Coastal Zone Management

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PREFACE

ACKNOWLEDGMENTS

The focus of the Coastal Zone Management Subgroup (CZMS) is on options for adapting to sea level rise and other impacts of global change on coastal areas. The CZMS held workshops in Miami, Florida, and in Perth, Western Australia, to generate information on available adaptive response options and their environmental, economic, social, cultural, legal, institutional, and financial implications. The countries that contributed to the work of the CZMS by sending experts to these workshops are listed below. Special acknowledgments are addressed to the United States and Australia for hosting these workshops.

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We wish to recognize and thank all of the participants and reviewers who contributed their time, energy, and knowledge to the preparation of this report. We hope that the report will help nations in beginning to prepare for the potential impacts of global climate change on their coastal areas.

PARTICIPATING COUNTRIES

Algeria, Antigua and Barbuda, Argentina, Australia, Bahamas, Bangladesh, Barbados, Benin, Brazil, Brunei, Canada, Chile, China, Colombia, Costa Rica, Denmark, Egypt, Fiji, France, Fed. Rep. of Germany, Ghana, Greece, Guyana, India, Indonesia, Iran, Italy, Ivory Coast, Jamaica, Japan, Kenya, Kiribati, Liberia, Maldives, Mauritius, Mexico, Micronesia, the Netherlands, New Caledonia, New Zealand, Nigeria, Pakistan, Papua New Guinea, Philippines, Poland, Portugal, Senegal, Seychelles, South Korea, Spain, Sri Lanka, St. Pierre and Miquelon, St. Vincent and the Grenadines, Thailand, Tonga, Trinidad and Tobago, Tunisia, Turkey, Tuvalu, United Kingdom, United States, 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).

—J.T.E. GILBERT & P. VELLINGA
The Hague, April 1990

EXECUTIVE SUMMARY

REASONS FOR CONCERN

Global climate change may raise sea level as much as one meter over the next century and, in some areas, increase the frequency and severity of storms. Hundreds of thousands of square kilometers of coastal wetlands and other lowlands could be inundated. Beaches could retreat as much as a few hundred meters and protective structures may be breached. Flooding would threaten lives, agriculture, livestock, buildings, and infrastructures. Saltwater 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 meter of high tide in each of the unprotected river deltas of Bangladesh, Egypt, and Vietnam. Half a million people live in archipelagoes and coral atoll nations that lie almost entirely within three meters of sea level, such as the Maldives, the Marshall Islands, Tuvalu, Kiribati, and Tokelau. Other archipelagoes 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 also has 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. *Retreat* 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. *Accommodation* 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.

Protection involves hard structures such as seawalls 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 implementation 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 meters or greater, making it difficult to determine the areas and resources vulnerable to impacts of a one-meter 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 solutions 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 for 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 of the necessary structures. The structures would protect economic development, but could adversely affect economic interests that depend on recreation and fisheries.

An annex of the Coastal Zone Management Subgroup Report shows that if sea level rises by one meter, about 360,000 kilometers of coastal defenses would be required at a total cost of U.S.$500 billion by the year 2100. (This sum only reflects the marginal or added costs and is not discounted.) This value does not include costs necessary to meet present coastal defense 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. *Therefore the overall cost will 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-meter 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 defenses 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 efficacy 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.

PROPOSAL OF THE CZM CHAIRMEN FOR FUTURE ACTIVITIES

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 that 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 data base or monitoring system be set up which would provide access to and information on adaption 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 5.1.

3) *Organizational 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 formalized 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 that 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 5.2) of essential actions for the formulation of such plans is suggested. Countries that do not currently have coastal management plans could use this timeline as a basis for their own planning process over the next decade.

TABLE 5.1: Possible Elements to Be Included in a Protocol on Coastal Zone Management and Sea Level Rise

Signatories endeavor 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.

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 organizations 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 5.3.

