Training Manual for Coastal Managers
On
DISASTER RISK REDUCTION

Coast Conservation Department
Sri Lanka
2009

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Prepared by
Anil Apremaratne
Additional Director
Coast Conservation Department

Manual Writing Group

Prof. Hemanthi Ranasinghe, University of Sri Jayewardenepura
Dr. Champa Nawaratne, University of Rhone
Prof L.P. Jayatissa, University of Rhone
Prof Saman Samarawickrama, University of Katubadda
Dr. Ranjana Piyadasa, University of Colombo
Mr. Kithsiri Abeyasinghe, Former Director Dept. Of Meteorology
Mr. B.H.J. Premathilaka, Coast Conservation Department
Mr. Kapila Gunaratne, IUCN Sri Lanka
Mr. Anil Premaratne, Coast Conservation Department

Technical Supports by: UNEP

Coast Conservation Department
Ministry of Fisheries and Aquatic Resources
Sri Lanka

Massage from Director Coast Conservation

Sri Lanka's coastal areas have been endowed with ample natural resources to enrich and sustain the lives of its people. The coastal region itself is one of the most densely populated areas, and most of the principal transportation infrastructure, tourist related facilities are located within this area. These factors amply demonstrate the need to manage the coastal zone in order to ensure that the carrying capacity of the zone and its resources are not surpassed many examples of the devastation and degradation of the coastal environment and livelihoods caused by natural disasters as well as lack of sufficient planning, management and incorporation of Disaster Risk Reduction aspect into the coastal development activities.

The Tsunami disaster of the 26th December 2004 was the worst natural calamity to have befallen Sri Lanka since historical times. Natural processes such as monsoon storms cause severe damage the coastal areas resulting in great loses to houses, hotels, roads and railway lines. Erosion coastal floods, degradation of coastal ecosystems are the main problems in our coastal areas.

The extent of the environmental damages due to the above problems was immediately visible throughout the country. In order to mitigate the long-term impacts, as well as to plan and prepare for the future it was decided to undertake a systematic awareness and training program on DRR using universally acceptable procedures.

Having recognized the requirement the Coast Conservation Department (CCD) of the Ministry of Fisheries and Aquatic Resources (MFAR) sought the assistance of the United Nations Environment Program (UNEP) to prepare comprehensive coastal managers.

This manual was done in close cooperation with all relevant international national local agencies and institutions and primarily by Sri Lankan scientists, from our universities, and other technical institutions under the guidance of the CCD. This training manual is a product of their effort. The outstanding quality of the manual is a testament at the in-country technical capacity of Sri Lanka.

I would like therefore like to record our sincere gratitude to all these who have contributed to this national exercise and to UNEP for its financial and technical support. I believe that through this training manual we can achieve out sustainable development goals while ensuring environmental sustainability of current and future generations of Sri Lanka.

The effective training of this manual depends on the efforts of many agencies and individuals from Sri Lanka. The training manual offers a direction of the development activities and other action in the coastal area for all concerned parties.

Eng. H.N.R. Perera

Director/Coast Conservation

Acknowledgements

The preparation of the disaster Risk Reduction (DRR) Training manual for coastal managers was funded by the United Nation Environment Program (UNEP) under the financial support from the Asian Disaster Preparedness Centre (ADPC). As the project coordinator I have the honour to thank many individual and organizations who contributed to the successful completion of the Project.

At the outset, my most sincere thanks go to Eng. Nissanka Perera, Director, Coast Conservation Department, Mr. W.R.M.S. Wickramasinghe, former Additional Secretary (Environment and Policy) Ministry of Environment and Natural resources and Mrs. Serena Fortuna UNEP Regional Office Bangkok for their valuable advice and guidance which contributed greatly to the success of the project.

The preparation of this manual has been made possible by the combined efforts of many dedicated persons, all of whom can not be mentioned. Those with important roles in the plan drafting process were:

Prof. Hemanthi Ranasinghe, Professor, Department. Of forestry and Environment, University of Sri Jayewardenepura.

Prof L.P. Jayatissa, Department of Botany, University of Ruhuna, Matara.

Mr. K.R. Abesinghe, former Director, Department of Meteorology

Dr. Ranjana Piyadasa, Department of Geography
University of Colombo.
Dr. Champa Navaratne, Department of Agriculture,
University of Ruhuna.

Mr. B.H.J. Premathilaka, Planning Officer,
Coast Conservation Department.

Mr. Kapila Gunarathne, Head Coastal Resources Unit, IUCN, Sri Lanka
Dr. Ananda Malawatantri, UNDP Sri Lanka

National Agencies which have provided information and assistance include:

Disaster Management Centre
Central Environmental Authority
All Universities in Sri Lanka
National Aquatic Resources Agency
Practical Action
IUCN Sri Lanka
UNDP Country Office, Sri Lanka
National Institute of Education
Department of Meteorology

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Abbreviations and Acronyms

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Centre
CBO	Community Based Organization
CCA	Coast Conservation Act
CCAC	Coast Conservation Advisory Council
CCCS	Centre for Climate Change Studies
CEA	Central Environmental Authority
CCC	Community Coordinating Committee
CCD	Coast Conservation Department
CEMP	Coastal P Erosion Management Plan
CMDRM	Community Based Disaster Risk Management
CMP	Coastal Resources Management Project
CRM	Coastal Resources Management
CZ	Coastal Zone
CZMP	Coastal Zone Management Plan
DMC	Disaster Management Centre
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DS	Divisional Secretariat
DWLC	Department of Wild Life Conservation
EIA	Environmental Impact Assessment
EPL	Environmental Protection License
EU	European Union
FFPO	Fauna and Flora Protection Ordinance
FMA	Fisheries Management Areas

GDP	Gross Domestic Product
GEP	Global Environmental Facility
GHG	Green House Gas
GIS	Geographical Information System
GSMB	Geological Survey and Mines Bureau
Ha	Hectares
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
ID	Irrigation Department
IEE	Initial Environmental Examinations
IMCC	Inter Ministerial Coordinating Committee
IPCC	International Panel on Climate Change
ISDR	
Km	Kilometres
MF& AR	Ministry of Fisheries and Aquatic Resources
MFF	Mangrove for the Future
MPA	Marine Protected Area
MPPA	Marine Pollution Prevention Authority
NARA	National Aquatic Resources and Development Agency
NAQDA	National Aquaculture Development Authority of Sri Lanka
NCDM	National Council for Disaster Management
NEA	National Environment Act
NEAP	National Environment Action Plan
NGO	Non governmental Organization
NSC	National Conservation Strategy
PA	Protected Area
PLA	Participatory Learning and Action

PRA	Participatory Rapid Appraisal
Rs.	Rupees
SAM	Special Area Management
SIA	Strategic Impact Assessment
SLLRDC	Sri Lanka Land Reclamation and Development Cooperation
SLSI	Sri Lanka Standred Institute
SLTB	Sri Lanka Tourist Board
UDA	Urban Development Authority
UNCSP	United Nations
UNDP	United Nation Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Conventions on Climate Change
UNISDR	United Nations
USAID	United States Agency for International Development
WG	Working Group
WMO	World Meteorological Organization

1.0 Module one: Introduction to the course

1.1 Background

Sri Lanka is endowed with a scenic, diverse and resources rich coastal area, mangroves estuaries, coral reefs, sea grass beds and beaches so common along Sri Lanka's coast line are among the most naturally productive ecosystems in the world. Many people depend directly on these resources for their livelihood. The coastal region itself is one of the most densely populated areas and most of the transportation infrastructure, tourist related facilities, are located within this area. Furthermore 80 percent of the total annual fish production, 65 percent of the urbanized land area, 67 percent of the nation's industrial facilities is coming from the coastal area of Sri Lanka. These factors amply demonstrate the need to manage the coastal zone in order to ensure that the carrying capacity of the zone and its resources are not surpassed. Many examples of the devastation and degradation of the environment caused by lack sufficient planning and management in the past, can be seen in our coastal zone.

Natural processes such as monsoons, cyclones, Tsunamis, floods and coastal erosion cause severe damage to the coastal areas resulting in great losses to lives, houses, hotels, roads and other infrastructures. These prevailing threats and the emerging issues (e.g. global warming, sea – level rise) have tremendous impacts in the coastal zone.

Our understanding of the dynamics of coastal areas is as yet incomplete. Science however, is rapidly pushing forward the frontiers of knowledge given us an ever increasing insight into nature. It is our duty towards the future generations to utilize current knowledge in the planning of human activities in the coastal zone. So that they will harmonize with nature. Thus it is essential to conserve the coastal ecosystem and there by reduce disaster risk in coastal communities. This requires the active participation of a broad range of stakeholders and builds their capacity to effectively integrate disaster risk reduction (DRR) in program planning and implementation.

1.2 Objective of the DRR Training Module

The main objective of the Disaster Risk Reduction training module is to build capacity of coastal resources managers in the coastal district on DRR by introducing DRR concepts, issues and opportunities for integrating DRR into coastal resources management projects and activities. Capacity building is the action needed to enhance the ability of individuals, institutions and systems to make and implement decisions and perform functions in an effective, efficient and sustainable manner. There are three capacity levels viz. individual, institutional and systemic. At the individual level, capacity building refers to the process of changing attitudes and behaviours, Capacity building at the institutional level focuses on overall. Organizational performance and functioning capabilities as well as the ability of an organization to adoption to change. At the systemic level, capacity building refers to the creation of an enabling environment within which institutions and individual operate.

This DRR manual is a national level training manual for coastal managers funded by the UNEP to train coastal districts coastal managers. It is expected that at the end of the training course, the coastal managers would have improved and enhanced their understanding on designing and implementing coastal resources management project and activities that would finally protect lives and livelihoods of coastal communities from natural disasters while improving environmental quality and ecosystem services.

1.3 Target Audience

The primary target ordinance of the module is the coastal planning officers in the divisional level, the district level and the environmental officers of the CEA at the divisional level.

1.4. Duration and Delivery Methods

The total course duration will be five days which is included five module including field visits. The level of delivery will be at coastal district level and maximum participants per one training program will be 20 to 25. The delivery methods will be power point presentations, group discussions, field visits, hand book, leaflets, videos, simulations, group works and models studies.

1.5 Module Structure

This document is divided to five modules namely;

Introduction

Coastal hazards, coastal disasters, vulnerabilities and risks

Risk Assessment

Coastal Risk Reduction and Management

Field exercise and report

The introduction module will include the introduction of the course, introducing the coastal environment, coastal resources users and coastal resources management Agencies.

The module two will provides the key terminologies related to climate change, coastal risk reduction and coastal resource management. These would enable the participants to have a very clear understanding of the terms used throughout these training modules. This module also provides the information to differentiate the disasters hazards risk vulnerabilities and climate change. The third section of the module will be the coastal hazards in Sri Lanka. The coastal hazards in Sri Lanka will divided into two groups namely natural hazards.

Module three will provide the information on Risk Assessment under this module. Several type of risk assessment will be explained. Risk assessment through mapping and community base risk assessment will be the key component.

Module four has been allocated to explain the Disaster Risk Reduction and Management. This module will explained the concepts of the DRR, available measures for DRR in the coastal zone, the institutional set up for the DRR in the coastal zone of Sri Lanka, the policies strategies and programs for the DRR in locally and internationally and role of effective communications in DRR.

Module five is the description of field exercise and visit areas. This module is expected to use all the methods that participants learnt to identify the hazards, risks and vulnerabilities and come up with a DRR strategy. The participants will conduct this exercise in groups and present their findings at the plenary.

1.6 Introduction of Coastal Environment

The coastal areas can be defined based on ecosystem or administrative boundaries or geo-physical feathers. In Sri Lanka Coastal Zone defined base on administrative system. Therefore many cases very important coastal ecosystems are go beyond the administratively defined coastal zone. The coastal zone in Sri Lanka has two boundaries namely;

Planning boundary

Management boundary

The planning boundary is included all coastal Divisional Secretaries and management boundary is the coastal zone defined by the Coast Conservation Act No. 51 of 1981. There are 67 coastal administrative units (DS Divisions) in the Sri Lanka coastal area. According to the Coastal Zone Management Plan of 1997, divisions contain;

24 percent of the land area and 32 percent of the Sri Lanka populations

About 65 percent of the urbanized land area

Approximately 80 percent of the hotel rooms

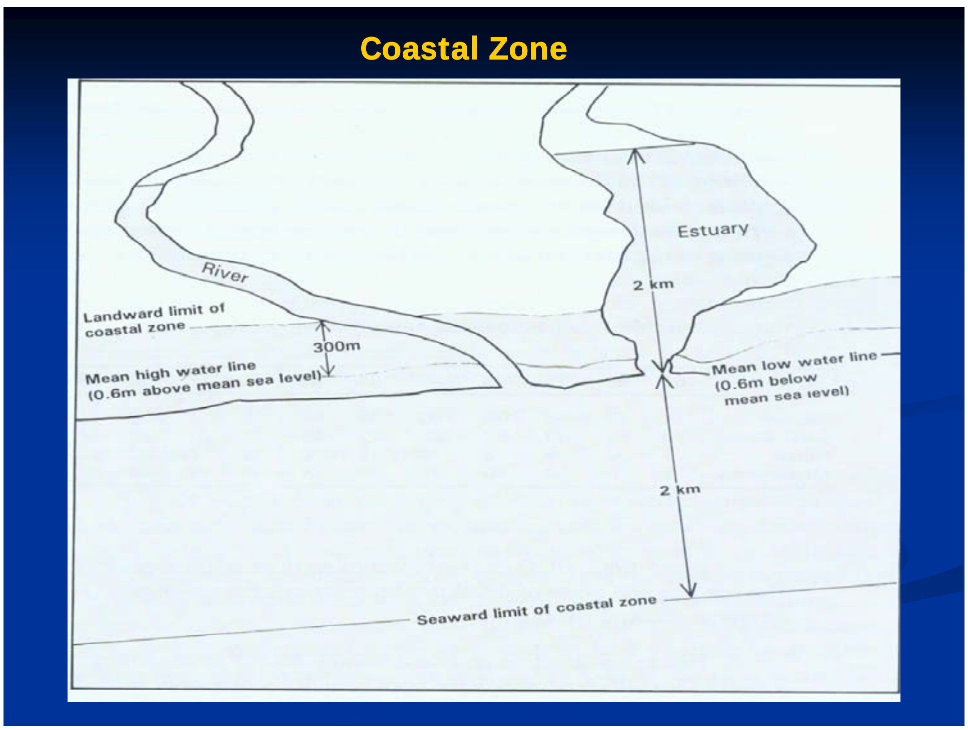
Principal road and rail transport infrastructures

80 percent fish production

Rich biodiversity reserves including coral reefs, sea grass beds and mangroves

In Sri Lanka the coastal zone has defined on the basis of administrative purpose under consideration of geo-physical considerations using linear dimension (Figure 1.1). This narrow coastal zone does not recognize the interconnections within coastal eco-systems, its resources and the human interactions. This lamination in the definition of the coastal zone could become a critical legal constraint when implementing action plans to Disaster Risk Reductions (DRR) and to respond to sea level rise.

Figure 1.1 Coastal Zones under the Coast Conservation Act of 1981



1.7 Physical and Biological features in the Sri Lanka's Coastal Zone

In Sri Lanka's coastal environment is greatly influenced by the island's location in the northern part of the Indian Ocean, between 50 54' and 90 52' North latitude and 790 39' and 810 53'East longitude. The Coastal area is positioned in the lowest of the three pen plains farming the island, and generally consists of flat coastal plains averaging an elevation of less than 100 feet (30 m). The lowest pen plain containing the coastal plains extends outward from the island and under the sea as the continental shelf for a width of 5 – 25 miles (about 8 – 40 km) in most parts, and at an average depth of 216 feet (about 65 m) below sea level. The continental shelf is narrow around the southern part of the island, but wideness considerably towards the north where it merges with the shelf around India.

Sri Lanka has a coast line of approximately 1620 km including the shoreline of bays and inlets, but excluding lagoons. The transverse type coast line in the southwest and northeast is characterized by a series of picturesque sandy bays – protected on either side by rocky headlands; the south-western coastline also has many complex systems of lakes, and lagoons with sinuous shapes. The north-western and southern coastlines exhibit lagoons, sand bars and spits that sometimes extend over many kilometres. The presence around the island of the continental shelf with shallow waters has permitted the formation of coral reefs along the coastline amidst well developed reefs of sandstone and rock. Large deposits of coral are also found inland in the coastal regions particularly between Ambalangoda and Matara. Some segments along the southwest coastline are retreating due to natural erosive action of the sea compounded by anthropogenic activities such as river sand mining and destruction of coral reefs.

The coastal landscape contains a very dynamic transition zone between the sea, land and atmosphere and is formed as a result of sea and atmospheric forces on the landmass and supply of sediments to the coast. Sri Lanka has around 103 rivers that radiate from the hill country and flow down to the sea forming estuaries that the important features of the coastal landscape and provide vital habitats for species of commercial and subsistence use. Throughout its length the coastal zone contains a variety of terrestrial habitats which include sandy beaches, barrier beaches, sand, and salt marshes. Equally important are the coral reefs lagoons, estuaries, and sea systems help maintain vital physical processes fulfil ecosystem services and functions and provide land, goods and services.

1.8 Climatic Conditions

Almost all major climatic divisions of the country are represented in the Coastal Zone. The western and south-western coasts are within the Wet Zone which is characterized by an annual rainfall of 2,500 mm to cover 5,000 mm, and a temperature of around 270 C. Most other areas of the Coastal Zone fall within the Dry Zone which averages an annual rainfall between 1,250 – 1,900 mm and a temperature of around 300 C. The two extra dry coastal strips in the northwest and southeast form the 'Aid Zone' which receives less than 1,250 mm of rain annually.

The wave climate around the island can be characterized as seasonal with moderate wave heights. The tide is micro tidal, mixed to semi – diurnal, with generally weak tidal currents. The wind climate is influenced by the shifting monsoons with light to moderate wind speeds. During May to September, the coastal areas of the south-western quarter of the island are exposed to heavy rains from the south west monsoon. The east coast receives its highest rainfall from December to February from the northeast monsoon which also provides rain to the rest of the island. The coastal areas also receive inter – monsoonal rains from April – May, and again from October – November when tropical cyclonic activity may occur.

Cyclones are not frequent phenomena in Sri Lanka although the island is located at the fringe of the northern Indian Ocean cyclone belt. Most cyclones have traversed the northern part of the island moving from southeast to northwest, with the northeast coast experiencing the highest impact. The mean annual occurrence of storms affecting the northern areas of the island is 0.2 – indicating a return frequency of a storm in every five years. This situation can vary, however, in the future with climate change, particularly as cyclone patterns in the equatorial zone have shown increasing frequency and intensity during the past two decades. Changes in the type and number of storms can vary the littoral drift budget which greatly influences coastline development.

1.9 Historical and Cultural Perspectives

Sri Lanka has had a distinctive island civilization with a long history of more than 2500 years. Due to migration from neighbouring countries as well as European nations in the past the Coastal Zone around the island developed ports, forts and sites of cultural and historical importance. Commercial and trade activities during the monarchical and colonial times, too have played a singular role in building up the coastal heritage of the island.

Movements and sites located along the coastal zone are of a diverse nature and of great significance. Archaeological sites of the coastal zone constitute pre-historic and Proto – historic (Early Iron Age), together with a large number of sites of the Historic period which include religious sites and secular sites such as forts, ports, lighthouses, residences etc. Some of the sites such as forts, ports and lighthouses stand by themselves as distinct entities confined to the coastal zone alone.

There are numerous coastal sites that are of considerable importance for the preservation of the cultural heritage of Sri Lanka. They are acutely prone to despoliation than the monuments in the hinterland due to natural causes like coastal erosion and human intervention including building activities and pollution.

1.10 Coastal Issues

In Sri Lanka, Coastal issues can be divided into tow main groups;

a. Natural

b. Man made (Anthropogenic)

The natural coastal issues are coastal erosion, sea level rise, cyclones and storm surges tsunamis and degradation of coastal habitats. The man made coastal issues are coastal pollutions improper coastal developments and excessive mining of coral and sand.

1.10.1 Natural Issues

(a) Coastal Erosion

Coastal erosion is a long standing problem in Sri Lanka, which results in the loss or degradation of valuable sandy beaches and coastal lands. Erosion occurs due to both natural features and human interventions and entails considerable public and private costs. These include the loss of beach and landscape quality, damage to or loss of private houses, public buildings, hotels and infrastructures. Approximately SL Rs. 1,520 millions has been invested on erosion management in the coastal zone during ten periods 1985 – 1999 and SL Rs. 3 billion has been spent by the government for coast protection activities from 2000 to 20005.

Erosion rate4s vary greatly between different locations and maximum local retreat rates of around 12 m / year have been observed in areas between Maha Oya and Lansigama.

(b) Sea Level Rise

Sea level rise on its own would, rise the mean sea level, leading to inundation of low lying coastal areas, shoreline retreat, intrusion of salinity and impacts on coastal habitats.

Increase wave height disturbing equilibrium beaches and making them more prone to erosion and interfering with existing long shore sediment transport rates and distribution.

Impacts due to sea level Rise

The most direct impact of the rise in sea level is the inundation of areas that have been located just above the water level prior to sea level rise. Low lying coastal settlements and coastal wetlands belong to this category.

(I) Coastal Settlements

Low lying coastal settlements which are highly populated will be directly affected by sea level rise. Impacts on such land should be assessed in the context of a sea level rise of the order of 1 m. In assessing the impacts, due consideration should be given to the combined influence of coastal erosion, flooding and storm drainage.

(ii) Coastal Wetlands

Coastal wetlands are generally found at elevations just above mean sea level and below the highest tide. These wetlands account for a significant proportion of land less than 1 m above sea level. With the rise in sea level marshes have generally kept pace by migrating inland and this has helped the prevention of wetland loss. However, if marshes are unable to keep pace with sea level rises, it would lead to a net loss of wetlands. Such losses would be greater if protection of developed areas prevents the inland migration and formation of new wetlands.

(iii) Coastal Erosion

A rise in sea level would increase the present rates of erosion, thereby resulting in the loss of land and increasing the vulnerability of coastal communities. The country has been experiencing an erosion rate of 0.30 – 0.35 m per year for 45% - 55% of its coastline. Any acceleration of erosion due to sea level rise will contribute to an increased loss of land, thereby affecting communities and economic activities.

The lowering or loss of sandbars due to sea level rise would increase the tidal prism of coastal water bodies with larger volumes of water entering during the tidal cycle. This would result in the risk of greater inundation of coastal areas, intrusion of salt water and associated environmental impacts on coastal eco-systems.

Estimates of land loss and inundation along the south – west coast of Sri Lanka has been made for the UNCSP (1998). Table 1.1 provides the estimates of land loss on the south – west coasts of Sri Lanka resulting from sea level rise.

Table 1.1 Land Loss of the SW Coast of Sri Lanka

Sea Level Rise Scenario m	Land Loss km2
0.30	6.0
1.00	11.5

Table 1.2 provides estimates of inundation around the lowlands adjacent to coastal wetlands of the south – west coast of Sri Lanka.

Estimated areas of Inundation around the Lowlands Adjacent to Marshlands, Lagoons and Estuaries of the SW Coast of Sri Lanka Table 1.2.

Type of Landforms Adjacent to :			Area Inundated Km2	
Marshlands	Lagoons	Estuary	Sea Level Rise 0.30 m	Sea Level Rise 1.0 m

	Garanduwa		2.5	4.0
Goyyapana			0	1.0
Galle – Magalle			0.5	2.0
		Gin Ganga*	1.0	3.5
	Ratgama		3.0	5.5
	Hikkaduwa, Ganga		2.5	3.25
Akurala			0	4.0
	Madampe		3.5	7.0
	Randombe Lake		1.0	5.0
Ahungalle			0	0.5
	Madu Ganga		1.0	2.5
Indouruwa			0	0.5
Bentota Ganga			4.0	6.5
Palliyawatta –Pinwatta			1.5	2.0
Nugape – Bopitiya			4.5	12.0
	Panadura Ganga		6.0	8.0
	Baire Lake		0	1.0
	Elenegoda		3.0	4.5
Endigastenna		Kelani Ganga	2.0	4.5
	Negombo Lagoon		12.0	23.0

Total			41.0	91.25

(iv) Flooding and Storm Damage

A rise in sea level could affect flooding and storm damage in coastal areas due to two main reasons. Firstly, higher water levels would provide storm surges with a higher base to build upon. Secondly, higher water levels would decrease natural and artificial drainage; this could also lead to pollution of water bodies. It is also recognized that change in climate due to global warming could contribute to the reduction of the return periods of storms and floods, thus increasing the frequency of extreme events. This will cause disasters in which there will be large losses of lives, property and infrastructure. It must be noted that in contrast to coastal erosion, flooding is a sudden occurrence leaving very little time for preparation for the disaster. The relevance of disaster preparedness should also be given due consideration.

(v) Salt Water Intrusion

The increase in inland penetration of salt water is another major impact of sea level rise. A rise in sea level increases the salinity of an estuary by altering the balance between fresh water and salt water hydraulic regimes. The impact would be widely felt during dry weather conditions with greater penetration of salt water.

Sea level rise will therefore cause a number of problems such as the penetration of salt water into cultivated areas, increase of saline water in aquifers, migration of fresh water fish and impacts on other habitats causing a breakage in the food chain of certain species.

The entry of saline water to fresh water intakes is also a major problem, which demands engineering interventions. Deepening of estuaries will also increase intrusion and care should be exercised in the planning of development work which includes dredging of estuaries.

(vi) Low lying Agriculture:

The impact of salt water intrusion on low lying agriculture should be given due consideration in analyzing the impacts of sea level rise because the implementation of litigator measures would require a considerable length of time. The loss and degradation of arable lands will significantly lower the agriculture should be given due consideration in analyzing the impacts of sea level rise because the implementation of litigator measures would require a considerable length of time. The loss and degradation of arable lands will significantly lower the agricultural output. The introduction of salinity tolerant varieties of crops, alternative land use or engineering interventions to maintain the existing regime will require investment funding and also time for planning and implementation. It will be necessary to study the impact on existing irrigation structures widely used in low – lying agricultural schemes

(vii) Fresh Water Intakes:

The prevention of salt water entering fresh water intakes could be achieved by either relocation of the intake or by constructing salt water barriers. Both options are costly and hence the long term behaviour of the aquatic system has to be studies prior to planning engineering interventions.

(viii) FISHERY INDUSTRY

The fishery industry too would be affected by the impacts of global worming and sea level rise. The level of impact of climate change will vary widely and will also depend on attributes of the species. A temperature rise of about 2o C may have substantial impacts on the distribution, growth and reproduction of fish stocks. Commercially important fish stocks may change their spawning areas and distribution patterns. A given population within a species is adapted to a hydrodynamic environment of specific temporal and spatial characteristics. Therefore, changes in the ocean circulation may lead to the loss of a certain population or the establishment of new ones, particularly at the periphery of the areas of species distribution.

Fishery activities which would be affected include, beach seine fishery, sea ranching in coastal areas, stilt fishery, boat landing sites and fisher folk settlements along the beach. Due attention should also be focused on shrimp fishing under coastal aquaculture.

(ix) Coral Reefs

Rising ocean temperatures will systematically bleach fragile coral reef systems. Ocean temperatures calculated by model projections indicate that thermal tolerances of reef building corals are likely to be exceeded within the next few decades. Increase in ocean temperatures has imposed a severe stress on coral reefs against their tolerance levels. Damage to coral reefs will depend very much on whether coral reef systems can adapt with the rate of change of ocean temperature.

(x) Coast Protection Structures and Breakwaters

Sea level rise will increase the hydraulic force regime on coast protection and port structures such as revetments, sea walls and breakwaters. These structures will become vulnerable to the impacts of increase erosion as well as the possible increase in the frequency of extreme events such as storms and flooding. To maintain their functions efficiently, such structures will have to be reinforced; this is likely to lead to an increase in the maintenance costs. Reinforcement of the structure may also necessitate an increase in crest levels to withstand the impacts of a higher sea level.

Sea defence and coast protection plans which form key elements of an overall Coastal Zone Management Plan should be based on Policy and Management Options which have taken into consideration the impacts of sea level rise. The IPCC has recognized the adaptive response strategy classified under three categories namely, Retreat, Accommodation and Protection. The selection of the appropriate adaptive strategy for a given area will have to be made after considering the economic, social environmental, legal and institutional implications of each of the responses. In order to implement the policy options, various management options are considered, provided they are appropriate for the coastal classification. These can be summarized as, Do nothing, Reinstate, Modify and Create. By defining Policy Options and management Options for the entire coast, the basis of a strategic approach for achieving long term stability is established.

(xi) NEARSHORE INFRASTRUCTURE

Near shore Land Based Infrastructure

The impacts of sea level rise should be taken into consideration in the planning of maintenance strategies for near shore land based infrastructure such as highways and rail tracks. Due attention should also be focused on impacts of sea level rise in the planning of new infrastructure development projects for urban areas located along the coast.

In the recent past, several proposals have been made by both the private and the public sectors in development projects, to acquire land via reclamation. The marine highway project from Colombo to southern parts of the city is such an example. While appreciating the need for such projects, the impacts of sea level rise have to be given very high consideration when preparing development proposals.

(xii) TOURIST INDUSTRY

Loss of prime land on the shore front has had impacts on the tourist industry, particularly in the case of beach resorts. A rapid rise in the sea level would therefore inevitably increase the cost of coast protection and the generation of beaches at locations where major investments have been made in the tourist industry. In the planning of new resorts, depending on the location, the policy of ‘retreat’ from the shoreline will have to be given serious considerations as opposed to the spending of excessive amounts on protection.

c) Cyclones and Storms Surges

Cyclones are not frequent phenomena in Sri Lanka, although the island is located at the fringe of the northern Indian Ocean cyclone belt. Most cyclones have traversed the northern part of the island moving from southeast coast experiencing the highest impacts. The mean annual occurrence of storms affecting the northern areas of the island is 0.2 – indicating a return frequency of a storm in every five years. This situation can very, very, however, in the future with climate change, particularly as cyclone patterns in the equatorial zone have shown increasing frequency and intensity during the past two decades.

One of the most serious cyclones in Sri Lanka occurred in November 1978 when it passed over the northern half of the island following a north-westerly path, starting south of Batticaloa and moving out at Mannar with wind speeds of 185 km/h. In the wake of the cyclone winds of hurricane intensity covered an area of 35 km width, resulting in heavy damage and devastation on the east coast and to a lesser degree in some areas of the North Central province.

The cyclone inflicted considerable damage to the Batticaloa town. Maximum water levels in the area rose to a maximum of 09 feet (2.73 m) above mean sea level at Kallady Bridge while waves and water over – topped the main coast road north of Batticaloa, indicating a local surge between 0.9 – 1.2 m. The penetration of water and waves in up rush reached up to half a mile from the shoreline. Much of the vegetation on the sand bar to the north and east at the urbanized area was destroyed.

Storm surges accompany cyclones. The coastal sandbars are the first line of defence against cyclones and the accompanying storm surges. Typically cyclones have wind velocities ranging from 20 – 30 mph (32 – 48 kHz) near the periphery to 70 – 100 mph. (113 – 161 kmh). Cyclones have major impacts on water surfaces, especially near the shoreline and in lagoons.

(d) Tsunami

The tsunamis can happen due to various reasons but mainly can occur due to earthquake in the sea. The Indian Ocean tsunami triggered a massive earthquake off the coastline of Sumatra in 2004; wreaked havoc in the region claming over 200,000 lives displacing hundred of thousands and destroying billions of dollars of property. In Sri Lanka, twelve coastal districts were affected in the country’s history.

(e) Degradation of Coastal Habitats

Sri Lanka has a variety of coastal habitats that include estuaries and lagoons, mangroves, sea grass beds, salt marshes, coral reefs and large extents of beaches including barrier beaches, spits and dunes. These habitats comprise a rich component of the country’s biodiversity, although much of the various groups of marine coastal organisms are as yet incompletely documented.

Most of Sri Lanka’s coastal habitats have been undergone degradation in different degrees during the post resulting in the decline of their resources as well as extents at an unprecedented rate. Underlying the apparent degradation of coastal habitats is the fact that they are very fragile and vulnerable to the many dynamic processes occurring on land and in the sea, due to both natural causes and human interventions.

Coral destruction in most shallow areas was evident in 1998 due to bleaching caused by high water temperature associated with “Elnino” Southern Oscillation effect. Other natural causes such as the proliferation of the crown of thorns starfish and other invasive species have compounded the damage to Sri Lanka’s coral reefs.

The sea grass beds have been destroyed due to siltation resulting from land – based activities such as changes in catchments hydrology through irrigation schemes. Sand bar formation in the coastal area also cause degradation of sea grass beds.

Lagoon and estuaries and biodiversity they contain are increasingly affected by pollution due to the inflow of sewage, untreated industrial effluents and urban waste. The salinity regimes in several lagoons / estuaries have been affected by changes in natural flows due to irrigation schemes. This sometimes triggers off the growth of invasive plant species such as Najas marina and salvinia molesta.

Main natural causes for destruction of mangrove ecosystem are water pollution and siltation. Other issues connected with this system are loss of functional lagoon / estuaries area due to unauthorized encroachment and land reclamation.

Degradation of sand dunes, barrier beaches and sand spits has taken place due to coastal erosion.

1.10.2 Man Made issues

(a) Coastal Pollution

The problem of water pollution in Sri Lanka's coastal zone has been increasing over the last two decades. Ocean waters, coastal waters and coastal area ground waters receive high pollution loads from development activities and human settlements located in and outside the coastal zone.

The main factors that underlie water pollution in the coastal region are the high human population densities such as in the industrial and tourism sectors. The pollutants that reach coastal waters very from faucal matters, visual pollutants that float or are in suspension.

(b) Improper Coastal Developments

Some development activities in the Coastal Zone including inadequately planned tourism have resulted in adverse impacts. Examples are the pollution of beaches and coastal waters due to the release of sewage, solid waste and wastewater. Infrastructure including dwellings located too close to the coastline restricts coastal processes and promotes erosion.

