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**TITLE:** Coastal Erosion Protection and Enhancing Sediment Deposition by  
Bamboo Wall at Samut Songkhram Province, Thailand

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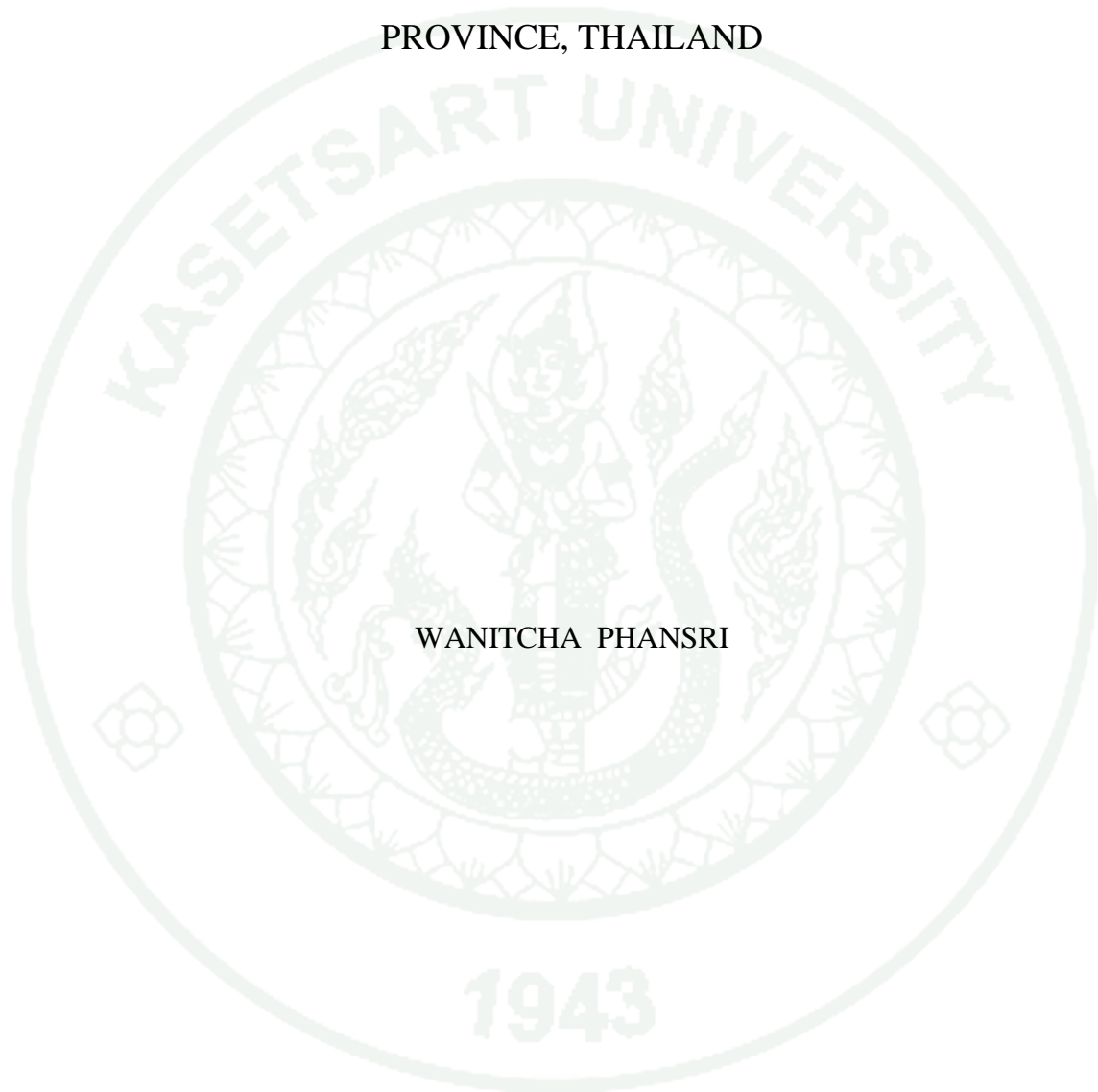
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THESIS

COASTAL EROSION PROTECTION AND ENHANCING SEDIMENT  
DEPOSITION BY BAMBOO WALL AT SAMUT SONGKHRAM  
PROVINCE, THAILAND



WANITCHA PHANSRI

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Wanitcha Phansri 2011: Coastal Erosion Protection and Enhancing Sediment Deposition by Bamboo Wall at Samut Songkhram Province, Thailand. Master of Science (Earth Science and Technology), Major Field: Earth Science and Technology, Department of Earth Science. Thesis Advisor: Associate Professor Veerasak Udomchoke, D.Tech.Sc. 87 pages.

This research aims to apply integrated knowledge for coastal erosion protection by using bamboo walls which function as barriers to decrease energy of the attenuated incident waves at Pak Klong Bang Bo, Samut Songkhram Province. The objectives of this research include factors that cause coastal erosion and sedimentation, the rate of sediment deposition and erosion at bamboo wall protected and unprotected area, and the properties of deposited sediments. Randomized samplings of the sediments were carried out, and then soil properties were analyzed in laboratory following the ASTM standards. Leveling telescope was used to assess the levels of sediment erosion and deposition during each wind direction. Wind speed and direction data were collected at 4, 7, and 10 m. Floating sonar platforms were installed at 10 m in front of and behind the bamboo wall in order to measure amplitude and period of the water waves. Data from protected and unprotected sites were analyzed and compared. The results revealed that the causes of erosion and sediment deposition are due to human activities on change from mangroves to shrimp farm, the softness of deposited sediments and strong winds that cause high water waves during monsoon season. It was shown that, during late Northeast to Southerly wind, the sediment was deposited while the bank was eroded during early Northeast wind and the coastal floor was eroded during Southwest wind. Bamboo walls can help damping the amplitude and, therefore, the energy of incident water waves. The soft sediment deposited behind the bamboo walls showed 156 to 199 in percent of water content and 10.4 to 11.8 kN m<sup>-3</sup> in unit weight that can also support the growth of young mangroves.

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Thesis Advisor's signature

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March 2011

**TABLE OF CONTENTS**

	<b>Page</b>
TABLE OF CONTENTS	i
LIST OF TABLES	ii
LIST OF FIGURES	iii
LIST OF ABBREVIATIONS	vii
INTRODUCTION	1
OBJECTIVES	2
LITERATURE REVIEW	3
MATERIALS AND METHODS	30
Materials	30
Methods	33
RESULTS AND DISCUSSION	44
CONCLUSION AND RECOMMENDATION	74
Conclusion	74
Recommendation	75
LITERATURE CITED	76
APPENDIX	82
CURRICULUM VITAE	87

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
1	Observed rate of sea level rise and eestimated of the various contributions of the present and past rates of sea level trend from different sources	19
2	ASTM Standard for laboratory test for soil properties	41
3	Water level, wave height, wave period and three level wind speed during strong northeast monsoon synoptic on December 17 <sup>th</sup> 2010	52
4	Area of landuse changed at 10 km from shoreline along Samut Songkhram coast in 2000 and 2007	57
5	Duration of measurement on sediments deposition and erosion at protected area by Bamboo wall	60
6	Amount and rate of sediment deposition and erosion at protected area by Bamboo wall	61
7	Duration of measurement on sediments deposition and erosion at no protected area	66
8	Amount and rate of sediment deposition and erosion at no protected area by Bamboo wall	66
9	Duration of measurement on sediments deposition and erosion at mangrove area	69
10	Amount and rate of sediment deposition and erosion at mangrove area by Bamboo wall	69
11	Properties of sediment deposited at Pak Klong Bang Bo, Samut Songkhram Province	73
<b>Appendix Table</b>		
1	Daily of wind speed at 4, 7 and 10 m respectively	83

## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
1	Subdivision of the coastal zones using both morphological and wave process terminology	3
2	Topography of the sea floor in the Gulf of Thailand	6
3	Contours depth in meters and four main rivers draining into the Inner Gulf of Thailand	7
4	Soil map of Coastline in the Gulf of Thailand	8
5	Local wind direction in each season at Samut Songkhram province	11
6	Monthly wind rose diagram at the navigation floating site, 10 km from the coast of Samut Songkhram Province	12
7	The current direction in The Gulf of Thailand influenced by the Southwest monsoon	14
8	The current direction in The Gulf of Thailand influenced by the Northeast monsoon	15
9	Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black)	20
10	Comparison of Milankovitch Cycles to stages of Pleistocene glaciation	22
11	The complex processes of coastal erosion and accretion	27
12	Coastal Protection measures	29
13	Flow chart of the method of study on coastal erosion protection and sediment enhancing by bamboo wall	34
14	Pak Klong Bang Bo, Samut Songkhram Province	35
15	Residential area that effected from coastal erosion at Ban Bang Kaew, Bang Bo district, Samut Songkram Province	36

## LIST OF FIGURES (Continued)

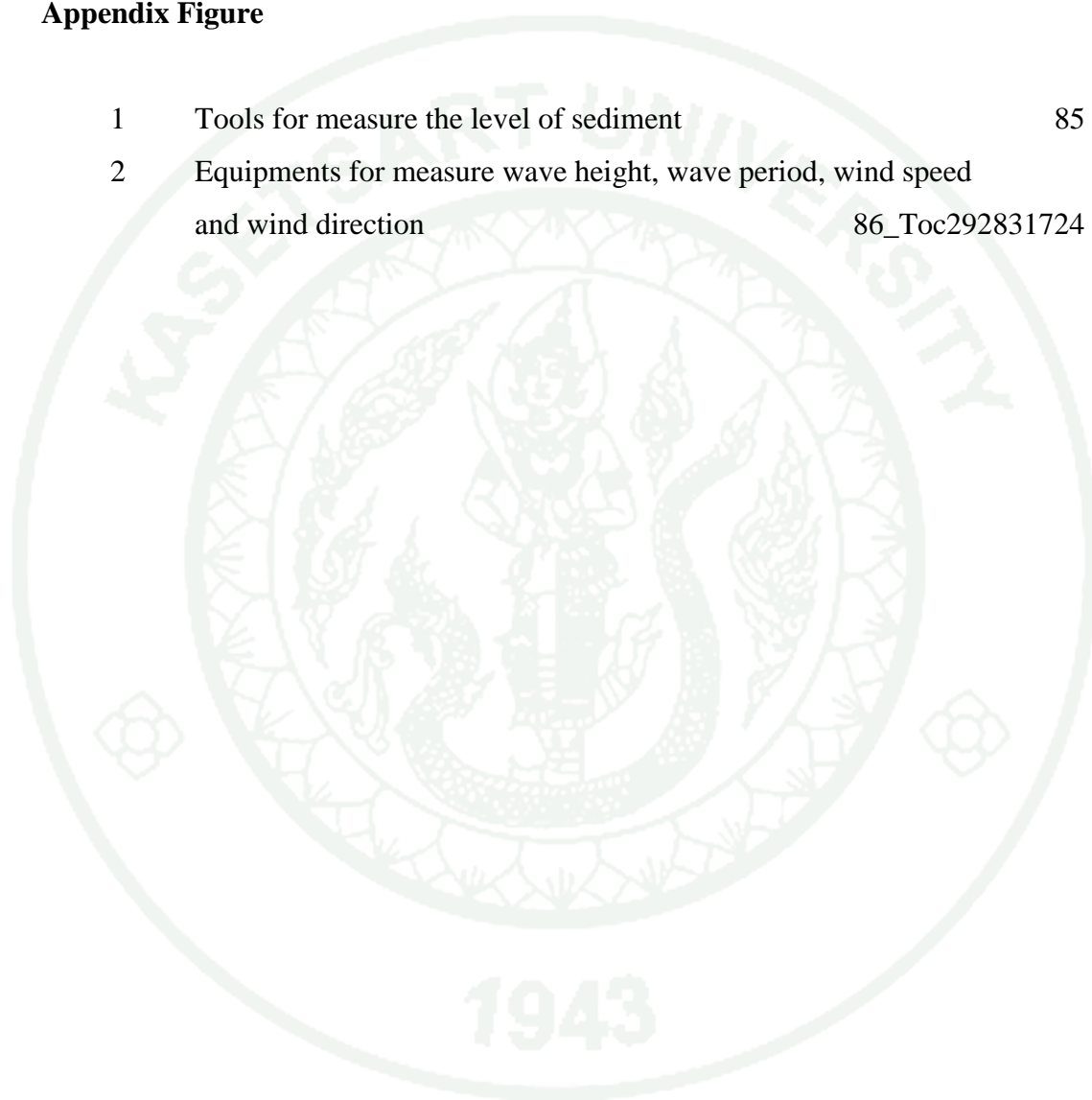
Figure		Page
16	Basic concept of use consecutive bamboo wall for coastal erosion protection then grow mangrove trees behind the wall	36
17	Three levels of wind speed and wind direction were measured at 4, 7 and 10 m from mean sea level	37
18	Floating sonar platform were installed in front of bamboo wall and behind the wall	38
19	Detail of installed floating sonar platform at behind the bamboo wall	39
20	Concept of significant wave height ( $H_{1/3}$ )	40
21	Sediment erosion and deposition measuring by leveling telescope	42
22	Soil sumping by soil cores for analyses in laboratory	42
23	Soil sampling by thin wall tube for analyses in laboratory	43
24	Monthly wind rose diagram at study area at 10 m MSL showed wind direction prevailing northeast during northeast monsoon season	46
25	Wind speed at level 4 m (MSL) during Northeast Monsoon Season from 6th November 2010 to 22nd January 2011	47
26	Wind speed at level 7 m (MSL) during Northeast Monsoon Season from 6th November 2010 to 22nd January 2011	48
27	Wind speed at level 10 m (MSL) during Northeast Monsoon Season from 6th November 2010 to 22nd January 2011	49
28	Significant wave height, $H_{1/3}$ (cm) at 10 m in front of bamboo wall and behind the bamboo wall during December 4 <sup>th</sup> , 2010 to January 22 <sup>nd</sup> , 2011	1
29	Distribution of wave number related to wave height at 10 m in front of Bamboo wall on December 17 <sup>th</sup> 2010	53
30	Distribution of wave number related to wave height at 10 m behind Bamboo wall on December 17 <sup>th</sup> 2010	54

## LIST OF FIGURES (Continued)

<b>Figure</b>		<b>Page</b>
31	Topographic map of Samut Songkhram Province at the estuary of Mae Klong River in 1968, 1991 and 2000 showed the reduction of mangrove areas due to shrimp farm increment over the tidal area and sediment	56
32	Satellite image of the Inner Gulf of Thailand in 2000 and 2007	58
33	Flow in and out of water from sea through culvert of shrimp farm caused mangrove trees tilted and toppled, then all lost and coastal eroded	59
34	Contours of measured sediments at Bamboo protected area during each period of prevailing wind direction	62
35	Contours of sediment erosion and deposition at Bamboo protected area during November 2009 to May 2010	63
36	Contours of sediment erosion and deposition at Bamboo protected area during May 2010 to October 2010	64
37	The deposition rate contour during October 2010 to December 2010	65
38	Contours of measured sediments at non protected area during each period of prevailing wind direction	67
39	Contours of sediment erosion and deposition at non protected area during 23 May 2010 to 5 Oct 2010 (top) and 5 Oct 2010 to 18 Dec 2010 (below)	68
40	Contours of measured sediments at mangrove area during each period of prevailing wind direction	70
41	Contours of sediment erosion and deposition at mangrove area during 23 May 2010 to 5 Oct 2010 (top) and 5 Oct 2010 to 18 Dec 2010 (below)	71

**LIST OF FIGURES (Continued)**

	<b>Page</b>
<b>Appendix Figure</b>	
1 Tools for measure the level of sediment	85
2 Equipments for measure wave height, wave period, wind speed and wind direction	86_Toc292831724



## LIST OF ABBREVIATIONS

$\mu\text{m}$	=	micrometer
40W	=	40 Watt
ASTM	=	American Society for Testing and Materials
$\text{cm yr}^{-1}$	=	centimeter per year
GB	=	Giga Byte
GIS	=	Geographic Information System
IPCC	=	Intergovernmental Panel on Climate Change
km	=	kilometer
$\text{km}^2$	=	square kilometer
$\text{kN m}^{-3}$	=	kilonewtons per cubic meter
LL	=	Liquid Limit
$\text{m s}^{-1}$	=	meter per second
$\text{m yr}^{-1}$	=	meter per year
m	=	meter
$\text{m}^2 \text{yr}^{-1}$	=	square kilometers per year
$\text{m}^2$	=	square kilometers
MH	=	High compressibility silt
ML	=	Low compressibility silt
mm	=	millimeter
MSL	=	Mean Sea Level
NM	=	Northeast Monsoon season
NRCT	=	Nation Research Council of Thailand
OH	=	High compressibility organic soil
OL	=	Low compressibility organic soil
PI	=	Plastic Index,
PL	=	Plastic Limit
SD	=	Secure Digital
SM	=	Southwest Monsoon season
SONAR	=	SOund Navigation And Ranging

# COASTAL EROSION PROTECTION AND ENHANCING SEDIMENT DEPOSITION BY BAMBOO WALL AT SAMUT SONGKHRAM PROVINCE, THAILAND

## INTRODUCTION

Coastal areas in Thailand, both along the Gulf of Thailand and the Andaman Sea, have long been confronted with erosion problems in 23 provinces, 485 km out of the 1,653 km coastline along the Gulf of Thailand and 114 km out of the 951 km along Andaman coast are in severe erosion (Department of Mineral Resources, 2007). Coastal erosion causes land lost and the deterioration of coastal resources. Based on recorded data from National Disaster Warning Center of Thailand, it was found that occurrence of coastal erosion is more frequent and severe especially at Ban Khun Samut Chin, Lham Fa Pha Subdistrict, Pra Samut Chadee District, the erosion could be greater than 25 meters per year (Kanparit, 2007 and Rattanamanee, 2008). The causes of coastal erosion are due to the flatness of coastal areas around the Gulf of Thailand, the softness of deposited sediment, human activities and strong waves during monsoon transition period.

The coastline protection measures can be carried out by understanding the transformations in natural phenomena of the coast, self-adaptation to live with dynamic natures, optimistic exploitation of the natural resource and research for the innovative measures to renovate the coastal erosion problem (Bennui *et al.*, 2008). This research aims to apply the integrated knowledge on coastline protection by using the rows of bamboo shoot which functions as breakwater to decrease the attenuated incident wave energy and it's mass for bearing the wave forces. This method would be a highly feasible option for coastal protection in tidal coast of Thailand. The study area was selected at the severely erosional coast, Bang Bo district, Samut Songkhram Province, Thailand.

## OBJECTIVES

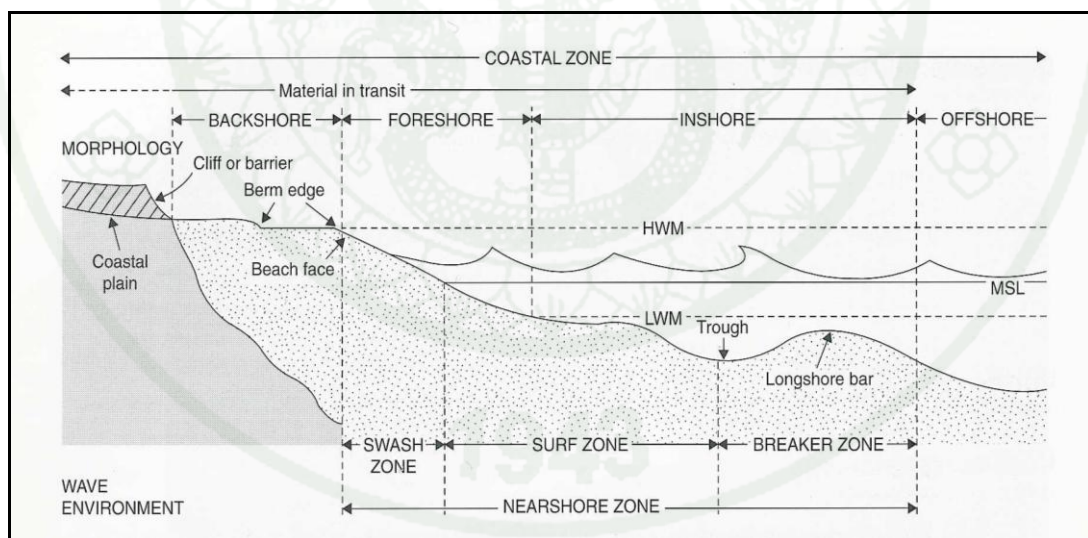
The target of this research aims to find out the measures to protect coastal erosion and enhance sediment deposition with the objectives as follows:

1. To study the factors that cause coastal erosion and coastal sedimentation at Bang Bo subdistrict, Samut Songkhram Province.
2. To study the rate of sediment deposition and erosion at protected and non-protected area by bamboo wall.
3. To study the properties of the deposited sediment in order to plant mangrove forests behind the bamboo wall.

## LITERATURE REVIEW

### 1. The Coast

The coast is simply defined as the place where the land finishes and sea began (Haslett, 2000). Similar, Carter (1988) defined that the coast is simply where land, water and air meet. This triple conjunction is further complicated by the fact that the water maybe fresh or salt water so the coast is best viewed as a zone of mix or adjustment. The coastal zone is the place where space with terrestrial environments influence on marine environments and vice versa. It is varies in width and may also change with time. Delimitation of zonal boundaries are difficult, more often such limits are marked by an environmental gradient or transition. The characteristic of coastal zones may be defined according to physical, biological or cultural criteria. The standard subdivision of the coastal zones is shown in Figure 1.



**Figure 1** Subdivision of the coastal zones using both morphological and wave process terminology.

**Source:** Haslett (2000)

One subdivides the coastal zone based on morphological changes such as backshore, foreshore, inshore and offshore, whilst the other is based on the types of wave processes that operated in different parts of the coastal zone such as swash zone, surf zone, and breaker zone which together comprise the nearshore zone (Haslett, 2000).

#### Morphological classification

- Backshore is the area of a shore that normally above the average high tide mark and the vegetation. The backshore is affected by waves only during severe storms.
- Foreshore is the area between high and low tide marks.
- Inshore is the area of sea near the coast.
- Offshore is the zone seaward of the breakers, but in which material is moved by the waves. The portion of the beach profile that extended seaward from the breaker zone to the edge of the continental shelf.

#### Wave processes classification

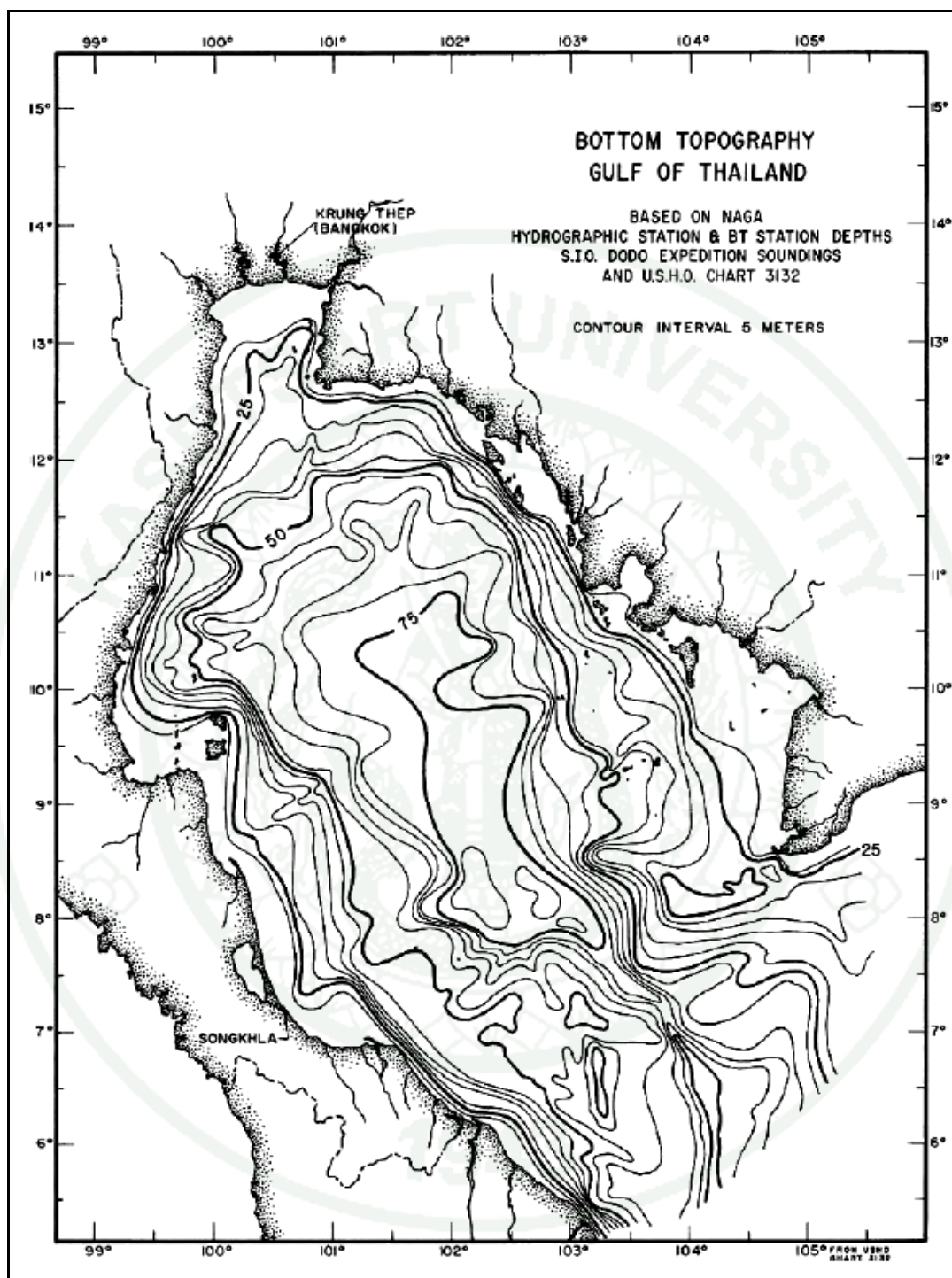
- Swash Zone is the nearshore area of the beach face that is intermittently covered by run-up of the wave swash and then exposed by the backwash. The zone of wave action on the beach, which moves as water levels vary, is extending from the limit of run-down to the limit of run-up.
- Surf Zone is the nearshore area in which bore-like waves occur following wave breaking. This portion of the nearshore extends from the inner breakers shoreward to the swash zone.
- Breaker Zone is the nearshore region where waves approaching the coastline become unstable and break (typically in water depths of between 5 and 10 meters).