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 5.2: Suggested Ten-Year Timeline for the Implementation of Comprehensive Coastal Zone Management Plans

1991	Designate (a) national coastal coordinating bodies, (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 international advisory group. For example: • Topographic information • Land use • Natural resources at risk • Tidal and wave range • Population statistics
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; strengthening of institutional mechanisms
1995	Completion of survey studies, including identification of problems requiring immediate solution and 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 the reaction from public and policymakers 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 5.3: 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 @ U.S.$10,000 per month	= U.S.$ 1,200,000
	Expenses and travel	= U.S.$ 800,000
		= U.S.$ 2,000,000
2	Training of 100 in-countries personnel to strengthen coastal zone technical and planning capabilities 100 people @ U.S.$30,000 each	= U.S.$ 3,000,000
3	Expenses for secretariat and advisory group	= U.S.$ 3,000,000
4	Conferences & workshops	= U.S.$ 1,000,000
5	Contingency	= U.S.$ 1,000,000
	Total for 5 years, 1992–1997	= U.S.$10,000,000

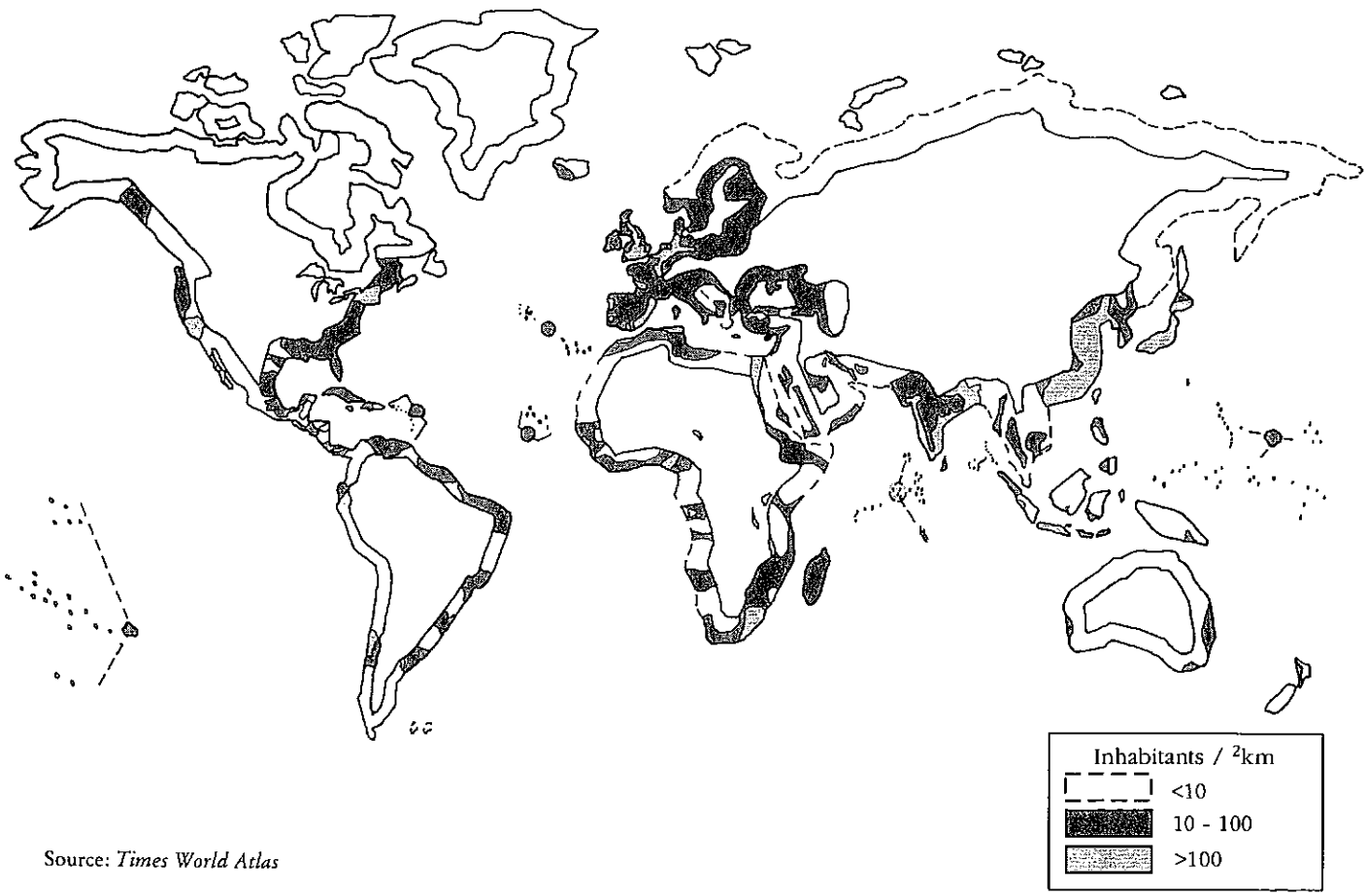
5.1 INTRODUCTION

5.1.1 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.

FIGURE 5.1: Schematic World Map of Population Densities in Coastal Areas



Source: *Times World Atlas*

