การเปลี่ยนแปลงชายฝั่งทะเลหลังการเกิดสึนามิวันที่ 26 ธันวาคม 2547 ระหว่างแหลมปะการัง-เขาหลัก จังหวัดพังงา ประเทศไทย

นายสุเมธ พันธุวงค์ราช

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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ปีการศึกษา 2549

SHORELINE CHANGE AFTER THE 26 DECEMBER 2004 TSUNAMI BETWEEN LAEM PAKARANG-KHAO LAK AREA, CHANGWAT PHANG-NGA, THAILAND

Mr. Sumet Phantuwongraj

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Earth Sciences
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Thesis Title	SHORELINE CHANGE AFTER THE 26 DECEMBER 2004 TSUNAMI BETWEEN LAEM PAKARANG-KHAO LAK AREA, CHANGWAT PHANG-NGA, THAILAND.
By	Mr. Sumet Phantuwongraj
Field of study	Earth Sciences
Thesis Advisor	Assistant Professor Sombat Yumuang, Ph.D.
Thesis Co-advisor	Assistant Professor Montri Choowong, M.Sc.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of the Faculty of Science

(Professor Piamsak Menasveta, Ph.D.)

THESIS COMMITTEE

Punya .... Chairman

(Associate Professor Punya Charusiri, Ph.D.)

S. Yumuang .... Thesis Advisor

(Assistant Professor Sombat Yumuang, Ph.D.)

Montri Choowong .... Thesis Co-advisor

(Assistant Professor Montri Choowong, M.Sc.)

T. Charoentitirat .... Member

(Assistant Professor Thasinee Charoentitirat, Ph.D.)

Niran Chaimanee .... Member

(Mr. Niran Chaimanee, M.Sc.)

สุเมธ พันธุวงค์ราช: การเปลี่ยนแปลงชายฝั่งทะเลหลังการเกิดสึนามิวันที่ 26 ธันวาคม 2547 ระหว่างแหลมปะการัง-เขาหลัก จังหวัดพังงา ประเทศไทย.(SHORELINE CHANGE AFTER THE 26 DECEMBER 2004 TSUNAMI BETWEEN LAEM PAKARANG-KHAO LAK AREA, CHANGWAT PHANG-NGA, THAILAND) อ.ที่ปรึกษา: ผศ. ดร.สมบัติ อยู่เมือง, อ.ที่ปรึกษาร่วม: ผศ.มนตรี ชูวงษ์, 214 หน้า.

เหตุการณ์สึนามิเมื่อวันที่ 26 ธันวาคม พ.ศ.2547 ก่อให้เกิดความเสียหายกับบริเวณชายฝั่งทะเลอันดามันของประเทศไทยเป็นอย่างมาก พื้นที่แนวชายฝั่งที่มีการเปลี่ยนแปลงมากที่สุดจากเหตุการณ์นี้คือ บริเวณแหลมปะการังถึงเขาหลัก จังหวัดพังงา ตะกอนชายหาดจำนวนมากถูกกัดเซาะอย่างรวดเร็วและถูกพัดพาไปสะสมตัวอยู่บนฝั่ง ซึ่งเป็นผลมาจากความรุนแรงของสึนามิ แนวชายฝั่งได้ร่นถอยเข้ามาในแผ่นดิน และปากคลองที่อยู่ติดกับทะเลเปิดกว้างขึ้นกว่าเดิม การศึกษาวิจัยนี้มีเป้าหมายที่จะติดตามกระบวนการฟื้นตัวของพื้นที่ชายหาดหลังจากที่ชายฝั่งมีการเปลี่ยนแปลงไปจากเหตุการณ์สึนามิ

ข้อมูลหลักที่ใช้ในการศึกษาวิจัยครั้งนี้ประกอบด้วย ข้อมูลโทรสัมผัสและข้อมูลที่ได้จากการสำรวจภาคสนาม การศึกษาแนวชายฝั่งและพื้นที่หาดทรายจะใช้ข้อมูลโทรสัมผัสโดยใช้ข้อมูลจากภาพถ่ายดาวเทียมใน 12 ช่วงเวลา ตั้งแต่ปี พ.ศ.2545 - 2549 การศึกษาการเปลี่ยนแปลงของชายหาดทั้งในแนวระนาบและแนวดิ่ง และลักษณะของตะกอนชายหาด จะใช้ข้อมูลจากการสำรวจภาคสนามทุก 3 เดือนในช่วงเดือน มกราคม ถึง พฤศจิกายน 2549

จากผลการศึกษาการเปลี่ยนแปลงของชายหาดทั้งในแนวระนาบและแนวดิ่งในช่วงปี 2549 แสดงให้เห็นว่าเป็นชายฝั่งแบบคงสภาพมีความสมดุลย์กันในเรื่องของการสะสมตัวและการกัดเซาะ ซึ่งจะเปลี่ยนแปลงไปตามฤดูกาล ขนาดของเม็ดตะกอนชายหาดในพื้นที่ศึกษาจะมีขนาดตั้งแต่ทรายหยาบจากทางตอนใต้ที่บริเวณบ้านบางเนียงและลดขนาดลงจนถึงทรายละเอียดทางตอนเหนือที่บลูวิลเลจ ปะการังรีสอร์ท ส่วนประกอบของตะกอนประกอบด้วย แร่ควอร์ซ 60% เศษหอยและเศษปะการัง 35% และส่วนประกอบอื่นๆ 5% และจากผลการวิเคราะห์ข้อมูลโทรสัมผัสและข้อมูลการสำรวจภาคสนามพบว่าแนวชายฝั่งและพื้นที่ชายหาดส่วนใหญ่ได้ฟื้นตัวกลับมาเกือบเท่าเดิมก่อนเกิดเหตุการณ์สึนามิแล้ว แต่พื้นที่ในบริเวณที่เป็นทางน้ำเข้า/ออกที่ติดกับทะเล (ยกเว้นที่บ้านบางเนียง) ยังไม่ฟื้นตัว โดยยังคงสภาพเหมือนเดิมหลังเกิดเหตุสึนามิ โดยสรุปแล้วจากการศึกษาจนถึงเดือนพฤศจิกายน พ.ศ. 2549 พื้นที่ที่ถูกกัดเซาะจากเหตุการณ์สึนามิเมื่อปี 2547 ได้ฟื้นสภาพกลับมาแล้ว ประมาณ 90 เปอร์เซนต์

ภาควิชา.................ธรณีวิทยา.................ลายมือชื่อนิสิต....................................

สาขาวิชา................โลกศาสตร์................ลายมือชื่ออาจารย์ที่ปรึกษา..............................

ปีการศึกษา.............2549.....................ลายมือชื่ออาจารย์ที่ปรึกษาร่วม..........................

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SUMET PHANTUWONGRAJ: SHORELINE CHANGE AFTER THE 26 DECEMBER 2004 TSUNAMI BETWEEN LAEM PAKARANG-KHAO LAK AREA, CHANGWAT PHANG-NGA, THAILAND. THESIS ADVISOR: ASST.PROF.DR. SOMBAT YUMUANG, THESIS COADVISOR : ASST.PROF. MONTRI CHOOWONG, 214 pp.

The 26 December 2004 tsunami had left an extremely damage to the Andaman Sea coast of Thailand. Lame Pakarang – Khaolak, Phangnga province was the most affected area in shoreline changed from this event. Numerous sediments from shoreface through beach area were eroded suddenly and moved inland rapidly due to the high energy of tsunami wave. Shoreline position was changed inland and inlet/outlet channels were wider. This study aims to monitor recovering process in beach area after shoreline was changed by this event.

Remote sensing data and field survey were mainly used in this study. Twelve periods from 2002 to 2006 of satellite images were used to calculate beach area and shoreline change. Field survey was carried out every 3 months for beach profiling and sediment sampling in four periods since January to November 2006. Beach profiles showed the balance of deposition and erosion which the change depends on season changes. Grain size of beach sediments at Ban Bang Niang was coarse to very coarse sand and finer to the north as fine to medium sand at Blue Village Pakarang Resort. Beach sediments were composed of quartz (60%), bio clasts (35%), and others (5%). In conclusion, according to the satellite images analysis and field survey, shoreline and beach areas in the study area were almost recovered after one year whereas inlet/outlet channels (except Ban Bang Niang) were not recovered. In general, eroded areas by 2004 tsunami were approximately 90 percent recovered until November 2006.

Department.................Geology.................. Student's signature....Sumet Phantuwongraj

Field of study.........Earth Sciences............Advisor's signature.....S. Yumuang

Academic year.................2006................. Co-advisor's signature..Montri Choowong...

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CHAPTER I

INTRODUCTION

1.1 Rationale

The 26 December 2004 Indian Ocean tsunami, triggered by the M 9.3 (Stein et al., 2005) Sumatra-Andaman earthquake, devastated coastal areas in the Indian Ocean region including extensive damage along the Andaman coast of Thailand. More than 200,000 of people died in this event, in Thailand 5,395 people died, 8,457 injured, and 2,995 lost. This is the most severely geo-hazard that have been recorded in the history of Thailand.

In Thailand, Lame Pakarang to Khao Lak, Phang-Nga province is one of the most affected areas from coastal erosion by this event. Numerous sediments from shoreface zone to backshore along this coast were eroded away and left behind scoured features in some tidal channels. Shoreline position was also changed and tidal channels were opened wider. According to the suddenly changed of shoreline and disappeared of beach area by erosion of tsunami, deposition and erosion pattern of sediment in this area may change from the past led to changing in shape and area of new recovered beach. Thus, monitoring in recovery process of shoreline is necessary. After the 2004 tsunami event, there are a lot of reports and published paper about damage and shoreline change in eroded area of affected country (e.g., Center for Remote Imaging, Sensing and Processing [CRISP] , 2005; Choowong et al., 2005; Choowong, 2006; Choowong et al., 2007; Department of Mineral Resources [DMR], 2005; Geo-Informatics and Space Technology Development Agency [GISTDA], 2005; Ministry of Natural Resources and Environment, Department of Mineral Resources , 2005; National Aeronautics and Space Administration [NASA], 2005; Polngam, 2005; Phantuwongraj et al, 2006; Sanguantrakool, 2005; Yumuang, 2005). These invaluable reports documented the valuable information that can use as secondary data in monitoring shoreline recovery process.

Unfortunately, recovery process of shoreline in systematic method, especially rate of recovery is not reported yet. Therefore, systematic monitoring in shoreline recovery process of affected area has performed. In this study, secondary data from series of satellite images were used in monitoring shoreline recovery process and primary data from field investigation also used in evaluate beach behavior and characteristics of beach sediment in annual year to understand beach cycle after recovery of shoreline in 2006 year.

1.2 Objectives

The prime objectives of this study are aimed to monitor recovering process in beach area after shoreline was changed by the 24 December 2004 tsunami and to understand beach behavior and characteristics of beach sediment in 2006 after shoreline was almost recovered. It is also significant need to understand the sediment transportation along the study area, and also oceanography and marine processes that provide geomorphology appearance in the recovered shoreline.

In order to achieve the better understanding shoreline recovery process in this study, the specific aims are:

1. To evaluate the changes of shoreline and beach area between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand after 2004 tsunami.
2. To monitor shoreline and beach area recovery between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand after 2004 tsunami.
3. To understand beach behavior and characteristic of beach sediment between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand in 2006 after shoreline and beach area are almost recovered.

1.3 Scope and limitation

This thesis is concerned with the understanding and analysis the processes of shoreline and beach area recovery between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand. Scope of this research is limited to the analyses using two types of data. Firstly, satellite images data was used in estimates lost area and monitoring shoreline recover process from 26 December 2004 tsunami event. Secondly, field investigation data was used in study beach behavior by performing beach profile measurement and sediment sampling to understand characteristic of beach sediment in physical properties in annual year.

Normally in studying shoreline change by using remote sensing data, especially in the small scale like this study, high resolution image are required. Unfortunately, high resolution image usually come with high budget so in this study four satellite image data from IKONOS, SPOT-5, ASTER, and LANDSAT-5 which resolution 1 m., 2.5 m., 15 m., and 30 m. respectively were combined together. IKONOS image with high resolution 1 m. were used to create reference shoreline for use as a baseline in comparing with another.

Detailed field investigation was conducted only in the main target areas that were analyzed as the most affected area from erosion by 2004 tsunami. In addition, characteristic of beach sediment in physical properties for this study were concentrated on grain size, composition, roundness, and sphericity to identify sediment source zone that provide sediment in recovered area.

1.4 Expected output

The expected outputs of this study consist of:

(1) Spatial shoreline change between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand after 26 December 2004 tsunami.

(2) Recovery process of shoreline and beach area between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand after 26 December 2004 tsunami.

(3) Beach behavior and characteristics of beach sediment between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand in 2006 after shoreline recovered from 26 December 2004 tsunami.

These results will explain the recovery process of shoreline between Lame Pakarang to Khao Lak, Changwat Phang-Nga, Thailand by fact from the study. Rate of recovery are also described in this study for understanding natural factor that control recovery process. Beach behavior and characteristic of beach sediment, these important data help us to understand the dynamic process in the coastal area which can offer us information about shoreline type for instance, eroded shoreline, stable shoreline or depositional shoreline.

CHAPTER II

THE STUDY AREA

This chapter describes the study area, aiming to present the environmental setting of Lame Pakarang-Khao Lak, Changwat Phang-Nga. The descriptions will be general topography, regional geology, bathymetry, climate, coastal processes, and beach morphology respectively.

2.1 General topography

Lame Pakarang-Khao Lak, Changwat Phang-Nga is the coastal area in Phang-Nga province which located in the southern part of Thailand. It is lies along the Andaman ocean, bounded by latitude 8^0 37´ to 8^0 45´ north and longitude 98^0 13´ to 98^0 15´ east with length approximately 13 km (Figure2.1). The study area is in a coastal plain that including significant landform such as mangrove, tidal flat, beach, inter-barrier depression, inner beach ridge, alluvial plain, barrier lagoon, and mountain area (Ministry of Natural Resources and Environment, 2005) (see Figure 2.2). The elevation ranges from 0 – 10 m above the present mean sea level. The long mountain range N – S direction limited the eastern boundary. To the west of the mountain range, alluvial plain are dominant followed with inner beach ridge, inter-barrier depression, barrier lagoon, and beach area. The study area has 4 inlet/outlet channels flowing westwards to the sea which also supplying a little bit the terrestrial sediments. Coastal plain along Lame Pakarang to Khao Lak was developed between Khao Lak headland and Lame Pakarang coral reef platform. Coastal plain was narrow at the south and wider at the north conforming to shape of alluvial plain. Rocky coast at Khao Lak usually suffered to the erosion by sea wave during monsoon season every year. Thus, rock fragment and some small sediment from rocky coast can transport to the north by longshore current to developed wider beach area in the north at Lame

Pakarang as its present shape. Apart from the coastal plain approximately 20 km. there is the mountain range of pebbly mudstone, Kaeng Krachan Formation (Permo-Carboniferous) laid down in NE-SW direction

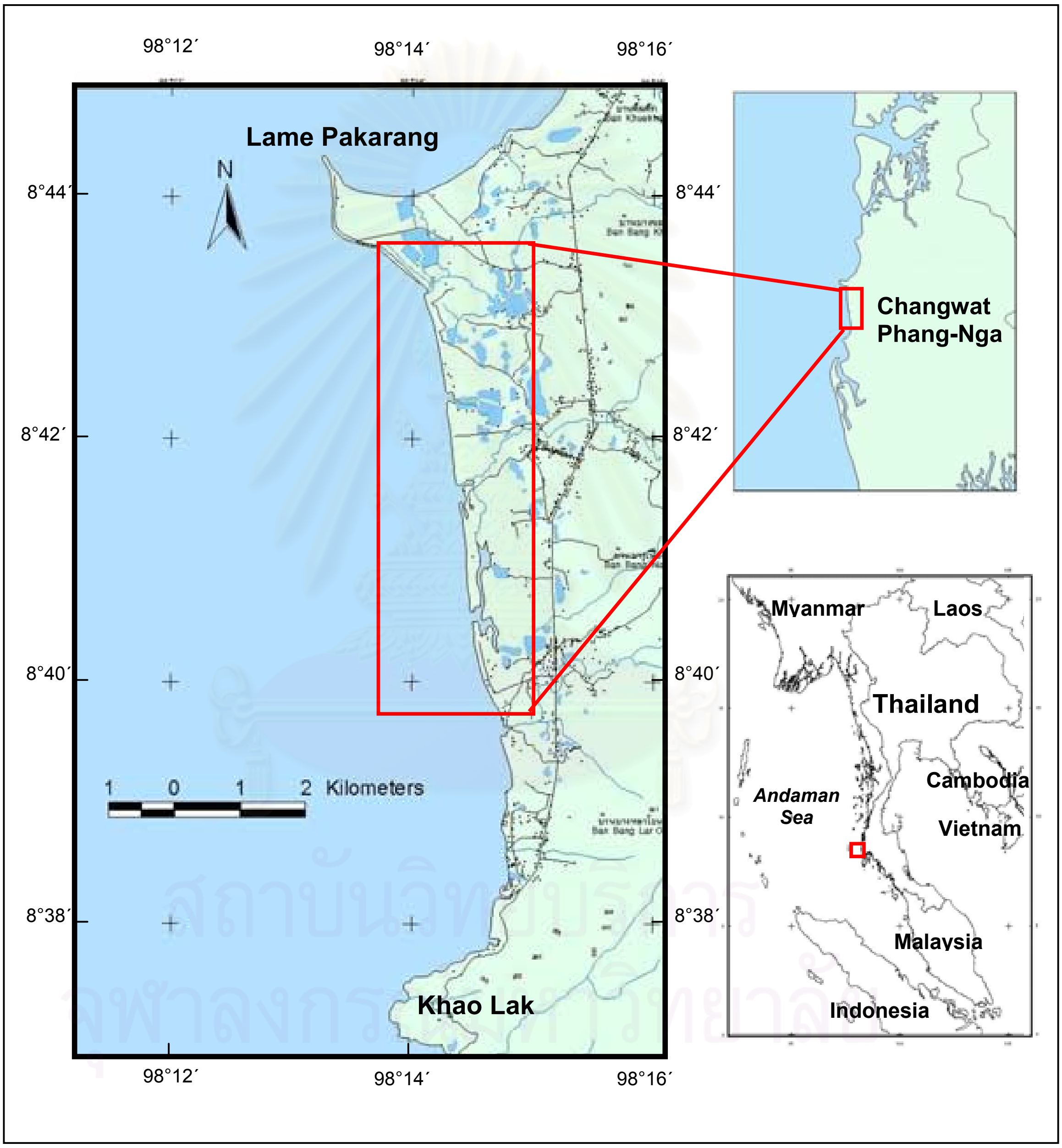

Figure 2.1 Map showing the study area (in red polygon) along Lame Pakarang – Khao Lak, Changwat Phang-Nga, the Andaman Coast of Thailand.

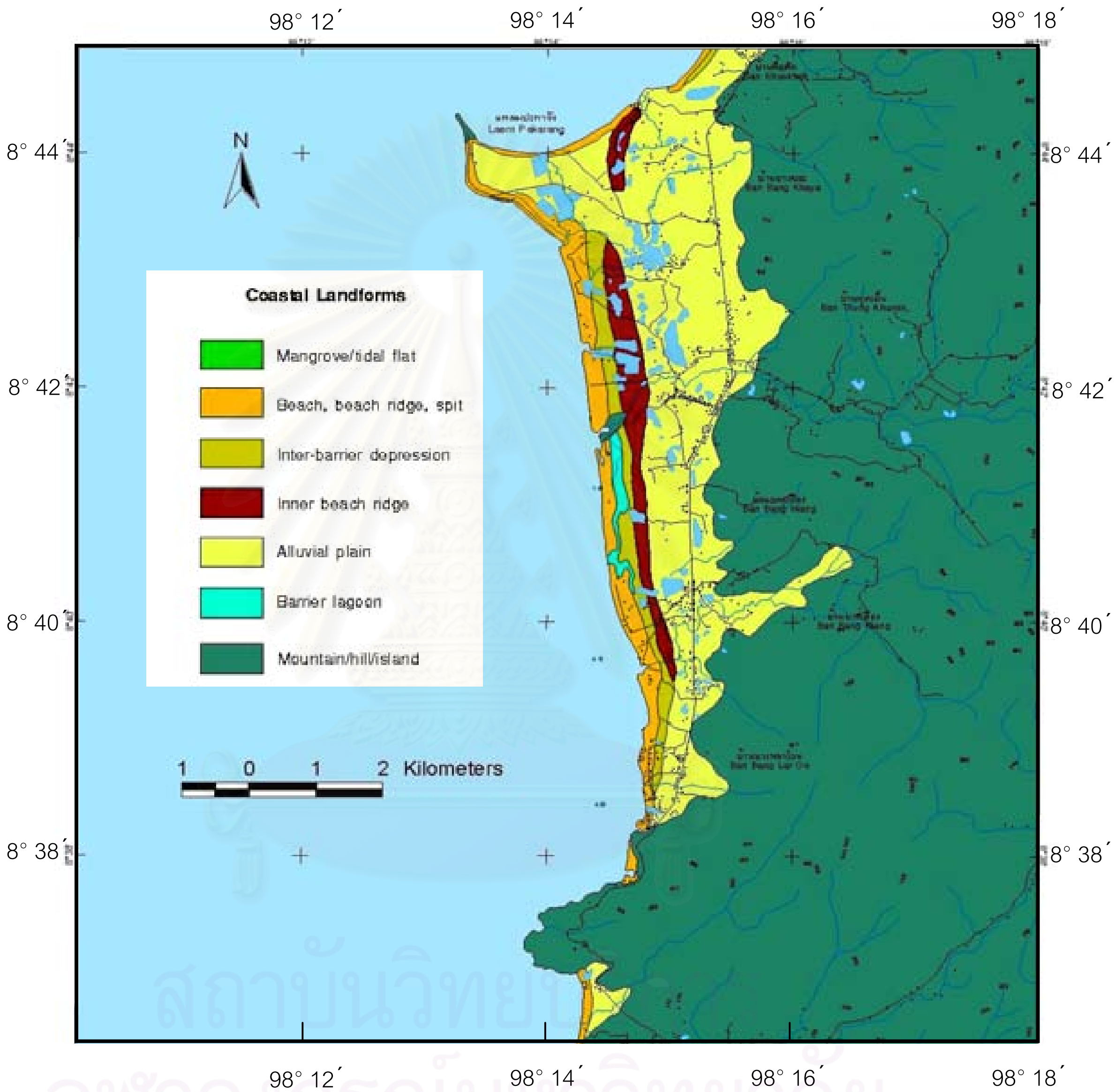

Figure 2.2 Geomorphological map of the study area (modified from Ministry of Natural Resources and Environment, 2005).

2.2 Regional geology

2.2.1 Offshore geology

The general geology of western coast, southern Thailand, from Ranong-Phangnga-Phuket provinces is composed of sedimentary rock, metamorphic rocks, igneous rocks and superficial deposits (Garson et al., 1975; Mantajit, N., 1975; Udomrat, C. and other, 1983). The predominant rocks are mudstones, slates and quartzites (metamorphosed sandstone), forming the Phuket group (Fig 2.3). The Phuket group was laid down in a shallow marine environment some 350-250 million years ago (Permo-Carboniferous) on top of more ancient (Precambrian) beds of deformed schists and slate 1 billion years old. After million of years of subsequent erosion and deformation (Permian), Ratburi limestone was laid down over the whole area, followed about 160-200 million years later (Jurassic) by conglomerates. Form 100-65 million years ago (Upper Cretaceous-Lower Tertiary) these rocks, now altered and compressed by powerful earth movements from the west, were intruded by a series of granite masses which trust up through the altered sedimentary rocks, thus causing further extensive deformation and dislocation. During this period, tin mineralization took place in association with the granites, though not necessarily at the time of intrusion; the mineralization may have accompanied later periods of uplift and cooling. There is evidence of other minor sedimentation in the region some 40 million years ago (Tertiary) when the sandstone and conglomerates were laid down, accompanied by sporadic volcanic activity. This appears to have been follow by a period of little tectonic activity until heavy erosional forces during the ice ages 1.5 to 2 million years ago (Pleistocene) reduced the landscape to its present form (Chiemchindaratana, 1993).

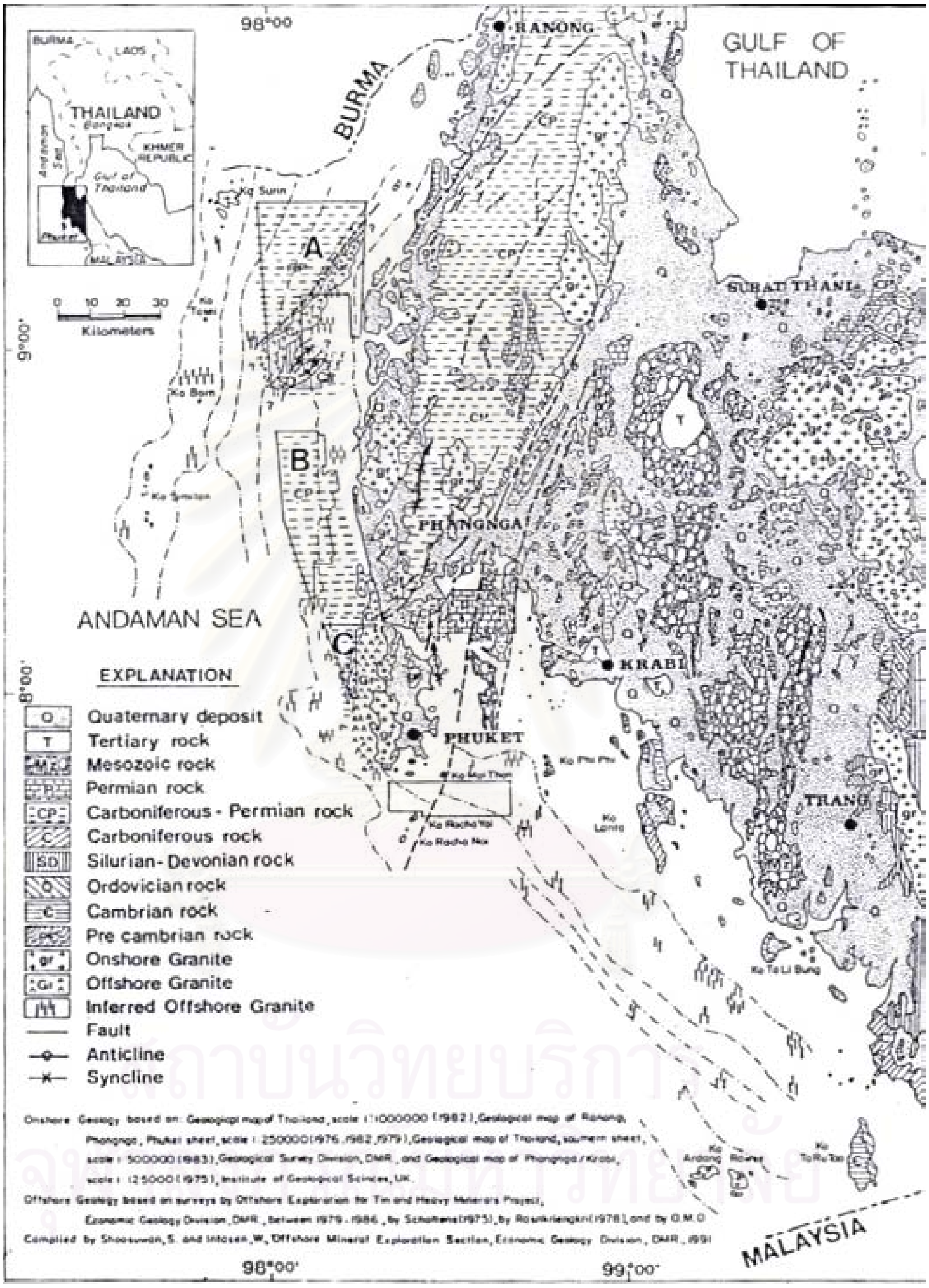

Figure 2.3 General geologic map of western coast, Southern Thailand (after Chiemchindaratana, 1993).

2.2.2 Onshore Geology

The inner mountain range around this area is approximately 20 km. from coastline which pebbly mudstone rock, Kaeng Krachan Formation (Permo-Carboniferous) laid down in NE-SW direction (Figure 2.4). Beside that the outer mountain range is Biotite-hornblende granite rock, Cretaceous age that is a source of sediment in generating fluvial plain in this coastal plain. Quaternary sediment was covered the whole lowland and show a morphology of coastal landform like its present day. Klong Thung Maphrao at the south of Khao Lak is the biggest channel in this area that should be the main inland source for sediment supply to the sea that received terrestrial sediments from two mountain range, pebbly mudstone rock, and biotite-hornblende granite rock.

