by the government.

8. Growing pressure on the FD to deliver participatory forestry programmes on a larger scale.

9. Views of development partners in funding forestry programmes.

The two major dimensions are:

(a) Very low income and high level of poverty, and

(b) Weak political and institutional structures.

Chapter 6

Extracting Shore area Topo-Features data and Detect Changes for the two periods

6.1 Shore Change Detection

Shore area is the area along the coastal belt of Bangladesh consisting of numerous islands formed by carried away sands and silts. These changes very rapidly due to erosion and deposition. Shore line is not defined and drawn in Bangladesh by any government organization. So a tentative line has been drawn along the edge of the main land of both the period and islands at the downstream of shore lines have been compared for changes. GIS model like that of river and forest could not be developed because of open area in the sea. So changes are detected by visual interpretation where layers are represented by different colours in two periods and overlaid on each other to detect erosion and deposition.

According to NOAA shoreline website, shoreline means the intersection of the land with the water surface. The shoreline shown on charts represents the line of contact between the land and a selected water elevation. In areas affected by tidal fluctuations, this line of contact is the mean high water line. In confined coastal waters of diminished tidal influence, the mean water level line may be used.

Shoreline variability and shoreline erosion-accretion trends is fundamentally critical to analysis. It is strictly defined as the intersection of water and land surfaces, for practical purposes, the dynamic nature of this boundary and its dependence on the temporal and spatial scale at which it is being considered results in the use of a range of shoreline indicators.

These proxies are generally one of two types: either a feature that is visibly discernible in coastal imagery (e.g., high water line [HWL]) or the intersection of a tidal datum with the coastal profile (e.g., mean high water [MHW]). Recently, a third category of shoreline indicator has begun to be reported in the literature, based on the application of image processing techniques to extract proxy shoreline features from digital coastal images that are not necessarily visible to the human eye.

Potential data sources for shoreline investigation include historical photographs, coastal maps and charts, aerial photography, surveys, and a range of digital elevation or image data derived from remote sensing platforms. The identification of a ‘‘shoreline’’ involves two stages: the first requires the selection and definition of a shoreline indicator feature, and the second is the detection of the chosen shoreline feature within the available data source.

To date, the most common shoreline detection technique has been subjective visual interpretation. Recent photogrammetry, topographic data collection, and digital image-processing techniques now make it possible for the coastal investigator to use objective shoreline detection methods. The remaining challenge is to improve the quantitative and process-based understanding of these shoreline indicator features and their spatial relationship relative to the physical land–water boundary.

Due to the following reasons, this research skipped to analyze shoreline change detection:

1. Lack of historical photographs (high resolution)

2. Shoreline not represented in the collected topographic maps

3. Only single type of map for Survey of Bangladesh identified to delimited shoreline, those maps are in 1:15000 scaled, but all sheets are not available to make seamless to make the line for particular time to compare with recent.

4. Delimit shoreline with high resolution also requires both high-tide and low-tide aerial photo which is not available.

5. Coastal baseline is also important to analyze shoreline changes. Coastal baseline of Bangladesh yet needed to fix.

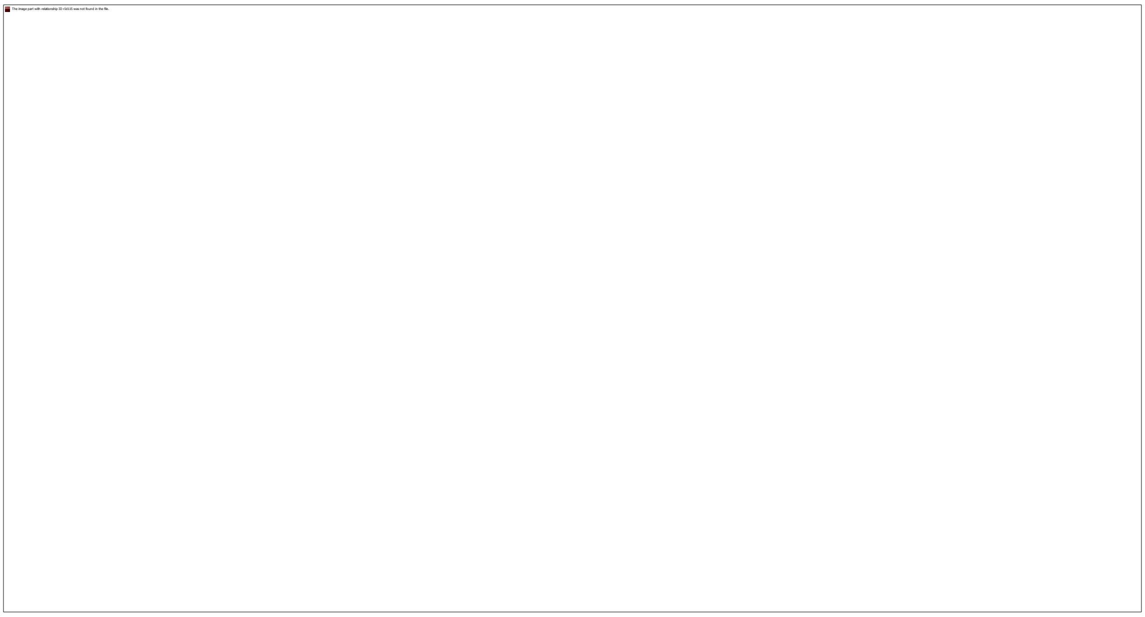
6. Daily tidal data is also needed to study to determine mean sea level along with surface model (DEM, at least 20m spatial resolution) which are not readily available to use in this study.

