การเปลี่ยนแปลงพื้นที่ชายฝั่งเนื่องจากน้ำขึ้นจากพายุระหว่างปี พ.ศ.2532-2549 บริเวณอำเภอหัวหิน จังหวัดประจวบคีรีขันธ์ ภาคใต้ของประเทศไทย

นางสาว วาสุนทรา ชัยรัตน์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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ปีการศึกษา 2551

COASTLINE CHANGE DUE TO STORM SURGE DURING 1989–2006 AT AMPHOE HUA HIN, CHANGWAT PRACHUAP KHIRI KHAN, SOUTHERN THAILAND

Miss Wasuntra Chairat

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Earth Science
Department of Geology
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Thesis Title	COASTLINE CHANGE DUE TO STORM SURGE DURING 1989-2006 AMPHOE HUA HIN, CHANGWAT PRACHUAP KIRI KHAN, SOUTHERN THAILAND
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วาสุนทรา ชัยรัตน์ : การเปลี่ยนแปลงพื้นที่ชายฝั่งเนื่องจากน้ำขึ้นจากพายุระหว่างปี พ.ศ.2532-2549 บริเวณอำเภอหัวหิน จังหวัดประจวบคีรีขันธ์ ภาคใต้ของประเทศไทย. (COASTLINE CHANGE DUE TO STORM SURGE DURING 1989–2006 AT AMPHOE HUA HIN, CHANGWAT PRACHUAP KHIRI KHAN, SOUTHERN THAILAND) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : ดร. สธน วิจารณ์วรรณลักษณ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม : อ.บุศราศิริ ธนะ, 95 หน้า.

ชายหาดอำเภอหัวหิน จังหวัดประจวบคีรีขันธ์ เป็นชายหาดที่ได้รับความนิยมในการท่องเที่ยวทั้งชาวไทยและชาวต่างชาติ ตั้งแต่ในอดีตจนถึงปัจจุบัน ซึ่งในปัจจุบันชายหาดหัวหินกำลังประสบปัญหาการกัดเซาะชายฝั่ง

การศึกษาการเปลี่ยนแปลงพื้นที่ชายฝั่งในระยะสั้นอันเนื่องมาจากน้ำขึ้นจากพายุที่ชายฝั่งอำเภอหัวหิน จังหวัดประจวบคีรีขันธ์ ในกรณีพายุเกย์เคลื่อนเข้าสู่ประเทศไทยเมื่อวันที่ 4 พฤศจิกายน พ.ศ. 2532 อำเภอประทิว จังหวัดชุมพร และพายุไต้ฝุ่นลินดาเคลื่อนเข้าสู่ประเทศไทยเมื่อวันที่ 4 พฤศจิกายน พ.ศ. 2540 อำเภอบางสะพาน จังหวัดประจวบคีรีขันธ์ นอกจากนี้ยังศึกษาการเปลี่ยนแปลงพื้นที่ชายฝั่งอันเนื่องมาจากลมมรสุมตะวันออกเฉียงเหนือมีกำลังแรงในปี พ.ศ. 2549 โดยใช้เทคนิครีโมทเซนซิ่ง วิเคราะห์ข้อมูลภาพถ่ายดาวเทียมแลนด์แซททีเอ็ม ในช่วงก่อนและหลังการเกิดพายุในปี 2532, 2540 และวิเคราะห์ข้อมูลภาพถ่ายดาวเทียมแลนด์แซททีเอ็ม ในช่วงก่อนและหลังช่วงมรสุมตะวันออกเฉียงเหนือมีกำลังแรงในปี 2549 ประกอบกันการศึกษาข้อมูลทางอุตุนิยมวิทยาเพื่อวิเคราะห์ความเร็วลม ทิศทางลม และความสูงคลื่น โดยในพื้นที่ศึกษานี้ได้มีการรายงานพื้นที่เสี่ยงภัยต่อการกัดเซาะชายฝั่งได้ปานกลาง 1-5 เมตรต่อปี

จากการศึกษาพบการกัดเซาะพื้นที่ชายฝั่งในช่วงการเกิดพายุไต้ฝุ่นเกย์ 25.39 เมตร การกัดเซาะในช่วงการเกิดพายุไต้ฝุ่นลินดา 10.36 เมตร และการกัดเซาะในช่วงมรสุมตะวันออกเฉียงเหนือมีกำลังแรง 1.23 เมตร โดยค่ารากที่สองของค่าเฉลี่ยของความคลาดเคลื่อนกำลังสอง (RMSE) น้อยกว่า 0.15 ซึ่งบริเวณที่ถูกกัดเซาะสูงสุดอยู่บริเวณพื้นที่ชายฝั่งหน้าสนามบินหัวหินถึงสะพานปลา ในเหตุการณ์เกิดพายุการกัดเซาะมีมากเนื่องจากลมพัดตั้งฉากเข้าสู่ชายฝั่งด้วยกำลังแรง ส่วนในช่วงมรสุมตะวันออกเฉียงเหนือมีกำลังแรง ลมพัดขนานกับชายฝั่งทำให้เกิดการกัดเซาะน้อย และจากการศึกษาในระยะยาวจากพ.ศ.2532-2549 พบว่าพื้นที่เกิดการกัดเซาะ 16.63 เมตร แสดงให้เห็นว่าหลังจากเหตุการณ์การกัดเซาะชายฝั่งจากพายุ ชายฝั่งเกิดการทับถมอย่างต่อเนื่องโดยมีการสะสมตัวมากกว่ากัดเซาะซึ่งขัดแย้งกับรายงานพื้นที่เสี่ยงภัยก่อนหน้านี้ ดังนั้นจากผลการศึกษานี้จะช่วยให้การศึกษาการเปลี่ยนแปลงพื้นที่ชายฝั่งในอนาคตถูกต้องและแม่นยำยิ่งขึ้น

ภาควิชา............ธรณีวิทยา.................. ลายมือชื่อนิสิต........วาสุนทรา ชัยรัตน์........

สาขาวิชา............โลกศาสตร์..................ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก........

ปีการศึกษา.............2551.................... ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์ร่วม...บุศราศิริ ธนะ...

4872601923 : MAJOR EARTH SCIENCE
KEY WORD: STORM SURGE/ HUA HIN / COASTLINE CHANGE

WASUNTRA CHAIRAT : COASTLINE CHANGE DUE TO STORM SURGE DURING 1989-2006 AT AMPHOE HUA HIN, CHANGWAT PRACHUAP KHIRI KHAN, SOUTHERN THAILAND. THESIS ADVISOR: MR. SATHON VIJANWANNARUK,Ph.D., MISS BOOSSARASIRI THANA, 95 pp.

Amphoe Hua Hin, Prachuab Kiri Khan province, which is a well-established beach destination and increasing in popularity among international travelers, is affected problems on shoreline erosion.

The short-term erosion is concentrated in this study; therefore, Typhoon Gay and Typhoon Linda, which are two of the severe storms passing the Gulf of Thailand and hit the southern coastal provinces in 1989 and 1997 respectively, There are the cases of tropical cyclones passing through Thailand and the strong northeast monsoon in December 2006. The strong wind generate high wave. This is cause of storm surge. The influence of wind wave is aim to coastline change on southern coastline. The risky area of erosion has been reported to have the land lost 1 to 5 m/y at Hua Hin area.

In this paper, remote sensing is applied for measure the change areas on coastline of Amphoe Hua Hin, Prachuab Kiri Khan province during typhoon Gay(1989), typhoon Linda (1997) moved over the Gulf of Thailand, and during the strong seasonal monsoon(2006) including with analyze meteorological data to determine wind direction and wave height during these event .The study result revealed that there were eroded of coastline of Amphoe Hua Hin, Prachuab Kiri Khan province during typhoon Gay is 25.39 meters, Typhoon Linda is 10.36 meters and the strong seasonal monsoon on 20-24 December is 1.23 meters. Root mean square error of these results was less than 0.15. In these events, the highest erosion was found between Hua Hin airport and pier of Hua Hin. Moreover, long-term measurement during 1989-2006 showed that there were erosion areas about 16.63 meters, so there was accretion of beach appeared after Typhoon Gay and Typhoon Linda passed. It contradicts the previous research. This result can be used to support coastal study and management in the future.

The case of typhoon passes to the Gulf of Thailand is not often, it generates during ten years. Nevertheless, the strong northeast monsoon can be generated 1-2 times per year. Therefore, shoreline protection should be considered with long term protection to protect the coastline.

Department..................Geology............Student's signature:.....Wasuntra Chairat.....
Field of study..........Earth Science...........Principal Advisor's signature: Sathon Vijanwannaluk
Academic year............2008................ Co-advisor's signature:.........B. Thana.........

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CHAPTER I

INTRODUCTION

1.1 Background Information

Naturally, Shoreline experiences the dynamic processes of erosion and deposition. Marine processes are the most important process affecting erosion and deposition in all coastal zones. Amphoe Hua Hin, Prachuab Khiri Khan Province is in the western region of Thailand. It is on the upper peninsula that lies in the west Gulf of Thailand, bounded by latitude 12° 30' to 12° 38' north and longitude 99° 45' to 100° 00' east. Along this coastline, many important historical places, temples, communities, aquaculture and agriculture areas, and various well-known tourist attractions with economic significance, which have been, throughout the years, sources of incomes to the local communities.

The rapid erosion along the length of the beach has occurred when there are strong wind, high wave actions and coastal structures. Storm surge and seasonal wave actions are the important causes of coastal erosion in this area. The top layer of sand has been washed away by wave action so much so that the sand berm and hard clay layer underneath becomes exposed.

Remote sensing is an efficient technology for management of coastal zone because it yields a large space and spends short time scales. In particular, the remote sensing has shown it usefulness for providing novel information on physical and biological processes of the coastal area. Remote sensing of the coastal zone finds application in studies of land cover, sediment transport, coastal runoff and circulation, and dynamic processes.

Therefore, this study was conducted to determine the coastline change due to storm surge during 1989-2006 at Ban Hua Hin Amphoe Hua Hin, Prachuap Khiri Knan province.

1.2 Objective of Study

To determine the coastline change due to storm surge during 1989-2006 at Ban Hua Hin Amphoe Hua Hin, Prachuap Khiri Knan province.

1.3 Scope of Study

1. The study area cover the coastline of Amphoe Hua Hin, Prachuab Khiri Khan Province as shown in Figure 1.1

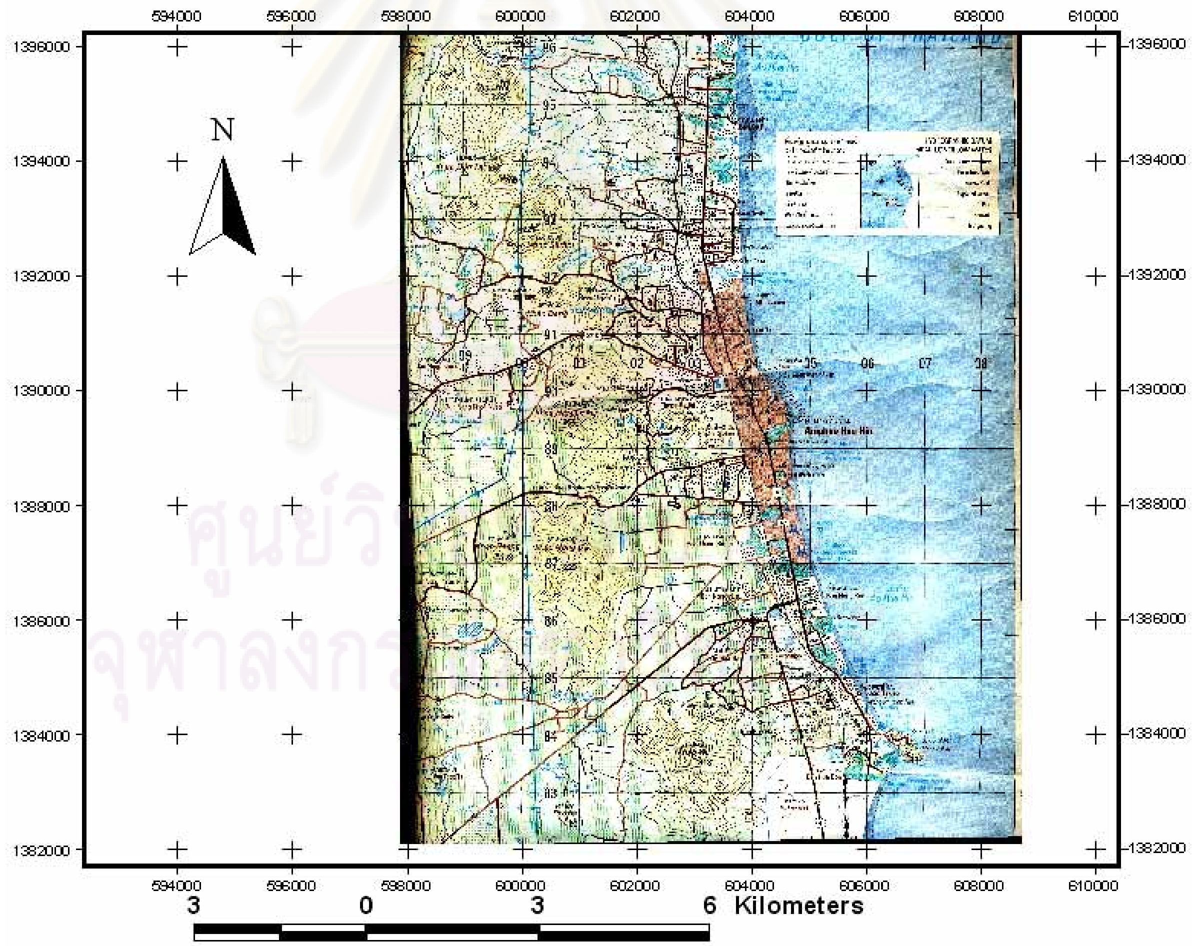

Figure 1.1 Topographic map showing the study area (Royal Thai Survey, 2000)

2. Study of coastline area before and after storm surge from Typhoon Gay on 4 November 1989, Typhoon Linda on 4 November 1997 and strong seasonal monsoon on 20-24 December 2006 by analyzed Landsat-5 Thematic Mapper images.

3. Study of coastal conditions together with their physical components, e.g., onshore and offshore geomorphology, direction and magnitude of wind, waves and currents, tidal water levels, and their associated seasonal changes.

4. Using geographical information system (GIS) and field survey, to identify coastline shape of Ban Hua Hin beach.

1.4 Method of study

This study used knowledge of geology, hydrology, oceanology, GIS, and remote sensing technique. The study was divided into three steps. Firstly, the data and information of previous works and literature studies were collected. Secondly, studied coastal conditions together with their physical components, e.g., onshore and offshore geomorphology; then the field investigation was carried out during September to October 2007 to construct the contour line at Ao Hua Hin to identify coastline shape. After that data of direction and magnitude of wind, waves and currents, tidal water levels, and their associated seasonal changes were analyzed. Then data were prepared and analyzed by GIS technique. This step used three satellite image sets of Landsat-5 TM images for detection of shoreline change. The first period was classification of shoreline changes before and after Typhoon Gay attacked the eastern coast of Thailand in November 1989. The second one was classification of shoreline changes before and after Typhoon Linda attacked the eastern coast of Thailand in November 1997. The last period was classification of shoreline changes before and after strong seasonal monsoon in December 2006. The prioritization of changed areas were done and preventive measures in the changed areas were proposed and the illustrated in the form of maps. Finally, includes integration of all results to recommend for solving the changed area of the study. The methods of study are shown on the schematic chart in Figure 1.2

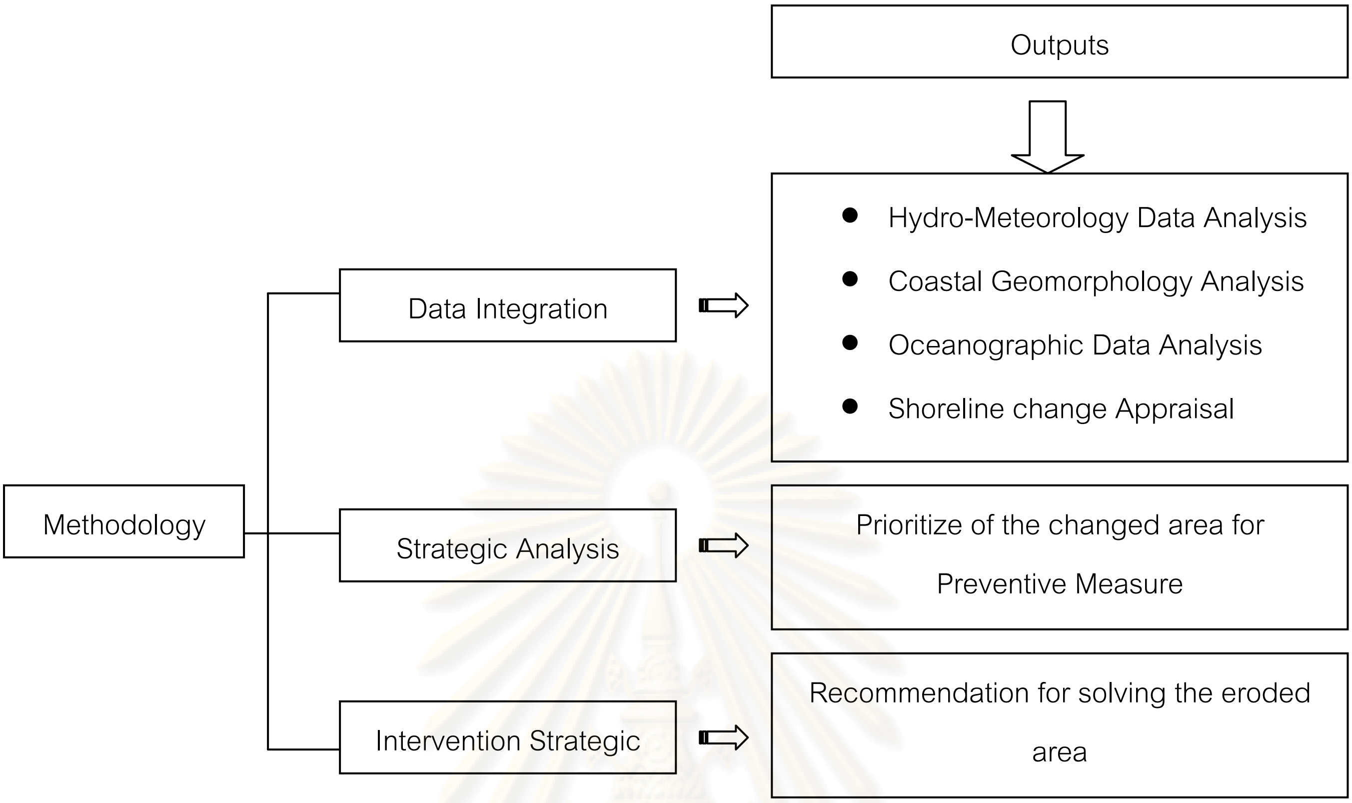

Figure 1.2 Work flow diagram for methodology used and outputs in this study.

1.5 Outcomes and Approaches

1. From literature study: collecting database of previous study that relate with this research, can supply for another useful research.

2. From remote sensing interpretation: estimating coastline change along the study area, the changing from geomorphology.

3. Locating present shoreline from survey: mapping contour line and beach profile.

1.6 Anticipated Benefits

Finding of the impacts of storm surge during 1989-2006 and physical components which effect to the coastline changes at Amphoe Hua Hin, Prachuap Khiri Knan province and this information can be used to support coastal planning and management in the future.

1.7 Study area

1.7.1 General topography

The study area covers the coastline of Amphoe Hua Hin, Prachuab Khiri Khan Province . It is on the upper peninsula that lies in the west Gulf of Thailand, bounded by latitude 12° 30’ to 12° 38’ north and longitude 99° 45’ to 100° 00’ east. The elevation ranges are from 0-10 meters above the present mean sea level. Beaches along the coastline in the eastern part of province are normally straight and long the coastline is 28.7 kilometers long.

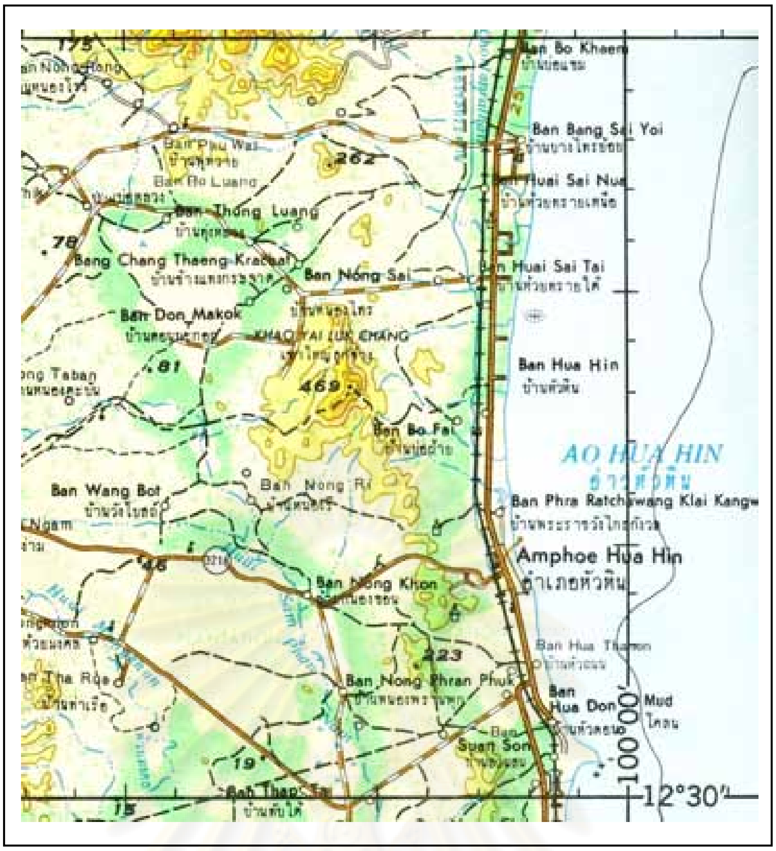

Figure 1.3 Topographic map showing the study area (Map sheet ND – 15 Royal Thai Survey, 1973)

1.7.2 Regional geology

The geological map of Amphoe Hua Hin is shown in Figure 2.6 which is redrawn from the Map Sheet ND47-15 at a scale of 1:250,000 (DMR, 1987). Main rock units of this region are composed of Inferred Pre-Cambrain, Permain rock periods which are included of sedimentary rocks, igneous rocks and metamorphic rocks.

The oldest unit rock is Inferred Pre-Cambrain rock period , there are the high grade metamorphic rocks; for example, paragneiss, orthogneiss, mica schist, silimanite schist, quartz schist, quartzite and marble, which are in the coastline area. They start from the lower part of Amphoe Hua Hin to the northern part of Samroyyod mountain that is in the area of Amphoe Pranburi.

Permain rock period is lime stone that located in both east side and west side of Amphoe Hua Hin. It is the massive and bedded Limestone which contains fossils such as fusulinids and brachiopods. Their ages are in the Lower to Mid Permain period.

In the plain and ravine there are the sediments in form of alluvium deposits. Besides, the southward of area there is a arrange of terrace. Their ages are in the Quaternary period. In addition, the Igneous rock in the study area can be divided in two types. One is foliated biotite muscovite granite the other is porphyritic biotite-muscovite granite. Furthermore, in this area the characteristic of Regional Metamorphism and Contact Metamorphism are found.

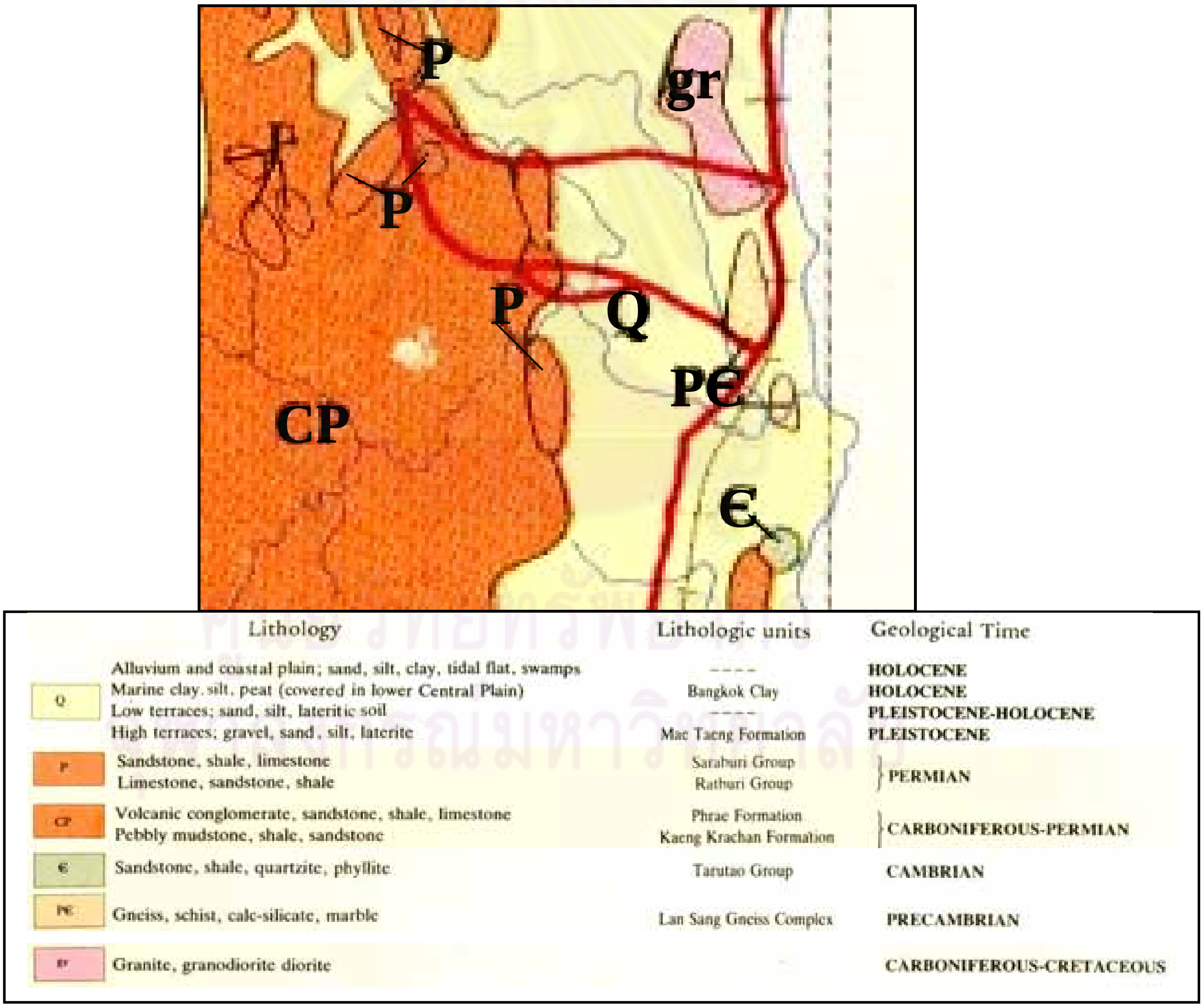

Figure 1.4 Part of geological map of Amphoe Hua HIn Sheet ND47-15 showing geology of Hua Hin area (DMR, 1987).

1.7.3 Climate

Prachuab Khiri Khan Province is located above the equator. Therefore, it has a tropical climate and is dominated by the northeast and southwest monsoons. The climate is generally divided into three seasons. Firstly, the rainy season with tropical storms normally coming from mid-May to October. Secondly, the dry winter season starts annually from November until February. Finally, the summer period occurs from the beginning of March to mid-May. During May to September, Southwest wind from Indian Ocean carries moisture causing frequent rains along the coastline of Andaman Sea with the strong wind and wave on the eastern coast of upper part of gulf. During November though February wind direction changes to northeast causing cold weather in the northern part of Thailand with high wave and strong wind on the western coast and frequent rainfall (Harbour department, 1996).

The southwest monsoon blows from about mid-May to November. Rainfall peaks in September with up to 2,200 mm/year. The average rainfall is about 1,400 mm/year and about 90% of the precipitation fall in the rainy season.

The mean annual temperatures range from 27° – 30° C. There are variations in the annual humidity from the study area. The relative humidity is greater in rainy season than the summer season.

The transportation of sediment in the area depends on wind and wave conditions. The rainy season from mid – May to November is characterized by moderate to heavy rain as a result of air masses traversing. The southwest winds also generate moderate waves along the east coast. Moreover, tropical cyclones are generated as a result of retreat of southwestern monsoon during September to October, which bring strong winds and intense waves, and during November to mid - February, the northeast monsoon generates the strong wind during the season’s end (Vongvisessomijai et al., 1992).

1.7.4 The current circulation in Gulf of Thailand

As the influence of Northeast monsoon season and Southwest monsoon season force the circulation of wave-current from South China Sea to the Gulf of Thailand. The Gulf of Thailand is located in Southeast Asia immediately to the west of the South China Sea (SCS). The gulf is a semi-enclosed sea covering an area of about 320,000 km^2. Its location in the global map is between 6°N to 14°N latitudes and 99°E to 105°E. The Gulf of Thailand is subjected to the monsoon system of the Western North Pacific Ocean or the South China Sea. Monsoons influence the surface currents, being clockwise during the southwesterly monsoon and counterclockwise during the northeasterly monsoon. Since the Gulf of Thailand is shallow and located in inland, it takes the effect of tropical storms.

In November to February Northeast monsoon season forces wave-current from South China Sea to the Gulf of Thailand, which affects high tide current in the Gulf of Thailand; on the other hand, Southwest monsoon season in May to October forces wave-current from the Gulf of Thailand to South China Sea. Figure 1.5 and figure 1.6 are shown the wind direction and wave-current in Northeast monsoon season. Figure 1.7 and 1.8 are shown the wind direction and wave-current in Southwest monsoon season respectively. The effect from two components; high tide current and strong wind in Northeast monsoon season, can generate high wave that is the main caused of coastline change.