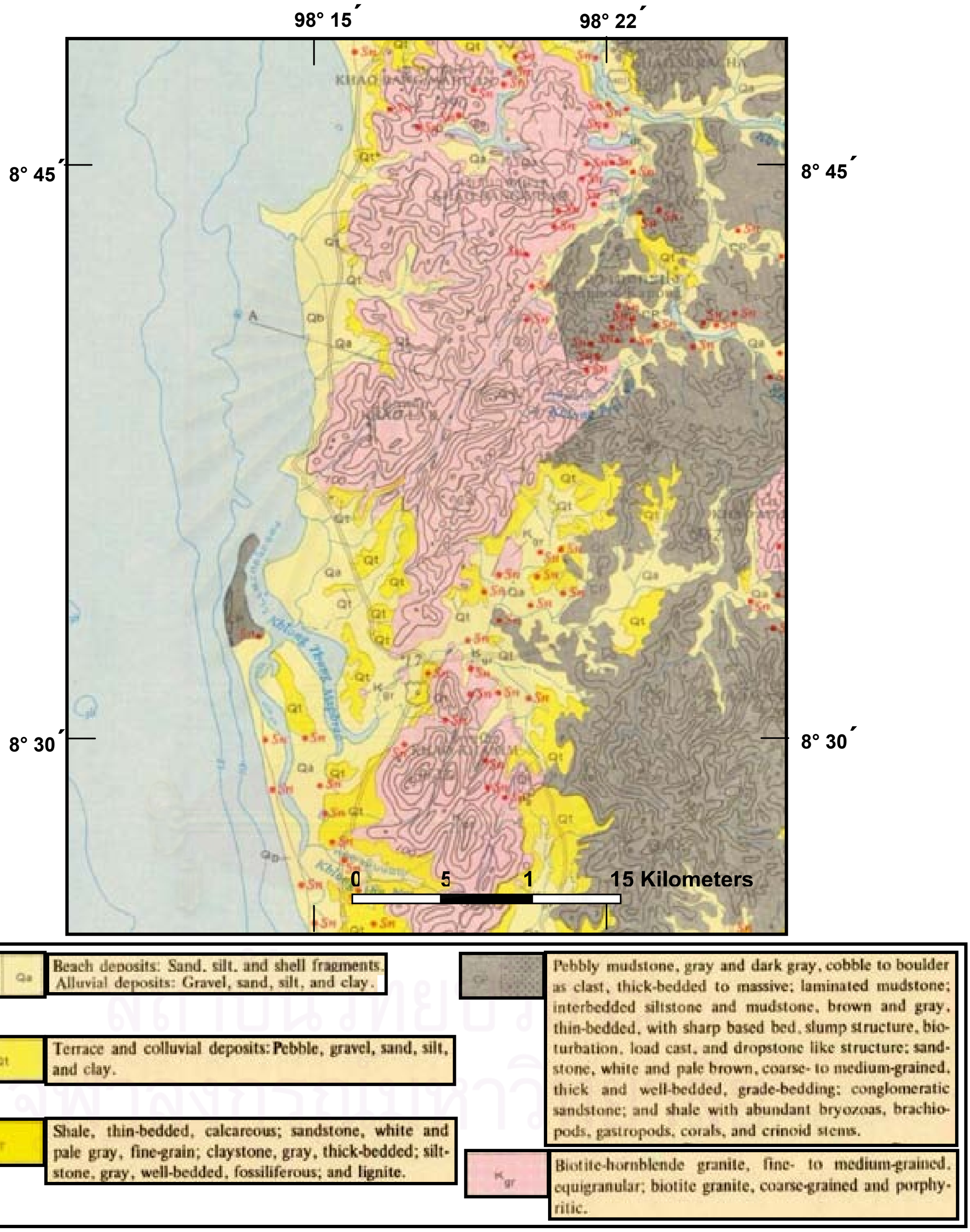

Figure 2.4 Part of geological map of Changwat Phang-Nga sheet NC 47-14 showing geology along Lame Pakarang to Khao Lak area (modified from DMR, 1976).

2.3 Bathymetry

Bathymetry is one of the several factors that control damage of shoreline. A tsunami can propagate long distances before it strikes a shoreline hundreds or thousands of kilometers from the earthquake source. In deep water tsunamis travel very fast, but their wavelength is long (some 200 km), and the amplitude is small (0.5 meter). As tsunamis approach land where the water depth decreases, the forward speed of the tsunami will slow, but wave heights increase to as much as 30 meters. Tsunamis can also travel up rivers and streams that lead to the ocean so flooding from tsunami can penetrate further inland by this topography and severely erosion of shoreline usually occurs at inlet/outlet or tidal channel that connects to the sea. Nearshore bathymetry of Lame Pakarang-Khao Lak before tsunami 2004 attacked is depth about 20 meters approximately 10 km. from shoreline (figure 2.5). Some sea floor channels that allow tsunami flow easily to the shoreline can recognize from the contour line (the red arrow in figure 2.5). These sea floor channels usually connect to the inlet/outlet or stream from inland so seriously damage in this study area was found concentrated at inlet/outlet channel area. At Lame Pakarang sea floor channel in southeast direction is one of the importance factors that control flow direction, speed, and energy of tsunami in damaging Lame Pakarang area. After the 2004 tsunami event, the Hydrographic Department of Royal Thai Navy has mapping a new bathymetry for investigating change of seafloor topography. From the Figure 2.6, comparing of before and after 2004 tsunami bathymetry shows that new seafloor topography is slightly shallower from the effect of tsunami event.

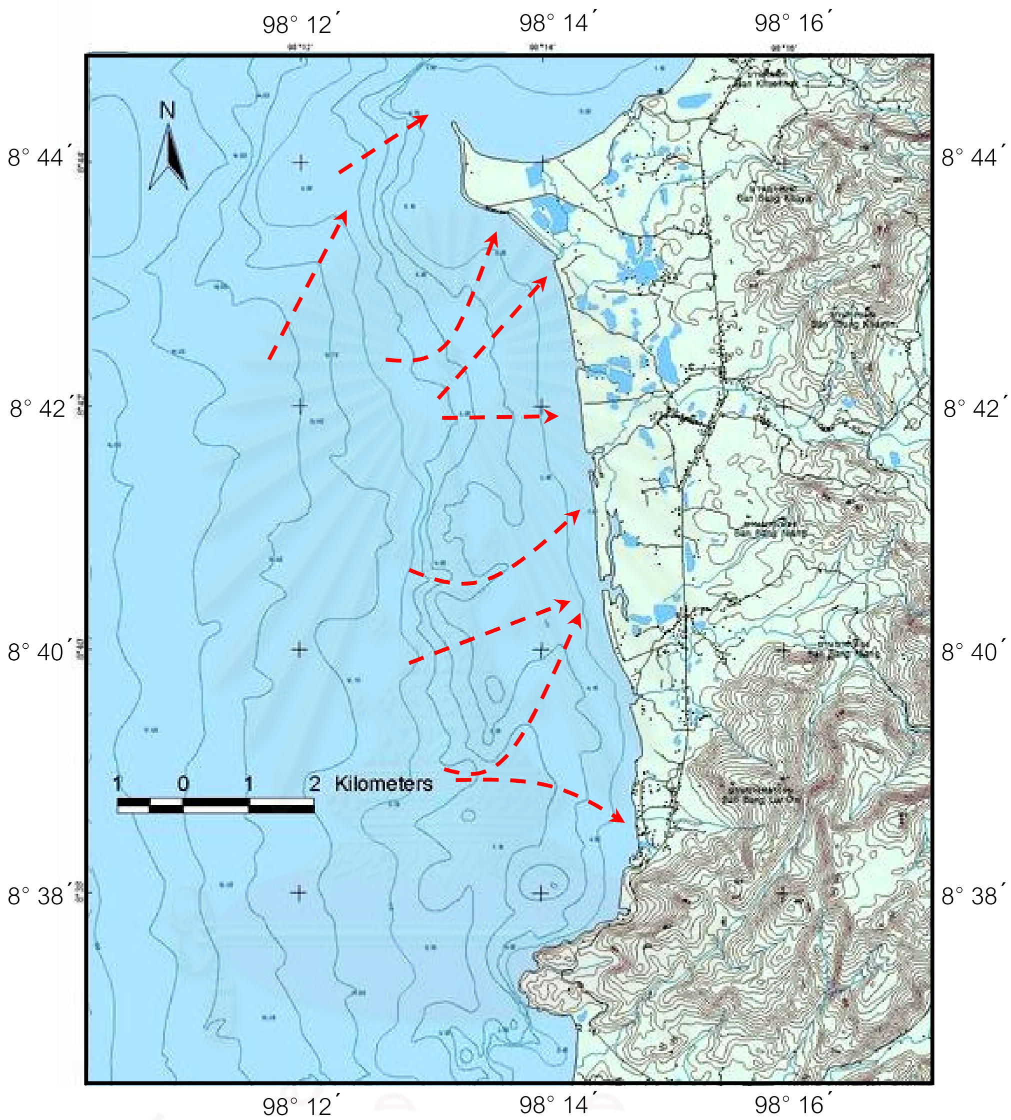

Figure 2.5 Bathymetry along Lame Pakarang to Khao Lak before 2004 tsunami, contour interval is 2 meters. Red arrow indicated flow direction of tsunami corresponds to seafloor channel. (modified from Ministry of Natural Resources and Environment, 2005)

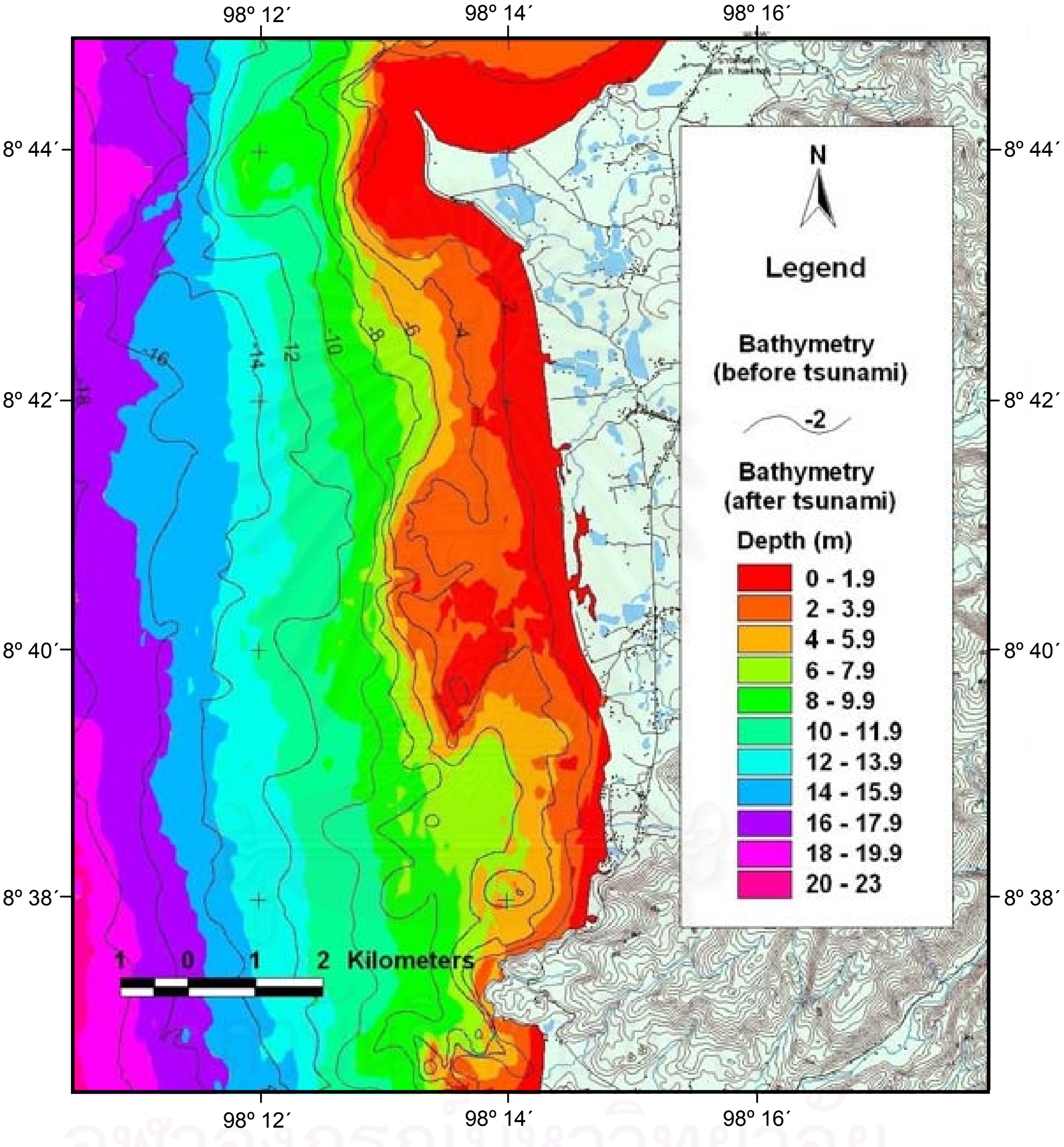

Figure 2.6 Bathymetry along Lame Pakarang-Khao Lak before 2004 tsunami overlay on bathymetry after 2004 tsunami. (Bathymetry after 2004 tsunami, source from Hydrographic Department, Royal Thai Navy, 2006)

2.4 Climate

The climate type of study area belongs to tropical monsoon forest climate (Am), according to Koppen's classification: Am – climate. Southwest monsoon winds and rains regularly occur normally between mid – May and October, causing flood seasons and frequently produce tropical storms that are less severe than typhoons. Northeast monsoon occurs between November and mid – February. The climate is generally divided into three seasons. Firstly, the rainy season with tropical storms normally coming from mid – May to November. Secondly, the dry winter season starts annually from November until February. Finally, the summer period occurs from the end of February to mid – May.

The study area is located in a tropical climate with two major 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 usually generate moderate waves about 0.3-1.5 meters along the west coast. Cyclones are generated as results of retreat of southwestern monsoon during September to October, which bring strong winds and intense waves in the Gulf of Thailand directly, also damage the coastal landform along the Andaman Sea too. Conversely during November to mid – February, the northeast monsoon represents of a reversal of air movement and waves are generally small. Winds are normally moderate during the northeast monsoon season with stronger winds during the season's end. Wind decrease during the southwest monsoon season (Thai Meteorological Department, 2007).

2.5 Coastal processes

This section explains coastal processes in term of the processes of wind, current, wave and tide influences in the study area.

2.5.1 Monsoonal wind

Base on geographical feature, there are 2 types of monsoon in the area: northeast and southwest monsoons. The northeast monsoon occurs during mid – October to February due to 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.

2.5.2 Current

Current along the Andaman Sea, coast of Thailand in north-south direction is stronger than the east-west direction current. Moreover ebb current is stronger than flood current so sediment can easily transport in the low tide time.

2.5.3 Waves

In general, waves in the area are the small wave. Their height is normally lower than 2 meters. However, during the monsoon wind, wave heights can be generated more than 5 meters.

2.5.4 Tides

Tides are the cyclic rising and falling of Earth's ocean surface caused by the tidal forces of the Moon and the Sun acting on the Earth. Tides cause changes in the depth of the sea and produce oscillating currents known as tidal streams, making prediction of tides important for coastal navigation. The strip of seashore that is submerged at high tide and exposed at low tide, the intertidal zone, is an important ecological product of ocean tides. The characteristic of tides in this study area is semidiurnal tide, two times of high tide and low tide in one day, with average 1.55 meters in tidal range calculated from tides table of Ao Tap Lamu ,Phang-nga province in 2006 (Figure 2.7).

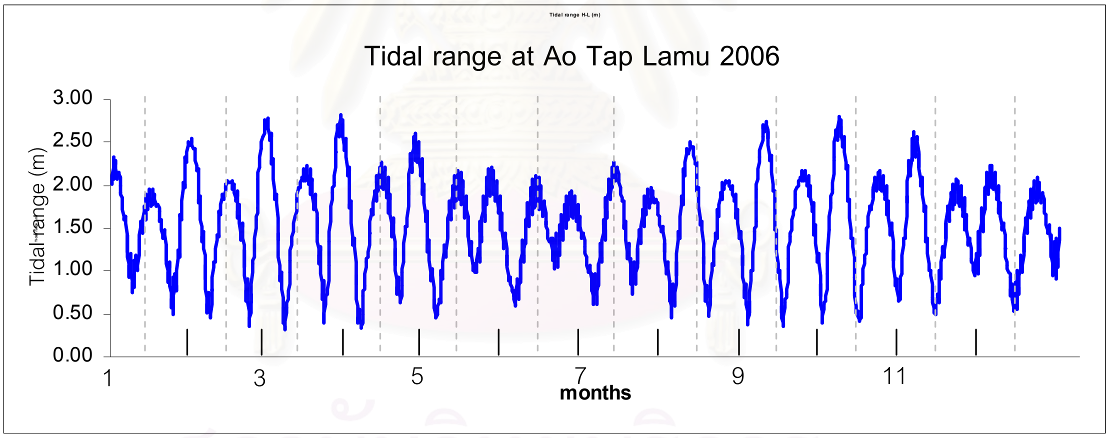

Figure 2.7 Tidal range at Ao Tap Lamu 2006

2.6 Beach morphology

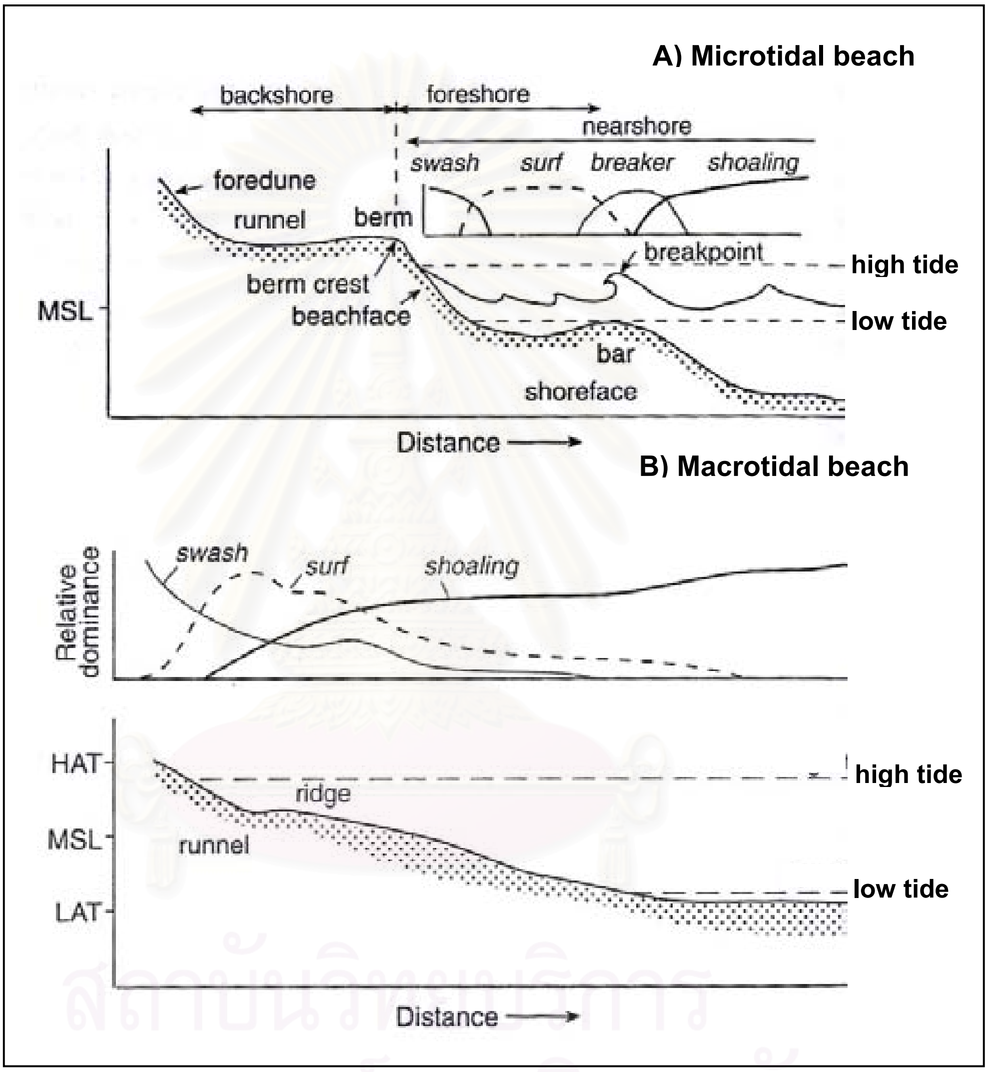

Figure 2.8 Beach morphology. A) profile of a microtidal wave-dominated beach. B) typical morphology of a mega-or macrotidal beach. Generalised distribution of the relative dominance of swash, surf, and shoaling activity is shown averaged over time across the beach.(modified from Woodroffe, 2002)

A beach system is shown schematically in profile in Figure 2.8A. On a typical microtidal wave-dominated beach, there are four zones define on the basis of wave characteristics: a zone of shoaling waves, a breaker zone, a surf zone, and a swash zone (on the beach face). Not all zones need be present on any one beach, and they very in width and through time. The surf zone presents a complex mix of wave and current motions, operating at a range of frequencies. As indicated above, the width of the surf zone is time-variant, as not all waves break at the same point. Indeed in the extreme case small waves reach a steep beach (reflective) and surge up it as swash, and the surf zone can be absent. The swash zone migrates across the beach as the tide varies; on microtidal beach its rate of migration can be rapid as 5 mm s^{-1}. Figure 2.8B shows a generalized distribution of the relative dominance of swash, surf, and shoaling activity averaged across a schematic macrotidal beach. Wave shoal at a different position across the wide beach depending on the stage of the tide.

The zone above the high-tide level is termed the backshore; it comprises the subaerial beach and aeolian landforms such as dunes. There is often a distinctive 'berm', a relatively narrow wedge-shape, high tide bench marked by a subtle steepening of the beach, or by a prominent berm crest. The beach between high and low tide is referred to as the beachface, and its grades into the shoreface as previously stated by Woodroffe (2003). In addition, Voigt (1998) documented the definition or terminology of beach morphology here.

Backshore: (1) The upper part of the active BEACH above the normal reaches of the tides (high water), but affected by large waves occurring during a high. (2) The accretion or erosion zone, located landward of ordinary high tide, which is normally wetted only by storm tides.

Foreshore: (1) The part of the shore, lying between the BERM CREST and the ordinary LOW WATER mark, which is ordinarily traversed by the UPRUSH and BACKRUSH of the waves as the tides rise and fall. (2) The same as the BEACH FACE where unconsolidated material is present. (3) In general terms, the BEACH between MEAN HIGHER HIGH WATER and MEAN LOWER LOW WATER.

Nearshore: (1) In beach terminology an indefinite zone extending seaward from the SHORELINE well beyond the BREAKER ZONE. (2) The zone which extends from the swash zone to the position marking the start of the offshore zone, typically at water DEPTHS of the order of 20 m.

Swash zone: The zone of wave action on the beach, which moves as water levels vary, extending from the limit of run-down to the limit of run-up.

Surf zone: The zone of wave action extending from the water line (which varies with tide, surge, set-up, etc.) out to the most seaward point of the zone (BREAKER ZONE) at which waves approaching the COASTLINE commence breaking, typically in water DEPTHS of between 5 m and 10 m.

Breaker: A wave that has become so steep that the crest of the wave topples forward, moving faster than the main body of the wave. Breakers may be roughly classified into four kinds, although there is much overlap

Runnel: A corrugation or trough formed in the foreshore or in the bottom just offshore by waves or tidal currents.

CHAPTER III

METHODOLOGY

3.1 Introduction

This research methodology started with extensive review of literatures concerning the relevant reports on the comparison between the pre and post 2004 Indian Ocean tsunami event using satellite images. Since there was no previous works study on the recovery of eroded beach in this research area, literature reviews were also aimed to understand technique on how to monitor short-term and long-term beach erosion from those reported in coastal erosion studies. Literature reviews are among important methods to select appropriate technique in a measurement of beach zone both from aerial view and ground survey. The advantage for this research came in part from the completion of series of satellite images taken before and after the 2004 Indian Ocean tsunami.

Different periods of satellite images taken from 2002 to 2006 were used in this research to monitor spatial shoreline recovery and also to calculate area of eroded shoreline, especially within foreshore and beach zone. Technique in Geographical Information System (GIS) was applied as a tool for the more precise calculation of beach area and helped in planning line survey of beach measurement. GIS technique came after the completion of careful interpretation of satellite images and aerial photographs. Field surveys including the measurement of beach profiles and a systematic collection of foreshore and beach sediments were carried out in 2006 in order to compare beach behavior and sedimentary characteristics in each season. Grain size analysis of beach sediments was done by sieving method and the calculation of statistic parameters was based on the moment method. The methodology used in this research was shown in following flow chart (Figure 3.1).

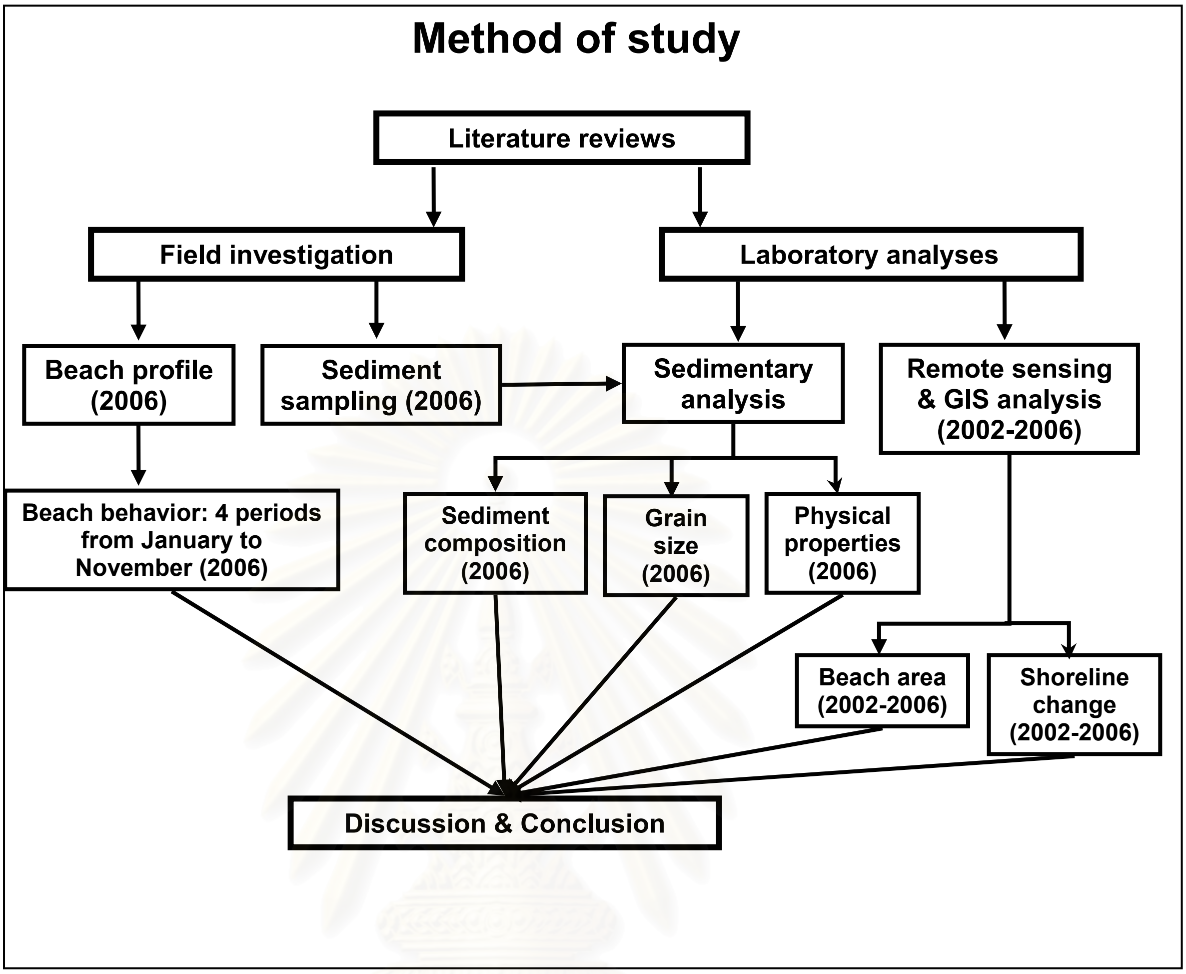

Figure 3.1 Flow chart showing methodology of this research.

3.2 Methodology

The detail methodology of this research was divided into 4 steps; literature reviews, field investigation and observation, laboratory analysis, and discussion and conclusion. This chapter will be focused mainly on literature studies concerned the 2004 Indian Ocean tsunami event. Detail fieldwork and laboratory analysis will be described later in detail.

3.2.1 Literature reviews

After the 2004 Indian Ocean tsunami event, several teams of researcher went down to investigate the affected areas. One benefit for this research came from a report published by staffs of the department of Geology, Chulalongkorn University in 2005. In terms of eroded beach zone, the area extending from Pakarang down to Khao Lak National Park was mentioned as the most severe eroded area (Ministry of Natural Resources and Environment, 2005). Scoured features of beach in this area and extensive inland deposits of the 2004 tsunami sediments were mentioned (e.g., DMR, 2005; Choowong et al., 2007) and NDVI value from Landsat-5 satellite to estimate the hazard zone of affected areas was also made (Yumuang, 2005) (Figure 3.2). Tsunami heights, run-up and inundation were measured by Thai research team and they showed difference from place to place (e.g., Ministry of Natural Resources and Environment, 2005; DMR, 2005). With these extensive studies and reports from several researchers, this thesis forms much attention in the changes of beach zone, especially focused on how large of the areas that were eroded away by the 2004 Indian Ocean tsunami and how these beach areas will be recovered to return to the equilibrium stage as record before the tsunami.

