Report on
Cyclone Shelter Information for Management of Tsunami and Cyclone Preparedness

Annex C: Catchments Area and Evacuation Route Mapping

April 2009

Printing supported by:

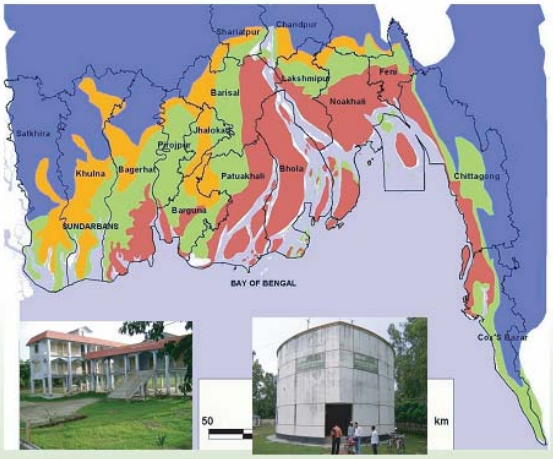
Comprehensive Disaster Management Programme
Ministry of Disaster Management and Relief

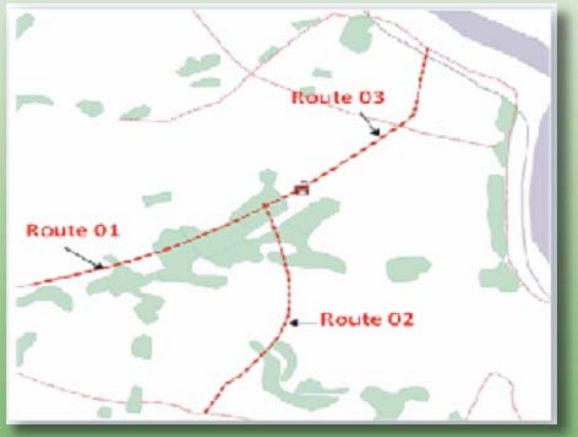
UKaid from the British people
European Union
NORWEGIAN EMBASSY
SWEDEN
Australian AID
UNDP
Empowered lives. Resilient nations.

Ministry of Food and Disaster Management
Comprehensive Disaster Management Programme

Report on
Cyclone Shelter Information for Management of Tsunami and Cyclone Preparedness

Annex C
Catchment Area and Evacuation Route Mapping





April 2009

CEGIS
Center for Environmental and Geographic Information Services
In Cooperation with Comprehensive Disaster Management Programme

CDMP DFID Department for International Development UNDP

Table of Contents

Table of Contents i
List of Figures i
List of Tables ii
Abbreviations iii
Chapter 1 Introduction 1
1.1 Background 1
1.2 Scope of the Work 2
1.3 Structure of the report 3
Chapter 2 Literature Review and Methodology 4
2.1 Literature Review 4
2.1.1 Multipurpose Cyclone Shelter Programme (MCSP) 4
2.1.2 Cyclone Shelter Preparatory Study (CSPS) 6
2.2 Study Approach 7
2.3 Methodology 8
2.3.1 Vulnerability Analysis 8
2.3.2 Accessibility Analysis 9
2.3.3 Cyclone Shelter Capacity and Vulnerability Analysis 12
2.3.4 Catchment Area Delineation 12
Chapter 3 Catchment Area Delineation 14
3.1 Vulnerability Analysis 14
3.2 Accessibility Analysis 19
3.3 Cyclone Shelter Capacity and Vulnerability Analysis 21
3.4 Catchment Area Delineation 26
Chapter 4 Conclusion 29
References 30
Appendix - C1: Compliance Report on Comments from TAG Committee 32

List of Figures

Figure 2.1: Population of interstitial areas unserved 5
Figure 2.2: Overlap of circular service areas 5
Figure 2.3: The most suitable theoretical shape for service areas: the hexagons 5
Figure 2.4: Overlay of settlement area & road network 6
Figure 2.5: The proposed primary school 6
Figure 2.6: Successive year planning of primary school 7

Figure 2.7: Overall Methodology for Catchment Delineation of Cyclone Shelters....7
Figure 2.8: Access route for settlement toward shelter....10
Figure 2.9: Access route for settlement toward shelter: Settlement near river....10
Figure 2.10: Access route for settlement toward shelter: Settlement has no connecting road....11
Figure 2.11: Access route for settlement toward shelter: Shelter within embankment....11
Figure 3.1: District-wise distribution of area under the risk zones....15
Figure 3.2: Base Map showing settlements, roads and shelters of Lata Chapli Union....18
Figure 3.3: District-wise distribution of communication routes under the risk zones....20
Figure 3.4: Distances of shelters from settlements....21
Figure 3.5: Distribution of shelters and PEDP-II buildings in risk zones....24
Figure 3.6: Cyclone Shelter Catchment and Evacuation Route Map for Lata Chapli Union....27
Figure 3.7: Output Table showing served population percent of settlements in Lata Chapli....28

List of Tables

Table 1.1: Previous Cyclones and their impacts....2
Table 2.1: District wise growth rate....8
Table 3.1: Area distribution of districts in different risk zones....14
Table 3.2: District-wise Population of 2001....15
Table 3.3: District-wise Population of 2009....16
Table 3.4: Population in 2001 for Lata Chapli Union....17
Table 3.5: Area of different risk zone....17
Table 3.6: District-wise communication network and FCDI area in different risk zone....19
Table 3.7: Communication network and FCDI area of Lata Chapli....20
Table 3.8: Number of different types of shelters in 16 districts....21
Table 3.9: District-wise Population Capacity....22
Table 3.10: District wise no. of shelters and PEDP-II buildings in different risk zone....23
Table 3.11: District-wise condition of shelter....24
Table 3.12: Usable Shelters Vulnerability distribution: Tsunami....25
Table 3.14: Shelter Vulnerability distribution: Cyclone....25
Table 3.15: Condition and distribution of shelters in Lata Chapli....26
Table 3.16: Capacity of shelters in Lata Chapli....26

Abbreviations

BBS	Bangladesh Bureau of Statistics
BDRCS	Bangladesh Red Crescent Society
BIDS	Bangladesh Institute of Development Studies
BNBC	Bangladesh National Building Code
BUET	Bangladesh University of Engineering and Technology
CDMP	Comprehensive Disaster Management Programme
CEGIS	Center for Environmental and Geographic Information Services
CSPS	Cyclone Shelter Preparatory Study
CYSMIS	Cyclone Shelter Management Information System
DEM	Digital Elevation Model
DFID-B	Department for International Development – Bangladesh
DMB	Disaster Management Bureau
DRRO	District Rehabilitation & Relief Officer
EC	European Commission
GIS	Geographic Information System
GO	Government Organization
GoB	Government of Bangladesh
HRA	High Risk Area
ICRD	Integrated Coastal Resources Database
ICZMP	Integrated Coastal Zone Management Plan
LGED	Local Government Engineering Department
MCSP	Multipurpose Cyclone Shelter Programme
MoFDM	Ministry of Food and Disaster Management
NGO	Non Government Organization
NWRD	National Water Resources Database
PWD	Public Works Department
RA	Risk Area
RS	Remote Sensing
ToR	Terms of Reference
UNDP	United Nations Development Programme
WARPO	Water Resources Planning Organisation

Chapter 1
Introduction

1.1 Background

The Comprehensive Disaster Management Programme (CDMP) of the Government of Bangladesh (GoB) is being implemented by the Ministry of Food and Disaster Management (MoFDM) and is supported by the United Nations Development Programme (UNDP), UK Department for International Development, Bangladesh (DFID-B) and the European Commission (EC).

In August, 2006 the European Commission and UNDP signed a cooperation agreement related to the funding of three new components within the CDMP framework. "Component 4a: Earthquake and Tsunami Preparedness" is one of them. This component has been divided into several clusters. Among these clusters CEGIS has been assigned the corresponding tasks of assignment entitled "Update available information on cyclone shelter management for tsunami and storm surge preparedness". The third task of this assignment is Catchment Area Delineation of cyclone shelters. Before this task two tasks, namely "Spatial distribution of cyclone shelters and their attributes" and "Structural Strength Analysis of Cyclone Shelters" have been completed under this assignment.

The coastal area of Bangladesh as defined by Integrated Coastal Zone Management Plan (ICZMP) of Water Resources Planning Organisation (WARPO), comprises 19 districts, located in the southern part of Bangladesh and influenced by the Bay of Bengal (PDO-ICZMP, 2005). Out of 19 districts, 16 districts of the coastal area has been considered for updating cyclone shelter information. Three districts namely Jessore, Narail and Gopalganj are not included in this study, as they are not exposed to the cyclone and tsunami storm surge. The 16 districts under this study are Bagerhat, Barguna, Barisal, Bhola, Chandpur, Chittagong, Cox's Bazar, Feni, Jhalokati, Khulna, Lakshmipur, Noakhali, Patuakhali, Pirojpur, and Satkhira. These districts fall within the latitude of N- 21° to N- 23°30′ and the longitude of E- 90° to E- 91°30′.

The coast of Bangladesh is approximately 710 km long, as estimated by measuring the distance around the Bay of Bengal between Indian and Myanmar borders. The coastal zone is mainly low-lying with 62% of the land having an elevation less than 3 metres and 86% less than 5 metres. Waves, tides, river flow, sediment movements, plants and animals interact constantly to shape the coastlines. This shaping is a continuous process for centuries. As a result the coastal topography, land pattern etc. are very much dynamic in nature.

The coastal zone comprises several ecosystems having important conservation value. The Sundarbans, world's largest uninterrupted stretch of mangrove ecosystem (6017 km^2 area) and a world heritage site is among them (IWM & CEGIS, 2007). The Sundarbans provide habitat for an abundance of plant species as well as an array of fish and wildlife.

About 11,915 km^2 of the coastal area is protected by the coastal polders. There are 123 polders, which were constructed in late sixties to protect the land from tidal and monsoon flooding, saline water and to increase the crop production. Most of the large islands are protected by coastal embankments.

According to the population census 2001, the total population of coastal area is about 28 million, which is about 22% of total population of Bangladesh. The ratio of urban-rural population in the coastal region is 17:83. According to ICZM (2006) the sex ratio is 105 female per 100 male, average literacy rate is 51% and average household size is 5.4 in the coastal zone (IWM & CEGIS, 2007). Average population density, considering the total land area is about 792 persons per sq.km (IWM &

CEGIS, 2007). The estimated population (2009) of the coastal 16 districts is about 38.2 million of which 48.8% are women.

The livelihood activities of coastal population are multidimensional (IWM & CEGIS, 2007). Major livelihood groups are farmer, fishermen and wage labourer. Farmer households are the largest group, which constitute 25% of the coastal households. The percentage of farmer is higher in relatively fresh water zones; mostly in Pirojpur, Barisal, Shariatpur, Narail, Jessore, Patuakhali and Barguna, which is about 30% and above. The number of fishermen households in the coastal region is about 0.20 million, which is about 3% percent of the total households. Wage labourer group constitutes 0.15 million household, which is about 24% of total household in coastal zone. Generally the proportion of agricultural labour is higher in rural areas and non-agriculture labour is higher in urban areas. Spatially, the proportion of labourer is higher in Cox's Bazar, Patuakhali, Chandpur and Jessore districts. Woman constitutes about 50% of the total population of the coastal region (IWM & CEGIS, 2007). Farmers and Fishermen groups are directly dependent to natural land and water resources, whereas most of the labour and woman are indirectly dependent on natural resources (IWM & CEGIS, 2007).

Bangladesh is one of the most disaster prone countries in the world. Natural hazards like floods, cyclones, droughts, earthquakes, tornadoes, etc. frequently affect The country almost in every year. Out of all these, the tropical cyclone causes huge damage to the coastal infrastructure, wealth and social livelihood. Historically major cyclones hit the coastal areas of the country in 1970, 1991, and 2007. Table 1.1 shows a summary of historic major cyclones and their impacts over the country. The high number of casualties is due to the fact that cyclones are always accompanied with storm surges. Lack of adequate shelters and preparedness facilities increased the casualties during the cyclone events.