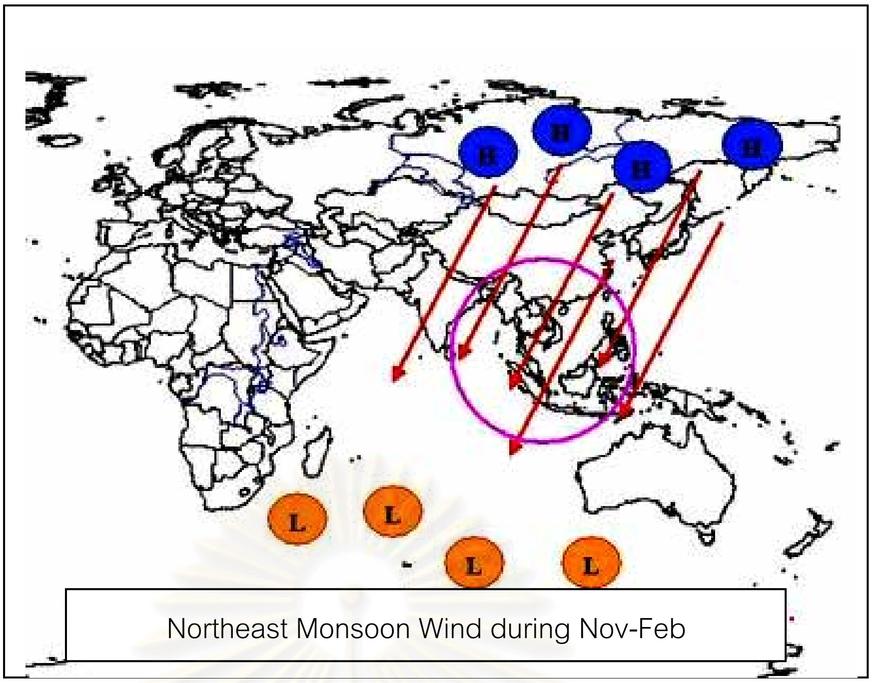

Figure 1.5 Wind direction in Northeast monsoon season (TMD, 2005)

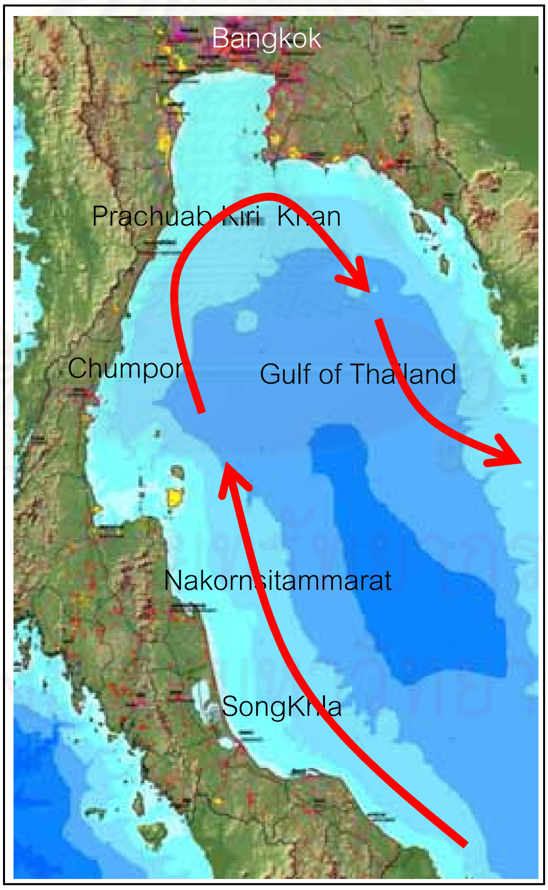

Figure 1.6 The circulation of current mass in Northeast monsoon season (TMD, 2005)

(Modified picture from www.gisthai.org)

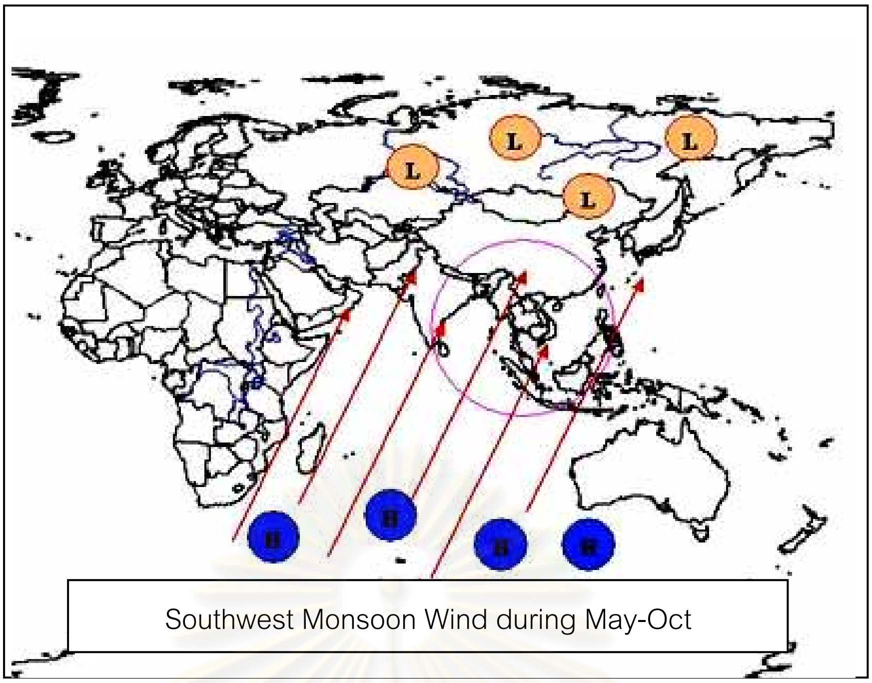

Figure 1.7 Wind direction in Southwest monsoon season (TMD, 2005)

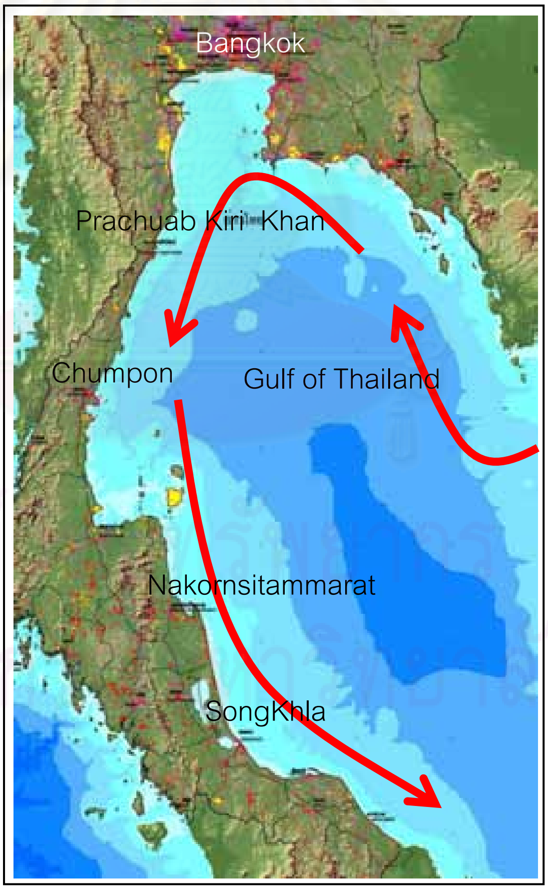

Figure 1.8 The circulation of current mass Southwest monsoon season (TMD, 2005)

(Modified picture from www.gisthai.org)

1.8 Coastal processes

The coastal process in this section is explained in term of the process of wind, wave and tide, which influence in the area.

1.8.1 Monsoonal wind

The monsoonal winds on geographical feature are northeast and southwest monsoons. The northeast monsoon occurs during November to February due to the migration of cold weather from Asian continent to equator around Indian Ocean. The northeast monsoonal wind is significant to wave occurrence in western area. The southwest monsoon occurs during May to September because temperature in the continent is higher than temperature of water in the ocean. This monsoonal wind effects coastal area in western and eastern parts of the area (Snidwongs, 1998).

1.8.2 Tropical cyclone

Official records of the Meteorological Department also showed traveling paths of the tropical cyclones which pass in this area are generated from South China Sea, which maybe divided into three types, namely:

- Tropical depression: its central velocity is lower than 63 km/hr.
- Tropical storm: its central velocity is between 63 to 118 km/hr.
- Typhoon: its central velocity is more than 118 km/hr.

Normally, most of storms that passed over Thailand were of depression category but few were tropical cyclones. The intensity of tropical cyclone can be increased, if they move over the sea sureface. On the other hand, their intensity decreases, if they move pass the continent or mountain. The storms generally formed in South China Sea near the Philippines and moved northwestward on to the Vietnam Coast or Southern China. They became very weak by the time when they move to the Gulf of Thailand. Only about 1 – 2 storms moved directly into the Gulf of Thailand which can be occurred during October to December. They caused strong wind, wave and heavy rainfall (Harbour Department, 1996).

1.8.3 The tropical cyclones that passed through Thailand during 1974-1999

Table 1.1 The tropical cyclones that passed through Thailand during 1974-1999

d/m/y	Type and Name	initial area	attacked area	affect
9-10 October1974	Depression	-	Chantaburi	-
25-26 December 1974	Tropical Storm KIT (7432)	-	SongKhla	-
10 September 1975	Depression	South China Sea	Mukdahan	F
11 November 1977	Depression	End Of Malay Peninsula	Nakonsritammarat	L
27 September 1978	Tropical Storm KIT (7820)	West Pacific Ocean	Nakonpanom	F
12 November 1978	Depression	Malay Peninsula	Naratiwat	L
20 May 1980	Cyclone	Bengal Bay	Ratchaburi	M
4-8 September 1980	Depression	South China Sea	Nakonpanom	F
12-17 September 1980	Tropical Storm RUTH (8015)	South China Sea	Nan	F
18 November 1980	Depression	Pacific Ocean	Trad	-
26-27 June 1983	Tropical Storm SARA (8301)	South China Sea	Nakonpanom	F
10 October 1983	Tropical Storm HERBERT (8312)	South China Sea	Surin	F
18 October 1983	Tropical Storm KIM (8315	South China Sea	SraKaw	F
8 Novmber 1983	Depression	Gulf of Thailand	Nakonsritammarat	L
12 October 1985	Depression	South China Sea	Trad	F
15 October 1985	Typhoon CECIL (8821)	North Pacific Ocean	Nakonpanom	F
4-6 May 1988	Depression	Andaman Sea	-	M
16-18 September 1988	Depression	Upper Andaman Sea	-	F
27-29 September 1988	Depression	South China Sea	-	M
15-17 October 1988	Depression	South China Sea	Ubonratchatani	M
21-29 October 1988	Typhoon RUBY	Pacific Ocean	-	M
4 November 1989	Typhoon GAY**	Gulf of Thailand	Chumpon	W
4 October 1990	Tropical Storm IRA (9022)	Lower part of South China Sea	Ubonratchatani	F
19 October 1990	Tropical Storm LOLA (9024)	Middle part of South China Sea	Prachinburi	F

Table 1.1 (Cont'd)

d/m/y	Type and Name	initial area	attacked area	affect
14 November 1990	Cyclone	Andaman Sea	-	M
27 October 1991	Depression	End Of Malay Peninsula	Prachaup Khiri Khan	M
30 October 1992	Typhoon ANGELA (9224)	South China Sea	Trad	W
15 November 1992	Tropical Storm FOREST (9226)*	West of MindaNoa island	Nakonsritammarat	W
29-30 August 1993	Tropical Storm WINONA (9312)	South China Sea	Nakonpanom	M
28-29 Noveber 1993	Depression	South China Sea	Nakonsritammarat	W
15-16 December 1993	Typhoon MANNY (9327)	Northwest Pacific Ocean	Songkhla	W
9-10 August 1995	Tropical Storm HELEN (9505)	Pacific Ocean	-	F
17-19 August 1995	Tropical Storm IRVING (9506)	Middle part of South China Sea	-	F
29-31 August 1995	Tropical Storm LOIS (9509)	Upper part of South China Sea	Nan	F
10-11 September 1995	Depression	Middle part of South China Sea	-	F
29-30 September 1995	Depression	Middle part of South China Sea	-	F
27 October 1995	Tropical Storm YVETTE (9519)	Pacific Ocean	-	F
30 November 1996	Depression	End Of Malay Peninsula	Prachaup Khiri Khan	M
3 November 1996	Depression	South China Sea	Ubonratchatani	M
18 November 1996	Tropical Storm ERNIE (9625)	Pacific Ocean	Chumpon	M
4 November 1997	Typhoon LINDA (9728)*	Lower part of South China Sea	Prachaup Khiri Khan	W

Remarks

( )	Used the two number of the end of the year and the order of storm that generated in Pacific Ocean
-	No data
*	The storms moved into Thailand while they were Tropical storms
**	The storms moved into Thailand while they were Typhoons

F	Flooding in Bangkok due to the storms
W	High wave due to storm
L	Low - medium rainfall
M	Medium - heavy rainfall

1.8.3.1 Typhoon Gay (32W)

Typhoon Gay (32W) was the first tropical storm in more than forty years that subsequently intensified to a typhoon in the Gulf of Thailand. It was also the storm that brought enormous destructions to southern Thailand and originated in the southern part of The Gulf of Thailand as a depression and then strengthened quickly to be a tropical storm which caused storm surge and enormous damage on the coast of Chumphon province and neighboring areas. The maximum wind of Typhoon Gay (32W) speed was 120 km/hr (TMD, 1989).

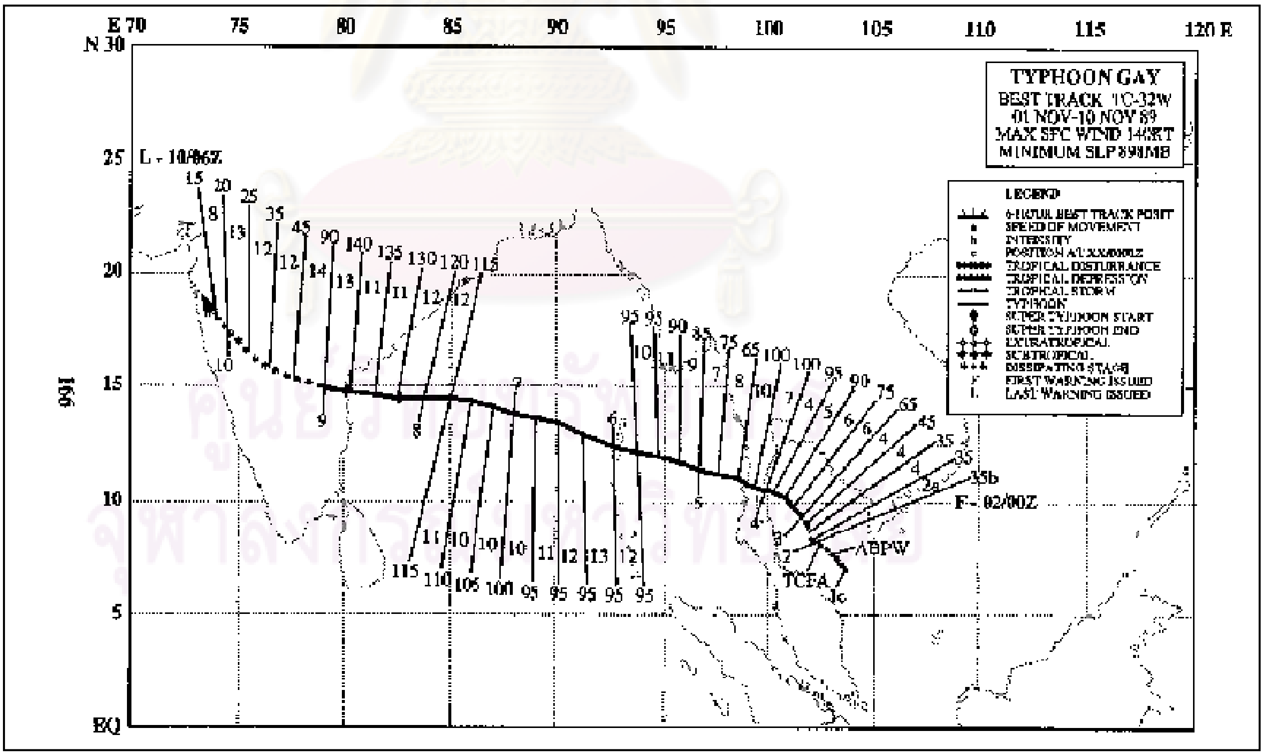

Figure1.9 Track of Typhoon Gay (32W) on 1-10 November 1989 (TMD,1989)

1.8.3.2 Typhoon Linda (30W)

The tropical disturbance that would become Typhoon Linda (30W) formed within an area of convection east of the Philippine Islands near 10 °N 130°E on 26 October 1997. Typhoon Linda (30W) crossed the Gulf of Thailand on 4 November 1997. Linda reached typhoon intensity shortly after entering the Gulf of Thailand. The cyclone turned northwestward following steering from the subtropical ridge (TMD, 1997). Consequently the storm surge that was seen along the shoreline north of the standing point was due to the strong onshore wind, piling up the water mass (Kanbua, 2005).

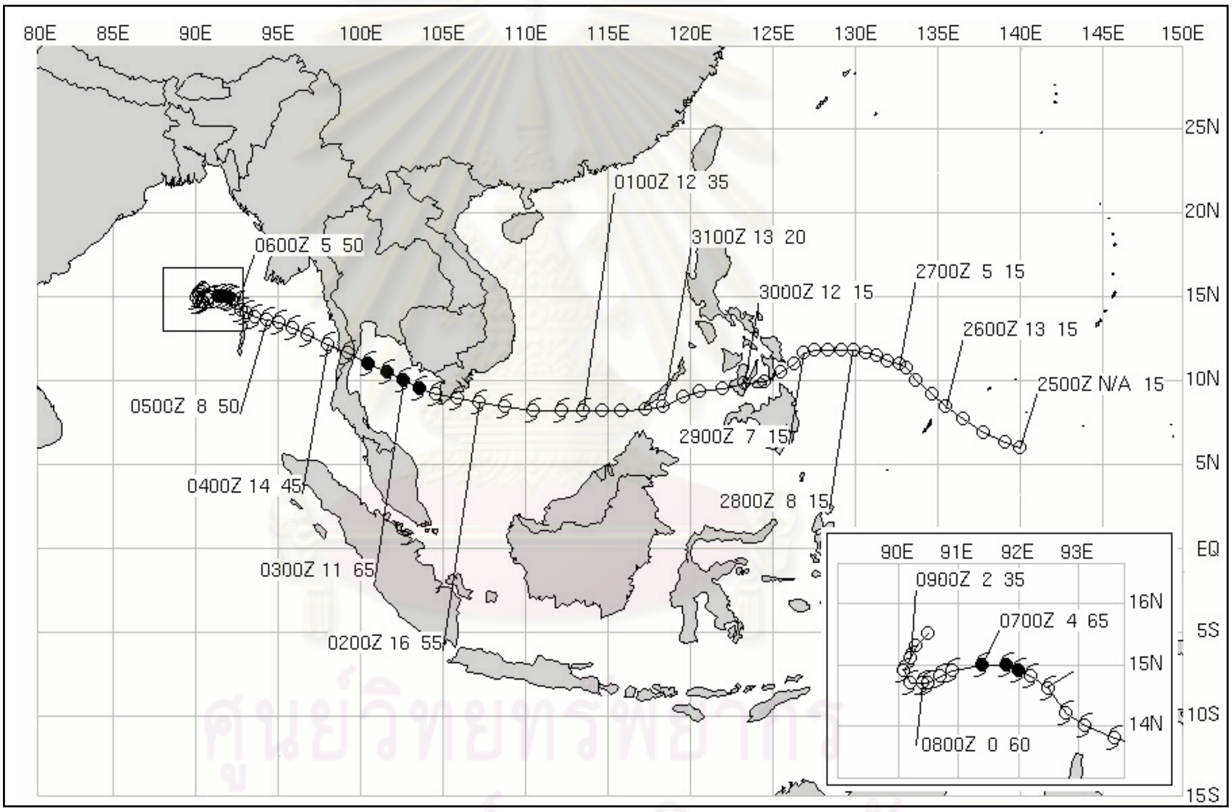

Figure1.10 Track of Typhoon Linda (30W) on 1-5 November 1997 (TMD,1997)

1.8.4 Waves

Wave condition is predicted by using wind speed and directions measured at Hua Hin meteorological stations with height and wave period adjustments to fit the real records during some periods of time. In general, waves along the coastline of the study area are small wave. Their height is lower than 2 meters, However, during the monsoon wind and storm wind, wave heights can be more than 5 meters.

1.8.5 Tides

Tides, the regular and predictable rises and falls of sea-level are important. They increase the vertical range which current and wave activity can take places. Tides are also responsible for currents which transport sediments. Where tidal range is limited, wave produce forms are more common.

The tide refers to the periodic rising and falling of water that results from the gravitational attraction of the moon and the sun acting on the rotating earth and also depend on topography. There are 3 types of tides in Gulf of Thailand with average 1.5 meters in tidal range (Harbour Department, 1996)

- Diurnal: one occurrence of high tide and low tide in a day.
- Mixed, semidiurnal dominated: two occurrences of high tide and low tide in a day.
- Mixed, diurnal dominant: mostly one occurrence of high tide and low tide in one day, but sometime two occurrences of high tide and low tide also occurred.

CHAPTER II

LITERATURE REVIEW

2.1 Coastal process and Coastline change

On coasts where the shoreline is unconsolidated sediment such as a clay, sand or silt, the energy from the waves, wind and tide can cause rapid change in the shape and dimensions of the shoreline. Waves are the most significant factor to cause shoreline change. As waves move from offshore to the beach they will often break, reform and break again. The process of breaking results in a portion of the wave energy being dissipated. Additional energy is dissipated on the beach with the resultant transport of the beach sediment. Figures 2.1 and 2.2 illustrate the principal features of the beach and near shore wave environment, or the littoral zone. The offshore region lies beyond the zone of wave breaking. On many sandy coasts the landward end of this region is characterized by the presence of a long shore bar. The inshore region extends from the bar (or bars) across the surf zone to position of the tidal low water line. The foreshore extends from the low water line to the upper limit of swash and the beginning of the beach backshore. On beaches where dunes are present, the seaward toe of the dune marks the end of the backshore. If dunes are not present on the beach, the landward limit of the beach backshore is generally considered to be the upper limit of storm wave impacts. Other important features illustrated in these figures include the berm and the trough (just inshore of the alongshore bar) (CERC, 1984).

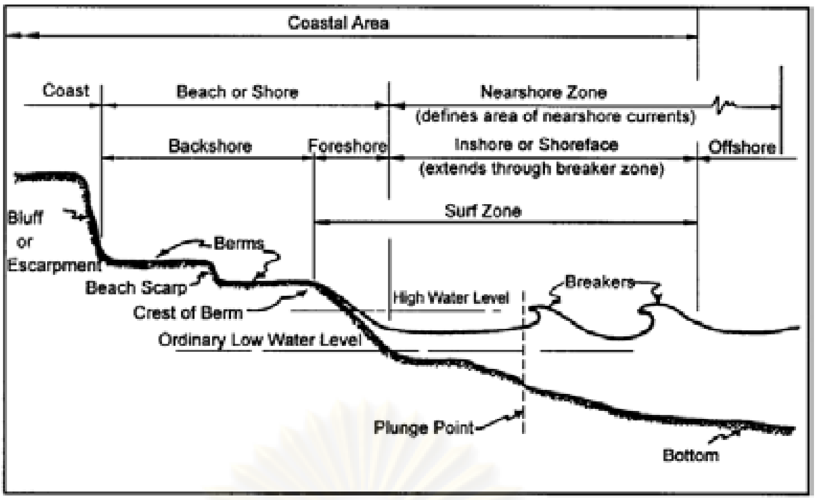

Figure 2.1 Visual Definition of Terms Describing a Typical Beach Profile (CERC, 1984).

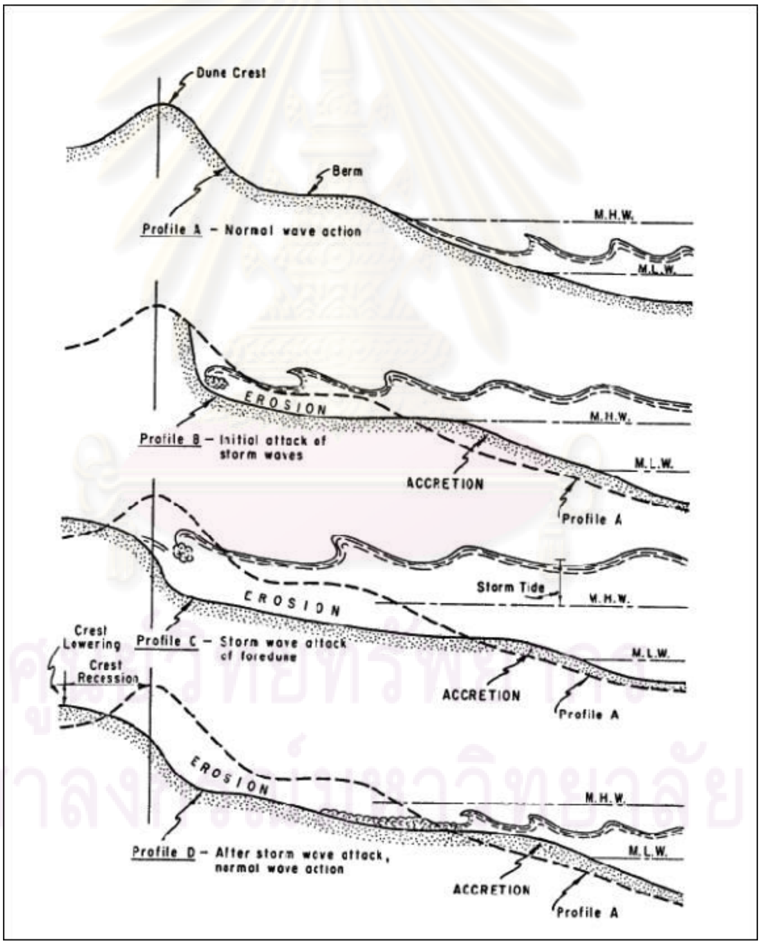

Figure 2.2 Schematic Diagram of Storm Wave Attack on Beach and Dune (CERC,1984).

During severe storms, such as hurricanes (or large northeasters), the higher water levels resulting from storm surge may lead to dune erosion. It is not unusual for

20 to 30 m wide dunes to disappear in a few hours. This dune erosion will be greater when the period of maximum storm surge coincides with a high astronomic tide (Figure 2.2, Profile C). After the storm has passed and the waves return to normal size and period, the beach goes through a period of recovery. Material is transported from the bar and near shore profile back to the beach above mean water level. The berm builds out, and when the sediment dries, is transported by the wind to rebuild the dune. This mechanism of beach rebuilding is illustrated in Figure 2.2, Profile D. During very large storms the combination of the surge and large waves may succeed in completely overtopping the dunes causing extensive coastal flooding. When this occurs, the water transports beach and dune sediments landward in a process referred to as overwash. In some cases, on barrier islands, the overwash may transport sediment completely across the island and deposit the material in the estuary (sound or bay). This transport of material out of the littoral zone represents a net loss of material from the beach and near shore (CERC, 1984).

Coastal zones are the most dynamic and changing areas. Their shorelines experience the dynamic processes of erosion and deposition. Wave activity is the most important process affects erosion and deposition in all coastal zones. Current generated by rising and falling tides are also important agents along oceanic shoreline. (Coch and Ludman, 1992).

Beaches continually deposit and erode depending on the balance among sediment deposition, longshore drift, and sand removal by storm waves. Erosion and deposition occure all shorelines. However, the one that dominant in forming shoreline features differents from coast to coast. Wherever, wave removes more material than deposite, net erosion occurs, and the beach is eroded. The various factors which affect to coastal change are mainly divided into three groups: terrestrial factors, marine factors, and biological factors (Hansom,1990).

The principle source of energy input into the coastal zone comes from wind generated waves. Sea surface is composed of waves of several sizes traveling in various directions. In deep water, water particles in a wave have only a local orbital motion. The orbital motion ceases entirely at depth equal to about one-half of the wavelength of the waves at the surface. This depth is the bottom limit of orbital water movement and is know as the wave base. Above of the wave base is a zone of agitated water, while the water below is not influenced by wave motion. Where waves approach shallow water, the wave base intersects the seafloor. They begin to feel the bottom and waves in this zone are called of shallowing waves (Coch and Ludman, 1992).

2.1.1 Previous researches in the study area.

Sinsakul et al (2002) reported the rate of coatal erosion at Hua Hin Bay. Aerial photos between 1967 and 1998 were interpreted. The rate of coatal erosion was 1-5 m/y.