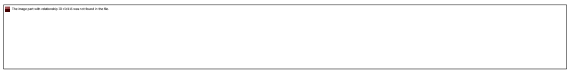
7. Shoreline which some time as dynamic as the feature it defines will not be reliable analysis based on traditional analog based created maps.

So a different approach has been taken to detect changes at shore areas by overlaying the layers in GIS at different colours for visual interpretation as described below.

6.2 Changes at Near-Meghna Estuary Channel: Changes at Near Meghna Estuary Channel are displayed at Figure 6.1 below.

Figure 6.1 : Changes at Near Meghna Estuary

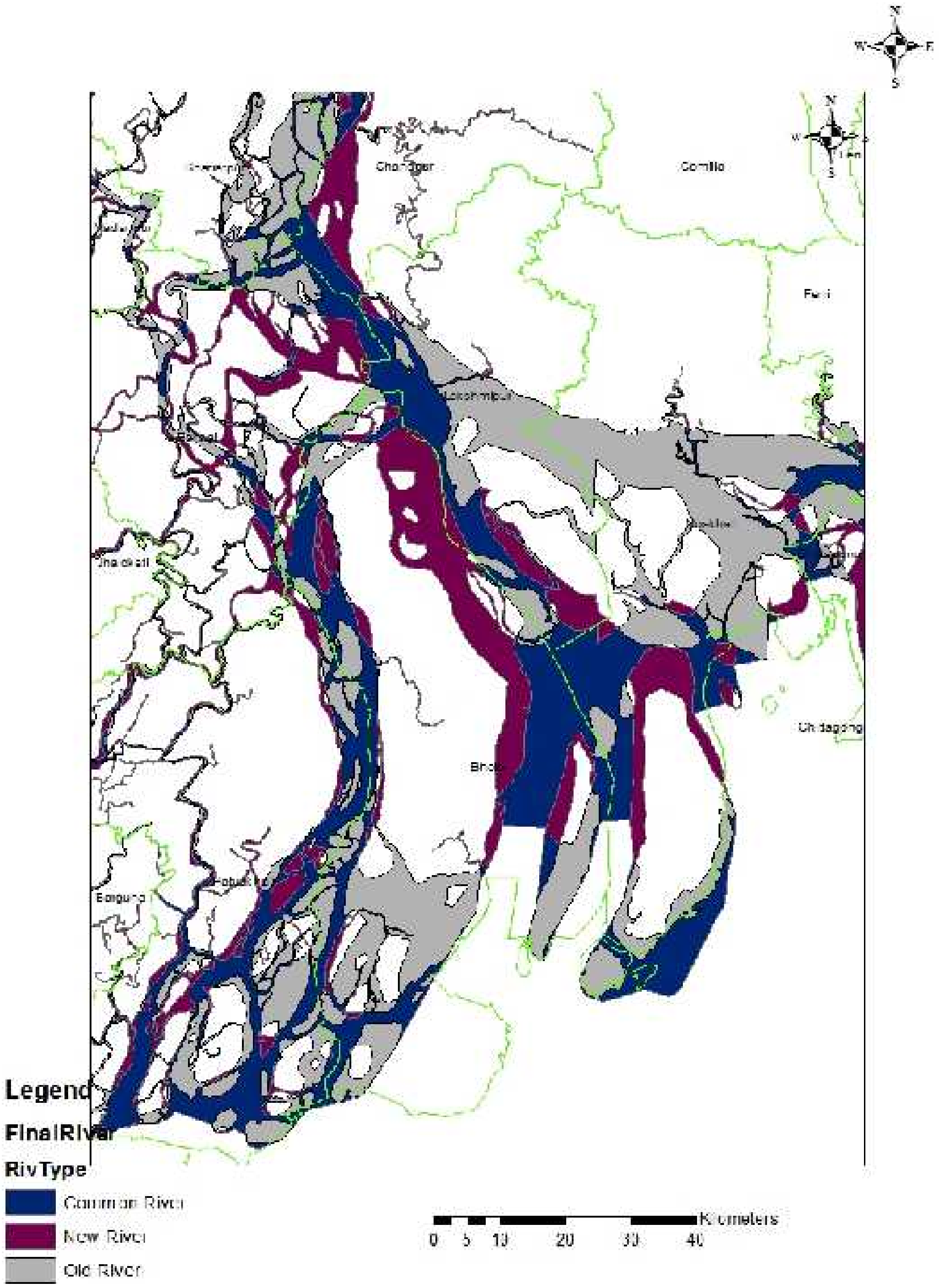




Source : Self Prepared

To detect the changes in the coastal Islands, the data of 1940s are overlaid on 2000s. The common part of the islands are in gray colour, old islands are in magenta colour and new islands are in light green colour. So the magenta colour islands has been dissolved into river now and the present islands will be the shape of combined gray and light green colour. Exception is the land mass of Kamalnagar, Ramgati and Subanachar in light gray colour which was an island before but has become part of mainland now due to major shift of the Meghna River towards west. In other words, the Meghna River had two main channels into