## 2. General oceanographic characteristics in the Gulf of Thailand

The Gulf of Thailand was characterized as an area those integration of shallow water estuary with low salinity that has been diluted by fresh water from in land flowing to the gulf and deep water with high salinity and relatively cool water from the South China Sea. This high salinity water fills into the central depression at the depth of approximately 50 m as shown in Figure 2. Superimposed on this two-layered system shows a complex current circulation, those are driven by monsoon winds and tidal currents. The interplay of forces due to the variable winds, tidal currents, fresh water runoff and excessive precipitation gives rise to localized areas of divergence where low temperature, high salinity water, usually of low oxygen content, are upwelled. These forces also establish areas of convergence between high temperature, low salinity and highly oxygenated water sinks (Robinson, 1974).

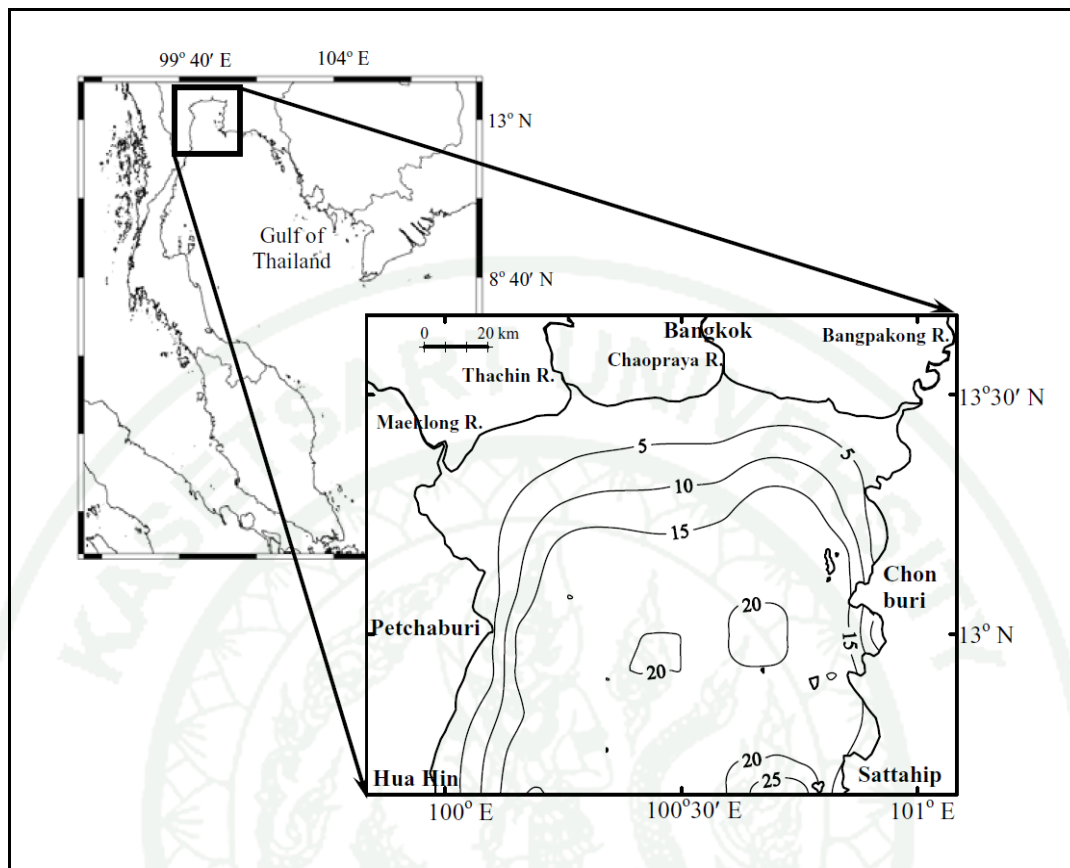
The Inner Gulf of Thailand has an approximate area of 104 km<sup>2</sup>, surrounded by land in all directions except in the south, which is open to the outer gulf and the averaged depth is 20 m. There are four main rivers draining into the head of the gulf namely the Bangpakong, the Chaopraya, the Thachin and the Maeklong from the east to the west, respectively (Buranpratheprat et al., 2006 and 2008) as shown in Figure 3.

Vongvisetsomjai (1992) quoted to Moormann and Rojanasoonthorn (1972) on the sediment deposited along the coast of the Gulf of Thailand that comprised of 5 majors: soil and landform units such as regosols, alluvial soils on recent marine alluvium, saline soil on recent marine alluvium, steepland of shallow Red - Yellow Podzolic, Residual Soils and steepland of Red - Brown Earths those weathered from limestone. Soil map of coastline in the Gulf of Thailand was shown in Figure 4.



**Figure 2** Topography of the sea floor in the Gulf of Thailand.

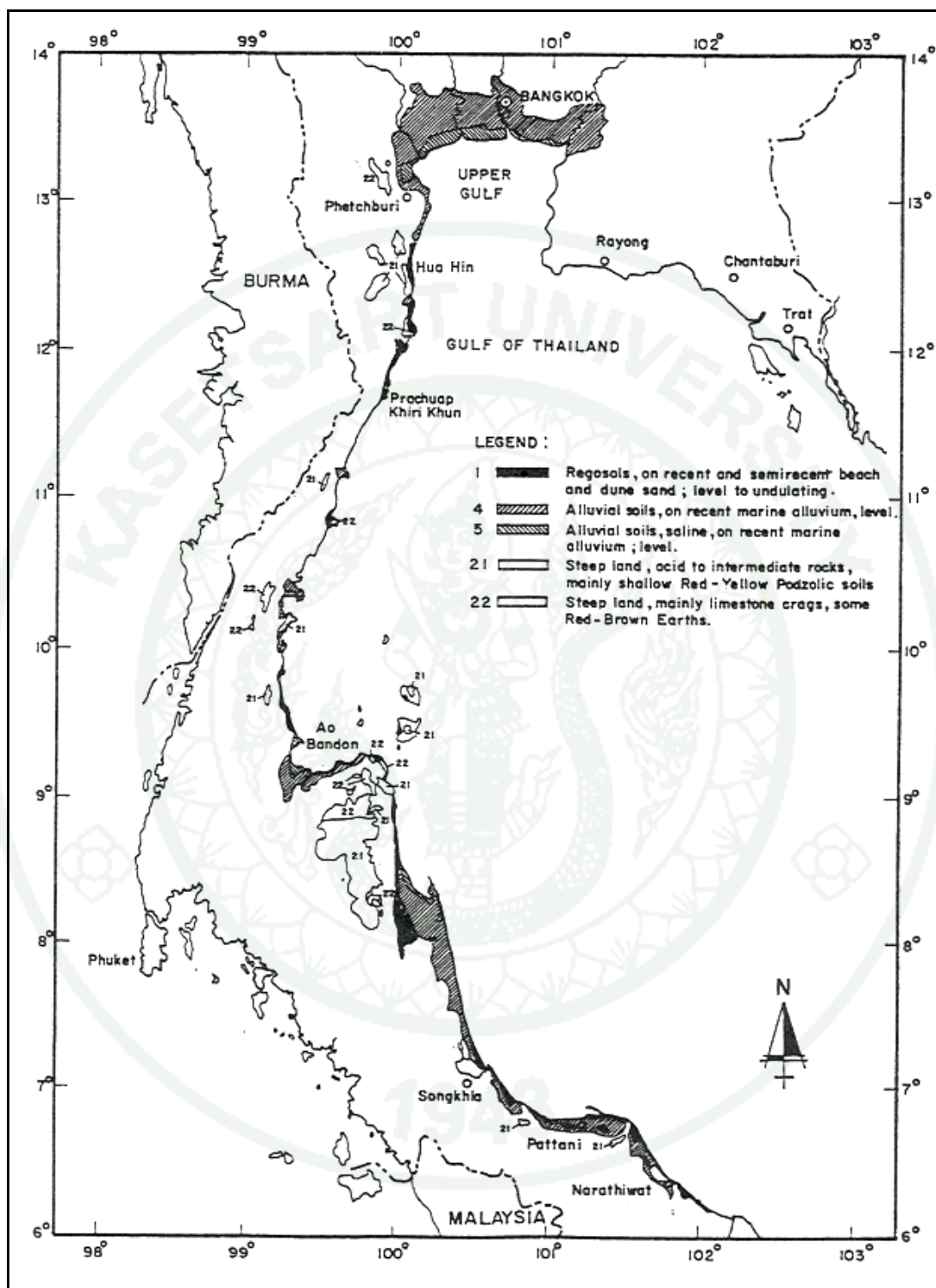
**Source:** Robinson (1974)



**Figure 3** Contours depth in meters and four main rivers draining into the Inner Gulf of Thailand.

**Source:** Buranprathprat *et al.* (2006)

1943



**Figure 4** Soil map of Coastline in the Gulf of Thailand.

**Source:** Vongvisessomjai (1992) refer to Moormann and Rojanasoonthorn (1972)

### A. Wind in the Gulf of Thailand

The wind climatologies, including both speed and direction, for localized coastal areas within this region are strongly influenced by the northeast and southwest monsoon circulation systems, tropical cyclones, land and sea breezes, frontal systems, mesoscale convective processes and topographical features (Traxler *et al.*, 1997).

Buranapratheprat (2002, 2006) revealed that the Gulf of Thailand is influenced by the reverse – monsoon system (the northeast and the southwest monsoons). The oceanographic conditions change seasonally due to variations in meteorological condition and prevailing wind.

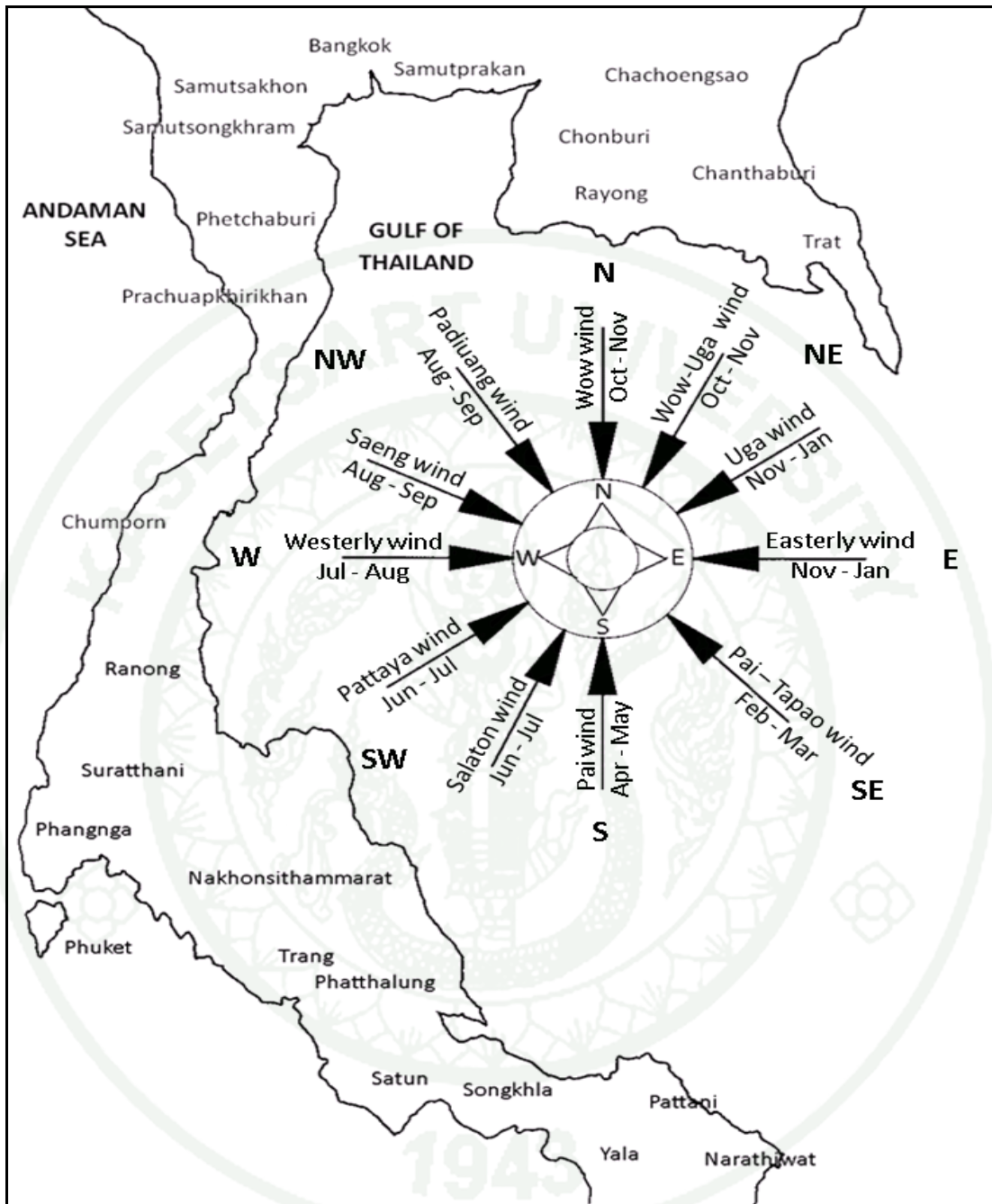
Prevailing winds over the upper gulf during the northeast monsoon are in the north and east directions during the early season, later becoming more variation and southerly. Winds speed during this season ranges between 4 to 8 knots. Wind directions vary more in the spring transition, but with approximately same speed. In the southwest monsoon season, the prevailing winds are more persistent from the south and west with wind speed range between 4 to 8 knots (Vongvisetsomjai *et al.*, 1996).

The southwest monsoon varies to some extent, but usually well establishes in May to September. These winds, having blown across the Indian Ocean and Bay of Bengal, come laden with moisture and brought moderate to heavy rain to Thailand. The southwest winds generate moderate wave along the eastern seaboard of the Gulf of Thailand. The prevailing of southwest winds direction of the Indian Ocean become more variable in speed and direction over Southeast Asian land and water. The dry season is under the influent of northeast monsoon which normally starts in November to February, but occasionally surges of the northeast monsoon may still be experienced in March or even in early April. The period is one of variable moderate winds over the Gulf and mild pleasant temperatures on land. The northeast monsoon winds blow across China and contain little moisture by the time they reach the coastal waters of South Viet Nam and the Gulf of Thailand. The northeast direction is steady

over the South China Sea but vary in the Gulf of Thailand (Vongvisetsomjai, 1992; Udomchoke *et al.*, 2008 and Buranapratheprat, 2008).

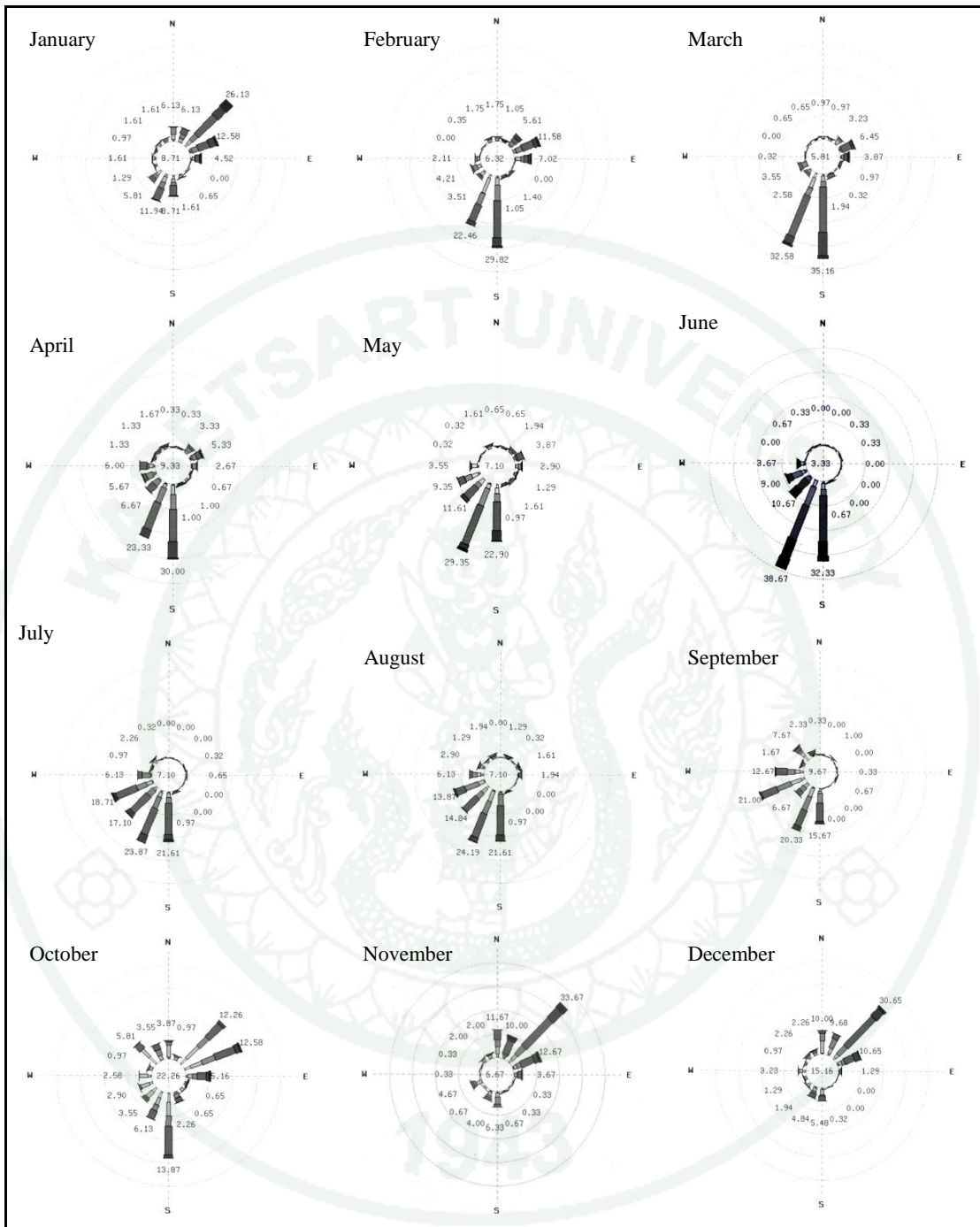
Chirawet (2008) stated that the wind directions by local wisdom in the Gulf of Thailand at Samut Songkhram Province are comprised of northerly wind and Southerly wind as shown in Figure 5.

Major wind directions as indicated from the monthly wind rose diagram at 10 kilometers from the coast of Samut Songkhram Province (Figure 6) are from South and Southwest during Southwest Monsoon season (SM) or rainy season (July to September), from South and Northeast during winter Inter Monsoonal season (October), from Northeast during November to January in early winter season Northeast Monsoon season (NM), then from South and South - Southwest with seldom the Northeast direction during February to April and change to the South and Southwest direction in May and June (Meteorological Department, 2010).



**Figure 5** Local wind direction in each season at Samut Songkhram province.

**Source:** Modified from Chirawet (2008)



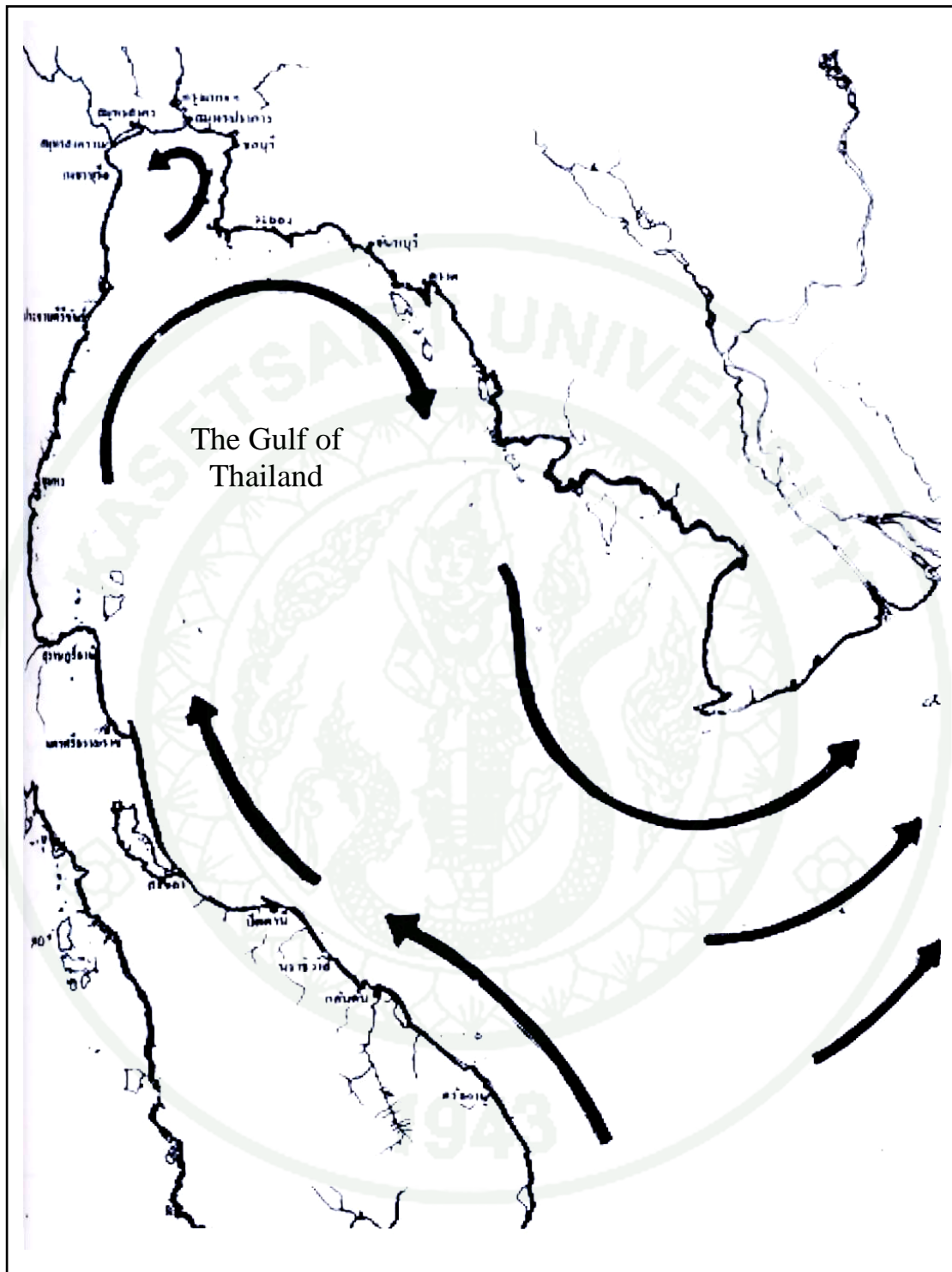
**Figure 6** Monthly wind rose diagram at the navigation floating site, 10 km from the coast of Samut Songkhram Province.

**Source:** Meteorological Department (2010)

## B. Currents in the Gulf of Thailand

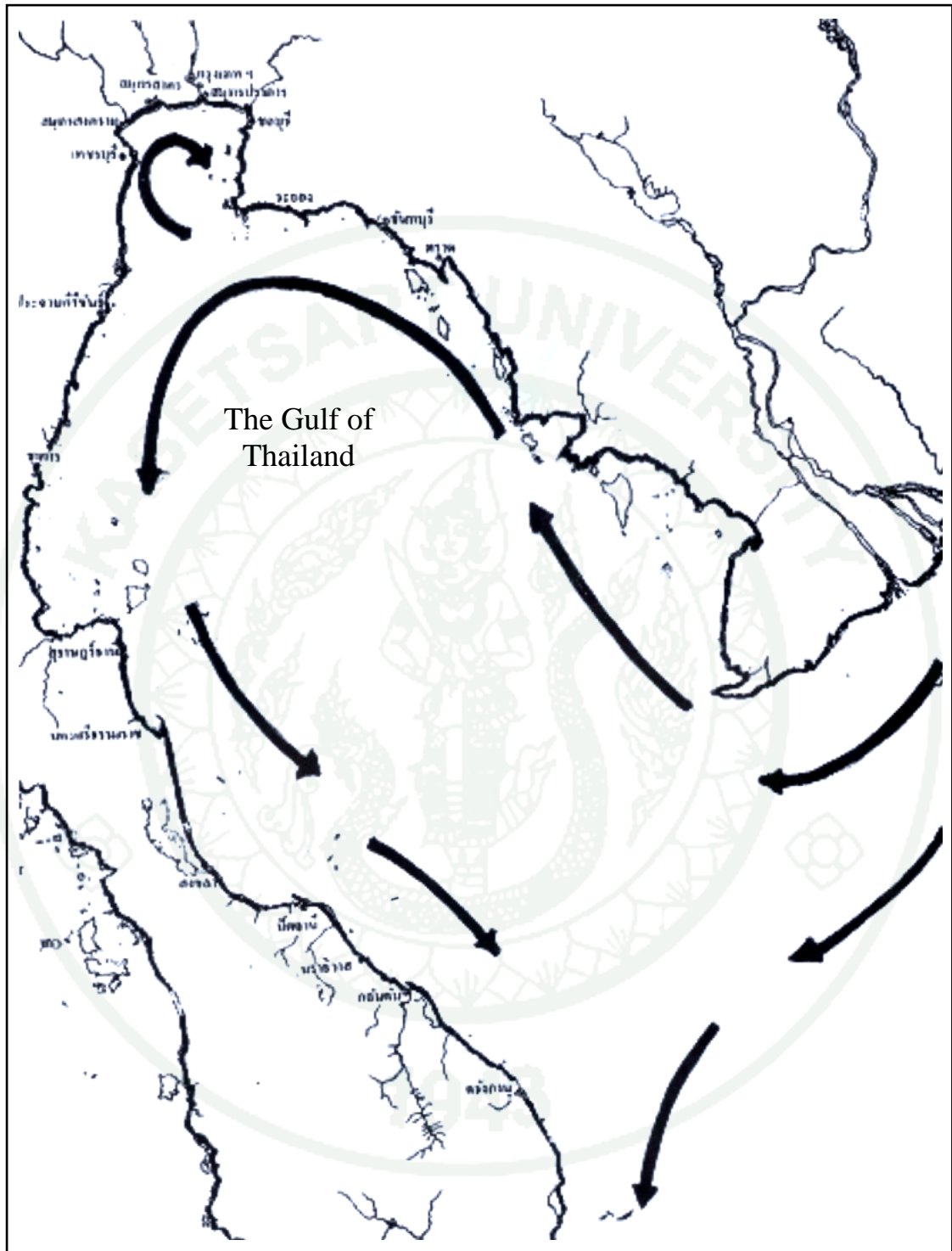
Lowwittayakorn (1998) studied the circulation pattern of the sea surface currents in the Gulf of Thailand, using a mathematical model and data from oceanographic bouys. The result of study showed that direction of currents were influenced by the reverse - monsoon system (the northeast and the southwest monsoons). During Northeast monsoon, the current enters the gulf from the east, making a counterclockwise circulation and leaves the gulf through the west. During Southwest monsoon, the current enters the gulf from the west, making a clockwise circulation, and leaves the gulf through the east. While during the transition monsoon in April and October the circulation in the Gulf of Thailand is varies. Similar to the resulted of Buranapratheprat (2006, 2008) that used a 2-dimensional model and meteorological wind data from local stations around the study area to investigate on current patterns in the inner Gulf of Thailand. He reported that the counter-clockwise circulation was occurred during the northeast monsoon. The pattern of circulation during the southwest monsoon could not be fixed due to its sensitive characteristic of wind fields and external flow from the outer gulf. In general, uniform west or southwest wind induces clockwise circulation or gyre to be generated.

