Engineering Implications of a Greenhouse-induced Sea Level Rise in Malaysia

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ENGINEERING IMPLICATIONS OF A GREENHOUSE-INDUCED SEA LEVEL RISE IN MALAYSIA

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Abstract

Malaysia is a littoral country with a coastline of about 4,800 km long. Our coastal zone not only sustains, but also contributes significantly to the economic development of the country. Major towns, ports, large agriculture and fisheries projects are located within the coastal zone. Thus, any significant rise in sea level can cause tidal inundation, initiate or exacerbate coastal erosion, impede coastal drainage, augment saline intrusion, and exert higher wave-induced stresses on coastal structures.

Mindful of the potentially adverse impacts brought about by an accelerated rise in sea level, the Department has participated and continues to participate in various international initiatives to set up the process by which people world-wide can understand the problem of greenhouse-induced sea level rise and the implications it engenders.

Based on the results of the above study efforts, it is noted that a marked disparity exists between the projected impacts induced by the two differing scenarios of future sea level rise (20 cm and 100 cm). While raising coastal bund may keep up with the rising sea under the 20 cm scenario, such latitude may not be available should the sea level rise reach 100 cm due to induced geotechnical instability and the compression of the coastal zone by human expansion and a rising sea.

Inadequate understanding of both mud coast processes and zonation pattern of mangroves, and uncertainties associated with large-scale climatic modelling are identified as the major knowledge deficiencies that require urgent attention. On socio-economic assessment, knowledge gaps relating to the coarse data coverage and inadequate understanding of physiological response of agricultural crops to prolonged flooding, water logging and elevated water table have been identified. Equally pressing is the need for a more robust relationship linking mangroves and fishery production. Over and above all these is the problem of aggregating discrete impacts to yield a national assessment.

It is contended that scientific certainty is not an affordable luxury. The projected risks that may result from both an accelerated sea level rise and inaction warrant factoring of such concern into the planning and design of coastal facilities. Hence, sea level rise during their design life should be taken into account along with other factors.

Paper presented at the 1990 Annual Conference of the Senior Engineers of the Department of Irrigation & Drainage held at Holiday Inn, Shah Alam, Selangor Darul Ehsan, Malaysia on 11 - 13 September 1990.

Introduction

Public consciousness of the threat to humanity posed by global climate change has grown appreciably in western countries where the issue has elevated from being a concern of the scientific community to now being a subject of diplomatic discourse and great attention by heads of state, the so-called Green Politics.

An acceleration of global sea level rise is one of the manifestations of greenhouse effect through thermal expansion of the upper layers of ocean and melting of mountain ice caps/glaciers as a result of global warming. While the causal link between greenhouse effect and global warming trend is substantially established, the issue of sea level rise is more controversial, being very much a function of local specifics such as geology, tectonics, and human activity.

In Malaysia, media coverage on the successfully hosted 1990 Common Heads of Government Meeting (CHOGM), in particular the **1989 Langkawi Declaration on Environment**, has generated some local interest on the main environmental problems facing the world. These problems have been identified as global warming induced by the greenhouse effect, ozone layer depletion, acid rain, marine pollution, land degradation, and the extinction of numerous animal and plant species. Specifically, the Declaration supports low-lying and island countries in their efforts to protect themselves and their vulnerable natural marine ecosystems from the effects of sea level rise.

More recently, the **1990 Baguio Resolution on Coastal Resources Management**, to which Malaysia is also a party, further expounds on the need to manage ASEAN's coastal resources for sustainable development. Issued by the Policy Conference on Managing ASEAN's Coastal Resources for Sustainable Development on 4 - 7 March 1990 at Manila and Baguio, Philippines, the Resolution was hailed as the world's first multinational commitment to integrated coastal planning and management. Specifically, the Resolution stresses the need to consider the implications of possible climate change and sea level rise in coastal area management.

In addition to demonstrating Malaysia's concern for and commitment to integrated social and economic management of coastal areas as eloquently expressed in the two declarations cited above, Malaysia also participates in regional studies initiated by the United Nations Environment Program (UNEP) and the United States Environment Protection Agency (US EPA), which are aimed at assessing the potential impacts, both bio-physical and socio-economic, that may result from climate change induced by global warming. Notable among these are the two UNEP-funded projects code-named **Implications of Climatic Changes in the East Asian Seas**, which is a regional study coordinated by Prof. Chou of the National University of Singapore, and **Socio-economic Impacts and Policy Responses Resulting from Climate Change**, which is a national study effort coordinated by the Department of Environment. Both studies include the sea level rise component, in addition to changes in precipitation and temperature and their impacts on other terrestrial resources. The Department has been actively involved in both studies, and still is in the latter.

At the same time, the Department has also participated in an international sea level rise program, which is funded by US EPA for engaging in-country resident professionals to study the problem of greenhouse-induced sea level rise in selected developing countries, and the implications for their respective countries. In this regard, a national assessment [Midun & Lee, 1989] has been prepared in the course of the study for the first phase.

The paper first presents the latest evidence of climate change scenarios as gleaned from international publications, notably those of the **Inter-Governmental Panel on Climate Change** (IPCC), an ad hoc inter-governmental working group jointly established by the World Meteorological Organisation (WMO) and UNEP. It then summarises the potential bio-physical and on a less rigorous basis, the socio-economic impacts that may result from an accelerated rise in global sea level in the Malaysian context as contained in the reports on the studies mentioned earlier, noting in particular the various caveats in order to present a balanced view of the likely outcomes. In the process, the relevant policy options and mitigating strategists are also examined. The paper concludes with the identification of knowledge gaps/research needs and suggests future works that are necessary to refine further the study results presented herein, which should be viewed as preliminary,

2. Climate Change Scenarios

The issue of climate variability and possible climate change first appeared in the scientific literature sometime in late nineteen century. In fact, the greenhouse effect is nothing new; after all the natural greenhouse gases have already kept the earth over 30°C warmer than it would otherwise be, and in the process, sustained human habitation. However, in the last decade, public attention has focused on man's activities on the environment through massive deforestation, changes in land use practices, the burning of fossil fuel and the emission of industrial waste gases into the atmosphere. As stated in the Project Document [UNEP, 1988] for the on-going UNEP project mentioned above, "[t]here is now considerable scientific consensus that these activities, in particular the alteration of the composition of the atmosphere, are leading to changes in the global radiation balance and are likely to result in long-term global warming with serious socio-economic effects." This present greenhouse effect, which is primarily anthropogenic in origin, is schematically depicted in Fig. 1.