There are several examples of human lives have been lost due to improper constructions in the Coastal area. In Hikkaduwa, Unawatuna and Arugam Bay many tourist and locals have been lost their lives due to staying hotels which have been constructed very close to the beach. Another problem due to improper coastal development is to maintain the access to beach and along the beach. The lack of proper access to the land area during an emergency situation like tsunamis and cyclones are very critical in the areas of heavy tourist hotel development areas.

(c) Excessive Mining of Coral and Sand from the coastal areas

Coral is the principal source of line for Sri Lanka's construction industry, supplying approximately 90% of the line is use. Part of this is supplied by sea coral mining. Overall coral extraction has increased in the west and south costal region from approximately 18,000 tons in 1984 to 19,820 and 30,500 tons in 1994 and 1998. The accumulated impact of many years of sea coral mining will also be felt for many years to come.

Sand mining in rivers is most severe in the North-western, Western and Southern Provinces where much of the construction activity and the major coastal erosion problems are concentrated. It should also be noted that the problem of river sand mining is of long – standing and its impacts are, in may instances, irreversible in the short and medium term. Thus initiatives taken now ill not serve to re-establish the sand supply to the coast from several affected rivers in the short or medium term.

1.11 Coastal Resources users in the coastal area

Sri Lanka's fisheries are significant to the nations as a source of (a) food, (b) employment, and (c) foreign exchange earnings. In Sri Lanka average annual fish consumption is 18.3 kg and providing more than 50 percent of the animal protein. Approximately 80,000 Sri Lankan are employed as fishermen. Coastal artisanal fishery production is largely for internal consumption but foreign exchange is earned through exports of shrimp, tune and ornamental fish.

Industries are the other stakeholder in the coastal areas in Sri Lanka. Many processing and production industries are located along the coastal areas. Of them some are high polluting industries such as leather manufacturing industries (near Colombo) paper factories (Valachchanai).

Tourism industry is the next largest industry the fisheries which is located in the coastal areas. The tourism industry provides the opportunity for the country to earn foreign exchange and to provide employment. Most of Sri Lanka formal tourism industry is in the coastal region with 82 percent of the "resort" hotel rooms in coastal areas.

There are other coasts resources uses such coastal resources miners, aqua culturists, infrastructure development agencies such as road Development Authority , Railway Department, Water Supply and Drainage Board, Sri Lanka Telecom etc.

1.12 Coastal Livelihoods

Sri Lanka's diverse and rich coastal resources provide a range of livelihood opportunities for local coastal communities. Among the dozens of livelihood strategies carried out with using coastal resources, fisheries, tourism and navigational activities are significance in terms of their contribution to the local economy.

Marine and coastal fisheries provide direct employments to about 150000 people and sustenance to at least a million. The sector currently contributes about 1.5% of the GDP and it has huge potential to increase this contribution through increased production and value adding. The sector contributed 2.7% of total foreign earnings of the country in 2007 and continues as an important source of foreign exchange. (Source: Fisheries Statistics – 2007, Ministry of Fisheries and Aquatic Resources)

Tourism is the fifth largest income earner in Sri Lanka and had netted in SLRs 18863.3 million in foreign exchange in 2001. (Revised National Coastal Zone Management Plan, 2005) It also provides more than 85000 direct employments while providing much more number of indirect employment opportunities. In the world tourism map, Sri Lanka is still in the coastal tourism segment and more than 70% of the registered tourist hotels are located along the coastline of the country. White sandy beaches and other diverse coastal ecosystems of the country provide great opportunity for further expansion of tourism sector. But it should be promoted in a proper planned manner so as to minimize negative impacts of the industry on the coastal environment and local people.

In addition to these main livelihood strategies, a considerable number of people have engaged in unsustainable forms of coastal resource extraction such as coral and sand mining, mangrove extraction resources.

Module 02 Coastal Hazards, Disasters, Vulnerabilities and Risk

2.1 Definitions

2.1.1 Climate Change related Definitions

Source: If not indicated: EXTRACTED FROM: GLOSSARY, IPCC 4th Assessment Report, Working Group 1 (http:/www.ipcc.ch/pdf/glossary/ar4-wg1.pdf),

(http:/www.ipcc.ch/pdf/glossary/ar4-wg1.pdf, http:/www.ipcc.ch/pdf/glossary/ar4-wg2.pdf, (http:/www.ipcc.ch/pdf/glossary/ar4-wg3.pd

Abrupt climate change: The nonlinearity of the climate system may lead to abrupt climate change, sometimes called rapid climate change, abrupt events or even surprises. The term abrupt often refers to lime scales faster than the typical time scale of the responsible forcing. However, not all abrupt climate changes need be externally forced. Some possible abrupt events that have been proposed include a dramatic reorganization of the thermohaline circulation, rapid deglaciation and massive melting of permafrost or increases in soil respiration leading to fast changes in the carbon cycle. Others may be truly unexpected, resulting from a strong, rapidly changing forcing of a nonlinear system.

Adaptation: (extracted from GLOSSAY, IPCC 4th Assessment Report, Working Group 2) Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities, various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:

- Anticipatory adaptation - Adaptation that takes place before impacts of climate change is observed. Also referred to as proactive adaptation.

- Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and buy market or welfare changes in human systems. Also referred to as spontaneous adaptation.
- Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have c

Adaptive capacity: (in relation to climate change impacts) (extracted from GLOSSARY, IPCC 4th Assessment Report, Working Group 2) The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The whole of capabilities, resources and institutions of a country or region o\to implement effective adaptation measures, (Source IPCC 4th AR, WG3, Glossary)

Atmosphere: The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio) helium and radioactively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapour, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols.

Climate: Climate in a narrow sense is usually defined as the “average weather”, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate Change: (extracted from GLOSSARY, IPCC 4th Assessment Report, Working Group 2) Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer, Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its article 1, Defines climate change as; a change of climate which is attributed directly or indirectly

To human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate system: The climate system is the highly complex system consisting of five major components the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcing such as volcanic eruptions, solar variations and anthropogenic forcing such as the changing composition of the atmosphere and land use change.

Climate variability: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also Climate change.

Extreme weather event: an extreme weather event is a vent that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite change the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season)

Global worming: IPCC 4th Assessment Report WG3 glossary) Global worming refers to the gradual increase, observed or projected, in global surface temperature, as one of the consequences of radioactive forcing caused by anthropogenic emissions.

Greenhouse effect: Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which is emitted. In the troposphere, the temperature generally decreases with height. Effective, infrared radiation emitted to space originates from an altitude with a temperature of, on average, - 19 C, in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average, + 14 C. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere, and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radioactive forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect.

Greenhouse gas (GHG): Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour ($H2O$), carbon dioxide ($CO2$), nitrous oxide ($N2O$), Methane ($CH4$) and ($O3$) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine – and bromine – containing substances, dealt with under the Montreal Protocol. Beside ($CO2$), ($N2O$) and ($CH4$), the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride ($SF6$), hydro fluorocarbons (HFCs) and per fluorocarbons (PFCs).

Climate Change Impacts: (source: IPCC 4th Assessment report WG2, glossary) the effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential Impacts and residual impacts: Potential impacts: all impacts that may occur given a projected change in climate, without considering adaptation. Residual impacts: the impacts of climate change that would occur after adaptation. See also aggregate impacts, market impacts, and non-market impacts.

Sea – level rise (source: IPCC 4th Assessment report WG2, glossary): An increase in mean level of the ocean. Eustatic Sea – level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea – level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land – level uplift, relative sea level can fall.

Sensitivity: IPCC 4th Assessment report WG2, glossary) Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

2.1.2 Disaster Risk Reduction related Terminologies (Source: UN/ISDR)

Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. A disaster is a function of the risk process it results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk.

Hazard: A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

H**a**zards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro meteorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability.

Vulnerability: The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community, top the impact of hazards.

Capacity: A combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk or the effects of a disaster, Capacity may include physical, institutional, social or economic means as well as skilled personal or collective attributes such as leadership and management, Capacity may also be described as capability.

Risk: The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems, it is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes.

Risk assessment/Analysis: A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

The process of conducting a risk assessment is based on a review of both the technical features of hazards such as their location, intensity frequency and probability; and also the analysis of the physical, social, economic and environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios.

Prevention: Taking measures in order to avoid an event turning into disaster. Planting trees, for example, prevents erosion and landslides. It can also prevent drought.

Mitigation: Measures that reduce vulnerability to certain hazards. For instance, there are building techniques that ensure that our houses, schools or hospitals will not be knocked down by an earthquake or a hurricane.

Preparedness : Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations.

Recovery: Decisions and actions taken after a disaster with a view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risk.

Disaster Risk Reduction: The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development.

The disaster risk reduction framework is composed of the following fields of action, as described in ISDR's publication 2002 " Living with Risk" a global review of disaster reduction initiatives", page 23:

Risk awareness and assessment including hazard analysis and vulnerability/capacity analysis;

Knowledge development including education, training, research and information;

Public commitment and institutional frameworks, including organizational, policy, legislation and community action;

Application of measures including environmental management, land-use and urban planning, protection of critical facilities, application of science and technology, partnership and networking, and financial instruments;

Early warning systems including forecasting, dissemination of warnings, preparedness measures and reaction capacities.

Sustainable Development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of " needs ", in particular the essential needs of the world's poor, to which overriding priority should be given: and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and the future needs (Brundtland Commission, 1987).

Sustainable development is based on socio-cultural development, political stability and decorum, economic growth and ecosystem protection, which all relate to disaster risk reduction.

Structural / Non structural measures: Structural measures refer to any physical construction to reduce or avoid possible impacts of hazards, which include engineering measures and construction of hazard – resistant and protective structures and infrastructure. Non-structural measures refer to policies, awareness, knowledge development, public commitment, and methods and operating practices, including participatory mechanisms and the provision of information, which can reduce risk and related impacts.

Early warning: The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.

Early warning systems include a chain of concerns, namely: understanding and mapping the hazard: monitoring and forecasting impending events: processing and disseminating understandable warnings to political authorities and the population, and undertaking appropriate and timely actions in response to the warning.

2.2 What is a Disaster?

A Disaster can be defined as 'a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources' (UNDP, 2004)

2.3 What is a Hazard?

A Hazard is a potentially damaging physical event, natural phenomenon or human activity that may adversely affect human life, property or social and economic disruption or environmental damage.

Types of Hazards

The hazards can be categorized based on the speed of onset, origin and cause as follows;

a. Speed of onset:

- Rapid onset: Earthquakes, tsunami, cyclones, floods, volcanic eruptions etc.
- Slow onset: Droughts, famines, environmental degradation, pest infestations etc.

b. Origin: Natural or Human made.

c. Cause: Primary or Secondary

Natural Hazards

Natural processes or phenomena occurring in the biosphere that may constitute a damaging event.

Geological

Natural earth processes or phenomena like earthquakes, tsunamis, volcanic activity, avalanches, mud flows etc.

Hydro-metrological

Natural processes or phenomena of atmospheric, hydrological or oceanographic nature. For example floods, tropical cyclones, rain/wind/dust storms, drought, desertification, wild land fires, extremes temperatures etc.

Biological

Processes or organic origin or those conveyed by biological vectors like pathogenic micro-organisms, toxins & bioactive substances. Like outbreaks of epidemic diseases (Avian flu), plant or animal contagion, insect plagues and extensive infestations.

2.4 Human Induced hazards/disasters

Processes or phenomena primarily governed by human influence that may constitute a damaging event.

Environmental Degradation: reduced capacity of the environment to meet social and ecological needs. May increase the frequency and intensity of natural hazards. Eg: deforestation, desertification, wild fires, land, water and air pollution, climate change ozone depletion.

Technological: danger originating from technological or industrial accidents, dangerous procedures, infrastructure failures or certain human activities. Eg: industrial pollution, nuclear activities, toxic wastes, dam failures; transport or industrial accidents (fires, spills etc).

Armed Conflict: A contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle related deaths.

Return period of hazards

Majority of hazards have return periods on a human time-scale. Eg: five-year flood, fifty-year flood and a hundred year flood. This reflects a statistical measure of how often a hazard event of a given magnitude and intensity will occur. Return period has implications on how prepared communities are to respond to/prepare a disaster.

The connection between hazard and disaster

HAZARD =/= DISASTER

A disaster is not always a hazard. The factors which contribute to this conversion are vulnerability, capacity and risk of the ecosystem to the disaster.

2.5 What is Vulnerability?

The negative conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

Some socio-economic indicators of vulnerability for Sri Lanka's population are:

Poverty

Population density

Unemployment

Migration

Malnutrition

Growth of large informal economies in unplanned cities

Socio-political tensions and uncertainty

Absence of sound regulatory practices, and

Unsustainable environmental practices

2.6 What is Capacity?

Capacity is a combination of strength or resources available within a community, society or organization that can be harnessed to reduce the level of risk or the effect of a disaster.

Coping capacity: manner in which people and organizations use existing resources to achieve counter adverse conditions after disasters. eg: Community kitchen set up by local villagers in a school of Kalutara after the 2003 floods.

Resilience: Capacity of a system, community or society to resist or change so that they can function despite the impacts of a disaster. Eg: Organization staff/volunteers reach out to the staffs that are over-burdened after a disaster event in their region.

2.7 What is Disaster Risk?

Risk is the probability of harmful consequences or expected/ anticipated losses from impact of a hazard at a given place over a specific period.

Some elements at risks after a disaster could be:

Physical: roads, railways, airports, bridges, schools, hospitals etc.

Economic: business and trade activities, access to work etc.

Societal: vulnerable groups like women, children, elderly, low income groups etc.

Environmental: loss of bio-diversity, damaged landscapes etc.

Disaster Risk = Hazard x Vulnerability

2.8 Natural Disaster Profile of Sri Lanka

The seven most frequently occurring disasters in

Sri Lanka is;

Epidemics (49.9%)

Animal attacks (19.5%)

Floods (11.8%)

Fire (8.5%)

Droughts (5.1%)

Landslides (2.6%)

Cyclones (2.6%)

Source: Sri Lanka Disaster Inventory Database (1974-2007)

2.9 Coastal Disasters in Sri Lanka

The coastal regions of Sri Lanka and South Asia in general have been facing atmospheric depressions resulting in cyclones, storm surges, tsunami, erosion and coastal flood. Seawater rise has threatened many coastal and deltaic regions from submergence. There is also man made disasters like oil spills, coastal pollution and ballast water exchange creating newer grounds for coastal and marine vulnerability in the region

The major disaster risks facing the coastal and marine areas of South Asia including Sri Lanka are as follows;

The Bay of Bengal and Arabian Ocean Basins of which a large portion of the South Asia coast is a part generate lesser numbers of the world's cyclone: yet their coastal impacts are comparatively very high and devastating especially when they strike coasts bordering the North Bay of Bengal. Higher sea temperatures are likely to lead to more intense tropical and extra-tropical cyclones. During the past three decades, the number of tropical cyclones of Category 4 and above has increased sharply from 8% to 25% in North Indian Ocean and 18% to 34% in South Indian Ocean basins – the largest hazard exposure in existing cyclone hotspots when combined with an increase in the concentration of population and economic activities in South Asian coastal regions. Higher sea temperatures may also alter cyclone tracks thereby increasing the hazard exposure to tropical storms creating new hotspots.

Storm surge is the catastrophic feature of cyclones. The degree of disaster potential depends on the storm surge amplitude associated with the cyclone at the time of landfall, characteristic of coast, phases of tides and the vulnerability of the area and the community. Their coastal impact is very large because of low and flat coastal terrain, high density of population, low awareness of community, inadequate response and preparedness and absence of hedging mechanism.

Tsunamis are an ever present threat to lives and property along the coasts of most f the world's oceans. In the vicinity of the countries of south and south- East Asia, there are two tsunamigenic zones, Andaman – Sumatra trench and the Makran Coast. The 2004 Indian Ocean Tsunami was one of the most devastating disasters in modern history. The earthquake which triggered the waves was the second largest earthquake ever recorded on a seismograph. The hardest hit countries were Indonesia, Sri Lanka, India, Thailand and the Maldives. Many coastal settlements of South Asia continue to live with the high risk from tsunami.

The IPCC (2007) report gives alarming scenarios on the potential of sea level rise; it is expected to rise by at least 40cm by 2100, inundating vast areas on the Asian coastline. In terms of direct impacts this is very likely to lead to a rapid increase in hazard exposure due to increased coastal flooding, wave and storm surges and erosion, particularly if population and economic activities continue to be concentrated in coastal areas. The rise in sea level can be impacts to the coastal community to move inland, increase coastal erosion, salt water intrusion and render agricultural land infertile. Sri Lanka among the other countries in South Asia like Bangladesh, India, Maldives is also having extensive low lying areas just above the sea level are likely to be hard hit. In addition to sea level rise, increase in sea temperature will intensify the coral bleaching. It may also cause migration of species towards polar region and increase in algal blooming.

Coastal erosion is a universal problem and it has been estimated that 70% of all the beaches in the world are eroding. Most of the existing and potential coastal erosion hazard problems arise because of coastal development having been undertaken too close to the sea. Coastal erosion is primarily associated with dynamic natural shoreline fluctuations and changes. At many places development has been undertaken without adequate measures to accommodate these natural shoreline movements. In South Asia, the continental shelf along the east coast is narrow whereas along the west coast the width of the shelf varies from about 340 km in the north to less than about 60km in the south.

Damage to coastal habitats and wildlife is increasingly becoming more severe in South Asia due to population growth and increased economic and development activities. Oil spill, pipeline leaks, accidents etc. contribute further to the coastal and marine pollution. The most affected coastal systems include wetlands, mangroves and coral reefs, which do provide natural cover to alleviate the impact of coastal disasters. Concentrations of heavy metals such as mercury, lead and cadmium in coastal water has become a cause of great concern. Significant amount of oil and oil by products are released into the environment mainly due to oil production, transportation and use affecting adversely marine and coastal environment. Although major oil spills constitute an estimated two percent of the coastal and marine pollution in the world, they cause severe damage to coastal environmental and serious degradation of the aesthetics of the shoreline.

Major disasters especially in the coastal regions n Sri Lanka which occurred since 1978 and the extent of damages are indicated in the Table 2.1.

Table 2.1 Major Disasters in the Coastal regions in Sri Lanka since 1978

Event	Year	Dead	Affected
Tsunami	2004	35,399	1 million
Cyclones	1978	740	1 million
Flood	1989	325	1.2 million
Flood	2003	235	695,000

Source: SAARC

2.10 Natural Coastal Disasters

2.10.1 COASTAL FLOODS

Introduction

Floods have always been part of nature and our world. They can happen just about anywhere there is too much water in one place, at one time. The opposite of a flood is drought-a period of water shortage when lack of precipitation produces dry conditions lasting as long as several years. Flood is one of the common natural hazards that is experiencing in Sri Lanka. This has been creating a numerous types of environmental as well as socioeconomic issues in the country. Environmental pollution, damage and degradation of valuable properties, lost of lives, many people lost their shelters .etc are some of the issues created by floods.

During a flood, water in a stream crests (reaches its highest peak), usually for a short time, and then recedes (goes down) at a slower rate. Most of the countries have a separate word for this type of flooding, called inundation. A rise in sea level has occurred globally, and a continuous rise in the level of the sea is one of the most certain impacts of global warming. One of the expected impacts of sea-level rise is inundation of coastal areas, which will have a negative impact on the livelihoods of the people living in those areas and on GDP. Therefore, develop infrastructure and strategies to address the flooding problems, which are expected to worsen due to climate change and lack of action.

Floods can be destructive, but they can also do a lot of positive impacts. The can leave behind important nutrients in flood pains (flat areas of normally dry land that are alongside many rivers, streams and lakes) that make them ideal for growing crops. They also bring water to wetlands (land that is often flooded), which is needed for many species of animals and plants to live.

Types of Floods

Riverine floods

When rivers or streams overflow their banks, these are called riverine floods. They can be caused by heavy and prolonged rains or when snowmelt (water from melting snow) happens too quickly in the springtime. They generally last for several days to weeks.

Urban floods

Flooding can happen in cities, also called urban areas, where pavement and rooftops prevent rainfall from soaking into the ground. Storm drains are made to carry the storm water away, but they can't always keep up.

Flash floods

During a flash food, water rapidly rises, and then falls within a few hours. In many cases, water quickly rushes down slopes, which can be dangerous. A flash flood is, in short, a sudden local flood of great volume and short duration which follows within a few (usually less than six) hours of heavy or excessive rainfall, or due to dam or levee failure. Heavy rains, most frequently connected with convection clouds, cover small regions and are short-lived (from a few minutes to a few hours), but very intense such as 100 mm (or 100 Litres per square meter) in the span of an hour or more. Violent rainfall causing flash floods can be accompanied by strong winds and heavy hail formation. They can also appear locally in a large area covered by rainfall. A flash flood can take place in a time duration that is span counted in minutes, or only a few hours from the event that causes it to happen (excessive rainfall, failure of hydraulic infrastructure etc.). During a flash flood there is a sudden rise in the water level in rivers and streams, and flow velocity can be very high. The force of the water can be so great as to tear away boulders, uproot trees, and destroy bridges and buildings that stand in its path.

Coastal floods

Coastal floods can occur as a result of sea level rise due to extreme wind storms or tsunami wave. When ocean water rises above a normal high tide and floods occur on the coast, it is called a coastal flood. Sometimes wind storms, such as typhoons, hurricanes or tropical cyclones push a large volume of water towards the coast, which is called a storm surge. The degree of coastal floods depends on: depth of water, duration, velocity, rate of rise, frequency of occurrence, seasonally. The Indian sub-continent (Bay of Bengal) and countries of Asia and Pacific are all typically subject to coastal floods. Globally about 200 million people lived in the coastal floodplain (below the 1 in 1,000 year surge-flood elevation) in 1990, equivalent to about 4% of the world's population. It is estimated that on average 10 million people a year experience flooding. Even without sea level rise this number will increase significantly because of increasing coastal populations.

Sea level rise as a result of climate change will also have a number of different physical and ecological effects on costal systems: inundation, flood and storm damage, loss of wetlands, erosion, saltwater intrusion, and rising water tables. Other effects of climate change, such as higher sea water temperatures, changes in precipitation patterns, and changes in storm tracks, frequency, and intensity, will also affect costal systems, both directly and through interactions with sea level rise. Rising surface water temperatures, for example, are likely to cause increased coral bleaching and the migration of costal species toward higher latitudes. Changes in precipitation and storm patterns will alter the risks of flooding and storm damage. The immediate effects of a rise in sea level therefore include inundation and increased frequency and depth of flooding of coastal land. Longer-term effects include morphological change, particularly beach erosion and salt marsh decline, as the coast adjusts to the new environmental conditions.

Tsunami, or long period gravity waves, is generated by disturbances of the ocean floor resulting from earthquakes, oceanic landslides or volcanic activities. Tsunami wave can move at speed of up to 800 km/h in the deep water of the ocean, diminishing in speed as the wave approaches the shore. They may strike the shore in a series of crashing waves inundating the coastal land up to 1.5 km (much further if it travels up river estuaries). The fist wave may not be the largest; successive wave crests, each typically arriving at 10-45 min intervals, may continue to pond the coast for several hours. The extent of flooding depends due to Tsunami behaviour varies in relation to topography, location (especially with respect to islands) and coastal geometry (Figure 2.1). Where the coastline is relatively even, vegetation can buffer the effects of the wave; in areas where there is considerable articulation, wave forces can be considerably higher.

Figure 2.1 Extend of Floods depends on Topography, Location and Coastal geometry

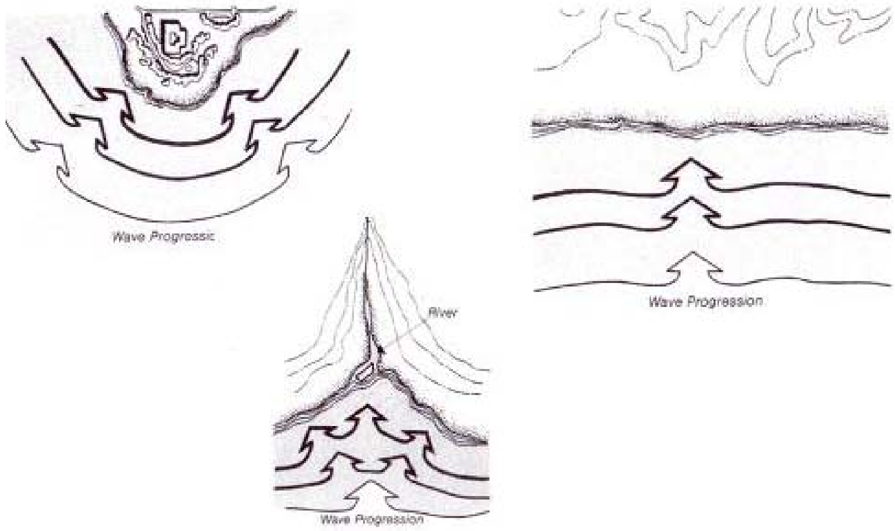


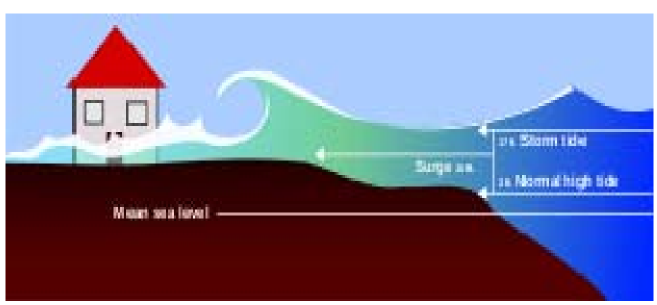
Figure 2.1. Wave intensity and inundation area may vary significantly depending on whether the coastal area is relatively straight, or whether waves are refracted off points or headlands, or funnelled into narrow bays

Some harbours may be in protected locations from the standpoint of wind energy because they are in narrow bays or have headlands that dissipate wind energy. On the other hand, such features can also focus or amplify the wave, in which case tsunami energy is focused against the infrastructure, causing extensive damage to harbour facilities and boats. Tsunamis treat rivers the same as harbours; once they enter the mouth, the wave travels significant distances upriver.

Sri Lanka’s southeast coast, which is characterized by riverine estuaries, narrow-mouthed bays and lagoons bordered by sand dunes, flat sandy beaches and headlands, experienced significant damage from the 2004 Indian Ocean tsunami. In four case study locations that suffered particularly severe damage, near shore transformation processes interacted with the shoreline geometry. In each location, tsunami waves were funnelled into a narrow bay or lagoon where the younger sand dunes in low-lying land between older dunes were breached. The combined interaction contributed to extensive damage to buildings and the devastation of vegetation, including mangroves, palm trees and shrubs (Hettiarachchi and Samarawickrama, 2006; Jinadasa and Wijerathne, 2005).

Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm (Figure 2. 2). This advancing surge combines with the normal tides to create the hurricane storm tide, which can increase the mean water level m meters or more. In addition, wind driven waves are superimposed on the storm tide. This rise in water level can cause severe flooding in coastal areas, particularly when the storm tide coincides with the normal high tides.

Figure 2.2 Storm surge and tidal wave level in the coastal area



The level of surge in a particular area is also determined by the slope of the continental shelf (Figure2.3). A shallow slope off the coast (left picture) will allow a greater surge to inundate coastal communities. Communities with a steeper continental shelf (right picture) will not see as much surge inundation, although large breaking waves can still present major problems. Storm tides, waves, and currents in confined harbours severely damage ships, marinas, and pleasure boats.

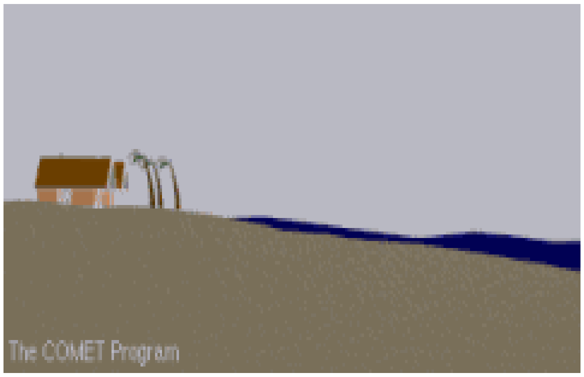


Figure2.3. Different inundation due to slop of the continental shelf

Coastal flooding is a result of the storm surge where local sea levels to rise often resulting in weakening or destruction of coastal structures. The resident population of the coastal zone (present or projected levels) could be affected by increased flooding or, ultimately, the need to move because of frequent flooding, inundation or land loss from erosion. There would also be changes in marketed goods and services, such as land, infrastructure, and agricultural and industrial productivity.

As the sea level rises from the storm surge, the constant battering waves and floating debris damage structures. It is these battering waves that cause most beach erosion and extensive damage to coastal structures.

Coastal flooding levels — categorized as low, moderate, high and extreme — are calculated based on the amount water rises above the normal tide in a particular area (Table 2.2).

Table 2.2. Different coastal flooding levels

Low	Prepare for the likelihood of minor flooding of low lying areas, with little or no damage. Moderate erosion and high waves may cause immediate waterfront roads to close
Moderate	Prepare for the likelihood of some coastal flooding of immediate beachfront property and structures. Significant erosion, high waves, and inundation may cause waterfront and coastal access roads to close.
High	Prepare for the likelihood of significant and life-threatening storm surge. Extensive inundation and extreme damage to roads, infrastructure, and buildings is likely. Surge flooding will also affect tidal bays and rivers. Many waterfront and coastal access roads will be closed, some potentially for an extended period of time.
Extreme	Prepare for the likelihood of extreme, life-threatening storm surge. Complete inundation and extreme damage to roads, infrastructure and buildings likely. Nearly all waterfront and coastal access roads will be closed. Many road closures will last for days or weeks

Coastal flood

Processes and Ecosystem

Ecosystems play a vital role in determining the hydrological response of a coastal region. It is, therefore, important to understand the various hydrological processes generating coastal floods, and how ecosystems interact with such processes to volume, magnitude and timing of floods events.

Estuary and deltaic process

Rive flows are the main source of fresh water, sediment, nutrients and silica for estuaries. The level of river in flow determines the sediment load that is delivered to the estuary. Flood deliver proportionately grater sediment loads than ordinary river flow, and form an important part in determining the hydrological regime of rivers that in turn play an important part in shaping the estuary morphology.

A river carries sediment to the coast and deposits it beyond its mouth. Tidal currents and waves rework the newly deposited sediments, affecting the shape and form of the resulting structure. A river delta results from the interaction of fluvial and marine forces in the vicinity of the river mouth. The long – time evolution of a deltaic plain becomes a function of the rate of riverine sediment input and the rate and pattern of sediment reworking, transport and deposition by marine processes after the initial deposition. Thus, a flow regime in fluvial systems influences the morphological processes of coastal zones. Structural flood control works, such as dams and diversion works alter the flow regime and consequent sediment supply to coastal areas, thereby heavily influencing the morphological and ecological processes of these areas.

Characteristics of coastal ecosystems

Water flow, through and across catchments soils, transport dissolved and suspended nutrients to the estuary downstream. Nutrient rich fresh waters from the catchments mix with highly oxygenated waters from the ocean, making estuary and deltaic areas the most biologically productive regions of the marine environment. Thus coastal fresh water and brackish habitats are determined by the character of the freshwater input into the system – quantity, quality and timing and the daily and seasonal influence of tides, causing changes in salinity, temperature, turbidity and energy flux. Such coastal ecosystems include mangroves, beach forests and peat swamps (tidal and floodplain forests) that contain considerable biological diversity. Coastal ecosystems provide valuable resources, habitat, subsistence and livelihood to forest dwellers, thereby supplying the means to hold these communities together. The socio – economic importance of these areas is especially evident in the more arid regions of developing countries. The seasonal ebb and flood determine the lifestyle and agricultural practices of communities dependent on these ecosystems.

Coastal ecosystems as buffers against flooding

Low – lying coastal areas in the tropics frequently experience coastal flooding caused by cyclonic storms, storms surges and tsunamis, as well as tidal flooding. Saltwater penetrates into deltaic watercourses and may flood low – lying delta lands. Coastal ecosystem protects inundation of inlands along the estuaries and coastal areas, through their physical presence and capacity to retain water and absorb the energy of coastal storms. For example as widely reported in the Indian Ocean tsunami (2004), extensive areas of mangroves can reduce the loss of life and damage caused by tsunamis by taking the first brunt of the impact and by dissipating the energy of the wave as it passes through the mangrove area. On the other hand, narrow strips of mangrove, when uprooted or snapped off at mid – trunk and swept inland, can cause extensive property damage and loss of life. Despite many examples of the positive role played by mangroves and other coastal forests in mitigating the effects of tsunamis and other natural disasters, there is, unfortunately, still insufficient information available to determine to what extent and under witch circumstances mangroves and coastal forests might provide an effective mitigation against natural disasters.

Synergizing coastal fluvial systems

Coastal morpho – dynamics and ecosystems are influenced by flow regime in the fluvial systems. Many coastal systems are under severe threat from water development activities including flood management projects and potential rise in sea level due to potential climate change. This “coastal squeeze” severely restricts the size and width of coastal wetlands and thus their adaptive capacity. In delta areas, over allocation and storage of available water in the upstream part of basins, without taking account of the environmental needs of the morpho – dynamic processes of deltas, coastal ecosystems and mangrove swamps, threaten their survival.

Adaptation

Given the commitment to sea level rise, the need for adaptation in coastal areas will continue for centuries. Against this backdrop, a "commitment to coastal adaptation" needs to be built into long-term coastal management policy. Natural systems have a capacity to respond autonomously to external pressures such as climate change, and this can be described as the natural ability of the system (here the coast) to respond. A healthy, unobstructed wetland would respond by depositing more sediment and growing vertically, keeping pace with sea level rise, and this would be an example of autonomous adaptation. In many places, however, human activities, such as development or pollution in the zone, coastal have reduced the natural system's ability to adapt. Planned adaptation to sea level rise should therefore include consideration of options to reverse these trends of "maladaptation" so as to increase the natural resilience of the coast and increase the capacity for autonomous adaptation.

