REPORT OF THE REGIONAL WORKSHOP

ON

REDUCTION OF VULNERABILITY TO SEA LEVEL RISE

21ST - 23RD FEBRUARY 1992

COLOMBO - SRI LANKA

PARTICIPATING COUNTRIES:

BANGLADESH, INDIA, PAKISTAN, MALDIVES, SEYCHELLES, SRI LANKA

SPONSORED BY -

CENTRAL ENVIRONMENTAL AUTHORITY, SRI LANKA

SOUTH ASIA COOPERATIVE ENVIRONMENTAL PROGRAMME

COAST CONSERVATION DEPARTMENT, SRI LANKA

CCD/GTZ COAST CONSERVATION PROJECT
SRI LANKA- GERMAN TECHNICAL COOPERATION PROGRAMME

NATIONAL OCEAN & ATMOSPHERIC ADMINISTRATION, USA

CENTRE FOR STUDY OF MARINE POLICY,
UNIVERSITY OF DELAWARE, USA

TABLE OF CONTENTS

ACRONYMS USED

1. CEA	-	Central Environmental Authority
2. CSMP	-	Centre for Study of Marine Policy, University of Delaware, USA
3. ESCAP	-	Economic and Social Commission for Asia and the Pacific
4. GTZ	-	German Agency for Technical Cooperation
5. IPCC	-	Intergovernmental Panel on Climate Change
6. NOAA	-	National Ocean and Atmospheric Administration, USA
7. SACEP	-	South Asia Cooperative Environmental Programme
8. UNCED	-	United Nations Conference on Environment and Development

E X E C U T I V E S U M M A R Y

The Workshop on *"Reduction of Vulnerability to Sea Level Rise"* was held in Colombo, Sri Lanka, during the period 21st to 23rd February 1992. The participating countries were the Indian Ocean Nations - Bangladesh, India, Pakistan, Maldives, Seychelles and Sri Lanka. The aim of the Workshop was to explore the relationship between integrated coastal management and the reduction of vulnerability to sea level rise and to evaluate the extent to which a common understanding of the key elements of integrated coastal management exists among these coastal nations.

Delegates from all the countries except Maldives attended the Workshop. Maldives was unable to send a delegate due to logistical reasons. However, the country paper prepared by the Maldivian authorities was tabled and discussed at the Workshop.

All the delegates expressed the keen interest of their nations in reducing vulnerability to sea level rise and agreed that any mitigatory action can best be planned and implemented within a framework of Integrated Coastal Management.

The following findings and recommendations were adopted by consensus at the Workshop :

- The participating delegates agreed that they have several common coastal problems including increasing coastal erosion; damage to important coastal ecosystems such as mangroves and coral reefs.

- The Workshop delegates were in general agreement with the definition of Integrated Coastal Management (ICM) given in the Workshop Discussion Document, and with the need for taking an integrated approach to coastal zone management.

- However, the Workshop emphasized the following points with respect to the ICM concept :

  (a) the assembly and analysis of the data and information, is a very formidable and continuing task which requires substantial technical assistance together with support from donor agencies.

  (b) Donor agencies should give priority assistance for developing mitigatory strategies for areas most vulnerable to impacts of sea level rise.

  (c) The adoption of clearly stated national coastal policies can only follow a long educational and coastal awareness-raising process.

  (d) The need for the nations of the region to *"tailor"* their individual coastal management programmes to fit their particular needs was stressed.

- The delegates felt that the ICM framework was appropriate to deal with the sea level rise threat, and asked that IPCC be so informed.

- The delegates were of the opinion that interested nations, working individually or through regional groupings, should seek to establish and/or strengthen mechanisms for international and regional cooperation and technical exchange regarding the application of ICM to problems such as the threat of sea level rise.

- The delegates were convinced that there are significant opportunities for increased regional cooperation on coastal issues.

- The Workshop delegates believe that the possibility of a joint or cooperative approach to the management of small coralline islands should be further explored.

- On the issue of sea level rise, the delegates felt that serious efforts had to be undertaken to stabilize and eventually reduce the emissions of greenhouse gases and that, given the long time constants involved, work had to begin to prepare for a possible sea level rise.

- The Workshop delegates, whilst accepting that the bulk of scientific evidence indicate that the sea level rise is accelerating, note the lack of consensus regarding the rate of increase. They consider that prudent planning requires action to reduce emission of greenhouse gases, particularly by the industrialized nations, and the need to develop and apply mitigatory strategies to reduce impact of sea level rise.

- The Workshop delegates note that the impact of other resource use activities may considerably affect coastal resources and increase vulnerability to sea level rise.

WORKSHOP REPORT

1. INTRODUCTION AND BACKGROUND

Coastal planning and management programs have been put in place by a growing number of nations in the last decade. A recent assessment has determined that coastal management programs of one type or another now exist in 34 coastal nations.

In recent years, increasing consideration of the issue of climate change and the associated prospect of accelerated sea level rise has focused attention on the role of coastal planning and management as one of the key response to these new threats.

A prime example of the heightened interest in coastal management is the November 1990 report of the Coastal Zone Management Subgroup of the Intergovernmental Panel on Climate Change (IPCC) which calls for coastal nations to formulate, by the year 2000, coastal management plans that incorporate response measures to reduce vulnerability to sea level rise and address other immediate coastal resource management concerns.

Under the leadership of the Netherlands and with the assistance of the United States, France, the United Kingdom, Venezuela, Japan and several other nations, and the Regional Seas Programme of the United Nations Environment Programme, a common methodology for coastal vulnerability assessment is being developed and field tested in over 30 locations, primarily in low-lying developing nations. The first results of these field studies are scheduled to be discussed at an IPCC workshop to be held on Margarita Island, Venezuela, from March 9-13 1992.

Because of the potentially important role that coastal management can play in providing the broader planning, policy and management context for a coastal nation's vulnerability reduction program, officials at the National Ocean Service of the U.S. National Oceanic and Atmospheric Administration (NOAA) decided that it would be worthwhile to undertake a parallel field effort involving coastal management.

In this connection, the Center for the Study of Marine Policy (CSMP) of the University of Delaware has been assisting NOAA in the organization of several small regional workshops to explore, in greater detail, the relationship between coastal management and the sea level rise problem and to assess the extent to which a common understanding of the key elements of integrated coastal management exist among coastal nations. Three workshops are being held to explore these issues: one in Caracas, Venezuela *(January 28-29, 1992)* involving representatives from Latin America and the Caribbean, one in Colombo, Sri Lanka *(February 21-22, 1992)* involving representatives from Indian Ocean nations, and one in the South Pacific *(April 1992)* involving representatives of the South Pacific island states.

The workshop in Colombo, Sri Lanka *[February 21-23, 1992]* was co-sponsored by the following organisations.

Central Environmental Authority, Sri Lanka (CEA)
South Asia Cooperative Environmental Programme (SACEP)
Coast Conservation Department, Sri Lanka (CCD)
Centre for Study of Marine Policy, University of Delaware, USA (CSMP)
National Ocean & Atmospheric Administration, USA (NOAA)

The National Ocean and Atmospheric Administration of USA, and the CCD/GTZ Coast Conservation Project - a Sri Lanka-German Technical Cooperation Project - provided the funding for the Workshop, whilst the other organisations provided logistical and organisational support.

This workshop had been preceded by a SACEP/ESCAP/CEA sponsored workshop on Coastal Resources Management and Planning in the SACEP Region, held in Colombo, Sri Lanka (*10-14 June 1991*) at which Sri Lanka, the Republic of Maldives and Pakistan had participated. The possible impacts of Sea Level Rise had been identified as a common concern of the participating countries at this workshop.

This summary reports the discussions and actions proposed by the participating experts from Bangladesh, India, Pakistan, Seychelles and Sri Lanka. The views expressed by Maldives in a Country Paper prepared for the Workshop by the Ministry of Environment, Republic of Maldives, was tabled and discussed. A delegate from the Republic of Maldives could not be present at the Workshop due to logistical reasons.

2. INTEGRATED COASTAL MANAGEMENT - REGIONAL RESPONSES

Building on past work, integrated coastal management can be defined as follows :

Integrated coastal management is a dynamic process by which decisions are taken for the use, development and protection of coastal areas and resources to achieve goals established in cooperation with user groups and national, regional and local authorities.

Integrated coastal management is a process that recognizes the distinctive character of the coastal zone - itself a valuable resource - for current and future generations. The coastal zone, be it continental or island-based, is a special area where the land and sea meet, which includes the following characteristics:

1. It is usually a dynamic area with frequently changing features;

2. It contains valuable ecosystems of high productivity and biodiversity and offers crucial nursery habitats for many living marine species;

3. The zone is often of great value to human populations as they seek to settle in, use, and enjoy coastal resources and space;

4. The coastal zone is the home base for all human activities in the ocean - from fishing, to marine transportation, to offshore mineral development and marine recreation.

5. Because the coastal zone is often highly desired by various users and populations and because it is of limited extent, conflicts are a frequent occurrence;

6. Management of the two sides of the coastal zone - land and sea - poses difficult challenges and complexities, based, in part, on the public character of the ocean area and the generally mixed private/public nature of the land area. The presence of general purpose governmental authorities on the land and, generally, of single-purpose authorities in the ocean further complicates the governance issue.

Integrated coastal management is multiple purpose oriented, it analyzes implications of development, conflicting uses, and inter-relationships between physical processes and human activities, and it promotes linkages and harmonization between sectoral coastal and ocean activities.

It should be noted that islands represent the maximum coastal condition - a maximum degree of marine influence - and, as such, require a high degree of integrated coastal management. They are unique in being surrounded by and enclosed by the sea. For small islands, the ocean and coastal environment is the dominant and often only environment. In small island nations, the coastal zone and ocean may be the only potentially developable assets. Consequently, the planning and management of these resources require great care if a long-term pattern of sustainable development is to be achieved.

Attributes of Integrated Coastal Management

1) It is a process that continues over time. Integrated coastal management is a continuous and dynamic process that usually will require continual review and updating.

2) It operates within established geographic boundaries that define a space (*coastal zone)* which extends inland from the ocean environment to some inland limit. In some cases, such as small islands, the entire land mass may properly be included in he coastal zone.

3) There is a governance arrangement to establish policies for making allocation decisions about the use of space and resources in the coastal zone, and, when the program is implemented, a governance arrangement for making actual allocation decisions.

4) The governance arrangement employs a system perspective which recognizes the interconnections among coastal systems and uses. The systems perspective usually requires that a multi-sectoral approach be used in the design and implementation of the management strategy.

5) The governance system encourages the development of appropriate coastal-dependent activities in the coastal zone through a program of studies and analyses of the economic and social benefits that can be derived from such activities and a system of incentives to encourage the most promising activities. Examples of coastal dependent uses include fisheries, aquaculture, coastal tourism, marine recreation, and offshore oil and gas development.

A typical integrated coastal management program may be seen as having three general parts:

Part I - A continuing process to collect the necessary scientific information and data on resources, coastal problems and issues, and on the needs and desires of the public.

Part II - A process to formulate a set of national coastal policies and to develop a coastal planning and management process which applies those policies to the nation's coastal zone;

Part III - The development, acquisition or strengthening of the means (*legal, institutional, technical, financial, human resources*) to achieve the purposes of the program.

Each part is briefly described below.

Part I - The data and information collection process

Clearly, the formulation of national coastal goals and policies should be founded upon as complete an understanding as can be obtained. In addition to inventories of resources found in a nation's coastal zone, information is needed on such problems as extent of coastal erosion, degradation of wetlands, condition of coastal fisheries, and health of the coastal waters and estuaries.

Part II - A coastal policy and goal formulation process

This phase of the coastal management process is built upon an assessment of the nation's coastal resources and the development opportunities and issues associated with them. It involves the adoption of national coastal policies and goals to ensure the maximum sustainable public benefit from such resources.

An adequate program would involve the formulation, in an open process, of at least two categories of public policies -

(i) Policies promoting sustainable coastal development.

Typically, the following kinds of policies are involved :

- protection and improvement of coastal water qualify including the reduction and eventual elimination of raw sewage and other untreated waste;

- protection of productive mangroves, sea grass beds, other wetlands, coral reefs and other productive coastal ecosystems;

- encouragement of coastal dependent uses of the coastal zone;

- careful regulation of new coastal development;

- Management of fish harvests to maximize benefit to society and to prevent overfishing;

- restoration of degraded coastal resources.

(ii) Policies pertaining to the reduction of coastal Vulnerabilty to accelerating sea level rise such as :

- policies with regard to retreat and defence and when to employ each;

- policies involving the prohibition of new development in areas defined as high risk areas;

- provision of relocation assistance for existing structures in areas defined as high risk areas;

- establishment of "***set-back***" lines related to estimated erosion rates and/or inundation zones.

Part III - Acquisition of adequate legal, institutional and technical means to achieve the purposes (goals and policies) of the coastal management program.

Clearly, one of the keys to achieving the goals and objectives of a nation's coastal management plan is having the necessary set of legal tools, institutional arrangements, and technical capacity available. Based on the types of policies likely to be incorporated into a coastal management plan that addresses both sustainable coastal development and vulnerability reduction, the following ***"means"*** would usually be needed:

-- legal and technical capacity to designate a coastal zone for management purposes;

-- legal capacity to restrict or prohibit future development in vulnerable zones;

-- institutional capacity to harmonize and, when necessary, reconcile coastal land and water use decisions among different government agencies and between levels of government and to resolve conflicts among them.;

-- legal capacity to inventory and designate areas of particular concern (*including important wetlands, etc*) and to develop and implement special management programs for such areas and for areas especially suitable for development.

Regional Responses

It was noted that all participating countries at the Workshop have a positive interest in developing Integrated Coastal Management Programmes. Programme activities were at various levels of development in the respective countries, viz.

Bangladesh:

There is no specific institutional or legislative arrangements for integrated Coastal Zone Management. However, an active coastal afforestation programme is under way. There is much concern about the extreme vulnerability of the coastal zone of Bangladesh. Programme development has, however, been delayed due to non-availability of funds.

Eighty-five percent of the development budget is presently financed through foreign aid, and such aid is presently fully utilised for the most pressing problems of poverty alleviation, flood control and rehabilitation of areas affected by natural disasters. Integrated Coastal Management is, however, identified as a primary need.

India

The institutional and legislative framework for Integrated Coastal Management had been instituted by framing rules for Coastal Zone Regulation under the Environment Protection Act of 1986. These rules were promulgated in 1990. Under these rules the Coastal Regulation Zone has been defined as extending 500m landwards of the High Tide Line and includes the inter-tidal zone. The rules classify the coastal zone into three categories and lists prohibitions and allowed activities. Guidelines have been formulated. Implementation is through the various state governments. The state governments have been required to prepare Coastal Zone Management Plans for their respective states. The plans will be based on the rules and guidelines, and will primarily be zoning plans and are expected to be completed shortly.

Maldives

There is a very high degree of consciousness regarding preservation, conservation and protection of the environment. The entirety of the area of the 26 natural atolls which form the republic is considered the coastal zone. All coastal management considerations are embodied in the National Environmental Action Plan. The institutional support for the Action Plan is provided by the National Commission for the Protection of the Environment established in 1988 *(formerly the National Council for the Environment)* and the Environment Research Unit of the Ministry of Planning and Environment.

Pakistan

At present there is no specific programme for coastal zone management, primarily due to development pressures on the coastal zone by Pakistan being extremely low, except in the Indus delta and in the environs of Karachi. There is an extensive programme for mangrove reforestation in the Indus delta.

The coastal areas of Pakistan are either uninhabited or very thinly populated due to lack of potable water supplies.

Seychelles

An Environmental Management Plan with a Coastal Zone Management component has already been prepared, but implementation is delayed due to non-avilability of funds. The existing institutional framework for environmental management is being reorganised with the creation of a separate Department of Environment. At the present time there is no separate legislation for Coastal Zone Management. A basic Beach Use Management Plan has been prepared in 1987 primarily with a view to controlling activities that contribute to beach erosion.

There is an awareness of the need for instituting arrangements for integrated coastal management, but this awareness needs strengthening if the subject is to achieve the level of priority it deserves in national planning.

Sri Lanka

The legislation and institutional arrangements for integrated coastal management have been in place since the early eighties. A National Coastal Zone Management Plan has been prepared in terms of the Coast Conservation Act of 1981. All development activities within a prescribed coastal zone are subject to a permit procedure since 1983.

A Master Plan for Coast Erosion Management has been prepared as a part of the coastal zone management effort. There is legal provision for updating and revising the Coastal Zone Management Plan every three years. Sri Lanka has a very active and ongoing programme for integrated coastal management.

3. SUMMARY OF WORKSHOP SESSIONS

The Country Papers presented at the Workshop were focused on -

(a) Existing legislative and institutional arrangements for integrated coastal management;

(b) Ongoing and contemplated plans, policies and programmes for reducing adverse impacts of sea level rise;

(c) Country participation in bilateral, regional and international initiatives on responses to sea level rise, and

(d) Preliminary identification of vulnerability level and environmental, social and economic consequences of impacts under low, medium and high scenarios for sea level rise.

The Workshop was conducted in seven sessions of one and a half hours each. Invited resource persons made presentations and lead discussions on the concepts of integrated coastal management vulnerability to sea level rise, responses and management options available and their policy implications.

A resume of the presentations and discussions as they apply to the participating countries is given below :

Bangladesh

Extremely vulnerable to the effects of sea level rise. Public awareness of the potential vulnerability is not very high. Planning response strategies would need donor assistance. There is a potential for instituting adaptive strategies if the necessary management framework can be established. Any regional, international, assistance in this regard is an urgent need.

India

The vulnerable coastal areas have been identified. The need for more precise assessment of sea level rise is identified and a 15-year research effort has been launched. This includes -

(a) Installation of gauging stations at 13 selection sites covering the entire coast;

(b) Detailed mapping of identified vulnerable areas.

(c) Continuing multi institutional data collection,

The legislative and institutional framework for integrated coastal management has been initiated.

Maldives

The vulnerability to sea level rise is extremely high. Has played a keynote in focussing international attention on the impacts of sea level rise. Coastal management has been incorporated within the national planning framework. Needs regional and international assistance to prepare and implement response strategies.

Pakistan

Vulnerable coastal reaches have been identified. Further strengthening of research efforts to improve estimates is being undertaken. There is no legislative and institutional framework for integrated coastal management at present. Work in this regard is in the formative stages. Welcomes regional and international efforts and is keen to participate in such efforts.

Seychelles

Blueprints for commencing integrated coastal management efforts are available. Implementation will depend on mobilising donor assistance. Vulnerability to sea level rise has been classified as follows :

(a) A sea level rise of up to 0.5 may be accommodated relatively easily;

(b) A sea level rise of between 0.5m to 1.0m will cause disruption and would need response strategies;

(c) Any rise above 1.5m would result in major calamities.

The low coralline islands which are ecologically very valuable and unique are considered the most vulnerable.

Donor assistance is required for planning response strategies and Regional and international initiative in this regard are most welcome

Sri Lanka

Strongly subscribes to reducing vulnerability to sea level rise through the existing and well accepted framework for integrated coastal management. Vulnerable areas are being classified and response strategies being worked out. Due to intense development activities based in the coastal regions the impacts are expected to cause serious disruptions.

Welcomes regional and international assistance for planning and implementing response strategies.

4. FINDINGS AND RECOMMENDATIONS

The findings and recommendations of the Workshop were as follows:

1. The participating delegates agreed that they have several common coastal problems including increasing coastal erosion; damage to important coastal ecosystems such as mangroves and coral reefs; and degraded potable water supplies

2. An integrated coastal management programme is an important tool in dealing with these shared problems and in moving towards sustained use of their coastal zones. The Workshop delegates were in general agreement with the definition of Integrated Coastal Management **(ICM)** given in the Workshop Discussion Document, including the elements and steps presented, and with the need for taking an integrated approach to coastal zone management.

3. However, the Workshop emphasized the following points with respect to the **ICM** concept :

   (a) The assembly and analysis of the data and information, a vital necessity to undertake **ICM,** is a very formidable and continuing task which requires substantial technical assistance together with support from international donor agencies together with support from appropriate regional organizations.

   (b) The adoption of clearly stated national coastal policies can only follow a long educational and coastal awareness-raising process. Concerning responses to sea level rise, this process can take place only when clear and unambiguous informatioin exists on the nature of the threat.

   (c) While concurring with the general characteristics of **ICM**, the delegates stressed the need for the nations of the region to ***"tailor"*** their individual coastal management programmes to fit their particular needs, especially in regard to the specific problems being addressed and the particular means to be employed to achieve the goals of the programme.

4. Subject to these caveats, the delegates felt that the **ICM** framework was the appropriate one with which to deal with the sea level rise threat. They asked that **IPCC** be so informed.

5. The delegates were of the opinion that interested nations, working individually or through regional groupings, should seek to establish and/or strengthen mechanisms for international and regional cooperation and technical exchange regarding the application of **ICM** to problems such as the threat of sea level rise.

6. The delegates were convinced that there are significant opportunities for increased regional cooperation on coastal issues. Specifically, increased cooperation and/or joint programmes in operating tidal network, in the exchange of oceanographic data, in training and in research programmes, were cited as possibilities. The Workshop delegates appreciated the interest shown by the Director of SACEP in pursuing this matter further.

7. The Workshop delegates believe that the possibility of a joint or cooperative approach to the management of small coralline islands should be further explored. The Indian Lakshadweep Islands, the small coralline islands of Seychelles and the atolls comprising the Republic of the Maldives were cited as possible subjects for collaborative studies and exchange of information.

8. On the issue of sea level rise, the delegates felt that a dual track had to be followed - Serious efforts had to be undertaken to stabilize and eventually reduce the emissions of greenhouse gases and, as well, given the long time constants involved, work had to begin to prepare for a possible sea level rise.

9. The Workshop delegates recognise that the bulk of scientific evidence indicates that the rate of sea level rise is accelerating although there is a lack of consensus about the rate of increase. Prudent planning requires strategies of reducing emission of greenhouse gases, particularly among those industrialized countries where per capita rates are highest. Planning also requires the development and application of mitigatory strategies that reduce the impact of sea level rise.

10. Coastal areas and resources are linked to a larger ecological and social web. The Workshop delegates noted that the impact of other resource use activities may adversely affect coastal resources and increase vulnerability to sea level rise.