It is no doubt that coastal zone was eroded away by the 2004 Indian Ocean tsunami faster than normal rate of erosion. One of the most important records of coastal deposition and erosion in this area was reported by Sinsakul et al (2003). This report benefits for this research as a basis for evaluating where the accretion and erosion occurred from Pakarang Cape to Khao Lak area (Figure 3.3). Sinsakul et al (2003) documented the rate of coastal erosion along Lame Pakarang to Khao Lak area and classified the characteristic of coastal behavior in this area into three types. Firstly, coastal area from the southern part of Lame Pakarang to the south tidal channel where Blue Village Pakarang Resort was located was characterized as a depositional coast with the accretion rate of 1-5 m/year. Secondly, from the Blue Village Pakarang Resort down south to Ban Bang Niang, this zone was defined as a stable coast with depositional rate of ±1 m/year. Lastly, the area extending from Ban Bang Niang to Khao Lak was identified as a moderately eroded coast with erosional rate of 1-5 m/year.

Comparison of satellite images before and after the 2004 Indian Ocean tsunami from Pakarang Cape was published just a few days after the event (e.g., CRISP, 2005). The more detail analysis in the area where erosion occurred was done by Ministry of Natural Resources and Environment (2005) and Choowong (2006). In a report of Ministry of Natural Resources and Environment (2005), a preliminary analysis from satellite images showing the areas where severe beaches were scoured especially tidal channels (Figure 3.4). In some areas such as back-barrier lagoon behind the beach ridge, the 2004 tsunami had washed away beach ridges and flooded into the back barrier lagoon, leading to the opening of new inlet/outlet. Phantuwongraj et al (2006) estimated that eroded beach area would be recovered within one or two years and the post 2004 tsunami sediments would be from the marine process rather than the transportation by inland fluvial process.

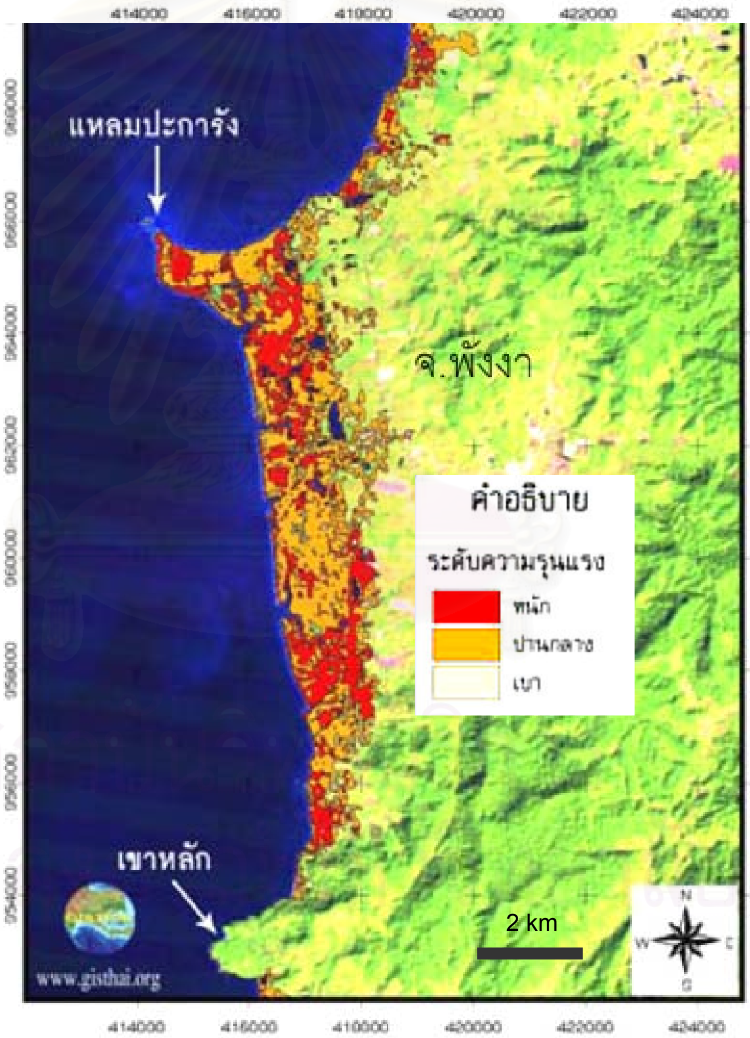

Figure 3.2. Satellite image interpretation shows degree of NDVI value from Landsat-5 satellite in tsunami hazard assessment in 6 affected provinces of Thailand by using NDVI value from Landsat-5 satellite (Yumuang, 2005).

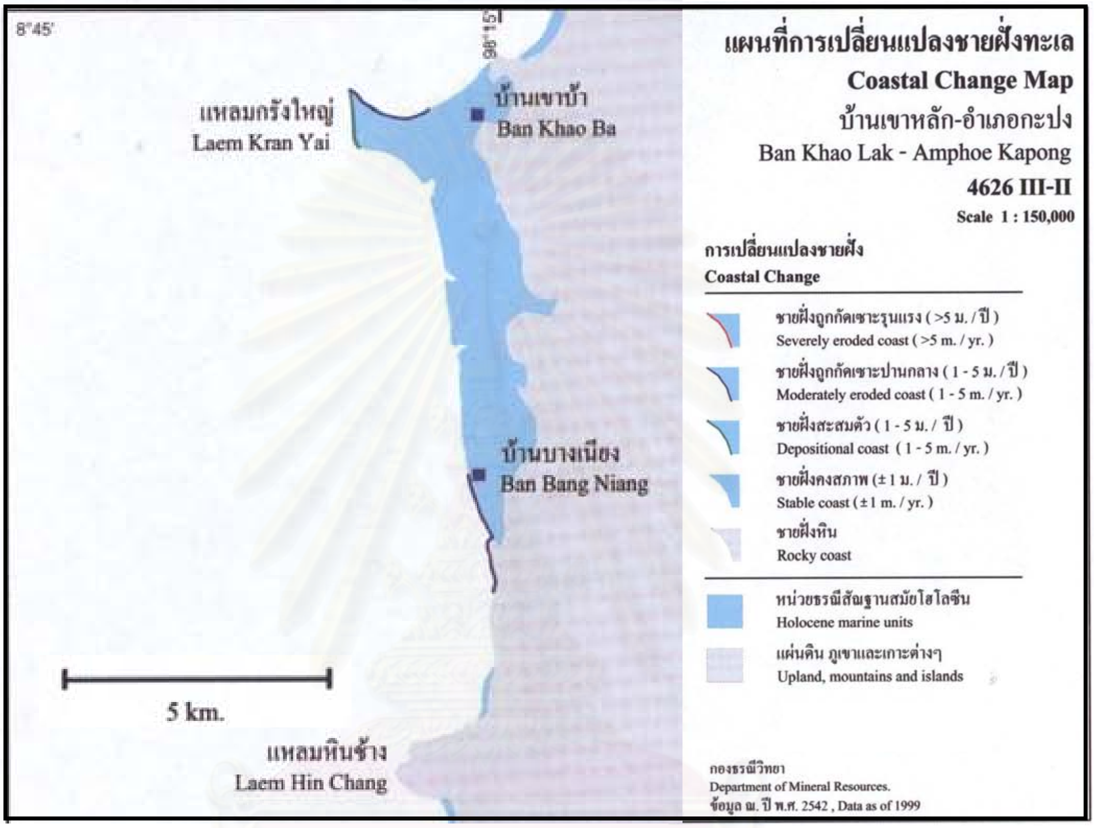

Figure 3.3. Coastal change map showing the shoreline change rate in the study area before the 2004 Indian Ocean tsunami (Sinsakul et al., 2003).

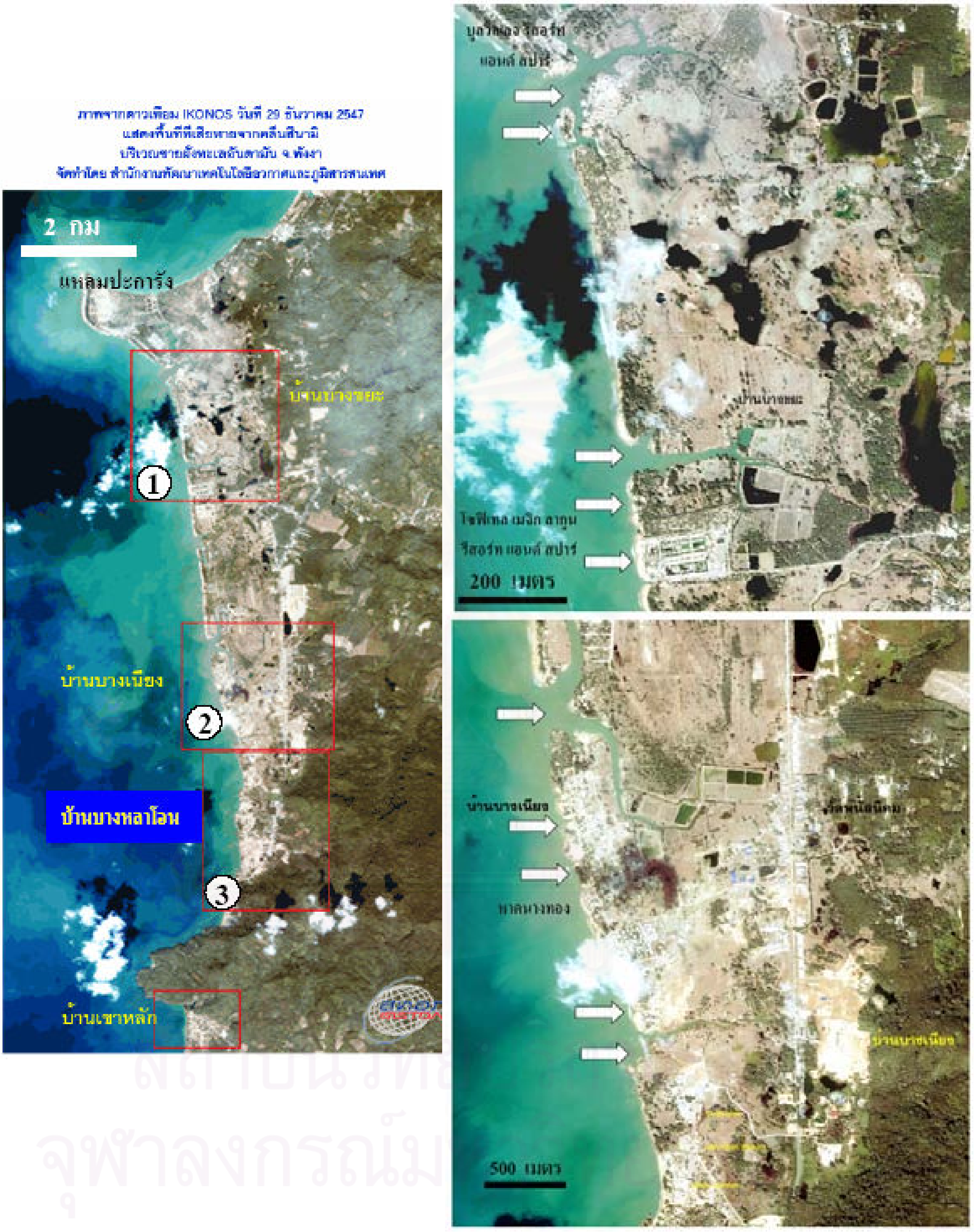

Figure 3.4 IKONOS satellite images taken a few days after the 2004 tsunami (GISTDA, 2005) and the interpreted areas where beaches were scoured and eroded (indicate as arrows) (Ministry of Natural Resources and Environment, 2005).

3.2.2 Field investigation and observation

Detail field investigation for this research included the measurement of beach profiles in four selected pre 2004 tidal channels where the 2004 Indian Ocean tsunami eroded away extensive amount of beach sediment and wider the channel mouth. Systematic collection in beach sediment along the survey lines was carried out. Post 2004 beach sediments were also described in the field.

3.2.2.1 Beach profile measurement

A beach profile is a topographic transects measured perpendicular to the shoreline. Having an accurate time series of beach profile measurements is essential for deciphering shoreline erosion and accretion trends and tracking beach recovery after storms or severe event like tsunami. This stage of the research was modified from several methods to be fit in the study areas. The first and important one is the measurement of beach and shoreface slope vertically and horizontally. The methodology initially developed by Foster and Savage (1989) and Foster (1992). First of all, the reference point is the most important part of the work in measuring beach profiles for each time. The monitoring consists of surveying the beach profile from a fixed point set up behind the beach. The fixed point is called “reference mark”, and is the starting point for the measurement. It is essential to always start the beach profile measurement at the reference mark. After the reference point making on land was set up, the beach profiles will be measured in the same point. This method makes clear also in analyzing beach sediment change both in horizontal and vertical collected along the transect lines. The profiles run at right angles across the beach and in most cases specific orientations for the beach profiles have been determined (Figure 3.5). The data will record when slope has changed. Beach profile will be displayed as shore perpendicular to cross sections that are repeatedly resurveyed four times in a year 2006, to complete one cycle of season in annual year.

Figure 3.5 Photographs showing measurement of beach profile and inlet/outlet cross-section in the study area.

3.2.2.2 Sediment sampling

The coastal zone is composed of many dynamic morphologic features that frequently change their forms and sediment distribution. Although a beach can display a large range of sizes and shapes, each beach is expected to characterize by particular texture and composition representing the available sediments. Textural trends alongshore and cross-shore are indicative of the depositional energy and the stability or instability of the foreshore and nearshore zones (Larson et al, 1997). Surface sediments provide information about the energy of the environment as well as the long-term processes and movement of materials, such as sediment transport pathways. In this research, surface grab samples were collected (typically several hundred grams of beach sand) every 20 meters interval from reference point along each beach profile, including the crest of the foredune ridge, at the dune toe, at mid-beach, and within the swash zone at low tide (figure 3.6).

Figure 3.6 Photographs show surficial beach sediment sampling from backshore to foreshore in swash zone at low tide time.

In this research, the profiling and surface sediment sampling areas were done in four areas usually close to the inlet/outlet channel where there were eroded by the 2004 Indian Ocean tsunami (Figure 3.7).

The detail field investigation and observation were carried out by four periods. Beach measurement and surface sand sample collection were done in all of four study sites at the same time (Table 3.1). Additionally, the changing in beach geomorphology and shoreline change within the focused area and the area nearby was also observed in several periods in annual year.

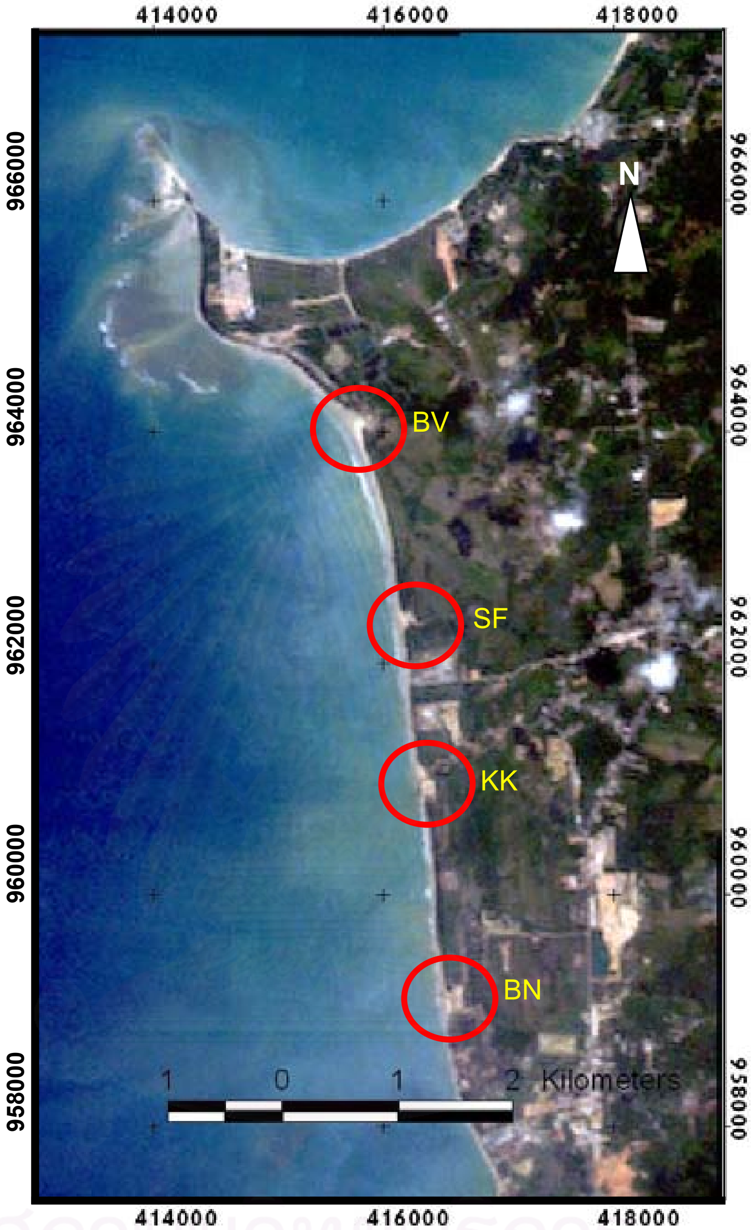

Figure 3.7 Beach profiling areas for this research (in circles) from north to south Blue Village Pakarang Resort (BV), Sofitel Magic Lagoon Resort (SF), Klong Khuek Khak (KK), and Ban Bang Niang (BN). Background is LANDSAT-5 satellite image taken a few months before the 2004 tsunami.

Table 3.1 Locations, time of beach measurement and surface sand sample collection for this research.

Location	**Field survey date**			
	First	**Second**	**Third**	**Fourth**
Blue Village Pakarang Resort	20-21/01/2006	11/05/2006	12/08/2006	07/11/2006
Sofitel Magic Lagoon	20/01/2006	03/06/2006	14/08/2006	09/11/2006
Klong Khuek Khak	21/01/2006	10/05/2006	13/08/2006	08/11/2006
Ban Bang Niang	07/02/2006	10/05/2006	14/08/2006	10/11/2006

3.2.3 Laboratory analysis

As mentioned earlier that this research will show result mainly derived from remote sensing data and field survey data. However, quantitative laboratory analysis is a necessary part of this study. Laboratory analysis was divided into two parts including sedimentological analysis in beach sediment by grain size analysis and the analysis in remote sensing data using GIS technique.

3.2.3.1 Sedimentological analysis in beach sediment

After surface beach sediments were collected during fieldworks, samples were prepared for the next step that is the analysis of sedimentary properties in laboratory. For this research, 288 samples of the post 2004 Indian Ocean tsunami were analyzed, aiming to characterize physical properties. Result of laboratory analysis will be used for comparing the characteristic of beach sediment from four sites at the same time of collection. The methods of laboratory were divided into 3 parts as follows:

3.2.3.1.1 Grain-size analysis Grain-size analysis of surface beach sediments in this research was modified after Friedman and Sanders (1978). Grain size distribution and the other statistic values of sediments were calculated by moment method. This moment method was used worldwide to calculate the statistic parameters in differentiating the type of sedimentary deposition. In this research, dry sieving and weight measurement were done by using sieve mesh, sieve shaker and weight measurement (Figure 3.8 to Figure 3.10). Detail grain size analysis method is described as follow:

A) Sieve experiment

- Dry samples in oven at temperature 80^{o} C about 5-6 hours for release water in samples which make grain of sediments sticking together.
- Mix sediments and then split the sample 2 times (4 piles).
- Weight a pile of sample which was spitted typically several hundred grams depend on grain size such as 500 gram for coarse grain, 200 gram for medium grain, and 100 gram is fine to fine grain.
- Prepare sieve meshes at equivalent sieve mesh no. 5, 10, 18, 35, 60,120 and 230 (A.S.T.M.) or in ø (phi) scale at –2.00, -1.00, 0.00, 1.00, 2.00, 3.00, and 4.00 respectively.
- Fill sample into sieve meshes which were prepared and put sieve meshes on sieve shaker.
- About 10 minutes later, contain beakers which prepared for each sieve mesh, with sieved samples by divide samples in each sieve mesh into each beaker.
- Weight samples in each beaker and note in weight table.

Figure 3.8 Photographs show preparing of samples before dry in oven and sieve in dry sieve mesh.

Figure 3.9 Photographs show drying samples in oven at temperature 80° C about 5-6 hours for release water in samples.

Figure 3.10 Photographs show sieve mesh and sieve shaker (picture A) and also weight measurement used in this study (picture B).

B) Calculation of statistic parameters

According to a large number of samples, the method of moments was selected. Method of calculations was described below.

Calculate all weight data into weight retained percentage and cumulative weight percentage (Figure 3.11) Then enter the sample weight in each size class (column 3 in Figure 3.12) Then multiply the weight in each size class (W in column 3) by the midpoint size (D in column 2) for that class interval and enter the product (D x W) in column 4. Sum all of the values in column 3 and 4. Divide ∑ (D x W) (sum of values in column 4) by ∑ W (sum of valued in column 3, which is equals to the total weight). This is the 1^{st} moment and is equal to the mean. Subtract the mean (M) from the midpoint size (D in column 2) and enter this value in column 5. This is the midpoint deviation (D - M). Take the midpoint deviation to the 2^{nd}, 3^{rd}, and 4^{th} power and enter these values in columns 6, 7, and 8 respectively. Make sure that any negative values from column 5 are carried to column 7 when (D – M) is cubed. All values in columns 6 and 8 will be positive no matter what the sign (+ or -) in column 5. Next multiply the weight (W in column 3) by the values in columns 6, 7, and 8 and enter these values in columns 9, 10, and 11 respectively. Then sum column 9, 10 and 11. Divide the summed value from column 9 by the total weight (∑ W from column 3) (Eqn 2). This is the 2^{nd} moment (m_2) which is also called the variance. The square root of the variance is the standard deviation (Eqn 3). To get the 3^{rd} moment (m_3 in Eqn 4) divide the summed value from column 10 by the total weight (∑ W from column 3). Skewness is calculated by dividing m_3 by $m_2^{3/2}$ (Eqn 5). Divide the summed value from column 11 by the total weight to get the 4^{th} moment (m_4 in Eqn 6). Divide m_4 by m_2^2 to get the kurtosis (Eqn 7)

Report on sieve analysis

Area
Profile
Date

Sample Number	Sample Weight	Screen Mesh Number	Particle Size	Weight Retained	Weight Percent	Cumulative Weight %	Remarks
		# 5	4 mm				
		# 10	2 mm				
		# 18	1 mm				
		# 35	500 µm				
		# 60	250 µm				
		# 120	125 µm				
		# 230	63 µm				
		tray					
		Total					
		Sieve loss					
					100	100	

Figure 3.11 Table to use in record weight retained of sample from sieve analysis.

1 Class interval (mm)	2 D Midpoint (mm)	3 W Weight (g)	4 $D \times W$ Product	5 $D - M$ Midpoint deviation	6 $(D - M)^2$	7 $(D - M)^3$	8 $(D - M)^4$	9 $W(D - M)^2$	10 $W(D - M)^3$	11 $W(D - M)^4$
1–2	1.5									
0.5–1	0.75									
0.25–0.5	0.375									
0.125–0.25	0.1875									
0.0625–0.125	0.938									
pan	0.031*									
		______	______					______	______	______

	Moment	Standard notation	Notation used in grain-size calculation		Calculation		Answer	Statistic
Eqn 1	m_1	$\sum x/n$	$\sum (D \times W)/\sum W$	=	______ / ______	=	______	mean (M)
Eqn 2	m_2	$\sum (x - \bar{x})^2/(n - 1)$	$\sum W(D - M)^2/\sum W$	=	______ / ______	=	______	variance
Eqn 3			$\sqrt{m_2}$	=	$\sqrt{\quad\quad}$	=	______	standard deviation
Eqn 4	m_3	$\sum (x - \bar{x})^3/(n - 1)$	$\sum W(D - M)^3/\sum W$	=	______ / ______	=	______	
Eqn 5			$m_3/m_2^{3/2}$	=	______ / ______	=	______	skewness
Eqn 6	m_4	$\sum (x - \bar{x})^4/(n - 1)$	$\sum W(D - m)^4/\sum W$	=	______ / ______	=	______	
Eqn 7			m_4/m_2^2	=	______ / ______	=	______	kurtosis

Figure 3.12 Table to use in calculating moment measures (millimeter midpoint) (After Fritz and Moore, 1988).

3.2.3.1.2 Analysis in sediment compositions The compositions of sediment was classified using binocular microscope (Figure 3.13) and the percentage was estimated also in binocular comparing to the standard chart of sediment's percentage composition (Figure 3.14).

Figure 3.13 Photograph show binocular microscope.

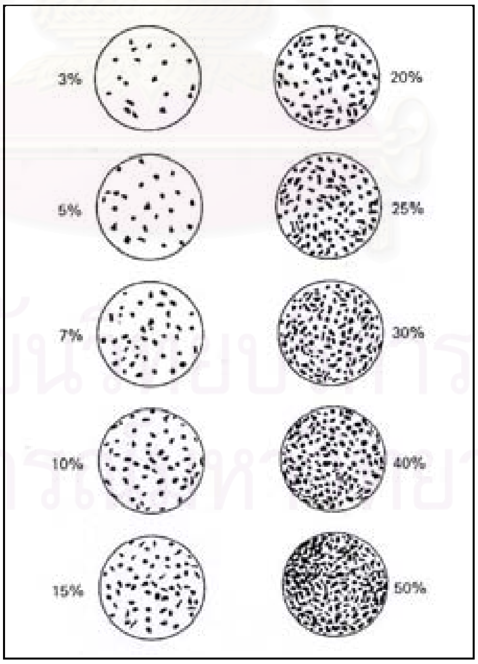

Figure 3.14 Comparison chart for estimating percentage composition (After Fritz and Moore, 1988).

3.2.3.1.3 Analysis in physical properties Physical properties of surface beach sediments analyzed in this research included sphericity and roundness. Roundness is grain morphology of sediments, and is basically concerned with the curative of the corners of the grain and the most common method of describing roundness is by comparison to standard images (e.g., Krumbein, 1941; Pettijohn, 1957; Barrett, 1980). However, roundness of sediments is measured in this research based on the comparison chart suggested by Powers (1953) (Figure 3.15).

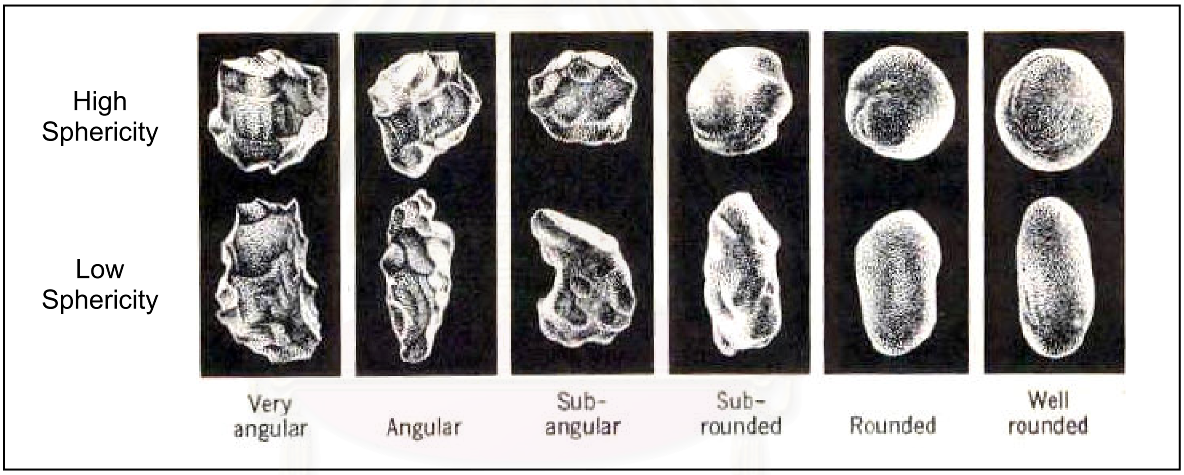

Figure 3.15 Comparison chart for estimating roundness of sediment (modified from Powers, 1953).

3.2.3.2 Remote sensing and GIS analyses

Remote sensing data of the study area were obtained from twelve dates spanning four years from 2002 to 2006 (Table 3.2) by four different resolution satellites (Table 3.3).

Table 3.2 Satellite images applied for this research with date, name, acquisition time, comparative tidal time when satellite images taken and source of satellite data.

DATE	SATELLITE	Acquisition Time (Thai)	Tidal time*	Source
15/11/2002	ASTER	-	Low tide	NASA**
13/1/2003	IKONOS	11:11:49 AM	Low tide	CRISP
1/3/2004	LANDSAT-5 TM	10:24:29 AM	Low tide	GISTDA
9/9/2004	LANDSAT-5 TM	10:29:09 AM	Low tide	GISTDA
29/12/2004	IKONOS	10:53:46 AM	-	GISTDA
30/12/2004	LANDSAT-5 TM	10:31:23 AM	-	GISTDA
31/12/2004	ASTER	-	-	NASA**
16/2/2005	LANDSAT-5 TM	10:32:03 AM	Low tide	GISTDA
5/4/2005	LANDSAT-5 TM	10:32:34 AM	High tide	GISTDA
29/6/2005	SPOT-5	11:13:26 AM	Low tide	GISTDA
16/3/2006	SPOT-5	11:11:30 AM	High tide	GISTDA
26/11/2006	SPOT-5	11:07:50 AM	High tide	GISTDA

Tidal time* = comparing with tides table at Ao Tab Lamu, Phang-Nga province

NASA** = NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team

Table 3.3 Four satellites with different resolution used in this research.