the Bay of Bengal keeping those islands in between the channels thus separating the islands from mainland. Now, the west channel is the only channel and the east channel has totally disappeared as shown in figures 6.2, 6.3 and 6.4 below.

Figure 6.2 : Map of Old and New Channel



Source : Self Prepared

Figure 6.3 : Map of Old River with Islands

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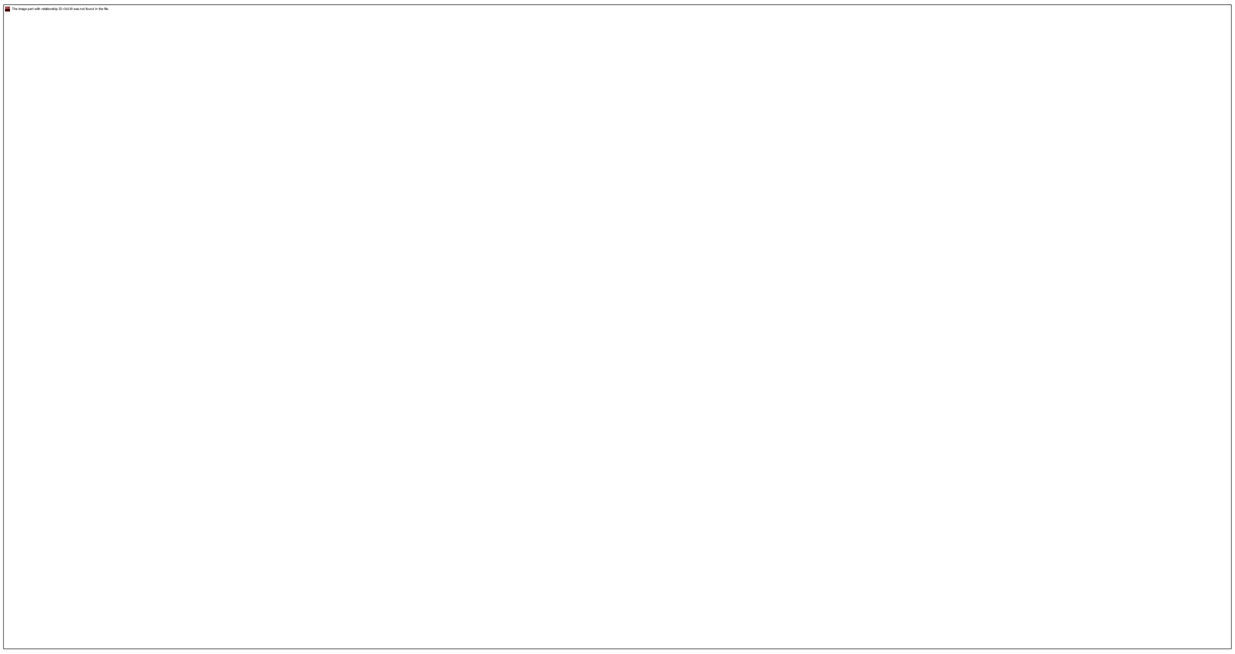
Source : Self Prepared

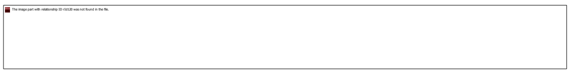
Figure 6.4 : Map of New River with Islands

Source : Self Prepared

6.3 Changes at Far-Meghna Estuary Channel : Changes at Far Meghna Estuary Channel are displayed at Figure 6.5 below.

Figure 6.5 : Map showing Vola, Hatia, swandip Area





Source : Self Prepared

Hatia and Sandwip islands have been eroded heavily in the north and deposited lightly on the south. Monpura has been elongated southward by deposition with some more islands deposition further down the channel. Bhola is also eroded in the north east and deposited southward and connected up to Char Fassion and beyond. A big island has also deposited in between Char Fassion and Golachipa. Some erosion is also observed at Mohesh Khali.

