GEOTECHNICAL CHARACTERISTICS OF HOLOCENE SEDIMENTS WITH REFERENCE TO GEOHAZARDS IN KIEN AN – DO SON, HAI PHONG COASTAL ZONE

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ABSTRACT: In recent years, after renovation policy launched by the Vietnamese government, the economy of Kien An – Do Son, Hai Phong coastal zone in Northern Vietnam has quickly changed with high income and fast economical grow rate. Unfortunately, together with the fast economical development, the environment in many areas has been severely damaged. In addition, the climate change also increases geohazards especially flooding, storms surges, sea level rise, salt intrusion ... causing the losses of human lives and properties to people living in this very sensitive zone. Basing on the results obtained in the recent site investigation and laboratory tests, the main geohazards recorded such as coastal and river bank erosion, salt intrusion… are studied and disscused in detail from geotechnical point of view. The results of this study help to propose the suitable longterm remedial measures to mitigate the hazards for the sustainable development of this coastal zone.

INTRODUCTION

Kien An – Do Son region is located in the Southwest of Hai Phong city - one of the most important seaports of Vietnam, about 100 km east of Hanoi city. Both Kien An and Do Son had newly become the main districts of Hai Phong city instead of small towns of the suburban districts (Fig. 1).

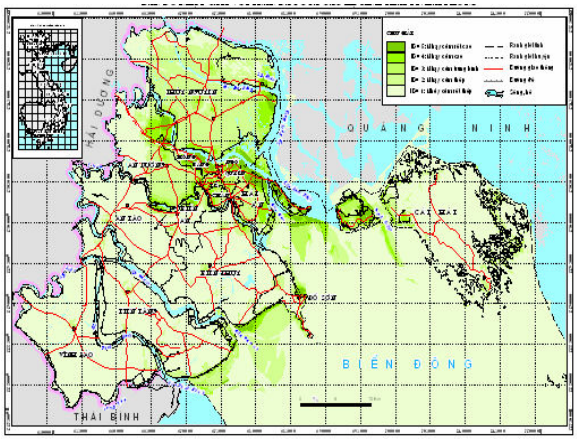

Figure 1 Location of the study area

Do Son, Hai Phong is one of important doors attracting foreign investment in Northern Vietnam having many industrial zones. Besides, it is also a dynamic center for tourism, aquaculture… so that this region has conflicts between socio-economical development and environmental protection. Each year it faces with about 4-5 typhoons causing great losses, even deadths for the habitants.

BACKGROUND ON NATURAL & GEOLOGICAL CHARACTERISTICS OF THE STUDY AREA

Geographical condition

Locating in the NE of the Red River Delta (RRD), the study area is comprised of 4 main types of relief: karst, remained low hill, plain and coastal mangrove land with the area of about 500 km^2.

Differentiated terrain with the gradual decrease in height in SE direction:

- Karst terrain: mainly distributed in Nui Voi with the elevation varying from 10 ÷ 300m, the plant cover is not regularly distributed.
- Remained low hill terrain is scatteredly distributed in Kien An with NE-SW orientation and comprising terrigenous sediments. The elevation is varying from 15 ÷ 140m. In Do Son this type of terrain also develops in Van Hoa, Nui Thap and Choi Mong jointed in range with the NW-SE orientation.
- Plain terrain is widely distributed in the South and the Southeast parts with elevation varying from 0.8 ÷ 1.2m. Composition is mainly clayey sand, silty clay of alluvial origin.

Climate in Hai Phong is of tropical – humid characters with high influence of the sea. The climate is sharply divided into two seasons: summer and winter. Summer is usually hot and humid, with lot of showers lasting from May to October (80-90% of the annual rainfall). Winter is cold lasting from November to April of the next year. Annual rainfall is 1600-1800mm. High humidity (85-86%).

Hai Phong is located in the area of frequently occurred storms and cyclones. There are 45 days of strong wind or storms during a year. Besides, mild drizzles and frogs are frequently occurred.

Hydrological conditions

All big rivers in Hai Phong are distributaries of Thai Binh river system which are flowing NW-SE with high meandering and wide sandbars. Main rivers are Bach Dang, Cam, Lach Tray, Van Uc, Hoa, Han and Thai Binh. The distributaries are Tam Bac, Da Do, Da Bach. Averagely, at distance of 20 km along the coast there is an river mouth flowing into the sea.

