Government of The Netherlands
Ministry of Foreign Affairs

Government of the Socialist Republic of Vietnam
Hydrometeorological Services

VIETNAM COASTAL ZONE VULNERABILITY ASSESSMENT and First Steps Towards Integrated Coastal Zone Management

REPORT No.2

DATA COLLECTION
June 1995

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List of Abbreviations

ASLR	Accelerated Sea Level Rise
BP	Before Present
CIS	Coastal Information System
CCP	Climate Change Programme (of Vietnam)
CSRG	Center for Remote Sensing & Geomatics, Institute of Geology, National Center for Natural Science & Technology, Vietnam
CZM	Coastal Zone Management
CZMC	Coastal Zone Management Centre of RIKZ
CZMS	Coastal Zone Management Subgroup, Response Strategies Working Group 3, IPCC
DEM	Digital Elevation Modelling
DGIS	Directorate General for International Co-operation
DH	Delft Hydraulics
DSS	Decision Support System
FNIS	Framework National Implementation Strategy
GIS	Geographical Information System
GMS	Geomanagement System
HCZ	Hydraulic Condition Zone
HMI	Hydrometeorological Institute, Ho Chi Minh City
HMS	Hydrometeorological Service, Hanoi
IPCC	Intergovernmental Panel on Climate Change
IBW-PAN	Institute of Hydro-Engineering, Gdańsk, Poland
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel for Climate Change
IS	Impact Segment
LTRA	Long Term Resident Advisor
MHC	Marine Hydrometeorological Centre, Hanoi
MS	Mekong Secretariat
MSL	Mean Sea Level
MTVA	Medium Term Visit Advisor
MWR	Ministry of Water Resources (Vietnam)
NIAPP	Nat. Institute for Agricultural Planning and Production, Ministry of Agriculture, Vietnam
RIKZ	National Institute for Coastal and Marine Management, Ministry of Transport, Public Works and Water Management of the Netherlands
RRMDP	Red River Delta Masterplan Development Project
RSWG	Response Strategies Working Group
SC	Steering Committee
SCS	State Committee for Sciences
SPC	State Planning Committee
STRA	Short Term Visit Advisor
STVA	Short Term Visit Advisors
ToR	Terms of Reference
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
VA	Vulnerability Assessment
VMS	Vietnamese Mekong Secretariat
WCC'93	World Coast Conference 1993 (The Hague, The Netherlands)
WMO	World Meteorological Organization

1 INTRODUCTION

1.1 Data collection objectives

The objective of the data collection was to gain information and data to enable a description of the present state of the coastal zone of Vietnam and its management to be compiled such that it suitably highlights the vulnerable areas and the critical issues with respect to the accelerated rate of sea level rise and the successful implementation of coastal zone management (CZM) in Vietnam. Examination of development scenarios and trends enabled the sensitivity of this assessment to human development factors to be assessed.

Within the scope of the Vietnam Coastal Zone Vulnerability Assessment project, as described in the project Inception Report (ref 1), the data was used for both a qualitative (descriptive) and (preliminary) quantitative assessment of the coastal zone vulnerability to the rise in mean sea level.

In accordance with the adopted "Common Methodology" for this project, referred to as the "7 Steps" (ref 2), Steps 2 and 3 require "Inventory of the Study Area Characteristics" and "Identification of Relevant Development Factors". The objective of the data collection has been focused on fulfilling the data requirements for these steps towards the goal of the full Vulnerability Assessment (VA).

A further objective in data collection has been to collect data to support the specific pilot studies at Nam Ha Province (sea dyke erosion), Hue Lagoon (flooding and water quality) and Vung Tau City (planning).

Data collection concerning the response strategies and costs for measures was not conducted in Phase II and is reported in Phase III (Report No.3) since the response measures and details could only be properly addressed after analysis of the data collected in Phase II.

1.2 Data requirements

1.2.1 Data Collection for the Vulnerability Analysis

The "Inventory of Study Area Characteristics" in Step 2 of the VA requires physical, environmental and socio economic data to be collected in such a way that both the qualitative and quantitative parts of the VA can be fulfilled. This data represents the "baseline" situation at the time of data collection, namely 1995. The "Identification of Relevant Development Factors" requires investigation of trends in land use, population growth and new infrastructure that will influence and change the baseline data over the coming decades. Applying these trends will result in a quantifiable 30-year scenario. This is required in the Common Methodology to enable the sensitivity of Vulnerability Assessment to time dependant trends to be "tested". Why a 30-year scenario has been chosen and not a 100-year scenario is because of the great uncertainty in predictions of these trends over a period of 100 years. The use of the 30-year scenario simply provides a first indication of the sensitivity to development.

The Tables of the 7-Steps which are presented as a guideline for the data collection needs

(ref 1) are copied in Appendix D of this report and are titled as follows :

"Natural system data : Physical characteristics" (Table 2A, ref 1)
"Natural system data : Habitats and species" (Table 2B, ref 1)
"Socio economic data : General information" (Table 2C, ref 1)
"Socio economic data : Uses and values" (Table 2D, ref 1)
"Physical effects and natural system responses" (Table 3, ref 1)

The data collection requirements have been focused on the requirements of these tables interpreted to achieve the overall objectives stated in 1.1.

In a broader sense the data collection has also been extended to include more description of institutional and decision making issues since this will uncover the background to facilitate the First Steps of Integrated Coastal Zone Management (ICZM).

1.2.2 Data Collection for the Pilot Studies

For the Pilot Studies, data collection has mainly been concentrated in the weeks preceding the mission in which the pilot study will take place. In Phase II of the project some data collection was conducted towards identifying the problem in the first Pilot Study case : Sea Dyke erosion along the Thai Binh - Nam Ha Province coastline. Data was also collected and reviewed to enable firm decisions about the location and topic of the remaining Pilot Studies, namely Hue Lagoon and Vung Tau. This data will not be further reported in this report since it is covered in the Pilot Study Reports (Reports 4, 5 and 6).

2 METHODOLOGY FOR DATA COLLECTION

2.1 General

The methodology for data collection was a combination of three activities:

(i) Collection and documentation of available material
(ii) Award of data collection contracts
(iii) Digitization contracts

Each of these is reported in the following sections.

2.2 First scan of available material

This activity concerned a detailed review of available information and reports. The Project Team carried out a first scan of all available data in data bases, reports, previous studies and other sources. This involved many meetings with Institutes and Ministries in Hanoi and Ho Chi Minh City and also acquisition of maps and reports.

Full access was provided by MHC to their extensive database containing marine and meteorological data. Similarly, various Ministries and Institutes were very cooperative in discussing their data and providing examples of the data formats. Subsequently data collection contracts were initiated with the relevant Vietnamese host organisations as reported in Section 2.3.

Examples were also acquired of topographical maps of various scales and detail and these initiated the digitization contracts reported in Section 2.4.

A full set of reports from both the Mekong Masterplan and the Red River Masterplan Development Projects was reviewed (refs 3 & 4). Other previous foreign and local studies were similarly acquired and reviewed (refs 5 to 10).