In the same document, it is also noted that if present emission trends continue, the combined effect of all greenhouse gases would be equivalent to a doubling of CO_2 concentration from pre-industrial levels, possibly as early as the 2030's. This will lead to a rise in global mean equilibrium temperature of between 1.5°C to 4.5°C. Such warming, it is estimated from past observations, will lead to a rise in global mean sea level of between 20 to 140 cm.

As a practical common datum for assessing the resulting impacts, the on-going UNEP Study adopts a future sea level rise of 1 m by the year 2090. On the other hand, the other completed UNEP study has adopted a future magnitude of a 20-cm rise only by the year 2025. Hence, when considered in combination, these study results do yield information on the sensitivity of resulting impacts to varying climate scenarios, albeit in a simplistic fashion. Likewise, the US EPA-funded study has also adopted the specific scenario of one-meter rise in global sea level. These adopted sea level rise scenarios are shown in relation to other predictions on probable sea level rise advanced by various scientists in Fig. 2.

Lately, there has been a downward revision in the range of predicted rise in global sea level, consistent with the enhanced knowledge and improved understanding of climate change mechanisms gained during the intervening period. In the latest draft document published by IPCC [1990], which is the report of Working Group 1 on scientific assessment, it is stated that "[s]ea level is expected to rise mainly due to the thermal expansion of the oceans and the melting of some land ice. Sea level will rise by about 20 cm (with a probable range of 10 cm to 32 cm) by 2030, and by 2070 it will have risen 45 cm (with a range of 33 cm to 75 cm). Within the next century, it is unlikely that there will be a major outflow of ice from the West Antarctic Ice Sheet due directly to greenhouse warming." These are the predictions based on the best tools available on potential changes induced by man-made emissions in the absence of other effects.

At this point in time, the level of technological advance is still unable to remove the uncertainties associated with the so-called General Circulation Models (GCMs) used in generating future climate scenarios. Especially in regional scale studies, this inadequacy has brought the predictive capability of the GCMs into question, if not disrepute. While some argue that the future scenarios will continue to be masked by natural climate variability, others have described them as "floridly fatuous", "crying wolf" and "doomsday forecasts". Yet perhaps the most lurid of all criticisms is the statement "[t]he shakiness of the physics of these models is astonishing, and to be making confident prediction about the future from them borders on alchemy."

On the other side, the National Academy of Science, USA, has come out with the statement that "[w]e have tried but have been unable to find any overlooked or underestimated physical effects that could reduce the currently estimated global warming to negligible proportions." In addition to acknowledging that uncertainties associated with particular climate feedback mechanisms such as the role of clouds and other changes to planetary albedos due to volcanic fallout still exist, generally these scientists agree to the caveat that climate simulations should be viewed as estimates from evolving computer models and not as reliable predictions applicable to the climate of specific regions. At the same time, other corroborative evidences in the form of historical observations, paleo-climate records and studies of other planetary bodies are also used.

While much of the scientific community fears the danger of losing credibility by crying wolf too soon, it is felt that a greater danger is to wait for too long. The climate system has ponderous inertia, so do the world's energy, economic and political systems. In this connection, prudence dictates that we should at least assess the magnitude of the potential impacts based on a range of future scenarios, and explore and perhaps implement mitigating strategies that are flexible enough to meet changing circumstances occasioned by varying climates in future.

3. Evidence of Sea Level Change in Malaysia

Evidence of climatic change in Malaysia is scarce due to a paucity of historical information and monitoring efforts. Also, little attention has been given to the phenomenon of sea level rise. There is, therefore, no long-term continuous measured data on tide and sea levels and their temporal fluctuations. Long-term continuous recording of tidal elevations with a view to establishing the mean sea level for a complete tidal epoch (18.6 years) only commenced in 1984. As depicted in Fig. 3 for some of the tide gauge stations, except for intra-annual variation that are principally meteorological and oceanographic in origin, there is no discernible trend in sea level change along tide gauge stations around Peninsular Malaysia. This is certainly not a scientific conclusion based on the fact that the record length is definitely too short for long-term prediction purposes. In contrast, Fig. 4 shows the trend of mean sea level dating as far back as 1940 for selected coasts of the United States, which indicates a definite rising trend. The damping array technique employed attenuates the amplitudes of all meteorological and oceanographic oscillations with period less than 5.5 years, and in the process, accentuates the depiction of a rising sea level. Ideally, these long-term data should be the sort of reliable data set on which we should be basing our determination of the extent of future sea level changes.

However, interpretative data on the historical variation of sea level along the Malaysian coastline do exist. Based on the analysis of more than 150 radiometrically (radiocarbon method) dated shoreline indicators (geomorphological, biogenic and sedimentological) collected on various parts of the country, which rests on the geologically stable Sunda Shelf, Tjia [1987] has constructed a history of sea level variation for the past

6,500 years relevant to the Malaysian coast as indicated in Fig. 5(a) and (b). The trend indicates that the sea level achieved its maximum Holocene position of about 5 m above present mean sea level and subsequently receded to its present position through a series of fluctuations of progressively lower peaks and depressions. The late Holocene fluctuations had an approximately 2-meter range with periods around 2,000 years. By projection, in the near future sea level may be expected to drop with rates between 1.5 and 2 mm/year.

Carbon dating methods are known to give error bands that may be small in geological time scale, but large in terms of human life span. While the threats posed by climate change are not exactly imminent, they have been predicted to occur within one or two human generations. Thus, considered in totality, the prognosis for sea level lowering based on fossil samples should not be viewed with complacency.

4. Potential Impacts of Sea Level Rise in Malaysia

4.1 Bio-physical Impacts due to a 20 cm Rise in Sea Level (Year 2025)

The report [Sieh & Lee, 1989] has examined the implications of a 20 cm rise in sea level on the East Asian Seas region in general and Malaysia in particular in two areas: coastal erosion and saline intrusion. Based on a rough approach and the use of Bruun's Rule [Bruun, 1962 & 1983], it is suggested that coastal erosion ranks as the more severe consequence, with further aggravation of the existing crisis of coastal erosion. Preliminary findings indicate that the impacts of a 20 cm rise in sea level by the year 2025 are likely to be insignificant in comparison with other factors operating in the coastal environment. But the results may be different if the impacts due to a higher magnitude of sea level rise were to be examined.