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L I S T O F P A R T I C I P A N T S

REGIONAL WORKSHOP
ON REDUCTION OF VULNERABILITY TO SEA LEVEL RISE
21 - 22 FEBRUARY 1992, COLOMBO, SRI LANKA

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APPENDIX 2 - WORKSHOP PROGRAMME

PROGRAMME FOR WORKSHOP

ON

REDUCTION OF VULNERABILITY TO SEA LEVEL RISE

21st February 1992 (Friday)

0900 - 0930	OPENING CEREMONY	
	(Addresses by Chairman	- CEA
	Director	- Coast Conservation
	Director	- SACEP)
0930 - 1000	TEA BREAK	
1000 - 1230	SESSION I -	PRESENTATION OF COUNTRY REPORTS
	(CHAIRMAN -	PROF. R.W. KNECHT)
	PAPERS FROM:	
		Sri Lanka, India, Maldives, Pakistan
		Bangladesh, Seychelles
1230 - 1400	LUNCH BREAK	
1400 - 1530	SESSION II -	VULNERABILITY TO SEA LEVEL RISE
	(CHAIRMAN -	PROF. WILLIE MENDIS)
	Introduction by	Mr E. Alersma,
		Dr Hanno J. Scheffer
	Discussion	
1530 - 1600	TEA BREAK	
1600 - 1730	SESSION III -	COASTAL ZONE MANAGEMENT
	(CHAIRMAN -	MR S.R.AMARASINGHE)
	Do we have a common understanding of what is meant by, *"Integrated Coastal Management"?*	
	Regional Concerns	
	Overview of, *"Integrated Coastal Management"*	
	Introduction by: Prof. R.W. Knecht	
		Mr. J. Wickremaratne
		Prof. Kem Lowry
	Discussion	

1730 - 1900 Planning Meeting for Resource Persons

22nd February 1992 (Saturday)

0900 - 1030	SESSION IV	-	DISCUSSION ON COUNTRY PAPERS
	(CHAIRMAN	-	MR J. WICKREMARATNE)
	Moderators	-	Prof. R.W. Knecht
			Prof. Kem Lowry
1030 - 1100	TEA BREAK		
1100 - 1230	SESSION V	-	RESPONSES TO SEA LEVEL RISE
		-	MANAGEMENT OPTIONS
	(CHAIRMAN	:	PROF. WILLIE MENDIS)
	Introduction by	:	Mr E. Alersma
			Prof. Kem Lowry
1230 - 1400	LUNCH BREAK		
1400 - 1500	SESSION VI	-	RESPONSES TO SEA LEVEL RISE
		-	POLICY IMPLICATIONS
	(CHAIRMAN	-	DR D. NESIAH)
	Introduction by	:	Prof. R.W. Knecht
	Discussion		
1500 - 1530	TEA BREAK		
1530 - 1700	SESSION VII	-	GENERAL DISCUSSION & CONCLUSIONS
	(CHAIRMAN	-	S. R. AMARASINGHE)
	Moderator	-	Prof. Kem Lowry
1900 - 2100	RECEPTION		

23rd February 1991 (Sunday) - FIELD TRIP

West Coast Sri Lanka, Colombo to Negombo

Departure from Hotel	-	0900 hours
Return to Hotel	-	1700 hours

APPENDIX 3 - COUNTRY REPORTS

COUNTRY PAPER OF THE REPUBLIC OF MALDIVES
FOR THE REGIONAL WORKSHOP CONCERNING
"REDUCTION OF VULNERABILITY TO SEA LEVEL RISE"
21 - 22 FEBRUARY 1992
COLOMBO, SHRI LANKA

COUNTRY BACKGROUND

Geography

The Republic of Maldives consists of 1190 coral island which form a chain 820 km in length and 130 km at its widest point, set in an area of 90,000 sq km of the Indian Ocean Geologically, the chain forms part of the Laccadive-Chargos submarine ridge, which extends into the central Indian Ocean from the south west coast of India.

The islands form 26 natural atolls, which, for purposes of administration are grouped into 19 units, also called atolls. Most of the islands are small, few with a land area in excess of one sq. km. They are low lying, with an average elevation of 1.6m above mean sea level. The territory of Maldives comprises some 900,000 of which the major part consists of sea.

Climate

The country extends from the equator to latitude 8 degrees North. It has a tropical climate, which is warm and humid, with two pronounced monsoon seasons. Daily temperatures vary little throughout the year. The annual mean temperature is 28°C with a maximum average of 32°C and a minimum of 25°C. Relative humidity ranges from 73% to 85%.

Annual average rainfall in the 1981 to 1990 was 1875mm. Monthly variations in rainfall are significant, ranging from 58mm in February to 231mm in September. While there are occasional gales (on average 12 days a year) and tropical thunder storms (23 days a year) Maldives falls outside the main areas of tropical cyclones.

Vegetation

As all the islands are of coral origin, the main components of the soil is coral sand and although it lacks in the organic and mineral component and is unsuitable for farming the land is still used for coconut production, farming of limited crops, vegetables and fruits both in the inhabited as well as in the uninhabited islands. The production of vegetables, fruits and other products include chillies, onions, sweet potatoes,

breadfruit, cassava, taro, alcasia, banana, lemon, beetle and aracnuts. The field crops include finger millets, millet, maize, zeamaize, sataria italica and foxtail millet. Besides the quality of soil, the coconut palms grow in abundance everywhere in the islands and the ones that stand tall fringed by the white sandy beaches of the island are admired to be one of the greatest natural beauties of the country also these coconut trees plays and important role in the livelihood of the Maldivians. The coconuts are considered to be one of the delicacy of the Maldivian diet and most of all the tree itself is used as timber for housing, construction of fishing vessels and for other uses.

Forests

As stated earlier, there are no large area of land on the islands and therefore there are no large forests, in a manner as they occur on the mainland. The thin topsoil on coral sand base can hardly support any substantial vegetation excepting coconut, shrubs and a few species of trees. However, there are over a dozen of trees which constitute forest wealth of inhabited and uninhabited islands. Apart from there ecological role the trees found on the islands are used for fuelwood, as timber for housing, construction of fishing vessels and miscellaneous uses.

Population

The population of the Maldives was estimated at 213,215 in July 1990. This population is scattered over 209 inhabited islands. The remainder of the islands are uninhabited, although more than 60 of these have been developed as tourist resorts. 90% of inhabited islands have a population less than 1000 and only four islands have more than 4000 people.

Around 26% of the nations population are to be found on Male' the capital island. The population of Male' has almost doubled in the past decade, and is currently growing at around 5% per annum.

Economy

Maldives has taken full advantage of its marine assets, with fisheries and tourism having emerged as the key sectors of the nations economy and the main engines of growth. The fisheries sector has under gone a major transformation with a subsistence fishing, based on sailed dhonis replaced by a commercial fisher based on mechanised vessels and organised fish collection. The total fish catch increased from 27,000 tones in 1987 to 71,200 tones in 1989 51,800 tones of which was exported. The growth in tourism and related activities has been even more spectacular. The number of tourist arrivals increased from 18,700 in 1977 to 195,000 in 1990. Besides fishing and tourism, there are other contributors to the economy like the industry sector eg. exporting of garments, exporting of marine resources. etc.

COASTAL FEATURES

The Maldives archipelago is the largest coral reef system in the Indian Ocean and sometimes it is considered as the largest coral reef system in the world.

Coral Reef

As these have been formed at the rim of atolls, the natural defense by the coral reefs is very important. It is because
(1) The coral reef face the ocean waves first and dampen their effect before they reach the islands. They act as a natural breakwater to the islands and

(2) The continuous attack of ocean waves also cause damage to the corals; their smothering, death and decay over the years produce a large quantity of coral sand which goes on moving towards the island and enriches their beaches with coral sand. The sandy beaches further dampen the fury of waves and gives protection to the islands. Thus the protection of coral reefs due to exploitation of coral has disturbed the delicate balance of this natural defense and at times cause erosion on same islands. Any damage to the reefs will amount to destroying this natural protection cover from motion waves and tides and undoubtedly lead to disaster.

Islands

As the islands are of coral origin they are formed of coral rock base, coral rubble and coral sand. The beaches are formed of beautiful silver white sand. These islands are very small with the largest of them measuring about 3 sq miles or 5 sq km. They are grouped into 19 atolls each of which is separated from the other by a deep channel. Within the atolls water depth is about 60 metres although within 5 km of some atolls depth in excess of 3000 metres are recorded. Located in the center of each atoll is comparatively shallow lagoon. On average the islands are 1.6m above mean sealevel, none are over 2 metres. Thus the surrounding reef of the islands protect them against the swells, current and waves of the Indian Ocean. Some times a seawall is constructed around the island in order to protect and preserve the shores of the island and sometimes the dwellings near the beach. This fragile nature of the islands often get disturbed by human actions such as construction of seawalls, construction of jetties, dredging of harbours, coral and sand mining. During 1971 - 1981 5 islands of Addu Atoll were linked by unvented causeways. The causeways joining the islands have been designed as solid coral storm jetties in a manner that the water cannot flow form one side to the other. As a result several changes in the neighbouring island occurred and consequently the direction of the current in the surrounding areas have been greatly changed erosion and accretion have ten place in almost all the islands.

It is felt that erosion occurred due to this stoppage in free flow of the water due to the construction of these solid coral stone causeways. Environmental changes also have occurred as a result of these causeways. Fishery in the atoll has also been affected and the current flow has also been greatly altered.

In recognition of these damages the government of Maldives requested assistance form the British Government to rebuild Addu Atoll cause ways on piles or culverts so that natural flow of current can be re-established and can bring sand to the islands and move around as before. and this project is in the process of implementation.

Life Style of the People

The traditional life style of the people had almost negligible impact on the environment but recent socio-economic developments have lead to mark the deterioration of the environment. Traditional sources of constructions materials are from coral reef and from shallow water areas of beach sand and coral gravel. The coral reef and rock is mined primarily from the reefs inside the atolls, but recently sites have included the lagoon side of the outer atoll reefs. These rocks and sand is used for building houses, construction seawall, jetties and cause ways. Minning of coral is carried out without an environmental impact assessment or without even knowing the damage it could cause. But earlier the damage caused by these activities has little impact because the amount of coral and sand mined were lower than the present. Now the damages of these activities are much more evident as the developmental activities are increasing. and the minning of coral is much more frequent than the natural growth of these rocks. As the damage risk is acute, the government is trying to find an alternative by encouraging the use of cement block instead of coral rock and also creating awareness among the public of the important role of the coral reef through media.

Cutting of trees to meet the requirements of fuelwood and timber is fast depleting the forest vegetative resources of the country. Therefore, afforestation of coastal areas with the fast growing casuarina to meet the increasing requirement of fuel and timber and also as an effective wind break on the islands is on the afforestration programme of Government. This include raising of casuarina seedlings, their plantation on selected islands, production of casuarina seeds and seedlings and extension of activity to other islands. Promotion of bamboo cultivation is another programme which aims at cultivation of giant variety of bamboo on selected islands, supply of bamboo cuttings to interested formers on other islands and develop the resource to meet the requirement of fishing industry for bamboo poles used in tuna fishing. The Ministry of Agriculture looks after the forest wealth and cutting of trees can be done only with the written permission of the Government.

PLANS AND POLICIES

Maldives is highly conscious nation in regard to the protection, conservation and preservation of environment, which has become an integral part of planning with an elevated level of a Ministry of Planning and Environment. The extreme flooding events in Male' in 1987 emphasised the need for environmental management and planning and Government of the Republic of Maldives has increasingly turned its attention to environmental issues. The government also has taken help from a number of International organizations and expers and missions to examine the problem and suggest measures to ensure ecologically safe economic development of the country. In the past few years a number of missions reports have been produced whihc contain varied and invaluable scientific information and ideas for the planned development of Maldives, including the marine sector. To achieve this planning capability within the country, considerable external assistance is required and to secure this assistance Government representatives at all levels have taken a high profile in international debates on environmental issues.

His Excellency, President Maumoon Abdul Gayoom has played a leading role internationally in drawing the attention of the World's leaders to the special situation and particular environmental problems of small island states. stimulating the Commonwealth Secretariat to initiate a study of Global Climate Change and Sealevel Rise impacts. The director of Environmental Affairs was himself a member of the six man team which produced this assessment.

In November 1989, the Government organised the Small States Conference on Sea Level Rise and invited Ministerial level of participants from small island states of the world, leading experts in the field, representatives of all International Organisations and representatives from many developed and developing countries to examine the problem of global sea level rise and its impact on the island nations. The Conference was agreat success and ended up with the Male' Declaration on Global Warming and Sea Level Rise which will play a significant role in attracting the attention and influencing the thinking of world community in averting the crisis caused by the anthropogenic global change. Male' Decleration goes on to bring out the seriouness of the problem and its disastrous impact on all the states, especially the small island nations. It calls upon the world community to think over this problem and find solutions to save the earth due to its imminent.

In addition, Government representatives of the Republic of Maldives have and continue to actively participate in the environmentally related regional activities of bodies such as UNEP, ESCAP, SACEP, SAARC and in the deliberations of the Inter Governmental Panel on Climate Change and its working groups. Maldives also continues to participate in the activities of the

Montreal Protocol for the Depletion of the Ozone Layer. There are some bilateral programmes that are ongoing such as "Establishing a Sealevel and Climate Monitoring Network in the Maldives agreed between the government of the Maldives and the government of Australia and the government of Canada also provide assistance to environmental activities.

The Environment Section of the Ministry of planning and Environment is the implementing agency of the government responsible for both the operational aspects of environmental management planning and the formulation and the implementation of overall policies and directions.

In 1989 the National Environment Action Plan was drawn up, a document aimed at Environmental Management and Planning in the Maldives. Following the development of the National Environment Action Plan, His Excellency President Maumoon Adul Gayoom, announced in June 1990 the formation of the Environment Research Unit (ERU), within the Ministry, as a mechanism to implement the National Environment Action Plan and associated work programmes. Since the Environment Section of the Ministry is responsible for all aspects of environmental policies, management and planning within the government, there are rules and regulations and strong public notices announced by the Ministry. There are notices discouraging coral and sand mining, the areas where coral should be mined and should not be mined is clearly stated. For every major development projects an EIA should be submitted to the Ministry by the project organisers before the implementation. There is a regulation prohibiting the utilization and exploitation of living and non living resources of the sea. there is another which prohibits discharging of wastes from the ships to the harbours of the islands. Ministry of Tourism also has rules and regulations for the coastal modifications of the resorts. There are other rules and regulations in order to protect the marine environment as well as environment in general of the county. The Environment Section of the MPE is the overall co-ordinating body for environmentally related matters.

The ministry at present is in the process of drafting an Environment Law for the whole country.

Due to the cross-sectoral nature of the environmental issues which arise in connection with all aspects of development the need for inter-departmental and cross-sectoral co-ordination of activities is of paramount importance. In recognition of this fact the government established in 1984 the National Council for the Environment, which later became the National Commission for the Protection of the Environment in 1988. This Commission is composed of senior (Deputy Director Level and above) representative of all environmentally related government Ministries, Departments and Authorities. Meets regularly, it serves as the highest level advisory board on environmental matters and as a forum for collaborating and co-operating in the examination of environmental issues.

The lack of qualified and experienced staff in the Environment Section of the Ministry is a major problem we face at present. To solve this problem a training and development programme has been worked out for the staff where in they are given required training abroad under bilateral and multilateral assistance.

Conclusion

All the islands are highly vulnerable to the threat form a rising sea due to the fragile nature of the islands. It is generally considered that the Maldives may be the one of the areas of greater peril should sea level rise as a result of global warming. In the context of global warming, it is also predicted that tropical storms will become more frequent and more intense with increased ocean temperature, the northern most atoll of the Maldives are likely to be affected by the passage of these storms and experience increased wind and rainfall

Regional Workshop on the Reduction of Vulnerability to

Sea Level Rise – Colombo , Sri Lanka

COUNTRY PAPER – SRI LANKA

by

H. N. R. Perera (1) and Mrs. R. Ellepola (2)

1.0 Introduction

Sea level rise is a direct consequence of a much more complex and yet not fully understood, phenomenon i.e. **"The Greenhouse Effect"**. This is the influence on the earth's climate due to the natural phenomena of absorption and emission of long wave radiation by certain trace gases in the atmosphere - notably Carbon Dioxide, Nitrous Oxide, Methane , Chloro Fluoro Carbons and tropospheric Ozone, which are referred to as green-house gases.

Global warming and consequent Sea Level Rise are matters of concern to an island country such as Sri Lanka, geographically located between $5^{o}55'$ and $9^{o}51'$N and $79^{o}41'$ and $81^{o}54'$E.

Administratively, the country is divided into nine provinces, five of which are coast based. These provinces are further sub-divided into 14 districts which in turn are delineated into a further 75 Assistant Government Agent (AGA) divisions (Fig 1). The assessment of the impacts is limited to these AGA divisions/Coastal Districts. The maximum width of any of the above mentioned AGA divisions exceed 50 km and thus is an ideal unit for considering the implications of Sea Level Rise.

2.0 Physical features

A major part of the coastline in particular south of Kokkilai on the east, and all of the south coast is characterized by rocky headlands.

These have a significant effect in resisting impacts due to the possi-bility of a rise in sea level.

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The northwestern coastline from Negombo to Mannar is susceptible to the fact that it is of more recent origin (younger quaternary). This reach of coastline in most instances, is straight with adjacent low lying hinterland, mostly of alluvial deposits, dotted with lagoons and flat marshes.

2.1a) Offshore

Sri Lanka has a coastline of 1585 km., a territorial limit extending 12 nautical miles, a contiguous zone from 12-84 nautical miles and Exclusive Economic Zone (EEZ) extending from 24-200 nautical miles. The continental shelf is on the average 20.0 km wide and 20-65 metre deep. The narrowest being at Kalpitiya, where the width is only 2.8 km.

The continental slope is very steep, with depths ranging from 1500m to 3000 m seaward of the shelf break.

The continental shelf itself is lacerated with numerous canyons and valleys with the Trincomalee submarine canyon being one of the twenty largest in the world (Ref Fig 2).

b) Nearshore features

The nearshore zone is characterized by the occurrence of reefs which by themselves can be divided into three major categories - i.e., Coral, sandstone, and crystalline rock (boulder) reefs.

All reefs in general provide protection to the beach from sea erosion. Research done by Lanka Hydraulic Institute on breaking waves indicate that depending on the depths of these reefs a major part of the wave energy is dissipated. Thus these reefs preclude such waves reaching the coast. In addition live coral reefs are an integral part of the marine ecosystems. However, extraction of coral for the production of lime, for the construction industry, has destroyed some of these coral formations. A few remain in their pristine state (Fig 2).

2.2 Oceanographic and Climatic Conditions

There is a general scientific consensus that global warming of the order of 1^{o} - 2^{o} C will occur by the year 2030. The attendant sea level rise which is expected to take place with this warming is likely to cause disruption of the economy and commerce primarily in countries which have appreciable coastlines, low plains in the immediate hinterland with dense settlements and seaports.

Recent studies done by the Department of Meteorology which has records of rainfall and temperature data for a period of more than a century at fourteen meteorological stations scattered over Sri Lanka have shown that annual rainfall and number of rainy days per year have decreased in most places (Sri Lanka Country report - The Greenhouse Effect and its Impact on the SAARC Region - 1991).

Decreasing trends in annual rainfall were evident in Colombo, Ratnapura, Galle, Kandy, Batticaloa, Hambantota, Trincomalee, Baddulla and Nuwara Eliya.

Similar to the other regional countries of Southeast Asia the climate is primarily governed by the monsoons, - Southwest and the Northeast. Of these the former has a significant impact on the coast, specifically the South, Southwest coastal reaches. Average wind speeds of 18 Knots per hr., can be expected during this period. The wave conditions can be primarily split up into two distinct wave trains in the Southern Swell (swell waves) and due to localized storms (wind waves).

Under the GTZ/CCD Coast Conservation project a directional wave measuring programme in deep water (70 m depth) is continuing since February 1989. Preliminary results indicate that significant wave heights of between 2.5m and 3.5m can be expected. In May/June 1991, a storm with a return period exceeding 100 yrs., (significant wave heights exceeding 5.5m) caused severe erosion along the south and southwestern sectors.

Fig.3 shows some indicative results of the wave recording programme.

The tidal range can be classified as moderate with maximum tidal ranges at spring, of 0.6m. These give rise to currents which are of very low magnitude 0.3 m/s. However the wave driven currents are more predominant.

Sediment transport is largely wave driven and depends on the direction of oncoming waves and the orientation of the coastline. A marked seasonal variation of the beaches is observed due to cross - shore transport. Preliminary estimates (qualified guesstimates) indicate a net northbound transport of 100,000 cu.m in magnitude. More detailed studies are underway to assess the annual sediment transport rates.

2.3 Coastal Features

Geologically 90% of the country is of Precambrian crystalline rocks. Since Miocene times the relative levels of sea and land, have remained without much change. However minor oscillations of the sea level have occurred during post-miocene times, and it is primarily these changes that have given the shape to the coastal regions.

Changes in the relative levels of sea and land can be evidenced by a number of characteristic features such as beach rock, old coral reefs, raised beaches, and inland deposits of coral and marine shells.

There is sufficient geological evidence to point towards a maximum rise of 36.0 m above the present mean sea level and also a drop of 91.0 m below (Swan 1983).

The present coastal development can be attributed to the changes that have taken place in the last 25,000 yrs.

2.4 Population and Economic Features of the Coastal Region

a) Population

Historically the country's ancient civilizations have flourished in the hinterland. Since the 15th Century AD (with the advent of the Portuguese), there has been a marked gravitation of the populace towards the coastal belt due to the expansion in trade and commerce, brought forth as a result of the country coming under foreign domination since 1505 AD.

Over the years this trend has increased exponentially. The population statistics as recorded by the Department of Census and Statistics are given in Table 1 and the growth trends shown in Fig. 5. It can be seen that at present over 55% of the population of the country is coast based. It is estimated that the country's population would keep on growing until the mid-twenty first century, at which time it is expected to stabilize itself at a level of 23 - 25 Million.

b) Economy

The coastal regions contribute approximately 40% to the Nation's Gross National Product (GNP). Ninety percent of the industrial units are located in the coastal areas. Contribution of coast based agriculture is marginal in comparison with the others contributing only 14% towards the Gross Domestic Product (Table 2).

The coastal fisheries industry is an important element contributing towards the national economy of the country. In 1983, the fish production reached a peak of 220,000 M.T.. However, over exploitation, has led to a decrease in the catch per unit in some areas. The total catch at present is 195,000 M.T. - 200,000 M.T.(Fisheries Statistics 1991). It is estimated that 250,000 M.T./ Yr is a sustainable level of fishing (Attapatu 1989). To achieve this level, the offshore fisheries sector has to be developed which would require additional shore facilities to serve this industry. Location of the existing Fishery Harbours is given in Fig 2.

The Tourist industry too, is primarily Coast based with 80% of the touristic attractions / infrastructure located in the coastal belt. Since 1977 there had been an increase in tourist traffic peaking in 1983, after which there has been a decline. However, with the improvement of the security situation, a resurgence is observed. Tourism itself is the 4^{th} largest foreign exchange earner. Many of the tourist hotels, have been constructed in close proximity to the beach whilst a few are even located on barrier spits.

The coastal region also contains the county's principle transport system with the main highways, and the coastal railway linking the coastal cities, in close proximity to the shoreline.

In addition, waste water and sewerage sea outfalls, two of which disgorge out to sea in Colombo, are found in the coastal sector.

There are also numerous outfall structures constructed by the Irrigation Department to facilitate salt water extrusion and for flood control. Since the country's economy is primarily based on agriculture, emphasis has been laid from time to time on the construction of these irrigation structures.

3.0 Environmental Conditions

The length of effective sea fronted coastline is found to be 1585 km. However, for purposes of a study of probable impacts due to rise in sea level, land lengths fronting Lagoons, and basin estuaries must be considered. If these are included the length of effective coast line that need to be considered is approximately 2000 km., (Fig. 4). When we consider the climatic conditions it is estimated that 45% - 55 % of the coastline is prone to recession of 0.3m - 0.35 m per year. The rates of erosion / accretion vary significantly in different areas but it is estimated that with the present trends and in the absence of any mitigating measures the coast could recede a further 5.0 m by the turn of the century with an annual recession rate of 0.5m/yr.

On going environmentally harmful activities such as coral mining and river sand mining have aggravated this problem. Surveys undertaken by the department in 1984, 1990 show an increase of such mining despite controls and regulations adopted within the last few years (Table 3).