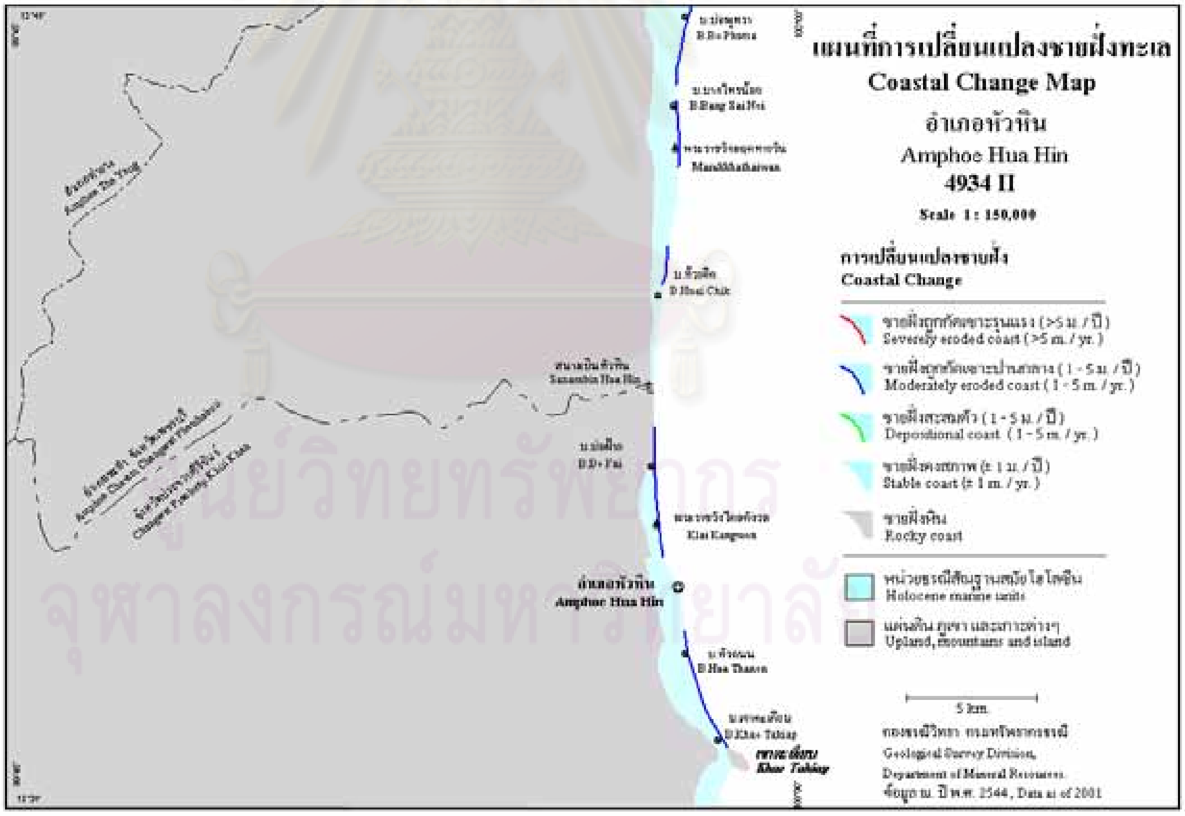

Figure 2.3 Coastline change map showing the rate of coatal erosion at Hua Hin Bay (Sinsakul et al., 2002)

Songmuang. R., 2005 studied seasonal coastline change at coastline of Prachuab Khiri Khan by using annual checked and integrated aerial photographs. His result reported that there was annual depositional rate more than erosion rate.

2.2 Tropical Cyclones

Tropical cyclones are dangerous because of their high winds, the storm surge produced as they approach a coast, and the severe thunderstorms associated with them (CERC, 1984).

2.2.1 Origin of Tropical Cyclones

For a tropical cyclone to form, several environmental conditions must be in place (Elsberry, 1987):

1. Warm ocean waters (of at least 26.5°C [80°F]) throughout about the upper 50 m of the tropical ocean must be present. The heat in these warm waters is necessary to fuel the tropical cyclone.

2. The atmosphere must cool fast enough with height to get potentially unstable atmosphere to enhance a convection. It is the thunderstorm activity which allows the heat stored in the ocean waters to be liberated and used for tropical cyclone development.

3. The mid-troposphere (5 km altitude), must contain enough moisture to sustain the thunderstorms. Dry mid levels are not conducive to the continuing development of widespread thunderstorm activity.

4. The energy source for the tropical cyclone is the latent and sensible heat gained from the warm tropical ocean.

5. There should be enough coriolis force to produce a circulation of airmass (i.e. Latitude between 5-25 degree).

2.2.2 Intense tropical cyclone

According to Willoughby 1995, the strongest horizontal wind is in the eyewall. Outside it, the wind descends. Moreover, echo-free areas such as eye and moat generally indicate vortex-scale descent. Figure 2.4 shows a radial profile of flight-level wind (cross section through the core of a tropical cyclone). From this figure, the strongest horizontal wind at eyewall is about 82 m/s. Outside the eyewall, wind descends abruptly to 30 m/s at the outer edge of moat and then rises to 35 m/s in the partial band of convection surrounding moat. There is a tendency for radial flow toward the wind.

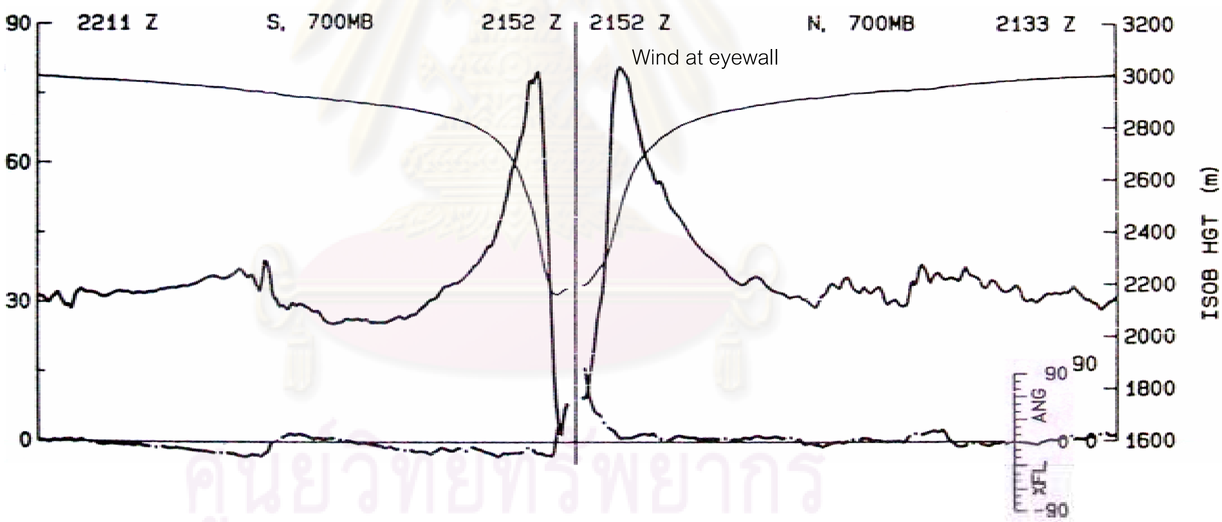

Figure 2.4 Radial profile of flight-level wind (Willoughby,1995)

2.2.3 Wind spiraling around the central core of storm

As the winds converge toward the central core, they spiral upwards, sending warm moist air upwards. As this air rises, it cools and releases its latent heat into the atmosphere to add further energy to the storm. The winds spiraling around this central core create the eye of the tropical cyclone and eventually spread out at high altitudes.

Eventually, cool air above the eye begins to sink into the central core. This dry descending air within the eye gives the core a clear, cloud free sky, with little to no wind.

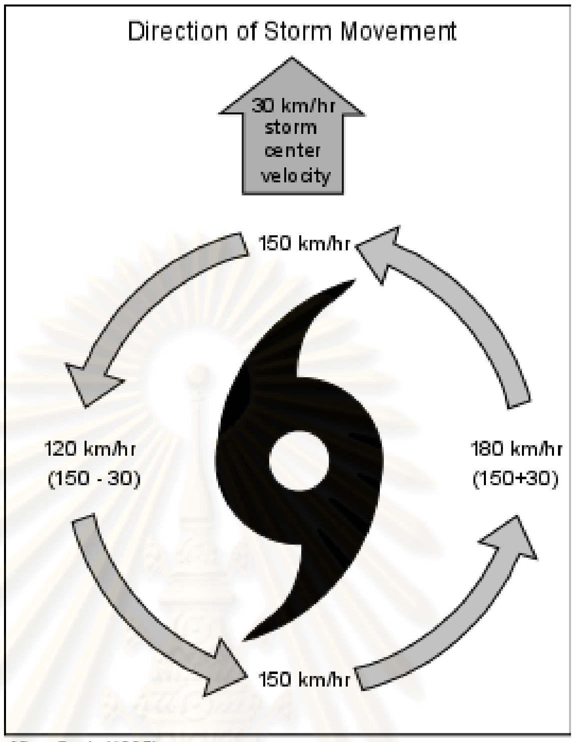

Figure 2.5 Wind spiraling around the central core of storm (Coch, 1995)

Winds spiraling counterclockwise (in the northern hemisphere) into the eye of the tropical cycle achieve high velocities as they approach the low pressure of the eye. The velocity of these winds is called the tropical cyclone-wind velocity. The central low pressure center of the eye also moves across the surface of the Earth as it is pushed by regional winds. The velocity at which the eye moves across the surface is called the storm center velocity. Thus, the velocity of winds around the tropical cyclone must take into account both the wind velocity and the storm center velocity. Depending on the side of the tropical cyclone, these velocities can either add or subtract. In the example at above, the tropical cyclone is traveling north with a storm center velocity of 30 km/hr, and a tropical cyclone-wind velocity of 150 km/hr. On the right hand side of the storm both velocities are to the north so the total wind velocity is 180 km/hr. On the left hand side of the storm, however, the wind is blowing to the south with the total wind speed velocity of 120 km/hr.

This is an important point. Winds are always stronger on the right side of a moving hurricane in the northern hemisphere. (The opposite is true in the southern hemisphere, since winds circulate in a clockwise direction, the winds are stronger on the left-hand side of the storm in the southern hemisphere).

2.2.4 The damage of Tropical cyclone Approach to Coast

The amount of damage that occurs when a tropical cyclone approaches a coast depends on the angle of approach. Two extreme examples illustrate this point.

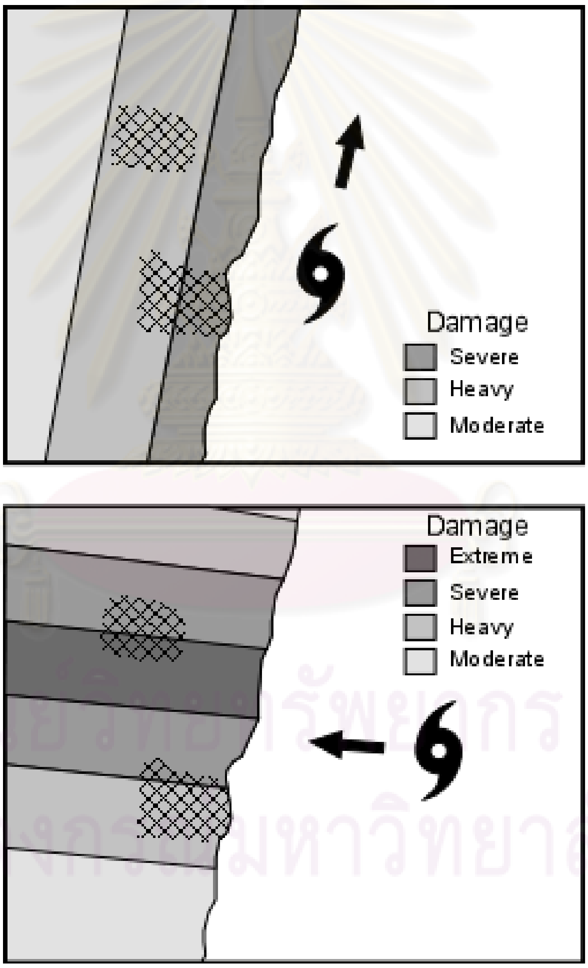

Figure 2.6 Angle of Tropical cyclone Approach to Coast (Coch, 1995)

- A hurricane that moves along the coast has a coast-parallel tropical cyclone track. From such a track extensive damage would occur along the coastline closest to the storm, with bands of lesser damage extending inland. Since this track (upper diagram) has the most intense winds offshore (on the right side of the tropical cyclone), the coast would not feel the highest wind velocities. Thunderstorm activity associated with this track would be most severe on the northern side of the storm, since the spiral rain bands would be feeding off the moist air above the ocean (Coch, 1995).

- A hurricane that approaches the perpendicular to the coast has a coast-normal track. Such a storm would produce extreme damage all along the right-hand side of its track, with bands of decreasing damage occurring both to the left and right of the track. Furthermore, as the storm approached the coast areas to right hand side of the storm would receive the heaviest thunderstorm activity, since the rain bands would be feeding off the moist oceanic air (Coch, 1995).

2.2.5 Storm Surges

A coastal storm has low pressure at its center, surrounded by winds that move counterclockwise. As such a storm approaches to coast, the central low pressure causes the sea surface below it to rise. In addition, its winds act similar to a bulldozer, pushing water ahead of the storm and raising the ocean surface further. The elevated water surface that results from all these is called a storm surge (Coch and Ludman, 1992).

High waves from storms erode large quantities of sediment from beach and dune areas. Some is shifted along the shore by accelerated longshore currents and some move offshore. After the storm, sand stripped from a beach is returned eventually through formation of an offshore ridge of sand and its migration landward. During its landward migration, the ridge is operated from the beach by a water-filled trough, called a runnel. The migration ridge can be welded itself to the damaged beach, restoring its width in little more than a week. Ridge and runnel formation is an important

beach-restoration process that is visible on many beaches after a storm, although the width of the beach may have been restore, the front of the beach now may be located further inland than before. Thus, net erosion occurs along many coasts
(CERC, 1984).

Heavy winds produced by hurricanes push the ocean in front of them. As this water gets pushed into the shallow zones along the coastline sea level rises. Since the storm surge is driven by the winds, the height of the rise in sea level is related to the velocity of the wind. For a moving storm the greater winds occur on the right side of the storm (in the northern hemisphere). Sea level also rises beneath the eye of the storm due to the low pressure in the eye. But, the surge generated by this low pressure is usually much less than the wind-driven surge. The height of the storm surge depends on wind speed, the shape of the coastline, and variations in the water depth along the coast line (Nelson, 2006).

2.2.5.1 Saffir-Simpson Hurricane Scale

The Saffir-Simpson Hurricane Scale was used to categorize wind speed and storm surge. Table 2.1 and table 2.2 classified the severity of tropical cyclone (Bell, T. S., 2007).

Table 2.1 The Saffir-Simpson Hurricane Scale (Bell, T. S., 2007)

Category	Mph (km/hr)	Ft (m)
1	74-95 (119-153)	4-5 (1.2-1.5)
2	96-110 (154-177)	6-8 (1.8-2.4)
3	111-130 (210-249)	9-12 (2.7-3.7)
4	131-155 (178-209)	13-18 (4.0-5.5)
6	156 (250)	>18 >5.5

Table 2.2 Additional Classification

State	Mph (km/hr)	Ft (m)
Tropical storm	39-73 (63-117)	0-3 (0-0.9)
Tropical depression	0-38 (0-62)	0 (0)

2.2.6 Storm events in Thailand

Tropical cyclone generally formed in eastern Philippines and moved northwestward to the Vietnam Coast or Southern China. Normally, they became very weak by the time after they move to the Gulf of Thailand. Record of tropical cyclone moving though Thailand in 55 years during 1951-2005 showed that they usually passed to the Gulf of Thailand during September to November (TMD, 2006).

2.3 Remote Sensing Theory

2.3.1 Remote Sensing Definition and Concept

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquires by a device that is not contact with the object, area, or phenomenon under investigation (Lillesand and Kuefer, 2000) Remote sensing uses electromagnetic wave or emits its own internal energy, which serves as a signature for its identification (Rajan, 1991).

Electromagnetic wave can be categorized by their wavelength location within the electromagnetic spectrum, consist of cosmic rays, gamma rays, x-rays, ultraviolet, visible light, infrared, microwave and radio waves (Lillesand and Kuefer, 2000).

The basic interaction of electromagnetic energy on any earth surface feature are reflection, absorption, and/or transmission. The proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending on their material type and condition. However, within a given feature type, the proportion will vary at different wavelength. The spectral reflectance is the percentage of reflectance characteristics of earth surface features which are measured as a function of wavelength. All spectral reflectance data are unique to the sample and the environment in which they are measured (Schowengergt, 1997). Thus, many earth surface features of interest can be identified, mapped, and studied on the basis of their spectral characteristics.

2.3.2 Data Analysis

The detection of electromagnetic energy can be performed either photographically or electronically. Therefore, the data interpretation can involve analysis of pictorial (image) and/or digital data. Visual interpretation techniques use the excellent ability of the human mind to qualitatively evaluate spatial patterns in an image. The spectral characteristics are not always fully evaluated in visual interpretation efforts.

Thus, in applications where spectral patterns are highly informative, it is therefore preferable to analyze digital image data rather than pictorial image data. The use of computer-assisted techniques permits more fully examine of the spectral patterns in remote sensing data.

Digital Image processing is the use of computer-assisted techniques to manipulate and interpret the digital images (Lillesand and Kiefer, 2000). Basically, there are three stages of digital image processing procedure involved: image pre-processing, image enhancement, and image analysis and classification.

1. Image pre-processing (or image reflection and restoration)

The intent of image rectification and restoration is to correct image data for distortions or degradations from the image acquisition process. The procedures vary considerably with such factors as the digital image acquisition type, platform, and total field of view. This step involves the geometric correction, radiometric correction and noise removal.

2. Image enhancement

Image enhancement involves techniques for increasing the visual distinctions Between features in a scene,order to more effectively display or record the data for subsequent visual interpretation. There are several techniques such as contrast stretching, spatial filtering, principal component analysis, band combination, etc (Rajan, 1991)

3. Image classification

These operations are the quantitative techniques for identification of feature in a scene and for categorization of all pixel into one of several land cover classes or theme, base on statistically decision rules. The decision rules are base on spectral, spatial, and temporal characteristics (Lillesand and Kiefer, 2000). The spectral pattern present within each pixel is used as the numberical basic for categorization.

Two types of methods use in image classification are supervised classification and unsupervised classification. In supervised classification, a representative sample (called training area) is selected and its spectral signatures are analyzed. Then, each pixel in the image data set is categorized into land cover class it most closely resembles. The different supervised classification schemes are minimum distance to means classifier, and maximum likelihood classifier (Rajan,1991: Lillesand and kiefer, 2000).

Unsupervised classification does not utilize training data as supervised classification. These classifier involved algorithms that examine the unknown pixels in an image and aggregate them into a number of classes base on the natural groupings or clusters present in the in the image values. The analysts must compare the classified data with some form of reference data, such as, large scale imagery, maps or field data, to determine the identity and informational value of the spectral classes (Lillesand and kiefer, 2000).

2.3.3 Landsat Data

Landsat satellites have provided repetitive, synoptic, global coverage of high-resolution imagery. Landsat thematic mapper (TM) data are available in seven narrow bands. The wavebands recorded by the TM and their application are shown in Table 2.1 Data from each of the seven band of TM can be viewed separately as black and white image. The color composite image can be obtained by combining single-band (assigning one color per band) in computer. The commonly used band combination and their applications are described by EOSAT as shown in Table 2.2.

Lansat TM data are composed of line formed by adjacent pixels, each pixel cover a ground surface of 30 x 30 meter, 120 x 120 meter in thermal infrared band. A complete scene consists of 5,760 lines with a maximum of 6,920 pixels on a line and cover an area of 185 x 170 kilometer (Rajan, 1991).

Table 2.3 Thematic Mapper spectral bands(Lillesand and Kiefer, 2000)

Band	Wavelength (µm)	Nominal Spectral Location	Principal Applications
1	0.45-0.525	Blue	Designed for water body penetration, marking it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest type mapping, and cultural feature identification.
2	0.52-0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63-0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76-0.90	Near infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55-1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from cloud.
6	10.4-12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08-2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

Table 2.4 Example of Landsat TM band combinations (EOSAT. cate in Rajan,1991).

Band Combinations (R,G,B)	Typical Applications
3,2,1	Penetrates shallow water and shows submerged shelf, water turbidity.
4,5,3	Shows land/water boundaries and highlights subtle detail not readily apparent in the visible band alone. Vegetation type and condition are shown as variations in hues (green, browns, and oranges) as well as in tone. Shows moisture differences. The wetter the soil, the dark it appears.
4,3,2	Sense peak chlorophyll reflection as red. The resulting red hues are easily discriminated by the human eye. Generally, deep red hues indicated broad leaf and healthy vegetation. Lighter reds indicate grasslands. Densely populated urban areas are shown in light blue. Water boundaries are defined clearer in the 3, 2,1 combination.
7,4,2	Retains the benefits or the infrared bands and yet presents vegetation in familiar green tone. Moisture content in both vegetation and oils is discriminated.

2.4 Remote Sensing for Coastal Erosion Study

Remote sensing has played an important role in coastal studies because it helps to speed up the research process.

Mapping of historical aerial photography coastline is a difficult task a result of two typical problems. The first concerns data quality which varies greatly due to acquisition apparatus, methods, and storage condition, such as object displacement, geometrical distortions, and low contrast. The second problem concerns coastal zone complexity and dynamics, due firstly to its wide range of components and their mixtures, and secondly to the fast rate of changes in their spatial distribution.

Coastline changing has been studies by comparison of aerial photographs taken from the same section at different dates.

Dolan, Hayden, and Heywood (1978) used historical aerial photographs as the data base for developing a common-scale mapping method in order to systematically measure shoreline erosion and storm surge penetration along extensive reaches of the United State Atlantic coast. Aerial photographs covering four decades were use to provide long-term baseline information on shoreline dynamics. The aerial photographs were then enlarged to the exact scale of the base map by projection onto the base map. After that, the shoreline and active sand zone line (storm penetration line) were traced from the projection. This study was concluded that of the available types of historical data only aerial photographs provide a record with sufficient spatial and temporal detail for a national mapping program.

Ly(1993) examined the applicability of remote sensing data for monitoring and predicting shoreline change in Rayong province, Thailand, without any sort of protective barrier. The study used TM data. Linear feature overlay method was used for qualitative data analysis. The result shown accretion and erosion area and accretion rate. The changes were mainly due to long time wave action, predominately by southwest waves from May to September, and construction of structures, such as jetties, breakwater etc. The study proved that remote sensing is a good potentials as tools for monitoring and predicting coastline changes and conclude that shoreline changes was mainly affected by new construction on the boundary of shoreline and wave action.

CHAPTER III

METHODOLOGY

3.1 Methodology

The methodology of this study was divided into three steps. Firstly, the data and information of previous works and literature studies were collected. Secondly, the data were studied and analyzed for coastal changes together with their physical components; meteorological data which concentrated in the influence of Typhoon Gay (32W), Typhoon Linda (30W). One of components which force the tropical cyclone conditions was sea surface temperature, this data are from National Oceanic and Atmospheric Administration (NOAA). When Typhoon passed to the Gulf of Thailand there was a strong wind, which generate wind wave to attack coastline and caused to coastline change; therefore, analysis wind speed and wind direction was used. A 3-hourly intervals wind direction and wind speed from Hua Hin meteorological station were used to calculate significant wave height together with to study current vector and the coastline shape at Ao Hua Hin to explain the cause of coastline change during typhoon passed to the Gulf of Thailand. Furthermore, tidal levels and their associated season were studied to explain coastline change in strong northeast monsoon on December 2006.

After these results were explained with the result of coastline changes which were analyzed by using GIS and remote sensing technique. This step used three satellite image sets of Landsat-5 TM images for detection of coastline change. The first period was classification of coastline changes before and after Typhoon Gay attacked the eastern coast of Thailand in November 1989, and the second was classification of coastline changes before and after Typhoon Linda attacked the eastern coast of Thailand in November 1997. And the last period was classification of coastline changes before and after strong seasonal monsoon in December 2006. The prioritization of changed areas were done and preventive measures in the changed areas were proposed and the illustrated in maps. Finally, includes integration of all results to recommend for solving the changed area of the study.

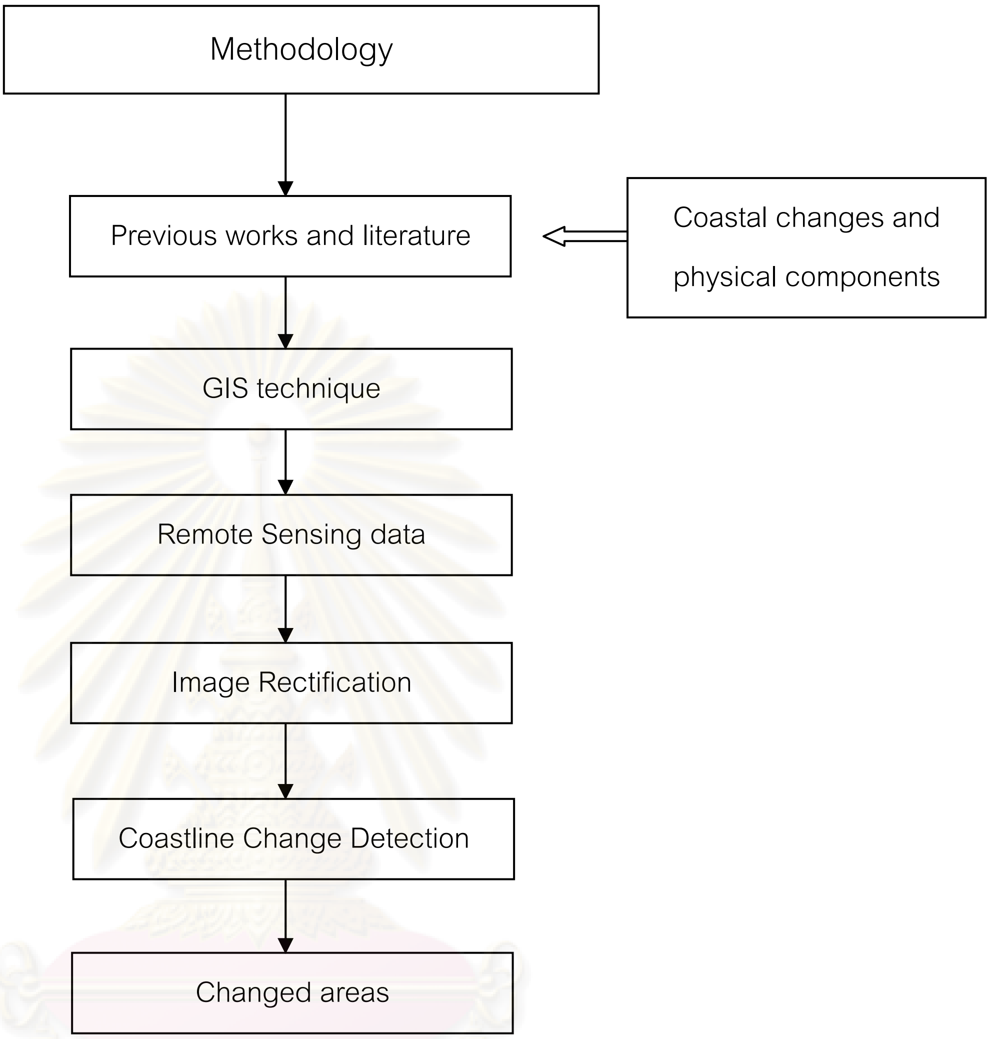

Figure 3.1 The steps taken in managing in the GIS system data

3.1.1 Analysis hydro-meteorological condition

Sea surface temperature, which reveal from National Oceanic and Atmospheric Administration (NOAA), was used to analyze the mean sea temperature during 1987-2006, during Typhoon Gay (32W) and Typhoon Linda (30) reached to the Gulf of Thailand. This factor originated and forced the origin of the tropical cyclone. Normally, when the tropical cyclone and tropical depression passed the Gulf of Thailand sea surface temperatures are greater than 26.5 degree Celsius (Elsberry,1987).

3-hourly surface wind data at Hua Hin, Prachuap Kiri Khan and Chumpon meteorological stations, showed wind direction and wind speed which affected the coastline when Typhoon Gay (32W), Typhoon Linda (30) passed to the Gulf of Thailand. It included with analysis cloud pattern from satellite images. In case Strong northeast monsoon passed to the Gulf of Thailand also analyzed 3-hourly surface wind data with wind chart and weather charts.

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The significant wave height was calculated by wind from Wave Climate Formulation at Hua Hin for the period of interest. The 3-hourly surface wind data assumed to apply over the entire region of interest. The first step in the analysis is to calculate a wind stress facter, U_A which will be used in the wave growth equation after that the significant height, H_s and the peak spectral period, T_p were calculated.

Significant wave height is an average measurement of the one-third largest waves. In many applications of wave data, larger waves are more "significant" than smaller waves. For example, the larger waves in a storm cause the most erosion on a beach; hence, a well developed significant wave is approximately equal to H_s, defined as four times the standard deviation of the instantaneous displacement from the mean sea level.

Calculating wind stress factor, U_A is given by (CERC, 1984):

$$U_A = 0.71U^{1.23} \qquad (3\text{-}1)$$

Where U is the one duration wind speed in knot

Since the fetch length are effectively infinite, it has been assumed that developed wave condition exist at the location of interest. The governing equation fully developed wave conditions are given by following:

$$\frac{g H_s}{U_A^2} = 0.2433 \qquad (3\text{-}2)$$

$$\frac{g\,T_p}{U_A} = 8.134 \qquad (3\text{-}3)$$

where: g = acceleration due to gravity (9.81m/s^2)

H_s = significant wave height (m)

T_p = Peak spectral wave period (s)

U_A = wind stress factor (m/s)

3.1.2 The method of field survey to measure beach profile of Hua Hin Bay.

The field survey was aimed to measure beach profile of Hua Hin Bay, which was located between the northern coastline area at Khoa Takiap and the coastline area at Sofitel Centara Grand Resort and Villa Hua Hin (UTM 604580E, 1384236N to 606222E, 1389737N). The area for measurement elevation covered a total distance of 5 km by using electronic distance meter (EDM) for detecting the elevation between two location marks. An instrument error was ± (1mm +2ppm) to ± (5mm+5ppm).

