Strategies for Adaptation to Sea Level Rise

By

J. Dronkers, J. T. E. Gilbert, L.W. Butler, J.J. Carey,
J. Campbell, E. James , C. McKenzie, R. Misdorp, N. Quin,
K.L. Ries, P.C. Schroder, J.R. Spradley, J.G. Titus,
L. Vallianos, and J. von Dadelszen

Coastal Zone Management Subgroup
Intergovernmental Panel on Climate Change
1990

Report Of The Coastal Management Subgroup

STRATEGIES FOR ADAPTION TO SEA LEVEL RISE

Adaptive responses:

Intergovernmental Panel On Climate Change
Response Strategies Working Group
November, 1990

Report Of The Coastal Zone Management Subgroup

STRATEGIES FOR ADAPTION TO SEA LEVEL RISE

Intergovernmental Panel On Climate Change
Response Strategies Working Group
November, 1990

TABLE OF CONTENTS

Acronyms:
IPCC = Intergovernmental Panel on Climate Change
RSWG = Response Strategies Working Group
CZMS = Coastal Zone Management Subgroup

PREFACE

This report represents the first survey on a global scale of adaptive options for coastal areas in response to a possible acceleration of sea level rise and the implications of these options. The report provides general information on options for a range of coastal areas which cover large continental states to small coastal islands.

Many hundreds of millions of people live in the world's coastal areas, where they enjoy the richness and beauty of the sea. The sea provides resources, links coastal cities and provides opportunities for trade.

On the other hand, the sea often threatens the inhabitants of the coastal areas, demanding its toll in human and natural resources. Heavy storms, hurricanes, tsunamis and typhoons can batter the coastal areas, causing disaster and distress.

It was common concern of the impacts of an acceleration in sea level rise which brought together delegates from some 70 countries in two workshops, where they shared their experiences in the vast range of coastal problems.

During the plenary sessions and especially during the "small group" discussions, expert knowledge from across the globe was exchanged, potential impacts of an acceleration in sea level rise were assessed and possible response alternatives were discussed. These efforts provided the basis for this report. The authors are very much indebted to the workshop participants for the many valuable contributions and to the reviewers of this report.

Additional work is required, however in order to provide more specific technical information, as requested by workshop participants, to assist developing countries in assessing their vulnerability to sea level rise and in managing their coastal areas to reduce their vulnerability. Included in the report is a proposal to provide that assistance to developing countries.

It is important that coastal states begin preparations for adaptation to sea level rise, because there are opportunities to avoid adverse impacts by acting now. Moreover, even with adoption of strategies to stabilize climate forcing by 2030, sea level rise is predicted to accelerate during the next century. Therefore, preparation for adaption is required.

May we take this opportunity to express the hope that this publication will be used as a guide in the development of comprehensive plans for management of the coastal areas. We wish to thank the core group and chapter authors and all those who have made this effort possible.

The Chairmen of the IPCC-Coastal Zone Management Subgroup

J. Gilbert	P. Vellinga
New Zealand	the Netherlands

ORGANIZATION OF THE CZM-WORK

In 1988, the World Meteorological Organization and the United Nations Environment Programme jointly established the Intergovernmental Panel on Climate Change (IPCC) under the chairmanship of Professor B. Bolin of Sweden. The Panel established three working groups:

- The Science Working Group (chaired by the UK) to assess the available scientific information on climate change.
- The Impacts Working Group (chaired by the USSR) to assess the environmental and socio-economic impacts of climate change.
- The Response Strategies Working Group (RSWG) (chaired by the USA) to formulate response strategies.

The RSWG established four Subgroups to carry out a work plan for formulating response strategies. Two of the Subgroups examined options to limit global climate change (Energy and Industry and Agriculture and Forestry); two examined adaptive options (Coastal Zone Management and Resource Use Management). In addition, the RSWG examined Educational, Technical, Economic, Financial and Legal implications of all the response strategies. The executive summary of the Policymakers Summary Report of the RSWG is provided in Appendix A. This executive summary is based on the findings of the IPCC Science and Impact Working Groups and sets out the strategy measures for limitation and adaptation for both the shorter and longer terms.

The Coastal Zone Management Subgroup (CZMS) (chaired by New Zealand and The Netherlands) in May 1989, received the following task:
"To provide information and recommendations to national and international policy centres, enabling decision making on:

(a) coastal zone management strategies for the next 10-20 years; and,
(b) long term policies dealing with limitation and/or adaptation with respect to climate change/sea level rise".

The CZMS adopted a work plan which included two workshops to generate information on available adaptive response options and their environmental, economic, social, cultural, legal, institutional and financial implications.

The first workshop was held in Miami, Florida, in the United States in November 1989 and the second in Perth, Australia, in February 1990. Representatives from about 70 countries participated in the workshops (including 50 developing countries). Both workshops identified adaptive options and listed tasks deserving priority attention.

The participants at the Miami Workshop listed the following tasks:

- identify coastal areas, populations and resources at risk
- develop global and regional research and monitoring systems
- develop public awareness of risks to coastal resources
- encourage integrated coastal area and resource management
- avoid further stress on coastal areas
- collect and disseminate relevant data
- provide technical and financial assistance for research and management of coastal areas and resources in developing countries
- use country-specific studies to evaluate available adaptive options
- adopt a framework convention on climate change to facilitate cooperative efforts to limit and/or adapt to climate change.

The participants at the Perth Workshop listed the following tasks:

- improve knowledge and understanding of physical processes involved in climate change
- develop global, regional and national monitoring systems
- identify coastal areas and islands at risk
- develop education, training and technology transfer mechanisms to increase awareness
- encourage and assist development of national, regional and international response strategies and coastal zone management plans
- pursue risk reducing strategies on a national level
- develop techniques for mitigation through cost effective approaches for adaptation
- take into consideration vulnerability, different needs and capacities of countries in financing
- produce guidelines for selection of adaptive options for sustainable management of the

coastal zone

- establish or strengthen within the United Nations existing mechanisms for information dissemination
- recognize the need for international mobilization of funds to be allocated to countries impacted by climate change

The CZMS report provides information on adaptive options for coastal areas. The adaptive options are categorized in the report as Retreat, Accommodation and Protection. The report presents general consideration on those options rather than specific sets of measures. For analyses of such country specific measures, analyses should be conducted.

Information on techniques and practices, including laws and policies, for coastal management is provided in Appendices B and C. These Appendices are a first effort to compile this type of information. They are not complete and they do not contain specific information regarding all coastal states.

Included in the report as Appendix D, is a global estimate of the costs of basic measures to protect populated coastal areas against a one meter sea level rise. This estimate is discussed in section 4.4. Examples of the adaptive options identified by the workshop participants are provided in Appendix E.

The principal authors of the CZMS report were J. Dronkers, R. Misdorp, P.C. Schröder (The Netherlands), J.J. Carey, J.R. Spradley, L. Vallianos, J.G. Titus, L.W. Butler, Ms. K.L. Ries (United States of America), J.T.E. Gilbert, J. Campbell, Ms. J. von Dadelszen (New Zealand) and N. Quinn, Ms. C. McKenzie and Ms. E. James (Australia).

There were representatives from 69 countries and 7 international organisations that participated in the CZM workshops and in the preparation of the report:

Participating Countries:

Algeria, Antigua & Barbuda, Argentina, Australia, Bahamas, Bangladesh, Barbados, Benin, Brazil, Brunei, Canada, Chile, China P.R., Colombia, Costa Rica,

Denmark, Egypt, Fiji, France, Germany F.R., Ghana, Greece, Guyana, India, Indonesia, Iran, Italy, Ivory Coast, Jamaica, Japan, Kenya, Kiribati, Liberia, Maldives, Mauritius, Mexico, Micronesia Fed.St, The Netherlands, New Caledonia, New Zealand, Nigeria, Pakistan, Papua New Guinea, Philippines, Poland, Portugal, Senegal, Seychelles, South Korea, Spain, Sri Lanka, St. Pierre & Miq., St. Vincent & Gr., Thailand, Tonga, Trinidad & Tobago, Tunesia, Turkey, Tuvalu, United Kingdom, USA, USSR, Vanuatu, Venezuela, Vietnam, Western Samoa, Yugoslavia.

Participating International Organizations:

Greenpeace, International Oceanographic Commission (IOC), Organization for Economic Coordination and Development (OECD), South Pacific Regional Seas Programme (SPREP), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Meteorological Organization (WMO).

The report of the CZMS was adopted by the RSWG in June 1990 as a part of its report to the IPCC. At its plenary meeting in Sundvall, Sweden, in August 1990, the IPCC, in turn adopted the CZMS Report as a part of the IPCC First Assessment Report.

EXECUTIVE SUMMARY

REASONS FOR CONCERN

Global climate change may raise sea level as much as one metre over the next century and, in some areas, increase the frequency and severity of storms. Hundreds of thousands of square kilometres of coastal wetlands and other lowlands could be inundated. Beaches could retreat as much as a few hundred metres and protective structures may be breached. Flooding would threaten lives, agriculture, livestock, buildings and infrastructures. Salt water would advance landward into aquifers and up estuaries, threatening water supplies, ecosystems and agriculture in some areas.

Some nations are particularly vulnerable. Eight to ten million people live within one metre of high tide in each of the unprotected river deltas of Bangladesh, Egypt and Vietnam. Half a million people live in archipelagos and coral atoll nations that lie almost entirely within three metres of sea level, such as the Maldives, the Marshall Islands, Tuvalu, Kiribati and Tokelau. Other archipelagos and island nations in the Pacific, Indian Ocean and Caribbean could lose much of their beaches and arable lands, which would cause severe economic and social disruption.

Even in nations that are not, on the whole, particularly vulnerable to sea level rise, some areas could be seriously threatened. Examples include Sydney, Shanghai, coastal Louisiana and other areas economically dependent on fisheries or sensitive to changes in estuarine habitats.

As a result of present population growth and development, coastal areas worldwide are under increasing stress. In addition, increased exploitation of non-renewable resources is degrading the functions and values of coastal zones in many parts of the world. Consequently, populated coastal areas are becoming more and more vulnerable to sea level rise and other impacts of climate change. Even a small rise in sea level could have serious adverse effects.

The Coastal Zone Management Subgroup has examined the physical and institutional strategies for adapting to the potential consequences of global climate change.

Particular attention was focused on sea level rise, where most research on impacts has been conducted. The Subgroup has also reviewed the various responses and has recommended actions to reduce vulnerability to sea level rise and other impacts of climate change.

RESPONSES

The responses required to protect human life and property fall broadly into three categories: retreat, accommodation and protection.

<u>Retreat</u> involves no effort to protect the land from the sea. The coastal zone is abandoned and ecosystems shift landward. This choice can be motivated by excessive economic or environmental impacts of protection. In the extreme case, an entire area may be abandoned.

<u>Accommodation</u> implies that people continue to use the land at risk but do not attempt to prevent the land from being flooded. This option includes erecting emergency flood shelters, elevating buildings on piles, converting agriculture to fish farming, or growing flood or salt tolerant crops.

<u>Protection</u> involves hard structures such as sea walls and dikes, as well as soft solutions such as dunes and vegetation, to protect the land from the sea so that existing land uses can continue.

The appropriate mechanism for implimentation depends on the particular response. Assuming that land for settlement is available, retreat can be implemented through anticipatory land use regulations, building codes, or economic incentives. Accommodation may evolve without governmental action, but could be assisted by strengthening flood preparation and flood insurance programmes. Protection can be implemented by the authorities currently responsible for water resources and coastal protection.

Improving scientific and public understanding of the problem is also a critical component of any response strategy. The highest priorities for basic research are better projections of changes in the rate of sea level rise, precipitation and the frequency and intensity of storms. Equally important, but more often overlooked, is the need for applied research to determine which options are warranted, given current information.

Finally, the available information on coastal land elevation is poor. Maps for most nations only show contours of five metres or greater, making it difficult to determine the areas and resources vulnerable to impacts of a one metre rise in sea level. Except for a few countries, there are no reliable data from which to determine how many people and how much development are at risk. There are many uncertainties and they increase as we look further into the future.

ENVIRONMENTAL IMPLICATIONS

Two thirds of the world's fish catch and many marine species, depend on coastal wetlands for their survival. Without human interference, (the retreat option), ecosystems could migrate landward as sea level rises and thus could remain largely intact, although the total area of wetlands would decline. Under the protection option, a much larger proportion of these ecosystems would be lost, especially if hard structures block their landward migration.

Along marine coasts hard structures can have a greater impact than soft solutions. Hard structures influence banks, channels, beach profiles, sediment deposits and morphology of the coastal zone.

Protective structures should be designed, as much as possible, to avoid adverse environmental impacts. Artificial reefs can create new habitats for marine species and dams can mitigate saltwater intrusion, though sometimes at the cost of adverse environmental impacts elsewhere. Soft structures such as beach nourishment retain natural shorelines, but the necessary sand mining can disrupt habitats.

ECONOMIC IMPLICATIONS

No response strategy can completely eliminate the economic impacts of climate change. In the retreat option, coastal landowners and communities would suffer from loss of property, resettlement costs and the costs of rebuilding infrastructure. Under accommodation, there would be changing property values, increasing damage from storms and costs for modifying infrastructure. Under the protection option, nations and communities would face the costs for the necessary structures. The structures would protect economic development, but could adversely affect economic interests that depend on recreation and fisheries.

Appendix D of this report shows that if sea level rises by one metre, about 360,000 kilometres of coastal defences would be required at a total cost of US$500 billion over the next 100 years. (This sum only reflects the marginal or added costs and is not discounted). This value does not include costs necessary to meet present coastal defence needs. The estimate does not include the value of the unprotected dry land or ecosystems that would be lost, nor does it consider the costs of responding to saltwater intrusion or the impacts of increased storm frequency. **The overall cost will therefore be considerably higher.** Although some nations could bear all or part of these costs, other nations, including many small island states, could not.

To ensure that coastal development is sustainable, decisions on response strategies should be based on long term as well as short term costs and benefits.

SOCIAL IMPLICATIONS

Under the retreat option, resettlement could create major problems. Resettled people are not always well received. They often face language problems, racial and religious discrimination and difficulties in obtaining employment. Even when they feel welcome, the disruption of families, friendships and traditions can be stressful.

Although the impacts of accommodation and protection would be less, they may still be important. The loss of traditional environments which normally sustain economies and cultures and provide for recreational needs could disrupt family life and create social instability. Regardless of the response eventually chosen, community participation in the decision making process is the best way to ensure that these implications are recognized.

LEGAL AND INSTITUTIONAL IMPLICATIONS

Existing institutions and legal frameworks may be inadequate to implement a response. Issues such as compensation for use of private property and liability for failure of coastal protection structures require national adjudication. For some options, such as resettlement (retreat option) and structures that block sediments (protection option), there are transboundary implications that must be addressed on a regional basis. International action may be required through existing conventions if inundation of land results in disputes over national borders and maritime boundaries, such as exclusive economic zones or archipelagic waters. New authorities may be required, both to implement options and to manage them over long periods of time in the face of pressures for development. National coastal management plans and other new laws and institutions are needed to plan, implement and maintain the necessary adaptive options.

CONCLUSIONS

Scientists and officials from some 70 nations have expressed their views on the implications of sea level rise and other coastal impacts of global climate change at Coastal Zone Management Subgroup workshops in Miami and Perth. They indicated that in several noteworthy cases, the impacts could be disastrous; that in a few cases impacts would be trivial; but that for most coastal nations, at least for the foreseeable future, the impacts of sea level rise would be serious but manageable if appropriate actions are taken.

It is urgent for coastal nations to begin the process of adapting to sea level rise not because there is an impending catastrophe, but because **there are opportunities to avoid adverse impacts by acting now**, opportunities that may be lost if the process is delayed. This is also consistent with good coastal zone management practice irrespective of whether climate change occurs or not. Accordingly, the following actions are appropriate:

National Coastal Planning

1. **By the year 2000, coastal nations should implement comprehensive coastal zone management plans.** These plans should deal with both sea level rise and other impacts of global climate change. They should ensure that risks to populations are minimized, while recognizing the need to protect and maintain important coastal ecosystems.

2. **Coastal areas at risk should be identified.** National efforts should be undertaken to (a) identify functions and resources at risk from a one metre rise in sea level and (b) assess the implications of adaptive response measures on them. Improved mapping will be vital for completing this task.

3. **Nations should ensure that coastal development does not increase vulnerability to sea level rise.** Structural measures to prepare for sea level rise may not yet be warranted. Nevertheless, the design and location of coastal infrastructure and coastal defences should include consideration of sea level rise and other impacts of climate change. It is sometimes less expensive to incorporate these factors into the initial design of a structure than to rebuild it later. Actions in particular need of review include river levees and dams, conversions of mangroves and other wetlands for agriculture and human habitation, harvesting of coral and increased settlement in low lying areas.

4. **Emergency preparedness and coastal zone response mechanisms need to be reviewed and strengthened.** Efforts should be undertaken. to develop emergency preparedness plans for reducing vulnerability to coastal storms, through better evacuation planning and the development of coastal defense mechanisms that recognize the impact of sea level rise.

International Cooperation

5. **A continuing international focus on the impacts of sea level rise needs to be maintained.** Existing international organizations should be augmented with new mechanisms to focus awareness and attention on sea level change and to encourage nations of the world to develop appropriate responses.

6. **Technical assistance for developing nations should be provided and cooperation stimulated.** Institutions offering financial support should recognize the need for technical assistance in developing coastal management plans, assessing coastal resources at risk and increasing a nation's ability, through education, training and technology transfer, to address sea level rise.

7. **International organizations should support national efforts to limit population growth in coastal areas.** In the final analysis, rapid population growth is the underlying problem

with the greatest impact on both the efficiency of coastal zone management and the success of adaptive response options.

Research, Data and Information

8. **Research on the impacts of global climate change on sea level rise should be strengthened.** International and national climate research programmes need to be directed at understanding and predicting changes in sea level, extreme events, precipitation and other impacts of global climate change on coastal areas.

9. **A global ocean observing network should be developed and implemented.** Member nations are strongly encouraged to support the efforts of the IOC, WMO and UNEP to establish a coordinated international ocean observing network that will allow for accurate assessments and continuous monitoring of changes in the world's oceans and coastal areas, particularly sea level change.

10. **Data and information on sea level change and adaptive options should be made widely available.** An international mechanism should be identified with the participation of the parties concerned for collecting and exchanging data and information on climate change and its impact on sea level and the coastal zone and on various adaptive options. Sharing this information with developing countries is critically important for preparation of coastal management plans.

CZM-CHAIRMEN'S PROPOSAL FOR FUTURE ACTIVITIES

INTRODUCTION

Based on the views of the delegates and the recommendations of the Miami and Perth IPCC-CZMS workshops, the chairmen of the CZM Subgroup and their advisers have undertaken the task to facilitate the implementation of the CZM actions. They suggest that three parallel efforts be undertaken:

1. Data Collection -- Efforts to build a current global data base on coastal resources at risk due to sea level rise need to be vigorously pursued. The IPCC-CZM Subgroup has developed a questionnaire which can serve as a first step in the collection of this information and in identifying the countries where additional work needs to be done. It is also suggested that a database or monitoring system be set up which would provide access to and information on adaptation techniques and which could be maintained in an international or regional "clearing house".

2. International Protocol -- Efforts should commence immediately on the development of an international protocol to provide a framework for international and multinational cooperation in dealing with the full range of concerns related to impacts of sea level rise and climate change impacts on the coastal zone. A protocol is needed to both establish the international frames of reference as well as to establish a clear set of goals and objectives. Possible elements contained in such a protocol are outlined in Table 1.

3. Organisational requirements -- A process should be set in motion to guide and assist countries, particularly developing countries in carrying out the IPCC-CZM actions. For this purpose IPCC could consider the formation of a small advisory group to assist in the development of more specific guidelines. Such an advisory group could be formalised at a later stage to support the secretariat for the parties to a future protocol on CZM and sea level rise.

The goals and actions presented in this report are based on problems common to all coastal nations; their achievement can benefit significantly from coordination at the international level.

The three activities described above are considered crucial steps in realizing the full potential of the IPCC process. The Miami and Perth Workshops demonstrated very clearly that many developing nations will not be able to respond effectively to the needs which have been identified, without some form of assistance.

Additionally and in accordance with the primary action for the development of comprehensive coastal zone management plans, a timeline (Table 2) of essential actions for the formulation of such plans is suggested. Countries which do not currently have coastal management plans could use this timeline as a basis for their own planning process over the next decade.

COMPOSITION AND FUNCTIONS OF A GROUP OF ADVISERS

Advisory Group: Composition and Functions

In order to facilitate the development of responses to the threat of sea level rise and other impacts of climate change on the world's coastal zones, a functional nucleus of experts is required. Its task should be limited to requests by coastal states for assistance in achieving the goal of having a comprehensive coastal zone management programme in place by the year 2000.

Upon receipt of a request for assistance the IPCC may send an investigative mission to the requesting country or encourage multilateral or bilateral aid organisations to do so. The mission should assess the country's institutional, technical and financial needs and means, i.e. its requirements in these three areas. The advisory group could prepare guidelines for such missions or provide other support, if asked for.

Countries should have the institutional capability to develop their own coastal management programmes and to establish a regulatory framework and the means for enforcement. The required technical capability should be brought to an adequate level by training programmes, expert advice and appropriate equipment. An estimate of the costs involved (excluding equipment) is presented in Table 3.

It should further be determined to what extent the necessary funding can be generated within the country itself and what part could be requested from outside financing institutions.

The mission report referred to above should then be considered against and in the light of worldwide data, synthesized from information supplied by countries with a marine coast. These data should initially be compiled on the basis of the responses to a comprehensive questionnaire sent to all coastal countries and augmented as required.

Finally the group of advisers would report to the IPCC panel on country assessments and priorities in terms of vulnerability to the coastal impacts of climate change and on related institutional needs.

TABLE 1. POSSIBLE ELEMENTS TO BE INCLUDED IN A PROTOCOL ON COASTAL ZONE MANAGEMENT AND SEA LEVEL RISE

Signatories endeavour to develop before the year 2000 a comprehensive coastal management programme. Giving priority to the most vulnerable areas, they agree to:

- provide support to institutions conducting research on sea level rise and other impacts of climate change on the coastal zone;
- cooperate in international efforts to monitor sea level rise and other impacts of climate change on the coastal zone;
- contribute to systematic mapping and resource assessment of coastal zones to identify functions and critical areas at risk;
- support international initiatives to provide information and technical assistance to cooperating countries for the preparation of coastal management programmes;
- contribute to the exchange of information, expertise and technology between countries pertaining to the response to sea level rise and other impacts of climate change on the coastal zone;
- promote public and political awareness of the implications of sea level rise and other impacts of climate change on the coastal zone;
- manage the coastal zone so that environmental values are preserved whenever possible;
- avoid taking measures that are detrimental to the coastal zones of adjoining states;
- provide emergency relief to coastal nations struck by storm surge disasters;
- establish a secretariat supported by a small advisory group to facilitate the implementation of the protocol agreements.

TABLE 2. SUGGESTED TEN YEAR TIMELINE FOR THE IMPLEMENTATION OF COMPREHENSIVE COASTAL ZONE MANAGEMENT PLANS

1991:	Designate (a) national coastal coordinating bodie(s), (b) national coastal work teams and (c) an international coastal management advisory group to support the IPCC-CZM Subgroup and assist national work teams
1991 - 1993:	Develop preliminary national coastal management plans; begin public education and involvement
1991 - 1993:	Begin data collection and survey studies of key physical, social and economic parameters assisted by an international advisory group. For example: ‣ Topographic information ‣ Tidal and wave range ‣ Land use ‣ Population statistics ‣ Natural resources at risk
1992:	Adoption of a "Coastal Zone Management and Sea Level Rise" protocol, with a secretariat of the parties, supported by the international coastal management advisory group
1992 - 1995:	Begin development of coastal management capabilities, including training programmes and strengthening of institutional mechanisms
1995:	Completion of survey studies, including identification of problems requiring an immediate solution and identification of possible impacts of sea level rise and climate change impacts on the coastal zone
1996:	Assessment of the economic, social, cultural, environmental, legal and financial implications of response options
1997:	Presentation to and reaction from public and policy makers on response options and response selection
1998:	Full preparation of coastal management plans and modifications of plans as required
1999:	Adoption of comprehensive coastal management plans and development of legislation and regulations necessary for implementation
2000:	Staffing and funding of coastal management activities
2001:	Implementation of comprehensive coastal zone management plans

TABLE 3. OPERATIONAL COSTS FOR IMPLEMENTATION OF CZM-ACTIONS 1, 6, 10

Estimated funding to provide the necessary support to meet the year 2000 coastal zone management plan proposal:

1)	120 consultant-months @ US$ 10,000 per month	= US$	1,200,000
	Expenses and travel	= US$	800,000
		= US$	2,000,000
2)	Training of 100 in-countries personnel to strengthen coastal zone technical and planning capabilities 100 people @ US$ 30,000 each	= US$	3,000,000
3)	Expenses for secretariat and advisory group	= US$	3,000,000
4)	Conferences and Workshops	= US$	1,000,000
5)	Contingency	= US$	1,000,000
	Total for 5 years, 1992-1997	= US$	10,000,000

1. INTRODUCTION

1.1 IMPORTANCE OF THE COASTAL ZONE

A large portion of the world's population has always inhabited coastal areas. Fertile coastal lowlands, abundant marine resources, water transportation, aesthetic beauty and intrinsic values have long motivated coastal habitation.

The coastal zone includes both the area of land subject to marine influence and the area of sea subject to land influence. Coastal economies include commercial, recreational and subsistence fisheries; ports and industrial facilities that rely on shipping; and tourism, agriculture and forestry dependent on the coastal climate. Coastal areas are a critical part of the economies of virtually all nations bordering the sea, particularly subsistence economies. Coastal habitats provide important areas for fish and wildlife, including many endangered species. They filter and process agricultural and industrial wastes and buffer inland areas against storm and wave damage.

1.2 EXISTING PROBLEMS

Throughout the world, nations are facing a growing number of coastal problems as a result of development and increased population pressures. In many areas the functions and values normally associated with coastal areas are being degraded[1]. Flooding, erosion, habitat loss and modification, structural damage, silting and shoaling, pollution and over exploitation of living resources, all have major public safety and economic consequences. Yet while these risks are substantial and commonly recognized, the local benefits of using coastal resources outweigh the risks, at times significantly and continue to attract human activity and development to the coastal zone.

Shoreline alterations, mangrove and coral harvesting, dredge and fill activities, sand and gravel extraction and disposal of wastes in the marine environment all result in changes to the natural character of the coast. Inland activities, particularly upstream of river deltas, can also have a significant impact on the coast. Construction of dams, diversion of river flows and removal of ground water or hydrocarbons can result in coastal erosion, subsidence and shifts in the fresh and salt water interface[2] which are so critical to the maintenance of coastal habitats and fisheries.

Obvious examples of the consequences of human activities include (1) the accelerated retreat of two Nile subdeltas following construction of the Aswan High Dam and loss of the sardine fishery[3]; (2) the rapid loss of land in the Mississippi River delta due to subsidence, river levees, canals and navigation channels[4]; and (3) the exposure of valuable agricultural land in Malaysia to ocean waves as a result of uncontrolled mangrove harvesting.

If populations in coastal areas continue to grow, balancing environmental and development concerns will be increasingly difficult. Changes in climate and sea level will exacerbate many of these problems, particularly for small islands, deltas and low coastal plains. High population density is therefore the most fundamental problem faced by coastal areas (Fig. 1).

1.3 GLOBAL CLIMATE CHANGE

An accelerated rise in global sea level is generally considered to be the most important impact of global climate change on coastal areas. The IPCC-Working Group I projects a rise in global sea level of 30 to 110 cm by the year 2100 (Fig. 2a), due principally to thermal expansion of the ocean and melting of small mountain glaciers. Such a rate of rise would be 3 to 10 times faster than the current rate. Even with actions to limit emissions, the IPCC Working Group I concludes that there appears to be enough momentum in the global climate system for a rate of accelerated rise in sea level to be inevitable (Fig. 2b)[5].

Sea level rise could increase flood related deaths, damage to property and the environment and cause some nations to lose territorial seas; and hence change the relative values of the coastal zone to society. This will inevitably lead to decisions regarding response options, for example, to retreat, accommodate or protect[6]. A number of researchers have further suggested that extreme events may become more frequent as a result of climate change[7]. For example, increased ocean temperatures may result in changes in the frequency, duration and intensity of tropical storms. Moreover, the effect of storm surges could be intensified by higher sea levels. Inundation of coastal areas is already common during tropical storms and any increases in the extent or frequency of inundation may render numerous heavily populated areas

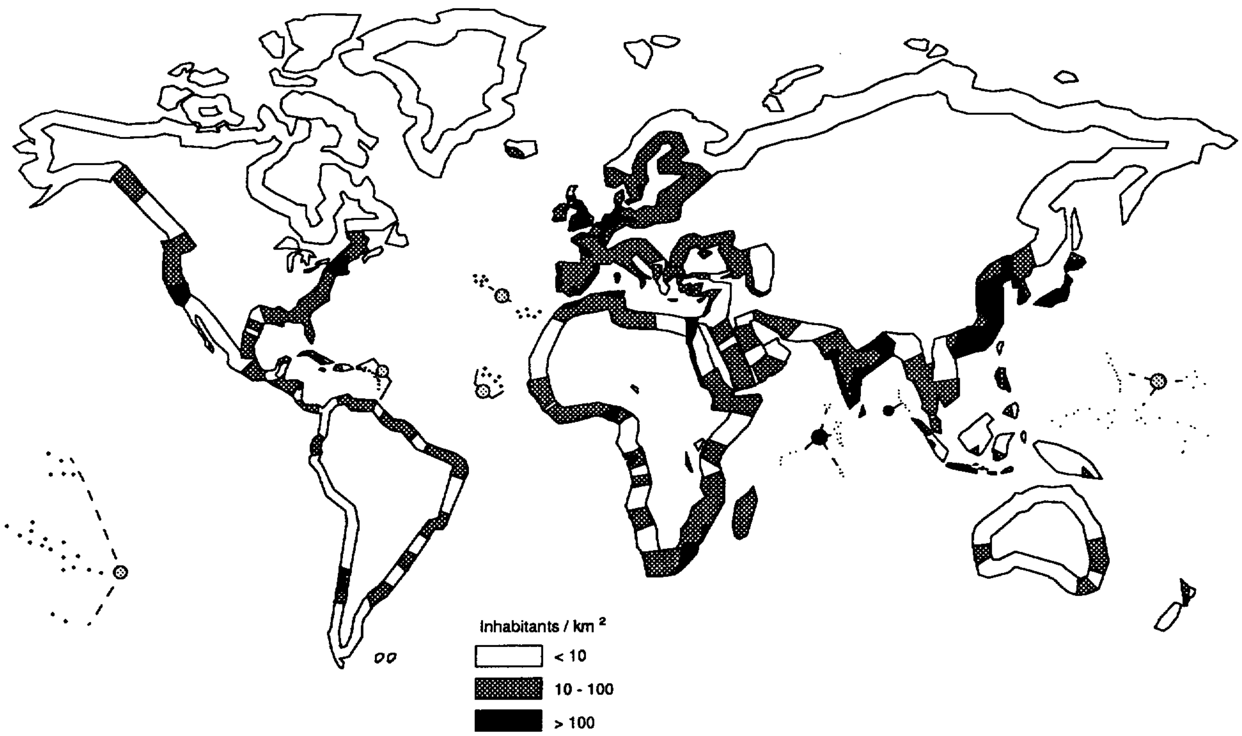


Fig 1: Schematic of World Map of Population Densities in Coastal Areas. (Source: Times World Atlas)

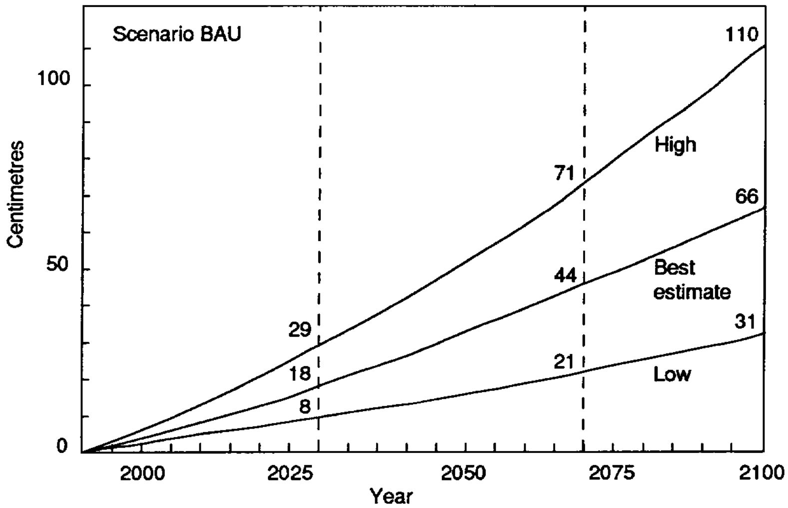


Fig 2.a: Global sea-level rise, 1990-2100, for Policy Scenario Business-as Usual (no limitation of greenhouse gases)

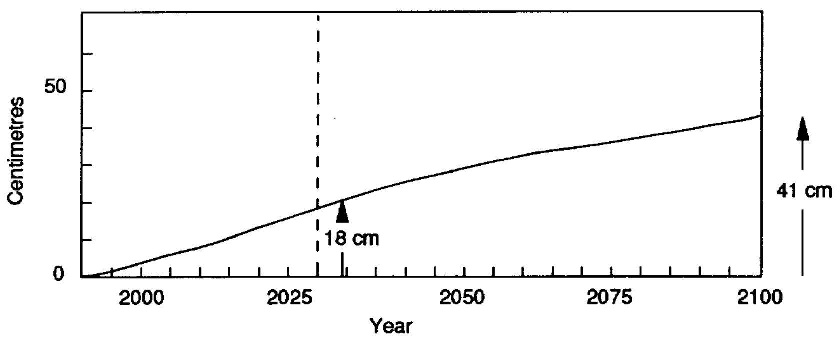


Fig 2.b: The curve shows the sea level rise due to Business-as-Usual emissions to 2030, with the additional rise that would occur in the remainder of the century even if the level of concentration of greenhouse gases are stabilised in 2030

marginal or uninhabitable.

Because the global climate system is complex, our understanding of it may progress slowly. The existing system for monitoring global sea level can not yet detect significant changes. Considerable uncertainties remain about the nature, timing and magnitude of future sea level rise and the local, national and regional impacts of human induced global climate changes.

1.4 ECOLOGICAL IMPACTS OF SEA LEVEL RISE

Working Group II[8] suggests that a rise in sea level could:
(1) increase shoreline erosion;
(2) exacerbate coastal flooding;
(3) inundate coastal wetlands and other lowlands;
(4) increase the salinity of estuaries and aquifers;
(5) alter tidal ranges in rivers and bays;
(6) change the locations where rivers deposit sediment;
(7) drown coral reefs.

Estuaries, lagoons, deltas, marshes, mangroves, coral reefs and seagrass beds are characterized by tidal influence, high turbidity (except coral reefs) and productivity and a high degree of human activity. Their economic significance includes their importance for fisheries, agriculture, shipping, recreation, waste disposal, coastal protection, biological productivity and diversity.

The direct effect of sea level rise in shallow coastal waters is an increase in water depth. Intertidal zones may be modified; mangroves and other coastal vegetation could be inundated and coral reefs could be drowned. In turn, this may cause changes in bird life, fish spawning and nursery grounds and fish and shellfish production. For example, coastal wetlands provide an important contribution to commercial and recreational fisheries, with an annual economic value of over US$10 billion in the United States alone[9]. Equally important is the contribution of wetlands to commercial and subsistence fisheries in many coastal and island states. Table 4 lists the areas of coastal wetlands of "international importance" for major regions of the world.

In general, the effects on shallow coastal ecosystems are strongly determined by local conditions. A good understanding of the physical and biological processes and topography is required to forecast local impacts. But if the accumulation of sediments cannot keep pace with rising waters, or if inland expansion of wetlands and intertidal areas is not possible[10] (because of infrastructure or a steeply rising coast), major impacts could occur.

The estuarine response to rising sea level is likely to be characterized by a slow but continually adjusting environment. With a change in estuarine vegetation there could be an adjustment in the animal species living in and around the wetlands. Climate change may also provoke shifts in the hydrological regimes of coastal rivers and lead to increased discharge and sediment yields and, consequently, to increased turbidity. These changes, together with a rise in sea level, could modify the shape and location of banks and channels. If no protective structures are built, wetlands can migrate inland; however, a net loss of wetlands would still result.

1.5 SOCIAL AND ECONOMIC IMPACTS OF SEA LEVEL RISE

Many developing countries have rapid rates of population growth, with large proportions of their populations inhabiting low lying coastal areas. A one metre rise in sea level could inundate 15 percent of Bangladesh[11], destroy rice fields and mariculture of the Mekong delta and flood many populated atolls, including the Republic of Maldives, Cocos Island, Tokelau, Tuvalu, Kiribati, the Marshall Islands and Tomes Strait Islands[12]. Shanghai and Lagos, the largest cities of China and Nigeria, lie less than two metres above sea level, as does 20 percent of the population and farmland of Egypt[13].

Four highly populated developing countries, India, Bangladesh, Vietnam and Egypt are especially vulnerable to sea level rise because their low lying coastal plains are already suffering the effects of flooding and coastal storms. Since 1960, India and Bangladesh have been struck by at least eight tropical cyclones, each of which killed more than 10,000 people. In late 1970, storm surges killed approximately 300,000 people in Bangladesh and reached over 150 kilometres inland. Eight to ten million people live within one metre of high tide in each of the unprotected river deltas of Bangladesh, Egypt and

Vietnam[14]. Even more people in these countries would be threatened by increased intensity and frequency of storms.

Sea level rise could increase the severity of storm related flooding. The higher base for storm surges would be an important additional threat in areas where hurricanes, tropical cyclones and typhoons are frequent, particularly for islands in the Caribbean Sea, the south eastern United States, the tropical Pacific and the Indian subcontinent. Had flood defences not already been constructed, London, Hamburg and much of the Netherlands would already be threatened by winter storms.

Many small island states are also particularly vulnerable[15]. This is reflected in their very high ratios of coastline length to land area. The most seriously threatened island states would be those consisting solely, or mostly, of atolls with little or no land more than a few metres above sea level. Tropical storms further increase their vulnerability and, while less in magnitude than those experienced by some of the world's densely populated deltas, on a proportional basis such storms can have a much more devastating impact on island nations.

Disruption could also be severe in industrialized countries as a result of the high value of buildings and infrastructure. River water levels could rise and affect related infrastructure, bridges, port structures, quays and embankments. Higher water levels in the lower reaches of rivers and adjacent coastal waters may reduce natural drainage of adjacent land areas, which would damage roads, buildings and agricultural land.

The potential impacts of sea level rise and climate change are varied and uncertain. Nevertheless, there is little doubt that adaptive responses will be necessary.

2. ADAPTIVE RESPONSES

The selection and timing of adaptive measures in response to sea level rise would depend on the physical, social, economic, political and environmental characteristics of the affected areas. Although such measures could be implemented on case by case bases, growing population pressures and conflicting demands in many of the world's coastal areas favour implementation of comprehensive and systematic coastal management programs.

2.1 COASTAL MANAGEMENT

The three principal objectives of coastal management are to:

1) Avoid development in areas that are vulnerable to inundation;
2) Ensure that critical natural systems continue to function;
3) Protect human lives, essential properties and economic activities against the ravages of the seas.

Accordingly, such programmes should give full consideration to ecological, cultural, historic and aesthetic values and to the needs for human safety and economic development[16].

Coastal management programmes usually include governmental controls and private sector incentives. Vulnerable areas are managed to minimize loss of life and property through such means as setback lines, limits on population densities, minimum building elevations and coastal hazard insurance requirements. Resilient natural protective features, such as beaches, sand dunes, mangroves, wetlands and coral reefs, are conserved and enhanced, which also maintains biological diversity, aesthetic values and recreation.

Comprehensive plans for protecting existing economic activities helps to ensure that defense measures are consistent with other coastal management objectives. Policies that specify which activities and development are permitted in new areas promote efficient private land use with the least risk of exposure to coastal hazards.

Successful coastal management programmes require public education to gain broad based support and public participation to ensure equal representation of interests.

Response strategies fall into three broad categories:

- **Retreat**: abandonment of land and structures in vulnerable areas and resettlement of inhabitants.
- **Accommodation:** continued occupancy and use of vulnerable areas.
- **Protection:** defense of vulnerable areas, especially population centres, economic activities and natural resources.

2.2 RETREAT

Options for retreat include:

1) Preventing development in areas near the coast;

2) Allowing development to take place on the condition that it will be abandoned if necessary (planned phase out);

3) No direct government role other than through withdrawal of subsidies and provision of information about associated risks.

Governmental efforts to limit development generally involve land acquisition, land use restrictions, prohibited reconstruction of property damaged by storms and reductions of subsidies and incentives for development in vulnerable areas. Many nations have purchased large areas on the coast and designated them as nature reserves. Preventing development can reduce future expenditures for adaptation. India, Sri Lanka, Tonga, Fiji, Mauritius, Australia and the United States already require new buildings be set back from the sea. These regulations could be modified to consider the future impacts from a rising sea level, but most nations would require compensation for coastal property owners[17].

The second option gives the government a more limited role in that it lays out the "rules of the game" (the eventual transgression of the sea[18]). Investors are accustomed to evaluating uncertainty and can determine whether development should proceed given the constraint. This approach can be implemented through

(a) regulations that prohibit private construction of protective structures, or

(b) conversion of land ownership to long term or conditional leases which expire when the sea reaches a particular level or when the property owner dies.

The third option would be to depend on the workings of the private market. Productive crop and timber lands may be left to slowly and progressively deteriorate as a result of salt intrusion into the groundwater or by surface flooding. Wells and surface water exposed to salt water intrusion would gradually be abandoned. Natural resources, such as mangroves, marshes and coral reefs, would be left to their natural processes as sea level rises.

Under this option, governments could take the more limited role of ensuring that all participants in potentially vulnerable areas have full knowledge about the expected sea level rise and its associated uncertainties.

Development would presumably not occur if developers, lenders and insurers were not willing to accept the risks. However, if people continue to build in vulnerable areas, governments must be prepared to take the necessary actions to ensure public safety.

For small island states, retreat does not offer a broadly applicable alternative. There would be little or no land for resettlement, in addition to loss of heritage and cultural upheaval.

2.3 ACCOMMODATION

The strategy of accommodation, like that of retreat, requires advanced planning and acceptance that some coastal zone values could be lost. Many coastal structures, particularly residential and small commercial buildings, could be elevated on pilings for protection from floods. To counter surging water and high winds, building codes could specify minimum floor elevations and piling depths, as well as structural bracing. Drainage could be modified. Storm warning and preparedness plans could be instituted to protect the affected population from extreme events. Where saltwater damages agricultural lands and traditional crops, salt tolerant crops may be a feasible alternative. Fundamental changes in land use may be desirable, such as the conversion of some agricultural lands to aquacultural uses.