2.3 Data collection contracts

Particularly in the review of available data in the databases of Institutes and Ministries it was clear that a huge amount of high quality data was available but that a good deal of explanation and preparation of data was required to be performed to make the data readily usable and fully understandable to the VA Project Team.

In order to meet the VA data requirements a large series of "data collection contracts" were issued. For each subject matter (eg water levels, wave climates, etc...) the procedure operated as follows:

- initial specification of data requirement made by the European Team, discussed and presented to the Vietnamese Team
- Identification of a number of Vietnamese Institutes which could supply the required data, followed by visits and review of the raw data
- Selection of preferred Vietnamese data supplier organisation
- Detailed specification of the data requirement and timing, discussed and agreed with the Vietnamese data supplier organisation
- Negotiation of financial terms (between the Vietnamese data supplier organisation and the MHC) and signing of the data supply contract
- Delivery of data collection report in Draft to the VA Project Team
- Discussions to clarify, edit and finalise the data collection report

A summary list of the data collection contracts and the organisations involved is given in Table 2-1 and a description of the reports delivered is given in Section 3.2.

The process operated very well and an excellent set of information was gathered, as well as useful insights and contacts built up during the discussions and meetings. As intended, the data collection was mainly performed by the Vietnamese team. A good integration of data collection efforts was brought about by spreading the load across more than 10 separate organisations and involving 20 to 30 Vietnamese scientists. Many of these attended the project workshop at the end of the data collection phase at which the use of the data was also demonstrated.

It should be stressed that these data reports do not form in themselves a digital database and much work is still required to bring this about to make use of the data in a general form for other projects. However summaries of key results, with emphasis on requirements for the VA study are given in Section 3.2.

Table 2-1 : Summary of data collection contracts

Contract number	Contract title (Data topic)	Organisation (and contact person)
PHYSICAL AND ENVIRONMENTAL DATA CONTRACTS		
A1	Coastline types of Vietnam	Vietnam National Centre for Natural Sciences and Technology, Institute of Geological Sciences (Prof.Dr. Nguyen Dich Dzy and Dr. Vu Cao Minh), Hanoi
A2	Inventory of Coastal protection and River Dykes in Vietnam's coastal zone	Ministry of Water Resources (Dr. Ton That Vinh), Hanoi
A3	Landuse and Topography of the Vietnamese coastal zone	See Section 2.4 : "Digitization Contracts"
A4	Subsidence of Vietnam's coastal areas	Vietnam National Centre for Natural Sciences and Technology, Institute of Geological Sciences (Prof.Dr. Nguyen Dich Dzy and Dr. Vu Cao Minh), Hanoi
A5	Tidal characteristics around Vietnam	MHC of HMS, Hanoi (Dr. Nguyen Tai Hoi, Nguyen Manh, Tran Phuong Dong etc.)
A6	River characteristics in Vietnam	MHC of HMS, Hanoi and Institute of Hydrology of HMS, Hanoi. (Hoang Minh Tuyen, Pham Kim Oanh)
A7	Storm characteristics on the Vietnam coast	MHC of HMS, Hanoi (Dr Nguyen Doan Toan, Tran Hong Lam, Nguyen Thi Hai etc.)
A8	Wave characteristics on the Vietnam coast	MHC of HMS, Hanoi (Dr Nguyen Doan Toan, Tran Hong Lam, Nguyen Thi Hai etc.)
A9	Flood prone areas	Ministry of Water Resources, Hanoi (Dr Nguyen Trong Sinh, Le Duc Nam, Le Huu Thuan, Truong Trong Luat, Le Hung Nam)
A10a	Littoral materials and littoral processes along the Vietnam coast	Sub-Institute of Physics, Ho Chi Minh City (Dr Hoang Xuan Nhuan)

Table 2-1 : Summary of data collection contracts (cont...)

A10b	Erosion and accretion on the sea coast of Vietnam	Vietnam National Centre for Natural Sciences and Technology, Institute of Geological Sciences, Hanoi (Prof.Dr. Nguyen Dich Dzy and Dr. Vu Cao Minh)i
A11	Groundwater characteristics in the Vietnam coastal zone	Ministry of Water Resources, Hanoi (Dr Nguyen Trong Sinh, Le Duc Nam, Le Huu Thuan, Le Hung Nam)
A12	Datum levels in Vietnam	MHC, Hanoi (Nguyen Tai Hoi)
A13	Design water levels in the Vietnam coastal zone	MHC, Hanoi (Nguyen Tai Hoi)
A14	Coastal flora habitats and ecological types	Mangrove ecosystem research Center, Vietnam National University, Hanoi (Prof.Dr.Sc. Phan Nguyen Hong)
A15	Fauna of Vietnam's coastal zone	Dept.of Vertebrate Zoology, Faculty of Biology, University of Hanoi (Prof.Dr. Vu Trung Tang)
SOCIO-ECONOMIC AND INSTITUTIONAL CONTRACTS		
SE1	Existing socio-economic factors and development of Vietnam with emphasis on the coastal zone	Institute for Strategic Development Planning, State Planning Committee, Hanoi (Dr. Anh)
SE2	Socio-economic development scenario for 2025 for Vietnam with emphasis on the coastal zone	Institute for Strategic Development Planning, State Planning Committee, Hanoi (Dr. Anh)
SE3	Legal and institutional affairs relating to the development and management of the coastal zone of Vietnam	Institute for Strategic Development Planning, State Planning Committee, Hanoi (Dr. Anh)

2.4 Digitization contracts

The data collection topic A3 : "Landuse and topography of the Vietnamese coastal zone", is one of the most important for the VA analysis as it provides the basic data for the quantitative analysis of the various systems for loss and risk estimates.

Early in the project, after the initial review of readily available data and maps, it was noted that a large amount of very good information on topography and landuse was already available in Vietnam. The data was, however not in digital format and was available as analog maps. The opportunity was recognised that once this data could be captured in digital format by digitization, geographically referenced to a common system and overlain (by GIS) then the spatial (horizontal and vertical) relation between landform and landuse would be totally available for detailed quantification. This would rapidly yield important relationships for the coastal zone vulnerability assessment, for example : How many hectares of rice are located below +2m elevation on the coast of Vietnam?

By combining the provincial boundaries (cutting out sub-areas with the shapes of the various coastal and delta provinces) the same question could be asked for a specific province : How many hectares of rice are located below +2m elevation in the coastal province of Nam Ha?

Further, by combining flooded area scenarios with the above information addresses the question : How many hectares of rice are located below +2m elevation in the coastal province of Nam Ha and of these how many become inundated by the design flood?

In view of the potential for providing direct quantitative answers for the VA analysis, it was decided to embark on a major campaign for digitization of the Vietnamese coastal zone.

Following this, data sources and digitization agencies were thoroughly researched. Primary data sources were :

Topography

The "upper" limit of the coastal zone was decided as the elevation +6m above MSL in Report No.1. During the data collection phase it became clear that this should be extended to +10m above MSL to allow for the sea level rise impacts on upstream river levels and consequently increased flooding.

Since for the VA Project a large amount of detail is required in the flat flood prone areas of the coastal zone, including the large river deltas and low coastal plains, then maps which provide 1m contours between the coastline and +10m elevation would be ideal for direct digitization.