Chap 7

Conclusions and recommendations

7.1 This research in its attempt to understand the human adaptation process focuses attention to the changes in topography of the region. The topographic changes of various times are recorded in the topographic maps produced by the country's main map-making agency the Survey of Bangladesh (SOB). This research takes up a map study based approach for comparing the topographic changes over time. In doing so the research concentrates on the validity and reliability of the topographic maps and making processes followed in this country by studying the activities of the Survey of Bangladesh over the last half century. Topographic Maps are a summary of the landscape and show important physical (natural and man-made) features in an area. The primary difference is that they show elevation in detail. The most common use of topographic maps is in the planning stages of projects to help design the layout and location of buildings, roads, dams, pipelines, landscapes, fire control routes, trails, etc. The distinctive characteristic of a topographic map is that the shape of the earth surface is shown by contour lines which make it possible to measure the height of mountains, depths of the ocean bottom, and steepness of slopes.

The Survey of Bangladesh came into existence in 1971 with the emergence of independent Bangladesh. The topographic mapping technologies in Bangladesh have thus seen two major transitions, the analogue mapping techniques of the British-Indian/Pakistan/Bangladesh Period (up to the 1980s) and the Bangladesh Period digital mapping techniques since the 1990s to the present times.

The first objective of the research, the study of history of the evolution of the Topographic Map-making and Map-making Technology in Bangladesh was accomplished, following an elaborate data collection procedure that included both primary and secondary data collection procedures. Valuable information also obtained from the study of old survey instruments. The second main objective to develop a methodology to merge the topographic map making technology of the two periods and study the changes in selected topographic features was pursued through the manuals available at SOB for preparation of topographic maps and custom made documents by experienced SOB officers. The study uses data from various secondary sources, SOB aerial photo of 20110/11 as well as satellite images from different sensors. Topographic map of 250k scale of SOB of 1940s and 2000s were the base map used for comparison. These raster data were in different projections and datums posing big challenge to effective comparison. All these raster data had to be brought in the same platform of BUTM projection and WGS84 datum for precise comparison using GIS. Then the desired topo features (river, forest and shore area) are extracted in vector format and edited in GIS for change detection analysis using GIS model.

7.2. SOB started its journey with analog topographic mapping from predecessors. Since the 1767, through this century, all cartographic works in this subcontinent had basically been carried out by the government survey department. The government survey department started its journey as "Bengal Survey" in 1767 in British India and conducted surveying and mapping activities till 1947. After the partition of the sub-continent on 14th August 1947, 'Survey of Pakistan' was created and established its Deputy Surveyor General (DSG) office at Dhaka. This DSG's office was transformed into 'Survey of Bangladesh' when Bangladesh emerged as an independent state in 1971.

The importance of mapping was felt from Sultan Sher Shah (1540-45) period in this sub-continent mainly for revenue collection. Some kind of land measurement continued in the periods of Emperor Akbar, East India company, Zamindars for revenue collection where the concept of Province, Pargana, etc were introduced. Then the major survey operations conducted in the Bangladesh territory so far are the Thakbast Survey (1845-1877); Revenue Survey (1846-1878); Khasra operations (1841-1854) and Diara Surveys (1862-1883).

The modern cadastral survey is an improvement on the khasra survey. The cadastral system is divided into (i) traverse survey, (ii) cadastral work, and (iii) settlement work. Aerial survey in Bangladesh is apparently well suited for cadastral mapping by vertical air photographic techniques. Field surveys are required to complete details of bushy and homestead areas. Unfortunately, air photography is costly, and also not cost effective. Remote sensing (satellite based survey) as in the case of air photography, the use of remotely sensed imagery in selected areas can be regarded as productive.

The geodetic control points in Bangladesh were originally established by the Survey of India at the beginning of the nineteenth century. The control points have been poorly and insufficiently maintained since they were installed, they have been left exposed to natural or artificial damages and most of them have now been lost or missing. Even what have been surveyed has shown a marked functional deterioration in terms of accuracy. The bench marks were found to have been far more seriously damaged than the control points in terms of accuracy with the passage of time as well as in the number of what have been lost or ruined. So from 1947 till 1990, SOB continued its mapping activities with those remnant geodetic control points. No of horizontal control points were about 70 and vertical control points about 100. For the above reasons the production of topographical maps and various kinds of civil engineering and construction projects encounter a great deal of difficulties in Bangladesh. Ultimately, JICA in 1990 aimed to reestablish the geodetic system in Bangladesh on a sound basis, including the determination of a horizontal datum station, a vertical datum station and mean sea level and the installation of control points and bench marks throughout the country and finally the establishment of the network of the geodetic control points. The national coordinate system used by SOB was in Everest 1830 datum and LCC projection. Recently it has been shifted to WGS84 datum and BUTM projection to be compatible with global data and GPS use.