Human activities that destroy the natural protection values of coastal resources can be prohibited. Perhaps the most important controls would be to prohibit filling wetlands, damming rivers, mining coral and beach sands and cutting mangroves. Undeveloped land with sufficient elevation and slope can be set aside to accommodate natural reestablishment of wetlands and mangroves. Within deltaic areas, natural processes can be maintained by diverting water and sediment. In response to salinity intrusion into groundwater aquifers, management controls can be implemented to regulate pumping and withdrawal practices.

Requiring private insurance coverage in vulnerable areas is an important method to compensate injuries and damages caused by natural disasters. It forces people to consider whether risks are worth taking and provides the necessary funds to repair damages and compensate victims.

2.4 PROTECTION

This strategy involves defensive measures and other activities to protect areas against inundation, tidal flooding, effects of waves on infrastructure, shore erosion, salinity intrusion and the loss of natural resources[19]. The measures may be drawn from an array of "hard" and "soft" structural solutions[20]. They can be applied alone or in combination, depending on the specific conditions of the site.

There is no single or generic "best solution", as each situation must be evaluated and treated on its particular merits. However, there are some basic steps in the selection of measures likely to produce the highest economic returns. First, those charged with planning, design or management responsibilities in the coastal zones should be cognizant of the potential for future sea level rise. Moreover, proposed plans should leave options open for the most appropriate future response. For example, many protection structures can be planned and designed with features that allow for future incremental additions which, if needed, could accommodate increased water levels and wave action. This can often be done without significant additional costs in the initial investment.

It should be noted that the capital costs associated with the "hard" set of options may prove a barrier to consideration of this option by developing countries and small island states.

Hard Structural Options:

Dikes, Levees and Floodwalls are raised embankments or walls constructed for flood protection purposes. Depending on circumstances, internal drainage may be accomplished by gravity flow, tide gates, or pumping systems.

Seawalls, Revetments and Bulkheads protect inland properties from the direct effects of waves and storm tides. Seawalls and heavy revetments (sloping armoured surfaces) are constructed along open coast areas to defend areas against severe wave attack. Lighter revetments and bulkheads usually serve as secondary lines of defence along open coast areas, or as first lines of defence along more sheltered interior shores with low to moderate wave exposure.

Groins are structures placed perpendicular to the shoreline. They generally extend from the land into the near shore zone, and trap sediment moving along the shore in order to widen the beach or prevent it from eroding.

Detached Breakwaters are robust structures placed offshore, usually parallel to the shoreline, for the purpose of dissipating the energy of incoming waves to reduce both erosion and damage from storms.

Raising Existing Defensive Structures may be facilitated through the incorporation of such a possibility in the initial design. Some dikes, levees, floodwalls, seawalls, revetments and breakwaters can be easily raised and strengthened in the event of sea level rise or increased storm exposure.

Infrastructure Modifications may involve the elevation of piers, wharves, bridges, road and rail beds; modifications to drainage systems; relocations of various facilities and the institution of flood proofing measures.

Floodgates or Tidal Barriers, which are adjustable, dam like structures, can be placed across estuaries to prevent the upstream flooding from storm tides. Such barriers are usually left open to avoid interfering with existing flows.

Salt Water Intrusion Barriers in surface water streams can consist of locks or dams which directly block upstream penetration of saline water. Dams upstream of a salt penetration zone may be operated so that water released from the reservoirs at appropriate times can act to minimize the upstream movement of saltwater. Under certain conditions, underground barriers can be placed by open cut or injection methods to prevent saline water intrusion in groundwater aquifers. Fresh groundwater lenses in coastal areas can be maintained by fresh water recharging techniques.

Soft structural options:

Beach Filling and Subsequent Renourishment involves the placement of sandy material along the shore to establish and subsequently maintain a desired beach width and shoreline position to dissipate wave energy and enhance beaches, particularly for recreational and aesthetic purposes[21].

Dune Building and/or the maintenance and preservation of existing dunes, in combination with adequate beach strands, provides an effective measure of protection to upland properties against the effects of storm tides and wave action.

Wetland/Mangrove Creation can be accomplished through the placement of fill material to appropriate elevations with subsequent plantations.

Other Possible Solutions may be found through increasing resilience and reducing vulnerability of coastal zone features that are under threat of degradation. Options include continued field research in the use of artificial seaweed, artificial reef creation, the rehabilitation of natural coral reefs and planting of seagrass, promoting the protection of corals from pollution in order to enhance growth, increasing coastal protection; instituting pollution controls and preventing the harvesting of mangroves.

3. ENVIRONMENTAL IMPLICATIONS OF ADAPTIVE RESPONSES

3.1 INTRODUCTION

Most coastal areas contain habitats that are important to fish, shellfish, sea turtles, sea birds and marine mammals. These areas also have high recreational, cultural and aesthetic values for many people. Working Group II concluded that a large net wetland loss would result as sea level rises, because the area onto which new wetlands might expand is less than the area of wetlands at risk.

3.2 RETREAT

Enabling wetlands to migrate inland is one possible motivation for a retreat strategy. Coastal wetlands can be found along most of the world's coastal margins, notably in the tropical and subtropical regions. From a global perspective, there is presently a large scale facto retreat in process, given that most of the world's coastal wetlands boarder on land areas with low population densities and little major development (Fig 3)[22]. Nevertheless, these areas may be developed in the future. Governments should focus attention on their wetland areas and where appropriate, establish zones to which wetlands will be allowed to retreat using the measures outlined in the previous section. However, even a retreat can not prevent a large net loss of coastal wetlands.

Developed nations with large land masses, such as the United States and Australia, have implemented retreat strategies along sections of their coasts in the interest of allowing coastal ecosystems, particularly tidal wetlands, to adjust to increased levels of the sea through a slow landward migration. By contrast, on small islands the lack of land for inland migration would restrict the applicability of this option. In the case of atolls, many ecosystems could be completely lost.

3.3 ACCOMMODATION

The implications of this option would be a compromise between retreat and protection. However, resource exploitation practices would change. For example, people may harvest mangrove wood for use as pilings to elevate houses. Flood control efforts might alter water flow patterns which could adversely affect the coastal environment.

3.4 PROTECTION

This strategy is most relevant for areas having relatively large populations and important infrastructure. These conditions inherently alter the environments. However, the structural measures related to a protection strategy can impose additional alterations not only to the immediate environment but also to the unaltered coastal ecosystems beyond the area of protection. Therefore, environmental impact assessments are particularly important when protective measures are estimate does not include the value of the unprotected dry land or ecosystems that under consideration.

3.4.1 Hard Structures

Along ocean coasts, seawalls constructed landward of the shorelines would have little immediate impact on the beach systems. However, an eroding shore would eventually reach the seawalls and result in a loss of the natural beaches. This impact can be avoided by means of beach nourishment. Similarly, structures could block the inland migration of coastal wetlands. For example, in the United States, the loss from a one metre rise would be 29-66 percent under the retreat option, but 50-82 percent if shores are protected with bulkheads[24].

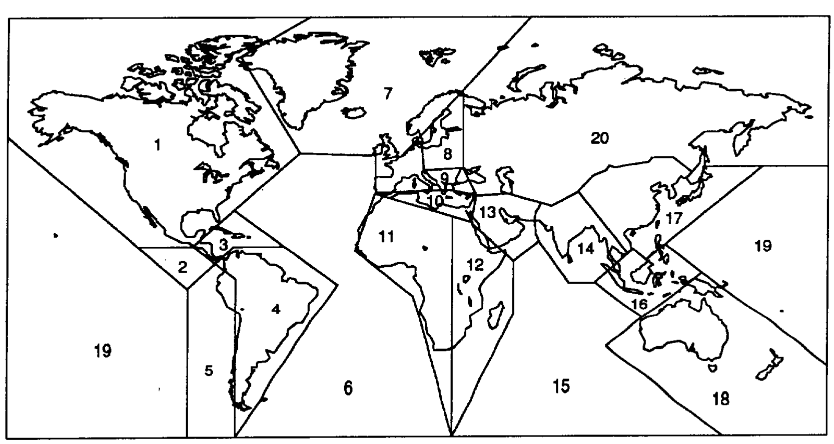
Groins trap sediment moving along the shore. However, protection of one area is generally at the expense of increased erosion downdrift from the protected area. Because these structures do not increase the total sediment available to beaches and barrier islands, their long term impact is primarily a geographic shift of the erosion. Detached breakwaters often have similar effects, although they allow for nearshore habitat shifts in some cases and often provide desirable fish habitats in much the same fashion as natural reefs.

Table 4. Areas of Coastal Wetlands* of "International Importance" in Sq. Km and as Percentage of Country Areas

	Region	Area of Wetlands in km^2	Wetlands as % of total country area
1	North America	32,330	1.639
2	Central America	25,319	0.882
3	Caribbean Islands	24,452	9.431
4	South America Atlantic Ocean Coast	158,260	1.132
5	South America Pacific Ocean Coast	12,413	0.534
6	Atlantic Ocean Small Islands	400	3.287
7	North and West Europe	31,515	0.713
8	Baltic Sea Coast	2,123	0.176
9	Northern Mediterranean	6,497	0.609
10	Southern Mediterranean	3,941	0.095
11	Africa Atlantic Ocean Coast	44,369	0.559
12	Africa Indian Ocean Coast	11,755	0.161
13	Gulf States	1,657	0.079
14	Asia Indian Ocean Coast	59,530	1.196
15	Indian Ocean Small Islands		
16	South-east Asia	122,595	3.424
17	East Asia	102,074	0.999
18	Pacific Ocean Large Islands	89,500	19.385
19	Pacific Ocean Small Islands		
20	USSR	4,191	0.019
	Totals	732,921	0.846

SOURCE: "A GLOBAL SURVEY OF COASTAL WETLANDS, THEIR FUNCTIONS AND THREATS IN RELATION TO ADAPTIVE RESPONSES TO SEA LEVEL RISE", paper by Dutch Delegation to IPCC-CZM Workshop, Perth, Australia, February 1990 (Note 22).

* Based on: Directories of Wetlands, issued by IUCN/UNEP (1980-90), 120 countries, excluding amongst others Australia, Canada, New Zealand, USA.



INDEX MAP OF REGIONS

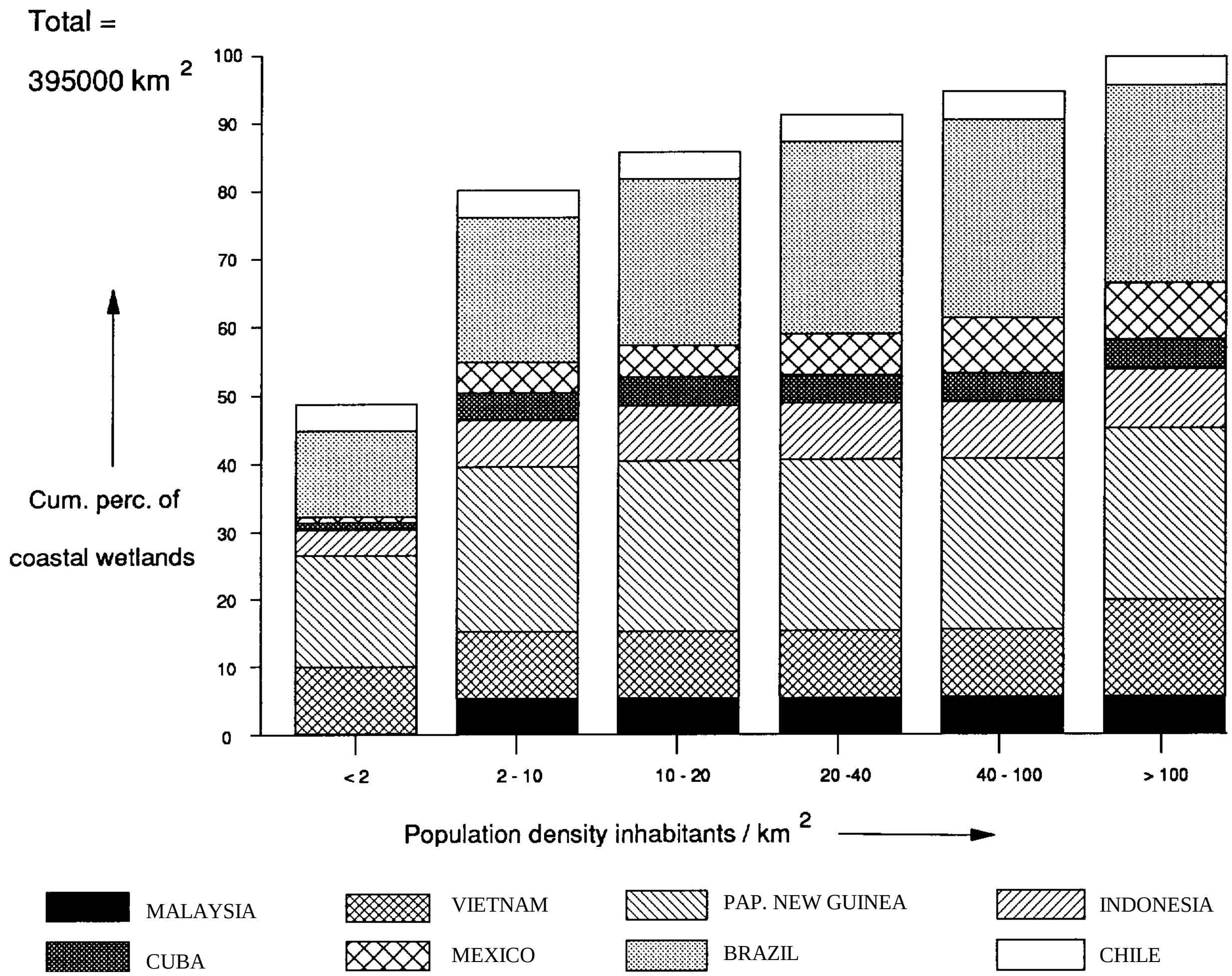


Fig 3: Graphs of cumulative percentages of major coastal wetlands
and their population densities

Dams and salt water intrusion barriers can protect water supplies and fresh water habitats. On the negative side, these structures can retain sediments which in turn can increase erosion of coastal headlands and impair the ability of deltaic wetlands to keep pace with sea level rise.

In deltaic areas, levees might be constructed along rivers to prevent flooding due to sea level rise. The resulting "channelising" of rivers could, in some cases, prevent annual river floods from providing sediment and nutrients necessary to enable deltas to keep pace with sea level rise and maintain the fertility of agricultural lands[25].

3.4.2 Soft Structures

Soft structures have a less severe impact than hard structures, since they usually consist of simulated natural features, such as beaches and wetlands 2g. The most common "soft engineering" approach is beach nourishment, which involves dredging sand from back bays, navigation channels, or offshore, or excavating material from a land based source and placing it on the beach. Because beach ecosystems are already adapted to annual erosion/accretion cycles, the placement of sand on the beach generally has little impact on beach ecosystems. By contrast, the dredging itself can seriously disrupt shallow water ecosystems and wetland habitats, both due to the direct effects of removing material and the resulting increase in turbidity.

4. ECONOMIC IMPLICATIONS

4.1 INTRODUCTION

The potential economic implications of responses to sea level and temperature rise over periods of 50 to 100 years are extremely difficult to quantify. The variables to be considered include both the cost of the strategies themselves and the effects of those costs on national economies. Thus far, only the cost of protecting against inundation and erosion has been estimated world wide. Much more research needs to be done.

The cost of an adaptive response is site specific. The nationwide impact of such costs will be greater on rural, subsistence economies, often found in coastal areas in developing countries. Losses of resources such as biologically productive wetland areas and important mangrove stands and their products would compound such hardship. Reduction in the productivity of fisheries and the loss of land, resources and jobs are a further consideration. Significant costs can also be associated with the establishment and operation of the institutional mechanisms necessary to implement retreat or accommodation strategies. Finally and especially if structural response options were exercised, operation and maintenance costs are a factor.

A fundamental element in the decision making process is a cost benefit assessment to weigh the life cycle costs and economic returns of the various alternatives[27]. Not all of the important factors are totally quantifiable in monetary terms, however. This is particularly so for cultural, environmental and social factors. Nevertheless, these non quantifiable aspects must be evaluated and given due consideration in an equitable trade off analysis in order to formulate and implement an acceptable adaptive response.

4.2 RETREAT

In densely populated and productive areas, retreat may prove to be the least economically viable response option because of nearly irretrievable losses involved, or, in the case of small islands, the lack of land on which people can resettle. Inundation of fertile coastal agricultural land and frequent flooding of industrial sites and urban centres would threaten the value of past investments and drastically limit future growth. In such cases, it is highly unlikely that the economic benefits of retreat would exceed the costs.

Large scale resettlements could severely tax the planning, infrastructural and distributive capabilities of most countries, especially for developing countries. In particular, small island nations would face the most serious economic implications of retreat. At its most extreme, it would involve resettlement of the populations of entire nations.

The slow (albeit increasing) rate of sea level rise permits appropriate planning and incremental implementation of retreat options and this may reduce costs[28]. However, in the case of arable lands, the inability to produce an adequate food supply may cause further national hardship through both unemployment and loss of exports.

4.3 ACCOMMODATION

Accommodation provides opportunities for inundated land to be used for new purposes. Thus, some compensatory economic benefits could be derived from accommodation or adaptation to inundation and flooding. For example, agricultural land may, in some instances, be found suitable for aquaculture; salt resistant crops may be grown in areas previously dependent on freshwater. Nonetheless, considerable costs may be involved in the planning and restructuring of land use. The necessary expenditure may place significant stress on national budgets, especially in developing countries. In the case of an increase in extreme events induced by climate change, such as tropical storms, altered wave regimes and storm surge frequencies, significant expenditures would be involved in disaster planning and preventing loss of life. Responding to such events would require considerable national planning and might involve compensation.

4.4 PROTECTION

The economic benefits accruing from protection depend on the values of the land being protected. Benefit categories, as measured against taking no action include (a) prevention of physical damage to property as a result of waves and flooding; (b) prevention of loss of (economic) production and income; (c) prevention of land loss through erosion; (d) the prevention of loss of natural resources (environmental and recreational).

Costs include capital, operation and maintenance of the protective measures, as well as any cultural, environmental and social changes that may result. For example, some hard structural protection works may cause beaches to disappear. For economies heavily dependent on tourism (e.g. Caribbean Islands) this may have serious adverse consequences. As previously stated, the non quantifiable aspects of cultural, environmental and social impacts must be considered when selecting any response strategy. Options may be restricted for some developing countries because of costs or lack of technology.

Cost estimates for protection

Although the potential economic developments in the next few decades are difficult to predict, an approximation of basic implementation costs is possible. Although any such calculations are only rough approximations, they provide a useful first estimate and a guide for future data collection efforts. Table 5 illustrates estimates based on a sea level rise scenario of one metre in 100 years, for 181 Countries and territories with a marine coast. These estimates show that preventing inundation alone would cost, at a minimum, some US$500 billion (none discounted).

This value only reflects the marginal or added costs of protecting against the effects of a one metre rise in water level over the next 100 years. It does not include any costs associated with basis coastal protection in place of necessary to meet present coastal defence needs. The estimate does not include the value of the unprotected dry land or ecosystems that would be lost, nor does it consider the costs of responding to saltwater intrusion nor the impacts of increase storm frequency[29].

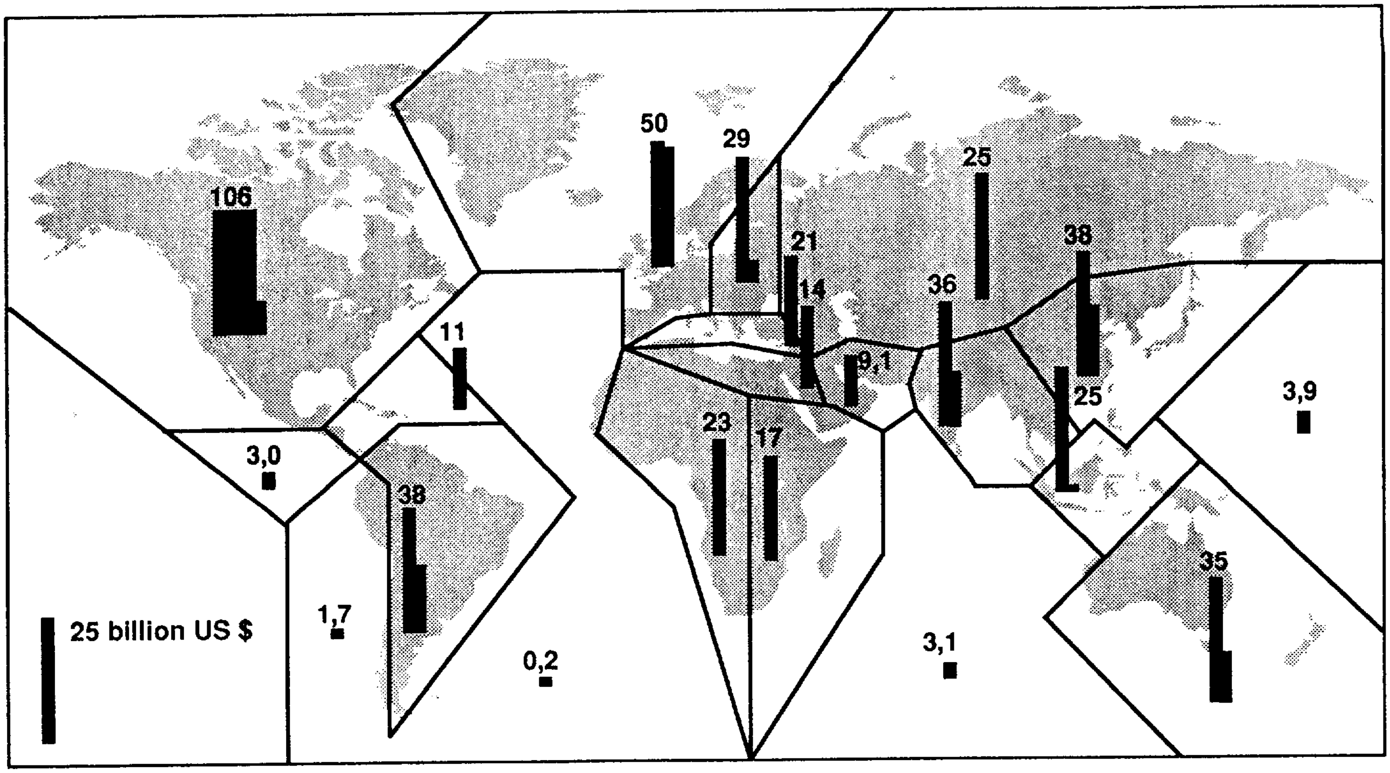
The annual cost of protection amounts to 0.037 percent of total Gross National Product (GNP). It is important to note, however, that the cost burden in terms of GNP is not uniform within the community of nations. For example, the small low lying island nations of the world would have to commit a relatively high proportion of their GNPs to protect against a one metre rise in sea level. Specifically, the small island states in the Indian and Pacific Oceans would, respectively, have to commit 0.91 of one percent and 0.75 of one percent of GNP in the one metre rise scenario. For some atoll islands the annual cost may be as much as 10-20 percent of their GNP.

The complete study on cost estimates can be found in Appendix D.

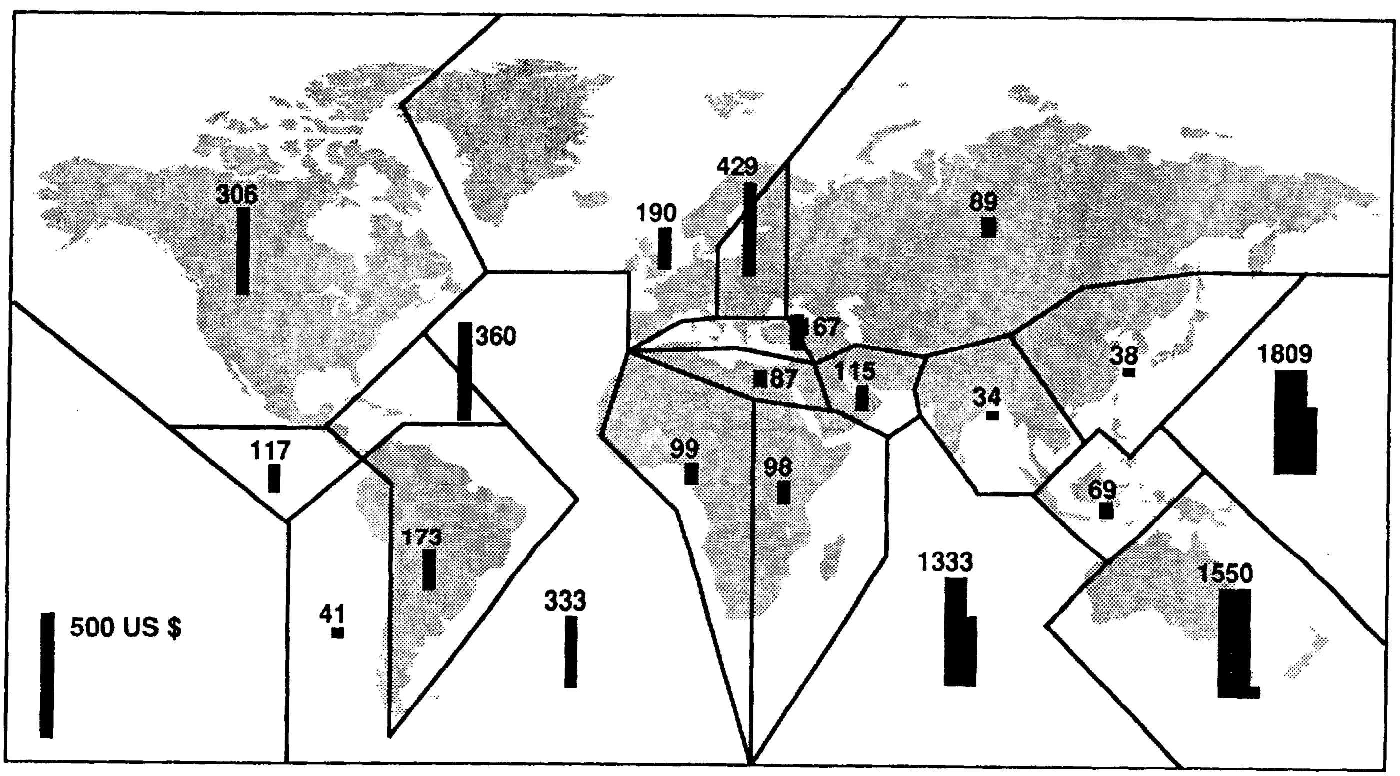
Table 5. Estimate of Marginal Costs Involved in Protecting Countries, Worldwide, Against the Effects of a 1 m Sea Level Rise in 100 Years (Billion US$).

	Region	Total Protective Costs (Billions US$)	Total Costs Per Capita (US$)	Annual Protective Costs as % of GNP
1	North America	106.2	306	0.03
2	South America	3.0	117	0.12
3	Caribbean Islands	11.1	360	0.20
4	South America Atlantic Ocean Coast	37.6	173	0.09
5	South America Pacific Ocean Coast	1.7	41	0.04
6	Atlantic Ocean Small Islands	0.2	333	0.12
7	North and West Europe	49.8	190	0.02
8	Baltic Sea Coast	28.9	429	0.07
9	Northern Mediterranean	21.0	167	0.04
10	South Mediterranean	13.5	87	0.06
11	Africa Atlantic Ocean Coast	22.8	99	0.17
12	Africa Indian Ocean Coast	17.4	98	0.17
13	Gulf States	9.1	115	0.02
14	Asia Indian Ocean Coast	35.9	34	0.14
15	Indian Ocean Small Islands	3.1	1333	0.91
16	South-east Asia	25.3	69	0.11
17	East Asia	37.6	38	0.02
18	Pacific Ocean Large Islands	35.0	1150	0.17
19	Pacific Ocean Small Islands	3.9	1809	0.75
20	USSR	25.0	89	0.01
	Total	488.1	103	0.04

SOURCE: "A WORLD WIDE COST ESTIMATE OF BASIC COASTAL PROTECTION MEASURES", paper by Dutch Delegation (Rijkswaterstaat / Delft Hydraulics, Note No. H1068) to IPCC-CZM Workshop, Perth, Australia, February 1990.



Total protection costs in billion US $ per region



Total protection costs per capita in US $ per region

5. SOCIAL AND CULTURAL IMPLICATIONS

5.1 INTRODUCTION

The social and cultural implications of adaptive response measures may affect hundreds of million people living in coastal zones with an average width of 50 kilometres[30]. In some coastal areas, inhabitants are highly concentrated in a narrow coastal belt (e.g. Java, India and China).

The lifestyles of many people are tied directly to the coast and its predominant local features. The coast also features strongly in the mythology of many cultures. Numerous places of particular cultural significance are situated on the coast and many people in developed and developing nations view the sea, coasts, reefs and beaches as central to their lives.

Social and cultural implications of adaptive options are likely to vary considerably from country to country and from site to site. Options that are socially and culturally beneficial in some situations may be less desirable in others. It is particularly important that the affected communities are consulted and participate in the decisions to adopt particular options. This is probably one of the best means available to identify the social and cultural implications for particular cases.

5.2 RETREAT

Retreat, as an option, may imply a partial, incremental process or a sudden large scale event. In some circumstances, there may be a need to relocate inhabitants, or even entire communities which could have major financial and social implications in developing countries. The loss of the traditional environment that normally sustains economies and cultures and provides for recreational needs, could severely disrupt family life and create social instability, with a resulting adverse impact on the entire community, especially on the young and the elderly. In addition, places of great cultural significance, for example, burial grounds, historic places, or religious centres, could also be lost if retreat occurs.

All retreat options have been identified as having potentially significant implications both socially and culturally. This is particularly the case with abandonment and the resulting need to resettle whole populations. Even though migration is relatively common in some areas, for example, the South Pacific, there remains the need for social adjustment. Situations where an individual's or a community's identity is closely associated with a particular piece of land or access to particular resources, as in most subsistence economies, can have implications which are difficult to resolve.

The greatest implications of retreat may lie in being denied access to the original coast. A well planned retreat that provides for access to alternative resources could minimize some of these impacts[31]. An associated issue is that of the social implications for the host people at the place of relocation. There exists a potential for conflict and existing social services may be heavily taxed in the host area if relocation is not well planned and managed. People may choose not to abandon even vulnerable coastal areas in anticipation of climate change impacts, if there is strong population pressure in adjacent areas.

5.3 ACCOMMODATION

The social and cultural implications of accommodation, while not as severe as those of retreat, may still be significant. A change in the economic activity of an area, for instance, from farming to aquaculture, will change lifestyles. Accommodating change may lead to living conditions being less desirable, for example, if properties are subject to periodic flooding, or if problems with sewage disposal occur. Public safety and health will thus be adversely affected by this option.

Accommodation is a more socially desirable option when applied in areas where there is a tradition of adapting to water, for instance, if people live in houses on stilts or in house boats.

5.4 PROTECTION

Protection has fewer identified social and cultural implications. However, hard structures are likely to have less aesthetic value than the original environment and access to the shore may also be restricted by some protective options. Beach losses could impair recreation, while loss of wetlands may affect fish stocks. If protective options involve non local labour, there may be social and cultural friction which could lead to community disruption. Options that can be implemented by communities themselves are less likely to have social and cultural implications than those which require outside labour.

If the protection structures cause alteration to places of cultural significance there could be opposition to their construction. The loss of any biological resources resulting from protection activities could also be of cultural significance. In some areas, for example, if a significant species is seriously threatened it may no longer be available for ritualistic or economic purposes.

6. LEGAL AND INSTITUTIONAL IMPLICATIONS

6.1 INTRODUCTION

Existing institutions and legal frameworks may be inadequate to plan and implement adaptive responses. New institutions and legal authorities may be needed in many coastal states. National legislation and institutions for coastal zone management can provide the needed planning. In addition, legal structures to require advance consideration of likely impacts, such as environmental impact review by those planning new projects, can encourage needed foresight.

One matter to consider is that virtually any adaptive option involves the use of "private" land. In some nations such use by individuals may be prohibited by law, while in other states the government may not have authority to use the land without the consent of the land owner. The government in some states may have the authority to use private land, but only upon providing compensation to the land owner[32].

An accelerated rate of increase in the global sea level also raises the possibility of legal issues pertaining to maritime boundaries and jurisdiction and transboundary matters. These issues may require a review of existing international arbitration procedures. An example of the first issue would be if a nation loses maritime boundary base points and therefore a legal claim to sea territory, or if beach nourishment measures are required in the vicinity of national borders. An example of the second issue would be if protective measures interrupt or impede the longshore sediment transport benefitting an adjoining coastal state. In the worst case, sea level rise may result in the total land loss of an island nation; the resulting legal implications are difficult to predict[33].

6.2 RETREAT AND ACCOMMODATION

The resettlement option could raise significant transboundary implications. The legal authority and institutional capability to manage or direct a relocation on a temporary or permanent basis must be clearly established. Authorities to facilitate and encourage relocation from vulnerable areas and to subsequently deal with the use of abandoned lands may be needed. In extreme cases when individuals will not leave areas subject to great risk, authorities for condemnation of land and facilities may also be necessary.

Whether relocation is on a temporary or a permanent basis, accommodation for displaced inhabitants must be provided. In some coastal states, relocation could involve tens of millions of inhabitants. The relocation may be further complicated by the lack of land within small coastal or island states. If relocation outside such states is required, then the assistance of regional or international institutions may be needed.

The first option for both measures is to discourage growth in population, or additional development in vulnerable areas that would increase either the risks of losses, or would increase the costs of later retreat to unacceptable levels. In order to implement this option, the coastal state must have the institutional facility for identifying vulnerable coastal zones. Many developing countries do not have the institutional structure and will require assistance to develop a national plan for management of coastal resources and coastal development. Alternatively, a state might choose to encourage private retreat and accommodation actions through nonregulatory measures, such as providing information to the affected population.

In addition to an institutional structure to plan and manage coastal development, legal authorities are needed to enforce restrictions or conditions on coastal development if a coastal or island state chooses to take an active regulatory role for implementing those strategies. Legal authorities may also be needed both to ensure the integrity of natural coastal protection systems and to avoid placing coastal populations and developments in jeopardy from sea level rise. For example, a coastal or island state may need new authority to restrict access or activities to certain areas in order to protect natural systems (such as from the use of mangrove for firewood) as well as have the authority to restrict residential and commercial development (such as new settlements on deltas).

6.3 PROTECTION

An important implication of selecting an option to protect against sea level rise is liability for the failure of public protection structures. Structures to protect against sea level rise enable commercial, agricultural and residential activities to continue in protected areas. Therefore, people and economic resources will be attracted to and concentrate in areas so protected.

Should the structure fail, significant loss of life and property could result. Each type of structure is different and each requires some type of maintenance in order to perform as designed. Where the entity responsible for maintenance is different from the entity which designed and/or constructed the structure, it may be difficult to assess any liability for damage resulting from a failure of the structure. Some public or private entity within each nation, therefore, must have responsibility for maintenance of the physical integrity of these structures.

7. PRIORITIES FOR ADAPTIVE RESPONSES

7.1 INTRODUCTION

The projected rise in sea level warrants urgent policy responses in many coastal states, particularly those with populated coral atolls and deltas, or those with estuary dependent fisheries. It is imperative that such actions focus on human safety and on sustainable development of coastal resources.

Even though sea level rise is predicted to be a relatively gradual phenomenon, adaptive strategies may require lead times in the order of 50 to 100 years, to tailor them to the unique physical, social, economic, environmental and cultural considerations of a particular coastal area. Moreover, even though there may be no need to begin building dikes that are not needed for 50 years, it is appropriate to begin planning now to avoid actions that could increase vulnerability to the impacts of sea level rise. It will take 10 years to implement plans, in view of the time required for the necessary analyses, training the people, developing the plans and mobilizing the public and political awareness and support. Therefore, the process should begin today.

Protection from coastal impacts of sea level rise and other impacts of global climate change include both capital investment in defence structures and maintenance costs. Moreover if the sea continues to rise these structures may have to be augmented or replaced. Similarly non structural options to reduce vulnerability to impacts of sea level rise, such as land use planning, may require actions to implement and enforce them.

It is important to recognize that decisions today on planning for coastal development will greatly influence costs for later adaptation to impacts of sea level rise. Venice, Shanghai, New Orleans and Lagos are all vulnerable because of decisions made 200-2,000 years ago. It is therefore necessary, to establish some immediate priorities for planning and management of coastal resources and for technical and financial assistance to developing countries to facilitate their planning.

There is a need to provide developing countries with the technical and financial assistance required to plan for coastal development in order to reduce vulnerability to impacts of sea level rise. There is also a need to estimate the future long term funding requirements for developing countries that may be required if protection options are needed[34].

Finally, the success of strategies to limit climate change is a factor to be considered. Limitation measures will be likely to reduce the costs of adaptation to the coastal impacts of sea level rise. It is likely, however, that some adaptation to sea level rise will be required regardless of the limitation strategies eventually implemented[35].

7.2 PRIORITIES FOR ADAPTATION

7.2.1 Science/monitoring

There is still considerable uncertainty regarding sea level rise and other impacts of global climate change. This makes the selection of adaptation options extremely difficult. In particular, there is a lack of regional, national and site specific data that is needed to make decisions on adaptive options.

For example, a system to monitor, detect and predict sea level rise is needed to assist in determining the need for construction of protective structures or relocation of coastal inhabitants. There is also a need for information on other impacts, such as changes in tropical storms, in order to plan for natural emergencies[36].

7.2.2 Information

There is a great need to identify those areas that are most vulnerable to the impacts of sea level rise. The identification should concentrate on densely populated low lying areas, deltas and small atoll islands.

The need for clearing house arrangements to facilitate exchange of information and international databases accessible to all nations has also been identified.

Development of models and assessment techniques to support coastal planning needs to be undertaken in order to provide decision makers insight into the complicated interactions and conflicting interests that are involved in coastal zone management. Equally important is the transfer to developing countries of existing coastal adaptation technologies and the provision of training in coastal zone management, engineering and environmental monitoring. Such training might also include technology research centres, extension services, technology advisory committees, technology research and development, technology conferences and pilot projects to enhance technology transfer.

7.2.3 Planning

Many priorities have been identified within the broad area of planning. These include:

Emergency management planning to reduce vulnerability of inhabitants in areas exposed to extreme weather events.

Coastal management planning to reduce impacts on development structures and on natural resources of the highest priority. Technical and financial assistance to developing countries may be required to develop and implement national plans for management of coastal development.

7.2.4 Education and community participation

Public education and education of decision makers regarding the impacts of sea level rise and the impacts of ongoing activities is essential, so that everyone understands the risks of development in coastal areas[37]. The involvement of members of the local communities in selecting and implementing response options is also essential for the success of adaptive responses.

7.3 PRIORITIES FOR IMPLEMENTING ADAPTIVE OPTIONS IN DEVELOPING COUNTRIES

7.3.1 Retreat

Technical assistance to developing countries is required for timely planning for resettlement and emergency management pending resettlement. Financial assistance also may be needed to facilitate the resettlement. Assessments of potential relocation sites should be made to minimise dislocation difficulties such as linguistic diversity, cultural differences and long term viability.

7.3.2 Accommodation

Education, technical assistance and training are required for developing countries so that their populations can understand the risks of development in coastal areas in order to reduce vulnerability to impacts of possible sea level rise.

Technical assistance on alternative economic activities, for example mariculture instead of agriculture, is required to mitigate the social, cultural and economic implications of various options. Experience in this field exists in several developing countries and should be shared. The same holds true for alternatives to current coastal development activities. For example, using coastal areas for tourism rather than for industrial or residential activities, may also be a solution.

7.3.3 Protection

Protection options involving structures in most developing countries is likely to require external assistance. For example, the building of hard structures could require assistance such as transfer of skills and/or capital. There may also be a need for transfer of planning skills to support the choice of appropriate options.

7.4 CRITERIA FOR ALLOCATION OF RESOURCES

In addition to identifying priorities for adaptive responses it is also appropriate to identify the priorities that might be used to allocate resources. As the necessary resources vary considerably depending on the adaptive option and the coastal area, allocation criteria must include consideration of both the options and the area.

A list of sample criteria are provided in Table 6. There is no intention to suggest that any one criterion should be preeminent. Some may be more significant in some situations while other criteria may be more important than others.

TABLE 6. CRITERIA FOR ALLOCATION

related to the coastal area:

1. The contribution of current activities within the coastal area that contribute to its vulnerability to sea level rise;
2. The importance of the coastal area in terms of:
   - urgency of risk;
   - proportion of national land area;
   - population affected;
   - environmental importance;
   - economic importance;
   - social and cultural importance; and
   - regional importance.
3. The national ability to finance the response option;
4. The institutional and political ability to realize implementation.

related to the adaptative response option:

1. The cost of the option;
2. The effectiveness of the option;
3. Cost effectiveness;
4. The economic, environmental, social, cultural, legal and institutional implications of the adaptive option;
5. The vulnerability of the option to the impacts of an accelerated sea level rise;
6. Performance under uncertainty;
7. Equity.

REFERENCES AND ENDNOTES

1. Misdorp, R., 1990. "Existing Problems in the Coastal Zones: A Concern for the IPCC?". In: Changing Climate and the Coast, op cit.

2. Commonwealth Secretariat, 1989. Global Climate Change: Meeting the Challenge, p 131, London.

3. Halim, Y., 1974. The Nile and the East Levantine Sea, Past and Present. In: Recent Researches in Estuarine Biology, Editor: R. Natarujan, p 76-84. Hindustan Publishing Cooperation, Delhi, India.

4. Day, J.W. and P.H. Templet. "Consequences of Sea Level Rise: Implications from the Mississippi Delta". In: Expected Effects of Climatic Change on Marine Coastal Ecosystems, Editors: J.J. Beukema, W.J. Wolff and J.J.W.M. Bronns, p 155165. Kluwer Academic Publishers, Dordrecht, Boston, London.

5. Warrick, R.A. and J. Oerlemans, 1990. IPCC Working Group I: Chapter 9: Sea Level Rise.

6. Barth, M.C. and J.G. Titus (ed), 1984. Greenhouse Effect and Sea Level Rise: A Challenge for this Generation. New York: Van Nustrov Reinhold; Dean, R.G. et al., 1987. Responding to Changes in Sea Level. National Academy Press, Washington, D.C.

7. Emmanuel, K.A., 1988. The Dependence of Hurricane Intensity on Climate. <u>Nature</u> 326: 483-85.

8. IPCC-Working Group II, 1990. Chapter 5: World Ocean and Coastal Zones.

9. U.S. National Marine Fisheries Service, May 1989. Fisheries of the United States 1988. NOAA/NMFS, 1335 East-West Highway, Silver Spring, MD 20910, U.S.A.

10. Misdorp, R., F. Steyaert, F. Hallie and J. De Ronde, 1990. "Climate Change, Sea Level Rise and Morphological Developments in the Dutch Wadden Sea, a Marine Wetland". In: Expected Effects of Climatic Change on Marine Coastal Ecosystems, Editors: J.J. Beukema, W.J. Wolff and J.J.W.M. Bronns, p 123-133. Kluwer Academic Publishers, Dordrecht, Boston, London.