4.0 Legislative Procedures for Management of the Coastal Zone

In 1983, the Coast Conservation Department enacted legislation titled the `Coast Conservation Act' to regulate development within the coastal zone (defined as 300m landward from the high water line - +0.6m MSL - and 2.0km seaward from the low water line -0.6m MSL-). It must be borne in mind that this legislation was drawn up with the primary aim of conserving the coastal resources and providing a management tool for mitigating the erosion.

All development within this Coastal Zone is regulated though a permit procedure under the requirements of the act. The Coastal Zone Management Plan was prepared and accepted by the Government, and serves to provide guidelines and policy regarding future development within the coastal zone. Although not specifically directed at the impacts of sea level rise, but rather at medium term conservation strategies it identifies sea level rise as an adverse impact which requires the adoption of mitigation measures. It is mandatory that this plan is updated once in three years.

Under the guidelines given in the plan, the setting up of development activities has to pay heed to designated **set back zones** which will allow a sufficient buffer. **No-build zones** (on barrier spits and heavy erosion prone reaches) provide some considerations along the lines of sea level rise.

Submission of Environmental Impact Assessment (EIA) for projects which are deemed to have greater degree of impact, has now been incorporated in to the policy and regulations of the Central Environmental Authority (CEA).

Research in coastal engineering, oceanography are been undertaken by Governmental and semi - Governmental Agencies. Preparation of sea charts and studying the oceanographic conditions are been carried out by National Hydrographic Office (NHO). Nearshore coastal engineering studies have been undertaken by Lanka Hydraulic Institute (LHI) for concerned clients like the Sri Lanka Ports Authority, Coast Conservation Department, Water Board etc,.

5.0 Erosion Trends and Management

Simultaneously with the enactment of legislation, the Department also embarked on formulating strategies and plans for Coast Erosion Management. In 1986 a Coast Erosion Management Plan was prepared with assistance from DANIDA. This plan gave outlines and strategies for conceptual control measures, studies and investigations. The total cost, estimated at the time of preparation was approximately Rs.350 Million. However, based on the present level of experience and understanding, this has been reestimated to Rs. 2000 Million. Implementation commenced immediately thereafter with two major projects being completed in Moratuwa and Negombo at a cost of Rs.380 M (offshore breakwaters coupled with a sand nourishment scheme, and revetments), and a further stage just completed to provide for upland protection to the threatened reaches of the main highway to the south at Rs. 580 M. Both these projects were carried out with funding assistance from DANIDA.

The cost of protection per unit reach of coastline varies between Rs. 40,000 and 48,000. The primary consideration was to combat the recession and if considerations for possible sea level rise were to be incorporated within these measures, the costs would rise to Rs. 60,000 - 70,000 depending on the extent of predictable rise. Further, urgent need for providing adequate protection requires that available funding be utilized on a priority basis.

6.0 Sea Level Rise

Worldwide observations and studies indicate a sea level rise of 1.0mm - 1.5mm per year during the past century. Studies and similar assessments in Sri Lanka have confirmed this trend. It has been estimated that with the increase in global atmospheric temperatures this increase would be much greater in the next century. This aspect of predicting future trends is a subject on which considerable research is being carried out. However the results available at present indicate a wide range of uncertainty. Due to such uncertainties , the resulting predictions too have a large degree of uncertainty as well as variation. Factually there appears to be a trend towards global warming and that mean sea level would rise, in the next century. Hereto one must hasten to add , there also exist points of view admittedly in the minority, theorizing that global warming would lower the sea level!

For completeness this paper considers a **eustatic sea level rise** of 0.5m (low), 1.0m (medium) and 1.5m (high) by the year 2100 AD, based on Hoffman (1983).

6.1 Impacts of Sea Level Rise on the Sri Lankan Coast

a) Environment

The degree of impact from such a sea level rise, would vary from that requiring limited responses to that requiring extensive mitigation measures.

Primarily an increase in the sea level would increase the hazard of erosion. The country is subject to an erosion rate of 0.30 - 0.35 m per year, for 45% - 55% of its coastline (MPCEM - 1986). At least 0.2m recession is attributed to the rise in sea level (H.Scheffer 1990).

An assessment of the erosion rates resulting from an increase of sea level based on `Bruun Rule' and those of `Linear Interpolation'(Dean 1979) is shown in Table 4 for the coastal reaches in each district. It can be seen that the coastline could recede by as much as 50m to 500m, depending on the scenario, within the next century, purely due to the rise in sea level.

However this estimate would be conservative if the implications of sediment transport is also included. Using shallow water forecasting techniques given in the Shore Protection Manual - U.S.Army Corps of Engineers - 1984 (SPM), a relationship could be deduced as follows;

$$dH/S = 0.75\ H/h$$

where dH - increase in wave height
S - Predicted Sea Level Rise
h - Water Depth

A significant wave height of 2.5m - 3.8m in the present would lead to a 7.5% - 8.5% increase in the wave heights. This increase would reflect in the sediment transport too increasing, resulting in a further increase in the rates of erosion. If, global warming gives rise to occurrence of storms with higher levels of recurrence and ferocity these erosion rates would be considerably larger in magnitude.

It can be seen from the above that the degree of variance is quite phenomenal and depends on a number of factors that have yet to be understood.

b) Coastal Habitats

The impacts of sea level rise, on the different habitats have more indirect consequences not directly observed, but with an equal degree of concern (Fig. 2).

Direct Impacts on coral reefs are difficult to assess, at present. A sea level rise itself would probably do the least damage to these reefs. However the effects of changes in the nearshore water temperatures and increase or decrease of salinity levels could be extremely harmful to the coral polyp. However evolutionary adaptation is a distinct possibility, which may marginalise these impacts.

Numerous river basin estuaries and lagoons numbering 40 and 45 respectively cover an area of 42,000 ha. In addition there also exists mangrove swamps, salt marshes, barrier spits etc, (Table 5). The lowering or loss of sand bars , could increase the Tidal prism, with larger volumes of water flowing in during a tidal cycle. This would result in risk of greater inundation, giving rise to loss of salt pans, and salt marshes.

c) **Economy**

A rise in sea level of 1.0m - 1.5m would inundate such low lying areas, and destroy these habitats. This would in turn cause the sustainability levels of the coastal / marine ecosystem to be lowered, reflecting in reduction of the fish production.

Barrier spits are located at most river outlets, along the coastal reaches of the country specifically in the reach of coastline from Hambantota to Chilaw. These barrier spits are on the average 1.0m - 2.0m above MSL, and are a natural barrier against salt water intrusion in time of dry weather (low runoff). With the rise in sea level most of these spits will be obliterated resulting in additional degree of salt water intrusion both upstream of rivers, and via the ground water table. This would mean the loss and degradation of adjacent arable lands thus lowering the agricultural produce of the country.

There also exists water supply schemes to provide drinking water to a number of heavily populated coastal cities. The intake structures are located 10 - 15 km upstream of the outlets. Some of these are prone to the effects of salt water intrusion in times of dry weather even at present. Increase of salinity levels upstream due to the effects of Sea level Rise would necessitate the relocation of these intakes if they are to serve the same purpose.

Reduction of coastal arable lands, loss of coastal habitats - drop in the fish catch, loss of scenic and recreational areas - tourism, are some of the repercussions.

7.0 Measures to be adopted

Coastal Engineering solutions to mitigate the rise in sea level are not readily available. Sea dikes are an option that have been given serious thought. Protection measures adopted at Akurala, for the main southbound highway, necessitated the construction of revetments with crest heights of +3.5 m MSL to prevent erosion and the threat of breach and subsequent inundation of the low lying hinterland. The highway itself is constructed at a very low level +1.8m MSL. These protection measures are similar to dikes and their function too are similar. However, the construction of structures impede beach usage.

Management options must be given serious considerations. Setback limits have to be reconsidered specifically for projects with a long rate of return for its capital investment.

Any solution or management option would initially have to be provided with a good data base. For this the coastal region must be mapped and contoured so as to assess the physical impacts of any of the predicted scenarios.

8.0 Regional and International response initiatives

In general, most of the International or Regional responses to Sea Level Rise do not directly address the problem of sea level rise per se. Most of the international and/ or regional initiatives focus on the much larger issue of the Greenhouse Effect and its attendant problems. Sea Level Rise being one of them.

Sri Lanka has in fact taken part in some of these International and Regional initiatives. Some of which are given below.

Montreal Protocol on Substance that deplete Ozone Layer

An International agreement on reducing the substances that deplete the Ozone layer, was drawn up and agreed upon, with a view to protecting the earth's Ozone layer. This aims at reducing the production and consumption of Chloro Fluoro Carbons (CFC'S) which are known to deplete the Ozone layer in the stratosphere resulting in increased global warming. This Protocol has been ratified by almost all developed countries and many of the developing countries.

In addition Sri Lanka is also a signatory to the Vienna Convention for the protection of the Ozone Layer.

The United Nations Environment Programme and several other related international agencies are in the process of drawing up a similar International Convention or Protocol and obtain agreement among countries with a view to reducing the emission of Carbon Dioxide. Understandably such an agreement would be much more complex than that for limiting the production / consumption of Chloro Fluoro Carbons, primarily due to difficulties in ensuring compliance.

SAARC Study on the Greenhouse Effect and its impact on the region

In recognition of the importance the Greenhouse Effect and its possible implications on the region, the SAARC member countries have unanimously decided to embark on a regional study of the subject. At the meeting of the expert group on the above study, it was decided to identify the linkages between the various sectors of the economy. In addition it was also decided to identify measures and programmes , both short and long term, at regional level for coordinating responses and strengthening national and regional capabilities to manage the problems arising out of the Greenhouse Effect such as Sea Level Rise.

Although the above steps are not directed towards a direct mitigation of Sea Level Rise, reduction would be possible if the trends of Global Warming are diminished.

It is hoped that regional conferences and seminars such as this on Sea Level Rise, would lead to an awareness of the impacts, and also formulate response strategies to counter successfully the threat of inundation or submergence by the oceans, thereby ensuring that our societies in the region would continue to exist without much hindrance for generations to come.

9.0 References :

1.0 Seminar on Causes of Coastal Erosion in Sri Lanka Colombo Sri Lanka February 1991.

Future Sea Level Rise Impact on Coastal Stability - Dr. H-J. Scheffer.

Geological Evolution of the Coastal Zone of Sri Lanka - P.G.Cooray and J. Katupotha.

Location and Condition of Reefs along Sri Lanka's Coast - A. Rajasuriya.

2. An Introduction to Coastal Geomorphology of Sri Lanka - B. Swan (1983).

3. Proceedings of the Adaptive Responses to Climate Change ; Coastal Zone Management Workshop - Perth , Australia (1990).

4. Master Plan for Coast Erosion Management - Coast Conservation Department (1986).

5. Coastal Zone Management Plan - Coast Conservation Department (1990).

6. Responding to Changes in Sea Level - Engineering Implications - National Academy Press Washington DC (1987).

7. National Sand Study for Sri Lanka Phase One - Netherlands Economic Institute - Draft Final Report (1992).

8. Coastal 2000: a Resource Management Strategy for Sri Lanka's Coastal Region - Coastal Resource Center University of Rhode Island - Draft Report (July 1991).

9. National Atlas of Sri Lanka - Survey Department (1986).

FIG. 1

ADMINISTRATIVE BOUNDARIES OF SRI LANKA

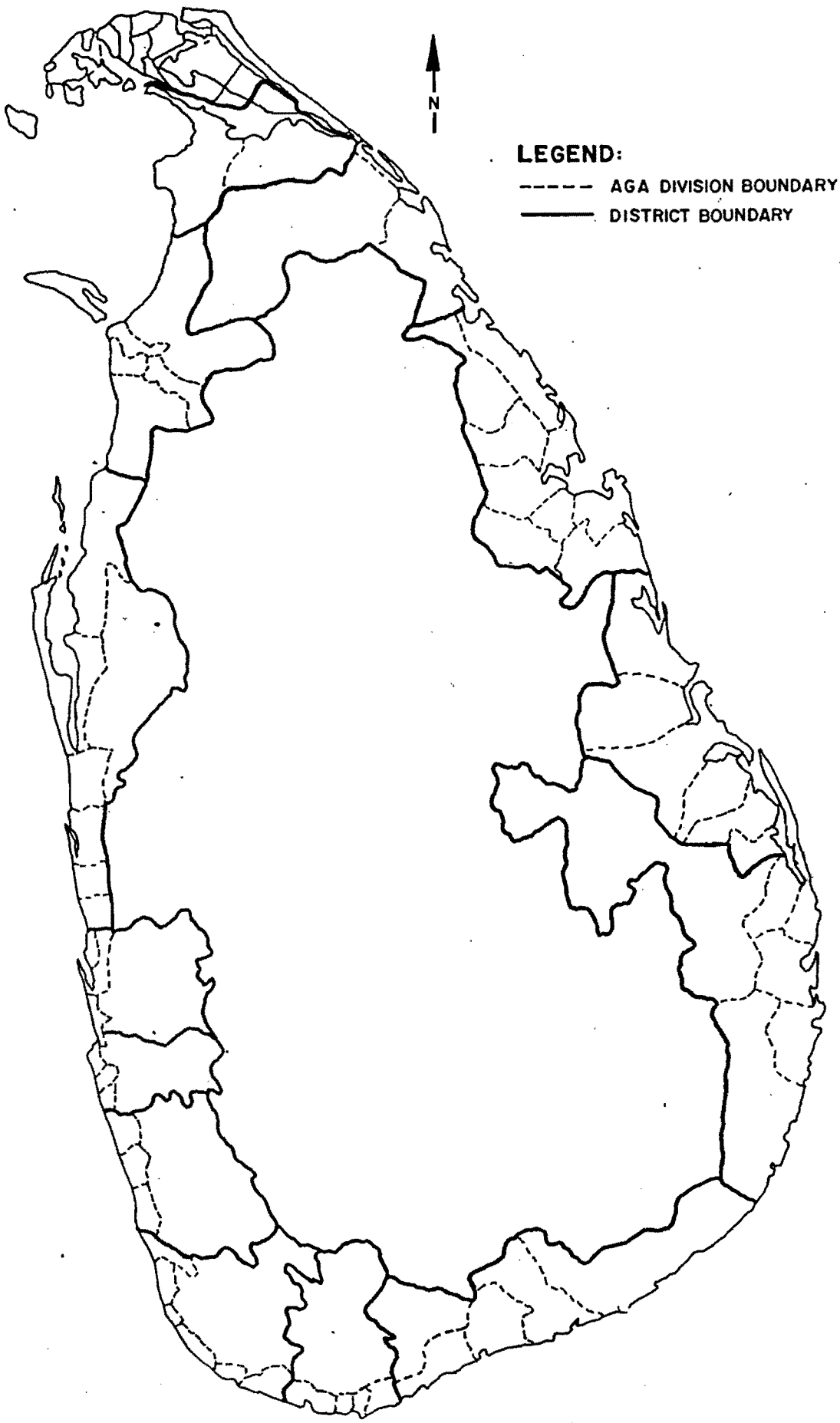
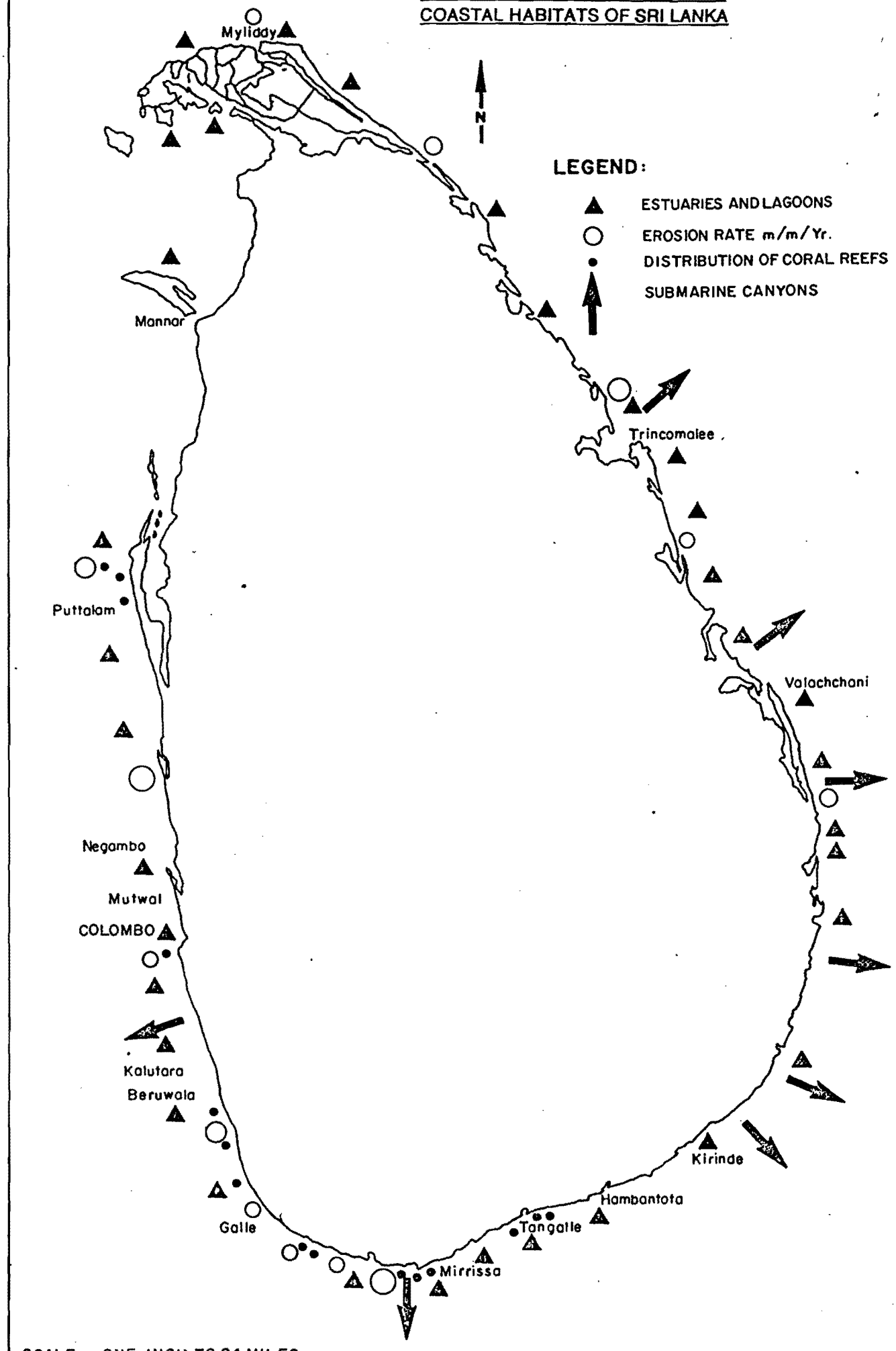


FIG. 2

COASTAL GEOMORPHOLOGY AND
COASTAL HABITATS OF SRI LANKA

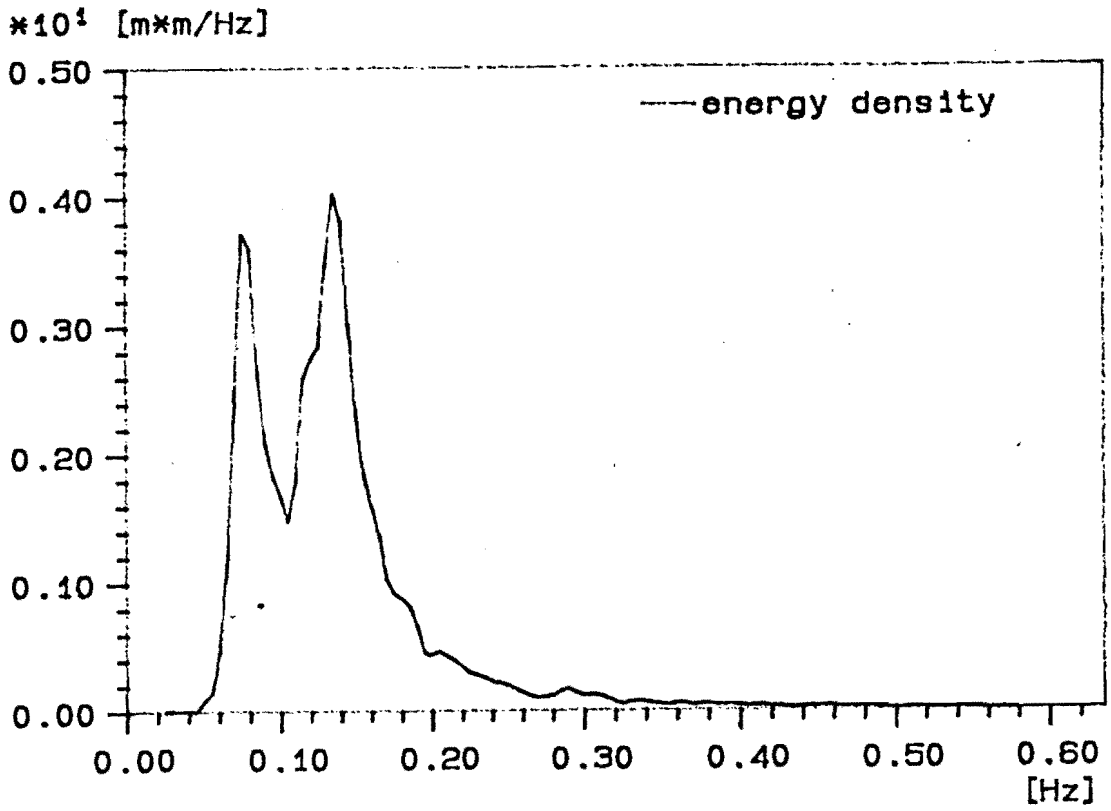


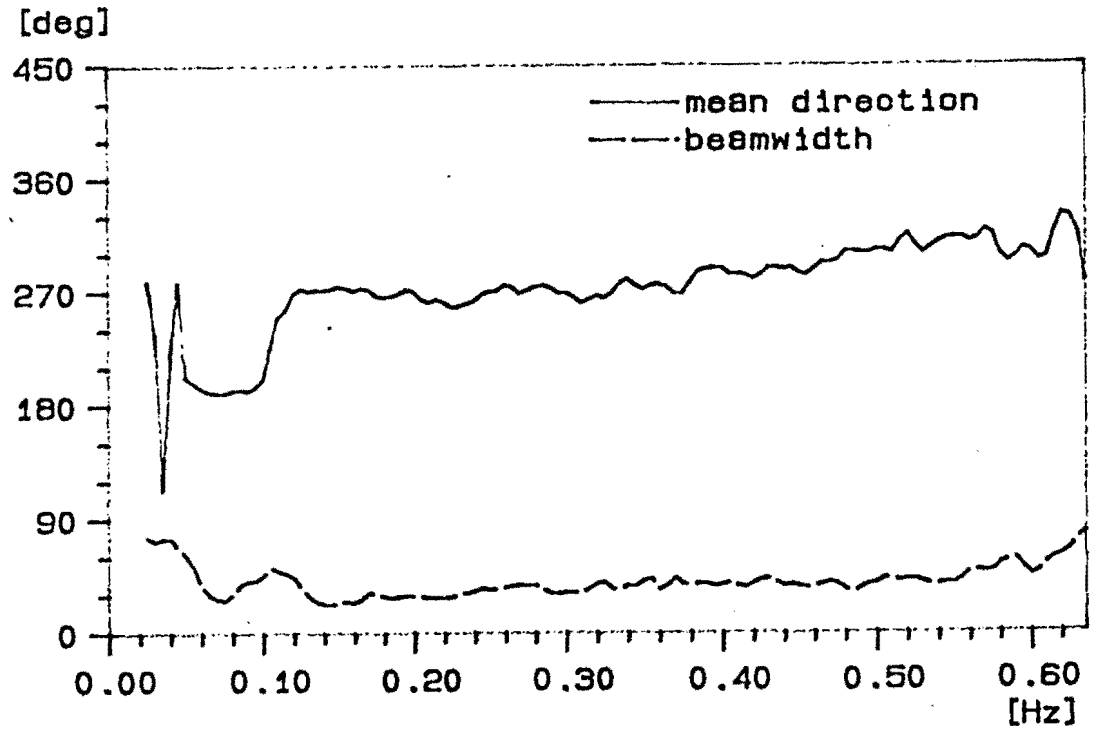
SCALE :— ONE INCH TO 24 MILES.