Satellite	Resolution (m)
IKONOS	1
SPOT-5	2.5
ASTER	15
LANDSAT-5 TM	30

Since a large amount of satellite data sets were involved in this research, the preprocessing of the data in the most efficient way was the first concern. It is necessary to geometrically correct all of satellite images to remove image distortion caused by variations of orbital parameters of the satellite and by imperfections of the sensor. The precise geometric correction was applied by using the known Ground Control Points (GCPs) from maps with a standard cartographic projection the Universal Transverse Mercator Projection (UTM) with WGS 84 datum. After taking known GCPs from the topographic map (scale 1:50,000), the satellite images were geo-rectified by using the first order nearest neighbor methods. Transformation matrices containing the coefficients for converting coordinates were calculated from the GCPs by the least square regression methods. The best GCPs were selected and adjust until the total RMS (Root Means Square) error was less than the tolerance level (0.5 of pixel size). The first-order transformation was applied which yields adequate result because of flat terrain of the study area. Nearest neighbor interpolation was followed during re-sampling.

According to the high resolution, one meter of IKONOS satellite image, it was used as a base line map in analyzing the change in shoreline and beach area in this research. The shoreline was divided into five areas using the inlet/outlet channel as a boundary (Figure 3.16).

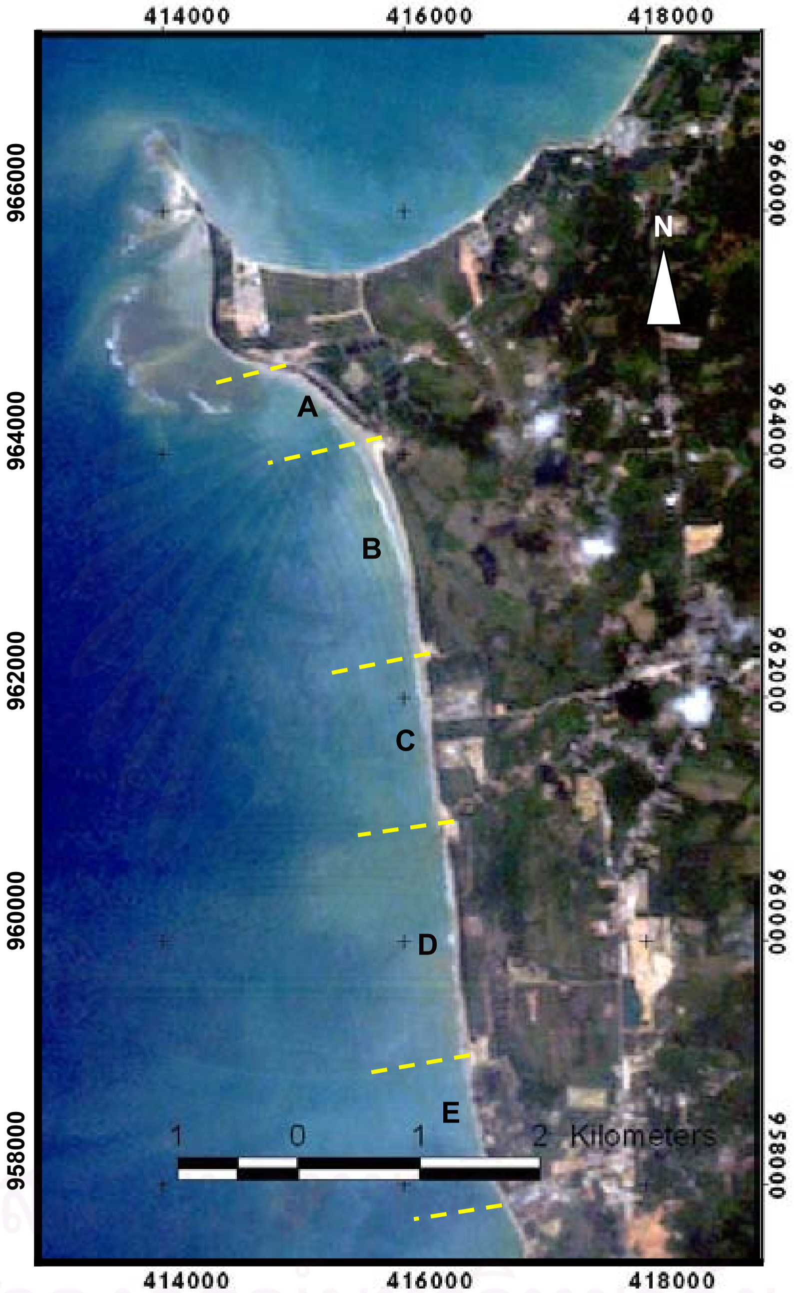

Figure 3.16 LANDSAT-5 TM satellite image showing areas in detail of study area in measurement of shoreline and beach area change, extending from southern part of Pakarang cape to inlet where Blue Village Pakarang Resort located (A), down south to inlet in the north of Sofitel Magic Lagoon Resort (B), north of Khuek Khak canal (C), Bang Niang northern inlet (D), and southern part of Bang Niang inlet (E).

3.2.3.2.1 Shoreline change and beach area analysis Satellite images were incorporated into a GIS for digitization of the shoreline reference feature as part of the change analysis. The shoreline identified by a difference in the tonal contrast between wet and dry sand, was used as the shoreline reference feature (Figures 3.17). Traditionally, the most commonly used proxy for shoreline position is the high water line (HWL) (e.g. Anders and Byrnes, 1991; Crowell, Leatherman, and Buckley, 1991; Dolan et al., 1980; Leatherman, 1983; Morton, 1991; Stafford, 1971). Once the shoreline reference features were digitized, the GIS will use to perform the change analysis.

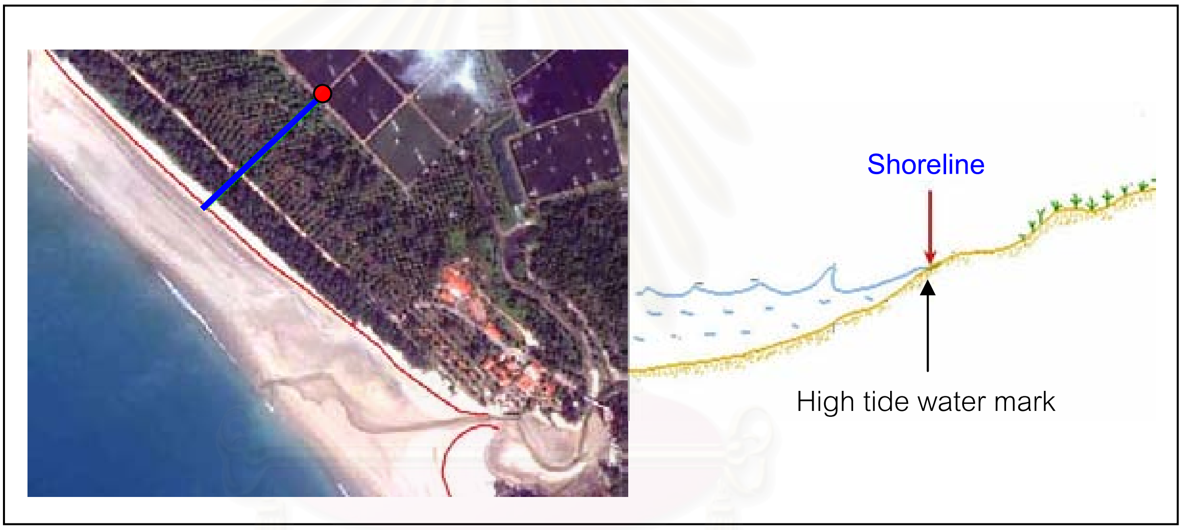

Figure 3.17 Line of shoreline (red line) drawing by use line of high tide water mark is shown superimposed on IKONOS satellite image taken one year before the 2004 tsunami.

This technique requires first creating a benchmark point to be used as a reference location in distance between shoreline and benchmark point (as a red dot in Figure 3.17). Once the benchmark was drawn, baseline-normal transects were then generated from benchmark point perpendicular to the shoreline in seaward direction (as blue line in Figure 3.17). After that, transect of each day in twelve periods was drawn. End-point shoreline change rates were calculated where each transect crosses a shoreline reference feature.

In addition to quantify the spatial distribution of shoreline change rates, an analysis of the patterns of beach area change was undertaken. Both the seaward and landward beach margins were digitized from the twelve dates of satellite images. Line of high tide water mark and edge of tree were used as a boundary of beach area (Figure 3.18).

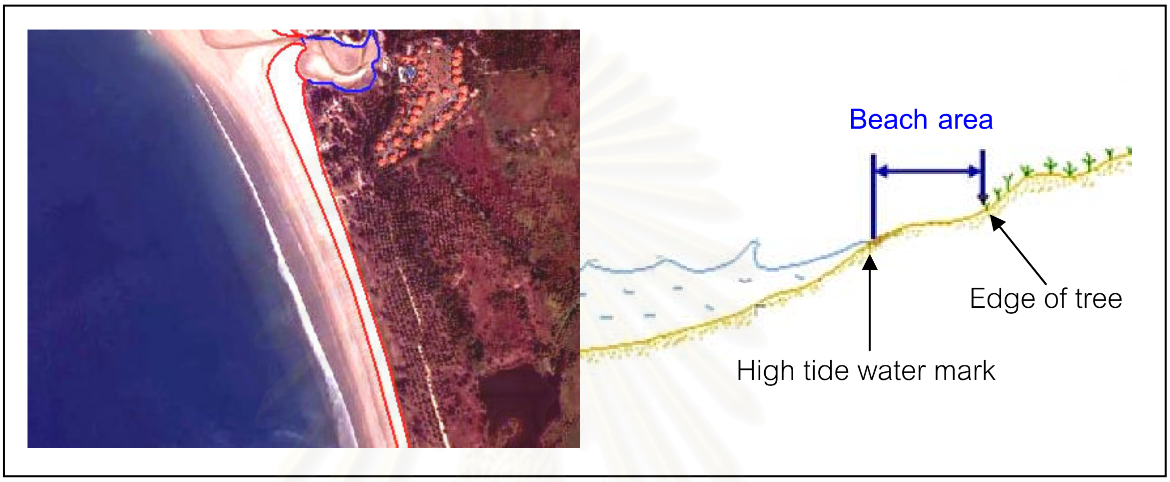

Figure 3.18 Polygons of beach area (red polygon) drawing by use boundary of high tide water mark and edge of tree is shown superimposed on IKONOS satellite image taken one year before the 2004 tsunami.

3.2.4 Discussion and conclusion

All of analyzed data including, beach profiles, sediment compositions, grain size, physical properties, beach area, and shoreline change were discussed in order to understand the recovery processes of shoreline after the 2004 Indian Ocean tsunami event. The discussion and conclusion parts will be explained in latter chapters. Discussion will be drawn upon the fact from field result in the context of how the shoreline was recovered within two years after the event. The physical properties and the distribution of beach sediments will also be discussed relatively to seasonal changes within the year 2006.

CHAPTER IV

RESULTS AND ANALYSIS

This chapter provides results of study including the interpretation from satellite images using GIS technique, beach profile measurement and sedimentological analysis from each area between Lame Pakarang to Khao Lak using data materials and methodology described in chapter III. Results were divided into three parts, starting with the analysis of shoreline change and beach area from remote sensing data and then result of field investigation, composing of measuring beach profile by surveying, and finally, the analysis in sediment samples collected from beach area. Results were analyzed in terms of the recovery process of eroded shoreline and shoreline changed after the 2004 tsunami in comparison from different periods of satellite images and field survey data.

4.1 Result from remote sensing and GIS analysis

4.1.1 Shoreline change

Shoreline was divided into five areas by using the inlet/outlet channel as a boundary. The following result will be explained area by area from north to south (Figure 4.1).

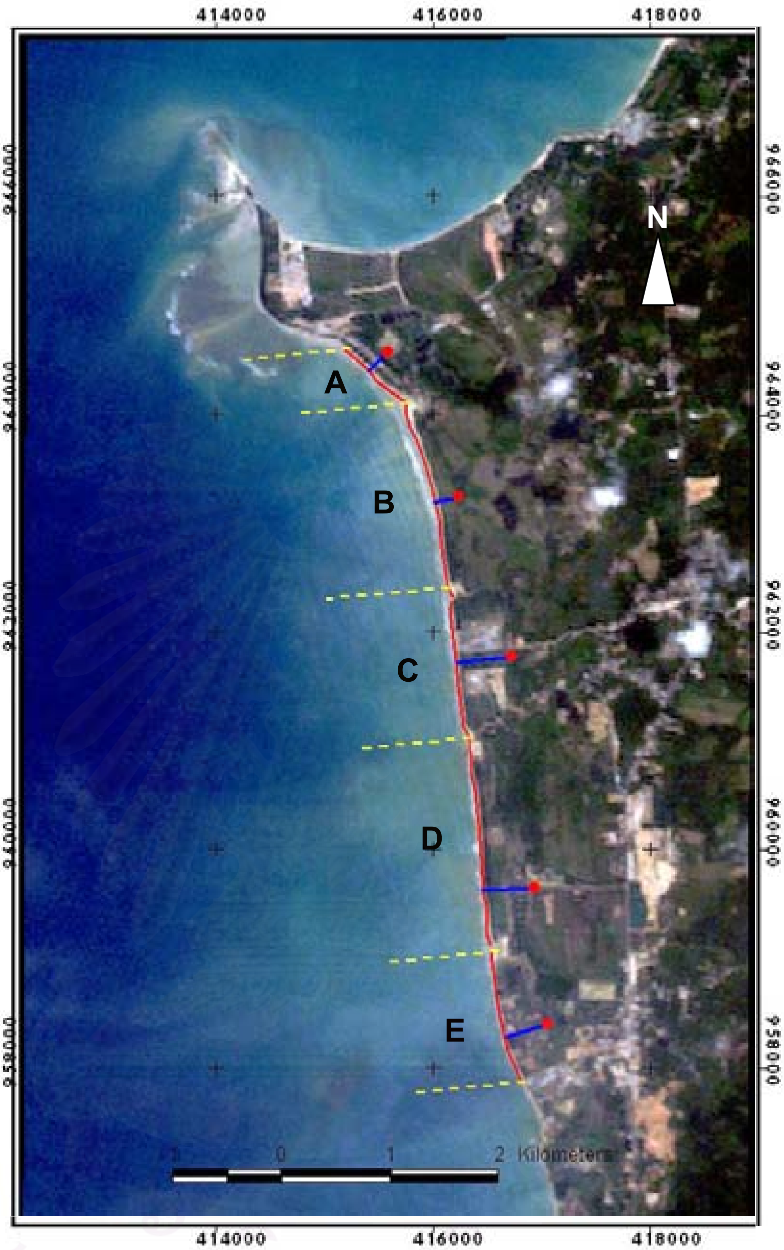

Figure 4.1 LANDSAT-5 TM satellite image showing areas in detail measurement of shoreline change, extending from southern part of Pakarang cape to inlet where Blue Village Pakarang Resort located (A), down south to inlet in the north of Sofitel Magic Lagoon (B), north of Khuek Khak canal (C), Bang Niang northern inlet (D), and southern part of Bang Niang inlet (E). Red dot is a benchmark point and blue line is a baseline-normal transects.

A) Area A

The result of the shoreline change analysis during 2002-2006 (Figure 4.2) shows that the shoreline here before the 2004 tsunami event was stable in t3position varied normally from ±1-5 m/year. After the 2004 tsunami attacked, the shoreline position was moved inland about 31.91 meters. However, after the erosion from the 2004 tsunami, shoreline keeps increasing seaward with high rate of accretion in period of December 2004 to June 2005. Shoreline accretion was calculated as 24.92 m increased. Six months after the 2004 tsunami event, the rate of accretion decreased and tended to be more stable with accretional rate of about ± 1 m (Figure 4.3). However, a recovery of shoreline in area A until November 2006 was still incomplete. Average distance of shoreline from reference point before the 2004 tsunami was 200.545 m whereas in period of June 2005 to November 2006, shoreline showed signal of more stability in accretion and erosion. Average distance of shoreline from reference point was 196.29 m. In conclusion, shoreline from area A is 97.8 % recovered.

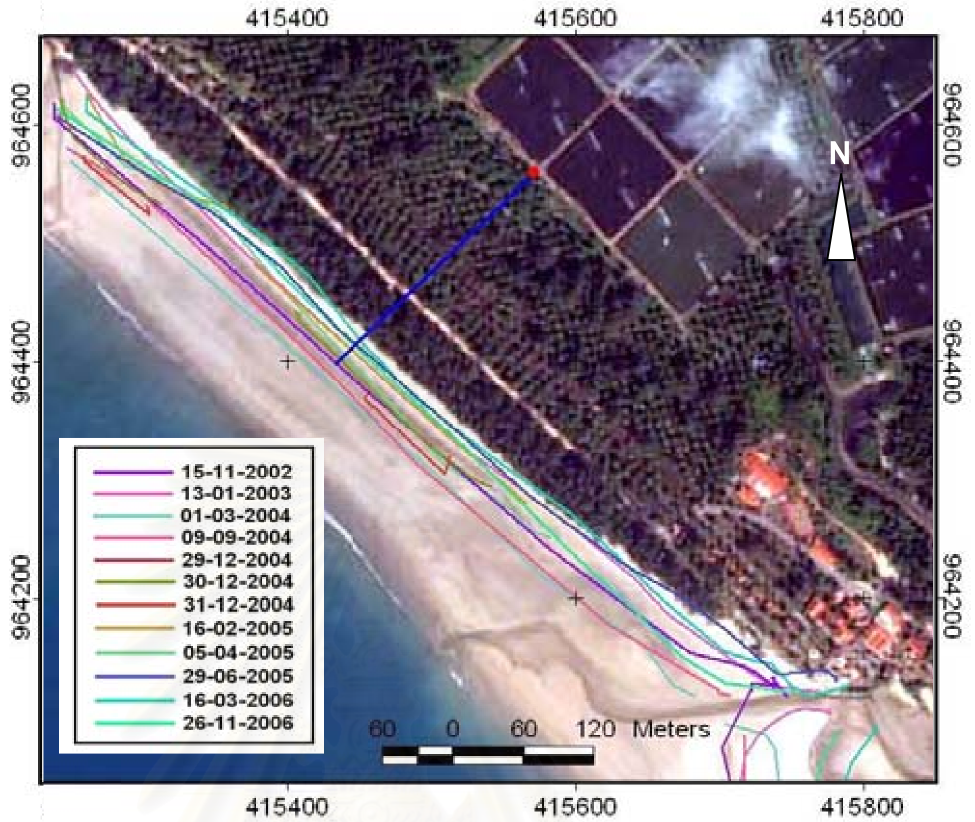

Figure 4.2 Different period of mean high tide shorelines at area A during 2002 to 2006 are shown superimposed on IKONOS satellite image taken one year before the 2004 tsunami.

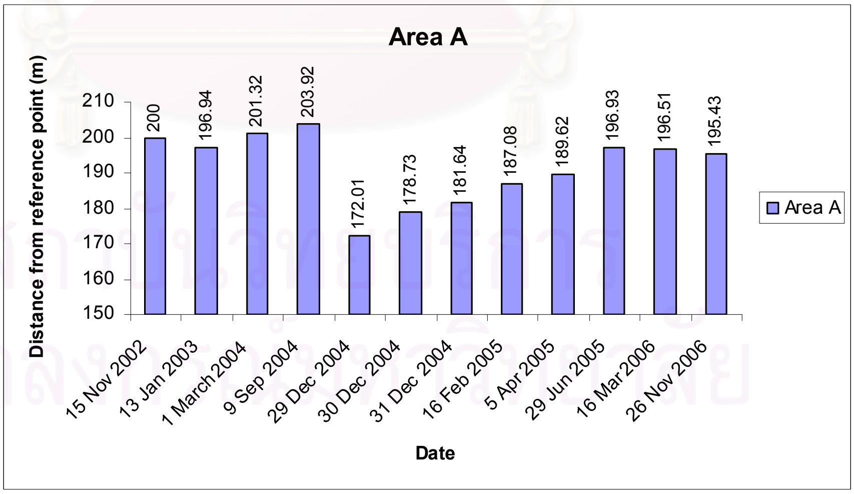

Figure 4.3 Graphic plots of shoreline change at area A. The calculation of distance from fixed reference point on different periods of satellite images was carried out.

B) Area B

The result of the shoreline change analysis during 2002-2006 from Area B (Figure 4.4) showed that the shoreline before the 2004 tsunami was stable in the equilibrium cycle as similar to area A. Shoreline here responses to the seasonal change with rate of accretion and erosion of about ±1-5 m/year. After the 2004 tsunami attacked, the shoreline position was moved inland about 13.32 meters. However, after erosion of shoreline from the 2004 tsunami, shoreline shows progradation seaward with high rate of accretion during period of January to June 2005 with accretional rate of about 12.86 m. Six months after the 2004 tsunami event, the rate of accretion decreased and almost reached stability with rate of accretion of about ± 1 m (Figure 4.5). Shoreline in area B measured until November 2006 shows almost recovered. Average distance of shoreline from reference point before the 2004 tsunami was 198.26 m, whereas in period of June 2005 to November 2006, shoreline showed more stable in accretion and erosion. Average distance of shoreline from reference point is 197.15 m. In conclusion, shoreline in area B is approximately 99.4 % recovered.

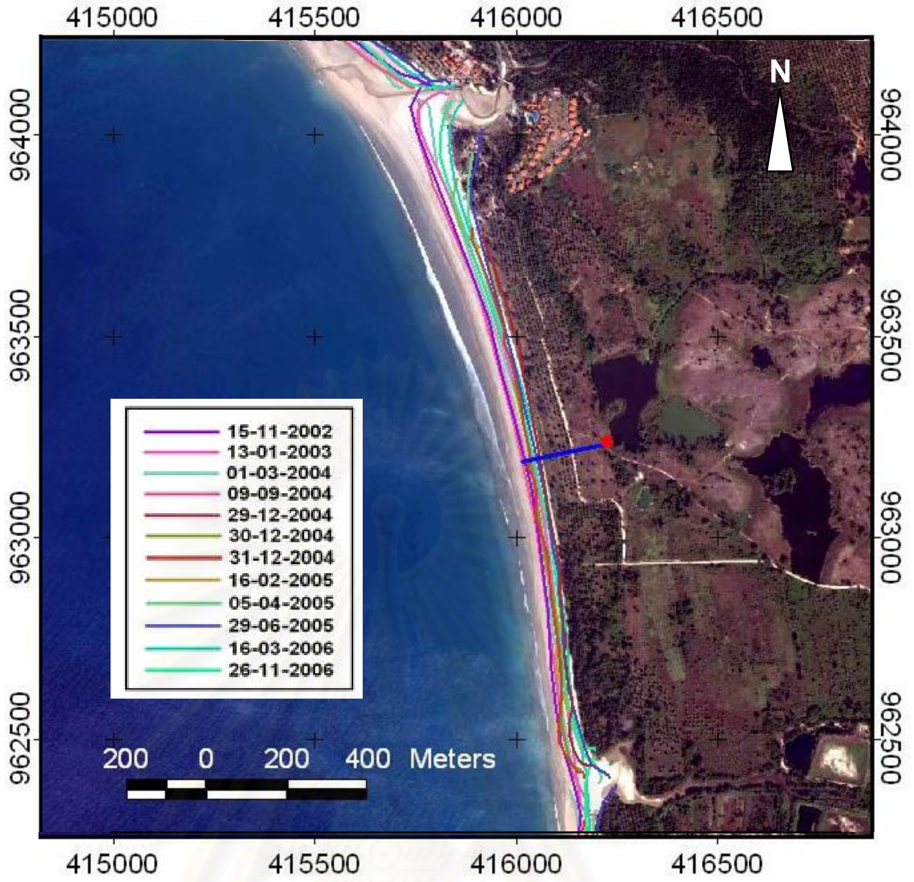

Figure 4.4 Mean high tide shoreline at area B delineated from different periods of time. Red dot indicates reference point used to calculate distance of shoreline from images. Background image is from IKONOS satellite taken one year before the 2004 tsunami.

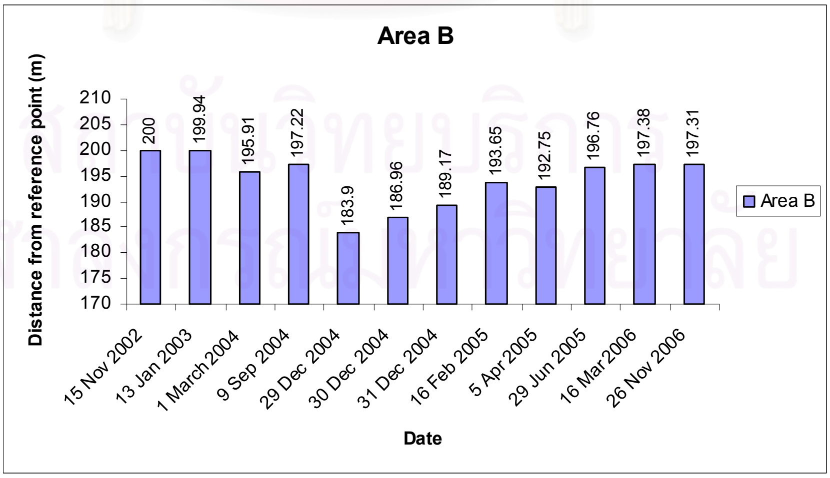

Figure 4.5 Graphic plots of distance of shoreline from similar reference point before and after the 2004 tsunami at area B.

C) Area C

The result of the shoreline change from 2002-2006 in Area C (Figure 4.6) showed stability of shoreline before the 2004 tsunami, almost in the equilibrium cycle as similar to those recognized from areas A and B. Shoreline changes here showed a response only to the seasonal change with stable rate of about ±1-5 m/year. After the 2004 tsunami attacked, the shoreline position was moved inland about 24.29 meters. However, after eroded of shoreline from 2004 tsunami, shoreline showed similar trend of progradation in seaward direction as similar trend from areas A and B with prograded rate from January to June 2005 about 13.11 m. Six months after the 2004 tsunami event, rate of accretion decreased because position of shoreline almost back to normal with stable rate of about ± 1 m (Figure 4.7). However, recover of shoreline in area C until November 2006 has not yet completed. Average distance of shoreline from reference point before the 2004 tsunami was 199.66 m whereas in period of June 2005 to November 2006, shoreline showed more stable in accretion and erosion with distance almost similar to the pre 2004 position of about 191.84 m. In conclusion, shoreline in area C is evaluated approximately 96 % recovered until 2006.

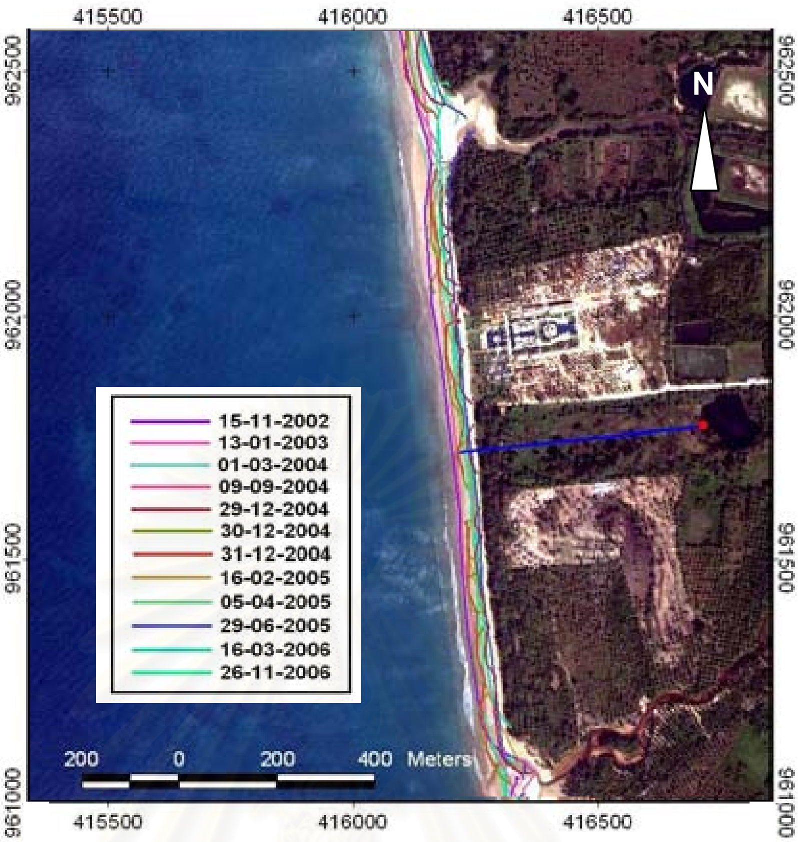

Figure 4.6 Different periods of high tide shoreline position used in calculating distance from fixed reference point at area C. Background satellite is from IKONOS image taken one year before the 2004 tsunami.