Geodetic network consists of horizontal and vertical network. Horizontal network consist of latitude longitude (X,Y) coordinates on nationwide spread monuments called GPS monuments, also known as ground control points(GCP). In analog era these used to be observed by triangulation method. Triangulation points used to be observed by constructing towers (60-90 feet high) of bricks called 'Buruz' or prefabricated iron angles called 'Bilbi' tower. Base length used to be measured using survey chains. Later on, theodolite traversing was introduced where baseline distance used to be measured by electro-optical distance measuring instrument (EDMI) called Tellurometer, Tellumate,etc using 'Helio', a kind of sun light reflector at day and Hazack light at night placed on the other tower. 20 to 25 km was possible to be measured in this way if the line of sight was clear. Angle used to be measured by theodolite, Wild T3 by SOB. Later on, Total Stations were introduced which can measure both angle and distance up to 5 km. For measuring more than five km distance, electronic distance meter (EDM) is still the answer.

Plane table was the common method to collect map data from the field. It used to take its location reference from the nearby geodetic control point and plot the features by drawing rays from different angles and intersecting the feature locations. In the process, operators used to follow a set of standard procedures to maintain the accuracy, specification and cleanliness of the map drawn on the plane table.

After the field collection of map features by plane tabling, the maps used to be finalized by "Fair Drawing" in the recess period by well trained and experienced cartographers. Best possible paper and ink were used for this purpose. This process also involved a set well specified procedure to up keep the desired standard of the maps. Grids and marginal information used to be introduced to prepare the final map ready for printing. The grid on maps provides a system of squares which simplify the location of points and the computation of azimuths and distances. Marginal information includes legends, neat lines, headings, notes, north arrow, etc.

The achievements of SOB in analog era are the departmental topo-maps of 1million, 500k, 250k, and 50k scale maps covering entire Bangladesh. SOB also created extra departmental topo maps of 1:15840, 1:7920, 1:10000 scale of some part of Bangladesh and 1:1200 scale of Dhaka city.

After studying the maps of analog era, the selected features i.e. river, forest and coastal area are extracted in vector format from the maps of 1940s/50s using GIS.

7.3. SOB kept pace with the advancement of technology and grabbed modern digital topographic mapping from 1990s. Digital map production line consists of six distinct disciplines closely integrated together. These are Geodesy, Photogrammetry and Imagery, Field Completion, GIS, Cartography and Printing. Geodesy is the infrastructure for mapping which provides control points for mapping and surveying. Photogrammetry and Imagery provides Aerial Photo and Satellite Image for mapping from where map features are extracted including relief. GIS does the topological correction to the map feature data and create database by attaching the attribute of each feature. Cartography generalizes the map feature data and prepare the map in final shape for printing by adding legend, neat line, graticules and marginal information. Printing deals with colour seperation in order to get desired print of hard copy of maps.

The modern geodetic control network in Bangladesh was established by SOB in 1990s with active assistance from JICA. Horizontal control points were observed by geodetic grade GPS and monuments built all over Bangladesh. First order geodetic network is adjusted with some International IGS stations and now it has much better accuracy than the old network. As on June 2014, SOB has 267 first order and 756 second order GPS monuments. Five GNSS CORS are also established in five divisions and national horizontal datum established at Gulshan Park, Dhaka. In order to establish the vertical control point SOB established tidal station at Rangadia, Chittagong to measure MSL. BMs are observed from tidal station and spread across the country establishing monuments mainly along roads using digital level machines. These also has got much better accuracy than the old network. As on June 2014, SOB has 665 first order and 1300 second order BM monuments. Out of the above networks, 629 monuments are in 3D (X,Y,Z). National vertical datum is established at Gulshan Park, Dhaka. This modern geodetic network now serves as the infrastructure for digital mapping and surveying as well as any development work.

Digital colour and NIR aerial photograph of 50cm and 25cm resolution was acquired in 2010/11 to create digital map of entre country except border belt. 2.5m resolution SPOT image is acquired for border belt. These photos are triangulated and features extracted by photogrammetric software in 3D for precise map creation.

Extracted features are then sent for field verification where surveyors used GPS and laptop to acquire the database for digital map. These database with the digital map features are handed over to GIS operators for basic GIS data preparation. They edit the data to GIS requirement, give topological correction and prepare the final Basic GIS data set as per specification. Then it is handed over to cartographers in cartographic data set in order to prepare final map. Cartographers generalize the data as per specifications, symbolizes the features, and insert marginal information as per specification for final printing. Quality is a major issue in the entire process and QC teams monitor and supervise in every stage to maintain the data quality as per specification.