FIG. 3

TYPICAL DIRECTIONAL WAVE RECORD OF THE SOUTHWEST MONSOON

Coast Conservation Project





Loc: Galle Date: 30.AUG 1991 Time: 9:30

Hs = 2.27 m Tz = 6.50 sec

FIG. 4

BASIN ESTUARIES AND COASTAL LAGOONS

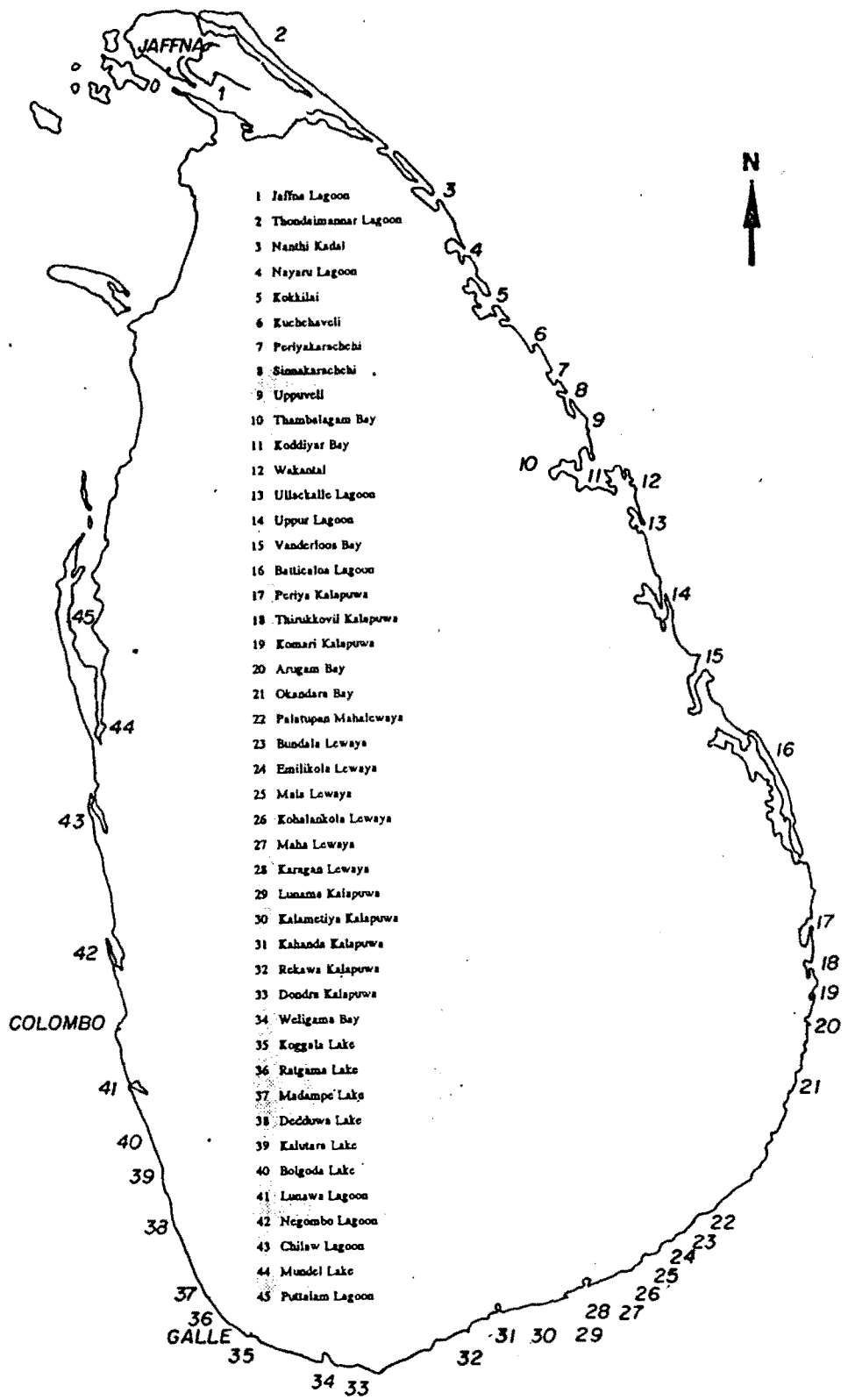


TABLE 1

NUMERICAL DISTRIBUTION OF POPULATION IN DISTRICTS WITH MARITIME BOUNDARIES IN CENSUS YEARS 1871 - 1989

District	Area sq km	1871	1901	1921	1931	1946	1953	1971	1981	1989	Pop. Den. (1989)
Colombo	657	428,980	690,535	923,143	1,081,249	1,420,332	1,738,726	1,458,393	1,699,241	1,911,000	2909
Gampaha	1387							1,173,872	1,390,862	1,506,000	1086
Kalutara	1589	145,741	279,493	367,785	456,572	523,550	631,457	829,704	829,704	925,000	582
Galle	1916	194,417	258,116	313,118	362,533	459,705	524,369	735,173	814,531	920,000	480
Matara	1283	143,336	203,750	238,509	283,292	351,947	413,431	586,440	643,786	755,000	588
Hambantota	2579	60,851	104,870	119,691	124,359	147,686	171,508	340,254	424,344	502,000	195
Amparai	4350							272,605	358,970	465,000	107
Batticaloa	2686	93,120	145,161	153,709	174,929	203,186	270,493	256,721	330,333	401,000	149
Trincomalee	2631	19,449	28,441	34,112	37,432	75,926	83,917	188,245	255,948	307,000	117
Mulaitivu	2517							43,625	77,189	90,000	36
Kilinochchi	1235								-	97,000	79
Jaffna	983	246,063	300,851	330,541	355,425	424,788	491,849	696,664	830,552	855,000	870
Mannar	1985	20,248	24,926	25,582	25,137	31,538	43,689	60,124	106,235	127,000	64
Puttalam	3013	68,110	104,197	137,984	149,278	182,847	228,892	378,430	492,533	580,000	192
Total	28,811	1,420,315	2,140,340	2,644,174	3,050,206	3,821,505	4,598,331	7,020,250	8,254,228	9,441,000	328
Total Con. P	65,610	2,400,380	4,090,995	4,497,854	5,306,863	6,651,339	8,097,895	12,689,897	14,846,750	16,807,000	259
% of Countr	44	59	52	59	57	57	57	55	56	56	

Based on Department of Census and Statistics

1989 Estimated (balance census years).

Fig 5

POPULATION GROWTH TRENDS FROM 1871 - 2040

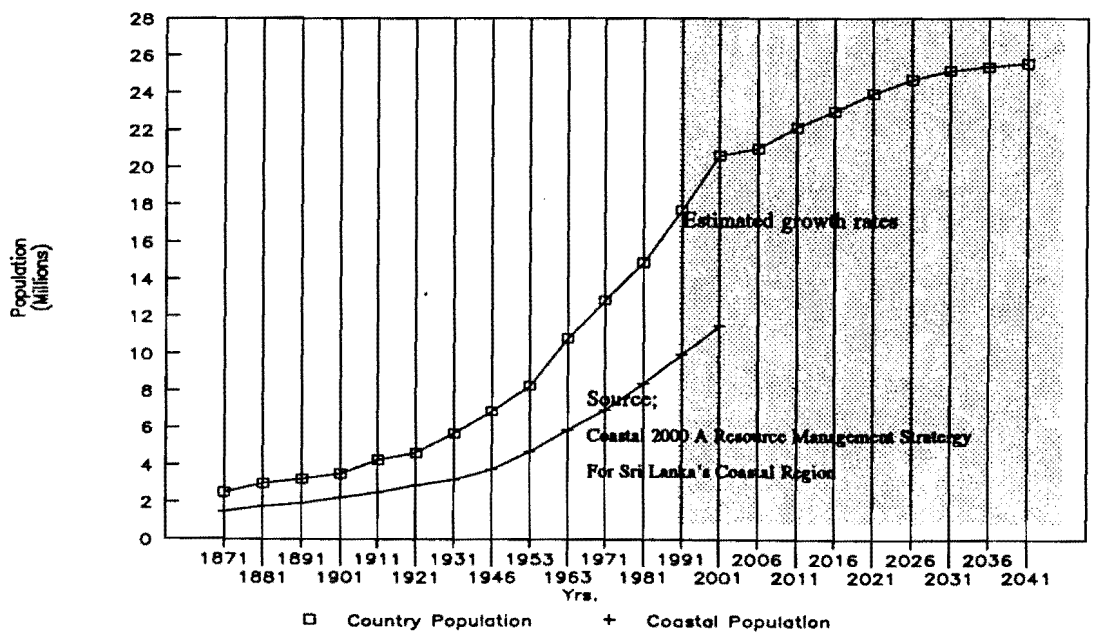


Table 2

Industrial and Agricultural Output in the Coastal Region of Sri Lanka and Maritime Provinces (1989).

GDP National or Coastal Region of Sri Lanka (Rs. Million)

	Activity	National	Coastal	% National
1.	Agriculture, Forestry & Fishing	59388	8958	15
2.	Mining & Quarrying	6157	245	4
3.	Manufacturing;	34941	18150	52
	Processing of Tea, Rubber and Coconut.	6825	1621	24
	Factory Industry	24106	16083	67
	Small Industry	1632	327	20
	Other	2378	119	5
4.	Construction	17332	6586	38
5.	Electricity, Water and Sanitation	2788	1588	57
6.	Transport and Communication	23109	9320	40
7.	Wholesale and Retail Trade	46625	25310	54
8.	Banking, Insurance & Real Estate	10496	6402	61
9.	Ownership & Dwelling	5850	3217	55
10.	Public Administration & Defence	13039	7171	55
11.	Services	8648	4341	50
12.	Gross Domestic Production	228373	91288	40

Sources;
National Estimates – Central Bank
Coastal Estimates made on study on economic potential of the Coastal Zone.
Coastal 2000;

Distribution of Coast Based Economy

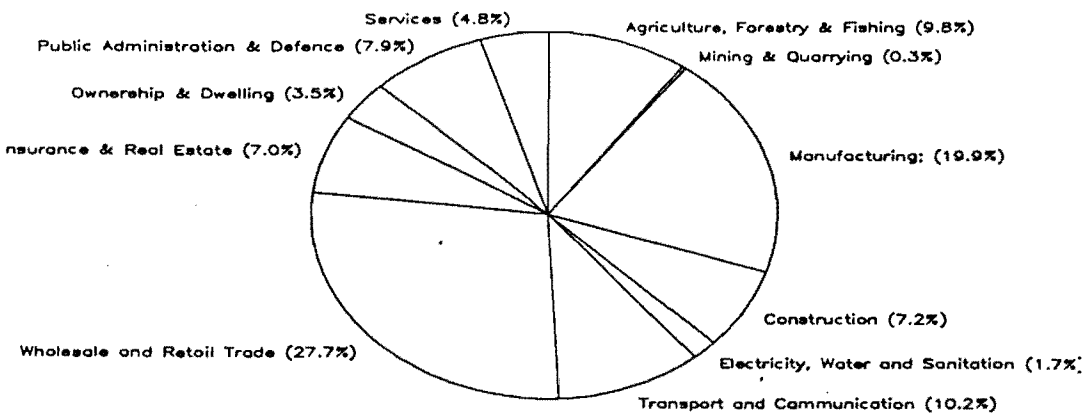


Table 3

Location and Estimated Volume of River Sand Mining
1984 and 1991

	Volume of sand removed (cum) 1984	1991	% Increase / decrease
Kelani Ganga	630,000	750,000	19.05
Maha Oya	320,000	630,000	96.88
Kalu Ganga	132,000	130,000	-1.52
Deduru Oya	65,000	2,841	-95.63
Gin Ganga	61,000	70,557	15.67
Nilwala Ganga	5,700	1,012	-82.25
Beach Based	16306	2841	-82.58
Total	1,213,700	1,584,410	30.54

Source;-

CCD Internal Report No. 7 - A Census of the Exploitation of Sand and Sea Shell Resources in the Coastal Zone of Sri Lanka (1984).

The exploitation of Sand Resources of Sri Lanka

Draft Report - 1991 ; Peoples Bank Research Division.

Coral Collected from Sri Lanka's Southwestern Coastal Sector 1984.

Location	Amount (metric tonnes)
Land based	
i) Inland of Coastal Zone	7,532
ii) Within the Coastal Zon	2,868
Beach	5,377
Offshore / Nearshore	2,282
Total	18,059

Coral Mining Estimates 1990 Selected areas

	Total (metric tonnes)	Sea Coral
Hikkaduwa	14,786	6,552
Habaraduwa	7,248	2,899
Rekawa	3,792	3,716
Madiha	2,460	1,722
Total	28,286	14,889

Source:-

CCD Internal Report No.3; Socio-economic survey of those engaged in the coral mining industry (1984).

A study on Lime Kilns Located in the Coastline from Ambalangoda to Hambantota - R.M. Ranaweera Banda - 1990.

Table 4

Coastline Development Trends – Present and Predicted 2100 AD.

District	Length of Coastline (km)	Present Rates of Erosion (m/m/yr)	Predicted shoreline change at 2100 AD (m/m/yr)					
			Low Scenario (0.5m)		Middle Scenario (1.0m)		High Scenario (1.5m)	
			Bruun Rule *	nterpolation	Bruun Rule	nterpolation	Bruun Rule	nterpolation
Puttalam	300	0.35	0.4	0.6	0.7	1.2	1.1	1.8
Gampaha	40	1.00	0.5	1.7	1.0	3.3	1.0	5.0
Colombo	40	0.10	0.4	0.2	0.8	0.3	0.8	0.5
Kalutara	40	0.30	0.5	0.5	0.9	1.0	0.9	1.5
Galle	75	0.30	0.4	0.5	0.8	1.0	0.8	1.5
Matara	55	0.95	0.5	1.6	1.1	3.2	1.1	4.8
Hambantota	135	0.20	0.6	0.3	1.2	0.7	1.2	1.0
Amparai	110	0.20	0.5	0.3	1.1	0.7	1.1	1.0
Batticaloa	100	0.15	0.5	0.3	0.9	0.5	0.9	0.8
Tricomalee	210	0.20	0.5	0.3	0.9	0.7	0.9	1.0
Mullaitivu	50	0.20	0.5	0.3	1.1	0.7	1.1	1.0
Jaffna	275	0.30	0.5	0.5	0.9	1.0	0.9	1.5
Mannar	155	0.50	0.5	0.8	1.0	1.7	1.0	2.5

Responding to Changes in Sea Level – Engineering Implications

National Academy Press Washington DC 1987.

* Bruun Rule ;- $x = X^*z/Z$ # Linear Interpolation ;- $R' = R^*S'/S$

Where x = Recession

X – Width of active profile R' – Rate of erosion

z – Eustatic Sea Level Rise S' – Eustatic Sea Level Rise at predicted yr.

Z – Active depth of profile S – Present Sea Level

Active depths vary from 7.5m – 9.5m depending on the location.

Width of active profile varies from 650m – 850m

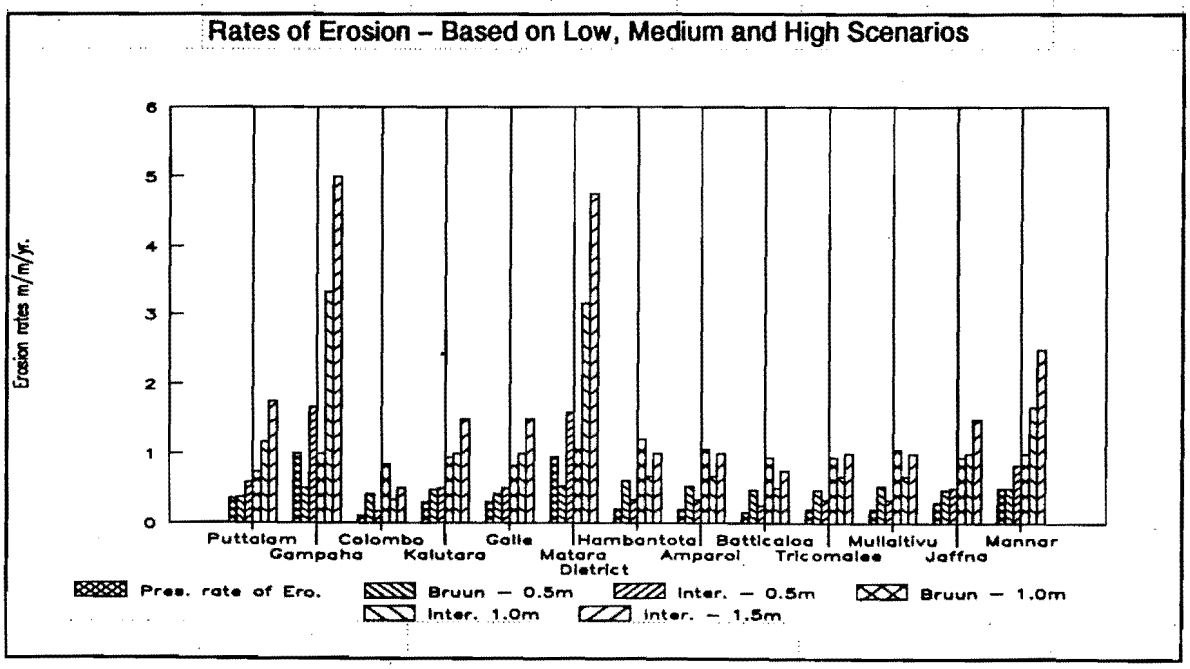
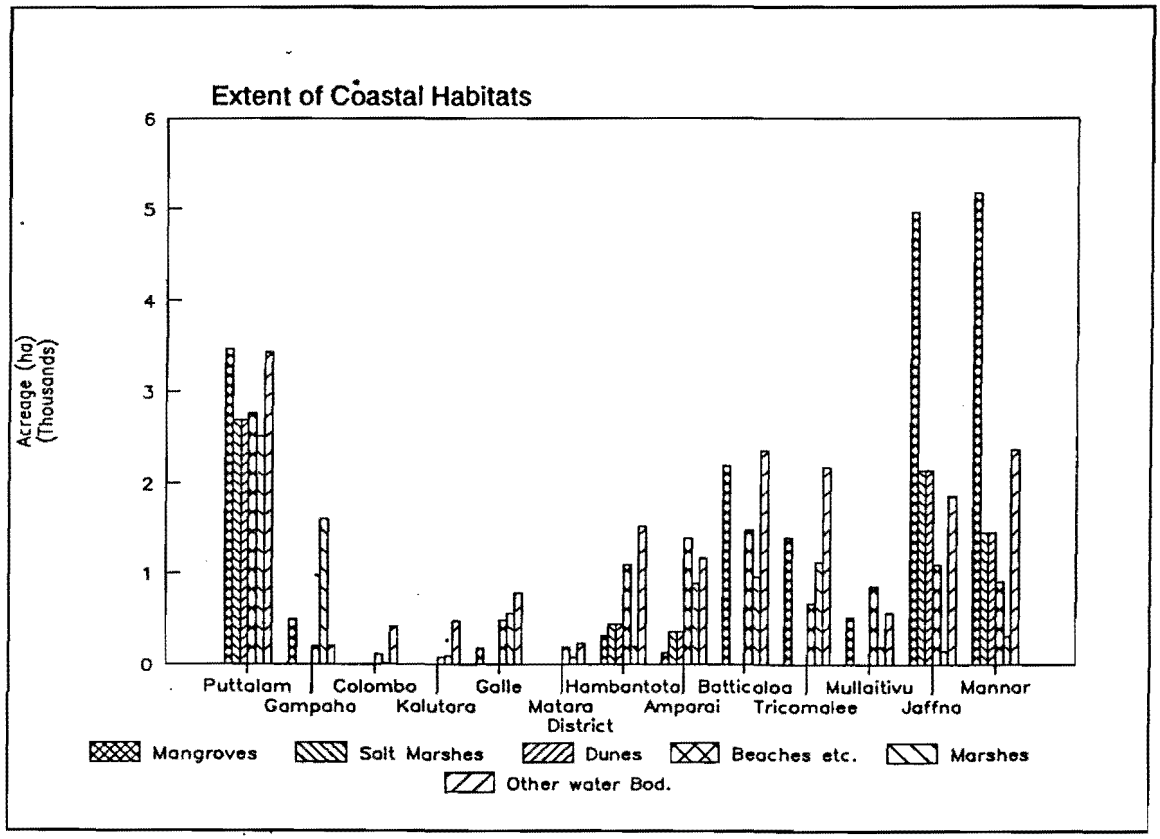


Table 5

Extent of Coastal Habitats per District (n hectares)

District	Mangroves	Salt Marshes	Dunes	Beaches, Barrier Spits	Lagoons, Basin Estuaries	ther Water Bodies	Marshes
Puttalam	3,210	3,461	2,689	2,772	39,119	3,428	2,515
Gampaha	313	497		207	3,442	205	1,604
Colombo	39			112		412	15
Kalutara	12		4	77	87	476	91
Galle	238	185		485	1,144	783	561
Matara	7			191		234	80
Hambantota	576	318	444	1,099	4,488	1,526	200
Amparai	100	127	357	1,398	7,235	1,171	894
Batticaloa	1,303	2,196		1,489	13,682	2,365	968
Tricomalee	2,043	1,401		671	18,317	2,180	1,129
Mullaitivu	428	517		864	9,233	570	194
Jaffna	2,276	4,963	2,145	1,103	45,525	1,862	149
Mannar	874	5,179	1,458	912	3,828	2,371	308



BANGLADESH COUNTRY PAPER FOR THE WORKSHOP ON ''REDUCTION OF VULENRABILITY TO SEA LEVEL RISE'' (Srilanka,21-22 February,1992).

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BANGLADESH COUNTRY PAPER FOR THE WORKSHOP ON
'REDUCTION OF VULNERABILITY TO SEA LEVEL RISE''
(Srilanka, 21-22 February,1992)

GENERAL BACKGROUND

Bangladesh lies roughly between latitudes 20D 34M .N and 26D 38M .N and longitudes 88D 01M .E and 92D 41M. It has an area of 144,000 square kilometers. It is mainly floodplain and delta with one-third of the area less than 10 meters above sea level. Three main rivers known as the Ganges, the Brahmaputra and the Meghna are flowing through Bangladesh upto the Bay of Bengal.This riversystem,which is known as one of the largest river system in the world,carries an estimated annual sediment load of 2.4 billion tons.