In 2008, Chirawet quoted the direction of current that exist in the Gulf of Thailand was influenced by the Northeast and Southwest monsoon circulatory systems. In Southwest monsoon season, the inner gulf current flows in the counter clockwise direction whereas the outer gulf current flows in the clockwise direction (Figure 7). In winter season the inner gulf current flows in the clockwise direction but the outer gulf current flows in the counter clockwise direction (Figure 8).



**Figure 7** The current direction in The Gulf of Thailand influenced by the Southwest monsoon.

**Source:** Chirawet (2008)



**Figure 8** The current direction in The Gulf of Thailand influenced by the Northeast monsoon.

**Source:** Chirawet (2008)

### C. Waves in the Gulf of Thailand

Wichaimekphat *et al.* (2006) applied WINDWAVE model and MIKE21 models to studying waves and currents at Bang Khun Thien Coast, in the Upper Gulf of Thailand. Wind data at the pilot station (20 year records) was used to generate waves and input to the model. The maximum wave height that ranged about 1.5 m high with a period of 5.0 - 5.4 second was found near the eastern coast. Most simulated currents at the Sichang Buoy showed Northeast - Southwest directions with a speed of 0.05 - 0.45 m s<sup>-1</sup>, while stronger current speed (about 0.9 m s<sup>-1</sup>) was found at the Petchaburi buoy and in the North - South direction.

Vongvisessomjai (1994, 2007) calculated the surges and wave heights of the disastrous tropical cyclones in the Gulf of Thailand and revealed that the Upper Gulf of Thailand with limited fetch length in of about 100 km in North - South directions and about 100 km wide in the East - West, resulted in a limited maximum wave height of 2.3 - 2.5 m that generated by Typhoon Vae in 1952, while the east coast, with longer fetch length but still limited by the existence of its shoreline, resulted in an increased maximum wave height up to 4 m and maximum storm surge height of 0.6 m into the Inner Gulf of Thailand that generated by Typhoon Linda (1997). The southern shoreline, with unlimited fetch length on the east by tropical cyclones approaching from the South China Sea, generated maximum wave height of 6 - 11 m by Typhoon Gay (1989), resulting in more casualties and damages.

### 3. Coastline in the Gulf of Thailand

Coast is dynamic environment. They always change shape and location in response to natural forces and human activities, as result in the coastline changes (Sinsakul *et al.*, 1999).

There are 1,653 km of coastline along the Gulf of Thailand and 1,000 km along the coast of the Andaman Sea. About 405 km out of 1653 km along the Gulf of Thailand and 114 km out of 1,000 km along Andaman coast are confronted severe erosion problem (Bennui *et al.*, 2008 and Department of Mineral Resources, 2007).

#### A. Sea level changes

Coast is dynamic environment; they always change shape and location in response to natural forces and human activities, as result in the coastline changes. Coastline also move in response to change in sea - level, a rise in sea - level will move the coastline inland (Sinsakul *et al.*, 1999). Sea level has risen and fallen repeatedly in the geologic past while coastlines have emerged and submerged that has been primarily in response to growth and melting of glaciers (Thomson and Turk, 2007). In 2007, The Intergovernmental Panel on Climate Change [IPCC] revealed Earth's warming since the early 1900's corresponds well with retreating mountain glaciers, decreasing snow cover in the Northern Hemisphere, reduction of Arctic ice and with other more subtle proxies, such as migrational patterns of birds and butterflies, and early growth season of certain plants. Although eustatic sea level is presently rising only a few millimeters per year, this condition has widespread influences on physical and ecological processes on coasts.

In tectonically stable Sundaland, the main cause of sea level changes was the periodically alternating depletion and refilling of ocean basin by melt water on account of continental glaciations and deglaciation. In Sundaland, the sea level rise at circa 2 cm yr<sup>-1</sup> result of the last deglaciation corresponds with the global average. However, unlike in the Northern hemisphere, during the past 6,000 years sea level had

reached maximum of 4 m above present datum. From the suggestion of Sundaland, more than 60 radiometrically dated shoreline since the mid - Holocene sea level fluctuated several times with an amplitude of 2 m, while the general trend had been descending; until it reached the present level about several hundred years ago, had created the coastal area of Thailand (Tjia, 1986 and Sinsakul *et al.*, 1999).

In 1988 Neelasri et al analysed the tidal records at Koh Lak, Prachuab Kiri Khan Province and at Sattahip, Choburi Province from 1942 to 1949 and from 1973 to 1987 showed that the fluctuation of mean sea level in the Gulf of Thailand had no indicated any changes during these periods, but the mean sea level at Koh Lak in the west fluctuated about 5 - 9 cm higher than the mean sea level fluctuation at Sattahip in the eastern part of the Gulf. Udomchoke *et al.* (2008) stated that these fluctuations were related with the effect of El - Nino and La - Nina phenomena as well as the effect of Indian Ocean Dipole phenomena as influential with climatic variation.

IPCC (2007) reported global average sea level rose at an average rate of 1.8 (1.3 to 2.3) mm yr<sup>-1</sup> over 1961 to 2003. The rate was faster over 1993 to 2003: about 3.1 (2.4 to 3.8) mm yr<sup>-1</sup>. Whether the faster rate for 1993 to 2003 reflects decadal variability or an increase in the longer term trend is unclear. There is high confidence that the rate of observed sea level rise increased from the 19<sup>th</sup> to the 20<sup>th</sup> century. The total 20<sup>th</sup> century rise is estimated to be 0.17 (0.12 to 0.22) m. For 1993 to 2003, the sum of the climate contributions is consistent within uncertainties with the total sea level rise that is directly observed (Table 1). These estimates are based on improved satellite and in situ data now available. For the period 1961 to 2003, the sum of climate contributions is estimated to be smaller than the observed sea level rise.

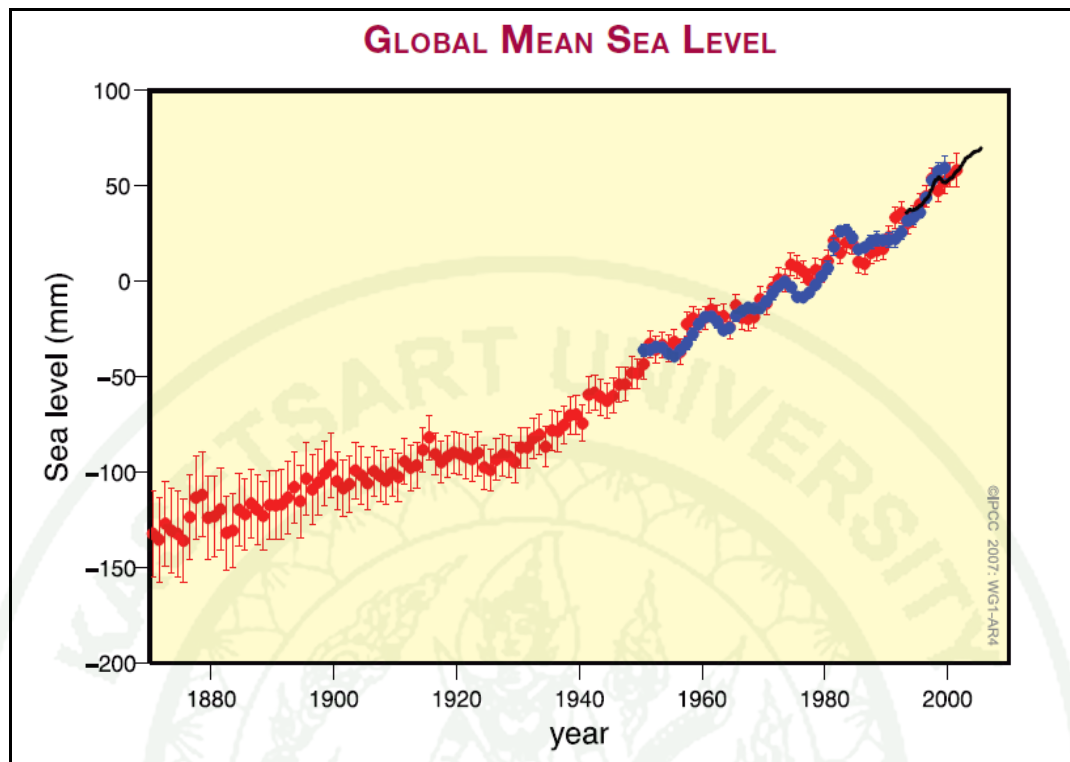
**Table 1** Observed rate of sea level rise and eestimated of the various contributions of the present and past rates of sea level trend from different sources.

Source of seal level rise	Rate of sea level rise (mm yr <sup>-1</sup> )	
	1961 - 2003	1993 - 2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland ice sheet	0.50 ± 0.12	0.21 ± 0.07
Antarctic ice sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate	1.1 ± 0.5	2.8 ± 0.7
Contributions to sea level rise	1.8 ± 0.5 <sup>a</sup>	3.1 ± 0.7 <sup>a</sup>
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

**Note:** <sup>a</sup> Data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry

**Source:** IPCC (2007)

Over the 1961 to 2003 period, the average rate of global mean sea level rise is estimated from tide gauge data to be  $1.8 \pm 0.5$  mm yr<sup>-1</sup> (Figure 9).



**Figure 9** Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black).

**Source:** IPCC (2007)

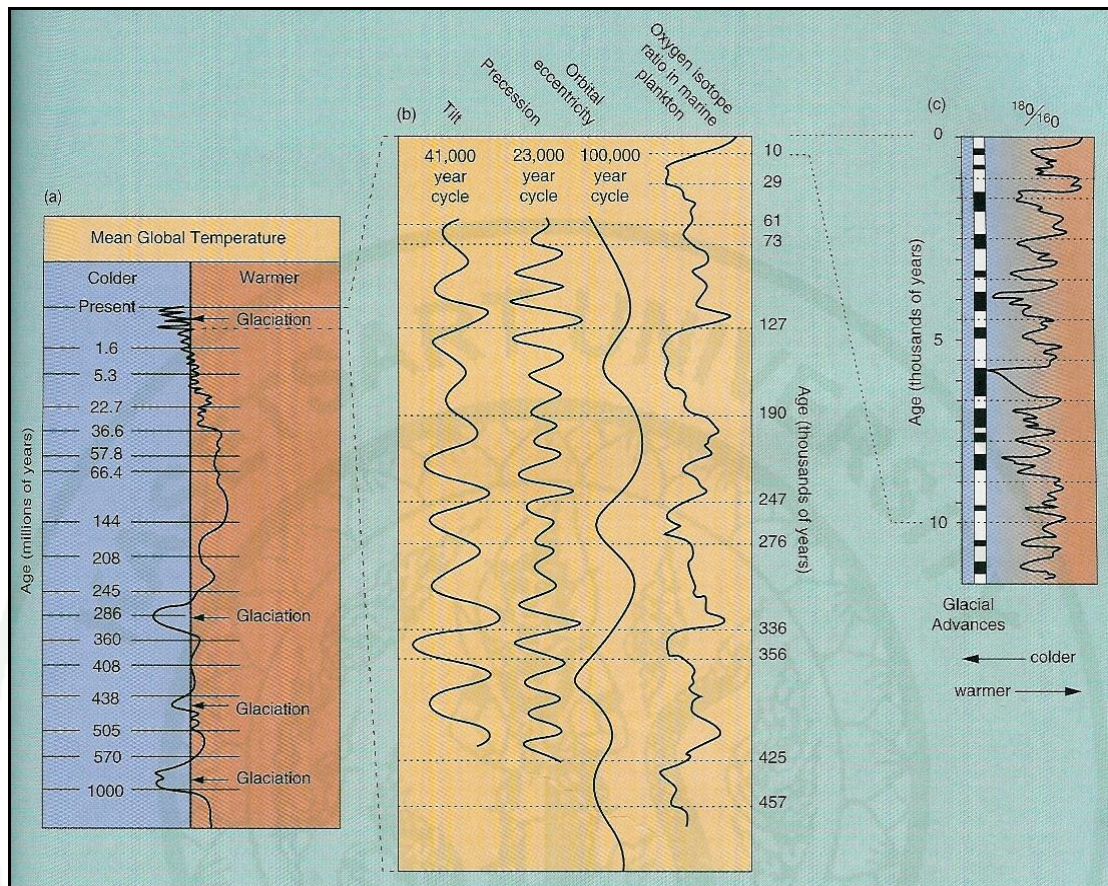
Trisirisatayawong *et al.* (2010) determined sea level changes from annual-average of four tide gauge stations since 1940 to 2004 reveals that long-term rates in the Gulf of Thailand mean sea levels are rising.

## B. Milankovitch Cycles

Milankovitch developed a mathematical theory of paleo climate based on the seasonal and latitudinal variations of solar radiation which received by the Earth. Milankovitch cycles are cycles in the Earth's orbit that influence the amount of solar radiation striking different parts of the Earth at different times of year (Thomson and Turk, 2007).

These cycles mean that at certain times, there is less sunshine incidenting on the Earth, so there is less melting of snow and ice. Instead of melting, these cold expanses of frozen water grow. The snow and ice last longer and, over many seasons, begin to accumulate. Snow reflects some sunlight back into space, which also contributes to cooling. Temperatures drop, and glaciers begin to advance (Figure 10a). There are three main variables. First, the shape of the Earth's orbit stretches from circular to more elliptical and back again that is called eccentricity, with a periodicity of about 100,000 years. Even though the average distance from the Earth to the sun is 150 million kilometers, for the most elliptical orbit the distance varies between limits of 140 to 160 million kilometers every year. As the heat received by the Earth drop off rapidly relative to its distance from the Sun, this variation can produce a profound change. Second, the Earth's spin axis wobbles, or 'precesses', like a tilting spinning top, the pole position making a complete loop every 23,000 years. Third, Earth axis is currently tilted at about  $23.5^\circ$  with respect to a line perpendicular to the plane of its orbit around the sun. The tilt oscillates by  $2.5^\circ$  on about a 41,000 year cycle (Thomson and Turk, 2007).

These changes affect both the total solar radiation received by Earth and the distribution of solar energy with respect to latitude and season. Seasonal changes in sunlight reaching higher latitude can reduce summer temperature. If summers are cool and short, winter snow and ice persist, leading to growth of glaciers (Thomson and Turk, 2007). The measurement of the oxygen isotopic composition of shells grown at different times permits to determine when the oceans were affected by the buildup of large volume of glacial ice (Figure 10b) In the recent years, the U.S. National Science Foundation, in cooperation with the Danish government, has conducted a drilling project in central Greenland, the goal of which is to retrieve a complete core through the ice sheet. The results are these two sets of cores and work to data on these samples has shown that climate in the northern regions shifted from "mild" to "glacial" much more rapidly (Davidson *et al.*, 1997). Some of these climate shifts occurred under 10 years, and most in far less than 100 years (Figure 10c).



**Figure 10** Comparison of Milankovitch Cycles to stages of Pleistocene glaciation.

**Source:** Davidson *et al.* (1997)

#### 4. Coastal sediment Systems

Supply, transfer and loss of sediment to and from coastal systems are seldom constant or continuous. Sediment transfer in the coastal zone arises from a number of forcing mechanism such as wave action, tidal current, river and estuary flow and wind. The term of literal drift or literal transport is taken to refer to any near coast movement of sediment between wave or current base and the shoreline, while longshore drift or longshore transport is reserved for the movement of material between the breaking waves and the shoreline.

### A. Sediment supply

The Coastal sediment source may be divided into primary or secondary sources. Primary sources are sediment eroded by wave action from cliffs, platforms or submarine outcrops. Biogenic sources such as corals, sabellariids, mollusca, vermetids, diatoms, foraminifera, crustaceans, and other marine organisms all supply significant quantities of skeletal material to coastal sediments, are also important. Primary sources are usually areal or line sources. Secondary sources of sediment are provided by rivers, glaciers, ice - sheet, waste disposal from man and eolian action. The sediment is likely to have undergone some kind of initial sorting, prior to inclusion in the coastal environment that associated with man's activities. Secondary sources sediment varied greatly along the coast and usually point sources (Carter, 1988).

Vongvisessomjai (1992) reported the erosional of shoreline at Samut Songkhram - Phetchburi is supplied by sand and silt from the Phetchburi river in the middle section and the Maeklong river in the north. The decrease of the silt supply from the Chao Phraya river, resulted in a net erosion since the accretion by the silt supply is less than the erosion by the wave action, while the decrease of sand supply alongshore or from nearby streams and the construction of rigid wall on beaches are the cause of erosion along the shoreline of Petchburi province and Hua Hin district.

In 1996, Vongvisessomjai suggested that the shorelines of the Gulf of Thailand have been formed by sediments carried by rivers drainage such as the head of Upper Gulf by the Chao Phraya and Maeklong River, Bandon Bay Tapi River, Nakorn Si Thammarat Bay by the Pakpanang River and Pattani Bay by the Pattani River. The most of the shorelines are sandy between rock outcrops, or muddy near the mouths of the big rivers.

Sinsakul *et al.* (1999) quoted that there are many large and long river that flow from the upland area to Gulf of Thailand. Damming of river reduced sediment flux into coastal areas and has encouraged coastal process, as in the case of Chao

Phraya, Mae Klong and Phetchburi River. In the case of Andaman Sea, most of rivers are short distance flows, upstream damming very few, only reservoir was constructed in the upland area.

#### B. Sediment transport

Most waves approach the shore at an angle rather than head on. When this happens, one end of the wave encounters shallow water and slow down, while the rest of the wave is still in deeper water and continues to advance at a relatively faster speed. As a result, the wave bends. This effect is called wave refraction. Refracted waves transport sand and other sediment toward the interior of a bay. As the headlands erode and the interiors of bays fill with sand, an irregular coastline eventually straightens. When waves strike shore at an angle, they form a longshore current that flow parallel to the shore. Longshore current flow transport sand for great distance along coastlines (Thomson and Turk, 2007). Thus, at the end of one completed wave cycle, the sand has move a short distance parallel to the coast. The next wave transports the sand a little further, until sediment moves long distance.

#### 4. Coastal erosion in Thailand

Coastal erosion and accretion occur irregularly along the coast, but an intensification of erosion noticed during the past decade (Thampanya *et al.*, 2006). The coastline severe erosion along the Gulf of Thailand can be found on the west of the Chao Phraya River estuary (-500 m), Phetchburi province (-200 m) and Hua Hin district (-100 m). The shoreline of Samut Songkhram – Phetchburi is accreting. From 1954 to 1957, the accreted area was +1,466,000 m<sup>2</sup> and the eroded -194,000 m<sup>2</sup>, a net accretion area was +1,272,000 m<sup>2</sup> (Vongvisessomjai, 1992).

From the report of Wichaimekphet et al (2006) they stated that The Bang Khun Thien coast is continually eroded with recession rate of 1.2 - 4.6 m yr<sup>-1</sup>. The Bang Khun Thien coast may suffer from severe erosion for the last 20 - 30 years.

Overall, the net erosion is approximately 1.3 to 1.7 m yr<sup>-1</sup> along the Southern of Thailand coastline. Total area losses amount to 0.91 m<sup>2</sup> yr<sup>-1</sup> for the Gulf coast and 0.25 m<sup>2</sup> yr<sup>-1</sup> for the Western coast. Most of the eroded areas increase with larger areas of shrimp farms, less mangrove forest area, and when dams reduce Riverine inputs and coastal land subsidence transpires. In areas where erosion has prevailed, the presence of mangroves has reduced erosion rates. Mangroves dominating coastal locations exhibit less erosion than areas with non-vegetated land or former mangrove areas (Prasetya, 2007).

The coast of Songkhla Lake is a case where the erosion of coastline occurs although the scale of impact is much less as compared to that along the Gulf of Thailand. The coastal areas of Songkhla Lake are continually under in moderate erosion, except at Had Sai Kaew that the shoreline is ranged in severe erosion (Bennui1 *et al.*, 2008).

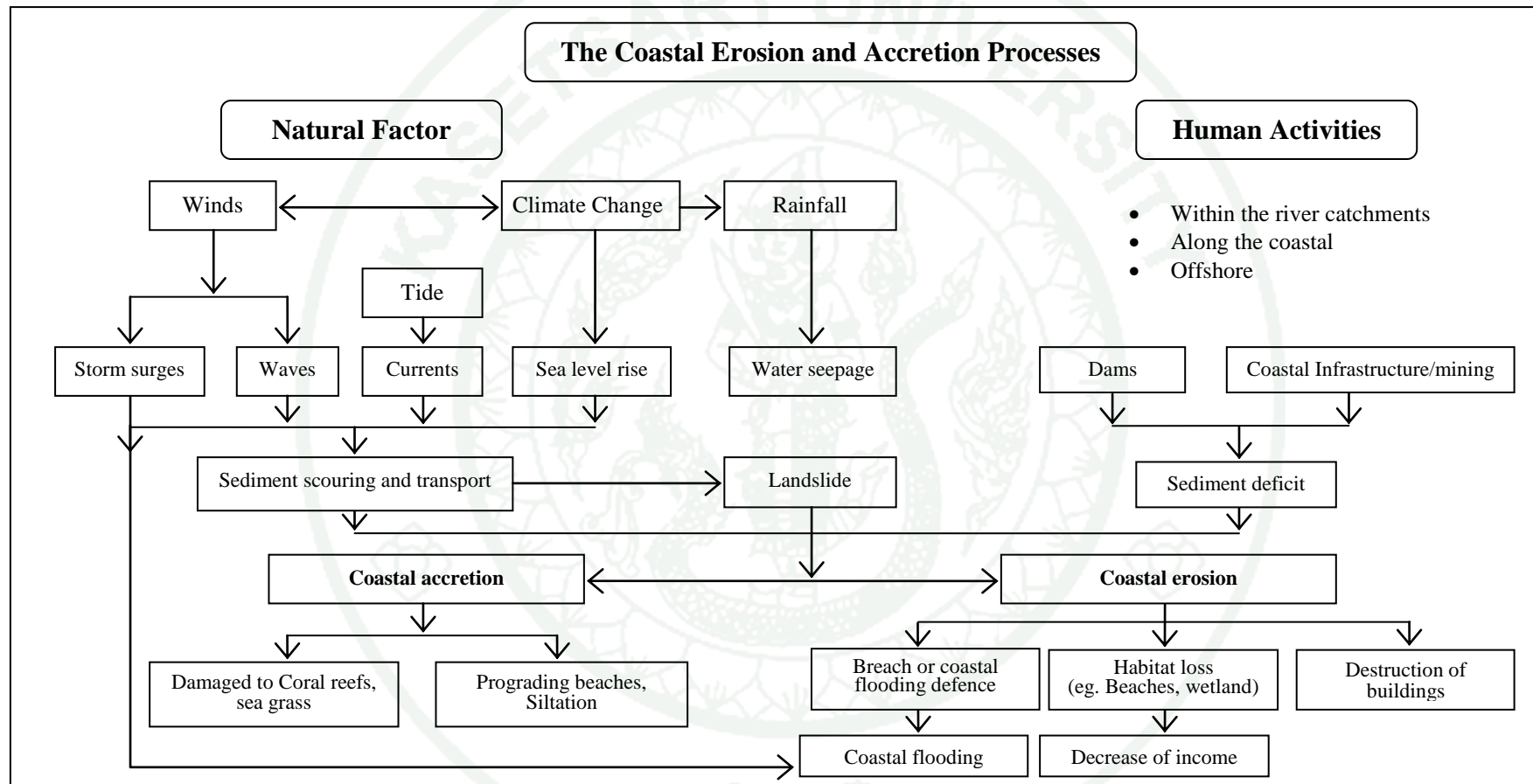
Ekphisutsuntorn *et al.* (2010) used the aerial photo to prepare the erosion rates at the Bangkhuntien shoreline revealed that about 1.80 m yr<sup>-1</sup> from 1980 - 1986, 4.75 m yr<sup>-1</sup> from 1987 - 1993, 15.28 m yr<sup>-1</sup> from 1994-1996 and 10.03 m yr<sup>-1</sup> from 1997 - 2002.