Socio-economic systems in coastal zones also have the capacity to respond autonomously to climate change. Farmers may switch to more salt-tolerant crops, and people may move out of areas increasingly susceptible to flooding. This is likely to become more important as sea level rise increases.

Because impacts are likely to be great, even taking into account autonomous adaptation, there is a further need for planned adaptation. Examples of initiatives that embrace planned adaptation for climate change are the adoption of strengthened and improved physical planning and development control regulations, and include those relating to Integrated coastal Zone Management (ICZM) and Shoreline Management Planning (see Box 5.1). They could also include implementation of an environmental impact assessment process and coastal disaster management.

Planned and therefore proactive adaptation is aimed at reducing a system's vulnerability by either minimizing risk or maximizing adaptive capacity. Five generic objectives of proactive adaptation relevant to coastal zones can be identified:

Increasing robustness of infrastructural designs and long-term investments. Infrastructure would be designed to withstand more intense and frequent extreme events.

Increasing flexibility of vulnerable managed systems. Systems would be designed and operated to cope with a wide variety of climate conditions. Flexibility can include improving a system's resilience, i.e., its capacity to recover from extreme events.

Enhancing adaptability of vulnerable natural systems. Natural systems can be made more adaptable by reducing stresses they currently face, such as degradation of habitat, and enabling them to adapt through such means as removing barriers to migration (e.g., removing hard coastal structures that can block inland migration of wetlands).

Reversing maladaptive trends. Many current trends increase vulnerability to climate change. For example, subsidizing development in flood plains can increase the number of people and amount of property in low-lying coastal areas vulnerable to sea level rise and increased coastal storms.

Improving societal awareness, preparedness and warnings. Education about risks from climate change and how to reduce or respond to them can help reduce vulnerability.

For coastal zones, another classification of three basic adaptation strategies is often used (e.g., IPCC, 1992):

Protect – to reduce the risk of an event by decreasing the probability of its occurrence

Accommodate – to increase society's ability to cope with the effects of the event

Retreat – to reduce the risk of the event by limiting its potential effects.

Each of these strategies is designed to protect human use of the coastal zone, and, if applied appropriately, each has different consequences for coastal ecosystems. Retreat involves giving up land by strategic retreat from or prevention of future major developments in coastal areas that may be affected by future sea level rise. Accommodation involves altered use of the land, including adaptive responses, such as elevating buildings above flood levels and modifying drainage systems. Retreat and accommodation help to maintain the dynamic nature of the coastline and allow coastal ecosystems to migrate inland unhindered, and therefore to adapt naturally. In contrast, protection leads to coastal squeeze and loss of habitats, although this can be minimized using soft approaches to defence, such as beach nourishment. This strategy involves defending areas of the coast, by building or maintaining defensive structures or by artificially maintaining beaches and dunes. It is generally used to protect settlements and productive agricultural land, but often involves the loss of the natural functions of the coast. Retreat and accommodation are best implemented proactively, whereas protection can be either reactive or proactive.

Options for adaptation to saltwater intrusion in groundwater are not explicitly covered by the three generic options of retreat, accommodation and protection. There are, however, a number of options:

Reclaiming land in front of the coast to allow new freshwater lenses to develop.

Extracting saline groundwater to reduce inflow and seepage.

Infiltrating fresh surface water.

Inundating low-lying areas.

Widening existing dune areas where natural groundwater recharge occurs.

Creating physical barriers.

Flood Management interventions

An integrated approach to flood management calls for a best mix of structural and non-structural measures. An isolated coastal flood management option may achieve a certain objective, e.g. protection of a certain area, but cannot address the various objectives that should be addressed at the coastal area. The residual risks associated with structural solutions, for example due to uncertainty in the input information for analysis of these options or due to a series of chain failures of structural control and protection works, have to be taken into account.

Lateral connectivity

By containing flows within embankments, impeding seasonal floodplain inundation, the floodplain area exposed to inundation is restricted. This disrupts the lateral hydrological connectivity along the river corridor, with various effects on both the ecology of the channel and its floodplain. Further, embankments that are too close to the main channel decrease the natural heterogeneity of the floodplain, and impede the creation of new side channels and wetland areas. This reduction in habitat heterogeneity can dramatically impact fish populations, as many backwaters that were periodically connected to the main watercourse during the river flood no longer receive seasonal flows. These backwaters can be critical breeding and feeding areas for fish.

Lack of floodplain inundation reduces transmission loss and groundwater recharge, thereby severely affective the groundwater resources and their associated ecological and economic benefits. This has consequences on base flow – groundwater interactions, and degrades riverine habitats. Flood water spreading onto the floodplain improves soil fertility by depositing silt, exchanging nutrients and carbon between floodplain and channel, creating new habitants, and reinstating floodplain refuges and spawning areas for river species. Embankments reduce floodplain fertility because sediments and their nutrients are no longer deposited and exchanged.

Since embankments cannot guarantee absolute flood prevention, they can be designed to only provide a moderate level of protection. The degree of protection is generally driven by economic considerations. For example, it may be appropriate to protect agricultural lands against floods of one – in – ten- year return period and allow them to be inundated during higher floods, there by still maintaining the natural benefits of flooding (e.g. delivery of nutrient and organic rich sediments). Embankments that are designed for protecting urban and industrial areas need to be combined with bypass/diversion channels and/or detention/retention basins. There is a need to give due weight to the environmental impacts of construction of embankments, while making these design decisions.

Embankment spacing

When designing the alignment for new embankments, one should keep their likely adverse impacts in view. Particularly, efforts should be made to include floodplain water bodies such as ponds, wetlands, oxbow lakes etc., within the embankments, setting them as far apart and as far away from the main channel as feasible.

Typically, embankment result in steep-sided, trapezoidal, single channel cross-sections, rather than more natural multiple channels with gentle bank slopes and flat – lying floodplain surfaces. By reducing the area that can be flooded, and by maintaining a large proportion of the flow in the main channel with lower roughness, embankments decrease the travel times and increase flood peaks downstream. The high depth – to – with ratio of embanked channels makes them inherently unstable during high flows, requiring continuous maintenance.

Removing of setting back the embankments, in parts of the floodplains that are not intensively used for human development, can result in lower water levels and flow velocities, leading to lager in- channel storage and reducing flood peaks downstream. In certain situations where floodplains are used extensively for economic activities, this may not be a viable option. In such cases a possible option for partly restoring the river floodplain interaction is to set back the embankments, further from the main channel thereby partially re-establishing the lateral connection with floodplain wetlands and backwaters and restoring the river's ability to move about. This also reduces the velocity of the stream, results in lower flood stages, and restores, in part the natural functions of the floodplain including temporary flood storage. A river corridor is an enormously complex system, which cannot be fabricated. A comprehensive integrated approach is, therefore, required to undertake removal of embankments including land use planning. Magnitude, frequency and characteristics of flood, geographical setting and socio- economic background of the region have to be taken into account in any given situation.

Detention and retention

Detention and retention basins are natural depressions or excavations, which can be used for temporarily storing coastal flood water to reduce the excess water. Detention basins are similar to retention basins except for the fact that the latter do not have controlled outlets. Detention basins hold the water temporarily and then slowly release it through a natural or man-made drainage channel, while water collected within retention basins slowly percolates into the ground or evaporates. According to the topography, the type and size of detention and retention basins can be different. They can be brought into operation at the desired stage of a flood wave, enabling reduction in flood peaks downstream. Often, natural depressions are also used for agricultural purposes.

Non-structural measures

Structural measures can never completely eliminate the risk of coastal flooding. Nevertheless, because of their physical presence, they have the potential to create a false sense of security, leading to inappropriate land use in the protected areas. Following non-structural measures play an important role in reducing not only the catastrophic consequences of residual risks, but also adverse impacts on the environment.

Flood forecasting and warning

Land use regulations

Flood proofing

Emergency preparedness, response and recovery

No internationally accepted guide lines or standards for well cleaning after seawater flooding. The following guidelines describe the best practices for cleaning shallow open domestic wells after a saltwater flooding event.

• Facilitate provision of safe and contaminant-free water for drinking and other domestic purposes

• Minimize the potential for irreversible damage to the coastal aquifer2

• Minimize the potential for saltwater intrusion (drawing saltwater into the well)

• Minimize the collapse or destruction of the well

The guidelines also give precautions for use of water from saltwater-contaminated wells and for protecting the wells in the aftermath of the event (Figure 2.4). Simple three-step procedure to cleaning and rehabilitating of the saltwater-contaminated shallow open wells after floodwater flooding are given below.

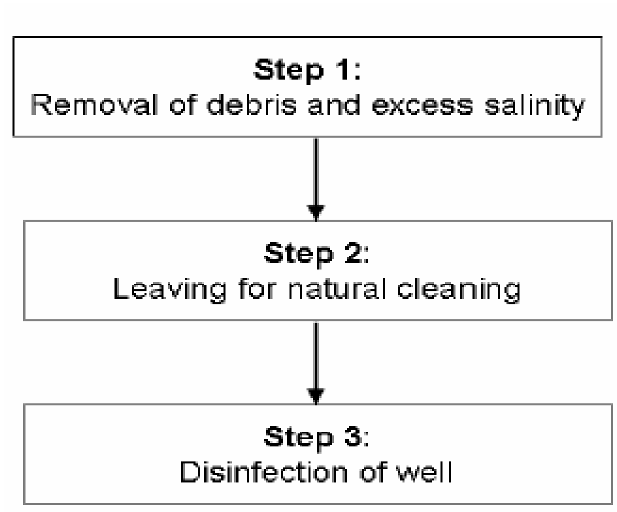


Figure 2.4 Step for cleaning a seawater flooding

2.10.2 COASTAL PROCESSES, COASTAL EROSION, CAUSES OF COASTAL EROSION AND COASTAL EROSION CONTROL METHODS

Professor Samantha Hettiarachchi and Professor Saman Samarawickrama

University of Moratuwa

SRI LANKA

COASTAL PROTECTION PLANNING IN THE CONTEXT OF COASTAL ZONE MANAGEMENT

Coastal zone management involves management, decision-making and programme design and implementation related to activities in the coastal zone, physical measures for coastal and flood protection and other associated coastal works. It also involves effective monitoring and control procedures to sustain multiple uses of the coastal zone without causing adverse impacts on the environment.

In engineering management of the coastal zone, the coastal stretch in often divided into, a number of coastal sections identified as 'coastal cells'. This division is based primarily on principal characteristics related to the coastal geomorphology, geophysical properties and coastal processes, also taking into consideration the nature and extent of the problems, economic values related to land use, the presence of existing protection works and administrative responsibilities.

Within the 'coastal cell' identified, coastal erosion and accretion can be understood, defined and explained in terms of the sediment balance (sediment budget) of that cell. It is clear that when the amount of sediment transported out of the area is larger than that transported into it, erosion takes place. Therefore, an understanding of the near shore sediment transport pattern is of primary importance in coastal erosion studies.

FACTORS OF IMPORTANCE FOR THE COASTAL PROCESSES

Physical phenomena such as winds and atmospheric pressure variations, waves and tides are the main factors of importance for the coastal processes. In addition Seiches, Tsunamis, Storm Surges, Shelf Waves, Inter-annual variability’s and the Global Sea Level Rise contribute to the coastal processes.

Wind

The wind and atmospheric pressure variations are responsible for generation of waves, wind set-up and surges as well as wind-generated currents. Furthermore, wind has a direct impact on the morphology of a coastal area through wind transport of sand on the beach and in the dunes.

The southwest monsoon is reckoned from May to September and the Northeast monsoon lasts from December to February. The period between February and May is the first inter-monsoon period and the period between September and December is the second inter-monsoon period. The regional wind system is influenced locally by the daily variation of sea to land and land to sea winds. It has been shown in some studies that the breeze affects the strength of the SW monsoonal winds without affecting the direction. However during NE monsoon period with rather weak average winds, a daily change of a sea to land wind (during the day) and land to sea wind can be established.

During the Southwest Monsoon Period the magnitude of the wind varies from 10-20 m/s and the main directions are from West and Southwest. During the North East Monsoon Period the magnitude varies from 10-15 m/s and the direction is from Northeast. Variable wind directions can be seen during two inter-monsoon periods having magnitudes of 5-15 m/s.

Waves

One distinguishes typically between short waves, which are waves with periods less than approximately 20 seconds, and long waves or long period oscillations, which are oscillations with periods between, say 30 seconds and 40 minutes. Water-level oscillations with periods or recurrence intervals larger than around 1 hour, such as astronomical tide and storm surge, are referred to as water-level variations. The short waves are wind waves and swell, whereas long waves are divided into harbour resonance, seiche and tsunamis.

The short waves are the single most important parameter in coastal morphology. Wave conditions vary considerably from site to site, depending mainly on the wind climate and on the type of water area. The short waves are divided into:

Wind waves (Sea waves): Generated and influenced by the local wind field. Winds waves are normally relatively steep (high and short) and are often both irregular and directional. Wind waves tend to be destructive for the coastal profile because they generate off-shore (as opposed to onshore) movement of sediments which results in a generally flat shore face and a steep foreshore.

Swell: Waves which have been generated by wind fields far away and have travelled long distances over deep water away from the wind field which generated the waves. Their direction of propagation is not necessarily the same as the local wind direction. Swell waves are often relatively long, of moderate height, regular and unidirectional. Swell waves tend to build up the coastal profile to a steep shore-face.

The average significant swell wave height during the southwest monsoon is 1.0 m and during the rest of the year is around 0.5 m (at a water depth of about 20 m). The average mean wave period is 10.5 seconds. The average significant sea wave height during the southwest monsoon is around 1.1 m (at a water depth of about 20 m). The average significant sea wave height during the northeast monsoon and the first inter-monsoon period (Mar-April) is around 0.5 m whereas during the second inter-monsoon period (Oct-Nov), the average height is 0.75 m. The average mean sea wave period is 5.5 seconds. These are based on the measurements carried out in Colombo.

Tides

The tides at the coast of Sri Lanka are mixed, predominantly semi diurnal tides with pronounced diurnal inequality. Tides are low with only marginal differences in the tidal constituents along the coast. Tidal range varies from 0.2 m (during the neap period) to 0.8 m (during the spring period). Tidal velocities are of the order of 5 cm/s. Storms may cause a limited set up on the narrow continental shelf, resulting in an additional rise of 0.3 m in extreme cases.

Currents

Tidal currents are formed by the gravity forces of the sun, the moon, and the other planets. These currents are of oscillatory nature with typical periods of around 12 or 24 hours, the so-called semi-diurnal and diurnal tidal currents. The tidal currents are strongest at large water depths away from the coastline and in straits where the current is forced into a narrow area.

The long shore current is the dominating current in the near shore zone. The long shore current is generated by the shore-parallel component of the stresses associated with the breaking process for obliquely incoming waves, the so-called radiation stresses, and by surplus water which is carried across the breaker-zone towards the coastline. This current has its maximum close to the breaker-line. The long shore current carries sediment along the shoreline, the so-called littoral drift; this mechanism will be discussed in the following section.

At certain intervals along the coastline, the long shore current will form a rip current. It is a local current directed away from the shore, bringing the surplus water carried over the bars in the breaking process, back into deep water.

SEDIMENT TRANSPORT PROCESSES

Sediment transport can be broadly classified into long shore and onshore/offshore transport. Long shore transport is also called littoral transport or littoral drift. When waves approach the shoreline obliquely, refraction will tend to turn the wave front towards being parallel to the shoreline. At the same time, when approaching the breaker zone, they will undergo shoaling which means that they will get steeper and higher. Finally, the waves will break. During the breaking process, the associated turbulence will cause some of the seabed sediments to be brought in to suspension. These suspended sediments, plus some of the sediments at the seabed, will thereafter be carried along the shoreline by the long shore current which has its maximum near the breaker-line.

The magnitude of the littoral transport of drift, Q, depends on parameters of which the most important are:

Wave Height: The littoral drift is proportional to the wave height to the power of approximately 3.

Grain Size: The littoral drift is inversely proportional to the grain size to the power of approximately 3.

Wave Incident Angle: The littoral drift is approximately proportional to Sin2.5 (2α), where α is the wave incident angle.

Figure 1 gives the variation of littoral transport with wave exposure and wave incident angle. As can be seen from the figure the protected coastlines with smaller wave heights have smaller sediment transport capacity. On the other hand the exposed coastlines with larger wave heights experiences high sediment transport capacity. In the case of wave direction; waves propagating with an angle of 45 degrees to the normal to the coastline give the maximum sediment transport capacity. Sediment transport capacity gradually reduces with the deviation of the angle from 45 degrees.

Varying wave conditions result in varying onshore and offshore transports over the coastal profile. These transports are to some extent reversible and therefore irrelevant in terms of long shore littoral drift.

When the coastal profile is exposed to high waves and storm surge, the sediments near the shoreline will be transported offshore and typically be deposited in a bar resulting in an overall flattening of the slope of the shore face (storm profile). However, the inner part of the shore face as well as the foreshore will get steeper in this process, and the shoreline will recede. During following periods of smaller waves, swell and normal water-level conditions, the bar will travel very slowly towards the coastline again, practically rebuilding the original coastal profile (swell profile). Figure 2.5 gives Storm and Swell Profiles of a coastline.

Figure 2.5 Strom and Swell profiles of a coast line

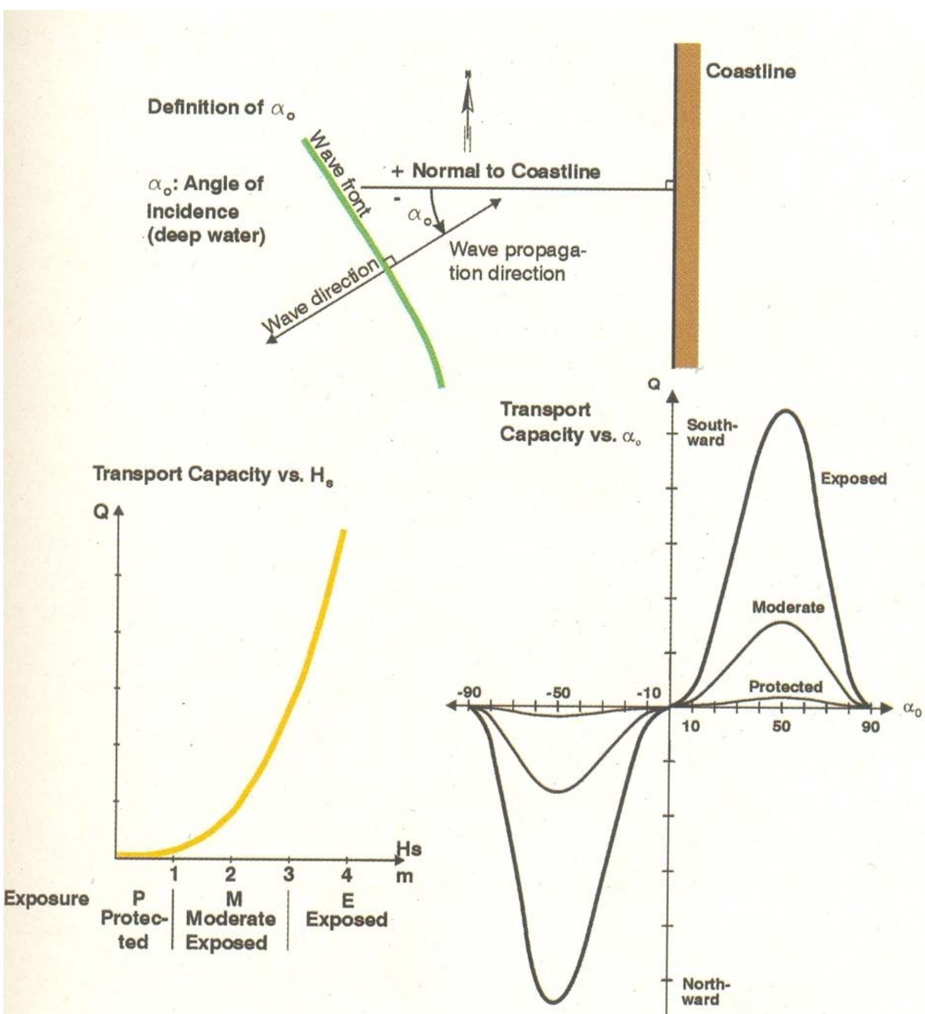
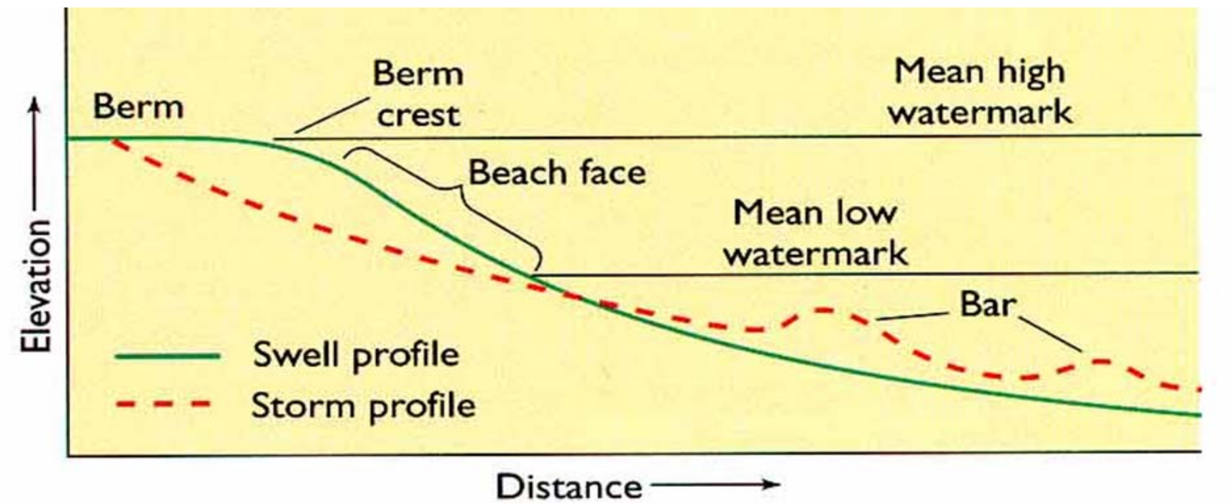


Figure 2.5.1: Variation of littoral transport with wave exposure and wave incident angle (After Shoreline Management Guidelines; Karsten Mangor, 2001)



integral part of an overall Coastal Zone Management Plan.

For an existing and projected scenario of coastal zone activities, the preparation and the implementation of a Coastal Zone Management Plan will ensure an orderly and balanced utilization of resources and maintain and, where possible, restore and enhance the environmental quality of the coastal zone. Within this framework it is necessary to prepare Coastal Protection Plans, which are coherent sets of measures, specified in time and space, to achieve a certain expected level of protection against existing or anticipated damage and of beach restoration, if appropriate. A project monitoring and control system is also incorporated as an important activity within this plan.

It is important to recognise that Coastal Protection Plans which form key elements of an overall Coastal Zone Management Plan have to be based upon Policy and Management Options which reflect the strategic approach for achieving long term stability. These options recognise the engineering interventions, which are required for sustaining multiple uses of the coastal zone. The identification of alternative coastal and flood protection measures in a Coastal Protect Plan is based on these options.

Policy and management options must be formulated preferably to function within the prevailing legal and institutional frameworks. However, if the need arises institutional improvements should be affected and new laws should be imposed. Commencing with clearly stated aims and objectives the overall strategy establishes guidelines on policy issues and then sets out appropriate response options, acknowledging both the natural processes and the constraints imposed by the guidelines. The policy options identify possible courses of action on shoreline, as,

Maintain existing line

Setback defence line

Retreat

Advance

The first option of maintaining the existing line applies to any existing line which is being defended and will generally be preferred whenever there is a substantial investment in infrastructure on the coast. On an eroding coast, the second option-set back - would be used to provide defences on the hinterland so that it is only necessary to defend against tidal inundation. This option can also allow natural features 'room to move' whilst retaining a level of defence against flooding. The third option - the retreat option - is a managed withdrawal, allowing the coast to return to its natural state and can be attractive where the tidal flood plain is relatively narrow. It would also apply where no defence is to be provided on a naturally eroding coast. Finally the fourth option, - the advance option - is included to provide for the possibility of limiting the exposure of low-lying areas by suitable reclamation or the use of tidal barriers. The choice of policy options is largely dependent on the infrastructure and the extent of the potential flood and erosion areas for any given length of coast.

In order to implement the policy options various management options are considered provided they are appropriate for the coastal classification, and can be summarized as:

Do nothing let nature take its course (preferably with a monitoring programme in force)

Reinstate beach nourishment (through sand pumping structural reconstruction etc)

Modify remove existing features or structures, structural alterations, beach stabilization etc.

Create embankments, linear protection, intervention (dredging, sand bypassing) etc

By defining Policy Options and Management Options for the entire coast, the basis of a strategic management plan is established. As actions based on this plan are undertaken, aspects of the coastal characteristics will be modified and this, in time, is likely to alter the coastal classification.

COASTAL PROTECTION METHODS

Background for and Classification of Coastal Protection Schemes

Various socio-economic reasons have led to human intervention in coastal systems, which can be classified broadly in two categories,

Active intervention in order to create new facilities such as harbours, land reclamation, artificial islands and beach development.

Passive intervention in order to protect existing assets against erosion and flooding such as shore protection and closing of inlets.

The background for a coastal protection scheme can normally be associated with one of the following categories.

Protection of a receding coastline endangering land and other assets.

Protection of low lying areas under natural protection of a beach barrier or dune system.

Control of undesired fluctuations of the coastal profile around tidal inlets and river estuaries.

Maintenance of coastal areas of recreational value, in particular, relating to tourism.

Specific protection around and in the vicinity of coastal installations such as harbours, cooling water intakes and marine highways.

Coastal protection schemes can be broadly divided into two categories namely,

Direct measures, which confront the problem. These measures prevent or alleviate the immediate effects of the problem. (Eg. protective structures)

Indirect measures to take away the cause of the problem such as preventing sand mining.

Direct measures, which include artificial nourishment, fields of groynes, artificial headlands, offshore breakwaters, armoured revetments and concrete seawalls are discussed later. Direct coastal protection measures which are part of a wider Coastal Zone Management Plan cannot take away the cause of coastal erosion but can contribute positively to reduce its negative effects to a very great extent. It is also noted that in the case of direct measures, with the exception of armoured revetments and seawalls most of the options can be classified as beach management or beach control schemes because their aim is to ensure the development of a healthy beach as a way of solving the problem of erosion.

It is emphasized that with respect to direct measures it is important to understand the near shore physical processes in the particular coastal region subjected to erosion and also the influence of adopted measures on neighbouring regions. It is extremely difficult to take materials out of the natural transport mechanism without contributing to new or increased erosion problems elsewhere. It is in this context that it is important that any major Coastal Protection Plan should form an integral part of an overall Coastal Management Plan which considers coastal erosion master planning.

As identified earlier there is a wide range of coastal protection works, which are used in practice to control a particular situation. Each of these works may perform a number of different functions and they will also have varying engineering life spans as well as different capital and maintenance costs. Depending on the situation it may also become necessary to adopt a combination of two methods for improved performance and efficiency. Such measures have already been implemented successfully on a global scale.

The standard Structural solution for the Coastal erosion control is given in the Module 4. They are includes:

Artificial nourishment

Field of groynes

Artificial headlands

Offshore breakwaters

Rock armoured revetments

Concrete armoured revetments

Concrete seawalls

In the above classification concrete seawalls refer to solid concrete seawalls as opposed to rubble mound revetments armoured with concrete armour units

More recently beach stabilization by reforestation has been adopted successfully. This method, which is to a great extent an extension of natural methods, is more effective in stabilization of dunes and prevention of erosion by wind are described in the following sections.

Artificial Nourishment

In artificial nourishment an external supply of sand is used to replenish an eroding stretch of a coast. This method may appear to be expensive and the need for repletion of the process may not attract coastal engineers to adopt this technique. However, careful planning and considerations of capital and maintenance cost have proved that this method can be used effectively, particularly when there is a need to preserve the recreational function of the beach without erecting structures at regular intervals. This method will not have structures interrupting the beach other than those used as terminal structures. Artificial nourishment is attractive when the long shore drift is comparatively small.

There is a need for maintenance in the form of recharging for which an economic source of sand supply is required. This method may not prove to be economically beneficial in the presence of severe wave climates which result in high rates of sediment transport. Beach nourishment schemes are generally considered the least objectionable of the coast protection methods from a view point of environmental impact as this method results in the substitution of beach material lost in the erosion process. Advanced and improved dredging techniques have greatly enhanced the viability of the application of these methods (Figure 2.6).

Figure 2.6 Artificial Nourishment of beaches

PRINCIPAL ELEMENTS OF A COASTAL PROTECTION PLAN

In preparing and implementing a Coastal Protection Plan the following steps are considered important,

Definition of coastal sections (coastal cells)

Identification of the issues and parameters essential to an overall Coastal Zone Management Plan

Assessment of the sediment budget for the coastal sections

Development of Policy and Management Options and the identification of coastal and flood protection measures

Assessment of measures and identification of alternative coastal and flood protection measures including cost-benefit analysis

Environmental impact assessment

Final evaluation

Definition of Coastal Sections (Coastal Cells) - It was identified that for coastal engineering purposes, a coastal stretch is often divided into a number of coastal sections and the basis on which this division is made was also discussed earlier.

Identification of issues and parameters relates to Coastal Characteristics and Usage, Coastal Forcing Parameters and Coastal Response Parameters as used in management frameworks. This permits the problem to be linked to or analysed within an overall Coastal Management Framework which would consider broader issues and parameters relating to the multiple uses of the coastal zone. Some of these aspects may not necessarily manifest themselves at an early stage but may have a considerable impact at a later stage. This also identifies the importance of analysing a problem in both local and broad physical contexts.

The assessment of the sediment budget is one of the most important steps because beach erosion/accretion is a direct result of the sediment budget deficit/surplus. As identified earlier, it may be necessary to adopt investigative techniques for its determination. This may include repetitive surveys, sediment modelling etc.

Policy and Management Options as described previously are considered next. A list of potential measures to alleviate or prevent coastal erosion and flooding is prepared based on these options. This may include, if required, measures which use a combination of protection methods, outlined previously.

An initial assessment of the measures is carried out in the form of a preliminary evaluation which is based on limited number of criteria such as technical feasibility, cost considerations and the degree of impact on the environment, in order to eliminate measures which are clearly inappropriate. Alternative coastal protection plan are then identified after detailed evaluation of the measures which survived the screening in the preliminary evaluation.

An Environment Impact Assessment (EIA) has to be carried out on alternative coastal protection plans in order to provide decision makers with the information required to evaluate the various plans. The EIA will necessarily involve a full specification of all relevant effects, including the impact on the environment, mitigatory measures, monitoring techniques and the overall benefit to society.

The final evaluation of the Coastal Protection Plan will be carried out by the decision makers on the advice of the coastal engineers and on the strength of evidence identified from the procedure described above. It will relate primarily to cost/benefit analysis - including those benefits which may not be definable in quantitative terms often using the 'do nothing', which carries obvious costs as the datum for comparison of options.

HYDRAULIC AND ENVIRONMENTAL INVESTIGATIONS

Design Issues

Coastal protection schemes often consist of large structures which have a significant impact on the environment both positive and negative. Since these are built as a long - term investment it is important to consider the environmental impact of such schemes in the same context. Increasingly these impacts are critically evaluated and hence it is necessary for the coastal engineer to ensure that coastal protection schemes are not only hydraulically and structurally efficient but also impose minimum adverse impact on the environment. It is therefore evident that in preparing and implementing a Coastal Protection Plan it is necessary to conduct detailed investigations in order to, support the engineering design and to assess the environmental impact of the overall protection plan.

It is recommended that environmental considerations be incorporated into the design process from its very inception. In this context it is advisable to conduct relevant environmental studies at project concept, planning and realisation stages. By doing so, it is possible to identify at an early stage major environmental constraints which may influence the project. This would enable the coastal engineer to take appropriate action at project concept or planning stages as opposed to at the project realisation stage.

In planning investigations for a coastal protection plan it is important to focus attention on the following issues;

The importance of the Sediment Budget

The role of coastal structures in coastal defence systems

The risks to current and potential development work

The sensitivity of the coastal environment to likely changes

The sediment budget needs to be analysed in detail because of the importance of the natural movement of sediment around the coastline in the form of drift in preserving natural coastal defence systems such as stable beaches, sand dunes and marshes. Such movements play a vital role in preserving recreation areas and sites of special interest.

Quantification of the sediment budget was initially achieved by using semi-empirical methods. However, recent developments in mathematical modelling and new data acquisition methods of near shore regions have led to the availability of advanced littoral drift models and on/offshore sediment transport models both of which have contributed towards improving calculations relating to the sediment budget. In this context it is important to conduct bathymetric and shoreline surveys at regular intervals.

Computations of the alongshore and onshore/offshore sediment transport rate can provide valuable information of the local balance or otherwise in the sediment budget. For example, it may reveal the reason for erosion for the following cases, either separately or in combination.

Sediment transport into the cell at one end is less than that which leaves out at the other end, due to a variation in wave climate along the shoreline,

Sediment is being lost offshore since water depths immediately offshore are deep and thus the beach slope is too steep to reach equilibrium in a storm,

The sediment budget is balanced by coast erosion at the site. Prevention of this by constructing a coast protection structure may well transfer the problem to another location and/or enhances the coastal erosion in the vicinity of the new structure.