11. British Commonwealth, op cit. and Broadus, J.M., J.D. Milliman, S.F. Edwards, D.G. Aubrey and F. Gable, 1986. "Rising Sea Level and Damming of Rivers: Possible Effects in Egypt and Bangladesh." In: Effects of Changes in Stratospheric Ozone and Global Climate. United Nations Environment Programme and Environmental Protection Agency, Washington, D.C.

12. Hulm, Peter, 1989. A Climate of Crisis: Global Warming and the South Pacific Islands; The Associations of South Pacific Environmental Institutions, Port Moresby, Papua New Guinea; and Lewis, James, 1989. Sea Level Rise: Some Implications for Tuvalu; AMBIO, v. XVIII, no. 8.

13. Broadus, J., J. Milliman and F. Gable, 1986. "Sea Level Rise and Damming of Rivers". In: UNEP Effects of Changes in Stratospheric Ozone and Global Climate.

14. Personal communication with Dr. Nguyen Ngoc Thuy, Marine Hydrometeorological Centre, 4 Dang thai Than Street, HANOI, Vietnam, at the Perth CZMS Workshop.

15. Jacobson, J.L., 1990. "Holding Back the Sea". In: Changing Climate and the Coast: Report to the IPCC from the Miami Conference on Adaptive Responses to Sea Level Rise and Other Impact of Global Climate Change (Proceedings of the Miami Workshop).

16. Jansen, M., 1990. "The Role of Coastal Zone Management in Sea Level Rise Response". In: Changing Climate and the Coast, op cit.

17. Leatherman, S.P., 1990. "Environmental Implications of Shore Protection Strategies along Open Coasts (with a Focus on the United States)". In: Changing Climate and the Coast, op cit.

18. Titus, J.G., 1990. Strategies for Adapting to the Greenhouse Effect. Journal of the American Planning Association;
Titus, J.G. 1991. Greenhouse Effect and Coastal Wetland Policy. Environmental Management.

19. Pope, J.J. and T.A. Chisholm, 1990. "Coastal Engineering Options by Which Hypothetical Community Might Adapt to Changing Climate." In: Changing Climate and the Coast, op cit.; and Sorensen, R.M., R.N. Weisman and G.P. Lennon, 1984. "Control of Erosion, Inundation and Salinity Intrusion." In: Barth and Titus (eds), op cit.

20. U.S. Army Corps of Engineers, Coastal Engineering Research Centre, 1977. Shore Protection Manual. Coastal Engineering Research Centre, Fort Belvoir, Virginia, U.S.A.

21. Misdorp, R. and R. Boeije, 1990. "A Worldwide Overview of Near Future Dredging Projects Planned in the Coastal Zone." In: Changing Climate and the Coast, op cit. See also Titus, J.G. Greenhouse Effect, Sea Level Rise and Barrier Islands. Coastal Management 18:1.

22. Misdorp, R., 1990. Strategies for Adapting to the Greenhouse Effect: A Global Survey of Coastal Wetlands. The Netherlands, Rijkswaterstaat, Tidal Waters Division, Note GWWS-90.008.

23. Howard, J.D., O.J. Pilkey and A. Kaufman, 1985. Strategy for Beach Preservation Proposed. Geotimes 30:12:15-19.

24. Titus, J.G., R. Part and S. Leatherman, 1990. The Coast of Holding Back the Sea. Coastal Management (in press).

25. Park, R.A., 1990. "Implications of Response Strategies for Water Quality". In: Changing Climate and the Coast, op cit.

26. Leatherman, S.P., 1990. "Environmental Impacts of Sea Level Response Strategies". In: Changing Climate and the Coast, op cit.

27. Moser, D.A., E.Z. Stakhiv and L. Vallianos, 1990. "Risk-Cost Aspects of Sea Level Rise and Climate Change in the Evaluation of coastal Protection Projects". In: Changing Climate and the Coast, op cit.

28. Yohe, G.W., 1990. "Toward an Analysis of Policy, Timing and the Value of Information in the Face of Uncertain Greenhouse-Induced Sea Level Rise". In: Changing Climate and the Coast, op cit.

29. The calculations underlying these estimates also assume a one metre sea level rise in 100 years; that externalities such as other effects of climate change are nil; that present boundary conditions (geomorphological, economic, social) are maintained; and that costs are based on present conditions. The estimates assume that current flood risks remain constant; e.g. areas flooded once every ten years today would still be flooded every ten years when sea level has risen one metre.

30. Charlier, R.H., 1987. "Planning for Coastal Areas". In: Ecology for Environmental Planning, F.C. Wollf ed., Norges Geologiske Underskolse, Trondheim, Norway.

31. Yohe, G.W., 1990. "Toward an Analysis of Policy, Timing and the Value of Information in the Face of Uncertain Greenhouse-Induced Sea Level Rise". In: Changing Climate and the Coast, op cit.

32. Fishman, R.L, and L. St. Amand, 1990. "Preserving Coastal Wetlands and Sea Level Rises: Legal Opportunities and Constraints". In: Changing Climate and the Coast, op cit.

33. Shihab, H. (ed). Proceedings of the Small States Conference on Sea Level Rise, Environment Section. Male, Republic of the Maldives.

34. Campbell, J., 1990. "Funding Implications for Coastal Adaptations to Climate Change: Some Preliminary Considerations". In: Changing Climate and the Coast, op cit.

35. Warrick, R.A. and J. Oerlemans, 1990. IPCC-

Working Group I: Chapter 9: Sea Level Rise.

36. Intergovernmental Oceanographic Commission of UNESCO. Global Sea Level Observing System (GLOSS) Implementation Plan. UNESCO/IOC Secretariat, 7, Place de Fontenoy, Paris, France, 75700.

37. Maroukian, K., 1990. "Implications of Sea Level Rise for Greece"; Erol, O., "Impacts of Sea Level Rise on Turkey"; Muehe, D. and C.F. Neves, "Potential Impacts of Sea Level Rise on the Coast of Brazil"; Andrade B. and C. Castro, "Impacts of and Responses to Sea Level Rise in Chile"; Adam, K.S., "Implications of Sea Level Rise for Togo and Benin"; and Ibe, A.C., "Adjustments to the Impact of Sea Level Rise Along the West and Central African Coast". In: Changing Climate and the Coast, op cit.

APPENDIX A

EXECUTIVE SUMMARY: POLICYMAKERS OF THE IPCC-RESPONSE STRATEGIES WORKING GROUP

EXECUTIVE SUMMARY: POLICYMAKERS OF THE IPCC-RESPONSE STRATEGIES WORKING GROUP

Working Group III (Response Strategies Working Group) was tasked to formulate appropriate (Fig. Al) response strategies to global change. This was to be done in the context of the work of Working Group I (Science) and Working Group II (Impacts) which concluded that:

"We are certain emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluoro-carbons (CFCs) and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface".

"The longer emissions continue at present day rates, the greater reductions would have to be for concentrations to stabilize at a given level".

"The long lived gases would require immediate reductions in emissions from human activities of over 6096 to stabilize their concentrations at today's levels".

"Based on current model results, we predict under the IPCC Business-as-Usual emissions of greenhouse gases, a rate of increase of global mean temperature during the next century of about 0.3°C per decade (with an uncertainty range of 0.2°C to 0.5°C per decade), greater than that seen over the past 10,000 years; under the same scenario, we also predict an average rate of global mean sea level rise of about 6 cm per decade over the next century (with an uncertainty range of 3 - 10 cm per decade)".

"There are many uncertainties in our predictions particularly with regard to the timing, magnitude and regional patterns of climate change".

"Ecosystems affect climate and will be affected by a changing climate and by increasing carbon dioxide concentrations. Rapid changes in climate will change the composition of ecosystems; some species will benefit while others will be unable to migrate or adapt fast enough and may become extinct. Enhanced levels of carbon dioxide may increase productivity and efficiency of water use of vegetation".

"In many cases, the impacts will be felt most severely in regions already under stress, mainly the developing countries".

"The most vulnerable human settlements are those especially exposed to natural hazards, e.g., coastal or river flooding, severe drought, landslides, severe storms and tropical cyclones".

Any responses will have to take into account the great diversity of different countries' situations and their responsibility for and negative impacts on different countries and consequently would require a wide variety of responses. Developing countries for example are at widely varying levels of development and face a broad range of different problems. They account for 7596 of the world population and their primary resource bases differ widely. Nevertheless, they are most vulnerable to the adverse consequences of climate change because of limited access to the necessary information, infrastructure and human and financial resources.

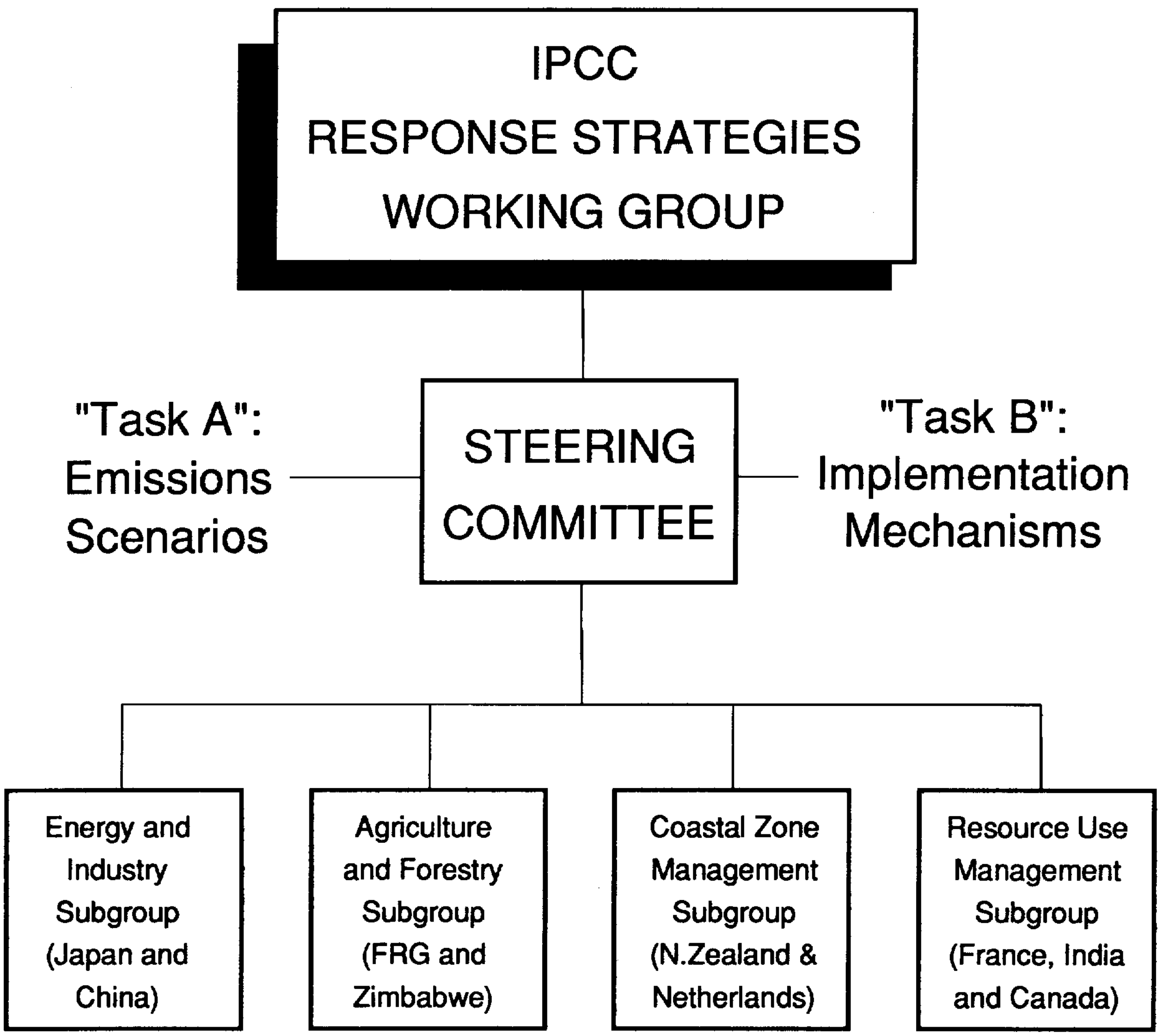

IPCC
RESPONSE STRATEGIES
WORKING GROUP
"Task A":
Emissions
Scenarios
STEERING
COMMITTEE
"Task B":
Implementation
Mechanisms
Energy and Industry Subgroup (Japan and China)
Agriculture and Forestry Subgroup (FRG and Zimbabwe)
Coastal Zone Management Subgroup (N.Zealand & Netherlands)
Resource Use Management Subgroup (France, India and Canada)

Fig A.1.

MAIN FINDINGS

1. Climate change is a global issue; effective responses would require a global effort which may have a considerable impact on mankind and individual societies.

2. Industrialized countries and developing countries have a common responsibility in dealing with problems arising from climate change.

3. Industrialized countries have specific responsibilities on two levels:
   a) major part of emissions affecting the atmosphere at present originates in industrialized countries where the scope for change is greatest. Industrialized countries should adopt domestic measures to limit climate change by adapting their own economies in line with future agreements to limit emissions;
   b) to cooperate with developing countries in international action, without standing in the way of the tatter's development, by contributing additional financial resources, by appropriate transfer of technology, by engaging in close cooperation concerning scientific observation, by analysis and research and finally by means of technical cooperation geared to forestalling and managing environmental problems.

4. Emissions from developing countries are growing and may need to grow in order to meet their development requirements and thus, over time, are likely to represent an increasingly significant percentage of global emissions. Developing countries have the responsibility, within the limits feasible, to take measures to suitably adapt their economies.

5. Sustainable development requires the proper concern for environmental protection as the necessary basis for continuing economic growth. Continuing economic development will increasingly have to take into account the issue of climate change. It is imperative that the right balance between economic and environmental objectives be struck.

6. Limitation and adaptation strategies must be considered as an integrated package and should complement each other to minimize net costs. Strategies that limit greenhouse gases emissions also make it easier to adapt to climate change.

7. The potentially serious consequences of climate change on the global environment give sufficient reasons to begin by adopting response strategies that can be justified immediately even in the face of significant uncertainties.

8. A well informed population is essential to promote awareness of the issues and provide guidance on positive practices. The social, economic and cultural diversity of nations will require tailored approaches.

A FLEXIBLE AND PROGRESSIVE APPROACH

Greenhouse gas emissions from most sources are likely to increase significantly in the future if no response measures are taken. Although some controls have been put in place under the Montreal Protocol for CFCs and halons, emissions of CO_2, CH_4, N_2O and other gases such as several CFC-substitutes will grow. Under these scenarios, it is estimated that CO_2 emissions will increase from approximately 7 billion (or 1000 million) tonnes carbon (BtC) in 1985 to between 11-15 BtC by 2025. Similarly, man made methane emissions are estimated to increase from about 300 teragrams (Tg) to over 500 Tg by the year 2025. Based on these projections, Working Group I estimated that a global warming of 0.3°C/decade could occur.

The climate scenario studies of Working Group I further suggest that control policies on emissions can indeed slow global warming, perhaps from 0.3°C/decade to 0.1°C/decade. The social, economic and environmental costs and benefits of these control policies have not been fully assessed. It must be emphasized that implementation of measures to reduce global emissions are very difficult as energy use, forestry and land use patterns are primary factors in the global economy. To take maximum advantage of our increasing understanding of scientific and socio-economic aspects of the issue, a flexible and progressive approach is required. Subject to their particular circumstances, individual nations may wish to consider taking steps now to attempt to limit, stabilize or reduce the emission of greenhouse gases resulting from human activities and to prevent the destruction and improve the effectiveness of sinks. One option that governments may wish to consider is the setting up of targets for CO_2 and other greenhouse gases.

Because a large increase in world population will be a major factor in causing the projected increase in global greenhouse gases, it is essential that global climate change strategies include strategies and measures to deal with the rate of growth of the world population.

SHORT-TERM

The Working Group has identified measures at the national, regional and international levels as applicable which, while helping to tackle climate change, can yield other benefits.

Limitations

- Improved energy efficiency reduces emissions of carbon dioxide, the most significant greenhouse gas, while improving overall economic performance and reducing other pollutant emissions and increasing energy security.

- Use of cleaner energy sources and technologies reduces carbon dioxide emissions, while reducing other pollutant emissions that give rise to acid rain and other damaging effects.

- Improved forest management and, where feasible, expansion of forest areas as possible reservoirs of carbon.

- Phasing out of CFCs under the Montreal Protocol, thus removing some of the most powerful and long lived greenhouse gases, while also protecting the stratospheric ozone layer.

- Agriculture, forestry and other human activities are also responsible for substantial quantities of greenhouse gas emissions. In the short term, reductions can be achieved through improved livestock waste management, altered use and formulation of fertilizers and other changes to agricultural land use, without affecting food security, as well as through improved management in landfill and waste water treatment.

Adaptations

- Developing emergency and disaster preparedness policies and programmes.

- Assessing areas at risk from sea level rise and developing comprehensive management plans to reduce future vulnerability of populations and coastal developments and ecosystems as part of coastal zone management plans.

- Improving the efficiency of natural resource use, research on control measures for desertification and enhancing adaptability of crops to saline regimes.

LONG-TERM

Governments should prepare for more intensive action which is detailed in the report. To do so, they should undertake now:

- Accelerated and coordinated research programmes to reduce scientific and socio-economic uncertainties with a view towards improving the basis for response strategies and measures.
- Development of new technologies in the fields of energy, industry and agriculture.

- Review planning in the fields of energy, industry, transportation, urban areas, coastal zones and resource use and management.

- Encourage beneficial behaviourial and structural (e.g. transportation and housing infrastructure) changes.

- Expand the global ocean observing and monitoring systems.

It should be noted that no detailed assessments have been made as yet of the economic costs and benefits, technological feasibility or market potential of the underlying policy assumptions.

INTERNATIONAL COOPERATION

The measures noted above require a high degree of international cooperation with due respect for national sovereignty of states. The international negotiation on a framework convention should start as quickly as possible after the completion of the IPCC First Assessment Report. This, together with any additional protocols that might be agreed upon, would provide a firm basis for effective cooperation to act on greenhouse gas emissions and adapt to any adverse effects of climate change. The convention should, at a minimum, contain general principles and obligations. It should be framed in such a way as to gain the adherence of the largest possible number and most suitably balanced range of countries while permitting timely action to be taken.

Key issues for negotiation will include the criteria, timing, legal form and incidence of any obligations to control the net emissions of greenhouse gases, how to address equitably the consequences for all, any institutional mechanisms that may be required, the need for research and monitoring and in particular, the request of the developing countries for additional financial resources and for the transfer of technology on a preferential basis.

FURTHER CONSIDERATION

The issues, options and strategies presented in this document are intended to assist policy makers and future negotiators in their respective tasks. Further consideration of the summary and the underlying reports of Working Group III should be given by every government as they cut across different sectors in all countries. It should be noted that the scientific and technical information contained in the Policy Makers Summary and the underlying reports of Working Group III do not necessarily represent the official views of all governments, particularly those that could not participate fully in all Working Groups.

APPENDIX B

COMPENDIUM OF INFORMATION ON TECHNIQUES AND PRACTICES IN ADAPTIVE COASTAL STRATEGIES

COMPENDIUM OF INFORMATION SOURCES PERTAINING TO TECHNIQUES AND PRACTICES APPLICABLE TO FORMULATING AND IMPLEMENTING STRATEGIES FOR ADAPTING TO SEA LEVEL RISE

This compendium is structured to provide a broad base of possible reference needs that can serve the mufti-disciplinary community of professionals having interest and responsibilities in formulating and implementing adaptive responses to a rise in sea level.

Specifically, it is an eclectic listing of sources of information covering the subject areas of:

(a) Climate Change and Related Impacts and Responses;

(b) Multi-Objective Planning Principles and Methodologies;

(c) Non-Structural Techniques and Practices in Coastal Zone Management (including example laws and regulations);

(d) Structural Measures Applied in Coastal Zone Management (including selected references in the basic Principles and Practices of Coastal Engineering).

These information sources, in combination with their respective bibliographical listings, should serve most reference needs.

I. <u>CLIMATE CHANGE AND RELATED IMPACTS AND RESPONSES</u>

REFERENCES:

Holdgate, M. W., et al. 1989, "Climate Change: Meeting the Challenge," Report by a Commonwealth Group of Experts, Commonwealth Secretariat, Marlborough House, Pall Mall, London SW 1 Y SHX, England.

The Beijer Institute, 1989, "The Full Range of Responses to Anticipated Climate Change," United Nations Environment Programme, UN Publications, Room DC 2-853, New York, New York 10017, USA.

Prime Minister's Science Council, 1989, "Global Climatic Change--Issues for Australia," Commonwealth of Australia, Manager GPO Box 84, AGPS Press, Canberra ACT2601, Australia.

Mehta, A. J., et al. 1988, "Workshop on Seal Level Rise and Coastal Processes," DOE/NBB-0086, National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, USA.

Committee on Engineering Implications of Changes in Relative in Relative Mean Sea Level, 1987, "Responding to Changes in Sea Level," Marine Board, National Research Council, Academy Press, 2001 Wisconsin Ave., N.W., Washington, D.C. 20418, USA.

Wind, H. G. (Editor), 1987, "Impact of Sea Level Rise on Society," <u>Report of a Project Planning Session</u>, Delft 27-29 August 1986, A.A. Balkema, P.O. Box 1675, 3000 BR Rotterdam, Netherlands.

II. MULTI-OBJECTIVE PLANNING PRINCIPLES AND METHODOLOGIES

REFERENCES:

Burke, R. and Heaney, J. P., 1975, "Collective Decision Making in Water Resource Planning," D.C. Heath and Company, 125 Spring Street, Lexington, Massachusetts 02173, USA.

Goodman, A. S., 1984, "Principles of Water Resources Planning," Prentice-Hall, Inc., Rte. 9W, Englewood Cliffs, New Jersey 07632, USA.

Hobbs, B. F., et al., 1989, "Impact Evaluation Procedures: Theory, Practice and Needs," <u>Journal of Water Resources Planning and Management</u>, Volume 115, No. 1, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Krutilla, J. V. and Fisher, A. C., 1978, "The Economics of Natural Environments," The Johns Hopkins University Press, 701 W. 40th Street, Suite 275, Baltimore, Maryland 21211, USA.

McAllister, D. M., 1982, "Evaluation in Environmental Planning," The MIT Press, 55 Hayward Street, Cambridge, Massachusetts 02412, USA.

Stakhiv, E. Z., 1986, "Achieving Social and Environmental Objectives in Water Resources Planning: Theory and Practice," <u>Proceedings of an Engineering Foundation Conference Sponsored by the Committee on Social and Environmental Objectives of the Water Resources Planning and Management Division</u>, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Water Resources Council, 1983, "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies," Superintendent of Documents, US Government Printing Office, Washington, DC 20402, USA.

Bentkover, J. D., et al., 1986, "Benefits Assessment: The State of the Art," D. Reidel Publishing Company, Post Box 17, Dordrecht, Netherlands.

Cohon, J. L., 1978, "Multi objective Programming and Planning," Academic Press, 1250 Sixth Avenue, San Diego, California 92101, USA.

Isard, W., et al., 1972, "Ecological-Economic Analysis for Regional Development," The Free Press, 866 Third Avenue, New York, New York 10022, USA.

Thompson, M. S., 1980, "Benefit-Cost Analysis for Program Evaluation," Sage Publications, Inc., 211 W. Hillcrest Drive, Newbury Park, California 91320, USA.

Douglas, M. T., 1985, "Risk Acceptability According to the Social Sciences," Russel Sage Foundation, Basic Books, Inc., 10 E. 53rd Street, New York, New York 10022, USA.

Haefele, E. T. (Editor), 1974, "The Governance of Common Property Resources," Resources for the Future, Inc., The John Hopkins University Press, 701 W. 40th Street, Suite 275, Baltimore Maryland 21211, USA.

Finsterbusch, K. and Wolf, C. P. (Editors), 1977, "Methodology of Social Impact Assessment," Dowden, Hutchinson & Ross, Inc., Box 699, Stroudsburg, Pennsylvania 18360, USA.

III. NON-STRUCTURAL TECHNIQUES AND PRACTICES IN COASTAL ZONE MANAGEMENT

A. SET-BACK LAWS/REGULATIONS - Prohibit development within a specified distance from the shoreline.

REFERENCES:

Cano, G. J., 1989, "Legal and Institutional Implications of Adaptive Options of Sea Level Rise in Argentina, Uruguay and Spain," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration, (N/IA), 1825 Connecticut Avenue, Washington, D.C. 20235, USA.

Coutts, B. J., 1989, "Mean High Water as a Cadastral Boundary," Ocean and Shoreline Management, 12(4), Elsevier Applied Science, Crown House, Lipton Road, Barking, Essex IG11 8JU, England.

Edgerton, L., 1990, Policy Recommendations to Respond to Accelerated Sea Level Rise from Global Warming, Natural Resource Defense Council, 40 W. 20th Street, New York, New York 10011, USA.

Mittler, E., 1989, "Natural Hazard Policy Setting," Monograph No. 48, Natural Hazards Research and Applications Information Centre, University of Colorado, P.O. Box 482, Boulder, Colorado 80309, USA.

Pilkey, O. H., Sr., et al., 1983, Coastal Design - A Guide for Builders, Planners, & Homemakers, Van Nostrand Reinhold, 115 Fifth Avenue, New York, New York 10003, USA.

Stutts, A. T., et al., 1985, "Effect of Ocean Setback Standards on the Location of Permanent Structures," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Tuttle, D. C., 1987, "A Small Community's Response to Catastrophic Coastal Bluff Erosion," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA. Law: Regulation 0007 (May 3, 1982) established by the Director of Ports and Coasts of the Brazilian Navy.
Purpose: It gives the "Capitania dos Portos" the

authority for fiscalization of the shores.
Relation to CZM: It prohibits building walls, fences or any construction in public use area ("terreno de marinha," see the Code for Water Resources further below) that may impeach the access to the beach. The plans for any construction near the shore should be submitted to the Navy (specifically, to the "Capitania dos Portos) for approval.
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/ Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

Law: Beach Control Ordinance (Cap. 297, 1959).
Purpose: Prohibits the use of the foreshore or floor of the sea except in accordance with a licence from the Minister.
Relation to CZM: Vests all rights in and over the foreshore and the 'floor of the sea' in the Crown and confers on the Minister (of Agriculture, Fisheries and Lands) the right to regulate the use of this area and adjoining land to a distance of "not more than fifty yards beyond the landward limit of the foreshore" and to license its use... "for any public purpose, or for, or in connection with, any trade, business or commercial enterprise to any person, upon such conditions and in such form as he may think fit." Section 5(1).
Reference: Freestone, D., 1989, "Coastal Zone Management in Antigua and Barbuda" abstract in Proceedings of 1989 Coastal Zone Management Symposium, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA. Full text available from Author, Institute of Estuarine and Coastal Studies and Law School, University of Hull, HU6 7RX, England.

Law: The "Ley Maritima-Terrestre" of 1977 (Coastal Management Law)
Purpose: Regulate coastal development and management in Costa Rica.
Relation to CZM: This law establishes a 50 meter set back protection line measured from mean high tide. No development is allowed seaward of the set-back line. Additionally a 200 meter strip adjoining the set-back line has been established in which development is regulated. Development within this strip must follow a specific management plan approved by a regulatory commission consisting of the Institute of Housing and Urban Development, Municipalities, the Forest Service and the Institute of Tourism. This regulation affects only those developments taking place after the law was issued.
Reference: Quesada, C.A., Director of ECODES, Ministero De Recursos Naturales, Engergia Y Minas. Apartado 10104, San Jose, Costa Rica.

Alabama: Coastal Construction Control Line, 1985 amendment. Provides long-term protection for coastal property, beaches and dune systems and for preservation of the aesthetics of the shoreline. Alabama Department of Economic and Commercial Affairs, P.O. Box 250347, Montgomery, AL 36125-0347 USA.

Delaware: Beach Preservation Act, Title 7, Chapter 68, 1972. Establishes setbacks. Delaware Department of Natural Resources and Environmental Control, P.O. Box 1401, Dover, DE 19903, USA.

Florida: Coastal Zone Protection Act of 1985. Provides a strict building code which defines the building zone as the seasonal highwater mark to 1,500 feet landward of the existing coastal construction control line for mainland areas and 5,000 feet landward of the coastal construction line for barrier islands. Florida Office of Coastal Management, 2600 Blair Stone Road, Tallahassee, Florida 32301, USA.

Hawaii: Shoreline Setback Law, chapter 205A-43, Part II, HRS. Hawaii Office of State Planning, State Capitol, Room 410, Honolulu, Hawaii, 96813, USA.

Maine: Sand Dune Law, 1987 Amendment. Prohibits enlargements or placements of seawalls or other erosion control structures in erosion hazard areas and requires consideration of sea level rise when siting shoreline development. State of Maine Planning Office, State House Station No. 38, Augusta, ME 04333, USA.

New Jersey: Coastal Area Facility Review Act (CAFRA), the Wetlands Act and the Waterfront Development Law Amendments. Places prohibition on development in erosion hazard areas, contains setback provisions and provides definition of conditions under which ocean front shore protection structures are allowed. New Jersey Department of Environmental Protection, Division of Coastal Resources, CN401, Trenton, NJ 08625, USA.

North Carolina: Coastal Area Management Act, 1985 Amendment. Prohibits any fixed structures as a method of preventing oceanfront erosion along the State's coastal area. North Carolina Division of Coastal Management, 512 North Salisbury Street, Raleigh, NC 27611, USA.

South Carolina: Beach Management Act, 1988. Establishes a 40-year retreat policy, baselines, setback lines and identifies the type of structures allowed within various portions of the beach and dune systems. South Carolina Coastal Council, AT&T Capitol Centre, 1201 Main Street, Columbia, SC 29201, USA.

B. STRUCTURAL STANDARDS -
Provide building codes for structures to resist the effects of high water levels, waves and winds.

REFERENCES:

Clark, R. R., 1982, "Structural Design Aspects of a Coastal Building Code," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

"Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas," 1981, Federal Emergency Management Agency Report FIA-7, U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Room 8100, 451 7th Street, SW, Washington, D.C. 20410, USA.

Directory of Building Codes and Regulations, 1989, National Conference of States on Building Codes and Standards, 481 Carlisle Drive, Herndon, Virginia 22070, USA.

Godschalk, D. R., et al., 1989, Catastrophic Coastal Storms: Hazard Mitigation and Development Management, Duke University Press, Box 6697 College Station, Durham, North Carolina 27708, USA.

Pilkey, O. H., Sr., et al., 1983, Coastal Design - A Guide for Builders, Planners, & Homeowners," Van Nostrand Reinhold, 115 Fifth Avenue, New York, New York 10003, USA.

C. ZONING -
Regulatory restrictions on land use in the coastal zone to prevent or diminish damage caused by storm surge and waves.

REFERENCES:

Cano, G. J., 1989, "Legal and Institutional Implications of Adaptive Options of Sea Level Rise in Argentina, Uruguay and Spain," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

"Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas," 1981, Federal Emergency Management Agency Report FIA-7, U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Room 8100, 451 7th Street, SW, Washington, D.C. 20410, USA.

Fischman, R. L. and L. St. Amand, 1989, "Legal Implications of Response Strategies to Mitigate Coastal Wetlands Loss from Sea Level Rise," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Godschalk, D. R., et al., 1989, Catastrophic Coastal Storms: Hazard Mitigation and Development Management, Duke University Press, Box 6697 College Station, Durham, North Carolina 27708, USA.

L. R. Johnston, Associates, 1989, "A Status Report on the Nation's Flood Plain Management Activity (An Interim Report)," Interagency Task Force on Flood Plain Management, Federal Emergency Management Agency, Federal Centre Plaza, 500 C Street, SW, Washington, D.C. 20472, USA.

Klarin, P. and M. Hershman, 1989, "Institutional Responses to Sea Level Rise: The Role of Coastal Zone Management Systems in Current Policy Development," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Moffatt and Nichol, Engineers, Wetland Research Associates, Inc. and San Francisco Bay Conservation and Development Commission Staff, 1987, "Future Sea Level Rise: Predictions and Implications for San

Francisco Bay", San Francisco Bay Conservation and Development Commission, 30 Van Ness Avenue, Room 2011, San Francisco, California 94102, USA.

I. C. F., Inc., H. Crane Miller and Steven P. Leatherman, 1989, "Developing Policies to Improve the Effectiveness of Coastal Floodplain Management", The New York/New England Coastal Zone Task Force, Division of Coastal Resources and Waterfront Revitalization, Department of State, 162 Washington Street, Albany, New York 12231, USA.

Office of Ocean and Coastal Resource Management, 1988, "Planning for Sea Level Rise," Natural Hazards Issues Study Group Information Memorandum, Issue No. 4, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Office of Ocean and Coastal Resource Management, 1989, "Shoreline Erosion: A Management Priority," Natural Hazards Issues Study Group Information Memorandum, Issue No. 5, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Pilkey, O. H., Sr., et al., 1983, "Coastal Design - A Guide for Builders, Planners, & Homemakers", Van Nostrand Reinhold, 115 Fifth Avenue, New York, New York 10003, USA.

Law: Federal Laws 2463 (July 10, 1934) and 852 (November 11, 1938). "Codigo de Aguas"
Purpose: These laws establish the uses of water resources, define their property, as well as the uses and property of the margins. The legislation covers: rivers, streams, lakes, coastal waters, aquifers, pollution of waters, hydroelectric power generation.
Relation to CZM: For coastal zone management, the laws establish that a strip of land 33 meters inland of the high water line in November 15, 1831, belongs to the Union. This strip is called "terrenos de marinha." Private use of the land is allowed, however the proprietary must grant free public access to the beach and shore, even across the lot. Along rivers and water bodies not subject to tidal fluctuations, the law establishes an area 15 meters wide.
Neves, C., Programa de Engenharia Oceanica, COPPE/Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

Law: Rio de Janeiro State Law 2330 (January 9, 1979).
Purpose: It establishes the System for Protection of Lakes, Lagoons and Streams in the State of Rio de Janeiro (SPLCA/RJ). The SPLCA/RJ is controlled by the State Committee for Environment Control (CECA).
Relation to CZM: The following tasks are included in the SPLCA/RJ: the "Projeto de Alinhamento de Rio" (a project for establishing location or rivers); the "Projeto de Alinhamento de Orla de Lago" (a project to demarcate the contour of lakes and coastal lagoons); the "Faixa Marginal de Protecao" (the strip of land around lakes and coastal lagoons where any construction is forbidden); and the "Licenca para Extracao de Areia" (regulation for sand mining). The fiscalization is done by SERLA and fines are established by this law.
Neves, C., Programa de Engenharia Oceanica, COPPE/Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

D. LAND-USE PLANNING -

Long range planning on use of coastal lands to minimize impact of high water levels. This may include purchase and clearance of lands as an alternative to protection.

REFERENCES:

Al-Gain, A., et al., 1987, "A Coastal Management Program for the Saudi Arabian Red Sea Coast," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Baines, G. B. K., 1987, "Coastal Area Management for the South Pacific Islands," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Birkemeier, W. A., et al., 1987, "Feasibility Study of Quantitative Erosion Models for Use by the Federal Emergency Management Agency in the Prediction of Coastal Flooding," TR CERC-87-8, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Brandani, A., 1987, "Coastal Management Efforts in Argentina," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New

York 10017, USA.

Burby, R. J., et al., 1985, Flood Plain Land Use Management: A National Assessment, Westview Press, 5500 Central Avenue, Boulder, Colorado 80301, USA.

Burby, R. J., et al., 1988, Cities Under Water, Natural Hazards Research and Applications Information Centre, University of Colorado, P.O. Box 482, Boulder, Colorado 80309, USA.

Cambers, G., 1987, "Coastal Zone Management Programmes in Barbados and Grenada," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Clark, J. R., 1989, "Coastal Zone Management: A State Program for Yucatan, Mexico," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Coastal Programs Division, 1988, "Coastal Management: Solutions to Our Nation's Coastal Problems," Technical Bulletin No. 101, Office of Ocean and Coastal Resource Management, National Ocean Service, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Coetzee, M. J. D. and N. D. Geldenhuys, 1989, "Progress with the Implementation of Coastal Management in Southern Africa," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Comfort, L. K., (Editor), 1988, Managing Disaster, Duke University Press, Box 6697 College Station, Durham, North Carolina 27708, USA.

Cornforth, R. C., 1984, "Towards a National Coastal Policy," Proceedings 3rd Biennial Coastal Zone Management Seminar, Nelson, Department of Lands and Survey, New Zealand, Information Series No. 15, Ministry of the Environment, P.O. Box 10362, Wellington, New Zealand.

Cullen, P., 1982, "Coastal Zone Management in Australia," Coastal Zone Journal, 10(3), Taylor and Francis, 79 Madison Avenue, New York, New York 10016, USA.

Fischer, D. W., 1989, "Response to Coastal Storm Hazard: Short-term Recovery Versus Long-term Planning," Ocean and Shoreline Management, 12(4), Elsevier Applied Science, Crown House, Lipton Road, Barking, Essex IG11 8JU, England.

Freestone, D., 1989, "Coastal Zone Management in Antigua and Barbuda," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Frischeisen, E. R., 1989, "The Coastal Management Program in Brazil," Coastlines of Brazil, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Fukuya, M., et al., 1989, "Laws and Regulations for Coastal Management in Japan," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Godschalk, D. R., et al., 1989, Catastrophic Coastal Storms: Hazard Mitigation and Development Management, Duke University Press, Box 6697 College Station, Durham, North Carolina 27708, USA.

Hildebrand, L. P., 1987, "The Canadian Experience with Coastal Zone Management," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Ibe, A. C., 1987, "Collective Response to Erosion Along the Nigerian Coastline," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Johnson, D. C., 1989, "Ocean Islands and Coastal Zone Management," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Katz, A., 1987, "Coastal Management Options in Belize," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Keillor, P. and A. H. Miller, 1989, "Teaching Investors to Evaluate Coastal Property," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kuroiwa, J., 1986, "Physical Planning for Multi-Hazard Mitigation," Natural and Man-Made Hazards, El-Sabh, M. I. and T. S. Murty (Editors), D. Reidel Publishing Company, Post Box 17, Dordrecht, Netherlands.

L. R. Johnston, Associates, 1989, "A Status Report on the Nation's Flood Plain Management Activity (An Interim Report)," Interagency Task Force on Flood Plain Management, Federal Emergency Management Agency, Federal Centre Plaza, 500 C Street, SW, Washington, D.C. 20472, USA.

Looi, C. K., 1987, "Coastal Zone Management Plan Development in Malaysia: Issues and Problems," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Lowenstein, F., 1985, "Beaches or Bedrooms - The Choice as Seal Level Rises," Oceanus, 28 No. 3., Woods Hole Oceanographic Institute, Box 6419, Syracuse, New York 13217, USA.

Meo, M., 1989, "Climate Change Impacts on Coastal Environments: Implications for Strategic Planning," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Mura, P. M., 1989, Coastal Planning and Conservation Policies in Italy," Coastlines of Italy, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Parker, D. J. and E. C. Penning- Rowsell, 1981, "Whitestable Central Area Coast Protection Scheme: Benefit Assessment," Paper No. 23, Flood Hazard Research Centre, Middlesex Polytechnic, Middlesex, England.

Pattison, R. C., 1987, Coastal Management: The Costa Rican Experience," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Pilkey, W. D. and O. Pilkey, 1985, "Are we Ready to Consider Shoreline Buildings as Being Expendable?," California's Battered Coast, Conference Proceedings, California Coastal Commission, 631 Howard Street, 4th Floor, San Francisco, California 94105, USA.

Salm, R. V. and J. A. Dobbin, 1989, "Coastal Zone Management, Planning and Implementation in the Sultanate of Oman," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Suman, D., 1987, "The Management of Coastal Zone Resources in Panama," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Titus, J. G. and M. S. Greene, 1989, "Appendix: An Overview of the Nationwide Impacts of Sea Level Rise," Potential Effects of Global Climate Change on the United States, Smith, J. B. and D. A. Tirpak (Editors), Office of Policy, Planning and Evaluation, Environmental Protection Agency, 401 M Street, SW, Washington, D.C. 20460, USA.

Tolentino, A. S., Jr., 1987, "Philippine Coastal Zone Management: Organizational Linkages," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Weaver, D. F. and D. L. Hayes, 1989, "Proposed Response to Sea Level Rise by a Local Government," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Wickremeratne, H. M. J. and S. R. Amarasinghe, 1987, "From Activity Management to Resource Management - Sri Lanka CZM Programme," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Yohe, G. W., 1989, "Appendix: The Cost of Not Holding Back the Sea: A Case Study of Long Beach Island, New Jersey," Potential Effects of Global Climate Change on the United States, Smith, J. B. and D. A. Tirpak (Editors), Office of Policy, Planning and Evaluation, Environmental Protection Agency, 401 M Street, SW, Washington, D.C. 20460, USA.

New Hampshire, 1987, Study entitled, "The Rise in Sea Level and Coastal Zone Planning", New Hampshire Coastal Program, Office of State Planning, 2 Bacon Street, Concord, NH 03301 USA.

The Sounds Conservancy, Inc., 1989, "Planning for SLR in Southern New England," The Sounds of

Conservancy, Inc., 43 Main Street, Box 266, Essex, CT 06426, USA.

Massachusetts: Report of New England/New York Coastal Task Force, July 1989, "Developing Policies to Improve the Effectiveness of Coastal Floodplain Management, Executive Summary (Volume 1) and Technical Appendix (Volume 2)", Massachusetts Office of Environmental Affairs, 100 Cambridge Street, Boston, MA 02202, USA.

Delaware: Delaware's Environmental Legacy Program, 1988, "Beaches 2000: Report to the Governor",

Department of Natural Resources and Environmental Control, P.O. Box 1401, Dover, DE 19903, USA.

California 1987: Study by the San Francisco Bay Conservation and Development Commission, "Sea Level Rise: Predictions and Implications for San Francisco Bay", Bay Conservation and Development Commission, 30 Van Ness Ave., Room 2011, San Francisco, CA 94102 USA.

California 1989: Report entitled, "Planning for an Accelerated Sea Level Rise Along the California Coast", California Coastal Commission, 631 Howard Street, 4th Floor, San Francisco, CA 94105 USA.

Hamnett, Jones and Schultz, 1989, report entitled "<u>Polices Development and Planning for Global Climate Change and Sea Level Rise in the Pacific Islands and Phase Two: Policy and Planning Options for Global Warming and Sea Level Rise in the Pacific Islands</u>", Pacific basin Development Council, 567 South King (Room 325), Honolulu, HI 96813 USA.

Jones, Christopher B, 1989, "Sea Level Rise: Assessing the Scientific Debate", Pacific basin Development Council, 567 South King (Room 325), Honolulu, HI 96813 USA.