5.1.2 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 overexploitation 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—sometimes significantly—and they 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]—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.

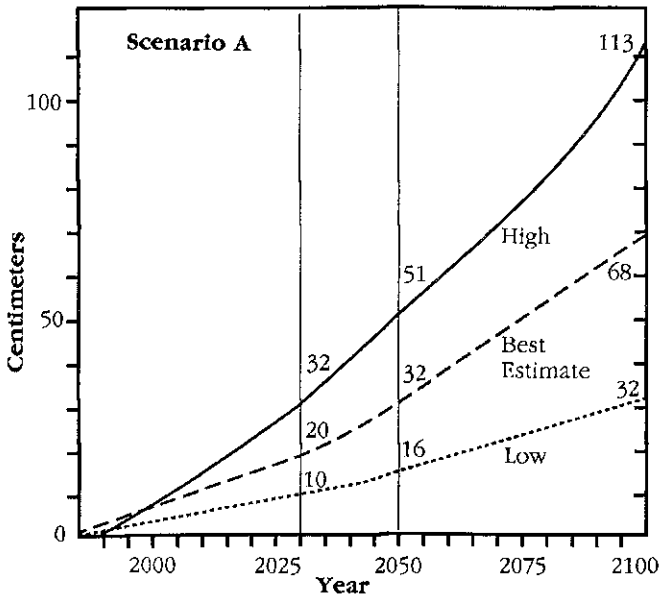
If populations in coastal areas continue to grow, balancing environmental and development concerns will be increasingly difficult. Changes in climate and sea level will exacerbate many of these problems, particularly for small islands, deltas, and low coastal plains. High population density is therefore the most fundamental problem faced by coastal areas (Figure 5.1).

5.1.3 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 (Figure 5.2), 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.[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

FIGURE 5.2: **Global Sea Level Rise, 1985–2100, for Policy Scenario A (No Limitation of Greenhouse Gases) IPCC-WGI, 1990**



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 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 cannot 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.

5.1.4 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; and (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 $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 5.4 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.

5.1.5 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-meter 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 Torres Strait Islands.[12] Shanghai and Lagos, the largest cities of China and Nigeria, lie less than two meters above sea level, as does 20 percent of the population and farmland of Egypt.[13]