Bangladesh is not only subject to seasonal flooding and meandering river channels,but the physiographic configuration of the Bay of Bengal also ensures that tropical cyclons and coastal inundtion are normal, regular phenomena occuring in this region.The last devastating one was in April 1991,which killed about 140,000 lives and economy suffered serious set backs with the damage in billions of U.S.dollars.

The Ganges - Meghna - Brahmaputra estuary is a dynamic region. There,ersion and accretion is a continuous process depending on the directional flow of river currents and tides. Massive changes have occured over the last two hundred years in the central regions. New land has formed south of Hatiya,Manpura and Bhola Islands, Char Clark,Char Balua and Urir Char. Accretion is upto 35.6 square kilometers per year.Erosion is occuring in the north eastern part of Bhola, the northern part of Hatiya. The western and the eastern region are stable. Mangrove Forest cover the western region,which lessen bank erosion.Accretion does not occur much here.The eastern coastal region is parallel to Chittagong. It is protected along the sea by mud flats and submerged sands.

page-2/

The population of Bangladesh is now (1991) estimated to be 108 million (according to preliminary census report of 1991) with 750 persons per km,most densely populated country in the world.Population growth rate is approximately 2% per annum.

Of the total land surface of 14.4 million ha.,9.1 million ha are used for agriculture,2.85 million ha are under forest (including community forest),2.31 million ha are settlements and the remaining are regarded as wetland and miscellaneous land.

The percentage of forest land has declined over the past few decades and presently about 14 percent of land area is under forest. The actual tree cover however is about only 9 percent. Government-owned forest area covers 2.121 million ha ,with the remaining 0.731 million ha being privately controlled homestead forests. Of the state owned forests,over 90 percent is concentrated in the east and south-eastern regions of the country. Mangrove forests cover approximately 0.58 million ha extending along the coast in isolated groups,with the exception of the extensive area of sundarbans,which accounts for 74 percent of reserve forests.

Bangladesh has four seasons over the year :

(a) Winter or northeast mosoon(December-February)
(b) Summer or pre mosoon (March-May)
(c) Southeast monsoon or monsoon (June-September)
(d) Autumn or post monsoon (October and November)

The average temperature ranges from 18 - 20 degree celsius during Winter and maximum 41-43 degree celsius during Summer.

page-3/

SEA LEAVEL RISE AND ITS EFFECT IN BANGLADESH.

A major challenge facing Bangladesh is to meet basic human needs while sustaining the very limited resource base upon which these needs depend.The problems of population growth, the over exploitation of natural resources,and environmental degradation have already complicated the situation in Bangladesh. To make things worse there is the mass poverty and illiteracy.At the same time environmental degradation in the region has increased the intensity of major natural calamities like flood and cyclones. Bangladesh has suffered repeatedly from these calamities. These have further damaged our resource base including flora & fauna. In the coming years,it is most likely that Bangladesh will be experiencing more frequent flooding, increasing soil erosion, unusual droughts,and inundation of vast coastal area as a consequence of global warming due to the much talked about 'Green house effect '.There are also possibility of desertification of some marginal areas which are subject to increased ecological and social pressure. There will be increase in water and air pollution because of increased industrial activities and increasing number of motor vehicles. The situation may be further aggravated because of increase in the use of pesticides and chemical fertilizers as well as their misuse.

A projected 140 million people by the year 2000 will further excerbate pressure on the very limited resource base and moreover the widespread apprehension of inundation of vast coastal area of the country due to possible sea level rise because of Green House Effect will also put further pressure on natural resources and cause major environmental degradation.

page-4/

The intergovernmental Panel on Climate Change predicts a rise in mean sea level of 8 to 30 centimeters by the year 2030 and 30 to 110 centimeters by the year 2100, although scientific opinion is still divided on whether such changes will occur. It has been estimated that a 100 centimeter rise a sea level in the Bay of Bengal would result in 12 - 18 percent of land area of Bangladesh being lost to the sea, including most of the Sundarbans. It is also suggested that the area subject to normal seasonal flooding would increase by 17 percent as higher sea level would slow drainage of flood water (and the existing seasonal flooding would be likely to become deeper and more prolonged).Another important effect is a drastic increase in salinity of both soils and ground water in affected areas . Although it is difficult to predict the timing and magnitude of the sea level rise it is anticipated that one of the most serious consequence for Bangladesh would be the reduction of an already minimal land-person ratio and consequentty exacerbating pressure on the remaining natural resources.One metre sea-level rise will inundate about 5.608 million acres of land (about 22,886 sq.km) of Bangladesh,

The area comprising of 65% of greater Khulna, 99% of Barisal, 100% of Patuakhali, 44% of Noakhali and 12% of Faridpur will be inundated. The total of 62 upazilas (out of 464 upazilas) of 13 new districts (out of 64 district in the country) will be effected by one metre sea-level change. As a result, 13.74% of net cropped area (2.915 million acres),28.29% of forest area (1.304 million acres) of the country will be lost due to sea-level change and it will not be possible to replace the cropland as the rural areas are already extensively used. Thus about 10 million of country's 110 million population (2.05 million households) will not have any option but to migrate to unaffected urban areas, especially major cities like, Dhaka,Chittagon Khulna and Rajshahi. Most of the displaced labour force will end up in rapidly growing urban informal sector and will have to live in perpetual poverty.

page-5/

The existing cropping intensities of the affected area is about 136% and the inundation of 2.915 million acreas of net cropped land due to sea-level change will cause production loss of more than 2 million tons of rice, 13,000 tons of wheat, 214,000 tons of sugercane, 405,000 tons of vegetable 10,000 tons of Jute, 97,000 tons of pulses, 37,000 tons of oil seeds and 97,000 tons of spices. The inundation of 2.915 million acres of cropland, in fact, will cause loss of nearly TK. 29.71 billion worth of agricultural crop. Moreover, 2.73 million of cattle and buffaloes, 986,000 of goats and sheep and 9.83 millions of poultry will be affecte A total of 97.777 household now engaged in various eottage industries will be out of work. The total loss of assets and production in these cottage and small industries are TK. 1077 million and TK. 98,532.9 million respectively.

The loss to housing and physical infrastructure will be extensive, about 1.87 millions of housing units and 8273 educational institutions are among them. 1,466 kms of railway track, 10,383 bridges and culverts, 706 Kms of unmetalled roads, 148 telegraph and telephone office s, 543 electrified villages, 1,757 market centres, 375 food/fertilizer godowns, 49 upazila health complexes and 133 Health and Family Welfar Centers will also be affected.

The value of the affected land and physical assets and other structures due to 1 metre sea-level change(Other than forest resources, T & T offices and Hats and Bazars) is about TK. 441.95 billion. Contribution of the affected are: to GDP of the country is about TK. 49.724 billion at 1984-8! prices.

page-6/

Sea-level rise will also affect Sundarbans (Mangrove forest) The sundarbans has according to the present mapping,a total land area of 401,600 ha, of which 395,500 ha is occupied by scrap, grassland or base ground, clearing and plantations. Ninety nine percent of the forest area is accounted for by 10 forest types of which Sundri and Gewa constitute more than 80% of the merchantable volume. Apart from Sundarban,a total of about 0.036 million hectre of mangrove forest has been established since 1966 in the coastal areas of Noakhali, Chittagong,Patuakhali and Barisal greater districts. The Coastal plantation has been establisehed for the protection against cyclone as well as for supply in wood biomas.

t Sundarban as well as newly established mangrove forest will be destroyed due to sea-level rise. In fact the mangrove forests will be destroyed gradually even before Sundarban and other coastal forest are inundated (due to sea-level rise) mainly due to gradual increase in salinity level.Already the western part of Sundarbans which have been subject to a progrssive decline in fresh water (mainly due to diversion of substantial amount of water by Farraka Barrage),has resulted in an increase in salinity, which in turn reduced the regeneration rate of Sundri.A study undertaken by ODA,suggests that,taking as a whole all the forest types in which Sundri is a major species,approximately 17% of the stem are moderately or severely affected by top-drying.

Any further interruption of the fresh water supply to the sundarbans or increase in salinity due to sea-level rise will have adverse effects on its ecology and hence its existence.

page-7/

COASTAL MANAGEMENT :

Coastal zone being the interface of land and the occan,are ecologically very sensetive. These areas are also receiving pollutants washed down from up lands,dumped directly and generated by onshore as will as nearshore developments.

The coast of Bangladesh compris ing the complex delta of the Ganges - Brihmaputra - Meghna river system has immense resources for development. The coast is about 710 km long and can be broadly divided into three distinct regions: the eastern, central and weatern regions.

- The easteen coastline can be classified as a 'Pacific type''coast running parallel to young mountain. It is regular and unbroken and protected along the sea by mud flats and submerged sands.

- Central region is characterized by heavy sediment input,formation of chars (new lands) and bank erosion This region is the most dynamic and most of the accretion and erosion occurs here.The coast line is highly broken and consists of a series of islands formed by sediment deposits. The funnel-shaped apex of the Bay-of Bengal in this region is relatively shallow and rivers and channels emptying in to the bay change their courses rapidly.

- The Weatern region can be termed ''Atlantic type'' in which the coastline in general is transverse to the structure of the continental margin. This is a stable region and is mostly covered with dense mangrove forests which lessen bank erosin so that scouring action is confined to the river chanels which are in general deeper than those in the other regions. Accretion does not occur much in this region, being mostly concentrated at a few points.

The coastal area of Bangladesh is within the tropical zone between 21 and 23 degree north latitude. Like the climate of the country as a whole, there are four distinct seasonal weather patterns governed mostly by two monsoons,namely the south-weat monsoon and the north east monsoon.

page-8/

Two different types of cyclones form in the bay one is the tropical cyclone, which forms during the pre and post mansoon seasons and the other in the nonsoonal depression which develop during south-west monsoon season. Tropical cyclones are the most destructive. Cyclones generally cause damage in three different ways : (a) storm surges (upto 7.5 meter) (b) flooding due to excessive rainfall and (c) Wind.

It is the practice in Bangladesh that as soon as a new formation rises and ecological succession starts with grass comming up as the first colonizer, the new land is takenover by people and cattle start grazing. For this reason successor vegetation cannot grow and ecological succession is thereby retarded. New formations remain unstable and surface erosion is a continuous phenomenon. Massive efforts in afforestation in these newly formed lands may help to develop nucleus forests which can give a wider coverage for consolidation of these otherwige seemingly unstable zones.

Realizing the importance of coastal afforestation for the consolidation of newly accreted land the forest Department has undertaken extensive afforestation projects in the coastal districts of Bangladesh, particularly in the central region. By 1976, an area of about 11,000 ha and by 1980, about 40,000 ha of plantation had been completed. During 1981 to June 1985 about 37,000 ba had been planted as against a massive target of 40,500 ha . During the financial year 1991-92 Govt. has undertaken a target of 4,105 ha of coastal land to be planted. According to a recent report the available area for future plantation in the coastal region of Bangladesh is about 91,000 ha.

page-9/

Unfortunately, forest areas in Bangladesh afe under relentless pressure from river erosion, timber merchants, fuelwood collectors, grazing animals and land clearance for rice or shrimp culture. Thus, the coastal afforestation project is only a small beginging towards improving the nation's wood supply and forest cover.

Empolderization has mostly been done in the coastal region below the salinity line of 1,000 micromhos (approx. 6.76 ppt.) About 4,800 km of embankments have been constructed to cover about 1,336,000 ha of coastal land. Cross-dam techniques have been applied in Bangladesh which achieved successful result. The gross protected area totals about 900 sq. km (net area about 200 sq km) from old river beds and the bay. Gradually, the process of sedimentation around this reclaimed landmass is increasing every year. It is predicted that the landmass may finally be consolidated into on economical land of around 1,300 sq.km (net 900 sq km) from the sea. The Bangladesh water Development Board (BWDB) is planning to construct more cross-dam and various model studies have been undertaken with Netherlands experts. It is strongly felt that newly emerged land in the coastal area will have to be developed through both short-range and long-range programmes.

RESPONSE STRATEGY TO SEA LEVEL RISE :

Responses to the sea level rise may be categorised as follows:.

(a) Biological responses would concentrate on developing alternatives to lost or threatend resources and habitats, or enabling the development of species that are more tolerant to the changed environment. The emphasis in this set of responses would be to assist the ecological systems to adapt to an environment that changes faster then their natural ability to adapt to it.

page-10/

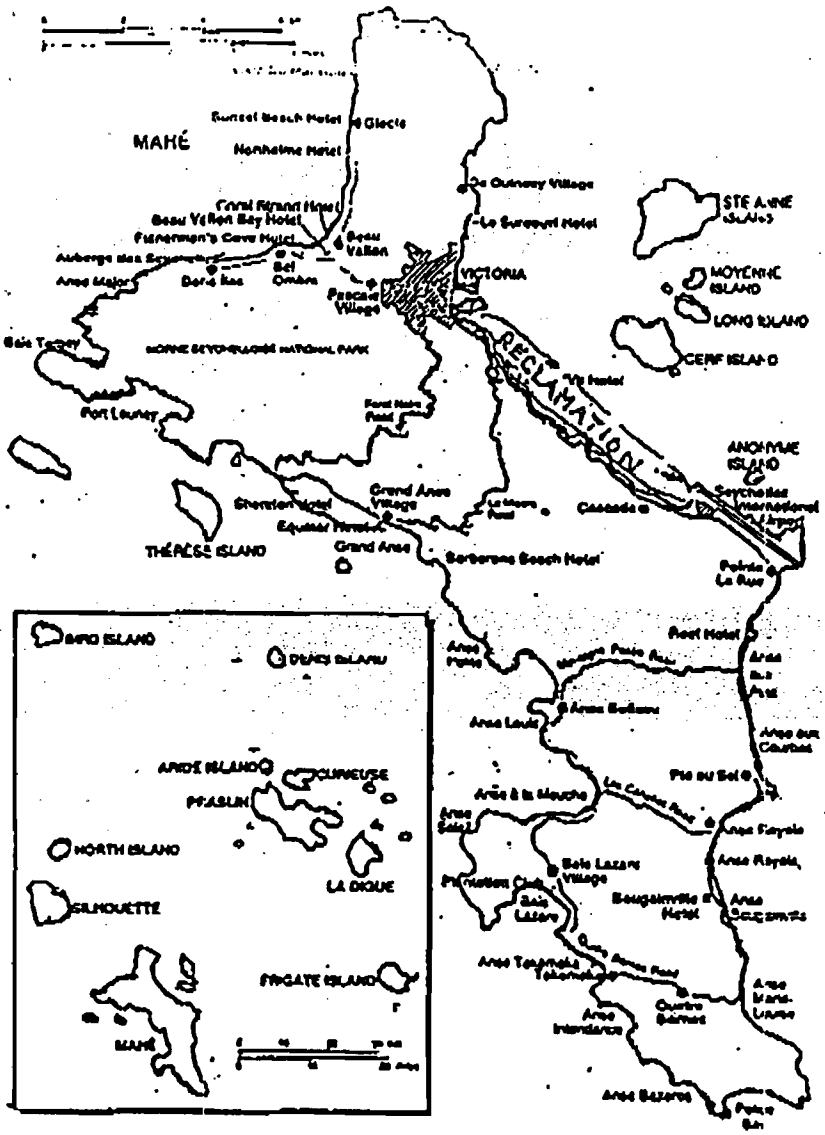
(b) Technical responses involve both 'hard'and 'soft' engineering options. These are essentially building of structures to protect the coast from submergence and overtopping. Dikes, groynes, bulkheads are the examples of hard engineering option and beach nourishment is an example of soft option.

(c) The third category of responses is institutional. As information about SLR increases, coastal users and uses are allowed to respond to the potential threats either naturally or by the use of legal and policy means.

There are various stages in the adoption of a response: (1) the scientific assessment of the problem for the country in question (2) the identification of potential effects of the projected SLR (3) the undertaking of research on the various adaptive options (4) choosing between alternative responses and (5) implementing the responses. All these call for a number of capabilities- a scientific and technological capability, an institutional capability, a financial capability and a managerial and organizational capability. Bangladesh including other South Asion countries may be short of all these, This, therefore calls for assistance from the more developed countries not only to identify the problem but to ensure that where the problem exists, and suitable measures can be undertaken to find a solution. Moreover, Bangladesh hardly contributes to the overall process of global warming, which in favour of an international agreement for assistance to vulnerable countries like Bangladesh to take necessary preparations and adapt measures to survive a sea level rise, increased flooding and more frequent storm surges.

SEYCHELLES: MACRO-LOCATION IN THE INDIAN OCEAN

SEYCHELLES' GRANITIC ISLANDS



STATISTICS:

COUNTRY
115 islands, of which 41 Granitic and 74 Coralline
Land Area: 445 sq km
Coastline: 600 km
Exclusive Economic Zone: 1.3 million sq km

CLIMATE (Average 1972-1988)
Rainfall: 2013 mm
Mean Max. Temp: 30.1°C
Mean Min. Temp: 24.9°C
Humidity: 80%
Sunshine: 6.7 hours per day
Maximum Gust: 49 knots

POPULATION (1988)
Mid Year Estimate: 66 627
Females: 33 339
Males : 33 288 Total Population
Under 30 years: 44 607 or 67%
Principal Town (Victoria): 23 000
Economically Active Population: 29 000
Birth Rates per '000: 24.7
Death Rates per '000: 7.6
Infants Deaths (Under 1 year): 17
Net Migration: -899

OFFICIAL DEVELOPMENT ASSISTANCE
(1989): SR 90 Million (estimate)

INFRASTRUCTURE
Roads: 269 km of which 167 km is surfaced. Air Travel: Air Seychelles plus about 7 Foreign Airlines.
Communications: 14 000 Radios, 6 000 Televisions, one Daily National Newspaper, 13 929 Telephones, 95 Facsimile, 199 Telex

ENERGY (1988)
Electricity Production (Mahe):
No. of Consumers: 12 520
Units of Electricity Generated: 78.30 MWh
Units of Electricity Sold: 68.55 MWh
Electricity Production (Praslin and La Digue):
No. of Consumers: 1 215
Units of Electricity Generated: 4.89 MWh
Units of Electricity Sold: 3.95 MWh

WATER
Water Use: 70% of population have access to safe drinking water (consumption: about 4.5 M m3/year) 2 water storage reservoirs - 4 major water treatment works.

AGRICULTURE
Areas: Annual Crops: 400 ha
Coconut Plantations: 6 000 ha
Tea Plantations: 36 ha
Main crops (1988 production in tonnes):
Vegetables and Fruits: 1 347
Copra: 1 176 Cinnamon Bark: 273
Tea: 70
Livestock (1989 production in tonnes): Poultry: 700
Pork: 600 Eggs: 500 Beef: 50

FISHERIES (1989)
Industrial Fishery:
Licensed Vessels Active in EEZ: 51 Purse Seiners, 167 Long Liners
Tuna Transhipped: 221 000 tonnes
Canned Tuna Production: 2 857 tonnes
Artisanal Fishery:
Total Catch: 4 166 tonnes (1988)

FORESTRY
Forests: Cover about 25% of total land area
Annual Volume Harvested: 2 000 m3 timber, 6 000 m3 fuelwood

PROTECTED AREAS
7 National Parks (43.6 sq km), 3 Special Reserves (154.8 sq km) of which 2 World Heritage Sites
2 Protected Areas, 4 Shells Reserves

BIOLOGICAL DIVERSITY
Biotic Communities: 16
Known Species: 850 of Flora and 4 000 of Fauna
Threatened or Endangered Species: 60 Fauna, 13 Flora

STATUS REPORT

COASTAL FEATURES - VULNERABILITY

Seychelles consist of 41 granitic islands and 74 coralline islands (many of which are atoll-formations).
The coralline islands are surrounded by coral-sand beaches.
The coralline islands are only elevated a few metres above mean sea level and are therefore extremely vulnerable to possible global sea level rise.

The granitic islands have either steep granitic shorelines, wide mud and gravel flats (formely mangrove swamps) or numerous small so-called "pocket-beaches" of coral-sand.

All the beaches of the Seychelles consist of eroded and decomposed coral reef material.

There are no cyclones over Seychelles (1 per hundred years) and very rarely severe storms.

The gradients (slope) of the beaches therefore tend to be relatively steep.

The dunes behind the beaches are consequently therefore also usually not higher than 1-2 metres and not wider than 5-10 metres. There is usually a flat coastal plateau behind the beaches varying in width between 50-500 metres and elevated a few metres above Mean Sea Level.

The plateaus consist of ancient beach sand.

Seychelles beaches are already subject to slight beach-erosion and consequent receding shorelines mainly from man-made causes.

It is felt that preventive measures may relatively easily accommodate a sea level rise of up to 0.50 metres.

A sea level rise between 0.50 metres-1.0 metres will be possible but very costly to accommodate.

Sea level rises above 1.50 metres would inundate all the coralline islands as well as most parts of the coastal plateaus of the granitic islands.

STATUS QUE: COASTAL ZONE MANAGEMENT:

Coastal Zone Management including Beach Erosion Control is mostly done on an ad-hoc basis through the participation of the Department of Environment in the "Town & Country Planning Authority" (which controls 90% of all development in Seychelles) and in the "Project Appraisal Committee" both of which are hosted by other Ministries.

There is very little CZM Legislation in place. Ancient (pre-independence) Legislation defines Land ownership out to the ambiguous "high-water-mark".

The Seychelles "Sand & Gravel Abstraction Act", however, offers some means of control

Beach Zone Management Plan 15

A very basic CZM plan was prepared 1987 (see SYNOPSIS page no. 5) and is being partly implemented on a piece meal basis.
Elements of this basic CZM plan is now incorporated in the ENVIRONMENTAL MANAGEMENT PLAN OF THE SEYCHELLES 1990-2000 (EMPS).

SEYCHELLES' PARTICIPATION IN BILATERAL, REGIONAL & INTERNATIONAL INITIATIVES: Seychelles' was represented at a UNEP-OAU MEETING OF EXPERTS IN ACCRA, GHANA MARCH/APRIL 1990 on Coastal Erosion Problems and at a Regional Workshop in Maputo, Mozambique December 1991 on lagoon Coastal Management and Seychelles' Minister for External Relations is attending the New York Meeting mid February 1992 on Global Warming and Sea Level Rise.

PLANS, POLICIES & PROGRAMMES

The ENVIRONMENTAL MANAGEMENT PLAN OF THE SEYCHELLES 1990-2000 (EMPS) calls for CZM plans & studies (see pages nos. 11 & 12). None of these EMPS Projects are implemented yet (except for EMPS No. I.3). It is expected that implementation will commence during 1992.

It will be noticed that the EMPS Project No. A5 "Impact Assessment of Climate Warming and Sea Level Rise" (Page no. 11) is rather "open-ended".

The Department of Environment (Seychelles) will now give priority to implementation of EMPS Project No. I.1 "Coastal and Marine Environment Baseline Study" and EMPS Project No. I.2 "Beach Erosion Control (General)" (Page No. 12).

EMPS Project No. I.3 "Alternatives to Reduce Sand in Construction" (Page No. 12) commenced a few years ago and is progressing reasonably well.

CONCLUSION:

It is concluded that it is socio-politically very difficult already now (1992) to prepare for the drastic steps required to accommodate projected sea level rises beyond year 2010, as long as Scientists and Organizations still disagree so much on the scope of projected Global Warming and consequent Sea Level Rise.

It is thought that the approach most likely to succeed is to initially put emphasis on general Coastal Zone Management Plans and to implement these first.
This will include "Set-back-lines" (domaine-public) for beach development and re-creation of artificial dunes and replenishing of the beaches from the coastal-plateau ancient beach sand.