SOB has definite achievement in digital era too. The establishment of modern geodetic control network is a great achievement that serves as infrastructure of digital mapping and national development works. All 50k maps covering entire country is digitized to create seamless database of the country. Digital 5k map is also created of greater Dhaka city with seamless GIS data, Orthophoto map and DEM. 6 GNSS CORS are established in 5 division cities which are continuously sending data to SOB server. Last but not the least is the IDMS project where SOB is preparing 25k digital base map of entire country with seamless GIS database, Orthophoto maps and DEM.

After studying the modern digital era mapping in SOB, the selected features i.e. river, forest and shore area are extracted from the maps of 2000s in order to compare with old era features of 1940s/50s.

7.4 For river change detection, a GIS model was developed for analysis. River layer of two periods were given as input to the GIS model and output was distinct in three segments. These were dead part of river, newly grown river and common river of both the periods. The major findings are as follows.

Result of this research on Padma River and compare with similar study by JICA:

1. Padma River has more erosion along left bank than right bank except near Faridpur on the left and Harirumpur on the right where the river expanded in both direction.
2. JICA study had similar findings where they mentioned that the bank materials of the Padma river along the left bank are highly susceptible to erosion because they consist of sand and contain little silt.
3. When the main flow of the river attacks bank, they found the erosion rate becomes several hundred meters per year. This research found around 100 meter per year analyzing six decades data where they used three decades data.
4. This research found an exception along left bank in Sureshwar where the river looks stable within last sixty years. JICA study had similar findings where they concluded that the relatively older floodplains of Sureshwar consisting of clay has a very insignificant erosion to a few meters when the flow attacks.
5. From Aricha to Paturia, no significant change has been found on the right bank in this research. JICA study also found that the presence of relatively erosion resistant bank material in this area has resisted the erosion. The floodplains along right bank are mostly composed of "Atri- gur" and "Tippera Surface" sediment the ages of which are probably several hundred to several thousand years, JICA study observed. These sediments are composed of clay and silt, and relatively consolidated sediment thus more resistant to erosion.
6. From Paturia to Dhulsunra, the erosion rate was found very high, nearly 100 meter per year. JICA study found that the floodplains in Harirumpur, which was formed recently and where the bank erosion rate is very high – several hundred meters per year considering their three decades data.
7. From Dhulsunra to Mawa the river has shifted more than 6 km towards north east near Dohar as observed in this research. JICA study found that erosion resistant bank material are available along this bank but they did not mention anything about the big retreat of river Padma at this stretch. This is because the JICA study considered three decades data starting from 1967.
8. Since the right bank is more consolidated composed of Tippera surface and the left bank is less consolidated and erosion prone, The Padma river has made a big retreat towards left within a short span of time. This is one very significant change in Padma river in last six decades that the river had retreated more than 6 kms most probably between 1940 to 1967 and flowing through a completely new channel. JICA study did not mention also about the moderate erosion along about 14 km upstream of Mawa including Mawa that has been observed in my research which is about 16 to 20 m/year. However, Mawa Ferry Ghat seems to be the least susceptible to erosion. Most probably, this has also happened within 1940 to 1967 if we compare the two study.
9. There is some moderate erosion found down-stream of Mawa in my study. JICA study found that although the floodplains at the downstream of Mawa appear to be composed of "Tippera Surface", they are found susceptible to erosion. The average rate of bank erosion has been 20 to 40m/years during last three decades, which is between the observed erosion rates in the recently formed and older flood plains at the upstream of Mawa. In my research, this is found to be 16 to 20m/year in last six decades.
10. JICA study concluded that all bank material of the Padma River are divided into three catagiries: highly erodible, moderately erodible and relatively erosion resisestant. It implies

that when a main channel of the Padma river attacks the bank, the erosion rate would be more than a hundred meters per year along the highly erodible bank, 20 to 50m/year along the moderately erodible bank and 0 to 15m/year along the relatively erosion resistant bank. In my research, similar is the erosion pattern with slightly less erosion rate since my study covers six decades data as opposed to three decades data of JICA study.

Result of this Research on Jamuna River and comparison with similar Research by WARPO:

River Width :

1. The river is becoming wider through retreat of both right and left banks.
2. WARPO study found that the average width of the river has increased about 130m per year since 1973. This research found an average increase of about 70 meter per year for last six decades. It means that the widening is faster in recent decades
3. WARPO study found that recent widening has occurred through retreat of both left and right banks. The average width of the river has increased from about 8 km to 11 km since 1973, an increase of 3 km or nearly 40 percent. My research shows similar result where the river has increased from 8 to 11.5 km in six decades.
4. Relative to the mean width increase, the minimum width is increasing faster and the maximum width is increasing slower. Thus, the overall river is becoming wider and more uniform. Widening of the river is likely to continue. Same trend has been observed in my research.
5. WARPO study observed that since adopting its present course sometime before 1830, the river has been widening. It seems to be creating an active corridor 16 kilometers across, a width sufficient to contain its braiding channels, bars and chars.
6. WARPO study found that based on historical and current trends, widening will continue of at least another two decades and possibly three or more.
7. WARPO study has shown four comparisons of river braiding in the Figure above. Amongst the four, the third one covering 1953-1996 matches most near to my study period i.e. 1940s-2000s.