Depending on the nature of the problem, the complexity of associated physical processes and the available information it is possible to adopt one of two approaches in understanding coastal erosion problems. The first approach is based on experience only, where by if the problem is similar to projects which have been implemented in the past, results from case studies of similar situations are used effectively in providing an appropriate solution. This approach necessarily requires the use of conceptual models which are considered valid for different situations. It is emphasized that care must be exercised in the application of conceptual models and in the interpretation of results from case studies of similar situations. A clear understanding of the individual case studies and of the different parameters used in their. Interpretation is required for this purpose. The second approach, if no acceptable standard solutions are available, is to model the problem by the use of physical models (scale models) or mathematical models. There have been major advances in the use of mathematical models on recent past.

The primary function of a coastal and flood defence structure is to defend the coast fr9m the action of the sea by preventing erosion and flooding. It is important to appreciate that such a structure is only one element, within the coastal defence system. Another important element is the beach itself. While some forms of defence structures may not contribute positively to preserve a good beach, their performance benefits immensely by being located behind a good beach. Fields of groynes and offshore breakwaters assist in preserving or restoring a healthy beach.

In meeting the demand of defending the coast against erosion and flooding it is not only important to ensure that the structure has sufficient strength and durability to withstand the hostile marine environment but also that the design is based on a clear understanding of how the beach will behave and, in particular, on the complex interaction between the structure and the beach. This arises due to the sensitivity of the beach to any form of change resulting from the structure and the significant impact which, this in turn would have on the structure itself as well as on the sediment budget. This sensitivity is not only confined to coastal processes but extends to the coastal environment as a whole.

The basis on which the design of defence structures is carried out is to assess possible modes of failure and to design against them. It is now common practice to adopt a 'fault tree' approach to identify possible modes of failure. Such an approach gives due consideration to all components of the structure, in terms of their relevance to its overall integrity.

The major impact that coastal defence structures have on the coastline is very much influenced by the degree of interference with the natural coastal processes that are taking place. It must be accepted that the protection of a particular stretch of coastline from erosion may well deprive the local and adjacent beach system of some of its natural sediment supply. Given that natural processes will necessarily contribute to the re-establishment of some form of dynamic equilibrium, that deficit in supply is accounted for by removal of material from elsewhere. This situation can also be worsened by the introduction of structures which reflect wave energy instead of absorbing as a natural beach does, thus leading to further problems.

Coastal defence structures must be carefully designed to ensure that the design objectives are achieved while maintaining a high hydraulic efficiency in the long term at reduced maintenance costs. Hard defence systems of any kind have the potential of contributing to their own failure. The high magnitude of wave reflection of the seaward face generates turbulence leading to erosion of beach material thus undermining its stability. A high degree of reflection of the incident waves can be considerable damage to the beach. It is due to these types of complex interactions that it is necessary to conduct detailed investigations prior to the implementation of a coast protection plan. The investigations usually consist of field studies and the application of physical and numerical models with the latter gaining increased popularity in recent years. Two-dimensional physical model studies are useful to assess modes of failure.

The assessment of risks, with and without coastal protection, to current and potential development work and to specific uses of land, is important. Attentions to be focused on the extent to which these risks may be minimised and to identify whether emergency measures could be conveniently adopted if and when an extreme event takes' place. Examination of levels of risk is required to identify priorities for such action.

It is now established that while due attention should be focused on the design of individual coastal structures and their impact to any form of change, it is equally important to assess the overall hydraulic performance of the coastal defence system as a whole and its impact on the environment.

Types of Investigations

The types of investigations, which are associated with the planning, design and construction and the environmental impact' assessment of a coastal protection plan are:

Determination of the wave climate (which is sometimes based on hind casting from winds), currents, tides, extreme water levels, transformation of waves as they approach the shoreline and if required the joint probability of these events. In the current context a considerable amount of mathematical modelling is used to study these processes, using data acquired through a well planned data acquisition programme.

Study of historic information from all sources available to assess trends and rates of erosion and accretion. Aerial photographs and the results of regular survey programmes are good sources of information

Estimate by measurement and/or prediction the movement of sediment on the beach and in the near shore zone, leading to the assessment of the sediment budget.

Determination of the influence of coastal works present in the neighbouring coastal stretches and predicting further trends.

Preparation of an initial environmental profile with regard to all of the uses of the shoreline and the overall coastal eco-system.

Identification of different types of coastal protection schemes that would provide possible solution with due consideration to available construction materials, methods and costs.

Assessment of the environmental impact of these schemes including the impact of the proposed works may have on both the local and regional regime and in general on the environment.

Evaluation of the level of service that is required from any protection schemes for alternative options against technical acceptance, capital and maintenance costs, overall benefit to society and environmental impact.

Evaluation of mitigatory measures and the associated monitoring techniques to alleviate undesirable impacts of the coastal works.

Recent advances in coastal hydrodynamics, coastal structures and numerical modelling have enabled the coastal engineer to obtain a clearer understanding of coastal processes, propagation of waves into shallow waters and the mechanics of wave-structure interaction. These developments, combined with extensive field studies, have led to the implementation of innovative schemes moving away where possible, from the traditional hard solution of sea walls or revetments.

REGULATORY MECHANISM

The CCD has in the past relied heavily on the regulatory framework of the Coast Conservation Act No: 57 of 1981 for managing the activities within the coastal zone. This is reflected in the CZMP's of 1990 and 1997. However, based on the policy guidelines as set out in the "Coastal 2000: A Resource Management Strategy for Sri Lanka's Coastal Region" the coastal zone management process in more recent years has seen a progressively increasing trend in adopting other management strategies such as obtaining greater community participation particularly through Special Area Management, interagency co-ordination, monitoring and research, and education and awareness on coastal zone management issues. Despite this trend, the enforcement of regulations continues to be an important tool by which the CCD ensures the health and the integrity of the coastal environment and its applicability in managing the activities in the coastal zone.

The regulatory mechanism pertaining to the Coastal Zone includes the following:

Implementation of a Permit system

Prohibition of activities

Designation of setback standards, variances and exemptions

Development restrictions

Compliance monitoring

Removal of unauthorized structures

Delegation of powers

Provision of guidelines and standards for specified activities

Requirement of Environmental Impact Assessment (EIA) and Initial Environmental Examination (lEE)

Designation of setback standards, variations and exemptions which is directly link to the coastal erosion is discussed in detail here.

A Setback Area is a geographical strip or band within the Coastal Zone within which certain development activities are prohibited or significantly restricted. The entire set back band is divided into segments viz. the Reservation Area and the Restricted Area lying between the Seaward Reference Line and the Landward Reference Line of the particular coastal segment (Figure 2.11).

The Seaward Reference Line is generally the plus 0.6 m line from the mean sea level (MSL). However, the CCD reserves the right to demarcate setbacks from the permanent vegetation line on the beach front where Coconut (Cocos nucifera), Maharawana ravula (Spinifex littoreus), Wetakeiya (Pandanus spp), or Mudilla (Barringtonia speciosa) are present, or in the absence of a permanent vegetation line, the Mean High Water Line (MHWL), an appropriate contour line above MSL, the landward toe of the dunes or the seaward edge of the top of the cliff will be considered to be the Seaward Reference Line. The Landward Reference line will generally be the landward boundary line of the Setback Area, if not stated otherwise.

Figure 2.7 Relative locations of set-back areas within the coastal zone

(After Coastal Zone Management Plan, 2004)

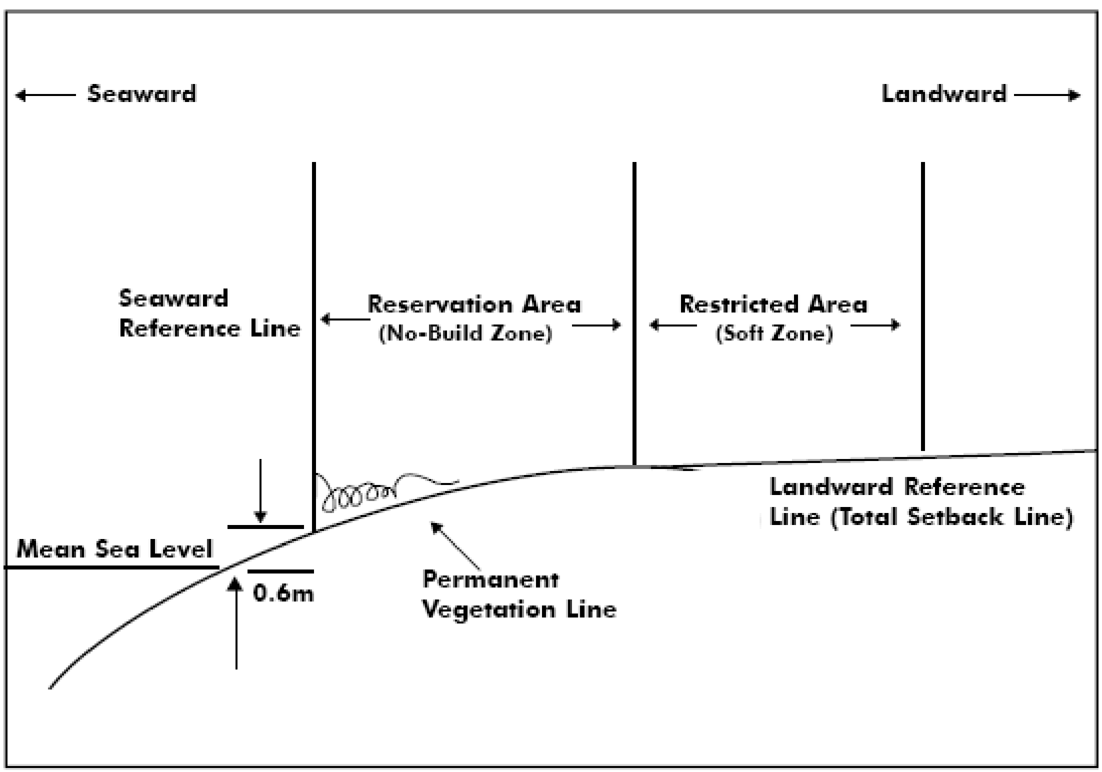


Figure 2.7 : Coastal set-back

Reservation Area is nearest to the shoreline and corresponds to a "no build zone" in which only uses/ activities which are absolutely essential are allowed, and a Restricted Area (or soft zone) can be used for a few low impact activities such as small dwelling units. The width of the Reservation Area and the Restricted Area will vary according to the vulnerability of the particular coastal segment to erosion.

The entire setback band of the country is divided into 99 segments with varying lengths and each segment is given a number from 1-99. The segments have been rated to convey coastal vulnerability to erosion (Table 2.3): "low" indicates those least vulnerable; "medium" represents those with moderate vulnerability while "high" indicates greater vulnerability (requiring broader setbacks). In determining "vulnerability", factors such as the current development densities, availability of free space and exposure to extreme natural events have been duly considered. Based on these, a lesser set back distance has been assigned in respect of coastal segments 1- 53 whereas in the segments 54-99 a broader set back has been assigned. Protected areas have setbacks as far landward as 300 m.

Table 2.3 Coastal Set-backs due to vulnerability

Level of Vulnerability	Coastal Segment Nos. 1-40		
	Reservation Area	Restricted Area	Total Setback
Low (-)	10	25	35
Low (+)	15	25	40
Medium (-)	15	30	45
Medium (+)	20	30	50
High (-)	20	35	55
High (+)	25	35	60
Protected Areas			300

Western Coastline

Level of Vulnerability	Coastal Segment Nos. 41-70		
	Reservation Area	Restricted Area	Total Setback
Low (-)	20	30	50
Low (+)	25	40	65

Medium (-)	30	50	80
Medium (+)	35	60	95
High (-)	40	70	110
High (+)	45	80	125
Protected Areas			300

Eastern Coastline

Table 2.3: Classification of Coastal Segments by Level of Vulnerability and Setback Distances (in meters)

Whilst it is good management practice to leave the restricted area free from any development activity, this may not always be socially acceptable in view of the already existing land use patterns, very high population densities and the small land parcel sizes within the coastal zone. Hence a less stringent management strategy will be required. While commercial structures of any kind will not be permitted, constructions within the restricted area will be limited to dwellings only, provided however that such dwellings do not restrict vertical and lateral access to the beach and meet the criteria laid down in the coastal zone management plan.

Setback exemption implies a significant deviation from the intent of the setback guidelines stipulated in this Plan. Exemptions will only be granted if public interest warrants it.

Setback variance implies a relatively minor deviation from the intent of the setback guidelines stipulated in this plan. Unlike in the case of an exemption, private interests may seek set back variations. However they may be granted only if the criteria laid down in the plan are met.

GLOBAL WARMING AND SEA LEVEL RISE

Against the above background Sri Lanka also faces the challenges of possible impacts of global climate change and sea level rise over the next few decades leading to the aggravation of existing environmental pressures. Global warming is expected to lead to a rise in sea level, higher temperatures, more frequent and prolonged droughts, high intensity rainfall and increased thunder activity. When assessing the impacts of global sea level rise on coastal regions, it is important to identify and understand the connectivity of these inter-related issues, all emerging as a result of global warming. It is also important to recognize the global, regional and local scales of impacts as it would be the resultant that would finally affect a given environment.

Sea level rise on its own would lead to

Inundation and displacement of low lying coastal areas and wetlands

Erosion and degradation of shorelines

Salinisation of estuaries and freshwater aquifers

Varying impacts on coastal habitats

A rise of the mean sea level will also lead to increased wave height thereby disturbing equilibrium beaches and making them more prone to erosion and interfering with existing long shore sediment transport rates and distribution. In addition, the combined effects of an increased mean sea level rise and increased wave heights would result in further impacts such as undermining the stability of coastal structures, and the altering of circulation patterns inside coastal embayment and estuaries. It is also recognized that a change in climate due to global warming would contribute to the changes in frequency and intensity of extreme events such as increased coastal flooding, thereby further complicating the analysis of overall impacts.

Some of the impacts of climate change and sea level rise on the coastal zone which have to be given consideration are,

Inundation of low lying areas, including coastal settlements and coastal wetlands

Coastal erosion

Flooding and storm damage

Quality of surface and groundwater leading to salinisation of estuaries and freshwater aquifers

Degradation of marine ecosystems – coral reefs

Changes in the hydraulic force regimes of sea defence structures and breakwaters leading to greater vulnerability to impacts of increased erosion and extreme events.

Climate change and sea level rise will also impose severe impacts on the Fishery industry and the Tourist industry. Impacts of sea level rise will have to be considered in the planning and design of land based infrastructure and land reclamation in near shore regions.

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2.10.3 Impacts of Lightning and Thunder to the Coastal Communities and their livelihoods

K. R. Abhayasingha, Managing Director, Krab Lightning Protection Solutions

Introduction

Lightning

Lightning is the discharge Static electric charges of Cumulonimbus clouds

Lightning is generated mostly in Cumulonimbus clouds. A well developed cumulonimbus cloud is electrically charged and the electro-static charges are distributed in the cloud so that the negative charges are concentrated in the lower part of the cloud and positive charges over the upper part. Under the influence of a charged cloud, the earth surface below the of electricity from a thunder cloud, technically named ‘Cumulonimbus’.

Cloud is positively charged by induction. Under the favourable conditions, electrical discharges occur from a charge centre in a cloud either to the induced charge on the earth, or to charge centres of another cloud or to a charge centre of the same cloud. Accordingly, lightning may be categorized mainly into two types –

Ground Flash – Discharge between a cloud and the earth

Cloud Flash– Discharge within a cloud or between clouds

Ground Flash

In a Ground flash, the electrical discharge usually occurs between the negative charge of the cloud and the induced positive charge on the ground or structures on the ground. (Figure 2.8)

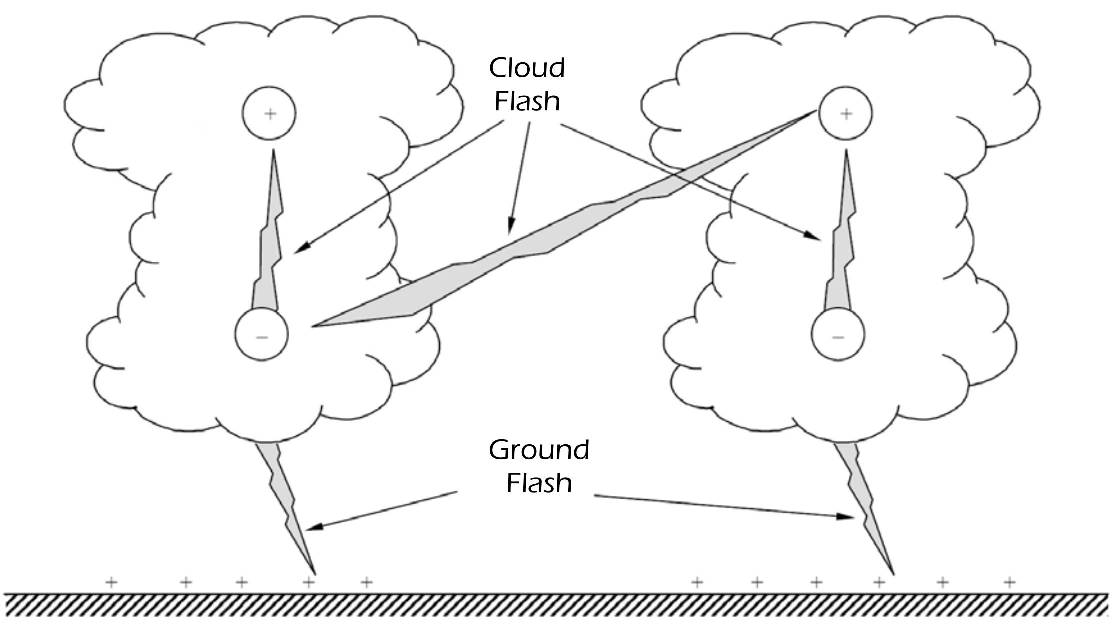


Figure 2.8 Ground flash

The magnitude of electric current associated with a ground lightning flash could range from 3,000 – 200,000 amperes with an average of about 25000 Amperes (25000 A or 25 kA) and the potential difference between a charged cloud and the earth is about 100 million Volts (108 V). The energy of a lightning flash bringing 5 coulombs to ground is about 500 million Joules. It is this sudden discharge of an extremely large current and the voltages it induces that cause the damage by lightning.

Thunder

Thunder is the acoustic wave resulted by the sudden expansion of the air within and around the path of a lightning flash.

The power of a ground flash heats up the air along the path of the flash to high temperatures like 6000 Celsius or more in a short duration of the order of 20 ms (a ms = 0.001 second). This sudden heating causes sudden expansion of the heated up air which will produce a vibration wave. During it’s travelling the vibration wave converts into a sound or acoustic wave which we can hear and it is called thunder.

Thunder day

The historical meteorological observations of weather parameters in Sri Lanka do not have instrumental observations of lightning activity covering a significantly long periods to be considered for statistical analysis. Hence the parameter ‘Thunder day”’ is used in estimating the frequencies of lightning activity in a particular area.

Thunder day is defined as ‘A calendar day during which thunder is heard at a given location’. The international definition of lightning activity is given as the number of thunder days per year (also called ‘isoceraunic level’ or ‘ceraunic level’)

Annual thunder days at meteorological stations located in coastal areas in Sri Lanka are shown in the table 1. (SLSI standard). Please note that the calculation of Annual thunder days has been based on thunder activity observed in 30-year period 1970-1999 considering only the peak months of the year March, April, October and November.

Thunderstorm

The stormy weather system accompanied by lightning and thunder is a ‘Thunderstorm’.

Table 2.4

Thunder days over Sri Lanka

Meteorological Stations (1)	Average Thunder days per year 91970 – 1999) (2)	Average Thunder days per year normalized from thunder activity in four peak months of the year (3)
Anuradhapura	71	132
Badulla	91	129
Bandarawela	114	174
Batticaloa	68	84
Colombo	99	159
Galle	64	105
Hambantota	52	96
Katigastota	95	168
Katunayake	87	147
Kurunegala	75	138
MI	60	114
Mannar	45	90
N Eliya	67	102
Pottuvil	27	36
Puttalam	62	120
Ratmalana	102	165
R Pura	105	162
Trinco	66	84
Vavuniya	59	99
Jaffna	29	51
KKS	38	60

Hazards of thunderstorms in Sri Lanka

Hazards of Lightning

Lightning is a natural phenomenon that has the potential of causing serious damage to both life and property over many parts of the world. Incidents of lightning normally tend to be more frequent in particular areas but could occur anywhere. On an average, the annual number of deaths to persons is around 50 per year in Sri Lanka. Property of millions of rupees are damaged or destroyed by lightning every year.

In recent years there has been an increase in damage to buildings and structures caused by lightning, due to the high buildings being constructed in vulnerable locations and also the installation of antennas of communication equipment on buildings without concern about the protective measures against lightning. The extensive use of electrical and electronic equipment without appropriate protective devices has contributed to the increase in incidents of injury/damage caused by lightning. Man’s exposure to the environment in vulnerable times in vulnerable locations has also contributed a lot to rise in lightning hazards.

Hazards of thunder

Thunder is not hazardous as lightning but it may result in property damage and injuries to hearing system of man and animal when it happens at close locations.

Vulnerable areas/ locations with frequent lightning hazards

The vulnerability of an area against lightning depends on the geographical features, topography and characteristics of lightning in that particular area. Among the features/characteristics that enhance the lightning hazards at a place, following are most important.

In open areas, any object is vulnerable to lightning. Height and electrical conductivity are the two main characteristics of the objects that decide the vulnerability.

In hilly or mountainous regions, a building at the higher elevations is usually more prone to damage by lightning than that located in a valley or sheltered area.

There is a greater probability of direct lightning strikes to buildings in areas with higher frequency of ground flashes than in areas with lower frequency

Elevated lands adjoining a flat, significantly large, extensive area are vulnerable. Locations close to the boundary between elevated and flat grounds are the most vulnerable.

Vulnerability of coastal regions to thunderstorms /lightning

As discussed in paragraph 2.3, the coastal areas are vulnerable to lightning particularly because majority of such grounds of any country are open spaces than those in interior lands and also the coasts (beach) and coastal lands are boundaries between elevated land blocks and the flat, extensive sea surface. The lightning generated by thunder clouds over sea near the coast are likely to be attracted by the elevated land, objects and the buildings in the coastal belt.

Industrial and densely populated coastal areas are more vulnerable to lightning as many protruding objects are available and more humans are exposed to the environment than in an unpopulated coastal area.

Historical examples

In the recent history, a number of lightning hazards in coastal parts were reported in media including,

1. Mr.Nalin Dilip Pereera (27) of Palangatura, Kochchikade, Negambo was killed on 17 April 2008 at 6.30pm when exercising on beach garden (werala udyanaya), Lankadeepa on 22.4.2008 and

2 Mr.J.A.Prasanna (23) of Medakatukenda was killed by lightning when fishing in Ginganga. Two injured youths were admitted to Marawila, Wennappuwa hospital. Lankadeepa 28.10.2006

Modes of lightning Strikes

Lightning can reach a person or an object by one of the following five ways.

- Direct Strikes
- Side Flash
- Contact Potential
- Step Voltage
- Surge Propagation

Direct Strikes

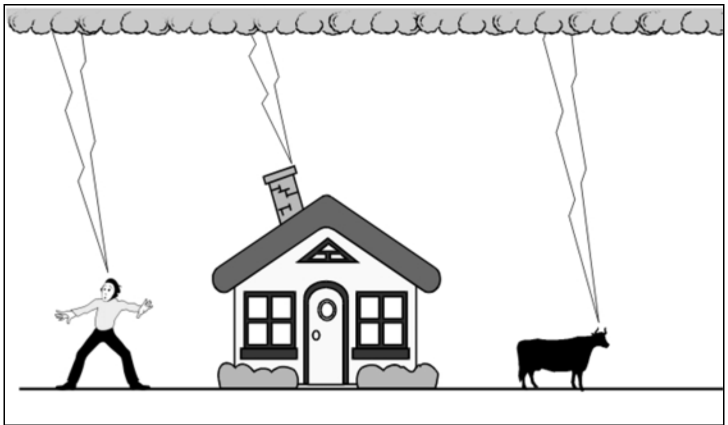
When a person or object is struck directly by a lightning stroke it is a Direct Strike. This is the source of the most significant damage by lightning (Figure 2. 9)

Side Flash

This is when a person or object is close to an object struck by lightning, the lightning current travels down the object and may jump across the gap to the person. A side flash may occur even from a lightning conductor (the copper strip conducting the current to earth) when the current jumps across to a person or object close to the conductor (Figure 2. 10)

Contact or Contact Potential

When a person stays in physical contact with an object struck by lightning, for example, leaning against a tree, the lightning current is diverted into the person at the contact point. This is because the resistance to the current of the tree or such object to earth is generally higher than the path through a person (Figure 2.11)



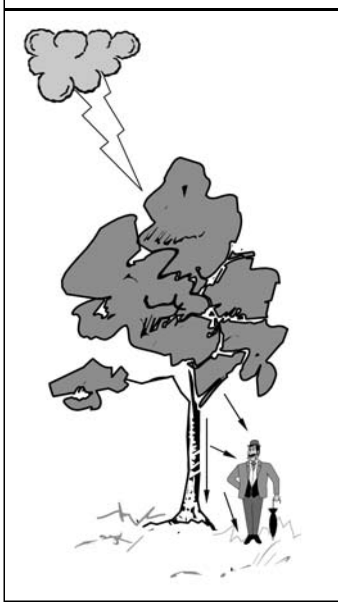


Figure 2.9 Direct Strike

Figure 2.10 Side Flash

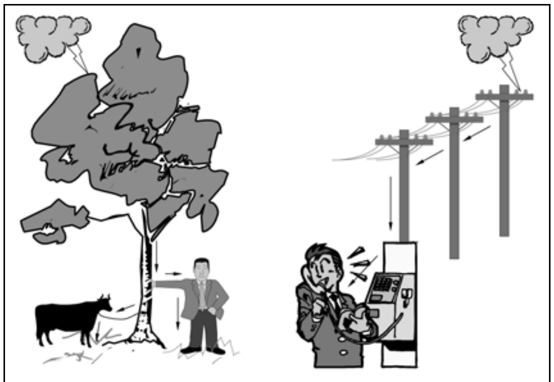


Figure 2.11 Contact or Contact Potential

Figure 2.12 Step Voltage

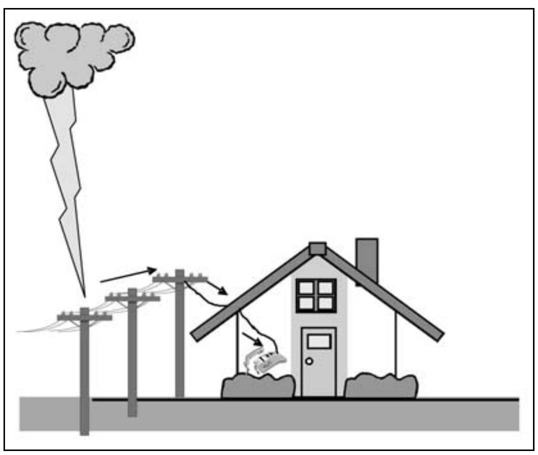


Figure 2.13 Surge Propagation

Step Voltage

This occurs when a person contacts the ground with several parts of his body. When the lightning strikes the ground some distance from him, the lightning current disperses on the ground surface, part of it enters him through the body part nearest the struck point, and leaves again from the part of body distant from the struck point. For example, for a person standing with his feet apart, a current path can be established up one leg and down the other. This is often how animals are killed or injured by lightning (Figure 2.12)

Surge Propagation

When lightning strikes a power or communication networks either directly or indirectly, it causes a voltage surge to be created in the network. This surge travels down the line causing a voltage surge to strike persons staying close to or in touch with electrical apparatus or appliances. Equipment and apparatus (not properly protected) are also frequently damaged by surges caused by lightning. This also may be the cause of fires. (Figure 2.13)

Lightning Activity over Sri Lanka

The incidents of lightning in Sri Lanka peak during certain times of the year (Figure2.17) and also there is a tendency for the occurrence of lightning to be more prevalent in particular parts of the country (Figure 4).

The peaks of lightning activity are during,

March –May First Inter Monsoon and initial part of the South West Monsoon seasons

September – December Second Inter Monsoon and initial part of North East Monsoon season

Lightning activity in any location of the world shows significant variations in the time frame. But the annual thunder days of a particular year may not have a significant deviation from the 30-year average.

Even though the values shown in column 3 of Table 2.4 may not be exactly valid for current situation, they are good enough to represent the general situation regarding the lightning activity over the coastal areas around Sri Lanka.

The lightning seems to be a natural hazard over all coastal areas with high probability in parts along western and south western coasts from Puttalam to Galle. The figure 2.14 is given details of thunders in each month of the coastal areas and Figure2.15 is giving thunder days contours in Sri Lanka. According to the figures the most prominent thunder and lightning month is the April and high probability parts in Sri Lanka is Western and Sothern parts.

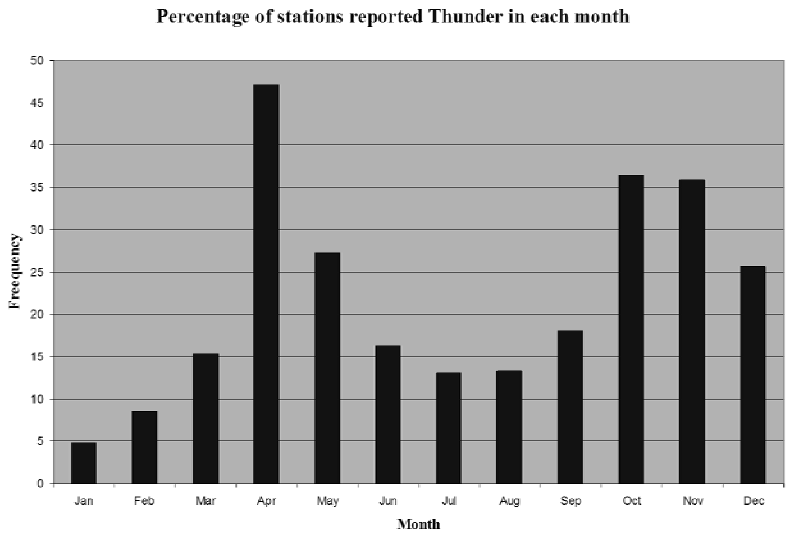


Figure 2.14 Percentage of Stations reported Thunder in each month

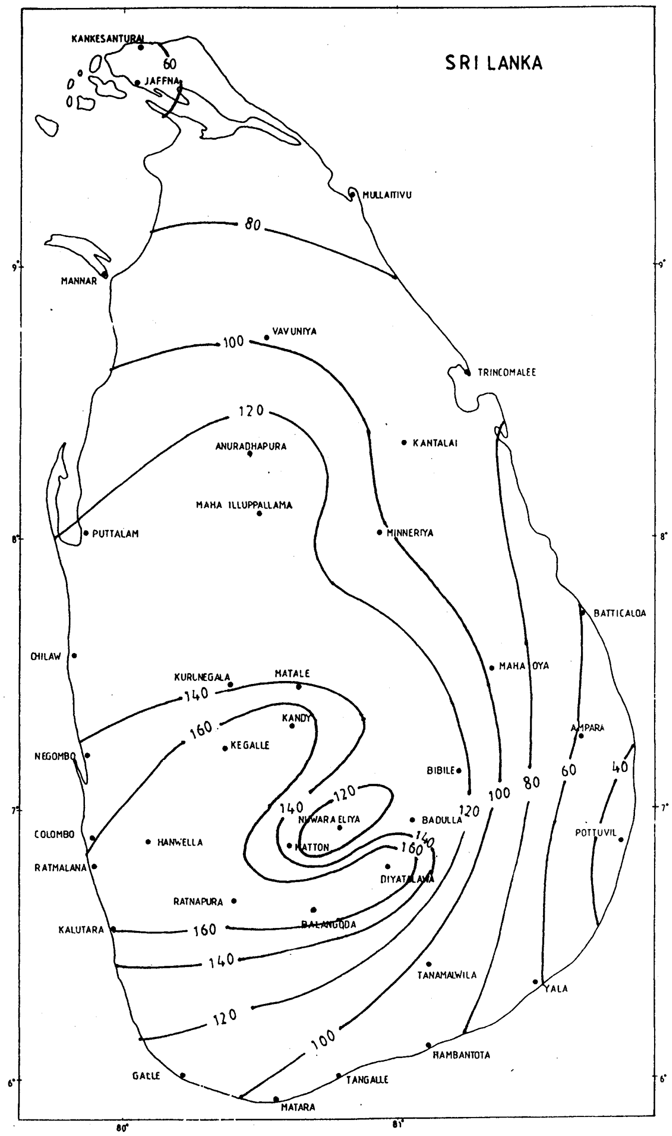


Figure 2.15 Thunder Days Contours

Protection Against lightning

Even though lightning is a natural phenomenon, it is a natural hazard as it causes death and property damages both indoors and outdoors. A number of precautionary steps have to be organized in order to manage the lightning disasters. Being in outdoors is more vulnerable to lightning than indoors. But the structures and houses used for the purpose of inhabit must have been protected against lightning for them to be regarded as safe locations during thunderstorms.

a. Protection of Buildings from Lightning Strikes

It is important to locate and design buildings and structures, particularly in lightning prone areas, incorporating features and devices that reduce the potential for damage by lightning strikes.

When planning and designing more substantial buildings and structures in such areas, professional advice should be sought on measures devices to be incorporated to reduce the potential for damage. Such measures should be cost effective and be planned and built into the structures right from the basic steps of the design.

The protection of buildings from lightning strikes and measures to mitigate the effects of such strikes require very careful study of the intended use of the building, the type of equipment to be installed and used in it, its location with respect to frequency of lightning strikes and the vulnerability of the location.

Structural Solutions for the Lightning and Technology used for protection of buildings are explaining in the Module 4.

Other Protective Measures

Protection of Electrical Equipment

Most household electrical items such as Televisions, Radio receivers, computers, electric iron, Refrigerators etc could be protected from voltage fluctuations by the installation of appropriately rated voltage stabilizers.