The river discharge is not equally distributed during the year round. The flooding season contains 75-85% of discharge volume (mainly in June, August and September) meanwhile the dry season contains only 15-25% (lowest discharge in March containing only 1%). The big volume of mud and sand carried during flood season makes the quick siltation in the harbors and high turbidity of seawater in all Do Son beaches.

Geological conditions

The Quaternary sediments overlying uncomfortably the Neogene deposits are composed mainly of sand and gravels, sometime with lenses of silt and clay. The sediments are thicker towards the sea, reaching up to 200m in thickness in the coastal area. The uppermost Quaternary sediments consist of four formations: Le Chi, Vinh Phuc, Hai Hung and Thai Binh .

Le Chi Formation consists of gravel, fine to medium sand and silty clay. Vinh Phuc Formation is composed of an upward fining succession of gravel and clay; Hai Hung Formation composed mainly of sand. Finally, the Thai Binh Formation is composed of an upward- fining unit of gravel, sand and clay. So that the coastal zone of the RRD is considered as propagating coastal system formed mainly as a result of river sediment supply.

The Holocene marine terraces are between 3 and 5m above mean sea level (MSL) and the coastal lowland area located seaward from that terrace is predominantly lower than 3m (Nghi et al., 2000). The coastline is always drowned in comparing with the continuous sea level rise of about 80m during the last 10,000 years.

Climatic condition

This study mainly focuses in geotechnical characteristics of two upper geological formations namely Hai Hung and Thai Binh.

General geotechnical characteristics

Geotechnical characteristics of typical soils in Holocene formations can be described as follows:

Fill materials (anQ_2)

The thickness of this type of sediments is 0.5-2.0 m comprising mainly sand, clayey sand, clay mixed with waste construction materials.

Alluvial-swamp sediments of Late Holocene, Upper Thai Binh formation ($abQ_2^3tb_2$)

These sediments are not widely distributed along small rivers and usually submerged with the thickness of around 1-3m. Composition is mainly clayey mud, clayey mud containing organics of dark grey or li-grey in color.

Alluvial-marine-swamp sediments of Late Holocene, Upper Thai Binh formation ($ambQ_2^3tb_3$)

Composition is clayey mud, silty-sandy mud of brownish grey containing organics, distributing in Lach Tray, Van Uc river mouths. Consistency is very soft to medium (B= 0.54-1.4), Bearing capacity is varying from 0.5-0.7 Kg/cm^2 (top part) to 1.7-1.8 Kg/cm^2 (bottom part).

Marine sediments of Early-Middle Holocene, Upper Thai Binh Formation ($aQ_2^3tb_3$)

Distributed in narrow range from Do Son to Van Uc, around Thai Binh river mouths. Composition is silty sand of grey color. Consistency is medium stiff (B = 0.65), Bearing capacity is of 2.2 Kg/cm^2.

Alluvial sediments of Late Holocene, Middle Thai Binh Formation ($aQ_2^3tb_2$)

This type of sediment is widely distributed along Van Uc, Thai Binh, Hoa rivers. Composition is mainly silty sand, silty clay of brown color, very soft. Void ratio is about 1.02-1.43, high compressibility with coefficient of compression a = 0.078 -0.026 cm^2/kg.

Alluvial-marine sediments of Late Holocene, Lower Thai Binh Formation ($amQ_2^3tb_1$)

Sediment composition is silty clay, silty sand of brownish and dark grey. It is widerly distributed in Thuy Nguyen, An Hai, Vinh Bao and inner Hai Phong. Thickness is around 17m.

Marine sediments of Late Holocene, Lower Thai Binh Formation (mQ_2^3 tb_1)

Sediment composition is mainly sand, silty sand of yellow, brownish yellow and brownish grey containing shell fragments. Thickness is around 2.6 m.

Alluvial sediment of Early-Middle Holocene, Lower Thai Binh Formation (mbQ_2^{1-2} hh_1)

The sediment is not seen on the surface but can be observed in boreholes with maximum thickness of 24m. Composition muddy sand, sandy mud containing organics, low consistency. Bearing capacity is 0.5 kg/cm^2.