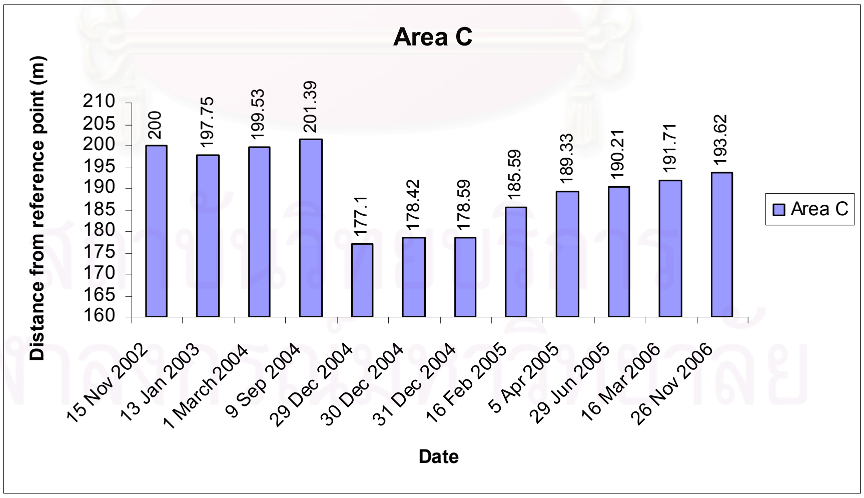

Figure 4.7 Graphic plots of distance of mean high tide shorelines from different satellite images in different periods of time at area C.

D) Area D

Shoreline change during 2002-2006 from area D (Figure 4.8) showed stability before the 2004 tsunami similar to areas A, B and C. Shoreline change before the 2004 tsunami event responded normally to seasonal change with rate of deposition and accretion fall within ±1-5 m/year. After the 2004 tsunami attacked, the shoreline position was moved inland about 24.18 meters. However, after erosion of shoreline from the 2004 tsunami, accretion of shoreline showed seaward progradation with rate of accretion in period of January to February 2005 of about 20.49 m. Two months after the 2004 tsunami event, the rate of accretion decreased and tended to approached stable state (Figure 4.9). Recovery of shoreline in area D until November 2006 shows a trend to be completely recovered. Average distance of shoreline from reference point before the 2004 tsunami was 205.82 m whereas in period of February 2005 to November 2006, shoreline showed more stable in accretion and erosion with average distance of shoreline from reference point of 204.32 m. In conclusion, shoreline from area C was analyzed approximately 99.2 % recovered.

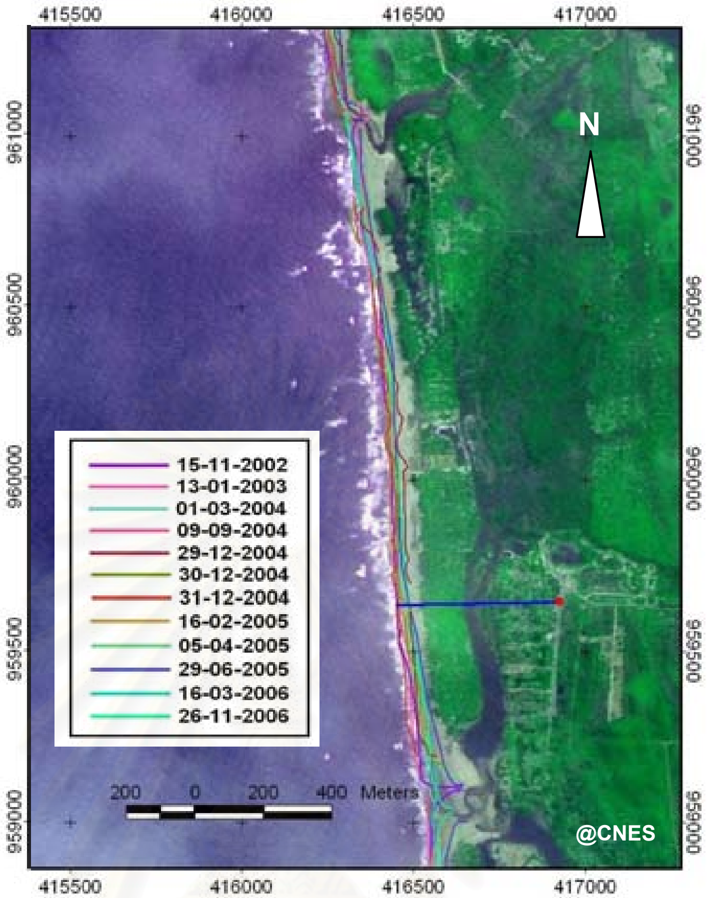

Figure 4.8 Different shoreline positions delineated from different periods of satellite images at area D. Background satellite is from SPOT-5 image taken six months after the 2004 tsunami.

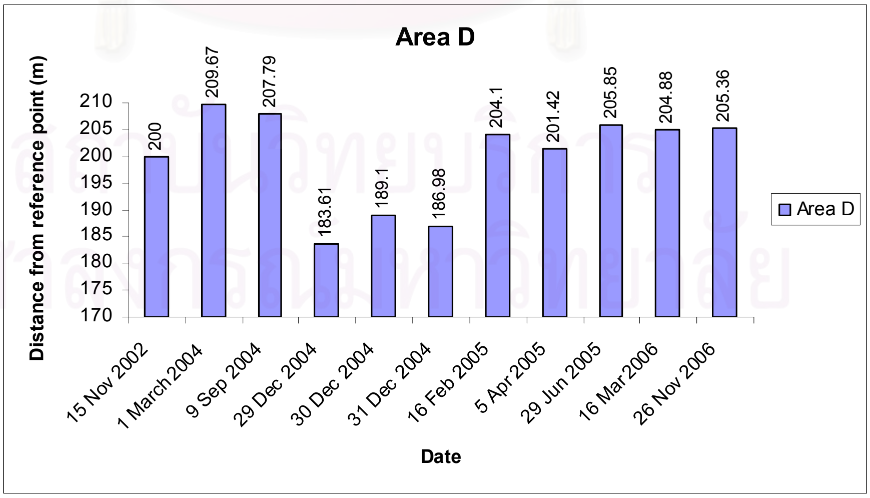

Figure 4.9 Graphic plots shows distance of shoreline from fixed reference point calculated from satellite images taken from different periods of time at area D.

E) Area E

The result of the shoreline change during 2002-2006 in area E (Figure 4.10) showed equilibrium as same as areas A, B, C, and D, but slightly differ in rate of deposition and accretion due to seasonal change with rate of about ±1-5 m/year. After the 2004 tsunami attacked, the shoreline position was moved inland about 22.23 meters. However, during January to February 2005, shoreline accretion was about 15.46 m. Two months after of the 2004 tsunami event, the rate of accretion decreased and tended to be the stable with rate of accretion almost back to normal at about ± 1 m (Figure 4.11). Recover of shoreline in area E until November 2006 was still incomplete. Average distance of shoreline from reference point before 2004 tsunami was 202.69 m, whereas in period of February 2005 to November 2006, shoreline position was closed to stable state in accretion and erosion. Average distance of shoreline from reference point was 196.36 m. In conclusion, shoreline from area E was approximately 96.8 % recovered.

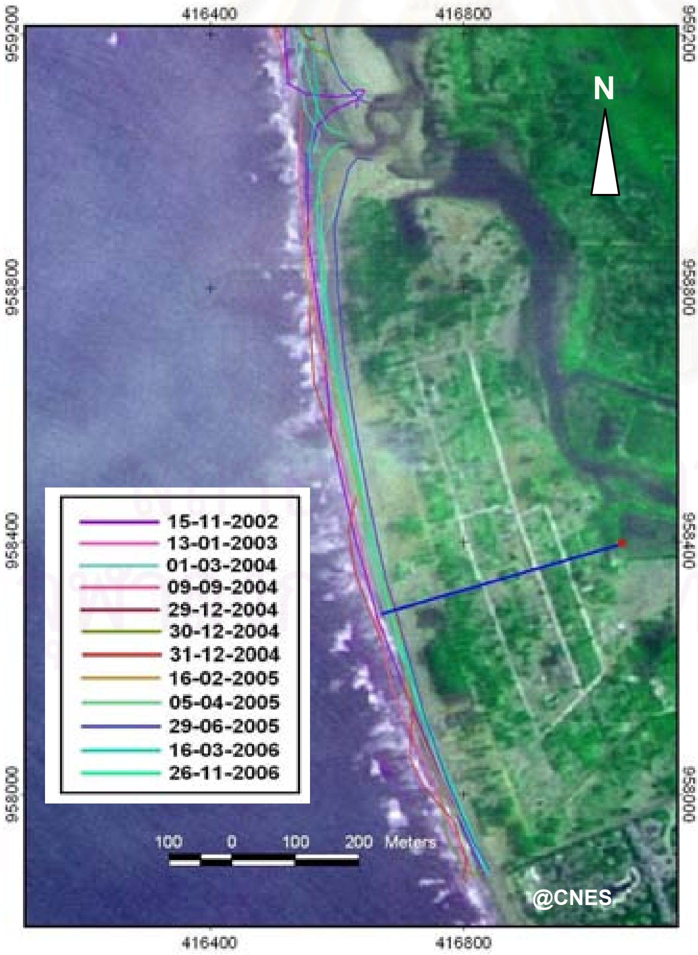

Figure 4.10 Different mean high tide shoreline position delineated from different satellite images taken in different periods of time at area E. Background satellite is from SPOT-5 image taken six months after the 2004 tsunami.

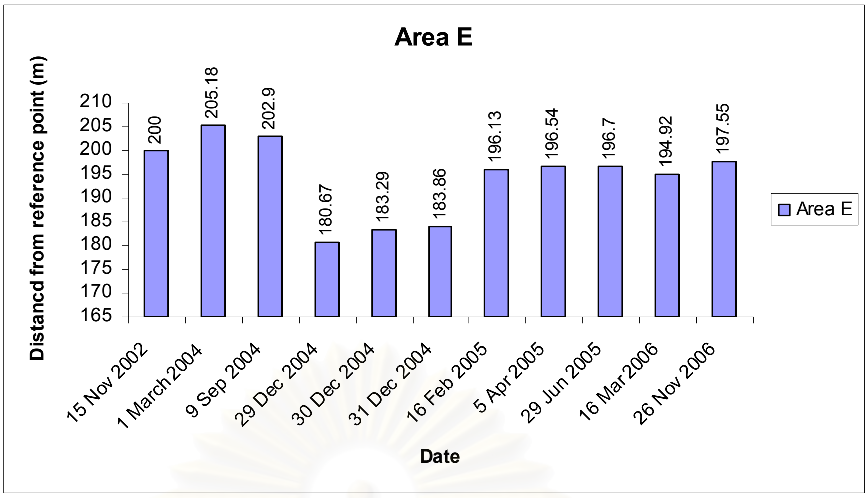

Figure 4.11 Graphic plots showing distance of shoreline from fixed reference point at area E.

4.1.1.1 Summary of analysis in shoreline change

From the result of shoreline change analysis during 2002-2006, shoreline was moved at all times (Table 4.1). Before tsunami attacked, shoreline at areas A, B, C, D, and E showed equilibrium cycle in accretion and erosion (Table 4.2). After the 2004 tsunami attacked, beach sediments were eroded, which some parts of eroded sediments were deposited inland and some parts were possibly moved back into the sea by tsunami outflow. As a result of erosion, shoreline position was moved in landward direction, then eroded sediments which were moved into the sea by tsunami slow outflow and began to transport alongshore. Thus, new beach sediment deposited into eroded shoreline and prograded in seaward direction. This is evidence by accretion of shoreline after the 2004 tsunami event in all areas (also see table 4.2). Comparison of the eroded areas makes clear that area A was affected from erosion more severe than the others. Areas C, D, and E showed moderate eroded area, whereas erosion by the 2004 tsunami in area B was lowest (Table 4.3). Five months after tsunami, shoreline had high rate of accretion of about 17.36 m, average in the whole area. Five months later, accretion rate seemed to decrease and shoreline showed a signal like stable shoreline which rate of accretion decreased to about ±1m. Finally, from the comparison in average distance of shoreline position before and after the 2004 tsunami events, areas

B and D are almost 100 % recovered, whereas area A, C, and E are still in recovery process (Table 4.4).

Table 4.1 Shoreline movement during 2002-2006.

Date / **Area**	Distance of shoreline to reference point **(m)**				
	A	**B**	**C**	**D**	**E**
15/11/2002	200	200	200	200	200
13/01/2003	196.94	199.94	197.75	(no data)	(no data)
01/03/2004	201.32	195.91	199.53	209.67	205.18
09/09/2004	203.92	197.22	201.39	207.79	202.9
29/12/2004	172.01	183.9	177.1	183.61	180.67
30/12/2004	178.73	186.96	178.42	189.1	183.29
31/12/2004	181.64	189.17	178.59	186.98	183.86
16/02/2005	187.08	193.65	185.59	204.1	196.13
05/04/2005	189.62	192.75	189.33	201.42	196.54
29/06/2005	196.93	196.76	190.21	205.85	196.7
16/03/2006	196.51	197.38	191.71	204.88	194.92
26/11/2006	195.43	197.31	193.62	205.36	197.55

Table 4.2 Accretion and erosion of shoreline during 2002-2006.

Date / Area	Distance of shoreline to reference point **(m)**				
	A	**B**	**C**	**D**	**E**
15/11/2002	200	200	200	200	200
13/01/2003	-3.06	-0.06	-2.25	(no data)	(no data)
01/03/2004	+4.38	-4.03	+1.78	+9.67	+5.18
09/09/2004	+2.6	+1.31	+1.86	-1.88	-2.28
29/12/2004	-31.91	-13.32	-24.29	-24.18	-22.23
30/12/2004	+6.72	+3.06	+1.32	+5.49	+2.62
31/12/2004	+2.91	+2.21	+0.17	-2.12	+0.57
16/02/2005	+5.44	+4.48	+7	+17.12	+12.27
05/04/2005	+2.54	-0.9	+3.74	-2.68	+0.41
29/06/2005	+7.31	+4.01	+0.88	+4.43	+0.16
16/03/2006	-0.42	+0.62	+1.5	-0.97	-1.78
26/11/2006	-1.08	-0.07	+1.91	+0.48	+2.63

\+ = accretion (compare to upper value)

\- = erosion (compare to upper value)

Table 4.3 Summary of shoreline recovered after the 2004 tsunami.

Date / **Area**	Distance of shoreline to reference point **(m)**				
	A	**B**	**C**	**D**	**E**
9 Sep 2004 (before)	203.92	197.22	201.39	207.79	202.9
29 Dec 2004 (after 3 day)	172	183.9	177.1	183.61	180.67
Lost by tsunami	**31.92**	**13.32**	**24.29**	**24.18**	**22.23**
26 Nov 2006	195.43	197.31	193.62	205.36	197.55
Recovery	**23.43**	**13.41**	**16.52**	**21.75**	**16.88**

Table 4.4 Comparison of distance of shoreline before and after tsunami attacked.

Area	**A**	**B**	**C**	**D**	**E**
Distance of shoreline*	200.55	198.27	199.67	205.82	202.69
Distance of shoreline**	196.29	197.15	191.85	204.32	196.37
Recovery percentage	97.88	99.44	96.08	99.27	96.88

* Average distance of shoreline from reference point before tsunami.

**Average distance of shoreline from reference point after tsunami which shoreline show signal of stable in accretion and erosion.

4.1.2 Change in beach area

Analysis in beach area changed was calculated by fixing mean high tide shoreline as the outer boundary of beach area. Areas were divided into five sectors similar to shoreline change analysis (Figure 4.12). The result of the study will be explained area by area from north to south.

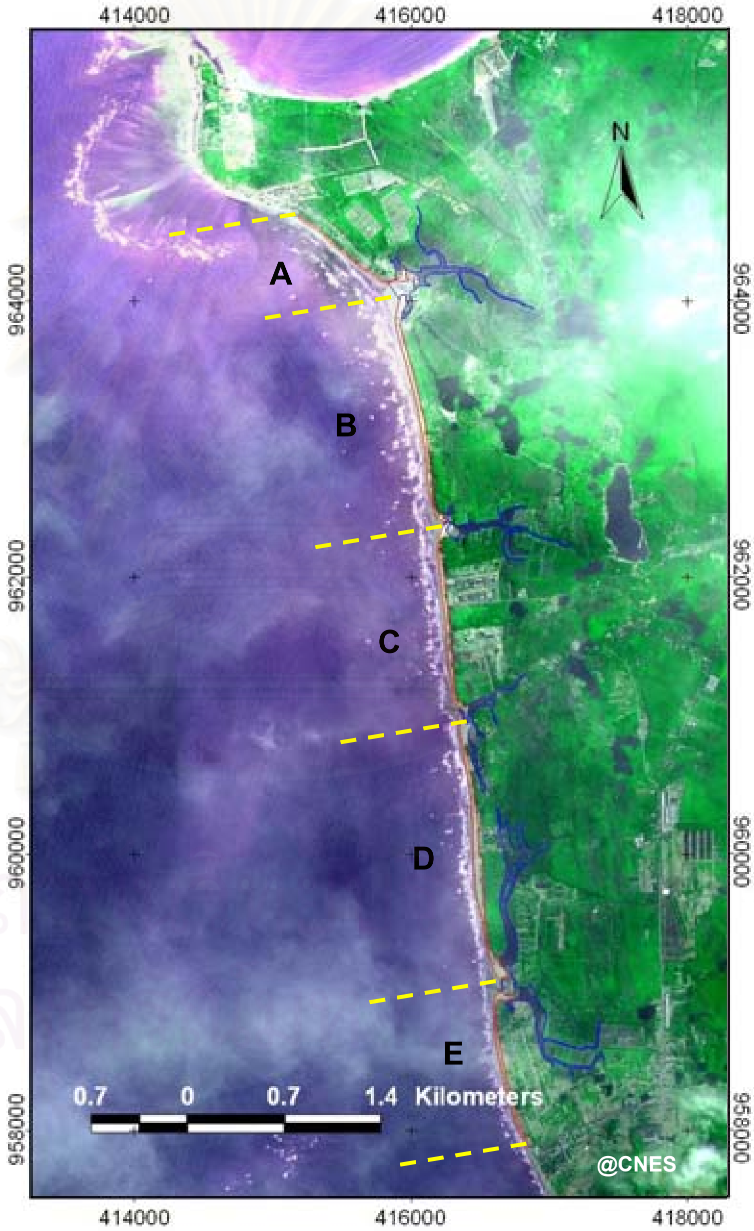

Figure 4.12 SPOT-5 satellite image showing coastal sectors used in calculating beach area changed, indicating by red polygon.

A) Area A

The result of the beach area change from 2002-2006 (Figure 4.14 and Table 4.5) showed that the beach area change before the 2004 tsunami event tended to increase spatially from 16,401 m^2 in November 2002 to 19,030 m^2 in September 2004. However, beach area was decreased to 11,141 m^2 in January 2003. Three days after the 2004 tsunami attacked, beach area was disappeared about 19,030.53 m^2 and beach shape was also deformed. It was eroded and split into two beaches from the erosion of the 2004 tsunami (Figure 4.14 picture 30/12/2004). However, after beach area was eroded by the 2004 tsunami, the recovery process showed an optimistic signal by keep increasing in beach area. Split beach areas continued to merge together into continuous beach again in April 2005, from the satellite image data evidence (Figure 4.14 picture 30/12/2004 to 5/04/2005). Beach area continued to increase from 0 m^2 in December 2004 to 23,109 m^2 in November 2006. It exceeds beach area before tsunami attacked (Figure 4.15). In conclusion, beach area within area A is completely recovered.

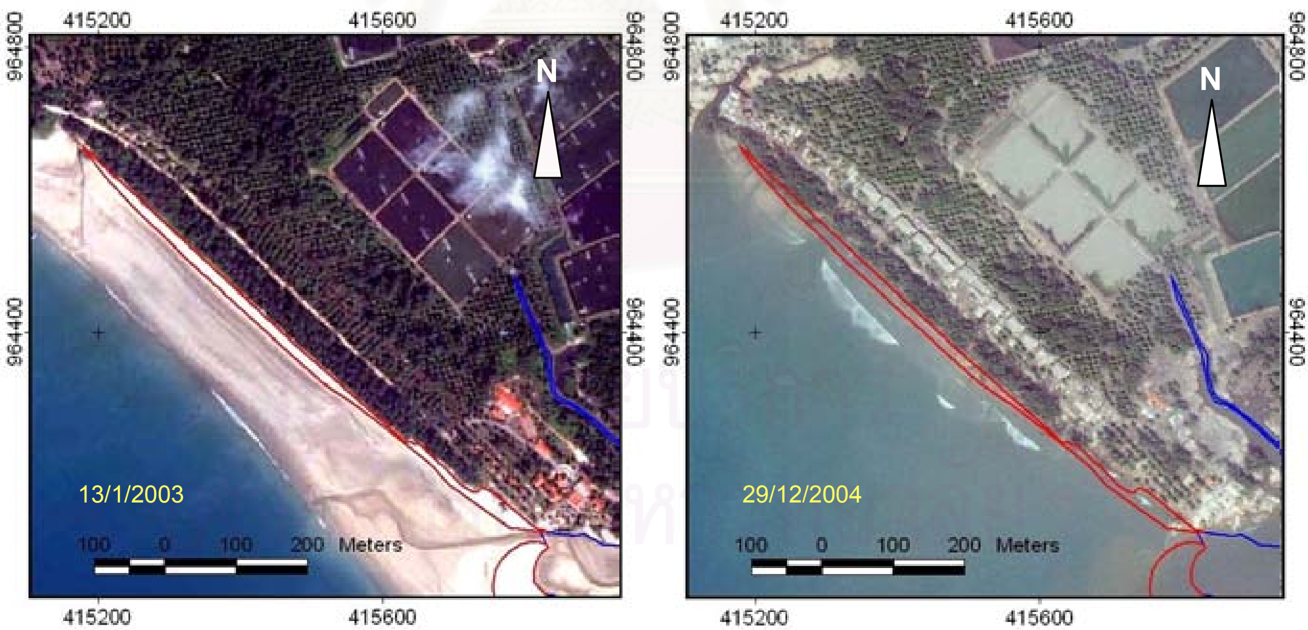

Figure 4.13 Comparing IKONOS satellite images taken before and after tsunami showing eroded beach area at area A. Left image, red polygon indicated beach area before the 2004 tsunami and right image red polygon shown beach area lost after tsunami.

Figure 4.14 Series of satellite images showing beach area change at area A before and after the 2004 tsunami event. Red polygon in each image indicated beach area from mean high tide shoreline.

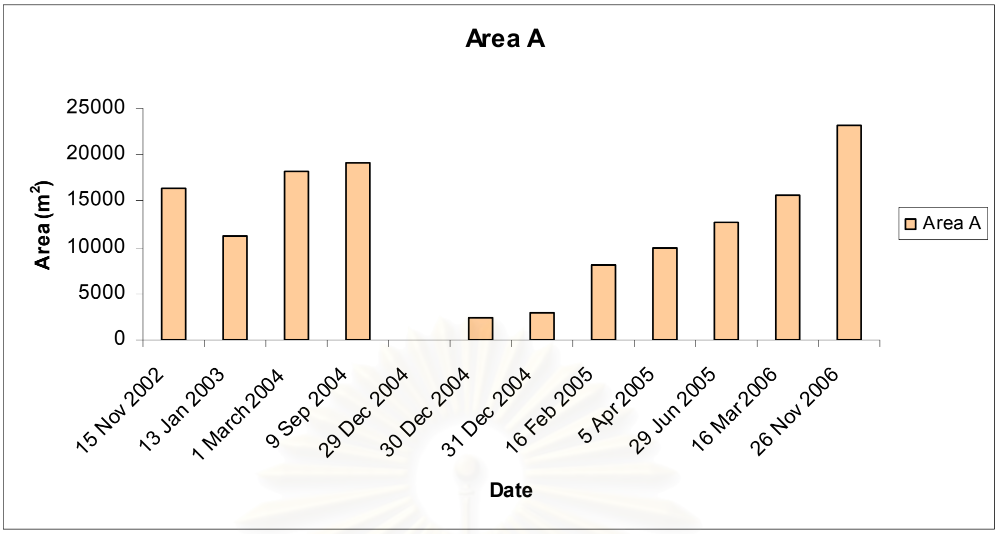

Figure 4.15 Graphic plots of beach area change at area A.

Table 4.5 Beach area change during 2002-2006 at area A

DATE	Area A (m^2)
15/11/2002	16,401.91
13/01/2003	11,141.16
01/03/2004	18,135.93
09/09/2004	19,030.53
29/12/2004	0.00
30/12/2004	2,393.85
31/12/2004	2,858.07
16/02/2005	8,010.8
05/04/2005	9,880.85
29/06/2005	12,750.09
16/03/2006	15,652.49
26/11/2006	23,109.02

B) Area B

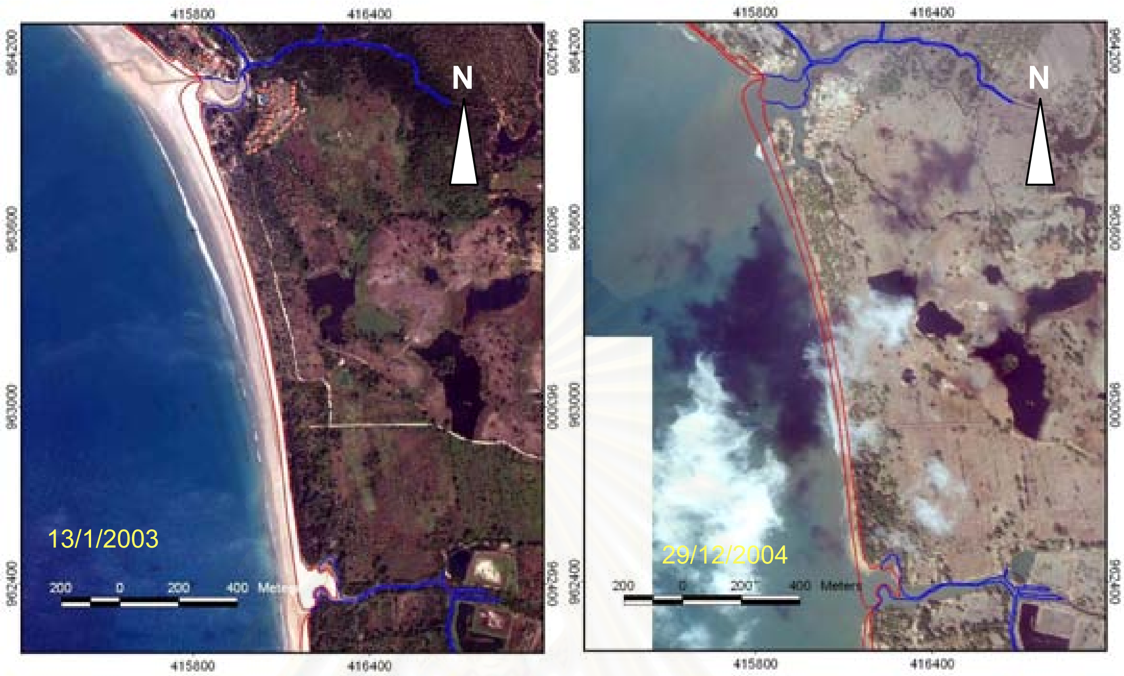

Figure 4.16 Comparing IKONOS satellite images taken before and after tsunami showing eroded beach area and new island appeared at the south of inlet/outlet channel at area B in right image. Left image, red polygon indicated beach area before the 2004 tsunami and right image red polygon shown beach area lost after tsunami.

The result of the beach area change analysis of 2002-2006 year (Figure 4.17 and Table 4.6) showed that the beach area changed before the 2004 tsunami had stable. Beach area is calculated with ranging from 61,741 to 69,526 m^2 with the change about ± 4,000 m^2 during 2002-2004. Three days after the 2004 tsunami attacked, beach area was disappeared about 56,393.17 m^2, and beach shape was also changed. It was eroded and split into two beaches, and new small sand island appeared at the south of inlet/outlet channel (Figure 4.16). Former sediment at mouth of inlet/outlet channel was completely eroded. However, after beach area was eroded by the 2004 tsunami, the recovery process showed an optimistic signal by keep increasing in beach area. New sand island at the inlet/outlet channel was merged with the land by new sediment deposited after tsunami and split beach areas continued to merge together into one continuous beach again in April 2005 (Figure 4.17 picture 29/12/2004 to 05/04/2005). Beach area continued to increase from 13,133 m^2 in December 2004 to 68,629 m^2 in March 2006 that closely to the beach area before tsunami attacked time (Figure 4.18). In conclusion, beach area at area B is completely recovered.