Law: Land Development and Control Act (No. 15 of 1977).
Purpose: Establishes a Development Control Authority which operates to implement the act.
Relation to CZM: Principal legislation governing land use planning levels: 1) granting or refusing development permission on specific proposals to develop land or a building; and 2) preparing a national development plan for the country. The plan is envisioned to be a proposed development strategy that formulates "the Authority's policy and general proposals in respect to the development and other use of land in the State (including measures for the improvement of the physical environment...)" (section 6).
Reference: Lausche, B., 1986, "Country Report on National Legislation Relating to Natural Resource Management," September 1986, Organization of Easter Caribbean States Natural Resources Management Project (in cooperation with OAS and GTZ). Mervyn Williams, OECS/NRMP, The Morne, Casties, P.O. Box 1383, St. Lucia.

Law: Crown Islands Ordinance (Cap. 130, 1917).
Purpose: Gives Government control over its own lands.
Relation to CZM: This act is typical of crown lands legislation for the commonwealth Caribbean. It gives the Government as much power as it needs to exercise with respect to terms and conditions on which government lands may be "rented, leased, occupied, sold or otherwise dealt with..." (section 4).
Reference: Lausche, B., 1986, "Country Report on National Legislation Relating to Natural Resource Management," September 1986, Organization of Easter Caribbean States Natural Resources Management Project (in cooperation with OAS and GTZ). Mervyn Williams, OECS/NRMP, The Morne, Casties, P.O. Box 1383, St. Lucia.

Law: Federal Law 6938 (August 31, 1981) "Politics Nacional de Meio Ambiente".
Purpose: It establishes the National Policy for the Environment and the institutions which form the National System for the Environment (SISNAMA).
Relation to CZM: The coastal environment is included in the law.
A National Committee for the Environment (CONAMA) is created including representatives from federal ministries and civil organizations for environmental protection. There is a close relation between the CONAMA and the Interministerial Committee for Sea Resources (CIRM) regarding management of coastal areas.
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/ Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

Law: Federal Law 7,661 (May 16, 1988) "Plano

Nacional de Gerenciamento Costeiro".
Relation to CZM: It establishes the formal steps and the execution of the PNGC (National Coastal Zone Management Plan).
Reference: Frischeisen, E. et al., "The Coastal Management Program in Brazil", Coastlines in Brazil, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Law: Federal Law 98352 (October 31, 1989)
Purpose: It creates the "Comissao Interministerial sobre Alteracoes Climaticas" (the Interministerial Committee for Climate Changes).
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/ Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

E. PROTECTION OF SENSITIVE AREAS

REFERENCES:

Law: The Public Utilities Act (No. 10 of 1973)
Purpose: Creates a Public Utilities Authority
Relation to CZM: This act gives the Minister power to make regulations to protect watercourses and catchments.
Reference: Lausche, B., 1986, "Country Report on National Legislation Relating to Natural Resource Management" September 1986, Organization of Eastern Caribbean States Natural Resources Management Project (in co-operation with OAS and GTZ).
Mervyn Williams, OECS/NRMP, The Morne, Castries, P.O. Box 1383, St. Lucia.

Law: Beach Protection Ordinance (Cap. 298, 1957)
Purpose: Provides Antigua/Barbuda power to prevent erosion caused by excavation of building materials on beaches.
Relation to CZM: Controls the taking of sand, stone, gravel, or shingle from any beach or seashore. Taking or conveying such material along any public road is prohibited except with a permit.
Reference: Lausche, B., 1986, "Country Report on National Legislation Relating to Natural Resource Management" September 1986, Organization of Eastern Caribbean States Natural Resources Management Project (in co-operation with OAS and GTZ).
Mervyn Williams, OECS/NRMP, The Morne, Castries, P.O. Box 1383, St. Lucia.

Law: 1977 Executive Decree.
Purpose: Provides protection of all mangroves areas in Costa Rica.
Relation to CZM: Decree provides for the protection of all mangrove areas. They are considered as forest reserves and although sustainable management is allowed, no changes in land use are permitted. This decree has been reformed a few times but the philosophy remains the same.
Reference: Quesada, C.A., Director of ECODES, Ministero De Recursos Naturales, Energia Y Minas. Apartado 10104, San Jose, Costa Rica.

Law: Federal Law 4771, September 15, 1965 "Codigo Florestal".
Purpose: It establishes the property, uses and protection of forests, natural vegetation and forest resources.
Relation to CZM: Vegetation on dunes and mangroves are considered as being under permanent protection.
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/ Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil

Law: Rio de Janeiro State Ordinance, CECA 063 (February 28, 1980).
Purpose: The Rio de Janeiro Committee for Environmental Control (CECA) establishes criteria for preservation of mangrove areas in the State.
Relation to CZM: This ordinance deals with the preservation of a sensitive coastal environment. The main areas are located in the State, the vegetation species are identified and the activities which are incompatible with the preservation of mangroves are listed such as: landfills, hydraulic works, tree cutting, disposal of industrial and domestic wastes.
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/ Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

Law: Federal Law 6902 (April 27, 1981).
Purpose: It regulates the creation of Ecological Stations (EE) and Areas of Environmental Protection (APA).
Relation to CZM: Several coastal areas have

benefitted from this law. The CONAMA establishes criteria and norms for the use and exploitation of resources within those areas (EE and APA).
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/ Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

Law: Resolution CONAMA 004 (September 18, 1985).
Purpose: It specifies areas of permanent protection and gives definition for geomorphological and biological terms used in environmental laws.
Relation to CZM: It includes among areas of permanent protection: (a) barrier islands; (b) spits and barrier beaches up to 300m inland from the highest water line; (c) mangroves; (d) vegetation for fixing dunes; (e) wetlands and other areas used by migrating birds; and (f) the land around lakes, lagoons and coastal reservoirs depending on the location.
Reference: Neves, C., Programs de Engenharia Oceanica, COPPE/Universidade Federal do Rio de Janeiro, Caixa Postal 68508, 21945 Rio de Janeiro, RJ, Brazil.

The Civil Code of 1869
Relation to CZM: An all-encompassing set of regulations establishing that territorial seas, internal waters, rivers and river basins, navigable lakes and coastal features such as river banks and islands in internal waters, are the property of the Nation and, as such, public estate.
Reference: Brandani and Schnook (1987): The Coastal Zone of Argentina: Environmental, Governmental and Institutional Features.
Information provided by Enrique J. Schnook, Argentina.
CIC de la Provincia de Buenos Aires and Universidad National de Mar del Plats, Centro de Geologia de Costas, PO Box 722, (7600) Mar del Plats, Argentina.

Law: Marine Agreement Regulation
Purpose: Provides the Chilean Government complete authority over coastal zone management.
Relation to CZM: The marine agreement regulation is the central basic legal instrument used for coastal zone. This regulation provides the Minister of Defense authority over the control, discharge of all fiscal duties and observer of all the territorial coast and sea and rivers and lakes which are navigable by vessels greater than 100 tons.
Reference: J.J. Escobar, CPPS, PNUMA, Calle 76 No. 9-88. Bogota, Colombia.

Law: The Chilean Presidential Declaration of June 23, 1947 and the Declaration of Santiago of August 18, 1952.
Relation to CZM: Proclaims the National sovereignty up to 200 nautical miles from the coast.
Reference: J.J. Escobar, CPPS, PNUMA, Calle 76 No. 9-88.
Bogota, Colombia.

Law: The Supreme Decree 711(M), of August 23, 1975,
Relation to CZM: Regulates the Scientific Studies and Marine Technology effective in the marine zone of the National Jurisdiction.
Reference: J.J. Escobar, CPPS, PNUMA, Calle 76 No. 9-88 Bogota, Colombia.

Law: Supreme Decree No. 781 of August 1947 (The Peruvian Marine Dominion).
Purpose: Establishes National jurisdiction over the sea.
Relation to CZM: The National jurisdiction over the sea, conceptualized as the marine zone is up to 200 miles from the coast.
Reference: J.J. Escobar, CPPS, PNUMA, Calle 76 No. 9-88. Bogota, Colombia.

Law: The Executive Decree of 1974
Purpose: To establish a structure of concepts and basic principles of environment over territorial areas.
Relation to CZM: Promotes sustainable development to regulate and manage coastal areas and resources in an interdependent and integral manner for the protection, preservation, production and recuperation of these areas.
Reference: Avellaneda, M., Information over the Activities on Environmental Regulation in Colombia. J.J. Escobar, CPPS, PNUMA, Calle 76 No. 9-88 Bogota, Colombia.

Law: Ecuadorian Marine Reserve Zone and The Coastal Resource Management Project, 1986.
Purpose: The general objective of the PMRC is the creation and execution of an integral program for the management of Ecuador's coastal resources.
Relation to CZM: In 1987, the Ecuadorian Government declared a Marine Reserve Zone within 15 miles from the coast, surrounding the Galapagos

Islands.
Reference: Perez, A.E., "Elementos Legales Y Administrativos Del Manejo De Recursos Costeros En La Republica Del Ecuador." Septiembre de 1988. Robadue, D. Jr., The University of Rhode Island, UR/AID Coastal Resources Management Project, Coastal Resources Centre, Narrangansett Bay Campus, Narragansett, RI 02882, USA.

Institution: The Institute of Renewable Natural Resources, 1985.
Purpose: Provides Panamanian Government means to regulate the environment and aspects of coastal zone.
Relation to CZM: By law, the institute has within its functions to define the criteria for the establishment of natural reserves and protected areas.
Reference: From abstract by Diaz, E., J.J. Escobar, CPPS, PNUMA, Calle 76 No. 9-88 Bogota, Colombia.

Flynn, T. J., et al., 1984, "Chapter 9: Implications of Sea Level Rise for Hazardous Waste Sites in Coastal Floodplains," Greenhouse Effect and Sea Level Rise: A Challenge for this Generation, Barth, M.C. and J. G. Titus (Editors), Van Nostrand Reinhold, 115 Fifth Avenue, New York, New York 10003, USA.

IV. STRUCTURAL MEASURES APPLIED IN COASTAL ZONE MANAGEMENT

A. GENERAL PRINCIPLES AND PRACTICES OF COASTAL ENGINEERING

REFERENCES:

Horikawa, K., 1987, "Nearshore Dynamics and Coastal Processes: Theory Measurement and Prediction Models," University of Tokyo Press, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan.

Thorn, R. B. and Roberts, A. G., 1981, "Sea Defense and Coast Protection Works," American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Horikawa, K., 1978, "An Introduction to Ocean Engineering," University of Tokyo Press, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan.

Silvester, R., 1979, "Coastal Engineering Vols. 1 and 2," Elsevier Scientific Publishing Co., Post Box 211, 1000 AE, Amsterdam, Netherlands.

Goda, Y., 1985, "Random Seas and Design of Maritime Structures," University of Tokyo Press, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan.

Wiegel, R. L., 1964, "Oceanographical Engineering," Prentice-Hall, Inc., Route 9W, Englewood Cliffs, New Jersey 07632, USA.

Sorenson, R. M., 1979, "Basic Coastal Engineering," Wiley- Interscience, 605 Third Avenue, New York, New York 10158, USA.

Department of the Army, Coastal Engineering Research Centre, 1984, "Shore Protection Manual," Vols. 1 and 2, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, USA.

B. HARD OR NON-COMPLIANT STRUCTURES MADE OF COMMON CONSTRUCTION MATERIALS SUCH AS STONE, CONCRETE, TIMBER AND STEEL.

REFERENCES:

1. Dikes, levees and floodwalls -
These are raised embankments or walls constructed for flood protection purposes. Exposed faces of earthen dikes or levees may have to be armoured to protect against wave or current forces.

REFERENCES:

P. Ph. Jansen, et al., 1979, "Principles of River Engineering," Pittman Publishing Limited, 39 Parker Street, London WC2B SPB, England.

Peterson, M. S., 1986, "River Engineering," Prentice-Hall, Englewood Cliffs, New Jersey 07632, USA.

Van Zyl, D. J. A. and Vick, S. G. (Editors), "Hydraulic Fill Structures," Geotechnical Special Publication No. 21, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

U.S. Army Corps of Engineers, 1989, "Engineering and Design of Retaining and Flood Walls," Engineering Manual #1110-2-2502, HQUSACE, Office of Public Affairs, Pulaski Building, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314, USA.

Shen, H. W. (Editor), 1971, "River Mechanics," Vols. I and 2, Colorado State University, P.O. Box 606, Ft. Collins, Colorado 80521, USA.

U.S. Army Corps of Engineers, 1978, "Design and Construction of Levees," Engineering Manual #1110-2-1913, HQUSACE, Office of Public Affairs, Pulaski Building, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314, USA.

Agostini, R. and M. Ciarla, 1987, "Gabion Structures in Coastal Protection Works," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Bakker, W. T. and J. K. Vrijling, 1980, "Probabilistic Design of Sea Defenses," Proceedings of the Seventeenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

de Vroeg, J. H., et al., 1988, "Coastal Genesis," Proceedings of the Twenty-first International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Fuhrboter, A., et al., 1976, "Response of Seadykes Due to Wave Impacts," Proceedings of the Fifteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Fukuchi, T. and K. Mitsuhashi, 1981, "Tsunami Countermeasures in Fishing Villages Along the Sanriku Coast, Japan," Tsunamis: Their Science and Engineering, Iida, K. and T. Iwasaki (Editors), Terra Scientific Publishing Company, Tokyo.

Nakashima, L. D., 1983, "Short Term Protection on a Rapidly Eroding Beach," Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Roelse, P. and W. T. Bakker, 1986, "Statistical Investigations on Dike Failure," Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Perdikis, H. S., 1967, "Hurricane Flood Protection in the United States," J. Waterways and Harbours Div., (WW1) American Society of Civil Engineers, 93 (WW1).

Pilarczyk, K., 1987, Sea Defenses: Dutch Guidelines on Dike Protection, Road and Hydraulic Engineering Department, Rykswaterstaat, Koningskade 4, Postbus 20907, 2500 Ex the Hague, Netherlands.

Sell, J. D., et al., 1987, "Coastal Flood Control Design Parameters," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Schroeder, R. H., Jr., 1989, "Accommodating Sea Level Rise in Coastal Louisiana," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Toyoshima, O., 1978, "Effectiveness of Seadikes With Rough Slope," Proceedings of the Sixteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Verhagen, H. J. and W. F. Volker, 1989, "Safety Against Inundation - The Dutch Approach," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Weggel, J. R., et al., 1989, "Appendix A: The Cost of Defending Developed Shorelines Along Sheltered Waters of the United States," The Potential Effects of Global Climate Chance on the United States, Smith, J. B. and D. A. Tirpak (Editors), Office of Policy, Planning and Evaluation, Environmental Protection Agency, 401 M Street, SW, Washington, D.C. 20460, USA.

2. **Sea walls and bulkheads -**
Rigid Structures separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

REFERENCES:

Dean, R. G., 1986, "Coastal Armoring: Effects, Principles and Mitigation," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Dennis, W. A., 1987, "Protection of Cape Hatteras Lighthouse," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

"The Effects of Seawalls on the Beach," Special Issue No. 4, Journal of Coastal Research, Autumn 1988, Coastal Education and Research Foundation, 4310 N.E. 25th Avenue, Ft. Lauderdale, Florida 33308, USA.

Gaythwaite, J., 1989, "Beach Erosion Control and Hurricane Protection for Virginia Beach, Virginia," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Goda, Y., 1985, Random Sea and Design of Maritime Structures, University of Tokyo Press, Tokyo Press, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan.

Harris, L. E., 1989, "Developments in Sand-Filled Container Systems for Coastal Erosion Control in Florida," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Heiberg, E. R. III, et al., 1982, "Responding to an SOS - Save our Shores," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kyper, T. and R. M. Sorensen, 1985, "Impact of Sea Level Rise Scenarios on the Beach and Coastal Structures at Sea Bright, New Jersey," Coastal Zone '85, Magoon, O. T., et al. (Editors), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Low Cost Shore Protection, 1981, U.S. Army Corps of Engineers, HQUSACE, Office of Public Affairs, Pulaski Building, 20 Massachusetts Avenue, Washington, D.C. 20314, USA.

Magoon, Orville T., et al., 1988, "Long Term Experience With Seawalls On An Exposed Coast," Proceedings of the Twenty-first International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Minikin, R. R., 1952, Coast Erosion and Protection, Chapman and Hall, 11 New Fetter Lane, London EC4P 4EE, England.

Seyama, A. and A. Kimura, 1986, "Critical Run-up Height on the Sea Wall," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Shore Protection Manual, 1984, 4th ed., U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Centre, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, USA.

van de Graaff, Jan and Eco W. Bijker, 1988, "Seawalls and Shoreline Protection," Proceedings of the Twenty-first International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Walton, T. L., et al., "Methodology to Establish Adequacy of Seawalls for Coastal Flood Protection," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

U.S. Army Corps of Engineers, 1985, "Design of Coastal Revetments, Seawalls and Bulkheads," Engineering Manual #1110-2-1614, HQUSACE, Office of Public Affairs, Pulaski Building, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314, USA.

3. Revetments -

Non-rigid structures placed on banks or bluffs in such a way as to absorb the energy of incoming waves or to protect the shoreline from water currents. They are usually constructed to preserve the existing uses of the shoreline and to protect the upland slope.

REFERENCES:

Ahrens, J. P. and M. Heimbaugh, 1989, "Dynamic Stability of Dumped Riprap," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Ahrens, J. P. and F. Camfield, 1989, "Dynamic Revetments," The CERCular, Vol. CERC-89-2, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180.

Ahrens, J. P., 1981, "Design of Riprap Revetments for Protection Against Wave Attack," CERC Technical Paper 81-5, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Bank and Shore Protection in California Highway Practice, 1970, State of California Department of Transportation, 1120 N Street, Sacramento, California 95814, USA.

Collinson, C. and W. A. Jansen, 1989, "Low-Cost Stacked Block Revetments for Great Lakes Shores," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Hayashi, R. M., 1986, "Beachwalls for Beach Erosion Protection," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kauffman, H. L., 1987, "Ocean Erosion Control for the Private Sector," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kobayashi, N. and A. Wurjanto, 1989, "Wave Overtopping on Coastal Structures," Journal of Waterway, Port, Coastal and Ocean Engineering, 115(2), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kobayashi, N. and A. K. Otta, 1987, "Hydraulic Stability Analysis of Armor Units," Journal of Waterway, Port, Coastal and Ocean Engineering, 113(2), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

McCartney, B. L., 1976, "Survey of Coastal Revetment Types," CERC MR-76-7, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Nathan, R. A. and D. Hawley, 1989, "Emergency Shore Protection," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Pope, J. and T. A. Chisholm, 1989, "Coastal Engineering Options for Adapting to Global Climate Change," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration, 1825 Connecticut Avenue, Washington, D.C. 20235, USA.

Ryu, C.-r. and T. Sawaragi, 1986, "A New Design Method of Rubble Mound Structures," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Thorn, R. B. and J. C. F. Simmons, 1971, Sea Defence Works, Butterworths & Co., 9-12 Bell Yard, Temple Bar, London WC2, England.

van der Meer, J. W. and K. W. Pilarczyk, 1986, "Dynamic Stability of Rock Slopes and Gravel Beaches," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Vick, D. M., 1989, "Integrated Monolayer Flexible Revetment Technology for Coastal Protection," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Bruun, P. (Editor), 1985, "Design and Construction of Mounds for Breakwaters and Coastal Protection," Elsevier Scientific Publishing Co., Box 211, 1000 AE, Amsterdam, Netherlands.

4. Groins -
Shore protection structures, usually constructed perpendicular to the shoreline, used for the purpose of trapping littoral drift or retarding erosion of the shoreline.

REFERENCES:

Bakker, W. T., et al., 1970, "The Dynamics of a Coast with a Groyne System," Proceedings of the Twelfth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New .York, New York 10017, USA.

Nichols, F. E., 1960, "Design and Construction of the Seal Beach Groin," Shore and Beach, 28(2), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94720, USA.

Panuzio, F. L., 1968, "The Atlantic Coast of Long Island," Proceedings of the Eleventh International Conference on coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Shore Protection Manual, 1984, 4th ed., U. S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Centre, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, USA.

5. Detached breakwaters -
Structures placed offshore, essentially parallel to the shoreline, to dissipate the energy of incoming waves. Structures with crests at or near the normal high water level function to trip incoming waves.

REFERENCES:

Adams, C. B. and C. J. Sonu, 1986, "Wave Transmission Across Submerged Near-Surface Breakwaters," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Abbruzzese, L., et al., 1987, "A Railway Protection - Coastal Structures on Tyrrehenian Calabrian Coastline," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Ahrens, J. P., 1987, "Characteristics of Reef Breakwaters," Technical Report CERC-87-17, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Ahrens, J. P., 1989, "Stability of Reef Breakwaters," Journal of Waterway, Pert. Coastal and Ocean Engineering, Volume 115, No. 2, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Anglin, C. D., et al., 1987, "Artificial Beach Design, Lake Forrest, Illinois," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Dally, William R. and Pope, J., 1986, "Detached Breakwaters for Shore Protection," Technical Report CERC-86-1, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Fulford, E. T., 1985, "Reef Type Breakwaters for Shoreline Stabilization," Proceedings of Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Gunyakti, A., 1987, "Beach Preservation by Means of Offshore Submerged Mound of Dredged Material," Coastal Zone '87, American Society of Civil Engineers, New York.

Hanson, H., et al., 1989, "Shoreline Change Behind Transmissive Detached Breakwaters," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Hendrickson, David G. and K. J. Eisses, 1989, "Alaska Floating Breakwater Anchor Force Program," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kadib, A. L., et al., 1986, "Shore Protection Plan for the Nile Delta Coastline," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Lesnik, J. R., 1979, "An Annotated Bibliography on Detached Breakwaters and Artificial Headlands," CERC MR-79-1, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Low Cost Shore Protection, 1981, U.S. Army Corps of Engineers, HQUSACE, Office of Public Affairs, Pulaski Building, 20 Massachusetts Avenue, NW, Washington, D.C. 20314, USA.

Macintosh, K. J. and C. D. Anglin, 1988, "Artificial Beach Units on Lake Michigan," Proceedings of the Twenty-First International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Pope, J. and D. D. Rowen, 1983, "Breakwaters for Shore Protection at Lorain, Ohio," Coastal Structures '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Pope, J. and J. L. Dean, 1986, "Development of Design Criteria for Segmented Breakwaters," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Pope, J., 1989, "Role of Breakwaters in Beach Erosion Control," Beach Preservation Technology '89: Strategies and Alternatives in Erosion Control, L. S. Tait (Editor), Florida Shore and Beach Preservation Association, 864 East Park Avenue, Tallahassee, Florida 32301, USA.

Stewart, J. B., 1989, "Man-Made Offshore Islands: An Innovative Solution to Coastal Erosion," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Toyoshima, O., 1982, "Variation of foreshore Due to Detached Breakwaters," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Walker, J. R., et al., 1980, "A Detached Breakwater System for Beach Protection," Proceedings of the Seventeenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Woodley, J. D. and J. R. Clark, 1989, "Rehabilitation of Degraded Coral Reefs," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

6. Raising structures -

Structures may be raised (added to) in elevation to prevent wave runup and overtopping, thereby reducing bank erosion, embankment sluffing, transmission of wave energy, etc.

REFERENCES:

Ahrens, J. P., 1988, "Methods to Reduce Wave Runup and Overtopping of Existing Structures," Technical Report REMR-CO-7, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Carver, R. D., 1989, "Prototype Experience With the Use of Dissimilar Armor for Repair and Rehabilitation of Rubblemound Coastal Structures," Technical Report REMR-CO-2, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Flynn, T. J., et al., 1984, "Chapter 9: Implications of Sea Level Rise for Hazardous Waste Sites in Coastal Floodplains," Greenhouse Effect and Sea Level Rise: A Challenge for this Generation, Barth, M. C. and J. G. Titus (Editor), Van Nostrand Reinhold, 115 Fifth Avenue, New York, New York 10003, USA.

Kyper, T. N. and R. M. Sorensen, 1989, "The Impact of Selected Sea Level Rise Scenarios on the Beach and Coastal Structures at Sea Bright, N. J.," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Markle, D. G. and M. S. Taylor, "Effectiveness of Expedient Levee-Raising Structures," Technical Report CERC-88-4, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Miller, T. and W. Hyman, 1989, "Raising Miami - A

Test of Political Will," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration, (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C., USA.

Shore Protection Manual, 1984, 4th ed., U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Centre, U.S. Superintendent of Documents, Government Printing Office, Washington, D.C. 20402, USA.

Whalin, R. W. and J. R. Houston,.1987, "Implications of Sea Level Rise to Coastal Structure Design," Proceedings of the First North American Conference on Preparing for Climate Change, Climate Institute, 316 Pennsylvania Avenue, SE, Washington, D.C. 20003, USA.

7. Preventing salinity intrusion -
Prevent the movement of saline water up estuaries and rivers, or into coastal aquifers.

REFERENCES:

Mizumura, K., 1982, "Multipurpose Gate Operation," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Soileau, C. W., et al., 1989, "Drought Induced Saltwater Intrusion on the Mississippi River," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Sorensen, R. M., et al., 1984, "Chapter 6: Control of Erosion, Inundation and Salinity Intrusion Caused by Sea Level Rise," Greenhouse Effect and Sea Level Rise: A Challenge for this Generation, Barth, M. C. and J. G. Titus (Editor), Van Nostrand Reinhold, 115 Fifth Avenue, New York, New York 10003,USA.

Sugio, S., et al., 1987, "Subsurface Seawater Intrusion Barrier Analysis," Journal of Hydraulic Engineering, 113(6), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Titus, J., 1989, "Responding to Global Warming Along the U.S. Coast: Past and Future," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration, (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

van der Kuur, P., 1985, "Locks with Devices to Reduce Salt Intrusion," Journal of Waterway. Port. Coastal and Ocean Engineering, 111(6), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

8. Modifying Infrastructure -
The coastal infrastructure includes those capital facilities constructed to serve public needs. The major threats to the coastal infrastructure from sea level rise are: flooding and inundation including exposure to waves and storm surge, saltwater intrusion and associated chemical and biological effects, foundation erosion and changes in drainability.

REFERENCES:

Arockiasamy, M., 1989, "Hurricane Damage Potential and Structural Safety of an Ocean Outfall," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Dreyfoos, W. W., et al., 1987, "Local Responses to Sea Level Rise: Charleston, South Carolina," Proceedings of the Symposium on Climate Change in the Southern United States, Bizzell Library, University of Oklahoma, 401 West Brook Street, Norman, OK 73070, USA.

Dreyfoos, W. W., et al., 1989, "Local Responses to Sea Level Rise: Charleston, South Carolina," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Miller, T. R., 1988, "Impacts of Global Climate Change on Metropolitan Infrastructure," Proceedings of the Second North American Conference on Preparing for Climate Chance, Climate Institute, 316 Pennsylvania Avenue, SE, Washington, D.C. 20003, USA.

Simpson, T. E., 1989, "Floating Hotels in the Coastal Environment," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Stokoe, P. K., 1988, "Strategies to Respond to Climate Change and Sea Level Rise in Atlantic Canada," Proceedings of the Second North American Conference on Preparing for Climate Change, Climate Institute, 316 Pennsylvania Avenue, SE, Washington, D.C. 20003, USA.

Titus, J. G., et al., 1987, "Greenhouse Effect, Sea Level Rise and Coastal Drainage Systems," J. Water Resources Planning and Management, ASCE 113(2), pages 216-227, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

9. Floodgates -
Structures placed across a river or estuary to prevent the upstream movement of water from high tides and/or storm surges.

REFERENCES:

Frassetto, R., 1989, "Sea Level Rise and the Safeguard of Venice," International Workshop on Sea Level Rise, National Oceanic and Atmospheric Administration, (N/IA), 1825 Connecticut Avenue, NW, Washington, D.C. 20235, USA.

Gilbert, S. and R. Horner, 1984, The Thames Barrier, Thomas Telford, Ltd., 1-7 Great George Street, Westminster, London SWIP 3AA, England.

Grice, J. R. and E. A. Hepplewhite, 1983, "Design and Construction of the Thames Barrier Cofferdams," Proceedings of the Institution of Civil Engineers, Part 1, 74, May, Thomas Telford Ltd., 1 Heron Quay, London E 149XF, England.

Jansen, P., 1964, "Man Against the Sea," Shore and Beach, 31(1), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94720, USA.

McAleer, John B., 1963, "Hurricane Flood Protection in New England," Shore and Beach, 31(2), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94720, USA.

Panuzio, F. L., 1970, "Jamaica Bay Hurricane Barrier," Proceedings of the Twelfth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Parkin, P. and J. H. Fleeting, 1983, "River Hull Tidal Surge Barrier Design and Operation," Coastal Structures '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Weggel, J. R., et al., 1979, "Wave Action on the Savannah Tide Gates," Coastal Structures '79, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Wilson, E. M., et al., 1968, "The Bristol Channel Barrage Project," Proceedings of the Eleventh International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

C. SOFT OR COMPLIANT STRUCTURAL SOLUTIONS

REFERENCES:

1. Beach nourishment -
Placement of material on a beach to rebuild and maintain eroding shorelines. Rising sea levels will require greater volumes of material to maintain the above water beach width and fill the offshore extent of the beach profile. Maintenance of protective beaches limits wave induced damages.

REFERENCES:

Adams, J. W., 1989, "The Fourth Alternative--Beach Stabilization by Beachface Dewatering," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Beumel, N. and L. Bocamazo, 1989, "Rebuilding the New Jersey Shoreline," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Cahil, J. J., et al., 1989, "Beach Nourishment with Fine Sand at Carlsbad, California," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Chapman, D. M., 1980, "Beach Nourishment as a Management Technique," Proceedings of the Seventeenth International Conference on Coastal

Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Delft Hydraulics Laboratory, 1986, "Manual on Artificial Beach Nourishment," Rijkswaterstaat, Koningskade 4, Postbus 20907, The Hague, Netherlands.

de Vroeg, J. H., et al., 1988, "Coastal Genesis," Proceedings of the Twenty-first International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Downie, K.A. and H. Salltink, 1983, "An Artificial Cobble Beach for Erosion Control," Coastal Structures '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Everts, C. H., et al., 1974, "Behavior of Beach Fill at Atlantic City, New Jersey, Proceedings of the Fourteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Everts, C. H., 1985, "Sea Level Rise Effects on Shoreline Position," Journal of Waterway, Port, Coastal and Ocean Engineering, Volume 111, No. 6, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Hall, J. V., Jr., 1952, "Artificially Nourished and Constructed Beaches," Beach Erosion Board TM-29, Coastal Engineering Research Centre, U.S. Army Engineers Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Heiberg, E. R. III, et. al., 1982, "Responding to an SOS--Save Our Shores," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Johnson, L. and W. Bauer, 1987, "Beach Stabilization Design," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kadib, A. L., et. al., 1986, "Shore Protection Plan for the Nile Delta Coastline," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kana, T. W., et. al., 1986, "Design and Performance of Artificial Beaches for the Kuwait Waterfront Project," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kana, T. W. and M. Svetlichny, 1982, "Artificial Manipulation of Beach Profiles," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kerckaert, P., et. al., 1986, "Artificial Beach Nourishment on Belgian East Coast," Journal of Waterway, Port, Coastal and Ocean Engineering, Volume 112, No. 5, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kieslich, J. M, and D. H. Brunt, III, 1989, "Assessment of a Two-Layer Beach Fill at Corpus Christi Beach, Texas," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kraus, N., 1989, "Beach Change Modeling and the Coastal Planning Process," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Kyper, T. and R. M. Sorenson, 1985, "Impact of Sea Level Rise Scenarios on the Beach and Coastal Structures at Sea Bright, New Jersey," Coastal Zone '85, Magoon, O. T., (Editor), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Larson, M. and N. C. Kraus, 1989, "Prediction of Beach Fill Response to Varying Waves and Water Level," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Leatherman, S. P., 1989, "Appendix: National Assessment of Beach Nourishment Requirements Associated with Accelerated Sea Level Rise," The Potential Effects of Global Climate Change on the United States, Smith, J. B. and D. A. Tirpak (Editors), Office of Policy, Planning and Evaluation, Environmental Protection Agency, 401 M Street, SW, Washington, D.C. 20460, USA.

Leatherman, S. P. and C. H. Gaunt, 1989, "National Assessment of Beach Nourishment Requirements Associated with Accelerated Sea Level Rise," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Leatherman, S. P., 1989, "Environmental Implications of Shore Protection Strategies Along the U. S. Coasts," International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Macintosh, K. J. and C. D. Anglin, 1988, "Artificial Beach Units on Lake Michigan," Proceedings of the Twenty-first International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

McCann, D. P., 1981, "Beach Changes at Atlantic City, New Jersey (1961-73)," CERC MR-81-3, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

McCarthy, M. J., et. al., 1982, "Construction of a Breach Closure in a Barrier Island," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Miller, M. C., et. al., 1980, "Beach Changes at Long Beach Island, New Jersey, 1962-73," CECR MR-80-9, U.S. Army Engineers Waterway Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Muraca, A., 1982, "Shore Protection at Venice: A Case Study," Proceedings of the Eighteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Nersesian, G. K., 1977, "Beach Fill Design and Placement at Rockaway Beach, New York Using Offshore Ocean Borrow Sources," Coastal Sediments '77, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Newman, D. E., 1974, "Beach Restored by Artificial Renourishment," Proceedings of the Fourteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Newman, D. E., 1976, "Beach Replenishment--Sea Defences and a Review of the Role of Artificial Beach Replenishment," Proceedings, 60: 445-460, Institution of Civil Engineers, Thomas Telford Ltd., 1 Heron Quay, London E149XF, England.

Pilarczyk, K. W., J. van Overeem and W. T. Bakker, 1986, "Design of Beach Nourishment Scheme," Proceedings of the Twentieth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Roellig, D. A. 1987, "Solutions to Harbor Induced Erosion," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Shore Protection Manual, 1984, 4th ed, U.S. Army Waterways Experiment Station, Coastal Engineering Research Centre, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, USA.

Simoen, R., et al., 1988, "The Beach Rehabilitation Project at Ostend-Belgium," Proceedings of the Twenty-first International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

State Department of Natural Resources, 1986, "A Proposed Beach Management Program for the State of Florida," Office of Coastal Management, Department of Environmental Regulation, Twin Towers Office Building, 2600 Blair Stone Road, Tallahassee, Florida 32301, USA.

Stauble, D. K., 1986, "Guidelines for Beach Restoration Projects, Part II -Engineering," Florida SeaGrant College Report No. 77, University of Florida, 6022 McCarty Hall, Gainesville, Florida 32611, USA.

Titus, J. G. (Editor), 1985, Potential Impacts of Sea Level Rise on the Beach at Ocean City, Maryland, Office of Policy, Planning and Evaluation, Environmental Protection Agency, 401 M Street, SW, Washington, D.C. 20460, USA.

Vallianos, L., 1974, "Beach Fill Planning -Brunswick County, North Carolina," Proceedings of the Fourteenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Watts, G. M., 1956, "Behavior of Beach Fill at Ocean City, New Jersey," Beach Erosion Board TM-77, Coastal Engineering Research Centre, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Watts, G. M., 1958, "Behavior of Beach Fill and Borrow Area at Harrison County, Mississippi," Beach Erosion Board TM-107, Coastal Engineering Research Centre, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Watts, G. M., 1959, "Behavior of Beach Fill at Virginia Beach, Virginia," Beach Erosion Board TM-113, Coastal Engineering Research Centre, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Weggel, J. R., 1986, "Economics of Beach Nourishment under Scenario of Rising Sea Level," Journal of Waterway, Port, Coastal and Ocean Engineering, 112(3), American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Wilcoxen, P. J., 1986, "Coastal Erosion and Sea Level Rise: Implications for Ocean Beach and San Francisco's Westside Transport Project," Coastal Zone Management Journal, 14(3), pages 173-191.

Williams, M. L. and T. W. Kana, 1987, "Beach Nourishment at Myrtle Beach, South Carolina: An Overview," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Winton, T. C., et al., 1981, "Analysis of Coastal Sediment Transport Processes from Wrightsville Beach to Fort Fisher, North Carolina," CERC MR-81-6, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Zarillo, G. A., et al., 1985, "A New Method for Effective Beach-Fill Design," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

2. **Dune building (vegetation and sand fences) -** Foredunes function as reservoirs of sand that nourish eroding beaches during high water and as levees that delay the inland penetration of waves and storm surges. These dunes are usually naturally created and maintained by the action of beach grasses which trap and hold blowing sand. Erosion occurs if this vegetation is damaged by drought, disease, overgrazing, traffic, rising water level, or waves during severe storms. Dune systems can be restored by constructing sand fences and planting beach grasses.

REFERENCES:

Anonymous, 1960, "Dune Building at Cape Hatteras National Seashore," Shore and Beach, 28(2), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94720, USA.

Barnett, M. R., 1989, "Utilization of Christmas Trees in Dune Restoration," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Gabriel, S. R., 1983, "Volunteer Based, Low Cost Sand Dune Development," Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Giardino, J. R., et al., 1987, "Nourishment of San Luis Beach, Galveston Island, Texas," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th

Street, New York, New York 10017, USA.

Googerham, K. and R. Workman, 1983, "Privately Funded Beach Vegetation Program" Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Knutson, P. L., 1977, "Planting Guidelines for Dune Creation and Stabilization," CETA 77-4, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Centre, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180.

Mack, W. W., 1935, "Sand Dune Building to Protect Ocean Beach Highways," Shore and Beach, 3(1), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94720, USA.

McKenzie, J. B. and D. A. Barr, 1980, "Research in Southern Queensland into the Management of Coastal Sand Dunes," Proceedings of the Seventeenth International Conference on Coastal Engineering, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Mauriello, M. N., 1989, "Dune Maintenance and Enhancement: A New Jersey Example," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Mauriello, M. N. and S. D. Halsey, 1987, "Dune Building on a Developed Coast: Lavallette, NJ," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Mendelssohn, I. A., et al., 1983, "Dune Building and Vegetative Stabilization in a Sand Deficient Barrier Island Environment," Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Rauch, D., et al., 1985, "Dune Construction on Perdido Key, Alabama," Coastal Zone'85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Savage, R. P., 1962, "Experimental Dune Building on the Outer Banks of North Carolina," Shore and Beach, 30(2), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94720, USA.

Scheffner, N. W., 1989, "Dune Erosion-Frequency of Storm Occurrence Relationships," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Seneca, E. D., et al., 1976, "Dune Stabilization with panicum amarum Along the North Carolina Coast," ER MR-7 - , U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Visser, C., 1983, "Design of Dunes as Coastal Protection in the Delta Area of the Netherlands," Coastal Structures '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

van de Graaff, J., 1983, "Probabilistic Design of Dunes," Coastal Structures '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Woodhouse, W. W., 1978, "Dune Building and Stabilization with Vegetation," Special Report No. 3, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Centre, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Zak, J. M. and E. Bredakis, 1963, "Dune Stabilization at Provincetown, Massachusetts," Shore and Beach, 31(2), ASBPA, 412 O'Brien Hall, University of California, Berkeley, California 94702, USA.

3. Marsh/wetland creation -

Marshes and other wetland types such as mangroves have been used extensively for revegetating coastal shorelines and dredged material. Rooted transplants are usually the most effective means of achieving revegetation. Once they are initially established, they can still waves, accumulate sediment and provide an environment that encourages natural colonization by other wetland plants. Marshes and wetlands can gradually accumulate enough sediment, provided there is an adequate supply, to evolve from low marsh to high marsh and even upland.

REFERENCES:

Allen, H. H. and J. W. Webb, 1983, "Erosion Control with Saltmarsh Vegetation," Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Allen, H. H. and S. O. Shirley, 1988, "Wetlands Created for Dredged Material Stabilization and Wildlife Habitat in Moderate to High Wave-Energy Environments," Environmental Effects of Dredging Technical Notes, EEDP-07-2, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Environmental Laboratory, 1978, "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation," Technical Report DS-78-16, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Gehrels, W. R. and S. P. Leatherman, 1989, "Sea Level Rise--Animator and Terminator of Coastal Marshes: An Annotated Bibliography on U.S. Coastal Marshes and Sea Level Rise," Public Administration Series Bibliography No. P-2634, Vance Bibliographies, P.O. Box 229, 112 North Charter Street, Monticello, Illinois 61856, USA.

Josselyn, M. (Editor), 1982, Wetland Restoration and Enhancement in California: Proceedings of a Workshop, University of California-San Diego, Central University Library, C-075, La Jolla, California 92093, USA.

Knutson, P. L. and W. W. Woodhouse, Jr., 1983, "Shore Stabilization with Salt Marsh Vegetation," Special Report No. 9, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Centre, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

Lewis, Roy R. III (Editor), 1982, Creation and Restoration of Coastal Plant Communities, CRC Press, Inc., 2000 Corporate Boulevard, NW, Boca Raton, Florida 33431, USA.

Louisiana Wetland Protection Panel and U.S. EPA, 1987, Saving Louisiana's Coastal Wetlands: The Need for a Long-Term Plan Action, Office of Policy, Planning and Evaluation, Environmental Protection Agency, 401 M Street, SW, Washington, D.C. 20460, USA.

Mason, C. O. and D. A. Slocum, 1987, "Wetland Replacement - Does it Work?," Coastal Zone '87, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Purseglove, J., 1988, Taming the Flood, Oxford University Press, 200 Madison Avenue, New York, New York 10016, USA.

Rogers, S. M., 1989, "Erosion Control: Marsh and Low-Cost Breakwater," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Siegel, S., 1989, "Wetlands Restoration: A Case Study of Turning Failure into Success," Coastal Zone '89, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Sorensen, J. and S. Gates, 1983, "New Directions in Restoration of Coastal Wetlands," Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Titus, J. G., 1985, "Sea Level Rise and Wetland Loss," Coastal Zone '85, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Williams, P. B. and H. T. Harvey, 1983, "California Coastal Salt Marsh Restoration Design," Coastal Zone '83, American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017, USA.

Woodhouse, W. W., Jr., et al.,1976, "Propagation and Use of Spartina alterniflora, for Shoreline Erosion Abatement," CERC TR-76-2, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA.

APPENDIX C

LAWS AND POLICIES FOR COASTAL MANAGEMENT OF SOUTH PACIFIC COASTAL AND ISLAND STATES

LAWS AND POLICIES FOR COASTAL MANAGEMENT OF SOUTH PACIFIC COASTAL AND ISLAND STATES

FIJI

The Town Planning Act (1946) requires the formation of a detailed town planning scheme and emphasises the conservation of the natural beauties of areas including coastal areas. The Subdivision of Land Act is relevant to general land use control. The Public Health Act (1956) contains provisions that cover the deposit of solid wastes. The Factory Act (1971) also contains provisions dealing with the deposit of solid waste.

The Land Conservation and Improvement Act (1955) empowers the Land Conservation Board to exercise general supervision over land and water resources. The Bird and Game Protection Act (1923) provides for protection of birds, game and fish by means of permits and has established a Wildlife Island Reserve. The Marine Space Act (1978) makes provision for the protection and preservation of marine environment of the exclusive economic zone and the conservation management of fisheries resources.