Bank Erosion:

1. Both river banks are retreating and eroding floodplain land.
2. Bank erosion is twice as likely to occur as bank accretion at any place along the river in any two to three year period as observed by WARPO study. Similar trend is also found in this research where deep maroon colour represents erosion and gray colour represents accretion in Figure above.
3. The left bank has retreated to the west by an average of 1.5 km since 1973, at an average rate of about 65 meters per year. In my study it is found around 50 meters per year over six decades.
4. Westward migration of the left bank has been particularly severe between Fulchari and Sirajganj as observed by both WARPO as well as my study.
5. The right bank has also retreated since 1973, but not at all locations. Eastward retreat is worse in the northern and southern thirds of the river. In the middle third, between the Old Brahmaputra offtake and Bhuapur, retreat through bank erosion and advance through bank accretion are almost matched. This observation is common for both the study as evident from Chapter 3.

Result of this Research on Meghna River:

1. Bhola and Potuakhali are the most affected by the Meghna river changes since these two districts are located at the Meghna Estuaries to the Bay of Bengal.
2. Mximum erosion and deposition had taken place here within the Division. Resultant growth of land/char is more than 100 km sq in Bhola district and more than 150 km sq in Potuakhali district between 1940s and 20000s.
3. This is quite understandable because the entire sediment of Padma-Brahmaputra basin is going down the Meghna channel to the Bay of Bengal resulting into deposition at the estuaries.
4. Barisal is the worst affected district where resultant loss of land is more than 120 km sq. This is due to lateral shift of main course of river Meghna from east to west direction near Lakshmipur. Resultant growth of land/char in Barisal Division is near about 100 km sq.
5. Chittagong division has a great impact due to changes in Meghna river. Noakhali district has a growth of land/ char of more than 550 km sq. This is a phenomenal change that had taken place within last 60 years.
6. Meghna had two main channels 60 years before, one through Lakshmipur-Noakhali and other through Lakshmipur-Bhola. Over the time, the entire Lakshmipur-Noakhali channenl had died down leaving a big chunk of land/char and Lakshmipur-Bhola is the main channel now with a subsidiary channel through Bhola-Potuakhali border which is likely to develop as one of the main channels.
7. Swandip was created by the deposition from Lakshmipur-Noakhali channenl and Hatia was created from Lakshmipur-Bhola channel. Now, erosion is taking place in both the islands due the impact of main channel from north-west to east direction. That's why the north of Hatia and west of Swandip has significant erosion as visible in the map above.
8. Lakshmipur and chadpur districts has also got significant changes due to river changes. Lakshmipur has been increased by almost 200 km sq. Similar phenomena like Noakhali is applicable here due to death of Lakshmipur-Noakhali channel. On the other hand, Chandpur district has eroded by more than 100 km sq. this is due to the natural shift of Meghna channel from west to east at lower part of the district. The shift is about 220 meter per year. Chadpur Sadar is the worst affected due to the erosion.
9. Significant change is also visible in Cox Bazar district. More than 150 km sq growth of land/char is found here. This is due to growth of deposition around Moheshkhali and Kutubdia island specially on the west bank of kutubdia. This is probably by the fine sediments carried by the Meghna channel which is passing in between Hatia and Swandip isands and rolling down the Chittagong-CoxesBazar coast line.
10. Significant change is also found in Rangamati district. There is a loss of land of more than 500 km sq. This is not due to the effect of river change rather due to the creation of catchment of Kaptai dam created during Pakistan period in 1956-1962 that created Kaptai lake.
11. The resultant growth of land/char is about 700 km sq without taking the Kaptai lake into consideration. This is understandable because Chittagong division is located at the maximum siltation zone of Padma- Brahmaputra basin.

Overall changes in Bangladesh in last 60 years:

The total old river water area was 12480 km sq and now it is 12380 km sq. Over all net changes in entire country is only 100 km sq erosion which is negligible in 60 years although commoners apparently think about huge erosion and loss of lands. It means that bank erosion and growth of land/char goes parallel due to meandering nature of the rivers. Erosion takes place mostly at mid and upstream of the river channels where as deposition takes place mostly at the lower part of river channels specially at the estuaries.

7.5. Change detection of forest between two periods were performed by developing a GIS model where input were the forest layers of two periods and output came in three distinct segments i.e. deforestation, afforestation and common forest of both the period. The major findings are as follows.