Additionally, the role of extreme events, which can cause episodic but catastrophic damages, has not been examined. It is possible that increased storm events may ensue and result in greater devastation. On saltwater intrusion, a general assessment for the case of Malaysia indicates that the risk of saline contamination of water abstracted for consumptive use may only worsen locally due to the present trend toward the use of impounding reservoirs since the more easily developed surface water sources have been developed. However, it can be reasonably concluded that the projected rise in sea level will aggravate the existing problem of saline contamination wherever it is already occurring.

4.2 Bio-physical Impacts due to a 1 m Rise in Sea Level (Year 2090)

The report [Midun & Lee, 1989] has examined the implications of a one-meter rise in sea level on the Malaysian coast in four areas: increased flooding, coastal erosion, wetland drowning/loss, and saline intrusion. Based on a similar approach as mentioned earlier, it is suggested that coastal erosion ranks as the most severe consequence, with further aggravation of the existing crisis of coastal erosion. Coastal areas that are low-lying, of erodible substrate and presently experiencing extensive erosion are most vulnerable to the threats posed by a projected rise in sea level. Increased tidal flooding following the breaching and subsequent collapse of coastal bunds may inundate 1,000 km^2 of agricultural land along the coastal belt. Back-water flooding may also prolong flooding duration of upland areas with possibly deleterious effects on crop yield.

On the other hand, while the drowning of the mangrove forests are expected to be extensive, their landward migration is restrained by shore development, which is usually stabilized with hard structures against sea attack. Presently, the mangrove forest is facing a much greater threat from man's action through conversion to other forms of economic utilization. Should the present rate of conversion continue unabated, the mangrove forest may disappear altogether before the impacts of a projected rise in sea level are realized. While saline intrusion is anticipated, potential saline contamination of water for consumptive use is judged not to be a problem due to a shift in water sourcing strategy toward reservoir systems.

4.3 Potential Socio-Economic Impacts

More than 70% of the Malaysian population of about 16.9 million are coastal inhabitants. Most state capital cities, most of which double as regional principal ports, are coastal cities. The extensive coastal plain is intensively cultivated for rice, the principal staple food for the country, and coconut. The sandy beaches are prime tourist attractions. A $2 billion coastal tourism development plan in Southeast Johor has just taken off. On a country-wide basis, more than 50% of Malaysia's annual fishery income of $1,500M - $1,800M is related to mangrove areas. This fishery and over 300,000 fishermen's livelihoods may be seriously affected if widespread loss of mangroves is allowed. In addition to the directly quantifiable losses of land, income and employment, there will be also the less tangible "losses" due to social dislocation and tension.

The above socio-economic assessment will most certainly be faulted with being too simplistic. However, it must be borne in mind that these impacts are derived in isolation of the other not less significant threats posed by climate change such as floods, droughts and possibly increased u-v radiation. The resultant impacts are likely to be mutually reinforcing rather than compensatory.

4.4 <u>Effects of Varying Scenarios</u>

As evident from the above, there is a marked disparity between the projected impacts induced by the two differing scenarios of sea level rise. While raising coastal bund may keep up with the rising sea under the 20 cm scenario, such latitude may not be available should the sea level rise reach 1 m due to induced geotechnical instability and the compression of the coastal zone by human expansion and a rising sea.

5. Policy Responses

When opening the Second meeting of the Project Steering Committee on the UNEP Project on *Socio-economic Impacts and Policy Responses Resulting from Climate Change*, which was held in Malaysia in January 1989, the Honorable Deputy Minister of Science, Technology and Environment outlined three options open to Malaysia to cope with the anticipated rise in sea level following the so-called greenhouse warming of the Earth. They are:

a) a wait-and-see attitude, which is deemed safe only if sea level rose gradually;

b) enforcement of policies aimed at reducing emission of greenhouse gases -- possibly too expensive for a developing countries like Malaysia; and

c) accepting that some climatic change from human activities is inevitable and initiating efforts to adapt to these changes which might occur on a regional basis.

While At the moment it may be too early for the Government to decide on the course of action due primarily to the lack of an adequate impact and risk assessment, certain policy options are gradually surfacing as potentially viable ones while others are perceived as less prudent based on the weight of available scientific consensus. The reactive posture implicit in Option (a) advocates responding to observed rather than hypothetical conditions. However, the issue of climate change and the associated sea level rise have left the realm of mere hypothesis. In the international arena and most climate change-related symposia, it is frequently contented that Option (a) is now untenable due to the overwhelming scientific evidence that points to a rise in sea level and the monumental cost of inaction that is likely to result.

While Option (b), which includes phaseout of chlorofluorocarbons (CFCs), improved energy efficiency and environmentally friendly alternatives, and reforestation, tackles the problem at source, its success also depends to a large extent on global effort and cooperation. Curbing greenhouse gas emissions may also be politically expedient, judging from the upsurge in green politics on a world-wide basis.

A combination of Options (b) and (c) is felt to be the most prudent move given the long response time we require in the face of a calamity. The pro-active leaning in these options imply careful planning for future events. Embodied in the adaptation approach are two different philosophies: retreat and entrenchment. While retreat is a conscious decision to abandon shorefront and seek alternative space, entrenchment implies staking a claim and confronting the sea through shoreline hardening measures. The decision is not an easy one, and hinges on economic viability, technical feasibility, social acceptability, environmental soundness, and political expediency. Toward this end, the possible solutions are explored in the succeeding section.

6. Likely Mitigation Strategies

Switching from policy considerations in limiting global warming, which requires global effort and cooperation, this section focuses primarily on the following coastal protection considerations in adapting to an accelerated sea level rise:

a) retreat from the shore;

b) armour the coast; and

c) nourish the beach.

The abandonment alternative is unlikely to be realistic for well-developed coast such as urban centres and port facilities. For less developed coast, the planning decisions are less clear-cut, but would largely depend on site-specific socio-economic factors.