In researching the available data the following organisations were approached and data was reviewed:

(i) VT-GEO : Center for Remote Sensing and Geomatics, NCST, MOSTE

(ii) NIAPP : National Institute for Agriculture and Planning, Min. of Agriculture

(iii) FIPI : Forest Inventory and Planning Institute, Min. of Forestry

(iv) Department of Land Administration

Topography maps were found to be available in a cascading series of scales from 1 in 5,000

to 1 in 1,000,000. However the coverage and quality varied from region to region. A good reference source was the Department of .**..... which publishes a detailed catalog of available maps. Discussions with the Department of Land Administration** revealed that in some places the vertical accuracy of the topographical maps was +/- 50%. In some maps a shift of over 1km in features was found relative to the adjacent map sheet. Detailed discussions were held to try to solve these inaccuracy problems. They arise from the difficulties of successive projection conversions being done by successive occupying governments (Chinese system, French system, US system in the south, Vietnamese system etc.).

It was discovered that the most appropriate topographical data was available in map form at a scale of 1 in 25,000. These maps were of the more accurate available and generally included elevations at 1 or 2m intervals. Even in this series, some maps were completely devoid of data from the coast to the +25m contour. Supplementary data (eg spot heights etc.) was extracted from maps of smaller scale.

Land use

Land use data was digitized from sheets of a scale of 1 in 250,000 by NIAPP. The sheets were available in analog form as polygons of various land use categories derived from satellite photography. The origin of the land use data was derived in previous tracing exercises from satellite photography LANDSAT TM-5 1989-1990. The fieldwork as calibration (ground truth) was conducted in 1992. The resulting maps were accepted by the General Statistical Service of Vietnam and used for statistical analyses and projections. While these are not representative of the 1995 land use situation, they are the best available source for the purposes of our analysis. Some changes in land use patterns, particularly in categories such as mangroves vs aquaculture can be expected to have occurred from 1990 to 1995 but the overall effect of this on our study outcome is judged to be very small.

Administrative border

The administrative border was digitized by NIAPP from a 1 in 500,000 topography map with adjustments for the recent new provincial boundary changes (1994).

Infrastructure

Major roads and railways were digitized from the 1 in 500,000 and 1 in 1,000,000 topography maps by NIAPP (North) and VT-GEO (South).

Dykes

Dykes were digitized from the 1 in 25,000 scale maps during digitization of topography. These were checked and adjusted using the dyke maps from the Department of Dyke Management and Flood Control of the Ministry of Agriculture and Rural Development.

Surface waters and coastline

Surface waters such as the outlines of lakes and lagoons as well as coastlines were digitized from the 1 in 25,000 scale maps during digitization of topography.

3 RESULTS OF DATA COLLECTION

3.1 General

The results of the data collection phase were contained mainly in the following categories:

- Data collection contract submissions to the VA study by Vietnamese specialists
- GIS data (topography and land use, administrative border maps, infrastructure, dykes)
- Existing reports (eg Delta Masterplans, statistical references etc.)

The primary references were the data collection contract submissions to the VA study by Vietnamese specialists. These were critically reviewed both by local peers in Vietnam and by the European Team. In every case interviews were held with the contractors to discuss comments and results. The finally submitted reports are available as Appendices to this report. A short abstract of each of the data reports is given below. The data was further checked and analysed to provide the data in a format suitable for the VA analyses and in Report No.7 (Final Report) more detailed figures and tables will be presented.

3.2 Physical and environmental data

3.2.1 Coastline types of Vietnam (Data report A1)

The seven coastline types were distinguished :

(1) high rock cliff; with (1a) or without (1b) beach in front of it;
(2) low rocky shore, with (2a) or without (2b) beach on its seaward side;
(3) sandy dune and beach;
(4) low coast and beach;
(5) lagoon and river mouth protected by sand spit(s) and/or barrier(s);
(6) mangrove coast;
(7) coral coast.

About 23% of the coastline of Vietnam is hard and rocky. These areas are concentrated in the far north (Quang Binh) and southern central coast (Binh Dinh to Binh Thuan). Some 22% of the coast is fronted by natural sand dunes, mainly in the north central coast (Quang Binh to Thua Thien Hue). The remaining percentage of the coast consists of generally low coast with sandy or muddy beaches representing the delta coastlines of the Red River Delta in the north and the Mekong Delta in the south.

Within 100 km of the coast of Vietnam there are over 1000 islands with a total coastline length of over 2000km (more than 50% of the coastline length of the national mainland). The vast majority of the islands are offshore of the coastal provinces of Quang Ninh and Haiphong in the far north of Vietnam.

3.2.2 Inventory of coastal protection and river dykes in Vietnam's coastal zone (date Report A2)

About 30% of the coast of Vietnam is protected by artificial structures. These are mainly low

dykes, 75% of which contain no armour protection.

Primary protection measures in Vietnam are river, sea and estuary dykes. The distinction between the two consists mainly in structural design and the resistance to waves and other environmental impacts. Sea dykes encompass both sea dykes proper and estuary dykes as well, the latter up to 8 to 12 km from river mouths. In this area the hydraulic load on the dykes consist mainly of waves, while the river dykes mainly have to resist the forces induced by river flow and flood impacts.

Sea dykes have been constructed over a total length of about 2,700 km along the coastal line and in the river mouths for protecting low lying agricultural land and cities in the coastal zone against inundation during high tide and storm surges. The sea dykes in the North have been built for centuries, while those in the Center and in the South only after 1975.

River dykes are extending from the end of the estuary dykes land inward along both sides of the river. The length of protected rivers is thus about half the length of the river dykes. The overall length of the river dykes is 4,615 km with most of them in the Red River Delta and Thanh Hoa Province. Further southward the length of river dykes is decreasing, while in the Central Southern Provinces only few river dykes with very limited length are present (here the mountains are reaching the coast).

The inland part of the Mekong Delta is only protected by a poor system of other defences including ring embankments/polder dykes and roads. This system, extending over a length of 2754 km, has been built by using local resources as manpower and funds.

3.2.3 Land use and topography of Vietnam's coastal zone (Data Report A3)

The elevation of the land in the coastal provinces is summarised in VVA classes determined by isolines of +10m, +5m, +2.5m and 0m HD respectively, for each coastal zone province. It is noteworthy that the Mekong Delta provinces are all below the +10m HD elevation, with almost 80% of the Mekong Delta land below the elevation of +2.5m HD. About 30% of the Red River Delta study area lies below the same elevation.

Section 2.4 describes the digitization process by which the topography, land use and other thematic maps were created in the GIS format, so the Reader is referred to it for more information.

3.2.4 Subsidence of Vietnam's coastal zone (Data report A4)

Generally, the geological subsidence in Vietnam is limited to less than 3mm/year in the deltas and less than 1 mm/year along the central coast.