Marine sediments of Early-Middle Holocene, Upper Hai Hung Formation (mQ_2^{1-2} hh_2)

Outcrop of these sediments were observed in An Hai, North of Thuy Nguyen, in the periphery of Phu Dien hill range and in boreholes at depths. Thickness is varying from 1-16.6m (2-2.5m in average). Sediment composition is silty sand, silty - clayey sand.

Geotechnical characteristics of some surface Late Holocene sediments can be seen in Table 1.

Table 1 Geotechnical characteristics of surface soils

No.	Properties		Sym-bol	Unit	Holocene formation & their typical soils			
					Silty clay ($mbQ_2^{1-2}hh_1$)	Clay ($mQ_2^{1-2}hh_2$)	Clayey silt ($amQ_2^3tb_1$)	Silty clay ($ambQ_2^3tb_2$)
1	Component	Sand		%	26,8	16,6	13,2	19,3
2		Silt		%	50,4	49,6	52,2	56,3
3		Clay		%	22,8	33,7	34,6	24,4
4	Water content		W	%	43,6	33,7	50,7	39,0
5	Unit weight		γ	g/cm^3	1,74	1,85	1,85	1,81
6	Dry unit weight		γ_C	g/cm^3	1,21	1,38	1,23	1,30
7	Specific gravity		Δ	g/cm^3	2,71	2,7	2,73	2,75
8	Void ratio		e	-	0,90	0,95	1,50	0,95
9	Porocity		n	%	52,3	48,8	59	54,6
10	Degree of Saturation		S	%	92,5	95,0	95	92
11	Liquid limit		W_L	%	34,6	40,4	44,3	35
12	Plastic limit		W_P	%	22,1	22,0	25	20
13	Plasticity index		I_P	%	12,4	18,4	19,7	14,4
14	Liquidity index		B	-	1,8	0,64	1,3	1,3
15	Cohesion		c	Kg/cm^2	0,054	0,13	0,059	0,06
16	Internal friction angle		φ	Degree	9^0	9^0	3^0	8^0
17	Coeff. of compresision		a_{1-2}	cm^2/Kg	0,09	0,073	0,09	0,057
18	Bearing capacity		R_0	Kg/cm^2	0,5	2,0	0,4	0,6

of Late Holocene formations in Hai Phong area

Generalized soil profile

Soil profile with variation of index properties of the soils against depths at the site of Van Huong high-grade villa are shown in Figure 2. It can be divided into 4 layers in a 18 m depth borehole:

i) *Fill* is characterized by sandy clay with gravel and broken brick. The layer is ranged from the ground surface to the depth of 2m.

ii) *Silty clay layer (CL),* soft to medium extends from the depth 2m to 7.5m. It is li-grey to dark grey colour with low plasticity. The water content is in range between 34% and 40%. The liquid limit (LL) is between 23% and 41%. In this layer, some organic matters are found.

iii) *Clay layer (CH)* of soft to medium consistency locates from the depth 7.5m to 12m. It is brownish gray colour to li-grey, grey colour with high plasticity. The water content is in the range of 40% to 52%, the LL is of 50% to 61%.

iv) *Clay layer* (CH) of medium stiff consistency is found at the depth about 12m and extend to 18m until the end of borehole. The soil is greyish brown in colour and high plastic. The water contend is in range of 40% to 50%, the LL is 55% to 65%. However there are some lenses of fine sand within this layer.

According to the authors, the age of the clay is estimated 20,000 - 40,000 years by using carbon isotope ^{14}C dating.

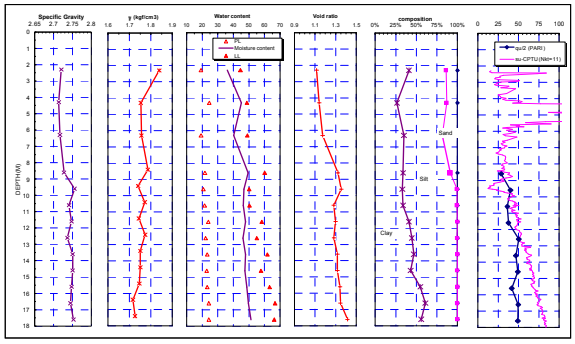

Figure 2 Generalized soil profile and physical properties in Van Hương, Do Son, Hai Phong area.