#### A. The causes of coastal erosion in Thailand

In 1992, Vongvisessomjai studied coastal erosion in the Gulf of Thailand. His result showed the causes of coastal erosion due to both natural processes and manmade activities such as (i) Wave and wave induced current, (ii) Decreasing of sediment supply from river, (iii) Constructing a reflective boundary on the shoreline, (iv) Trapping of alongshore sediment supply by coastal structures, (v) Land subsidence or sea level rise and (vi) Mining of sand or shell. Especially for the first three are seen to be the major factors in causing shoreline erosion of the Gulf of Thailand.

The causes of coastal erosion and accretion are complex processes that need to be investigated from the angles of sediment motion under wind, wave and tidal current action; beach dynamics within a sediment/littoral cell; and human activities along the coast, within river catchments and watersheds and offshore, both at spatial and temporal scales. In terms of temporal scales, the issue of sea-level rise is complex and it produces a range of environmental problems. As the sea level rises, the water depth increases and the wave base becomes deeper; waves reaching the coast have more energy and therefore can erode and transport greater quantities of sediment (Prasetya, 2007). Thus, the coast starts to adjust to the new sea level to maintain a dynamic equilibrium. In Figure 11 show lists the processes of coastal erosion and accretion as well as natural factors and human activities.

Bennuil *et al.* (2008) explained the causes of coastal erosion in Songkhla Lake Basin as (i) the flatness of coastal areas around Songkhla Lake, (ii) the softness of deposited sedimentation, (iii) the strong wind waves during monsoon transition period and (iv) the human activities such as dredging of canal estuaries, construction of coastal structures around Songkhla Lake.



**Figure 11** The complex processes of coastal erosion and accretion.

**Source:** Modified from Prasetya (2007)

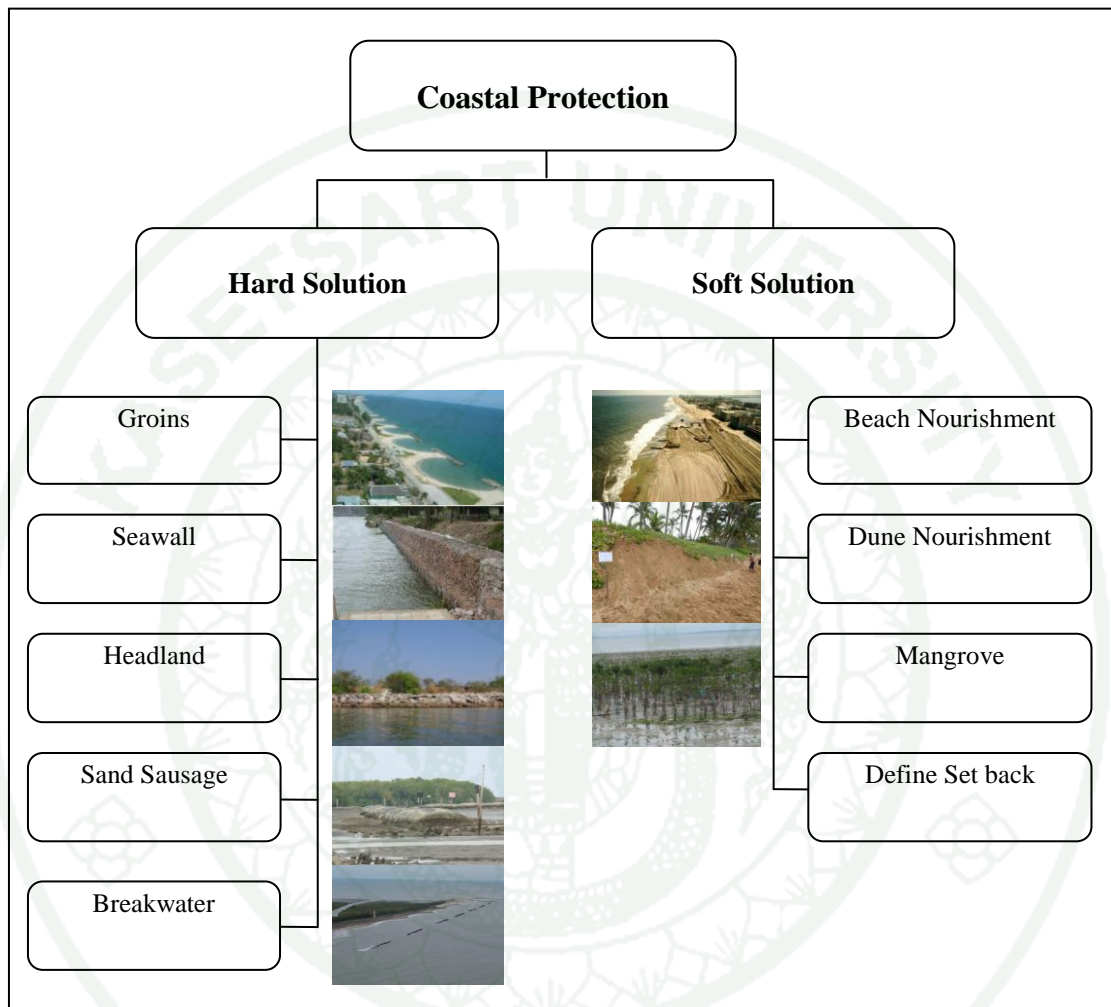
## B. Coastal erosion protection in Thailand

In 2009, coastal erosion is becoming a serious problem of Thailand. There was various types of coastal defense projects, both hard and soft solutions (Figure 12), proposed by government sectors. Hard solutions were applied to the coastal structures, called as “structural method”, to protect the beaches. Breakwater, groin, seawall and headland are typically used in shoreline protection. Hard solutions were generally appropriate for chronic and severe erosion sites. These measures were fully affected to the project areas, but caused erosion to adjacent areas. Soft solutions were suitable for coastal resource restoration zones where the wave action was quite low such as beach nourishment and mangrove forestation (Rattamanee *et al.*, 2008).

The Songkhla coastline has been confronted the severe erosion widespread, in the last ten years have been constructed at all river mouths along the coast of Songkhla such as groins, jetties and breakwaters. The engineering coastal structures pose a very complex hydrodynamic problem with strong interactive effects between the waves, currents and the structures. Observation of Songkhla coastline revealed the maximum retreat of 11 m yr<sup>-1</sup> (Pornpinatepong *et al.*, 2005)

Bennui1 *et al.* (2008) suggested that the shoreline protective measures of Songkhla Lake Basin can be done by (i) understanding the natural changing phenomena of the coast, (ii) self-adaptation to live with the dynamic natures, (iii) optimistic exploitation of the natural resources, and (iv) research for the innovative measures to renovate the coastal erosion problem. The establishment of designed artificial reefs is an instance of activities that mitigate the incidences in a holistic manner. In 2008, Rattanamanee *et al.*, designed the individual reef unit, properly both its shape for enhancement the marine ecology and its mass for bearing the wave forces. It is also low impact to aesthetic view of the reaction beach and the construction cost is also lower. Wichaimekphat *et al.* (2006) suggested about the protection shoreline erosion of Bang Khun Thien should be by construction of groin series instead of detached breakwater. In addition, it was found that the construction of series of detached breakwater has contra-productive effect. Though, they can

reduce wave energy or wave height (about 30 - 40 %) and also prevent sediment movement from the offshore to transport towards the shoreline.



**Figure 12** Coastal Protection measures.

**Source:** Modified from Rattanamanee *et al.* (2008)

## MATERIALS AND METHODS

### Materials

Materials and apparatus required in this research work are as follows:

#### 1. Maps and Data of Samut Songkhram Province

Secondary data of Samut Songkram Province was retrieved from the information system center, textbook or research that related in the study area.

- 1.1 Provincial Geological maps of Samut Songkhram Province by Department of Mineral resources.
- 1.2 Topographic maps scale 1:50,000 series L7018 sheet 5035 I and 5035 IV by Royal Thai Survey Department.
- 1.3 Arial photo of Samut Songkhram Province by Royal Thai Survey Department.
- 1.4 Provincial Soil maps scale 1:50,000 of Samut Songkhram Province by Land Development Department.
- 1.5 Bathymetric map of The Inner Gulf of Thailand by Survey and Engineering Bureau, Royal Thai Navy.
- 1.6 Meteorological data of Samut Songkhram Province from Department of Meteorology.
- 1.7 Satellite Image of Samut Songkhram Province from Google or Point Asia.
- 1.8 Soil profiles from well logging that relate study area.

#### 2. Soil Properties Analysis

Materials and apparatus used for soil analysis in laboratory are as follow:

- 2.1 Sieve mesh
- 2.2 Rotary shaker

- 2.3 Atterberg's Limit apparatus
- 2.4 Spatulas
- 2.5 Soil container
- 2.6 Hot oven
- 2.7 Papers and pens or pencils
- 2.8 Digital camera
- 2.9 Scanner

### **3. Tool for Sediment Level Measurement**

Leveling telescope, tripod, staff gage and field book were used in the leveling method for measure the level of sediment as shown in Appendix Figure 1.

### **4. Materials for Wave Height, Wave Period, Wind Speed and Wind Direction**

Wave height, wave period were measured by the floating SONAR platform that use the distance sounding sensor and wind speed and wind direction use wind speed and wind direction sensor. All data were recorded in data logger (Appendix Figure 2) and supported electric power by 40W photovoltaic or solar cell. Accuracy of these apparatus less than 3% in error was controlled. All materials used in apparatus are as follow:

- 4.1 Board microcontroller : ET - EASY MEGA1280 (Duino Mega)
- 4.2 Real time clock : MINI DS 1307
- 4.3 OpenLog data logger
- 4.4 Inspeed Vortex Pole Mount Anemometer : Vortex wind sensor
- 4.5 Ultrasonic Range Finder - XL - Maxsonar WRL1 : Brand - Maxbotix,  
Model - MB7060
- 4.6 MicroSD cards up to 2GB
- 4.7 Foam sheets
- 4.8 Battery 12 volt
- 4.9 40W photovoltaic cell or photoelectric cell

4.10 PVC column pile

4.11 Data logger housing

## **5. Data Processing and Offices Accessories**

Data collection from field surveying and analytical data from laboratory as well as manuscript required the following materials.

5.1 Desktop computer

5.2 Notebook computer

5.3 Analysis software

5.4 Data storage drive 200 GB or more

5.5 LCD Monitor and video graphic accelerator card

5.6 Laser printer and Ink jet color printer

5.7 Digital camera and memory cards

5.8 Scanner and driver

5.9 Office stationary

## Methods

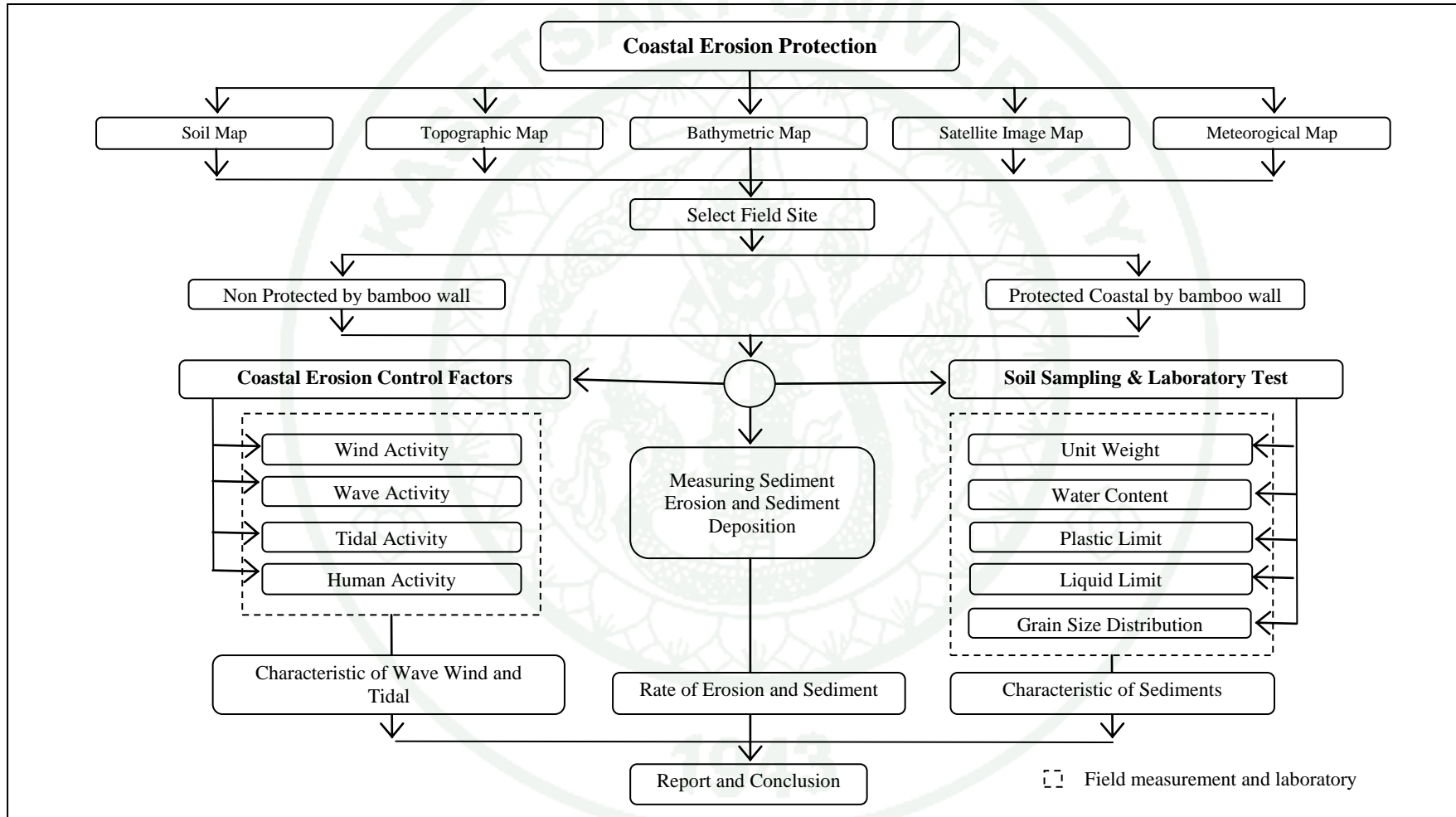
Methodology and step of study are show in Figure 13 as follows:

### 1. Selected Field Sites

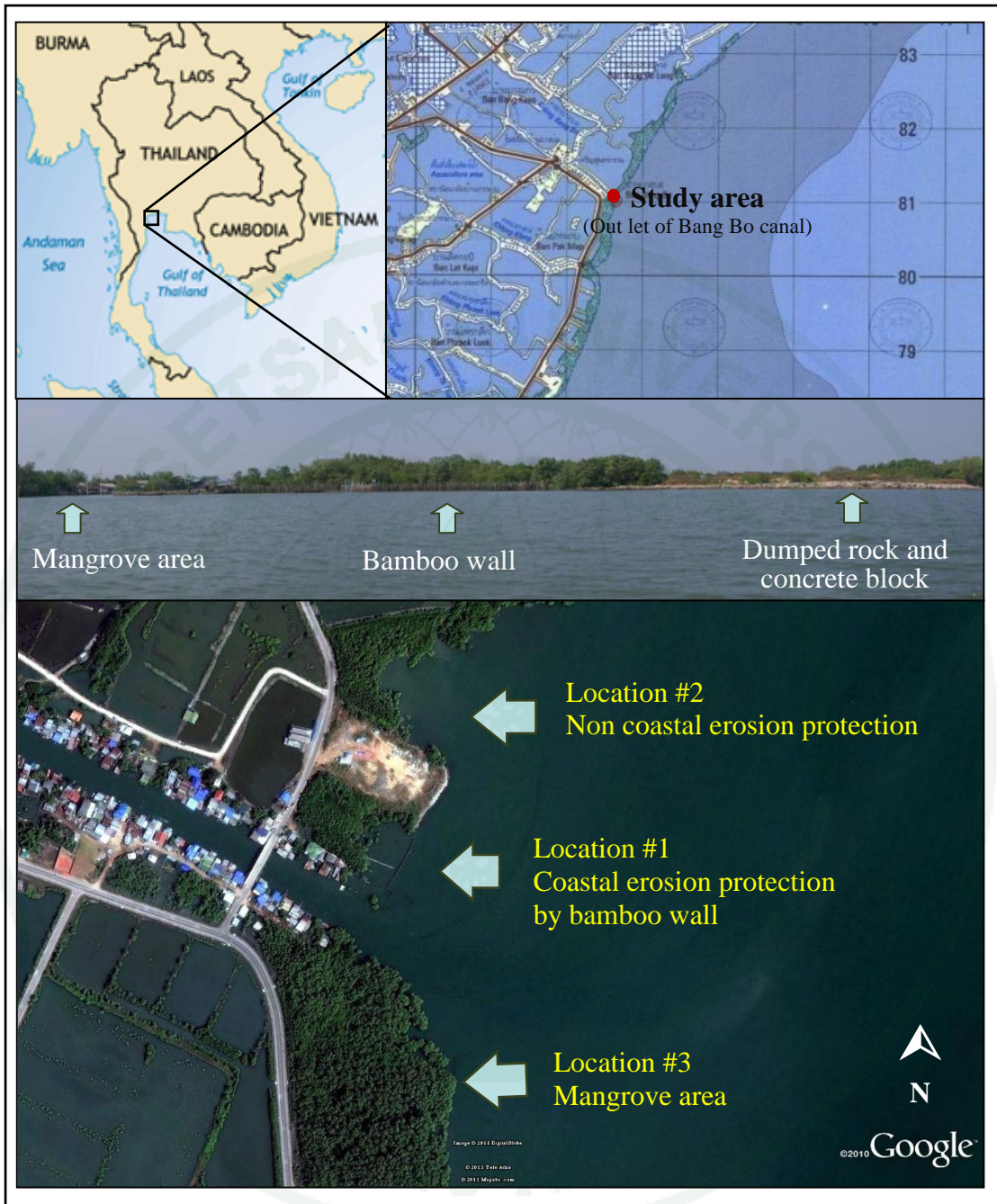
The study area is located at Pak Klong Bang Bo (outlet of Bang Bo canal), Bangkaew Subdistrict, Muang Samut Songkhram District, Samut Songkhram Province as shown in Figure 14. This area confronted with coastal erosion that caused people moved their house consequently with displacement up to now about 300 m as shown in Figure 15.

This field site was selected under the requirement of Mr. Visoot Nuamsiri, the leader of Ban Bang Bo village and Mr. Vorraphol Duanglomchan who started to use local knowledge on rows bamboo wall for wave energy reduction and sedimentation behind the wall, then grow new mangrove and conserve mangrove forest. Consecutive Bamboo wall for 50 m in each step for three years of Bamboo life as shown in Figure 16. In 2008 and 2009, Samut Songkram province provided fund 50,000 bath from donation about 209,000 baht for 102 m of Bamboo wall.

This field site was classified into 3 sites as location No.1 is area under coastal erosion protection by Bamboo wall, location No.2 is area of naturally eroded and location No.3 is in mangrove.



**Figure 13** Flow chart of the method of study on coastal erosion protection and sediment enhancing by bamboo wall.

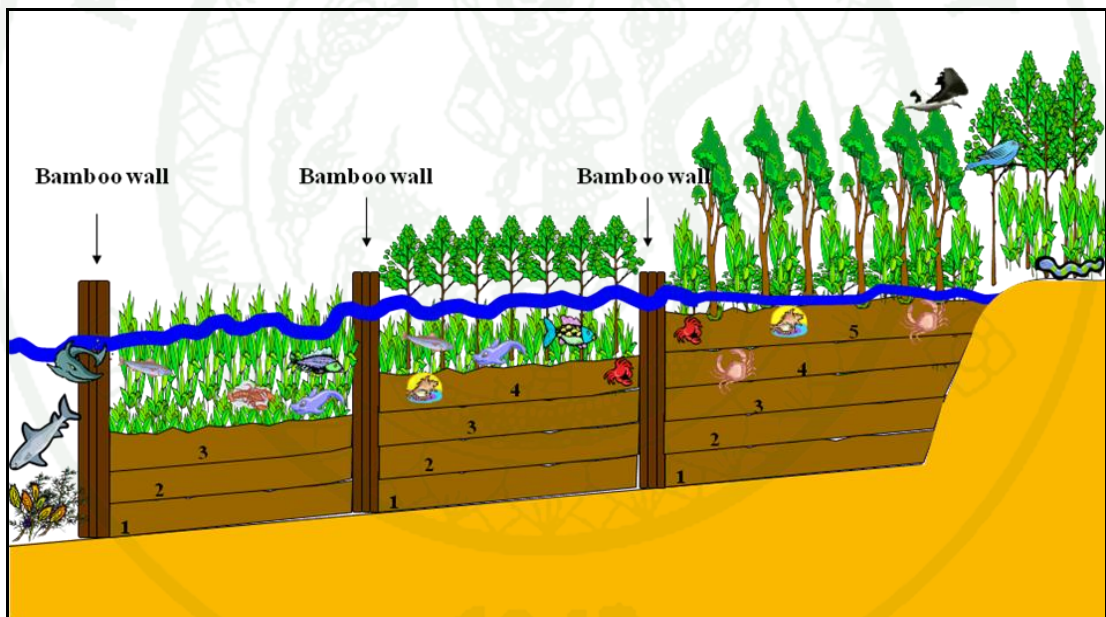


**Figure 14** Pak Klong Bang Bo, Samut Songkhram Province.

**Source:** Google (2011)



**Figure 15** Residential area that effected from coastal erosion at Ban Bang Kaew, Bang Bo district, Samut Songkram Province.

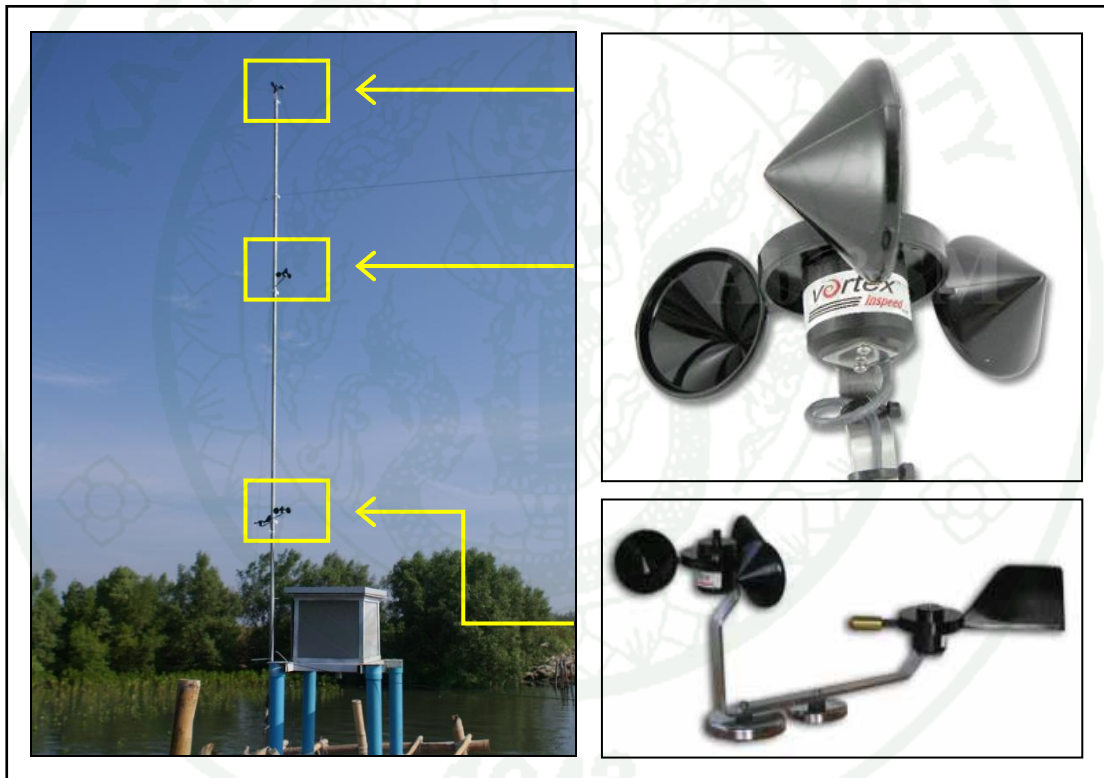


**Figure 16** Basic concept of use consecutive bamboo wall for coastal erosion protection then grow mangrove trees behind the wall.

## 2. Wind and Wave Measuring

### A. Wind speed and wind direction measuring

Wind speed and wind direction were measured in three levels from mean sea level at 4, 7 and 10 m respectively (Figure 17). Wind speed was recorded in term of number of count of rotational three cups in one minute and wind direction was the average wind direct in one minute.