Other Acts that may affect the coastal area include the Native Land Trust Act (1940), Mining Act (1966), Petroleum Exploration and Exploitation Act (1978), Agricultural Landlord and Tenant Act (1967), Forestry Act (1953), The Preservation of Archeological and Palaeontological Interest Act (19??), National Trust of Fiji (1978), Fisheries Act (1942) and the proposed Water and Land Resources Management Act.

WESTERN SAMOA

The Building Alignment Ordinance 1932 prohibits the construction of any new building upon any land situated seaward of the Main Beach Road in Apia.

The Land Ordinance 1959 empowers the land board to reserve from and lease, for soil and water conservation purposes, a strip of land of "necessary" width along the mean high water mark of the sea, bays, inlets or creeks.

The Shipping Act 1972 empowers the Head of State acting on the advice of Cabinet to make regulations relating to use or occupation of the foreshore and bed of any lagoon, tidal area or navigable areas. It also prohibits discharge or flow into the harbour or territorial waters of any oil or tar etc.

The Survey Ordinance 1961 requires that every scheme plan reserve a ten metre wide strip along high water for public use.

The Taking of Lands Act 1964 empowers the Head of State to take any customary or freehold land for any public purpose.

The draft Natural Resource and Environment Act 1989 (Bill to be tabled at current [1989] session of Parliament) requires the Director of Natural Resources and the Environment to prepare management plans for, amongst others, the protection, management and control of coastal zones. The Act also contains specific provisions to prevent unauthorised excavation or deposition of any type of fill from the foreshore. It also prohibits the construction or erection of any structure within the foreshore with out authorisation.

COOK ISLANDS

The following acts and bylaws exist in the Cook Islands which describe and control the coastal areas.

The 1986/87 Conservation Act controls development of the coastal zone and other activities carried out in the area. The outer islands Local Government Act 1986 provides for the protection of the local fisheries and the creation of parks and reserves which could be used for mitigating purposes. Other relevant legislation is; The 1971/72, Ministry Act 1984, Trochu; Territorial Sea Zone Act 1977.

VANUATU

The Physical Planning Act 1986 provides for control over the development of land in Physical Planning Areas; the Fisheries Act 1982 provides for control over the taking of sand and gravel; the Forestry Act 1982 provides for control over mechanised clearing operations close to the seashore.

Coastal management legislation has been discussed and should be drafted sometime in 1990.

AUSTRALIA - NORTHERN TERRITORY

A Northern Territory Coastal Management Policy was adopted by Government in July 1985. The principal aim of the policy is to integrate conservation and development in the coastal zone through the preparation of Coastal Management Plans and coordination of management effort through an interdepartmental Coastal Management Committee.

The approach takes into account existing administrative and jurisdictional arrangements. Two major pieces of legislation are the Planning Act, which control land use throughout the Territory through the mechanisms of zoning and assessment of subdivisions and development applications. The Environmental Assessment Act, provides for the review of public and private sector developments likely to have significant environmental effect. The greenhouse effect and sea level rise are increasingly being taken into account in the application of both the Planning and Environmental Assessment Acts.

More than twenty acts influence management of the coastal zone.

AUSTRALIA - VICTORIA

Coastal management in Victoria occurs through coordination by a Cabinet Committee supported by a group of officers representing the ministries and agencies involved.

In September 1988 the Government released "A Coastal Policy for Victoria" aimed at protecting and guiding development of coastal areas. The policy is based on the principles of sustainable development outlined in the State Conservation Strategy (June 1987).

The strategy does not at this stage include specific plans for adaptation of development to sea level rise and other coastal impacts.

Under the framework of the State Coastal Policy, Regional policies are currently being developed.

Policies cover; water quality, wetlands, Landforms, flora and fauna, beaches and coastal systems, rising sea levels, the cultural heritage, urban settlement and services, residential development, siting and design, road and road traffic, port and industrial developments, commercial fisheries, primary industries, tourism and commercial recreation development, marinas and boating facilities, reconciling recreation demands, community awareness, community participation, community action.

The Government has identified a range of specific measures which will assist in the implementation of this policy. Many of these measures form part of existing government agency programmes, a number are ongoing actions and some will be progressively undertaken by agencies as other tasks are completed.

AUSTRALIA - SOUTH AUSTRALIA

Planning and development control are carried out under the South Australia Planning Act according to procedures established in that act. While there is provision in the Coast Protection Act for coastal controls, overlap with the Planning Act has been deliberately avoided.

There has been a recent move away from having coastal planning policy in coastal management plans (Coast Protection Act), to having them included in supplementary development plans (Planning Act) where they have more legal force.

A schedule of the Planning Act designates the coast as a special area requiring local councils to forward development applications to the South Australian Planning Commission for consultation. The Coastal Management Branch and the Coastal Protection Board define hazard standards and recommend minimum building levels and set backs on eroding coasts.

A series of policies have been developed by the Coast Protection Board. At 14 December 1988 these were still in draft form, however a similar policy was endorsed by the Minister for Environment and Planning in mid 1988 for interim use. The policy is regarded as interim until better information on sea level rise becomes available.

The policies deal with both sea level rise and current coastal erosion. A figure of 0.8 metres rise in sea level within 100 years has been used.

AUSTRALIA - WESTERN AUSTRALIA

Coastal management commenced in Western Australia in the early 1970s. In 1982 a decision was made not to introduce specific coastal legislation. It was decided to plan and manage the coast line by coordinating state department activities and by cooperative involvement with local authorities. A Coastal Management Coordinating Committee was formed and a secretariat was based in the Department of Conservation and Environment.

After negotiation with approximately 15 State Departments the Country Coastal Planning Policy was approved in late 1987. The policy has three broad objectives; To encourage orderly and balanced development on and adjacent to the coast consistent with the protection of coastal resources; To protect, conserve and enhance, as appropriate, coastal resources; To permit public access to the coast consistent the protection of coastal resources.

The policy sets a guideline of 100 metre set back on sandy coast lines measured from the line of permanent vegetation. In addition a component is added if the coastline is receding. The height and type of developments allowed in the coastal zone, which is up to 500 metres inland, is also controlled.

AUSTRALIA - NEW SOUTH WALES

Coastal development is covered, under the provision of the EPA Act, by things such as:

Environmental Planning Instruments including:
- State Environmental Planning Policies
- Regional Environmental Plans
- Local Environmental Plans

Environmental Planning Control which may relate to, for example,
- Matters for consideration by a consent authority in determining development applications
- Restrictions, concurrences, advertising
- Designated development procedures
- Appeals to the Land and Environment Court
- Commissions of Enquiry
- Determination of Development Applications by the Minister.

Protection and management of the state's heritage and coastal areas is provided under the Heritage Act, 1977 and, to a lesser extent, by Part II of the Coastal Protection Act, 1989 (the remainder of the Act is the responsibility of the Minister for Public Works).

State Environmental Planning Policies (SEPPs) identify matters of significance for state environment planning, such as major economic developments. Although state policies provide a framework for local planning, they do not always take precedence. Local plans may vary in specific circumstances.

Regional Environmental Plans (REPs) aim to balance development and employment with the need to protect the significant environmental qualities of the region. Once approved REPs become law and directly influence local environmental plans.

Local Environmental Plans (LEPs) usually establish specific zones, such as residential or industrial zones. The plans can be prepared only by a local government council and are intended to provide statements of the council's local planning policy as a framework for future development control decisions. Any discrepancies with the SEPP or REP must be reported to the Minister administering the EPA act.

NEW ZEALAND

The present administrative and legal basis for coastal zone management in New Zealand is currently extremely complex. There are numerous acts which presently have jurisdiction over coastal areas. The main ones are:
- Territorial Sea and Exclusive Economic Zone Act 1977
- The Coal Mines Act 1979
- Iron and Steel Industry Act 1959
- Sand Drift Act 1908
- Petroleum Act 1937
- Marine Reserves Act 1971
- Marine Mammals Protection Act 1978
- Marine Farming Act 1971
- Water and Soil Conservation Act 1967
- Soil Conservation and Rivers Control Act 1941
- Marine Pollution Act 1974
- The Fisheries Act 1983
- The Town and Country Planning Act 1977
- Harbours Act 1950

In total 43 statutes are involved and administered by over 20 agencies. The result has been inadequate and ineffective planning, largely due to overlapping administrative boundaries and conflicting purposes.

In 1987 a major review of coastal legislation was initiated by the Minister of Conservation. This review was integrated with the Resource Management Law Reform in 1988, enabling a more comprehensive review and ensuring that planning and processes on the coast would be compatible with those established for resource management.

The Resource Management Bill was introduced to Parliament in December 1989. The coastal management regime established under the Bill provides for a partnership between the Minister of Conservation and regional councils. The Minister will prepare national coastal policy statements stating government policies of national importance in the coastal environment.

Each regional council must prepare a coastal plan for their region which is not inconsistent with the national coastal policy statement. These plans will provide the framework for all planning and licensing decisions in the coastal marine area. In effect, the plan acts as the blueprint for the day to day management of the area between mean high water spring and the outer limits of the territorial sea.

The Minister of Conservation will be responsible for both approving regional coastal plans and also acting as consent authority for specified "restricted" coastal activities.

Although the Resource Management Bill has not yet been reported back to Parliament by the Select Committee, the Minister of Conservation has released a draft of the first New Zealand coastal policy statement for public comment. The Bill is expected to be passed this parliamentary session.

APPENDIX D

A WORLD WIDE COST ESTIMATE
OF BASIC
COASTAL PROTECTION MEASURE

PREFACE

This report is meant to further the expressed desire within the IPCC for quantification of the complex issues raised in relation to sea level rise. Its contents reflect the first results of an exercise with coastline lengths, basic coastal defence options and costs. Whereas this was the only possibility at this stage, these were based on numerous assumptions, estimates and schematizations.

The quantified results clearly need considerable improvement and refinement before they can serve as a basis for anything like planning real action in the area of coastal defence.

No recommendation of any kind is intended with respect to any country's coastal defence options and/or decision criteria. Figures of coastline lengths, defence options and costs, etc. are merely approximations, due to a lack of actual, accurate information.

The rationale of this report, then, is mainly limited to three things. First, to give a rough but realistic estimate of the order of magnitude of costs, world wide, if a 1 m sea level rise were to be responded to with basic coastal defence options. Second, to indicate that the method used, crude and tentative as it is, may open a fruitful path to follow in subsequent analyses with a different scope or a different aim. A third use of this report is that it forms a stimulus for all coastal nations to further develop their own information system to better define their individual needs and options with respect to sea level rise.

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXES

0. SUMMARY

The present study has yielded preliminary estimates of coastal defences and their costs world wide. These approximations for 181 coastal nations and territories, of both protective measures and the expenditures required if they were constructed, do not constitute recommendations. They do, however, provide the international community for the first time with a general quantified assessment of the global financial consequences of protection against sea level rise and, equally important, with the impetus to work for further elaboration and refinement.

Based on available information, the study shows that some 360,000 km of coastal defences of several categories, at a total cost of about US$ 500 billion, are required "if the sea level rises by 1 metre". For this study, it is assumed that sea level rises in a single step and that all adaptive measures are executed in a single step as well. This value does not include costs necessary to meet present coastal defence needs. The estimate does not include the value of the unprotected dry land or ecosystems that would be lost, nor, in fact, does it consider the cost of responding to saltwater intrusion or the impacts of a possible increase in storm frequency.

Furthermore, price and exchange rate fluctuations may affect the estimated values used in this report. It should also be noted that values used were not discounted. In addition, as more detailed information is obtained, real coastline lengths may be greater than those upon which the estimates were based, resulting in greater defence costs.

Finally, uncertainties exist in the cost estimates of basic coastal defence measures. These lead to considerable overall uncertainties, which may cause the global cost to be higher than the present estimate, perhaps by as much as a factor 2.

The overall cost of measures to respond to a 1 m sea level rise may, therefore, be considerably higher than US$ 500 billion.

The main categories of coastal "features" considered in this study, when expressed in kilometres to be protected, come to 339,185 km low coasts, 12,128 km beaches and 6,399 km city waterfronts. Small islands, if low and flat, were considered separately in terms of both land surface elevation and other protective measures.

Per head of population in all 181 coastal countries, the cost of coastal defence amounts to US$ 104. The annual costs as a fraction of the total Gross National Product of the 181 countries is 0.038 percent. These costs for the small islands and island groups in the Indian and Pacific Oceans are very much higher at 0.93 percent and 0.75 percent, respectively. In addition, costs per head of population on these island groups are well above those for any other listed country.

1. INTRODUCTION

1.1 GENERAL FRAMEWORK

The potential threat to coastal areas all over the world by a global sea level rise creates the need for a quantitative insight into the seriousness of this threat, the effort required to respond to it and the costs aspects (i.e. costs of damage and of response measures).

The necessity for quantified studies is evident for three reasons:

- as a basis for decision making to reduce or even eliminate the source of the threat (greenhouse gas emission control on a global scale)
- as a means to establish the extent and the global "distribution" of the threat and its implications for all coastal countries
- as a stimulus, at the national level, to gather appropriate quantitative information for effective long term physical planning of the coastal zone development.

At the International Workshop ("Adaptive Options and Policy Implications of Sea Level Rise and Other Coastal Impacts of Global Climatic Change", Ref. 1) of the Coastal Zone Management Subgroup of the Intergovernmental Panel on Climate Change (IPCC) Working Group III, held in Miami from November 27 to December 1, 1989, the identification of coastal areas, populations and resources at risk from sea level rise was given the highest priority.

The Netherlands, co-chairing Working Group III, has taken the initiative to respond to this recommendation in an effort to present an initial global cost estimate of protective measures for coastal areas, populations and resources at risk from sea level rise (Ref. 11) at the Perth, Australia, Working Group III Coastal Zone Management Workshop to be held from February 19 to 23, 1990.

The prime consideration of the present study is to assess world wide the cost of basic coastal defence measures required, on the general assumption the present susceptibility to attack by the sea is neither decreased nor increased by a sea level rise of 1 m. It is emphasized that the study does not address the potential global impact, i.e. damages resulting from sea level rise if no measures were taken.

Of course, to eventually arrive at more than a first approximation, it will be indispensable and indeed imperative, that all nations with marine coasts participate actively in this assessment.

1.2 AIM

The aim of this study is to make a world wide cost estimate for coastal defence measures in response to sea level rise. The emphasis, therefore, is not on specific measures. It is clear that to make a cost estimate one simply cannot avoid referring to certain specified defence measures. This is only done with the intention of arriving at a realistic cost estimate and not with any intention to suggest, let alone recommend, that these defence measures are actually taken. Decisions on whether and when response measures of any kind are implemented remains, of course, a national prerogative.

Response measures of whatever nature, wherever along the world's coastlines, will involve expenditures of widely varying magnitude. To safeguard the well being of the millions of people living in coastal areas, however it is crucial that the composition of financial (national) burdens is known. This knowledge must be based on objective, relevant information.

The cost estimates presented here are intended to provide a reasonable indication of the order of magnitude of the additional coastal defence costs per coastal country and for the whole world, assuming the necessity to keep up with a threat of an additional 1 m sea level rise.

The aim of the current effort deviates markedly from most previous studies that have been carried out on sea level rise problems and their implications for coastal areas. Thus far, mostly qualitative studies of impacts, effects and response measures have been conducted. Acknowledging a small number of excellently quantified case studies, however, no attempt has been made to quantify and assess the magnitude of the cost of response measures world wide.

In 1986 an international group of scientists, at a workshop held in the Netherlands under the auspices of Delft Hydraulics, laid the groundwork for the approach to the impact of sea level rise on society

(ISOS).

They attempted to "analyze the effects of sea level rise on society in a unified way, so that it can be useful to those responsible for coastal lowlands, by showing possible alternative courses of action and the time that may be needed to implement them" (Ref. 7). Three case studies were presented: the Netherlands, Bangladesh and the Maldives.

In 1988 a first attempt was made to compile a global inventory of areas at high risk from sea level rise (Ref. 2). That study was carried out for the United Nations Environment Programme (UNEP). Its aim was in essence limited to identification of low lying coastal areas, deltas and island nations vulnerable to sea level rise in terms of population safety and economic and ecological impacts.

The current study is not an impact assessment, nor does it contain a cost/ benefit consideration of impacts and response options. Rather, the present study concentrates on costs of defence measures which are devised in such a way as to neutralize the threat of a 1 m sea level rise. As such, the present study assesses the costs of measures which should broadly preserve the "status quo" in terms of coastal land use, thereby disregarding for the moment the temporal element of a gradual sea level rise.

1.3 SCOPE

The above mentioned aims demand a global approach in which all of the world's coastal areas are considered separately and together. This scope at this stage necessitates a limited "depth", or in other words a high level of aggregation.

A global approach is enormously complex. Spatially, more than one million km of extremely diverse coastline of vastly varying susceptibility to sea level rise needs to be considered. Temporally, sea level rise at an as yet uncertain rate is spread over many decades or even 100 years or more, while variables such as future discount rates, population growth and economic development are virtually imponderable.

Even a simple investigation aimed at arriving at cost estimates for basic coastal defence measures in every country with a marine coast is, therefore a considerable task which cannot be accomplished without a deliberately devised set of simplifications, assumptions and schematizations. An outline of the approach applied is presented in the next section.

1.4 APPROACH

The limited time frame for the present study, referred to in Section 1.1, necessitated the adoption of a strategy which combines:

- a rigorous reduction of the inherent complexity of the problem, leading to:
- a set of pragmatic and simplifying, yet realistic, assumptions with respect to:
    - the sea level rise scenario
    - basic coastal defence measures and their unit cost
    - estimation of coastline length for some 180 nations
- estimation of areas to be defended along those coasts.

Moreover, it was found necessary to incorporate the following elements in the study approach:

- specified description of assumptions and quantification procedures, for reproducibility of the results
- spreadsheet application, for easy handling of data and flexibility with respect to future interfacing with data bases
- specified error bands for all quantified estimates, to indicate accuracy
- comparison of resulting costs with national population and Gross National Product (GNP), for relative burden indication.

1.5 CONSTRAINTS

The present effort of global scope obviously has many constraints. Within the time frame referred to in Section 1.1, three main obstacles in the collection of information were encountered:

(1) the information existed but was not (readily) available
(2) the information was (readily) available but inconsistent or ambiguous
(3) the information probably did not exist.

The above obstacles necessitated maintaining a high level of aggregation in order to maintain, simultaneously, a high level of consistency of information.

The thus required selection of a limited number of standard reference works brought its own constraints, preventing in fact valuable in depth cross referencing. Using a relatively small number of standard reference works also brought with it the frequent need to translate generalities into specifics, with all its inherent inaccuracies. This necessitated rough estimates and approximations and in many instances (sometimes daring) extrapolations and assumptions.

Personal experience was utilized to fill the gaps as much as possible, but often the constraint was that such knowledge was highly site specific rather than broad and general.

Throughout the study a constraining factor was the requirement that the end product should be suitably structured to permit future interfacing with other (existing) data bases.

Finally, the result should also be structured in such a manner that further addition to and elaboration of the information is facilitated.

1.6 TASK TEAM

The preliminary world wide cost estimate was carried out by a task team comprising representatives of Rijkswaterstaat as well as private companies in the Netherlands.

The task team was formed by
G.A. Beaufort (RWS), R. Boeije (RWS), J. Dronkers (RWS), J.G. Grijsen (WL), P. Giinther (RWS), C.H. Hulsbergen (WL), W. Korf (RWS), R. Maaten (WL), R. Misdorp (RWS), H.A. Pennekamp (WL), G.H. van Raalte (Hydronamic/Boskalis Westminster Group), P.C. SchrtSder (WL), J.W. Wesseling (WL) and D.H. Wilkens (WL).

Dr. J. Dronkers had overall responsibility for the study.
Mr. C.H. Hulsbergen was project leader.

RWS = Rijtswaterstast, Ministry of Transport and Public Works
WL = Delft Hydraulics

2. METHODOLOGY

2.1 GENERAL

This chapter describes the main methodological considerations forming the conceptual framework, which is the basis for the subsequent quantitative assessment of the world wide cost of coastal protection against a 1 m sea level rise.

The methodological framework combines systematic and pragmatic assumptions and limitations. Together, they form a logical connection between the starting point, i.e. the conceptual aim of this report and, via the particular procedures which will be applied to produce the quantitative elements, the resulting world wide estimated costs.

These links of logical manipulations, for obvious reasons, must meet a number of requirements for the results to be relevant, valid, consistent, accurate and reproducible. These qualifications lack an absolute norm, yet indicate that certain methodological standards should be met for the results of this study to be useful.

The basic concern of the present study is to answer the simple question: "What does it cost, world wide, to defend our coasts against an accelerated sea level rise?" There are many good reasons to reply: "We don't know", since profound uncertainties of many kinds exist. To name a few:

a) How fast will sea level rise? (IPCC, Working Group I).
b) What will a rising sea level precisely do to the world and to society? (IPCC, Working Group II).
c) How to respond to sea level rise in a way which is economically, socially, environmentally, legally, etc., viable and wise?
d) What coastal defence designs are most appropriate, if one of the response options is "defending the coast"?
e) What is the length of the coastline to be defended?
f) What do coastal defence options cost world wide?

Clearly, a realistic estimate of what actually will be relevant for the next 100 years or so in terms of all sea level rise response costs world wide is very difficult to give. This means that the original question cannot be answered easily in an accurate, valid and relevant manner.

By making a number of assumptions where accurate data is lacking, however, it is possible to state the problem in such a way that a reasonably accurate answer can be given without too great a loss of validity and relevance, provided that the assumptions made and quantification procedures adopted are sufficiently realistic and consistent.

If so, reasonably reproducible answers will result, provided that all assumptions, procedures and data assessment protocols are explicitly described.

One of the main difficulties was to maintain full reproducibility in a situation where experience, intuition and professional judgement appear to be the only substitute for inconsistent, ambiguous or lacking data.

From the point of view of "efficiency" of the study, consistency is, among others, an important factor. This means, amongst others, that the efforts in maintaining accuracy and relevancy should be allocated to the various conceptual elements in the same degree to reflect their respective weight for the final result. For example, if "total dike costs" form the bulk of world wide total costs, the accuracy with which the coastline length is estimated should be similar to the accuracy of the cost rate per km dike.

The detailed method applied will be discussed as follows. First, Section 2.2 will describe the manner in which the problem has been reduced to manageable proportions, by stripping a number of aspects which were deemed to affect the overall consistency negatively (partly due to lack of data).

Then, in Section 2.3, a cost formula will be presented involving the main elements of this study. Finally, these respective elements and their detailed operational functions quantifying the respective formula entries are explained and discussed in Chapter 3, which concludes the description of the methodology. The results of this study in terms of costs are presented in Chapter 4 and are discussed in Chapter 5. Final remarks are made in Chapter 6.

2.2 REDUCTION AND REFINEMENT OF THE PROBLEM

In Chapter 1, the aim, scope, approach and some constraints have already been addressed in a descriptive sense. A more detailed, description of the problem is given in a document which was discussed at the Miami Workshop (see Section 1.1) and which forms the original framework for the present study:

"Socio-economic, Legal, Institutional, Cultural and Environmental Aspects of Measures for the Adaptation of Coastal Zones at Risk to Sea Level Rise (Ref. 11)".

In this document, the following strategies for the adaptation of coastal zones were mentioned:
- protection
- land use adaptation (including retreat).

Of these, only "protection" is considered further in the present study. Protection measures can serve to:
- protect land from flooding
- protect land from erosion
- protect land and freshwater from seepage and salt water intrusion.

Of these, mainly the protection of land from flooding and erosion is considered further in the present study. Protection from seepage and salt water intrusion is only marginally considered.

Protection works consist of civil engineering structures, such as beach replenishment, dikes, revetments, closure dams and elevation of very low areas; these will be discussed in detail in Chapter 3.

As to the design conditions of these civil engineering works, the following description serves as a basic concept. Starting point for the protection measures considered here is maintaining the present protection level of human beings and infrastructure in the coastal zone at risk. (As an example, the above formulated starting point implies for a region protected by dikes, assuming that other conditions remain the same, a raising of dikes approximately equal to the rise of sea level). It should be noted that this starting point often does not coincide with optimal coastal protection and may even leave coastal regions with too low a protection level. In particular this is the case for coastal zones which at present are insufficiently protected due, for example, to recent land occupation or subsidence. These situations ask for a solution, but in principle this is independent of sea level rise.

A reduction in the scope is that only civil engineering aspects of these protection measures are considered. Institutional, legal and technical aspects, all essential to maintain infrastructural integrity, are not considered in this appendix, nor are their costs, which might be substantial.

Environmental aspects, such as the impact of sea level rise on coastal wetlands, are not considered in the present study. Also, cultural aspects are not considered.

Socio-economic aspects are, in the present study, reduced to the costs for construction of the civil engineering works. Chapter 3 gives a further description of the manner in which these costs are defined.

The above mentioned procedure of narrowing the original scope to manageable proportions is regarded as a necessary limitation for the present study. In subsequent world wide studies, which could be set up according to a procedure similar to the present work, further aspects might be incorporated.

In addition to the above mentioned procedure of narrowing the scope of the problem as an essential part of the methodological constraints, a number of other considerations was applied as follows. To maintain optimal consistency throughout at an initially necessarily high level of aggregation, the following rules were applied:
- A strictly limited number of standard reference books was consulted. They are listed in the section References and, where appropriate, indicated throughout this report.
- Every inclination toward subjective judgement and/or injection of personal local knowledge was carefully weighed in the context of consistency and verifiability.
- All assumptions made were considered on the basis of suitable future interfacing with other (existing) data bases.
- All definitions used were screened for general acceptability and recognizability.
- All calculation methods were screened on suitability and applicability.

To maintain consistency and conciseness with respect to the climate change and sea level rise aspects as the key triggers for protection measures, the following assumptions were formulated:

- Climate boundary conditions:
  Changes in storminess and wind climate, inevitably impinging upon and, thus, causing significant changes in a large set of boundary conditions relevant to the coastal areas, were set at zero to maintain consistency.

- Sea level rise:
  A "1 m sea level rise" scenario was decided upon as a starting point for this study, representing the order of magnitude of sea level rise expected on the basis of model simulations for the next 100 years.

- Event time frame:
  A 1 m sea level rise occurring "tomorrow" was chosen to initially circumvent any consideration of numerous imponderables, such as future discount rates, varying population growth projections, unpredictable economic development, etc.

- From sea level rise to dike level rise:
  To "freeze" a large set of extremely divergent and different effects of a 1 m sea level rise, present overtopping frequencies, if any, were strictly maintained in the sense that coastal dikes etc. were simply raised by 1 m, whereas undefended low coasts were protected by 1 m high dikes (or equivalent strengthening). This assumption means, amongst others, that in the present analysis an increased wave run up as a result of a rise in sea water level is ignored. In other words, what has so far loosely been indicated as a 1 m sea level rise scenario is now transferred into a 1 m dike level rise scenario throughout the further study.

2.3 COST FORMULA

This section presents a schematic cost formula and a flow chart, encompassing all elements which play a role in the algorithm to arrive at world wide cost figures or which may help to interpret these figures.

The core of the formula is in principle the same for each country and can be represented as follows:

unit cost of measure type 1	*	country cost factor	*	length (or area) to be protected by measure type 1	=	cost 1
unit cost of measure type 2	*	country cost factor	*	length (or area) to be protected by measure type 2	=	cost 2
unit cost of measure type n	*	country cost factor	*	length (or area) to be protected by measure type n	=	cost n
					+	
				(cost 1+2+..n)	=	total cost per country

For each country the relevant elements must be determined, quantified and inserted into this formula. The adopted methodology for the estimation of the total length of protection works per country is summarized as follows:

- step 1: selection of low lying coastal zones in regions with a population density exceeding $10/km^2$
- step 2: measurement of the coastline length "as the crow flies" in the selected zones
- step 3: estimation of a multiplier for calculation of the total shoreline affected by sea level rise, with the coastline measured "as the crow flies"
- step 4: estimation of the total length of beaches to be nourished
- step 5: estimation of the length of sea defences for coastal cities.

All elements mentioned above are defined and described in Chapter 3.

3. DATA ASSESSMENT PROCEDURES

3.00 GENERAL

This Chapter describes the precise manner in which the various elements participating in the cost formula and appearing in the spreadsheet results, as outlined in Section 2.3, have been defined and quantified. Where applicable, the margins of error involved in the quantitative estimate is discussed.

3.10 LIST OF 181 COUNTRIES AND TERRITORIES

To obtain a comprehensive overview of the world's coastlines which will be affected by sea level rise, countries and territories indicated in the Encyclopedia Britannica (Ref. 15) as having territorial seas and thus possessing a marine coast, were listed. It yielded 181 countries and main territories, shown in Annex D1 in alphabetical order. Separate inclusion of the main territories was maintained on the geographic consideration that they possess a significant part of the world's marine coastlines. Listing of territories, therefore, has no political significance.

It was felt that some minor inconsistencies arising from the use of this list did not detract from the comprehensive overview sought.

3.20 LABELING OF ENTRIES

Listed entries (countries and territories) were labelled according to the continent on which they are located and the oceans on which they border. Some countries, however, can be put in more than one class at the same time, because they border more than one of the identified seas or oceans. For example, Spain borders both the Atlantic Ocean and the Mediterranean. The category (Northern and Southern) Mediterranean also includes the borders of the Black sea. Romania, for example, is labelled under Northern Mediterranean. The exact classification of each country can be found in Annex D.3.

A separate distinction was made for small islands. Small islands were defined as those where it may reasonably be assumed that they are influenced entirely by the sea and where it is particularly difficult to escape from the effects of sea level rise. A list of the small islands is provided in Table 4.4.

3.30 BASIC STATISTICAL DATA FOR LISTED ENTRIES

Basic statistical data for all listed entries was obtained from standard reference works and include:

Type of data	Reference
Population	Encyclopedia Britannica (Ref. 15) The World in Figures (Ref. 16)
GNP	Encyclopedia Britannica The World in Figures
Tourist numbers and income	Encyclopedia Britannica The World in Figures
Marine transportation	Guide to Port Entry (Refs. 5, 6)
Area	Encyclopedia Britannica The World in Figures
Per capita income classes	World Bank Annual Report (Ref. 14)

3.40 BASIC COASTAL DEFENCE MEASURES, UNIT COSTS AND COUNTRY COST FACTORS

Basic coastal defence measures are proposed for the protection of cities, harbours, beaches and cultivated lowlands. No provisions are designed for protection of typical coastal wetlands.

Cost estimates are established for construction works of basic coastal defence measures to offset a 1 m sea level rise, based on the following assumptions and conditions.

- Standard measures are defined for various possible construction works. The definitions include dimensions, construction materials and construction methods.
- The measures are based on existing Dutch procedures and provisions to accommodate future relative sea level rise, in combination with experience obtained during numerous construction works all over the world.

- Basic unit costs are 'all in' for the Dutch situation, including provisions for design, execution, taxes, levies and fees, but excluding royalties and costs for financing.
- Construction method and cost estimates are based on the assumption of construction in one continuous operation per project. Cost effects (positive or negative) of a gradual implementation of the works over a longer period are ignored. Also quantum effects, by a combined execution of various smaller projects, are not taken into account.
- Cost estimates are based on the price level of end 1989.
- Provisions for increased maintenance, increased drainage capacity, etc. are specified where applicable.
- Assessment of world wide construction costs is obtained by multiplying the (Dutch) unit costs with a Country Cost Factor. This factor takes into account local circumstances, such as:
  - presence of a "wet" civil construction industry
  - availability and costs of human resources
  - availability and quality of construction material
  - possibility for mobilization of (foreign) equipment
  - possible effects of the size (on an economic scale) of the project
  - (land) acquisition costs the local market situation.
- Country Cost Factors are distinguished for a few groups of more or less identical construction works. These factors, within one country, are not necessarily the same for all types of structures. These factors and their respective normalized standard deviations are specified in Annex D.2.
- It is very likely that for some countries costs are under estimated while for others total costs are over estimated. These discrepancies will for a large part even out in the total number of world wide activities considered.

In the following, standard measures of coastal defence against a 1 m sea level rise and their unit costs (Dutch cost level), are presented. Costs are expressed in millions US dollars (1 US$ = 2 Dfl., 1989).

1.a **Construction of a 1 m high sea dike**

dimensions:	height: 1 m top width: 4 m slopes: 1:4 cross section: 8m^3/m
construction:	with local materials by hydraulic crane and bulldozer; slope protection; asphalt penetrated stone
unit cost:	0.4M$/km

1.b **Construction of a 1 m high sea dike, with regular maintenance due to peak wave attack/storm surges**

dimensions and construction:	as under 1.a
unit cost	assume capitalized maintenance cost at 50% of construction cost; thus total 0.6M$/km

Note: For reasons of uniformity, at the same time taking into account some provisions for organisation of maintenance, for both 1a and 1b 0.6M$/km is calculated.

1.c **Raising of low sea dikes with 1 m, in rural areas**

dimensions:	1 m top cover 1 m inside slope cover
construction:	with local materials and simple slope protection
unit cost:	0.5 M$/km (cost for increased drainage capacity included or considered being part of depreciation).

1.d **Raising of high (4-7m) sea dikes with 1 m, in rural areas**

dimensions:	1 m top cover 1 m inside slope cover
construction:	with local materials and original slope protection
unit cost:	1 M$/km (drainage costs: see under 1.c)

Note: In the definition of rural dikes, the types 1a/1b, 1c and 1d are mixed, with an average ratio of 50/40/10. The total dike length can thus be multiplied with an weighted average unit cost of 0.6M$/km.

2. **Raising of sea dikes with 1 m in urbanized areas**

construction:	by dike widening at sea side of dike with local materials and firm slope protection or by installation of concrete sea walls on top of existing dike.
unit cost:	10 M$/km (drainage costs: see under 1.c)

3.a **Closure dams of shallow (max. 10m deep) sea arms**

construction:	sand, clay or rubble mound core; slope protection with asphalt penetrated stone drainage sluices (culverts)
unit cost:	15 M$/km

3.b **Closure dams of shallow (max. > 10 m deep) sea arms**

construction: as under 3.a

unit cost: 25M$/km

3.c **Additional discharge sluices for river or basin outlets**

unit cost: 50 M$/km sluice (This figure cannot be applied for major river arms)

Note: Closure dams etc. have not been applied in this study for reasons explained in Section 3.73

4.a **Beach nourishment of sandy beach without protection works**

dimensions: 1 m thick sand layer over morphologic active zone; up to MSL -8 m contour line, approx 1000 m wide

construction: nourishment by "tshd" (trailing suction hopper dredge) from offshore sources or by "csd" (cutter suction dredge) from nearshore/inshore sources

unit rates:

- project length: 2-6 km, sand from near (<10km) sources: 3.5M$/km
- project length: > 6km, sand from nearby sources: 3M$/km
- project length: 2-6 km, coarse sand from remote (>10km) sources:6 M$/km
- project length: >6 km, coarse sand or sand from remote sources: 5.5M$/km

average unit cost: 4M$/km

4.b **Beach nourishment of sandy beach with existing protection works**
(groynes, under water beams, etc.)

dimensions: 1 m thick sand layer, over 75% of morphologic active zone, 750m wide
1 m raising of existing construction with 50 ton stone/m

construction:

- nourishment by "tshd" from offshore sources or by "csd" from nearshore/inshore sources
- stones placed by land dumping or crane placement

unit rates: nourishment 3 M$/km (see 4.a)

stone work:

- over land from local sources: 0.4 M$/km
- over water from local sources: 0.8 M$/km
- over water from remote sources: 1.25 M$/km

average unit cost: 4 M$/km

4.c **Tourist beaches**

construction of additional works to preserve specific recreational functions of existing facilities, by various (not specified) measures.

unit cost: estimated additional value of 50% of beach nourishment costs: totally 6 M$/km

Note: It is assumed that tourist beaches cover some 25% of the total beach length to be replenished. Calculations are, therefore, made with a unit rate of 4.5 M$/km beach length, without any further discern of function.

Note: Technical feasibility has been assumed for beach nourishment, including areas where sand sources are expected to be scarce.

5. **Industrial area and harbours**

construction:	–	low lying outer dike areas will be raised 1 m; quay walls will be strengthened
	–	petrochemical areas are protected by raising or construction of sea dikes
	–	buildings and infrasturcture are not adapted as normal depreciation period is far less than 100 years
unit cost:	15 M$/km^2 low lying area	

6. **Island elevation**

construction:	–	existing (coral) island will be raised 1 m by placing material from other (abandoned) islands
	–	for buildings and infrastructure: see 5
	–	strengthening of sea defences included where applicable
unit cost:	12.5 M$/km^2	

Remarks:

- Technical and financial effects of changes in salinity of groundwater or in salt water intrusion are not considered; however possible methods to combat salt water intrusion are mentioned in Section 3.73.
- Unit costs for item 5 are expressed per k2 m , instead of per km, because the effective lengths of water front in harbour areas are difficult to assess. Estimation of cost per area is assumed to present a realistic average.
- The uncertainty range of the unit cost figures can be roughly indicated as a factor 2, except for China where the uncertainty is considerably higher.

3.50 SELECTION OF COASTAL ZONES TO BE PROTECTED

Two selection criteria were adopted to avoid that protection measures would be calculated for conditions that would not require any measures: the presence of human activity and the presence of a low coast which is, in principle, susceptible to a sea level rise of 1 m.

For human activity, population density was used as a parameter, as described in Section 3.51. To accurately determine whether a coast is low, detailed maps or descriptions are indispensable. These were not readily available for most of the countries. In section 3.52 a rather rough, alternative discrimination method is therefore applied.

3.51 Population density

Although no cost benefit analysis was made, it was assumed that in very sparsely populated coastal areas the costs of protection would not be justified from an economic point of view. Arbitrarily it was assumed that in general no coastal protection would be provided in areas with a population density less than 10 persons per square kilometre. Data on population density in coastal zones were derived from a world map in the Times Atlas (Ref. 18, plate nr. 6). The map shows sufficient detail and (most likely) accuracy for the present global analysis.

3.52 Low lying coastal zones

Coastal protection was not considered necessary for all coastal zones in areas with a population density greater than $10/km^2$. Areas below the 100 m contour with a coastal zone width of less than about 25 km were generally considered to be steep enough not to require any protection. Exceptions were made for small deltas and for wide bays with a dense population in a rather narrow coastal zone. Maps on a scale of 1:2,500,000 or 1:5,000,000, as available in the Times Atlas (Ref. 18), generally show contour lines for 100 m above mean sea level and higher. Using these maps, the selection was made of low lying coastal zones to be protected.

The above approach may lead to some underestimation of the length of the coastline to be protected. On the other hand, heavy dune ridges or steep coasts up to, for example, 20 or 50 m above mean sea level with flat land over a large distance behind it, can not be recognized on the maps. Such areas may actually not require any protection against sea level rise, except for nourishment of recreational beaches, if any. In general, all populated (>10/kms) coastal areas with a wide zone below the 100 m contour line (wider than 25 km) have been included in the total coastline to be protected. Only in a few cases, where a steep coast below 100 m was known to exist, have such stretches been excluded. This may, therefore, lead to some overestimation of the length of the coastline to be protected.

3.60 DETERMINATION OF COASTLINE LENGTH

3.61 Coastline length "as the crow flies"

For the above selected low lying coastal areas, with a population density greater than 10/km ~, the length of the coastline measured "as the crow flies", was used as a basis for estimating the total shoreline length affected by sea level rise. For each country the total length of its coastline to be protected was determined by measuring its general coastline length in steps of 50 to 100 km in the Times Atlas (Ref. 18).

3.62 Multiplier for coastline length

The total required length of shoreline protection in a low lying coastal zone is a multiple of the coastline measured "as the crow flies". Often it may be 5 to 15 times as long, due to the presence of nearshore islands, large estuaries, the irregularity of the coast and backwater effects of sea level rise on rivers, which have to be protected on both sides.

In case of large rivers in flat deltas, often with a depth of 10 to 20 m and a surface water slope in the order of 2 to 5 cm/km, sea level rise may penetrate over some hundreds of kilometres. The main river also often bifurcates in the delta into a number of minor branches, which may have to be protected on both sides over their entire length. Finally, numerous smaller local rivers and man made channels are often found in deltas. Multipliers to calculate the total tidally affected shoreline (including the banks of estuaries, islands, tidal rivers and channels) from the straight coastline measured "as the crow flies", may therefore reach values of up to 20.

In the event of a rather straight coastline without estuaries and coastal islands, with only a few rivers draining into the sea, a rather low value for the multiplier may be expected, viz. between 1 and 3.

The above multipliers available for all coastal states in the USA (Ref. 19), are listed in Table 3.1. The Ref. 19 figures result in a "general coastline" length of 5,604 km and in a "tidal shoreline" of 73,571 km, yielding an overall multiplier of 13.1)For the Mississippi delta in Louisiana, for example, a multiplier of 19.4 is indicated, while for California, with a rather straight and steep coastline and relatively few estuaries and rivers draining into the Pacific Ocean, only a factor 4.1 is found. The data indicate that often a multiplier exceeding 5 will be found for low lying coastal zones, with values up to 15 to 20 for large deltas. The four right hand side columns of Table 3.1 will be discussed in Section 3.74.

Typical map images for regions with a multiplier of S, 10 and 15 are presented in Figures 3.1 to 3.3. These images were used as a reference base for the worldwide estimation of multipliers for all coastal zones to be protected. The procedure was "calibrated" for all coastal states in the USA. Table 3.1 indicates both the estimated multipliers and the values available from literature (Ref. 19).

In general one tends to underestimate the multiplier, one of the reasons being that only part of the tidal rivers and channels are indicated on maps on a scale of 1:2,500,000 or more. An analysis based on backwater effect calculations for the rivers displayed on large scale maps is, therefore, bound to seriously underestimate the total shoreline to be protected. Many smaller rivers and man made channels are not displayed on the maps, while irregularities in the coastline and smaller coastal islands also cannot properly be accounted for. Moreover, it would be impossible to properly assess the zone with backwater effect of sea level rise for most of the numerous (smaller) rivers, because data on high flows, water depths and surface water slopes are generally not easily available, except for some of the larger rivers. The multiplier approach, as calibrated for all coastal states in the USA (excluding Alaska because of its low population density), was, therefore, adopted for world wide application.

The multipliers, as available for the USA, refer to the total tidally affected shoreline. This is not necessarily equivalent to the total shoreline affected by sea level rise of 1 m. Calculations of backwater effects of a one meter sea level rise for some rivers in deltas have been made however, (see Annex D4) and the results indicated that the tidally affected shoreline would provide a fair estimate of the total shoreline to be protected against sea level rise.

The analysis of backwater effects along the rivers in some large deltas is discussed in Annex D4. Based on the calculated and measured distances along the delta coast and the rivers (displayed on the maps 1:5,000,000) requiring protection, multipliers in the order of 5 to 10 were derived for deltas. For reasons as explained above, it is expected that these multipliers are easily underestimated by a factor 2 and that values in the order of 10 to 20 are more likely to be expected for the larger deltas in the world.