Since a large investment has been expended in developing the agriculture potential along the coast, it is incumbent upon the implementing agency concerned to assess the likely impacts resulting from a projected sea level rise vis-a-vis the adequacy of present mitigation approaches, and recommend rational responses in the process.

To obviate increased tidal flooding, the main concern is likely to be whether the dike height is adequate to prevent wave overtopping. For a modest rise in sea level, the near-term impact could be either catered for by the normal freeboard and the conservatism inherent in the extreme events adopted for design, or easily incorporated into routine maintenance in dike raising, usually carried out to compensate for anticipated settlement of the underlying soft stratum. Geotechnical stability then becomes the overriding criterion since any topside weight increases the driving force for rotational slip. Provided the dike raising is completed in increments, such tendency for slip development could conceivably be arrested by flattening the seaward slope of rock armor or incorporating a stability berm on the seaward toe. Such an incremental technique in responding to a gradual sea level rise has been successfully employed in the Netherlands as shown in Fig. 6.

It has been suggested that the impacts of a sea level rise may be contained if shore progradation from fluvially supplied sediments can keep up with the rising sea. The direct relationship between upstream sediment diminution due to dam construction and coastal instability is all too well-known. In the same vein, mud nourishment can conceivably be a viable means of preserving mangroves, which are subject to a range of environmental stresses (burial, shifting substrate, reduction in sediment/freshwater supply, timber harvesting, and substrate stripping due to wave reflection from coastal bunds).

This is in concurrence with the view of Titus et al [1984] that "sedimentation can offset the impact of sea level rise." They write that "if sea level rises slowly enough for sedimentation and peat formation to keep pace, the marsh can maintain its position at the seaward edge and expand inland." However, they view this somewhat balanced situation as likely only for major river deltas given the accelerated rise in sea level after 2050.

On tidal wetlands, the San Francisco Bay Conservation and Development Commission-initiated study [1988] asserts that the key to understanding the effect of rising relative sea level is to know the rate of sedimentation and its spatial distribution within the Bay. If sedimentation keeps pace with relative sea level change, tidal marshes will maintain equilibrium. Similarly, the options considered for curtailing coastal erosion in Louisiana's coastal wetlands include marsh building/restoration (sediment replenishment), marsh management (water flow management), regulatory measures, and diversion of water [US EPA, 1987].

In addition, a mud bottom achieved through profile nourishment can attenuate in-coming waves due to wave-fluid mud interaction. Subsequent artificial mangrove replanting, possibly protected by a low level rock escarpment protection on its seaward fringe, can hasten substrate stabilisation. This combination of soft and hard approach to shoreline protection is worthy of further examination. A more thorough discussion on mitigating strategies can be found in the publication Responding to Changes in Sea Level -- Engineering Implications [National Research Council, US, 1987].

Implicit in the above effort at shoreline protection is the need to factor accelerated sea level rise into coastal planning and design methodology. A gradual structural topping/shoring up of shoreline protection in tandem with a rising sea level is likely to cost less than a complete replacement of failed structures due to the rising sea.

This approach is also in line with the Conference Statement of the Changing Atmosphere (Implication for Global Security) Conference, which was held on 27 - 30 June, 1988 in Toronto, Canada. The Conference Statement, among other things, urges that "the implications of climatic change for coastal zone planning must be considered, particularly the risk of sea level rise and/or the potential need to locate new developments inland," which is one of the Specific Recommendations of the Coastal and Marine Resources Working Group. Similar sentiments have also been echoed in subsequent international deliberations such as the Noordwijk Declaration on Climate Change of November 1989 and the Cairo Compact : Toward a Concerted World-wide Response to the Climate Crisis of December 1989. Two avenues whereby such a planning philosophy can be incorporated is the National Coastal Erosion Control Program under the ambit of the National Coastal Erosion Control Council, Prime Minister's Department, and the proposed South Johor Coastal Resources Management Plan, which is now in the final stages of formulation, with a view to extending the integrated and multi-sectoral management approach to the entire nation in future.

7. Research Needs/Future Works

Our understanding of coastal processes, especially along mud coast, is still inadequate to permit quantification of the likely shore response in the event of a projected rise in sea level. It is noted that while the use of the Bruun Rule to predict shore response on sandy coasts is, despite its conceptual simplicity and the consequent restriction on its validity, intuitively appealing, our capability to similarly predict the response of a mud coast, which dominates half of the shoreline of Malaysia, leaves much to be desired.

The pattern of mangrove demise (dieback on the landward fringe as opposed to retrogression from the seaward margin) and zonation, which are important in assessing the impact of a sea level rise on mangroves, constitute another notable knowledge gap. Apart from these fundamental deficiencies, there is also the problem of aggregating discrete impacts in order to yield an overall assessment.

Over and above the knowledge gaps in response function enumerated above are of course the forecasting problems associated with large-scale climatic modeling, particularly with respect to simulating changes in hydrological cycle and the ocean component. Furthermore, the GCMs need to be fine-tuned in order to yield reliable climate change data down to a regional or even national level of resolution. In this respect, an urgent need exists to establish a reliable and cost-effective data collection program to bolster the foundation of future prediction.

On socio-economic assessment, the input from plant scientists and agronomists is essential in order to evaluate the physiological response of agricultural crops to prolonged flooding, water-logging and elevated water table. Future work will then entail incorporating these added knowledge to refine further the assessment of socio-economic implications and the concomitant costs of action/inaction.

Presently, works are underway to expand the scope of the UNEP study to include a policy exercise, which is a flexibly structured process designed as an interface between academics/experts and the policy makers to elicit policy responses to a problem. Specifically, it is an iterative interaction between Science (represented by the knowledge experts), which entails the assessment of impacts of climatic change scenarios on valued components in the form of a matrix tabulation, and Policy (represented by the policy makers), which centers on evaluating adaptive/strategic responses and the associated potential gains/losses. It is hoped that questions on institutional mechanism, funding allocation and public participation can be explored through the proposed policy exercise.

8. Concluding Remarks

Admittedly our understanding of the mechanics of air-land-ocean interaction and mud coast processes still leave much to be desired. However, this deficiency does not preclude adoption of a pro-active posture in parallel with on-going research aimed at improving our basic knowledge regarding climate change. In this respect, sensationalistic reporting serves no purpose except to discredit the painstaking work of the scientific community in making humanity better prepared for this global threat. We should inform based on logical projections, and alert the power-that-be of the likely consequences in a rational manner so that informed decisions can be made.