Major man-induced subsidence stems from groundwater extraction; precautionary steps should be taken to avoid similar subsidence likely to emerge as a result of oil and gas extraction. At present, the water demands of the households, agriculture and industry in Vietnam's coastal zone are met by surface water exploitation, with the exception of the larger coastal cities. Of concern is the potential subsidence for cities such as Hanoi and Ho Chi Min City and others due to groundwater extraction, which is relatively new to Vietnam and for which reliable measurements and controls are scarce. However, as population and

industrial demands for water increase, if the exploitation rate remains unchecked, a subsidence of several centimeters per year is possible in these areas. Such subsidence rates are already apparent near Hanoi.

3.2.5 Tidal characteristics around Vietnam

Tide ranges (astronomical tides neglecting meteorological effects) generally are largest in the north with highest tide levels of about 1.8m HD. The range reduces toward the central coast a highest tide level off Thua Thien Hue barely reaches 0.4m HD. Tide range increases again towards Vung Tau in the south with a highest tide level of 1.6m and reduces again around the Mekong Delta to the west.

3.2.6 River characteristics in Vietnam

There are 9 major river systems entering the sea from the coast of Vietnam, from north to south: Kycung, Thai Binh R., Red R., Ma R., Ca R., Thu Bon R., Ba R., Dong Nai, and Mekong River. In each of the two main deltas of the Red and Mekong Rivers there are 2 large rivers (Red R. + Thai Binh R. and Mekong R. + Dong Nai R., respectively) with gradually sloping, broad catchments. A further 5 are shorter, steeper rivers draining the upland mountain ranges behind the northern and souther central coast. The largest river in Vietnam, by far, is the Mekong River which has over 4 times the average discharge of its closest contender, the Red River, in the North. Despite this, the combined annual sediment discharge of the Red River Delta (above 100 million tons per annum) exceeds that of the Mekong Delta, because most of the Mekong River sediment load (estimated at 215 million tons at Phnom Penh) settles down before reaching the sea.

3.2.7 Storm characteristics for Vietnam's coast

The climate of Vietnam is subject to the SE Asia monsoon seasons whereby the SW monsoon dominates with S-SW winds in summer months. The NE monsoon winds bring cold continental air streams from the Chinese mainland which brings down temperatures in the north in winter months.

Every year typhoons and violent storms strike the coast of Vietnam, causing death toll, damage to sea dikes and losses to agricultural crops and infrastructure. An average of 6 typhoons cross the coast of Vietnam per year, mostly from a SE'ly direction heading NW. These typhoons travel long distances across the South China Sea and arrive at the Vietnamese coast laden with high rainfall and extreme wind speeds with associated high waves and storm surges. The northern provinces encounter the majority of typhoon events (4 per year pass north of Thua Thien Hue Province) while the Mekong delta area is relatively free from typhoon attack (1 every 3 to 5 years).

Typhoons are normally accompanied by storm surges.

In the north, the storm surge reaches 1.5m in extreme cases (typhoons) but, due to its low tide range, the central coast is more vulnerable. In the south, particularly along the Mekong Delta, typhoons are very rare and extreme storm surges are related to monsoon winds and barely exceed 0.5m at the coast.

3.2.8 Wave characteristics for Vietnam's coast

Deepwater significant wave heights are greatest off the central coast where the 1 in 10 years wave is approximately 10 to 12m. In the far north and far south the design wave heights reduce considerably due to shelter of Hainan Island in the north and the changed climatic conditions (no typhoons) in the south.

3.2.9 Flood prone areas

Typhoons and violent storms strike the coast of Vietnam every year, with high rainfall, extreme wind speeds, high waves and storm surges. The northern provinces encounter the majority of typhoon events. Typhoons are normally accompanied by storm surges.

The high water levels caused by typhoons and the accompanying phenomena frequently destroy sea dykes, and bring about flooding of lowland coastal areas through overtopping and breaching of dykes. These destructive storms bring intense rainfall accompanied by strong winds, resulting in overall flooding due to atmospheric, landborne and sea-induced factors. Combination of seaborne and landborne factors may cause extreme flooding. The salinisation of the flooded soil can render farms inoperative for several years.

Rainfall is highest in the central coastal areas near Thua Thien Hue with over 3000 mm/year, mostly falling in the short season from October to January. In the Red River and Mekong Deltas the figure reduces to around 2000 mm/year. The driest coasts are those of the southern central coast with less than 1000 mm/year.

Flooding is one of the most negative influences in Vietnam's development at present. It is most serious in areas which are among the most economically active such as the Red River Delta and the Mekong Delta. The most flood-prone area in Vietnam is the Mekong Delta where annual floods cause havoc to all provinces but particularly to the inland delta provinces such as Dong Thap, An Giang and Long An. Other hot-spots for flooding include the Red River Delta provinces of Ha Tay and Hai Hung as well as the central coast provinces of Thua Thien Hue and Thanh Hoa.

The flood prone nature of the Mekong Delta is clear when considering that almost the entire delta lies below an elevation of +2.5m (as far inland as the Cambodian border) which is 1m below the once per 5 year flood level at the border with Cambodia of +3.5m HD. Weak low dykes in the Mekong delta are often unable to withstand floodwaters. A strategy adopted in these provinces is a first line of defence that holds against "lower" early season floods for protection of summer-autumn crops but which fails against the main annual floods in October-November. These weak defences are repaired and rebuilt each year by local people largely with their own resources and total almost 2,750 km in length.

From 1954 to 1995 there have been 212 typhoons hitting or directly affecting Vietnam. Recent extreme floods occurred in the Red River in 1971 (a 100 year return period) and in the Mekong Delta in 1978 (approx. 1 in 75 years). Extreme floods were again encountered in the Mekong in 1994 and 1995 and in the Thua Thien Hue - Quang Ngai - Binh Dinh Provinces region of the central coast in 1995. In the month of October to November 1995 (during drafting of this report) the central areas of Vietnam from Quang Binh to Binh Dinh provinces bore the brunt of the loss of life and the damage to property inflicted by three

powerful typhoons, Ted, Yvette and Zack. The three typhoons were all of strength 11 or 12, which occur only once every few years. The typhoons left in their wake 137 deaths, 199 injuries and 46 missing in one month from October 5 to November 3, 1995.

3.2.10 Littoral materials and processes

The summary in this subsection is based on two reports: A10a by Hoang Xuan Nhuan (1995) reflected in 3.2.10.1 and A10b by Nguyen Dich Dzy et al. (1995) referred to in 3.2.10.2. Report 10Aa provides a tentative but integrated information on the littoral material, river sediment load, longshore sediment transport, typical material budget and the most important littoral processes in various time scales, which is summarized below.