Table 1.1: Previous Cyclones and their impacts

Cyclone events	1970	1991	2007
Storm Surge	6-9 m	6-7.5 m	Up to 10 m
Maximum Wind Speed	223 km/hr	225 km/hr	Up to 240 km/hr
Affected District	5	19	30
Affected People	1,100,000	13,798,275	6,851,147
No of Dead People	470,000	138,882	3,292

Source: DMB, 2008; GoB, 2008

Cyclone shelters provide shelter to the coastal community and help a lot to reduce the number of casualty in the coastal areas during cyclone and tsunami. Normally people of the surrounding area took shelter in the shelters. But, as a part of preparedness for disasters, population should be evacuated to the shelters/safe locations as early as possible. If people know where they should go during disaster, they could move faster to the shelter. When catchment area for each shelter is identified, people will know when and where to go during disasters. For this, delineation of catchment area for evacuation is very important.

1.2 Scope of the Work

According to ToR the task for this deliverable is to develop buffer zone for each cyclone shelter for evacuation. During TAG meeting on Inception Report, several members of the TAG commented on

the word "Buffer zone" and suggested to use "Catchment area" instead of "Buffer zone". So, as per the guidance of TAG, the task has been changed to "Develop Catchment area for each cyclone shelter for evacuation". This task involves the delineation of catchment area for each shelter in the coastal areas.

To address the defined scope several activities are required. These are:

- Assessment of location, capacity and structural vulnerability of cyclone shelters based on the cyclone shelter inventory.
- Assessment of population to be evacuated to the shelters. This includes, distribution of population in individual settlements surrounding each shelter.
- Accessibility analysis for identification of evacuation routes for each shelter connecting the settlements to the shelters.
- Delineation of catchment area for the cyclone shelters and allocation of settlement population to each shelter for evacuation during disasters.

1.3 Structure of the report

This annex on Catchment Delineation for the cyclone shelters comprises four chapters. Chapter 1 includes the background, scope of the work and structure of the report. Chapter 2 describes the Literature Review and Methodology. Chapter 3 comprises the detail description of analysis process regarding vulnerability analysis, accessibility analysis, cyclone shelter analysis and finally the catchment area delineation for evacuation. Chapter 4 describes the concluding remarks. Besides the report this annex contains an Appendix – C1 presenting the Compliance Report on Comments from TAG Committee meeting.

Chapter 2

Literature Review and Methodology

2.1 Literature Review

The study on catchment area delineation of cyclone shelters includes literature review of previous initiatives taken in this regard. Previous studies on cyclone shelters have been reviewed to search for methods for catchment area delineation. This includes the reports of the Multipurpose Cyclone Shelter Programme (BUET & BIDS, 1993a, 1993b and 1993c), Cyclone Shelter Preparatory Study (Sener Ingenieria Y Sistemas, et al. 1998) and Cyclone Shelter Management Information System (CEGIS, 2004). A brief summary of the relevant sections are presented in the following sections.

2.1.1 Multipurpose Cyclone Shelter Programme (MCSP)

The Multipurpose Cyclone Shelter Programme attempted to delineate the catchment area of a cyclone shelter (or killa), which is the area where people (or livestock) come to take shelter during the cyclonic storms and surges. The size and shape of a catchment area was determined based on the following factors: (a) the distance which most families were willing to move when winds pick up gale speed; (b) the density of habitations, settlement pattern and the number of people for which the shelter was designed to serve and (c) access to the shelter. These three factors are briefly discussed in the following paragraphs:

The distance, which most families were willing to move was determined by topographic features, overall security situation (e.g. risk of looting), communication network and the direction of the main storm. One observation was that most families move only when winds picked up gale speed.

Other important factors in catchment area delineation were road network and topography. People were generally unwilling to cross-waterways once the winds picked up gale speed. It is also a fact that all major cyclonic storms over the past four decades have hit the Bangladesh coast at night. Obviously people have had to move by nightfall and the distance they moved was largely determined by ease of communication. Heavy rainfall preceding the storm makes it difficult to cover even a kilometer. In the char areas of Noakhali, people moved up to 4 km before the April 1991 storm hit because they did not bother about the security of their belongings and the sense of insecurity was high due to the absence of any embankment to protect their area.

On the other hand, in the Cox's Bazar area, many families did not move out at all, fearing for their possessions. Moreover, in some places, a sense of security had developed due to the existence of coastal embankments. It must be mentioned here that this was a false sense of security, as the embankments were not designed to prevent inundation due to storm surges. Rather, the basis of design is to protect the area against inundation due to high spring tides and to protect agricultural land from salinity. The design standard of the sea facing coastal embankment has recently been modified under the Cyclone Protection Project-II. The Consultants' close interactions with the relevant people of the coastal belt led to a decision that the preferable maximum travel distance should not exceed one kilometer wherever possible.

The density of habitations was obviously a factor in determining the catchment area. Where density was high (e.g. Tazumuddin Thana) it would be smaller. The distance to the shelter would also be less in areas where holdings are larger (e.g. southern part of Hatiya). The density of habitation can be determined by dividing the population of a given settlement by the area of that settlement (i.e. homestead area, not total village area

Road network was a vital factor in shaping the catchment area. In order to optimize on the investment being made towards a multipurpose use of shelters, a good communication network is essential.

The determination of the catchment area was a complex matter, and was dependent on each particular location. The construction of a good road network changed the shape and size of a catchment. The willingness of the people in the catchment to fully utilize the facility would obviously depend on awareness, training, community development education and shelter management.

The MCSP study report stated that if it was assumed that the distribution of population is completely uniform and the people would move in any direction without any difficulty, the catchment area of a facility would ideally be circular. However, if three or more tangent circles are inscribed in an area, either unserved spaces would exist (Figure: 2.6) or there would be overlaps in the areas (Figure 2.7). The best theoretical shapes would be hexagons, the closest geometrical figures to circles, which would completely fill an area (Figure 2.8).

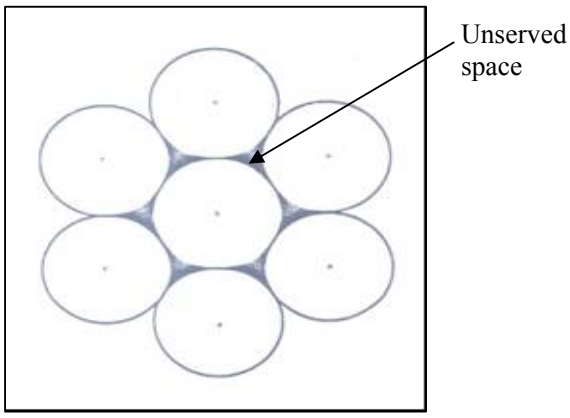


Figure 2.1: Population of interstitial areas unserved

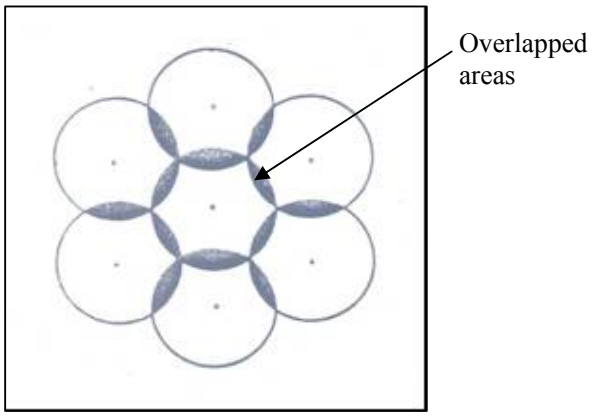


Figure 2.2: Overlap of circular service areas

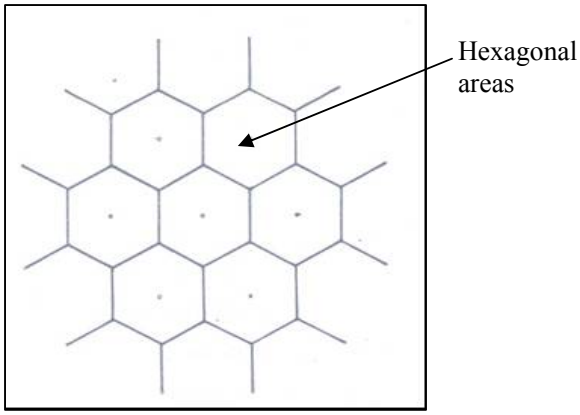


Figure 2.3: The most suitable theoretical shape for service areas: the hexagons

The MCSP report also identified the following limitations: a) the assumption of uniform population distribution was not realistic; b) the direction of movement was also constrained by lack of transportation facilities and c) hexagonal service areas were not observed as realistic.

2.1.2 Cyclone Shelter Preparatory Study (CSPS)

The Cyclone Shelter Preparatory Study (CSPS) study revealed that LGED prepared union (Burirchar) based primary school planning maps using a GIS model at a scale of 1:50,000 considering the school service area. But no maps have been prepared for the catchment of cyclone shelters. Figures 2.9, 2.10, and 2.11 show overlaid information of settlement area and road network, the proposed primary school and successive year planning of the primary school in Burirchar union. (Source: CSPS, stage 1 supporting Vol. 9).

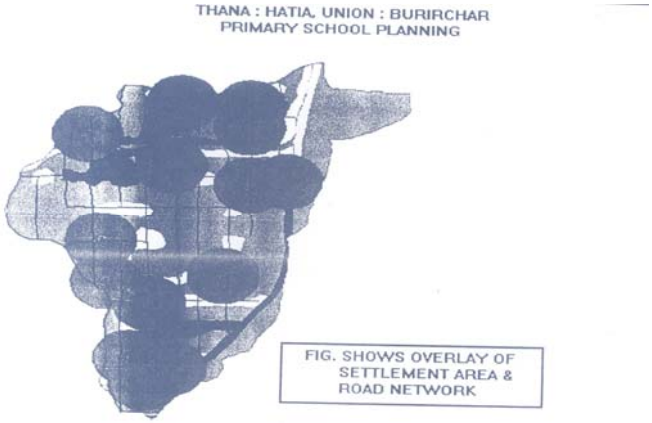


Figure 2.4: Overlay of settlement area & road network

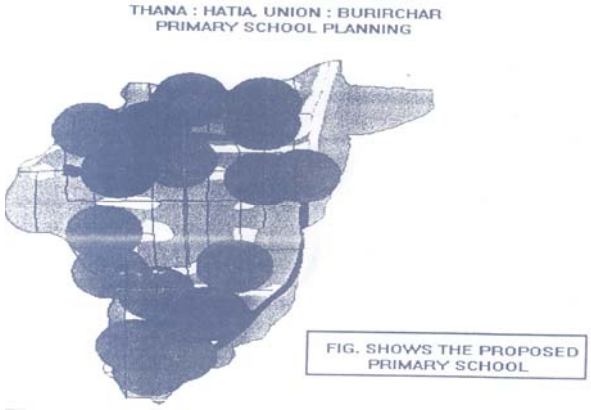


Figure 2.5: The proposed primary school

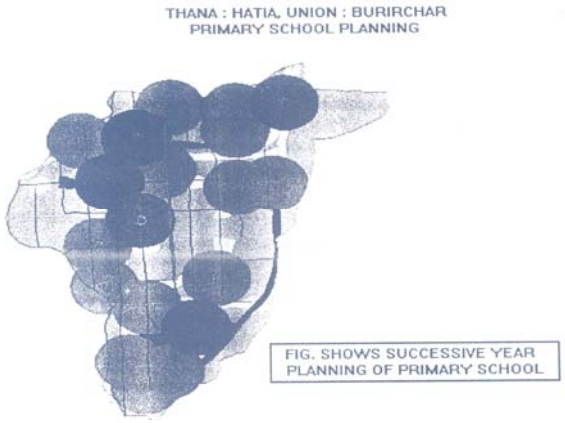


Figure 2.6: Successive year planning of primary school

2.2 Study Approach

Information need and the methodology for catchment area delineation of cyclone shelter have been described in detail in the inception report. To attain the objective of the study a need assessment was done with the guidance from the inception report. Based on the need assessment data were collected from primary data collection survey conducted. Details of survey are presented in Annex-A. Other than primary data secondary sources like Multipurpose Cyclone Shelter Programme (MCSP), Cyclone Shelter Management Information System (CYSMIS) survey data etc. were also used. An overall methodology for catchment area delineation is presented in the figure 2.7.