It is contended that the long lead time required to transform a policy into reality does not permit a wait-and-see attitude as regards addressing the implications of sea level rise. Careful planning for future events is a prudent move. We should begin to find ways to incorporate the concern engendered by a rise in sea level into development and land use planning. These actions should not await the resolution of remaining scientific uncertainties. A rethinking of the rationale and re-assessment of project feasibility is judicious in order that limited resources are used wisely.

LSC/didsec2/070890.

Appendix I : **References**

Bruun, P., "Sea level rise as a cause of shoreline erosion," **Jour. Waterways and Harbor Division**, ASCE, Vol. 88, 1962, pp. 117 - 130.

Bruun, P., "Review of conditions for uses of the Bruun Rule of erosion," **The Dock and Harbor Authority**, 64(753), 1983, pp. 79 - 82. (cited in Gibb, 1987).

Bruun, P., "The effects of changing the atmosphere on the stability of sea level and shore stability," **P.I.A.N.C. Bulletin N°58**, 1987, pp. 129 - 132.

Department of Environment, **Global Warning, Global Warming**, DOE Environmental Awareness Pamphlet No. 2, undated.

Gibb, J.G., **A Coastal Hazard Management Plan for Hokitika**, Water and Soil Technical Publication No. 29, National Water and Soil Conservation Authority, New Zealand, 1987, 44 p.

Hicks, S.D., "United States Sea Level Variations Through 1986," Shore & Beach, the American Shore and Beach Preservation Association, July 1988, pp. 3 - 7.

Inter-Governmental Panel on Climate Change (IPCC), **Policymakers Summary of the Scientific Assessment of Climate Change**, report to IPCC from Working Group 1, 2nd Draft, 12 March 1990.

Midun, Z. & Lee, S.-C., **Implications of a Greenhouse-Induced Sea Level Rise -- A National Assessment for Malaysia**, report presented at the International Sea Level Rise Workshop, the Center for Global Change, University of Maryland, USA, 9 - 23 Sept. 1989.

National Research Council, USA, **Responding to Changes in Sea Level -- Engineering Implications**, Committee on Engineering Implications of Changes in Relative Mean Sea Level, 1987.

San Francisco Bay Conservation and Development Commission, **Sea level Rise: Predictions and Implications for San Francisco Bay**, Report prepared by Moffatt & Nichol, Engineers, Wetlands Research Associates, Inc. & Commission Staff, Dec. 1987 (Revised Oct.1988), 100 p.

Sieh K.-C. & Lee, S.-C., **Implications of Climatic Changes in the East Asian Seas -- Coastal Erosion and Saltwater Intrusion**, final report presented at the 2nd Task Team Meeting on Climatic Change Implications in the East Asean Seas Region, Temasik Hall, National University of Singapore, 25 - 26 May, 1989.

Titus, J.G., Henderson T.R. & Teal, J.M., "Sea level rise and wetlands loss in the United States," **National Wetlands Newsletter**, Vol. 6, No. 5, Sept. - Oct. 1984, pp. 3 - 6.

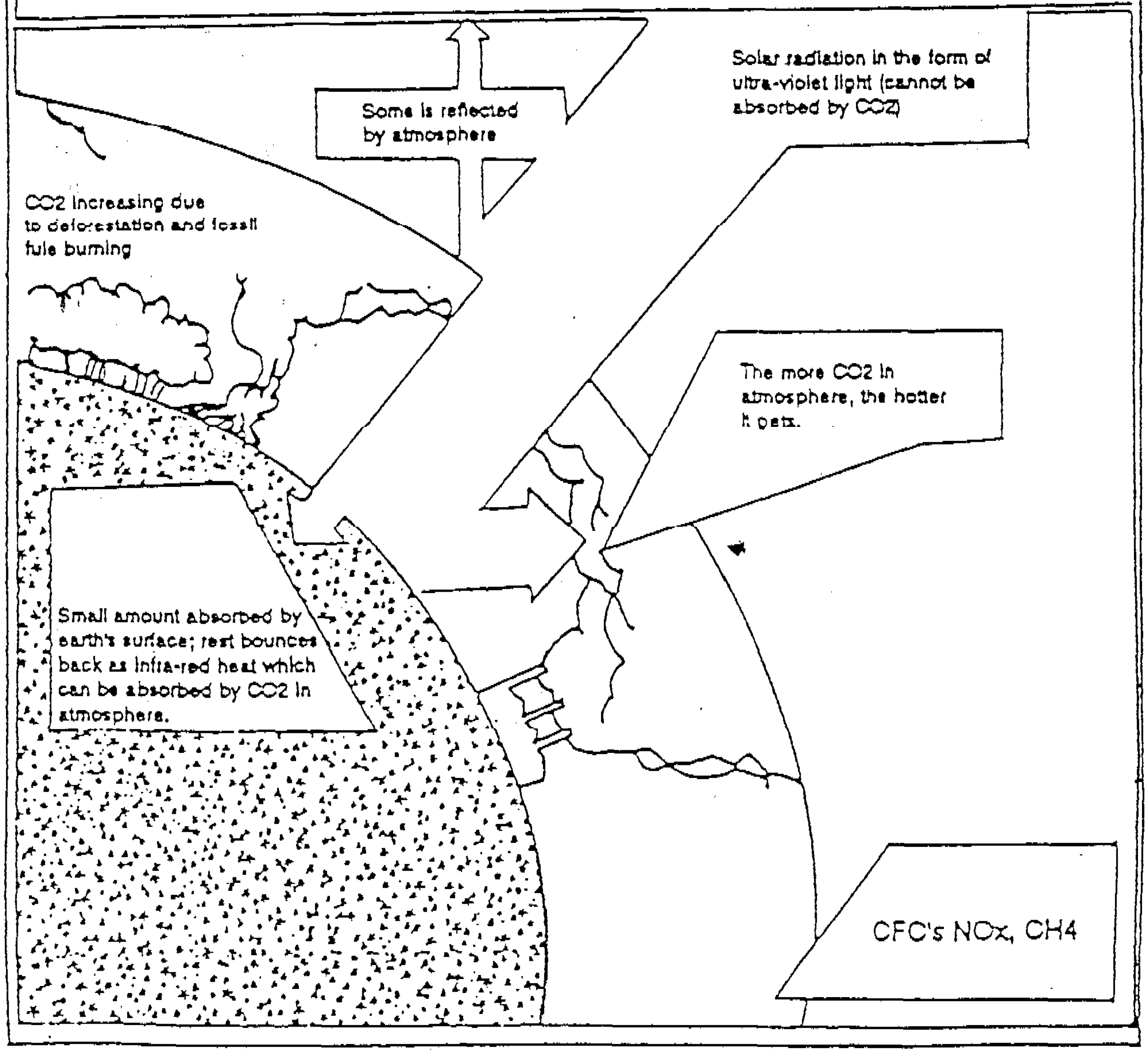
Tjia, H.D., "Ancient shorelines of Peninsular Malaysia," **SPAFA Final Report on Seminar in Prehistory of Southeast Asia**, SPAFA Coordinating Unit, Bangkok, Thailand, Aug. 1987, pp. 239 - 257.