On the scale of the entire Vietnamese coast the following summary was provided :

- Muddy coasts of Vietnam are young alluvial bodies nourished by river sediment, mainly not more than 3,000 years old. They need continuous river supply to compensate for the fine material washing by waves and currents. The sand exchange between the muddy coasts and the surrounding areas is negligible;

- Nearly 95% of the total river sediment load is concentrated in two distinctive coastal sections to nourish separately the Red River and Mekong River alluvial bodies. The cohesive coast of the Red River Delta is supplied with the river sediment load of 72,600,000 t/year, the composition of which is 11.6% sand, 59.2% aleuritic and 29.2% clay. Not more than 29% of this sediment load with about 41% sand, 44% aleuritic and 13% clay are contributed to maintain and to develop the sandy ridges and the tidal plain (depths below 2 m). The remaining part (not less than 71%) with ~5% sand, ~62% and ~32% clay passes the tidal plain to nourish the offshore slope (depths of 2 m to 30 m);

- The human impact on river sediment supply could be considered as the primary reason of the large erosion of muddy coast with the time scale of 10^2 years. Such impacts could be long-term modification of the river network by dike system or spontaneous actions such as building a large reservoir, closing a river branch (etc..);

- The quantities of dredged materials from the Haiphong Port access-channel have been measured since 1915; they have varied in the range 1.2→3.5 million m3/year. They seem to increase steadily with time. The quantities of dredged materials from the access-channel of Cua Lo Port have been recorded since 1980 to vary in the range 0.14→1.18 million m3/year. The sand protective dam effectively reduces channel accretion, but its effectiveness seems to be temporary.

3.2.10.2 *Estimates of erosion rates*

Nguyen Dich Dzy et al. (1995) have focused attention on the processes of accretion and erosion all over the Vietnam's coast. Erosion rates, from metres to nearly 200 m per year are listed by provinces. The highest erosion rates are given for Bac Cua Ganh Hao in Minh Hai as an average of 193 m/yr over 15 years between 1976 and 1991; 162 m/yr at Nghi Yen (Nghe An, between 1982 and 1991); 112 m/yr at Dien Du'ong (Quang Nam Da Nang, 1975-1995); ab. 100 m/yr at Hiep Thanh and Dan Thanh (both Tra Vinh, 1982-1992) and 100 m/yr at Nam Cua Ganh Hao (Minh Hai, 1945-1991). Some other locations with similar erosion

rates are also named, although for shorter periods of averaging. By and large, these figures are felt extremely high, and perhaps should be verified by independents methods. They may represent local erosion, not a structural morphodynamic process. the erosion rates given for the Nam Ha Province, Hai Trieu in particular, seem more realistic and consistent with other sources --- they vary around 30 m/yr.

3.2.11 Groundwater characteristics in Vietnam's coastal zone

Some basic groundwater characteristics have been described in 3.2.4. Box 3.2-1 provides good illustration of the groundwater problems encountered in the three regions of Vietnam, North, Central and South.

Similar to salinity, drainage is very problematic in the deltaic coastal provinces, where waterlogging of the areas behind dykes can result in flood damage. The challenge to allow drainage but prevent seawater (salinity) intrusion is a serious issue on the Red River Delta coast (Thai Binh/Nam Ha). Also in the central coast provinces, the very high rainfall intensity, steep catchments and high storm surge levels at sea (in typhoons once or twice a year) cause devastating drainage problems in low-lying areas such as around Hue City and the Tam Giang - Cau Hai lagoons.

3.2.12 Datum levels in Vietnam

Two datum level systems have been existing in Vietnam, one for the south and one for the north of Vietnam. An exercise has recently been completed in Vietnam to link the north and the south. All levels throughout the nation can now be given relative to the standard datum in the north which is at Hon Dau station. Al levels in the VA study reports refere to Hon Dau datum (HD) unless otherwise stated.

3.2.13 Design water levels in Vietnam's coastal zone

Design water levels at the coast are a combination of extreme storm surges and high tides. As such the 100 year storm surge level varies from 2.6m HD in the far north to less than 1.3m HD in the southern central coast and rising again to 1.7m HD in the far south at Vung Tau, reducing again across the Mekong Delta coast.

3.2.14 Coastal flora habitats and ecological types

One can distinguish the ecosystem types of coral reefs, estuaries, deltas, coastal lagoons and tidal inlets, tidal marshes, and wetland forests (mangroves).

Coral reefs are concentrated on the rocky coasts and islands of the far north (Quang Ninh and Haiphong Provinces) and the southern central coast. On the delta coasts (Red River and Mekong) and on the north central coast the coral is limited to reefs on the few offshore islands. In general the coral reefs are under serious threat due to human activities such as dynamite fishing, coral mining for the cement industry and pollution.

Estuaries of the major rivers, outside the delta areas (eg Ca River, Ma River etc.), experience varying salinity regimes depending on the season. The average annual salinity varies from 5 - 10 ppt near the coast and the suspension concentration in the rainy season ranges from

20 - 100 g/m^3. Mangroves dominated by Rhizophoracae develop well, while algae, seagrass and plankton (and invertebrates and shrimp larvae as well) in particular are also abundant.

Deltas : Among deltas the Red River Delta and the Mekong Delta have dynamic coastlines with mud and fine silts which accrete (eg Thai Binh coast) or erode (eg Nam Ha coast) at a rate of tens of metres per year. Close to the coast the salinity of the river branches and groundwater remains high, particularly in the dry seasons. The brackish water environment and the brownish red mud with high contents of iron and manganese and intensive oxidation favour the development of mangrove such as Rhizophora, Kandelia and Cyprus.

Coastal lagoons occupy 5% of Vietnam's coastline and occur only in the central region from Quang Tri to Ninh Thuan province, where tidal range is small (0.5-2.5 m). These lagoons, 280 - 21,600 ha in area, are enclosed by 2-25 m high sand barriers or dunes, and are connected to the sea through narrow lagoon inlets. In general, the coastal lagoons are productive ecosystems due to their high nutrient levels which exceed those of the sea, even in the dry season. *Gracilaria*, fish, shrimps, crabs and molluscs are exploited.

Tidal marshes (also referred to as wetlands) are mainly distributed along the northern coast from Mong Cai in Quang Ninh to Thanh Hoa Province (74,520 ha), and in the South from Vung Tau to Kien Giang (207,480 ha). In the central region, only a few tidal marshes occur (18,000 ha). The total area of tidal marshes is about 300,000 ha, 80% of which possess mangroves (nearly 100 species) and seagrass. By their dynamic and inter-related nature, wetlands are also particularly prone to pollution, changes in water flow water levels, rate of sedimentation, salinisation, etc. The area of present wetland forests represents about 30% of the wetland area covered in 1940.

Destruction of wetlands was devastating during Vietnam's war years due to defoliant spraying, particularly in the Mekong area, but recovery efforts have been fairly successful. However, the recovery made by replanting in these areas has been rapidly overtaken by the expansion of aquaculture activities with the creation of fish and shrimp ponds. The fish pond creation is not only unwise environmentally but is also carried out in an uneconomic and careless way with the result that due to acidification and eutrophication of pond waters.

Non-vegetated tidal marshes are mainly found in the Red River and Mekong Deltas, extending seawards from large mangrove stands. In general, the tidal marshes are economically vital as they provide the spawning and nursery grounds for numerous fish, prawns and mollusc species. Famous are such sites as the Xuan Thuy bird reserve area at the mouth of the Red River, which is a RAMSAR site.

Nearshore waters are typical of tropical seas. The total number of marine algae identified is 653 species including 301 species of rhodophytes, 151 chlorophytes, 124 phaeophytes and 77 cyanophytes.