Note: Layer 1 *(0-2m):* Fill,
Layer 2 *(2-7.5m):* Soft to medium silty clay (CL),
Layer 3 *(7.5-12m):* Soft to medium clay (CH),
Layer 4 *(12-18m):* Medium stiff clay (CH)

GEOLOGICAL HAZARDS

Coastal erosion

The Northeast coast of Do Son had the average erosion speed of 5-14 m/year (Dinh Vu- Bach Dang and along road No.14. In Bach Dang mouth area, within 60 years (1936-1996) an amount of 1055 ha of agricultural land with vegetation cover and 2844 ha without vegetation cover were lost. The evarage erosion rate for three beaches in Do Son was varying from 0.36 – 0.45 m/year [1], causing great loss to the infrastructure and sea dyke system (photos 1 & 2). This hazard could be particularly exaggerated by storm with high SWL rise (photos 4 & 5).

The average rate and width of erosion can be seen in Table 2.

Table 2 Average rate and width of erosion at Bach Dang estuary and Do Son beaches

No.	Area	Average erosion rate (m/ yaer)	The width of erosion area during 50 years (m)
1	Dinh Vu	0,8	40
2	Beach 1-Do Son	0,45	22.5
3	Beach 2-Do Son	0,36	18
4	Beach 3-Do Son	0,40	20

Photo 1 Sea dyke in Ward 2, Ngoc Hai Commune, Do Son – Hai Phong under erosion.

The Southwest part of the study area is highly productive in rice cultivation and with a high population density for a predominant rural community. The human activities such as: shrimp and fish pond digging, sand exploitation, excavation with a large filling material volume, mangrove three cutting...not only influence geodynamic proccesses but also all natural conditions. At some places the shrimp ponds were digged closely to the dyke embankment. This could lead to severe damage to the dyke embankment.

Photo 2 Dong Hai fishery port under threat of erosion.

This erosion situation will be particularly vulnerable in the event of accelerated sea level rise.

Salinity intrusion

Salinity intrusion in the coastal zone is increasing due to fresh water extraction for irrigation and drinking water and due to the dam constructions in the catchments. Accelerated rate of the sea level rise also causes a higher penetration of saline water into rivers as well as into the ground water system.

The inland extend of salinity intrusion (1 $^{0}/_{00}$ and 4 $^{0}/_{00}$) in the river system varies from Bach Dang to Thai Binh rivers (Table 3).

Table 3 Distance of salinity intrusion from river mount (km). (Ca V.T., 1989) [1].

River mouth (km)	Maximum ($1^{0}/_{00}$)	Maximum ($4^{0}/_{00}$)	Average ($1^{0}/_{00}$)	Average ($4^{0}/_{00}$)	Minimum
Bach Dang	35-40	30	25-30	20	-
Van Uc	28	20	18	8	1
Thai Binh	26	25	15	5	1

After the Hoa Binh reservoir operation, the 4 0/00 boundaries has retreated 5-10 km from the shore line. It is noted that for agricultural crops, damage occurs above 1g/l (or 1 $^{0}/_{00}$) and beyond 4g/l rice crops are not sustainable.

Salinity intrusion is the main cause for soil degradation in Do Son area. This comprises of two proccesses: the leaching of salt presented in the soils from their formation, not yet properly dissolved out becauce lying in lowland area and satl intrusion caused by infiltration into coarse grain sandy layer widely distributed at the depths of 80-120 cm and sometimes found even in the sub-surface (30-50 cm) layer.

Flooding

At present flooding is one of the hazards causing most negative influence to the socio-economical development in Vietnam, especially in areas of the most economically active such as Red River Delta (RRD) and Mekong Delta, causing great losses to human and their properties.

In the RRD provinces the flooding is most severe nowadays during storm surges that happen rather often (around 4-5 times/year) in the areas of coastal zones. Recent extreme flood occurred in the RRD in 1971 (approx.1 in a hundred years) broke RR dyke system in three locations and killed thousands of peoples and an area of about 25000 ha was flooded, 2.7 mill. persons had suffered from this severe flood hazard.