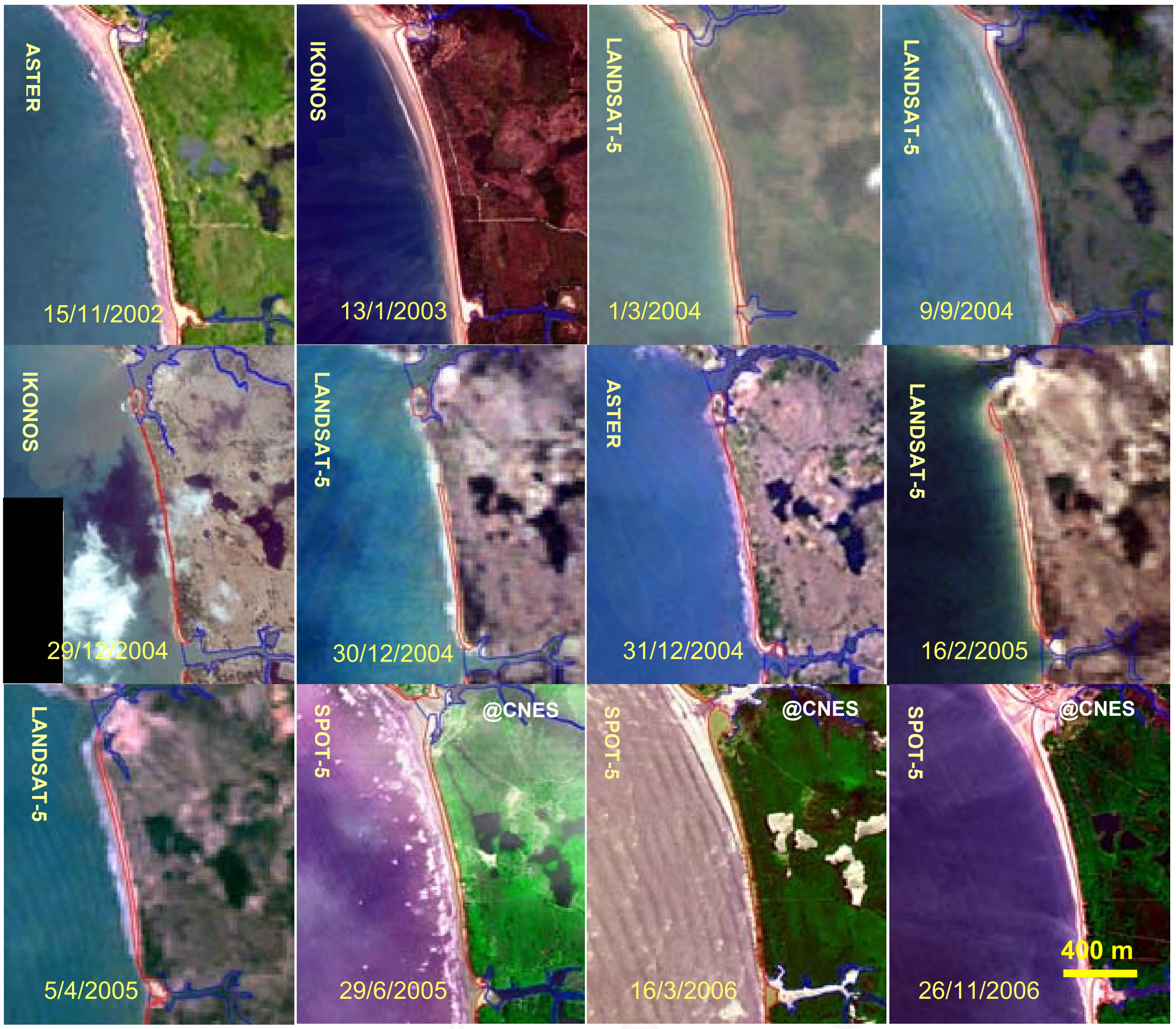

Figure 4.17 Series of satellite images taken before and after the 2004 at area B showing the change of beach area and completely recovered in 2006. Red polygon in each image indicated beach area from mean high tide shoreline.

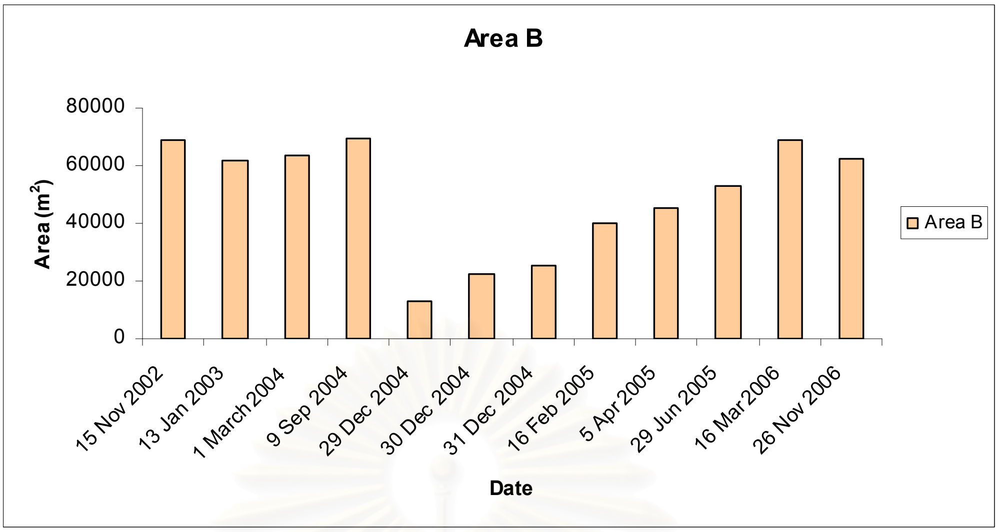

Figure 4.18 Graphic plots of beach area change at area B before and after the 2004 tsunami.

Table 4.6 Beach area change during 2002-2006 at area B.

DATE	Area B (m^2)
15/11/2002	68,730.68
13/01/2003	61,741.93
01/03/2004	63,590.59
09/09/2004	69,526.36
29/12/2004	13,133.19
30/12/2004	22,182.83
31/12/2004	25,379.70
16/02/2005	39,880.24
05/04/2005	45,113.29
29/06/2005	53,199.11
16/03/2006	68,629.68
26/11/2006	62,113.13

C) Area C

Figure 4.19 Comparing IKONOS satellite images taken before and after tsunami show eroded beach area at area C which split into several parts from the erosion of tsunami and shape of beach is change into half-circle shape similar to the cuspate beach morphology. Red polygon indicated beach area in each period.

Beach area changed before the 2004 tsunami from Area C (Figure 4.20, Figure 4.21 and Table 4.7) exhibited equilibrium with area normally changed from 36,155 to 55,405 m^2. Average of area was about 46,235 m^2 with the change of about ± 10,000 m^2 during 2002-2004. Three days after the 2004 tsunami attacked, beach area was disappeared about 33,024.28 m^2 and beach shape was also changed. Beach face was eroded away and split into several parts by the erosion of tsunami. Shape of beach was became half-circle as cuspate beach morphology (Figure 4.19) and also sediments at mouth of inlet/outlet channel were completely eroded. However, after eroded of beach area from the 2004 tsunami, the recovery process showed an optimistic signal by keep increasing in beach area. Beach cuspate-liked shape was merged together again by new sediment deposited in February 2005 (Figure 4.20 picture 29/09/2004 to 16/02/2005). Beach area continued to increase from **15,579.23**m^2 in December 2004 to **51,701.62** m^2 in November 2006. However, beach area seemed to stable since June 2005 (Table 4.7). Average beach area from June 2005 to November 2006 was

47,400 m^2 that exceeds the average beach area before the 2004 tsunami attacked time. In conclusion, beach area at area C was completely recovered.

Figure 4.20 Series of satellite images used for calculating beach area change at area C. Red polygon indicated beach area which shows rapid return of beach sediment within two years (January 2005-November 2006).

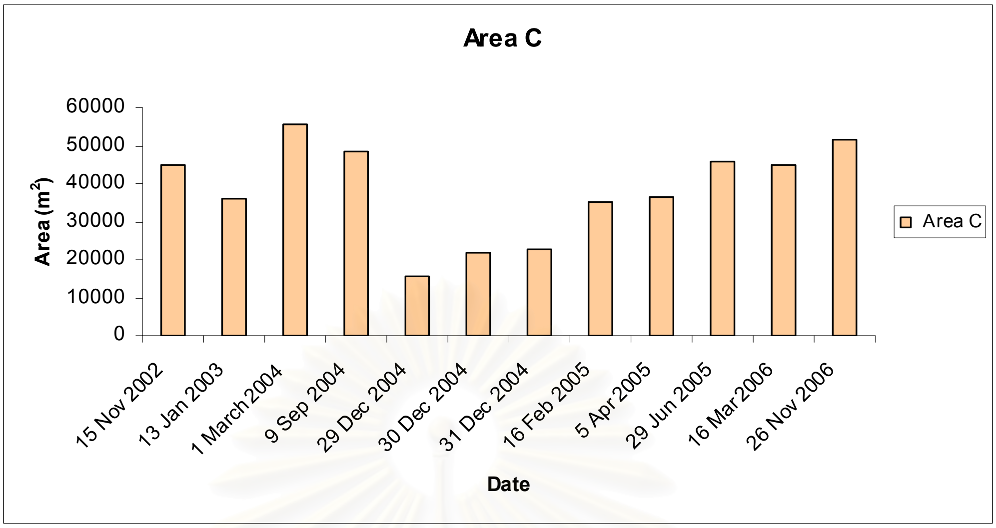

Figure 4.21 Graphic plots showing beach areas changed during 2002-2006 from satellite images interpretation at area C.

Table 4.7 Beach area change during 2002-2006 at area C.

DATE	Area C (m^2)
15/11/2002	44,779.08
13/01/2003	36,155.45
01/03/2004	55,405.86
09/09/2004	48,603.51
29/12/2004	15,579.23
30/12/2004	21,828.77
31/12/2004	22,621.30
16/02/2005	35,046.45
05/04/2005	36,424.47
29/06/2005	45,675.36
16/03/2006	44,823.58
26/11/2006	51,701.62

D) Area D

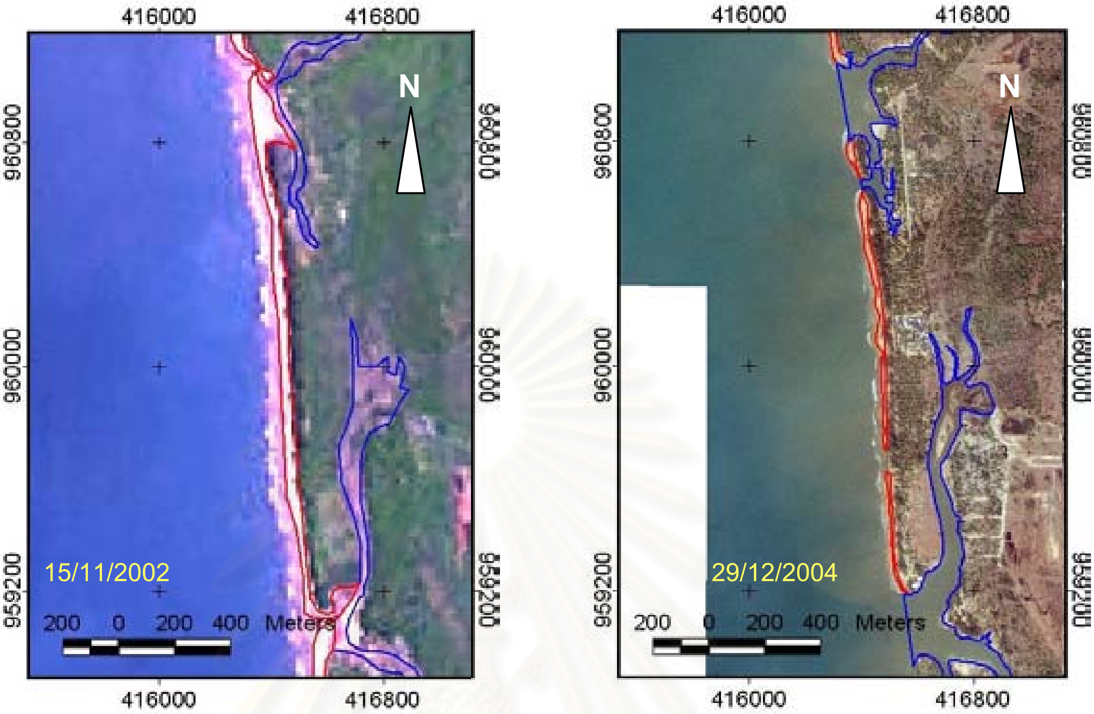

Figure 4.22 Comparing of satellite images before and after tsunami show eroded of sediment at beach area and mouth of inlet/outlet channel. Right image showing new island appear at the south of and inlet/outlet channel after tsunami attacked at area D (red polygon indicated beach area in each period).

From 2000 to 2006, beach area in Area D showed erosion from **86,656.23** m^2 in November 2002 to **70,561.83** m^2 in September 2004 (Figure 4.23 Figure 4.24 and Table 4.8). Beach area was eroded about 16,094 m^2 during 2002-2004. Three days after the 2004 tsunami attacked, beach area was disappeared about 46,774.77 m^2 and beach shape was deformed. New sand island appeared at the south of inlet/outlet channel (Figure 4.22), and former sediments at mouth of inlet/outlet channel were completely eroded. However, after the 2004 tsunami, the recovery process showed seaward progradation. Sandy island at the inlet/outlet channel was merged with the land by new sediment deposited in April 2005 (Figure 4.23 picture 29/12/2004 to 05/04/2005). Beach area continued to increase from **23,787.06** m^2 in December 2004 to **98,182.34** m^2 in November 2006 that exceeds beach area before tsunami attacked time (Table 4.8). In conclusion, beach area at area D is completely recovered.

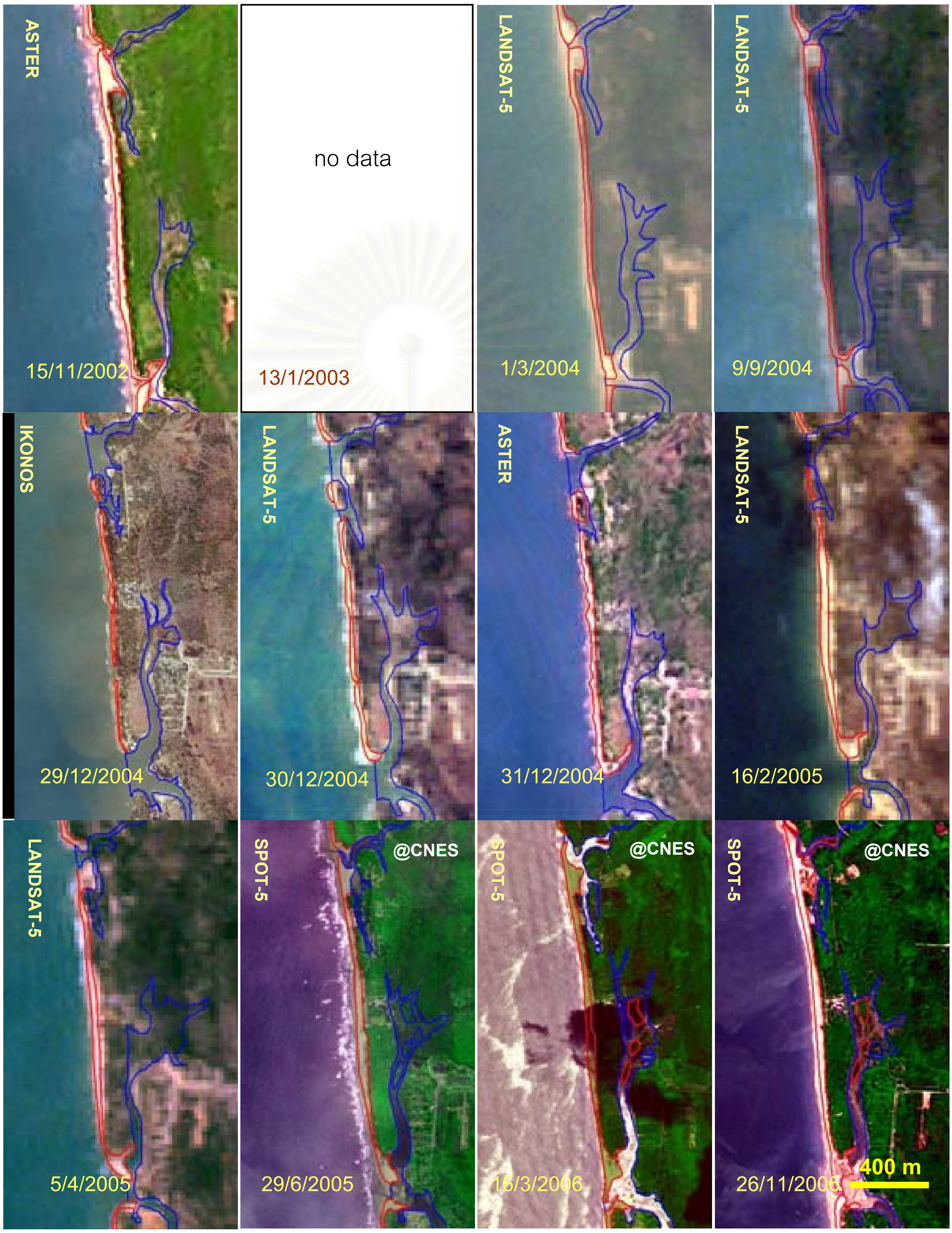

Figure 4.23 Series of satellite images used for calculating beach area change at area D. Red polygon in each image indicated beach area from mean high tide shoreline.

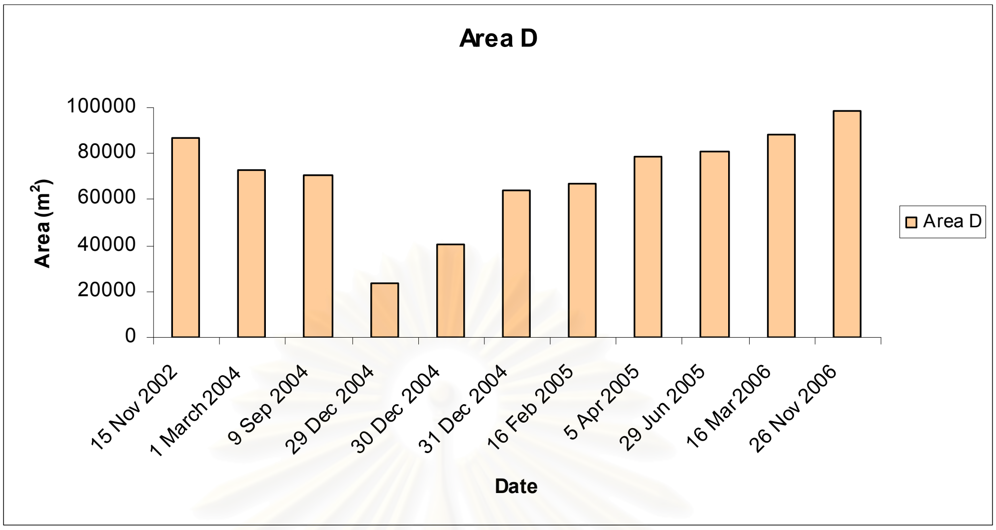

Figure 4.24 Graphic plots showing beach area change at area D.

Table 4.8 Beach area change during 2002-2006 at area D.

DATE	Area D (m^2)
15/11/2002	86,656.23
13/01/2003	(no data)
01/03/2004	72,679.54
09/09/2004	70,561.83
29/12/2004	23,787.06
30/12/2004	40,208.44
31/12/2004	63,959.92
16/02/2005	66,858.13
05/04/2005	78,506.21
29/06/2005	81,085.26
16/03/2006	88,144.74
26/11/2006	98,182.34

E) Area E

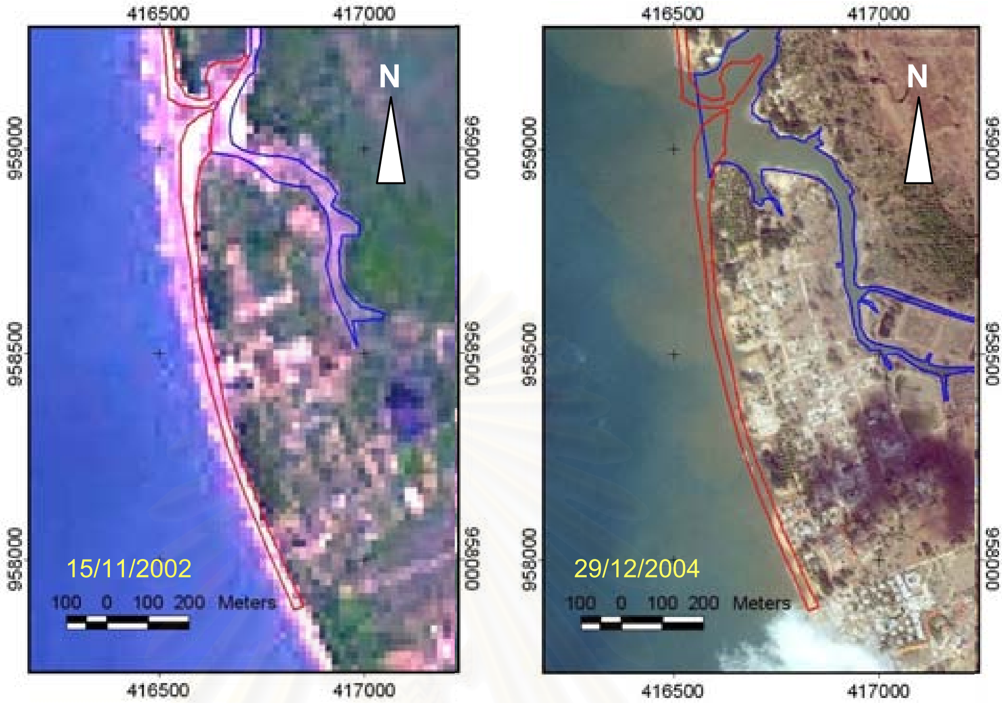

Figure 4.25 Comparing of satellite images before and after tsunami show eroded of sediment at beach area and mouth of inlet/outlet channel at area E. Red polygon indicated beach area before tsunami which almost disappear after the disaster event as shown in right image

Area E showed equilibrium of erosion and deposition during 2002 to 2004 with area change ranging from **35,291.91** to **36,476.63** m^2 (Figure 4.26, Figure 4.27 and Table 4.9) Average change of area was about 33,254 m^2 with changing in area was ± 5,000 m^2 during 2002-2004. Three days after the 2004 tsunami attacked, beach area was eroded about 36,476.63 m^2 and the pre 2004 sediments at mouth of inlet/outlet channel was completely eroded (Figure 4.25). However, after the 2004 tsunami, the recovery process made beach return in seaward progradation. New sediments were filled up at mouth of inlet/outlet channel and completed beach area (Figure 4.26 picture 26/06/2005 to 26/11/2006). Beach area continued to increase from **0** m^2 in December 2004 to **25,898.47** m^2 in November 2006. However, beach area seemed to stable since April 2005 that average beach area from April 2005 to November 2006 was 27,731.03 m^2 and changing in area was about ± 1,500 m^2 that is still less than the average beach area before tsunami attacked time (Figure 4.27). In conclusion, beach area at area E is incompletely recovered.

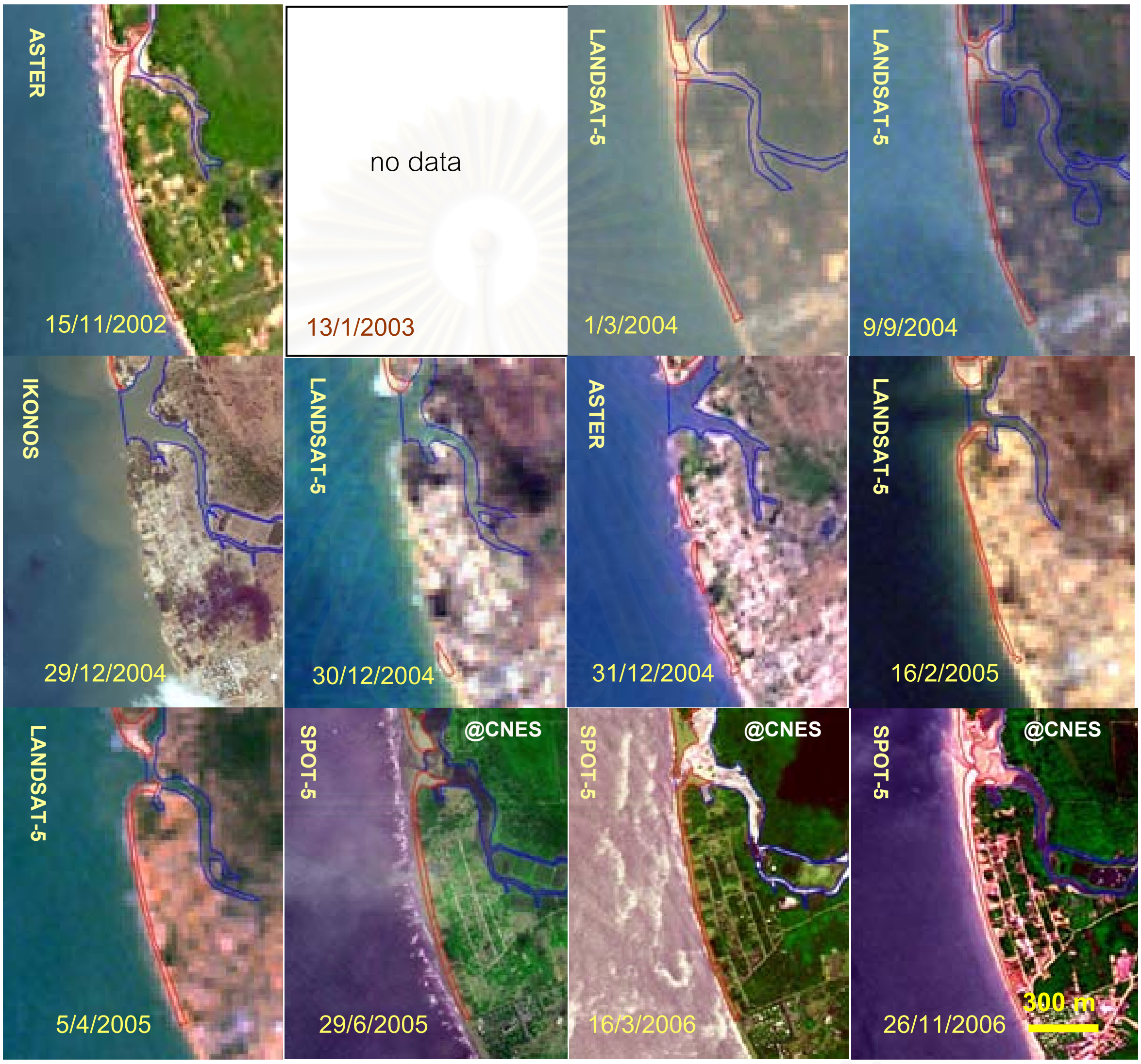

Figure 4.26 Series of satellite images used for calculating beach area change at area E. Red polygon in each image indicated beach area from mean high tide shoreline

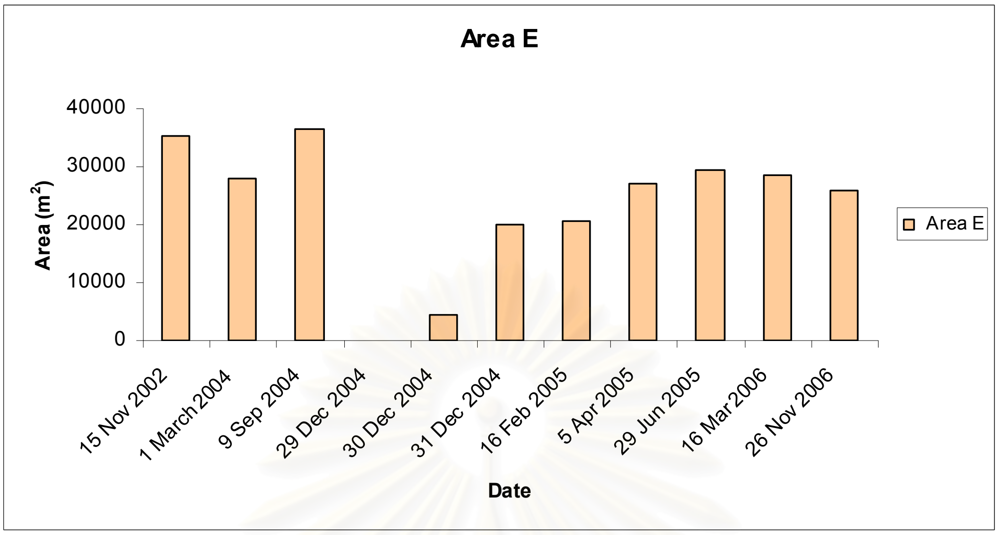

Figure 4.27 Graphic plots of beach area change at area E.

Table 4.9 Beach area change during 2002-2006 at area E.

DATE	Area E (m^2)
15/11/2002	35,291.91
13/01/2003	(no data)
01/03/2004	27,994.37
09/09/2004	36,476.63
29/12/2004	0.00
30/12/2004	4,401.46
31/12/2004	20,071.35
16/02/2005	20,542.55
05/04/2005	27,118.62
29/06/2005	29,482.64
16/03/2006	28,424.37
26/11/2006	25,898.47

4.1.2.1 Summary of analysis in beach area change

From the result of analysis in beach area change during 2002-2006, beach area changes through time (Table 4.10). Before the 2004 tsunami attacked, beach area at areas A, B, C, D, and E showed equilibrium cycle in accretion and erosion (Table 4.11). After tsunami attacked, beach sediments were eroded, which part of eroded sediments was deposited in land and some parts were moved into the sea possibly by tsunami outflow. Beach areas were increased which could recognize from a continue accretion of beach area (Table 4.11). Comparing the eroded area to the whole study area show that areas A and E are the most eroded area, whereas, area B is moderate eroded area, and areas C and D are the fewest eroded area (Table 4.12). The first six months after the 2004 tsunami event, areas C and E exhibited high rate of accretion of beach area, then six months later, accretion rate seemed to decrease and beach area show signal of balance in rate of accretion and erosion. In contrast, areas A, B, and D continued to deposit and gained more area and exceeded beach area before tsunami attacked.