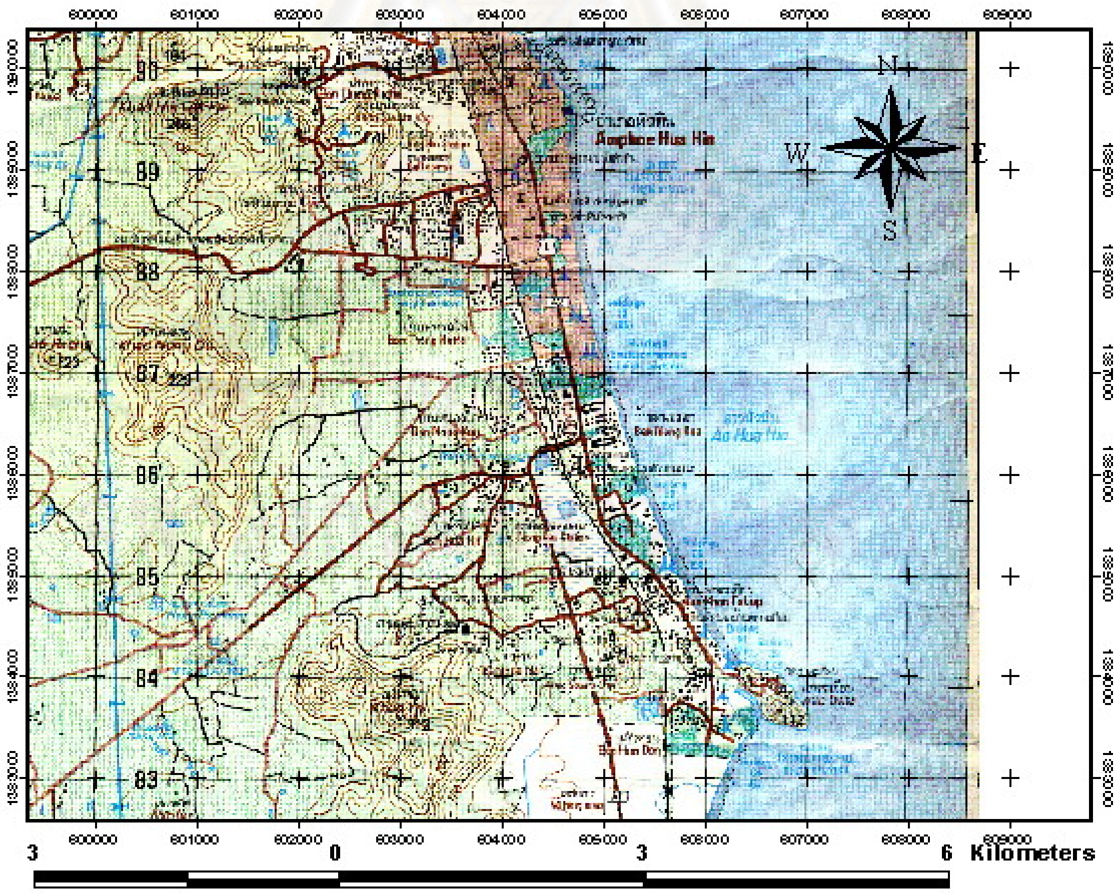


Figure 3.2 The topographic map of Ao Hua Hin

Depth measurement of Hua Hin Bay was carried out during October before starting of northeast monsoon (November- February). The measurement was done when lowest tide. Besides, randomized block designs was used to define the observation area. Therefore, selected area every 100-200 meters was measured the elevation of Hua Hin bay, 50 meters to 200 meters landward. The datum was refered to Kao Takeab, its height is from topographic map. Figure 3.3 was shown the field observation.

Figure 3.3 Field observation at Ao Hua Hin

3.1.3 Identification of the shoreline change

3.1.3.1 Data Collection

The existing data related to the study were collected as follows:

1. Topographic maps at scale 1: 50,000 in 7017 series. The required sheet included map number 4934 II prepared and published by The Royal Thai Survey Department.

2. Radiometrically and system corrected Landsat-5 Thematic Mapper (TM) image in path Path 129 Row 052 was required as follows:

   6 sets of Satellite images are used in this study :

   2.1) Satellite image was taken on 7 July 1989 (representing shoreline before Typhoon Gay moved to the Gulf of Thailand)

   2.2) Satellite image was taken on 30 December 1989 (representing shoreline after Typhoon Gay moved to the Gulf of Thailand)

   2.3) Satellite image was taken on 15 September 1997 (representing shoreline before Typhoon Linda moved to the Gulf of Thailand)

   2.4) Satellite image was taken on 5 January 1998(representing shoreline after Typhoon Linda moved to the Gulf of Thailand)

   2.5) Satellite image was taken on 27 November 2006(representing shoreline before the strong seasonal monsoon passed to the Gulf of Thailand)

   2.6 Satellite image was taken on 29 December 2006 (representing shoreline after the strong seasonal monsoon passed to the Gulf of Thailand)

The data was provided by the National Research Council of Thailand (NRCT).

3. Data of rain fall, wind direction and wind speed by 3 hourly surface wind at Hua Hin Meteorological Station acquired from The Meteorological Department of Thailand.

4. Tide data and Hydrographic Chart acquired from The Hydrographic department, Royal Thai Navy, 1935-1993.

5. Data and information of Typhoon Gay in 1989, Typhoon Linda in 1997 and strong seasonal monsoon in 2006 acquired from The Meteorological Department of Thailand.

The condition of tide when the satellite passed before and after Typhoons and strong seasonal monsoon attacked the west of coastline of the Gulf of Thailand was used the data at Hua Hin station acquired from Royal Thai Navy. The data of tide are shown in the table 3.1

Table 3.1 The condition of tide when the satellite passed the study area.

Date Month Year	Imaging Time	Tide condition	Level of water (m) above MSL
7 7 1989	03:05:45	LW-4	-1.1
30 12 1989	03:01:14	LW+1	0
15 9 1997	03:10:37	LW-1	-0.86
5 1 1998	03:13:29	LW-1	-0.94
27 11 2006	03:32:45	LW-2	-0.98
29 12 2006	03:32:59	LW-1	-0.9

3.1.3.2 Software Used

ENVI program version 4 was used for processing and analysis of satellite image data.

ArcView GIS program version 3.1 was used for utilization of GIS data.

Suffer program version 8 was use to generate contour at Ao Hua Hin.

3.1.3.3 Analysis of satellite images

Digital Image processing was the use of computer-assisted techniques to manipulate and interpret the digital images. Basically, there are three stages of digital image processing procedure involved: image pre-processing, image enhancement, and image analysis and classification (Lillesand and Kiefer, 2000). Details referenced in chapter 2.

CHAPTER IV

RESULT AND DISCUSSION

This chapter provides a result of study from each component by using data material and methodology described in chapter III. This chapter starting with the detailed description of meteorological data analyzed together with coastline changes from remote sensing interpretation and also provides a result of field investigation, which is composed of beach profile. Result from data analysis phase was shown in this chapter, which provides the coastline changes in comparison with before and after period satellite images.

4.1 Analysis result of hydro-meteorological condition

The study area was affected by the pattern of surface wind directions characterized by the monsoon system. The prevailing winds are north to northeast during the northeast monsoon season and are southwesterly over the Gulf of Thailand during the southwest monsoon. Tropical cyclones affecting Thailand usually move from the western North Pacific Ocean or the South China Sea. Their strengths may be characterized by wind speed. The Gulf of Thailand normally was affected by tropical depressions because of its location farther inland. In November to February northeast monsoon forced wave-current from South China Sea to the Gulf of Thailand, which affected high tide current in the Gulf of Thailand; on the other hand, Southwest monsoon in May to October forced wave-current from the Gulf of Thailand to South China Sea, which affected low tide current.

Since the storm surge was driven by the winds, the height of the rise in sea level was related to the velocity of the wind. Figure 4.1 showed a tendency of significant wave height which was due to wind speed of tropical cyclone. It calculated by using equation 3-2. Data of tropical storm provided from Table 1.1 in Chapter I; depression Chantu, Durian and Muifa; tropical storm Linda and typhoon Gay.

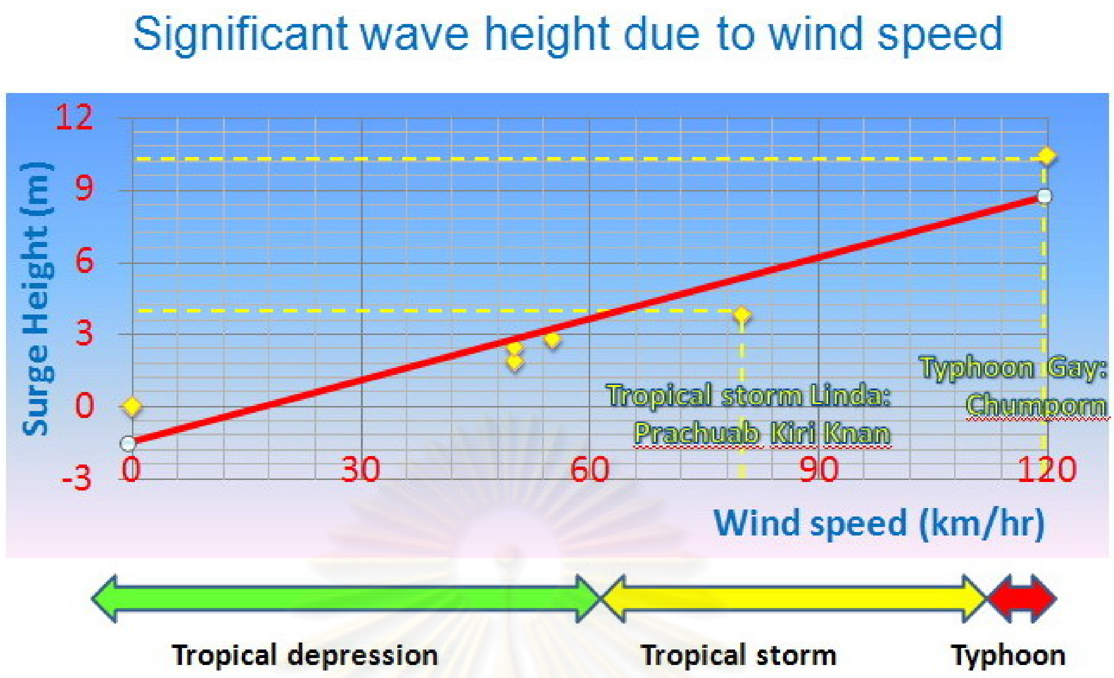


Figure 4.1 The significant wave height was due to wind speed

4.1.1 Result of Sea surface temperature analysis

The reanalysis of sea surface temperature from NOAA during 1987-2006 was 27 degree Celsius (Figure 4.2). The sea surface temperature was important for the origin of the tropical cyclone. According to Elsberry (1987), when the tropical cyclone and tropical depression originated sea-surface temperatures was greater than 26.5 degree Celsius. During Typhoon Gay (32W) originated in lower the Gulf of Thailand on 31 October 1989, sea surface temperature was about 29 degree Celsius (Figure 4.3) and it was 28.5-29 degree Celsius through 4 November 1989. In addition to Typhoon Linda (30W) passed to the Gulf of Thailand on 1November 1997, sea surface temperature was 30 degree Celsius (Figure 4.4) and it was 29-30 degree Celsius through 4 November 1997. Therefore, these results could originate and force the tropical cyclone, which them caused of strong wind and high wave along the coastline.

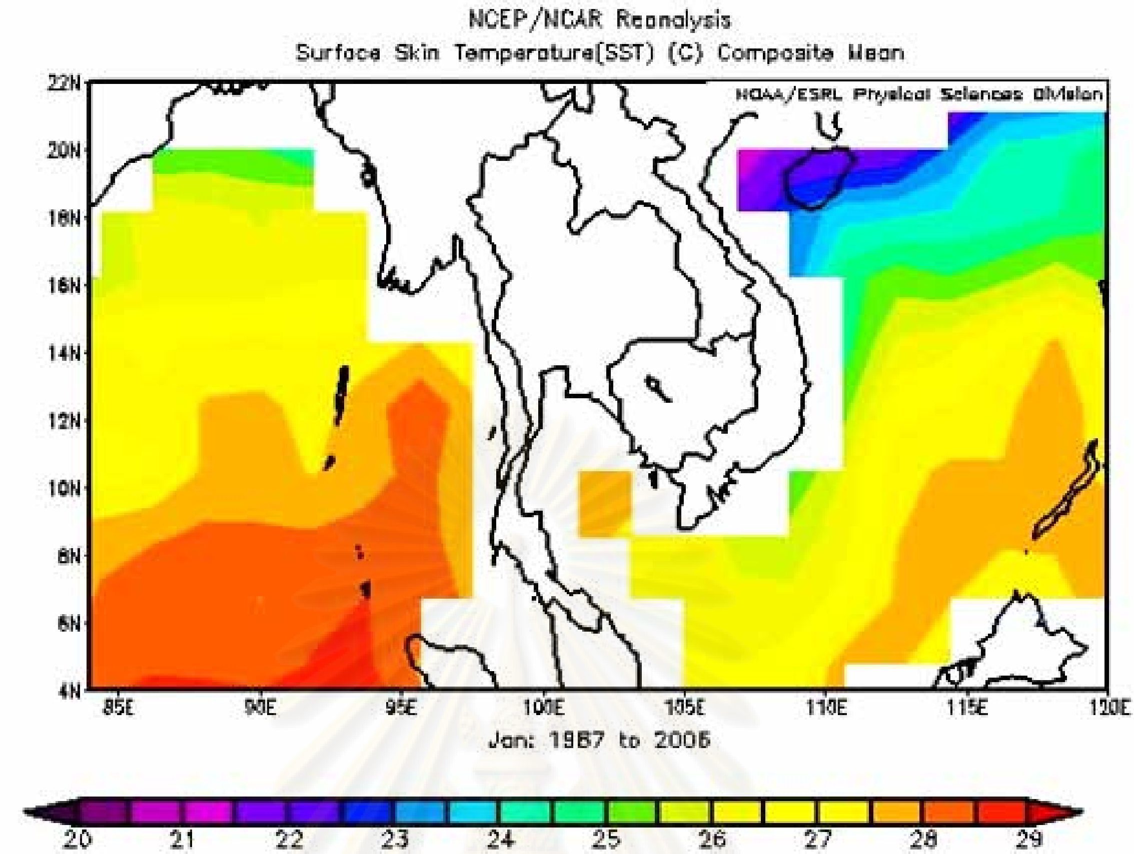


Figure 4.2 Sea SurfaceTemperature during 1989 – 2006 between 4°N to 22°N latitudes and 84°E to 120°E longitudes (National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)

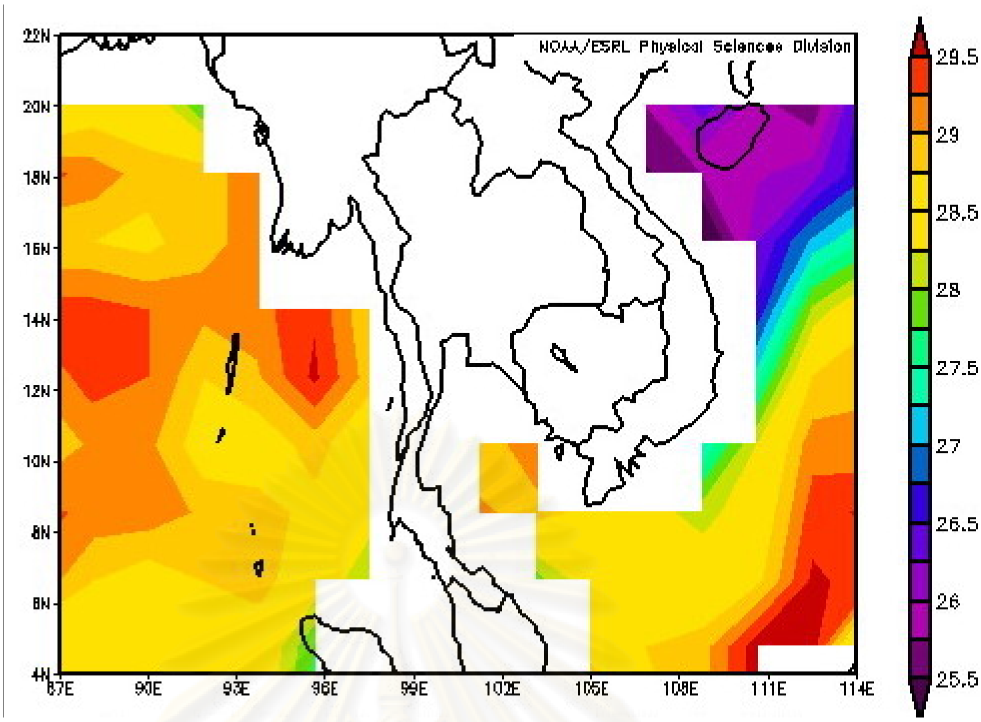


Figure 4.3 Sea Surface Temperature 31 October 1989

(National Oceanic and Atmospheric Administration:

http://www.cdc.noaa.gov)

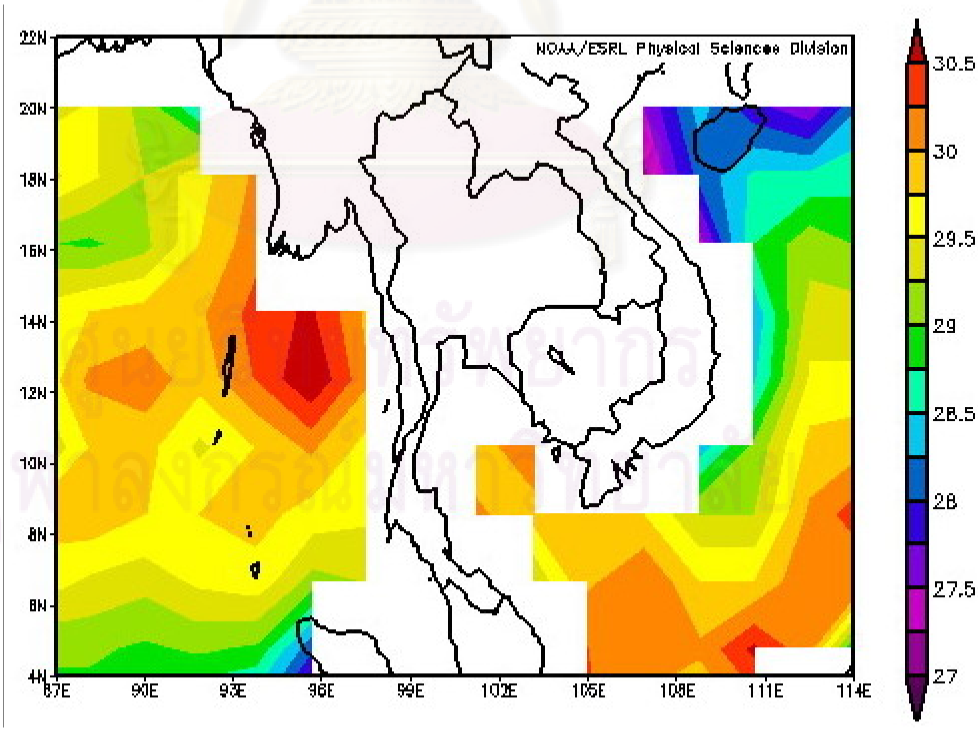


Figure 4.4 Sea Surface Temperature 1 November 1997

(National Oceanic and Atmospheric Administration:

http://www.cdc.noaa.gov)

4.1.2 Result of wind analysis when Typhoon Gay (32W) moved to the southern coastline.

The influences of strong wind were interpreted from satellite images. Figure 4.5 was shown the positions and effective strong wind on 4 November 1989. The intensity of typhoon drove strong wind and tidal wave, which attacked the coastline and large damage properties, interval wind speed on 1-5 November was about 5-40 knots (9-75 km/hrs). 3-hourly surface wind showed wind direction and wind speed in figure 4.6. It was analyzed from 3 meteorological stations; Chumpon, Prachub Kiri Khan and Hua Hin meteorological station. There was strong wind speed on 3-5 November, which influenced the tidal wave along the coastline.

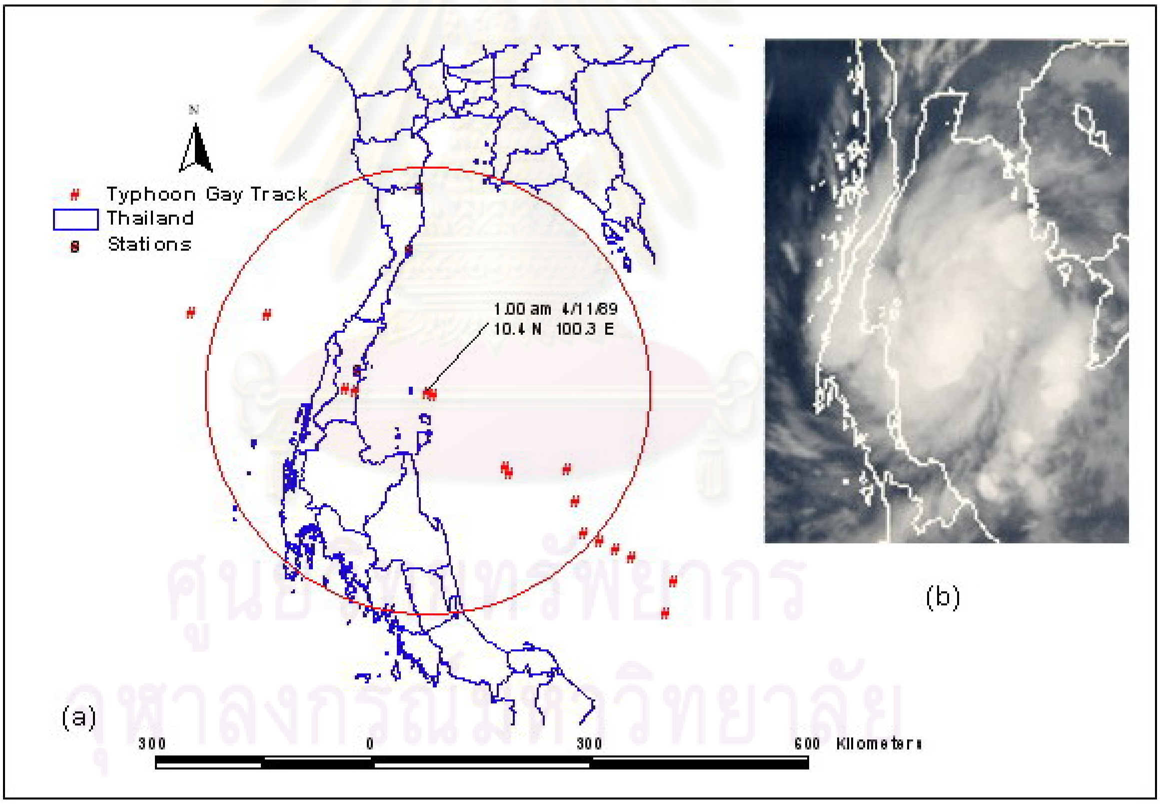


Figure 4.5 *(a)* The position and radius of Typhoon Gay (32W) on 1.00 a.m. 4 November 1989 at 10.4 N 100.3 E. *(b)* Satellite image on 2 November 1989 (TMD,1989)

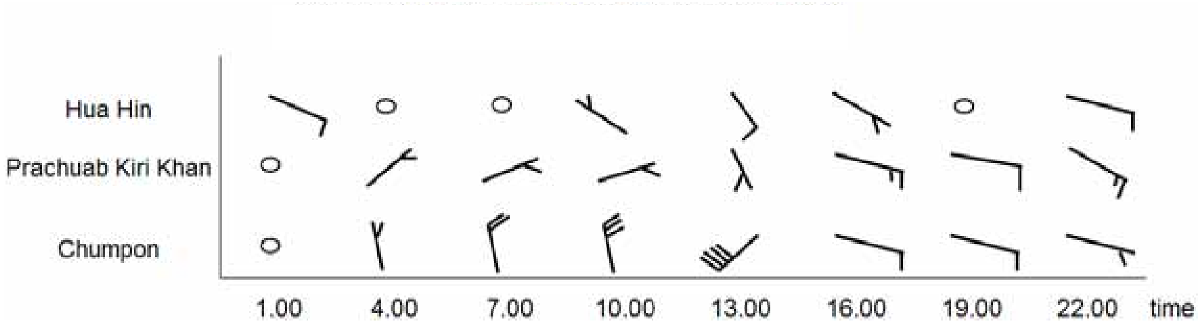


Figure 4.6 3-hourly surface wind analyzed on 4 November 1989

When Typhoon Gay (32W) passed to the Gulf of Thailand, the center of storm moved to northwest to the coastline of Chumpon province. Wind direction at Hua Hin meteorological station was perpendicular to the coastline about 10 Knots in velocity. The satellite image from GEOS-9 on 3 November 1989 was not operated, so using satellite image on 2 November 1989 to present cloud bands. On this day Hua Hin meteorological station was in moat of storm, which was Echo-free area. And it indicated vortex-scale descent. Besides, outside the eyewall, the wind descended. There was a tendency for radial flow toward the wind (Willoughby,1995). Therefore, Hua Hin was less wind velocity. When typhoon moved northwest to Gulf of Thailand, the current circulation also moved northwest and also wind drove a surface flow toward the land. These effects added to the variation in tides and were further complicated by waves. The damage was due to steep of coastline. As a result, there was an opportunity that sand was carried out by wave to offshore causing of coastal erosion.

In addition, the wind induced circulation inside the gulf is characterized by the migration of water from the southeast to the north of the gulf. The current vector in case of Typhoon Gay (32W) approached to The Gulf of Thailand, the sea surface elevation rose to the maximum height at this time. The center of the counterclockwise circulation was quite far away from the shore, about 320 km south of Hua Hin. During this time, the current vector flowed directly to the north of Hua Hin caused to coastal erosion.

4.1.3 Result of The significant wave height when Typhoon Gay (32W) moved to the southern coastline.

The influence of wind speed when Typhoon Gay (32W) passed the Gulf of Thailand was generated the wind wave and move toward to the coastline. In this section we analyze the wind direction, wind speed and significant wave high during Typhoon Gay (32W) by using the 3-hourly surface wind.

The result of significant wave height during Typhoon Gay (32W) passed to the Gulf of Thailand on 1-5 November 1989 was shown in figure 4.7. The result of wave analysis was shown that wave height was peak 2.23 meters at 01.00 am on 5 November 1989 at Prachuab Kiri Khan meteorological station. Because of the center of storm moved nearly the coastline of Prachub Kiri Khan until it passed to Bengal bay.

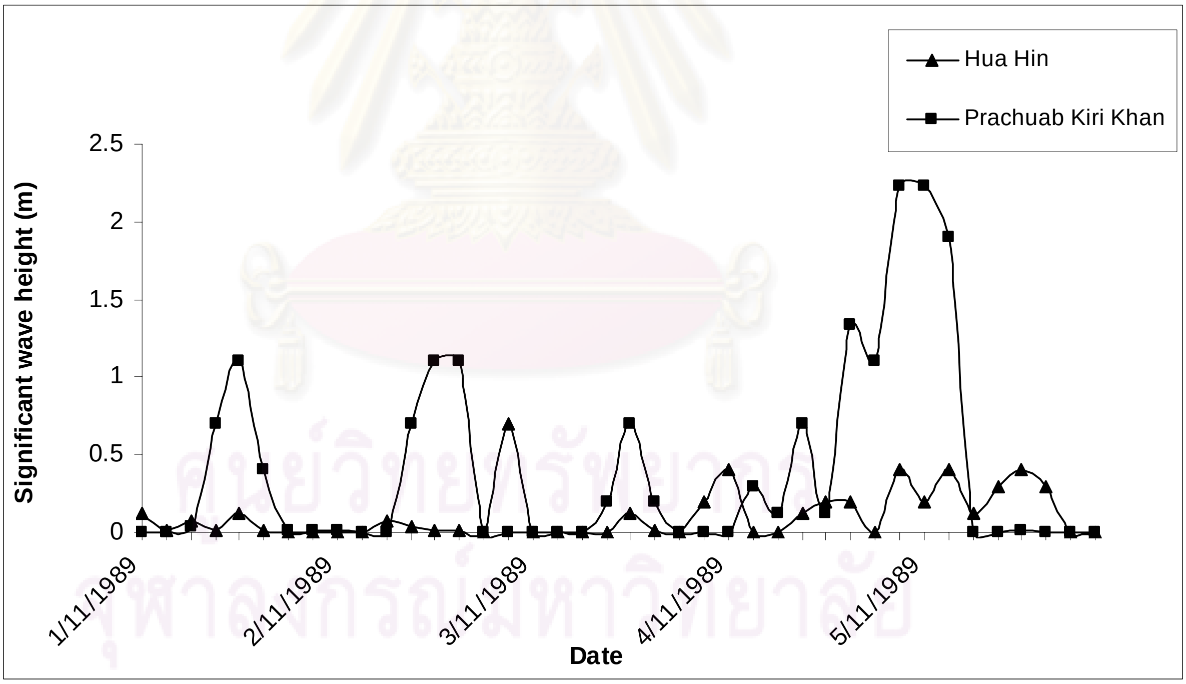


Figure 4.7 Significant wave height on 1-5 November 1989

Whenever a tropical storm threatened to strike a coast, it was desirable to have an estimate of the height of the peak storm surge. The wave height coincided with a high astronomic tide. According to Longuett-Higgins and Stewart (1964), if the storm made landfall during high tide, the effect would be a higher water level than if the surge hit the shore during low tide.

Therefore, this significant wave height was considered with tide whenever there were high tide and high wave, there was the high surge causing of high coastline erosion areas. The determination tidal elevation in 1989, 1997 and 2006 was calculated and presented in figure 4.8. The average of all tidal elevation was Mean Sea Level (MSL). The term MSL was often incorrectly used to refer to the zero datum for topographic maps. And the maximum tide range was defined as the vertical difference between the Highest High Tide and the Lowest Low Tide.