However, if the building is not properly protected against direct and indirect effects of lightning, the most effective means of protecting all electrical equipment from damage by lightning is by disconnecting i.e. removing the plug from the wall socket during thunderstorms. Merely switching off the equipment will not protect the equipment from damage by lightning.

Authority and standards in Lightning Protection

Lightning protection systems should be installed or fitted with the support and advice of experts in the field. There are institutes registered as LPS providers. It is important to note that the installation of a LPS should be performed according to the accepted standards such as SLSI 1261-2004.

All the lightning protection systems should be installed to the accepted standards. Code of practice (SLS No.1261-2004) for lightning protection systems has been prepared by the Sri Lanka Standard Institute, SLSI. In absence of local standards, information pertaining to assessment of the need for protection, specifications of material to be used and other relevant information for the design and installation of lightning protection systems standards developed in other countries can be referred (BS 6651, AS 1768-1991 and NZS/AS 1768-1991)

General Precautions against Lightning

During a thunderstorm, lightning can have disastrous influences in many ways. Some of them may end up with death. Lightning causes more casualties in open locations than inside structures. But the man made structures have been constructed or installed in all kind of locations disregarding the lightning characteristics of relevant locations. With some modern technical facilities used in buildings the vulnerability of attracting lightning or invading the surges seem to have enhanced. Special alert has become necessary for the protection of life and property.

In cases where houses and buildings are not properly protected against lightning, precautions should be taken to avoid lightning surges approaching the equipment and the vicinity of them. It is stressed that most of the suggested precautionary steps can be ignored if the relevant location/building has been properly and technically protected against lightning.

A few precautionary steps to be considered in order to reduce effects of lightning are given below. These precautions are mainly three types since the precautionary steps for protection life and property should be taken before, during and after thunderstorms.

Before thunderstorm

precautions

This includes all the technical precautionary steps discussed in 5.1in relation with the protection of buildings and structures, particularly the buildings with inhabitants. Installation of LPS takes time and therefore such installation should be well planned and performed in time.

General practices

a Avoid any conducting connection (like wires) between buildings and the close-by-trees. The cloth-line wire and the wire used as supports to old and weak trees are two hazardous examples.

b. Take care to keep clearance of at least two meters between the buildings and nearby structures or trees.

During thunderstorms

Electrical Equipment

*. Keep electrical instruments disconnected from the main power supply.

*. Television antennas should be disconnected from the television sets and the antenna socket should be placed close to the earth outside the house. Best precaution is connecting the antenna to an earthed conductor.

*. As far as possible avoid handling / touching electrical instruments like refrigerator, electric iron, electric kettle, phone chargers, metal frame, TV and radio.

*. Avoid touching or standing close to tall metal structures, wire fences and metal clothes lines.

*. Limit the use of cable telephones when a thunderstorm is very close or overhead. Best advice is not to touch the telephone in such instances.

General precautionary steps

* Find shelter in a safe place to avoid exposing yourself in the open (beach or coastal water). If the time interval between lightning flash and hearing thunder becomes less than 15 seconds, move quickly to a protected location, as there is immediate danger of a lightning strike nearby.

*. Avoid being in open areas. Specially avoid working in open air holding metal tools like mammoty, knife and iron rods.

* If you are exposed in an open area, crouch down, singly, with feet together. By sitting down, reduce the effective height of the body. Footwear or a layer of any non-absorbing material, such as plastic sheet, will offer some protection against ground currents.

* Do not seek shelter under or near isolated tall trees and in high grounds. If the vicinity of a tree cannot be avoided, seek a position just beyond the spread of the foliage.

*. If in an open boat, keep a low profile. Additional protection is gained by anchoring under relatively high objects such as jetties and bridges, provided that no direct contact is made with them.

* Avoid riding horses or bicycles, or riding in any open vehicle such as a tractor.

*. Avoid swimming or wading.

Life of a thundercloud is short as 30 minutes. As a result, fatal lightning occurs during a very short period like 10-20 minutes. If we are careful to take necessary precautionary steps during that period it is obvious that the lightning hazards can be reduced. It should be stressed that the first lightning flash and the flash following a short break of activity cause most of severe damage to life.

After thunderstorms

After thunderstorms, particularly after a lightning incident, immediate steps should be taken to save the life of people affected by direct and indirect effects of lightning surges.

First aid

Lightning hazards are not always fatal. The state of the damage depends on the path of the lightning discharge through the body and the intensity of the current. In case of lightning strikes to persons, first aid should be given to the injured before taking him for medical treatment.

Body should be massaged to treat in case of temporary paralysis due to lightning strikes. If respiration is disturbed, artificial respiration should be tried. This could be done by blowing air into the patient’s body through his mouth. In many cases, massage and artificial respiration have to be given simultaneously.

There is no danger in touching, holding or carrying a person struck by lightning. However, before moving the inured person, ensure no live electrical wires are in contact with the injured person and also that he has not suffered any fractures or other serious injuries due to say a fall following the lightning strike.

Hazards by lightning cannot be perfectly predicted in advance. Therefore people living in vulnerable areas must be keen to take all precautions against lightning instantly if they feel that the lightning occurs in the vicinity. Also people should have the basic understanding of giving first aid to a lightning victim. The trained personnel in this field are very much helpful in lightning incidents. Awareness programs on first aid at community level would highly capable of training public in the field.

Medical Treatments

The injuries occurred in many way are very common in lightning incidents. Injuries may be resulted by burns and falling in lightning strikes and injuries of hearing systems by thunder. Injuries are also caused by collision of fast moving objects in bursts of electrical/electronic equipments and any part of the buildings. Critical injuries have to be immediately attended either by first aids and or taking the affected people for medical treatments.

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2.11 *Man Made* Hazards

2.11.1 Degradation of Coastal Habitats due to Climate Change and Sea Rise Level

Professor L. P. Jayatissa

Department of Botany, Faculty of Science, University of Ruhuna, Matara, Sri Lanka

Introduction

Among an array of different environmental problems faced by each and every country today, such as pollution, loss of biodiversity, depletion of natural resources, ecosystem degradation, deterioration of fertile agricultural land, etc, impacts of climate change can be considered the most important. Because it is a global problem and its adverse impacts or punishment goes not only to the culprit who is responsible, but also to the innocent. Therefore it is everybody's duty to fight against causes of global warming, and decisions have to be taken at the international level. For that, the knowledge on observed and predicted impacts of climate change is a prerequisite.

The purpose of this chapter is to review the impacts of climate change on habitats as it will affect not only the environmental aspect, but also the economic sectors of every country.

Man should have a list of basic needs to survive, live and maintain their tribe. There is a covering term for the environment that supplies all those needs, i.e. '***habitat***'. Human habitat is the ecological area where human beings live, work, play and move about. It is not just a home, but the sum of all factors that constitute the total environment such as cities or even countries.

In ecological point of view, a habitat is an area where organisms live. However it is more than a home. For an example the habitat of an animal includes all the land the animal needs to hunt, gather food, find a mate, and raise a family.

Although the term 'habitat' can be described with reference to single species, no species occur in isolation; but as communities. A combination of habitats of all the species in a community and the community itself together form an ecosystem. So, if anything happens to a habitat, it will affect the relevant ecosystem also.

Habitat degradation is the reduction of habitat quality and its ability to support biological communities. It may alter the relevant species' fitness or suitability to an extent that the species is no longer able to survive and hence becomes extinct.

Various combinations of different levels of ecosystem components such as light, air, water and soil, together with variations in climate and topography, create different habitats. So, changes in climate may affect the ecosystem health.

Since the recent past, humans are altering the global climate at rapid rates compared to the historical changes. Climate change can disrupt ecological systems if it take place during a time scales shorter than ecosystem response time. It causes alterations in ecological function that foster changes in ecosystem structure also leading to habitat degradation.

Climate change, one of the major environmental issues subjected to profound discussions today, is initiated by the increase of the global temperature as a consequence of increasing concentration of green house gases in the atmosphere. This temperature increase is called **global warming** (See the Chapter …for details). Although the global warming appears as a change of a single climatic factor, it initiate a series of changes in many other climatic and ecological factors leading to an aggravation of existing environmental pressures on ecosystems.

Followings are some of major changes initiated by the temperature rise;

- increase the amount of water vapour in the atmosphere leading to a further increase of the green house effect
- decrease cover by ice and glaciers
- affect the cloud cover
- increase the intensity of precipitations
- increase the frequency and intensity of coastal flooding and storms
- increased thunder activity
- increase the frequency and duration of droughts
- increase the photosynthesis and transpiration (only up to a certain level of temperature increase)
- alter ocean currents
- sea level rise

Except the sea level rise, all the other changes given above may affect almost all the terrestrial habitats; but the impact of the sea level rise is particular for the coastal zone. Sea level rise is an explicable outcome of global warming. It can happen through two dimensions; by thermal expansion of sea water and by melting of land ice and addition of it to the sea. Sea level rise on its own may lead to;

- higher intensity of coastal erosion
- intrusion of saline water into freshwater aquifers
- increase the salinity of lagoons
- inundation and displacement of low lying coastal habitats including estuaries and other wetlands
- varying other impacts on coastal habitats

According to reports by IPCC, the global mean surface temperature has risen by 0.6^0C ($0.4-0.8^0C$), during the last 100 years with 1998 being the warmest year (IPCC, 2002).

Furthermore it predicts that the globally averaged surface temperature will increase further by 1.4 to 5.8 ^{0}C over the period 1990 to 2100.

Based on tide gauge records which has been corrected for vertical land movements, it has been reported that average annual rise in sea level was 1-2mm during the 20th century (≈ 10 – 20cm per 100year) and this observed rate of sea level rise is consistent with model simulation (IPCC, 2002). The same report indicate that the global mean sea level is predicted to rise by 0.09 to 0.88 m between the year 1900 and 2100, with substantial regional variations. For the periods 1990 to 2025 and 1990 to 2050 the projected rises are 0.03 to 0.14 and 0.05 to 0.32 m respectively.

Coastal habitats

Global warming in general and sea level rise in particular, affect each and every habitat in the coastal region in the whole world. However, in this chapter the attention is mainly focused on more vulnerable coastal habitats in Sri Lanka.

Among the variety of coastal habitats or coastal ecosystems found in Sri Lanka, table 2.5 is given the most important and most vulnerable habitats (CCD, 1986, 1997);

Table 2.5: Categories of coastal habitats in Sri Lanka and their coverage

Habitat	**Extent (ha)**
Coral reefs	Not estimated
Mangroves	12189
Sea grass meadows	Not estimated
Sea shore (Beaches)	11788
Sand dunes	7607
Salt marshes (tidal flats)	23819
Lagoons and estuaries	158017
Other water bodies	18839
Marshes	9754

All these habitats are very important in ecological and economic point of view. However the destruction and degradation of these habitats due to human activities were taking place and are continuing. Therefore, irrespective to the impacts of climate change and sea level rise, the conservation of these habitats was a critical requirement. Table 2.6 gives the most important coastal habitats in Sri Lanka, their economic and ecological uses, and threats on those habitats.

Table 2.6: Categories of coastal habitats in Sri Lanka and their uses and major threats

	Uses (Products and services)	**Threats**
Coral reefs	² Reduce coastal erosion and impacts of tsunami and tidal waves ² Important nursery areas, breeding grounds and feeding grounds for many faunal species, including those of food value and ornamental value ² Possess a very high diversity and abundance of fauna ² Support for successful fishery due to above higher production rate ² Some medicinal compounds are extracted from coral polyps ² Suitable sites for eco tourism	² Coral mining ² Dynamite fishing ² Sedimentation enhanced by soil erosion in inland areas ² pollution ² anchoring ² removal of reef organisms (for aquarium trade) ² harbour construction ² Crown-of-thorns starfish ² corallivorous gastropods ² tunicates ² sponges ² algae species (*Halimeda, Ulva*) ² Bleaching (due to global warming) and subsequent coral death

Mangroves	² Reduce the coastal erosion. ² Act as breeding grounds, nursery grounds, and feeding grounds for many fish and shellfish species, and hence very important in fisheries. ² Protect the properties and lives in inland areas from ocean surges such as wind, storms, sea spray, and tsunami etc. ² Work as a filter to retain silt coming from inland areas without allowing going to the sea; hence protecting coral reefs and sea grass beds by reducing the sedimentation on them. ² Provide timber, fire wood, some food items, tannin, herbal medicines, fodder and thatching materials ² Ideal place for eco tourism	² Prawn farming ² Unsustainable fishing methods ² Pollution ² Timber felling and mangrove clearing ² Land filling ² Housing and infrastructure construction ² Refuse dumping, including refuse from illicit breweries in mangrove hideouts ² Improper hydrological changes by some irrigational works
Sand dunes	² Buffer zones between the land and the sea. ² Protect inland areas from tsunami and tidal waves ² Possess a unique vegetation	² Development projects ² Removal of sands ² Destruction of the vegetation mat

Sea grass beds	² Important nursery areas, refugee and feeding grounds for many faunal species, including those of commercial and recreational value. ² Stabilizes sediments and prevents erosion along coastline ² Take up dissolved nutrients and trap sediments in the water resulting in high water clarity	² Eutrophication (excessive input of nitrogen and phosphorus is directly toxic to sea grasses) ² Under eutrophic conditions, higher growth of free-floating and epiphytic macro and micro algae reduce the sunlight reaching the sea grass. ² Mechanical destruction of habitat ² Water pollution ² Over fishing of top predators could indirectly increase the growth of algae.
Sea shore (Beaches)	² Buffer zones between the land and the sea. ² Protect the inland areas from ocean surges including tsunami, storms, sea spray and tidal waves ² Possess a diverse vegetation with a particular zonation and it helps to reduce the coastal erosion	² Encroachments and conversion to settlements and agricultural lands destroying the sea shore vegetation ² Erosion ² Pollution
Other coastal wetland (Lagoons, estuaries, marshlands etc)	² Prevent floods - ² Prevent droughts ² Filter and purify the surface water ² Provide foods for fish, birds, and many other animals ² Serve as feeding grounds, breeding grounds and nursery grounds for many animals that live in other habitats ² Erosion control ² Highly productive ² Serve as important areas for recreation	² Siltation headed by soil erosion in inland areas ² Development project ² Unplanned irrigation projects ² Encroachments and conversions ² Pollution

Changes in the climate create new challenges for the conservation of this habitat and biodiversity conservation. Species diversities and ecological dynamics are already responding to recent changes in the climate (Heller and Zavaleta, 2009). These problems are exacerbated by other global changes such as sea level rise.

Observed and predicted impacts of climate change and sea level rise on more vulnerable coastal habitats

a) **Coral reefs**

Coral reefs are larger, stony or rocky platforms that is made up of limestone and covered by colonies of shaped animals called polyps. A single coral polyp may be as large as a saucer or smaller than the head of a pin. Millions of polyps working together in a cooperative colony generation after generation create the limestone skeletons that form the framework of the beautiful coral reef.

Many coral reefs occur at or closer to the temperature tolerance limit. Therefore, coral reefs have been adversely affected by the rising sea surface temperature. Small but prolonged rises in sea temperature force coral colonies to expel their symbiotic, food-producing algae, a process known as bleaching. Rising water temperatures block the photosynthetic reaction that converts carbon dioxide into sugar. This results in a build-up of products that poison.

the zooxanthellae. To save itself, the coral spits out the zooxanthellae and some of its own tissue, leaving the coral a bleached white. The bleached coral can recover, if cooler water temperatures return soon and the algae are able to grow again. Without the zooxanthellae, the coral slowly starves to death.

Many corals have undergone bleaching when the sea surface temperature has increased even by 1^0C above the mean sea surface temperature. Since the early 1980s, episodes of coral reef bleaching and mortality, due primarily to climate-induced ocean warming, have occurred quite frequently in various places of the world's tropical or subtropical seas. As an example, in 1998 an El Nino weather pattern triggered the worst coral-bleaching event ever observed. Some reports say that over 16 percent of the world's coral reefs were lost in that year. Bleaching episodes have resulted in catastrophic loss of coral cover in some locations, and have changed coral community structure in many others, with a potentially critical influence on the maintenance of biodiversity in the marine tropics. Bleaching has also set the stage for other declines in reef health, such as increases in coral diseases, the breakdown of reef framework by bioeroders, and the loss of critical habitat for associated reef fishes and other biota. Secondary ecological effects, such as the concentration of predators on remaining coral populations, have also accelerated the pace of decline in some areas. Bleaching disturbances are likely to become a widespread chronic stress in many reef areas in the coming decades as sea surface temperature is predicted to increase by at least 1-2 ^{0}C during the next century. If the water temperature increase more than 3^0C and sustain at that level over several months, it will result an extensive mortality of many coral species. As a result, the diversity of coral communities are likely to be reduced to their most hardy or adaptable constituents (Baker et al, 2008).

In addition to bleaching, the increase of atmospheric CO_2 will lead a higher concentration of oceanic CO_2 also. This elevated CO_2 concentration could reduce the reef calcification and hence the vertical growth of the reef that is necessary with the sea level rise.

Both, the sea surface temperature increase and elevated CO_2 concentration in sea water, together could result in reduced species diversity in coral reefs and more frequent outbreaks of pests and diseases in the reef system (IPCC, 2002).

This degradation of coral reefs will adversely affect populations of marine mammals and birds also.

a. Mangroves

Mangroves are tropical and semi-tropical forests that grow at sheltered inter-tidal sites.

The estimated mangrove cover in Sri Lanka is not more than 12000 ha, however the species diversity of mangroves in Sri Lanka is remarkable as 21 species of true mangroves are recorded (Jayatissa et al, 2002). It is about one third of the global diversity.

Mangroves are amongst the most productive of all ecosystems, and provide a range of goods and services (Table 2.6). Although still widespread, mangroves in the world are under enormous pressure from human impacts, with around 35% of the original area degraded or destroyed since 1980 and current global rates of loss running at between 1-2% per annum (Valiela *et al*. 2001). Whilst direct exploitation for various purposes is the main current threat, climate change (interacting in multiple ways with other pressures) is likely to become the largest single cause of mangrove destruction in the future (Gilman et al., 2008).

Some scientists have suggested that mangroves will move landward with increasing air temperatures (UNEP 1994; Field 1995; Ellison 2005). Geological records also indicate that previous sea-level fluctuations have created both crises and opportunities for mangrove communities, and they have survived or expanded in several refuges (Field 1995). Such natural resilience of mangroves to climate change provides hope for their long-term survival. However, mangrove resistance and resilience to relative sea-level rise will depend on four main factors (Gilman et al., 2008):

(i) The rate of change in sea-level relative to the sediment accretion on the mangrove land: Mangroves produce peat from decaying litter fall and root growth and by trapping sediment in the water. The process helps mangroves keep up with sea level rise.

(ii) Mangrove species composition: Different mangrove species have different capacities and rates to be adapted for the changing situation. Different species may be able to move into new areas at different speeds, making some species capable of accommodating a higher sea-level rise rate than others (Semeniuk 1994).

(iii) The physiographic setting, including the slope of land upslope from the mangrove relative to that of the land the mangrove currently occupies, and presence of obstacles to landward migration of mangroves such as such as infrastructure (e.g., roads, agricultural fields, dikes, urbanization, seawalls, and shipping channels) and topography (e.g., steep slopes) and

(iv) Cumulative effects of all stressors influence mangrove resistance and resilience: As an example temperatures above 35°C have led to thermal stress affecting mangrove root levels of CO2 significantly increased photosynthesis and the average growth rates in two Australian mangrove species, *Rhizophora stylosa* and *Rhizophora apiculata*, but only when grown at lower salinity levels (Ball et al. 1997).

b. Sea grass meadows

Sea grasses are the group of Angiosperm plants (*ie*. flowering plants) in marine habitats. They are living submerged at least for a part of their life cycle. As an adaptation to the wave action, leaves are tapering in shape and somewhat leathery in texture. Therefore, the appearance is rather similar to grasses, but actually they are not in the grass family. Plants are rooted or attached or to a substrate and growing as a dense mat in shallow areas of the sea. About 60 species of sea grasses are recorded from the continental shelf of Sri Lanka and it represent about 25% of the global diversity. The importance of sea grasses and threats are given in Table 2. 6.

It is predicted that the production rate of sea grasses could be increased over the increase of the water temperature. In contrast, with the sea level rise, the production rate could be decreased at least of deeper areas due to the low light availability.

b. Sea shore (Beaches)

Out of the different coastal types occur along the coastline of Sri Lanka, the general beach or sea shore occupies a large percentage. The sea shore in Sri Lanka can be divided in to following three categories;

1. Sea shore with steep slopes
2. Sandy beaches with a slow elevation
3. Rocky shores without a high and steep slope

A rise of the mean sea level will also lead to increased wave height thereby disturbing equilibrium of beaches and making them more prone to erosion and interfering with existing long shore sediment transport rates and distribution. Sandy shores with a slow elevation are the highest affected beach types by sea level rise and accelerated wave action. As a result it will face increased erosion. Hard rocky coasts will be the least affected by accelerated sea-level rise.

In addition to the erosion, the combined effects of an increased mean sea level rise and increased wave heights would result in further impacts such as undermining the stability of coastal structures, and the altering of circulation patterns inside coastal embayment and estuaries.

e. Sand dunes

Coastal sand dunes are simply piles or small hills of sand, which generally originate as a result of continuous sand accretion around certain creepers, shrubs and/or dwarf trees growing on clumps of coast. A considerable fraction (≈ 20%) of the coastline of Sri Lanka is covered by sand dunes and well developed dunes in Sri Lanka sometimes exceed 10-15 m in height and occur in Mannar, Talaimannar, Batticaloa, Jaffna, Yala, Hambantota and Puttalam. The role of sand dunes and major threats on them are given in the Table 2.6.

Sand dunes are fragile and dynamic ecosystems. However, they are in two types as active and fixed. Fixed sand dunes are older and covered by distinct vegetation well adapted to withstand and tolerate dry desiccating sandy environment. Hence they are rather stable and more resistant to wind induced and water induced erosion. Active dunes may be naked or partially covered only by some creepers which provide some degree of shelter and protection. They are rather unstable and owing to building up as well as to wind induced or water induced erosion. A fixed dune may turn active under the action of very strong winds or prolonged droughts followed by higher precipitation rate (Yizhaq et al, 2009). Particularly the short-term but heavy precipitation associated with global warming are believed to collapse sand dune ecosystem through erosion and demolition of species (Hurst and Glennie, 2008)

f) Salt marshes (tidal flats)

A *salt marsh* is a low lying plat area occurs as a transitional intertidal zone between the land and salty or water. It is dominated by halophytic (salt tolerant) herbaceous plants. Salt marshes are one of the biologically productive habitats.

It is also recognized that a change in climate due to global warming would contribute to the changes in frequency and intensity of extreme events such as increased coastal flooding, thereby further destroying salt marsh communities.

Extensive intertidal habitats such as salt marshes could vanish in the future due to rising sea levels that squeeze tidal flats against established sea defences. The remaining intertidal area is likely to become steeper with coarser sediment, and saline water may intrude upstream due to increased water depth and enhanced wave energy.

g) Other coastal wetlands

This category includes lagoons, estuaries and marshlands. A series of interactive processes between the land and the sea, between the dynamic force of rivers and the sea, between the natural and human processes are taking place in these habitats. Global warming and sea level rise create changes in storm frequency and intensity, and changes in the input of freshwater, sediment, and nutrient. As a result, these wetlands will be most affected by the climate change. Such alterations in climatic and environmental factors pose serious risks for coastal wetlands, and they may adversely affect numerous critical services they provide to human populations. Some of them could be vanished. Saline water may intrude upstream of these wetlands due to increased water depth and enhanced wave action. It will result changes of biodiversity in remaining wetlands. The productivity of coastal wetland ecosystems also will be significantly altered by increases in water temperatures. Warmer waters are naturally more productive, but the particular species that flourish may be undesirable or even harmful. For example, the blooms of "nuisance" algae that occur in many waters during warm, nutrient-rich periods can be expected to increase in frequency in the future.

Mitigation efforts and adaptation options

The Intergovernmental Panel on Climate Change scenarios indicate a tremendous threat to coastal habitats and coastal biodiversity (IPCC, 2002). Predicted global changes will challenge us to develop forward-looking strategies and respond with innovative solutions. We must find ways to address those threats at all levels. Each and every country has a dual role in mitigation effort as joining with other countries in global effort and taking individual efforts for mitigation and adaptation measures relevant to habitats in their own country.

As an individual attempt to mitigate the impacts of climate change, only effort that can be taken by any country, is the lessening of the environmental pollution and improvement of ecosystem health that will maximize the tolerance of ecosystems against climate change and ability of adaptation.

Minimizing the adverse impacts of human activities through policies that promote more science-based management of coastal resources is the most successful path to continued health and sustainability of these ecosystems. The Table 2.7 gives the legislations which have been imposed to prevent the degradation of coastal habitats in Sri Lanka. A great care should be taken to empower these legislation and new rules should be imposed if necessary for the protection and restoration of threatened habitats as well as to improve their health.

Table 2.7: The legislation in action to prevent the anthropogenic degradation of coastal ecosystems in Sri Lanka.

Législation	Provisions
The Seashore Protection Ordinance, Gazette No.7710 (1929)	Ban the removal of coral, sand , etc
The Fauna and Flora Protection Ordinance, Gazette No.8675 (1940) and subsequent Amendments such as the Amendment Act, No 49 (1993)	Protects threatened and endangered wildlife including sea turtles and their nesting habitats. The Hikkaduwa Nature Reserve was declared on 14.8.1998 under this Act

The Fisheries Ordinance, Gazette No.12304 (1961)	Ban the use of destructive fishing gear and supports sustainable fishing activities; related regulations under Section 33 bans the possession of lobsters with eggs.
Adoption of the Coastal Zone Management Plan by Parliament in 1991	Transforms common-property open access fisheries into a managed industry, with a licensing system of all fishing operations and provisions for establishing "committees" of stakeholders, recognizing a participatory approach.
The Tourist Development Act No.14 (1968)	Regulates services and prevents indiscriminate and unplanned development in resort areas.
The Natural Heritage and Wilderness Act (1980) amended in 1988	Requires Environmental Impact Assessments and licenses for industries, which may produce air, water and/or land pollution.
The National Aquatic Resources Research and Development Agency (NARA) Act No. 54 (1981)	Established NARA to bring about the conservation of aquatic resources in aquatic habitats including coastal and offshore areas, as well as to undertake research, disseminate information and provide advisory and consultancy services
The Coast Conservation (CCD) Act No.57 (1981)	Mandated CCD to develop a Coastal Zone Management Plan, regulate and control activities within the Coastal Zone, and formulate and execute coast conservation projects. It defined Coastal Zones to include portions of lagoons, estuaries and rivers. It also established uniform procedures for permit applications without distinction between development activities undertaken by private and state sectors. Among other provisos, this legislation encouraged collaboration among various government agencies involved in research and development activities within the Coastal Zone, specified penalties for violation of the law, and authorized the Director of CCD to demolish unauthorized structures. It also made possible the establishment of horizontal links between the relevant legislation.
Coast Conservation Amendment Act No. 64 of 1988	Empowers the Director of CCD to delegate powers, duties and functions to Government Agents or public officers of any administrative district, which contains a portion of the Coastal Zone. It bans the mining, collection, possession, storage, burning and transportation of coral, and the possession of limestone kilns. It authorizes the demolition of

	kilns and the seizure of boats engaged in illegal activities within the Coastal Zone. Importantly, it grants the public the right to use any beach.
The Forest Ordinance No.3 (1945) Amendment No.13 (1966) and Act No.13 (1988)	Provides for the issue of permits for the harvesting, possession, sale and transportation of timber and provides for the prosecution of offenders. This law is of relevance to mangroves and their harvesting.
The Marine Pollution Prevention Act No.59 (1981)	Authorizes the Marine Pollution Prevention Authority to prevent, reduce, and control pollution in Sri Lankan waters.
The Specified Tourist Services Code (1984)	Provides for the registration and licensing of all tourism related establishments as well as enabling their classification
The National Environmental Act No.47 (1980) and Amendment No.56 (1988)	Establishes the Central Environment Authority (CEA) and provides for the protection of the environment against environmental degradation and the prevention and control of pollution. The Amendment provides greater environmental quality control including the EIA and EPL

As a contribution to the global effort, each county should mitigate the global greenhouse gas emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels. All sectors such as transport, industry, energy supply, and agriculture, should be encouraged to implement all possible mitigation technologies, without a delay. Delays in cutting emissions would lead to higher levels of green house gases and increase the risk of more severe climate change in the near future.

However, we may not be able to find best mitigation effort and adaptation measures for the impacts of global warming and sea level rise, because most specific ecological responses by coastal habitats to climate change cannot be predicted, and new combinations of physical and biological factors will interact in novel situations.

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2.12: Climate Change and its impacts to the coastal area

By Dr. Champa Navaratne

University of Ruhuna

Climate change is any long-term significant change in the expected patterns of average weather of a specific region over an appropriately significant period of time. Climate change reflects abnormal variations to the expected climate within the Earth's atmosphere and subsequent effects on other parts of the Earth, such as in the ice caps over durations ranging from decades to millions of years.

In recent usage, especially in the context of environmental policy, climate change usually refers to changes in modern climate.

The climate system

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years). Solar radiation powers the climate system. Fig.2.16 shows the components of climate system.

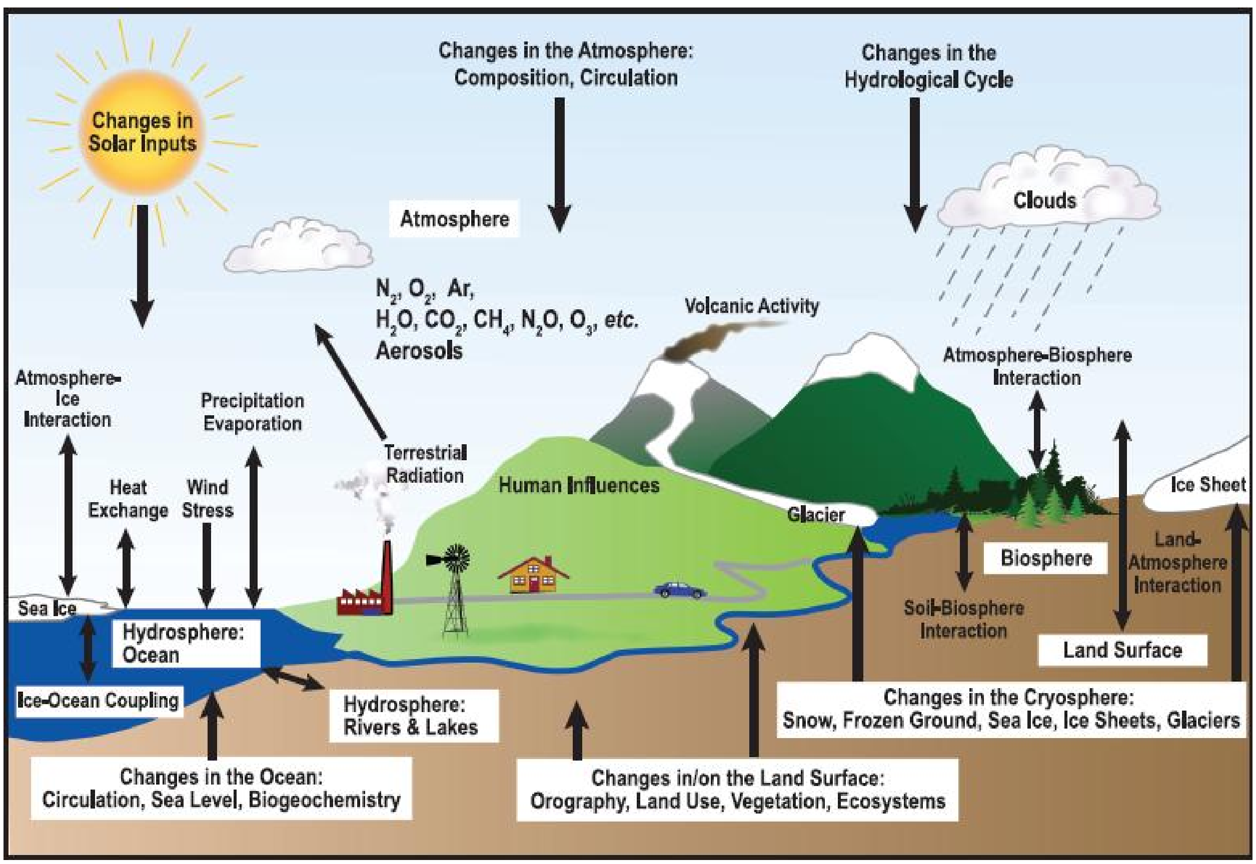


Figure 2.16: Schematic view of the components of the climate system, their processes and interactions. (Source: 4th assessment report IPCC- 2007)

There are three fundamental ways to change the radiation balance of the Earth:

1) By changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself);

2) By changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation); and

3) By altering the long wave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations).

Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

The amount of energy reaching the top of Earth's atmosphere each second on a surface area of one square meter facing the Sun during daytime is about 1,370 Watts m-2 second-1 and the amount of energy averaged over the entire planet is about 342 (1,370/4) Watts m-2second-1. About 30% of the sunlight that reaches the top of the atmosphere is reflected back to space. Roughly two-thirds of this reflectivity is due to clouds and small particles in the atmosphere known as 'aerosols'. Light-coloured areas of Earth's surface – mainly snow, ice and deserts – reflect the remaining one-third of the sunlight. (Fig.2.22)

The energy that is not reflected back to space is absorbed by the Earth's surface and atmosphere. This amount is approximately 240 W m–2. To balance the incoming energy, the Earth itself must radiate, on average, the same amount of energy back to space. The Earth does this by emitting outgoing long wave radiation. Everything on Earth emits long wave radiation continuously. To emit 240 W m–2, a surface would have to have a temperature of around –19°C. This is much colder than the conditions that actually exist at the Earth's surface (the global mean surface temperature is about 14°C). Instead, the necessary –19°C is found at an altitude about 5 km above the surface. (Fig, 2.17).