In the event that the low lying coastal zone in a country consisted of various subzones with a marked difference in multipliers, for example a large delta with a high multiplier and rather straight zones with a low one, a weighted average multiplier was determined for the entire zone to be protected. Thailand (Figure 3.4), for example, in general shows a coast with an appearance somewhere between Oregon (multiplier 5; Fig. 3.1) and Carolina (multiplier 10; Fig. 3.2) and would get a multiplier of 7 to 8. Part of the densely populated area however, is found in the Chao Phraya delta where besides the capital Bangkok (taken into account under cities; Section 3.71) a complex system of river branches and canals is found, for which a multiplier of over 12 would be applicable. Since one multiplier per country is applied at this stage of the project, it has been decided to allocate a multiplier 10 for Thailand.

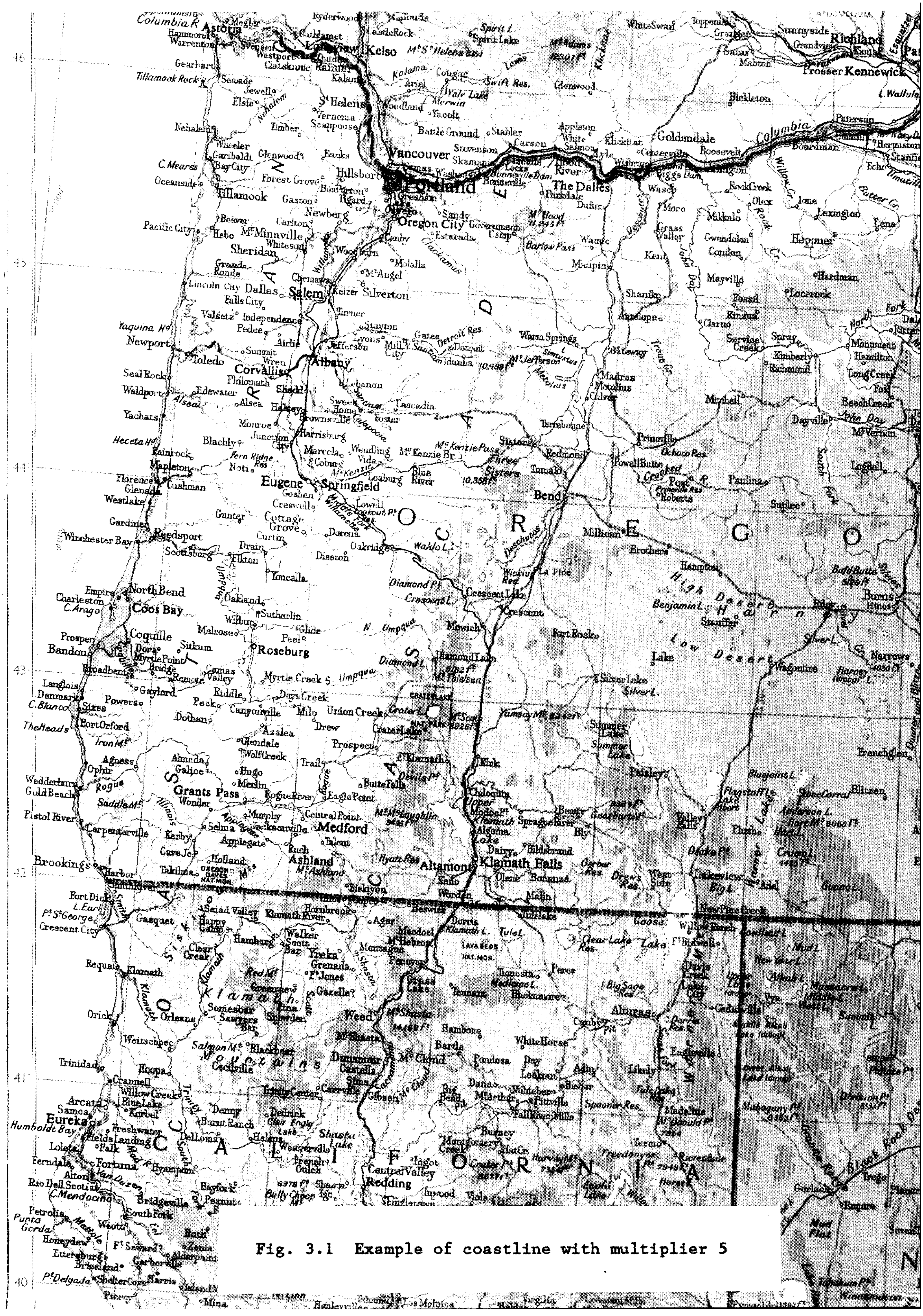


Fig. 3.1 Example of coastline with multiplier 5

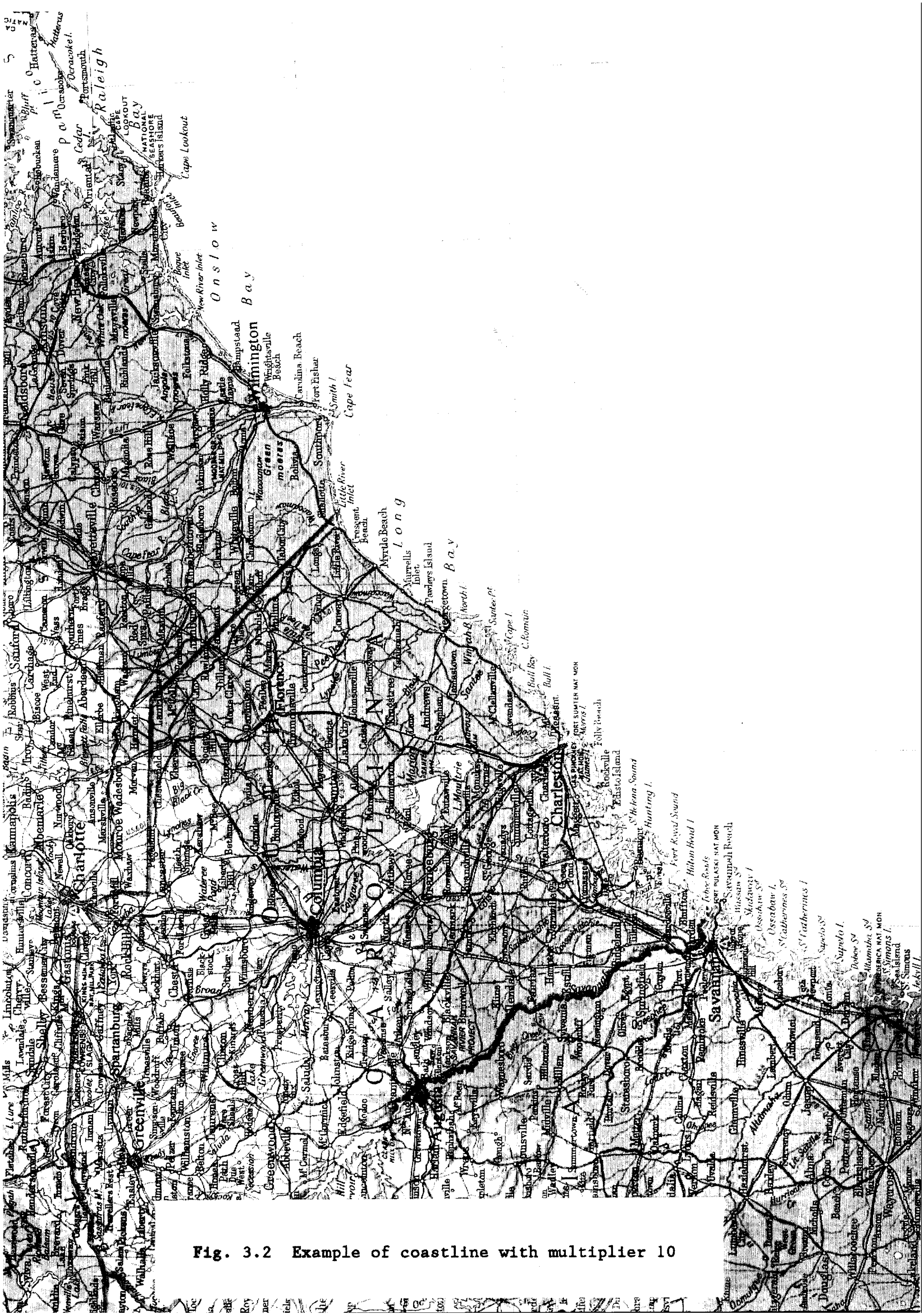


Fig. 3.2 Example of coastline with multiplier 10

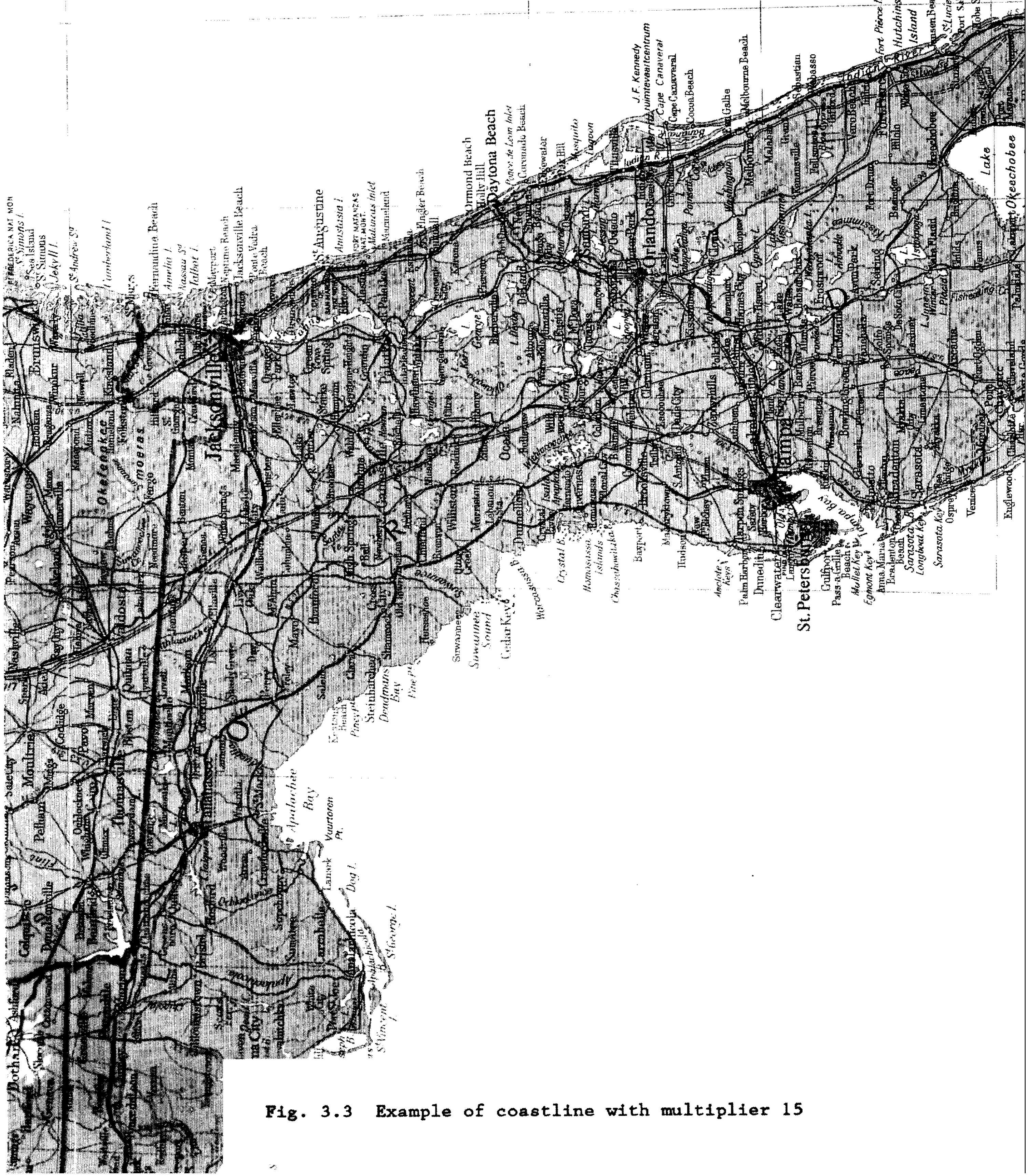


Fig. 3.3 Example of coastline with multiplier 15

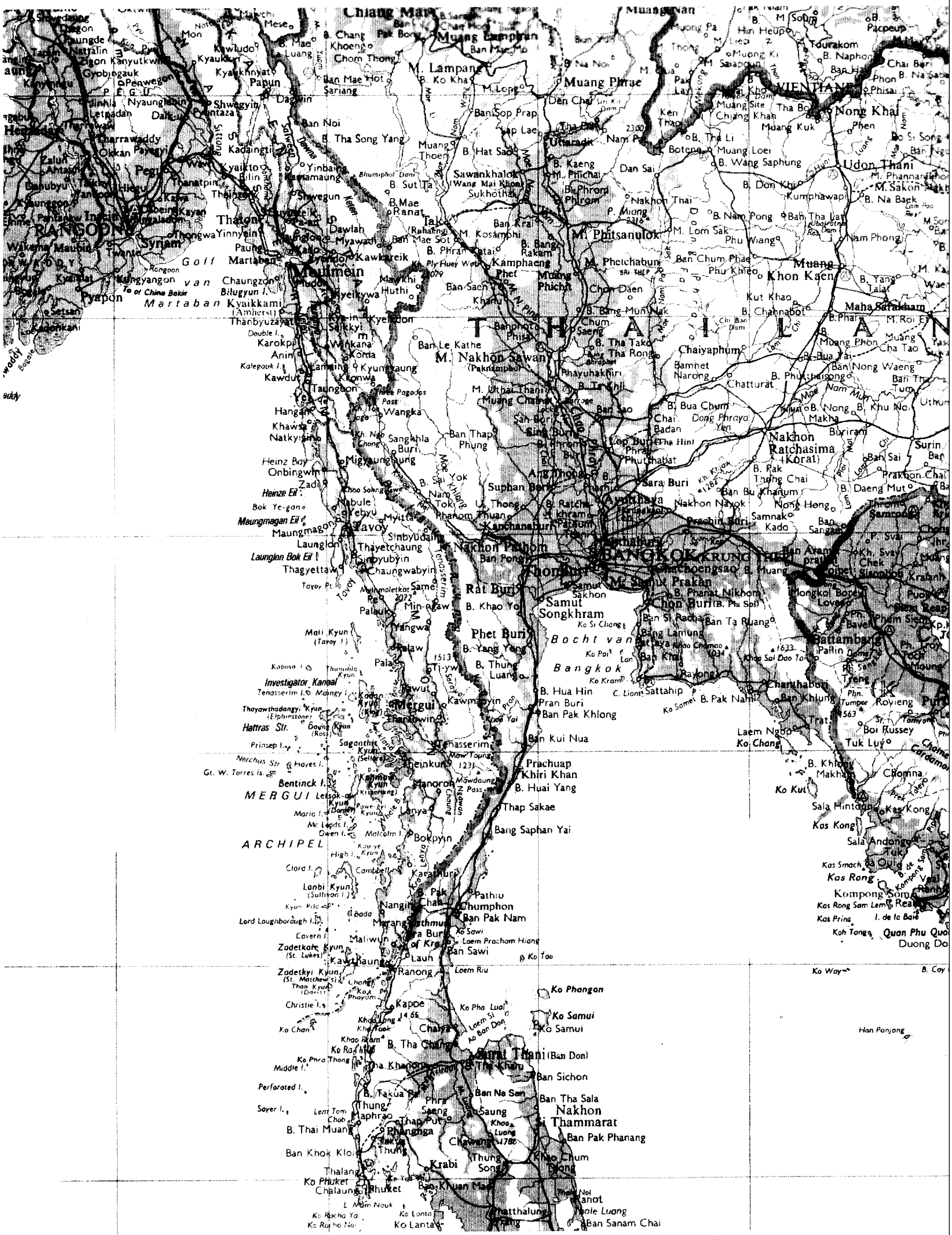


Fig. 3.4 Weighted average multiplier for Thailand: 10

Butang Eil Yaha Naratniwat

3.70 PROTECTION OF THE COAST

3.71 Coastal cities

In first instance, the waterfront length of coastal cities was measured from maps. This was done for those cities which could be recognized as important urban centres on the available maps on a scale of 1:5,000,000 or 1:2,500,000 in the Times Atlas (marked as grey hatched areas, Ref. 18). Urban centres located at some distance inland along a river, where significant backwater of sea level rise is expected to occur, are also included in the analysis. For some countries the capital cities, located at the coast, could not be recognized as important urban centres on the map. In that event a minimum distance of 5 km to be defended was adopted.

The length of the waterfront was measured on the maps and includes both sides of a river, if appropriate. In reality the total distance to be protected in a city will be larger due to irregularities in the course of the waterfront and the existence of smaller rivers or channels not shown on the maps. A suitable range of multipliers to cope with this problem was not available. This aspect is included in the unit cost rate for sea dikes in urbanized areas (Section 3.40, item 2). The costs of protecting the numerous smaller coastal cities and villages are assumed to be included in the unit cost rates for the construction of dikes and beach nourishment.

Secondly, the cities not included in the above mentioned method were accounted for according to a different procedure. The following classification of various city sizes was applied in accordance with the Rand McNally atlas (Ref. 13).

city type	city population
small	under 25,000
medium	25,000 - 250,000
large	250,000 - 1,000,000

The cities were counted on the atlas maps. In principle they were all included in the analysis, except for those areas (see above) where "important urban centres" and coastal villages have already been included. The uncertainty range of the number of cities counted in this manner is estimated at 30 percent.

For each class of city an average waterfront length was assumed. For small cities the waterfront length to be protected by dikes was assumed at 1 km (see Section 3,40 item 1). For medium and large cities the waterfront length was assumed to be 3 km and 5 km, respectively, both to be protected according to Section 3.40 item 2 (sea dikes in urbanized areas). The uncertainty range of these unit waterfront lengths is estimated at a factor 2 lower and a factor 4 higher.

3.72 Beaches

For the USA, Leatherman (Ref. 17) has made a detailed analysis of the total quantity of sand required for raising barrier islands and nourishment of major recreational oceanic beaches in order to stabilize the shore in, often heavily developed, resort areas. Of the 11,000 km of sandy shoreline in the USA, some 3,000 km of beaches were considered to require nourishment.

The selected areas were considered to be the principal recreational beaches in the country. Estimates were made for various scenarios. For a sea level rise of 1 m some 3,000 million mg of sand would be required for beach nourishment and raising of barrier islands. This is equivalent to a sand layer of 1 m thickness and a width of 1 km along the coast length to be nourished. The same quantity has been adopted worldwide for raising islands and beach nourishment, i.e. 1 million m^3 of sand per km of beach.

The choice of beach lengths to be nourished per country is highly arbitrary. Maps in the Times Atlas do not display any information on sandy beaches. Other sources (Ref. 20) give some information on the total length of sandy beaches, but these data also include coastal zones with a population density less than 10/km z and steep coastal zones, which are not considered for protection against sea level rise. More detailed information is available in The Pilot (Ref. 12), but this information was too voluminous to be consulted within the short time available for the present analysis. Only rough estimates could, therefore, be made and the total coastline length to be nourished was mainly estimated on the basis of expected requirements for maintaining important tourist resort areas. The variance of the thus determined beach length is estimated at 0.25.

3.73 Low coasts

Based upon the coastline length "as the crow flies" (Section 3.61) and the multiplier for low coast (Section 3.62), the total length of low coast to be defended has been determined for each country.

After subtraction of the waterfront length of cities (Section 3.71) and beaches (Section 3.72) to be protected, a low lying coastal zone remains. The resulting low coastline length is assumed to be protected by dikes (see Section 3.40, item 1). The resulting uncertainty range of this length can vary and is determined by the above mentioned elements of the calculations of the length of the coastline.

A major part of the low coasts to be protected by dikes can be found in deltaic areas and the like, where through many estuaries and river mouths, seawater may penetrate far into the mainland.

Increased salt water intrusion is one of the threats accompanying sea level rise. As one of various possible counter measures, barrier dams built across the estuaries will be able to effectively reduce salt water intrusion, though at a high cost per unit length (see Section 3.40, items 3 a, b, c). Depending on the depth and other dimensions of a particular estuary, such a closure dam may be less or more expensive as compared to the option of low dikes all along the inland estuary borders while leaving the estuary open. Of course many more considerations play a role in such a decision, among which ecological and infrastructural aspects. Profound insight in local conditions could be necessary before such major infrastructural works would be initiated. For the present study it was assumed that, from a total cost point of view, the application of simple dikes gives a realistic estimate.

Just constructing dikes along all threatened coasts may, of course, not be a good idea. The presence of dikes may bring along many disadvantages, such as adversely affecting natural drainage systems and natural sedimentation patterns. These effects should be carefully considered before actually building dikes.

3.74 Case study USA

In an early stage of the present study the adopted method of analysis (viz. estimating "crow" lengths and multipliers) was applied for all coastal states in the USA to test its validity ("calibration"). Each state was considered as a country. Alaska was excluded because of its low population density. The results are presented in Table 3.1. In the final stage of the present study, a more consistent determination of the "crow" lengths was used for all countries. Due to the difference in methods used, a slight difference in the coastline length ("crow") for the USA is shown in Annex D.2 and Table 3.1.

State	1 CLPcrow (km)	2 Mult. Lit. (Ref. 19)	3 Mult. Estim.	4 Total (km)	5 Beach (km)	6 City (km)	7 Dike (km)
California	300	4.1	5	1,500	125	110	1,265
Oregon	125	4.8	5	625	44	0	581
Washington	150	19.3	15	2,250	77	25	2,148
Maine	140	15.3	5	700	50	10	640
New Hampshire	25	10.1	5	125	14	0	111
Massachusetts	240	7.9	10	2,400	160	20	2,220
Rhode Island	60	9.6	10	600	44	25	531
Connecticut	150	4.1	5	750	102	25	623
New York	400	14.6	10	4,000	192	150	3,658
New Jersey	190	13.8	15	2,850	200	125	2,525
Delaware	40	13.6	15	600	16	15	569
Maryland	50	102.9	5	250	14	25	211
Virginia	160	29.6	15	2,400	27	50	2,323
N. Carolina	80	11.2	10	800	229	20	551
S. Carolina	25	15.4	10	250	149	0	101
Georgia	25	23.4	15	375	26	20	329
Florida	525	6.2	5	2,675	870	200	1,555
Alabama	75	11.5	10	750	58	15	677
Mississippi	100	8.2	5	500	68	0	432
Louisiana	450	19.4	15	6,750	137	140	6,473
Texas	100	9.2	10	1,000	368	50	582
Total	3410	13.4	9.4	32,100	2,970	1,025	28,105

Notes:

CLPcrow:	Coastline to be protected, measured 'as the crow flies'; pop. density > 10/km^2; low lying coastal zones
Mult.Ref.19:	The World Almanac and Book of Facts 1990
Mult. Est.:	Multiplier for tidally affected coast, including river banks
Beach:	Protection with beach nourishment (measures 4a/4c)
City:	Water front line in coastal cities (measure 2)
Dikes:	Protection with dikes (measures 1b/1c/1d)

Table 3.1 Shoreline protection USA

For each state the low lying coastal zone with a population density greater than $10/km^2$ was measured "as the crow flies" (CLPcrow) and multiplied with an estimated multiplier to obtain the total shoreline to be protected. This resulted in a total distance of 32,100 km. Use was made of the estimate by Leatherman (Ref. 17) for the coastline to be protected through beach nourishment and raising of barrier islands, in total 2,970 km. The length of the waterfront in coastal cities was determined at 1,025 km. The remaining distance of 28,105 km should be protected through the construction of low dikes (levees).

Weggel et al (Ref. 17) identified some 4950 km of shoreline to be protected for 84 developed coastal areas in the USA. These sites represent 13.696 of the US sheltered shorelines. The total shoreline to be protected would thus be about 36,400 km, excluding the areas to be protected through beach nourishment and raising of barrier islands, as identified by Leatherman. This compares to 29,130 km in the present analysis (cities + dikes, Table 3.1), equivalent to 80 percent of the estimate by Weggel. includes waterfront to As stated before, this length is underestimated in our approach, but compensated for through a higher unit cost rate. The approach adopted in the present analysis, therefore, yields a reasonable cost estimate of required protection works in the USA.

The average weighted multiplier (9.4 -Table 3.1) is underestimated by 30 percent in relation to the multiplier from Lit. Ref. 19 (13.4). This falls within the maintained order of accuracy. Even though it is an underestimation (of 3096), the approach used to find the multiplier as found in the third column of Table 3.1 has been applied for the entire world in order to maintain consistency.

Weggel's estimate, however, a detailed inventory of the be protected in coastal cities.

3.80 PROTECTION OF SMALL ISLANDS

Not included in the approach discussed in the previous section (the so called "crow approach") are the costs of protecting so called small islands. For the determination of the protection costs of these islands a different approach was followed.

The following protection measures are considered for this group of countries:

- beach protection (tourist beaches)
- protection of low lying (parts of) islands with dikes
- island elevation (only for low lying islands)
- protection of city waterfronts - protection of harbours.

The protection of harbours will be dealt with in Section 3.90. The protection of city waterfronts is included in Section 3.71. In the present section only the first three protection measures will be addressed.

3.81 Beaches on small islands

Based on maps (Times Atlas) and information about tourism (tourist numbers and revenues from tourism), major tourist beaches were identified on small islands. Based on knowledge of the local situation and on the above mentioned information, a beach length to be defended with beach nourishment measures was estimated for the respective islands. A general uncertainty range of a factor 4 is assumed.

3.82 Dikes on small islands

Based on maps of the various islands, the low lying parts were identified and a dike length was estimated (with an estimated uncertainty range of a factor 4). This was done for all the islands other than the islands which were identified as lower than 6-8 meters above MSL. For the low lying islands (mostly atolls or the like) and for the low lying parts of small island countries with a mixed shape (partly high, partly low) a different approach was followed.

3.83 Elevation of low lying small islands

Some really low lying islands, with a freeboard of sometimes little over 0.5 m, require a different set of measures. Protection by dikes alone will not always

suffice. Such islands will have to be elevated as a whole or in part. From experience with the situation on the Maldives it is known that not all the surface area of these archipelagos is inhabited (Ref. 8). Usually the population is concentrated on a limited number of rather densely populated islands, thereby providing a reasonable basis for social subsistence. A part of the remaining population may reside on relatively high parts of the islands. Thus protection of the complete surface area will not be necessary.
To estimate the area for island elevation and the length for dikes, the following procedure was adopted:

1 - Determine total population minus population living on higher areas: POPLO
2 - Determine total area to be protected by assuming population density of 2000/km^2:

$$AREAPR = \frac{POPLO}{2000}$$

3 - Assume that half of AREAPR has to be raised by 1 m and the other half is to be surrounded by dikes, meaning that:
4 - Area to be elevated is AREAPR/2
5 - Area to be diked is also AREAPR/2. In order to determine dike length, island circumference (form and size) must be defined
6 - Assume square island form with sides of 0.5 km, thus circumference of 2 km.
7 - Then dike length is given as AREAPR*4 (km).

For the area to be elevated as well as for the dike length an uncertainty of a factor 4 was estimated.

3.90 HARBOURS

3.91 Protection of harbours

There is no doubt that harbours need adaptation measures to sea level rise. Usually a port represents considerable capital investments, not only in the port facilities as such, but also in adjacent industrial areas. There are of course harbours that are less frequently or less efficiently used than they could be, but even these harbours usually fulfil an important function for their hinterland.

A decrease of their functionality due to sea level rise will not be acceptable. In this study, therefore, the assumption is made that every seaport, small or large, needs adaptation with respect to sea level rise, in order to maintain the same functionality as it has now.

It is further assumed that the traffic volumes and their composition remain the same over the years. Changes like a probable decrease in oil transport or a further increase in container traffic, are not taken into account.

To arrive at a figure for the cost of adaptation measures, several approaches are possible. Most straightforward is the one where for all significant ports an inventory is made of the total length of the berths, of the surface of the quay and storage areas and of the adjacent industrial areas. This approach requires an amount of information that could neither be made available nor analyzed in the short period that was available. Maps and reports on several thousands of seaports would have to be collected and screened.

For practical reasons an approach has been followed where traffic flows are converted into port areas. The advantage is that traffic flows are rather well documented for each country and for major ports and that these data were readily available.

3.92 Relation between traffic volume and port area

A manner of calculating the area of harbours to be protected, is to determine a general relation between traffic volume and corresponding port area. To determine this relation, the following steps are taken:

1. Convert the total amount of cargo into "equivalent" cargo by:
    a. Convert the total amount of bulk and oil traffic handled into equivalent cargo by multiplying with 0.23 (to take into account the different space that is required for both categories).
    b. Add to this amount "other" cargo ("other" cargo = total cargo - bulk and oil)
2. Convert the amount of equivalent cargo into km^2 harbour area with the ratio: 1 km^2 harbour area can handle 3 * lO^6 ton/y equivalent cargo.

The cost of harbour protection is determined by multiplying the harbour area with the appropriate unit cost rate (see section 3.40 item 5) and the country cost factor.

An internal note of the Port of Rotterdam (Ref. 9) provides data on the area that is required for the transshipment and storage of various goods. From this note the following figures were derived.

1. bulk/oil: $30 * 10^6$ ton handled per km^2 port area
2. other cargo: $7 * 10^6$ ton handled per km^2 port area

The Rotterdam data show that bulk goods require 23 percent (=7/30) of the space that is required for other cargo. These figures will not apply for all ports as in many ports goods are handled in a less efficient way than in Rotterdam. Neither do these figures take into account the amount of area required for general purposes, for related industry, etc. This effect can be brought into the analysis by a multiplier. To verify the Rotterdam figures and to obtain this multiplier, data for other ports were analyzed. The results of this exercise were as follows.

For individual ports considered, the percentage of bulk was taken from Ref. 10 (or an estimate was made if no figures were available) and the bulk traffic for these ports was converted into tons of 'equivalent' cargo ('equivalent' with respect to required port area).

The data on port area and the amount of equivalent cargo are presented in Table 3.2 and were plotted in two separate graphs with different scales to cover the wide range of figures (see figure 3.5).

As could be expected, the figures show a considerable scatter. The various ports are situated in Europe, Africa and the Pacific area. No significant difference was found between the three regions.

A large ratio between port area and the handled traffic can be caused by low efficiency, but also by relatively high industrial activities in the port area. The available map material was usually not very clear in this respect. For larger berth lengths the port area appeared to increase more than proportional, or in other words the larger the port the wider the zone adjacent to the quays.

From the graphs the following relation was derived:

- 3 million t/y 'equivalent' cargo requires 1 km^2 port area

Finally, the following remarks with respect to the determination of the costs of protecting port areas are made:

- Traffic figures refer to international sea traffic as given in Ref. 16. For some countries with considerable national coastal shipping traffic, however, such traffic was also included.
- The areas calculated comprise quays, storage areas (open and covered), roads, general areas (offices, etc.) and industrial areas (mainly petrochemical industry).
- It is assumed that all port areas are flat and that their existing level above MSL should be kept the same, in order to maintain the present risk level for inundation, wave overtopping, etc.
- Adaptations to breakwaters, entrance sluices, open oil and ore jetties, etc. have not been taken into account. Their cost is supposed to be either included in the unit area cost or not relevant as the structure has a depreciation period which is less than the period .in which the sea level rise is supposed to occur (see section 3.40, item 5).
- With respect to the variation in the applied ratios, no statistical analysis was performed, as the data is rather scarce. For most ports, the ratio cargo/port area will fall in the range between 1.5 - 4.5 x 10^6 t/y per km^2, or a 50% deviation with respect to the 3 x 10^6 t/y per km^2 applied in the analysis. The cargo figures are rather accurate and they will not deviate more than 10-15%. A combined uncertainty range was estimated at a factor 2.

Country	Port	Total cargo handled (10^3 t/y)	Fraction bulk and oil	Port area (km^2)	Equivalent cargo (10^3 t/y)
Belgium	Antwerp	86343	0.2	20.0	73090
Belgium	Zeebrugge	6679	0.2	2.0	5654
Denmark	Copenhagen	9127	0.2	5.5	7726
Denmark	Aarhus	4205	0.3	1.8	3237
Denmark	Aalborg	3670	0.5	2.6	2262
Finland	Helsinki	8442	0.2	3.1	7146
France	Marseille	108690	0.6	16.0	58642
France	Le Havre	54959	0.6	18.0	29652
Germany, Fed. Rep	Hamburg	51087	0.6	30.0	27563
Italy	Genoa	36257	0.4	16.0	25127
Italy	Trieste	23547	0.3	5.0	18126
Netherlands, The	Rotterdam	251412	0.4	40.0	174234
Portugal	Lisbon	13780	0.6	5.0	7435
Spain	Barcelona	18155	0.6	3.5	9795
Spain	Pasajes	5449	0.2	0.8	4613
Australia	Newcastle	22940	0.5	4.5	14137
Australia	Melbourne	4724	0.3	4.0	3636
New Zealand	Auckland	3218	0.3	2.0	2477
New Zealand	Taharoa	1437	0.8	0.6	555
New Zealand	Lyttleton	1326	0.3	1.6	1021
Algeria	Algiers	5712	0.2	1.8	4835
Cameroon	Douala	3915	0.2	3.0	3314
Liberia	Buchanan	8872	0.8	0.8	3425
Morocco	Casablanca	17058	0.4	0.8	11822
South Africa	Durban	17814	0.3	5.0	13713
South Africa	Table Bay	4908	0.2	1.5	4155
South Africa	East London	3970	0.2	1.5	3361

Table 3.2 Port area versus handled cargo for specific ports

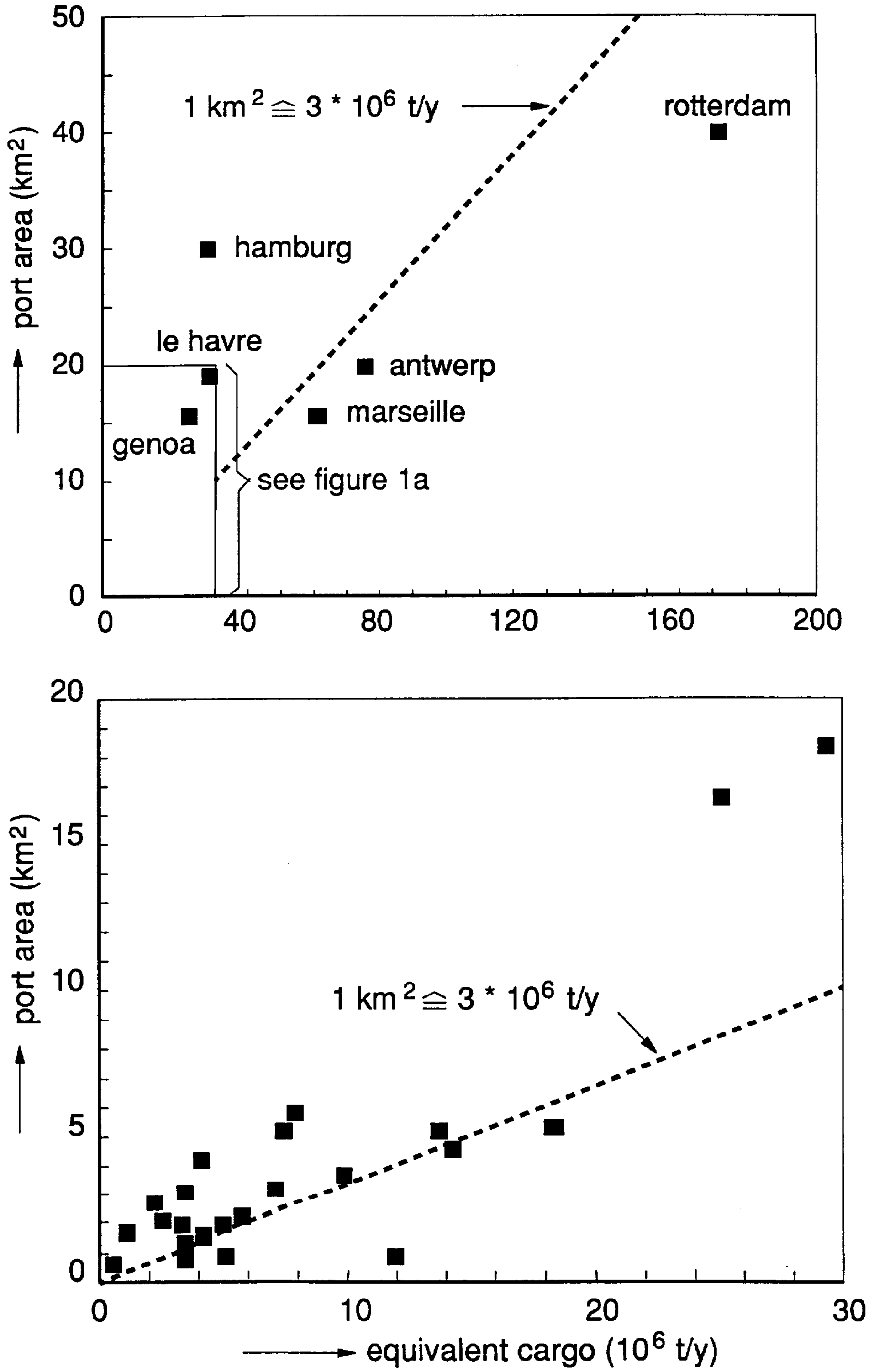


Fig 3.5 : Port area versus equivalent cargo

4. PRESENTATION OF RESULTS.

The list of country total costs by type of protection, total costs per capita and annual costs as a percentage of the GNP, is presented in Annex D.1. In Annexes D.2 and D.3 the underlying country estimates and country classification can be found.

The total costs refer to the protection costs to be made in the next 100 years (but calculated as if spent at once). Two indicators are used to reflect the relative weight of the burden which is placed on society by the costs of protection against sea level rise: total costs (over 100 years) per capita and the annual protection costs as a fraction of gross national product (GNP).

In order to relate the protection costs to the GNP in the various countries, the total costs were divided by 100 to obtain an annual average cost figure, which was then divided by the GNP.

The costs are expressed in terms of 1989 US dollars, whereas the GNP data refer to 1985 US dollars. Due to the fact that the relative value of the US dollar in the period between 1985 and 1989 has shown a significant decline, the actual percentages on a 1989 basis will be lower for many countries.

From Annex D.1 several significant groups of figures were selected for separate presentation. Table 4.1 shows protection costs per region for the five categories of measures described in Chapter 3. It should be noted that the choice of the regional delineations, of course, influences the level of total regional costs. If, for instance, all European regions were summed (including the USSR), their total costs would be higher than the North American costs.

In Table 4.2 countries have been grouped according to their per capita income. For the grouping of the countries The World Bank classification has been used. The countries classified as low income countries have a per capita income of less than US$ 400. Those classified as middle income countries have a per capita income between US$ 400 - 1600. The World Bank classification makes a distinction between high income oil exporting countries, industrial market economies and other countries not belonging to the preceding groups, with a per capita income of more than US$ 1600: the upper middle income countries, including, for example, most of the eastern European countries.

To this country classification by The World Bank a special group was added, namely the small islands. This was done because of the prevailing concern for these countries which are generally considered to be highly susceptible to impacts of sea level rise.

Although it is recognized that uncertainties in the present study results can have a significant effect on estimated protection costs, the preliminary ranking of countries was regarded as useful.

In Table 4.3 an overall ranking is made according to the annual protection costs as a fraction of the GNP for the top 5O countries. Because of the special concern for and the high ranking of the small islands (see Table 4.3), a list of all 55 small island states and their total protection costs over a period of 100 years is shown in Table 4.4.

A final remark is needed with respect to precision. Figures and values given in the accompanying tables were not rounded off, in order to maintain consistency. However it is recognized that they may convey an apparent precision not justified in view of the multitude of uncertainties throughout the available data upon which this study was based.

In this context it should be noted that a detailed study of the Netherlands (Ref. 21) indicates a cost level for this country which is about twice that of the estimate reached in the present study. This lies within the range of uncertainty maintained throughout this study. The difference is mainly due to the fact that in the present report estimates are based on an adaptation performed in a single step while in Ref. 21 a progressive adaptation is assumed. This example shows the great sensitivity of the cost estimates to the manner of execution of the protective works.

Regions	Type of protection							
	Low coasts	Cities	Harbors	Island elev.	Beach nour.	Total costs	Total costs per capita (US$)	Annual costs as % of GNP
North America	47.2	25.3	5.4	0.0	28.3	106.2	306	0.03%
Central America	2.3	0.1	0.1	0.0	0.5	3.0	117	0.12%
Carribean islands	3.3	1.3	2.2	0.1	4.4	11.1	360	0.20%
South America Atlantic Ocean coast	27.8	5.7	2.6	0.0	1.5	37.6	173	0.09%
South America Pacific Ocean coast	0.1	1.4	0.2	0.0	0.1	1.7	41	0.04%
Atlantic Ocean small islands	0.0	0.1	0.0	0.0	0.1	0.2	333	0.12%
North and West Europe	19.0	12.5	5.5	0.0	14.7	51.7	197	0.02%
Baltic Sea coast	21.9	3.0	1.1	0.0	2.9	28.9	429	0.07%
Northern Mediterranean	4.6	6.5	2.2	0.0	13.6	26.9	214	0.05%
Southern Mediterranean	4.6	3.8	3.1	0.0	2.3	13.8	89	0.06%
Africa Atlantic Ocean coast	16.8	3.7	1.2	0.0	1.2	22.8	99	0.17%
Africa Indian Ocean coast	13.2	1.9	0.9	0.0	1.4	17.4	98	0.17%
Gulf States	4.7	0.8	3.5	0.0	0.2	9.1	115	0.02%
Asia Indian Ocean coast	23.6	8.2	0.7	0.0	1.9	34.4	33	0.13%
Indian Ocean small islands	0.6	0.3	0.0	1.6	0.6	3.1	1352	0.93%
South-east Asia	16.3	4.8	1.5	0.0	2.7	25.3	69	0.11%
East Asia	12.1	14.9	7.9	0.0	3.1	38.0	30	0.02%
Pacific Ocean large islands	22.9	6.2	1.8	0.0	4.1	35.0	1550	0.17%
Pacific Ocean small islands	1.0	0.2	0.1	2.1	0.5	3.9	1809	0.75%
USSR	18.5	1.8	1.0	0.0	3.8	25.0	89	0.01%
Total	260.6	102.7	40.9	3.8	87.6	495.5	104	0.038%

Table 4.1 Protection costs per region (billions of US dollars unless otherwise indicated)

Country classification	Type of protection							
	Low coasts	Cities	Harbors	Islands	Beaches	Total costs	Total costs per capita (US$)	Annual costs as % of GNP
Low income	55.7	13.8	1.6	1.2	5.1	77.4	33	0.122%
Lower middle income	33.7	10.5	4.6	0.8	6.1	55.7	81	0.106%
Upper middle income	66.5	16.0	11.9	1.7	19.6	115.7	125	0.033%
High income oil exporters	4.4	1.0	2.5	0.0	0.3	8.2	407	0.038%
Industrial market economies	100.2	61.5	20.3	0.0	56.5	238.4	326	0.029%
Total coastal countries	260.6	102.7	40.9	3.8	87.6	495.5	104	0.038%
Small islands	2.5	0.8	1.6	3.8	4.9	13.5	1876	0.733%

Table 4.2 Protection costs of different types of economies (billions of US dollars unless otherwise indicated)

No	Country	Annual costs as % of GNP	Total costs per capita (US$)	Total costs (min US$)
1	MALDIVES	34.33	10,172	1,923
2	KIRIBATI	18.79	8,673	564
3	TUVALU	14.14	8,838	71
4	TOKELAU	11.11	9,025	14
5	ANGUILLA	10.31	11,786	83
6	GUINEA-BISSAU	8.15	1,463	1,303
7	TURKS AND CAICOS	8.10	24,739	223
8	MARSHALL ISLANDS	7.24	8,691	322
9	COCOS (KEELING) ISL	5.82	11,221	8
10	SEYCHELLES	5.51	12,103	799
11	FALKLAND ISLANDS	4.75	30,900	62
12	FRENCH GUIANA	2.96	6,197	533
13	BELIZE	2.93	3,085	527
14	PAPUA NEW GUINEA	2.78	2,026	6,889
15	BAHAMAS, THE	2.67	10,915	2,565
16	LIBERIA	2.66	1,141	2,629
17	GAMBIA, THE	2.64	621	475
18	MOZAMBIQUE	2.48	782	11,064
19	ST. CHR. & NEVIS	2.33	3,033	140
20	NIUE	2.18	2,900	9
21	GUYANA	2.12	1,250	995
22	SURINAME	1.94	6,638	2,622
23	SIERRA LEONE	1.86	557	2,078
24	ARUBA	1.85	9,447	646
25	PITCAIRIN ISLAND	1.71	9,375	1
26	FIJI	1.53	2,695	1,914
27	SAO TOME AND PR.	1.46	399	44
28	NAURU	1.25	10,900	87
29	BRITISH VIRGIN ISL	1.24	7,725	93
30	TONGA	1.14	929	91
31	CAYMAN ISLANDS	1.04	10,350	228
32	COOK ISLANDS	1.03	1,213	21
33	EQUATORIAL GUINEA	1.02	190	61
34	ANTIGUA & BARBUDA	1.01	1,870	152
35	SRI LANKA	0.89	313	5,030
36	TOGO	0.87	207	636
37	ST. LUCIA	0.82	879	123
38	BURMA	0.77	132	5,083
39	BENIN	0.74	153	785
40	MICRONESIA, FED. ST.	0.73	881	84
41	NEW ZEALAND	0.70	5,004	16,454
42	PALAU	0.69	825	10
43	GRENADA	0.67	554	54
44	NETH, ANTILLES	0.66	5,159	908
45	SENEGAL	0.65	238	1,596
46	GHANA	0.64	229	3,005
47	SOMALIA	0.62	141	847
48	WESTERN SAMOA	0.59	467	75
49	MADAGASCAR	0.56	142	1,465
50	ST. VINCENT & GR.	0.55	497	55

Table 4.3 Top 50 countries ranked according to annual protection costs as a percentage of gross national product.