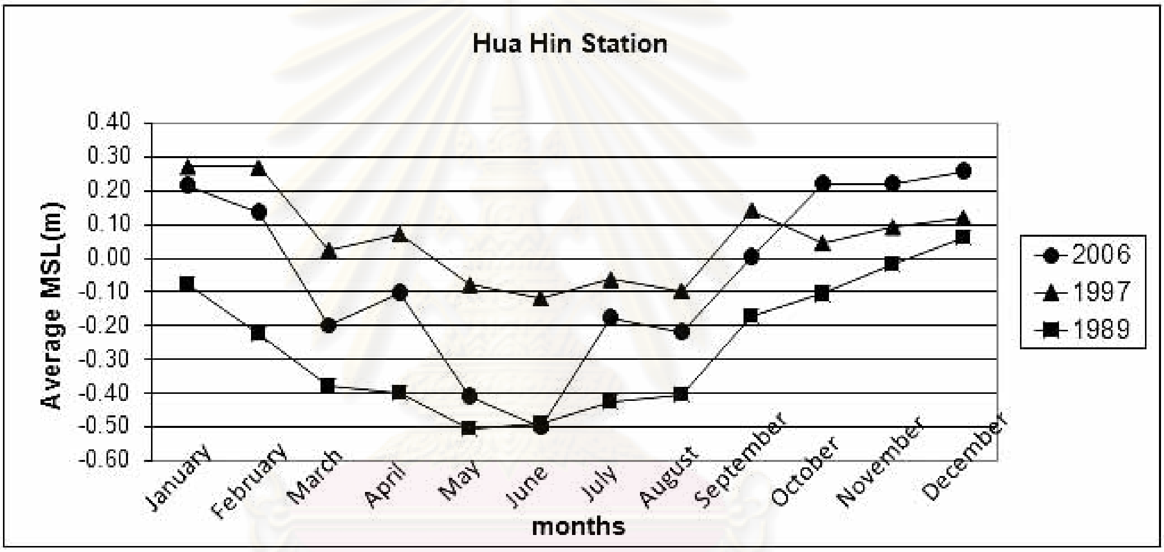


Figure 4.8 Monthly mean tidal elevation at Hua Hin Station (Royal Thai Navy, 2006)

The result represented that mean tidal elevations were vary. It was due to influence of seasonal monsoon. During May to September mean tidal elevation was lower than MSL. In contrast, during northeast monsoon mean sea elevation was upper than MSL. The mean tide range is defined as one meter, which close to the mean tide range at Prachuab Kiri Khan, province. During Typhoon Gay (32W) passed to the Gulf of Thailand, it was the Northeast monsoon season. The high tide was about 40 centimeters above MSL. Therefore, the wave height coincided with a high astronomic tide at coastline of Hua Hin was about 1.1 meters above MSL. It peaked for 36 hours during 01.00 am on 4 November 1989 to 13.00 pm on 5 November 1989. These results were considered with the coastline shape which providing from field investigation and remote sensing. It was applied for measure the change areas on coastline of Amphoe Hua Hin, Prachuab Kiri Khan, province during typhoon moved over the Gulf of Thailand. The result of coastline change was shown in part of analysis Landsat-5 images.

4.1.4 Result of wind analysis when Typhoon Linda (30W) moved to the southern coastline.

The influences of strong wind were interpreted from satellite images. Figure 4.9 was shown the positions and effective strong wind on 3 November 1997 before it attacked coastline of Amphoe Bangsapan Prachuab Kiri Khan, province at 19.00UTC on 4 November 1997 at 11.4N 99.5E, and showing the wind direction and high wind speed by analyzing 3-hourly surface wind data on 3-4 November 1997. In figure 4.10 and figure 4.11 showed wind component from 2 meteorological stations; Prachub Kiri Khan and Hua Hin meteorological station which shows wind speed and wind direction when Typhoon Linda (30W) passed to the Gulf of Thailand.

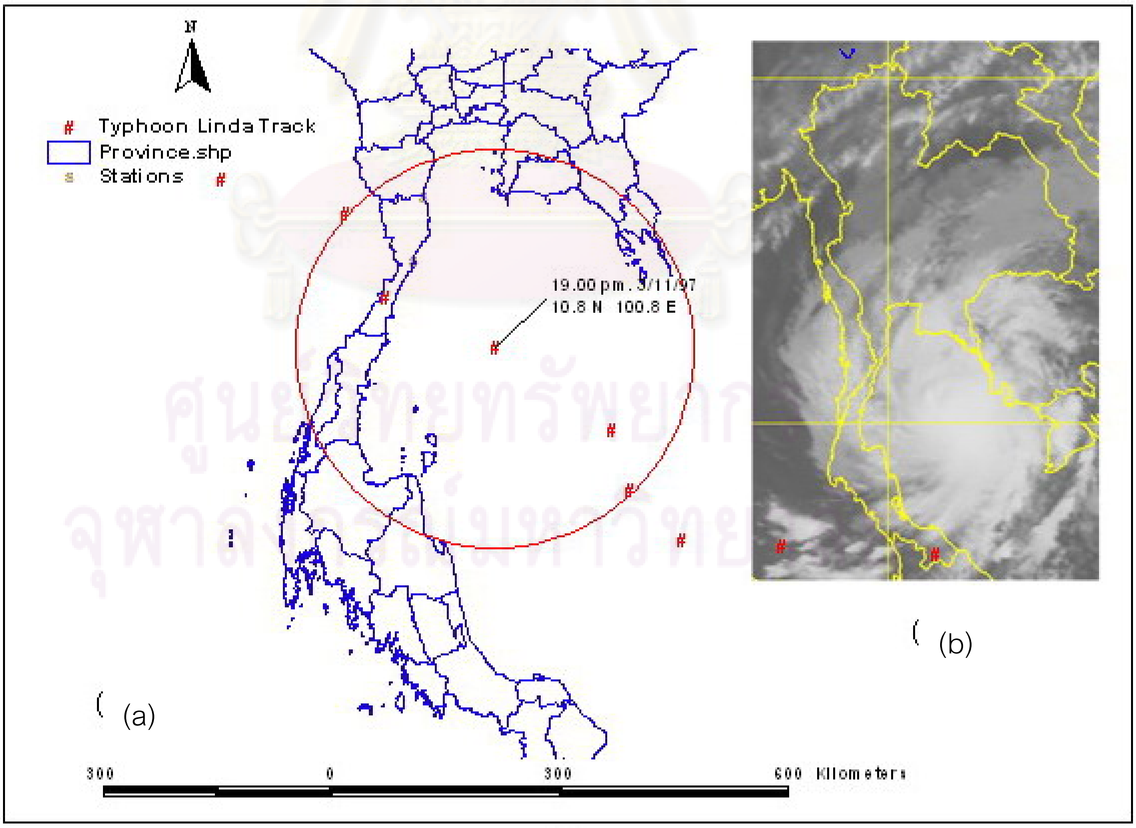


Figure 4.9 *(a)* The position and radius of Typhoon Linda (30W) on 19.00 p.m. 3 November 1997 at 10.8 N 100.8 E. *(b)* Satellite image on 3 November 1997 (TMD,1997)

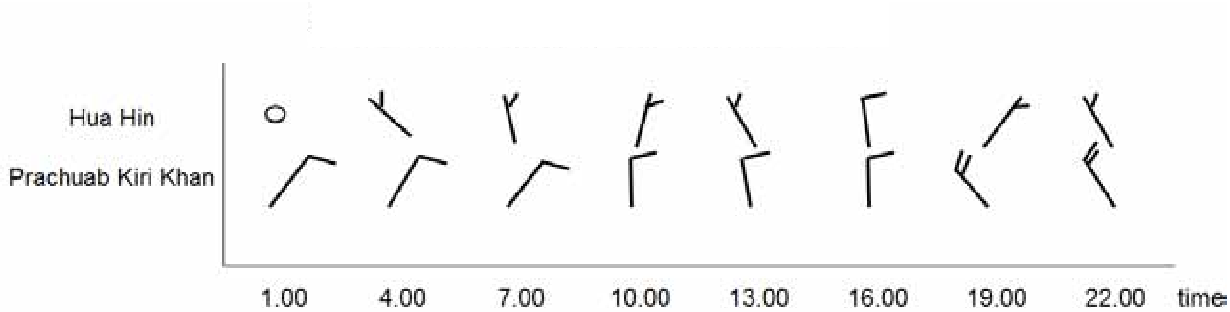


Figure 4.10 3-hourly surface wind analyzed on 3 November 1997

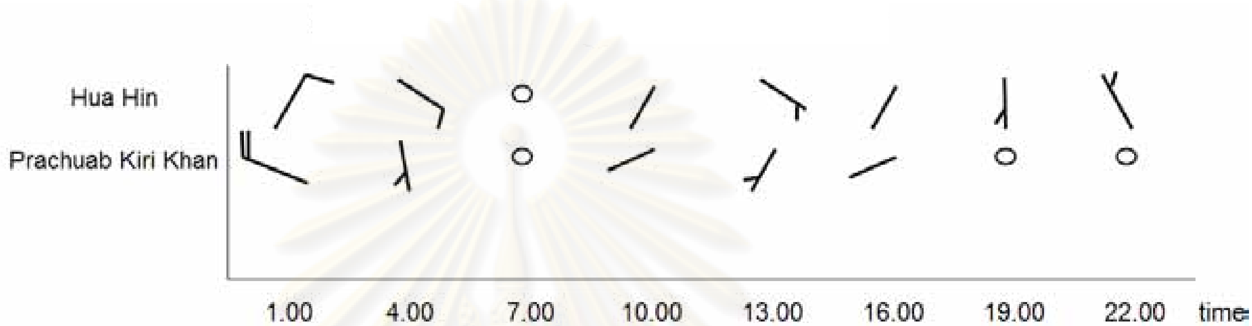


Figure 4.11 3-hourly surface wind analyzed on 4 November 1997

When Typhoon Linda (30W) passed to the Gulf of Thailand, the center of storm moved to northwest to the coastline of Prachub Kiri Khan province at 11.4N 99.5E; 2.00 a.m. 0n 4 November 1997. The radius of storm reached to Hua Hin meteorological station. Wind direction at Hua Hin meteorological station was not perpendicular to the coastline. It was from northeast. The satellite image from GEOS-9 on 3 November 1997 (Figure 4.9 (b)) presented cloud bands because cloud bands disbanded on 4 November 1997. It showed that Hua Hin meteorological station was in moat of storm, which was Echo-free area. And it indicated vortex-scale descent. Besides, outside the eyewall, the wind descended. There was a tendency for radial flow toward the wind (Willoughby,1995). Therefore, Hua Hin was less wind velocity. This result was similar to the result from Typhoon Gay (32).

When typhoon moved northwest to Gulf of Thailand, the current circulation also moved northwest and wind also drove a surface flow toward the land. These effects added to the variation in tides and were further complicated by waves.

4.1.5 Result of The significant wave height when Typhoon Linda (30) moved to the southern coastline.

The significant wave height calculated from Wave Climate Formulation.Wind direction at Hua Hin was available for the period of interest. This wind was assumed to apply over the entire region of interest and using the similar method to analyze the significant wave height.

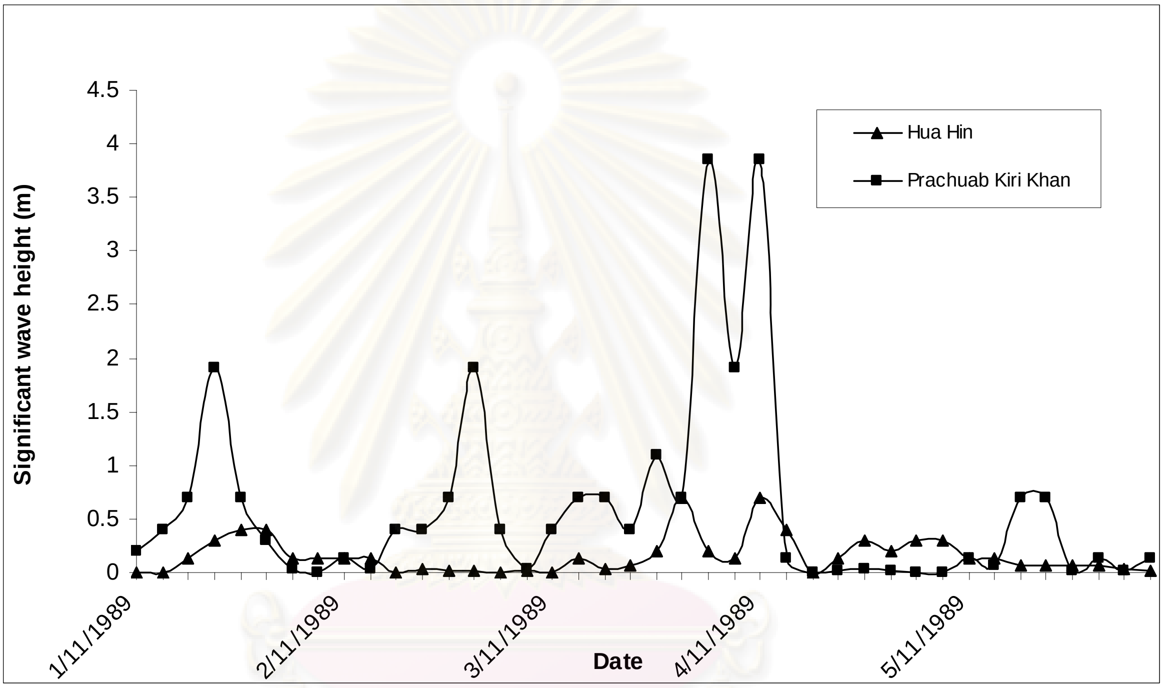


Figure 4.12 Significant wave height on 1-5 November 1997

This significant wave height from figure 4.12 was considered with tide. The height wave coincided with a high astronomic tide. The coastline was eroded. When Typhoon Linda (30W) passed to the Gulf of Thailand the determination tidal elevation1997 was calculated.

As a result, during Typhoon Linda (30W) passed to the Gulf of Thailand was in the northeast monsoon season, which was high tide about 40 centimeters above MSL. Therefore, the maximum wave height coincided with a high astronomic tide which calculated at Hua Hin meteorological station was about 1.1 meters above MSL. It peaked for 12 hours during 16.00 pm on 3 November 1997 to 01.00 am on 4 November 1997, because of the center of storm moved to northwestward and the radius of storm covered the coastline of Hua Hin. Typhoon moved northwestward when it moved through the northern part of the Gulf of Thailand. A wind from the northeast drove a surface flow toward the land. Therefore, it was clearly that sand was transported to offshore which caused coastline change. These results were considered with the coastline shape which provided from field investigation and imaginary remote sensing. The result of coastline change was shown in part of analysis Landsat-5 images

4.1.6 Result of wind analysis during the strong northeast monsoon in December 2006.

Northeast monsoon season during 20- 24 December 2006, there was strong wind in the upper Gulf of Thailand. Weather charts were considered with wind charts. Figure 4.13 and figure 4.14 presented weather chart and upper wind chart at 600 meters on 21 December 2006, respectively.

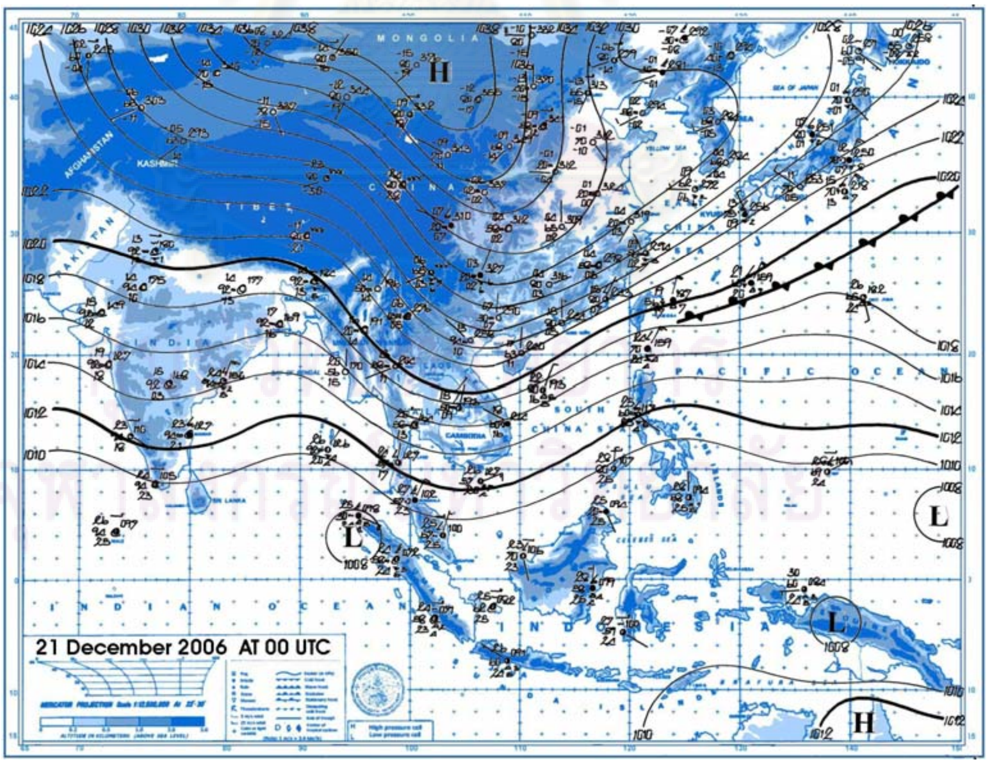


Figure 4.13 Weather chart on 21 December 2006

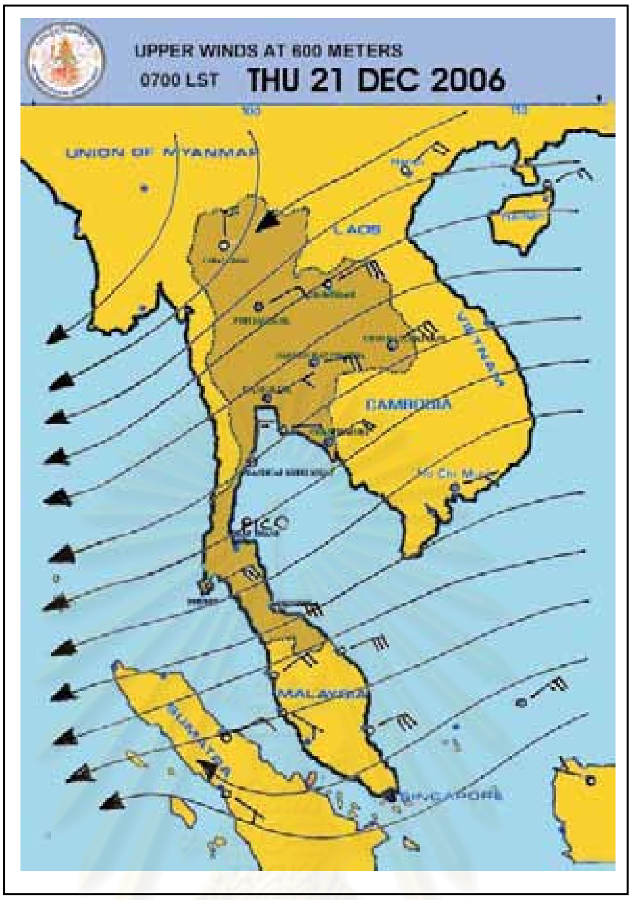


Figure 4.14 Wind chart at 600 meters on 21 December 2006

The result of analysis weather charts showed that cold air mass covering upper part of Thailand during 20-24 December 2006. It forced strong wind. Upper wind chart at 600 meters showed wind speed about 30 knots. As the position of coastline was north to south wind direction blown parallel coastline, this result confirmed with 3-hourly surface wind analyzed. Furthermore, cool mass from China was affecting the steep pressure gradient, this result forced to intensely and continually strong wind on 20-24 December 2006.

The wind direction and wind speed by analyzing 3-hourly surface wind measurement during strong northeast monsoon passed Thailand during 20-24 December 2006 provided from 2 meteorological stations; Prachub Kiri Khan and Hua Hin meteorological station were shown in figure 4.15 to figure 4.19. As a result, main wind directions were parallel to the coastline of Hua Hin.

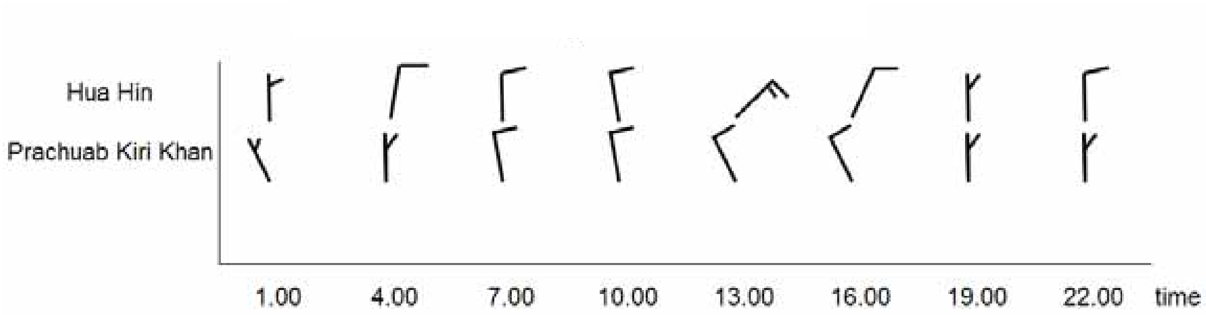


Figure 4.15 3-hourly surface wind analyzed 20 December 2006

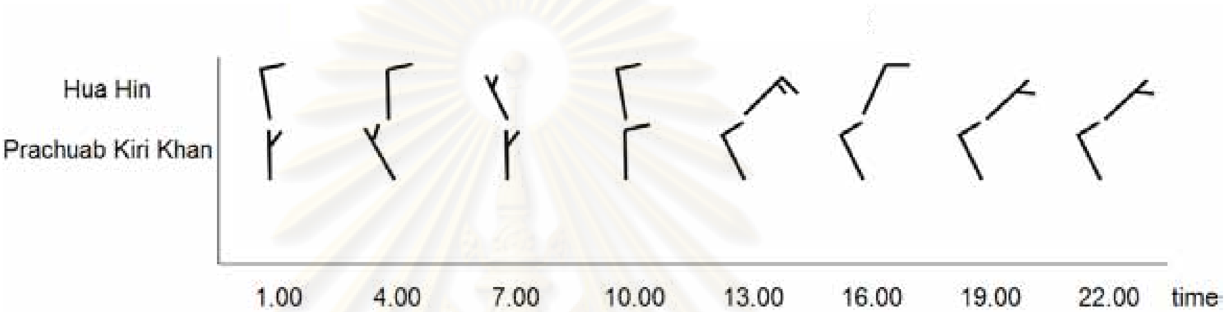


Figure 4.16 3-hourly surface wind analyzed 21 December 2006

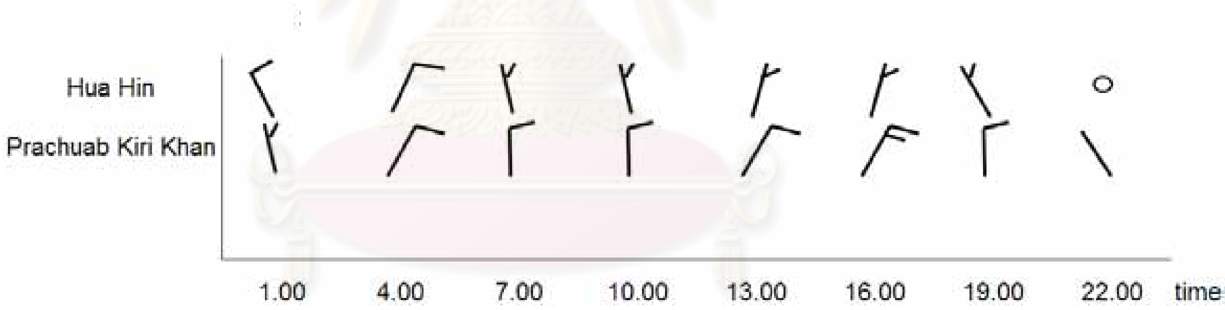


Figure 4.17 3-hourly surface wind analyzed 22 December 2006

Figure 4.18 3-hourly surface wind analyzed 23 December 2006

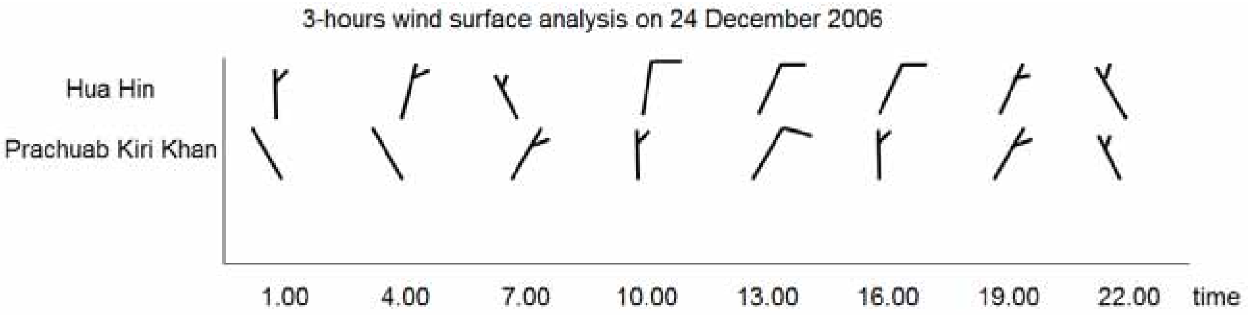


Figure 4.19 3-hourly surface wind analyzed 24 December 2006

4.1.7 Result of The significant wave height during the strong northeast monsoon in December 2006.

The result of significant wave height, which was shown in figure 4.20, was considered with tide. When there was high tide and high wave. The coastline was eroded. The current vector was forced from northeast wind drove a surface flow toward the land and the sediment transport at Amphoe Hua Hin area in northeast monsoon season was moved from north to south.

The result of wave analysis was shown that wave height was peak during 13.00 pm on 20 December 2006 to 13.00 pm on 21 December 2006 at Hua Hin station represented with tide that mean tidal elevation from Hua Hin Station. During May to September mean tidal elevation was lower than MSL, 60 centimeters while during northeast monsoon mean sea elevation was upper than MSL, 40 centimeters. As a result, strong northeast monsoon season on 20-24 December 2006 was high tide about 0.4 meters above MSL. Therefore, the maximum wave coincided with a high astronomic tide, which measured at Hua Hin station, was about 1.4 meters above MSL. It peaked for 24 during 13.00 pm on 20 December 2006 to 13.00 pm on 21 December 2006. Wind direction blowing out to the sea was considered with the current direction and direction of sand transportation which moved north to south. Therefore, sand was transported to offshore which caused coastline change. These results were considered with the coastline shape which providing from field investigation. And considered with remote sensing which was applied for measure the change areas on coastline of Amphoe Hua

Hin, Prachuab Kiri Khan, province during typhoon moved over the Gulf of Thailand. The result of coastline change was shown in part of analysis Landsat-5 images

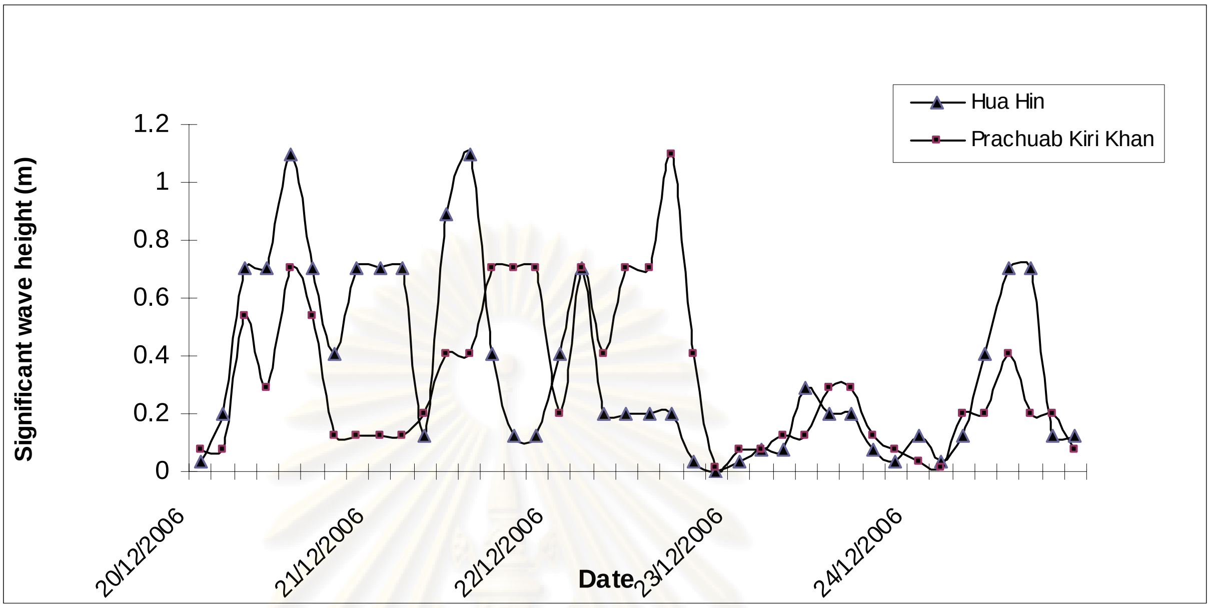


Figure 4.20 Significant wave height on 20-24 December 2006

4.2 The result of elevation measurement at Hua Hin Bay.

The coastline shape at Ao Hua Hin was shallow, its elevation was shown in figure 4.21. This figure showed that Ao Hua Hin was shallow and risked to high storm surge, this result was supported by the correction for the bottom topography; bathymetry, which was very complicated because the bathymetry along the coasts has dramatic changes. In general the more shallow the water and the wider the continental shelf at a given location the higher the storm surge.

Besides, the comparison between field observation with field observation of Office of Environmental Policy and Planning research, 2003 by using GPS in the same area. It was shown in figure 4.22- 4.23. These results showed slope in front of the Sofitel Centara Grand Resort and Villa Hua Hin UTM 604580E/1389737N and in front of northern Kao Takeab UTM 60619E/1384246N. They were shallow. Besides, beach contour was created to identify coastline shape. The result showed that coastline of Hua Hin was shallow. After storm surge was a rise sea level along coastline of Hua Hin, it caused of erosion because of surface winds above the ocean's surface push water toward typhoon's eye, creating a mound of water. It was then influenced by the slope of the coastline as the typhoon approaches land. In case coastline of Hua Hin was shallow, more erosion was occurred more than other coastline which was deep.