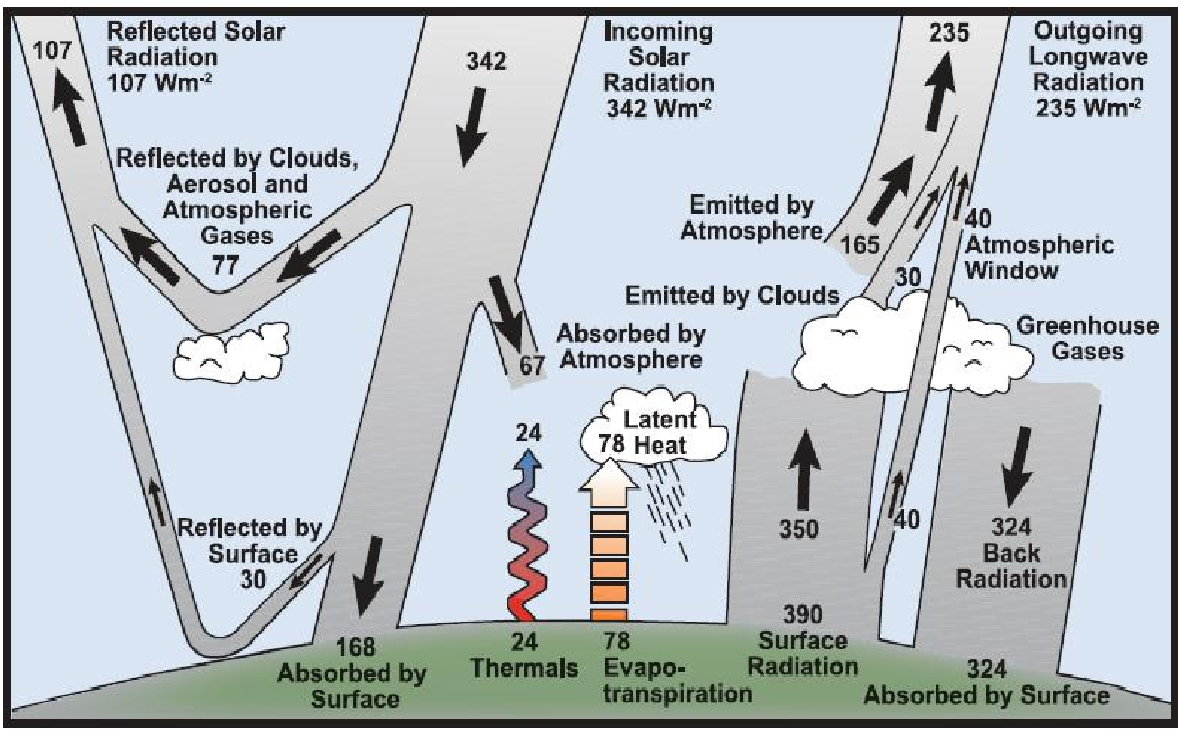


Figure 2.17 Estimate of the Earth's annual and global mean energy balance (Source: 4th assessment report IPCC- 2007)

Green House Effect

The reason the Earth's surface is this warm is the presence of greenhouse gases, which re-radiate the long wave radiation coming from the surface. This is known as the natural greenhouse effect. The most important greenhouse gases are water vapour and carbon dioxide. Clouds too emit them similar to that of the greenhouse gases; however, this effect is equalized by their reflectivity, such that on average, clouds tend to have a cooling effect on climate.

Human activities intensify the greenhouse effect through the release of greenhouse gases. For instance, the amount of carbon dioxide in the atmosphere has increased by about 35% in the industrial era, and this increase is known to be due to human activities, primarily the combustion of fossil fuels and removal of forests. Thus, humankind has dramatically altered the chemical composition of the global atmosphere with substantial implications for climate.

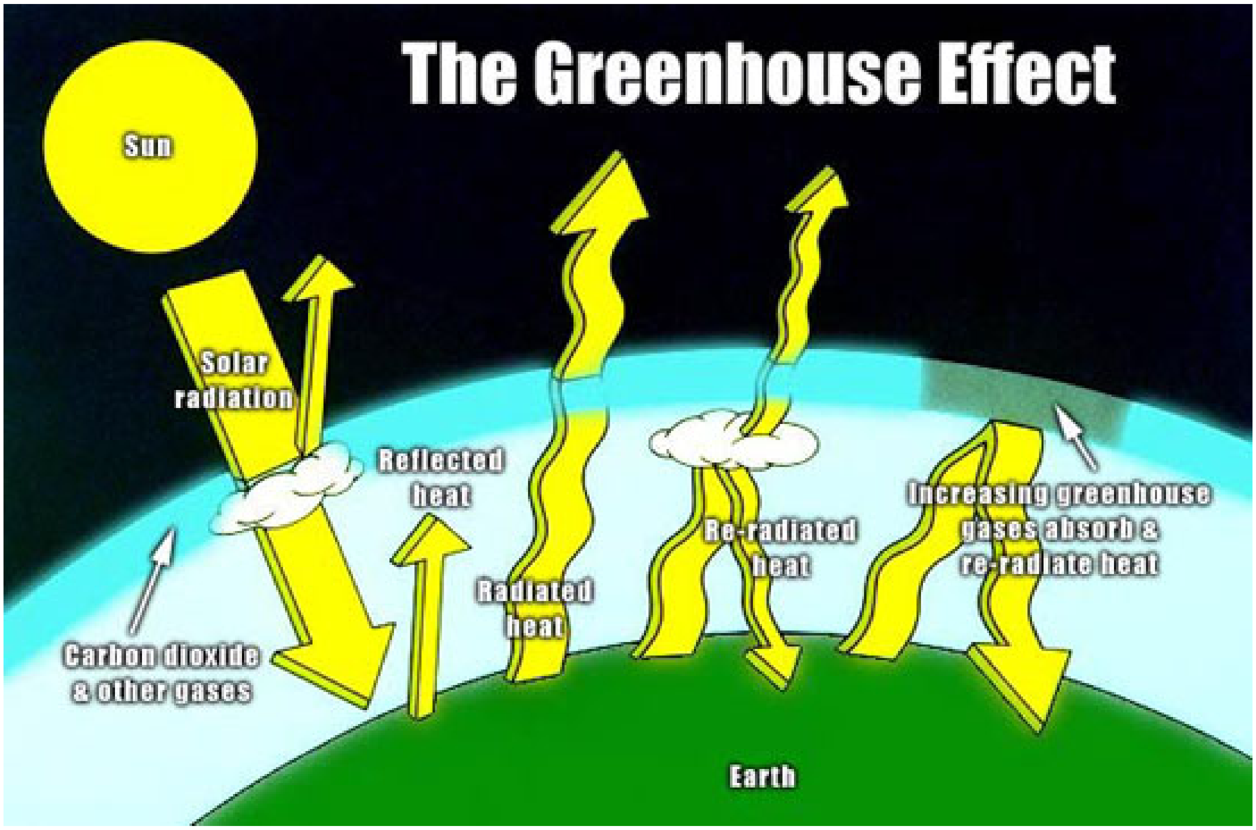


Fig.2.18: Green House Effect

Impact of climate change on coastal zone

Coastal zones are predominantly vulnerable to climate variability and change. Climate change would enforce serious impacts on the natural environment, biodiversity, agriculture, livelihood and human health in the coastal zone.

The coastal zones experience climate change in several ways. The most apparent impact on the coastal zone is sea-level rise. Global mean sea level has increased at an average rate of 1-2 mm during the past century (IPCC TAR 2001).

Meteorological patterns will change as a result of shifts in the global heat balance. For the coastal zone, this (together with the changes in the behaviour of the oceans) is likely to mean more storminess, with greater storm surges and a modified wave climate regime.

Why coastal zone is particularly concerned

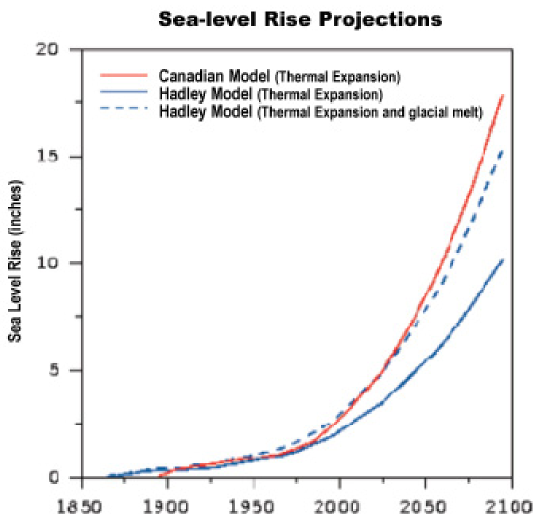
The oceans cover 70% of the Earth's surface and play a vital role in the global environment.

They regulate the Earth's climate and modulate global biogeochemical cycles. They are of significant socioeconomic value as suppliers of resources and products worth trillions of dollars each year (IPCC, 1998). Approximately 20% of the world's human population live within 30 km of the sea, and nearly double that number live within the nearest 100 km of the coast (Cohen et al., 1997; Gommes et al., 1998). Based on Nicholls and Mimura (1998) 600 million people will occupy coastal floodplain by 2100. Further, oceans function as areas of recreation and tourism, as a medium for transportation, as a repository of genetic and biological information and as sinks for wastes.

Impacts

Sea Level Rise

Some of the possible harmful impacts of climate change include increases in global ambient temperatures, thermal expansion of ocean waters, subsidence of coastal lands and increased melting of sea ice. These factors can, in various combinations, contribute to sea level rise. Some estimates predict that sea level rise of approximately 50 cm could result from these factors, while others predict as much as 65 cm by 2100. (Figure 2.19) Of course local sea level rise events will differ from the global average because of many factors including (but not limited to) local climatic conditions, local physical coastal features, local tidal cycles etc. [NASA, 1996; Darwin, Richards and Tol, 2001].



Historic and projected changes in sea level based on the Canadian and Hadley model simulations. The Canadian model projection includes only the effects of thermal expansion of warming ocean waters. The Hadley projection includes both thermal expansion and the additional sea-level rise projected due to melting of land-based glaciers. Neither model includes consideration of possible sea-level changes due to polar ice melting or accumulation of snow on Greenland and Antarctica.

Fig.2.19: Sea Level Rise Projections

Shoreline Erosion and Human Communities

Coastal erosion is already a widespread problem in much of the country and has significant impacts on undeveloped coastal areas as well as on coastal development and infrastructure. Shorelines are especially vulnerable to long term sea-level rise as well as any increase in the frequency of storm surges. Most erosion events on these coasts are the result of storms, and the slope of these areas is so gentle that a small rise in sea level produces a large inland shift of the beach. When buildings, roads, and seawalls block this natural shift, the beaches and shorelines erode, especially during storm events. This increases the threats to coastal development, transportation infrastructure, tourism, freshwater aquifers, and fisheries (which are already stressed by human activities). Coastal cities and towns, especially those in storm-prone regions such as the Southeast, are particularly vulnerable to extreme events. Intensive residential and commercial development in such regions puts life and property at risk.

Threats to Estuarine Health

Estuaries are extremely productive ecosystems that are affected in numerous ways by climate. Temperature is projected to increase resulting in a rise of the annual water temperature range of many estuaries. This causes for species' ranges to shift and increase the vulnerability of some estuaries to non-native invasive species. Either increases or decreases in runoff would very likely create impacts to estuaries. Increased runoff would likely deliver increased amounts of nutrients such as nitrogen and phosphorous to estuaries, while simultaneously increasing the stratification between freshwater runoff and marine waters. Both nutrient additions and increased stratification would increase the potential for blooms of algae that deplete the water of oxygen, increasing stresses on sea grasses, fish, shellfish, and other living things on the bottom of lakes, streams, and oceans. Decreased runoff would likely reduce flushing, decrease the size of estuarine nursery zones, and allow predators and pathogens of shellfish to penetrate further into the estuary.

Coastal Wetland Survival

Coastal marshes and swamps are particularly vulnerable to rising sea level because they are generally within a few feet of sea level (IPCC, 2001). Dramatic losses of coastal wetlands have already occurred in past decades. Coastal wetlands (marshes and mangroves) are highly productive ecosystems that are strongly linked to fisheries productivity. They provide habitat for many species, and play a key role in nutrient uptake, Further, they serve as the basis for many communities' economic livelihoods and provide recreational opportunities, and protect local areas from flooding. As the sea level rises, the outer boundary of these wetlands will erode, and new wetlands will form inland as previously dry areas are flooded by the higher water levels. The amount of newly created wetlands could be much smaller than the lost area of wetlands. The IPCC suggests that during the next century, sea level rise could convert as much as 22% of the world's coastal wetlands to open water. (Figure 2.20)(IPCC, 2001). Tidal wetlands are generally found between sea level and the highest tide over the monthly lunar cycle.

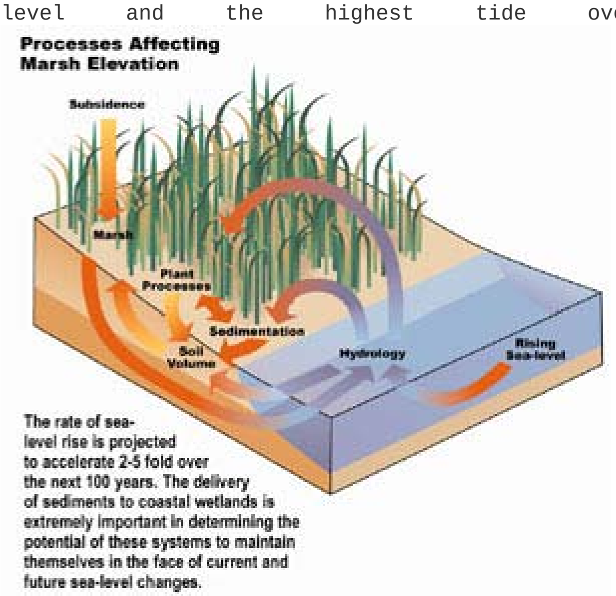


Fig. 2.20: Sea level rise could convert coastal wetlands to open water.

Coral Reef Die-offs

Coral reefs play a major role in the environment and economies. Coral reefs are valuable economic resources for fisheries, recreation, tourism, and coastal protection. In addition, reefs are one of the largest global storehouses of marine biodiversity, with untapped genetic resources. The demise or continued deterioration of reefs could have profound implications for the coastal security.

The last few years have seen unprecedented declines in the health of coral reefs. In addition, increasing atmospheric CO_2 concentrations could possibly decrease the calcification rates of the reef-building corals, resulting in weaker skeletons, reduced growth rates and increased vulnerability to erosion. Model results suggest that these effects would likely be most severe at the current margins of coral reef distribution.

Storms and Flooding

Sea level rise also increases the vulnerability of coastal areas to flooding during storms for several reasons. Shore erosion also increases vulnerability to storms, by removing the beaches and dunes that would otherwise protect coastal property from storm waves (FEMA 2000). Sea level rise also increases coastal flooding from rainstorms, because low areas drain more slowly as sea level rises. Flooding from rainstorms may become worse if higher temperatures lead to increasing rainfall intensity during severe storms. An increase in the intensity of tropical storms would increase flood and wind damages.

Coastal Water Supplies

Rising sea level increases the salinity of both surface water and ground water through salt water intrusion. If sea level rise pushes salty water upstream, then the existing water intakes might draw on salty water during dry periods. Salinity increases in estuaries also can harm aquatic plants and animals that do not tolerate high salinity.

Shallow coastal aquifers are also at risk (IPCC, 2007). River which may become saline in the future. In all of these cases, water management authorities currently prevent excessive salinity by uplifting water intake points during droughts. One possible response to sea level rise would be to store more water during wet seasons so that more water can be released during droughts.

The followings are the other effects of sea level rise;

Altered tidal range in rivers and bays

Changes in sedimentation patterns

Decreased light penetration to organisms.

Changes in the distribution of pathogenic micro organisms

Increased loss of property and coastal habitats

Damage to coastal protection works and other infrastructure

Increased disease risk

Loss of renewable and subsistence resources

Loss of tourism, recreation, and transportation functions

Loss of nonmonetary cultural resources and values

Impacts on agriculture and aquaculture through decline in soil and water quality.

Some of these effects may be further compounded by other effects of changing climate.

Socioeconomic Impacts

There will be negative impacts on several sectors, including tourism, freshwater quality and supply, fisheries and aquaculture, agriculture, human settlements, financial services, and human health.

The number of people potentially affected by storm-surge flooding is expected to double (or triple) in the next century, ignoring potential adaptation and population growth.

Protection of low-lying island states and nations with large deltaic areas is likely to be very costly.

Solutions

Evolution of Coastal Adaptation Options

Biljsma et al. (1996) identified three possible coastal response options:

Protect, which aims to protect the land from the sea so that existing land uses can continue, by constructing hard structures (e.g., seawalls) as well as using soft measures (e.g., beach nourishment)

Accommodate, which implies that people continue to occupy the land but make some adjustments (e.g., elevating buildings on piles, growing flood- or salt-tolerant crops)

Retreat, which involves no attempt to protect the land from the sea; in an extreme case, the coastal area is abandoned

Adaptation Strategies

Enforcement of set-back regulations

Protection (groynes, rock armoring ect.)

Stabilization programmes (coastal planting)

Delineate buffer areas and set-back criteria and implementation mechanisms (set-backs and buffers –from 25m to 100m)

Wetland management (Unblocking of outlets) Local development plans

Well designed drainage systems (widen bridges and culverts)

Roof water harvesting

Regular and effective maintenance of drainage systems

Raising of foundation level

Enforcement against wetland reclamation

Enforcement of planning/environment regulations

Use of bio indicators in the assessment of environmental quality

Planned Retreat Strategies

Fore-go development within certain areas of high impact

Relocate critical infrastructure

Accommodation Strategies

Management and protection of coastal habitats

Elevation and modification of infrastructure and buildings

Upgrade and maintain drainage systems

Develop an adequate insurance mechanism

Defence Strategies

Study and construct hard coastal protection infrastructure

Technology Transfer in the design and management of "intelligent" coastal protection options

Explore opportunities for research and introduction of soft coastal protection options

Baseline characterization, selection of monitoring locations

Preparation of vulnerability and risk maps

Insurance scheme

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[NASA, 1996; Darwin, Richards and Tol, 2001].

3.0 Module 3 Risk Assessment Approaches

3.1 Technical Approach using mapping Techniques

This section will be explained various techniques to be used in mappings disaster prone areas using GIS information and other mapping techniques

3.1.1 Introduction

Tsunamis are scientifically described as a series of very long wavelength ocean waves caused by the sudden displacement of water by earthquakes, landslides, or submarine slumps. A great earthquake occurred off the West Coast of northern Sumatra on 26th December 2004 triggered giant tsunamis in the Indian Ocean that devastated the coastal regions of Indonesia, Malaysia, Thailand, Sri Lanka and India. In India, the impact was quite severe in the coasts of Andaman and Nicobar group of Islands. This tsunami has left a feeling that we need to be better prepared for such events. It is necessary to prepare a coastal vulnerability map to assess the areas, which are vulnerable to coastal disasters. Therefore, an attempt has been made for coastal disaster Risk Mapping for the Sri Lanka.

In general, seven parameters such as elevation, geology, geomorphology, sea level trends, horizontal shoreline displacement, tidal ranges and wave heights are considered to demarcate the vulnerability line all along the Coast. But a vulnerability study based on wave travel and flooding should be the first step in the setting up of an all-hazards warning and management system. Since the run-up cannot be calculated, the safest and easiest option for the identification of the potential inundation zone is to define it as the area between the coastline and the contour of the highest recorded tsunami.

The Tsunami affected areas are observed well with in that 0-20 m contour region of Sri Lanka. More community lost their lives were observed, ultimately the settlements in this zone should be moved away to avoid damages in future. For this resettlement plan, thematic layers such as Land use / land cover, transport, CRZ, Slope and Disaster prone areas are integrated in Arc GIS to suggest suitable sites for Resettlement.

The island of Sri Lanka is frequently struck by natural disasters many times though this has not recorded properly, such as landslides, floods, cyclones. Hazard is a condition or a process (natural or anthropogenic) of environment, which can exert an adverse influence on human life, properties or human activities. Currently many people discuss about the disaster risk reduction methodologies (DRR) is a means of bridging the gap between development and humanitarian programmes and can be seen as a means of strengthening livelihood security of the community. In countries faced with recurrent crises, development can only be sustained if there is a proper understanding of and response to the negative impact of disasters. DRR interventions seek to assist in the development of this understanding, to support livelihoods and to protect assets. It is hoped that DRR interventions will reduce vulnerability of the community and increase their opportunities of pursuing sustainable livelihoods.

Costal area of the country has huge resource concentration in comparison to other areas so it is vital important to have concern of disaster preparedness plans in the area. Coastal hazards mainly are floods, inlands and sea water uprising, tsunami, cyclones, oil spill, lightening and coastal erosion.

Hazard mapping provide easy understandable information on the extent of impact and vulnerable areas according to various hazards, potential risk to human habitat, property, activity and the environment. The ultimate goal of hazard mapping is to minimize damage from disaster by improving response and resilience of local people to any kind of coastal disasters.

The main objective of this attempt is to introduce available various kinds of mapping techniques that can be used in hazards mitigation by and use vulnerability maps to identify an appropriate disaster-preparedness plan and mitigation activities for the coastal area.

Specific objectives of the maps are to,

• Assess the nature of coastal hazards in terms of type, magnitude, and recurrence intervals and impacts in terms of losses by using available mapping methods locally.

• Identify and delineate areas affected by coastal disasters in possible maps and susceptible to the same in future.

• Assess and map the degree of risk, incorporating all the elements of

Biophysical, socioeconomic, and service infrastructure located in areas

Susceptible to coastal hazards with probable magnitude and recurrence intervals.

• Assess and map the vulnerability to coastal hazards in terms of perception,

Response, and recovery capabilities of individuals, households, communities,

and government and non-government institutions in the study areas.

• Recommend appropriate disaster mitigation and management strategies a

GIS are nowadays widely used by authorities as a tool for identify the hazard zones for disaster risk reduction. The GIS have the capability of spatially representing data on the land surface and linking additional data related to this spatial depiction through tables and charts as well as maps. But community is still not much familiar with the high technical mappings. This attempt is to introduce various kind of mapping techniques available and that can be used at ground level community in case of disaster to address the issue and planed for reduce the risk by planning.

3.1.2 Important of DRR mapping

Reduction of tsunami disasters in a region and a community is attained with a comprehensive approach involving the integration of land use planning, construction of coastal protection facilities and measures for increasing the people's self-protecting capability against disasters. Tsunami disaster management maps indicate tsunami hazards and vulnerability in the region and community as well as countermeasures against the tsunamis. A tsunami disaster management map is a good tool to investigate and establish comprehensive disaster mitigation system, since it provides necessary graphical information to manage tsunami disasters and minimize damage in the region as well as regional tsunami hazards and vulnerability.

Mapping is a tool if wisely used in managing disasters which can accumulate a large numbers of data and information available. One data sheets provide various types of data which can be used in mitigating, Planning and reducing the casualties if planned properly.

These data collected can be analyzed historical trend and develop future scenarios and adjust planning and development activities to mitigate property and lives losses.

DRR planning at the site can be used as a tool for disaster preparedness.

3.1.3 Advantage of mapping in DRR

There are several advantages in mapping one of key advantage is locate the area precisely with exact extent. If it is floods the possible extent of floods threat can be mapped. in

the same time mapping will abele to provide exact direction where the treated coming from and where it would go and where is the safer areas.
Maps will give wider range of information in one sheet. It may be hazards, settlement, roods, infrastructure such as communication, hospital safer area exactly can be shown in the map without complication. Less complicate to understand.

It is also easy to analyze data back and fourth. Historical information as well as future trend can be easily analyses by using maps; this may be topographic maps, Arial photographs or GIS maps.

Understanding special distribution of hazards evacuation roots, and buffer zone for various disasters, buffer zone is depend on the disaster, Tsunami buffer zone is difference from erosion buffer zones. As an example 10 m to 20 m would be enough buffer zone for coastal erosion but would not adequate for Tsunami or sea serge uprising.

3.1.4 Available Mapping Techniques

Topography maps
There are various mapping techniques available at the movement. Topographic maps were the oldest and mostly used mapping techniques in Sri Lanka. From the early. Still these maps are using for planning purposes. Topography maps prepared by survey department of Sri Lanka and available in deference scales. -1:100,000, 1:50,000 and 1:10:000

Arial Maps
Arial maps were also using as a planning tool in decision making but no longer using them as much as earlier. These data are using as to develop historical scenario building today.
What is a Tsunami Disaster Management Map?

Tsunami disaster management map contains two types of information to mitigate the tsunami disasters:

- Information of tsunami inundation areas predicted by possible tsunamis and recorded by historical tsunamis This type of information provides tsunami hazard and vulnerable areas against tsunami in the community (Tsunami Inundation Map or Tsunami Hazard Map)

- Information for enhancing people's awareness of tsunami disaster, ensuring readiness, and reducing tsunami damages

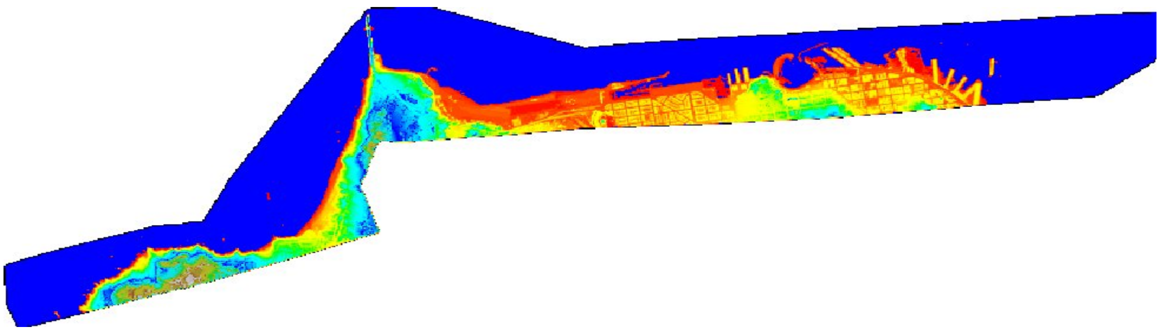
Remote sensing
- Satellite Image (Google Earth Images -Quike Bird-IKONIS)
- Community maps.

3.1.5 Light Detection and Ranging (LIDAR)

Recent advancements in remote sensing technologies have introduced new and efficient methods to acquire information about the earth. One such technology currently being investigated by the NGS Remote Sensing Research and Development Team is Light Detection and Ranging (LIDAR). LIDAR is an active remote sensing system that can be operated in either a profiling or scanning mode using pulses of light to illuminate the terrain. LIDAR data collection involves mounting an airborne laser scanning system onboard an aircraft along with a kinematic Global Positioning System (GPS) receiver to locate an x, y, z position and an inertial navigation system to monitor the pitch, roll, and heading of the aircraft. By accurately measuring the round trip travel time of the laser pulse from the aircraft to the ground, a highly accurate spot elevation can be calculated. Depending upon the altitude and speed of the aircraft along with the laser repetition rate it is possible to obtain point densities that would likely take months to collect using traditional ground survey methods.

LIDAR has been tested in a wide variety of applications including assessing post storm damage to beaches, mapping the Greenland ice sheet, and measuring heights within forest timber stands. NGS is examining the possibility of implementing LIDAR into the production of shoreline manuscripts and airspace obstruction charts. LIDAR is also playing a role in recent research into automated shoreline definition by using the VDatum tool to derive a mathematical shoreline from the LIDAR point data.

The image below is a pseudo-color ramp on a DEM from LIDAR data collected in San Francisco. These data were collected in September 2002 using an Optech 1233 ALTM LIDAR system aboard the NOAA Cessna Citation aircraft. The Golden Gate Bridge is the peak protruding at the top left of the image, while the Fisherman's Wharf and downtown commercial district along the bay are at the right in the image.



See more information about the **San Francisco LIDAR** experiments.
Important of mapping techniques in Disaster Risk Reduction

Natural disaster management can be supported by using various information sources. The methods of mapping and image analysis make it possible to provide up-to-date and accurate information over the whole disaster area. Nevertheless, many disaster-prone countries have not yet established any operational information systems that would integrate earth observation data analysis and modern information technology including mobile communication and web technology into the operative disaster management process.

3.1.6 GIS as a tool for DRR

A Geographic Information System (GIS) is a set of computer programs used to input, store, analyze and output geographically referenced data. Input may include the digitalization of hard copy maps. The analysis and modelling functions might include the manipulation, overlay, measurement, computation and retrieval of the digital spatial data. Output may be in form of new map products or tabular resource information showing results of the spatial analysis.

GIS is one of the method can be used for disaster risk reduction such as save lives, reduce human suffering and preserve economic assets before, during and after a catastrophic event. Correct and timely information is a critical part of any successful disaster management program. A geographic information system (GIS) can provide that sort of information. Use of GIS is in disaster risk reduction because disasters are usually spatial events (for example floods, earthquakes, hurricanes, wildfires, hazardous spills, public unrest, famine, epidemics, etc). Mapping and spatial information acquisition is therefore critical in disaster management. Therefore Geographic Information System (GIS) has great potential in contributing towards hazard, vulnerability mapping and disaster reduction planning. Its use in response to disasters is equally important

Using GIS technology can be identified the disaster regions and vulnerable areas. The output maps can be used to spatially visualize the affected areas and vulnerable areas. With the help of the satellite images GIS has proven to be one of the most successful tools for Disaster mapping. Zonation mapping can be completed using terrain categorization. With the help of zonation mapping, impact assessment for the damages can be done more efficiently. GIS can be used effectively in disaster management in the field of planning, mitigation and response to disaster.

Using GIS, potential disaster areas can be demarcate on a map example,

- Landslide areas can be identified using soil type of the area.
- Flood area can be identified by contours and then interpolated for 1 meter contour interval to get the inundation Map. The inundation zones can be mark as low, medium, high and very high hazard zones respectively using spot height. The Villages along the river banks were relatively highly vulnerable to hazard due flooding than the other villages. The river side villages Vulnerability can map using the buffering technique. The rivers were buffered to 1km radius and vulnerability zoned.
- Use of contour and topographic mapping serves as a base for future projects. Topographic maps are very valuable in the project of exploration, natural resource planning, rural and urban development.
- Preparation of historical map including disaster areas. This is important to understand the type and extent of possible impacts and areas

3.2 Community Mapping

Key content points:

- Mapping is a visual technique of presenting information on the coastal and marine resources in the area that can be easily understood by community members. Maps can also reveal much about the socio-economic conditions and how participants perceive their community.

- Such maps generally serve to reflect the locations/boundaries of villages, coastal and fisheries resources, forests, agricultural and urbanized lands, water resources as well as their present uses and key activities including corresponding issues and problems.

- The use of a barangay base map is important to closely approximate the spatial patterns and other characteristics being revealed in the map.

Maps are some of the most important tools in planning and implementing CRM projects. By laying the various zones, resources, infrastructures, development activities, opportunities, threats and issues on the map, the community is able to situate the condition of their coastal area in a visual and tangible manner.