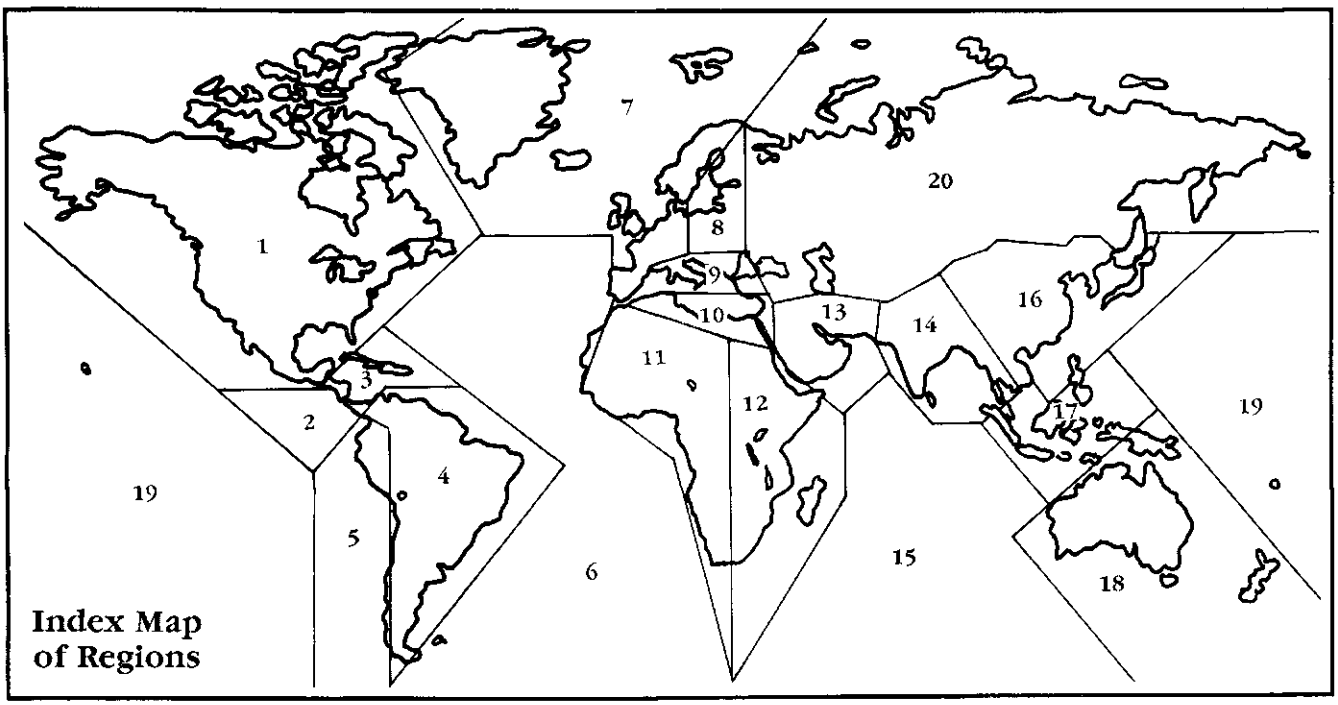
Four highly populated developing countries, India, Bangladesh, Vietnam, and Egypt, are especially vulnerable to sea level rise because their low-lying coastal plains are already suffering the effects of flooding and coastal storms. Since 1960, India and Bangladesh have been struck by at least eight tropical cyclones, each of which killed more than 10,000

TABLE 5.4: Areas of Coastal Wetlands* of International Importance in Sq km and As Percentage of Country Areas

	Region	Area of Wetlands in km²	Wetland as % of total country area
1.	North America, excluding Canada and USA	32330	1.639
2.	Central America	25319	0.882
3.	Caribbean Islands	24452	9.431
4.	South America Atlantic Ocean Coast	158260	1.132
5.	South America Pacific Ocean Coast	12413	0.534
6.	Atlantic Ocean Small Islands	400	3.287
7.	North and West Europe	31515	0.713
8.	Baltic Sea Coast	2123	0.176
9.	Northern Mediterranean	6497	0.609
10.	Southern Mediterranean	3941	0.095
11.	Africa Atlantic Ocean Coast	44369	0.559
12.	Africa Indian Ocean Coast	11755	0.161
13.	Gulf States	1657	0.079
14.	Asia Indian Ocean Coast	59530	1.196
15.	Indian Ocean Small Islands		
16.	South-East Asia	122595	3.424
17.	East Asia	102074	0.999
18.	Pacific Ocean Large Islands, excluding Australia and New Zealand	89500	19.385
19.	Pacific Ocean Small Islands	—	—
20.	USSR	4191	0.019
	TOTALS	732921	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.