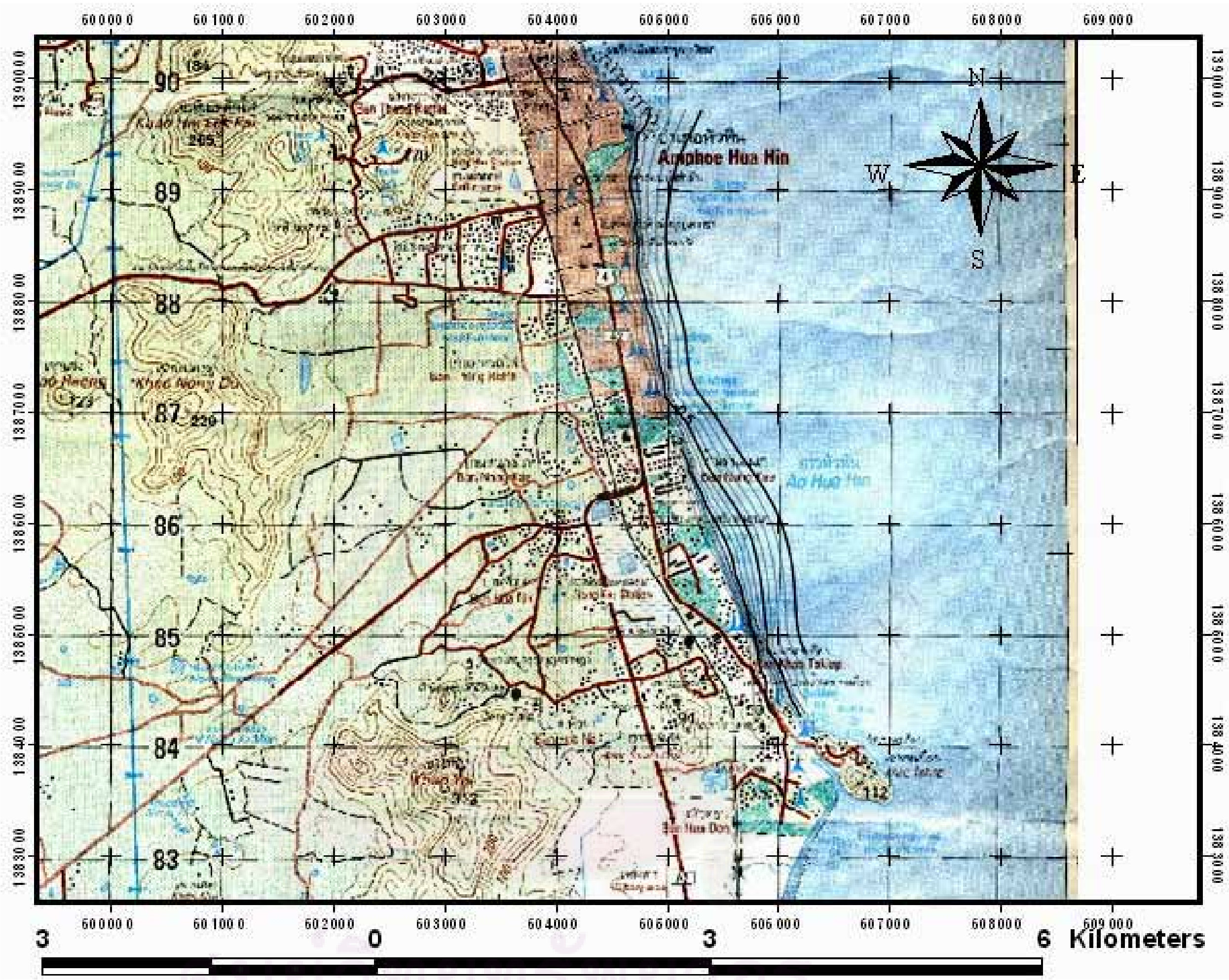


Figure 4.21 The elevation measurement at Hua Hin Bay

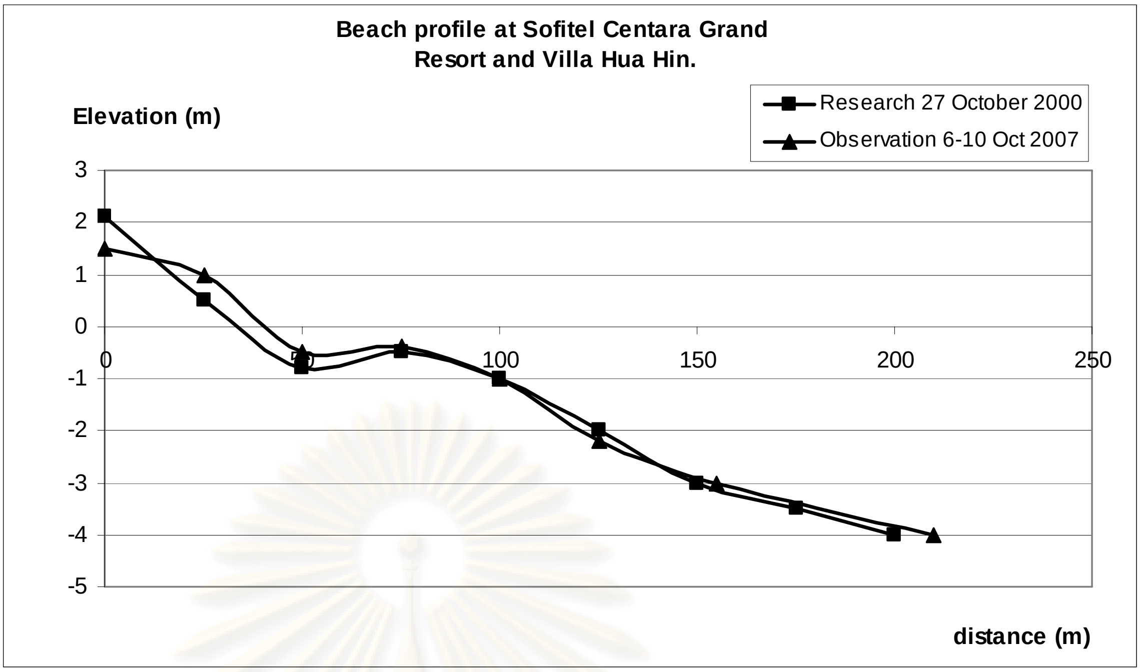


Figure 4.22 The comparison of slope between field observation and Office of Environmental Policy and Planning research at Sofitel Centara Grand Resort and Villa Hua Hin UTM 604580E/1389737N

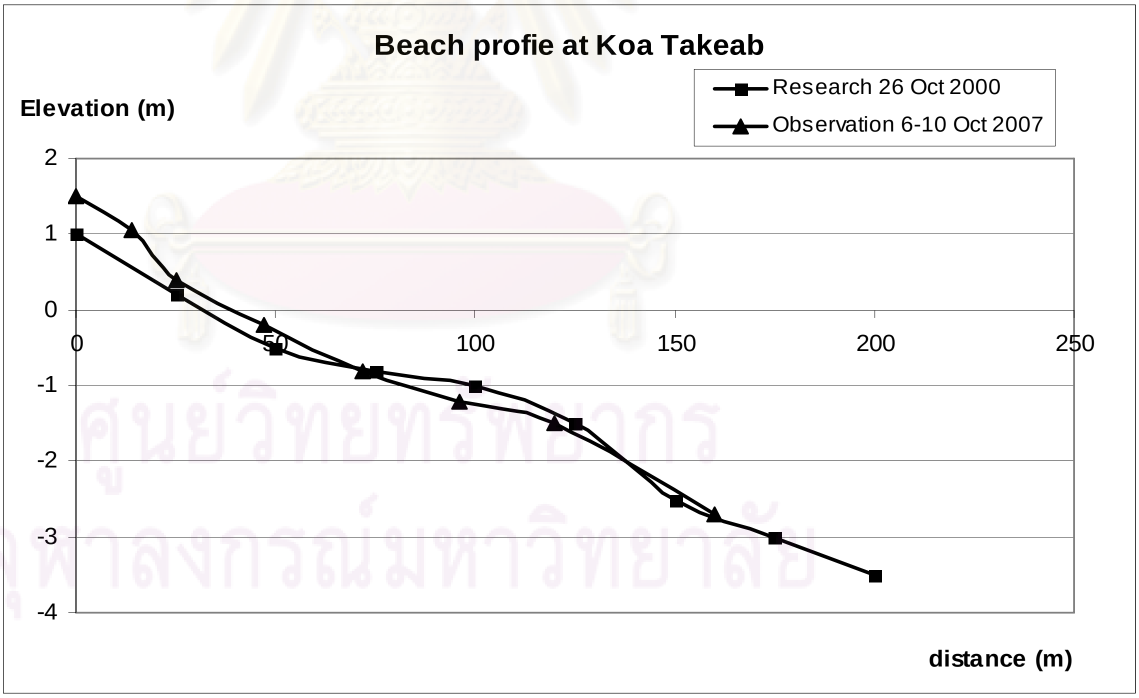


Figure 4.23 The comparison of slope between field observation and Office of Environmental Policy and Planning research at Kao Takeab UTM 60619E/1384246N

Considering beach profile with mean tidal elevation, which was analyzed in part of significant wave height, showed that during Typhoon Gay (32W) passed to the Gulf of Thailand. The maximum wave high including with high tide was about 1.1 meters. It ran up and spilled over beach berm about 50 meters and wind direction was perpendicular to the coastline. It peaked for 36 hours during 01.00 am on 4 November 1989 to 13.00 pm on 5 November 1989. It caused to beach erosion which measured by satellite images classification. When Typhoon Linda (30W) passed to the Gulf of Thailand the maximum wave high including with high tide was about 1.1 meters. It ran up and spilled over beach berm about 50 meters, but wind direction was not perpendicular to the coastline. It came from northeast and peaked for 12 hours during 16.00 pm on 3 November 1997 to 04.00 am on 4 November 1997. It caused to beach erosion which measured by satellite images classification. Even though there was high wave coincided with a high astronomic tide about 1.4 meters, there was less erosion than effect of storm because wind direction blew out to the sea.

4.3 Analysis results of Landsat-5 images

Satellite image coordinates were corrected with the use of transformation matrix determine by using a set of ground control points (GCPs). A set of GCPs was collected from satellite image in pixel and line coordinate, and then specified in the Universal Transverse Mercator (UTM) coordinate obtained from topographic map, at a scale of 1:50,000. The best GCPs are the points which are easy to be recognized and located on both image and the topographic map and distribute over the whole image. Multistage Sampling was method of inventory, where progressively more detailed information was collected from a successively smaller number of samples. This method approached to image acquisition involves acquiring complete coverage of a study area with low resolution imagery, and additional higher resolution imagery from a sample of locations. This study selected a number of GCPs from road intersection, road and rail way intersections, and irrigation canals. The result of Geometric correction for images are shown in table 4.1

Table 4.1 The result of geometric correction for images

Date Month Year	Path/Row	Ground control point	RMS
7 7 1989	129/52	42	0.12
30 12 1989	129/52	30	0.12
15 9 1997	129/52	38	0.13
5 1 1998	129/52	42	0.14
27 11 2006	129/52	30	0.10
29 12 2006	129/52	30	0.15

The coastal changes were detected by using Landsat-5 image before and after Typhoon hit the coastline of Amphoe Hua Hin. The result of coastline changes from short term events are show in figure 4.24 to 4.26 which showed that during Typhoon Gay, Typhoon Linda and strong northeast monsoon move to the coastline they affected to erode area along the coastline.

Identification of the coastline during the space of satellites images had to consider. Therefore, using meteorological reported to confirm that there was not strong wind and high wave during that space of time by comparing with the case of strong north east monsoon on December 2006. After that net erosion can define by this equation.

$$\text{Net Erosion (m)} = \frac{\text{Changed area (m)} - [\text{normal rate/month x periods (months)}] - \text{Erosion by Strong NE}}{\text{periods (months)}} \quad (4\text{-}1)$$

$$\text{Normal rate/month} = \frac{\text{Long term changed (m) (1989-1997)} - \text{Changed area by Typhoon \& Typhoon Linda (m)}}{\text{periods (months)}} \quad (4\text{-}2)$$

$$= \frac{-31\text{ m.} - (-36.2\text{ m.})}{8\text{ years X }12\text{ months}} = \frac{4.52}{96} = \text{deposition rate } 0.05\text{ m/month}$$

During space of satellite images there was deposition rate 0.05 m/month which calculated from equation 4-2 and the meteorological reported confirmed that there was not strong wind and high wave during that space of time, so there was not strong north east monsoon. If there was depression, there was not surge (Bell, T. S., 2007).

Therefore, net erosion could define and long-term changed in study area was shown in table 4.2.

Table 4.2 Long-term changed in study area

Long Term Changed	Changed area (m^2)	Length along coastline (m)	Years	Distance (m)
1989-2006	-331,142.16	19,901.30	17	-16.63
1989-1997	-630,492.58	19,901.30	8	-31.68
1997-2006	322,946.50	20,750.48	9	15.56

The results of long-term changed in this study area during 1989-2006 showed that there were erosion areas about 16.63 meters. Therefore, after Typhoon Gay and Typhoon Linda passed, there was accretion of beach. Moreover, if carried out erosion areas which affected by two storms, there was a rate of deposition about 0.52 meter per year during 1989-1997. Furthermore, during 1997-2006, there was a rate of deposition about 1.72 meters per year. This result was supported by report of Songmuang. R., 2005. There was annual depositional rate more than erosion rate in this area.

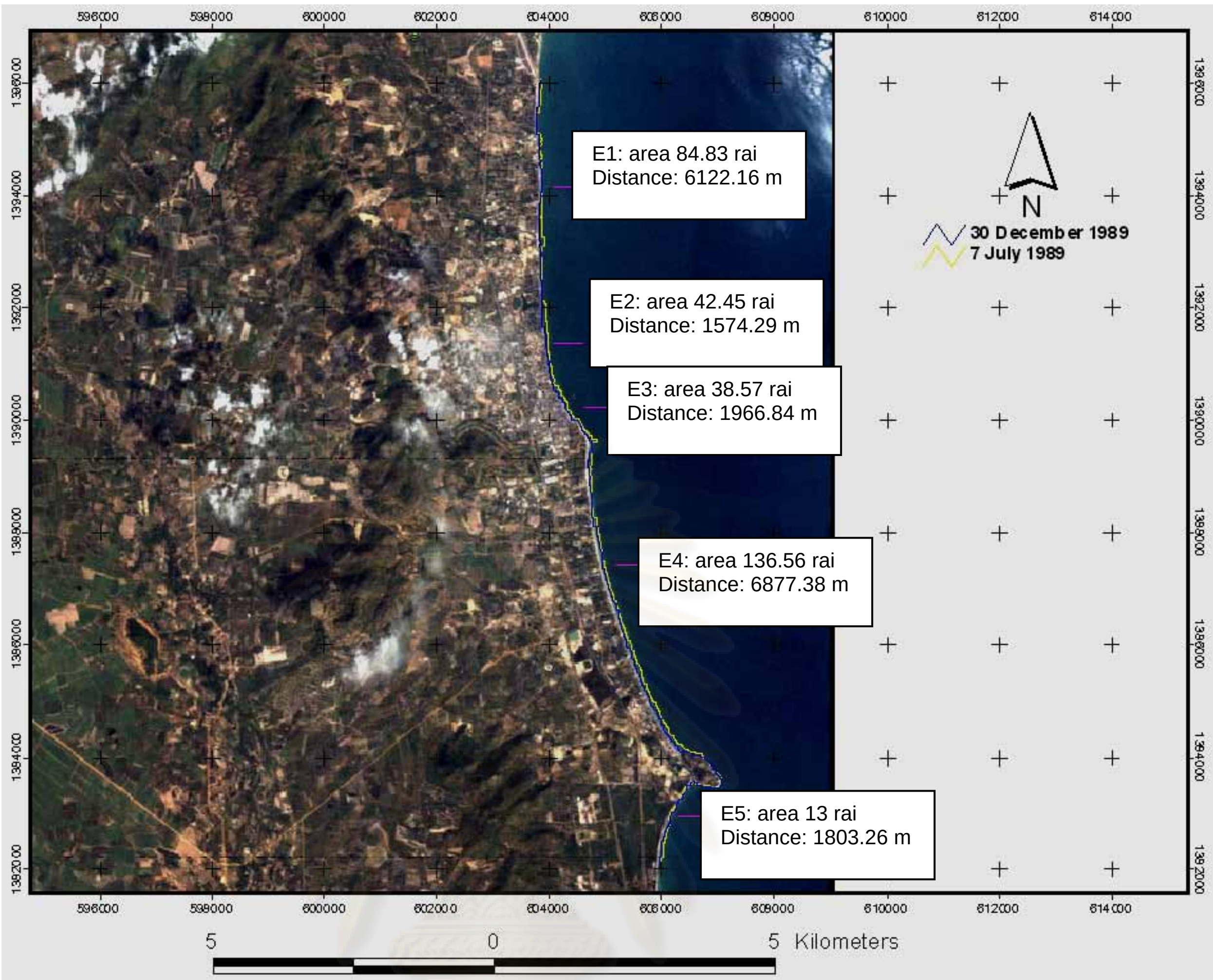


Figure 4.24 Coastline change at Amphoe Hua Hin, Prachuab Kiri Khan, province after Typhoon Gay affected to coastline in November 1989

Table 4.3 Total erosion areas when Typhoon Gay passed to the Gulf of Thailand

Event	Erosion Area(m^2)	Length along coastline (m)	Erosion (m)	Normal Deposition Rate (m/month)	periods (month)	Erosion by strong NE(m)	Net erosion (m)
Typhoon Gay	519,785.62	19,901.31	25.64	0.05	5	0	25.39

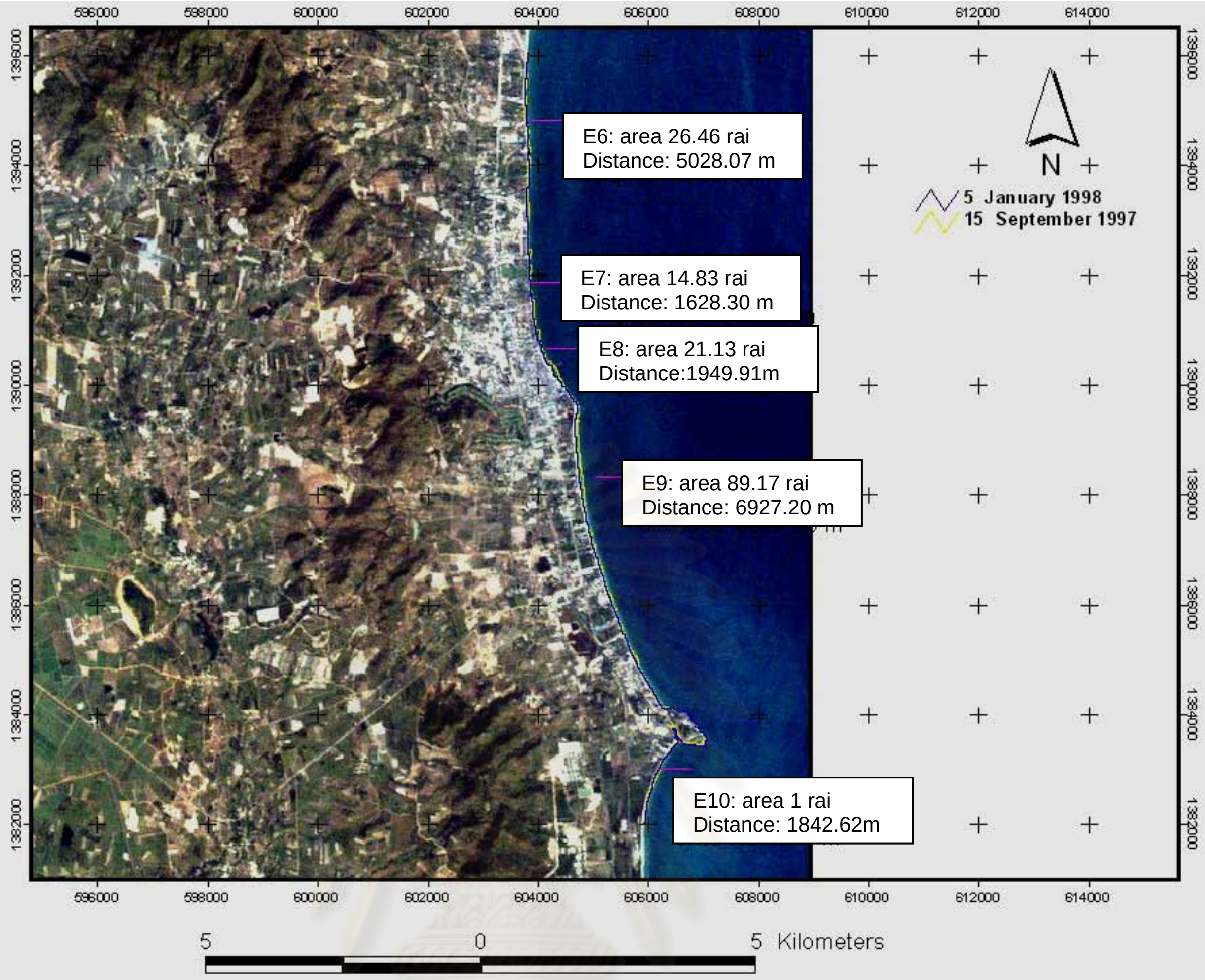


Figure 4.25 Coastline change at Amphoe Hua Hin, Prachuab Kiri Khan, province after Typhoon Linda affected to coastline in November 1997

Table 4.4 Total erosion areas when Typhoon Linda passed to the Gulf of Thailand

Event	Erosion Area(m^2)	Length along coastline (m)	Erosion (m)	Normal Deposition Rate (m/month)	periods (month)	Erosion by strong NE(m)	Net erosion (m)
Typhoon Linda	210,510.79	20,750.48	10.56	0.05	4	0	10.36

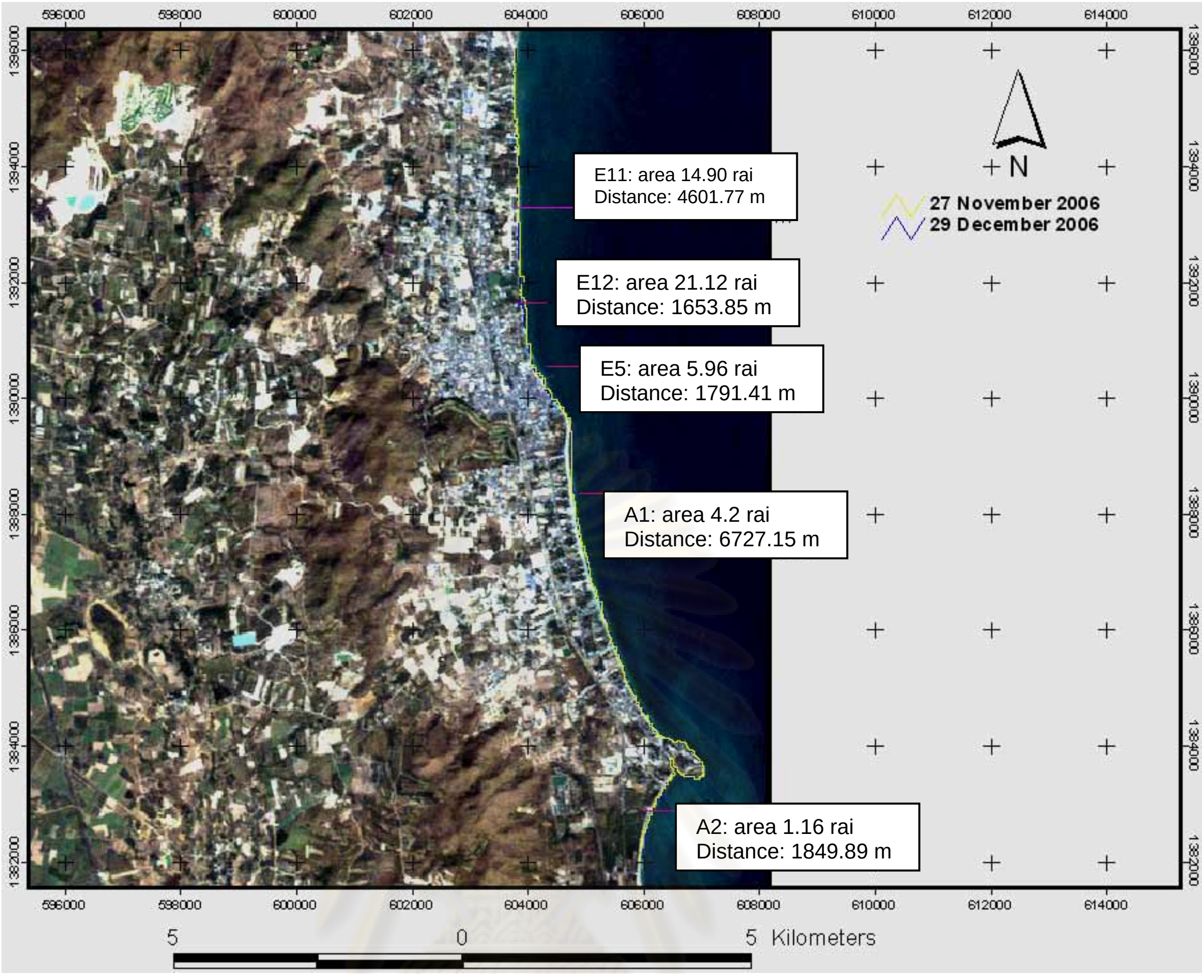


Figure 4.26 Coastline change at Amphoe Hua Hin, Prachuab Kiri Khan, province during strong northeast monsoon passed to the Gulf of Thailand on 20-24 December 2006

Table 4.5 Total erosion areas strong northeast monsoon passed to the Gulf of Thailand

Event	Erosion Area (m^2)	Length along coastline (m)	Erosion (m)	Normal Deposition Rate (m/month)	periods (month)	Net erosion (m)
Strong Northeast monsoon	23,596.09	19,975.33	1.28	0.05	1	1.23

Table 4.6 Changed area by sites in 1989, 1997 and 2006

Year	Site	Area		Length along coastline(m)	Distance(m)
		m^2	Rai		
1989	E1: Bofai-Klaikungwon	-135724.84	-84.83	5122.16	-26.50
	E2: LowerKlaikungwon	-67915.27	-42.45	1574.29	-43.14
	E3: Peir	-61707.98	-38.57	1966.84	-31.37
	E4: Ao Hua Hin	-218491.10	-136.56	6877.38	-31.77
	E5: LowerKoa Takeab	-20740.00	-13.00	1803	-11.50
1997	E6: Bofai-Klaikungwon	-42331.23	-26.46	5028.07	-8.42
	E7: LowerKlaikungwon	-23732.43	-14.83	1624.30	-14.61
	E8: Peir	-33807.49	-21.13	1949.91	-17.34
	E9: Ao Hua Hin	-142675.21	-89.17	6927.20	-20.60
	E10: LowerKoa Takeab	-1002.00	-1.00	1843	-0.50
2006	E11: Bofai-Klaikungwon	-23842.43	-14.90	4601.77	-5.18
	E12: LowerKlaikungwon	-33785.98	-21.12	1653.85	-20.43
	E13: Peir	-9539.51	-5.96	1791.41	-5.33
	A1: Ao Hua Hin	20438	4.2	6727.15	3.03
	A2: LowerKoa Takeab	30120	1.16	1849.89	16.28

Eventually, the result was shown that the critical erosion area was from Klai Kung Won palace to the pier of Hua Hin and normal erosion was in narrow area; coastline area at Ban Bo Fai.

Moreover, table 4.6 defined the erosion area by sites for showing the relationship of erosion area, rate of erosion and length of erosion along the study area. As a result, erosion area in case of strong north monsoon is less than case of Typhoon pass to the Gulf of Thailand. These erosion areas which affected by Typhoon Gay and Typhoon Linda were high length in shore and this result were supported by previous storm surge researches in other countries. Hurricane Alicia, 1983 attacked the front of Galveston Island, south of Louisiana. It sustained wind to 127 mph (203 km/hr) and maximum water levels along the Galveston Island varied from 6 to possibly as much as 9 feet (1.8–2.8 meters).Beach erosion was 100 feet (30.50 meters) (NOAA, 1983). When Hurricane Hugo which sustained wind to 135 mph (216 km/hr) attacked the northern coastline of Charleston, South Carolina by generated a maximum storm surge of 20 feet (6 meters) and eroded beach average 100 feet (30.50 meters), with some profile comparisons indicating 150 feet (46 meters) of beach erosion and the damage concentrated to areas where the beaches were narrow and dunes small to absent (Stephen,1989). Moreover, On September, 2004 the barrier islands in Alabama and Florida that were impacted by Hurricane Ivan which sustained wind to130 mph (208 km/hr) and decreased to 70 mph (112 km/hr) before it crossed Alabama. The center of Hurricane Ivan moved on shore near Gulf Shores, Alabama which caused of eroded Alabama's coast an average of 40 (12.5 meters) feet (USGS, 2004). Furthermore, in the case of the Hoa Duan breach, Vietnam was attacked by the tropical cyclone EVE which was estimated to be near 40 mph (65 km/hr) in November 1999 and caused of eroded beach average 25 meters (Thieu Quang Tuan, 2006). Therefore, these storm events caused of eroded beached along the coastline in different places, their intensities affected on coastline either on beach or properties. Although, they generated and sustained wind in different intensities, their affects eroded beach at least 12.5 meters to 46 meters in some locations because they approached along the open sea. Consequently, the maximum wind speed of Typhoon Gay (32W) and Typhoon Linda (30W) could be affected to beach erosion at Hua Hin beach.

CHAPTER V

CONCLUSION AND RECCOMENDATION

5.1 Conclusion

This study, used the knowledge integration of various science relevant to find and prioritize the coastal area that had been affected from storm surge in three events during 1989-2006 at Amphoe Hua Hin, Prachuab Kiri Khan province. There were the coastal change due to Typhoon Gay in 1989, Typhoon Linda in 1997, and strong northeast monsoon in 2006.