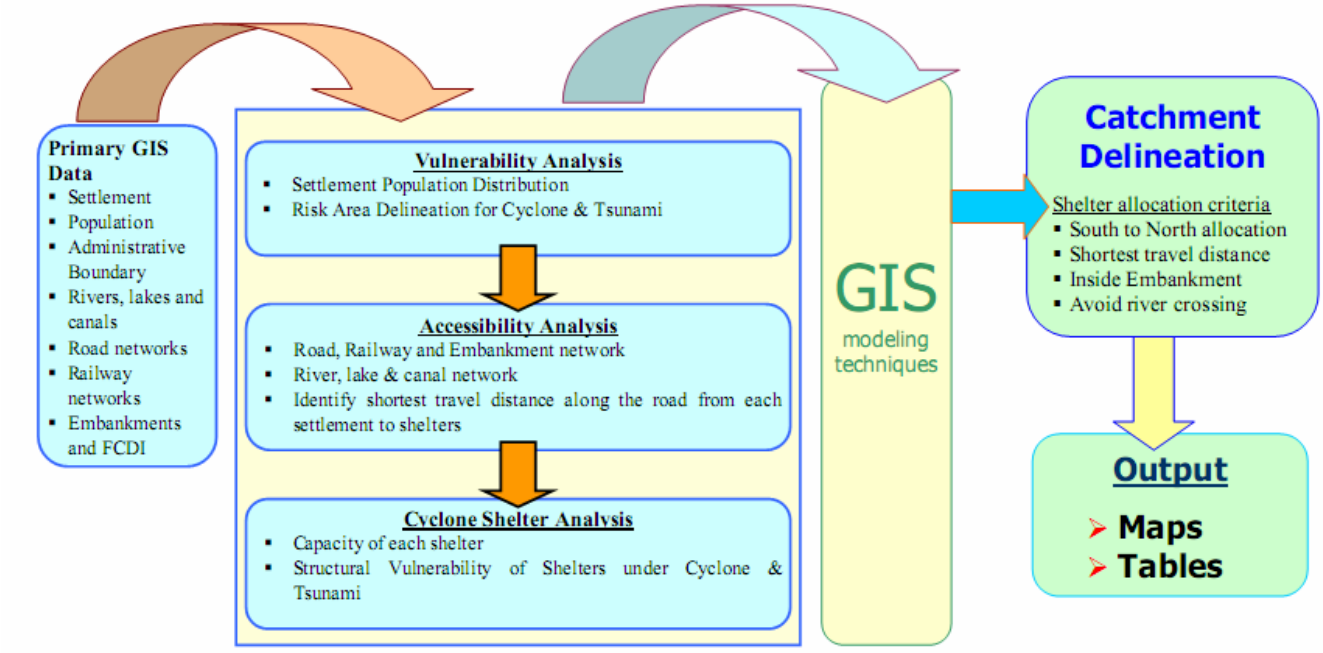


Figure 2.7: Overall Methodology for Catchment Delineation of Cyclone Shelters

2.3 Methodology

The Methodology for catchment area delineation for each cyclone shelter follows a four-step procedure. The steps are:

- Vulnerability analysis
- Accessibility analysis
- Cyclone shelter capacity and vulnerability analysis
- Catchment area delineation

2.3.1 Vulnerability Analysis

The coastal area of Bangladesh is highly populated. For delineating the catchment area for each shelter, first the level of risks for hazards in different areas of the coast has been analysed. Risk maps for cyclone and tsunami have been generated based on inundation risk map prepared under the study titled "Use existing data on available digital elevation models to prepare useable tsunami and storm surge inundation risk maps for the entire coastal region" by the Institute of Water Modelling (IWM) (IWM, 2008). From these inundation risk maps, risk area maps have been created using GIS analysis methods. The risk areas are defined as High Risk (more than 3 meter inundation depth), Moderate Risk (1-3 m), Low Risk (up to 1 m) and No/Wind Risk (0 m). When the inundation depth is 0 m there is no risk for tsunami. This is due to the reason that, during tsunami there is no stormy wind. But when cyclone hits, it involves storm surge and also severe wind forces. So, for cyclone 0 m inundation areas are in risk from wind forces. Based on the risk areas for Cyclone and Tsunami, vulnerable area and population has been identified.

Union-wise population for the coastal districts has been collected from Population Census, 2001 (BBS, 2001). This population is classified in age groups and also according to gender. For our analysis, population is divided into three age groups. The age groups are below 5 years, 5-60 years and more than 60 years. The age group of below 5 years has been considered as child population, whereas above 60 years population has been considered as elderly people. Besides this, population is subdivided on Male and female population. Population of 2009 has been estimated using the population of 2001 and increasing it by district wise growth rate (Table 2.1) given in the population census 2001. In this population estimation inward or outward migration of population is not considered.

Table 2.1: District wise growth rate

District	Growth Rate (1991-2001)
Bagerhat	1.63
Barguna	1.96
Barisal	1.35
Bhola	2.11
Chandpur	2
Chittagong	3.04
Cox's Bazar	3.02
Feni	1.79
Jhalokati	2.92
Khulna	2.91
Lakshmipur	1.88
Noakhali	1.83
Patuakhali	2.31
Pirojpur	1.32
Satkhira	2.99
Shariatpur	1.89

Source: BBS, 2001

After risk area identification, population for each settlement has been computed. Settlement is defined as a cluster of houses within a close proximity. Location of settlements in the coastal area has been captured using Remote Sensing (RS) data. There is a unique ID for all settlement in the coastal area.

The population in each settlement under a union is not known. So, it has been assumed that the density of population in each settlement under a union is same. Based on this assumption, The population of each settlement (P_S) within a union is calculated by the following expression.

$$P_{S_{i=n}}^{U=j} = \frac{P_U^j}{\sum_{i=n} A_{S_i}} \times A_{S_i}$$

where, $P_{S_{i=n}}^{U=j}$ =Population of settlement i of Union j

P_U^j =Population of Union j

A_{S_i} =Area of settlement i

$\sum_{i=n} A_{S_i}$ = Total area of the settlements of Union j

In distributing the population, settlements having less than 5000 m^2 area have been ignored.

When population for each settlement under a union has been estimated, then this information is stored in a GIS attribute file. In this attribute the settlement area and population are entered according to Settlement ID and Geocode. So, all information of a settlement are linked with its unique ID.

2.3.2 Accessibility Analysis

Accessibility analysis incorporates the analysis of communication networks that could be used for rapid access to the cyclone shelters during disasters. The communication networks include Roads (National Highway, Regional Highway, District roads, Rural roads etc.), Embankments, Flood Control, Drainage & Irrigation (FCDI) project areas and Railways. Information of road, embankment and railway networks have been collected from ICRD, LGED, RHD data. The accessibility analysis computes the shortest distances along the road from a settlement to several shelters. This process is completed using GIS based network analysis. During distance computation along the road distances are considered instead of aerial distance, as it is more logical and also acceptable to the community.

The accessibility analysis has been carried out with some assumptions. The road network used in the analysis is believed to cover all types of roads in the coastal area. But there may be some village level small roads which are not included in the network.

All settlements were previously given an unique ID. Positions of settlement centroids are calculated using GIS techniques. The specific location of these centroids are added to the attribute of the corresponding settlements. Using GIS network analysis, along the road distances of nearest four

shelters have been computed for each settlement. Distances are calculated between settlement centroid and shelters. After the analysis all distances are entered into the attribute of the settlement.

During the accessibility analysis several cases are observed which influence this analysis. These cases are described in the following section.

Case-I

According to the preference of the community, acceptable distance of shelters from settlements should be within 1.5 km. Shelters that have good road communication with settlements are generally preferred by people. Figure 2.8 illustrates this situation.

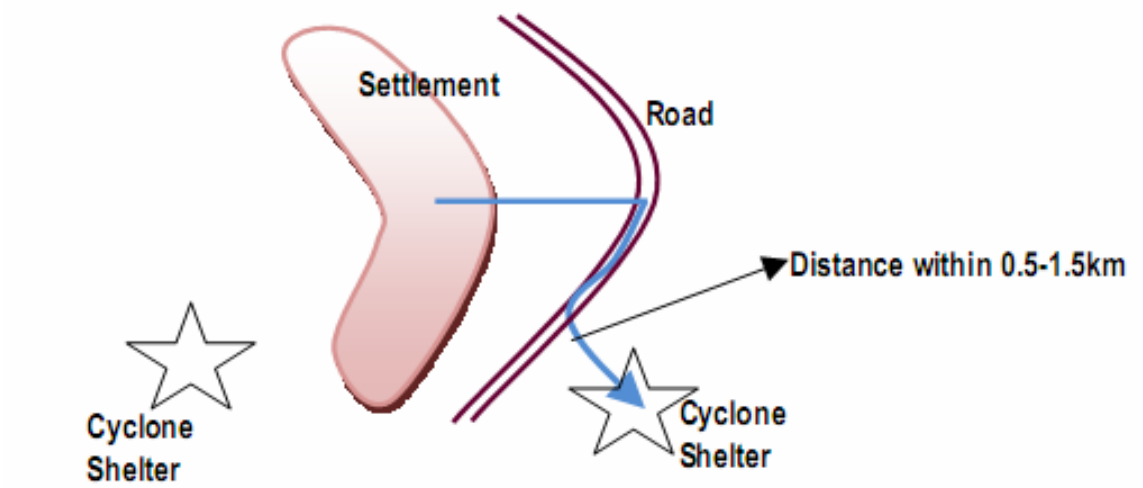


Figure 2.8: Access route for settlement toward shelter

Case-II

People do not want to cross large river or flowing river. They do not prefer to cross river for going to shelter. Sometimes shelters on the opposite side of the river may be closer than a shelter on the same side of the river. Figure 2.9 illustrates this issue.

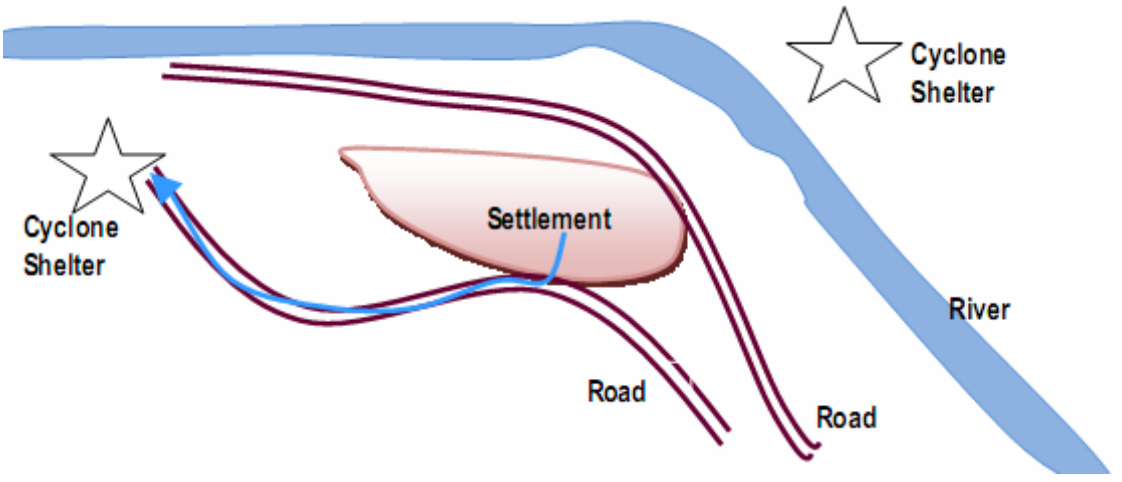


Figure 2.9: Access route for settlement toward shelter: Settlement near river

Case-III

If there is a large gap between the settlement and the nearest road then a straight line link from the centroid of the settlement to the road is assumed. In this case the distance calculation includes this link along with distance along the road. Figure 2.10 illustrates this situation.