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



people. In late 1970, storm surges killed approximately 300,000 people in Bangladesh and reached over 150 kilometers inland. Eight to ten million people live within one meter 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 southeastern United States, the tropical Pacific, and the Indian subcontinent. Had flood defenses 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 meters 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.

5.2 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 favor implementation of comprehensive and systematic coastal management programs.

5.2.1 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; and (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 help 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 centers, economic activities, and natural resources.

5.2.2 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 that 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 saltwater 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.

5.2.3 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.

5.2.4 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 that, 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.

5.2.4.1 *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 armored surfaces) are constructed along open coast areas to defend areas against severe wave attack. Lighter revetments and bulkheads usually serve as secondary lines of defense along open coast areas, or as first lines of defense 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, and 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.

Saltwater Intrusion Barriers in surface water streams can consist of locks or dams that 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 move-

ment of salt water. 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.

5.2.4.2 *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 enhance growth, increasing coastal protection; instituting pollution controls, and preventing the harvesting of mangroves.

5.3 ENVIRONMENTAL IMPLICATIONS OF ADAPTIVE RESPONSES

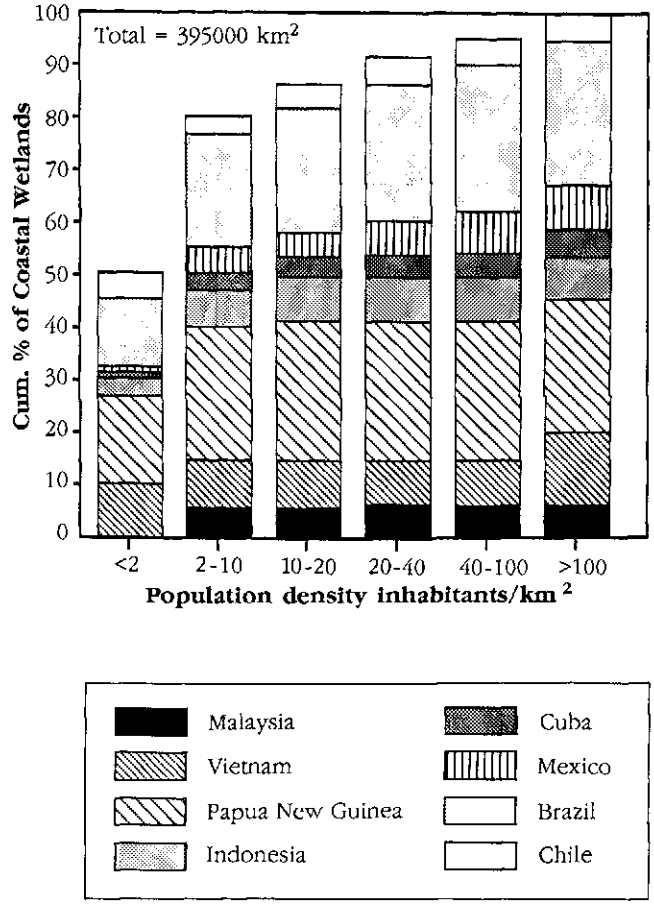
5.3.1 INTRODUCTION

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.

5.3.2 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 de facto retreat in process, given that most of the world's coastal wetlands border on land areas with low population densities and little major development (Fig. 5.3).[22] Nevertheless, these areas

FIGURE 5.3: **Cumulative Percentages of Major Coastal Wetlands and Their Population Densities**



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 cannot 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.

5.3.3 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 that could adversely affect the coastal environment.

5.3.4 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 under consideration.

5.3.4.1 *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 beach.[23] 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-meter 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.

Dams and saltwater intrusion barriers can protect water supplies and freshwater habitats. On the negative side, these structures can retain sediments that 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 "channeling" 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]

5.3.4.2 *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.[26] 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.