United Nations Environment Program (UNEP), Project Document for Socio-economic Impacts and Policy Responses Resulting from **Climate Change : A Study in Southeast Asia**, May 1988.

US Environmental Protection Agency (EPA), Saving Louisiana's **Coastal Wetlands: The Need for a Long-term Plan of Action**, Report of the Louisiana Wetland Protection panel, Rep. No. EPA-230-02-87-026, April, 1987.

Appendix II : **List of Figures**

Fig. 1: The Green House Effect



(After DOE Environmental Awareness Pamphlet No.2)

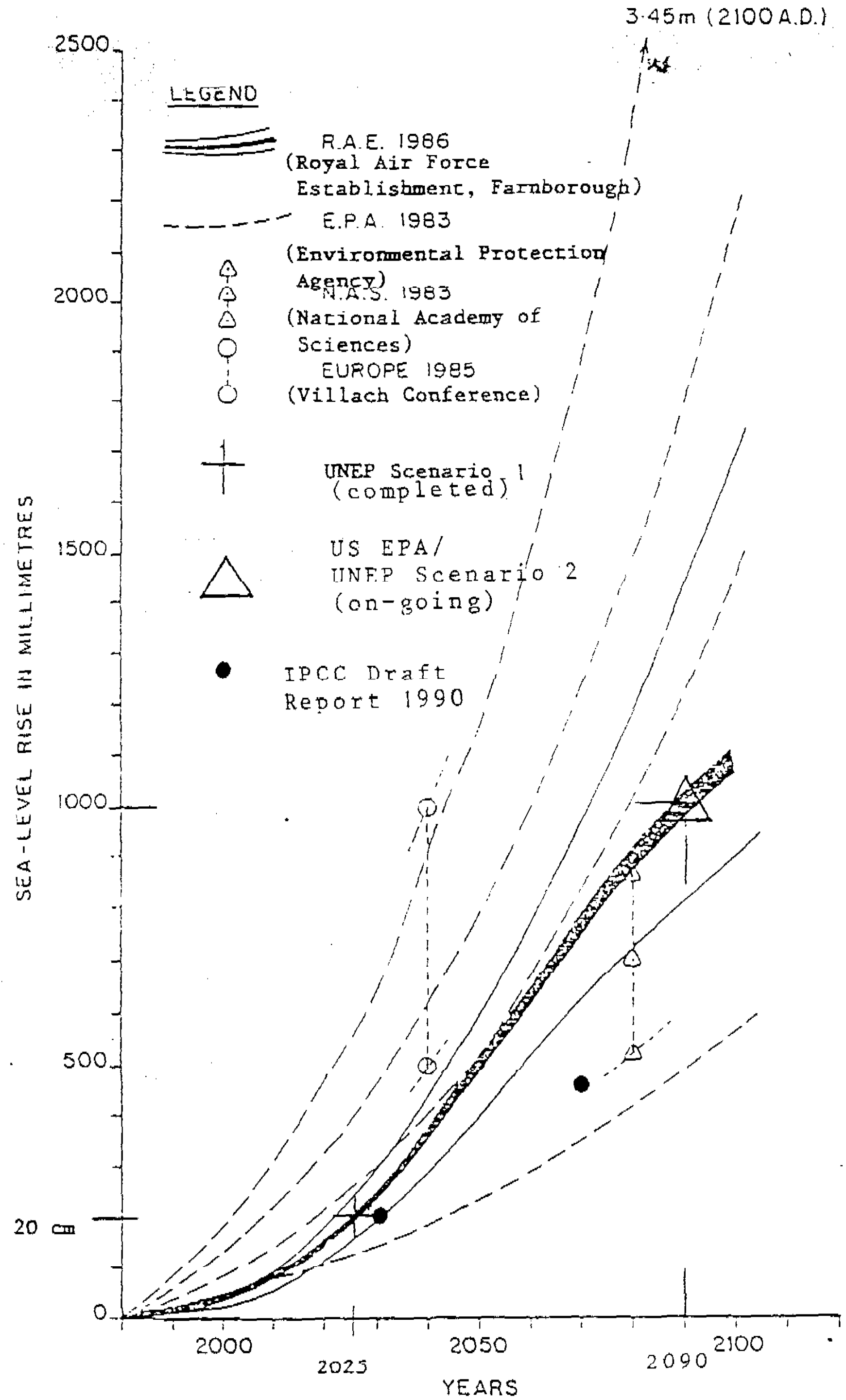


Fig. 2 Sea Level Rise Predictions for the Next Century (1986-2100 AD).
(Adapted from Gibb., 1987)