During the past 100 years, a number of 26 historical floods, predominantly rivers flooding were recorded in the RRD provinces. Most severe floods occur during occasions of high storm surges lifting the sea water level and inhibiting the discharge of high run-off from heavy rains downpours in the catchments areas.

Photo 3 Road in Do Son city was flooded during the storm No. 7 (September 2005).

In addition, in many locations of RRD the dykes are weaker and lower in comparing with their exceeding water levels. In the coastal zone, for preventing flooding from the sea due to sea dyke failure, a second line of sea dyke should be constricted behind the seaward dyke. Managed retreat strategies need to be applied for the most critical parts of the RRD coast. The estimation of the total annual budget for maintenance of sea and estuary dykes in the whole country is USD 1.54 millions.

Storm surges

From 1954 up to 1991 about 250 storm surges and cyclones landed or directly affected to many areas in Vietnam (Figs. 3). One fifth of these has arrived to the study area. Almost of the storms occurred during summer season (July-November) (Fig. 4).

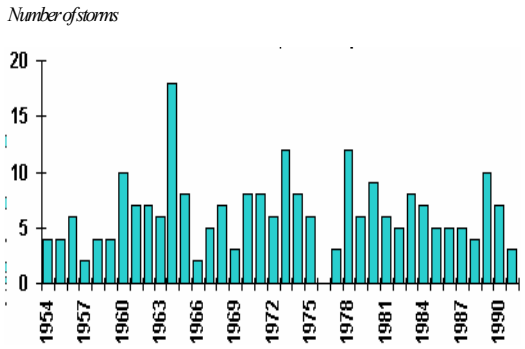

Figure 3 Number of storms enterred Vietnam coast per year (1954 -1991).

During storm surges the sea water level (SWL) raised more than 1m, among them 30% of storms raised the SWL more than 1,5 m and 11% of them raised the SWL more than 2,5 m. The area of 40 km wide from the seacoast could be severely affected. These kinds of storms also caused flooding and destruction to sea dyke system and infrastructure.

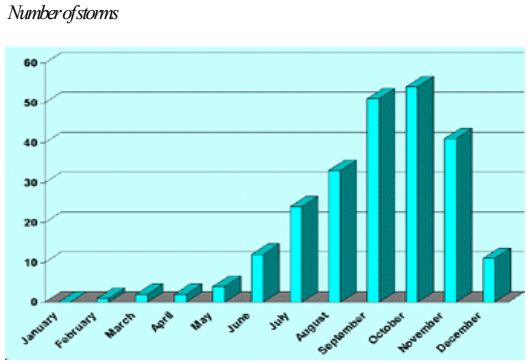

Figure 4 Number of storms vs. months in the years.

According the flash report of Do Son Economical Department many roads, pavement areas along the sea coast and beaches had been seriously destroyed by storm No. 7 (September 27, 2005). Sands from the sea were flown into the roads and residental areas. Agricultura crops have been lost of 300 hectars; 300 houses were flooded, 30 houses suffered blown up their roofs, hundred of hectars of aquaicultural lands were submerged... The sea dyke Do Son I has destroyed around 90 m^3 and Do Son II around 800 m^3 of their embankments. The loss of upto 17 billions VND was estimated only for area of Hai Phong city (Photos 3 to 6).

Photo 4 Sea dyke Do Son I during the storm No. 7, September 2005.

Photo 5 Tourism facilities and houses under threat during the storm No. 7, September 2005.

Photo 6 The destroyed infrastructure by Storm No. 7, September 2005.

Sea level rise (SLR)

The increased green house effect is making the earth warmer, with melting ice in two poles in addition and the over-exploitation of underground water in urban areas has raised sea levels.

According to senario 1 (ASLRT1) of Vietnam Coastal Zone Vulnerability Assessment (CVCZVA, 1996) with 1m sea level rise and no additional protection measures about 40.000 km^2 of coastal zone of Vietnam will be subject to annual flooding. About 10% of lands in the Kien An – Do Son, Hai Phong coastal zone could be partially or almost completely affected.