Finally, from the comparing of average area of beach before and after tsunami event, areas A, C and D are completely recovered, whereas areas B and E are still in recovery process.

Table 4.10 Calculation of beach area during 2002-2006.

Date / Area	Beach area (m^2)				
	A	**B**	**C**	**D**	**E**
15/11/2002	16,401.91	68,730.68	44,779.08	86,656.23	35,291.91
13/01/2003	11,141.16	61,741.93	36,155.45	(no data)	(no data)
01/03/2004	18,135.93	63,590.59	55,405.86	72,679.54	27,994.37
09/09/2004	19,030.53	69,526.36	48,603.51	70,561.83	36,476.63
29/12/2004	0.00	13,133.19	15,579.23	23,787.06	0.00
30/12/2004	2,393.85	22,182.83	21,828.77	40,208.44	4,401.46
31/12/2004	2,858.07	25,379.70	22,621.30	63,959.92	20,071.35
16/02/2005	8,010.80	39,880.24	35,046.45	66,858.13	20,542.55
05/04/2005	9,880.85	45,113.29	36,424.47	78,506.21	27,118.62
29/06/2005	12,750.09	53,199.11	45,675.36	81,085.26	29,482.64
16/03/2006	15,652.49	68,629.68	44,823.58	88,144.74	28,424.37
26/11/2006	23,109.02	62,113.13	51,701.62	98,182.34	25,898.47

Table 4.11 Beach area increased and decreased during 2002-2006.

Date / Area	Beach area (m^2)				
	A	B	C	D	E
15/11/2002	16,401.91	68,730.68	27,694.03	86,656.23	35,291.91
13/01/2003	-5,260.75	-6,988.75	-8,623.63	(no data)	(no data)
01/03/2004	+6,994.77	+1,848.66	+19,250.41	-13,976.69	-7,297.54
09/09/2004	+894.6	+5,935.77	-6,802.35	-2,117.71	+8,482.26
29/12/2004	-19,030.53	-56,393.17	-33,024.28	-46,774.77	-36,476.63
30/12/2004	+2,393.85	+9,049.64	+6,249.54	+16,421.38	+4,401.46
31/12/2004	+464.22	+3,196.87	+792.53	+23,751.48	+15,669.89
16/02/2005	+5,152.73	+14,500.54	+12,425.15	+2,898.21	+471.2
05/04/2005	+1,870.05	+5,233.05	+1,378.02	+11,648.08	+6,576.07
29/06/2005	+2,869.24	+8,085.82	+9,250.89	+2,579.05	+2,364.02
16/03/2006	+2902.4	+15,430.57	-851.78	+7,059.48	-1,058.27
26/11/2006	+7,456.53	-6,516.55	+6,878.04	+10,037.6	-2,525.9

+ = increased (compare to upper value)

- = decreased (compare to upper value)

Table 4.12 Summary of beach area change showing the value lost and recover of beach area before and after the 2004 tsunami.

Date / Area	**Beach area (m^2)**				
	A	**B**	**C**	**D**	**E**
9 Sep 2004 (before)	19,030.53	69,526.36	48,603.51	70,561.83	36,476.63
29 Dec 2004 (after 3 day)	0.00	13,133.19	15,579.23	23,787.06	0.00
Lost by tsunami	**19,030.53**	**56,393.17**	**33,024.28**	**46,774.77**	**36,476.63**
Lost percentage	*100.00*	*81.11*	*67.95*	*66.29*	*100.00*
26 Nov 2006	23,109.02	62,113.13	51,701.62	98,182.34	25,898.47
Recovery	**23,109.02**	**48,979.94**	**36,122.39**	**74,395.28**	**25,898.47**
Recovery percentage	*121.43*	*89.34*	*106.37*	*139.14*	*71.00*

4.2 Result from field investigation

As stated in previous chapters, measurement of beach profiles was one of the methods to recognize the change in beach and foreshore configuration in different season. In this research, the measurement has been carried out since January to November 2006. Beach profiles were done in four areas that were eroded by 2004 Indian Ocean tsunami. The areas are located close to the inlet/outlet channel (Figure 3.7). The result of the study will be explained area by area from the north to the south.

4.2.1 Blue Village Pakarang Resort

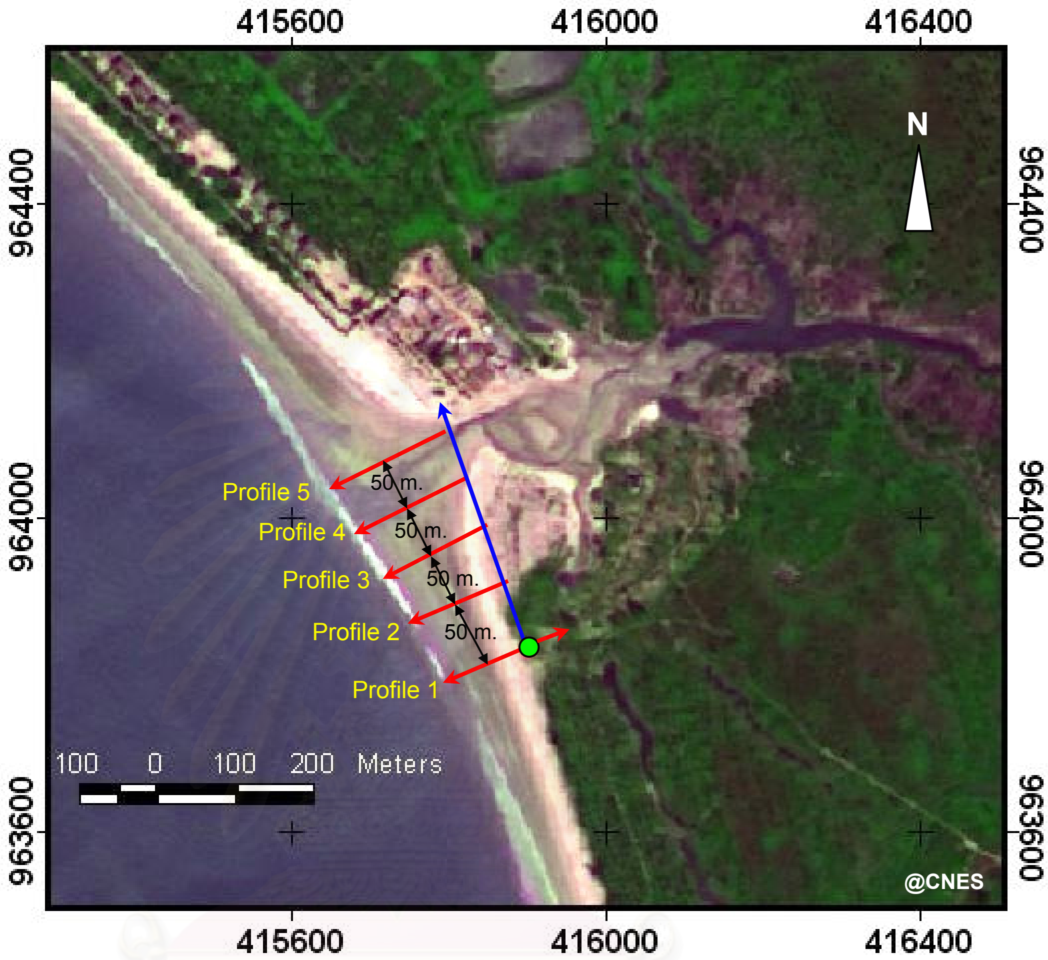

Figure 4.28 Beach profiling lines both perpendicular and parallel to the shoreline at Blue Village Pakarang Resort. Green dot is a reference point. Red line is east-west beach profile and blue line is south-north inlet/outlet cross-section.Background image is from SPOT-5 satellite taken two year after the 2004 tsunami.

4.2.1.1 Beach profile

Profile 1

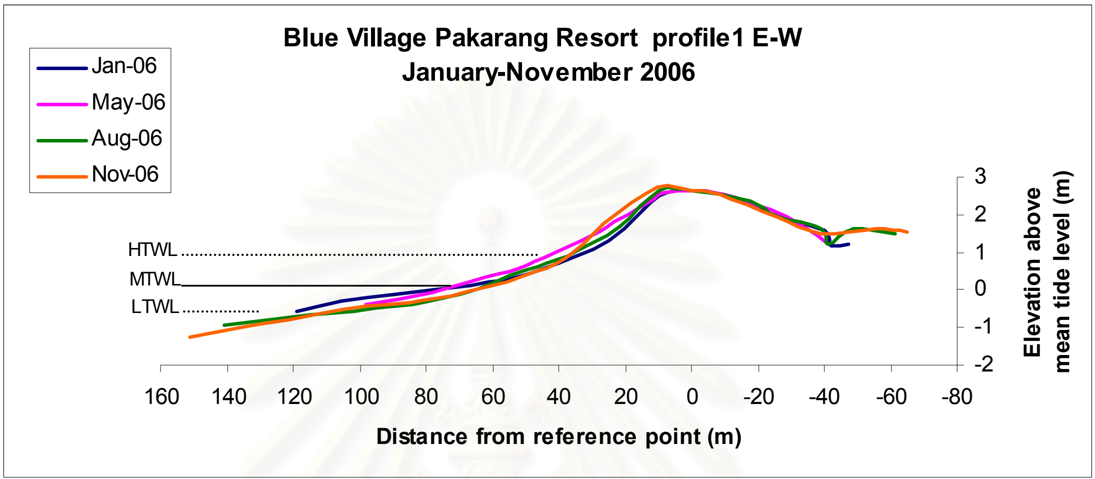

Figure 4.29 Beach profiles of Blue Village Pakarang Resort area showing configuration changed annually. Beach profiles measured in all seasons of 2006.

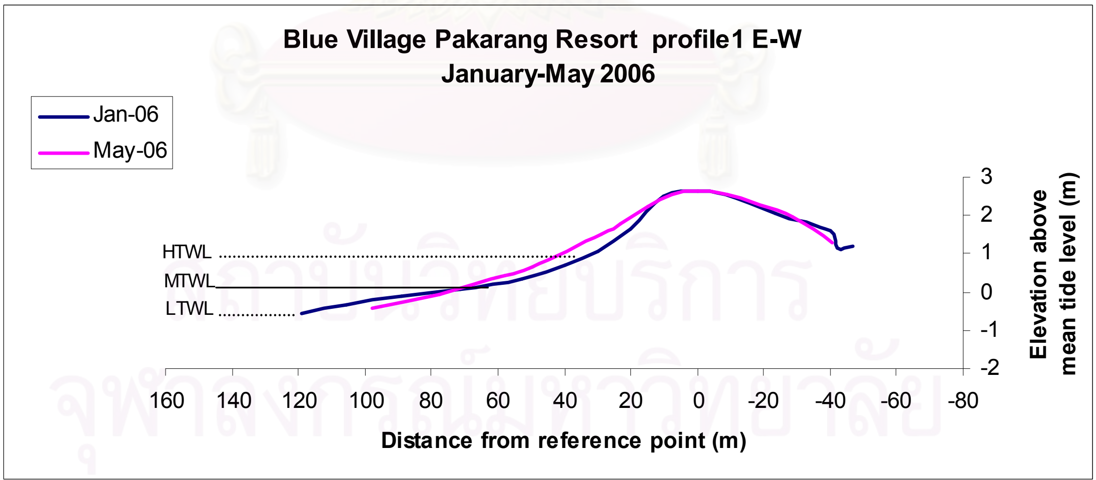

Figure 4.30 Beach profiles of Blue Village Pakarang Resort area compared in period of January to May 2006 showing deposition in vertical at foreshore during transition of summer and rainy season.

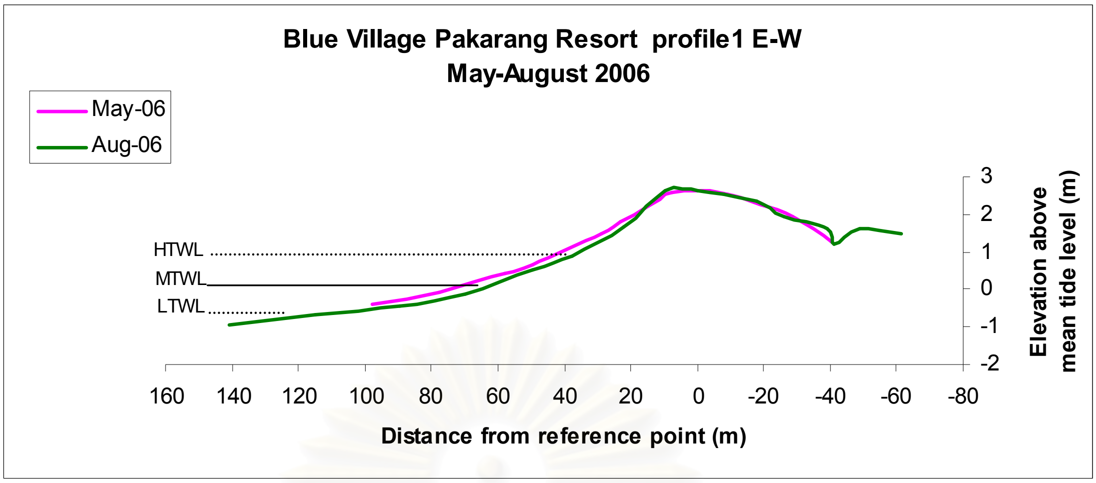

Figure 4.31 Beach profiles of Blue Village Pakarang Resort area compared in period of May to August 2006 showing erosion in vertical at foreshore during rainy season.

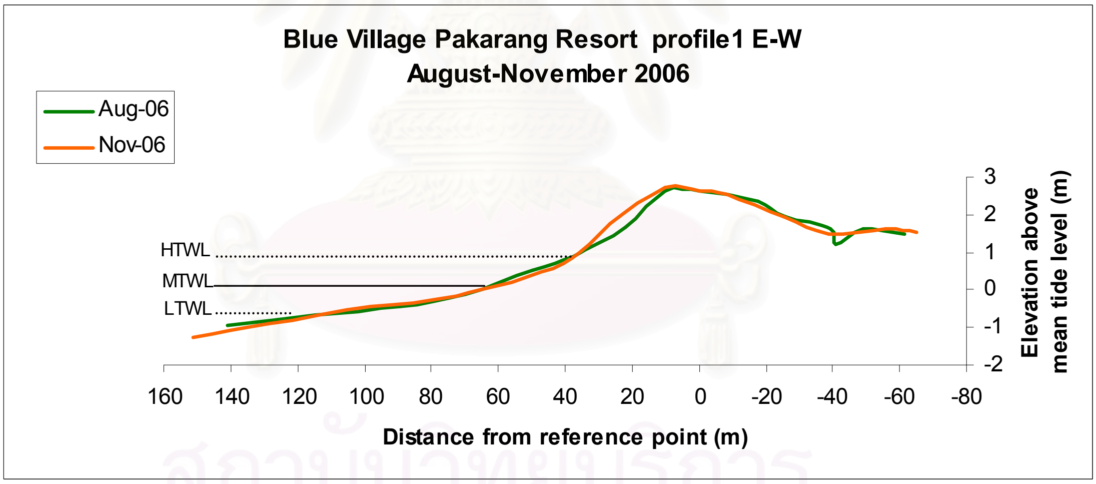

Figure 4.32 Beach profiles of Blue Village Pakarang Resort area compared in period of August to November 2006 showing deposition in vertical at foreshore during transition of rainy and winter seasons.

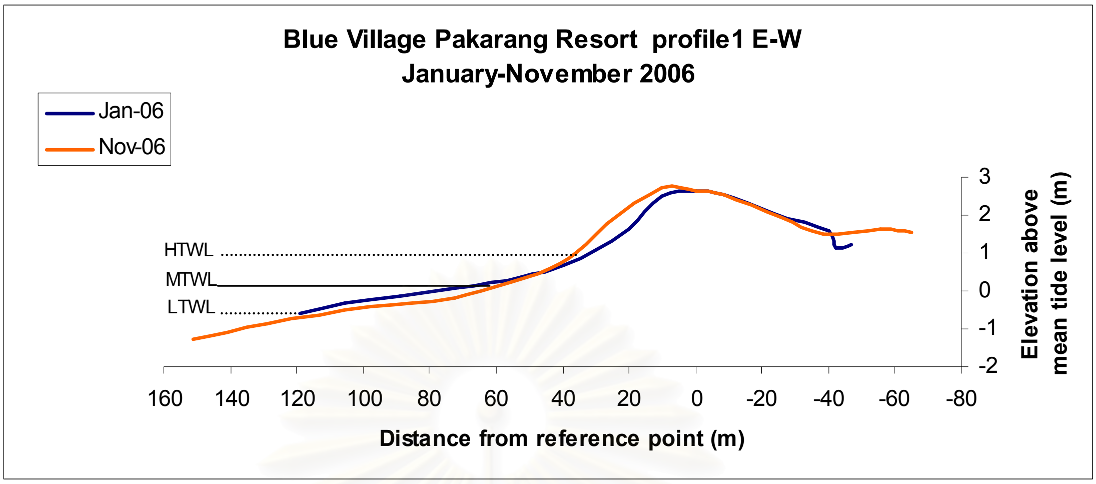

Figure 4.33 Beach profiles of Blue Village Pakarang Resort area compared in period of January to November 2006 showing balance in deposition and erosion at foreshore.

In analyzing beach profile at Blue Village Pakarang Resort area profile 1 was choose to described here as itself location is in the southern part of tidal channel which far away from human activity that are in the northern part of channel so it was not disturbed by human activity. Detailing of another profile please see in Appendix A. Result from analyzing beach profile changes through time, between the initial surveys in January to May 2006, it seems likely that in the middle of foreshore vertical, the degree of accretion is more than erosion (Figure 4.30). After that, during May to August 2006, foreshore was eroded vertically and top of beach ridge level was slightly higher, and the slope of foreshore was steeper (Figure 4.31). During the August to November 2006, foreshore shows accretion in vertical and beach ridge was continuously higher due to a change of convex slope of foreshore (Figure 4.32). During January to November 2006, further accretion of the foreshore was occurred, and foreshore was slightly eroded (Figure 4.33). Therefore, it appears to be a trend for equilibrium cycle on accretion and erosion of foreshore in this area. In term of horizontal change of shoreline, beach profile of Blue Village Pakarang Resort area shows equilibrium cycles of beach state (cycle of beach shows balance in erosion and deposition). Average distance of shoreline in year 2006 measured from high tide level to beach profile reference point was about 40.5 m and rate of changing in horizontal distance in 2006 year was about ±1-5 m (Tables 4.13 and Table 4.14).

Table 4.13 Changing in horizontal and vertical distance of beach profile at Blue Village Pakarang Resort (BV) in 2006.

Period / Area	BV	
	Horizontal* (m)	**Vertical** (m)**
January	37	1.825
May	46	1.825
August	39	1.925
November	40	2.025
Average	*40.5*	*1.9*

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

Table 4.14 Comparing change of horizontal and vertical distances of beach profile at Blue Village Pakarang Resort (BV) in 2006.

Period / Area	BV	
	Horizontal* (m)	**Vertical** (m)**
January	0	0
May	+9	0
August	-7	+0.1
November	+1	+0.1

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

+ = increase (compare to upper value)

- = decrease (compare to upper value)

4.2.1.2 Sedimentary analysis

A) Grain size of surface beach sediments Grain size of surface beach sediments shows majority of grain diameter of fine to medium sand (Figure 4.34).

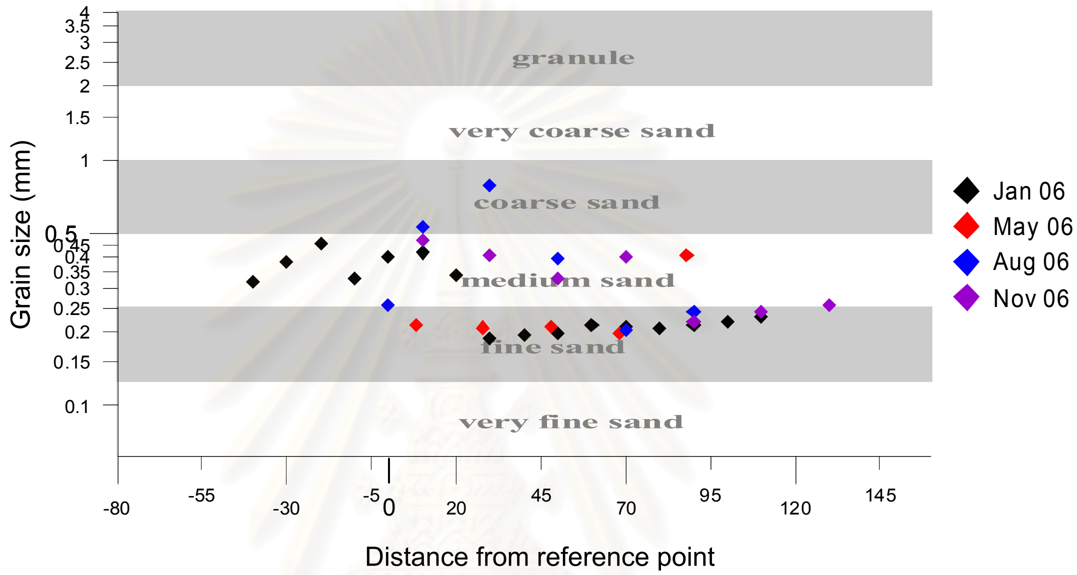

Figure 4.34 Grain size analysis of Blue Village Pakarang Resort area in 2006.

Table 4.15 Changing in grain size of beach sediments at Blue Village Pakarang Resort area in 2006.

Period	Size (mm)	Size comparable
January	0.258	fine sand
May	0.246	decrease
August	0.403	increase
November	0.333	decrease

Grain size analysis of Blue Village Pakarang Resort area in 2006 exhibits some differences of grain size in each season of the year 2006 (Figure 4.35 and Table 4.15). In January, grain size of beach sediments was characterized by fine sand with average diameter 0.258 mm. while in May, grain size was slightly decreased to 0.246 mm.. During rainy season in August, grain size was increased to 0.403 mm. and decreased in November about 0.333 mm. after the beginning of winter season.

B) Composition of beach sediment Surficial beach sediments are composed of quartz about 60%, bioclasts about 35% and others about 5% (Figures 4.35 to Figure 4.38). The Average percentage of quartz and bioclasts in surficial beach sediment exhibits some differences of compositions in each season of the 2006 (Tables 4.16 and Table 4.17). Percentage of quartz was slightly changed during the May whereas changing in percentage of bioclasts can obviously observe all of the year. In January quartz was 58.13% while bioclasts were 34.38 %. After that, in May quartz percentage was increased about 7.08 % while bioclast was decreased about 5.38 %. Then during monsoon season in August, quartz percentage was decreased about 10.03 % while bioclasts were increased about 13.00 %. Finally, after the end of monsoon season in November, quartz percent was slightly decreased about 0.31% while bioclasts was decreased about 5.57 %.

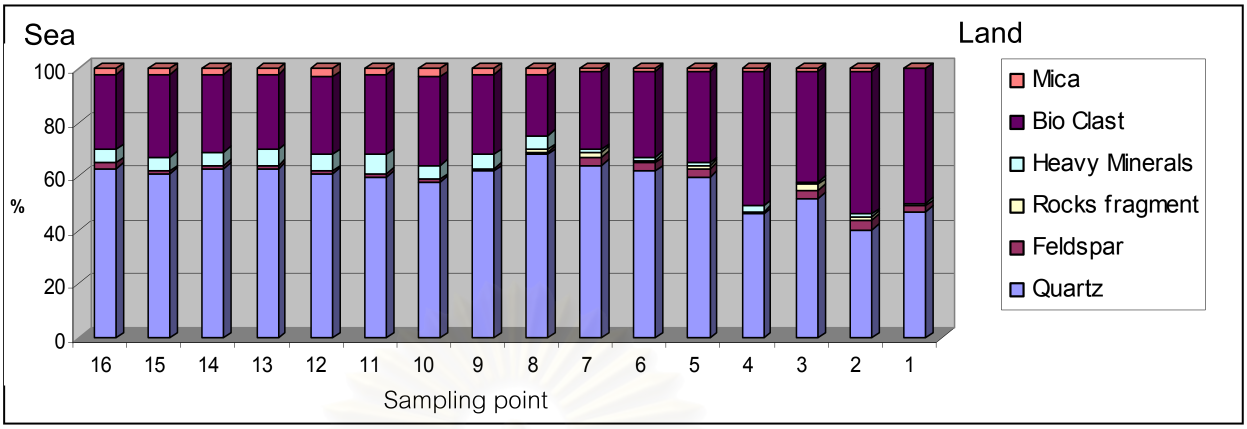

Figure 4.35 Graph of sediment compositions profile 1 at Blue Village Pakarang Resort area in January 2006. Major compositions are quartz and bioclasts. Heavy minerals and mica were found increasing in percentage in seaward direction. Samples were collected with 10 m. distance interval (Position of sampling point can be see in Appendix C).

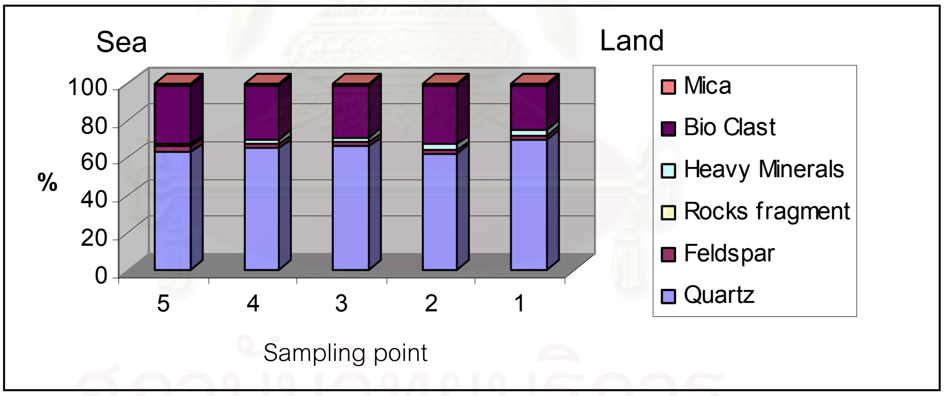

Figure 4.36 Graph of sediment compositions profile 1 at Blue Village Pakarang Resort area in May 2006. Major compositions are quartz and bioclasts. Heavy minerals were decreased in seaward direction. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

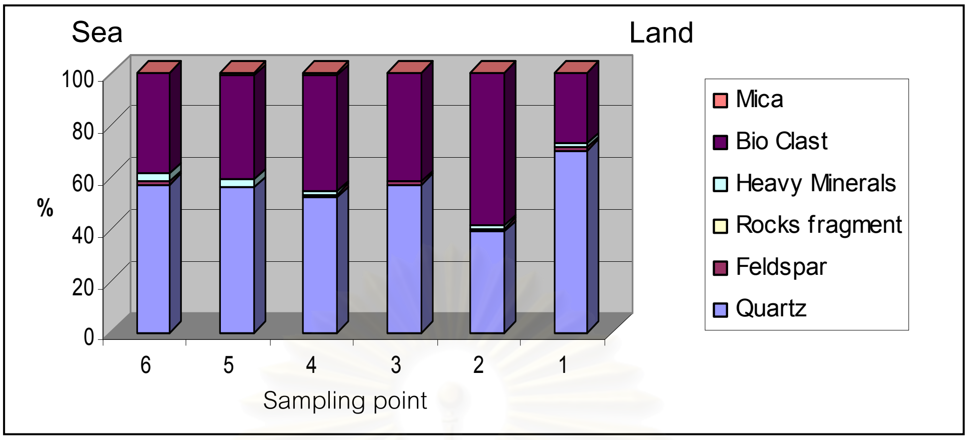

Figure 4.37 Graph of sediment compositions profile 1 at Blue Village Pakarang Resort area in August 2006. Major compositions are quartz and bioclasts. Heavy minerals were increased in seaward direction. Samples were collected with 20 m. distance interval (Position of sampling point can be seeing in Appendix C).

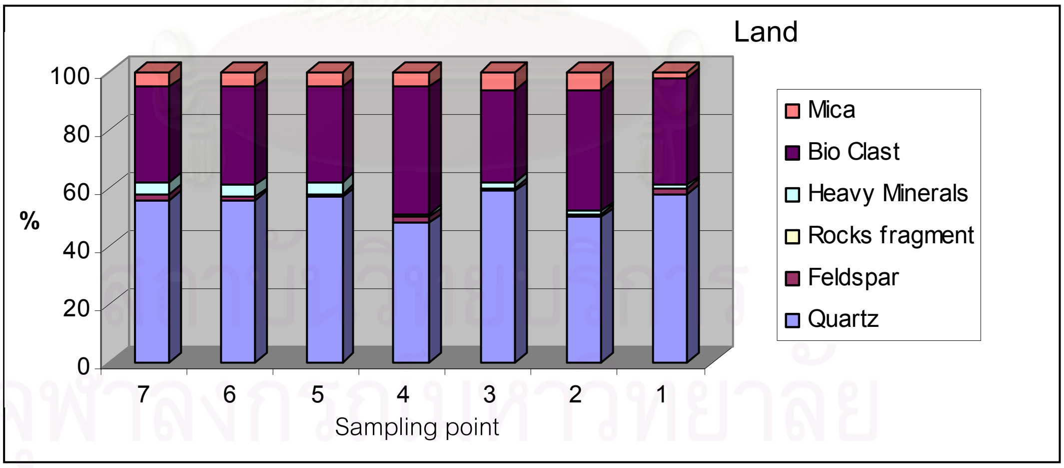

Figure 4.38 Graph of sediment compositions profile 1 at Blue Village Pakarang Resort area in November 2006. Major compositions are quartz and bioclasts. Heavy minerals and mica were increasing in seaward direction. Samples were collected with 20 m. distance interval (Position of sampling point can be seeing in Appendix C).