After implementation of general Coastal Management Plans,- the groundwork will have been prepared and the situation will lend itself more easily to further measures as and when more reliable and less contradictory data become available.

It would be essential to establish sea-water-level monitoring stations globally, installations and measuring methodology being standardized (WMO).

Meanwhile it is also thought that as "prevention is better than cure" international efforts should be coordinated to identify the human causes for global warming (carbon dioxide emissions etc.) and devise means to address these causes.

NOTE:	GLOBAL SEA-LEVEL SCENARIA REFERENCE		
	(1995-2010)	(2010-2040)	(2100)
SCENARIA:	MIDDLE-TERM	LONG-TERM	DISTANT FUTURE
LOW:	0.10 metres	0.05 metres	0.50 metres
MEDIUM:	0.30 metres	0.60 metres	2.00 metres
HIGH:	0.50 metres	1.10 metres	3.50 metres

From "Worldwide Sea-Level Rise Scenarios - Summary of Seven Authors" W. Bach, H. Flohn, G. Golizyn, ICSU/UNEP/WHO, K. Kondratjev, J.G. Titus, M.C. Barth presented by W. Kertzscher.

BEACH-ZONE MANAGEMENT PLAN: S Y N O P S I S OF ACTION PLAN

DETERIORATION OF SEYCHELLES' BEACHES:
Our beaches are deteriorating, eroding, receding and slowly being obliterated. Some beaches have already disappeared.

CAUSES:

* The main cause is excessive abstraction (removal) of sand from the total beach-system during the years and accelerated when the traditional frame-house went out of fashion. (Increased demand for concrete).

* An other cause is the close proximity (to the beaches) of certain erosion promoting structures and roads.

* Natural causes would include storm-damage (cyclone-tails),- however such damage is repaired naturally by the beach itself unless the beach system is already damaged by removal of sand from the storage reservoirs (dunelands, "dry beach", sand banks etc.).

REMEDIAL ACTION: "PRESERVATION OF OUR BEACHES"

* Establish extension to existing "DOMAINE PUBLIC" covering the "wet beach", the "dry beach", the dunelands and a "green belt" buffer-zone.

* Enforce a total ban on sand abstraction within the "Domaine Public" now.

* Prevent lorries and other motor vehicles to enter "Domaine Public" as soon as possible (after appropriate legislation, surveys and fencing).

* Regulate and control the clearing of river mouths by installation of automatic flexible-pipe outlets for all rivers. (Drainage benefits also).

* Do not over-exploit the plateau sand or the remainder sand flats (outside the "Domaine Public").
An emergency supply should be reserved for future restoration of dunelands if required.

* A beach-survey-monitor-team should be set up to perform regular monitoring and check-surveys of the beach profiles.

* A civil engineer should be seconded to assess excessively damaged beaches and make recommendations in respect of emergency measures including possible repairs to existing waterfront structures.

* New waterfront structures including groynes, sea-walls & bulkheads should only be considered when other methods have failed.

PARALLEL ACTION TO RECONCILE THE NEED FOR "PRESERVATION OF OUR BEACHES" WITH DEVELOPMENT i.e., SUFFICIENT SUPPLY OF SAND FOR CONSTRUCTION

* Regulate & control plateau sand from remaining sand flats.
* Prepare (refit, re-schedule) existing quarry crusher plants (SPU., UCPC.) for a tenfold increase in production of granitic crusher-dust.
* Identify, develop & utilize inland gravel pits.
* Identify, develop & utilize river gravel deposits in estuaries, lagoons, river mouths and former mangrove swamps (mud flats).

ADDITIONAL ACTION:

* Plateau sand, gravel & granitic crusher-dust should be price-regulated in such a way as to discourage the use of plateau sand.
* Government "royalty" charges may be an instrument for such price-regulation. The "royalties" may also be used to finance the cost of the Beach preservation measures and the parallel measures to develop alternative sand and gravel sources.

REVIEW OF CERTAIN MYTHS, COMMON BELIEFS & MISCONCEPTIONS CONCERNING SAND ABSTRACTION & STRUCTURES ON THE BEACH

---

1. "BEACH SAND IS A RENEWABLE AND THEREFORE INEXHAUSTIBLE COMMODITY"!!! Sand from our beaches is not a renewable and inexhaustible "commodity". The Seychellois beach-system probably developed during the last 10,000 to 30,000 years from the slow breaking-up and pulverizing of dead coral and the modern-day configuration and parameters took shape during the last 5000 to 6000 years.

   The replenishment rate is extremely slow. Sand abstraction above the replenishment rate will irevitably lead to erosion & recession and obliteration of the beaches.

   This is unfortunately happening in Seychelles. Many beaches are eroding and receding, some beaches have already disappeared

2. "BEACH SAND FROM THE DUNES AND THE "DRY BEACH" IS SURPLUS SAND AND CAN SAFELY BE REMOVED WITHOUT ADVERSE EFFECTS TO THE BEACH"

   The dunelands and the "dry beach" form storm-water barriers and natural sand storage reservoirs for natural beach repair.

   Removal of sand from this area will deplete the beach of "repair material and lead to erosion & recession of the beaches

3. "CERTAIN OUT-OF-THE-WAY BEACHES COULD BE SACRIFICED AND QUARRIED FOR ALL THE BEACH SAND WITHOUT ANY ADVERSE EFFECTS ON THE ADJACENT BEACHES" !!!

   All the island beaches form part of a total beach system "connected" by the coastal drift and are therefore interdependent.

   Sacrificing whole beaches or partially abstracting from other

beaches create "holes" in the total beach system. Other beaches will start eroding and the total sand-mass (including duneland & submerged storage) will diminish leading to general erosion & recession of other beaches.

4. "SAND CAN SAFELY BE MINED (DREDGED) FROM THE SAND BANKS, BARS & RIDGES IN THE NEAR-SHORE ZONE" !!!

The sand banks, bars & ridges are formed from beach erosion during storms and form storage reservoirs for natural repair of the beaches.
This is not surplus sand and it should be left alone.

* However sand may be mined (dredged) from deposits in the ocean far enough away from the beaches as to not disturb the total beach system.

(It is possible, however, that such abstractions may in the long run affect the natural oceanic sand replenishment process).

5. "CONSTRUCTION OF GROYNES WILL BRING BACK THE SAND AND RESTORE THE BEACH" !!

Construction of groynes is a controversial matter. They are very costly and they often do more harm than good.

Groynes cannot re-create sand which is lost through sand abstractions.

Groynes form barriers perpendicular to the direction of the coastal drift thereby trapping the drift-sand but also depriving down-drift beaches of their normal supply of sand for natural beach repair.

Especially in Seychelles where the two biannually monsoon winds blow from diametrically opposite directions,-the constructions of groynes is a very tricky affair and should only be undertaken on an initial trial & error basis with regular monitoring of the nearby beaches. (Survey of beach profiles).

6. "CONSTRUCTION OF SEA-WALLS PROTECT THE SHORE AND SAFEGUARD THE BEACHES"

Sea walls constructed on eroded beaches (dunes and backshore "dry beach" obliterated) will initially protect the shore behind the sea-walls,- but in the long run sea-walls and bulkheads have an adverse effect on the beaches themselves.

Sea-walls and bulkheads do not dissipate the wave energy but reflect the wave energy causing a scouring action near the foot of the walls digging-out/washing-out the sand undermining the walls till they crumble-up and collapse. In the process the beaches are losing further amounts of sand causing more erosion than before.

7. "PLATEAU-SAND" FROM THE SAND FLATS ON THE COASTAL PLATEAU (BEHIND THE DUNELANDS) CAN SAFELY BE REMOVED WITHOUT ADVERSE EFFECT TO THE BEACH"

This statement is correct. However, this plateau took about 6000 years to formate and at the present rate of abstraction,- most of the available plateau sand might be finished within 25 years.
As these sand flats are mined for sand,- the excavation holes are usually backfilled with red earth.
Obviously the overall drainage will be adversely affected.

* Mining of plateau sand should only be undertaken as a transitional emergency measure pending indentification and utilization of alternative gravel and granitic resources.

8. "CLEARING OF BLOCKED RIVER MOUTHS IS NOT ONLY NECESSARY, BUT THE SAND REMOVED FROM THE RIVER MOUTHS MAY SAFELY AND CONVENIENTLY BE ABSTRACTED"

Clearing of blocked river mouths is necessary in order to ensure a steady drainage to the sea from the low-lying coastal plateau and marshes.

This operation is normally performed by building contractors, concrete blockmakers etc...who are
supposed to clear the river mouth itself for part of the blocking sand barrier and also clear the culvert under the coastal road. The contractors are allowed to abstract and take away the so cleared sand.

Unfortunately this operation contributes to the overall depletion of sand from the beaches,- further aggravated by the actions of ignorant, greedy or unscrupulous contractors. Some contractors really "have-a-go-at-it' and remove much more sand than necessary for clearing the river mouths.

Other contractors stay with their lorries on the bridges and only dig deep pits within easy reach - not even clearing the river mouths.

* If permanent sea-outfalls (flexible piping etc...) were installed through the (blocking) sand barriers,- very little contractor-assisted clearing would be required,-and incidentally perhaps 50% of the drainage problems on the low coastal plateau would be solved as well.

9. CONCLUSION:

The BEST and CHEAPEST way to preserve and restore our beaches is to maintain the natural beach process by avoiding sand abstractions from all parts of the beach system, restore the dunelands and establish, restore, maintain a "green belt" behind the dunelands,- and finally to discourage structures on the beach.

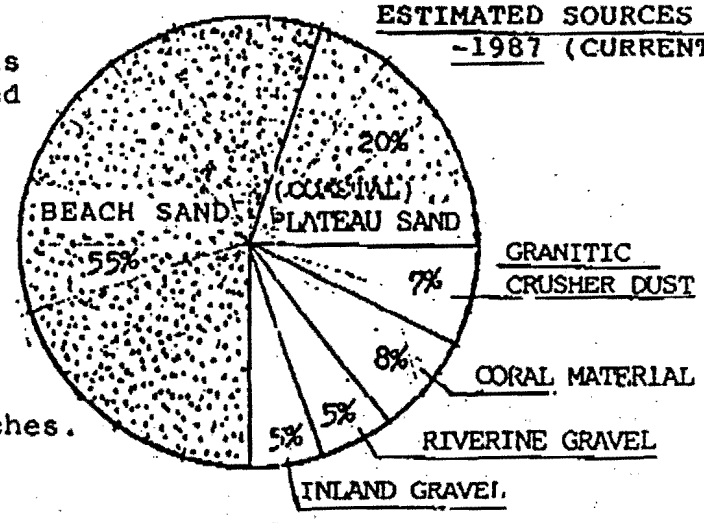
So-called beach protection structures like groynes and sea-walls should only be Constructed in connection with maintenance and repair of existing structures. New structures should only be considered when other methods have failed and then only on a strictly monitored trial and error basis.

I- **STATUS QUO:**

Currently enormous amounts of beach sand is excavated (abstracted from our beaches causing, eroding, receding and slow obliteration.

It is proposed to extend the "Domaine Public" to include the total beach area, and enforce a total ban on sand abstraction from the beaches.

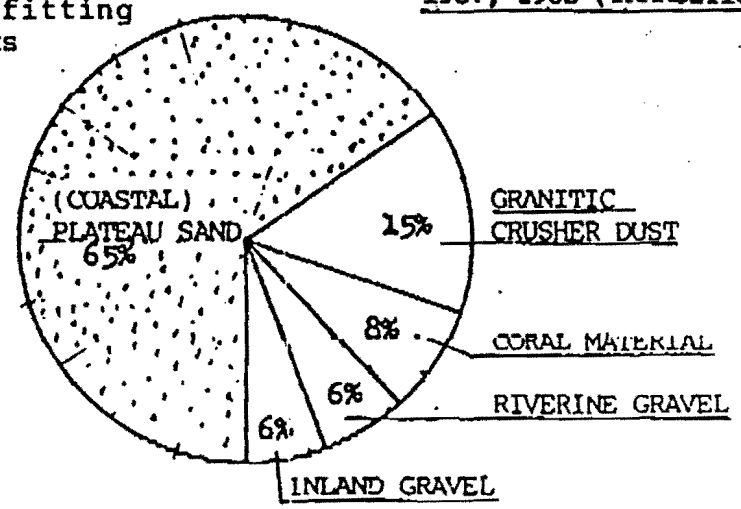
ESTIMATED SOURCES OF SAND -1987 (CURRENTLY)



II- **TRANSITIONAL STAGE:**

Pending rescheduling & refitting of SPU. & UCPS's crusher plants it is proposed to substitute the beach sand resource with a stepped-up production of (recycling) granitic crusher dust and increased use of gravel sources and fill-in the gap with provisional over-utilization of Plateau Sand.

PROBABLE SOURCES OF SAND 1987, 1982 (TRANSITIONAL)

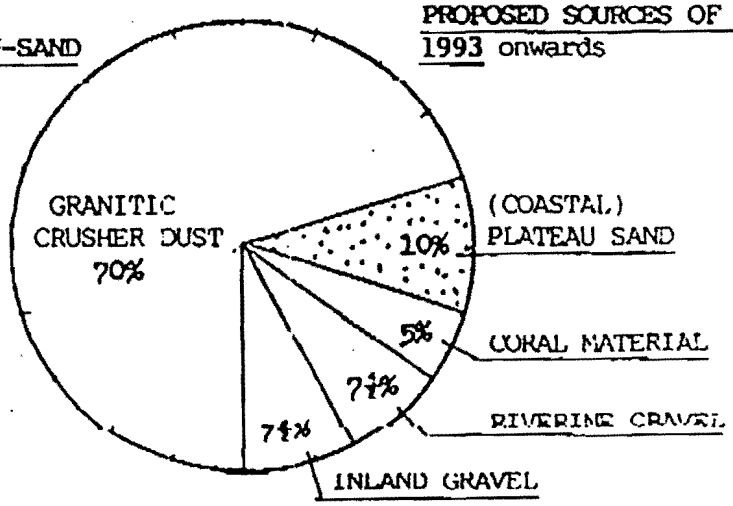


II- **THE FUTURE:**

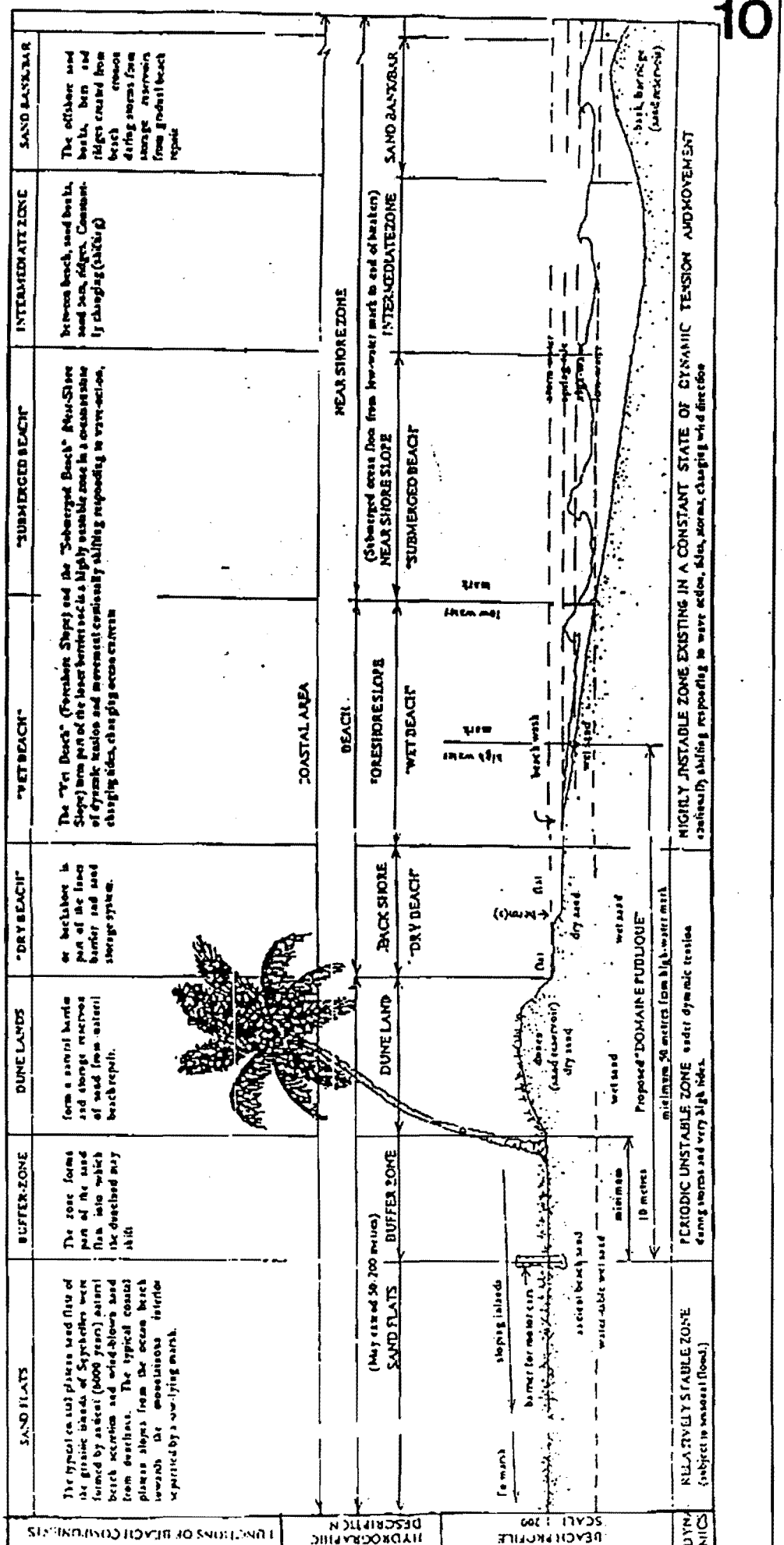
CONSERVATION OF BEACH SAND
REDUCED UTILIZATION OF PLATEAU-SAND
by identifying & developing substitute sources: (after rescheduling and refitting of the crusher plants)

REVENUE COLLECTION
from price-regulating "royalty" charges per ton.

PROPOSED SOURCES OF SAND 1993 onwards



TYPICAL BEACH-PROFILE OF AVERAGE BEACHES IN THE SEYCHELLES



NOTES:

All the beaches of the Seychelles consist of decomposed coral-reef material.

There are no cyclones over Seychelles and very rarely severe storms.

The gradients of the beaches therefore tend to be quite steep.

The dunes behind the beaches are usually not higher than 1-2 metres and not wider than 5-7 metres.

There is usually a flat coastal plateau behind the beaches varying in width between 50-500 metres consisting of ancient beach-sand.

Plan Chapter N°: 5 Project N°: A5

Project Title : Impact Assessment of Climate Warming and Sea Level Rise

Lead Responsible Agency : DOE

Implementing Agency(ies) : DOE

Start Date : 1990 Duration : 1991-2000

Estimated Cost (SR) : 645 000
(US $) : 115 000

Financing : External Funds Required (US $) : 115 000
Local Financing (SR) :

External Partner(s) :

Project Description :

Scientists now estimate that climate warming could lead to significant sea level increases over the next decades. If these trends are confirmed, the economic, social and ecological impact on the Seychelles could be devastating. The Government of Seychelles would have to plan and undertake major relocation and reconstruction programmes for a large part of the population, buildings and infrastructure on the narrow and shallow coastal plains.

The Seychelles must therefore actively support and monitor international research on climate trends and implications.

It is proposed to join Kenya, Mauritius and Tanzania in the Eastern African Task Force on the Implications of Climate Change which was recently established by UNEP.

That Task Force will assess the impact of various climate change scenarios on the region's water resources, coastal ecosystems, marine environment, agriculture, forestry and fisheries as well as the region's infrastructure, industry, tourism and coastal settlements. The Task Force will then develop a series of policy options for decision-makers in the region.

Detailed Cost Estimates and Implementation Modalities :

Appropriate expertise is not available in Seychelles at present to undertake even a preliminary study of the implications of climate change and sea level rise for the country.

It is therefore proposed to engage an external expert by mid-1991 to undertake a preliminary study and to work closely with and train relevant local specialists to carry out that analysis (1,5 months of external expertise, SR 120 000).

In order to benefit from the knowledge and expertise of other specialists in the region and as an occasion to highlight the issue and inform the local people on the implications of climate change and the need for international cooperation and action, it is proposed to host in Seychelles a meeting of the Eastern African Task Force in early 1992 (SR 120 000).

For the rest of this decade, only a modest annual budget will be required on this issue to cover the costs of the exchanges of information and expertise with other island countries, the participation in the East African Task Force on the Implications of Climate Change and other key meetings, and occasional external advice and assistance on particularly complex new issues and implications which will inevitably emerge (provision of SR 45 000 per year from 1992).

Cost/year *	91	92	93	94	95	96	97	98	99	20
Consultants	120									
Task Meeting		120								
Provision		45	45	45	45	45	45	45	45	45
Total	120	165	45	45	45	45	45	45	45	45

* (SR 000 's)

Project Status : Ready for implementation

Environmental Management Plan for Seychelles

I. Coastal Environment Management Programme

I.1 Coastal and Marine Environment Baseline Study (SR 5 500 000)

Prepare and implement a research and monitoring programme for Mahé, Praslin, La Digue and other main inner islands (i) to inventory and collect baseline data on living marine resources, the state of coral reefs, mangrove areas and marshes, marine water quality and hydrodynamic parameters; (ii) to assess the extent, kind, causes and sources of coastal and marine pollution and degradation; and (iii) to identify the policy and technical options for remedial and preventive management action.

I.2 Beach Erosion Control (National Action : SR 760 000 for Design Study only) (*Regional Action, 5 COI Members : SR 3 700 000*)

Assess the extent, risks and causes of coastal erosion on the main inner islands and the policy and technical options for beach protection and erosion prevention.

Train a special technical team to monitor, combat and prevent beach erosion. Undertake a public information campaign on unsafe practices in coastal zones.

I.3 Alternatives to Reduce Sand Use in Construction (SR 330 000)

It is proposed to conduct in-depth investigation on possible long term alternatives to the use of beach and plateau sand for the construction industry by :

i) assessing plateau sand resources and investigating on alternative sources of sand,

ii) promoting the use of granite crusher products, as a substitute to sand,

iii) investigating and promoting other possible sand saving construction techniques, practices and materials,

iv) identifying adequate sites for future granite quarries,

v) preparing detailed environmental guidelines for sand and granite quarrying activities.

I.4 Review of Coastal Zone Management Plans (SR 320 000)

This project, based on the findings and results of projects I1, I2, and, to a lesser extend, of projects A5 and I3, will :

- Review and precise the land use and management plans for the coastal zones on Mahé, Praslin and La Digue elaborated under the PAT project (D1).
- Establish coastal construction setback lines in erosion prone areas, give special attention to protecting mangroves areas and marshes.
- Review supporting guidelines and legislation to regulate coastal development and potentially harmful practices such as dredging, land reclamation and the removal of beach sand and gravel.