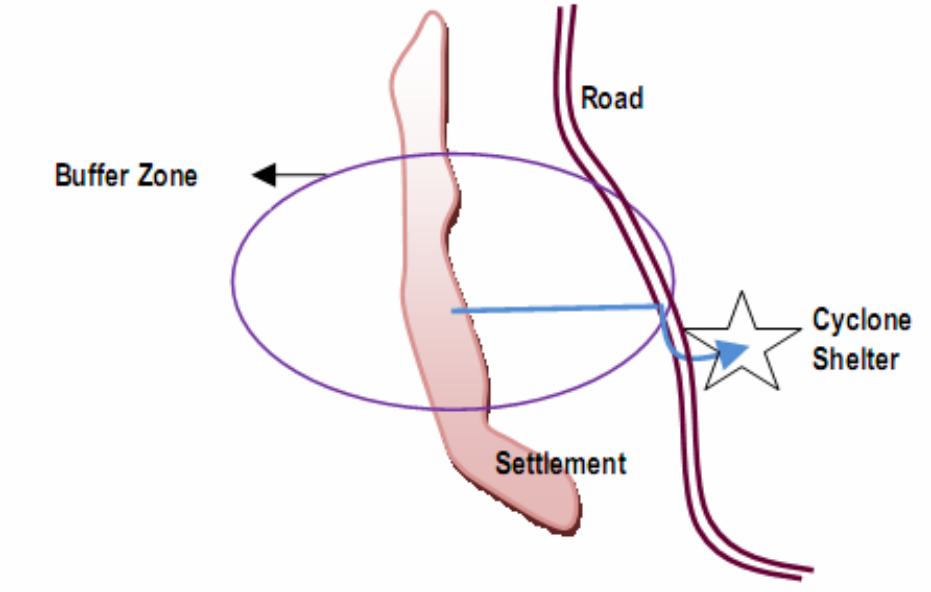


Figure 2.10: Access route for settlement toward shelter: Settlement has no connecting road

Case-IV

Community normally prefers to stay within the coastal embankments (polder). If the nearer shelter is located outside the embankment, then people do not prefer to go to that shelter. Instead, they go to a shelter within the embankment, which may be located at a larger distance. Besides this, people try to move away from the sea during disaster. Therefore, the people who reside in the southeast zone prefer the shelter situated in the east rather than the shelter situated in the west and people of the south zone prefer the shelter situated in the north rather than the shelter of south. Figure 2.11 shows a pictorial view of this case.

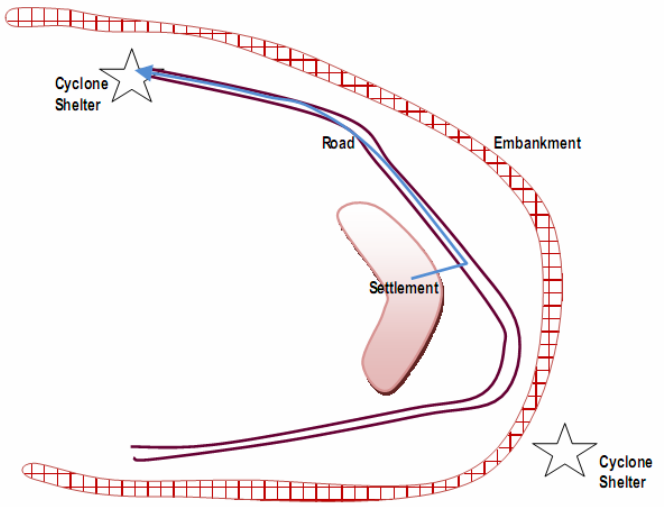


Figure 2.11: Access route for settlement toward shelter: Shelter within embankment

2.3.3 Cyclone Shelter Capacity and Vulnerability Analysis

Tropical cyclone and tsunami induced storm surge and wind has devastating natural forces. In order to withstand these massive forces, special types of buildings are required. As Bangladesh is a least developed country, most of the people here are poor. Similarly it is true for the coastal areas also. As a result, most of the coastal population do not afford to built such a strong house that can withstand the forces of storm surge and wind during cyclone / tsunami. For this reason, Government, BDRCS and other donors and humanitarian organizations are building cyclone shelters that are safe and sufficiently strong to withstand the forces. This study component has done field survey to update the information on cyclone shelters along the coast. From the survey, a total of 3,753 shelters and school buildings (PEDP-II) were found. The survey has identified Specific location, capacity and description of every shelter. Detail information was presented in Annex-A.

There are various types of structures used as cyclone shelters. Due to the differences in structure and shape, floor area and population capacity of these shelters vary a lot. Shelter capacity has been estimated in three ways. These are:

(a) No. of people taking shelter in a cyclone shelter during cyclone SIDR has been estimated during the survey. This estimations are approximate values by local people.

(b) MCSP used 2 square feet (sft) area per person to calculate the capacity of a shelter (BUET & BIDS, 1993a). According to this assumption, capacity of a shelter is half of the shelters floor area.

(c) After the cyclone SIDR expert committees suggested that per person requirement of area in a shelter should be 3 sft. If this assumption is used, then capacity of a shelter is one-third of its floor area.

Capacity of shelters has been estimated using all three procedures. Among these the process followed by MCSP has been used in the current study. After computing the capacity of shelters, this information is linked with the shelter ID and entered in the shelter attribute.

Besides this, the condition of many shelters are not good due to poor construction / lack of proper maintenance. Annex-B on structural analysis of shelters has detail analysis about the vulnerability of shelters under different disaster situations. From this analysis level of vulnerability of each shelter and its current condition from survey is linked to the respective shelter ID and added to the attribute.

2.3.4 Catchment Area Delineation

The catchment area of a cyclone shelter (or killa) is the area from which people (or livestock) come to take shelter during cyclonic storms and surges (BUET & BIDS, 1993c). Based on the literature review of previous studies, we have selected a criteria based approach to delineate catchment area of each shelter for evacuation. Community people have their specific preferences about shelters. These are the basic criteria for our current analysis. The criteria are:

i) People prefer to go to the nearest shelter. Acceptable distance of shelter is about 1.5 km from their houses.

ii) People do not like to cross waterways to go to a shelter.

iii) People want to go northward (in south zone) or eastward (in southeast zone) during cyclones. They do not like to travel against the wind.

iv) People feel secured to stay inside the coastal embankments. During disaster, they travel even 3-4 km for taking shelter in cyclone shelter inside the embankment.

v) People prefer shelters having good road communication.

After computing settlement population, distance from four nearest shelters to that settlement is computed. All these information are stored in the attribute of settlement and linked with the attribute of shelters. After this, based on shortest distance, shelters are filled with population from settlements. If a shelter is not filled by the first settlement, then people from the second nearest settlement are used. This process is followed until the shelter is filled. If a shelter cannot accommodate the full population of a settlement, then the left population is allocated to the next nearest shelter. Shelters are filled geographically, moving from south to north (south zone) and west to east (southeast zone). All these tasks are completed using GIS techniques.

After allocating the population to shelters, Maps are generated showing the settlements, shelters, communication network, river network and administrative boundaries. These maps show settlements with ID of shelters where the settlement population will be evacuated during the disaster.

Chapter 3

Catchment Area Delineation

3.1 Vulnerability Analysis

To assess the level of vulnerability of an area due to cyclone and tsunami, Inundation risk map is of great importance. Based on Inundation risk maps for the coastal area, the area has been classified into four risk zones according to inundation depth. The risk zones are:

- Wind/No Risk: When inundation depth is 0 m - the zone is called wind/no risk zone and there are only risk from wind forces.
- Low Risk: When inundation depth is 0 to 1 m - the zone is called low risk zone and in this zone storm surge of up to 1 m may occur.
- Moderate Risk: When inundation depth is 1 to 3 m - the zone is called moderate risk zone and in this zone storm surge of 1-3 m may occur.
- High Risk: When inundation depth is greater than 3 m - the zone is called high risk zone and in this zone storm surge of more than 3 m may occur.

Based on this classification, a distribution of area under different risk zone in the coastal districts has been done. Table 3.1 and figure 3.1 illustrates this distribution.

Table 3.1: Area distribution of districts in different risk zones

Districts	Area (km^2)			
	High Risk (> 3 m)	Moderate Risk (1–3 m)	Low Risk (0-1 m)	No Risk
Bagerhat	856	1,492	577	915
Barguna	403	773	287	0
Barisal	842	1,116	309	250
Bhola	2,239	295	0	0
Chandpur	32	187	214	1,264
Chittagong	995	1,090	0	2,412
Cox's Bazar	484	965	0	784
Feni	452	217	65	167
Jhalokati	0	486	252	0
Khulna	0	1,554	810	1,522
Lakshmipur	689	548	149	119
Noakhali	2,118	511	115	13
Patuakhali	1,766	702	305	0
Pirojpur	13	1,036	163	60
Satkhira	0	1,204	389	2,064
Shariatpur	13	247	168	794
Total	**10,902**	**12,423**	**3,803**	**10,364**

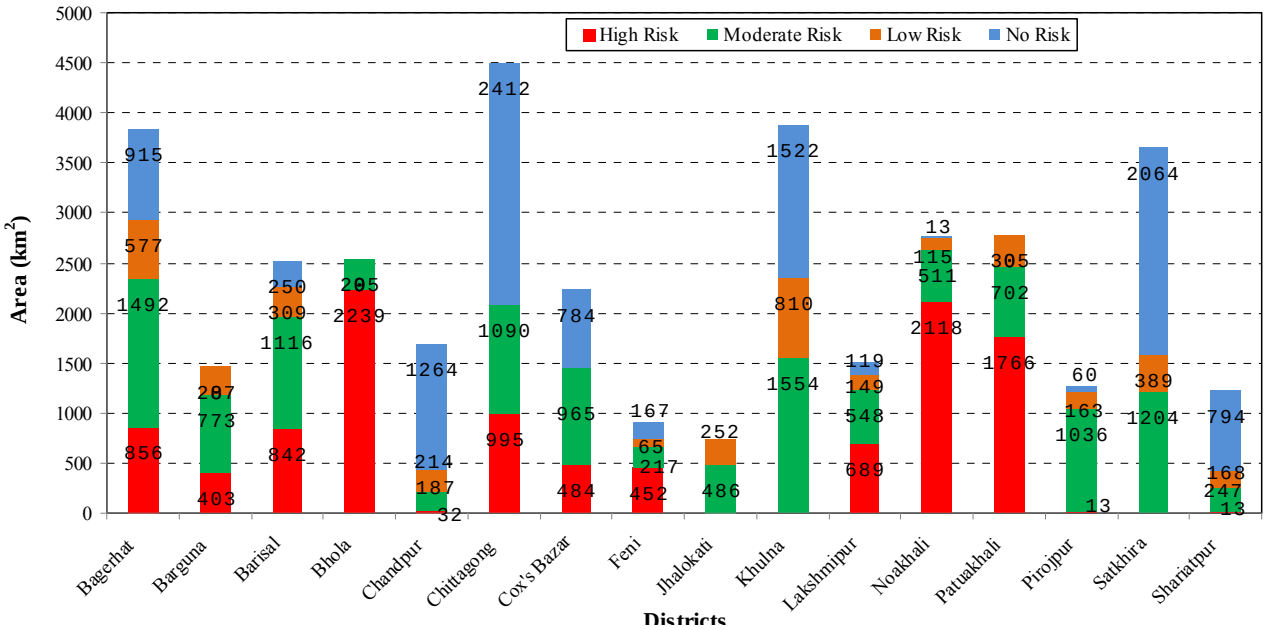


Figure 3.1: District-wise distribution of area under the risk zones

From this distribution it has been found that high risk area is larger in the districts of Bhola, Noakhali and Patuakhali. Area under moderate risk has been seen in Khulna, Bagerhat, Satkhira, Barisal, Chittagong and Pirojpur districts mainly. Low risk area is almost small in all districts. Wind/No risk areas are in great amounts in Chittagong, Satkhira and Khulna.