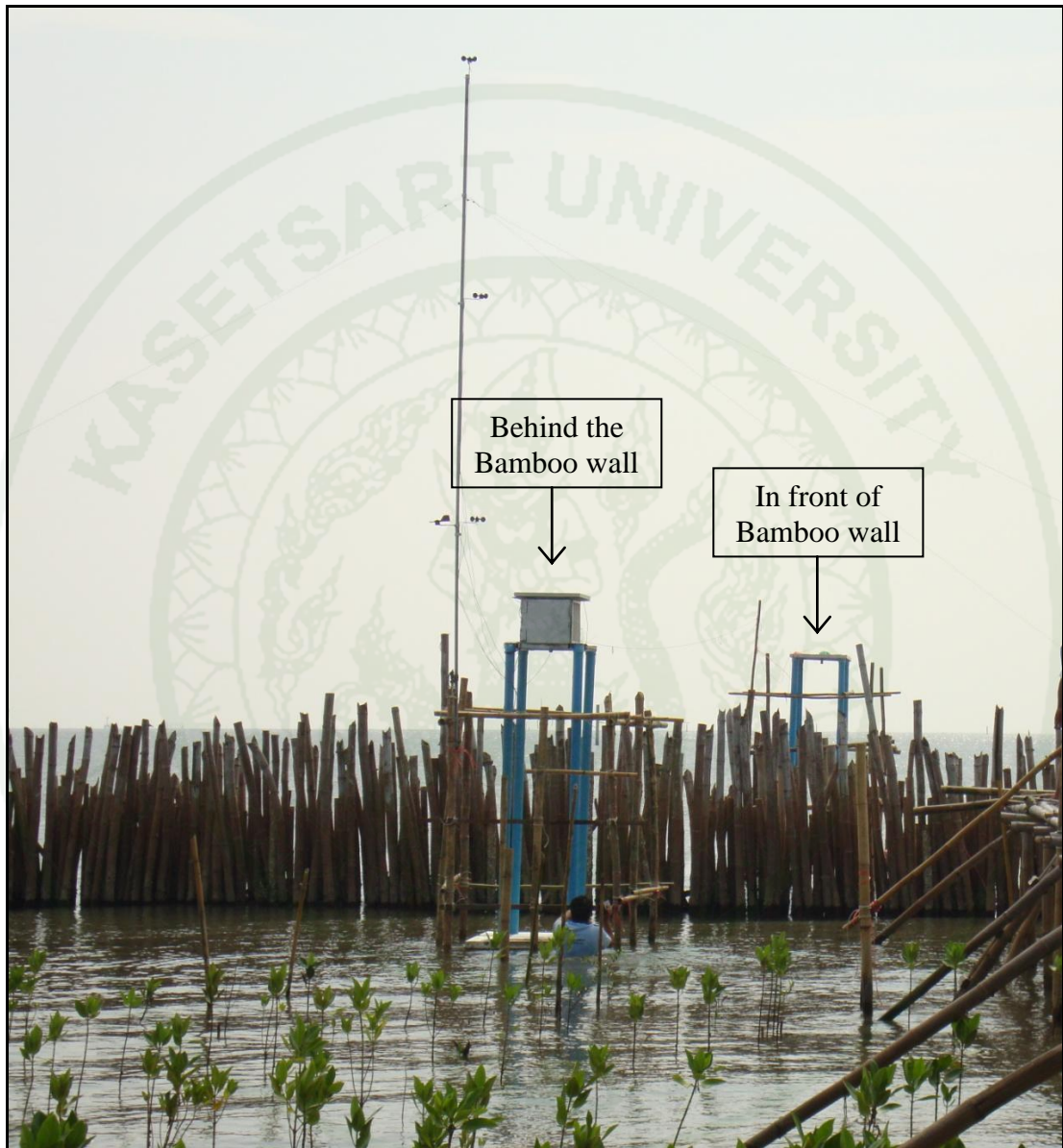


**Figure 17** Three levels of wind speed and wind direction were measured at 4, 7 and 10 m from mean sea level.

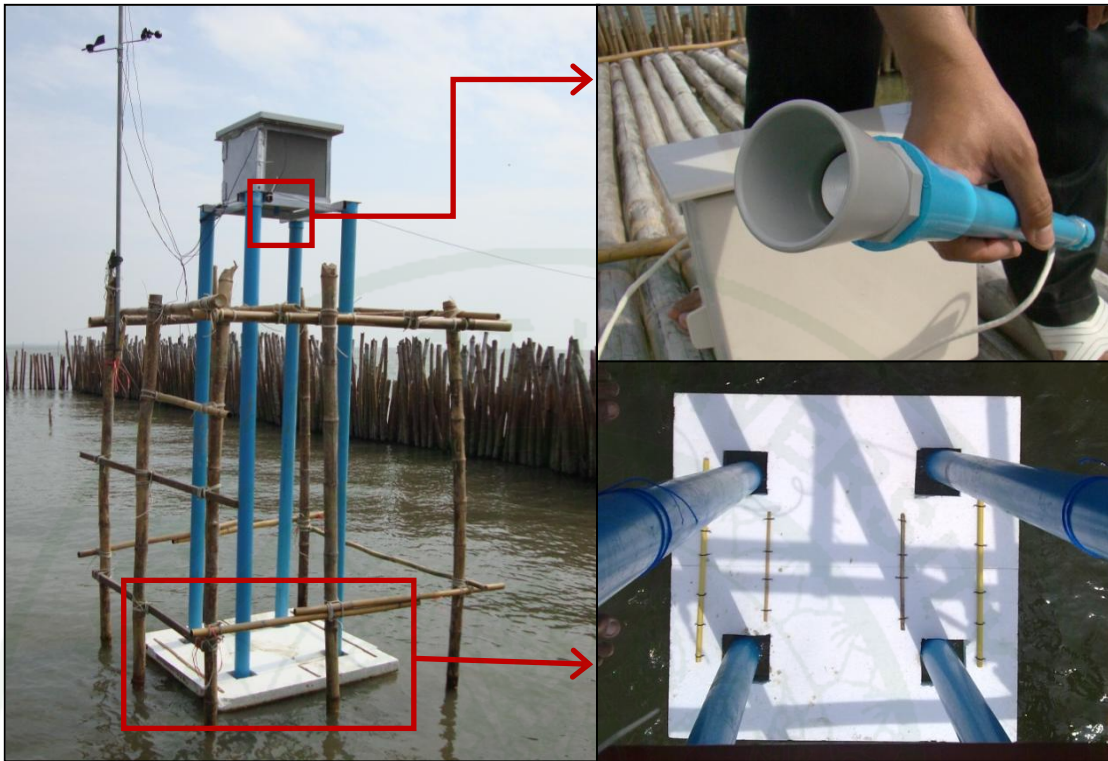
### B. Wave height and period

Floating sonar platform were installed in front of bamboo wall and behind the wall (Figure 18) in order to measure wave height and period (Figure 19), then

wave height and period of waves were calculated and compared with sediment erosion and sediment deposition at the site.

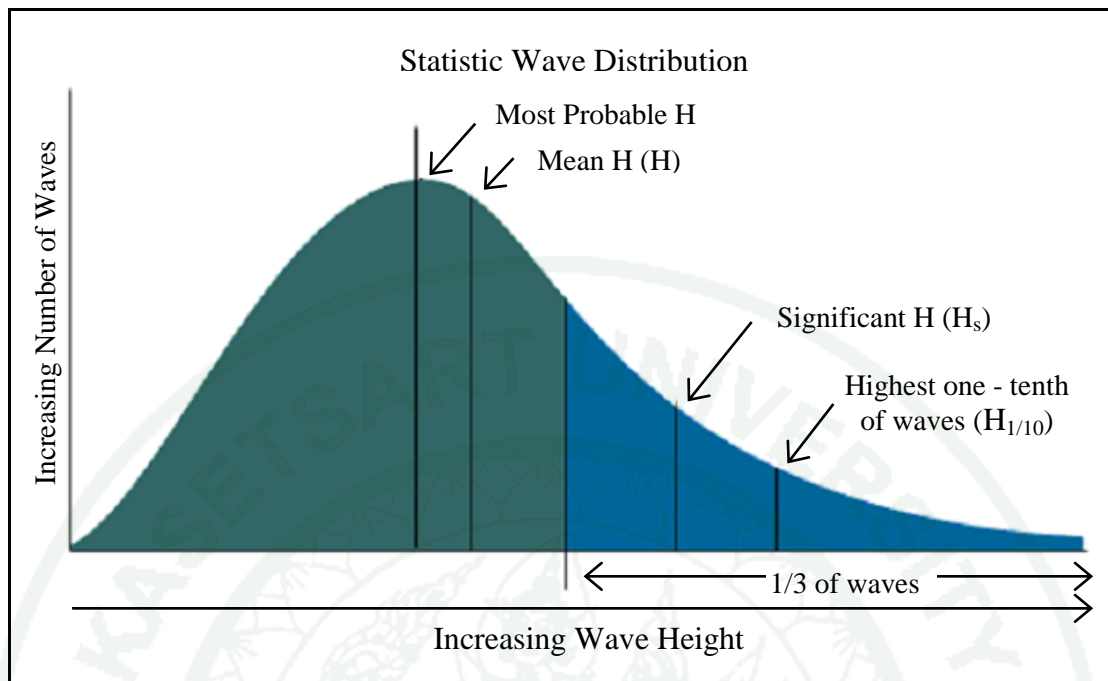


**Figure 18** Floating sonar platform were installed in front of Bamboo wall and behind the Bamboo wall.



**Figure 19** Detail of installed floating sonar platform at behind the bamboo wall.

Wave height in this study was calculated and presented in term of significant wave height ( $H_{1/3}$ ). The significant wave height ( $H_{1/3}$ ) is the average height of the highest one-third (33%) of waves (measured from trough to crest) that occur in a given period as showed in Figure 20. Due to the larger waves are usually more significant than the smaller waves, hence, the larger waves in a storm cause the most beach erosion, or the larger waves can cause navigation problems for mariners. Since the Significant Wave Height is an average of the largest waves, but some of higher individual wave should be aware (National Weather Service Weather Forecast Office, 2009).



**Figure 20** Concept of significant wave height ( $H_{1/3}$ ).

**Source:** National Weather Service Eastern Region Headquarters (2011)

### C. Human activity or land use changed assessment

Human activity on land use was compared by satellite image from Royal Thai Survey Department and Google earth, Point Asia and aerial photo included used shapefile for analyzed in Geographic Information System (GIS) program.

### 3. Rate of Sediment Erosion and Deposition Measuring

Leveling three selected sites by measuring telescope in order to measure sediment erosion and sediment deposition during each prevailing wind direction as shown in Figure 21 then calculated rate of sediment changed of all sites and compared with wind direction and wave height.

#### 4. Soil Sampling and Laboratory Test

Randomized sampling of sediment were carried out from non coastal protection and coastal protection by bamboo wall from the study area by soil cores and thin wall tube (Figure 22 and Figure 23) for analyze soil properties in laboratory at department of Earth Science, Kasetsart University. Soil properties analysis were followed the ASTM standard (American Society for Testing and Materials) as shown in Table 2.

**Table 2** ASTM Standard for laboratory test for soil properties.

ASTM Standards	Standard methods
ASTM D4318	Test method for liquid limit, plastic limit and plasticity index of soil
ASTM D4959	Test method for determination of water (moisture) content of soil by direct heating method
ASTM D7263 - 09	Standard test methods for laboratory determination of density (unit weight) of soil specimens
ASTM D 854 - 00	Standard test methods for specific gravity of soil solids by water pycnometer
ASTM D4221-99	Standard test method for dispersive characteristics of clay soil by double hydrometer
ASTM D - 422	Standard test method of particle size analysis of soils

**Source:** American Society for Testing and Materials [ASTM] International (2010)



**Figure 21** Sediment erosion and deposition measuring by leveling telescope.



**Figure 22** Soil sampling by soil cores for analyses in laboratory.



**Figure 23** Soil sampling by thin wall tube for analyses in laboratory.

1943

## RESULTS AND DISCUSSION

This research aims to carry out the influential factors on erosion and deposition as well as the efficiency of bamboo wall on erosion protection and enhancing sediment deposition. The properties of deposited sediment were also analyzed in order to support the root of new generation mangrove forest. Steps of results in detail are as follows:

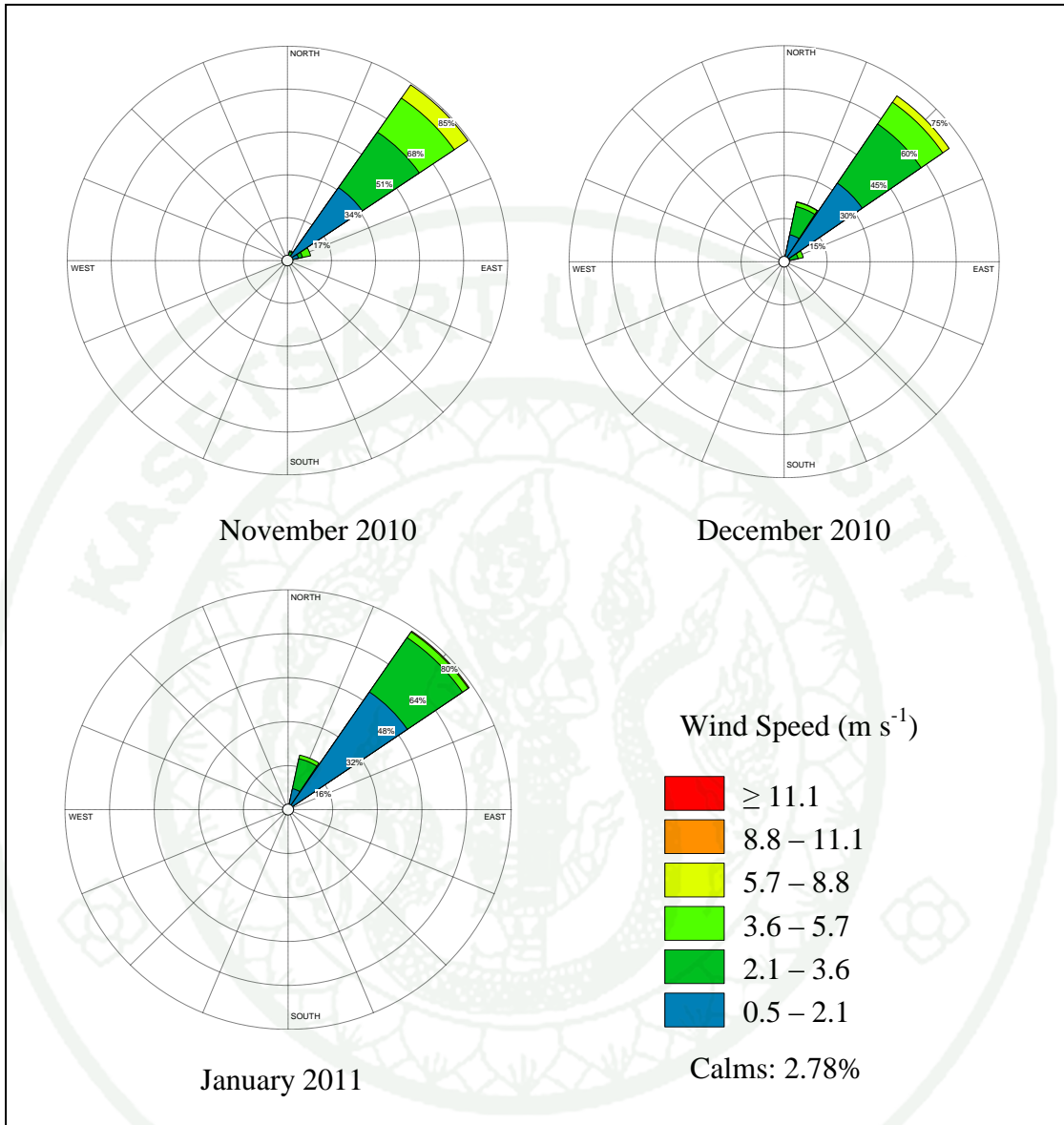
### 1. Coastal erosion and deposition factors

#### A. Wind Activity

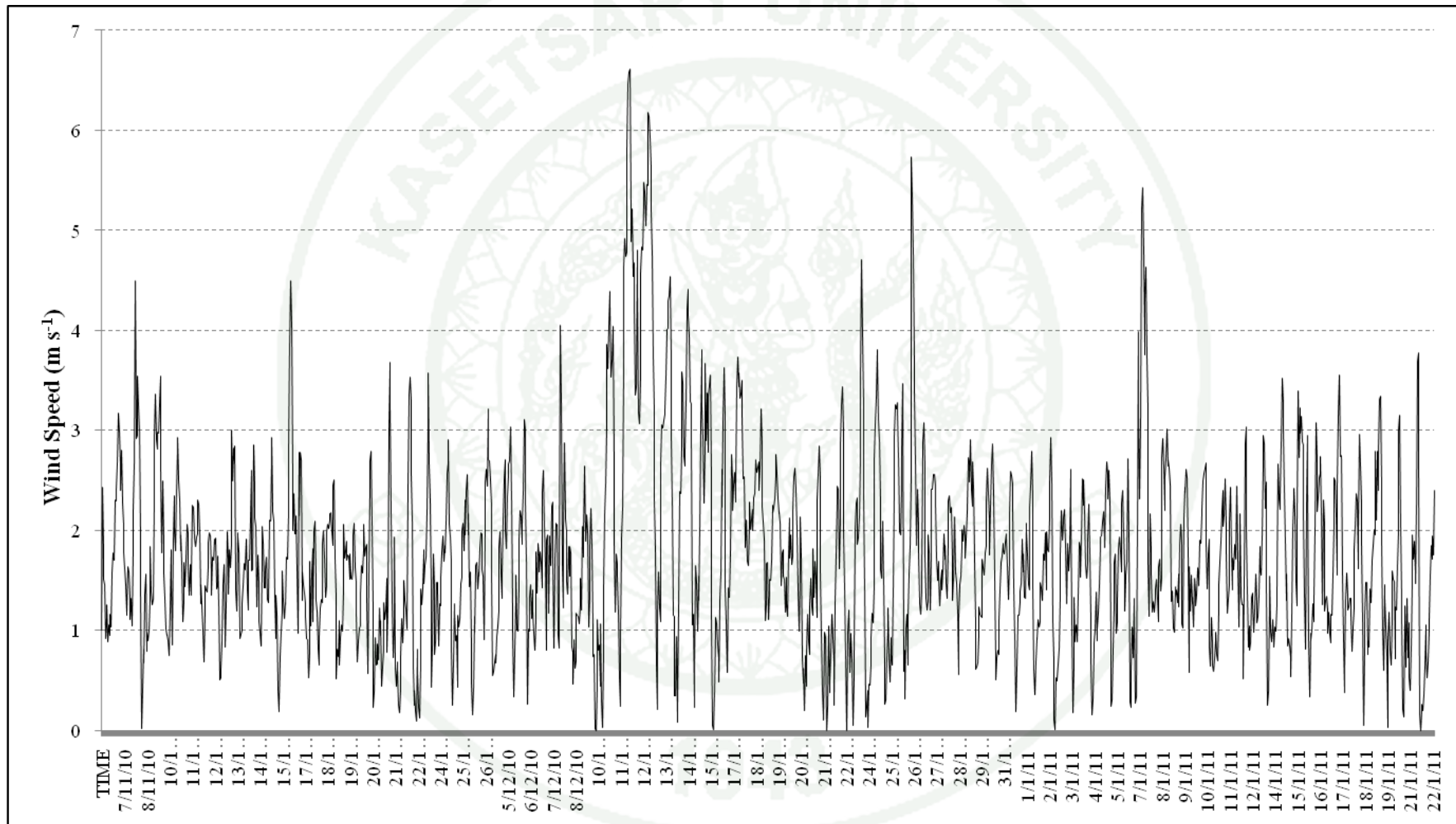
Regarding to local wisdom that quoted by Phuyai Bann Mhoo 10 (village leader No. 10). Wisoot Nuamsiri, a government officer of the Ministry of Interior who was formerly a fisherman. He informed that wind velocity during southwest monsoon always gently blown from the sea to the coast at speed ranged between 1 to 2 m s<sup>-1</sup> at 10 m MSL except during the active southwest monsoon synoptic weather condition windblown at speed ranged between 3 to 5 m s<sup>-1</sup> at 10 m MSL. During the active high pressure northeast monsoon, very strong northeast windblown at speed range between 3 to 5 m s<sup>-1</sup> at 10 m MSL that caused strong wave and shear the paleo- tidal flat sediment at the coast and nearby the coast then transported by longshore current along the coastline. Confirmation with Phuyai Wisoot Nuamsiri, wind speed and direction during day time and sea level regress and during day time sea level transgress were analyzed. During Southwest monsoon season, day time sea level regress can induce seabreeze from sea perpendicularly to land until sea level transgression, wind direction was changed to prevailing southwest direction. Wind speed became stronger during noon and afternoon of daytime sea level transgression day. During Northeast wind season or day time sea level transgression, seabreeze was induced during day time at strong level and in the same direction of prevailing wind, but caused weak wind speed in nighttime sea level regression due to the opposite of landbreeze and prevailing wind.

Monthly wind direction at the study area during northeast monsoon season was plotted as shown in Figure 24. Monthly wind rose diagram at the Navigation Floating site, 10 km from the coast of Samut Songkhram Province, showed the major wind direction prevailing the South and Southwest direction during Southwest Monsoon season (SM) or rainy season (July to September) and prevailing the South and Northeast during winter Intermonsoonal season (October) and prevailing the Northeast direction during November to January in early winter season Northeast Monsoon season (NM), then the prevailing South and South-Southwest with seldom the Northeast direction during February to April and change to the South and Southwest direction in May and June as shown in Figure 5, in literature review.

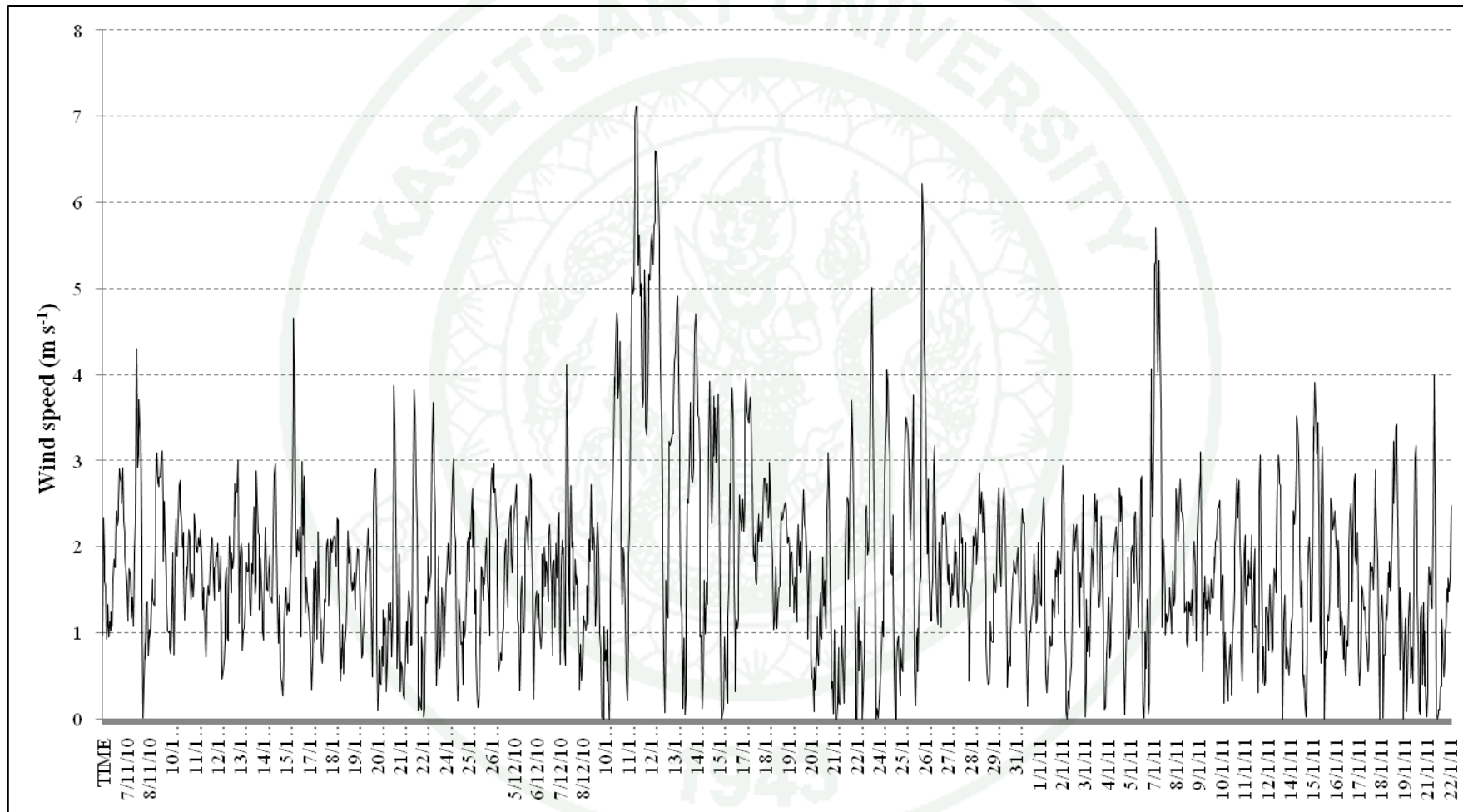
Wind speeds at three levels (4, 7 and 10 m) during northeast monsoon from 6<sup>th</sup> November 2010 to 22<sup>nd</sup> January 2011 were analyzed (Appendix Table 1). The maximum wind speed at level 4, 7 and 10 m on 11 December 2010 were 6.4, 7.1 and 7.4 m s<sup>-1</sup> respectively as presented in Figure 25 to Figure 27. These ranges of wind speed may cause strong wave that continuously attack the bamboo wall and the coast, then erode the coastal bank during the transgressive tide and erode the deposited sediment during the regressive tide.