5.4 ECONOMIC IMPLICATIONS

5.4.1 INTRODUCTION

The potential economic implications of responses to sea level and temperature rise over periods of fifty to one hundred 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 worldwide. 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 are 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.

5.4.2 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 centers 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.

5.4.3 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.

5.4.4 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; and (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 nonquantifiable 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.

5.4.4.1 *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 5.5 illustrates estimates based on a sea level rise scenario of one meter 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 U.S.$500 billion (not discounted over time).

This value reflects only the marginal or added costs of protecting against the effects of a one meter rise in water level by the year 2100. It does not include any costs associated with basic coastal protection already in place or necessary to meet present coastal defense 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 increased 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-meter rise in sea level. Specifically, the small island states in the Indian and Pacific Oceans would, respectively, have to commit 0.91 of 1 percent and 0.75 of 1 percent of GNP in the one-meter rise scenario. For some atoll islands the annual cost may be as much as 10–20 percent of their GNP.

5.5 SOCIAL AND CULTURAL IMPLICATIONS

5.5.1 INTRODUCTION

The social and cultural implications of adaptive response measures may affect hundreds of millions of people living in coastal zones, which have an average width of 50 kilometers.[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.

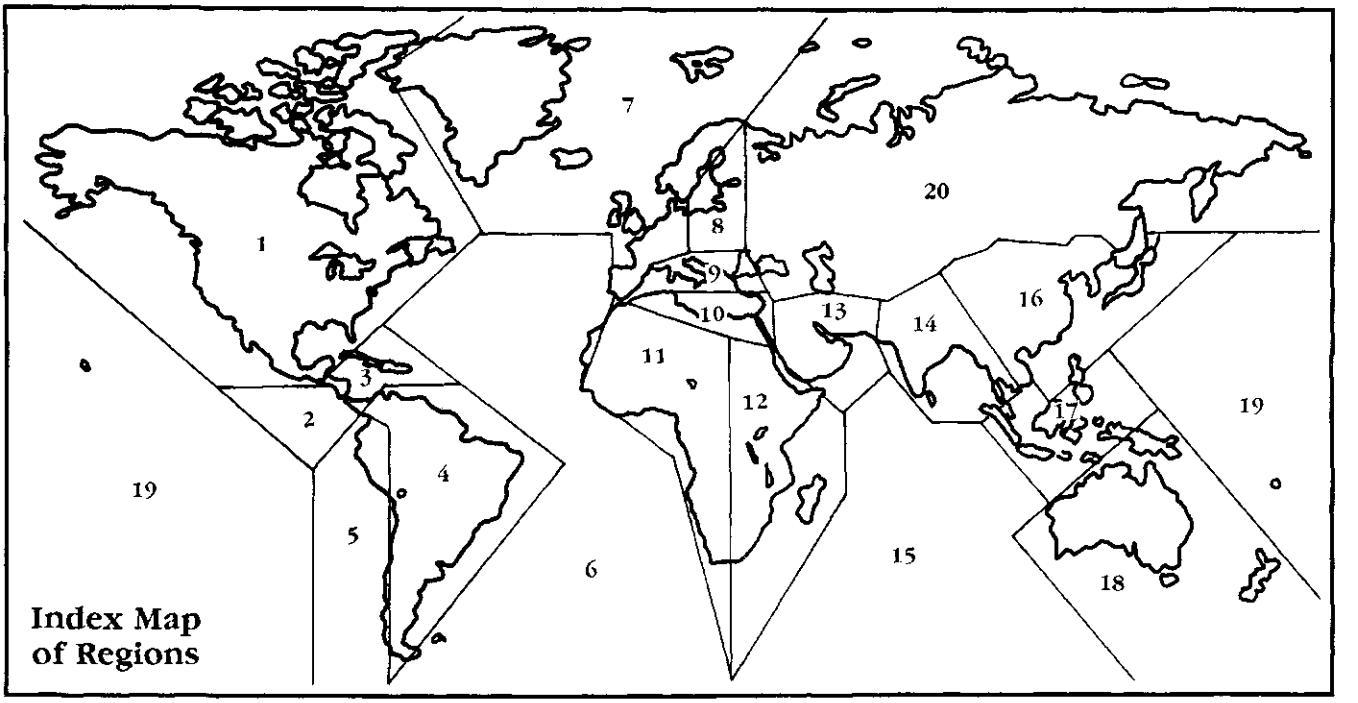
5.5.2 RETREAT

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

TABLE 5.5: Estimate of Marginal Costs Involved in Protecting Countries Worldwide Against the Effects of a 1-Meter Sea Level Rise in 100 Years