Various information that can be mapped in the community maps as follows:

Boundaries

Roads

Settlements

Other infrastructures

Natural resources

Land use

Zonations

Others

3.3 Sample code for uses, livelihood, and opportunities

3.3.1 Traditional gleaning

B. hooks and line area

C. seaweed farm

D. fish drying area

E. marine protected area

F. lighthouse

G. fish port

3.3.2 Sample code for problems, issues, and conflicts

I. Blast fishing

II. Lack of land tenure

III. Beach erosion

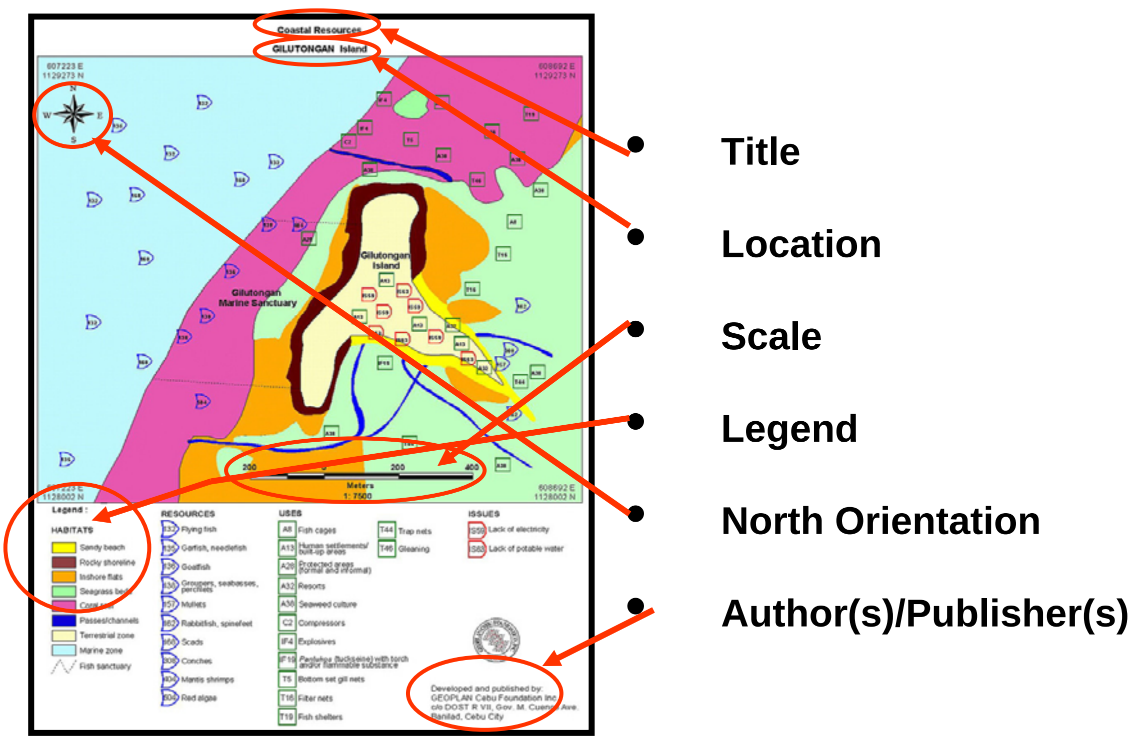
IV. Mangrove cutting

V. Commercial fishing intrusion

VI. Lack of alternative livelihood

The standard features of a DRR map is given in the figure 3. 1.3

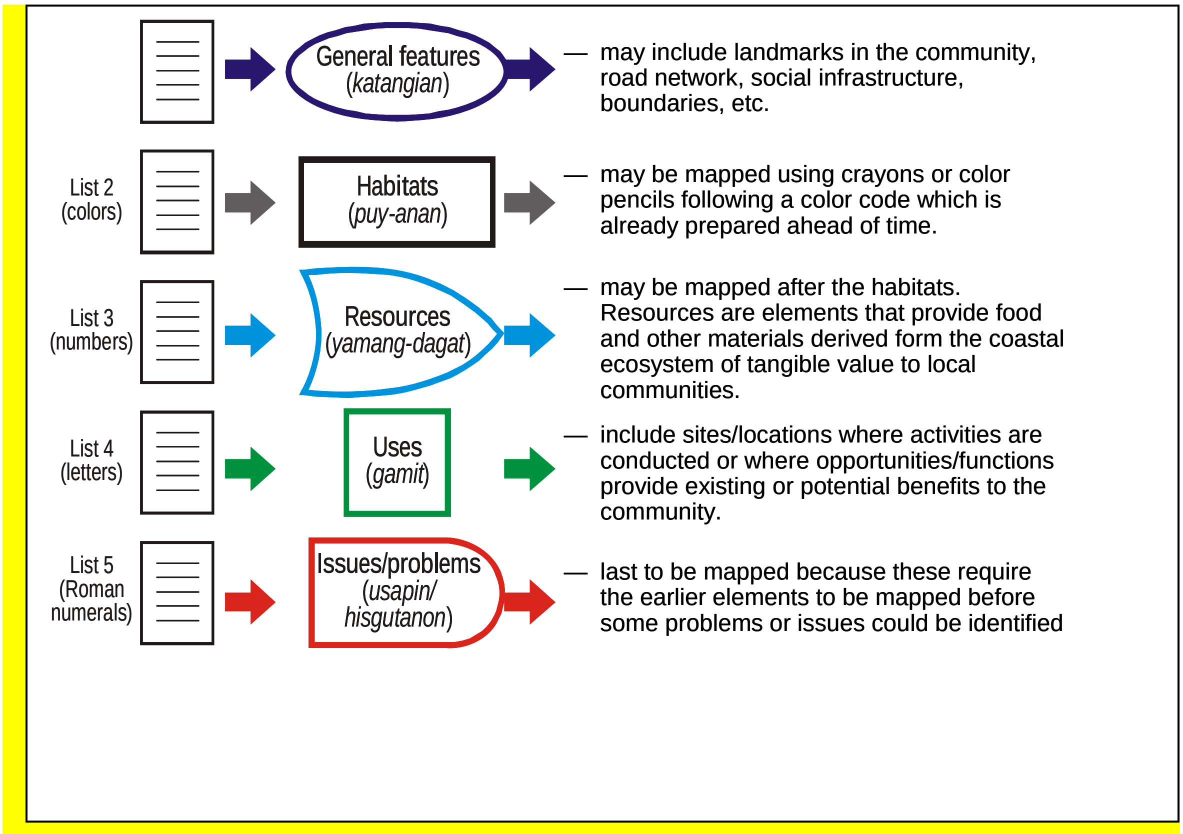
Figure: 3.1 Standard features of a map



Sample of a community-drawn coastal resource map of Badian, Cebu

There are various information need to be map for the preparation of DRR maps. The example is given in the figure 3.2

Figure: 3.2 various information for preparation of map



Habitat color codes

Mangrove (dark green)

Sea grass (light green)

Beach/offshore

Sandbar (yellow)

Rocky Shoreline (brown)

Mudflats (black)

Inshore flats (orange)

Coral reef (red)

Natural disasters, whether of meteorological origin such as Cyclones, Floods, Tornadoes and Droughts or of having geological nature such as earthquakes and volcanoes, are well known for their devastating impacts on human life, economy and environment. With tropical climate and unstable land forms, coupled with high population density, poverty, illiteracy and lack of infrastructure development, developing countries are more vulnerable to suffer from the damaging potential of such disasters. Though it is almost impossible to completely neutralize the damage due to these disasters, it is, however possible to (i) minimize the potential risks by developing disaster early warning strategies (ii) prepare developmental plans to provide resilience to such disasters, (iii) mobilize resources including communication and telemedicine services and (iv) to help in rehabilitation and post-disaster reconstruction.

Space borne platforms have demonstrated their capability in efficient disaster management. While communication satellites help in disaster warning, relief mobilization and telemedicine support, Earth observation satellites provide the basic support in pre-disaster preparedness programmes, in-disaster response and monitoring activities, and post-disaster reconstruction. The paper examines the information requirements for disaster risk management, assess developing country capabilities for building the necessary decision support systems, and evaluate the role of satellite remote sensing. It describes several examples of initiatives from developing countries in their attempt to evolve a suitable strategy for disaster preparedness and operational framework for the disaster management using remote sensing data in conjunction with other collateral information. It concludes with suggestions and recommendations to establish a worldwide network of necessary space and ground segments towards strengthening the technological capabilities for disaster management and mitigation.

3.4 Community Based Disaster Risk Management (CMDRM)

This is a process of disaster risk management in which at risk communities are actively engaged in the identification, analysis, treatment, monitoring and evaluation of disaster risks in order to reduce their vulnerabilities and enhance their capacities. The involvement of the most vulnerable is paramount and the support of the least vulnerable is necessary. In CBDRM the local and national governments are involved and supportive (ADPC – CMDRM, 2003). The figure 3.3 is explained the various stakeholders in the process of CBDRM.

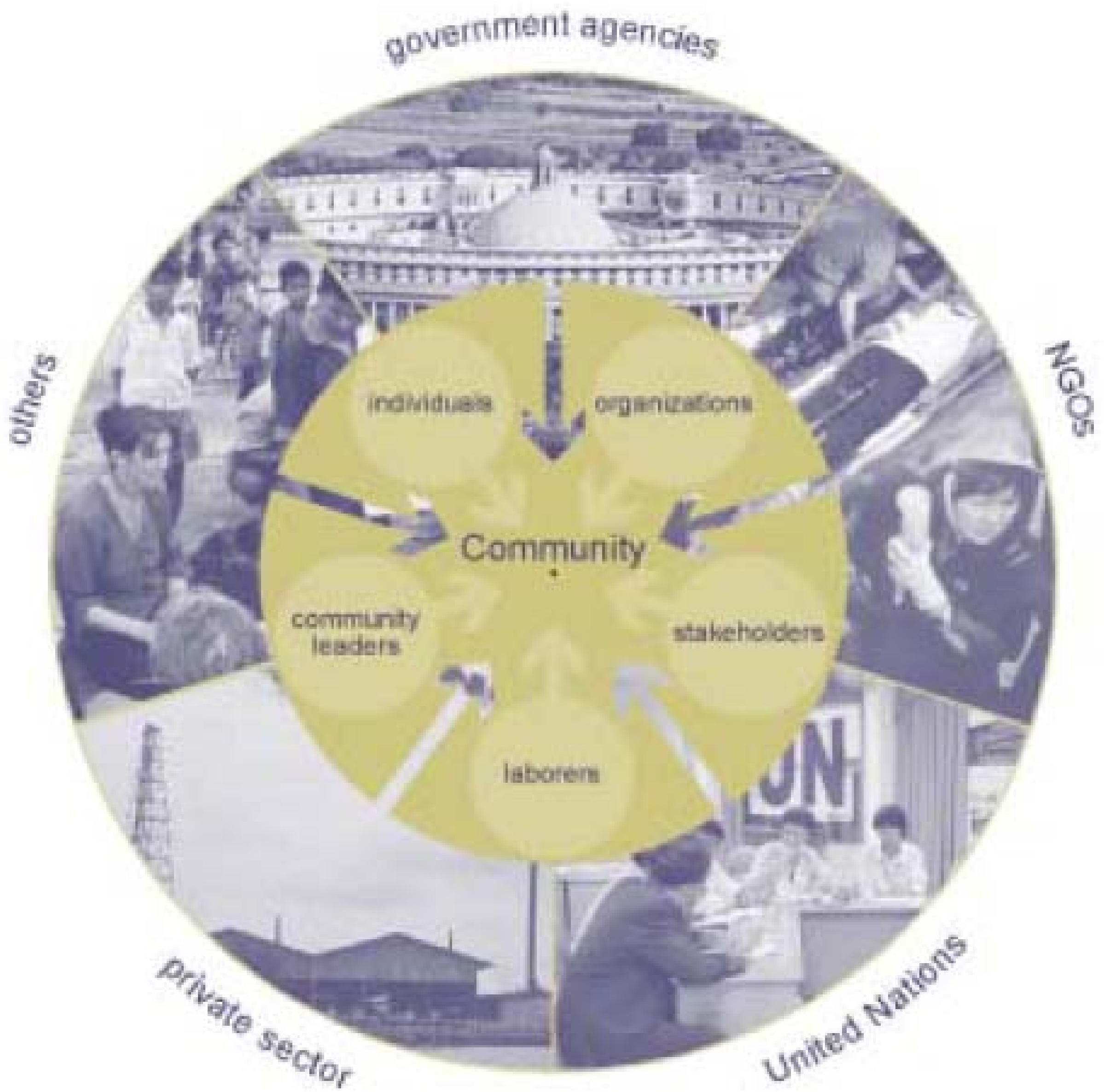


Figure 3.2.1: Stakeholders in CBDRM

3.4.1 CBDRM Process

In the CMDRM Process, a thorough assessment of the community's hazard exposure and analysis of their vulnerabilities as well as capacities is the basis for activities, projects and programs to reduce disaster risks. The community should be involved in the process of assessment, planning and implementation. This approach will guarantee that the community's real needs and resources are considered. There is a more likelihood that problems will be addressed with appropriate interventions through this process.

The Steps in Community Based Disaster Risk Management are;

Select Community

Rapport Building

Participatory Assessment

Participatory Disaster Risk Management Planning

Building and Training Community on Disaster Risk Management Organisation

Community Managed Implementation

Participatory Monitoring and Evaluation

The outcomes of the CBDRM Process lead to progressive improvements in public safety and community disaster resilience. It should contribute to equitable and sustainable community development in the long term.

3.4.2. The tools used to implement CMDRM

Participatory Rapid Appraisal (PRA)

This is a set of approaches, behaviours and methods for enabling people to do their own appraisal, analysis and planning, take their own actions, and do their own visuals, such as diagrams and maps. It is also called, Participatory Learning and Action (PLA).

The Characters of PRA tools:

The following are the key characters of the PRA tools;

Key Resources – Local People Capabilities

Main innovation – Change of behaviour and attitudes

Mode – Facilitating, Participatory.

Type of Instrument – Visual

Objective – Empowerment of local community

Outsider’s roles – Catalyst and Facilitator

Insider’s role – Investigator, Analyst & Planner

A means for – Interaction

On whose demand – Insiders

Long term outcomes – Sustainable local action & Institution

The following are some PRA tools

Interviews

Focused Group Discussion

Observation /Survey

Venn diagram

Timeline/Seasonality/Historical Transect

Mapping Exercises

Social Mapping

Resource Mapping

Hazard Mapping

Vulnerability Mapping

Interviews:

Semi-structured Interviews eg: loose use of an interview checklist with questions in the order of the conversation.

Informal Conversations eg: with various people to get a feel of the community environment.

Key Informant Interviews eg: community leaders

Community Interviews eg: with a group of different community members.

Focus Group Discussions:

Topic Focused eg: risk to livelihoods.

With homogenous groups eg: women crafts persons

Direct Observations:

By observing people and relationships, objects, structures, events and processes we can start to develop a picture of community issues

Folk songs, stories and poetry:

These can reveal indigenous knowledge, beliefs and practices

Mapping:

This involves drawing the areas main features and landmarks as a map. This might include houses and community facilities vulnerable to particular hazards and the location of key resources in an emergency. Maps can be drawn on the ground using sticks, leaves and stones, with chalk on a blackboard or with pens or pencils on a large sheet or a large piece of paper.

Timeline:

This is used to gather information about what happened in the past in order to understand the present situation.

Seasonal calendar:

This shows when agricultural activities, festivals and other significant events take place in the local area. Hazards can be added to the chart to show which activities will be affected.

Venn Diagrams:

This shows the key organizations and individuals in the local area and their relationships with each other.

Transect Walk:

This is a planned walk through the local area to explore different land uses (such as economic activities, agriculture, open spaces, houses) while taking notes, photographs and asking questions.

3.4.3 Guidelines for organizing a PRA:

Pre Field work: Work 2-3 weeks before the field work.

Access and review and secondary data

Develop sub topics for discussion through brainstorming

Mobilize funds for refreshments, supplies like flip chart, markers.

Train the team for common understanding.

PRA results are influenced by the length of time of the exercise.

Preparation should be made for writing reports immediately after the field work, based on notes from PRA team members.

During Field Work

Rapport building with the local people mainly the CBOs.

Greet the villagers in their traditional way and try to socialize.

Try to meet the local leader/officials/ elected representatives in that area

Clearly explain the reason of your visit to the villagers to clarify doubt and enable open discussion.

Choose time and venue that is convenient to different communities among local people.

The original copy of the PRA exercise maps etc. should be left with the community.

After Field Work

Have team discussions about information collected and gaps identified in information. Gaps can be filled up by going to the area again.

Findings should be shared with strategic actors in the community who were not present during PRA.

Share findings among a larger group.

Comments / suggestions should be incorporated in the final report.

3.4.4. Strengths of PRA

Visibility

Participation

Teamwork

Flexibility

Optimal Ignorance

Triangulation

Observation

Effective PRA Facilitator should

Listen attentively & say little.

Have good presentation skills.

Be clear about objectives, content & method

Rapport building with the participation is a must

Rehearsal before attempt

Maintain eye contact

Avoid artificial behaviour

Share life examples

Create responsive environment

Ensure active participation

Do not hurry

Be relevant

Follow main Sequence

Concentrate on the Issue

A good PRA Facilitator will

Creates an atmosphere of friendliness and equality

Stimulates Community members to reflect on their problems and needs

Gives opportunities to all participants, encourages those who are not used to speak in group meetings.

Listen, is patient and non-dominating, not biased or judgmental

Is modest

Helps people to analyze their situation and to plan activities together

Deepens the analysis by raising relevant questions facilitating decision-making by mediating between different interests groups.

3.4.5 Lessons for CBDRM and PRA

CBDRM has been tested and developed in various parts of Asia. e.g.: ADPC has developed a Handbook for CBDRM.

Use of PRA tools by development practitioners has helped its use by DRM practitioners.

PRA used for assessment, planning and evaluation of disaster risks and response. E.g.: Peoples Consultations after the 2004 Tsunami in Sri Lanka.

Remember the 7 steps of CBDRM.

Preparation for application of CBDRM is a must. e.g.: spend time in reviewing secondary data on the community.

Facilitation is key to CBDRM and use of PRA tools. e.g.: they should be skilled and sensitised to community cultures and dynamics.

PRA is a time consuming process: PRAs work more effectively when carried out over a sufficient length of time, with the facilitators living amongst the community under survey and absorbing themselves in community life.

4.0 Module 4 Disaster Risk Reduction and Management

4.1 Disaster Risk Management

A systematic process of using administrative decisions, organizations, operational capacities to implement policies, strategies, coping capacities to lessen impacts of hazards. It comprises of prevention + mitigation + preparedness

It includes:

Risk awareness and assessment,

Knowledge development,

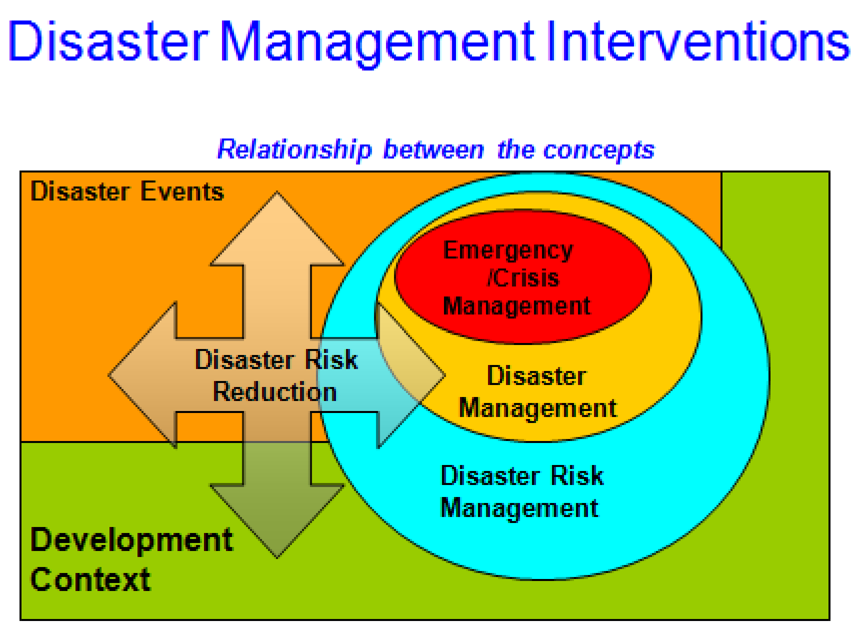
Institutional frameworks,

Application of land-use protection, science and technology, partnerships, financial,

Early warning systems

The disaster management interventions have several overlapping stages and activities. These are indicated in the figure 4.1

Figure 4.1: Disaster Management Interventions



4.2 Entry points for DRR

Before the Disaster has occurred (prevention, mitigation and preparedness)

The activities that are involved in this are as follows;

Risk Assessments

Early Warning Systems

Mainstreaming

Programmes for DRR

Capacity Building

Institutional Strengthening

Advocacy

Awareness Rising

Knowledge Development

Community Involvement

Development of risk reduction tools

4.3 During Disaster (Response, relief)

The activities that are involved in this are as follows;

Warnings and Evacuations

Damage Assessment

Needs Analysis

Emergency Operations

Provision of aid

Shelter

Strengthen coordination mechanisms

Evaluate and apply lessons learnt

Mainstreaming

4.4 After the Disaster (Recovery, rehabilitation and reconstruction)

The activities that are involved in this are as follows;

Risk Assessments

Development of recovery strategies, frameworks, policies and projects that reflect DRR considerations

Restoration of critical services in context of DRR

Reconstruction activities

Awareness-raising

Community involvement

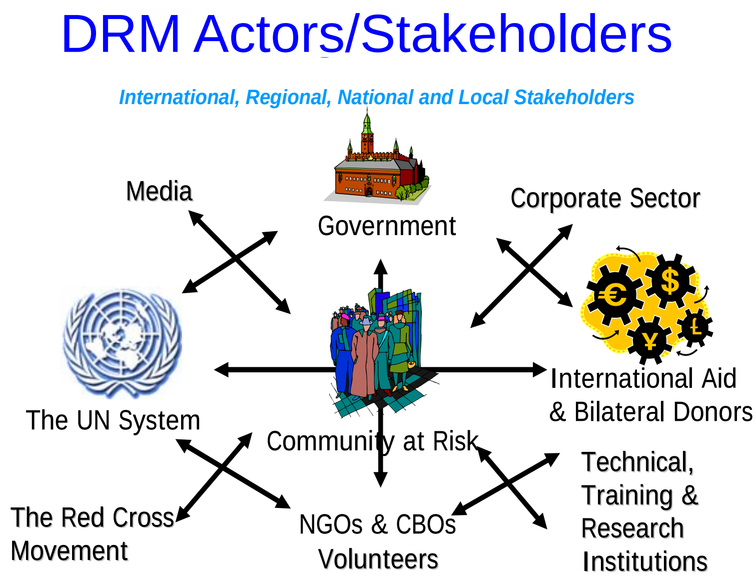
Ongoing development

Evaluate and apply lessons learnt

Development Practices

DRR process there are several actors need to be involved in several stages and those caters are given in the figure 4.2

Figure 4.2 Different actors for DRR



4.5 Cross cutting issues in Disasters

Gender

Human Rights

Conflict

Livelihood

Environment

Governance

Others

Gender

Both men and women have varying levels of capacity (owing to their physiological aspects and social positioning) to reduce disaster risks. Women are more vulnerable because of

Physiological aspects

Cultural constraints

Economic and social burden

Limited access to education and resources

Age

Both Elderly and Young children are more susceptible to disasters than others. Elderly personnel are more susceptible due to lack of mobility, physical disabilities and being isolated from the others. Young children are more susceptible due to lack of physical strength and practical skills for evaluation, being totally dependent on their parents and also some having nutritional deficiencies.

Disability

Disable people are more prone to disasters as their mental and physical capacities are sometimes impaired, they lack mobility and they have difficulty in understanding or communicating depending on the type of disability.

Ethnicity or foreignness

Migrants or refugees have language, educational and cultural barriers may restrict access to information and risk avoidance. They may be subjected to hazardous jobs where health and safety standards are poor

4.6 Methods of reduction of the vulnerability to coastal disasters and adaptation

This has been addressed both at global and national levels.

4.6.1 Global Efforts

At global level, primarily Intergovernmental Oceanographic Commission (IOC) under UNESCO and WMO has been dealing with coastal and marine risk reduction issues. The efforts have helped considerably in setting up as well as improving the quality of Early Warning Systems (EWS) and thus enhanced the risk reduction capacities worldwide.

The common ocean basins of Bay of Bengal and Arabian Sea bring in several common elements of coastal and ocean science, technologies, policies, planning, experiences and lessons learnt to share with and work together in the framework of regional cooperation for coastal and marine risk reduction. At regional level, the mitigation needs for tsunami for example would include the assessment of relative vulnerability/risk across the region and sub region, networking of seismic stations/Tide Gauges/Deep Ocean Assessment and Reporting of Tsunami (DART) etc. With regards to cyclone, it starts from hazard detection (often having trans-boundary origins) to monitoring, tracking and prediction of intensity and landfall.

4.6.2 National Efforts

Structural mitigation measures

Construction of cyclone shelters to safeguard the lives of the communities living along the disaster prone stretches of the coasts

Construction of sea walls to absorb the impact of the force being exerted by the sea waves, and to check coastal erosion

Protection of the sand dunes in the back beach area with their vegetation cover. These dunes form a natural barrier to high storm surges and waves, protecting the back beach environment from the hazards of these storms

Development and regeneration of bio shields for the protection of coastal environment

Non Structural mitigation measures:

Prediction of coastal hazards in time and space using the advances in enabling technologies – including ICT, space, modelling and better scientific understanding of the coastal processes.

Micro –zonation and risk mapping to target all kinds of technological, physical, financial and policy related interventions

Regulatory measures to impose restrictions on land use pattern as a part of a coastal zone management can be adopted

Community education programmes to serve as both mitigation as well as preparedness measures to build resilience in vulnerable coastal communities

4.7 Community contribution for control of coastal disasters

In the context of disaster risk management, a community can be defined as people living in one geographical area, who are exposed to common hazards due to their location. They may have common experience in responding to hazards and disasters. However, they may have different perceptions and exposure to risk.

4.8 Available measures for DRR in Coastal Area of Sri Lanka

4.8.1 Structural measures

4.8. 1. (a)Structural measures for Coastal Flood Management

An integrated approach to flood management calls for a best mix of structural and non-structural measures. An isolated coastal flood management option may achieve a certain objective, e.g. protection of a certain area, but cannot address the various objectives that should be addressed at the coastal area. The residual risks associated with structural solutions, for example due to uncertainty in the input information for analysis of these options or due to a series of chain failures of structural control and protection works, have to be taken into account.

Lateral connectivity

By containing flows within embankments, impeding seasonal floodplain inundation, the floodplain area exposed to inundation is restricted. This disrupts the lateral hydrological connectivity along the river corridor, with various effects on both the ecology of the channel and its floodplain. Further, embankments that are too close to the main channel decrease the natural heterogeneity of the floodplain, and impede the creation of new side channels and wetland areas. This reduction in habitat heterogeneity can dramatically impact fish populations, as many backwaters that were periodically connected to the main watercourse during the river flood no longer receive seasonal flows. These backwaters can be critical breeding and feeding areas for fish.

Lack of floodplain inundation reduces transmission loss and groundwater recharge, thereby severely affective the groundwater resources and their associated ecological and economic benefits. This has consequences on base flow – groundwater interactions, and degrades riverine habitats. Flood water spreading onto the floodplain improves soil fertility by depositing silt, exchanging nutrients and carbon between floodplain and channel, creating new habitants, and reinstating floodplain refuges and spawning areas for river species. Embankments reduce floodplain fertility because sediments and their nutrients are no longer deposited and exchanged.

Since embankments cannot guarantee absolute flood prevention, they can be designed to only provide a moderate level of protection. The degree of protection is generally driven by economic considerations. For example, it may be appropriate to protect agricultural lands against floods of one – in – ten- year return period and allow them to be inundated during higher floods, there by still maintaining the natural benefits of flooding (e.g. delivery of nutrient and organic rich sediments). Embankments that are designed for protecting urban and industrial areas need to be combined with bypass/diversion channels and/or detention/retention basins. There is a need to give due weight to the environmental impacts of construction of embankments, while making these design decisions.

Embankment spacing

When designing the alignment for new embankments, one should keep their likely adverse impacts in view. Particularly, efforts should be made to include floodplain water bodies such as ponds, wetlands, oxbow lakes etc., within the embankments, setting them as far apart and as far away from the main channel as feasible.

Typically, embankment result in steep-sided, trapezoidal, single channel cross-sections, rather than more natural multiple channels with gentle bank slopes and flat – lying floodplain surfaces. By reducing the area that can be flooded, and by maintaining a large proportion of the flow in the main channel with lower roughness, embankments decrease the travel times and increase flood peaks downstream. The high depth – to – with ratio of embanked channels makes them inherently unstable during high flows, requiring continuous maintenance.

Removing of setting back the embankments, in parts of the floodplains that are not intensively used for human development, can result in lower water levels and flow velocities, leading to lager in- channel storage and reducing flood peaks downstream. In certain situations where floodplains are used extensively for economic activities, this may not be a viable option. In such cases a possible option for partly restoring the river floodplain interaction is to set back the embankments, further from the main channel thereby partially re-establishing the lateral connection with floodplain wetlands and backwaters and restoring the river's ability to move about. This also reduces the velocity of the stream, results in lower flood stages, and restores, in part the natural functions of the floodplain including temporary flood storage. A river corridor is an enormously complex system, which cannot be fabricated. A comprehensive integrated approach is, therefore, required to undertake removal of embankments including land use planning. Magnitude, frequency and characteristics of flood, geographical setting and socio- economic background of the region have to be taken into account in any given situation.

Detention and Retention

Detention and retention basins are natural depressions or excavations, which can be used for temporarily storing coastal flood water to reduce the excess water. Detention basins are similar to retention basins except for the fact that the latter do not have controlled outlets. Detention basins hold the water temporarily and then slowly release it through a natural or man-made drainage channel, while water collected within retention basins slowly percolates into the ground or evaporates. According to the topography, the type and size of detention and retention basins can be different. They can be brought into operation at the desired stage of a flood wave, enabling reduction in flood peaks downstream. Often, natural depressions are also used for agricultural purposes.

4.8.1. (b) Structural measures for Coastal Erosion management:

The standard Structural solution for the Coastal erosion control is given in the Module 4. They are includes:

Artificial nourishment

Field of groynes

Artificial headlands

Offshore breakwaters

Rock armoured revetments

Concrete armoured revetments

Concrete seawalls

In the above classification concrete seawalls refer to solid concrete seawalls as opposed to rubble mound revetments armoured with concrete armour units.

Artificial Nourishment

In artificial nourishment an external supply of sand is used to replenish an eroding stretch of a coast. This method may appear to be expensive and the need for repletion of the process may not attract coastal engineers to adopt this technique. However, careful planning and considerations of capital and maintenance cost have proved that this method can be used effectively, particularly when there is a need to preserve the recreational function of the beach without erecting structures at regular intervals. This method will not have structures interrupting the beach other than those used as terminal structures. Artificial nourishment is attractive when the long shore drift is comparatively small.

There is a need for maintenance in the form of recharging for which an economic source of sand supply is required. This method may not prove to be economically beneficial in the presence of severe wave climates which result in high rates of sediment transport. Beach nourishment schemes are generally considered the least objectionable of the coast protection methods from a view point of environmental impact as this method results in the substitution of beach material lost in the erosion process. Advanced and improved dredging techniques have greatly enhanced the viability of the application of these methods (Figure 4.3).

Figure 4.3 Artificial Nourishment of beaches

Field of Groynes

A field of groynes can be used effectively on an eroding part of the coast to reduce locally the long shore sediment transport capacity and thus control coastal erosion. In effect it is possible to transfer areas of erosion to less harmful locations. There are many successful applications of fields of groynes having been used to reduce littoral movement and developing the shoreline. Groynes are comparatively easy to construct and their effectiveness may be increased by initially adopting artificial nourishment as required.

On the negative side, a field of groynes does cause a regular interruption along the beach and a certain extent of maintenance is required. Groynes can induce local scour and as identified earlier can cause down drift erosion. Hence in the design of groynes due attention has to be focused on the length and permeability which influence the degree of littoral material that is trapped by the groyne, the cost and the level of efficiency required by the groyne field for a particular problem (Figure 4.4).

Artificial Headlands

The fundamental difference between a groyne and an artificial headland is that the latter is a more massive structure designed to eliminate problems of down drift erosion and promote the formation of beaches. Although these structures may take a number of different forms their geometry is such that, as with the offshore breakwater, wave diffraction is used to assist in holding and developing the beach in the lee of the structure. A particular development of this type of structure, identified as the fishtailed breakwater, due to its shape, has been used very effectively. It is important to conduct detailed investigations in the planning and design of these types of structures.

Offshore Breakwaters

Offshore breakwaters are placed generally parallel to and at a certain distance from the shore. These structures can be used to change the transport capacities, both alongshore and onshore/offshore to the coast, resulting in accumulation in the lee of the breakwater. Therefore, in general, offshore breakwaters provide stable beach plan forms and promote the development of natural beaches. These structures demand comparatively less maintenance (Figure 4.5).

On the negative side, offshore breakwaters are fairly large structures and constructing them in near shore regions can be difficult. Since these structures control littoral movement they can cause erosion down drift if designed without considering this aspect.

Figure 4.5: Offshore breakwaters

Concrete Seawalls and Revetments

The main purpose of a concrete seawall (vertical or sloping) or a rubble mound armoured sloping revetment is to protect the land or water behind from the effects of wind or swell waves. In the past these have been the most widely used option for coastal and flood defence ranging from massive vertical retaining walls to sloping revetment. It is the action of wind-generated and swell waves that give rise to principal forces or movements that have to be resisted. Other water movements such as tides and surges may affect water levels at the structure and may give rise to local currents. There are a many situations where hard solutions have to be provided in order to ensure sufficient protection, at an acceptable level of risk, to valuable assets located along the coastal zone. Under these conditions it is customary to use concrete seawalls and revetments.

It is observed that concrete seawalls and rubble mound armoured revetments are essentially rigid and steep relative to a mobile foreshore and therefore can have a substantial impact on the shoreline both in visual or amenity terms and in their effect on coastal processes. The latter can be by wave reflection or the removal of littoral material from the sediment transport system. In effect this type of structure is used to fix the shoreline. Because of potential vulnerability to toe scour, these structures are frequently used together with some system of beach control such as groynes and/or beach nourishment. If these structures are used in isolation it is very important to provide adequate toe protection and, in the case of concrete seawalls, stability problems may occur unless the foundation of the structure is well below the seabed.

It is noted that concrete seawalls offer a wide range of alternative designs. The availability of a promenade at the top is considered an important recreational feature and the use of steps provides easy access to the beach. These steps could also be used effectively for dissipation of wave energy. The presence of high wave reflection leading to scour is a major problem with this type of structure. Scour at the toe erodes the beach leading to further problems. In this respect regular maintenance is required and, as identified earlier, these structures do not aid beach stability.

Rubble mound sloping revetments armoured with rock or concrete units can be designed to offer good hydraulic performance. These structures are fairly easy to construct and little maintenance required. However it is important that these structures are designed with due consideration to the desired relationships between the geometrical characteristics of the individual layers as well as the stability of the toe and the head. If due attention is not focused rapid failure could set in under storm attack and in this respect regular monitoring is required. When using these structures it is necessary to provide means to access the beach.