VARIATION OF MEASURED SEA LEVEL

a. At Port Kelang, Selangor

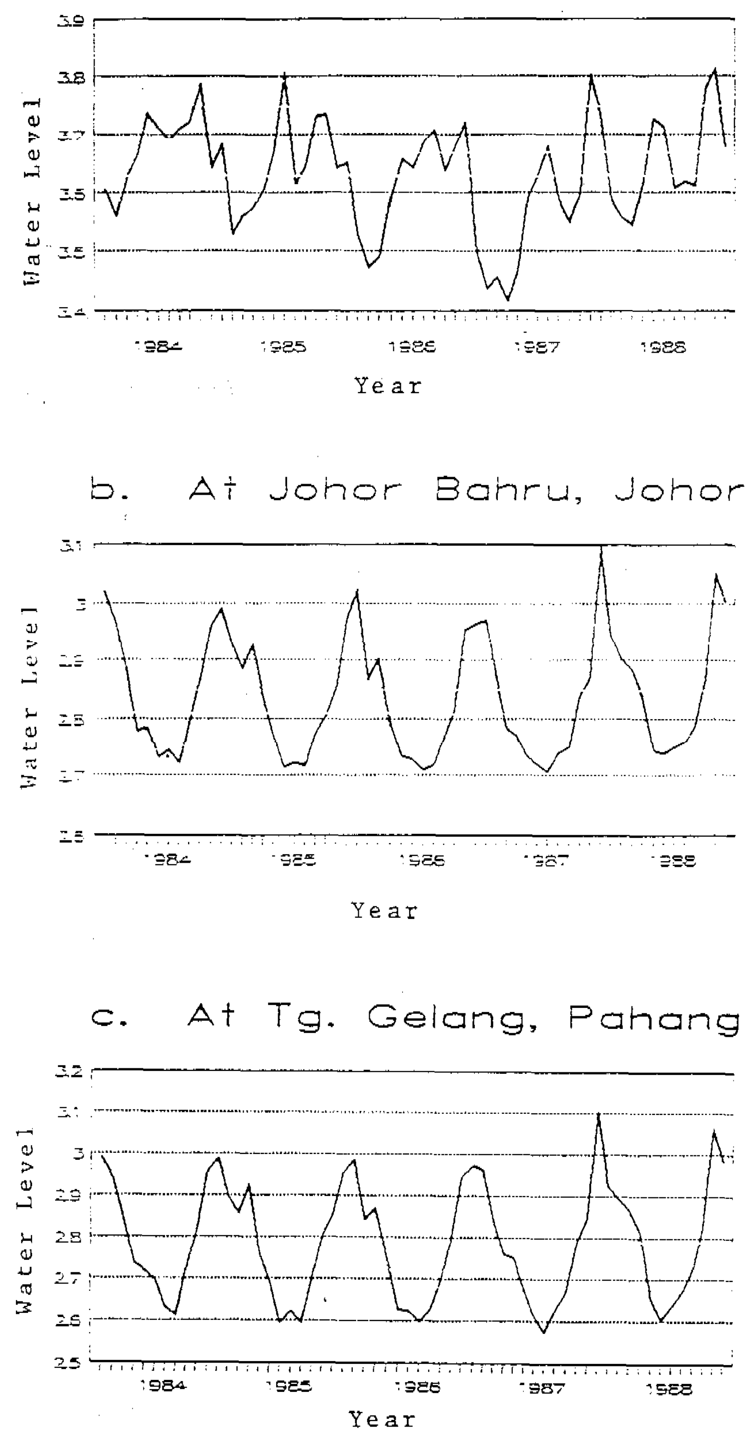


Fig. 3 : VARIATION OF MEASURED SEA LEVEL

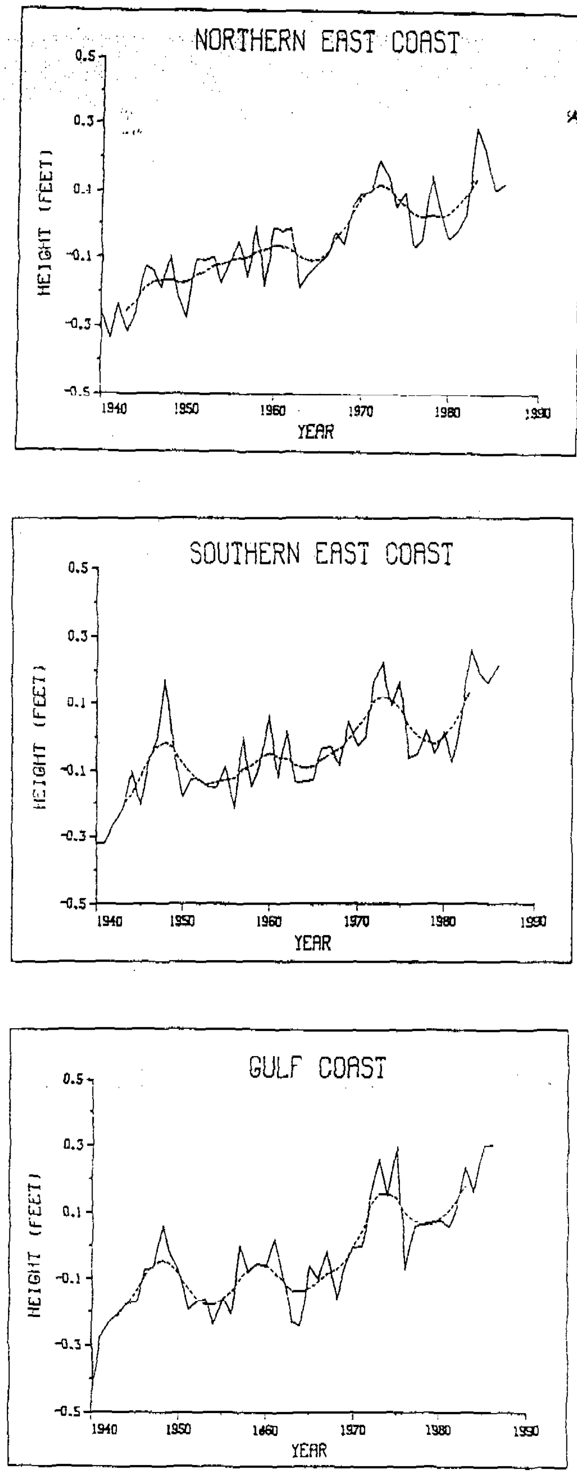
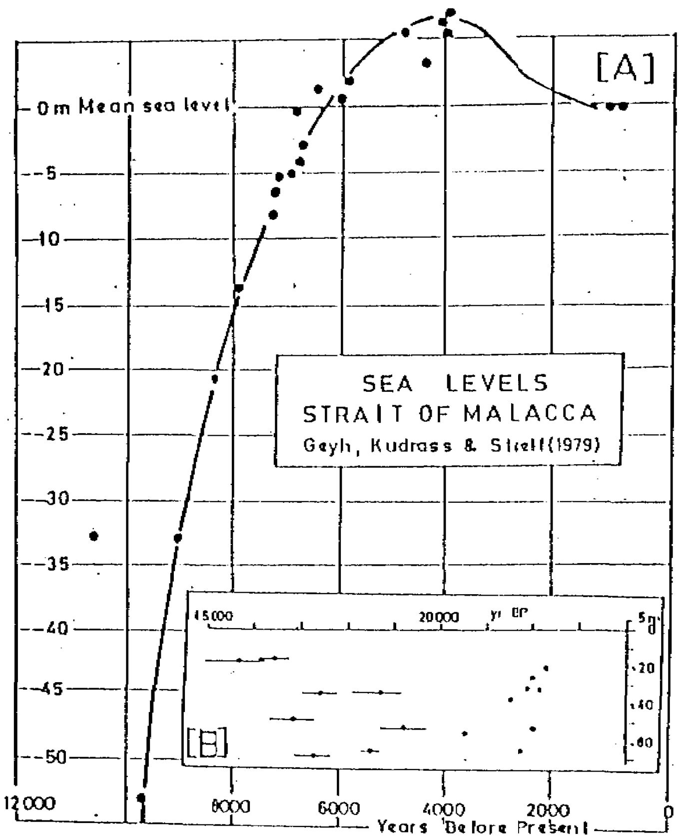
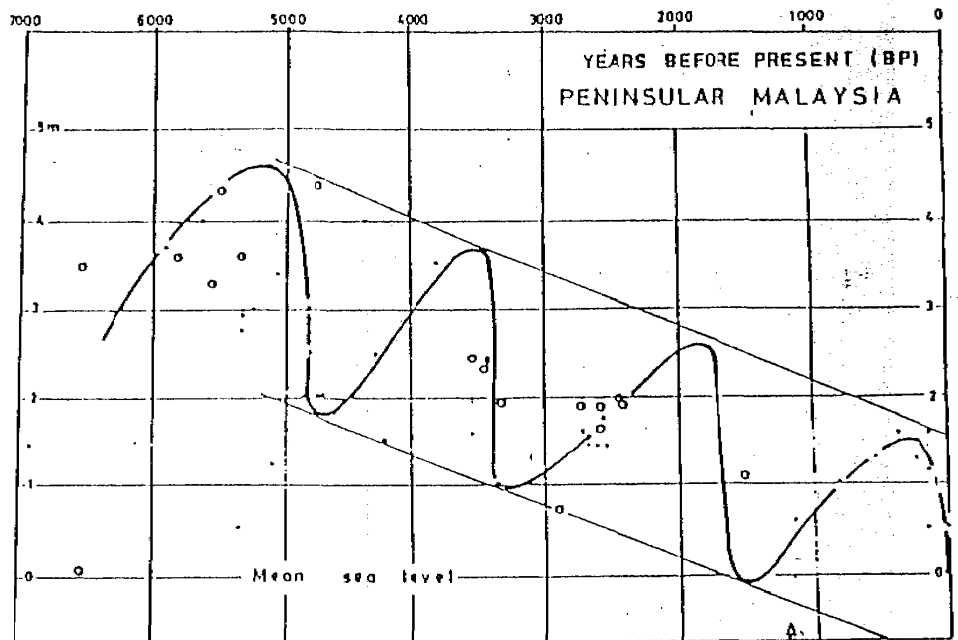


Fig. 4 : VARIATION OF MEAN SEA LEVEL ALONG SELECTED COASTS OF US (after HRcks, 1988)
Solid straight lines connect averaged yearly mean sea level values. Short-dashed curves are from damping array.