No	Country	Total costs per capita (US$)	Pop.	Total costs (min US$)	Annual costs as % of GNP
1	FALKLAND ISLANDS	30,900	2,000	62	4.75 %
2	TURKS AND CAICOS ISLANDS	24,739	9,000	223	8.10 %
3	SEYCHELLES	12,103	66,000	799	5.51 %
4	ANGUILLA	11,786	7,000	83	10.31 %
5	COCOS (KEELING) ISLANDS	11,221	700	8	5.82 %
6	BAHAMAS, THE	10,915	235,000	2,565	2.67 %
7	NAURU	10,900	8,000	87	1.25 %
8	CAYMAN ISLANDS	10,350	22,000	228	1.04 %
9	MALDIVES	10,172	189,000	1,923	34.33 %
10	ARUBA	9,447	68,400	646	1.85 %
11	PITCAIRIN ISLAND	9,375	64	1	1.71 %
12	TOKELAU	9,025	1,600	14	11.11 %
13	TUVALU	8,838	8,000	71	14.14 %
14	MARSHALL ISLANDS	8,691	37,000	322	7.24 %
15	KIRIBATI	8,673	65,000	564	18.79 %
16	BRITISH VIRGIN ISLANDS	7,725	12,000	93	1.24 %
17	NETHERLANDS ANTILLES	5,159	176,000	908	2.33 %
18	ST. CHRISTOPHER AND NEVI	3,033	46,000	140	2.18 %
19	NIUE	2,900	3,000	9	1.53 %
20	FIJI	2,695	710,000	1,914	0.27 %
21	VIRGIN ISLANDS (U.S)	2,018	114,000	230	1.01 %
22	ANTIGUA AND BARBUDA	1,870	81,000	152	0.41 %
23	AMERICAN SAMOA	1,839	36,000	66	0.25 %
24	FRENCH POLYNESIA	1,794	180,000	323	0.20 %
25	CHRISTMAS ISLAND	1,317	2,278	3	0.20 %
26	NEW CALEDONIA	1,221	151,000	184	1.03 %
27	COOK ISLANDS	1,213	17,000	21	0.27 %
28	BARBADOS	1,172	253,000	297	0.06 %
29	BERMUDA	1,004	57,000	57	1.14 %
30	TONGA	929	98,000	91	0.73 %
31	MICRONESIA, FED. STATES OF	881	95,000	84	0.82 %
32	ST. LUCIA	879	140,000	123	0.69 %
33	PALAU	825	12,000	10	0.20 %
34	GUADELOUPE	708	334,000	236	0.10 %
35	ST. PIERRE AND MIQUELON	650	6,000	4	0.14 %
36	MARTINIQUE	585	328,000	192	0.67 %
37	GRENADA	554	97,000	54	0.55 %
38	ST. VINCENT & THE GRENAD	497	111,000	55	0.59 %
39	WESTERN SAMOA	467	160,000	75	0.12 %
40	REUNION	410	556,000	228	1.46 %
41	SAO TOME AND PRINCIPE	399	110,000	44	0.05 %
42	NORFOLK ISLAND	300	2,000	1	0.02 %
43	MONTSERRAT	225	12,000	3	0.03 %
44	ST. HELENA, ASC. & TR. DACUN	195	7,700	2	0.09 %
45	VANATU	169	137,000	23	0.19 %
46	MAURITIUS	162	1,034,000	168	0.15 %
47	DOMINICA	161	84,000	14	0.26 %
48	FAEROE ISLANDS	135	46,000	6	0.17 %
49	SOLOMON ISLANDS	118	277,000	33	0.11 %
50	WALLIS AND FUTUNA	107	14,000	2	0.20 %
51	MAYOTTE	73	70,000	5	0.13 %
52	NORTHERN MARIANA ISLANDS	71	21,000	2	0.22 %
53	CAPE VERDE	45	342,000	15	0.15 %
54	COMOROS	33	409,000	14	0.13 %
55	GUAM	30	121,000	4	0.00 %
	TOTAL	1,870	7,180,742	13,427	0.73 %

Table 4.4 Small islands ranked according to total costs per capita

5. DISCUSSION OF RESULTS

Calculations made in this study result in an overall, world wide cost figure for basic coastal protection against sea level rise of nearly US$ 500 billion over a 100 year period. This amounts to some US$ 5 billion a year, or, for the 181 countries and territories considered, to about US$ 1 per head of population per year. As a fraction of the GNP of all coastal countries, the total world average annual protection cost comes to about 0.04 percent.

The total sum only reflects the marginal or added costs and is not discounted. This value does not include costs necessary to meet present coastal defence needs. The estimate does not include the value of the unprotected dry land or ecosystems that would be lost, nor does it consider the costs of responding to saltwater intrusion or the impacts of increased storm frequency. The overall costs may, therefore, be considerably higher.

More than half of the total estimated costs is taken up for the protection of low coasts, some 20 percent for the protection of city waterfronts, 18 percent for beach nourishment, 10 percent for harbour adaptations and less than one percent for island elevation.

Based on the data presented in Annex D.1, in 128 countries the protection costs as a fraction of the GNP lies above the world average of 0.038 percent. In 53 countries this fraction is more than tenfold the world average. In 12 countries the relative protection costs are more than 100 times the world average and the Maldives ranks the highest with a GNP fraction for protection costs almost 1000 times the world average. Of these twelve countries eleven are small island groups, six of them territories. The single exception in this list of twelve is Guinea-Bissau, a small continental West African state.

The total world average cost per capita over 100 years is US$ 104 (Table 4.1). The regions that include many island states top the list in terms of cost per head of population. They are the Indian Ocean small islands with US$ 1352 per century, the Pacific Ocean large islands with US$ 1550 and the Pacific Ocean small islands with US$ 1809.

We can also see that, on a regional basis, North America has the highest total protection costs, followed by North and West Europe. The North American costs are more than double those of any other region.

Five regions show relatively low total protection costs: Central America, South America Pacific Ocean Coast, Atlantic Ocean small islands, Indian Ocean small islands and Pacific Ocean small islands. The latter two regions also show a similar distribution over the protection categories and share a very high cost per capita as well. The Pacific Ocean large islands also show a high cost per capita, but in this region the annual cost as a fraction of the GNP is much lower than that for the Indian Ocean and Pacific Ocean small islands.

In fact, the study reveals that annual protection costs expressed as a percentage of the GNP for the Indian Ocean small islands at 0.93 percent and Pacific Ocean small islands at 0.75 percent are much higher than those for any other region. They contrast with only 0.04 percent for all the regions together. Other relatively high regional GNP fractions can be found for the Caribbean islands, Africa and, as mentioned above, the Pacific large islands.

Table 4.2 shows that on the basis of income group categories, as used by The World Bank, the industrial market economies have almost half of the world's total protection costs in absolute figures. The same table shows that the low income countries have the highest annual protection costs expressed as a percentage of GNP at 0.12 percent or about three times the world average. On a cost per capita basis over 100 years, however, this category ranks lowest with US$ 33. For small islands as a group, a category added to this table for the sake of comparison, the annual costs as a percentage of GNP at 0.73 percent, is significantly higher than that for any of The World Bank categories.

Although large in number, the group of small islands accounts only for 2.7 percent of the total world costs. However, when an overall ranking is made according to the annual protection costs as a fraction of GNP for the top 50 countries, the high cost burden for small islands and island groups stands out. Table 4.3 shows that no fewer than 29 of the list of 50 of the countries with the highest annual protection costs as a percentage of GNP are small islands, c.q. island groups. Of the top ten countries on this list, only one is not an island (Guinea Bissau).

Small islands as a group (Table 4.4) have a total of 7.2 million inhabitants, a total GNP of US$ 18.4 billion and protection costs over 100 years estimated at US$ 13.5 billion, or 0.73 percent as a fraction of GNP, which is nearly twenty times the world average of 0.04 percent. This compares unfavourably even with the group of 31 countries classified by The World Bank as low income countries (see Table 4.2), for which 0.12 percent as a fraction of GNP was found. Although for small islands the costs per country in absolute terms do not stand out significantly, their total costs per capita over a period of 100 years at US$ 1876 are high in comparison with the world average of US$ 104.

It must be concluded then that, world wide, coastal protection costs for small islands, c.q. island groups, are the highest both in terms of annual costs as a fraction of GNP and on a per capita basis. Thus, from this study it is evident that small islands as a group, are in what must be called a "least desirable" position, both physically and economically. It is interesting to note, however, that on the basis of income per capita, this group falls into The World Bank category of upper middle income countries.

One might well ask whether "least desirable" implies "vulnerable". Up to the present, vulnerability to sea level rise has, in various studies, been expressed in terms of potential damages, financially or economically, socially and ecologically. Some studies, however, additionally consider the costs of response measures (Ref. 21).

This study does not indicate the cost of potential damages nor the benefits of their prevention. In fact, the present study only shows the costs per country and world wide of maintaining the status quo, i.e. the costs of defence measures against a 1 m sea level rise, so that the effects of a 1 m sea level rise are neither increased nor decreased. Therefore, from this study alone no conclusions can be drawn about the extent of vulnerability.

6. REMARKS

Efforts such as the present study traditionally conclude with recommendations. Those recommendations generally imply that what the study has achieved need not be duplicated, while further activities are specifically outlined.

Whereas the results of this study do not plead for duplication, in the strict sense of the word, but essentially for carrying out the very same thing in a better, more refined and detailed manner at a much lower level of aggregation, there is room here for an inverse approach. For instance, this study does not pretend to predict that the sea level will rise by 1 m "tomorrow". Nor that coastline lengths were measured precisely. It does not state that any assumed protection is actually needed., Perhaps the coast will refind its natural equilibrium in time. The assumed population density of more or less than 10/km may or may not be the correct cut off between densely and not densely populated coastal areas. Nor does the study suggest acceptance of an equal population density cut off point applicable for all countries.

This study also does not assume that the methods of protection used are the only viable options, if protection is necessary at all, nor that the used protection measures represent standard methods. There may be other methods better suited to local conditions.

The costs of coastal protection presented in this study in no way constitute recommendations or even appropriate suggestions. Estimates of lengths of tourist beaches, city waterfronts, dikes and size of the port complexes to be defended are no more than that. Better approximations probably exist and if they do, they should be incorporated in later studies.

That, in fact, is the message of this study. All parameters can be improved upon. All assumptions can be refined and many even eliminated. The questions that will be raised by investigators will form the basis from where we can strive to attain a more complete picture of what the impact of sea level rise, as a consequence of global warming caused by greenhouse gas emissions, will be on society.

REFERENCES

1. Workshop Report to the Coastal Zone Management Subgroup. 1989. IPCC/ UNEP/WMO
2. Criteria for Assessing Vulnerability to Sea level Rise. A Global Inventory to High Risk Areas. 1989. Delft Hydraulics.
3. A General Theory of Flow in Alluvium. 1987. G. Lacey. Journal supplement, Instn. of Civ. Engrs, no. 8, paper 5518, pp. 425-451.
4. Open Channel Hydraulics. 1959. V.T. Chow. McGraw-Hill, New York.
5. Guide to Port Entry 1985-86 Port Information. Shipping Guides, Ltd., Reigate, Surrey, England.
6. Guide to Port Entry 1985-86 Port Plans and Mooring Diagrams. Shipping Guides, Reigate, Surrey, England.
7. Impact of Sea level Rise on Society. 1987. H.G. Wind ed. A.A. Halkema, Rotterdam.
8. Republic of Maldives: Implications of Sea level Rise. 1989. Delft Hydraulics.
9. Port of Rotterdam. 1988. Internal note on the relation between traffic and port area.
10. Ports of the world. 1988. Edition 1988, Lloyds, London.
11. Socio-economic, Legal, Institutional, Cultural and Environmental Aspects of Measures for the Adaptation of Coastal Zones at Risk to Sea Level Rise. 1989. Rijkswaterstaat (Min. of Public Works and Transportation), Tidal Waters Division Report, nr. GWWS 89.011 The Hague, Netherlands.
12. The Pilot. 1 968- 1985. The Hydrographer of the Navy, London.
13. The International Atlas. 1979. Rand McNally & Co., Chicago.
14. World Bank Annual Report. 1987. Oxford University Press, London.
15. The New Encyclopedia Britannica. 1987. Encyclopedia Britannica, Inc., Chicago.
16. The World in Figures. 1987. The Economist, London.
17. The Potential Effects of Global Climate Change on the United States -Appendix B: Sea Level Rise. 1989. United States Environmental Protection Agency, Washington, D.C.
18. The Times Atlas of The World. 1981. Times Books, London.
19. The World Almanac and Book of Facts 1990. 1989. World Almanac, New York.
20. The World's Coastlines. 1985. E.C.F. Bird and M.L. Schwartz eds. Van Nostrand Reinhold Co., New York.
21. Rijkswaterstaat, Delft Hydraulics (in press): Impacts of Sea Level Rise on Dutch Society, a description of the ISOS case study for the Netherlands. Rijkswaterstaat, Tidal Waters Division: note GWAO-90.016 Delft Hydraulics: report nr. H750.

ANNEX D.1

Protection costs per country

No.	Country	Type of protection (millions of US dollars)						Total costs per capita (US$)	Annual costs as % of GNP
		Low Coast	Cities	Harbors	Island elev.	Beach nour.	Total costs		
1	ALBANIA	168	42	8	0	0	218	72	0.08 %
2	ALGERIA	126	405	248	0	169	948	42	0.02 %
3	AMERICAN SAMOA	8	0	13	0	45	66	1,839	0.41 %
4	ANGOLA	242	280	32	0	0	554	63	0.07 %
5	ANGUILLA	36	0	2	0	45	83	11,786	10.31 %
6	ANTIGUA & BARBUDA	60	0	2	0	90	152	1,870	1.01 %
7	ARGENTINA	2,673	765	262	0	270	3,970	128	0.06 %
8	ARUBA	1	0	510	0	135	646	9,447	1.85 %
9	AUSTRALIA	2,799	3,810	1,701	0	3,375	11,685	734	0.06 %
10	BAHAMAS, THE	480	0	285	0	1,800	2,565	10,915	2.67 %
11	BAHRAIN	243	165	126	0	169	703	1,616	0.16 %
12	BANGLADESH	861	120	50	0	169	1,200	12	0.10 %
13	BARBADOS	18	0	9	0	270	297	1,172	0.27 %
14	BELGIUM	112	341	418	0	322	1,193	121	0.01 %
15	BELIZE	525	0	2	0	0	527	3,085	2.93 %
16	BENIN	509	193	4	0	79	785	153	0.74 %
17	BERMUDA	4	0	9	0	45	57	1,004	0.06 %
18	BRAZIL	17,910	3,380	1,567	0	900	23,757	172	0.10 %
19	BRITISH VIRGIN ISL	1	0	2	0	90	93	7,725	1.24 %
20	BRUNEI	1	30	101	0	0	132	568	0.03 %
21	BULGARIA	105	84	203	0	158	550	61	0.02 %
22	BURMA	4,482	585	16	0	0	5,083	132	0.77 %
23	CAMEROON	305	228	18	0	0	550	56	0.07 %
24	CANADA	5,352	1,880	960	0	1,350	9,542	372	0.03 %
25	CAPE VERDE	12	0	3	0	0	15	45	0.15 %
26	CAYMAN ISLANDS	1	0	2	0	225	228	10,350	1.04 %
27	CHILE	43	780	59	0	0	883	72	0.04 %
28	CHINA	6,420	2,628	483	0	2,025	11,556	11	0.04 %
29	CHRISTMAS ISLAND	2	0	1	0	0	3	1,317	0.20 %
30	COCOS (KEELING) IS	3	0	1	4	0	8	11,221	5.82 %
31	COLOMBIA	144	440	110	0	90	784	30	0.02 %
32	COMOROS	12	0	2	0	0	14	33	0.13 %
33	CONGO	3	53	44	0	0	100	48	0.05 %
34	COOK ISLANDS	5	0	2	14	0	21	1,213	1.03 %
35	COSTA RICA	210	0	22	0	0	232	92	0.08 %
36	CUBA	1,128	560	252	0	90	2,030	199	0.13 %
37	CYPRUS	78	78	32	0	0	188	278	0.08 %
38	DENMARK	8,424	1,014	199	0	1,755	11,392	2,228	0.20 %
39	DJIBOUTI	2	45	10	0	0	57	125	0.19 %
40	DOMINICA	12	0	2	0	0	14	161	0.17 %
41	DOMINICAN REPUBLIC	8	100	39	0	90	238	37	0.04 %
42	ECUADOR	7	285	43	0	0	335	35	0.03 %
43	EGYPT	948	360	1,271	0	506	3,085	64	0.09 %
44	EL SALVADOR	11	0	17	0	0	27	5	0.01 %
45	EQUATORIAL GUINEA	7	53	1	0	0	61	190	1.02 %
46	ETHIOPIA	4	0	16	0	0	20	0	0.00 %
47	FAEROE ISLANDS	1	0	5	0	0	6	135	0.01 %
48	FALKLAND ISLANDS	1	60	1	0	0	62	30,900	4.75 %
49	FIJI	457	60	15	1,156	225	1,914	2,695	1.53 %
50	FINLAND	9,224	468	234	0	675	10,600	2,151	0.20 %
51	FRANCE	2,909	1,752	805	0	4,320	9,785	177	0.01 %
52	FRENCH GUIANA	486	45	2	0	0	533	6,197	2.96 %
53	FRENCH POLYNESIA	60	60	5	063	135	323	1,794	0.25 %
54	GABON	14	193	40	0	0	247	208	0.09 %
55	GAMBIA, THE	420	53	2	0	0	475	621	2.64 %
56	GERMAN, DEM.REP.	851	209	117	0	371	1,549	93	0.02 %
57	GERMANY, FED. REP.	1,063	1,034	629	0	1,485	4,210	66	0.01 %

No.	Country	Type of protection (millions of US dollars)						Total costs per capita (US$)	Annual costs as % of GNP
		Low Coast	Cities	Harbors	Island elev.	Beach nour.	Total costs		
58	GHANA	2,520	298	30	0	158	3,005	229	0.64 %
59	GIBRALTAR	0	0	2	0	12	13	478	0.10 %
60	GREECE	476	780	316	0	3,510	5,082	509	0.10 %
61	GREENLAND	3	0	4	0	0	7	127	0.02 %
62	GRENADA	7	0	2	0	45	54	554	0.67 %
63	GUADELOUPE	24	60	17	0	135	236	708	0.20 %
64	GUAM	1	0	2	0	0	4	30	0.00 %
65	GUATEMALA	578	0	36	0	394	1,007	123	0.11 %
66	GUINEA	630	53	97	0	0	779	125	0.43 %
67	GUINEA-BISSAU	1,302	0	1	0	0	1,303	1,463	8.15 %
68	GUYANA	936	45	14	0	0	995	1,250	2.12 %
69	HAITI	10	100	14	0	0	124	23	0.07 %
70	HONDURAS	13	0	19	0	0	32	8	0.01 %
71	HONG KONG	99	250	227	0	45	621	112	0.02 %
72	ICELAND	441	150	15	0	0	606	2,463	0.27 %
73	INDIA	15,571	5,055	498	0	1,350	22,475	29	0.11 %
74	INDONESIA	5,904	1,176	488	0	1,080	8,648	51	0.10 %
75	IRAN	1,350	120	807	0	0	2,277	49	0.01 %
76	IRAQ	360	75	566	0	0	1,001	63	0.03 %
77	IRELAND	106	572	67	0	0	745	210	0.04 %
78	ISRAEL	5	525	132	0	338	999	228	0.05 %
79	ITALY	3,264	5,280	1,286	0	7,200	17,030	297	0.04 %
80	IVORY COAST	2,037	175	69	0	394	2,674	250	0.44 %
81	JAMAICA	10	100	83	0	270	462	197	0.19 %
82	JAPAN	4,644	10,860	5,974	0	900	22,378	184	0.02 %
83	JORDAN	1	0	5	0	0	6	2	0.00 %
84	KAMPUCHEA	2	0	1	0	0	3	0	0.00 %
85	KENYA	9	88	35	0	236	369	17	0.06 %
86	KIRIBATI	156	0	2	406	0	564	8,673	18.79 %
87	KOREA, NORTH	150	450	35	0	0	635	31	0.04 %
88	KOREA, SOUTH	360	490	484	0	113	1,446	35	0.02 %
89	KUWAIT	90	45	221	0	0	356	199	0.01 %
90	LEBANON	2	315	223	0	68	608	224	0.13 %
91	LIBERIA	2,331	140	158	0	0	2,629	1,141	2.66 %
92	LIBYA	1,668	320	383	0	90	2,461	623	0.08 %
93	MACAU	0	75	6	0	0	81	187	0.10 %
94	MADAGASCAR	1,250	210	6	0	0	1,465	142	0.56 %
95	MALAYSIA	1,818	430	234	0	180	2,662	165	0.09 %
96	MALDIVES	455	60	2	1,181	225	1,923	10,172	34.33 %
97	MALTA	51	65	10	0	59	184	549	0.15 %
98	MARSHALL ISLANDS	89	0	2	231	0	322	8,691	7.24 %
99	MARTINIQUE	24	60	18	0	90	192	585	0.14 %
100	MAURETANIA	2	0	69	0	0	72	42	0.10 %
101	MAURITIUS	1.2	60	17	0	90	168	162	0.15 %
102	MAYOTTE	3.6	0	2	0	0	5	73	0.22 %
103	MEXICO	8,771.3	595	326	0	197	9,889	123	0.06 %
104	MICRONESIA, FED. ST.	22.8	0	2	59	0	84	881	0.73 %
105	MONACO	0.0	39	1	0	3	43	1,479	0.13 %
106	MONTSERRAT	1.2	0	2	0	0	3	225	0.09 %
107	MOROCCO	393.8	770	250	0	197	1,611	72	0.11 %
108	MOZAMBIQUE	10,515.8	280	72	0	197	11,064	782	2.48 %
109	NAMIBIA	3.2	0	1	0	0	4	4	0.00 %
110	NAURU	22.8	0	14	50	0	87	10,900	1.25 %
111	NETH. ANTILLES	30.0	60	548	0	270	908	5,159	0.66 %
112	NETHERLANDS, THE	1,551.0	510	1,138	0	1,013	4,211	289	0.03 %
113	NEW CALEDONIA	15.6	60	19	0	90	184	1,221	0.20 %
114	NEW ZEALAND	13,410.0	2,265	104	0	675	16,454	5,004	0.70 %

No.	Country	Type of protection (millions of US dollars)						Total costs per capita (US$)	Annual costs as % of GNP
		Low Coast	Cities	Harbors	Island elev.	Beach nour.	Total costs		
115	NICARAGUA	945.0	0	11	0	0	956	282	0.35 %
116	NIGERIA	2,052.8	665	247	0	197	3,162	32	0.04 %
117	NIUE	7.2	0	2	0	0	9	2,900	2.18 %
118	NORFOLK ISLANDS	0.0	0	1	0	0	1	300	0.05 %
119	N. MARIANA ISLANDS	0.0	0	2	0	0	2	71	0.06 %
120	NORWAY	128.7	624	286	0	180	1,219	293	0.02 %
121	OMAN	180.0	0	64	0	0	244	189	0.03 %
122	PAKISTAN	482.4	300	85	0	169	1,036	10	0.03 %
123	PALAU	8.4	0	2	0	0	10	825	0.69 %
124	PANAMA	25.2	140	19	0	79	263	118	0.06 %
125	PAPUA NEW GUINEA	6,720.0	158	11	0	0	6,889	2,026	2.78 %
126	PERU	35.1	360	48	0	68	511	25	0.03 %
127	PHILIPPINES	1,962.0	930	171	0	0	3,063	55	0.09 %
128	PITCAIRN ISLANDS	0.0	0	1	0	0	1	9,375	1.71 %
129	POLAND	1,940.4	378	342	0	472	3,133	84	0.02 %
130	PORTUGAL	495.0	407	88	0	743	1,732	169	0.09 %
131	PUERTO RICO	16.8	160	112	0	45	334	102	0.02 %
132	QATAR	135.0	45	56	0	0	236	757	0.04 %
133	REUNION	1.2	180	2	0	45	228	410	0.12 %
134	ROMANIA	525.0	42	200	0	158	924	41	0.02 %
135	SAO TOME AND PR.	3.2	0	1	0	39	44	399	1.46 %
136	SAUDI ARABIA	2,299.5	330	1,433	0	0	4,062	348	0.03 %
137	SENEGAL	1,412.3	140	43	0	0	1,596	238	0.65 %
138	SEYCHELLES	159.6	0	2	413	225	799	12,103	5.51 %
139	SIERRA LEONE	1,926.8	140	12	0	0	2,078	557	1.86 %
140	SINGAPORE	213.0	300	281	0	81	875	338	0.05 %
141	SOLOMON ISLANDS	26.4	0	6	0	0	33	118	0.20 %
142	SOMALIA	735.0	105	7	0	0	847	141	0.62 %
143	SOUTH AFRICA	312.0	920	676	0	900	2,808	83	0.04 %
144	SPAIN	549.9	1,742	774	0	2,925	5,991	154	0.03 %
145	SRI LANKA	1,446.0	1,860	37	0	203	3,545	220	0.63 %
146	ST. CHR. & NEVIS	48.0	0	2	0	90	140	3,033	2.33 %
147	ST. HELENA &ASC.	0.0	0	2	0	0	2	195	0.19 %
148	ST. LUCIA	30.0	0	3	0	90	123	879	0.82 %
149	ST. PIERRE & MIQ.	2.4	0	2	0	0	4	650	0.10 %
150	ST. VINCENT & DR.	8.4	0	2	0	45	55	497	0.55 %
151	SUDAN, THE	6.3	53	31	0	0	90	4	0.01 %
152	SURINAME	2,520.0	45	57	0	0	2,622	6,638	1.94 %
153	SWEDEN	9,906.0	1,963	426	0	1,350	13,645	1,633	0.14 %
154	SYRIA	2.7	45	94	0	68	210	20	0.01 %
155	TAIWAN	450.0	160	708	0	0	1,318	68	0.02 %
156	TANZANIA	404.3	193	31	0	79	706	31	0.16 %
157	THAILAND	2,790.0	975	205	0	1,350	5,320	101	0.12 %
158	TOGO	315.0	140	24	0	158	636	207	0.87 %
159	TOKELAU	3.8	0	1	10	0	14	9,025	11.11 %
160	TONGA	28.3	0	2	61	0	91	929	1.14 %
161	TRINIDAD & TOBAGO	1,176.0	120	244	0	180	1,720	1,431	0.21 %
162	TUNISIA	1,188.0	510	113	0	338	2,149	293	0.24 %
163	TURKEY	630.0	1,230	582	0	675	3,117	59	0.05 %
164	TURKS AND CAICOS	117.6	0	4	56	45	223	24,739	8.10 %
165	TUVALU	19.2	0	2	50	0	71	8,838	14.14 %
166	UNITED ARAB EMIR	3.6	45	187	0	0	236	139	0.01 %
167	UNITED KINGDOM	3,227.4	4,312	1,062	0	1,980	10,581	186	0.02 %
168	UNITED STATES	33,088.6	22,840	4,160	0	26,730	86,819	360	0.02 %
169	URUGUAY	1,242.0	390	4	0	169	1,805	595	0.31 %
170	USSR	18,454.8	1,778	968	0	3,780	24,981	89	0.01 %
171	VANUATU	21.6	0	2	0	0	23	169	0.26 %

No.	Country	Type of protection (millions of US dollars)						Total costs per capita (US$)	Annual costs as % of GNP
		Low Coast	Cities	Harbors	Island elev.	Beach nour.	Total costs		
172	VENEZUELA	1,848.0	620	597	0	90	3,155	177	0.05 %
173	VIETNAM	3,657.0	960	11	0	0	4,628	76	0.46 %
174	VIRGIN ISL. (U.S.)	3.6	0	2	0	225	230	2,018	0.26 %
175	WALLIS AND FUTUNA	0.0	0	2	0	0	2	107	0.13 %
176	WESTERN SAHARA	1.1	0	1	0	0	2	16	0.02 %
177	WESTERN SAMOA	13.2	60	2	0	0	75	467	0.59 %
178	YEMEN, NORTH	630.0	45	41	0	0	716	102	0.18 %
179	YEMEN, SOUTH	126.0	240	10	0	0	376	159	0.33 %
180	YUGOSLAVIA	34.4	210	132	0	2,520	2,879	124	0.04 %
181	ZAIRE	336.0	140	19	0	0	495	16	0.12 %
	Totals	260,557	102,693	40,913	3,755	87,579	495,479	104	0.038

ANNEX D.2

Country estimates

No.	Country	coast length ("crow") (km)	coast length multiplier	length low coast (km)	total city water front (km)	Beach length (km)	Harbor area (km^2)	Country cost factors			
								low coast	city	beach nour.	other infr.
1	ALBANIA	40	5	200	3	0	0.4	1.4	1.4	1.4	1.4
2	ALGERIA	60	3	140	27	25	11.0	1.5	1.5	1.5	1.5
3	AMERICAN SAMOA	--		7	0	5	0.4	2.0	2.0	2.0	2.0
4	ANGOLA	60	4	230	16	0	1.2	1.8	1.8	1.8	1.8
5	ANGUILLA	--		30	0	5	0.1	2.0	2.0	2.0	2.0
6	ANTIGUA & BARBUDA	--		50	0	10	0.1	2.0	2.0	2.0	2.0
7	ARGENTINA	380	8	2970	51	40	11.7	1.5	1.5	1.5	1.5
8	ARUBA	--		1	0	15	17.0	2.0	2.0	2.0	2.0
9	AUSTRALIA	480	8	3110	254	500	75.6	1.5	1.5	1.5	1.5
10	BAHAMAS, THE	--		400	0	200	9.5	2.0	2.0	2.0	2.0
11	BAHRAIN	100	3	270	11	25	5.6	1.5	1.5	1.5	1.5
12	BANGLADESH	360	20	7175	8	25	2.8	0.2	1.5	1.5	1.2
13	BARBADOS	--		15	0	30	0.3	2.0	2.0	2.0	2.0
14	BELGIUM	65	4	170	31	65	25.3	1.1	1.1	1.1	1.1
15	BELIZE	100	5	500	0	0	0.1	1.8	1.8	1.8	1.8
16	BENIN	100	5	485	11	10	0.2	1.8	1.8	1.8	1.8
17	BERMUDA	--		3	0	5	0.3	2.0	2.0	2.0	2.0
18	BRAZIL	3025	5	14925	169	100	52.2	2.0	2.0	2.0	2.0
19	BRITISH VIRGIN ISL	–		1	0	10	0.1	2.0	2.0	2.0	2.0
20	BRUNEI	--		2	3	0	6.7	1.0	1.0	1.0	1.0
21	BULGARIA	30	5	125	6	25	9.7	1.4	1.4	1.4	1.4
22	BURMA	750	10	7470	39	0	0.7	1.0	1.5	1.5	1.5
23	CAMEROON	60	5	290	13	0	0.7	1.8	1.8	1.8	1.8
24	CANADA	585	8	4460	94	150	32.0	2.0	2.0	2.0	2.0
25	CAPE VERDE	--		10	0	0	0.1	2.0	2.0	2.0	2.0
26	CAYMAN ISLANDS	--		1	0	25	0.1	2.0	2.0	2.0	2.0
27	CHILE	25	3	48	52	0	2.6	1.5	1.5	1.5	1.5
28	CHINA	2720	10	26750	219	300	26.8	0.4	1.2	1.5	1.2
29	CHRISTMAS ISLAND	--		2	0	0	0.0	2.0	2.0	2.0	2.0
30	COCOS (KEELING) IS	--		1	0	0	0.0	2.0	2.0	2.0	2.0
31	COLOMBIA	20	7	120	22	10	3.7	2.0	2.0	2.0	2.0
32	COMOROS	--		10	0	0	0.1	2.0	2.0	2.0	2.0
33	CONGO	--	3	3	3	0	1.7	1.8	1.8	1.8	1.8
34	COOK ISLANDS	--		0	0	0	0.1	2.0	2.0	2.0	2.0
35	COSTA RICA	40	5	200	0	0	0.8	1.8	1.8	1.8	1.8
36	CUBA	160	6	940	28	10	8.4	2.0	2.0	2.0	2.0
37	CYPRUS	20	5	100	6	0	1.6	1.3	1.3	1.3	1.3
38	DENMARK	1395	8	10800	78	300	10.2	1.3	1.3	1.3	1.3
39	DJIBOUTI	--		2	3	0	0.5	1.5	1.5	1.5	1.5
40	DOMINICA	--		10	0	0	0.1	2.0	2.0	2.0	2.0
41	DOMINICAN REPUBLIC	5	5	7	5	10	1.3	2.0	2.0	2.0	2.0
42	ECUADOR	5	6	8	19	0	1.9	1.5	1.5	1.5	1.5
43	EGYPT	325	10	3160	24	75	56.5	0.5	1.5	1.5	1.5
44	EL SALVADOR	--	6	10	0	0	0.6	1.8	1.8	1.8	1.8
45	EQUATORIAL GUINEA	--		7	3	0	0.1	1.8	1.8	1.8	1.8
46	ETHIOPIA	--	3	4	0	0	0.6	1.8	1.8	1.8	1.8
47	FAEROE ISLANDS	--		1	0	0	0.2	2.0	2.0	2.0	2.0
48	FALKLAND ISLANDS	--		1	3	0	0.0	2.0	2.0	2.0	2.0
49	FIJI	--		11	3	25	0.5	2.0	2.0	2.0	2.0
50	FINLAND	995	12	11825	36	100	12.0	1.3	1.3	1.5	1.3
51	FRANCE	820	6	4040	146	800	44.7	1.2	1.2	1.2	1.2
52	FRENCH GUIANA	90	6	540	3	0	0.1	1.5	1.5	1.5	1.5
53	FRENCH POLYNESIA	--	--	30	3	15	0.2	2.0	2.0	2.0	2.0
54	GABON	10	2	13	11	0	1.5	1.8	1.8	1.8	1.8
55	GAMBIA, THE	50	8	400	3	0	0.1	1.8	1.8	1.8	1.8
56	GERMAN, DEM.REP.	275	5	1290	19	75	7.1	1.1	1.1	1.1	1.1
57	GERMANY, FED. REP.	330	6	1610	94	300	38.1	1.1	1.1	1.1	1.1
58	GHANA	485	5	2400	17	20	1.1	1.8	1.8	1.8	1.8

No.	Country	coast length ("crow") (km)	coast length multiplier	length low coast (km)	total city water front (km)	Beach length (km)	Harbor area (km²)	Country cost factors			
								low coast	city	beach nour.	other infr.
59	GIBRALTAR	--	--	0	0	2	0.1	1.3	1.3	1.3	1.3
60	GREECE	155	8	610	60	600	16.2	1.3	1.3	1.3	1.3
61	GREENLAND	--	--	3	0	0	0.2	1.5	1.5	1.5	1.5
62	GRENADA	--	--	6	0	5	0.1	2.0	2.0	2.0	2.0
63	GUADELOUPE	0	--	20	3	15	0.6	2.0	2.0	2.0	2.0
64	GUAM	--	--	1	0	0	0.1	2.0	2.0	2.0	2.0
65	GUATEMALA	100	6	550	0	50	1.4	1.8	1.8	1.8	1.8
66	GUINEA	120	5	600	3	0	3.7	1.8	1.8	1.8	1.8
67	GUINEA-BISSAU	155	8	1240	0	0	0.1	1.8	1.8	1.8	1.8
68	GUYANA	130	8	1040	3	0	0.6	1.5	1.5	1.5	1.5
69	HAITI	--	5	8	5	0	0.5	2.0	2.0	2.0	2.0
70	HONDURAS	--	5	12	0	0	0.7	1.8	1.8	1.8	1.8
71	HONG KONG	100	2	165	25	10	15.1	1.0	1.0	1.0	1.0
72	ICELAND	50	10	490	10	0	0.7	1.5	1.5	1.5	1.5
73	INDIA	3280	10	32440	337	200	22.2	0.8	1.5	1.5	1.5
74	INDONESIA	2845	7	19680	98	200	27.1	0.5	1.2	1.2	1.2
75	IRAN	300	5	1500	8	0	35.9	1.5	1.5	1.5	1.5
76	IRAQ	40	10	400	5	0	25.2	1.5	1.5	1.5	1.5
77	IRELAND	25	8	160	52	0	4.1	1.1	1.1	1.1	1.1
78	ISRAEL	25	3	5	35	50	5.9	1.5	1.5	1.5	1.5
79	ITALY	520	7	2720	164	800	42.9	2.0	2.0	2.0	2.0
80	IVORY COAST	400	5	1940	10	50	2.6	1.8	1.8	1.8	1.8
81	JAMAICA	5	5	8	5	30	2.8	2.0	2.0	2.0	2.0
82	JAPAN	530	8	3870	543	100	199.1	2.0	2.0	2.0	2.0
83	JORDAN	--	--	1	0	0	0.2	1.5	1.5	1.5	1.5
84	KAMPUCHEA	--	--	6	0	0	0.1	0.5	1.5	1.5	1.5
85	KENYA	10	5	9	5	30	1.3	1.8	1.8	1.8	1.8
86	KIRIBATI	--	--	0	0	0	0.1	2.0	2.0	2.0	2.0
87	KOREA, NORTH	100	5	500	30	0	1.5	0.5	1.5	1.5	1.5
88	KOREA, SOUTH	80	10	750	49	25	32.3	0.8	1.0	1.0	1.0
89	KUWAIT	50	2	100	3	0	9.8	1.5	1.5	1.5	1.5
90	LEBANON	10	2	2	21	10	9.9	1.5	1.5	1.5	1.5
91	LIBERIA	445	5	2220	8	0	6.0	1.8	1.8	1.8	1.8
92	LIBYA	470	3	1390	16	10	12.8	2.0	2.0	2.0	2.0
93	MACAU	--	--	0	5	0	0.3	1.5	1.5	1.5	1.5
94	MADAGASCAR	170	7	1190	12	0	0.2	1.8	1.8	1.8	1.8
95	MALAYSIA	385	8	3030	43	40	15.6	1.0	1.0	1.0	1.0
96	MALDIVES	--	--	1	3	25	0.1	2.0	2.0	2.0	2.0
97	MALTA	20	4	65	5	10	0.5	1.3	1.3	1.3	1.3
98	MARSHALL ISLANDS	--	--	0	0	0	0.1	2.0	2.0	2.0	2.0
99	MARTINIQUE	0	--	20	3	10	0.6	2.0	2.0	2.0	2.0
100	MAURETANIA	–	–	2	0	0	2.6	1.8	1.8	1.8	1.8
101	MAURITIUS	--	--	1	3	10	0.6	2.0	2.0	2.0	2.0
102	MAYOTTE	--	--	3	0	0	0.1	2.0	2.0	2.0	2.0
103	MEXICO	1230	7	8354	34	25	12.4	1.8	1.8	1.8	1.8
104	MICRONESIA, FED. ST.	--	--	0	0	0	0.1	2.0	2.0	2.0	2.0
105	MONACO	--	--	0	3	0.5	0.1	1.3	1.3	1.3	1.3
106	MONTSERRAT	--	--	1	0	0	0.1	2.0	2.0	2.0	2.0
107	MOROCCO	140	3	375	44	25	9.5	1.8	1.8	1.8	1.8
108	MOZAMBIQUE	1675	6	10015	16	25	2.7	1.8	1.8	1.8	1.8
109	NAMIBIA	--	--	3	0	0	0.1	1.8	1.8	1.8	1.8
110	NAURU	--	--	3	0	0	0.5	2.0	2.0	2.0	2.0
111	NETH. ANTILLES	--	--	25	3	30	18.3	2.0	2.0	2.0	2.0
112	NETHERLANDS, THE	355	8	2585	51	225	75.9	1.0	1.0	1.0	1.0
113	NEW CALEDONIA	--	--	13	3	10	0.6	2.0	2.0	2.0	2.0
114	NEW ZEALAND	1510	10	14900	151	100	4.6	1.5	1.5	1.5	1.5
115	NICARAGUA	180	5	900	0	0	0.4	1.8	1.8	1.8	1.8
116	NIGERIA	200	10	1955	38	25	9.4	1.8	1.8	1.8	1.8