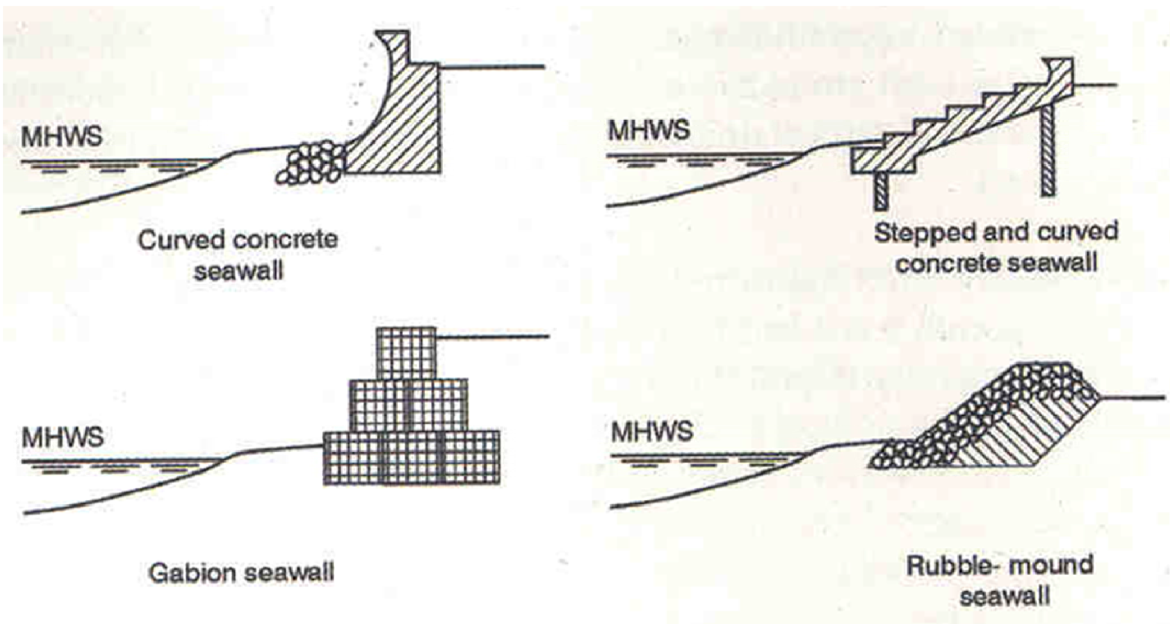


Figure 4.6: Examples of Sea walls

(After Shoreline Management Guidelines; Karsten Mangor, 2001)

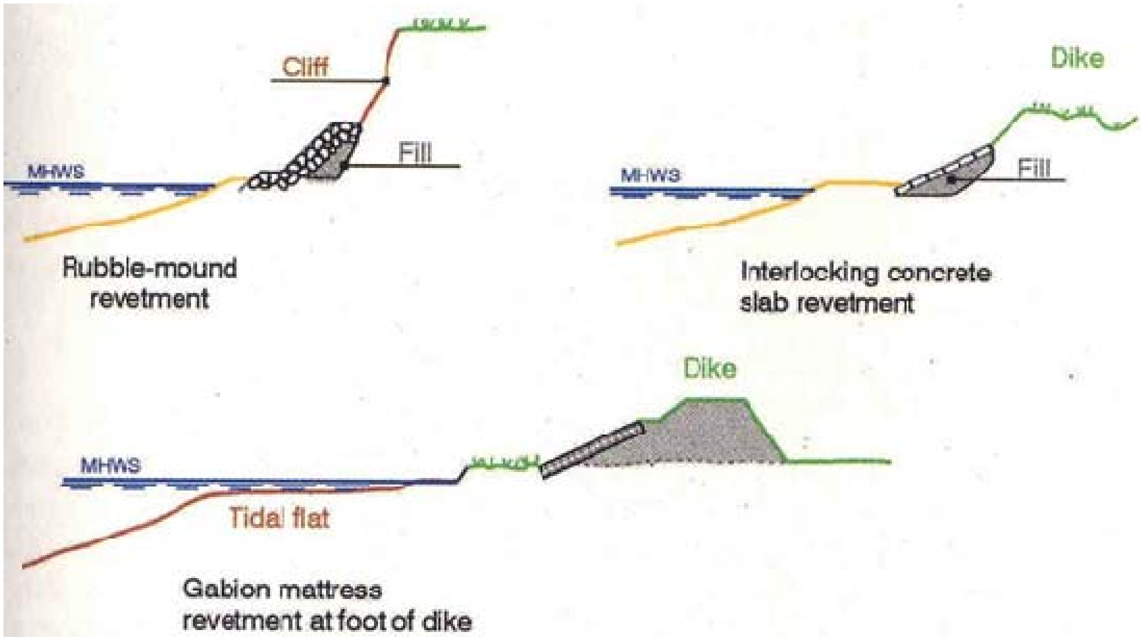


Figure 4.7: Examples of Revetments

(After Shoreline Management Guidelines; Karsten Mangor, 2001

4.8.1(c) Structural measures for controlling Lightning and Technology used for protection of buildings

Lightning conductor

Buildings are affected both by direct and indirect lightning strikes. When a building is higher than the close by structures, it attracts most of the lightning flashes that produced by the overhead clouds in the location. Therefore, lonely, fairly high buildings should be protected against the direct lightning.

Protection of the large and more specialized buildings needs to be done by competent professionals. It is of utmost importance to design and plan the protection system from the planning and designing stage of the building.

The most effective and simplest means of providing protection to most buildings located particularly in lightning prone areas is the installation of a lightning conductor comprising of Air Terminal, Down Conductors and Earth termination or termination networks (Figure 4.8)

Figure 4.8 Air Terminal, down conductors and Earth termination

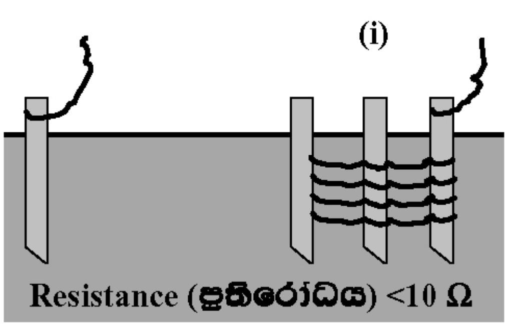


Figure: 4.9 installing of a set of parallel rods

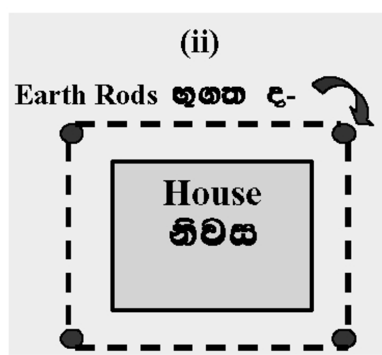


Figure: 4.10 installing several earth rods

Surge diverters

Damage to electrical and electronic equipment could be minimized by installation of a surge diverter. The function of this device is to divert voltage surges, resulting from lightning strikes or other disturbances on the electrical and communication (telephone/data) lines, from the electrical and electronic equipment in the building.

Earth rods

The earth wires of electrical circuits of buildings should be properly connected to the earth rods, which should be installed to have their electrical resistance less than 10 ohms.

When the electrical resistance of the earth rod is high, the high voltages induced in the electric circuit caused by a lightning flash or any other electrical short circuit may find its way through electrical appliances like TV, Radio, electrical bulbs etc. to discharge to earth, damaging or destroying those appliances, instead of discharging to earth through the earth rod.

Therefore, the resistance of the earth rod should be measured regularly and efforts have to be taken to maintain the resistance at a low value.

There are number of ways of installation of earth rods to have its resistance low. Two economical and easy methods are,

a. Installing a set of parallel rods.

A number of rods installed in a place are connected electrically with each other with a conducting wire like copper or iron (Figure4.9)

b. Installing several number of earth rods around the building and connecting each to the earth-wire of the electric circuit of the building at several points (Figure 2.10).

It has been suggested that the second method gives better results since this reduce damages resulted by step potential induced when high power surges are discharged from earth rods.

4.9 Restoration of Coastal Ecosystems

Ecosystems provide multiple services and they are highly interlinked. People are benefited by these services in different ways and some of them are given in the table 4.1.

Table 4.1: Ecosystem Services

Provisional Services	Food and Water
Regulating services	Flood and disease control
Cultural Services	Spiritual, recreational, and cultural benefits
Supporting Services	Nutrient cycling that maintains the conditions for life on earth

The role of the coastal ecosystems were highly discussed in different circles after the Indian Ocean, 2004 tsunami and the Cairo principles adopted by the parties involved in reconstruction and rebuilding of tsunami affected countries have emphasized the use of coastal ecosystems as bio-shields against natural hazards.

The table 4.2 illustrates role of three coastal ecosystems; coral reef, mangroves and sand dunes in reducing impacts of coastal erosion and coastal floods.

Table 4.2 Role of three ecosystems

	Coastal Erosion	Coastal Floods
Coral Reefs	Protect shoreline through acting as a natural wave breaker and reducing wave energy	Reduced wave energy travel of waves more interior
Mangroves	Protect shoreline through absorbing wave energy	Absorbing wave energy prevents travel of waves more interior, provide flood attenuation , prevent soil loss and
Sand Dunes	Act as a dike to prevent entering waves inside.	Act as a dike to prevent entering waves inside.

During last four year period after Tsunami, December, 2004 Sri Lanka carried out an extensive program to restore coastal ecosystems damaged by tsunami or other anthropogenic activities with the aim of protecting coastal people and their properties from a future disaster. This effort was fuelled by the activities carried out by government, non governmental and academic agencies. A recent survey undertaken by the coast conservation department reveals that an extent of 162 ha mangroves area in Ampara and Baticaloa districts in eastern coast was restored under this program.

Details of locations and extents of restored mangroves in Ampara district is detailed in table 4.3.

Table 4.3 Mangrove Locations and Extents in the Ampara District

Panama	15.66
Arugambay	5.50
Potuwila	12.34
Komari	3.43
Murugathenna	4.16
Periyakalapu	10.00
Panagala	05.00
Palakuda	2.50
Kunugala	5.00
Urani	5.00
Kudakalliya	5.00
Potuwil lagoon	5.00
Panama lagoon	20.00
Panama north lagoon	15.00

Even before the tsunami, Sri Lanka has identified the importance of healthy coastal ecosystems and provided the required regal framework for conservation and management of these to ensure sustainable benefits to people. The Coastal Zone Management plan provides policies and strategies for conservation and management of coastal ecosystems.

IUCN Sri Lanka with consultation of relevant government and academic agencies has prepared guidelines for restoration of mangrove ecosystems. The aim of this document is to provide detailed technical directions to the organizations involved in mangrove ecosystems restoration.

4.10 Non- Structural measures

Disaster Risk Reduction is defined as the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and poverty, wise management of land and the environment, and improved preparedness for adverse events.

Risk is a function of the hazard as well as the exposed population and their capacity to manage risk and respond to disasters (UN ISDR 2004).

$$R = H.V.E$$

Here, R: Risk, H: Hazard, V: Vulnerability, E: Exposure

Economic development pressures along the coast, population density and distribution and human-induced vulnerabilities, coupled with increasing frequency and duration of episodic and chronic coastal hazards increase risk and set the stage for more frequent and severe disasters and reduced time and capacity to recover. Therefore policy makers, practitioners and communities must identify their exposure to hazard impacts to proactively address disaster mitigation.

This chapter discusses the non-engineering measures practiced in Sri Lanka to reduce the potential risks of four major coastal hazards namely Coastal erosion, Coastal flooding, lightening & thunder and Coastal Resource Degradation on socio-economical and ecological environments. Here, while Coastal flooding and lightening & thunder are categorized as episodic hazards, shoreline erosion and Coastal Resource Degradation are called as chronic type hazards.

4.10.1 Definition of Non –structural measures

As per the definition given by UNISDR, Non engineering measures are considered as any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Non –Engineering measures focus on managing disasters rather than controlling through addressing the parameters; Vulnerability and Exposure of the risk equation. There are dozens of such measures being practiced by various organizations involved in disaster management in Sri Lanka aiming to reduce risk through prevented physical exposure and reduced vulnerability of the community. The table 4.4 illustrates some of the measures practiced to reduce disaster risk of four major coastal hazards; Coastal erosion, Coastal floods, lightening & Thundering and Coastal Resource Degradation.

Table 4.4 Non Structural Measures Taken to Reduced Vulnerabilites and Risks

Hazard	Reduce Physical Exposure	Reduce Vulnerability
Coastal Erosion	Setback, Awareness creation and Education, Land use Plans, Coastal Bio-shields, Risk profiles	Building Codes & Construction guidelines, Awareness creation and Education, Lad use Plans , , Early warning
Coastal floods	Setbacks, land use plans, Awareness & Education, Risk Profiles	Building Codes & construction setbacks, Awareness & Education,

		Early warning
Thundering & Lightening	Set up protective devices, Risk profiles	Awareness & Education
Coastal Resource Degradation		Law& regulations enforcement, awareness & Education, policy development

4.10.2 Coastal Setbacks

Coastal setback is a geographical strip or band within the coastal zone within which certain development activities are prohibited or significantly restricted. (National Coastal Zone Management Plan 2005)

4.10.3 Disaster Risk Reduction Function

As per definition, development activities are prohibited or control significantly within the defined setback area. So setback is used to reduce physical exposure of the development activity to hazards and to restrict investments in high risk areas. On the other way, maintaining a setback in the beach front allows the dynamism of the coastal environment and it helps to minimize development pressure on coastal ecosystems.

The Coastal Zone Management Plan (CZMP), 1990 introduced coastal setbacks to practice first time in Sri Lanka and subsequently amended by 1997 Revised CZMP. It was not unique setback for entire coastline of the island and the setbacks were determined by the social, economical and ecological conditions of the coastal segment introduced by the plan. The following criteria were used by the Coast Conservation Department in revision of coastal setbacks in 1997.

Coastal erosion rate

Significance of cultural and archaeological sites

Level of use conflicts

Legal status

Special Area Management sites

Extent of coast protection measures carried out

Protected areas

Exposure to extreme natural attributes such as cyclones, storm surges

Geomorphologic characteristics

Vulnerability of coastal habitats

Significance of other natural components such as scenic beauty, naturalistic and recreational values

Level of development

The main objective of introducing coastal setbacks is to minimize the potential damages and restrict investments in the sea front which is more susceptible to coastal hazards. The coast conservation department currently uses setbacks standards stipulated by NCZMP 1997 and they are given in the annex 01.

4.10.4 Issues to implement coastal setbacks

Scarcity of coastal lands

There are competing demand for coastal lands from different sectors like tourism, fisheries and navigational activities. Statistics also reveal that the coastal area has the high population density in the country. The situation is more severe in western, Southern and some parts of the eastern coast. Hence short-term social and economical benefits attract more and more socio-economical activities in to the coastal areas and scarcity of land make difficulties to maintain a sufficient setback.

Inadequate enforcement

The coast conservation department is responsible to ensure implantation of coastal setback standards and has developed a system by incorporating with coast conservation permit system. However it continuously suffers from inadequate resources to make enforcement in timely and efficient manner. The result is appearing a large number of unauthorized constructions long the coastal belt. That makes coastal environment more socio-economic vulnerable

Inadequate awareness

Adequate awareness among developers and general public on coastal setback standards and their benefits to individuals and largely to the country ensure compliance with existing laws and regulations. The coast conservation department implements a separate environmental awareness and education program targeting various stakeholder groups including developers, policy makers, enforcement officers and general public. The permit compliance surveys recently undertaken by the department reveals that high compliance rate in some coastal districts has been supported by the successful awareness creation.

4.10.5 Coastal Green Belts

Definition

A green belt could be defined as a strip of natural or artificially created vegetation designed to mitigate adverse impacts of natural coastal hazards on human lives and property – Technical Guidelines for Establishment of a Green Belt, Coast Conservation Department and IUCN

Disaster Risk Reduction Function

Coastal vegetation is used in many parts of the world, not even in coastal areas to reduce potential impacts of natural hazards like sea erosion, high waves, tsunami and storms. eg: Hibiscus tiliaceus–a large shrub or tree native to Southeast Asia is commonly used in Japan for green belts to protect housing against tsunamis (Hiraishi and Harada, 2003). Number of scientific researches conducted in different parts of the world to investigate the disaster reduction function of coastal vegetation shows that they have abilities to absorb wave and wind energy and consolidate sediments. In case of shoreline erosion, vegetation protects shoreline from erosion through improving slope stability, consolidating sediments and diminishing wave energy. Also vegetation is used as effective wind barriers to protect from storms and salt sprays to inland areas. However effectiveness of a green belt as a disaster risk reduction measure depends on number of factors which are to be addressed in planning stage of the measure. They are width of the Green Belt, density and structure of the vegetation. Analytical models show that 30 trees from 100sq m in a 100m wide belt may reduce the maximum tsunami flow pressure by more than 90 %(Hiraish and Harada, 2003)

Implementation in Sri Lanka

Sri Lanka has adopted guiding principles for post-tsunami rehabilitation and reconstruction (Cairo Principles) which have emphasized use of green belts as a measure to reduce vulnerability of coastal communities to natural hazards. However,

We have applied the concept of green belts as disaster mitigation measure even before the Indian Ocean Tsunami, 2004. The 10 to 15 year old well functioning green belts in the southern and eastern provinces have mainly aimed to reduce the impacts of cyclone and high winds on socio-economic environment of the coastal areas. The green belt established along the Kalido beach, Kalutara provides evidence to potential use of green belt for beach stabilization. The massive damage of tsunami caused to open eyes of all parties to take all possible options to avoid such a disaster in future. Accordingly the government initiated Green Belt Establishment project under the coast conservation department and the forest department to promote establishment of green belt around the island. During last three years, number of government, non government and community organizations have contributed to this effort in different manner.

Studies undertaken by various scholars around the world have illustrated potential application of ecosystem services provided by a green belt as disaster mitigation. The table4.5 illustrates ecosystem services provided by a Green Belt and their role in reduction of impacts of coastal erosion, coastal flooding, lightening & thunder and resource degradation

Table 4.5: Ecosystem services provided bt a greenbelt

Green Belt	Costal Erosion	Costal Flooding	Lightening & Thunder	Resource Degradation
	Absorption wave energy and reduction of wave velocity, stabilization sand beaches gives more resilience to waves	Flood attenuation, soil loss reduction	Protect people and their property by shielding	Support to dynamism of sand dunes Conservation of coastal biodiversity Prevent wind erosion

Assistance to establish green belts

Technical guidelines: Hence effusiveness of a green belt as a disaster risk reduction measure widely depends on its correct technical design; the coast conservation department in collaboration with IUCN and relevant agencies has prepared technical guidelines for green belt establishment. They provide directions to establish a correctly designed green belt that may be resilient and stable enough to prevent or mitigate the devastating effects of coastal hazards. Copies of this document are available at the coast conservation department or IUCN.

Nursery & Planting Guidelines: The Department of Forest has prepared a manual for nursery management and a set of guidelines for planting. These documents are available at the Forest Department

Issues related in implementation

The experience gained through establishing of Green Belts as a non-engineering measure to reduce risk of coastal hazards reveals that there are several issues to be solved for ensure effectiveness and sustainability of green belt establishment programs. They are;

Issues related to land ownership: It is vital to have a clear understand of ownership of the land which is to be used for green belt development prior to commencement of planting activities. Landownership in some areas is not clear and sometimes, number of parties claim for the same plot of land. Divisional secretary of a particular area is the sole owner of state lands in his jurisdiction. It is vital to reach an agreement with divisional secretary on the land in very early stage of planning so as to avoid unnecessary issues in implementation phase.

Inadequate community participation: as per the experience of the agencies involved in coastal green belt development, it is obvious that people show reluctant to participate in green belt development activities due to a number of reasons. Minimal of short term economic benefits to local community, inadequate awareness on green belts and dependence mentality created by the bad tsunami programs are the main causes behind this plight situation.

Insufficient project periods: number of implementation agencies highlighted that short project period impedes to implement a program in sustainable and efficient manner. Due to the restrictions made by donor agencies, some green belt programs are designed to cover within one year or less period.

Lack of technical Know-how: the survey reveal that some green belt programs established in the eastern province have not been designed in technically correct manner. Poor structure and wrong species selection have reduced the effectiveness of the established green belt in disaster risk reduction

Conflicts with other coastal users: coastal area is normally supported for multiple uses and fisheries, tourism and navigation are important sectors linked with coastal area. Therefore it is important to consider other coastal uses in the project areas in designing stage of the project.

Public Awareness

Knowing about risks that lead to disasters, understanding how they affect our livelihoods and environment, and dedicating collective efforts to manage those conditions are crucial to protect our lives, our possessions, our social assets and indeed the land, water and natural resources on which human life depends(knowing risks). In this sense, transferring risk knowledge into the public is vital in disaster risk reduction. Raising public awareness is a very important first step in disaster risk reduction process. Awareness doesn’t work alone, but it is vital to implement most of non structural measures. ISDR defines Public awareness as the process of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their exposure to hazards. Awareness is particularly important for public officials in fulfilling their responsibilities to save lives and property in the event of a disaster.

Public awareness is though the most commonly applied disaster risk reduction strategy, it is vital to carefully design the approach, methodology and media for communication in accordance with the target audience. A Simple stepwise procedure for designing an awareness program is illustrated bellow;

Step 01: Deciding the target group and analyze their background (academic level, past experience, participation for similar programs etc...)

Step 02: Design the message to be delivered. The message should be simple and easy to understand to the target audience.

Step 03: Based on the target group and message to be delivered, select appropriate awareness tools, techniques and communication channels. Communication channels can be used for public awareness are described bellows:

Mass media : Television, radio, newspaper, cinema

Electronic media : Website, Email, electronic conferencing, SMS,MMS

Audio-visual: Video, audio, multi-media, artworks, photographs, slide shows, model, Map.

Postal: Direct mailing

Telephone: Dial-in conversion

Face to face: Meeting, seminar, workshop, March, exhibition, demonstration,

Stand-alone print: Billboard, poster, banner, warning sign,

Distributor print: Leaflet, brochure, booklet, newsletter, journal, research paper, report

Folk media: Story, drama, dance, song, music, street entertainment

People: community leader, volunteer, project worker

(Source: Disaster Risk Reduction in Asia: ADPC)

Step 04: Decide an appropriate venue, date and time for conducting the program

It is very important to have appropriate human and knowledge/material resources for conducting an awareness strategy in an effective manner. The table 4.6 provides information on agencies, materials, and human resources sources in regard with the main coastal hazards in Sri Lanka.

Table 4.6: Information on agencies, materials and human resources sources on Disasters

No	Hazard	Material/Human Resources availability for awareness creation
01	Coastal Erosion	Coast Conservation Department, Maligawatte Colombo 10 Tele: 011-2449754 Email: nissanka-dcc@fisheries.gov.lk Web site: www.coastal.gov.lk
02	Floods	Irrigation Department 238,Budhaloka Mawatha, Colombo 07 telephone: 2581162 email : infor@irrigation.slt.lk website: www.irrigation.gov.lk Disaster Management Centre 2-222,BMICH Complex, Budhaloka mawatha, Colombo 07
03	Lighting & thunder	Meteorological department 383,Bauddhaloka Mawatha, Colombo 07 telephone: 2694846 email: meteo@slt.lk website: www.meteo.slt.lk
04	Coastal Resource Degradation	Coast Conservation Department National Aquatic Resources Development Agency Crow Island Colombo 15 Telephone: 2521000/2521006 Email: postmaster@nara.ac.lk Website: www.nara.ac.lk
05	Cyclones/storm surges	Meteorological department 383,Bauddhaloka Mawatha, Colombo 07 telephone: 2694846 email: meteo@slt.lk website: www.meteo.slt.lk Disaster Management Centre 2-222,BMICH Complex, Budhaloka Mawatha, Colombo 07

4.10.6 Land use planning:

Land use planning is an approach to determine the most suitable options in which land is to be utilized. It addresses the changing relationship between people and their environments through evaluating various socio- economic and environmental conditions. Land use planning ensures sustainable utilization of land resource and reduces people's vulnerability to hazards through controlling human activities. According to the ISDR definition, land use planning is;

Branch of physical and socio-economic planning that determines the means and assesses the values or limitations of various options in which land is to be utilized, with the corresponding effects on different segments of the population or interests of a community taken into account in resulting decisions.

Land-use planning involves studies and mapping, analysis of environmental and hazard data, formulation of alternative land-use decisions and design of a long-range plan for different geographical and administrative scales.

Land-use planning can help to mitigate disasters and reduce risks by discouraging high-density settlements and construction of key installations in hazard-prone areas, control of population density and expansion, and in the sitting of service routes for transport, power, water, sewage and other critical facilities.

(Source: ISDR website)

Land use planning legislation is the way to implement land use policies and plans. Under the Urban Development Act following land use legislations introduced and implemented through permitting system.

4.10.7 Zoning Regulations:

It controls the physical development of land and the kind of uses to which each individual property may be allocated. Local authorities implement these regulations under the provisions of Urban Development Act.

Sub division regulations: it is the division of land into two or more parcels for the purpose of sale or building development. Urban land use plans has minimum block size to ensure basic environmental conditions for living and to avoid unnecessary concentration of population.

Acquisition and relocation: land acquisition is to ensure the land to be utilised only for the allocated purposes. UDA Act has provisions for land acquisition lands and relocation of people in the identified hazard prone areas to avoid disaster risk. After Indian Ocean tsunami, 2004, all coastal dwellers within the coastal reservation areas were relocated to more interior safer lands.

4.10.8 Building codes and construction guidelines:

Main purpose of building codes and construction guidelines are to ensure disaster resistant buildings and other constructions. Specially dwellings and other constructions coming within a particular hazard prone area eg: flood prone area should be designed so as to meet those hazard resistant construction standards. Irrigation Department has developed flood resistant construction guidelines which can be applied in planning constructions within a flood prone area. Implementation of these guidelines can be done through local authorities by incorporating into the permit procedure.

4.11 Institutional policies on Coastal Resources Management

4.11.1 Brief History of Costal Resources Management Policy Development

An interest in the management of coastal resources in Sri Lanka dates backs to the 1920s, with the primary focus on coastal erosion control. Further co-ordination efforts led, in 1963, to the establishment of Coast Protection Unit in the Colombo Port Commission. The need for an organization with a wider remit was recognised by the creation of the Coast Conservation Division (CCD) in the Ministry of Fisheries (MoF) in 1978.

The legislative foundations for its more comprehensive role were established in the Coast Conservation Act (CCA) no. 57of 1981, which gave the CCD responsibility for first designing and constructing coastal erosion control structure, and second, regulating development activity within a coastal zone. The area of this zone is limited to 300m inland from the mean high water line and 2 km seaward from the low water line. Coastal erosion is a problem of considerable significance in Sri Lanka, which is buffeted by waves driven, in turn, by the south–west and north-east monsoons. But it is the coasts directly facing these winds that are the most heavily eroded and accretion takes place to the South of the island. The CCD, given the function of its antecedents, naturally assumed its role in coastal erosion control. But with limited means and 10 other agencies with overlapping jurisdictional responsibilities for the management of coastal resources, it chose to focus its activities on arresting t he degradation and depletion of coastal habitats and sites of historic significances.

The means at CCD’s disposal to pursue its mandate for resource management was limited. All developments within the legally defined coastal zone required a CCD permit. Where there was uncertainty about the potential effect of a proposed scheme, the CCD was able require an Environmental Impact Assessment (EIA). The Act also required the development of a management plan, to be updated every four years. As a result, in 1990, Sri Lanka was the first tropical country to have centrally managed Integrated Coastal Zone Management (ICZM) programme.

Further evaluation of policy took place within the Coastal 2000 document, funded by USAID. This called for the programme to be implemented simultaneously at different institutional levels and for the adaption of participatory approaches. In recognition of the limitations of the CCD permit system or dealing with environmental degradation caused either by discrete activity outside the narrow coastal strip or by the cumulative effect of diffused activities, it called for the establishment of Special Area Management (SAM) plans by the CCD or any national agency.

The SAM process was tested by CCD, in Rakawa lagoon and in the Hikkaduwa, and the CEA in the Muturajawela. The approach was endorsed further in the revised CZMP of 1997, which identified and ranked 23 potential SAM sites and defined SAM procedures, as well making more minor adjustments to the approach set in the original Plan.

Despite the introduction of SAMs, which apply over only a few small areas, CCD activities do not deliver fully integrated resources management.

The legislation supporting coastal zone management pre se, its overlap with other areas of legislation and the issues omitted has recently been analysed. Tables 2.2a and 2.2b highlight the key pieces of enabling legislation and associated policy decisions to coastal zone management.

Table 2.2a: Coastal Management Policy

1963	Coast Protection Unit established at the Port Commission
!978	Coast Conservation Division starts at Ministry of Fisheries
1981	Coast Conservation Act No. 57 passed
1984	Coast Conservation Division upgraded to Department
1986	Master Plan for Coast Erosion Management adopted
1988	Coast Conservation Act Amendment (No.4) passed
1990	Coastal Zone Management Plan adopted by Cabinet
1992	Publication of Coastal 2000: Recommendations for a Management Strategy for Sri Lanka's Coastal Regions.
1993	Special Area Management Process approved for two sites.
1994	Coastal 2000 policies adopted by Cabinet

1997 Revision of Coastal Zone Management Plan

1997 Hambantota Integrated Coastal Zone management Project initiated

2000 Coastal Zone Management extensively reviewed and plans developed for Hambantota

2002 Seven more SAM sites were selected to implement

2004 CZMP revised

Table 2.2b: Other Policies Affecting Management of Coastal Resources

1937 Fauna and Flora Protection Ordinance (No. 2), with its amendments in 1970 (No.1) And 1993 (No. 49).

1978 Urban Development Act (No. 41).

1980 National Environment Act (No.47) as amended by No.56 of 1988

1992 Mines and Minerals Act (No. 33)

1996 Fisheries and Aquatic Act (No. 2)

5.0 Module 5 Field Exercises an*d* reporting

5.1 Objectives of the Field Exercises

The main objective of the field exercise is to use and test all information and methods they have learnt on DRR during the workshop period and to identify the coastal hazards, risks and vulnerabilities on the ground and come up with a good proposals on DRR strategy. The participants will conduct this field exercise in groups and present their findings at the plenary.

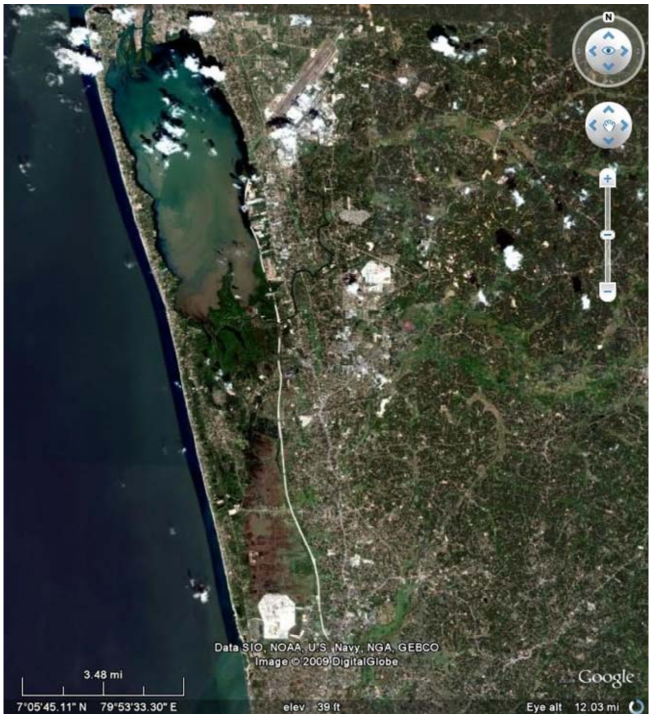
All participants will be requested to give a detailed description of how they will incorporate DRR into their day to day work.

Each chapter writers and resource persons will require preparing a suitable field visit program based on their subject area. Field visits will be in appropriate sites according to the training location. However it should be fulfilled the thematic areas of the training module. The resource person therefore must prepared a field visit program indicating objective of the field visit, activities to be done by the participants, exercise to be done after the field visit and expectations from the participants indicating in the presentation to be done by the participants ect before the field visit. However it should not be given all information to participants since the participants have to identify more things by themselves during the field exercise.

An example of the field exercise is explaining below. But this example is not necessary to follow in all areas or all cases. Therefore basic information will always depend on the different sites situation.

The study area map or details of the area is necessary o provide. It can be a sketch, topographic map, or areal photograhp. A sample map is given below as Figure 5.1

Figure5.1: Map of Negambo Estuary area



The area basic background information also needs to be provided. It is also need to explain the objective of the field exercise. The given area is an estuary and therefore this field visit exercise objectives are to;

- **Examine and assess information on coastal ecosystems and resources; social and economic conditions and the institutional mechanisms for management;**
- **Make as assessment of the present ecological conditions, their linkages to society and economy, the issues concerned and the cause effect relationship, an trends of the Negambo estuary by using secondary data and field observations**
- **Examine and assess information on Coastal estuaries and wetland resources, social and economic conditions and the institutional and legal mechanisms for coastal area management**
- **Identify major management issues in the estuarine and wetland area and their interactions and linkages**
- **Identify constraints as well as opportunities for management**
- **Examine and assess information on coastal ecosystems and resources; social and economic conditions and the institutional mechanisms for management;**
- **Make as assessment of the present ecological conditions, their linkages to society and economy, the issues concerned and the cause effect relationship, an trends of the Negambo estuary by using secondary data and field observations**

It was also briefly given the methodology of the data collection during the field exercise. The methodology which we have given for the Negambo field exercise is explained below:

- **Collection of data and information from secondary sources such as published and unpublished reports, maps, and aerial photographs.**
- **Focused group discussions with key stakeholders such as local residents and community based organizations**
- **Participatory Rapid Appraisal (PRA) technique**
- **Direct observations and enumeration technique**
- **Field tours with stakeholders**

Since the field exercise need to be done within a half day time period it is appropriate for participants to gave information on basic socio economic information, existing issues in the area in relation to the disasters or coastal issues and details of each issues.

In the Negambo estuary area issues have been categorize as Environmental, Institutional, and Socio Economic. Then each nature of each issue was explained with some photographs and details of the issues are given below.

Environmental issues:

Figure 5.2: Environmental Issues in the Negambo Estuary

The environmental issues were given through several slides and those slides are in the figure 5.2. Using these information participants were asked to:

Study level of issues

Identify most affected communities

Possible risk or vulnerabilities and disasters

Prepare a management plan or proposal to minimize the impacts

Similarly details of other two problems also explained with visuals and requested to prepare proposals to minimize the impacts.

5.2 Pre-arrangements for field works

There are several pre-arrangements need to be done for the convenient of participants and as a time saving measures. In this aspect we have invited to the several area community leaders to join the field work group to meet community members in the field. It was also arranged the key person of each issue areas to meet the study group at given time to discuss the and to provide required information. We have prepared a list of places to be visited and given to the participants at the field visit briefing lecture.