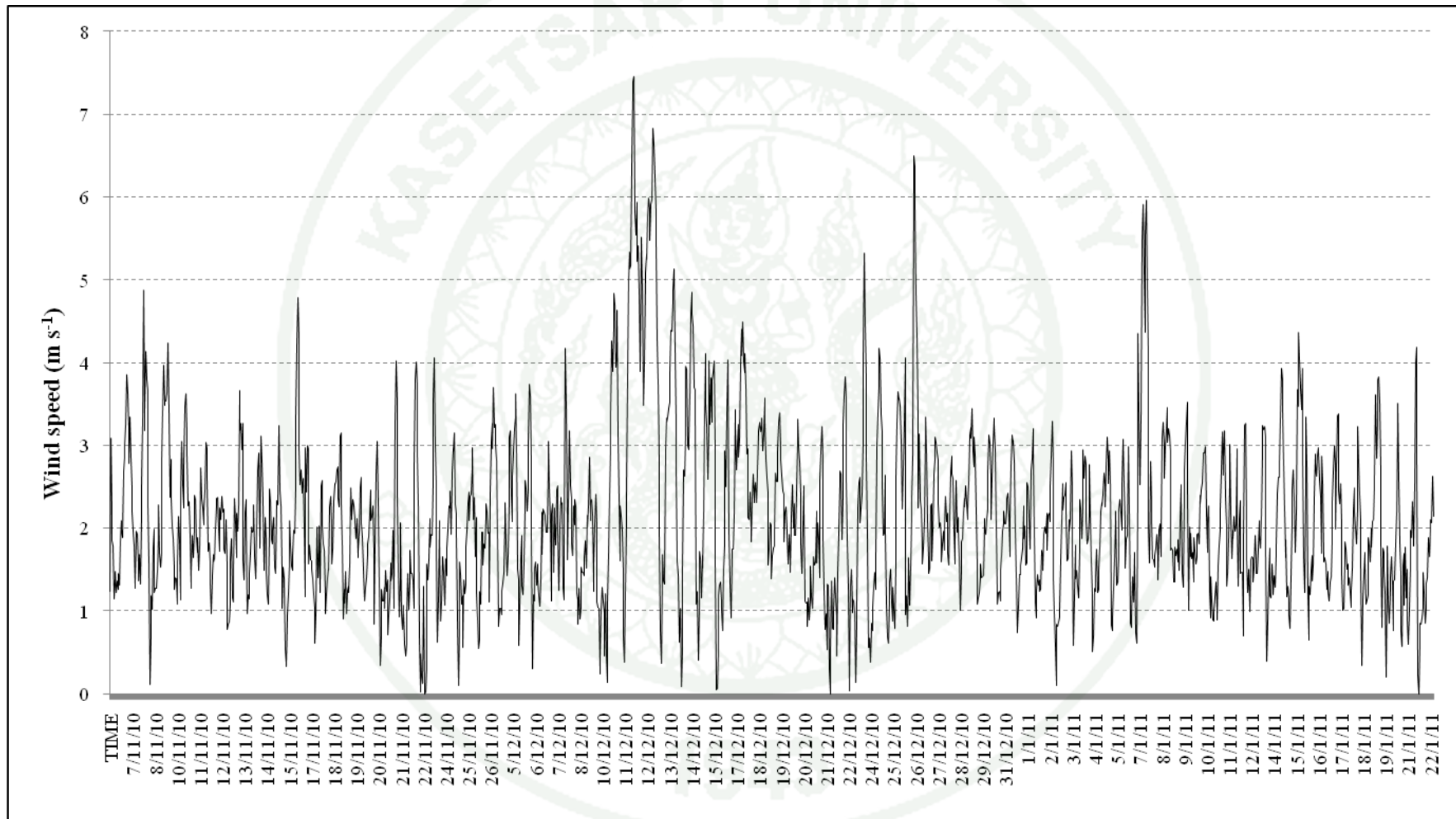
**Figure 24** Monthly wind rose diagram at study area at 10 m MSL showed wind direction prevailing northeast during northeast monsoon season.



**Figure 25** Wind speed at level 4 m (MSL) during Northeast Monsoon Season from 6th November 2010 to 22nd January 2011.



**Figure 26** Wind speed at level 7 m (MSL) during Northeast Monsoon Season from 6th November 2010 to 22nd January 2011.

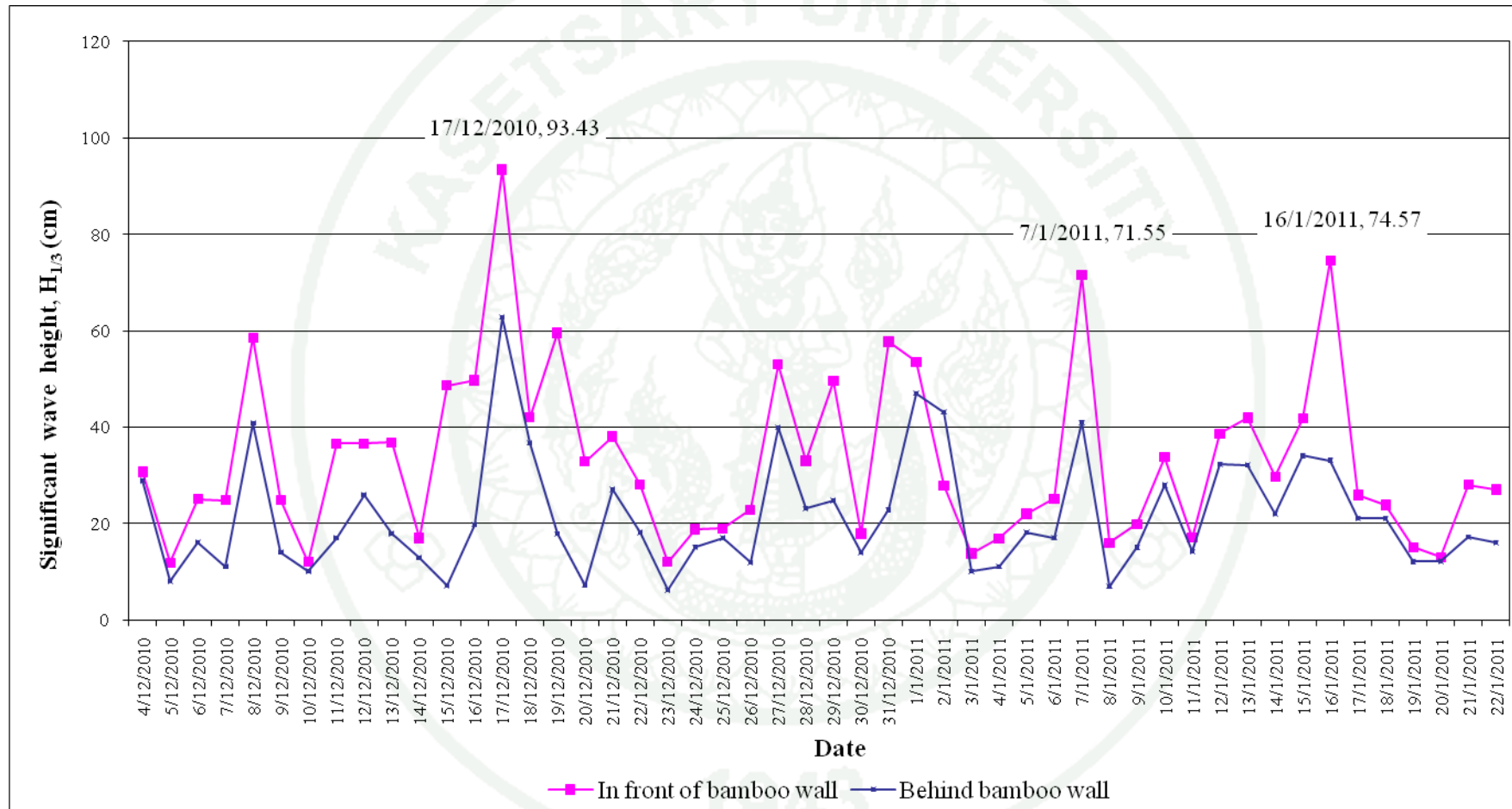


**Figure 27** Wind speed at level 10 m (MSL) during Northeast Monsoon Season from 6th November 2010 to 22nd January 2011.

## B. Wave Activity and Tidal Activity

Wave height at 10 m in front of bamboo wall and behind Bamboo wall at Bang Bo tidal coast was recorded. Wave form during very strong active high pressure (northwest monsoon wind) synoptic condition, Westerly wind, South and Southwest wind were analyzed in term of wave period and significant wave height ( $H_{1/3}$ : significant wave height or the average height only one third of high amplitude from all waves). Daily significant wave height at 10 m in front of Bamboo wall and behind Bamboo wall during December 4<sup>th</sup>, 2010 to January 22<sup>nd</sup>, 2011 as shown in Figure 28 that implied the Bamboo wall can decrease the amplitude of waves during their attenuation.

The result showed that, on December 17<sup>th</sup>, 2010 during Northeast Monsoon season, very strong wind started from 3 am to 12 am, caused very strong wave (wave height range between 60 to 100 cm) attack the coast. Very high wind speed  $4.5 \text{ m s}^{-1}$  (at 10 m level) occurred during 3 am to 4 am and caused wave height at 140.7 cm with 3.19 second in period during the regressive tide situation as shown in Table 3 . Hourly distribution of wave number respected to wave height at 10 m in front of Bamboo wall and behind Bamboo wall showed the reduction of maximum wave height as exhibited in Figure 29 and 30.

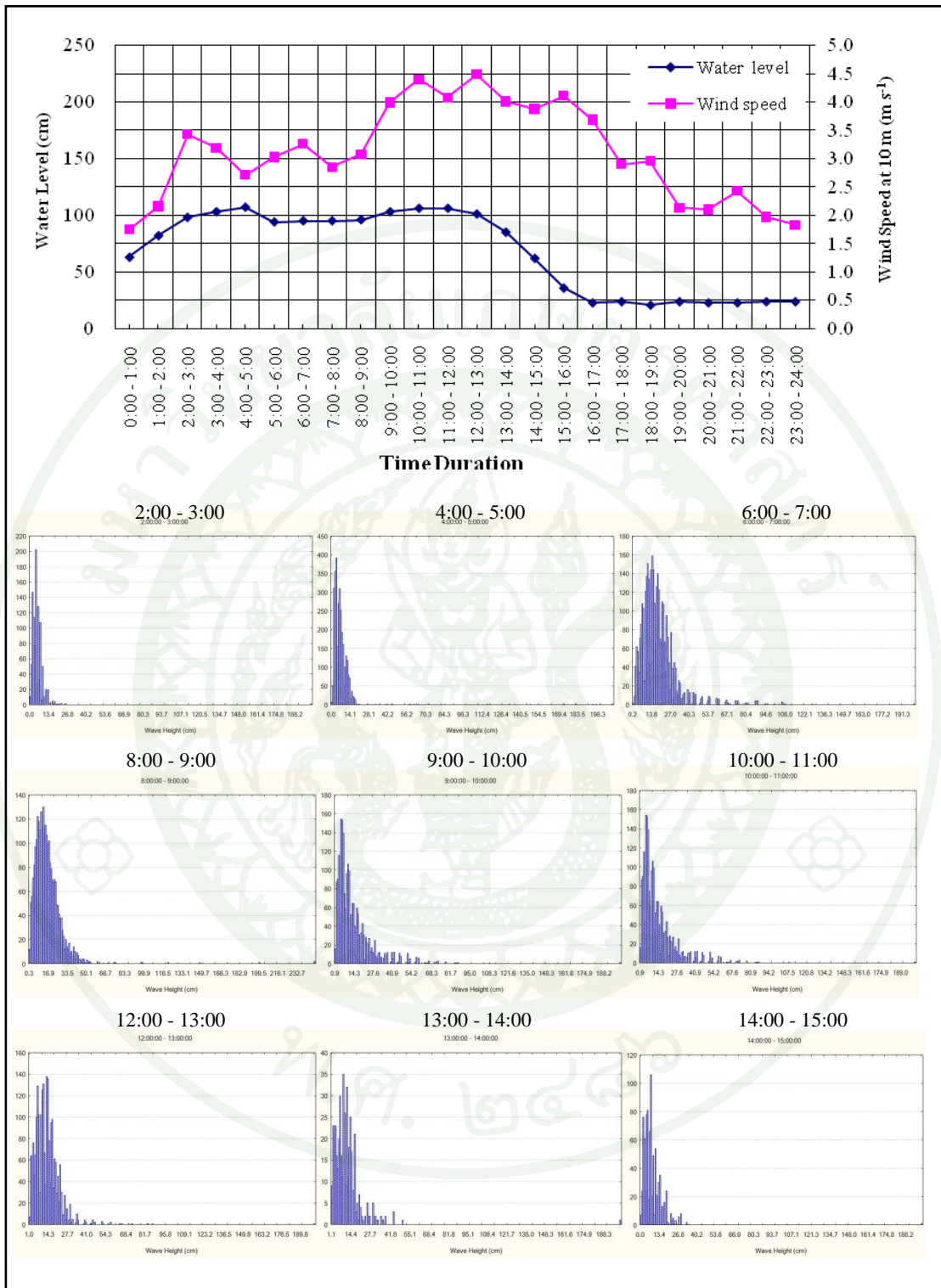


**Figure 28** Significant wave height,  $H_{1/3}$  (cm) at 10 m in front of bamboo wall and behind the bamboo wall during December 4<sup>th</sup>, 2010 to January 22<sup>nd</sup>, 2011.

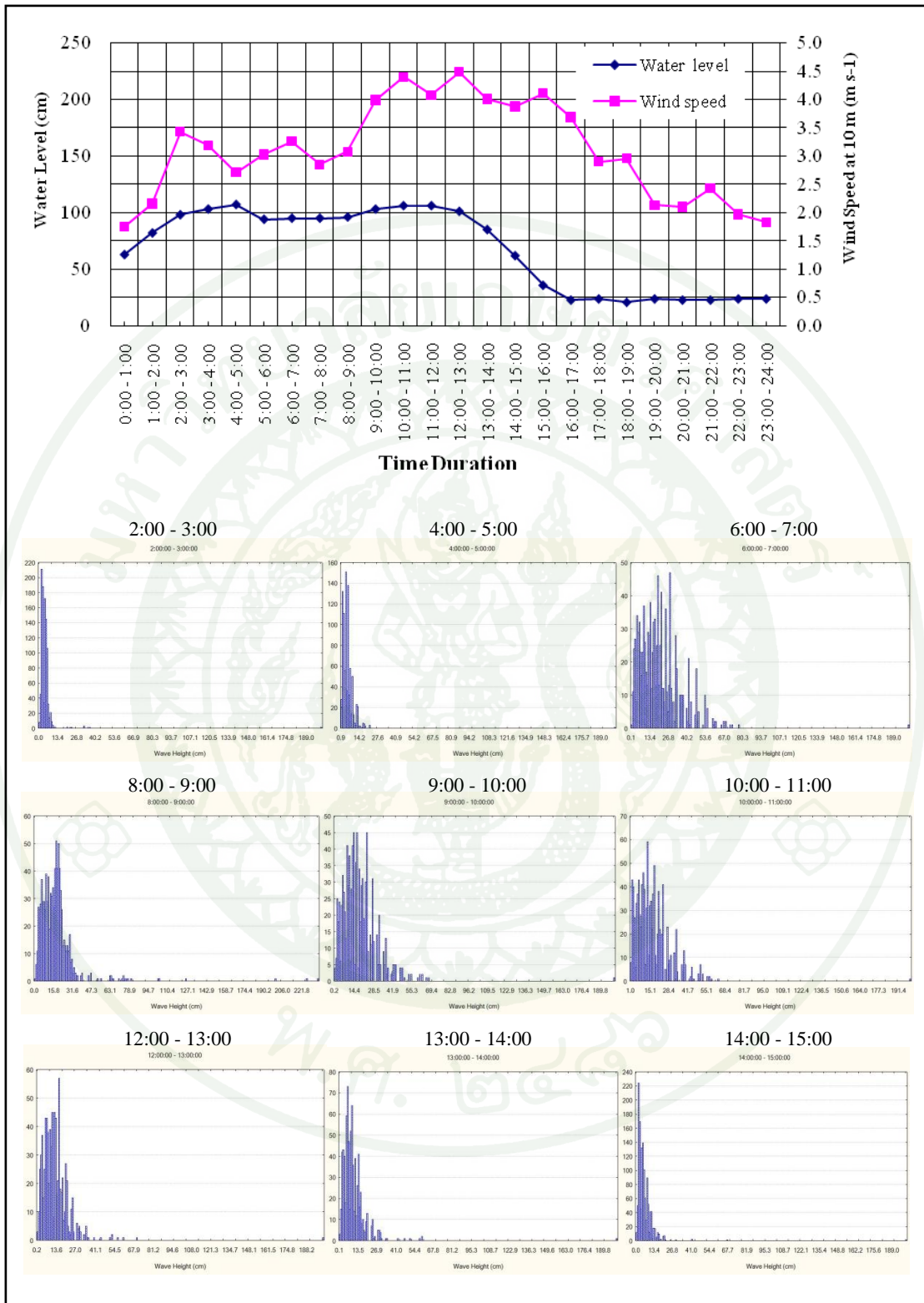
**Table 3** Water level, wave height, wave period and three level wind speed during strong northeast monsoon synoptic on December 17<sup>th</sup> 2010.

Time	Water level (cm)	Behind bamboo wall		In front of bamboo wall		Wind speed ( $m\ s^{-1}$ )		
		Significant wave height ( $H_{1/3}$ ) in cm	Wave period (s)	Significant wave height ( $H_{1/3}$ ) in cm	Wave period (s)	4 m	7 m	10 m
0:00 - 1:00	63	N/A	N/A	N/A	N/A	1.33	1.18	1.75
1:00 - 2:00	82	7.9	7.97	16.2	6.87	1.8	1.69	2.16
2:00 - 3:00	98	2.2	3.4	16.4	4.55	2.76	2.6	3.43
3:00 - 4:00	103	32.2	3.77	140.7	2.29	2.51	2.33	3.19
4:00 - 5:00	107	15.6	4.09	111.3	2.63	2.2	2.25	2.71
5:00 - 6:00	94	45.4	3.84	65.1	2.36	2.45	2.19	3.03
6:00 - 7:00	95	56.2	3.52	78.6	2.54	2.58	2.55	3.26
7:00 - 8:00	95	62.3	3.7	93.4	2.53	2.28	2.17	2.85
8:00 - 9:00	96	55.3	3.99	75.6	2.85	2.48	2.51	3.08
9:00 - 10:00	103	48.5	3.95	67.6	3.15	3.45	3.64	3.99
10:00 - 11:00	106	45.8	3.67	67.6	3.67	3.73	3.96	4.4
11:00 - 12:00	106	42.8	4.49	60.8	5.31	3.43	3.58	4.08
12:00 - 13:00	101	45.7	4.6	53.9	2.92	3.57	3.49	4.49
13:00 - 14:00	85	28.5	4.79	34.7	5.88	3.32	3.44	4.01
14:00 - 15:00	62	18.9	7.97	23.5	6.87	3.36	3.58	3.88
15:00 - 16:00	36	N/A	N/A	N/A	N/A	3.5	3.73	4.11
16:00 - 17:00	23	N/A	N/A	N/A	N/A	3.13	3.34	3.69
17:00 - 18:00	24	N/A	N/A	N/A	N/A	2.52	2.67	2.9
18:00 - 19:00	21	N/A	N/A	N/A	N/A	2.54	2.71	2.96
19:00 - 20:00	24	N/A	N/A	N/A	N/A	1.87	1.91	2.13
20:00 - 21:00	23	N/A	N/A	N/A	N/A	1.83	1.83	2.1
21:00 - 22:00	23	N/A	N/A	N/A	N/A	2.1	2.15	2.43
22:00 - 23:00	24	N/A	N/A	N/A	N/A	1.69	1.63	1.97
23:00 - 24:00	24	N/A	N/A	N/A	N/A	1.64	1.56	1.83

Note: N/A means non available wave data during neap tide



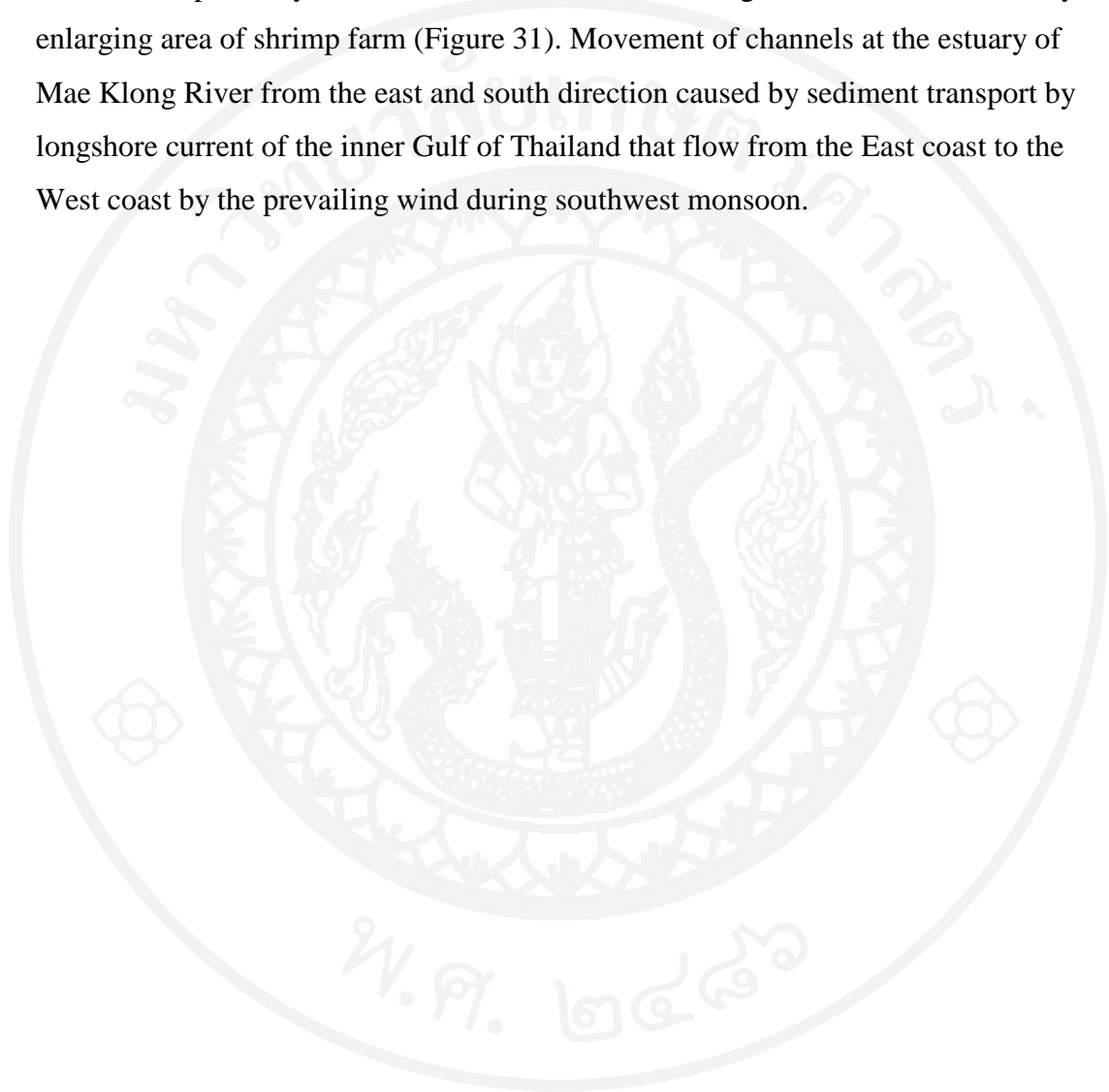
**Figure 29** Distribution of wave number related to wave height at 10 m in front of Bamboo wall on December 17<sup>th</sup> 2010.

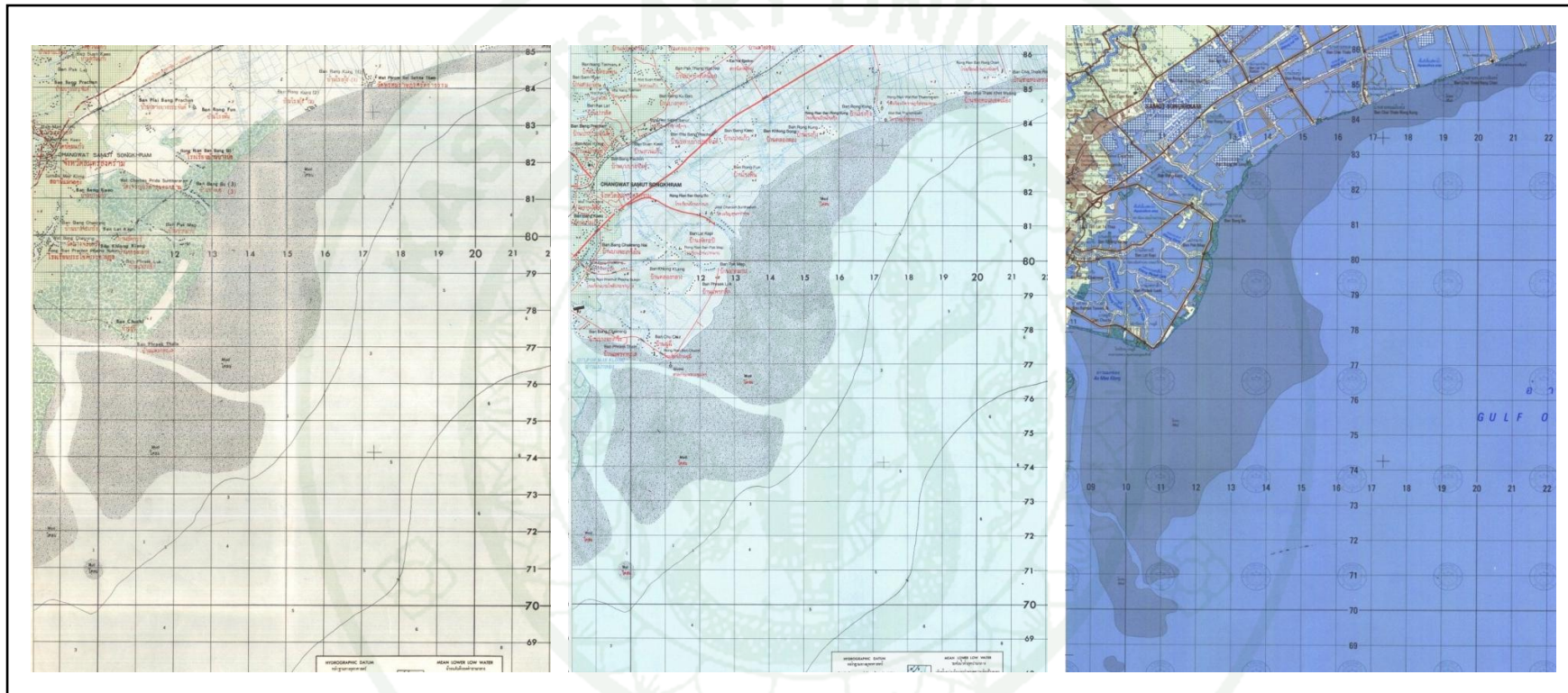


**Figure 30** Distribution of wave number related to wave height at 10 m behind Bamboo wall on December 17<sup>th</sup> 2010.