According to the research of scientists announced recently in the Workshop on "Climate change issues and management of tourism development of urban coastal areas" organised in Do Son from 4-6 January 2008, speed of climate change in our country is increasing. In 40 years, average temperature in Vietnam has increased 0.6^0 C in 20 years and sea level has to rise in 6cm more; storms more powerful and strength, rain becomes stronger with more water, the cycle of drought and heat longer than in the last decades… .

Forecast to the year 2070, temperatures in the North will increase 2-4^0C, in the South will increase 2-3^0C. By the year of 2050 the sea level will rise 33cm more and in 2070 will increase more than 50cm. This is a great risk for the coastal provinces of Vietnam.

However, SLR is not the sudden change but a gradual proccess lasting over time and space. Therefore the approach should be gradual and in asymptote of ecological environment, adapting to cope with the changes of nature. Engineering and non-engineering solutions to the changes must be built flexibly in accordance with the gradual increase of the rasing in sea water level. It is neccessary for basic research of hydraulic, physical, environmental conditions, climate, promoting the research and development of sloping land... to reduce the negative impact if any.

One of the projects in the strengthening, protection and upgrading of the sea dyke systems available from Quang Ninh to Quang Nam is "Strengthening, protecting and upgrading the Sea Dyke Line No. II in Kien Thuy and Do Son districts, Hai Phong" with total investment of over 104 billion VND, invested by the Department of Agriculture and Rural Development. The project was implemented with the goal of strengthening and upgrade more than 10km in the sea dyke line No. II for preventing salinity intrusion, high tides and ensuring the dyke will be safe at the designed level. This project is under progress during 2008-2010.

Earthquake hazards

The study area is situated in Red river deep fault zone stretching along Red River from Vietnam-China border to the Eastern Sea with total length of more than 600km. According to geophysical studies, the Red river zone is still activated in the period of Quaternary- present with the right sliding movement of 4.5-5m in velocity and the NE part of RRD and still subsiding of average rate 2.mm/

year that's why Red River tectonic zone has the average stress-released equivalent with magnitude earthquake Ms= 4.5.

Although the study area is situated far from the most seismic activated region (Son La, Lai Chau) with Ms = 6-8, it is situated in a large basin filled with weak zone deposit (sand, silt, clay). Under this special condition earthquake can occur at distance of 500-600km from the source (epicenter region).

Then much of the destruction can be occurred due to significant amplification of earthquake ground motions by this thick soft soil deposits. The subsoil of Thai Binh Formation with various compositions from silty sand to sandy-clayey silt can also be easy to get into liquidified condition under the earthquake's vibrations.

The most effective measure for mitigating seismic risk in the urban area taken into account is to introduce the suitable design requirements for new, especially economically important construction such as high rise buildings, ports and sea dyke…. It is needed to adopt in Vietnam the seismic design requirements (codes and standards) as most quickly as possible.

Sea level change

Data recorded of 126 stations along the coastal zone in Vietnam show that, the sea level has raised averagely 1-2mm/year. According to different scenarios, the sea level will rise about 0.2-0.4m within the next 50 years and about 0.5-1.0m within the next 100 years.

According to ASLRT1 of CVCZVA (1996) with 1m sea level rise and no additional protection measures about 40.000 km^2 of coastal zone of Vietnam will be subject to annual flooding after sea level rise of 1m. About 10% of this land will be in the RRD provinces which will be almost completely insulated annually.

Environmental pollution and other problems

The coastal areas also cope with some kinds of pollutions such as: pollution sediment and water by heavy metals, lack of elements (iod), solid and water wastes, oil polution, threats ...

The hazards, pollution and threats mentioned above can lead to the following problems/impacts:

- Altered morphology of shorelines and loss of self-protection ability of the coast.
- Loss of landscapes and recreational value, resulting in reduction of benefits to coastal communities.
- Increase of negative impacts from natural disasters and environmental incidents/accidents.
- Over - and destructive exploitation of resources, leading to their exhaust and incapability to be renewable, seriously impacting to the economy and reducing job opportunities for community.
- Environmental pollution by domestic, industrial and aqua- cultural waste, and the waste from ships, leading to increased pollutants in the soil, air and water environment, and foods, threatening human health.