COUNTRY REPORT - INDIA

Sea-level Rise and its impact on coastal areas of India

Increasing global warming due to emission of green house gases is believed to cause increase in Sea-level rise through melting of glaciers and polar ice. It has been estimated by Munk and Forbes (1989) that due to increase of global warming over the years there is an increase of global temperature by Ø.Ø5°C per decade. Based on such figures available in the literature, the extent of rise in sea level has been predicted to levels of Ø.9 m to 2.3 m by 2Ø5Ø A.D. Such rise of sea level is anticipated to cause deleterious effect to the coastal areas resulting into the following :

(1) Reduction of land areas, leading to disturbance in the present land-use patterns;

(2) Coastal areas becoming more prone to cyclones and storm surges;

(3) Coastal erosion and accretion;

(4) Changes in estuarine hydrochemistry and impacts on the groundwater reservoirs/freshwater aquifers;

(5) Impact on existing industrial, power, municipal and other installations;

(6) Changes in the composition of marine life in coastal and estuarine ecosystems; and

(7) Socio-economic impacts like displacement or disruption in their livelihood.

Sea level rise in the Indian context

India has a coastline of more than 72ØØ km. The coastline of the mainland as well as the islands exhibit a complex geomorphology with unique coastal processes generated by its geography and other phenomena like seasonal monsoons. A general view of its coastal geomorphology in terms of Mean Sea Level

(MSL) indicates that the peninsular India by and large has elevated coastlines with the exception of a few sectors in the mainland and the islands. Map-I indicates the observed low lying areas in the mainland. Regarding the islands, especially in the Lakshadweep group the MSL at the highest point is hardly more than 2 m.

Rise in sea level, if at all occurs, is going to be a gradual phenomena. Even though, the ecosystem is expected to respond to the changes correspondingly, considering the needs of future generations, preparatory plans to overcome the anticipated sea level rise as a precautionary measure is almost the need of the hour. Before discussing the future plans, it is worth viewing the past record whether other phenomena of sea level rise has been prevalent along the Indian coasts in the past 100 years.

Emery and Aubrey (1989), using statistical methods, assessed the reliability of tide gauge data collected from 12 principal tide gauges in India and found acceptable records from Bombay, Madras, Cochin and Visakhapatnam. Brief details about the data are given below :

Station	Lat. (^{o}N)	Long. (^{o}E)	Time span
Bombay	18^{o} 55′	72^{o} 50′	1886-1986
Madras(i)	13^{o} 06′	80^{o} 18′	1881-1933
Madras(ii)	--	--	1953-1986
Cochin	09^{o} 58′	76^{o} 16′	1955-1986
Vishakhapatnam	17^{o} 41′	83^{o} 07′	1953-1986

Accuracy of the reading is ± 1 cm for Bombay and ± 2 cm for other locations. Analysis of the records by Das and Radhakrishna (1991) indicated that they do not show a uni-directional trend and application of Mann-Kendell test revealed evidence of raising

trend from 1940 to 1986 at a rate of 0.8 mm/yr in Bombay and 0.4 mm/yr from 1910 to 1933 in Madras over a short period. There was no other evidence of a statistically significant trend. The investigations also revealed existence of a definite pattern between fluctuations of monsoon rain and relative sea level in Bombay.

The impact of such minute increase in sea level was surpassed by the human interferences in the form of developmental activities over the years and therefore assessment of the direct impact of sea level rise which has occurred in these locations becomes difficult.

Certain theoretical predictions on impact of rising sea level to the extent of 0.5 m, 1 m and 1.5 m from the present MSL, indicate the possibility of serious threat of inundation in certain low lying areas of the country (Fig. 1). Others predict that increase of 90 cm from the present level may lead to submergence of some coral islands in the Indian Ocean regions.

Need for scientific investigations

Recent awareness on global warming and consequent likely sea level rise have demanded need for a close watch on sea level variations, so that the direct impact of this phenomena on various aspects on coastal zone can be studied in isolation. This needs following strategy as far as India is concerned:

(1) Systematic collection of regular time series tide level data using modern digital tide gauges atleast over a period of 10-15 years.

(2) Preparation of 1 m interval contour maps at the scale of at least at 1:25000 scale for all the low lying areas and generation of digital data.

(3) Subjection of data so collected to mathematical models for precise assessment of impact of sea level increases.

In order to realise the above tasks, the government departments have taken following steps :

(1) Installation of modern tide gauges at 13 locations indicated in Map-I. First tide gauge has been installed and by December, 1992 installation of all tide gauges will be completed.

(2) Survey of India has already initiated the task of preparation of fine scale mapping of most vulnerable areas to sea level rise.

(3) A multi-institutional data collection, analysis and modelling programme has finalised strategy for development of models.

With the completion of the above tasks, the precise assessment of impact of sea level rise on complex coastal processes, their likely damages to the marine ecosystem, socio-economic aspects can be achieved.

Management Strategies

Since the sea level rise is mainly due to global warming, efforts should be made to contain the emission of green house gases to the extent it does not increase the global atmospheric temperature. It is hoped that the proposed UNCED Conference (1992) will find a solution to this problem.

The present Coastal Zone Regulation Act of Government of India is primarily formulated to preserve the ecology of the coastal environment. (Highlights of this Act is given in Appendix -I). In the absence of studies indicating the precise estimation of impact of sea level rise on coastal zone and the coastal processes, enactment of pertinent legislations needs a deep thought. However, while planning all coastal developmental activities the sea level rise need to be taken as a factor that needs worth considering.

APPENDIX-I

COASTAL ZONE REGULATION RULES OF THE GOVERNMENT OF INDIA

Under the Environment Protection Act (1986) rules for Regulation of Coastal Zone have been framed. Under this rule coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) up to 500 metres from the High Tide Line (HTL) and the inter-tidal zone has been declared as Coastal Regulation Zone (CRZ) and it prohibits/regulates following activities :

Prohibited activities :

The following activities are declared as prohibited within the Coastal Regulation Zone, namely :

(i) setting up of new industries and expansion of existing industries, except those directly related to water front or directly needing foreshore facilities;

(ii) manufacture or handling or storage or disposal of hazardous substances;

(iii) setting up and expansion of fish processing units including warehousing (excluding hatchery and natural fish drying in permitted areas);

(iv) setting up and expansion of units/mechanisms for disposal of wastes and effluents, except facilities required for discharging treated effluents into the water course with approval under the Water (Prevention and Control of Pollution) Act, 1974; and except for storm water drains;

(v) discharge of untreated wastes and effluents from industries, cities or towns and other human settlements.

Schemes shall be implemented by the concerned authorities for phasing out the existing practices, if any, within a reasonable time period not exceeding three years from the date of this notification;

(vi) dumping of city or town waste for the purposes of landfilling or otherwise; the existing practice, if any, shall be phased out within a reasonable time not exceeding three years from the date of this Notification;

(vii) dumping of ash or any wastes from thermal power stations;

(viii) land reclamation, bunding or disturbing the natural course of sea water with similar obstructions, except those required for control of coastal erosion and maintenance or cleansing of waterways, channels and ports and for prevention of sandbars and also except for tidal regulators, storm water drains and structures for prevention of salinity ingress and for sweet water recharge;

(ix) mining of sands, rocks and other substrata materials, except those rare minerals not available outside the CRZ areas;

(x) harvesting or drawal of ground water and construction of mechanisms therefor within 200 m of HTL; in the 200 m to 500 m zone it shall be permitted only when done manually through ordinary wells for drinking, horticulture, agriculture and fisheries;

(xi) construction activities in ecologically sensitive areas as specified in Annexure-I of this Notification;

(xii) any construction activity between the Low Tide Line and High Tide Line except facilities for carrying treated effluents and waste water discharges into the sea, facilities for carrying sea water for cooling purposes, oil, gas and similar pipelines and facilities essential for activities permitted under this Notification; and

(xiii) dressing or altering of sand dunes, hills, natural features including landscape changes for beautification, recreational and other such purpose, except as permissible under this Notification.

Regulation of Permissible Activities :

All other activities, except those prohibited in para 2 above, will be regulated as under :

(1) Clearance shall be given for any activity within the Coastal Regulation Zone only if it required water front and foreshore facilities.

(2) The following activities will require environmental clearance from the Ministry of Environment & Forests, Government of India, namely :

(i) Construction activities related to Defence requirements for which foreshore facilities are essential (e.g. slipways, jetties, etc.); except for classified operational component of defence projects for which a separate procedure shall be followed. (Residential buildings, office buildings, hospital complexes, workshops shall not come within the definition of

operational requirements except in very special cases and hence shall not normally be permitted in the CRZ);

(ii) Operational constructions for ports and harbours and light houses requiring water frontage; jetties, wharves, quays, slipways, etc. (Residential buildings & office buildings shall not come within the definition of operational activities except in very special cases and hence shall not normally be permitted in the CRZ);

(iii) Thermal power plants (only foreshore facilities for transport of raw materials facilities for in-take of cooling water and outfall for discharge of treated waste water/cooling water; and

(iv) All other activities with investment exceeding rupees five crores.

ANNEXURE-I

COASTAL AREA CLASSIFICATION AND DEVELOPMENT REGULATIONS

Classification of Coastal Regulation Zone :

6(1) For regulating development activities, the coastal stretches within 500 metres of High Tide Line of the landward side are classified into four categories, namely :

Category I (CRZ-I) :

(i) Areas that are ecologically sensitive and important, such as national parks/marine parks, sanctuaries, reserve forests, wildlife habitats, mangroves, corals/coral reefs, areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding natural beauty/historical/heritage areas, areas rich in genetic diversity, areas likely to be inundated due to rise in sea level consequent upon global warming and such other areas as may be declared by the Central Government or the concerned authorities at the State/Union Territory level from time to time.

(ii) Area between the Low Tide Line and the High Tide Line.

Category-II (CRZ-II) :

The areas that have already been developed upto or close to the shore-line. For this purpose, "developed area" is referred to as that area within the municipal limits or in other legally designated urban municipal limits or in other legally designated urban areas which is already substantially built up and which has been provided with drainage and approach roads and other infrastructural facilities, such as water supply and sewerage mains.

Category-III (CRZ-III) :

Areas that are relatively undisturbed and those which do not belong to either Category-I or II. These will include coastal zone in the rural areas (developed and undeveloped) and also areas within Municipal limits or in other legally designated urban areas which are not substantially built up.

Category-IV (CRZ-IV) :

Coastal stretches in the Andaman & Nicobar, Lakshadweep and small islands except those designated as CRZ-I, CRZ-II or CRZ-III.

Norms for Regulation of Activities.

6(2) The development or construction activities in different categories of CRZ areas shall be regulated by the concerned authorities at the State/Union Territory level, in accordance with the following norms :

CRZ-I

No new construction shall be permitted within 500 metres of the High Tide Line. No construction activity, except as listed under 2(xii), will be permitted between the Low Tide Line and the High Tide Line.

CRZ-II

(i) Buildings shall be permitted neither on the seaward side of the existing road (or roads proposed in the approved Coastal Zone Management Plan of the area) nor on seaward side of existing authorised structures. Buildings permitted on the landward side of the existing and proposed roads/existing authorised

structures shall be subject to the existing local Town and Country Planning Regulations, including the existing norms of FSI/FAR.

(ii) Reconstruction of the authorised buildings to be permitted subject with the existing FSI/FAR norms and without change in the existing use.

(iii) The design and construction of buildings shall be consistent with the surrounding landscape and local architectural style.

CRZ-III

(i) The area upto 200 metres from the High Tide Line is to be earmarked as 'No Development Zone'. No construction shall be permitted within this zone except for repairs of existing authorised structures not exceeding FSI, existing plinth area and existing density. However, the following uses may be permissible in this zone - agriculture, horticulture, gardens, pastures, parks, playfields, forestry and salt manufacture from sea water.

(ii) Development of vacant plots between 200 and 500 metres of High Tide Line in designated areas of CRZ-III with prior approval of MEF permitted for construction of hotels/beach resorts for temporary occupation of tourists/visitors subject to the conditions as stipulated in the guidelines at Annexure-II.

(iii) Construction/reconstruction of dwelling units between 200 and 500 metres of the High Tide Line permitted so long it is within the ambit of traditional rights and

customary uses such as existing fishing villages and goathans. Building permission for such construction/reconstruction will be subject to the conditions that the total number of dwelling units shall not be more than twice the number of existing units; total covered area on all floors shall not exceed 33 per cent of the plot size; the overall height of construction shall not exceed 9 metres and construction shall not be more than 2 floors (ground floor plus one floor).

(iv) Reconstruction/alterations of an existing authorised building permitted subject to (i) to (ii) above.

CRZ-IV

Andaman & Nicobar Islands

(i) No new construction of buildings shall be permitted within 200 metres of the HTL:

(ii) The buildings between 200 and 500 metres from the High Tide Line shall not have more than 2 floors (ground floor nd 1st floor), the total covered area on all floors shall not be more than 50 per cent of the plot size and the total height of construction shall not exceed 9 metres;

(iii) The design and construction of buildings shall be consistent with the surrounding landscape and local architectural style;

(iv) Corals and sand from the beaches and coastal waters shall not be used for construction and other purposes;

(v) Dredging and underwater blasting in and around coral formations shall not be permitted; and

(vi) However, in some of the islands, coastal stretches may also be classified into categories CRZ-I or II or III, with the prior approval of Ministry of Environment and Forests and in such designated stretches, the appropriate regulations given for respective Categories shall apply.

Lakshadweep and small Islands :

(i) For permitting construction of buildings, the distance from the High Tide Line shall be decided depending on the size of the islands. This shall be laid down for each island, in consultation with the experts and with approval of the Ministry of Environment & Forests, keeping in view the land use requirements for specific purposes vis-a-vis local conditions including hydrological aspects erosion and ecological sensitivity;

(ii) The buildings within 500 metres from the HTL shall not have more than 2 floors (ground floor and 1st floor), the total covered area on all floors shall not be more than 50 per cent of the plot size and the total height of construction shall not exceed 9 metres;

(iii) The design and construction of buildings shall be consistent with the surrounding landscape and local architectural style;

(iv) Corals and sand from the beaches and coastal waters shall not be used for construction and other purposes;

(v) Dredging and underwater blasting in and around coral formations shall not be permitted; and

(vi) However, in some of the islands, coastal stretches may also be classified into categories CRZ-I or II or III, with the prior approval of Ministry of Environment & Forests and in such designated stretches, the appropriate regulations given for respective Categories shall apply.

ANNEXURE-II

GUIDELINES FOR DEVELOPMENT OF BEACH RESORTS/HOTELS IN THE DESIGNATED AREAS OF CRZ-III FOR TEMPORARY OCCUPATION OF TOURISTS/VISITORS, WITH PRIOR APPROVAL OF THE MINISTRY OF ENVIRONMENT & FORESTS

- - - - -

7(1) Construction of beach resorts/hotels with prior approval of MEF in designated areas of CRZ-III for temporary occupation of tourists/visitors shall be subject to the following conditions :

(i) The project proponents shall not undertake any construction (including temporary constructions and fencing or such other barriers) within 200 metres (in the landward side) from the High Tide Line and within the area between the Low Tide and High Tide Line;

(ii) The total plot size shall not be less than 0.4 hectares and the total covered area on all floors shall not exceed 33 per cent of the plot size i.e. the FSI shall not exceed 0.33. The open area shall be suitably landscaped with appropriate vegetal cover;

(iii) The construction shall be consistent with the surrounding landscape and local architectural style;

(iv) The overall height of construction upto the highest ridge of the roof, shall not exceed 9 metres and the construction shall not be more than 2 floors (ground floor plus one upper floor);

(v) Ground water shall not be tapped within 200 m of the HTL; within the 200 metre-500 metre zone it can be tapped only with the concurrence of the Central/State Ground Water Board;

(vi) Extraction of sand, levelling or digging of sandy stretches except for structural foundation of building, swimming pool shall not be permitted within 500 metres of the High Tide Line;

(vii) The quality of treated effluents, solid wastes, emissions and noise levels, etc., from the project area must conform to the standards laid down by the competent authorities including the Central/State Pollution Control Board and under the Environment (Protection) Act, 1986;

(viii) Necessary arrangements for the treatment of the effluents and solid wastes must be made. It must be ensured that the untreated effluents and solid wastes are not discharged into the water or on the beach; and no effluent/solid waste shall be discharged on the beach;

(ix) To allow public access to the beach, atleast a gap of 20 metres width shall be provided between any two hotels/beach resorts; and in no case shall gaps be less than 500 metres apart; and

(x) If the project involved diversion of forest land for non-forest purposes, clearance as required under the Forest (Conservation), Act, 1980 shall be obtained. The requirements of other Central and State laws as applicable to the project shall be met with.

(xi) Approval of the State/Union Territory Tourism Department shall be obtained.

7(2) In ecologically sensitive areas (such as marine parks, mangroves, coral reefs, breeding and spawning grounds of fish,

wildlife habitats and such other areas as may be notified by the Central/State Government/Union Territories) construction of beach resorts/hotels shall not be permitted.

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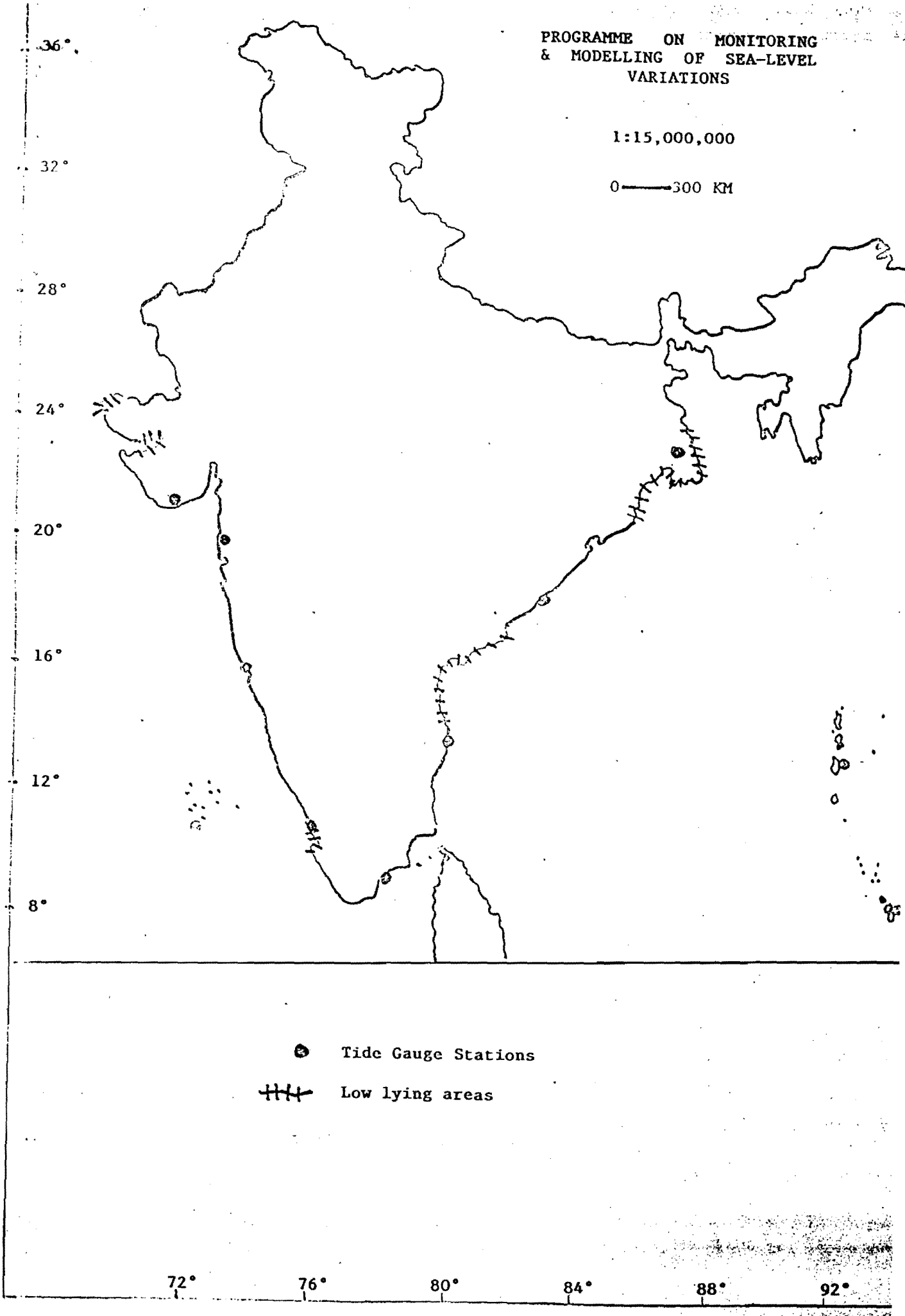

PROGRAMME ON MONITORING
& MODELLING OF SEA-LEVEL
VARIATIONS
1:15,000,000
0——300 KM
36°
32°
28°
24°
20°
16°
12°
8°
Tide Gauge Stations
Low lying areas
72°
76°
80°
84°
88°
92°

Map 1.

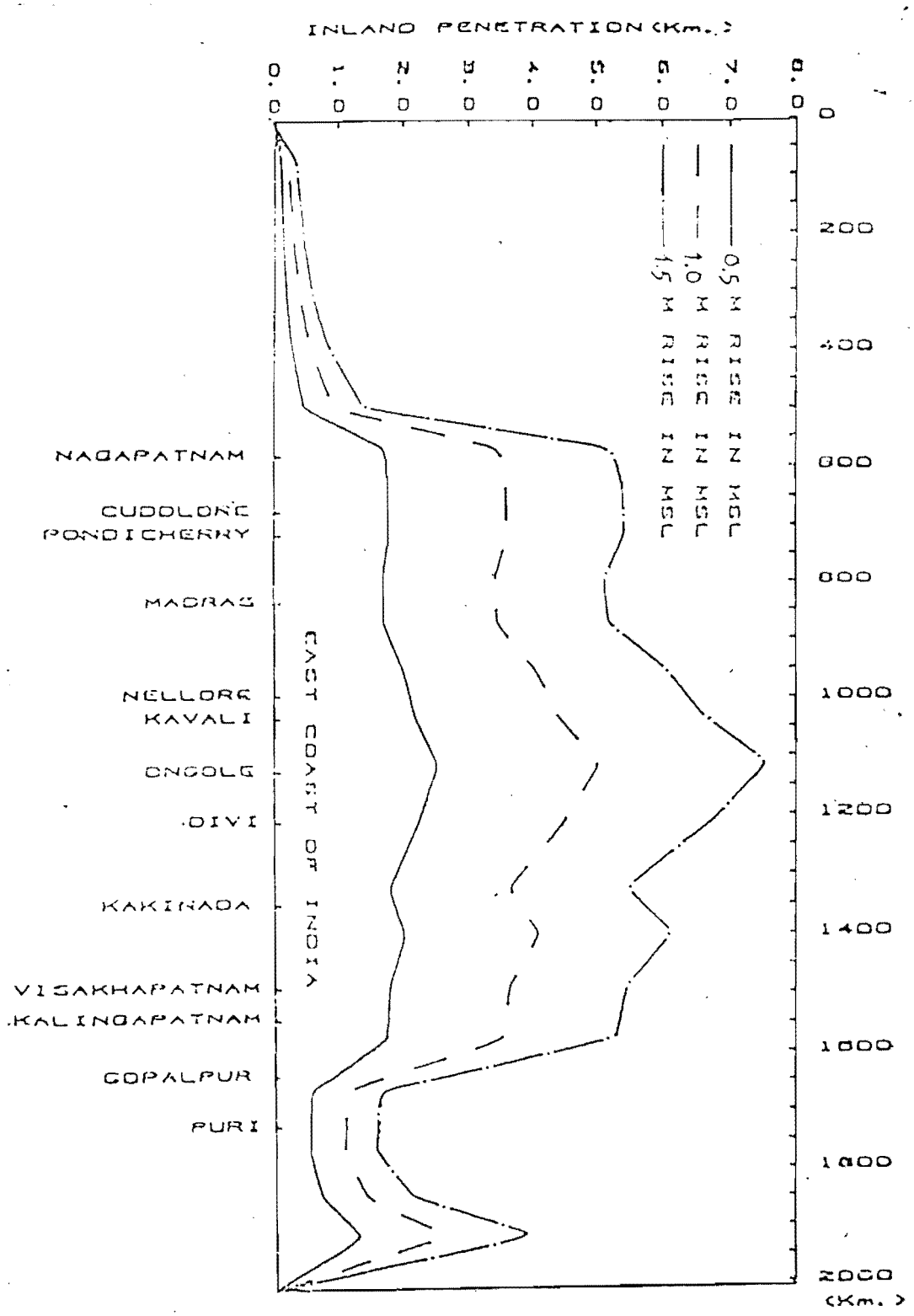


Fig.1. Possibilities of inundation due to sea level rise.