Population census 2001 (BBS, 2003), gives a detail description about population distribution in the 16 coastal districts. From the population census (2001) the total number of male and female population has been found according to their ages. From this information district-wise male, female and total population are shown in table 3.2. Besides this, the child and elderly population are also identified. Table 3.2 shows the distribution of child and elderly population in the coastal districts.

Table 3.2: District-wise Population of 2001

Districts	Population			Less than (<) 5 yrs			Greater than (>) 60 yrs		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Bagerhat	804,143	744,888	**1,549,031**	95,697	86,846	**182,543**	67,368	51,722	**119,090**
Barguna	430,322	418,232	**848,554**	51,711	47,536	**99,247**	38,877	28,415	**67,292**
Barisal	1,197,722	1,158,245	**2,355,967**	159,168	146,024	**305,192**	98,074	76,061	**174,135**
Bhola	884,028	819,089	**1,703,117**	141,380	127,647	**269,027**	59,032	38,035	**97,067**
Chandpur	1,124,882	1,146,347	**2,271,229**	161,496	148,792	**310,288**	97,659	78,204	**175,863**
Chittagong	3,477,178	3,134,962	**6,612,140**	405,925	367,119	**773,044**	204,195	167,934	**372,129**
Cox's Bazar	927,196	846,513	**1,773,709**	155,433	140,826	**296,259**	46,057	31,587	**77,644**
Feni	616,128	624,256	**1,240,384**	82,004	75,099	**157,103**	49,340	41,728	**91,068**
Jhalokati	345,735	348,496	**694,231**	44,526	42,126	**86,652**	32,593	24,827	**57,420**
Khulna	1,244,226	1,134,745	**2,378,971**	134,440	123,098	**257,538**	82,757	65,663	**148,420**

Districts	Population			Less than (<) 5 yrs			Greater than (>) 60 yrs		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Lakshmipur	744,741	745,160	**1,489,901**	113,879	103,092	**216,971**	58,466	45,212	**103,678**
Noakhali	1,281,756	1,295,488	**2,577,244**	200,910	182,792	**383,702**	96,585	79,536	**176,121**
Patuakhali	739,331	721,450	**1,460,781**	101,288	93,028	**194,316**	59,663	45,307	**104,970**
Pirojpur	561,972	549,096	**1,111,068**	69,906	64,950	**134,856**	50,499	38,388	**88,887**
Satkhira	955,198	909,506	**1,864,704**	111,954	103,981	**215,935**	67,559	56,688	**124,247**
Shariatpur	543,838	538,462	**1,082,300**	81,664	75,709	**157,373**	45,541	37,567	**83,108**
Total	**15,878,396**	**15,134,935**	**31,013,331**	**2,111,381**	**1,928,665**	**4,040,046**	**1,154,265**	**906,874**	**2,061,139**

Population census 2001 gives a district wise growth rate presented in table 2.1. Using this growth rate the population for 2009 has been estimated. Based on the estimated population of 2009, district-wise distribution of population is presented in table 3.3. From the total population it can be seen that about 48.8% of the population is women. Other than this, about 18.3% of the total population belongs to child and elderly people. During disaster, children, elderly people and women are the most vulnerable. The statistics of deaths from previous cyclones proves this.

Table 3.3: District-wise Population of 2009

Districts	Population			Less than (<) 5 yrs			Greater than (>) 60 yrs		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Bagerhat	930,108	861,568	**1,791,666**	109,808	99,652	**209,459**	77,302	59,348	**136,650**
Barguna	512,472	498,066	**1,010,525**	59,336	54,545	**113,881**	44,609	32,605	**77,214**
Barisal	1,351,370	1,306,809	**2,658,166**	182,638	167,555	**350,193**	112,535	87,276	**199,812**
Bhola	1,066,779	988,431	**2,055,226**	162,227	146,469	**308,696**	67,736	43,643	**111,380**
Chandpur	1,344,334	1,369,991	**2,714,329**	185,309	170,732	**356,041**	112,059	89,735	**201,794**
Chittagong	4,552,817	4,104,733	**8,657,530**	465,779	421,251	**887,031**	234,304	192,696	**427,000**
Cox's Bazar	1,211,896	1,106,430	**2,318,343**	178,352	161,591	**339,943**	52,848	36,245	**89,093**
Feni	722,798	732,341	**1,455,142**	94,096	86,172	**180,268**	56,615	47,881	**104,496**
Jhalokati	447,957	451,545	**899,504**	51,091	48,338	**99,429**	37,399	28,488	**65,887**
Khulna	1,610,695	1,468,976	**3,079,694**	154,263	141,249	**295,512**	94,960	75,345	**170,305**
Lakshmipur	880,645	881,160	**1,761,806**	130,671	118,293	**248,964**	67,087	51,879	**118,966**
Noakhali	1,508,992	1,525,158	**3,034,143**	230,535	209,745	**440,280**	110,827	91,264	**202,090**
Patuakhali	908,022	886,082	**1,794,098**	116,223	106,745	**222,968**	68,460	51,988	**120,448**
Pirojpur	632,366	617,877	**1,250,245**	80,214	74,527	**154,741**	57,945	44,048	**101,994**
Satkhira	1,245,222	1,185,663	**2,430,898**	128,462	119,313	**247,775**	77,521	65,047	**142,567**
Shariatpur	643,651	637,291	**1,280,954**	93,705	86,872	**180,578**	52,256	43,106	**95,362**
Total	19,570,124	18,622,121	**38,192,269**	**2,422,709**	**2,213,049**	**4,635,759**	**1,324,463**	**1,040,594**	**2,365,058**

For example, a detail analysis of Lata Chapli union of Patuakhali districts' Kalapara Upazila has been presented in the report. Figure 3.2 presents a map of Lata Chapli Union.

Figure 3.2 shows the settlements, road network, river and Bay of Bengal around the union. From the Map it is also seen that there are 13 cyclone shelters in the union.

Table 3.4 shows population distribution in Lata Chapli Union. Total population, male and female population and population of child and elderly in Lata Chapli Union for years 2001 and 2009 has been shown in table 3.4. From the table it is found that, about 59% of the total population belongs to child and elderly population for Lata Chapli.

Table 3.4: Population in 2001 for Lata Chapli Union

Year	Total Population	Less than (<) 5 yrs			Greater than (>) 60 yrs		
		Total	Female	Male	Total	Male	Female
2001	27,004	14,171	12,833	2,028	1,782	1,084	683
2009	30,986	16,261	14,725	2,327	2,045	1,244	784

From risk area analysis it has been found that in Lata Chapli union, major part (40 km2) of the union is in Low Risk zone. Table 3.5 represents the distribution of area under different risk zone.

Table 3.5: Area of different risk zone

Union Name	Zone	Area (km^2)
Lata Chapli	High Risk	5
	Low Risk	40
	Moderate Risk	3
	No Risk	0
	Total	**48**

This estimated population is then distributed into individual settlements assuming a uniform population density. The distribution is done utilizing the following expression. Here, Ps and As indicates the settlement population and area respectively, while P_U is the total union population.

$$P_{S_{i=n}}^{U=j} = \frac{P_U^j}{\sum_{i=n} A_{S_i}} \times A_{S_i}$$

The calculated population of each settlement has been entered into the attribute of the respective settlement.

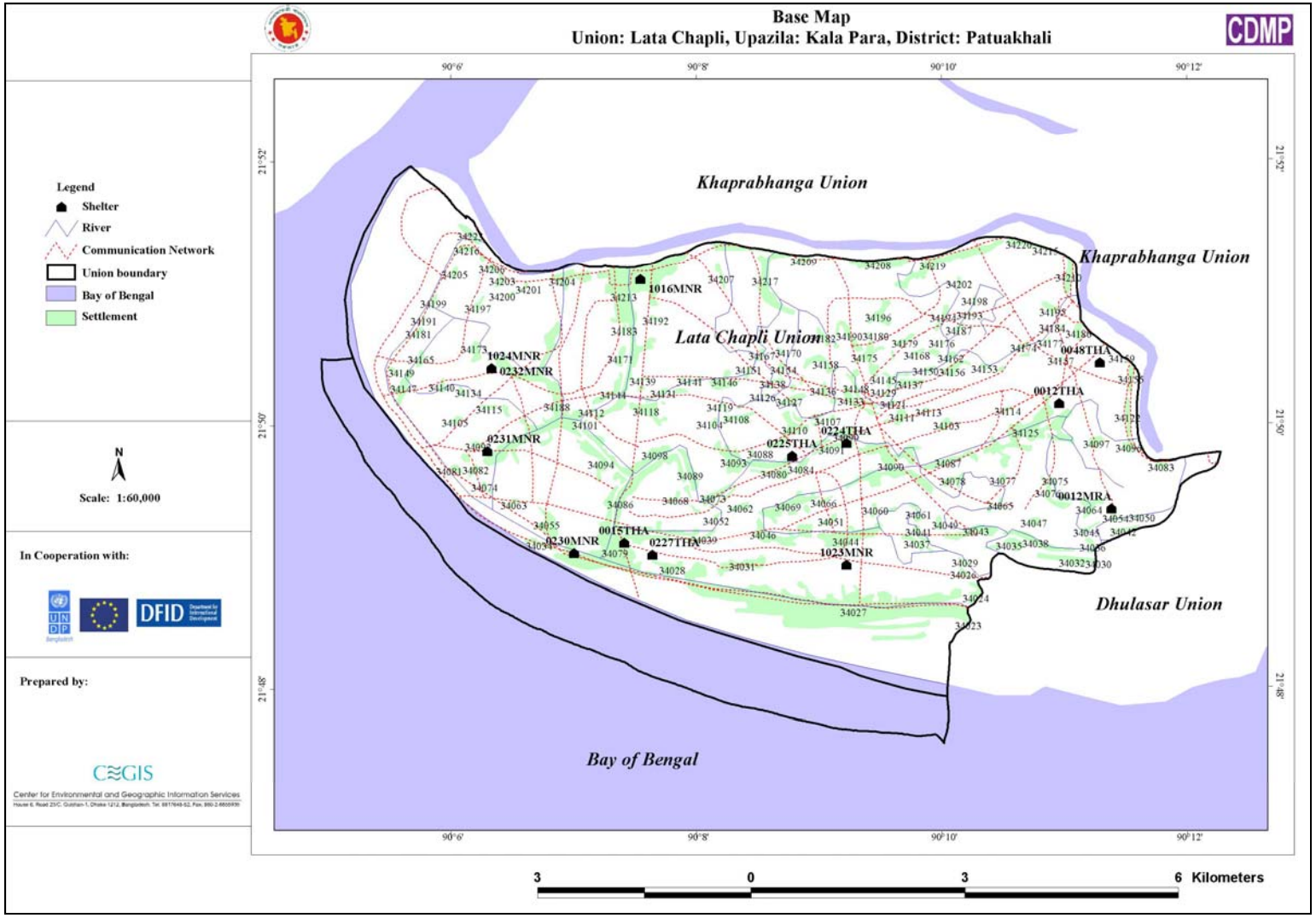


Figure 3.2: Base Map showing settlements, roads and shelters of Lata Chapli Union

3.2 Accessibility Analysis

During disaster, people prefer to travel less to go to a shelter. According to IWM study on inundation risk map (IWM, 2008), the lead-time for tsunami is 50 minutes to 6 hours. So, in the worst case, a maximum of 30 minutes may be available for people to move after being warned. People can travel 0.5 km within 30 minutes. At the time of cyclone people do not wish to travel more than 1.5 to 2km. For this reason, the road condition should be favorable for them.