No.	Country	coast length ("crow") (km)	coast length multiplier	length low coast (km)	total city water front (km)	Beach length (km)	Harbor area (km^2)	Country cost factors			
								low coast	city	beach nour.	other infr.
117	NIUE	--	--	6	0	0	0.1	2.0	2.0	2.0	2.0
118	NORFOLK ISLANDS	--	--	0	0	0	0.0	2.0	2.0	2.0	2.0
119	N. MARIANA ISLANDS	--	--	0	0	0	0.1	2.0	2.0	2.0	2.0
120	NORWAY	20	10	165	48	20	14.7	1.3	1.3	2.0	1.3
121	OMAN	100	2	200	0	0	2.8	1.5	1.5	1.5	1.5
122	PAKISTAN	150	7	1005	20	25	3.8	0.8	1.5	1.5	1.5
123	PALAU	--	--	7	0	0	0.1	2.0	2.0	2.0	2.0
124	PANAMA	--	5	24	8	10	0.7	1.8	1.8	1.8	1.8
125	PAPUA NEW GUINEA	640	10	6400	9	0	0.4	1.8	1.8	1.8	1.8
126	PERU	20	3	39	24	10	2.1	1.5	1.5	1.5	1.5
127	PHILIPPINES	220	10	2180	62	0	7.6	1.5	1.5	1.5	1.5
128	PITCAIRN ISLANDS	--	--	0	0	0	0.0	2.0	2.0	2.0	2.0
129	POLAND	400	6	2310	27	75	16.3	1.4	1.4	1.4	1.4
130	PORTUGAL	185	5	750	37	150	5.3	1.1	1.1	1.1	1.1
131	PUERTO RICO	--	5	14	8	5	3.7	2.0	2.0	2.0	2.0
132	QATAR	75	2	150	3	0	2.5	1.5	1.5	1.5	1.5
133	REUNION	--	--	1	9	5	0.1	2.0	2.0	2.0	2.0
134	ROMANIA	65	10	625	3	25	9.5	1.4	1.4	1.4	1.4
135	SAO TOME AND PR.	--	--	3	0	5	0.1	1.8	1.8	1.8	1.8
136	SAUDI ARABIA	855	3	2555	22	0	63.7	1.5	1.5	1.5	1.5
137	SENEGAL	270	5	1345	8	0	1.7	1.8	1.8	1.8	1.8
138	SEYCHELLES	--	--	1	0	25	0.1	2.0	2.0	2.0	2.0
139	SIERRA LEONE	230	8	1835	8	0	0.4	1.8	1.8	1.8	1.8
140	SINGAPORE	100	4	355	30	15	18.7	1.0	1.0	1.2	1.0
141	SOLOMON ISLANDS	--	--	22	0	0	0.2	2.0	2.0	2.0	2.0
142	SOMALIA	350	2	700	6	0	0.3	1.8	1.8	1.8	1.8
143	SOUTH AFRICA	100	4	260	46	100	22.5	2.0	2.0	2.0	2.0
144	SPAIN	245	5	705	134	500	39.7	1.3	1.3	1.3	1.3
145	SRI LANKA	990	5	4820	124	30	1.6	0.5	1.5	1.5	1.5
146	ST. CHR. & NEVIS	--	--	40	0	10	0.1	2.0	2.0	2.0	2.0
147	ST. HELENA &ASC.	--	–	0	0	0	0.1	2.0	2.0	2.0	2.0
148	ST. LUCIA	--	--	25	0	10	0.1	2.0	2.0	2.0	2.0
149	ST. PIERRE & MIQ.	–	--	2	0	0	0.1	2.0	2.0	2.0	2.0
150	ST. VINCENT & DR.	--	--	7	0	5	0.1	2.0	2.0	2.0	2.0
151	SUDAN, THE	--	2	6	3	0	1.2	1.8	1.8	1.8	1.8
152	SURINAME	350	8	2800	3	0	2.5	1.5	1.5	1.5	1.5
153	SWEDEN	1300	10	12700	151	200	21.9	1.3	1.3	1.5	1.3
154	SYRIA	5	3	3	3	10	4.2	1.5	1.5	1.5	1.5
155	TAIWAN	150	5	750	16	0	47.2	1.0	1.0	2.0	1.0
156	TANZANIA	80	5	385	11	10	1.2	1.8	1.8	1.8	1.8
157	THAILAND	490	10	4650	65	200	9.1	1.0	1.5	1.5	1.5
158	TOGO	65	5	300	8	20	0.9	1.8	1.8	1.8	1.8
159	TOKELAU	--	--	0	0	0	0.0	2.0	2.0	2.0	2.0
160	TONGA	--	--	4	0	0	0.1	2.0	2.0	2.0	2.0
161	TRINIDAD & TOBAGO	200	5	980	6	20	8.1	2.0	2.0	2.0	2.0
162	TUNISIA	345	4	1320	34	50	5.0	1.5	1.5	1.5	1.5
163	TURKEY	140	6	700	82	100	25.8	1.5	1.5	1.5	1.5
164	TURKS AND CAICOS	--	--	80	0	5	0.1	2.0	2.0	2.0	2.0
165	TUVALU	--	--	0	0	0	0.1	2.0	2.0	2.0	2.0
166	UNITED ARAB EMIR	--	--	4	3	0	8.3	1.5	1.5	1.5	1.5
167	UNITED KINGDOM	610	9	4890	392	400	64.4	1.1	1.1	1.1	1.1
168	UNITED STATES	3285	10	27574	1142	2970	138.7	2.0	2.0	2.0	2.0
169	URUGUAY	285	5	1380	26	25	0.2	1.5	1.5	1.5	1.5
170	USSR	2830	8	21970	127	600	46.1	1.4	1.4	1.4	1.4
171	VANUATU	--	--	18	0	0	0.1	2.0	2.0	2.0	2.0
172	VENEZUELA	260	6	1540	31	10	19.9	2.0	2.0	2.0	2.0
173	VIETNAM	510	12	6095	64	0	0.5	1.0	1.5	1.5	1.5
174	VIRGIN ISL. (U.S.)	--	--	3	0	25	0.1	2.0	2.0	2.0	2.0

No.	Country	coast length ("crow") (km)	coast length multiplier	length low coast (km)	total city water front (km)	Beach length (km)	Harbor area (km^2)	Country cost factors			
								low coast	city	beach nour.	other infr.
175	WALLIS AND FUTUNA	--	--	0	0	0	0.1	2.0	2.0	2.0	2.0
176	WESTERN SAHARA	--	--	1	0	0	0.1	1.8	1.8	1.8	1.8
177	WESTERN SAMOA	--	--	11	3	0	0.1	2.0	2.0	2.0	2.0
178	YEMEN, NORTH	350	2	700	3	0	1.8	1.5	1.5	1.5	1.5
179	YEMEN, SOUTH	50	3	140	16	0	0.4	1.5	1.5	1.5	1.5
180	YUGOSLAVIA	50	8	41	15	400	6.3	1.4	1.4	1.4	1.4
181	ZAIRE	40	8	320	8	0	0.7	1.8	1.8	1.8	1.8
	Totals	46,185		339,185	6,399	12,128	1,757				

Coast length ("crow"): -- not applicable: small islands and/or coastline length ("crow): <5 km
Coast length multiplier: -- not applicable: small islands or coastline length ("crow") <5 km

ANNEX D.3

Country estimates and country classification

No.	Country	Number of Additional Coastal Cities			Harbors		Small Islands			Country Classification		
		large	medium	small	marine transport (mln tons)	Fraction bulk & oil	Popul. higher islands	elev (km2)	low coast (km)	Econ. type	Small Islands	Region
1	ALBANIA	0	1	0	1.2	0.0	0	0.0	0.0	B		Northern mediterranean
2	ALGERIA	1	4	0	71.4	0.7	0	0.0	0.0	C		Souther mediterranean
3	AMERICAN SAMOA	0	0	7	1.3	0.0	0	0.0	0.0	C	SI	Pacific small islands
4	ANGOLA	0	2	0	9.6	0.8	0	0.0	0.0	B		Africa atltantic coast
5	ANGUILLA	0	0	2	0.0	0.0	0	0.0	0.0	B	SI	Caribbean islands
6	ANTIGUA & BARBUDA	0	0	3	0.0	0.0	0	0.0	0.0	C	SI	Caribbean islands
7	ARGENTINA	2	7	0	37.9	0.1	0	0.0	0.0	C		South America Atlantic coast
8	ARUBA	0	0	1	51.0	0.0	0	0.0	0.0	C	SI	Caribbean islands
9	AUSTRALIA	0	8	0	268.0	0.2	0	0.0	0.0	E		Pacific large islands
10	BAHAMAS, THE	0	0	18	28.5	0.0	0	0.0	0.0	C	SI	Caribbean islands
11	BAHRAIN	0	2	0	16.8	0.0	0	0.0	0.0	D		Gulf states
12	BANGLADESH	1	1	0	9.9	0.2	0	0.0	0.0	A		Asia Indian Ocean coast
13	BARBADOS	0	0	7	0.9	0.0	0	0.0	0.0	C	SI	Caribbean islands
14	BELGIUM	0	2	0	123.2	0.5	0	0.0	0.0	E		North and West Europe
15	BELIZE	0	0	0	0.3	0.0	0	0.0	0.0	B		Central America
16	BENIN	0	2	0	0.8	0.5	0	0.0	0.0	A		Africa Atlantic coast
17	BERMUDA	0	0	3	0.9	0.0	0	0.0	0.0	E	SI	Atlantic Ocean small islands
18	BRAZIL	6	23	0	203.5	0.3	0	0.0	0.0	C		South America Atlantic coast
19	BRITISH VIRGIN ISL	0	0	1	0.0	0.0	0	0.0	0.0	C	SI	Caribbean islands
20	BRUNEI	0	1	2	20.2	0.0	0	0.0	0.0	D		Southeast Asia coast
21	BULGARIA	0	2	0	29.0	0.0	0	0.0	0.0	C		Northern mediterranean
22	BURMA	0	3	0	2.3	0.1	0	0.0	0.0	A		Asia Indian Ocean coast
23	CAMEROON	0	1	0	4.4	0.7	0	0.0	0.0	B		Africa Atlantic coast
24	CANADA	0	8	0	177.9	0.6	0	0.0	0.0	E		North America
25	CAPE VERDE	0	0	10	0.3	0.0	0	0.0	0.0	A	SI	Atlantic Ocean small islands
26	CAYMAN ISLANDS	0	0	1	0.1	0.0	0	0.0	0.0	E	SI	Caribbean islands
27	CHILE	0	14	48	17.1	0.7	0	0.0	0.0	C		South America Pacific coast
28	CHINA	6	23	0	104.5	0.3	0	0.0	0.0	A		East Asia coast
29	CHRISTMAS ISLAND	0	0	2	1.3	0.0	0	0.0	0.0	C	SI	Indian Ocean small islands
30	COCOS (KEELING) IS	0	0	1	0.0	0.0	0	0.2	1.4	C	SI	Indian Ocean small islands
31	COLOMBIA	1	4	0	14.3	0.3	0	0.0	0.0	B		South America Atlantic coast
32	COMOROS	0	0	10	0.1	0.0	0	0.0	0.0	A	SI	Indian Ocean small islands
33	CONGO	0	1	3	8.2	0.5	0	0.0	0.0	B		Africa Atlantic coast
34	COOK ISLANDS	0	0	0	0.0	0.0	14790	0.6	4.4	B	SI	Pacific small islands
35	COSTA RICA	0	0	0	3.3	0.3	0	0.0	0.0	B		Central America
36	CUBA	1	6	0	25.2	0.0	0	0.0	0.0	B		Caribbean islands
37	CYPRUS	0	2	0	4.9	0.0	0	0.0	0.0	C		Southern mediterranean
38	DENMARK	1	6	0	44.1	0.4	0	0.0	0.0	E		North and West Europe
39	DJIBOUTI	0	1	2	1.4	0.0	0	0.0	0.0	B		Africa Indian Ocean coast
40	DOMINICA	0	0	2	0.1	0.0	0	0.0	0.0	B	SI	Caribbean islands
41	DOMINICAN REPUBLIC	1	0	7	5.7	0.4	0	0.0	0.0	B		Caribbean islands
42	ECUADOR	1	3	8	12.5	0.7	0	0.0	0.0	B		South America Pacific coast
43	EGYPT	2	3	0	200.2	0.2	0	0.0	0.0	B		Southern mediterranean
44	EL SALVADOR	0	0	10	2.2	0.2	0	0.0	0.0	B		Central America
45	EQUATORIAL GUINEA	0	1	7	0.1	0.0	0	0.0	0.0	A		Africa Atlantic coast
46	ETHIOPIA	0	0	4	2.4	0.3	0	0.0	0.0	A		Africa Indian Ocean coast
47	FAEROE ISLANDS	0	0	1	0.5	0.0	0	0.0	0.0	E	SI	Atlantic Ocean small islands
48	FALKLAND ISLANDS	0	1	1	0.0	0.0	0	0.0	0.0	C	SI	Atlantic Ocean small islands
49	FIJI	0	1	11	1.5	0.0	525000	46.3	370.0	C	SI	Pacific small islands
50	FINLAND	1	7	0	51.9	0.4	0	0.0	0.0	E		Baltic sea coast
51	FRANCE	4	22	0	248.6	0.6	0	0.0	0.0	E		North and West Europe
52	FRENCH GUIANA	0	1	0	0.3	0.0	0	0.0	0.0	C		South America Atlantic coast
53	FRENCH POLYNESIA	0	1	30	0.5	0.0	170000	2.5	20.0	C	SI	Pacific small islands
54	GABON	0	2	13	7.5	0.5	0	0.0	0.0	C		Africa Atlantic coast
55	GAMBIA, THE	0	1	0	0.3	0.0	0	0.0	0.0	A		Africa Atlantic coast

No.	Country	Number of Additional Coastal Cities			Harbors		Small Islands			Country Classification		
		large	medium	small	marine transport (mln tons)	Fraction bulk & oil	Popul. higher islands	elev (km2)	low coast (km)	Econ. type	Small Islands	Region
56	GERMAN, DEM.REP.	0	3	0	25.1	0.2	0	0.0	0.0	C		Baltic sea coast
57	GERMANY, FED. REP.	2	8	0	135.0	0.2	0	0.0	0.0	E		North and West Europe
58	GHANA	1	4	0	4.5	0.3	0	0.0	0.0	A		Africa Atlantic coast
59	GIBRALTAR	0	0	0	0.3	0.0	0	0.0	0.0	E		Northen mediterranean
60	GREECE	2	10	0	63.1	0.3	0	0.0	0.0	C		Northern mediterranean
61	GREENLAND	0	0	3	0.6	0.0	0	0.0	0.0	E		North and West Europe
62	GRENADA	0	0	6	0.0	0.0	0	0.0	0.0	B	SI	Caribbean Islands
63	GUADELOUPE	0	1	14	1.7	0.0	0	0.0	0.0	C	SI	Caribbean Islands
64	GUAM	0	0	1	0.2	0.0	0	0.0	0.0	C	SI	Pacific small islands
65	GUATEMALA	0	0	0	4.8	0.2	0	0.0	0.0	B		Central America
66	GUINEA	0	1	0	11.1	0.0	0	0.0	0.0	A		Africa Atlantic Coast
67	GUINEA-BISSAU	0	0	0	0.1	0.0	0	0.0	0.0	A		Africa Atlantic Coast
68	GUYANA	0	1	0	1.8	0.0	0	0.0	0.0	B		South America Atlantic Coast
69	HAITI	1	0	8	1.4	0.0	0	0.0	0.0	A		Carribean Islands
70	HONDURAS	0	0	12	2.8	0.3	0	0.0	0.0	B		Central America
71	HONG KONG	0	0	0	53.7	0.2	0	0.0	0.0	C		East Asia coast
72	ICELAND	0	0	0	2.0	0.0	0	0.0	0.0	E	SI	North and West Europe
73	INDIA	4	59	0	86.3	0.3	0	0.0	0.0	A		Asia Indian Ocean coast
74	INDONESIA	3	21	0	132.0	0.5	0	0.0	0.0	B		Southeast Asia coast
75	IRAN	1	1	0	199.5	0.6	0	0.0	0.0	C		Gulf states
76	IRAQ	1	0	0	106.4	0.4	0	0.0	0.0	C		Gulf states
77	IRELAND	1	4	0	17.4	0.4	0	0.0	0.0	E		North and West Europe
78	ISRAEL	1	5	0	22.9	0.3	0	0.0	0.0	C		Southern mediterranean
79	ITALY	7	48	0	228.7	0.6	0	0.0	0.0	E		Northern mediterranean
80	IVORY COAST	1	0	0	10.2	0.3	0	0.0	0.0	B		Africa Atlantic coast
81	JAMAICA	1	0	8	10.4	0.3	0	0.0	0.0	B		Caribbean islands
82	JAPAN	15	91	0	776.1	0.3	0	0.0	0.0	E		East Asia coast
83	JORDAN	0	0	1	1.5	0.7	0	0.0	0.0	B		Southern mediterranean
84	KAMPUCHEA	0	0	6	0.1	0.0	0	0.0	0.0	A		Southeast Asia coast
85	KENYA	1	0	9	6.6	0.5	0	0.0	0.0	A		Africa Indian Ocean coast
86	KIRIBATI	0	0	0	0.0	0.0	0	16.3	130.0	B	SI	Pacific small islands
87	KOREA, NORTH	0	10	0	4.6	0.0	0	0.0	0.0	B		East Asia coast
88	KOREA, SOUTH	1	8	0	125.7	0.3	0	0.0	0.0	C		East Asia coast
89	KUWAIT	0	1	0	63.7	0.7	0	0.0	0.0	D		Gulf states
90	LEBANON	1	2	2	29.8	0.0	0	0.0	0.0	C		Southern mediterranean
91	LIBERIA	0	1	0	19.5	0.1	0	0.0	0.0	B		Africa Atlantic coast
92	LIBYA	0	2	0	99.2	0.8	0	0.0	0.0	D		Southern mediterranean
93	MACAU	1	0	0	0.8	0.0	0	0.0	0.0	C		East Asia coast
94	MADAGASCAR	0	4	0	1.0	0.4	0	0.0	0.0	A		Africa Indian Ocean coast
95	MALAYSIA	0	11	0	67.4	0.4	0	0.0	0.0	C		Southeast Asia coast
96	MALDIVES	0	1	1	0.1	0.0	0	47.3	378.0	A	SI	Indian Ocean small islands
97	MALTA	0	0	0	1.6	0.0	0	0.0	0.0	C		Northern mediterranean
98	MARSHALL ISLANDS	0	0	0	0.1	0.0	0	9.3	74.0	B	SI	Pacific small islands
99	MARTINIQUE	0	1	8	1.8	0.0	0	0.0	0.0	C	SI	Caribbean islands
100	MAURETANIA	0	0	2	8.6	0.1	0	0.0	0.0	B		Africa Atlantic coast
101	MAURITIUS	0	1	1	2.0	0.2	0	0.0	0.0	B	SI	Indian Ocean small islands
102	MAYOTTE	0	0	3	0.0	0.0	0	0.0	0.0	A	SI	Indian Ocean small islands
103	MEXICO	0	8	0	80.5	0.7	0	0.0	0.0	C		North America
104	MICRONESIA, FED. ST.	0	0	0	0.0	0.0	85500	2.4	19.0	B	SI	Pacific small islands
105	MONACO	0	1	0	0.0	0.0	0	0.0	0.0	E		Northern mediterranean
106	MONTSERRAT	0	0	1	0.0	0.0	0	0.0	0.0	C	SI	Caribbean islands
107	MOROCCO	1	8	0	33.8	0.2	0	0.0	0.0	B		Africa Atlantic coast
108	MOZAMBIQUE	0	2	0	8.9	0.1	0	0.0	0.0	A		Africa Indian Ocean coast
109	NAMIBIA	0	0	3	0.0	0.0	0	0.0	0.0	B		Africa Atlantic coast
110	NAURU	0	0	3	1.4	0.0	0	2.0	16.0	C	SI	Pacific small islands

No.	Country	Number of Additional Coastal Cities			Harbors		Small Islands			Country Classification		
		large	medium	small	marine transport (mln tons)	Fraction bulk & oil	Popul. higher islands	elev (km2)	low coast (km)	Econ. type	Small Islands	Region
111	NETH. ANTILLES	0	1	4	54.8	0.0	0	0.0	0.0	C	SI	Caribbean islands
112	NETHERLANDS, THE	2	7	0	328.4	0.4	0	0.0	0.0	E		North and West Europe
113	NEW CALEDONIA	0	1	13	1.9	0.0	0	0.0	0.0	C	SI	Pacific small islands
114	NEW ZEALAND	0	17	0	17.9	0.3	0	0.0	0.0	E		Pacific large islands
115	NICARAGUA	0	0	0	1.7	0.4	0	0.0	0.0	B		Central America
116	NIGERIA	1	6	0	73.2	0.8	0	0.0	0.0	B		Africa Atlantic Coast
117	NIUE	0	0	6	0.0	0.0	0	0.0	0.0	B	SI	Pacific small islands
118	NORFOLK ISLAND	0	0	0	0.0	0.0	0	0.0	0.0	C	SI	Pacific small islands
119	N. MARIANA ISLANDS	0	0	0	0.0	0.0	0	0.0	0.0	B	SI	Pacific small islands
120	NORWAY	1	11	0	81.6	0.6	0	0.0	0.0	E		North and West Europe
121	OMAN	0	0	0	22.1	0.8	0	0.0	0.0	C		Gulf states
122	PAKISTAN	0	0	0	16.4	0.4	0	0.0	0.0	A		Asia Indian Ocean coast
123	PALAU	0	0	7	0.0	0.0	0	0.0	0.0	B	SI	Pacific small islands
124	PANAMA	1	1	24	4.6	0.7	0	0.0	0.0	C		Central America
125	PAPUA NEW GUINEA	0	3	0	3.4	0.8	0	0.0	0.0	B		Pacific large islands
126	PERU	0	3	39	13.9	0.7	0	0.0	0.0	B		South America Pacific coast
127	PHILIPPINES	1	14	0	29.7	0.3	0	0.0	0.0	B		Southeast Asia coast
128	PITCAIRN ISLANDS	0	0	0	0.0	0.0	0	0.0	0.0	C	SI	Pacific small islands
129	POLAND	0	4	0	48.9	0.0	0	0.0	0.0	C		Baltic sea coast
130	PORTUGAL	2	4	0	23.1	0.4	0	0.0	0.0	C		North and West Europe
131	PUERTO RICO	1	1	14	11.2	0.0	0	0.0	0.0	C		Caribbean islands
132	QATAR	0	1	0	16.0	0.7	0	0.0	0.0	D		Gulf states
133	REUNION	0	3	1	0.0	0.0	0	0.0	0.0	C	SI	Indian Ocean small islands
134	ROMANIA	0	1	0	37.1	0.3	0	0.0	0.0	C		Northern mediterranean
135	SAO TOME AND PR.	0	0	3	0.0	0.0	0	0.0	0.0	A	SI	Atlantic Ocean small islands
136	SAUDI ARABIA	0	4	0	354.1	0.6	0	0.0	0.0	D		Gulf states
137	SENEGAL	0	1	0	5.9	0.2	0	0.0	0.0	A		Africa Atlantic coast
138	SEYCHELLES	0	0	1	0.2	0.0	0	16.5	132.0	C	SI	Indian Ocean small islands
139	SIERRA LEONE	0	1	0	1.7	0.3	0	0.0	0.0	A		Africa Atlantic coast
140	SINGAPORE	0	0	0	104.2	0.6	0	0.0	0.0	C		Southeast Asia coast
141	SOLOMON ISLANDS	0	0	22	0.6	0.0	0	0.0	0.0	B	SI	Pacific small islands
142	SOMALIA	0	2	0	1.2	0.4	0	0.0	0.0	A		Africa Indian Ocean coast
143	SOUTH AFRICA	3	2	0	87.8	0.3	0	0.0	0.0	C		Africa Indian Ocean coast
144	SPAIN	3	38	0	171.8	0.4	0	0.0	0.0	E		North and West Europe
145	SRI LANKA	1	8	0	7.0	0.4	0	0.0	0.0	A		Indian Ocean coast
146	ST. CHR. & NEVIS	0	0	3	0.1	0.0	0	0.0	0.0	B	SI	Caribbean islands
147	ST. HELENA &ASC.	0	0	0	0.0	0.0	0	0.0	0.0	B	SI	Atlantic Ocean small islands
148	ST. LUCIA	0	0	7	0.3	0.0	0	0.0	0.0	B	SI	Caribbean islands
149	ST. PIERRE & MIQ.	0	0	2	0.1	0.0	0	0.0	0.0	C	SI	Atlantic Ocean small islands
150	ST. VINCENT & DR.	0	0	7	0.2	0.0	0	0.0	0.0	B	SI	Caribbean islands
151	SUDAN, THE	0	1	6	4.2	0.2	0	0.0	0.0	A		Africa Indian Ocean coast
152	SURINAME	0	1	0	7.6	0.0	0	0.0	0.0	C		South America Atlantic Ocean
153	SWEDEN	3	17	0	94.6	0.4	0	0.0	0.0	E		Baltic sea coast
154	SYRIA	0	1	3	23.3	0.6	0	0.0	0.0	C		Southern mediterranean
155	TAIWAN	2	2	0	183.9	0.3	0	0.0	0.0	C		East Asia coast
156	TANZANIA	1	2	0	3.8	0.1	0	0.0	0.0	A		Africa Indian Ocean coast
157	THAILAND	0	5	0	35.6	0.3	0	0.0	0.0	B		Southeast Asia coast
158	TOGO	0	1	0	3.5	0.3	0	0.0	0.0	A		Africa Atlantic coast
159	TOKELAU	0	0	0	0.0	0.0	0	0.4	3.2	B	SI	Pacific small islands
160	TONGA	0	0	4	0.1	0.0	88200	2.5	19.6	B	SI	Pacific small islands
161	TRINIDAD & TOBAGO	0	2	0	35.3	0.4	0	0.0	0.0	C		Caribbean islands
162	TUNISIA	0	8	0	24.5	0.5	0	0.0	0.0	B		Southern mediterranean
163	TURKEY	1	14	0	91.6	0.2	0	0.0	0.0	B		Southern mediterranean
164	TURKS AND CAICOS	0	0	1	0.4	0.0	0	2.3	18.0	C	SI	Caribbean islands
165	TUVALU	0	0	0	0.0	0.0	0	2.0	16.0	B	SI	Pacific small islands

No.	Country	Number of Additional Coastal Cities			Harbors		Small Islands			Country Classification		
		large	medium	small	marine transport (mln tons)	Fraction bulk & oil	Popul. higher islands	elev (km2)	low coast (km)	Econ. type	Small Islands	Region
166	UNITED ARAB EMIR	0	1	4	64.7	0.8	0	0.0	0.0	D		Gulf states
167	UNITED KINGDOM	9	64	0	357.9	0.6	0	0.0	0.0	E		North and West Europe
168	UNITED STATES	0	39	0	675.0	0.5	0	0.0	0.0	E		North America
169	URUGUAY	0	2	0	1.3	0.7	0	0.0	0.0	C		South America Atlantic coast
170	USSR	8	19	0	138.3	0.0	0	0.0	0.0	C		USSR
171	VANUATU	0	0	18	0.1	0.0	0	0.0	0.0	B	SI	Pacific small islands
172	VENEZUELA	1	7	0	96.8	0.5	0	0.0	0.0	C		South America Atlantic coast
173	VIETNAM	1	13	0	1.4	0.0	0	0.0	0.0	A		Southeast Asia coast
174	VIRGIN ISL. (U.S.)	0	0	3	0.0	0.0	0	0.0	0.0	C	SI	Caribbean islands
175	WALLIS AND FUTUNA	0	0	0	0.0	0.0	0	0.0	0.0	B	SI	Pacific small islands
176	WESTERN SAHARA	0	0	1	0.1	0.0	0	0.0	0.0	B		Africa Atlantic coast
177	WESTERN SAMOA	0	1	11	0.1	0.0	0	0.0	0.0	B	SI	Pacific small islands
178	YEMEN, NORTH	0	1	0	5.5	0.0	0	0.0	0.0	B		Asia Indian Ocean coast
179	YEMEN, SOUTH	0	2	0	2.8	0.7	0	0.0	0.0	B		Asia Indian Ocean coast
180	YUGOSLAVIA	0	5	41	30.7	0.5	0	0.0	0.0	B		Northern Mediterranean
181	ZAIRE	1	1	0	3.1	0.4	0	0.0	0.0	A		Africa Atlantic coast
	Totals	117	828	552	7,682			150	1202			

ANNEX D.4

Backwater effects of sea level rise along rivers in deltas

1. Objective

The total required length of protection against sea level rise in a large deltas is a multiple of the coastline measured "as the crow flies", due to the presence of islands for the coast, large estuaries, the irregularity of the coast and backwater effects of sea level rise on rivers. These rivers have to be protected on either side.

In case of large rivers in flat deltas, often with a depth of 10 to 20 m and a surface water slope in the order of 2 to 5 cm/km, sea level rise may penetrate over some hundreds of kilometres. The main river also often bifurcates in the delta into a number of minor branches, which may have to be protected on either side over their entire length. Finally, numerous smaller local rivers and man-made channels are often found in deltas.

Multipliers to calculate the total tidally affected shoreline (including the banks of estuaries, islands, tidal rivers and channels) from the straight coastline measured "as the crow flies", may therefore reach values in the order of 15 to 20 for large flat deltas, such as the Mekong delta in Vietnam or the Mississippi delta in the USA.

In this Annex an attempt is made to estimate the distance with significant backwater effects for some of the major deltas in the world. Next the total length of required protection works is estimated for the rivers and coastline as displayed on the maps in the Times Atlas (Ref. 18), at a scale 1:5,000,000 and 1:2,500,000. Division of this length by the coastline length of the delta, measured "as the crow flies", yields the multiplier to calculate the total tidally affected shoreline from the straight coastline.

2. Calculation of backwater effects

Provided the critical flow depth in a river is much less than the equilibrium depth, the general formula for the backwater curve for gradually varied steady flow in a wide rectangular channel reads approximately:

$$L = (U_0 - U_l + F(U_l) - F(U^0)) * H_e/i$$

where:

L	=	distance from river mouth
H_e	=	equilibrium water depth
i	=	bottom slope
U_0	=	H_0/H_e (relative change of the water depth at river mouth)
Ho	=	water depth at river mouth = H_e + dH
dH	=	expected sea level rise (at river mouth)
U_1	=	H_l/H_e (relative change of water depth at distance L)
H_1	=	depth at distance L from river mouth = He + dh
dh	=	backwater effect at distance L from river mouth
F(U)	=	varied-flow function

The varied flow function is tabulated in "Open channel hydraulics" (Ref. 4). Tidal effects have not been considered.

Near the river mouth the banks have to be raised with dH, which reduces gradually in upstream direction. Hence, the costs of embankments reduce also gradually in upstream direction. An upstream limit for protection works has to be set. For the purpose of this analysis it was assumed that no protection would be provided in areas where the backwater effect of sea level rise is less than 2096 of the rise at the river mouth. This distance, called L0.2, has been calculated for equilibrium depths of 2.5 to 20 m and the required average height of levees was 0.5m for all depths and dH =lm (1 m at the river mouth and 0.2 m at L0.2).

The unit cost rate for the construction of a levee of 1 m height are assumed to consist for 5096 of fixed costs (purchase of land, etc.) and for the remainder of variable costs, depending on the height of the bank. The costs of a dike of 0.5 m are therefore set at 7596 of the costs of a dike of 1 m.

The total costs for the construction of levees along rivers with backwater effects due to a sea level rise of 1 m are therefore equivalent to the costs of the construction of a dike with a height of 1 m over 7596 of the distance L0.2. The latter in turn is, for the range of conditions considered, equivalent to the distance L0.3, defined as the distance upstream from the river mouth, where the backwater effect of the expected sea level rise dH is reduced to 3096 (dh = 0.3 * dH and Ul = 0.3 * Uo + 0.7). The costs of the apparent overprotection over the distance L0.3 are expected to balance the costs of necessary protection works further upstream along the rivers.

The above equation for L then can accurately be approximated by:

$L0.3 = 0.40 * (Uo * 1.234) * H_e/i$

The expected sea level rise dH has been set at 1 m, thus:

$U_0 = 1 + 1/H_e$

The remaining parameters i and He (bottom slope and equilibrium water depth) were determined as follows.

The average river slope i is derived from the distance 1,100 ("as the crow flies") between the coastline and the 100 m contour line at its crossing with the river, which is indicated on the maps in the Times Atlas. The average valley slope between the coastline and the 100 m contour line is 1 /L I 00.

The average slope of the river in the reach with a significant backwater effect will be less than the above average valley slope, because the slope of the valley generally decreases in downstream direction, while the length of the river measured along the river axis exceeds the distance "as the crow flies" due to meandering. As a result of the latter effect the length of the river can easily exceed the straightforward distance through the valley with 100 to 20096. Therefore, the river valley slope has been reduced with a factor 0.3 to obtain an estimate for the river slope, i.e.:

i = 0.3/L100

The above factor 0.3 has been determined by comparing the average river valley slopes for a number of rivers with available information from literature on actual slopes at high water. In the latter case the average slope in the area where a significant backwater effect can be expected, has been taken. The results are presented in Table D.4.1.

River	L100 (km)	Valley slope (cm/km)	River slope (cm/km)	Factor
Rhine	650	15.4	5.0	0.33
Po	300	33.3	8.0	0.24
Nile	1200	8.3	8.0	0.96
Tana River	500	20.0	8.0	0.40
Niger	700	14.3	3.5	0.25
Magdalena	600	16.7	5.5	0.33
Orinoco	1000	10.0	5.0	0.50
Amazone	2500	4.0	2.0	0.50
Parana	1400	7.1	2.0	0.28
Yangtse Kiang	1200	8.3	1.5	0.18
Mekong	850	11.8	15	0.13
Chao Phya	500	20.0	3.5	0.18
Irrawaddi	1000	10.0	3.6	0.36
Ganges/Brahmaputra	1500	6.7	2.7	0.41
Mississippi	1000	10.0	3.3	0.33

Table D.4.1 Comparison of valley slopes and river slopes at high water

The equilibrium water depth of a river can be derived from regime equations.

According to Lacey (Ref. 3) the bankfull water depth of a river is:

Rh = 0.473 * (Q * 0.333)/f * 0.333

with:
Q = bankfull discharge (m^3/s)
f = 1.76 * SQRT(D_{50}) = silt factor
D_{50} = mean grain size diameter (mm)

By approximation the bankfull discharge Q equals three times the average annual river discharge, which for the large rivers in the world can be derived from literature. In the event the main river bifurcates in the delta into a number (N) of branches, the average maximum discharge per branch Q/N should be used in the calculations.

Setting D_{50} at 0.2 mm yields f = 0.8.

The depth at which flooding occurs generally exceeds the bankfull water depth and it is therefore assumed that:

H_e = Rh + 2 (m)

With the formulas given above, the characteristic length L0.3 of the backwater curve can be calculated from the average annual river discharges, the number of main branches in the delta and the average river valley slopes.

The characteristic length L0.3 has been used as a guideline to determine on the basis of maps in the Times Atlas for some large deltas the total length of rivers to be protected (on either side) for a sea level rise of 1.0m.

Three types of rivers have been considered, i.e.:
- the main branches to be protected over a distance L0.3, denominated L1;
- minor river branches, which bifurcate relatively close to the shoreline (at a distance less than L0.3) and which have to be protected over their full length, denominated L2; and
- local smaller rivers in the delta, which do not bifurcate from the main river in the delta, denominated L3.

The results of the analysis are presented in Table D.4.2. The symbols Q and CLD denote respectively the average annual discharge and the coastline of the deltas, measured "as the crow flies". The other symbols are explained in the above text. The total required length of levees equals twice the sum of the distances L1, L2 and L3, augmented with the distance CLD. The multiplier (Mult) for the calculation of the total shoreline affected by sea level rise is obtained by dividing the above sum by the distance CLD. The estimated multipliers generally range from 5 to 10.

Only part of the tidal rivers and channels are indicated on maps at a scale of 1:2,500,000 or more. This analysis based on backwater effect calculations for the rivers displayed on large scale maps is therefore bound to seriously underestimate the total shoreline (including the rivers) to be protected. Many small rivers and manmade channels are not displayed on the maps, while irregularities in the coastline and small coastal islands also could not properly be accounted for. For these reasons it is expected that the above multipliers are easily underestimated by a factor 2 and that values in the order of 10 to 20 are more likely to be expected for the larger deltas in the world. This seems to be consistent with the high multiplier values available for some of the coastal states in the USA.

It would be impossible to properly assess the zone with backwater effect of sea level rise for most of the numerous (smaller) rivers in the world, because data on high flows, water depths and surface water slopes are generally not easily available. Therefore, the multiplier approach, as developed for this study and calibrated for all coastal states in the USA, was adopted for world wide application.

River	Q (m^3/s)	L100 (km)	N	L0.3 (km)	L1 (km)	L2 (km)	L3 (km)	slope (cm/km)	He (m)	CLD (km)	Mult	Remark
Guadalquivir	500	200	1	24	75	120	50	15.0	8	100	5.9	
Ebro	600	200	1	25	40	0	0	15.0	8	40	3.0	
Po	1500	300	1	47	50	100	250	10.0	10	250	4.2	
Danube	6400	1000	1	225	225	200	100	3.0	16	300	4.5	
Vistula	1000	450	1	63	65	100	50	6.7	9	100	5.3	
Oder	530	400	1	49	125	100	100	7.5	8	100	7.5	
Nile	3000	1200	2	58	100	0	400	8.0	10	300	4.3	slope corrected
Tana	120	250	1	23	50	25	0	12.0	6	50	4.0	
Niger	5700	700	2	127	250	600	1500	4.3	12	500	10.4	pop. < 10/km2
Magdalena	7000	600	1	138	140	0	150	5.0	16	100	6.8	
Orinoco	25000	1000	3	241	550	1000	500	3.0	17	400	11.3	pop. <10/km2
Parana	10000	1400	2	294	500	300	100	2.1	15	70	26.7	
Yellow River	4000	700	1	139	200	200	500	4.3	14	500	4.6	
Yangtse River	28000	1500	1	509	500	100	500	2.0	24	800	3.8	
Red River	2940	300	2	46	180	200	0	10.0	10	150	6.1	
Mekong			2	247	500	600	0	1.5	8	250	9.8	slope/depth available
Chao Phya	960	500	1	120	150	0	300	3.5	9	100	10.0	slope corrected
Irrawaddi	13000	1000	3	202	500	600	100	3.0	14	400	7.0	
Ganges+Brahma	33000	1100	2	321	400	700	900	2.7	21	600	7.7	
Mahanadi	3200	250	1	47	100	650	350	12.0	13	350	7.3	
Hoogly		600	1		250	0	650	5.0		250	8.2	
Godavari	3980	300	2	50	150	50	100	10.0	11	200	4.0	
Krishna		300	1	45	100	200	100	10.0	10	250	4.2	
Coleroon		170	1	21	50	250	150	17.6	8	300	4.0	
Indus	2000	800	1	133	150	300	50	3.8	11	250	5.0	
Shatt et Arab	856	800	1	109	100	0	550	3.8	9	250	6.2	
Mississippi	18000	1000	1	299	300	375	525	3.0	21	500	5.8	
Average Multiplier											6.9	

Table D.4.2 Estimation of multipliers for deltas

APPENDIX E

ADAPTIVE OPTIONS IDENTIFIED BY CZM WORKSHOP PARTICIPANTS DURING A BRAINSTORMING SESSION

APPENDIX E: ADAPTIVE OPTIONS IDENTIFIED BY CZM WORKSHOP PARTICIPANTS DURING A BRAINSTORMING SESSION

Technical, Engineering, and Structural options

Identify local coastal management tools and techniques that could be shared with other countries

Encourage use of Geographic Information Systems in coastal assessments and decision making.

Maximise opportunities for saving/conserving fresh water resources, e.g. changing from ditch water irrigation to drip techniques.

Develop efficient techniques for desalinisation

Reconsider design criteria for urban and regional infrastructure in the coastal zone (includes electrical, pipe and communication systems and other utilities).

Ensure adaptability and effectiveness of coastal defense structures to protect against rising sea level through flexible design and long term maintenance. These structures include dikes, polders and groins, particularly where they protect densely developed areas.

Develop improved flood drainage techniques(include a use of windmills to pump water).

Develop low cost, low technical protection including artificial reefs.

Implement a uniform global sea level monitoring network to document changes in sea level and to enhance predictive capability

Increase use of dredged sediments to reclaim or build shore lands, ouch as wetlands.

Spray marshes with dredged material slurries to allow the level of marsh to keep pace with increasing sea level rise.

Increase use of soft engineering beach replenishment.

Undertake research on how coasts react to changes in wave climate and the increased frequency and intensity of storm surges due to climate change.

Expand research in how to improve early warning systems for hurricanes and mitigate their potential damage.

Increase research on energy conservation and suitable energy resources to reduce dependence and use of fossil fuels.

Develop new chemistries to restrict or retard the effects of salt water intrusion on structures.

Biological options

Develop salt tolerant plants

Shift gradually from aquaculture to mariculture in the coastal zone

Allow wetlands to migrate into agricultural areas as sea level rises

Increase productivity of aqueous environments.

Develop genetic banks and genetic engineering techniques to increase rates of adaption of impacted plant, fish and animals (for example salt resistant crops, etc.)

Develop wildlife and fisheries management plans and techniques for the changing environment.

Facilitate species migration or transplant species, with special consideration for endangered species.

Develop an integrated process for managing a multinational regional ecosystem.

Non-structural options

Develop accurate information on different values (economic, social, cultural, aesthetic and recreational) of coastal land for the purpose of evaluating alternative uses.

Explore alternative coastal resource uses.

Educate the public and government officials concerning the potential impact of climate change, including sea level rise.

Develop and implement coastal zone planning and management techniques, including set back lines.

Coordinate foreign aid organisations support of sea level rise response strategies in developing countries to provide sustained funding for these activities. This support should also include training and vulnerability assessment.

Prohibit subsidies for inappropriate development, or compensation for damage caused by effects of sea level rise, in vulnerable coastal areas.

Develop and implement coastal zone management techniques, as appropriate, including: inventory and mapping vulnerable resources; zoning; land purchase; land preserves; enforcement; relocation (physical, economic); and new habitations.

Develop laws regarding coastal occupation including permits for activities to protect individual property and regulations to assure that those activities do not affect neighbours adversely.

Create mechanisms to deal with famines and refugees resulting from sea level rise

Negotiate treaties to protect important habitats.

Retreat to allow roll over of dunes and allow marginal land to return to nature.

Improve sediment management techniques.

Colophon

Publisher	: Ministry of Transport and Public Works Rijkswaterstaat Tidal Waters Division Ministry of Public Housing, Physical Planning and Environment Directorate-General for Environment
Editors	: Robbert Misdorp, Job Dronkers, J.R. Spradley
Corrector	: Peter Gunther
Word Processing	: Ms Thea Westerveld
Cover Design	: Willem Storm
Printed by	: Rijkswaterstaat Survey Department Section Graphic-technics

Additional copies available from:

Ministry of Transport and Public Works
Rijkswaterstaat
Tidal Waters Division
Library
P.O. Box 20907
2500 EX The Hague
The Netherlands