1. We can see from the Chapter 5 that both deforestation as well as afforestation has taken place over the ages where red colour represents deforestation and magenta represents afforestation.
2. Most of the deforestation is found in Dhaka Division which is approximately 795 sq km in size. A big chunk of forest has altogether been deforested at Haluaghat which started from 1970s by providing govt permits to collect timber. Later on, a port for coal import has been established and it turned into a busy area to aggravate the situation further.
3. Rest of the deforestation is found in Gazipur and Modhupur forest which is due to the unholy collaboration between forest officials and business peoples. Of course some afforestation of approximately 323 sq km is found around the same area which is done mainly under "Community Afforestation" scheme taken by the government.
4. In Chittagong division, an area of approximately 727 sq km has been deforested mainly from Chittagong, Khagrachari, Bandarban and Coxesbazer city neighborhood area. On the other hand, an area of approximately 1176 sq km has been afforested mainly in Khagrachari area and some in Rangamati and Coxesbazar.
5. A good amount of afforestation is noticeable along coastal belt of Noakhali, Vola, Potuakhali and Borguna districts. This is done mainly under the projects of Coastal belt protection schemes.
6. In Sundarban mangroove forest, deforestation has mostly taken place in Barguna and Satkhira districts due to expanding human habitation near Sundarban. Rest of the deforestation is visible along the banks of the khals and rivers flowing through Sundarban.
7. *Sundarbans* supplies raw materials to newsprint mills, match factories, and packing box industries in Khulna and surrounding cities; thus, it is a major entry point for people involved in forest extraction industries. Another possible reason for deforestation in this area is that since the mid-1970s, it has experienced substantial ecological change because of the commissioning of the Farraka Barrage. Diversion of dry season water from the Ganges might have resulted in higher soil salinities
8. The other main area of deforestation, along the western edge of the study area, is near the Indian border. The northern part of this border area is adjacent to a region that has experienced dramatic growth in shrimp farming. Wikramanayake *et al*. (2001) reported that immature shrimp are being collected from the *Sundarbans* at unsustainable levels and that mangrove forests are being cleared to build shrimp farms leading to habitat loss. Iftekhar and Islam (2004) suggest that the *Sundarbans* ecosystem is not well understood, the forest management system is inadequate, and that too many people are economically dependent on the forest.

7.6. To detect the changes in the coastal Islands, the data of 1940s are overlaid on 2000s. The common part of the islands are in gray colour, old islands are in magenta colour and new islands are in light green colour as shown in Chapter 5. So the mageta colour islands has been dissolved into river now and the present islands will be the shape of combined gray and light green colour. The major findings are as follows.

1. The land mass of Kamalnagar, Ramgati and Subarnachar which was an island before but has become part of mainland now due to major shift of the Meghna River towards west. In other words, the Meghna River had two main channels into the Bay of Bengal keeping those islands in between the channels thus separating the islands from mainland. Now, the west channel is the only channel and the east channel has totally disappeared
2. Hatia and Sandwip islands have been eroded heavily in the north and deposited lightly on the south.
3. Monpura has been elongated southward by deposition with some more islands deposition further down the channel.
4. Bhola is also eroded in the north east and deposited southward and connected up to Char Fassion and beyond.
5. A big island has also deposited in between Char Fassion and Golachipa. Some erosion is also observed at Mohesh Khali.

7.7. Recommendations:

1. Erosion and accretion is a natural process in the biggest river system of the world flowing over Bangladesh. Any physical development project should always consider this phenomenon.

2. Aforestation is found to be slightly more than deforestation. Aforestation should be encouraged and deforestation should be resisted by enforcing laws in order to reach ideal situation of 30 percent forest coverage.

3. SOB should open its archive for research works since it is the only topographic map making organization having valuable assets in the form of maps, aerial photo, satellite image, DEM, orthophoto maps, etc.

4. A research and development wing equipped with modern technology can be opened up at SOB to analyze its own product as per requirements of stakeholders. This will contribute in precise and quick decision making at various government development activities and enable them making value added products.

5. Knowledge about maps should be imparted from primary education level like developed countries and related subjects should be introduced at higher education since maps are now integral part in internet browsing, navigation, mobile application, travelling and so many applications. children may be encouraged by participating their map works in specialized museum and publics may be encouraged by open examination on maps and providing honorary degree like Japan.

6. Maps should be made open to the public and book stores should have sufficient supply of maps.

7. Government should introduce location based e-governance using spatial data at government offices which will ensure precise and better decision making.

8. Digital topo map data is the fundamental data for national spatial database infrastructure (NSDI) which serves as central data hub for a country from where data can be used by various stake holders depending on their purpose. This helps in avoiding repetition of effort and make it cost effective. SOB should take the initiative to provide leadership in this regard.

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