During disaster, roads of different types, embankments and railways are used by the people as evacuation routes. So, for the accessibility analysis all these networks are considered. Table 3.6 represents district-wise distribution of communication routes and FCDI project areas in different risk zones. Figure 3.3 illustrates the distribution of communication network in different districts.

Table 3.6: District-wise communication network and FCDI area in different risk zone

Districts	Communication network (km)				FCDI Area (km^2)
	High Risk	Low Risk	Moderate Risk	Wind Risk	
Bagerhat	63.36	655.47	1027.04	1825.98	698.61
Barguna	554.55	970.16	1247.70	0.00	999.01
Barisal	1145.23	703.34	2441.41	465.09	215.00
Bhola	3214.39	0.00	15.14	0.00	1361.15
Chandpur	6.36	504.54	97.06	2563.98	621.13
Chittagong	2078.61	0.00	2476.70	3320.20	1192.35
Cox's Bazar	678.80	0.00	869.47	957.65	524.36
Feni	880.12	70.17	375.01	342.60	654.23
Jhalokati	0.00	604.73	1260.58	0.00	148.82
Khulna	0.00	941.32	31.28	2684.92	1625.58
Lakshmipur	775.28	468.53	1140.17	436.57	810.75
Noakhali	2936.79	324.76	1289.26	18.94	1677.98
Patuakhali	2624.50	870.78	1959.38	0.00	1517.02
Pirojpur	5.24	260.84	2393.69	54.36	431.18
Satkhira	0.00	386.93	74.49	3726.36	1755.24
Shariatpur	0.00	250.71	326.27	1105.69	67.04
Total	**14963.23**	**7012.28**	**17024.65**	**17502.34**	**14299.45**

From the table it can be said that, major amount of communication network are in moderate and wind risk zones. From the table it is also seen that a total of 14300 km2 area in the coastal districts are protected by FCDI projects.

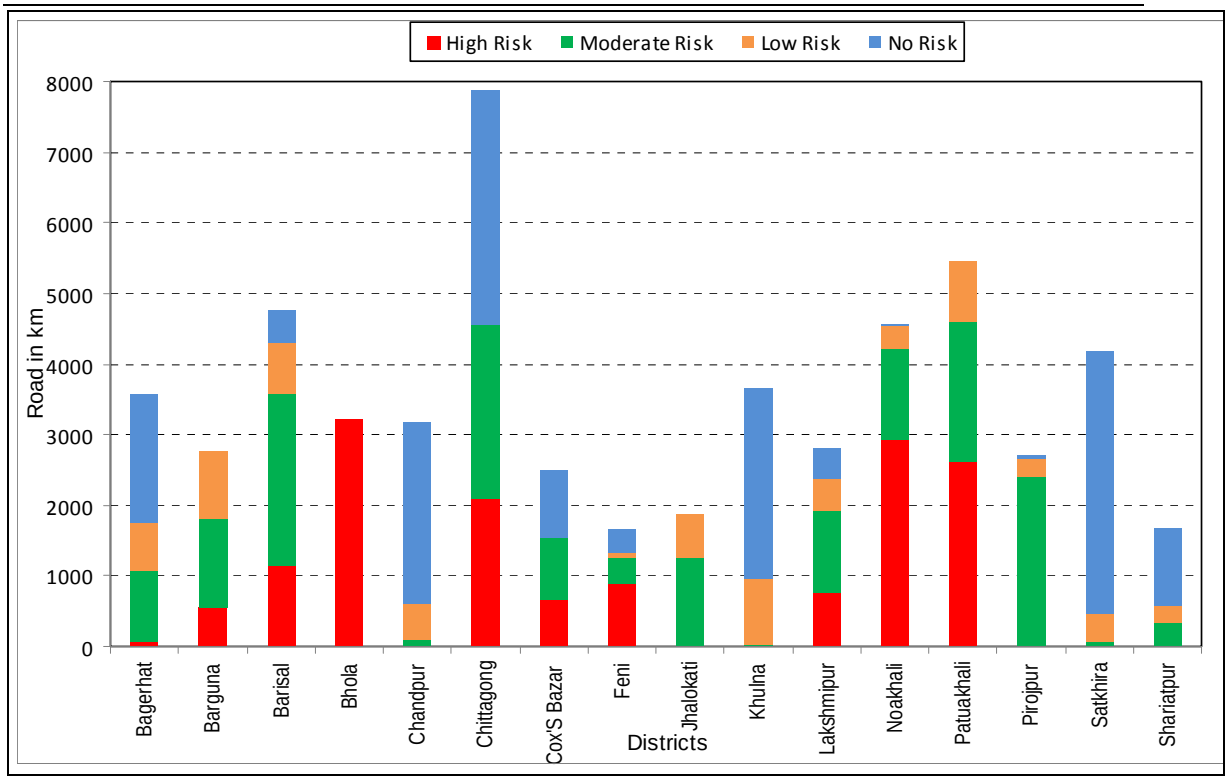


Figure 3.3: District-wise distribution of communication routes under the risk zones

In Lata Chapli Union length of communication network is about 114 km and 43.4 km^2 area of the union are protected by embankment (polder 48). Table 3.7 shows the distribution of road in different risk zone.

Table 3.7: Communication network and FCDI area of Lata Chapli

Union Name	Communication network (km)		FCDI Area (km^2)
	Low Risk	Risk	
Lata Chapli	105.80	8.19	43.42

Using GIS network analysis methods the shortest distances between settlements and shelters have been identified. For each settlement, distances of the nearest four shelters are computed. After distance computation, the distances are linked with respective settlements and shelters through the unique IDs of the settlements and shelters. An example of the output from the analysis showing the distances for some settlements of Lata Chapli union is presented in Figure 3.4.

Settlement Code	Distance (km)													
	0011MRA	0012MRA	0012THA	0015THA	0048THA	0224THA	0225THA	0227THA	0230MNR	0231MNR	0232MNR	1016MNR	1023MNR	1024MNR
33622					0.7									
33624					0.6									
33625					1.3									
33629			1.7											
33631			1.6											
33632					1.3									
33633					0.8									
33635					0.8									
33639					1									
33646					1.4									
33648												0.3		

Figure 3.4: Distances of shelters from settlements

3.3 Cyclone Shelter Capacity and Vulnerability Analysis

From the field survey for updating the spatial distribution of cyclone shelters (details in Annex-A), 30 different types of shelter structures were found. These types are BDRCS (Type 1 & 2), BRAC, Cabinet Division, Caritas, CDSP (Type 1 & 2), EU (Type 1 & 2), Facilities (Type 1 & 2), German/KFW, Grameen Bank, JICA (Type 1 & 2), LGED (Types 1-6), Proshika (Type 1 & 2), PWD (Type 1 & 2), Saudi (Type 1 & 2), Union Parishad, USAID and some other types. These various types of shelters have different structural shapes, variations in no. of floors and capacities. District wise total number of different type cyclone shelters surveyed in the study is summarized in table 3.8.

Table 3.8: Number of different types of shelters in 16 districts

Design Type	District															Total (By type)
	Bagerhat	Barguna	Barisal	Bhola	Chandpur	Chittagong	Cox`s Bazar	Feni	Jhalokati	Khulna	Lakshmipur	Noakhali	Patuakhali	Pirojpur	Satkhira	Shariatpur	
BDRCS Type 1	19	21		50		52	104	4		4	9	54	42	3	4		**366**
BDRCS Type 2		2				3	3			2			1				**11**
BRAC						1	18										**19**
Cabinet Division	1			1							1		1				**4**
Caritas	4	2		5		11	22			5			8		2		**59**
CDSP Type 1						4						29					**33**

Design Type	District																Total (By type)
	Bagerhat	Barguna	Barisal	Bhola	Chandpur	Chittagong	Cox`s Bazar	Feni	Jhalokati	Khulna	Lakshmipur	Noakhali	Patuakhali	Pirojpur	Satkhira	Shariatpur	
CDSP Type 2												17					**17**
EU Type 1				1		54	29	19			51	35					**189**
EU Type 2						3	2										**5**
Facilities Type 1	13	15		51					1	2			18	1	7		**108**
Facilities Type 2				1	5												**6**
German KFW	5	14	8	14	4	6	17	1		10	3	4	7	6	8	5	**112**
Grameen Bank		7				5	4				1		3				**20**
JICA Type 1						25	9					10		1			**45**
JICA Type 2						19	8					1					**28**
LGED Type 1	7	33	13	60	4	24	41	12	11	2	1	9	38	7			**262**
LGED Type 2	54	59	15	195	58	71	104	5	3	46	119	16	103	33	16	27	**924**
LGED Type 3	3	16		121	6	43	8			18	4	1	3	2	1	5	**231**
LGED Type 4		1		27		6	1						1				**36**
LGED Type 5		5		5		4	5	4			4						**27**
LGED Type 6	1	2		1		14	22										**40**
Others	21	16	11	32	3	61	29	5		5	15	39	27	12	7	1	**284**
Proshika Type 1						7											**7**
Proshika Type 2							1					3					**4**
PWD Type 1		6		68		17	6	3			7	28	78	1			**214**
PWD Type 2		1		1		6	1	5			4	5	1				**24**
Saudi Type 1	18	2		9		1			2	17			1	4	14		**68**
Saudi Type 2						220	162	15			13	36					**446**
Union Parishad	8	14	5	35		16	22	1		4	3	7	8		10		**133**
USAID	9									10					12		**31**
Total Shelter (By District)	**163**	**216**	**52**	**677**	**80**	**673**	**618**	**74**	**17**	**125**	**235**	**294**	**340**	**70**	**81**	**38**	**3753**

The population capacity of these shelters has been calculated using three methods described in the methodology. Population capacity for 2 ft^2 per person, capacity for 3 ft^2 per person and population capacity from the number of people took shelter in the last disaster are summarized in table 3.9.

Table 3.9: District-wise Population Capacity

District	Capacity (2 ft^2)	Capacity (3 ft^2)	Capacity (Use on last disaster)	Ratio: column 4 & column 2	Ratio: column 4 & column 3
1	**2**	**3**	**4**	**5**	**6**
Bagerhat	138,809	92,552	107,700	78%	116%
Barguna	206,065	137,389	255,300	124%	186%
Barisal	53,425	35,621	16,660	31%	47%
Bhola	613,550	409,018	398,377	65%	97%
Chandpur	74,900	49,931	7,850	10%	16%
Chittagong	761,125	507,418	535,630	70%	106%
Cox's Bazar	703,310	468,911	558,642	79%	119%

District	Capacity ($2\ ft^2$)	Capacity ($3\ ft^2$)	Capacity (Use on last disaster)	Ratio: column 4 & column 2	Ratio: column 4 & column 3
1	2	3	4	5	6
Feni	74,895	49,928	20,760	28%	42%
Jhalokati	11,525	7,687	2,900	25%	38%
Khulna	116,066	77,375	70,790	61%	91%
Lakshmipur	224,375	149,566	80,232	36%	54%
Noakhali	309,762	206,512	131,125	42%	63%
Patuakhali	311,860	207,930	320,360	103%	154%
Pirojpur	60,375	40,252	37,470	62%	93%
Satkhira	68,271	45,514	31,965	47%	70%
Shariatpur	36,650	24,432	3,980	11%	16%
Total	**3,764,965**	**2,510,039**	**2,579,741**	**--**	**--**

From the table it is clear that for almost all districts capacity (2 sft) is greater than that of the other two capacities except for Barguna and Patuakhali. At Barguna district, 24% more people than capacity (2 sft) and 86% more people than capacity (3 sft) took shelter. From the tables 3.3 and 3.9, it can be said that only 10.6% of the total population of the coastal districts can be evacuated to shelters with population capacity based on 2 sft/ person. This percentage is further reduced to 7% if capacity based on 3 sft/ person is used.