### C. Human Activity

Interpretation on the topographic maps scale 1:50,000 series L7017 and L7018 sheet 5035 I and 5035 IV named Samut Songkhram Province in 1968, 1991 and 2000 respectively revealed the reduction rate of mangrove forest was caused by enlarging area of shrimp farm (Figure 31). Movement of channels at the estuary of Mae Klong River from the east and south direction caused by sediment transport by longshore current of the inner Gulf of Thailand that flow from the East coast to the West coast by the prevailing wind during southwest monsoon.





**Figure 31** Topographic map of Samut Songkhram Province at the estuary of Mae Klong River in 1968, 1991 and 2000 showed the reduction of mangrove areas due to shrimp farm increment over the tidal area and sediment.

**Source:** Topographic maps scale 1:50,000 series L7017 and L7018 sheet 5035 I and 5035 IV (Samut Songkhram Province) since 1968, 1991 and 2000.

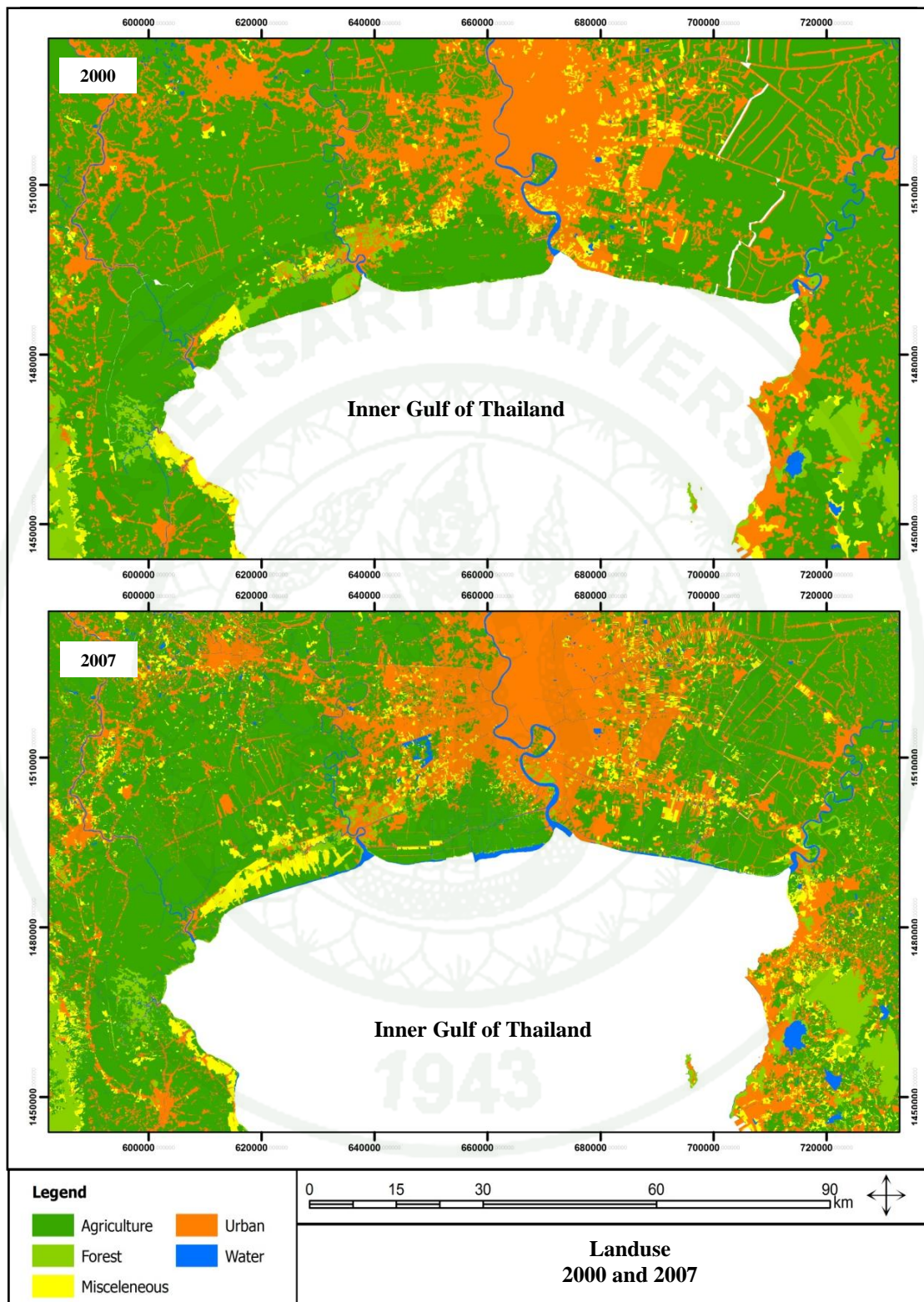
Satellite image interpretation at Pak Klong Bang Bo during 2000 and 2007 confirmed the reduction of mangrove due to the increasing of shrimp farm, then cause coastal erosion in this area as shown in Table 4 and Figure 32.

**Table 4** Area of landuse changed at 10 km from shoreline along Samut Songkhram coast in 2000 and 2007.

Unit: km<sup>2</sup>

Landuse	Area		Changes
	Year 2000	Year 2007	
Agricultural areas	247.2	233.7	-13.5
Mangrove areas	20.2	18.4	-1.7
Urban	13.8	27.0	13.2
Water and reservoirs	7.7	8.8	1.1
Etc.	22.0	22.6	0.6

Note: - is decrease  
+ is increase



**Figure 32** Satellite image of the Inner Gulf of Thailand in 2000 and 2007.

The remnant of culvert that drain sea water in and out the shrimp farm implied the former location of the coast that densely growth of mangrove trees. The concaved shape of the coast and tilting of mangrove trees showed bank erosion along the coast by strong wind and strong wave during transgressive tide as well as tilting of culvert implied erosion of young sediment at the floor during regressive tide as shown in Figure 33.



**Figure 33** Flow in and out of water from sea through culvert of shrimp farm caused mangrove trees tilted and toppled, then all lost and coastal eroded.

The factors of coastal erosion are human activities on land use change from mangroves to shrimp farm that caused erosion on coastal bank and coastal floor erosion. Coastal bank erosion can be confirmed with high wind speed data and high sea level data during winter season. Unfortunately, due to unfinished in time of wind speed and wave measuring apparatus, then no wind speeds data before winter season and after winter season to confirm the coastal bank erosion. However, wind speed at

10 km from Samut Songkhram coast showed stronger wind in winter season than other season and Robinson (1974) reported that during this time water level is quite high due to flow of fresh water from inland watershed and high salinity water from Tonkin Gulf to Inner Gulf of Thailand.

## 2. Rate of sediment deposition and erosion

The level of sediments deposition and erosion at Bamboo protected area (location 1) were measured (4 times) by leveling telescope during each prevailing wind direction in order to obtain the rates of deposition and erosion (Table 5 and Figure 34). Volume of sediment deposition or erosion was calculated by 1 m × 1 m grid on surface of the coastal floor. The erosion and deposition rate contour of sediment behind the bamboo wall during 15 November 2009 to 23 May 2010, 23 May 2010 to 5 October 2010 and 5 October 2010 to 18 December 2010 were -0.11, -0.02 and +1.57 cm month<sup>-1</sup> respectively as shown in Table 6 and Figure 35, 36 and 37.

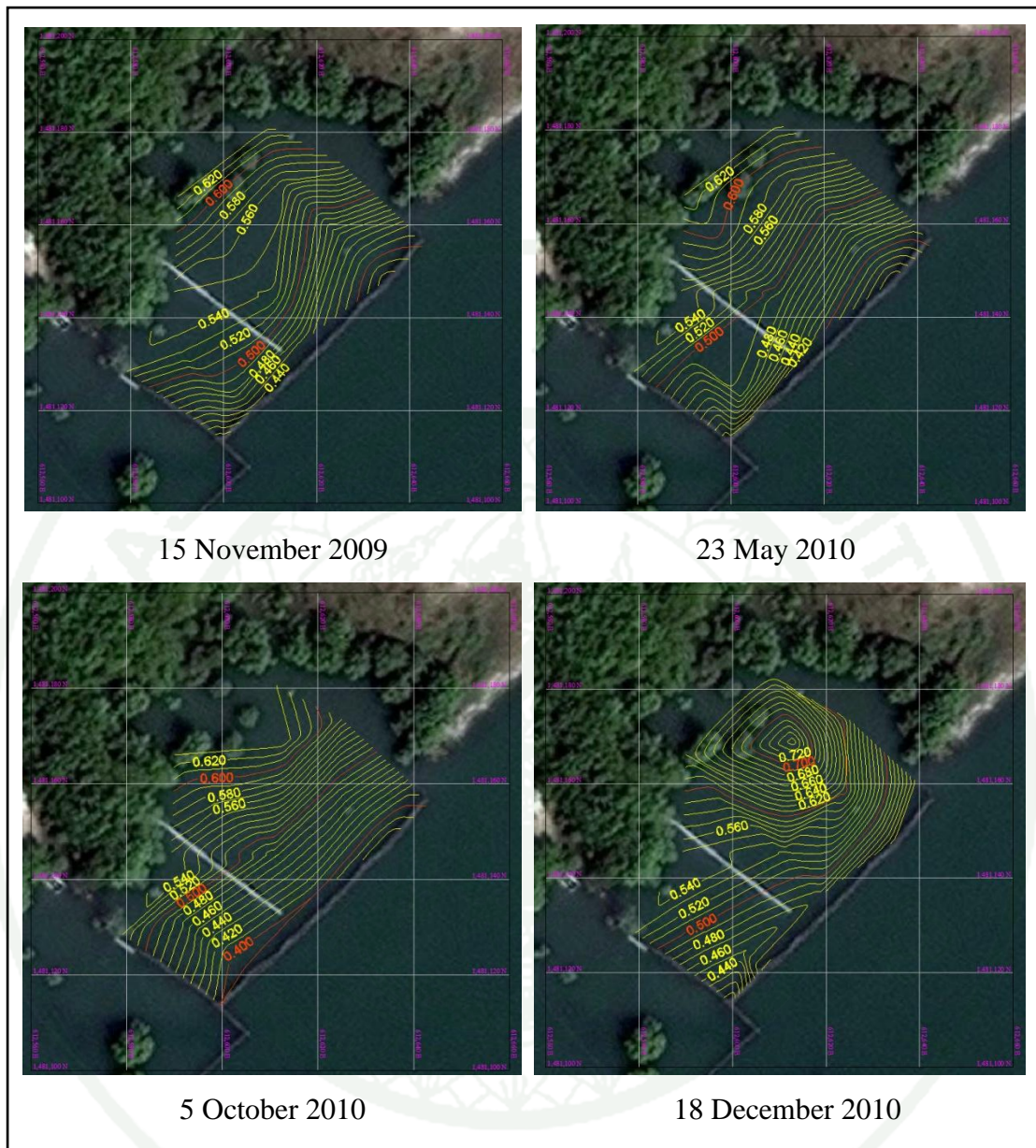
**Table 5** Duration of measurement on sediments deposition and erosion at protected area by Bamboo wall.

Time	Date (Day/Month/Year)	Wind Direction
1	15 November 2009	NE
2	23 May 2010	S, SW
3	5 October 2010	NE
4	18 December 2010	NE

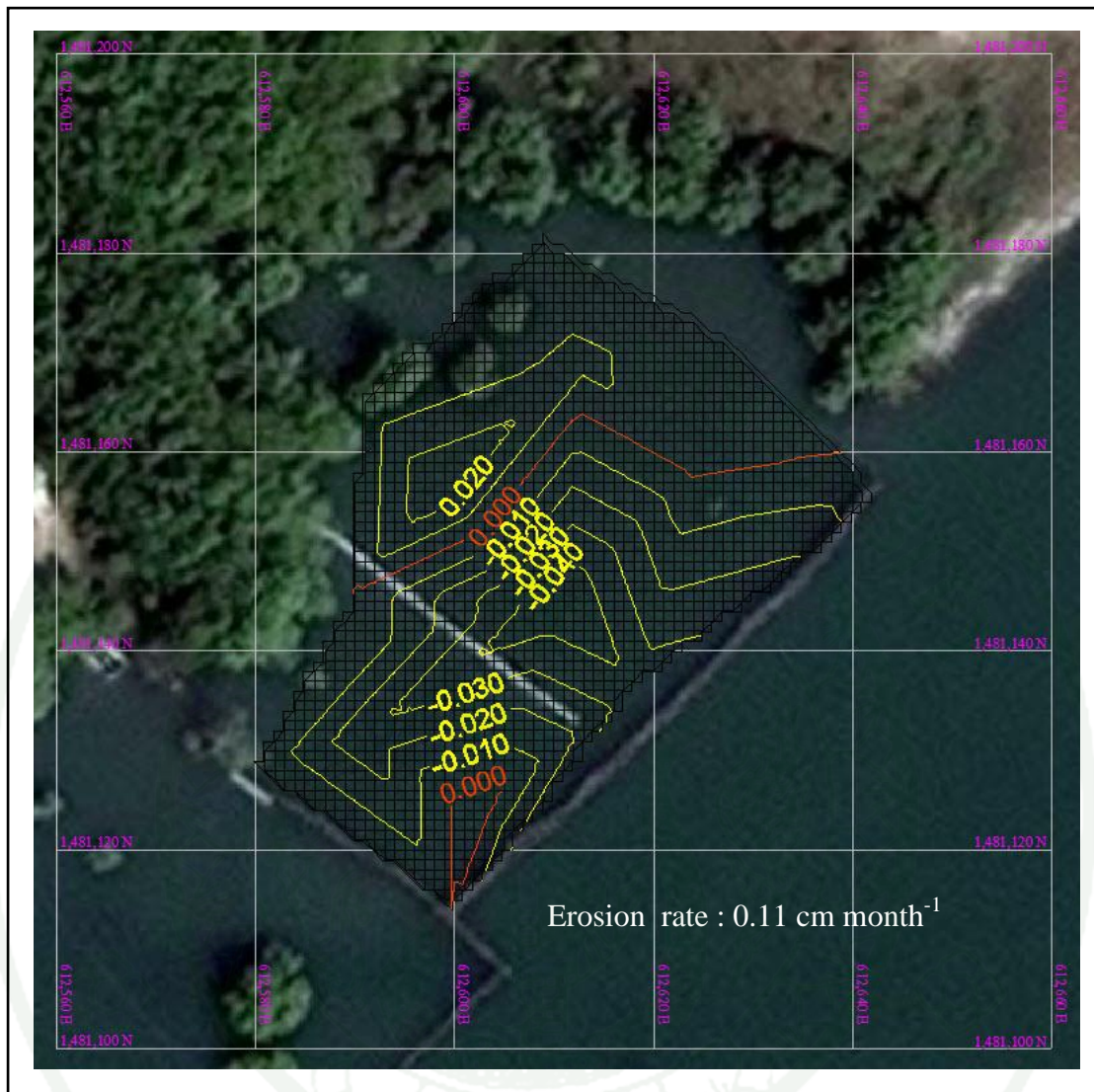
**Table 6** Amount and rate of sediment deposition and erosion at protected area by Bamboo wall.

Compare	Grid (1 m x 1 m)	Eroded (m <sup>3</sup> )	Deposited (m <sup>3</sup> )	Total (m <sup>3</sup> )	Rate (cm month <sup>-1</sup> )
1 and 2	2239	23.65	5.80	- 17.85	- 0.11
2 and 3	2241	22.16	20.71	- 1.99	- 0.02
3 and 4	2231	-	105.22	+ 105.22	+ 1.57

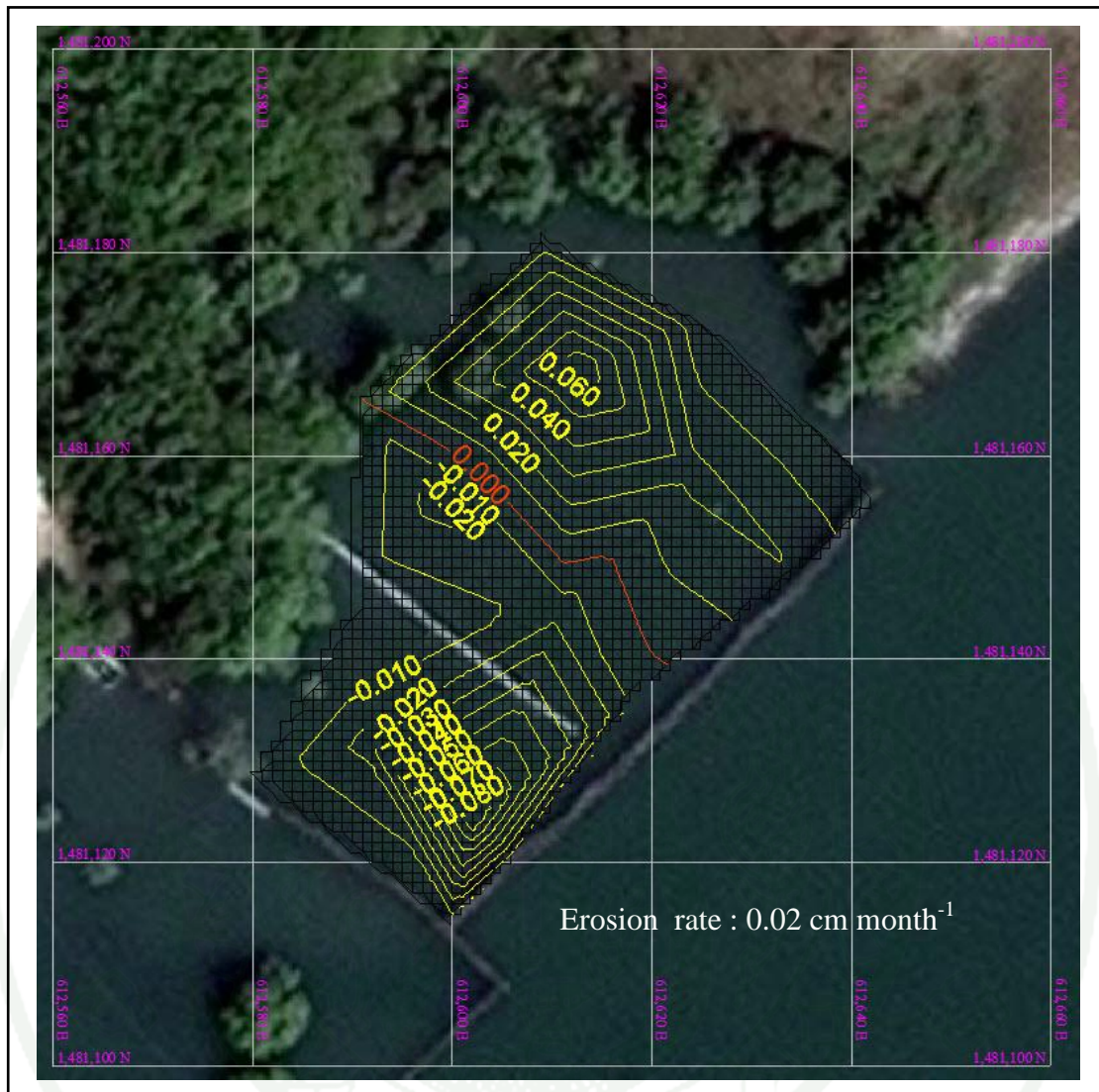
Note: - imply coastal erosion  
+ imply coastal deposition



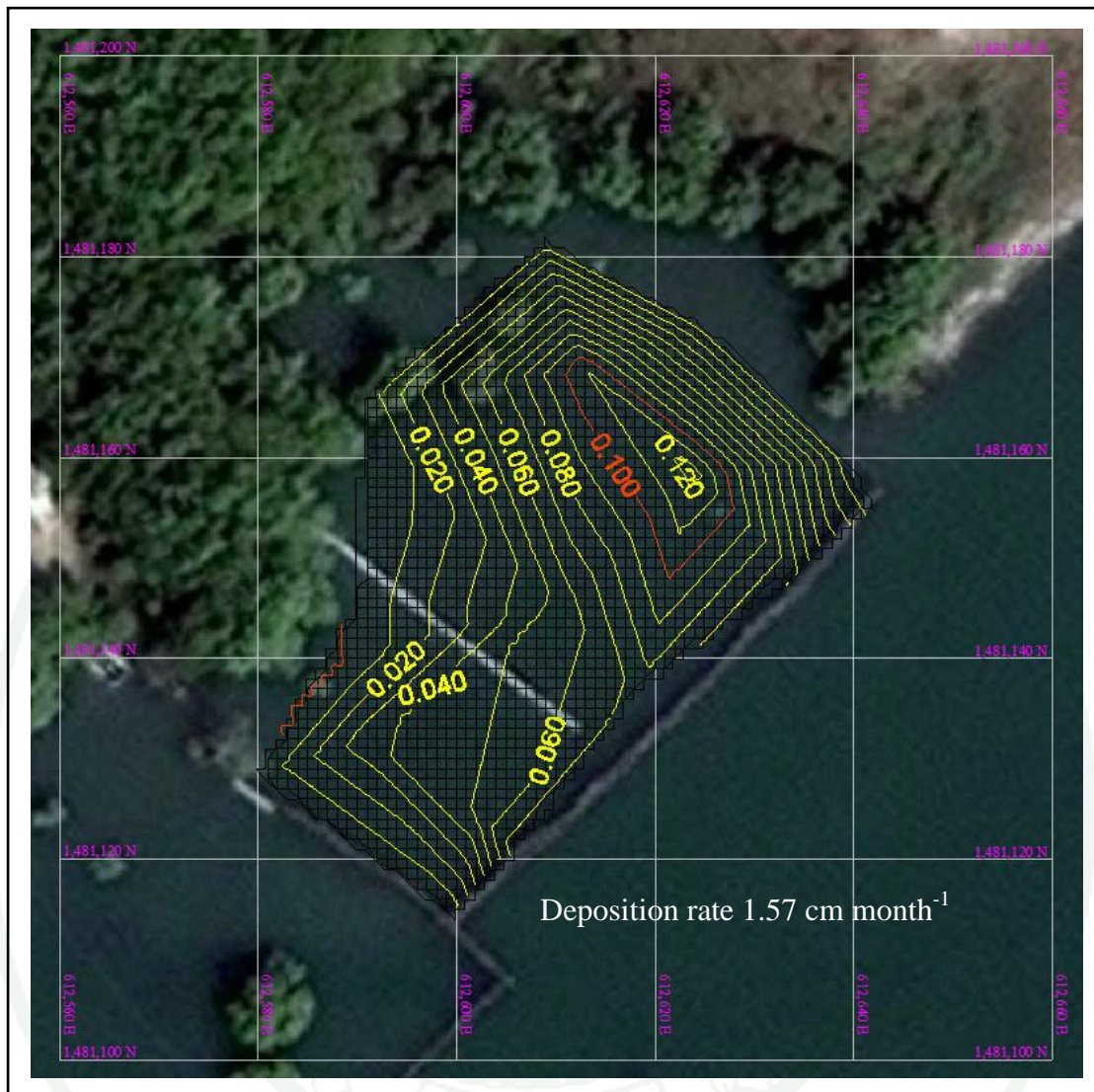
**Figure 34** Contours of measured sediments at Bamboo protected area during each period of prevailing wind direction.



**Figure 35** Contours of sediment erosion and deposition at Bamboo protected area during November 2009 to May 2010.



**Figure 36** Contours of sediment erosion and deposition at Bamboo protected area during May 2010 to October 2010.



**Figure 37** The deposition rate contour during October 2010 to December 2010.

1943

The level of sediments deposition and erosion at non protected area (location 2) were measured (3 times) by leveling telescope during each prevailing wind direction in order to obtain the rates of deposition and erosion as shown in Table 7 and Figure 38. Volume of sediment deposition and erosion were calculated by 5 m × 5 m grid on surface of coastal floor. The contour of erosion and deposition rate during 23 May 2010 to 5 October 2010 and 5 October 2010 to 18 December 2010 were -0.64 and -1.21 cm month<sup>-1</sup> respectively as presented in Table 8 and Figure 39.