During severe storms, the higher water levels resulting from storm surge may lead to coastal erosion. The erode area will be greater when the period of maximum storm surge coincided with a high astronomic tide. In the morning of 4 November 1989, the Typhoon Gay approached the coast of Amphoe Pratiw and Tase, Chumphon province at 03.30 GMT, the center wind velocity was 120 kilometers per hour. Typhoon Linda moved to the Gulf of Thailand as a typhoon and it was a tropical storm when approached the coast of Amphoe Bangsapan, Prachuap Kiri Khan, province at 19.00 GMT. The center wind velocity was 80 kilometers per hour. Moreover, there was the strong northeast monsoon on 20-24 December 2006. The maximum wind speed was 22.2 kilometers per hour.

From the study was found that Typhoon Gay, Typhoon Linda and strong northeast monsoon caused coastline change. The identification of metro-hydrographic factors in Amphoe Hua Hin, Prachuab Kiri Khan, province was identified. The effect of coastal erosion was occurred by the northeast monsoon. Wind direction was northeast-easterly and the maximum wind speed approximate 12-13 kilometers per hour. The significant wave height was about 0.5-1 meter. The tidal mean sea level in Amphoe Hua Hin area has diurnal component which high in northeast monsoon season. The mean tide range is defined as 1 meter. Normally, the sediment transport at Amphoe Hua Hin area in northeast monsoon season was moved from north to south (Office of Natural Resources and Environment Policy and Planning, 2003). Especially, the major effect of coastal erosion was happened when Typhoons Gay and Typhoon Linda hit the coastline. When Typhoon Gay passed to southern coastline on 4 November 1989, the 3-hourly surface wind at Hua Hin meteorological station was analyzed. Furthermore, wind direction was perpendicular to the coastline. Maximum wind speed was about 18.5 kilometers per hour and the maximum surge was about 1.1 meters. The existence of wind intensity was 36 hours. Moreover, Typhoon Linda approached to the southern coastline on 4 November 1997, the 3-hourly surface wind at Hua Hin meteorological station was analyzed. Wind direction was not perpendicular to the coastline. Maximum wind speed was about 18.5 kilometers per hour and the maximum surge was about 1.1 meters. The existence of wind intensity was 12 hours. Besides, during 20-24 December 2006 the wind speed at Hua Hin meteorological station was approximate 22 kilometers per hour, and the maximum surge was about 1.4 meters. The existence of wind intensity was 24 hours, but wind direction was blown out to the sea; therefore, there was less erosion area in this event.

This study focused on coastline change which affected by storm surge, which caused short term erosion on the coast. The remote sensing was used to analyze the coastal change. From the analysis, it can be defined areas after storm passed the Gulf of Thailand. When Typhoon Gay and Typhoon Linda passed to the Gulf of Thailand, there were eroded areas along the coastline of Amphoe Hua Hin. The erosion area was the recession of shoreline towards the land and the critical erosion area was from Klai kung won palace to pier of Hau Hin. Besides, after strong northeast monsoon passed in December 2006, the result shown there was erosion areas in the same location.

Table 5.1 Net erosion areas and conditions when Typhoon Gay, Typhoon Linda and strong northeast monsoon passed to the Gulf of Thailand

	Typhoon Gay (W32)	Typhoon Linda(W30)	Strong Northeast Monsoon
Tidal amplitude (m)	0.4	0.4	0.4
Maximum surge(m)	1.1	1.1	1.4
Effective duration(hours)	36	12	24
Main wind direction to coastline	perpendicular	Not perpendicular	Not perpendicular
Beach erosion (m)	25.39	10.36	1.23

Table 5.1 shows that Typhoon Gay Typhoon Linda and strong northeast monsoon affected to coastline erosion, there were 519,785.62 m^2, 210,510.79 m^2, and 23,596.09 m^2, respectively. The erosion shoreline towards the land in case of Typhoon Gay was 25.39 meters in shore, Typhoon Linda caused to erosion, which was 10.36 meters in shore. Finally, the erosion rate from strong north monsoon was 1.23 meters in shore.

However, the results of long-term changed in this study area during 1989-2006 showed that there were erosion areas about 16.63 meters, so there was accretion of beach appeared after Typhoon Gay and Typhoon Linda passed. Moreover, if carried out erosion areas after two storms passed, there was a rate of deposition about 0.52 meter per year during 1989-1997 and also during 1997-2006, there was a rate of deposition about 1.72 meter per year.

5.2 Recommendation

5.2.1 In some of areas, which protect with seawall and others structures, without proper environmental impact study, thus inadvertently causing erosion in nearby coastal areas. Construction of any seawall along the beach, causes wave reflection which washes away the beach sand. The width of the beach consequently becomes narrower and the beach level becomes lower; therefore, when study the coastline change should to measure the total sand deposition also because some areas there was changed in vertical area but there was not change in horizontal area.

5.2.2 The critical erosion area should be treated with long term protection. The engineered structures, which proper environmental impact study were appropriated solution for protection and resolution of coastal erosion in the severely affected areas. The coastal structures were appropriate solution for protection and resolution of erosion in the severely affected areas. The recommended method was detached breakwater: the detached breakwaters were built parallel to the coastline. Gaps between breakwaters were between 300-1000 meters. Appropriate gaps can not only reduce forces of waves but also adjust the coast conditions for new and more balanced beaches.

From the field survey in the project area reveal that there were sea walls in area of Hua Hin airport to Klai Kung Won palace. In some areas sea walls caused of coastal erosion. These coasts are low level so that the tidal wave can sweep across sea wall and erode the coast as well as sweep away sand on the beaches. Therefore, the detached breakwaters was one of effective method to reduce the wave forces before attacking the coastline, especially coastline areas of Ao Hua Hin, which was high economic value and it was attractive beach.

REFERENCES

Bell, T. S. 2007. Hurricane, Typhoon, and Cyclone. Science 101 weather. Hydra Publishing 129 Main Street Irvington, NY 10533, p. 148.

Coastal Engineering Research Center. 1984. Shore Protection Manual 1. Coastal Engineering Research Center, U.S. Government Printing Office, Washington D C.

Coch, N.K., and Ludman, A. 1992. Physical geology. Macmillan College Publishing.

Coch, N.K. 1995. Geohazards, Natural and Human. Prentice Hall, p. 481.

DMR. 1987. Geological map of Thailand. Cartographic Unit, Geological Survey Division, Royal Thai Survey Department.

Dolan, R., Hayden, B., and Heywood, J. 1978. A new photogrammetric method for determining shoreline erosion. Coastal Engineering. 2: 21-39.

Elsberry, R. L. 1983. Tropical cyclone motion. Chap. 4, A Global View of Tropical cyclones. Office of Naval Research, 6, p. 171.

Gisthai. 2006. Geographic Information System [Online]. Available from: http://www.gisthai.org.

Hansom, D.W. 1990. Coasts. Cambridge: Cambridge University Press.

Meteorological Department. 1989. Report on Typhoon Gay (8929). Weather forecast Division, Meteorological Department, pp. 1-36.

Harbour Department. 1996. Feasibility study and preliminary design for the protection of the coastline erosion on the upper Gulf of Thailand. Bangkok: Harbour Department.

Kanbua, W. 2005. A Recent Storm Surge Event in Thailand. Marine Meteorologist, Thai Meteorological Department.

Lillesand, T.M., and R.W. Kiefer. 2000. Remote sensing and image interpretation. 4th ed. New York: John Wiley & Sons.

Longuet-Higgins, M. S. and R. W. Stewart. 1964. Radiation stress in water waves: A physical discussion with applications. Deep Sea Research, 11(4): 529-563.

Ly, L. 1993. Moitoring coastline changes using remote sensing techniques on the Rayong coastline, Thailand. Master's Thesis, Asian Institute of Technology.

Meteorological Department. 1989. Report on Typhoon Gay (8929). Weather forecast division. Meteorological Department, pp. 1-36.

Meteorological Department. 1997. Report on Typhoon Linda during 31 October – 5 November 1997. Weather forecast division. Meteorological Department, pp. 1-23.

Meteorological Department. 2005. The Monsoon period and cyclone paths in Thailand [Online]. Available from: http://www.tmd.go.th/knowledge/know season n.html.

NOAA. 2006. Earth system research laboratory [Online]. Available from: http://www.cdc.noaa.gov/cgi-bin/Composites/printpage.pl.

Nelson, S.A. 2006. Exceptional Weather - Tropical Cyclones. Natural Disasters, Tulane University, LA.

Office of Environmental Policy and Planning. 2003. Master Plan for Coastal Erosion Management from Phetchaburi River-Mounth, Phetchaburi Province to Pranburi River-Mounth, Prachuap Khiri Khan provines. Office of Environmental Policy and Planning.

Rajan, M.S. 1991. Remote sensing and geographic information system for natural resource management. Manila : Asian Development Bank.

Schowengerdt, R.A. 1997. Remote sensing models and methods for image processing. 2nd ed. San Diego: Academic Press.

Sinsakul, S., Tiyapairach, S., Chaimanee, N., and Aramprayoon, B. 2002. Coastal change along the Gulf of Thailand coast.The Royal Thai Survey Department.

Snidwongs, A. 1998. The oceanography of the Gulf of Thailand. Research and management priorities, in Johnston, D.M., eds., SEAPOL integrated studies of the Gulf of Thailand. 1. Selected papers at the first meeting of export, Hua Hin, Thailand, pp. 1 -68.

Songmuang, R. 2005. Seasonal shoreline changes of the Prachuab Khiri Khan coast. Master's Thesis, Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand, p. 84.

Willoughby, H. E. 1995. Mature structure and Evolution. Chap. 2, A Global View of Tropical cyclones. Office of Naval Research, 6, pp. 24-26.

APPENDICES

APPENDIX A

METEOROLOGY DATA

Official Best track for Typhoon Gay (32W)

Date: 1-10 NOV 1989

Super Typhoon #32

DATE	LOCAL TIME	LAT	LONG	MAX.WIND (knots)	STATE
11/01/89	7.00	7.1	103.7	25	TROPICAL DEPRESSION
11/01/89	13.00	7.7	103.1	25	TROPICAL DEPRESSION
11/01/89	19.00	8	102.6	25	TROPICAL DEPRESSION
11/01/89	1.00	8.1	102.4	30	TROPICAL DEPRESSION
11/02/89	7.00	8.2	102.2	35	TROPICAL STORM
11/02/89	13.00	8.3	102	35	TROPICAL STORM
11/02/89	19.00	8.7	101.9	35	TROPICAL STORM
11/02/89	1.00	9.1	101.8	45	TROPICAL STORM
11/03/89	7.00	9.3	101.5	65	TYPHOON-1
11/03/89	13.00	9.8	101.2	75	TYPHOON-1
11/03/89	19.00	10.2	100.8	90	TYPHOON-2
11/03/89	1.00	10.4	100.3	95	TYPHOON-2
11/04/89	7.00	10.5	99.9	100	TYPHOON-3
11/04/89	13.00	10.7	99.2	100	TYPHOON-3
11/04/89	19.00	11.2	98.3	65	TYPHOON-1
11/04/89	1.00	11.3	97.5	75	TYPHOON-1
11/05/89	7.00	11.4	96.8	85	TYPHOON-2
11/05/89	13.00	11.7	95.9	90	TYPHOON-2
11/05/89	19.00	12	94.8	95	TYPHOON-2
11/05/89	1.00	12.2	93.8	95	TYPHOON-2
11/06/89	7.00	12.4	92.6	95	TYPHOON-2
11/06/89	13.00	13	91.4	95	TYPHOON-2
11/06/89	19.00	13.4	90.2	95	TYPHOON-2

Official Best track for Typhoon Gay (32W) (Cont'd)

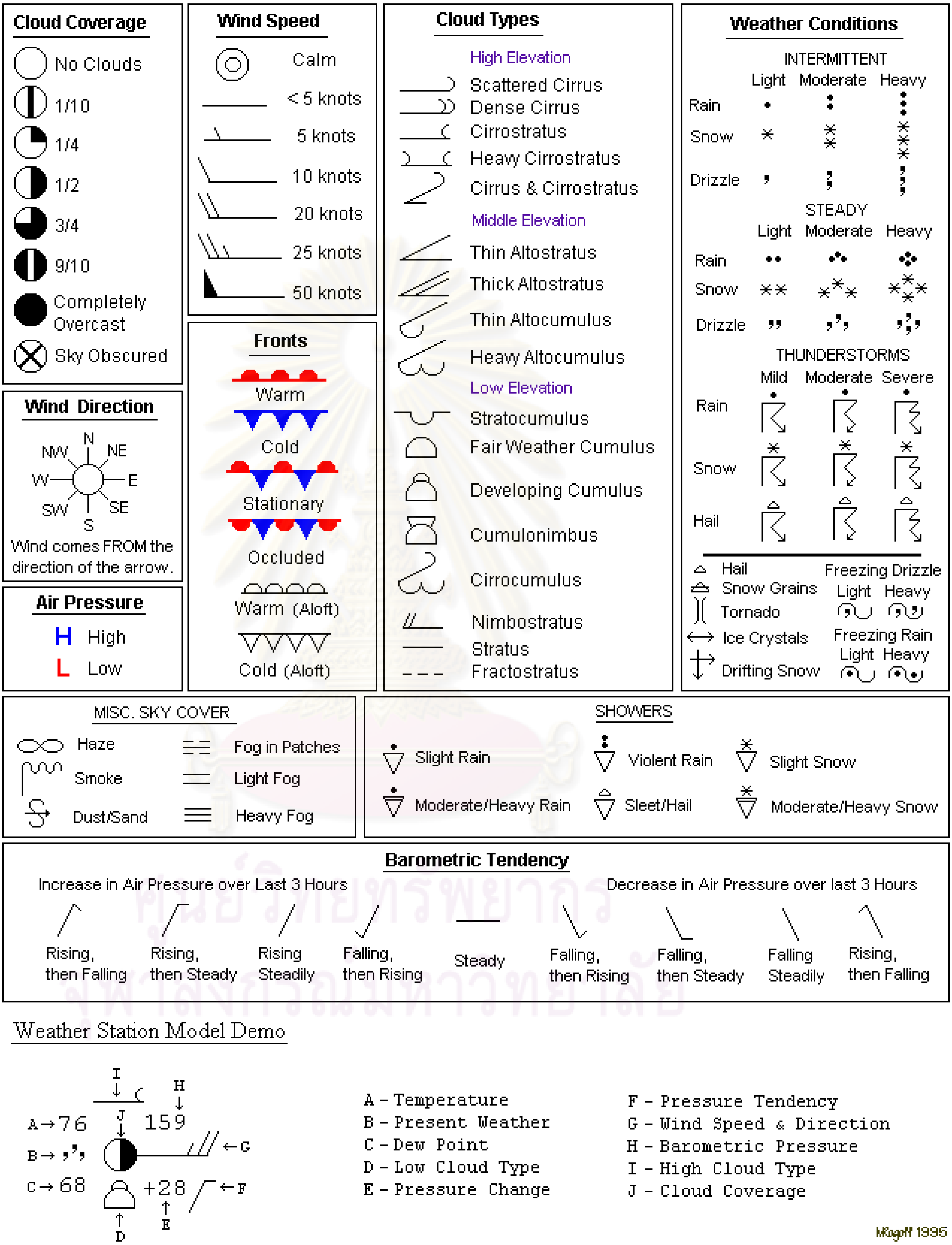
11/06/89	1.00	13.7	89.1	95	TYPHOON-2
11/07/89	7.00	13.9	88.1	100	TYPHOON-3
11/07/89	13.00	14.2	87.1	105	TYPHOON-3
11/07/89	19.00	14.5	86.1	110	TYPHOON-3
11/07/89	1.00	14.6	85	115	TYPHOON-4
11/08/89	7.00	14.6	83.8	120	TYPHOON-4
11/08/89	13.00	14.6	82.6	130	TYPHOON-4
11/08/89	19.00	14.7	81.5	135	TYPHOON-4
11/08/89	1.00	14.8	80.4	140	TYPHOON-5
11/09/89	7.00	15.1	79.1	90	TYPHOON-2
11/09/89	13.00	15.4	77.7	45	TROPICAL STORM
11/09/89	19.00	15.8	76.5	35	TROPICAL STORM
11/09/89	1.00	16.6	75.5	25	TROPICAL DEPRESSION
11/10/89	7.00	17.6	74.6	20	TROPICAL DEPRESSION
11/10/89	13.00	18.1	74	15	TROPICAL DEPRESSION

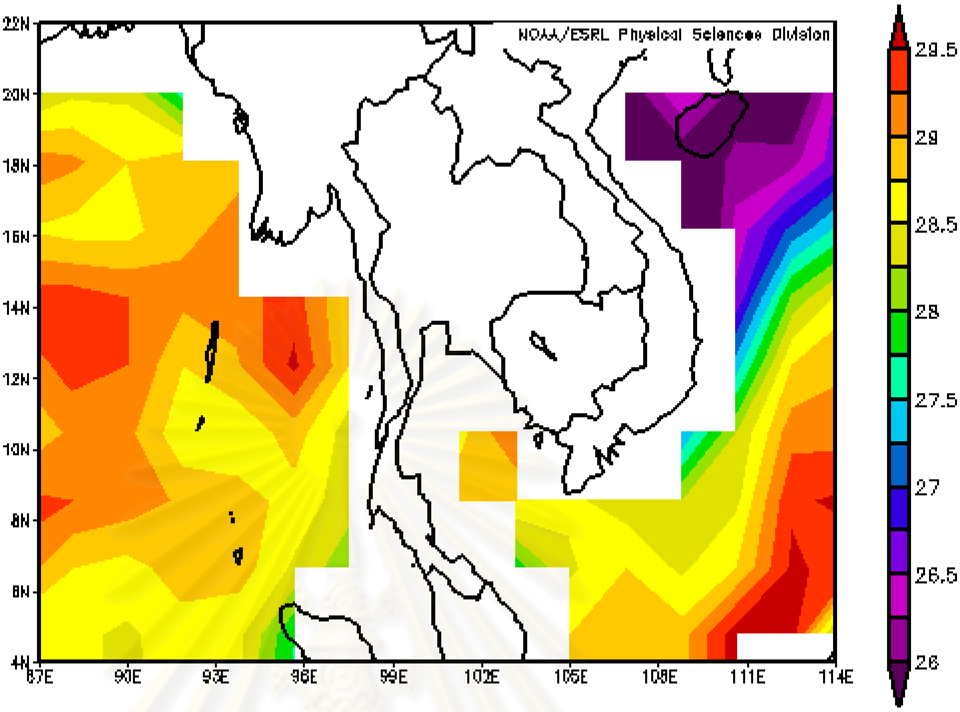
Official Best track for Typhoon Linda (30W) when moved to the Gulf of Thailand

Date: 1-4 NOV 1997

DATE	LOCAL TIME	LAT	LONG	MAX.WIND (knots)	STATE
31/10/97	19.00	8.0	115.0	28	TROPICAL DEPRESSION
1/11/97	01.00	8.0	115.0	30	TROPICAL DEPRESSION
	07.00	8.3	112.0	30	TROPICAL DEPRESSION
	13.00	8.0	115.5	35	TROPICAL CYCLONE
	19.00	8.1	110.0	40	TROPICAL CYCLONE
2/11/97	01.00	8.2	108.8	45	TROPICAL CYCLONE
	07.00	8.2	107.3	45	TROPICAL CYCLONE
	13.00	8.3	106.0	45	TROPICAL CYCLONE
	19.00	8.4	104.2	45	TROPICAL CYCLONE
3/11/97	01.00	8.5	103.0	45	TROPICAL CYCLONE
	07.00	9.1	102.4	50	TROPICAL CYCLONE
	13.00	9.8	102.2	65	TYPHOON
	19.00	10.8	100.8	65	TYPHOON
4/11/97	01.00	11.4	99.5	50	TROPICAL CYCLONE
	07.00	12.4	99.0	35	TROPICAL CYCLONE
	13.00	12.8	97.5	35	TROPICAL CYCLONE
	19.00	13.0	96.5	40	TROPICAL CYCLONE
	01.00	13.2	95.5	40	TROPICAL CYCLONE
	07.00	13.6	94.8	40	TROPICAL CYCLONE

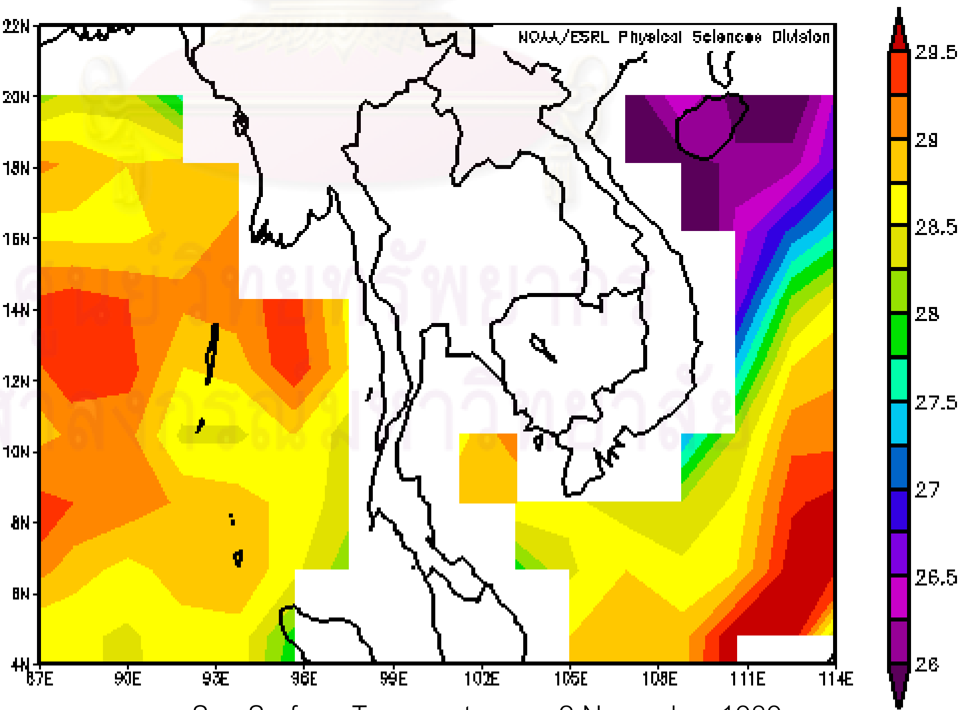
Weather Symbol





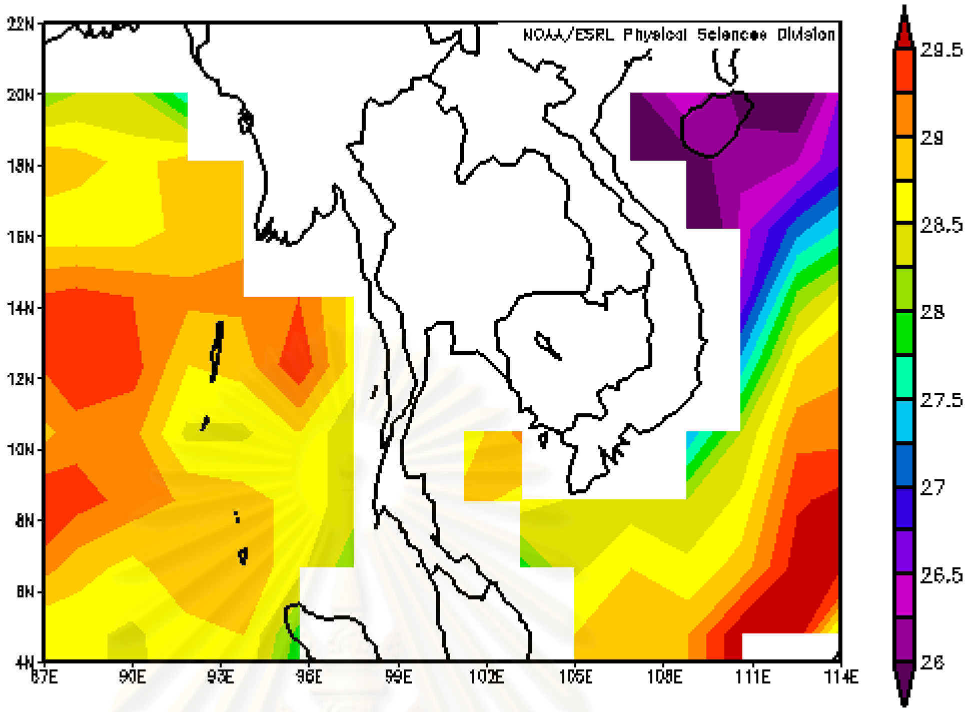
Sea Surface Temperature on 1 November 1989

(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)



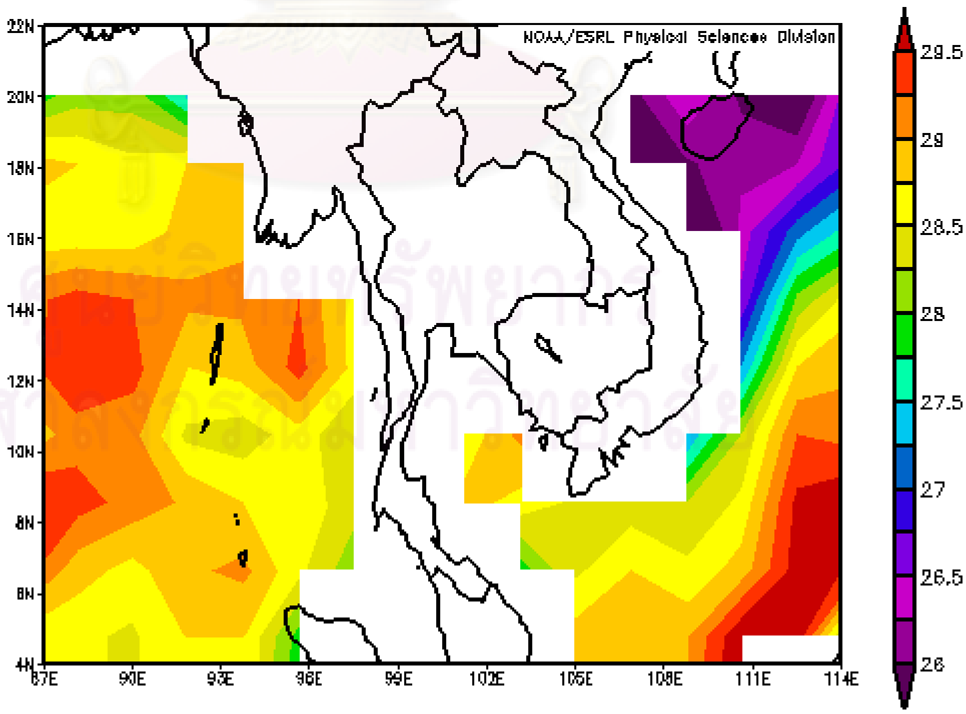
Sea Surface Temperature on 2 November 1989

(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)



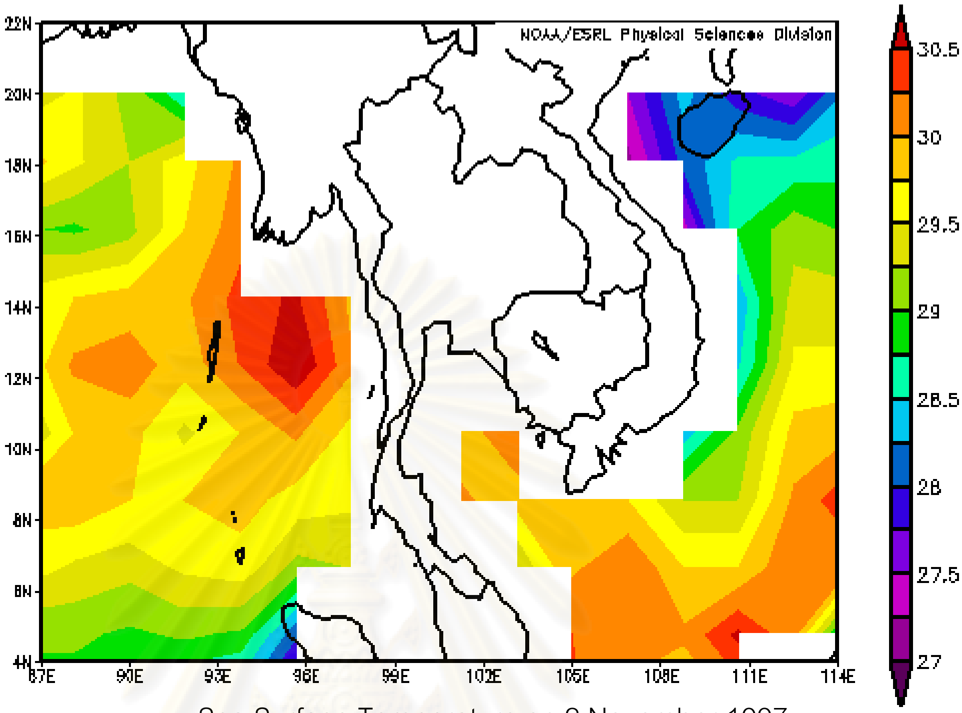
Sea Surface Temperature on 3 November 1989

(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)