The number of shelters and PEDP-II buildings surveyed in 16 districts has also been classified into different risk zones. Table 3.10 shows this distribution. Figure 3.5 illustrates the district-wise distribution of shelters in different risk zones.

Table 3.10: District wise no. of shelters and PEDP-II buildings in different risk zone

Districts	Risk Zone				District total
	High Risk	Risk	Low Risk	No Risk	
Bagerhat	13	68	61	21	**163**
Barguna	44	135	35	2	**216**
Barisal	13	25	10	4	**52**
Bhola	649	21	6	1	**677**
Chandpur	5	11	7	57	**80**
Chittagong	525	109	26	13	**673**
Cox`s Bazar	227	224	60	107	**618**
Feni	57	11	2	4	**74**
Jhalokati		16	1		**17**
Khulna	2	7	20	96	**125**
Lakshmipur	127	59	42	7	**235**
Noakhali	288	5		1	**294**
Patuakhali	158	140	42		**340**
Pirojpur	1	55	13	1	**70**
Satkhira		4	15	62	**81**
Shariatpur	1	6	8	23	**38**
Risk Zone Total	**2110**	**896**	**348**	**399**	**3,753**
Percentage (%)	**56%**	**24%**	**9%**	**11%**	**100%**

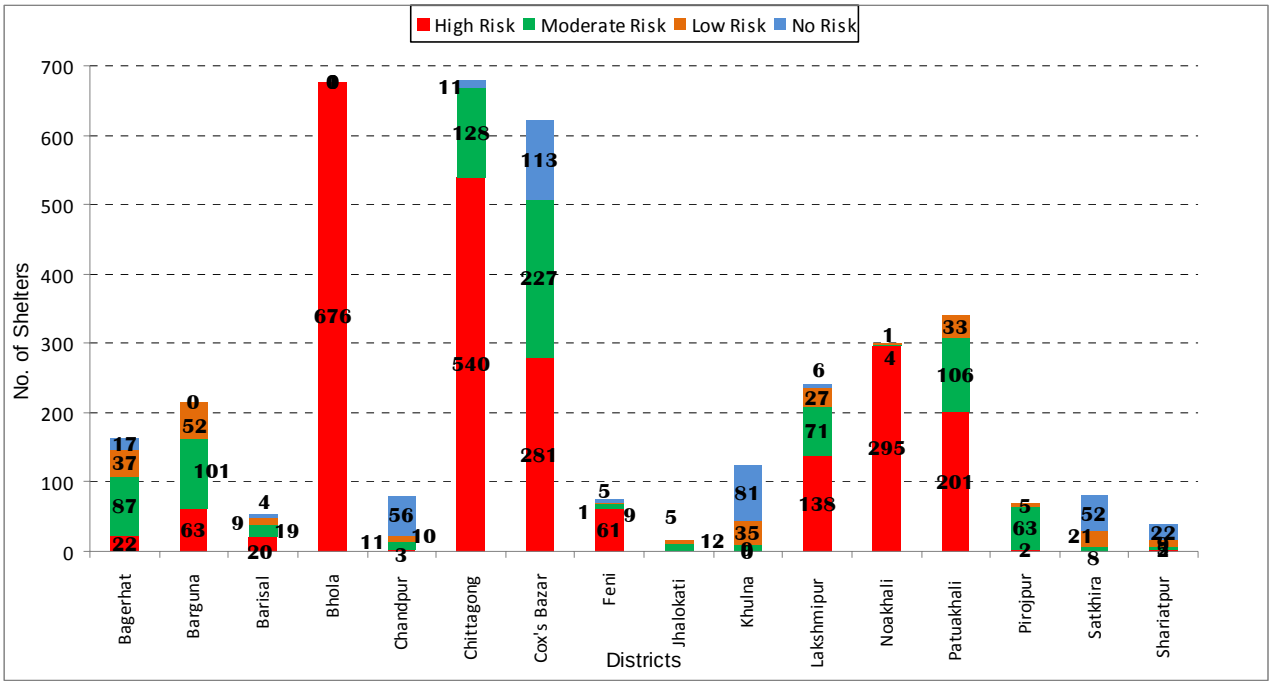


Figure 3.5: Distribution of shelters and PEDP-II buildings in risk zones

During primary field survey, some shelters were observed in vulnerable condition. This happened due to poor or no maintenance of the shelters. The next table 3.11 shows district-wise number of shelters grouped as Usable (shelters in good condition), Pending for Maintenance (shelters in need of maintenance) and Not Usable (shelters in unusable condition) and PEDP-II buildings. From this table it is found that 246 shelters are in not usable condition and 55 other require maintenance.

Table 3.11: District-wise condition of shelter

Districts	Usable	Moderate Usable	Not Usable	PEDP-II	District Total
Bagerhat	97	1	11	54	**163**
Barguna	139	8	10	59	**216**
Barisal	36	1	-	15	**52**
Bhola	425	4	53	195	**677**
Chandpur	19	2	1	58	**80**
Chittagong	562	11	29	71	**673**
Cox`s Bazar	491	13	10	104	**618**
Feni	55	2	12	5	**74**
Jhalokati	12	-	2	3	**17**
Khulna	77	-	2	46	**125**
Lakshmipur	105	1	10	119	**235**
Noakhali	238	7	33	16	**294**
Patuakhali	161	4	72	103	**340**
Pirojpur	35	1	1	33	**70**
Satkhira	65	-	-	16	**81**
Shariatpur	11	-	-	27	**38**
Total	**2,528**	**55**	**246**	**924**	**3,753**
Percentage	**67%**	**1%**	**7%**	**25%**	**100%**

From structural strength analysis of the cyclone shelters (Annex-B), vulnerable shelters distribution is found for two type of disasters:

- Tsunami
- Cyclone: (Wind speed 161.5 mph/260 km/h and Storm surge >10 ft/3 m)

District-wise distributions of vulnerable shelters for these conditions are summarized in tables 3.12, 3.13 & 3.14.

Table 3.12: Usable Shelters Vulnerability distribution: Tsunami

District	Not Vulnerable	Vulnerable	Not Assessed	Total
Bagerhat	81	5	12	**98**
Barguna	132	2	13	**147**
Barisal	26		11	**37**
Bhola	386	19	24	**429**
Chandpur	17	1	3	**21**
Chittagong	511	13	49	**573**
Cox`s Bazar	453	22	29	**504**
Feni	53	1	3	**57**
Jhalokati	12			**12**
Khulna	67	5	5	**77**
Lakshmipur	93		13	**106**
Noakhali	212	1	32	**245**
Patuakhali	145	9	11	**165**
Pirojpur	24		12	**36**
Satkhira	55	3	7	**65**
Shariatpur	10		1	**11**
Total	**2,277**	**81**	**225**	**2,583**
Percentage	**88%**	**3%**	**9%**	**100%**

Table 3.14: Shelter Vulnerability distribution: Cyclone

District	Not Vulnerable	Vulnerable	Not Assessed	Total
Bagerhat	79	7	12	**98**
Barguna	126	8	13	**147**
Barisal	26		11	**37**
Bhola	339	66	24	**429**
Chandpur	17	1	3	**21**
Chittagong	482	42	49	**573**
Cox`s Bazar	434	41	29	**504**
Feni	53	1	3	**57**
Jhalokati	12			**12**
Khulna	67	5	5	**77**
Lakshmipur	89	4	13	**106**
Noakhali	197	16	32	**245**
Patuakhali	139	15	11	**165**
Pirojpur	24		12	**36**
Satkhira	56	2	7	**65**
Shariatpur	10		1	**11**
Total	**2150**	**208**	**225**	**2583**
Percentage	**83%**	**8%**	**9%**	**1**

From these tables it is clear that about 208 usable shelters are vulnerable for cyclone where 81 usable shelters are vulnerable under tsunami.

In Lata Chapli union there are 13 cyclone shelters among which 10 are in good condition, one requires maintenance and other two are unusable. Among the 13 shelters, 11 are in low risk zone and two are in moderate risk zone. Table 3.15 shows the distribution of shelters in Lata Chapli.

Table 3.15: Condition and distribution of shelters in Lata Chapli

Union Name	Usability Condition	No. of Shelters	Risk zones	No. of Shelters
Lata Chapli	Not Usable	2	Low Risk	11
	Pending for Maintenance	1	Moderate Risk	2
	Usable	10	--	--

Table 3.16 represents the capacity of the cyclone shelters in Lata Chapli. From this table it is observed that, during last disaster (cyclone SIDR) 89% of the capacity (2 sft) is used.

Table 3.16: Capacity of shelters in Lata Chapli

District	Capacity ($2\ ft^2$)	Capacity ($3\ ft^2$)	Capacity (Use on last disaster)	Ratio: column 4 & column 2	Ratio: column 4 & column 3
1	2	3	4	5	6
Lata Chapli	13325	8885	11850	89%	133%

3.4 Catchment Area Delineation

The task of catchment area delineation and allocating settlements to cyclone shelters for evacuation has been done using GIS network analysis. For this a step by step process has been followed. The process is illustrated as:

1. Establish links between settlement ID and Shelter ID.
2. Select Shelters based on their geographic location and orientation and start allocating population for evacuation from the southern-most (south zone) and western most (southeast) shelter and proceed to the northern and eastern respectively.
3. Fill each shelter with population from the nearest settlement first, then the second one and similarly the others.
4. When a shelter fills up move to the second shelter selected by step 2. This shelter is filled in a similar process as described in step 3.
5. If a shelter fills before accommodating the population from a settlement, then try to allocate this remaining population to the second nearest shelter (if available).
6. Draw shelter evacuation catchment maps of the area showing settlements, shelters, communication routes, rivers and waterways, shelter ID and settlements marked with shelter IDs to which the settlement population will be evacuated.

For example, map showing cyclone shelter catchments for evacuation has been presented in figure 3.6. It shows the distribution of served population in Lata Chapli union.