**Table 7** Duration of measurement on sediments deposition and erosion at no protected area.

No.	Date	Wind Direction
1	23 May 2010	S, SW
2	5 October 2010	NE
3	18 December 2010	NE

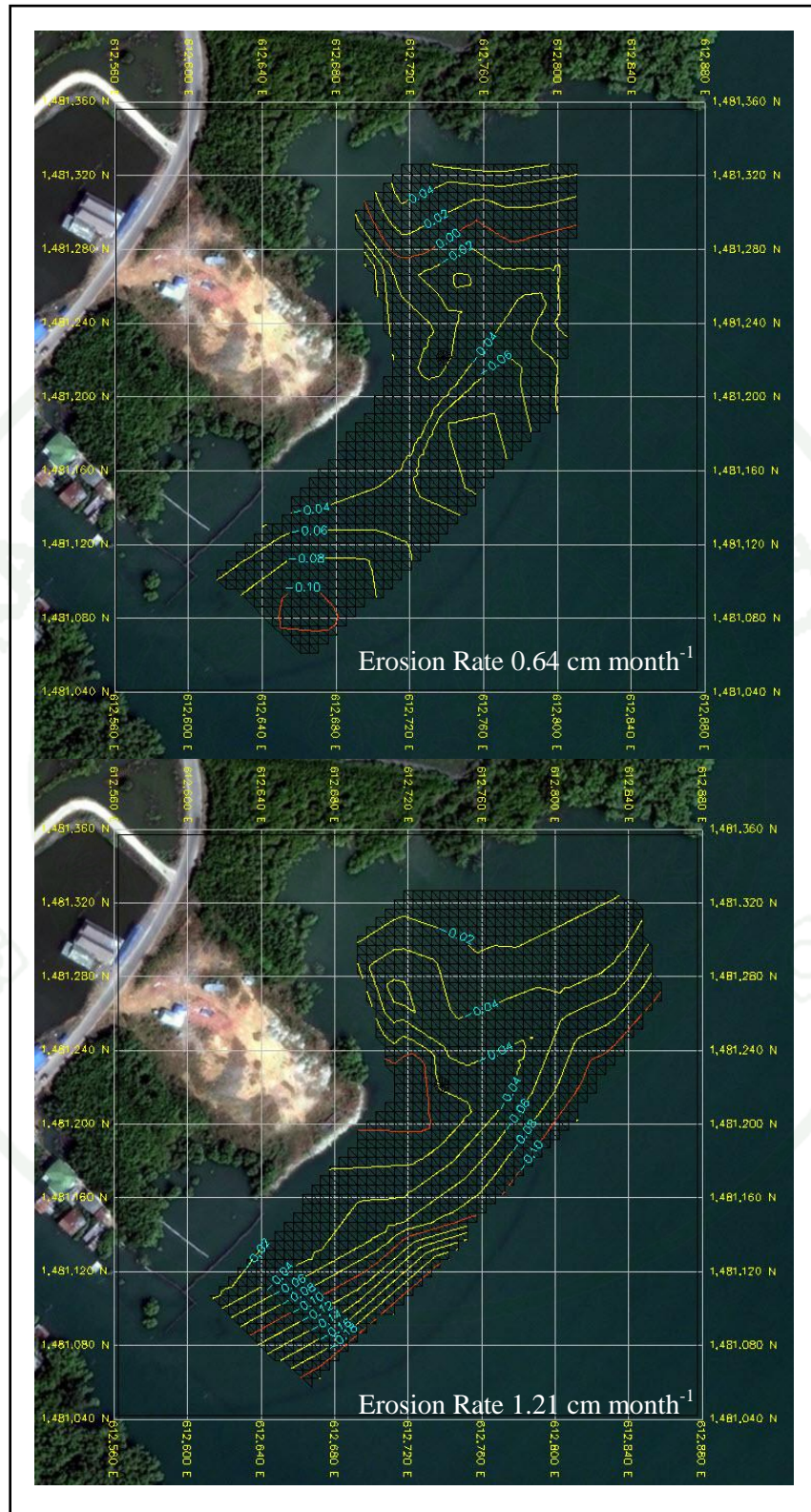
**Table 8** Amount and rate of sediment deposition and erosion at no protected area by Bamboo wall.

Compare	Grid (5 m x 5 m)	Eroded (m <sup>3</sup> )	Deposited (m <sup>3</sup> )	Total (m <sup>3</sup> )	Rate (cm month <sup>-1</sup> )
1 and 2	1081	739.38	45.19	-694.19	-0.64
2 and 3	1287	-	1171.84	-1171.84	- 1.21

Note: - imply coastal erosion  
+ imply coastal deposition



**Figure 38** Contours of measured sediments at non protected area during each period of prevailing wind direction.



**Figure 39** Contours of sediment erosion and deposition at non protected area during 23 May 2010 to 5 Oct 2010 (top) and 5 Oct 2010 to 18 Dec 2010 (below).

The level of sediments deposition and erosion at mangrove area (location3) were measured (3 times) by leveling telescope during each prevailing wind direction in order to obtain the rates of deposition and erosion at mangrove area as shown in Table 9 and Figure 40. Volume of sediment deposition and erosion was calculated by 2 m × 2 m grid on the surface of coastal floor. The erosion and deposition rate contour of sediment at mangrove area 23 May 2010 to 5 October 2010 and 5 October 2010 to 18 December 2010 were -0.13 and +1.71 cm month<sup>-1</sup> respectively as present in Table 10 and Figure 41.

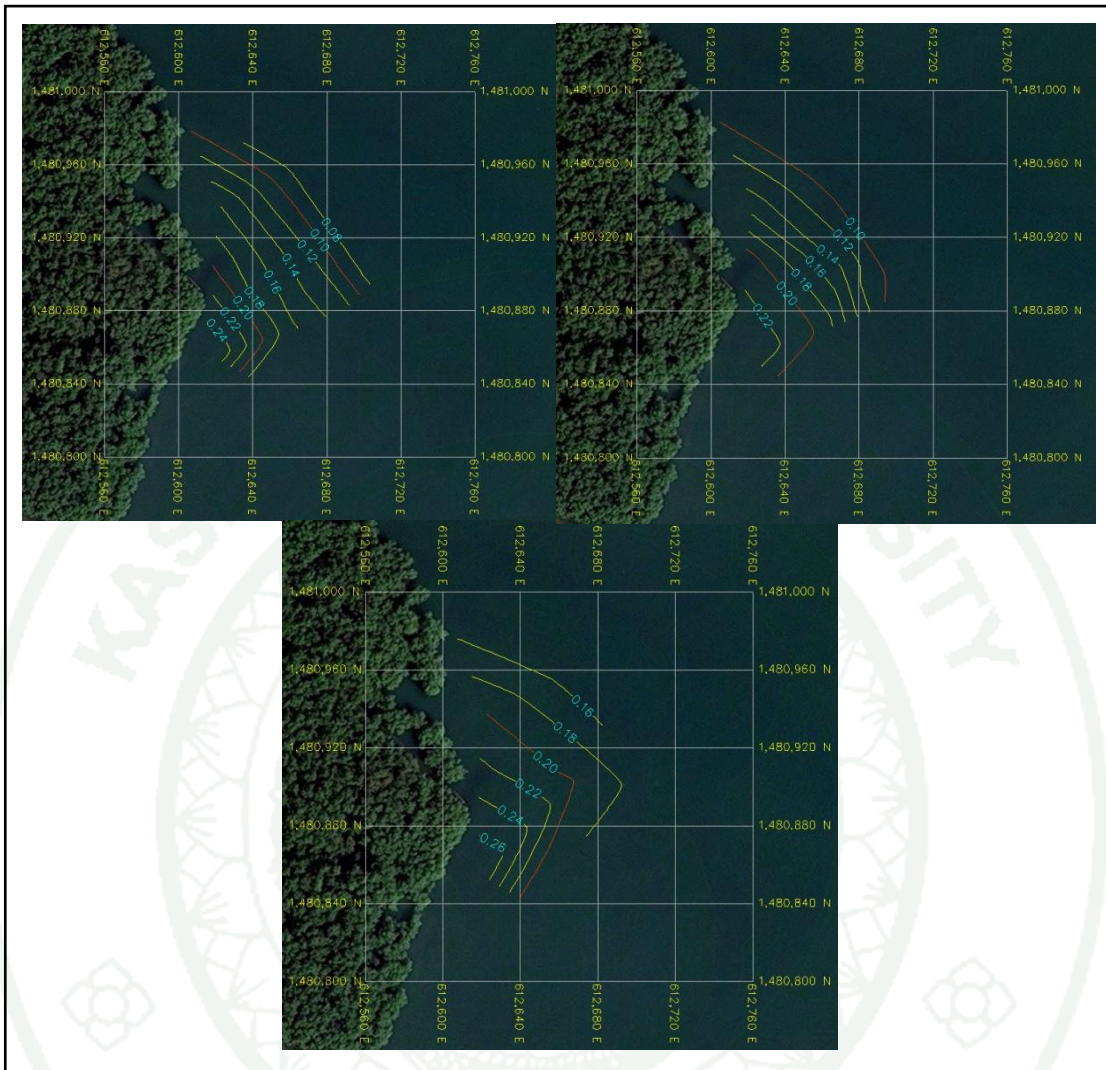
**Table 9** Duration of measurement on sediments deposition and erosion at mangrove area.

No.	Date	Wind Direction
1	23 May 2010	S, SW
2	5 October 2010	NE
3	18 December 2010	NE

**Table 10** Amount and rate of sediment deposition and erosion at mangrove area by Bamboo wall.

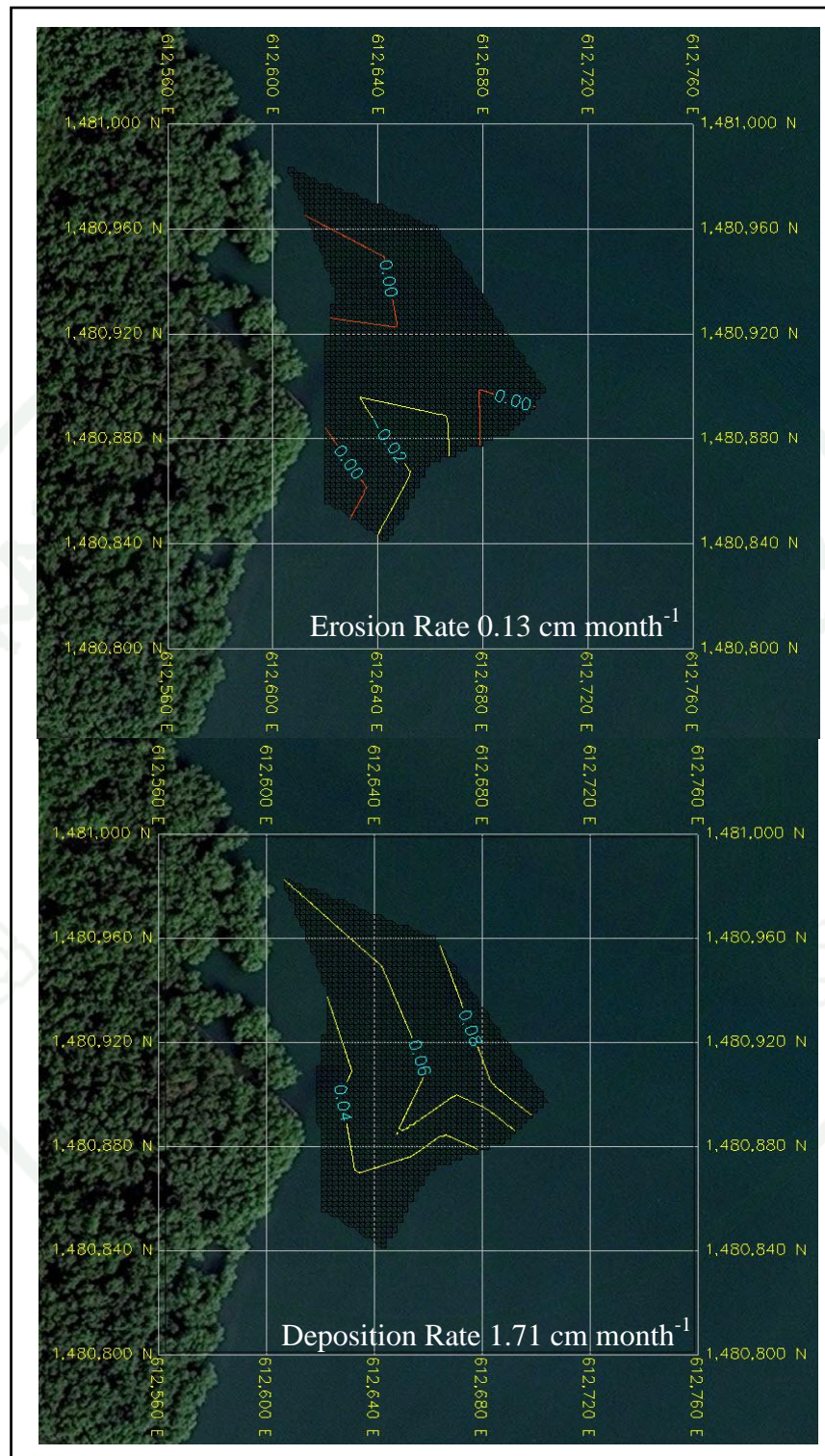
Compare	Grid (2 m x 2 m)	Eroded (m <sup>3</sup> )	Deposited (m <sup>3</sup> )	Total (m <sup>3</sup> )	Rate (cm month <sup>-1</sup> )
1 and 2	1871	39.62	1.95	37.68	- 0.13
2 and 3	1868	-	384.10	384.10	+ 1.71

Note: - imply coastal erosion  
+ imply coastal deposition



**Figure 40** Contours of measured sediments at mangrove area during each period of prevailing wind direction.

1943



**Figure 41** Contours of sediment erosion and deposition at mangrove area during 23 May 2010 to 5 Oct 2010 (top) and 5 Oct 2010 to 18 Dec 2010 (below).

During November to January, small amount of sediment deposited along the coast due to the influent of daytime sea level transgression and prevailing wind accompanied with seabreeze push transparent sea water from outer gulf to the inner gulf and coast. During those period, high tide and strong prevailing wind caused strong wave attack the coastal bank, and then erode both mangrove trees and soil. From February to April and May, south and southwest wind or Salhaton wind (local name) blown to the coast. During this time, low tide from nighttime sea level regressive and prevailing wind accompanied with landbreeze disturbed mud, then transported as muddy longshore current to the east coast. The contours of sediment deposited during the southwest and early northeast wind (May to December) and sediment eroded during the northeast and southerly wind (January to April).

Coastal floor erosion are mainly caused by direct attack of wave at soft sediment on the coastal floor during at the beginning of neap tide and at the end of spring tidal especially in rainy season. During rainy season, strong wind from southwest monsoon causes floor erosion than bank erosion due water level in this season lower than in the maximum winter season.

Small amount of deposited sediment behind bamboo wall at the study area may due to two open channels at nearby the bank of rock dump area, then all sediment in turbid water leak out from these channels even through from interspacing of Bamboo wall.

Measuring sediment level by leveling telescope measurement were carried out during high tide that can cause error due to compressive stress of staff gauge platform during laying down on soft sediment.

### **3. Properties of sediment**

Randomized soil sampling was carried out from non protected and protected area by bamboo wall. Disturbed and undisturbed samples were taken from protected area (location No.1), no protected area with no mangrove forest (location No.2), and

non protected area with mangrove forest (location No.3). The properties of sediment revealed very soft or very high moisture content and high plasticity clay to silty clay (Table 11). The sediment in the protected area showed higher moisture content and lower unit weight than no protected area. The sediment under the eroded stage in front of bamboo wall and the concave coast harder than sediment under the deposited stage behind the bamboo wall due to loss of moisture content and lost of the upper layer sediment during the erosion stage. Their liquid limits, plastic limits and unit weight implied the soft clay sediment those overlain on top of sediment from the previous period.

**Table 11** Properties of sediment deposited at Pak Klong Bang Bo, Samut Songkhram Province.

Location No.	Depth (m)	Group symbol	Atterberg limits (%)			Moisture content (%)	Unit weight (kN m <sup>-3</sup> )	Grain size analysis (% finer than)	
			LL	PL	PI			2 mm	75 µm
			1	0.0 to 0.5	OL or ML			49.0	39.1
	0.5 to 1.0	OH or MH	50.6	48.0	2.6	186.1	9.8		
2	0.0 to 0.5	OH or MH	51.5	42.0	9.4	155.5	11.8	100	80.8
	0.5 to 1.0	OL or ML	49.1	40.6	8.6	179.9	11.8		
3	0.0 to 0.5	OH or MH	50.8	36.0	14.8	178.1	11.8	100	98.4
	0.5 to 1.0	OH or MH	50.6	41.1	9.5	186.5	10.8		

Note: LL : Liquid Limit, PL : Plastic Limit, PI : Plastic Index,  
 OH : High compressibility organic soil, MH : High compressibility silt,  
 OL : Low compressibility organic soil, ML : Low compressibility silt.

## CONCLUSION AND RECOMMENDATION

### Conclusion

From the experimental results and discussion of this study, the conclusion can be drawn as follow:

1. The causes of erosion and sediment deposition are due to human activities and land use change from mangrove to shrimp farm, the softness of deposited sediments and strong winds that cause strong water waves during monsoon season.
2. During each prevailing wind, the sediments was deposited on coastal floor during late Northeast Monsoon Season and Southerly wind while the coastal bank was eroded during late Northeast wind on bank erosion due to high tide and the coastal floor was eroded during Southwest wind due to low tide.
3. Bamboo walls can help damping the amplitude of wave height at behind the Bamboo wall from 15.2 to 86.6 percent of wave height in front of the Bamboo wall. Therefore, the energy of incident water waves were dissipated by Bamboo wall.
4. The soft sediment deposited behind the bamboo walls can support the growth of young mangroves due to their strength in deeper layer still strong enough to support young mangrove trees.
5. Bamboo is natural materials that very cheap and easily taken and can be designed to put coastal floor as group of Bamboo become to the Bamboo wall

### **Recommendation**

The results of this study showed many problems that can be studied in future.

1. Level of sediment should be monthly measured in order to know actual monthly rate of sediment deposition or erosion. Another method or new effective technique to measure sediment deposition and erosion should be carried out.
2. The attack force due to wave during normal condition and strong monsoon condition in front of the bamboo wall and behind the bamboo wall should be measured.
3. Coastal current and suspended sediment should be measured in order to confirm with the prevailing wind direction.

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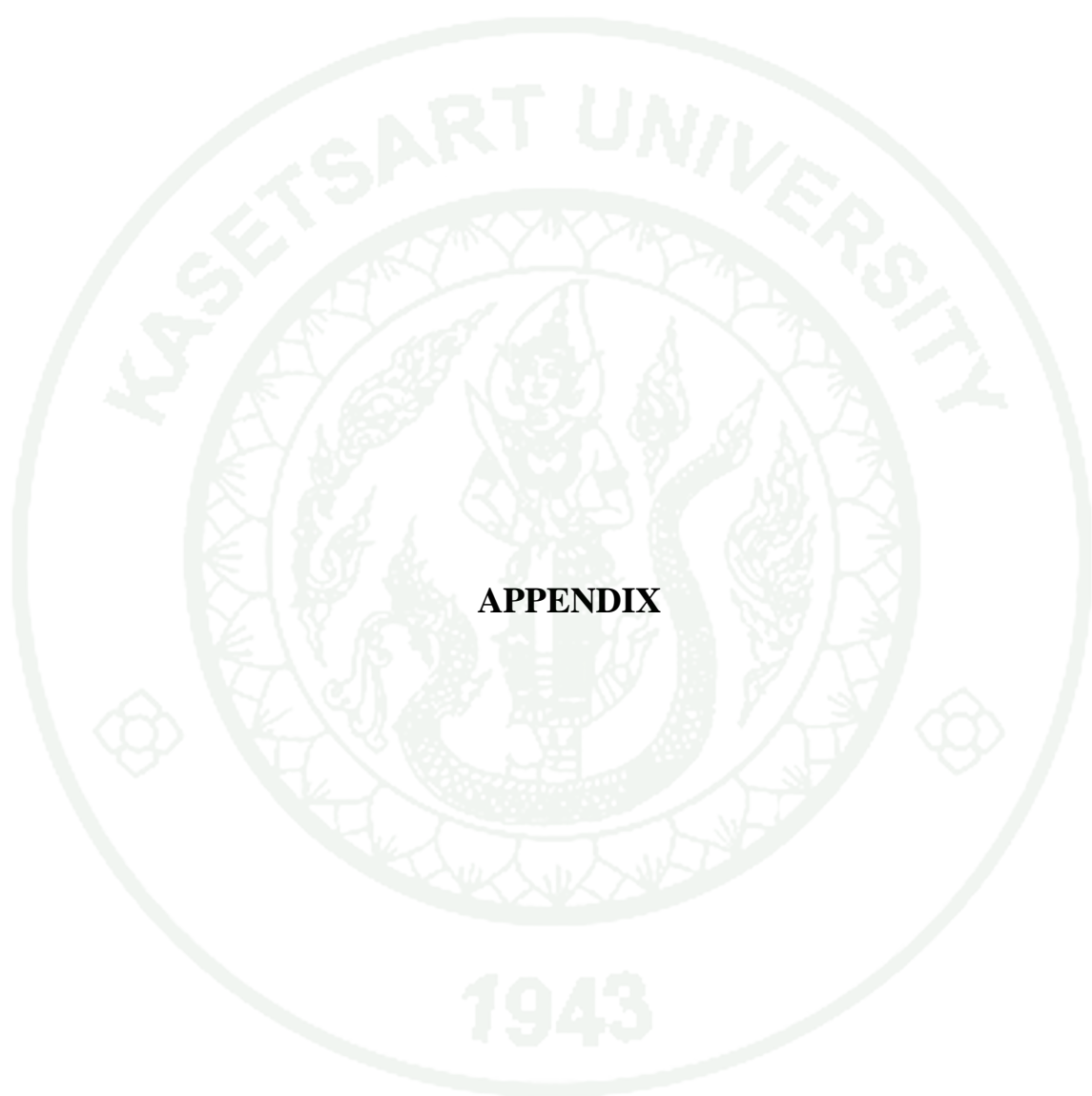
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**APPENDIX**

**Appendix Table 1** Daily of wind speed at 4, 7 and 10 m respectively.

Data	Wind Speed ( $\text{m s}^{-1}$ )					
	4 m		7 m		10 m	
	Average	Max	Average	Max	Average	Max
4/12/2010	1.58	3.22	1.56	2.97	1.98	3.70
5/12/2010	1.81	3.04	1.77	2.73	2.17	3.62
6/12/2010	1.57	3.10	1.58	2.84	1.87	3.74
7/12/2010	1.75	2.60	1.72	2.40	2.09	3.05
8/12/2010	1.74	4.05	1.67	4.12	2.07	4.17
9/12/2010	1.51	2.64	1.54	2.72	1.77	2.86
10/12/2010	1.96	4.39	2.03	4.71	2.28	4.83
11/12/2010	3.38	6.61	3.59	7.13	3.83	7.46
12/12/2010	4.77	6.18	5.09	6.60	5.32	6.83
13/12/2010	2.85	4.75	3.02	5.16	3.18	5.40
14/12/2010	2.37	4.41	2.50	4.70	2.69	4.85
15/12/2010	2.33	3.81	2.38	3.92	2.61	4.11
16/12/2010	1.51	3.63	1.42	3.84	1.82	4.03
17/12/2010	2.59	3.73	2.61	3.96	3.10	4.49
18/12/2010	2.24	3.21	2.22	2.98	2.68	3.58
19/12/2010	1.84	2.76	1.84	2.52	2.24	3.40
20/12/2010	1.54	2.62	1.51	2.67	1.96	3.32
21/12/2010	1.28	2.84	1.28	3.10	1.62	3.23
22/12/2010	1.52	3.43	1.53	3.70	1.83	3.83
23/12/2010	1.72	4.70	1.79	5.01	2.04	5.32
24/12/2010	1.63	3.80	1.65	4.05	1.97	4.17
25/12/2010	1.78	3.47	1.79	3.77	2.11	4.06
26/12/2010	2.21	5.73	2.31	6.22	2.78	6.49


**Appendix Table 1** (Continued)

Data	Wind Speed Wind Speed ( $\text{m s}^{-1}$ )					
	4 m		7 m		10 m	
	Average	Max	Average	Max	Average	Max
27/12/2010	1.86	3.07	1.84	3.17	2.24	3.34
28/12/2010	1.66	2.34	1.66	2.38	2.04	2.87
29/12/2010	1.81	2.91	1.73	2.86	2.24	3.45
30/12/2010	1.72	2.87	1.61	2.68	2.15	3.33
31/12/2010	1.59	2.59	1.51	2.44	2.02	3.13
1/1/2011	1.51	2.79	1.39	2.58	1.90	3.20
2/1/2011	1.40	2.93	1.31	2.94	1.68	3.29
3/1/2011	1.50	2.61	1.44	2.60	1.85	2.93
4/1/2011	1.50	2.52	1.45	2.62	1.89	2.95
5/1/2011	1.66	2.69	1.62	2.68	2.04	3.10
6/1/2011	1.46	2.71	1.42	2.82	1.85	3.07
7/1/2011	2.85	5.42	2.96	5.71	3.36	5.96
8/1/2011	1.95	3.02	1.82	2.78	2.34	3.45
9/1/2011	1.60	2.61	1.62	3.10	2.02	3.52
10/1/2011	1.65	2.67	1.51	2.54	1.98	2.98
11/1/2011	1.57	2.52	1.44	2.80	1.95	3.18
12/1/2011	1.58	3.03	1.39	3.06	1.85	3.26
13/1/2011	1.55	2.95	1.48	3.07	1.89	3.24
14/1/2011	1.71	3.52	1.55	3.52	2.06	3.93
15/1/2011	2.07	3.40	2.03	3.91	2.51	4.37
16/1/2011	1.74	3.08	1.58	2.57	2.05	2.98
17/1/2011	1.78	3.56	1.54	2.84	2.03	3.38
18/1/2011	1.53	2.96	1.32	2.89	1.73	3.22

**Appendix Table 1** (Continued)

Data	Wind Speed Wind Speed ( $\text{m s}^{-1}$ )					
	4 m		7 m		10 m	
	Average	Max	Average	Max	Average	Max
19/1/2011	1.80	3.34	1.79	3.42	2.21	3.82
20/1/2011	1.25	3.15	1.07	3.18	1.53	3.51
21/1/2011	1.25	3.78	1.13	4.00	1.57	4.19
22/1/2011	1.40	2.40	1.29	2.48	1.65	2.63

**Appendix Figure 1** Tools for measure the level of sediment.

 <p data-bbox="424 640 715 674">Board microcontroller</p>	 <p data-bbox="1023 636 1225 669">Real time clock</p>
 <p data-bbox="424 1028 715 1061">OpenLog Data Logger</p>	 <p data-bbox="999 1028 1251 1061">Vortex wind sensor</p>
 <p data-bbox="424 1431 715 1464">XL - Maxsonar WRL1</p>	 <p data-bbox="1031 1431 1225 1464">MicroSD cards</p>
 <p data-bbox="496 1834 644 1868">Foam sheet</p>	 <p data-bbox="1031 1823 1219 1856">Battery 12 volt</p>

**Appendix Figure 2** Equipments for measure wave height, wave period, wind speed and wind direction.

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