	Region	Total Protection Costs (Billions U.S.$)	Standard Deviation Total Costs (in %)	Total Costs per Capita (U.S.$)	Annual Protection Costs as % of GNP
1.	North America	106.2	43	306	0.03
2.	Central America	3.0	19	117	0.12
3.	Caribbean Islands	11.1	17	360	0.20
4.	South America Atlantic Ocean Coast	37.6	36	173	0.09
5.	South America Pacific Ocean Coast	1.7	30	41	0.04
6.	Atlantic Ocean Small Islands	0.2	28	333	0.12
7.	North and West Europe	49.8	14	190	0.02
8.	Baltic Sea Coast	28.9	23	429	0.07
9.	Northern Mediterranean	21.0	23	167	0.04
10.	Southern Mediterranean	13.5	16	87	0.06
11.	Africa Atlantic Ocean Coast	22.8	11	99	0.17
12.	Africa Indian Ocean Coast	17.4	27	98	0.17
13.	Gulf States	9.1	17	115	0.02
14.	Asia Indian Ocean Coast	35.9	26	34	0.14
15.	Indian Ocean Small Islands	3.1	27	1333	0.91
16.	South-East Asia	25.3	18	69	0.11
17.	East Asia	37.6	56	38	0.02
18.	Pacific Ocean Large Islands	35.0	23	1550	0.17
19.	Pacific Ocean Small Islands	3.9	22	1809	0.75
20.	USSR	25.0	36	89	0.01
	TOTALS	488.1	12	103	0.04

Source: "Sea Level Rise: A Worldwide Cost Estimate of Basic Coastal Defense Measures." Paper by Dutch Delegation (Rijkswaterstaat/Delft, Hydraulics, Note No. H1068) to IPCC-CZM Workshop, Perth, Australia, February 1990.



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 centers, 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 that 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.

5.5.3 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 houseboats.

5.5.4 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 labor, 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 labor.

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.

5.6 LEGAL AND INSTITUTIONAL IMPLICATIONS

5.6.1 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; in other states the government may

not have authority to use the land without the consent of the landowner; and, in others, the government may have the authority to use private land, but only upon providing compensation to the landowner.[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 benefiting 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]

5.6.2 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, accommodations 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 non-regulatory 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).

5.6.3 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 that 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.

5.7 PRIORITIES FOR ADAPTIVE RESPONSES

5.7.1 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 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 defense 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; however, it is likely that some adaptation to sea level rise will be required regardless of the limitation strategies eventually implemented.[35]

5.7.2 PRIORITIES FOR ADAPTATION

5.7.2.1 *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]

5.7.2.2 *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 clearinghouse arrangements to facilitate exchange of information and international data bases 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 centers, extension services, technology advisory committees, technology research and development, technology conferences, and pilot projects to enhance technology transfer.

5.7.2.3 *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.

5.7.2.4 *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.

5.7.3 Priorities for Implementing Adaptive Options in Developing Countries

5.7.3.1 *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 minimize dislocation difficulties such as linguistic diversity, cultural differences, and long-term viability.

5.7.3.2 *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.

5.7.3.3 *Protection*

Protection options involving structures in most developing countries are 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.

5.7.4 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 5.6. There is no intention to suggest that any one criteria should be pre-eminent. Some may be more significant in some situations while other criteria may be more important than others.

TABLE 5.6: Criteria for Allocation of Resources

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 ADAPTIVE 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.

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