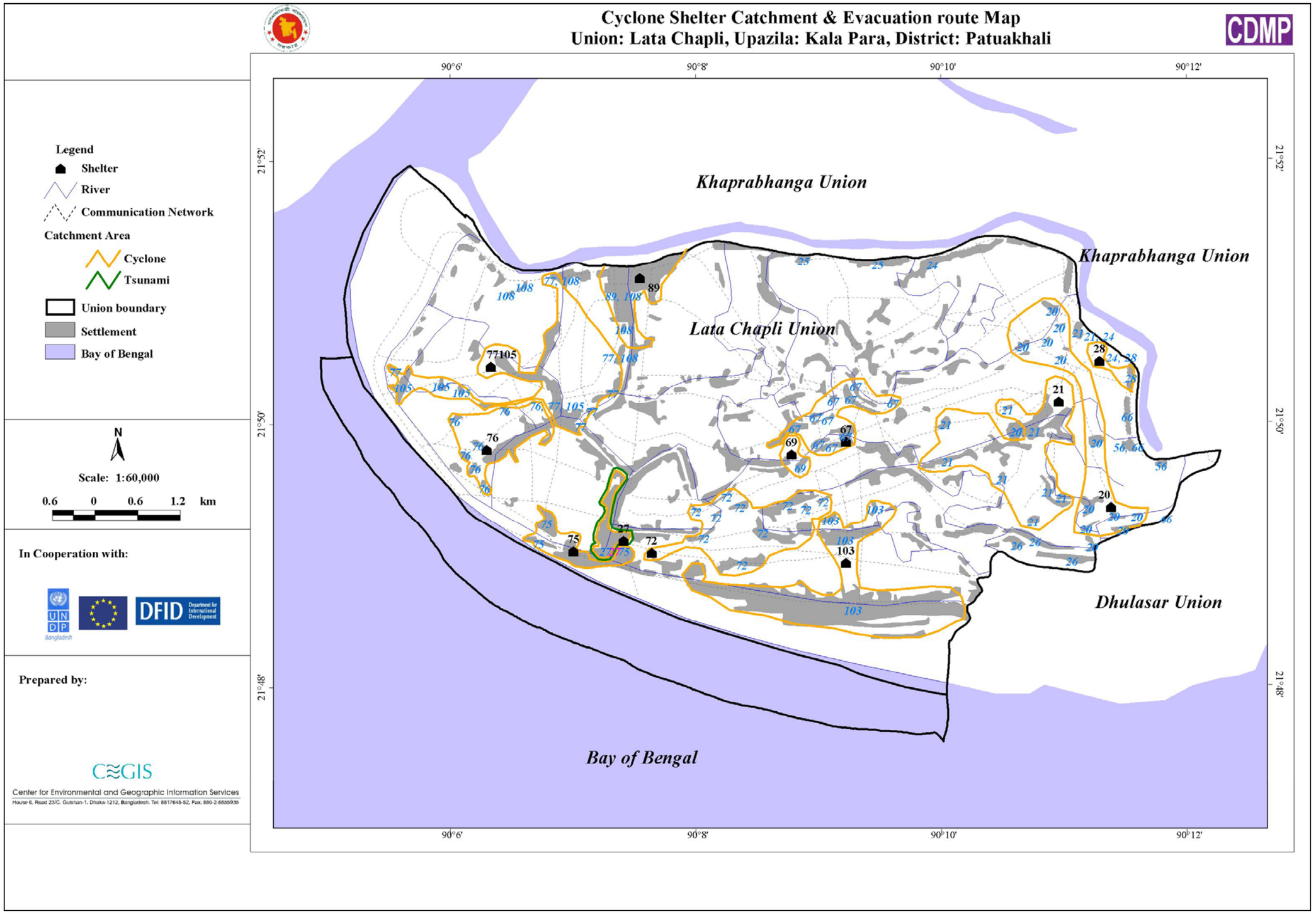


Figure 3.6: Cyclone Shelter Catchment and Evacuation Route Map for Lata Chapli Union

In figure 3.6 settlements are marked with two sets of IDs, for tsunami and cyclone. These are the ID of the shelter where the population should take shelter during tsunami/cyclone. Besides this, catchment of shelters have been identified for tsunami (green outline) and cyclone (orange outline).

Figure 3.7 shows a view of the attribute table for Lata Chapli union. Here settlement ID, Shelter ID, percent of population of the settlement allocated to a specific shelter and a total percent of population evacuated by the shelters are presented.

Settlement Code	Shelter ID														Total
	0011MRA	0012MRA	0012THA	0015THA	0048THA	0224THA	0225THA	0227THA	0230MNR	0231MNR	0232MNR	1016MNR	1023MNR	1024MNR	
33622					100										100
33631			100												100
33632					100										100
33646					46										46
33648												100			100
33819	62														62
34027													6		6
34039								100							100
34047			57												57
34079				73					9						82
34109						100									100
34110						42									42
34125		52	48												100
34188										37	28			35	100
34204											43				43
34213												90			90

Figure 3.7: Output Table showing served population percent of settlements in Lata Chapli

Detail Maps has been prepared for all 16 coastal districts and are presented Upazila-wise in Annex-D.

Chapter 4

Conclusion

Delineation of catchment areas for each cyclone shelter is an essential for evacuation planning and shelter management practices. Catchment area of the cyclone shelters have been delineated for evacuation during cyclone / tsunami. Using GIS and RS techniques, the distribution of settlement, population, shelter and communication networks have been assessed. Using a criteria based approach, the allocation of population in different shelters for evacuation have been assessed. Finally maps showing catchment of shelters and settlements with shelter ID have been prepared for tsunami and cyclone. In these maps, each settlement that has been allocated to a specific shelter have been marked with the respective shelter ID. The system has been organized in such a way that, any changes, addition, removal or increasing of shelter capacity could be done very easily.

The analysis done under the current task has some limitations. These are: (1) Cyclone risk area has been given only for severe event, not for different cyclonic intensities. (2) For the current task, all the shelters, except the not usable shelters, are considered for catchment delineation. (3) Informal shelters and private buildings are not considered in this analysis. (4) Distance from settlement to the nearest shelter has been computed from settlement centroid. This may cause some problems in large settlements, where centroid to shelter distance is larger than some parts of the settlement which are nearer to the shelter. In actual condition, traveling distance for people near the shelter is less than the computed distance considering settlement centroid.

References

Bangladesh Bureau of Statistics (BBS), 2003. *Population Census 2001,* Ministry of Planning, Government of Bangladesh, 2003.

BUET & BIDS, 1993a. *Multipurpose Cyclone Shelter Programme Final Report, Part 1, Volume I: Main Report,* Bangladesh University of Engineering and Technology (BUET) and Bangladesh Institute of Development Studies (BIDS), Planning Commission, Government of Bangladesh, United Nations Development Programme/World Bank, Dhaka, 1993.

BUET & BIDS, 1993b. *Multipurpose Cyclone Shelter Programme Final Report, Part 2, Volume II: Cyclone Shelter and Killas,* Bangladesh University of Engineering and Technology (BUET) and Bangladesh Institute of Development Studies (BIDS), Planning Commission, Government of Bangladesh, United Nations Development Programme/World Bank, Dhaka, 1993.

BUET & BIDS, 1993c. *Multipurpose Cyclone Shelter Programme Final Report, Part 4, Volume IV: Cyclone Planning and Implementation Issues,* Bangladesh University of Engineering and Technology (BUET) and Bangladesh Institute of Development Studies (BIDS), Planning Commission, Government of Bangladesh, United Nations Development Programme/World Bank, Dhaka, 1993.

CEGIS, 2004. *National Survey on Current Status of Shelters and Developing an Operational CYSMIS,* CARE Bangladesh, Dhaka, 2004.

CEGIS, 2008. *Inception Report on Update available information on cyclone shelter management for Earthquake Hazard (Tsunami) and storm surge preparedness,* Comprehensive Disaster Management Programme, Ministry of Food and Disaster Management, Government of Bangladesh, Dhaka, 2008.

Disaster Management Bureau, Ministry of Food and Disaster Management, GoB, *Major Natural Disaster in BANGLADESH*, **Retrieved on march 2008**, from http://www.dmb.gov.bd/pastdisaster.html

Disaster Management Information Centre, Disaster Management Bureau, Ministry of Food and Disaster Management, GoB, *Situation Report December 29, 2007*, **Retrieved on march 2008**, from http://www.dmb.gov.bd/situation.pdf

GoB, 2008, *Cyclone Sidr in Bangladesh: Damage, Loss and Needs Assessment for Disaster Recovery and Reconstruction*, Government of Bangladesh.

IWM & CEGIS, 2007. *Investigating the Impact of Relative Sea-Level Rise on Coastal Communities and their Livelihoods in Bangladesh,* IWM /CEGIS/GoB/DEFRA, Dhaka, June 2007.

IWM, 2008. *Preparation of Inundation Map Considering the Decay Factors for Landuse, Geomorphology and Slope,* Comprehensive Disaster Management Programme, Ministry of Food and Disaster Management, Government of Bangladesh, Dhaka, 2008.

PDO-ICZMP, 2005. *Project Completion Report of Program Development Office for Integrated Coastal Zone Management Plan,* Water Resources Planning Organization (WARPO), Ministry of Water Resources, Government of Bangladesh, Dhaka, 2005.

Sener Ingenieria Y Sistemas SA, Spain, Mott MacDonald Ltd, Danish Hydraulic Institute, Bangladesh Consultants Ltd, Engineering Science Ltd, Resource Planning and Mgt Consultants Ltd, Bangladesh Disaster Preparedness Centre, 1998, Cyclone *Shelter Preparatory Study, Stage I: Feasibility Phase, Final Report, Main Report*, Part A: Text, European Commission, Directorate General External Economic Relations, Technical Unit for Asia.

Appendices

Appendix - C1: Compliance Report on Comments from TAG Committee

Presentation on Catchment Area and Evacuation Route Maps

Comments Received form: **Professor Dr. Jamilur Reza Choudhury,** Vice Chancellor, BRAC University

Sl No.	Comments	Responses
1.	Instead of Union wise population why Mouza wise population has not been used in catchment area delineation task	In reply the Chairperson's comment, Mr. Ahmadul Hassan of CEGIS mentioned that union wise population is more consistent with upazila and district than mouza wise population.
2.	How risk area delineation has been executed respective to cyclone and tsunami	Replying on the issue Mr. Hassan mentioned that risk area classification was done by other component which is being executed by IWM.
3.	Comprehensively, south to north ward direction has been considered in catchment area delineation whereas for the south-east zone (Chittagong and Cox's Bazar) it should be west to east.	Thanks. CEGIS agreed regarding the issue and we will incorporate the issue in our report.
4.	Appreciated the CEGIS approach but after the finalization of the proceedings of the tsunami workshop that held recently lead time for tsunami can be finalized for analytical use.	Thanks for the kind information.
5.	Space requirement calculation for a single person during hazard sheltering could be conducted followed by the test results of the Red Crescent executed in 1994	In response to Chairperson's suggestion, CEGIS appreciated and informed that in our analysis we followed the MCSP report where a person space requirement is 2sft.
6.	Sources of network routes that were used in catchment area delineation are not clearly mentioned in report	Mr. Hassan informed the meeting that IRS remote sensing data, LGED and NWRD database were used as sources of network routes.
7.	Seasonal population at some gathering places (e.g. Dublar Char) whether considered in catchment area delineation	In reply to the comment, Mr. Hassan informed that seasonal migrated population was not considered in this context.
8.	Area wise population growth rate whether taken into account in catchment area delineation	Thanks for the comment. CEGIS assumed the single growth rate which is national average of the growth rate.
9.	For easy identification of formal shelters a spatial mark can be put on the roof top	Thanks. Suggestion by the chairperson is a good idea. Mr. Hassan added that it would be considered in future and formal shelters could be detected by satellite imagery. Spatial mark may be like the cross mark used by Red Crescent.

Sl No.	Comments	Responses
10.	Definition of formal shelters should be comprehensible for better understanding and recognition	Thanks. Mr. Hassan replied that shelter structure that has name as shelter, ground floor open and local people recognize the structure as shelter, these three criteria were considered in shelter definition.
11.	Exclusion of PEDP-II type shelters from the formal shelter list would be more authentic	Thanks. CEGIS agreed on this issue and CEGIS also requested CDMP to curtail PEDP-II type shelters from the formal shelter list earlier. For that reason, CEGIS surveyed those structures and reflected in the map but mentioned in the legend as PEDP-II in different symbol other than shelters.
12.	Defined the basis of signifying Category-I & Category-V which were used in structure strength test analysis; Whether the new early warning system of government was considered in this context	Thanks for the comments. Mr. Hassan replied that detailing of the comments will be addressed in the joint presentation of CEGIS and BUET on structure strength analysis. The presentation will be held on 28 March, 2009 at CDMP.
13.	Spatial location maps of shelters for Monpura and Ramgati need to be brought in the next TAG meeting that will be held on 28th instant	Request will be made available in the meeting which will be held on 28 March, 2009 at CDMP.

Comments Received form: **Prof. Dr. A.M.M. Safiullah,** Vice Chancellor, BUET

Sl	Comments	Responses
1.	Whether the private buildings were considered in catchment area delineation task	Thanks for comments but private buildings were not considered in catchment area delineation task.
2.	Why the PEDP-II type shelters will be failed during sheltering the affected people	Reason behind the failure of PEDP-II type shelters explained in the report. Nevertheless, detailing of the comment will be addressed in the meeting which will be held on 28 March, 2009 at CDMP.

Comment Received form: **Professor Monirul Hoque,** Vice Chancellor, Darul Ihsan University, Dhanmondi, Dhaka

Sl	Comments	Responses
1.	What is the basis of population projection which was used in catchment area delineation	Thanks; BBS statistics data were explored for 2001 population and for projection upto 2009 population current population growth rate was considered.