SEA LEVEL RISE ALONG PAKISTAN COAST

INTRODUCTION

There is a growing consensus among scientists that there is increase in green house gases in the atmosphere which has induced climatic changes. According to scientific evidence, the earth's atmosphere could warm by anywhere from 1.5 to 4.5 degrees centigrade by the middle of the next century and the rise in sea level could by between 20-140 cm by the end of the 21st century. The study of mean sea level, the causes and effects of its changes received world wide attention. In Pakistan an attempt is made to evalute mean sea level. This is a first attempt in Pakistan. In this investigation Manora (Karachi) Tidal records are used. Along Pakistan coast line Manora is the only tidal station from which we received long record. All other station has only few years or few month observation, which is not sufficient to correlate with this study.

Our present study had two main aims.

(1) To evalute mean sea level trend
(2) To investigate mean sea level maxima

Manora (Karachi) Tidal observation

located at LAT 24° 48' N
LONG 66° 58' N

The mangrove ecosystem in the Indus Delta contributes significantly to the coastal economy of Sindh Province, Pakistan. Various factors, particularly the reduction of flows of fresh water, silt and nutrients down the Indus and the rise in mean Sea level are combining to threaten this ecosystem. Global warming and the resulting sea level rises need careful consideration for conservation measures to be taken. The local rate of sea level

rise of 1.1 mm/yr over the last 100 years is lower than the present eustatic sea level rise of 2.0 mm/yr. and considerably lower than predicted "business as usual" rates of 6.0 mm/yr.

Two processes will be affected by "Sea level rise", the balance between delta erosion and sedimentation and the increase in the tidal range. Reduced flows down the Indus due to further upstream abstraction will mean that less silt is available to build up the soils in which the mangroves are growing; the raising of substrate levels will not be able to keep pace with rapidly rising sea levels. It is predicted that for sea level rise up the 2.0 mm/yr, the balance will favour mangrove survival and growth. Above this rate the balance will be shifted towards progressive loss of mangrove areas.

THE REALITY OF SEA LEVEL RISE

The last glacial period reached a peak between 24,000 to 18,000 years ago. As the ice sheets started retreating 10,000 years ago, world wide sea levels rise by 40 meters to reach modern sea levels around 5000-6000 years ago, giving a mean sea level rise of approximately 8 mm/yr. ~~(Fig.1)~~

The observed Sea level results from the real vertical movement of the sea surface relative to the movement of the land itself caused by tectonic changes, uplift or subsidence. Global warming causes the sea to rise in two ways.

i) The first is through thermal expension of Ocean waters.

ii) Through the melting of glaciers and ice caps, adding to the total volume of water in the oceans.

- An increase of 3 to 5 °c in global temperature willresult in a rise of 10 to 30 cm in sea level, as a result of thermal expension of the oceans.

- The melting of small glaciers and ice caps will contribute 6 cm to sea level rise.

- The melting of the Greenland ice cap may rise the sea level by about 8 cm. This figure is on the high side, since there is some evidence that the Antarctica and Greenland glaciers appears to be growing rather than shrinking. If this is true, sea level would be lowered by over 1 mm/yr. Fig-2

SEA LEVEL CHANGES IN THE KARACHI AREA

From the Karachi tide - gauge records of the past 100 years a rate of 1.1 mm/yr rise in the local level has been estimated. (Fig. 3).

The gradient of this rise remains more or less the same when the data is analysed in 30 year segments, even for the most recent period (1960 - 1990). The observed change in sea level is virtually equal to the real one, since the Indus delta is on a passive continental margin and isostatically stable. This rate of change is lower than the present mean sea level rise worldwide.

CHANGES IN THE TIDAL RANGE.

The present levels of the semi-diurnal tides in the creeks at Port Qasim and the projected levels after 100 years at a 6.0 mm/yr rise are as follows:- Fig-4

Tidal state	Present level (metres)	Projected level (metres)
Lowest Astronomical Tide	- 0.49	+ 0.11
Mean Lower Low Water	+ 0.97	+ 1.57
Mean Higher Low Water	+ 1.43	+ 2.03
Mean Sea Level	+ 2.04	+ 2.64
Mean Lower High Water	+ 2.65	+ 3.25
Mean Higher High Water	+ 3.38	+ 3.98
Highest Astronomical Tide	+ 3.84	+ 4.44

SEA LEVEL RISE AND EROSION

Global warming will accelerate the present sea level rise by a factor of 5 to 10 (i.e. resulting in a rise of 0.5 m to 1.0 m over the next century). Sea level rise is considered to be the most important single effect on coastal zone processes and activities. As long as global mean temperature continues to rise, so will be the sea level. While there is nopossibility of influencing the long term geologically induced sea level rise, the human induced component can be influenced by slowing down climate change such as;

* Beach erosion
* Farm land loss
* Wet land loss (including mangroves and coral reefs)
* Frequency and severity of flooding
* Infrastructure improvement
* Hydrologic systems disturbance

These impacts are severe indeed. They can affect the lives of many millions of people living in the deltas and low lying areas. They can threaten unique ecosystems, and they have enormous negative economic impacts.

COASTAL INUNDATION

Using the figure of 0.1^{o} for the slope of the delta lands assumed by Wells and Coleman (1984) the encroachment by the sea level rise can be calculated. The present highwater line is very approximately 370 km long. Based on these figures the

encroachment of the sea in 100 years at the predicted rates would be:-

Rate of MSL rise (mm/yr)	Distance encroached (m)	Area Encroached (sq. km.)
1.1	64	24
2.0	116	43
6.0	346	128

OCEAN CIRCULATION AND SW MONSOON

Circulation of the Arabian Sea, and physical processes and related phenomenae have direct impact on the economic development of the countries in the region. Seasonal changes in the Arabian sea and reversal of monsoon are well known phenomenae which are studied together to understand their influence on various oceanographic aspects.

The circulation of the Arabian Sea has also been observed to contain warm and cold core eddies from records of satellite imageries using high resolution infrared radiometer. The eddy circulations appear to get intensified and in some areas persist in the S.W. monsoon (May-September). these months are dominated by upwelling along Somalia and the Arabian coast and the cold water plume and wedge extend eastward. Upwelling, comparatively weak, also appears along the Pakistan coast, west of Karachi.

The S.W. Monsoon atmospheric and oceanic circulation have been noted to be persistent in the geological past even when the temperature varied to about 5°C and sea level changed by about 75 m in Holocine time. The variation in the wind system due to the increase in temperature is likely to affect oceanic

circulation. The wind stress pattern is likely to change, resulting in shifting of gyres, rings and eddies, mixing of waters from rivers will increase, nutrients in the sea will be redistributed and so will primary productivity and fish stock.

TROPICAL CYCLONES AND STORM SURGES

A storm surge is an abnormal rise of sea level caused by a cyclone moving over a continental shelf. The surge is generated due to interaction of air, sea and land. The cyclone provides the driving forces in the form of very high horizontal atmospheric pressure gradient and consequent strong surface winds. As a result, sea level rises and continues to rise as the cyclone moves over shallower waters, and reaches a maximum on the coast near the point of landfall (i.e. the point of crossing of land by the cyclone).

CONCLUSION

Rising in mean sea level, maximum and seasonal variation more observation are required to fill up missing data and correlate it with neighbouring countries and to improve results. A study is planned to investigate the effected area along the Pakistan coast because Pakistan most depends upon natural resources for its development and loss of land certainly affects its economics.

RECOMMENDATIONS

i) Plantation of more saline tolerant species or strains of mangrove.

ii) Plantation of larger propagule species in lower-lying areas.

iii) Experimentation of planting slightly higher areas which are irregularly inundated with smaller propagule species.

iv) Experimentation of various methods of stabilising eroding mangrove substrates, and encouraging increased rates of deposition of autochthonous sediment.

v) Strict control on removal of mangrove trees for which community participation is intrinsic.

vi) Carrying out a topographical survey of coastal and mangrove areas to identify areas most at risk from sea level rise, and those suitable for different management options.

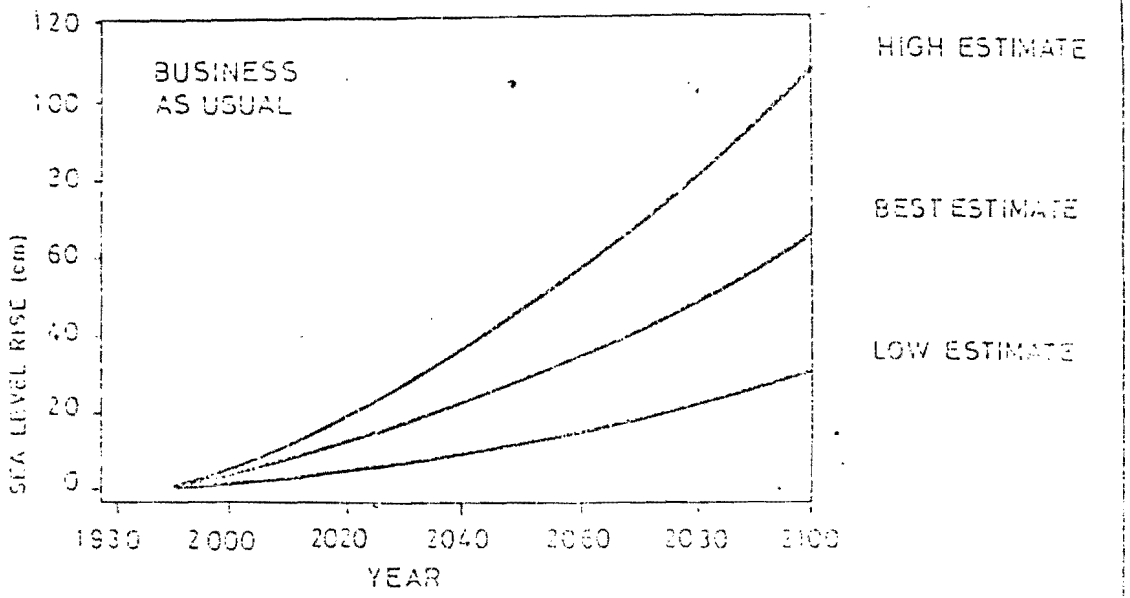


FIG.2. SEA LEVEL RISE PREDICTED TO RESULT FROM BUSINESS AS USUAL EMISSIONS

Source: World Meteorological Organisation

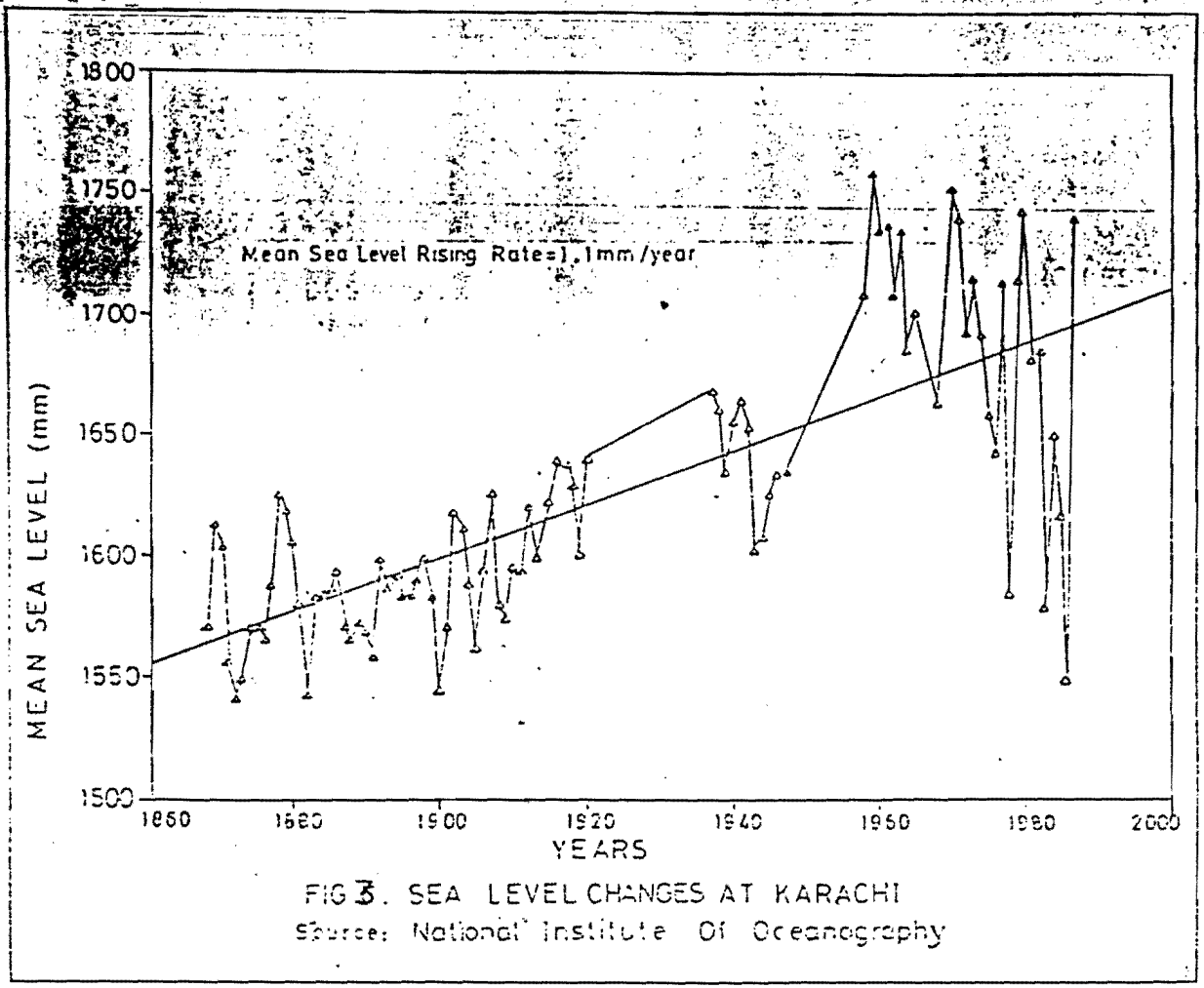
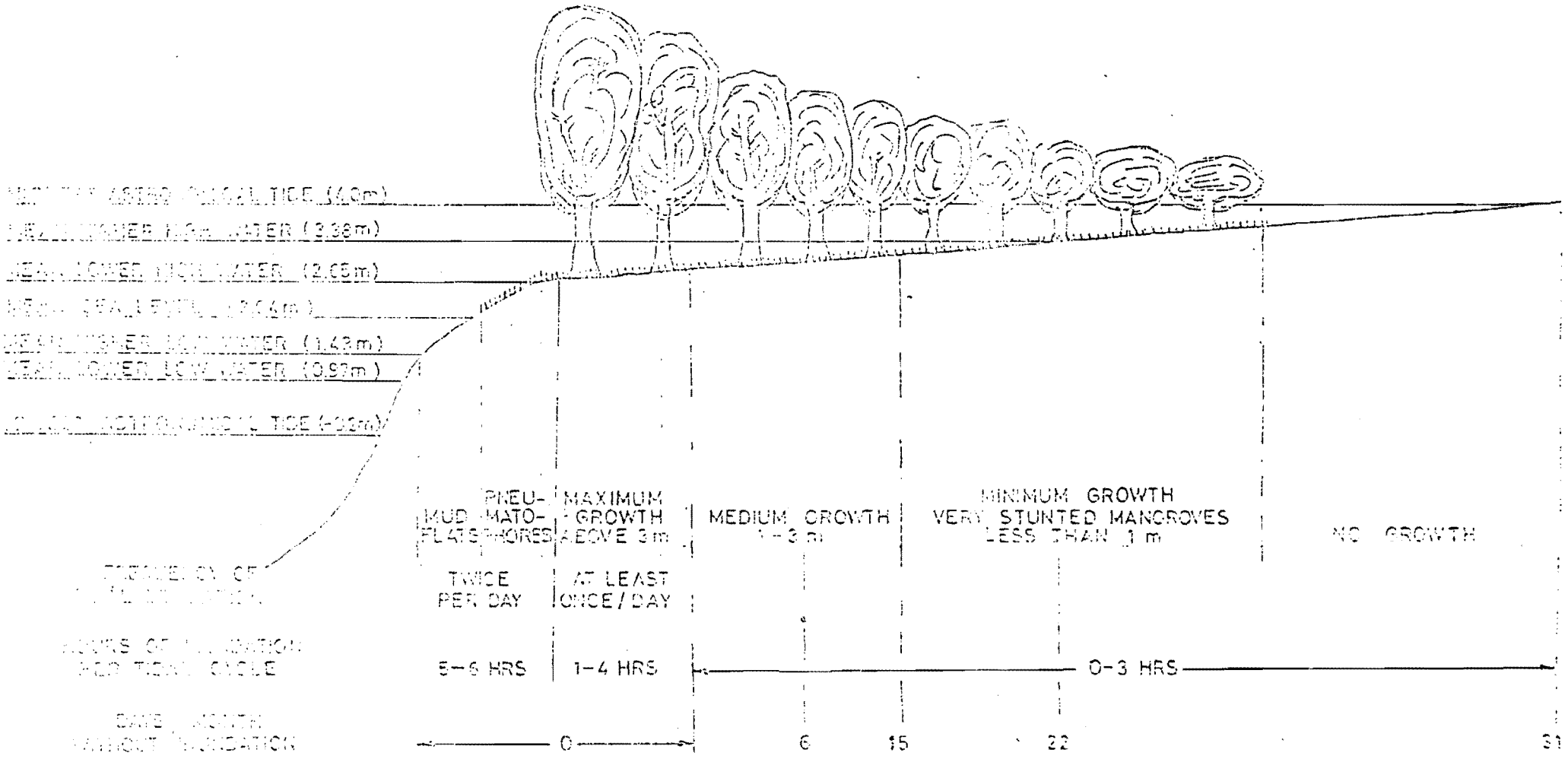
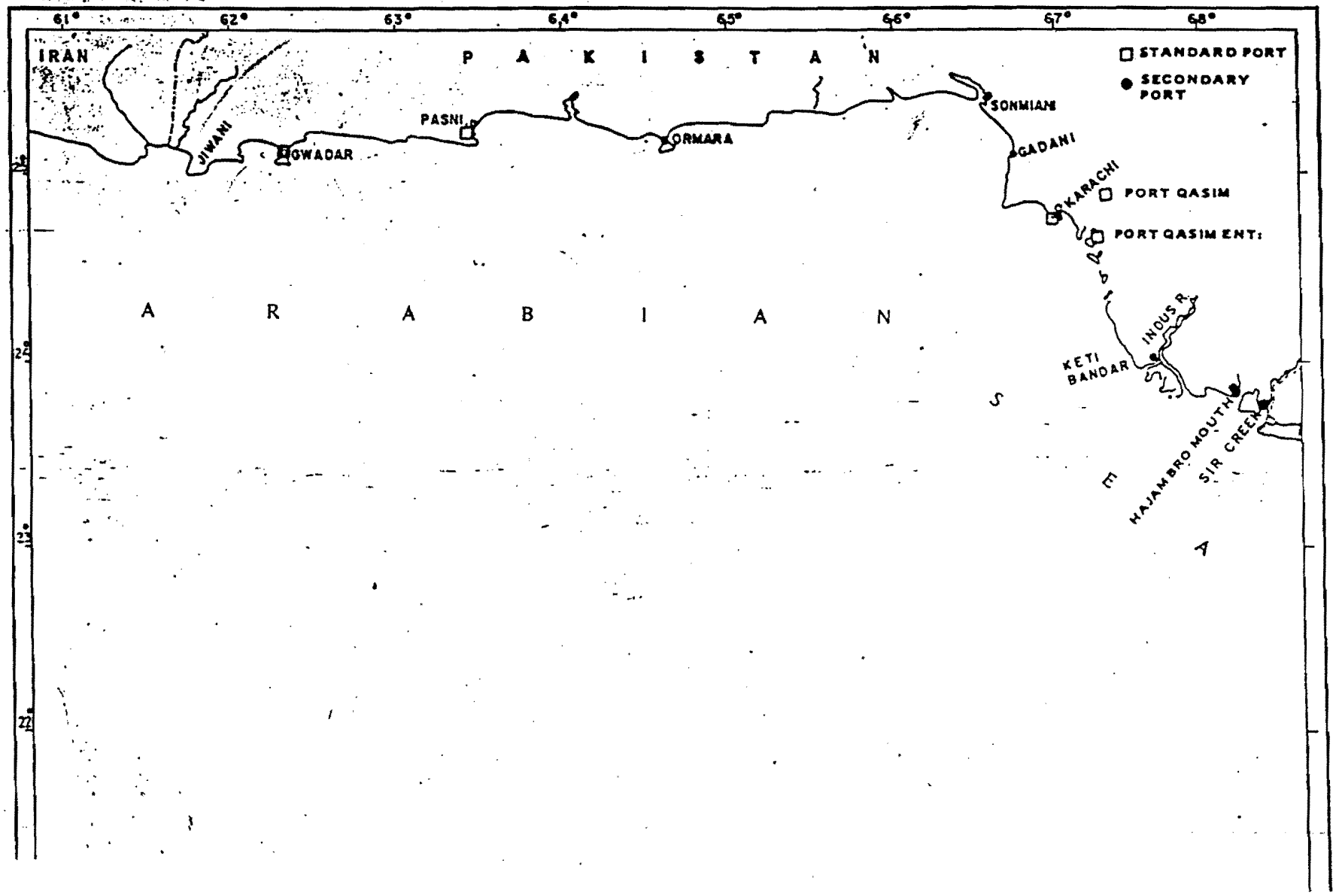


FIG 3. SEA LEVEL CHANGES AT KARACHI
Source: National Institute Of Oceanography

IN INDUS DELTA CREEKS



Note:-Heights of tides are shown as above chart datum
Tidal information from Pakistan Tide Tables 1991. Using Dec. 1991 figures.


61°
62°
63°
64°
65°
66°
67°
68°
IRAN
P A K I S T A N
STANDARD PORT
SECONDARY PORT
JIWANI
GWADAR
PASNI
ORMARA
SONMIANI
GADANI
KARACHI
PORT QASIM
PORT QASIM ENT:
A R A B I A N
INDUS R.
KETI BANDAR
HAJAMBRO MOUTH
SIR CREEK