3.2.15 Fauna of Vietnam's coastal zone

Among the marine invertebrates, over 300 species of scleractinian coral (including 62 reef building corals) have been identified in addition to 2,500 species of molluscs, 1,500 crustacea, 700 polychaete, 350 echinoderm, 150 porifera and some other groups. The shrimp Metapenaeus ensis is an important resource for both the Red and Mekong River deltas.

The total number of marine fish species recorded is 2,038, 70% of which are demersal species. Marine fishes of Vietnam are predominantly tropical with a small proportion of sub-tropical species mainly distributed in the Gulf of Tonkin. Recent studies of the coral reef fish fauna have revealed a total of 346 species.

Only four species of marine mammals are recorded. However, several other species of whales and dolphins can be expected to settle. At present 5 species of marine turtles inhabit Vietnam's coastal zone, mostly coral areas of the far north and the southern central coast. About 200 species of water birds and 10 species of serpents are recorded in the coastal zone of Vietnam.

Biodiversity in Vietnam's coastal waters is modest but is rapidly decreasing. Inter alia, over 60 species of fish, 146 molluscs, 107 crustacea and many waterbirds and mammals inhabit the *tidal marshes* of Vietnam. The hazards are of such national concern that Vietnamese scientists have recently published the *Sach Do Viet Nam* (Vietnamese Red Book) summarising the status of threatened animals in the country. Table 3.2-1 presents the status of the major groups in terms of endangered, vulnerable, threatened, rare or undetermined. In addition, the country totals and the coastal zone totals are also listed. Of the 150 species and subspecies of fish and invertebrates listed in the Red Book, 83 are marine including 37 fishes and 46 corals, molluscs, crustacea and enchinoderms. There are also some 40 species of rare and endangered fresh and brackish water fishes. A separate Red List has been prepared for 350 endangered and threatened plants.

TABLE 3.2-1: Red Book Categories of Vietnam (Ref. Biodiversity Action Plan(1994))

	Fishes	Inverts	Mammals	Birds	Reptiles	Total
Endangered	6	10	30	14	8	68
Vulnerable	24	24	23	6	19	96
Threatened	13	9	1	32	16	71
Rare	29	29	24	31	11	124
Undetermined	3	3				6
Total species in	75	75	78	83	54	365
Total species in	2500	7000	275	800	260	10835
Total species in	2038	5500	4	200	10	7752

The total of species in danger is high for a single country and reflects the seriousness of the threats to wild habitats in Vietnam. In particular, fishery, industry, ports and tourism are the threats to the Marine and Coastal Biodiversity in Vietnam.

The extensive coastal waters and estuaries are abundant fishery resources with an annual exploitation potential of about 1.2 million tonnes, of which 60% to 70% is from capture fishery. Overfishing (large quantities, undersized fish, undersized mesh nets, dynamiting) is a main threat to the various fish species. Another threat is the destruction and degradation of

coastal vegetation and coral reefs by human activities as marine-based tourism, port operations, oil and gas winning. These activities lead to coastline erosion and consequently to loss of habitat and loss of critical shelters for fishermen. Serious losses to mangrove areas as mentioned are a further threat.

The single most important factor affecting wildlife in Vietnam is habitat loss or change. Protected areas such as parks are designed to protect wildlife habitat, and are an indicator for future efforts to maintain the biodiversity and ecosystem functions. Some of the reserves are very valuable for biodiversity conservation, but unfortunately many are too small and contain only areas of interest for historic or recreation reasons. The Tropical Forest Action Plan (TFAP) concluded that the protected area system required considerable revision as it was inadequate in area, forest quality and standards of management to meet its objectives. That plan proposed 18 reserve extensions and four new reserves, including 5 special reserve areas situated in the Coastal Zone (comprising the land between MSL and +10 m) of Vietnam.

However the management of wetlands in general in Vietnam is not well defined in terms of roles, functions and responsibilities. The Ministry of Forestry manages several wetland sites that fall into forest estates including important mangrove areas and a few lakes and rivers that pass through nature reserves, but the Ministry of Fisheries is responsible for production rates of fishing in lakes, rivers and marine areas.

3.3 Socio-economic data

The socio economic data has been gathered mainly by reference to the "SE" reports in Appendix B. These have been supplemented by other available reports from the General Department of Statistics in Hanoi.

The socio-economic data will be discussed in full in the Final Report and will not be further summarised here.

3.4 Future development scenario

Similarly, the future development scenario has been derived with the aid of Appendix B and will be described more fully in Report No.7.

3.5 Data collection for the Pilot Studies

Data collection for the pilot studies was conducted as part of the Pilot Studies and will be reported in Reports 4, 5 and 6 (refs ** to **).

4 Conclusions

The data collection was successfully completed and has provided an excellent basis for the further analysis work.

The basic decision to opt for a GIS method of analysis placed great pressure on the data collection programme. The achievement of the data collection objectives was not without significant difficulties but these were overcome.

The most rewarding part of the data collection period has been the wide involvement of Vietnamese specialists and organisations cutting across ministerial, disciplinary and geographical boundaries throughout Vietnam. In this way the VA Project has received much publicity but also part "ownership" by the many contributors. This has been an important mechanism for integration and its success is a good sign for future ICZM in Vietnam.

Remaining problems to be overcome are the confusion of datum levels and the data ownership issues. Particularly the latter has inhibited the sharing and distribution of strategic data which is vital for good ICZM..

References

1 Vietnam VA Project : Report No.1 : Inception Report, March 1995

2 Vietnam VA Project : Report No.2 : Data Collection, June 1995

3 Vietnam VA Project : Report No.3 : Methodology, September 1995

4 Vietnam VA Project : Report No.4 : Pilot Study : Sea dyke erosion in Nam Ha Province, July 1995

5 Vietnam VA Project : Report No.5 : Pilot Study : Flooding and lagoon management, Thua Thien Hue Province, November 1995

6 Vietnam VA Project : Report No.6 : Pilot Study : Coastal management and planning, Baria-Vung Tau Province, March 1996

7 Vietnam VA Project : Report No.7 : Pilot Study : Final Report, April 1996

APPENDIX A : Physical and Environmental data

VIETNAM NATIONAL CENTRE FOR NATURAL SCIENCE AND TECHNOLOGY
INSTITUTE OF GEOLOGICAL SCIENCES

SUBJECT A.1

COASTLINE TYPES OF VIETNAM

Authors :

Dr.Pr. Nguyen dich Dzy - chief author
Dr. Vu Cao Minh
Dr. Tran Minh
Dr. Do Van Tu
Ing. Dinh Van Thuan
Ing. Mai Thanh Tan

- Hà Nội, 1995 -

A2

SUBJECT A2

INVENTORY OF COASTAL PROTECTION AND RIVER DIKES

A3

Digitization

Contracts

No report

(Data supplied digitally)

NIADP

VT-GEO

VIETNAM PROJECT V/A

A4

REPORT

ON

THE SUBSIDENCE OF VIETNAM'S COASTAL AREAS

A4

received 06-07-'95

Hanoi 6, 1995

MARINE HYDROMETEOROLOGICAL CENTER
VIETNAM VA PROJECT

REPORT
ON

TIDAL CHARACTERISTICS (SUB.A5)
DESIGN WATER LEVELS (SUB.A13)