VULNERABILITY ASSESSMENT OF THE COASTAL ZONE OF KIEN AN-DO SON, HAI PHONG

Methodology

Vulnerability - the extent to which an individual, community, sub-group, structure, survice or geographic area is likely to be damaged or disrupted by the impact of a particular disaster hazard. (Kotze and Halloway, 1996). Later Cutter (2003) combined some factors that determined vulnerability between physical and social aspect suported aech other to create vulnerability (Fig. 5).

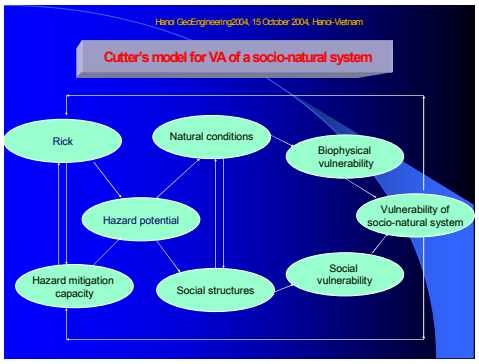

Figure 5 Cutter's model for vulnerability assessment (VA) of socio-natural system.

Steps for Vulnerability Assessment

For evaluating the vulnerable level of socio- natural system of coastal zone, a series of investigation points in the site have been established with grid of 1 km^2 and 4km^2 to 1: 50.000 and 1: 100.000 topographic map respectively, covering different areas with different characteristics of geological formations, topography, hydrogeology, and human activities, … Finally, the information collected from field study in combination with the collected data can be gathered in groups such as: i) type or category, ii) history of appearance, iii) intensity, iv) scale, v) signs and impact of the hazard with vulnerable socio-natural characters. Hazard mitigation activities applied for studying the current state and predicting the potential of losses caused by human activity in the area (irrigation, transportation, sea, and

mining, tourism activities...) (Nhuan M.T., Luyen D. V. et al., 2002).

Recognize the hazard type and calculate total points of risk level for each square:

$$DI_i = SH_i / SH_{tb} \quad (1)$$

In which:

DI i : dangerous level for each square,
SH i : total points of the i square , and
SHtb : average dangerous density for the whole region.

Basing on the points of single and integrated potential hazard, the zonation of risk caused by hazards along the Kien An – Do Son coastal zone can be done with 4 zones with the Dii values as follow:

DIi < 1 - Low risk potential
1 < DIi < 1.7 - Intermediate rick potential
1.7 < DIi < 3.4 - High risk potential
DIi > 3.4 - Very high risk potential

i) Zone of very high risk hazard potential composed of the areas stretching along the cost containing at least 4-6 types of disasters (erosion, salinity intrusion, storms, flood and the effect of SLR …) with DIi value > 3.4 such as part of coast from Ngoc Hai fish boats parking to Cua Cam river mouth including sea dyke Do Son I and areas of Bang La to Van Uc river mouth includes Bang La sea dyke.

ii) The high rick potential zone comprising areas from Dong Lo (Nortwest of Van Uc mouth) - Ha Sen – Nghia Phuong to Ngoc Hai port to stretching 10 km in length.

iii) The intermediate risk potential zone is distributed in the areas behind the sea dyke about 500-800m apart from sea coast.

iv) Zone of low risk potential hazard is mainly located in the areas of Do Son penisular and low to medium high hills in Kien An town's suburb areas including Nui Voi, Nui Xuan Son, Nui Phu Lien and Nui Cuu Vien.

Density zoning of vulnerable socio-natural objects

Based on Cutter's criteria (1996, 2000) and NOAA (1999) with the analysis results of the social object in the study area, 10 socio- natural vulnerable objects can be determined: 1- tourist sites, 2- port, 3- boat parking area, 4- petrol station, 5- salt field, 6- agricultural pond, 7- amount of boats and ships (in port, coastal and off shore), 9- national reserve park and 10- historical & cultural place of interest.

For zoning of vulnerable socio-natural objects, the following works need to be done:

- The vulnerable socio- natural objects in a certain area should be recognized and classified into different vulnerability level. These vulnerable objects are closesly related with impact and participation of the human such as tour places, ports, aquaculture ponds, factories…

- Counting points for vulnerable socio-natural objects in each square and combining with evaluation from expert on the study area.