(b) Sea level behavior in the south of the Straits of Malacca during the last 10,000 years.



(a) Radiocarbon ages of shoreline indicators from Peninsular Malaysia.

Fig. 5 History of Sea Level Variation Relevant to the Malaysian Coast [After Tjia, 1987]

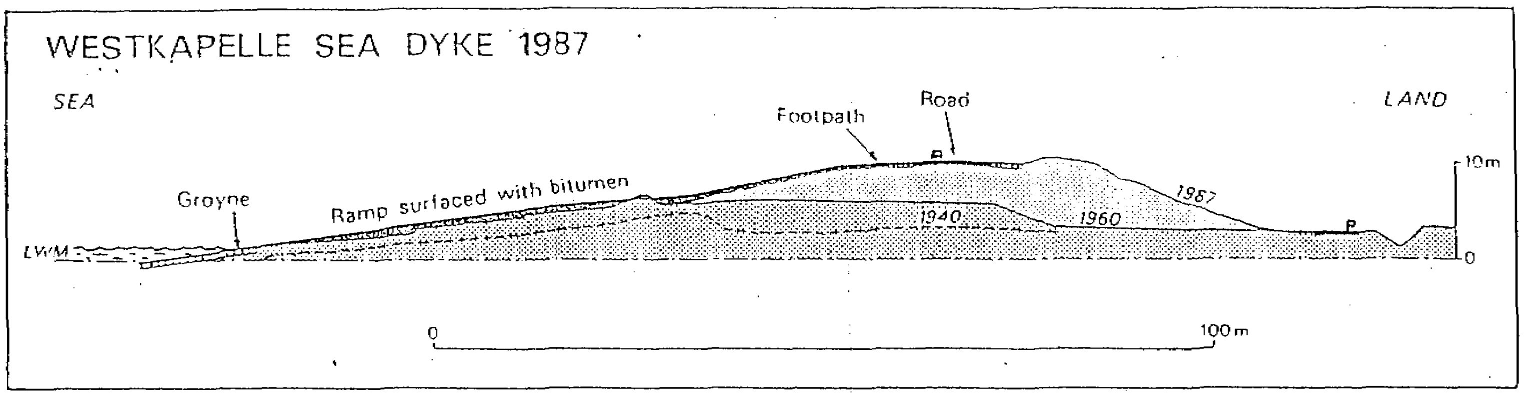


Fig. 6 : The sea dyke at Westkapelle, north-western Netherlands, has been enlarged and raised in response to relative sea level rise due mainly to coastal land subsidence. **(Courtesy of Dr. Eric Bird)**