By :
Nguyen Tai Hoi

Hanoi, June 1995

MARINE HYDROMETEOROLOGICAL CENTER
VIETNAM VA PROJECT

REPORT ON

RIVER CHARACTERISTICS

(SUBJECT A6)

PREPARED BY :

Research associate. HOANG MINH TUYEN

Eng. PHAM KIM OANH

HANOI, SEPT. 1995

HYDROMETEOROLOGICAL SERVICE
MARINE HYDROMETEOROLOGICAL CENTER

VIETNAM COASTAL ZONE VULNERABILITY ASSESSMENT

Report

on

STORM CHARACTERISTICS

A7

By Nguyen Doan Toan
Tran Hong Lam
Nguyen Thi Hai
and other co-authors

Hanoi, July 1995

HYDROMETEOROLOGICAL SERVICE
MARINE HYDROMETEOROLOGICAL CENTER

VIETNAM COASTAL ZONE VULNERABILITY ASSESSMENT

Report

on

WAVE CHARACTERISTICS

A8

By Nguyen Doan Toan
Tran Hong Lam
Nguyen Thi Hai
and other co-authors

Hanoi, July 1995

MINISTRY OF WATER RESOURCES
INSTITUTE OF WATER RESOURCES PLANNING AND MANAGEMENT

SUBJECT No.A9

FLOOD PRONE AREAS

Prepared by : Dr. Nguyen Trong Sinh
Eng. Le Duc Nam
Eng. Le Huu Thuan
Eng. Truong Trong Luat
Eng. Le Hung Nam

arrived in PO
20/4/95

Hanoi May 1995

A10a

General Department of Hydro-Meteorology of Vietnam
Center for Marine Hydro - meteorology
Subinstitute of Physics in Ho Chi Minh City

Project:

Vulnerability assessement of Sea Level Rise

subject A 10-a
"Sediment transport etc"
arrived in PO
appr. 7/6/95

A10a

REPORT

Subject: Littoral materials and littoral processes.

Accomplished by: ***Department of River and Marine Engineering***
SUB-INSTITUTE OF PHYSICS
in HO CHI MINH CITY

Ho Chi Minh City- May 1995

MINISTRY OF WATER RESOURCES
INSTITUTE OF WATER RESOURCES PLANNING AND MANAGEMENT

All

SUBJECT No.11

GROUNDWATER CHARACTERISTICS

Prepared by : Dr. Nguyen Trong Sinh
Eng. Le Duc Nam
Eng. Le Huu Thuan
Eng. Le Hung Nam

Hanoi May 1995

MARINE HYDROMETEOROLOGICAL CENTER
VIETNAM VA PROJECT

REPORT

ON

DATUM LEVELS IN VIETNAM
(SUB. A12)

By:
Nguyen Tai Hoi

Hanoi, June 1995

Vietnam Vulnerability Assessment in relation to
Climate Change and Sea Level Rise

****

A14

COASTAL FLORA HABITATS

AND

ECOLOGICAL TYPES

Prof. Dr.Sc. Phan Nguyen Hong
Mangrove Ecosystem Research Center
Vietnam National University, Hanoi
91 Nguyen Khuyen Street, Hanoi

Hanoi - June 1995

Subject A 14
2nd Draft
Received per 26 June 1995 !
(plus 1 set of 18 coloured vegetation maps)

A15

VIETNAM NATIONAL UNIVERSITY
UNIVERSITY OF HANOI

Ass. Proff. Dr. VU TRUNG TANG

FAUNA OF THE VIETNAM'S COASTAL ZONE

Draf Report, 13-04-95

Hanoi, June 1995

APPENDIX B : Socio economic data

VIETNAM VA PROJECT

REPORT SE1

EXISTING SOCIO-ECONOMIC FACTORS AND DEVELOPMENT OF VIETNAM WITH EMPHASIS ON THE COASTAL ZONE

JULY 1995

Delivered on 4 September 1995
by Mr. Ahn

VIETNAM VA PROJECT

REPORT SE3

LEGAL AND INSTITUTIONAL AFFAIRS RELATING TO THE DEVELOPMENT AND MANAGEMENT OF COASTAL ZONE OF VIETNAM

question
(See page 8

SEPTEMBER 1995

APPENDIX C : Future Scenarios

VIETNAM VA PROJECT

REPORT SE2

SOCIO-ECONOMIC AND DEVELOPMENT SCENARIO FOR 2025 WITH EMPHASIS ON THE COASTAL ZONE

SEPTEMBER 1995

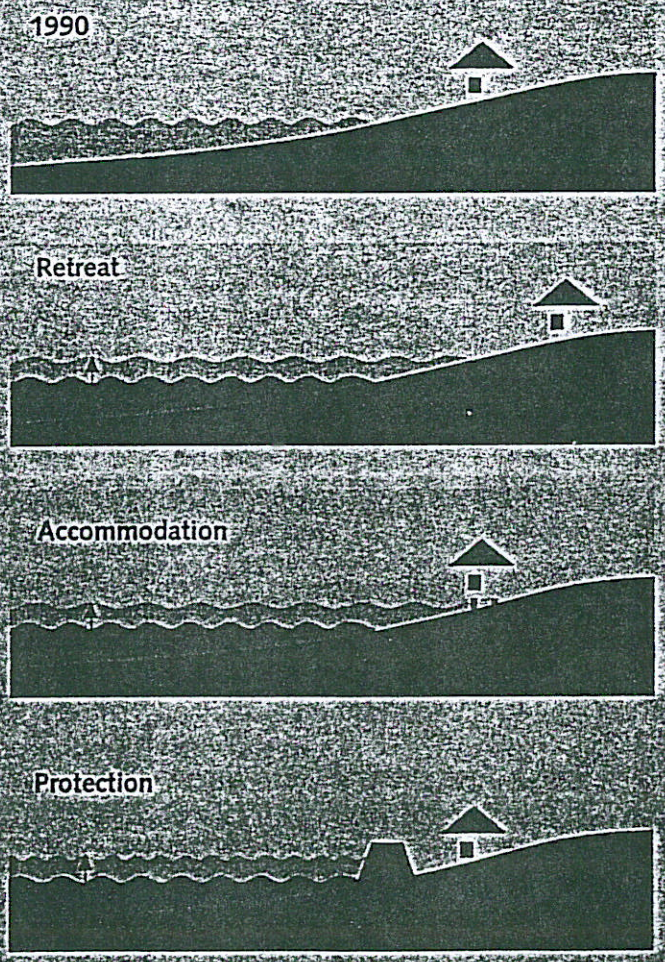
Received 10/10 at P.O. Discussed with Dr. Anh. OK. GT. 10/

APPENDIX D : Tables required by The Common Methodology

THE SEVEN STEPS TO THE

ASSESSMENT OF THE VULNERABILITY OF COASTAL AREAS TO SEA LEVEL RISE

A COMMON METHODOLOGY



Intergovernmental Panel on Climate Change
Response Strategies Working Group

Advisory Group on
Assessing Vulnerability to Sea Level Rise
and Coastal Zone Management

20 September 1991
Revision no. 1

TABLE 1 BOUNDARY CONDITIONS RELATED TO SEA LEVEL RISE AND CLIMATE CHANGE

BOUNDARY CONDITIONS	UNITS	ASLR1	ASLR2	UNFAVORABLE
Accelerated Sea Level Rise				
sea level increase 2100	m	0.3	1.0	1.0
maximum rate of change	mm/yr	3.5	15	15
Possible other conditions				
increase in storms	%	-	-	10
increase in peak river discharge	%	-	-	10
change in temperature	^{o}C	-	-	+4
change in precipitation	% or mm	-	-	+10%
change in evaporation	% or mm	-	-	+15%

Note 'Possible other boundary' conditions can be combined in an unfavorable set. This in order to investigate the sensitivity of a coastal area to such changes. Regional information concerning these conditions are not yet available. The in this table proposed default values, were used for the case study the Netherlands.