Average density of vulnerable socio-natural objects (SOD_{tb}) can be calculated for the whole area with formula:

$$SOD_{tb} = \sum SODi / N_{(i=1,2,3...n)} \quad (2)$$

In which: SODi- point of vulnerable objects belonging to the square;
N - the number of square in the study area.

Basing on the density of vulnerable objects SODi (max) and SODi (average) could be identified and then the vulnerability of social objects was classified in 4 classes according to vulnerable social factors (VSF):

- low density of VSF: ≤ 2.5
- rather high density of VSF: 2.5 - 4.0
- high density of VSF: 4..0 – 6.0
- very high density of VSF. ≥ 6.0

Zonation and evaluation of vulnerable level for the socio-natural system can be conducted basing on the overlying combination and analysis of the above two component maps. In the coastal zone of Kien An and Do Son there are 3 sub-zones of different vulnerable degee (VD), including: sub-zone 1- high VD, sub-zone 2- intermediate VD, and sub-zone 3- low VD.

DISCUSSIONS AND RECOMMENDATIONS

Result of VA in study areas

The VA results allowed to divide the study areas into 3 sub-zones:

i) Sub-zone 1 – high vulnerable degree: the coastal areas from Ngoc Hai fish boats parking to Cua Cam river mouth including sea dyke Do Son I and as well as areas of Bang La to Van Uc river mouth.
ii) Sub-zone 2 - the areas from Dong Lo (Nortwest of Van Uc mouth) - Ha Sen - Nghia Phuong to the South of Kien An town streching 30km in length belong to the intermediate vulnerable degree.

iii) Finally, the last sub-zone with lowvulnerable degree is comprising the aquatic part, mostly areas with water depth of 20-30 m and rocky and sandy/silty clay hills: Ngoc Xuyen, Van Hoa (Do Son penisular) and low mountains such as Nui Voi, Nui Xuan Son, Nui Phu Lien and Nui Cuu Vien (suburb Kien An town).

For the sustainable development in this particular coastal zone the use of vulnerability assessment (VA) is very affective and necessary and the Government should formally approve VA as a beginning step towards Integrated Coastal Zone Management (ICZM).

The following are some short term and long term actions need to be taken in priority: i) to work on the strategy and action plan for ICZM for the pilot areas and for the whole country; ii) to improve the knowledge and understanding of local habitants on land and water resources in the coastal zone including posible conflicts through the development of coastal information system and decisions support systems and iii) strengthening capacities and facilities of govermental and non-govemental offices and organizations working on ICZM by internal or/and international cooperation funds.

CONCLUSIONS

1. The Holocene sediments in Kien An-Do Son area is comprising 4 Holocene formations such as Hanoi, Vinh Phuc, Hai Hung and Thai Binh with maximum thickness of 25-30m. Two upper layers contain mainly deposits of swamp, shalow marine or alluvial origins with mainly clay, silty clay or silty /clayey sand of grey or greyish brown of medium to high consistency with fine grain components varying from 73-87%.

2. The results of the investigation and the analysis show that the study region is possibly impacted by various types of geoenvironmental hazards including: i) coastal erosion, ii) salinity intrusion iii) storm surge & torpedo, iv) flood, v) earthquake, vi) sea level rise and vii) pollution threat like oil contamination and heavy metal pollution.

3. Zonation of risk caused by hazards is rather correspondant with that of social vulnerability factors. It shows that human activities have seriously affected to the natural environment. The use of VA as the first step towards ICZM is necessary, valuable and important in preparing Strategy and Action Plan for sustainable ICZM.

4. Based on the VA results, the most critical areas (with higest VD value) are comprised the coastal areas from Ngoc Hai fish boats port to Cua Cam river mouth, including Do Son I sea dyke and areas of Bang La to Van Uc river mouth which includes Bang La sea dyke.

5. Upgrading sea dyke and river dyke systems by raising 50 cm more in height towards 2020 to cope with sea level rise is likely a remedial measure but not most effective solution. The coast in the study area should be in good adaptation situation by planting mangrove forests. It was clearly seen that during the heavy storm (storm No. 7 in 2005 landing to RRD with intencity's level of 12), all sea dykes protected by mangrove forests were not broken, meanwhile solidified concrete dyke in Hai Hau facing direct wave had been completely destroyed.

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