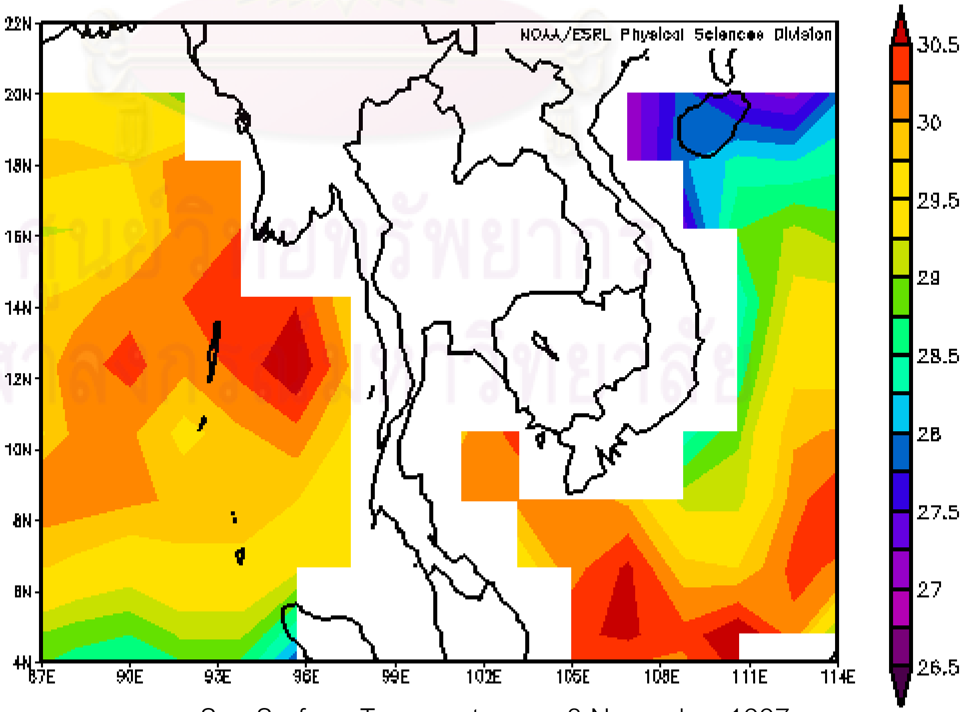
Sea Surface Temperature on 4 November 1989

(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)



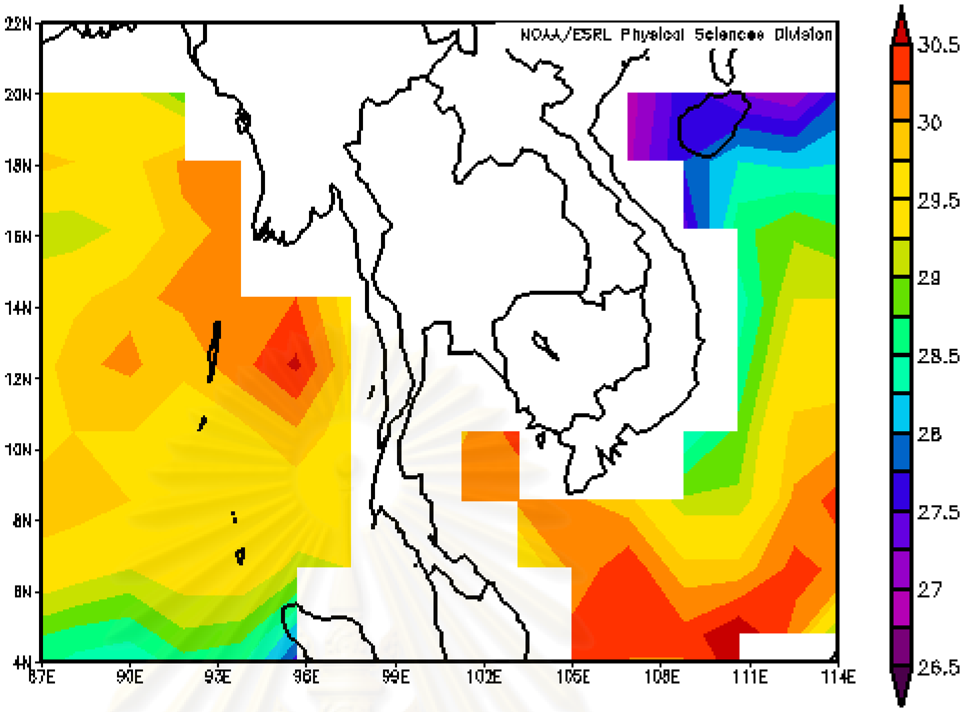
Sea Surface Temperature on 2 November 1997

(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)



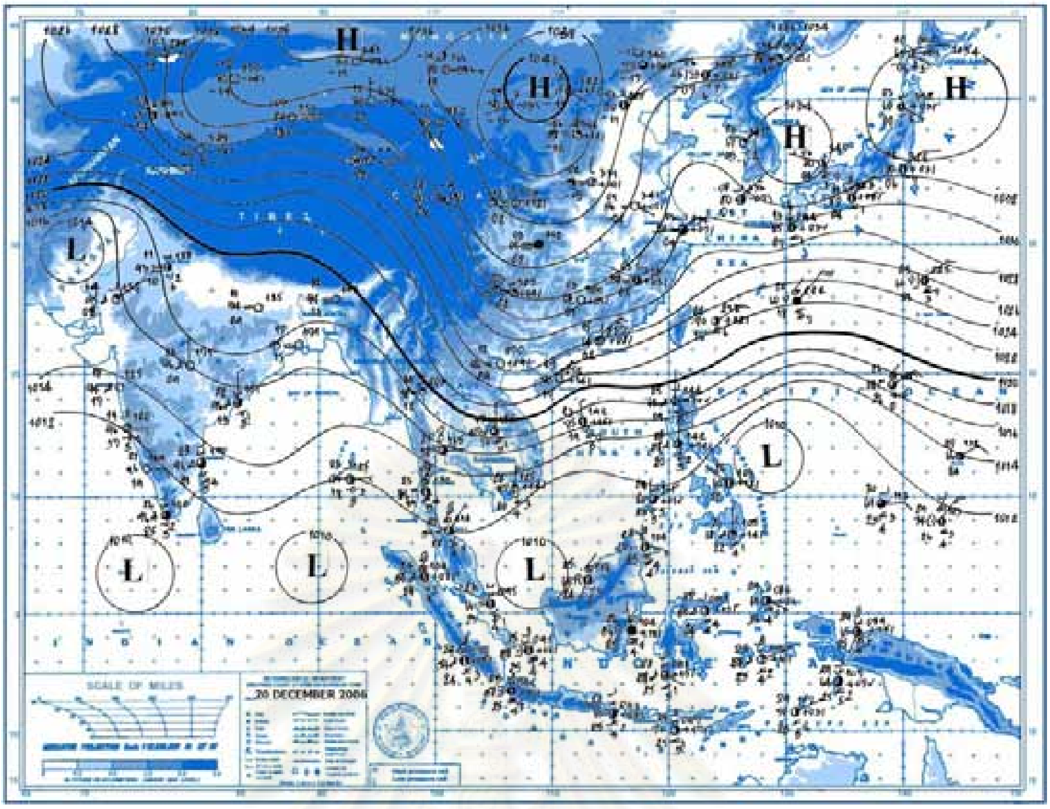
Sea Surface Temperature on 3 November 1997

(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)

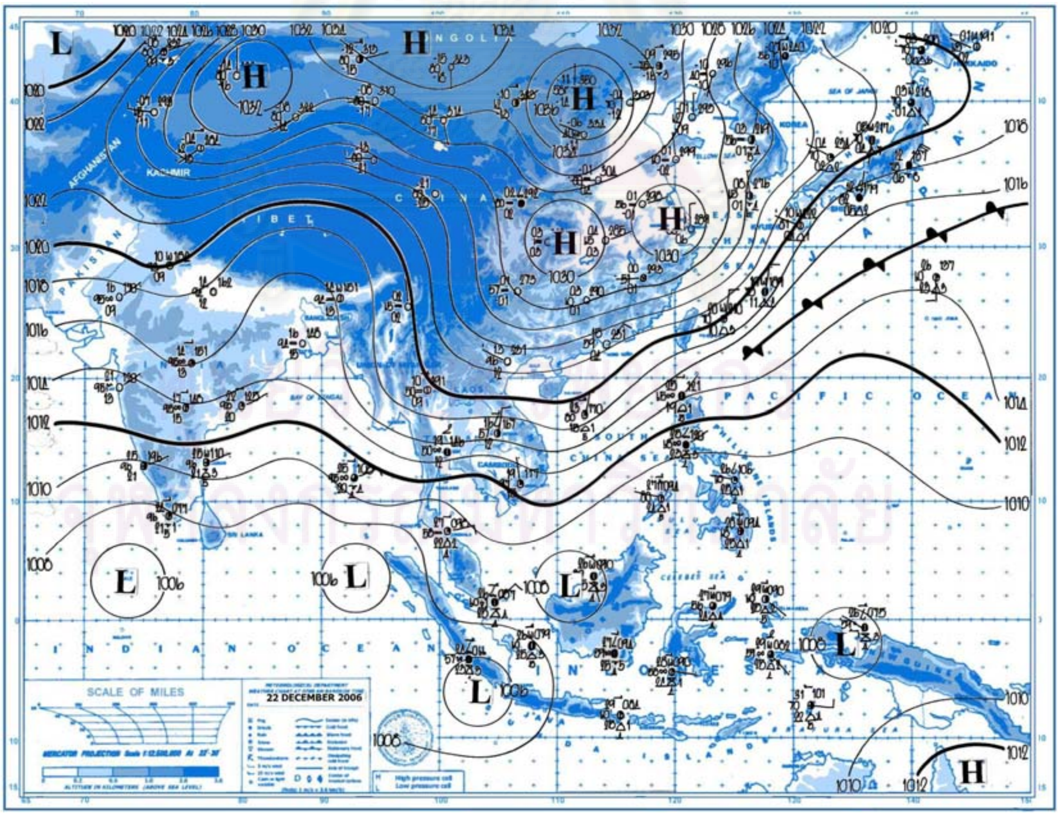


Sea Surface Temperature on 4 November 1997

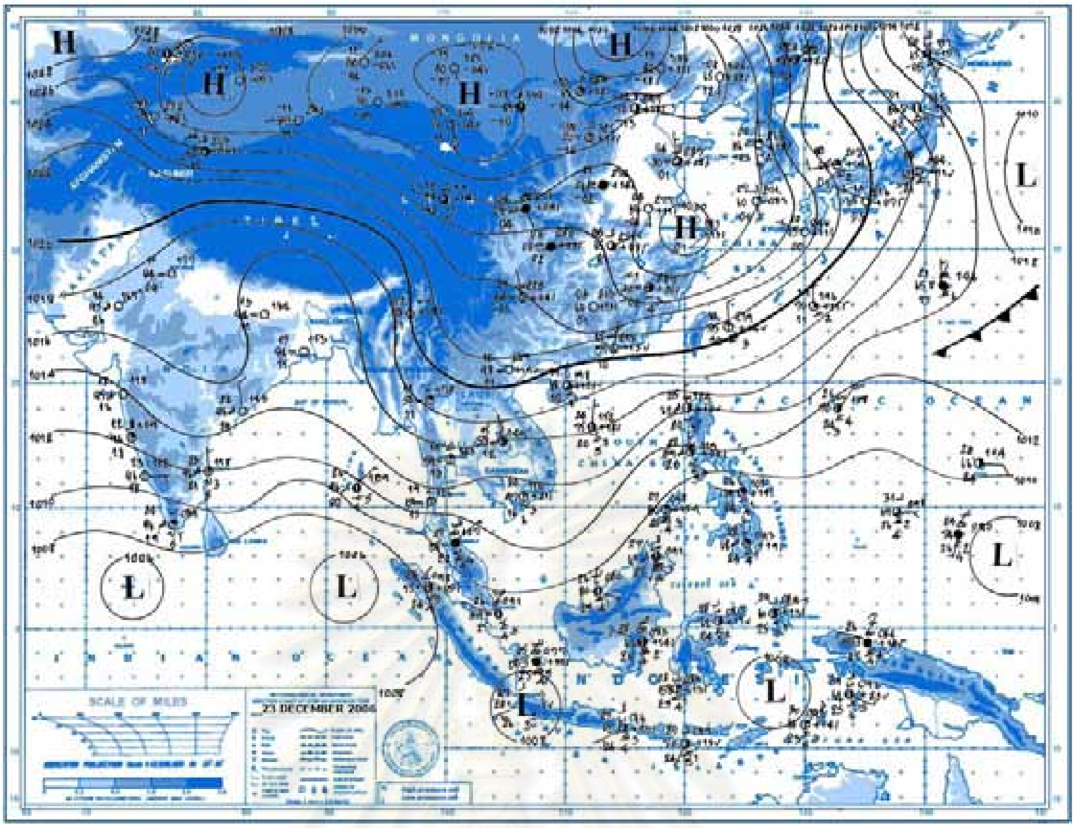
(National Oceanic and Atmospheric Administration: http://www.cdc.noaa.gov)



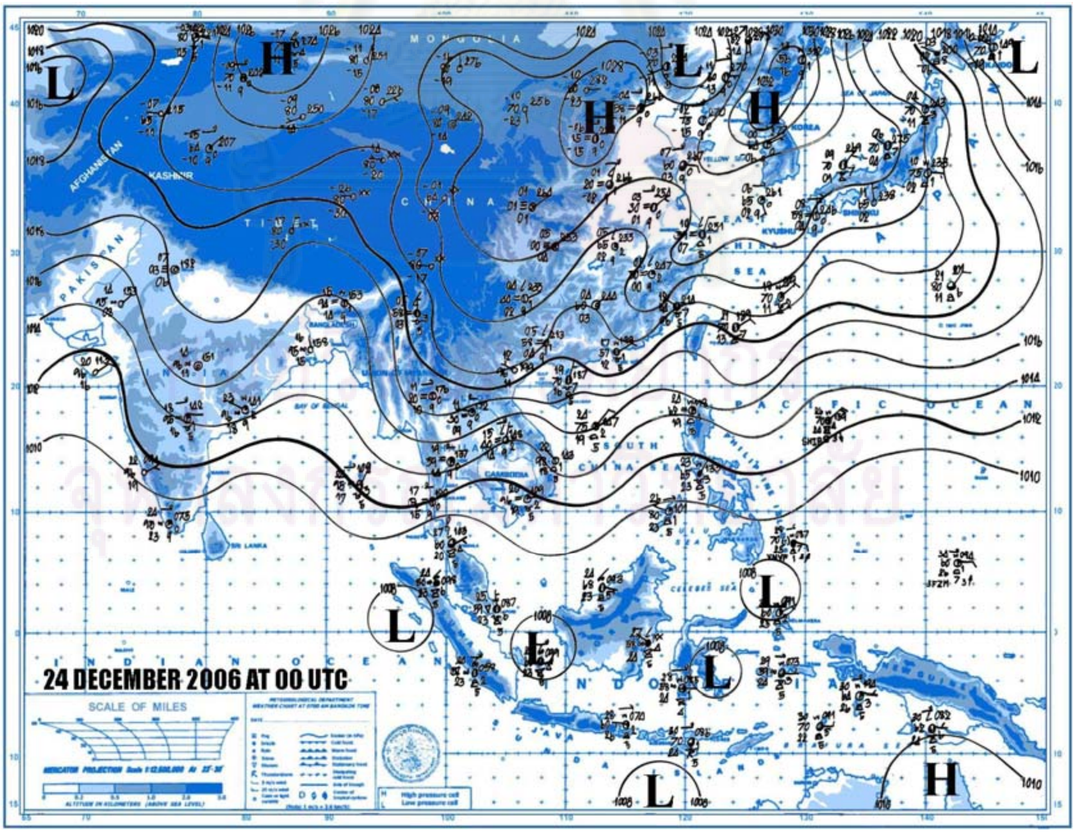
Weather chart on 20 December 2006



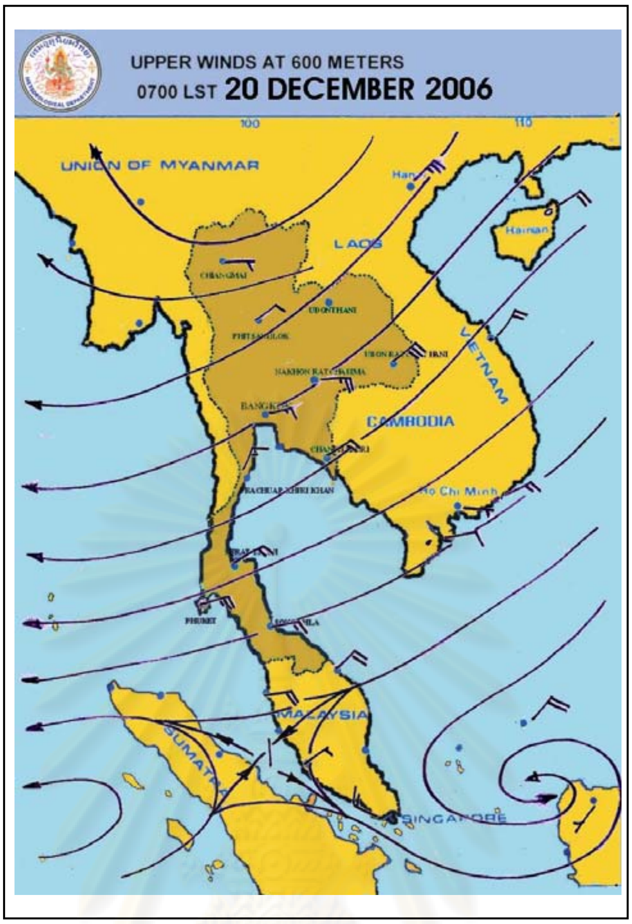
Weather chart on 22 December 2006

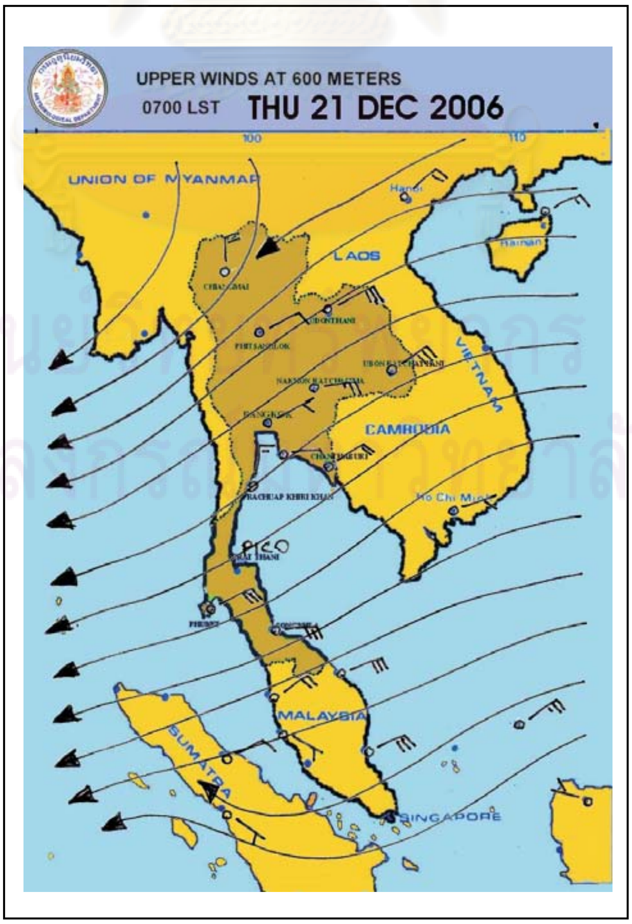


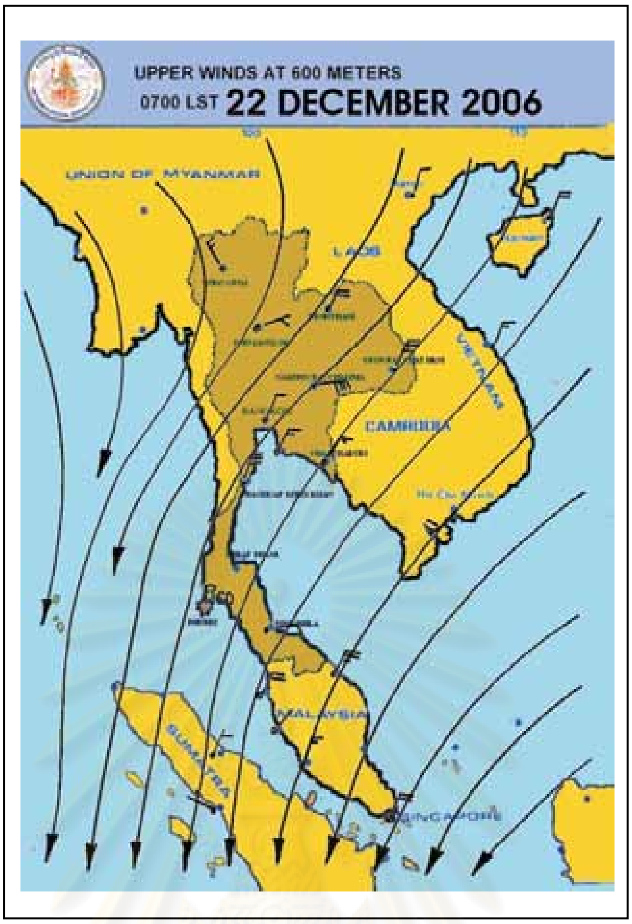
Weather chart on 23 December 2006

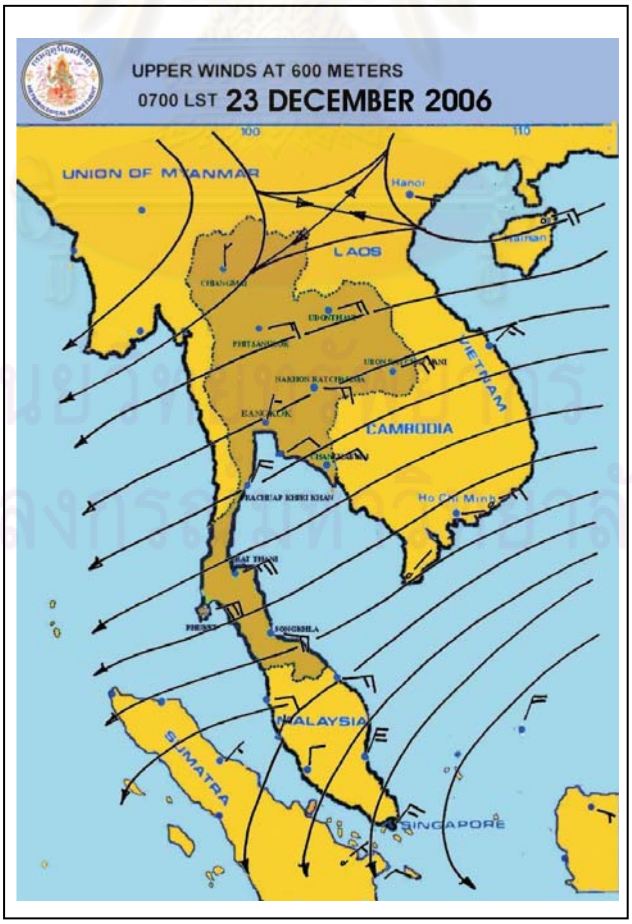


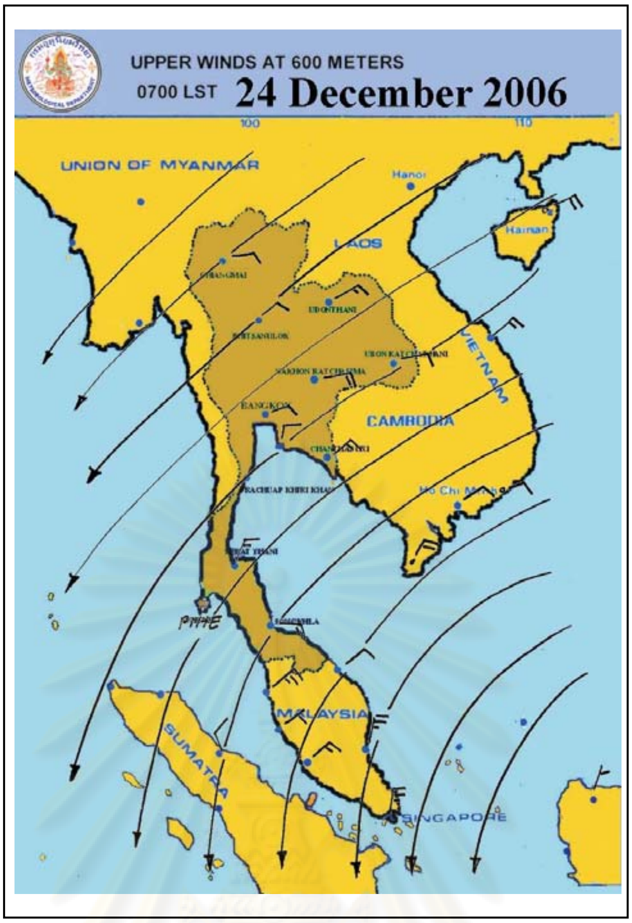
Weather chart on 24 December 2006


UPPER WINDS AT 600 METERS
0700 LST 20 DECEMBER 2006
100
110
UNION OF MYANMAR
LAOS
Hainan
VIETNAM
CAMBODIA
Ho Chi Minh
MALAYSIA
SUMATRA
SINGAPORE


UPPER WINDS AT 600 METERS
0700 LST THU 21 DEC 2006
100
110
UNION OF MYANMAR
LAOS
Hainan
VIETNAM
CAMBODIA
Ho Chi Minh
MALAYSIA
SUMATRA
SINGAPORE


UPPER WINDS AT 600 METERS
0700 LST 22 DECEMBER 2006
UNION OF MYANMAR
LAOS
VIETNAM
CAMBODIA
MALAYSIA
SUMATRA
SINGAPORE


UPPER WINDS AT 600 METERS
0700 LST 23 DECEMBER 2006
100
110
UNION OF MYANMAR
Hanoi
LAOS
VIETNAM
CAMBODIA
BANGKOK
Ho Chi Minh
MALAYSIA
SUMATRA
SINGAPORE


UPPER WINDS AT 600 METERS
0700 LST 24 December 2006
UNION OF MYANMAR
Hanoi
LAOS
Hainan
VIETNAM
CAMBODIA
BANGKOK
MALAYSIA
SUMATRA
SINGAPORE

APPENDIX B

DATA SHEET OF BEACH CONTOUR

Instrument Station	UTM		Elevation (m)	Horizontal Distance (m)
	E	N		
1	606169	1384246	0	0
	606189	1384257	-0.52	27.95
	606205	1384261	-0.23	40.43
	606222	1384268	-0.57	58.57
	606152	1384241	0.31	76.48
	606142	1384236	1.66	27.15
2	606053	1384450	0.35	234.99
	606082	1384466	-0.36	34.14
	606096	1384473	-0.32	50.71
	606109	1384479	-0.7	63.47
	606025	1384441	0.93	26.88
	606019	1384437	0.29	35.05
	606009	1384433	0.065	44.49
3	605945	1384591	1.06	173.69
	605973	1384603	0.2	33.68
	605999	1384614	0.2	58.5
	605933	1384584	1.51	14
4	605806	1384843	1.55	290.4
	605832	1384854	0.4	27.67
	605881	1384878	-0.28	81.76
	605860	1384868	0.06	58.48
	605797	1384845	2	12

Instrument Station	UTM		Elevation (m)	Horizontal Distance (m)
	E	N		
5	605690	1385054	3.92	242.23
	605699	1385062	2.73	13
	605728	1385078	1.49	49.52
	605685	1385055	4	7.79
6	605598	1385287	3.84	247.62
	605629	1385294	2.42	22.68
	605641	1385301	2.17	44.37
	605590	1385283	3.97	12.17
7	605501	1385510	3.89	245.95
	605523	1385510	2.79	22.5
	605540	1385526	2.48	41
	605495	1385506	3.91	8.31
8	605260	1386155	3.76	688
	605270	1386157	2.83	13
	605304	1386165	2.24	41.86
	605310	1386167	1.91	54.16
	605245	1386150	3.17	16
9	605165	1386431	3.77	293
	605182	1386435	1.55	19
	605220	1386446	1.15	58.35
	605159	1386428	3.75	10

Instrument Station	UTM		Elevation (m)	Horizontal Distance (m)
	E	N		
10	605082	1386690	2.51	271.54
	605103	1386691	1.27	12.17
	605123	1386698	1.45	40
	605134	1386700	1	53
	605068	1386684	2.84	17.4
11	604955	1387100	0.53	429.71
	604984	1387108	-0.76	32.1
	604994	1387108	-0.16	40.35
	605016	1387115	-0.75	58.5
	604936	1387096	1.16	18.9
12	604886	1387349	1.08	261
	604922	1387359	-0.43	35
	604927	1387359	0	38.1
	604935	1387362	-0.35	49.86
	604869	1387346	1.1	17.3
	604770	1387896	1.16	556.4
13	604793	1387900	-0.42	28.8
	604800	1387900	0.14	34.55
	604813	1387903	-0.26	47.5
	604757	1387896	1.06	9.6
14	604702	1388204	0.35	374.1
	604733	1388268	-0.72	30.5
	604740	1388270	0	39.46
	604751	1388272	-0.7	51
	604691	1388260	0.6	11

Instrument Station	UTM		Elevation (m)	Horizontal Distance (m)
	E	N		
15	604673	1388612	0.91	348.59
	604697	1388613	-0.69	24.82
	604703	1388613	0	30.41
	604713	1388614	-0.45	41.27
	604649	1388610	1.58	19.6
16	604638	1389029	0.21	421.7
	604665	1389028	-0.9	22.9
	604668	1389028	-0.6	27.78
	604677	1389027	-0.35	36.68
17	604647	1389451	1.2	420.92
	604659	1389449	0	12.7
	604665	1389449	0.62	17.48
	604681	1389447	0	33.93
	604632	1389451	2	20.12
18	604636	1389678	1.11	227.59
	604648	1389687	1.1	13.6
	604626	1389676	1.1	11
	604613	1389670	1.7	28.42
	604580	1389737	1.34	81.79
	604646	1389604	1.5	77.6
	604662	1389591	1.5	83.62

BIOGRAPHY

Miss Wasuntra Chairat was born on May 29, 1982 in Songkhla. She completed high school at Mahavajiravudh shool Songkhla and graduated with a Bachelor degree in Education, Faculty of Education, at Chulalongkorn University in 2004. After graduated she worked at Yamato-Esulon (Thailand) Co.,Ltd. Presently, she is completing a Master's course in Earth Science at the Department of Geology, Faculty of Science, Chulalongkorn University.