TABLE 2A NATURAL SYSTEM DATA: PHYSICAL CHARACTERISTICS

TYPE OF DATA	UNITS	DATA VALUE
Natural coast types		
flat/sandy (beaches/dunes)	km	
flat/mud (salt marshes, mangrove swamps)	km	
cliff soft	km	
cliff hard	km	
glaciated/periglaciated	km	
lagoon/spit	km	
barrier coast	km	
estuarine/delta	km	
coral reefs	km	
Artificial coast types		
sea dikes/sea walls	km	
river dikes/revetments	km	
detached breakwaters/groynes	km	
other	km	
Local subsidence at different locations		
natural subsidence	mm/yr	
man induced subsidence	mm/yr	
Design water level at different locations	m	
Flood prone area (area flooded at design water levels)	km^2	
Average tidal range	m	
Seasonal fluctuation mean sea level	m	
Annual average wave climate at different locations (Hsig, for morphological aspects)	m	
Design wave height at different locations (Hsig, for structural aspects)	m	
Average annual sediment load rivers	tons/yr	
Average annual river discharge	m^3/s	
Peak discharge (1 in 100 years)	m^3/s	
Area with (potential) salinity problems	km^2	

TABLE 2B NATURAL SYSTEM DATA: HABITATS AND SPECIES

TYPE OF DATA	UNITS	DATA VALUE	
		NATION	STUDY AREA
o Mangroves - area - biodiversity - red data book species (endangered/vulnerable/rare)	km^2 # species/km^2 # of species		
Same information for other habitats, e.g. o lagoons and barrier seas o coral reefs o sea grass beds o salt marshes o dunes o intertidal flats o fresh water swamps o peat dones	same as above		
(All above information for different impact zones)			
o Total 'ecological' area o Total 'special' ecological area	km^2 km^2		

TABLE 2C SOCIO-ECONOMIC SYSTEM DATA: GENERAL INFORMATION

TYPE OF DATA	UNITS	DATA VALUE	
		NATION	STUDY AREA
Gross Domestic Product	lc		
Population	# people		
Population distribution in study area			
- impact zone I	# people		
- impact zone II	# people		
- impact zone III	# people		
- etc.			
Subsistence population	# people		
Capital value	lc		
Agriculture area	km^2		
Recent average growth rates:			
- GDP	%/yr		
- Capital value	%/yr		
- Population	%/yr		

lc = local currency (year)

TABLE 2D SOCIO-ECONOMIC SYSTEM DATA: USES AND VALUES

TYPE OF DATA	UNITS	DATA VALUE
Land use - production		
- Agriculture area		
. high intensity (e.g. irrigated)	km^2	
. low intensity (e.g. rainfed)	km^2	
Same for aquaculture, fisheries, forestry, mining, industry, urban, recreation area, insofar these areas have a production or capital value		
Land use - subsistence		
- Agriculture area		
. high intensity	km^2	
. low intensity	km^2	
Same for aquaculture, fisheries, forestry, wetland, mangrove area insofar these areas have a subsistence value		
(All above information for different impact zones)		
Production or capital value		
- Agriculture area		
. high intensity	lc/km^2	
. low intensity	lc/km^2	
Same for aquaculture, fisheries, forestry, mining, industry, urban, recreation area, insofar these areas have a production or capital value		
Subsistence value		
- Agriculture area		
. high intensity	pe/km^2	
. low intensity	pe/km^2	
Same for aquaculture, fisheries, forestry, wetland, mangrove area insofar these areas have a subsistence value		

lc = local currency

pe = # people

TABLE 3 PHYSICAL EFFECTS AND NATURAL SYSTEM RESPONSES

TYPE OF EFFECT/RESPONSE	UNITS	NO ASLR	ASLR1	ASLR2
PHYSICAL EFFECTS				
Shoreline development				
- erosion	m/yr			
- accretion	m/yr			
Water levels and frequencies of exceedance				
- sea/estuary	m			
- river system	m			
- groundwater	m			
Salinity				
- salt wedge penetration tidal rivers	km			
- seepage rate	m/yr			
- seepage salinity	ppm			
NATURAL SYSTEM RESPONSES				
Areas lost				
- Production areas:				
. agriculture - low intensity	km^2			
. agriculture - high intensity	km^2			
Same for aquaculture, fisheries, forestry, mining, industry, urban, recreation, etc.				
- Subsistence areas:				
. agriculture - low intensity	km^2			
. agriculture - high intensity	km^2			
Same for aquaculture, fisheries, forestry, wetland, mangroves, etc.				
- Habitats:				
. lagoons and barrier seas	km^2			
. coral reefs	km^2			
. intertidal area	km^2			
. salt marshes	km^2			
. mangroves	km^2			
. etc.				
Flooding frequency (for different impact zones)	yr^{-1}			
Water resources situation (for different impact zones)				
- drainage rates	m/yr			
- salinity drainage water	ppm			
- salinity irrigation water	ppm			
- fresh water availability	Mm^3/yr			

TABLE 4 RESPONSE STRATEGIES: SPECIFICATIONS AND COSTS

TYPE OF STRATEGY	UNITS	ASLR1	ASLR2
Retreat (R)			
- people transferred to other locations	#		
. within/outside study area	% - %		
- GDP transferred to other locations	lc		
. within/outside study area	% - %		
- area substituted	km^2		
. within/outside study area	% - %		
- opportunity cost 'new' area	lc		
- capital investment substitute areas	lc		
- cost of replacement	lc		
Accommodation (A)			
- adaptation cost existing infrastructure (e.g. water intakes, drainage and pumping facilities, drinking and waste water treatment plants)	lc		
- incremental cost of operation (e.g. pumping cost, treatment cost)	lc/yr		
- area of land to be elevated	km^2		
- cost of land elevation	lc/km^2		
- cost of adaptation production activities	lc		
- production losses of adaptation (e.g. agriculture to fisheries, industry or tourism)	lc/yr		
Protection (P)			
- length of dikes and sea walls (new and adapted)	km		
- costs of dikes and sea walls	lc/km		
- volume of beach nourishment	Mm^3/yr		
- costs of beach nourishment	lc/Mm^3		
- length of coast protected with breakwaters (new and adapted)	km		
- costs of breakwaters	lc		

lc = local currency (year)