Table 4.16 Average percentage of quartz and bioclasts in surficial beach sediment at Blue Village Pakarang Resort area in 2006.

Month	Quartz %	Bio clast %
January	58.13	34.38
May	65.20	29.00
August	55.17	42.00
November	54.86	36.43

Table 4.17 Comparison of increasing and decreasing in percentage of quartz and bioclasts in surficial beach sediment at Blue Village Pakarang Resort area in 2006.

Month	Quartz %	Bioclast %
January	58.13	34.38
May	+7.08	-5.38
August	-10.03	+13.00
November	-0.31	-5.57

\+ = increase (compare to upper value)

\- = decrease (compare to upper value)

C) Physical properties Physical properties of surficial beach sediment at Blue Village Pakarang Resort area in 2006 exhibits trend of roundness in sub-angular and also sphericity of sediment grain is presented in unit of high sphericity. Sediment grain with sub-angular in roundness present that it is new sediment which transport not far from their source. High sphericity of sediment grain also present that it was done by high energy of abrasion which usually occur in swash zone.

Inlet/outlet cross-section

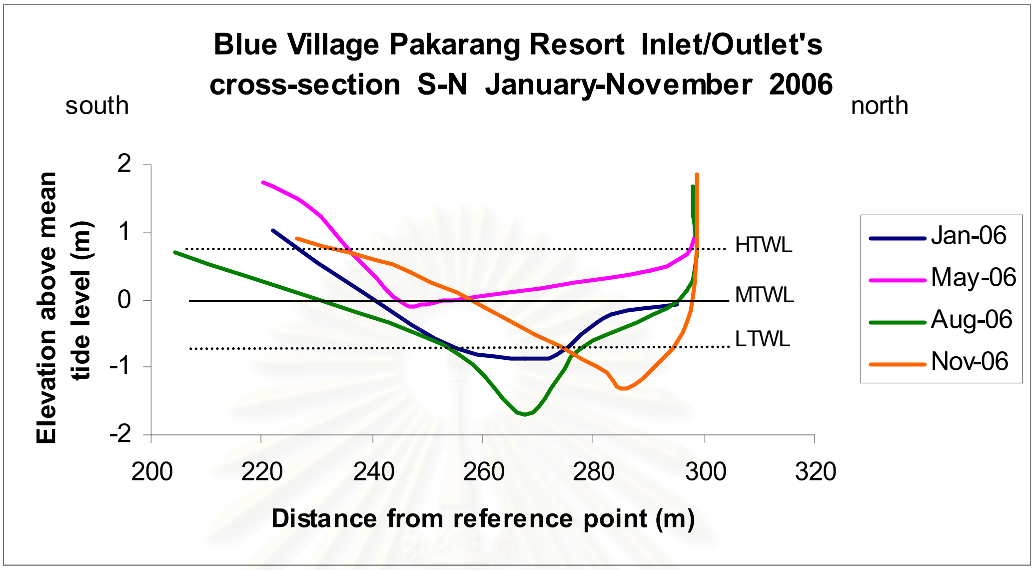

Figure 4.39 Inlet/outlet cross-section of Blue Village Pakarang Resort area showing configuration changed annually.

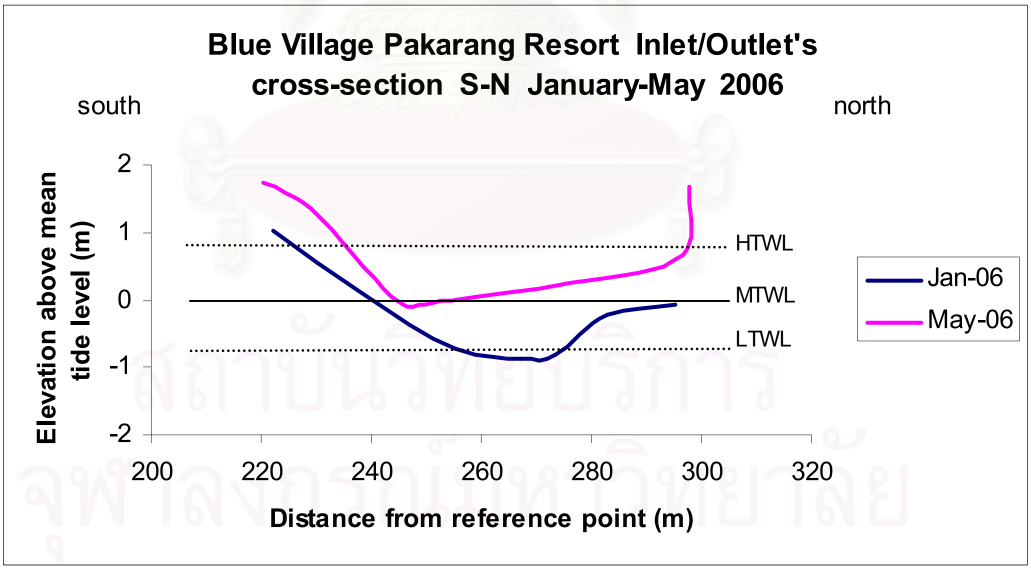

Figure 4.40 Inlet/outlet cross-section of Blue Village Pakarang Resort area in period of January to May 2006 showing deposition of channel during transition of summer and rainy seasons.

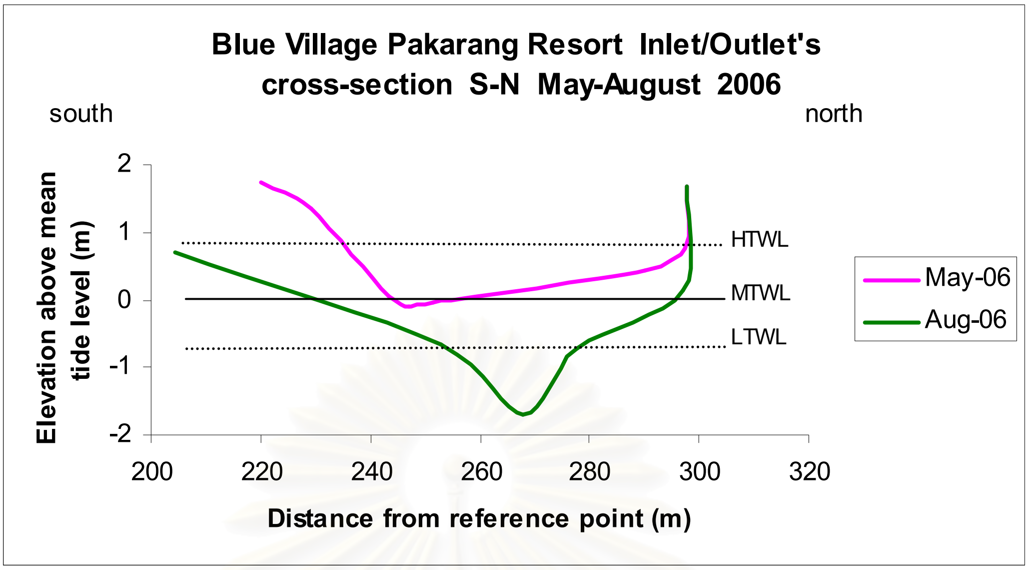

Figure 4.41 Inlet/outlet cross-section of Blue Village Pakarang Resort area in period of May to August 2006 showing erosion of channel which incised channel bed deeper into V-shaped during monsoon season.

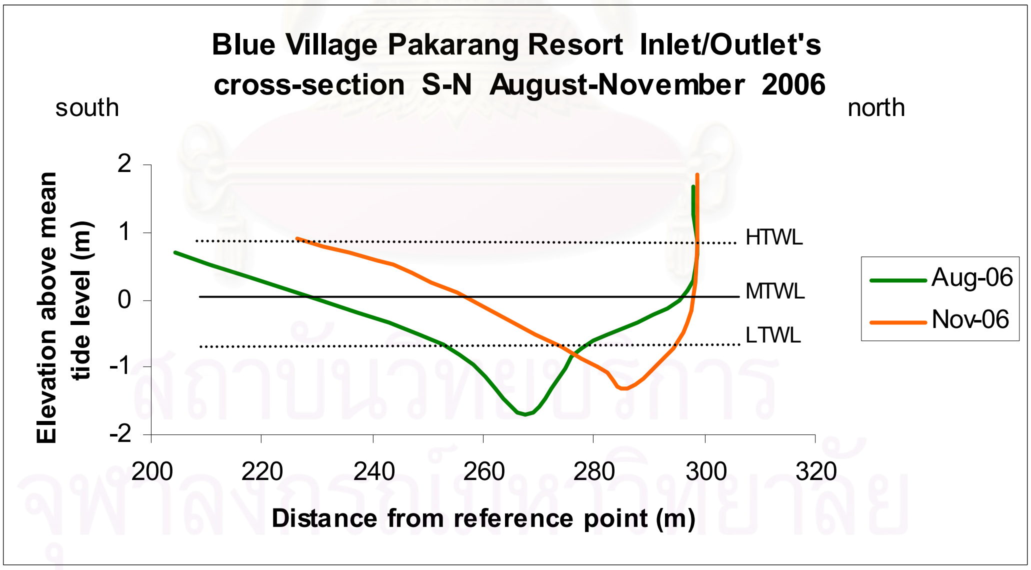

Figure 4.42 Inlet/outlet cross-section of Blue Village Pakarang Resort area in period of August to November 2006 showing movement of channel which V-shaped channel moved to the north and channel bed was shallower.

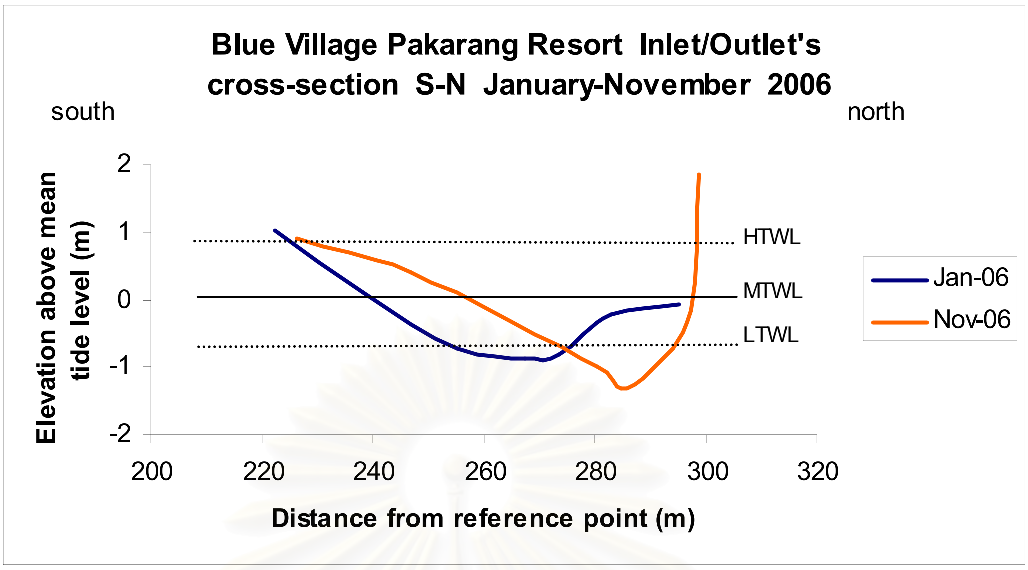

Figure 4.43 Inlet/outlet cross-section of Blue Village Pakarang Resort area in period of January to November 2006 showing configuration changed both in vertically and horizontally of channel as a result of sediment supply quantity from fluvial process in different seasons and meandering of channel in annual.

4.2.1.3 Field observation

Eroded shoreline at Blue Village Pakarang Resort area was almost recovered after one year of the 2004 tsunami event as mentioned in result of remote sensing and GIS analysis. However, human activity is one of several factors that induce rate of recovery. Sea wall was built by local government to protect erosion of shoreline from wave in the north side of channel (Figures 4.44 to Figure 4.46).

Figure 4.44 Photograph showing new sea wall was built in early 2005 in the north side of inlet/outlet channel at Blue Village Pakarang Resort area.

Figure 4.45 Photographs showing new sea wall was constructed parallel to the shoreline (A) and sea wall along the tidal channel (B).

From field observation in period of January to November 2006, new deposition of sand after the 2004 tsunami was clearly observed. New sediment was deposited in front of the sea wall approximately 1.5 meters in vertical thickness. Moreover, new tidal channel trended to expand in north-south direction parallel to the shoreline (Figure 4.47).

Figure 4.46 Comparing photographs of inlet/outlet mouth (looking south) at Blue Village Pakarang Resort showing deposition of sand in front of new sea wall. Deposition was clearly observed at concrete pipe (red arrow).

Figure 4.47 Photographs showing tidal delta emerged (as arrows indicated) at low tide time in 2006 that expanded its size in north-south direction parallel to the shoreline (looking north).

4.2.2 Sofitel Magic Lagoon Resort

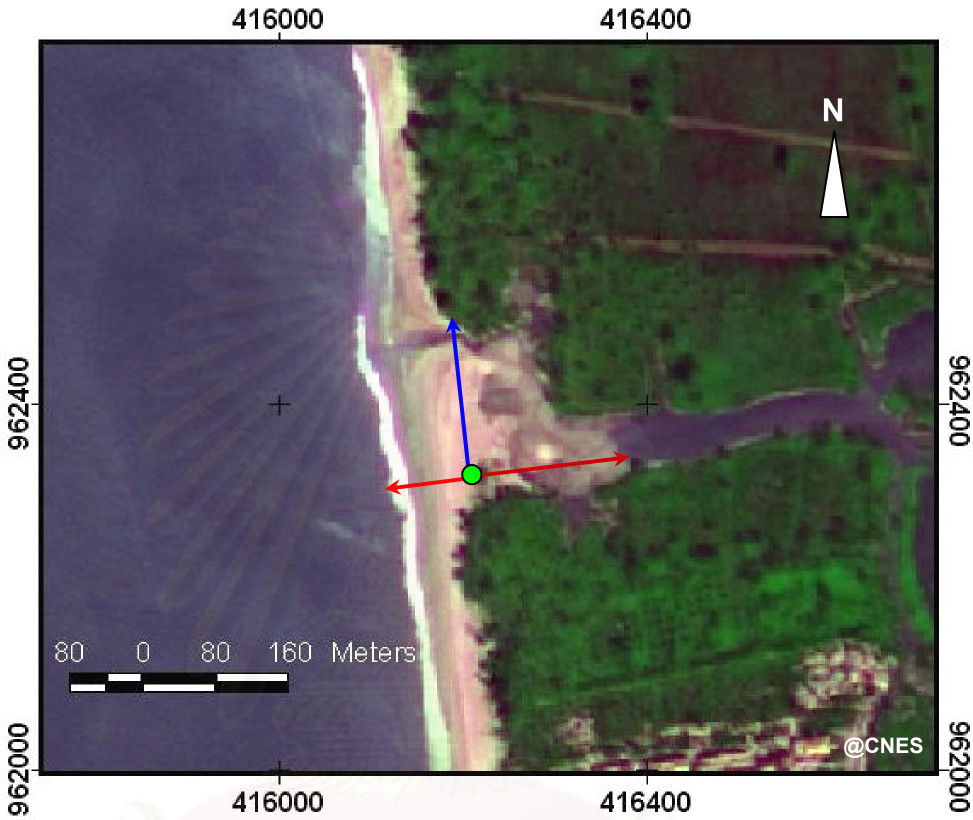

Figure 4.48 Beach profiling lines both perpendicular and parallel to the shoreline at Sofitel Magic Lagoon Resort. Green dot is a reference point. Red line is east-west beach profile and blue line is south-north inlet/outlet cross-section. Background image is from SPOT-5 satellite taken two year after the 2004 tsunami.

4.2.2.1 Beach profile

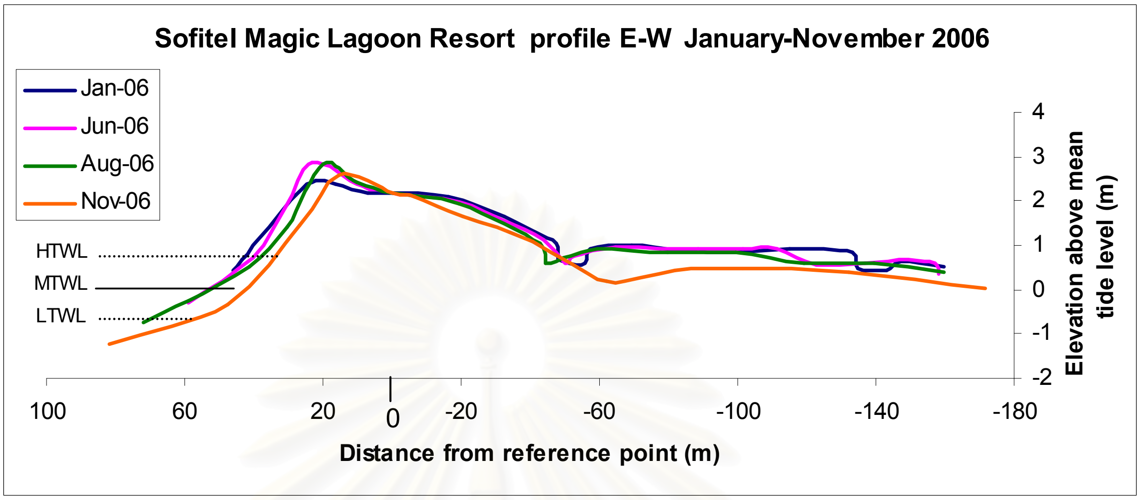

Figure 4.49 Beach profiles of Sofitel Magic Lagoon Resort area showing configuration changed annually.

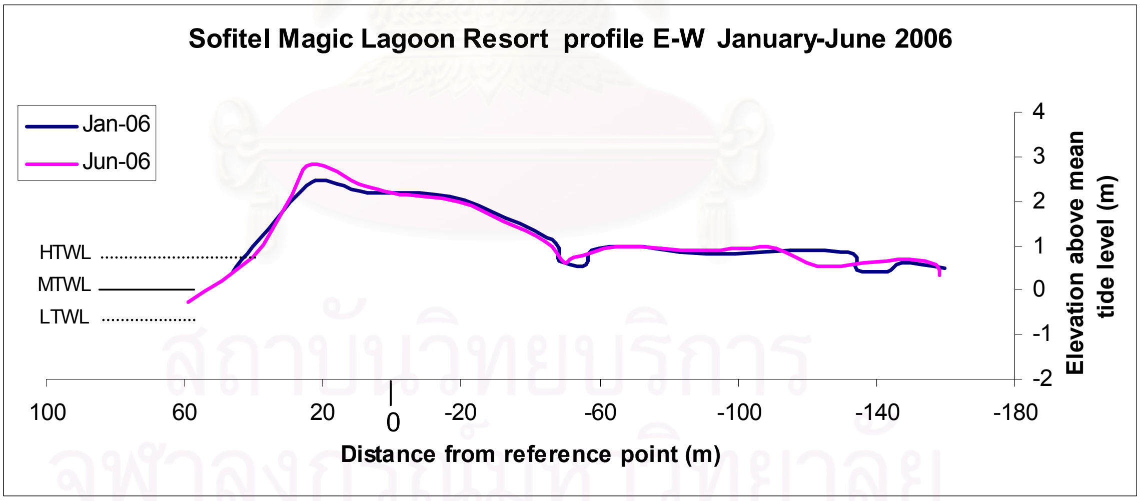

Figure 4.50 Beach profiles of Sofitel Magic Lagoon Resort area in period of January to June 2006 eroded of foreshore was marked by steep slope and higher of beach ridge during transition of summer and monsoon seasons.

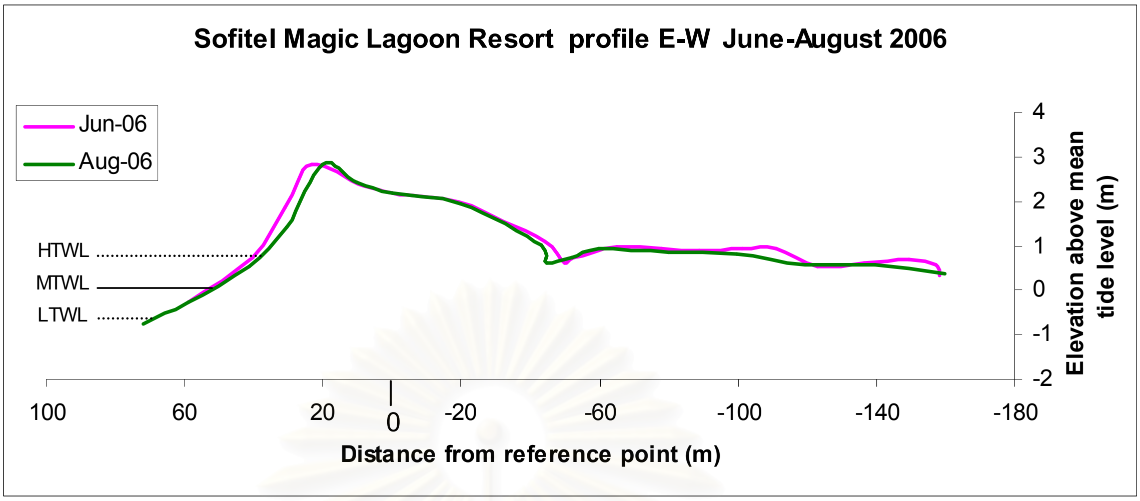

Figure 4.51 Beach profiles of Sofitel Magic Lagoon Resort area in period of June to August 2006 showing erosion of foreshore which retreat of shoreline during monsoon season.

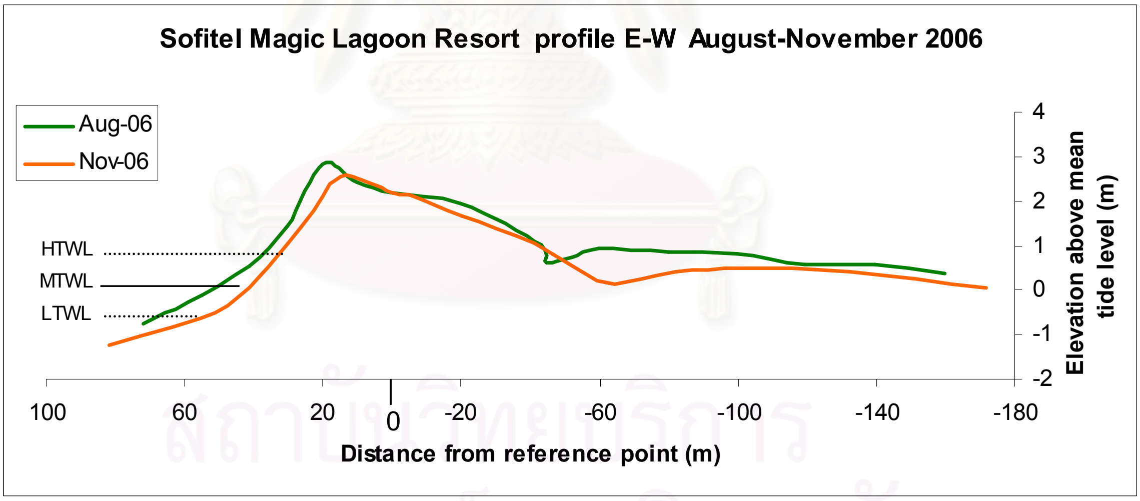

Figure 4.52 Beach profiles of Sofitel Magic Lagoon Resort area in period of August to November 2006 suffered from erosion of foreshore which retreat landward and also runnel behind backshore became deeper and wider after end of monsoon season.

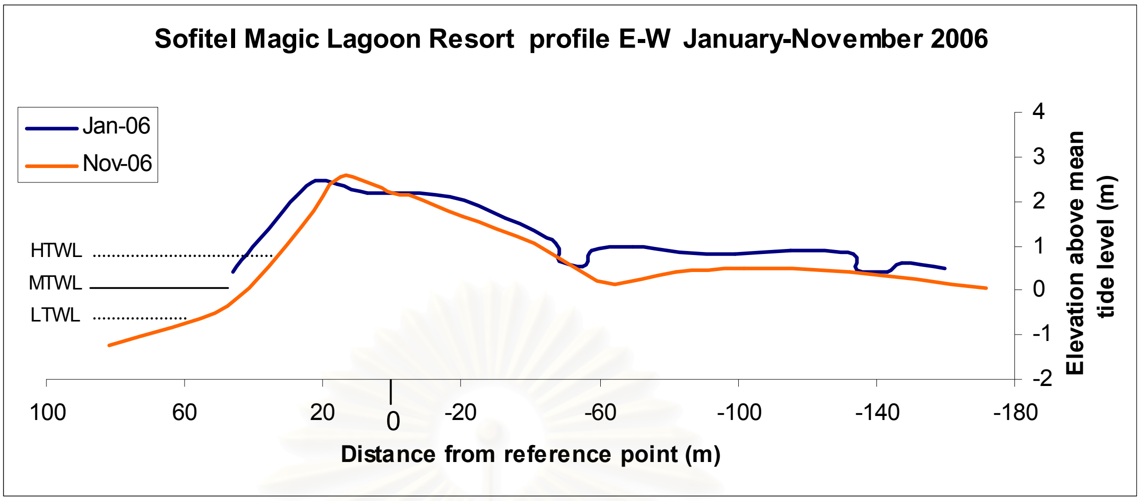

Figure 4.53 Beach profiles of Sofitel Magic Lagoon Resort area in period of January to November 2006 showing erosion both in vertical and horizontal.

Inlet/outlet cross-section

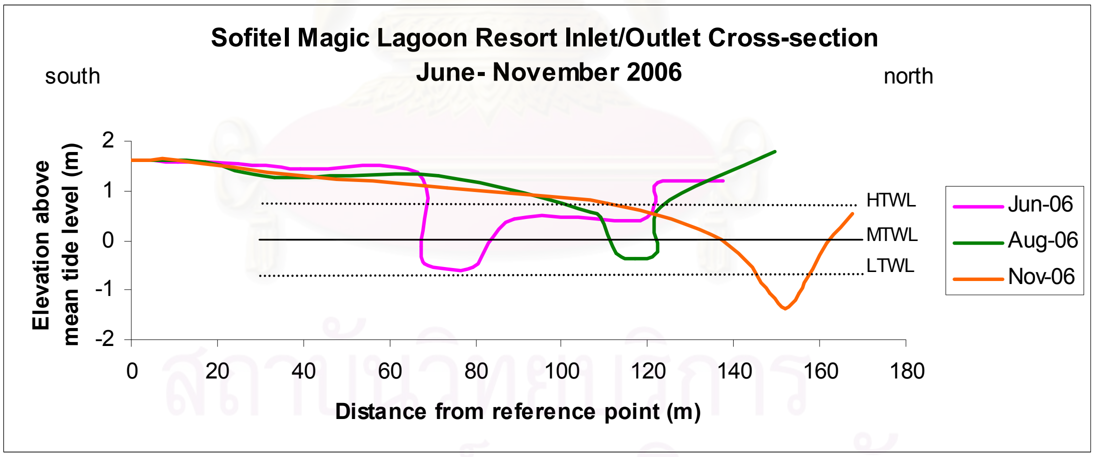

Figure 4.54 Inlet/outlet cross-section of Sofitel Magic Lagoon Resort area showing configuration changed annually.

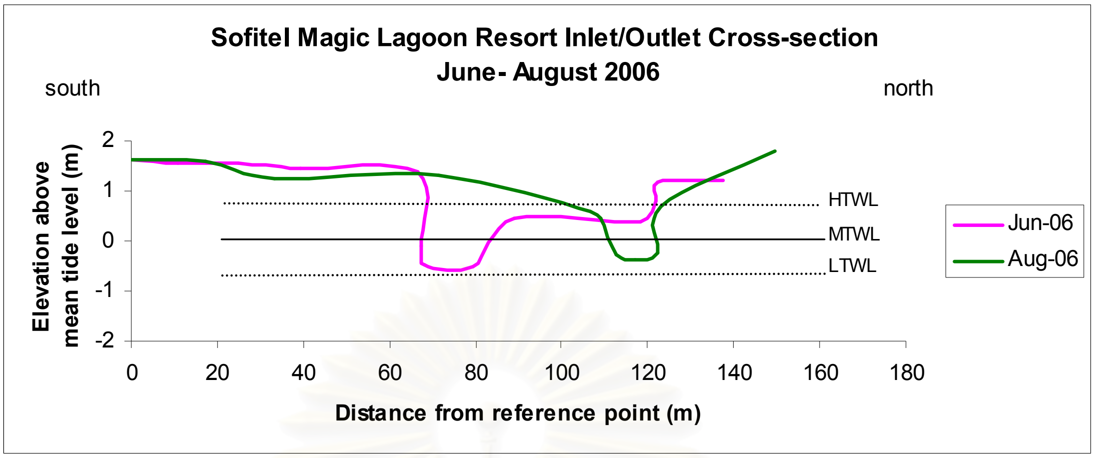

Figure 4.55 Inlet/outlet cross-section of Sofitel Magic Lagoon Resort area in period of June to August 2006 showing movement of channel to the north as a result of meandering of channel.

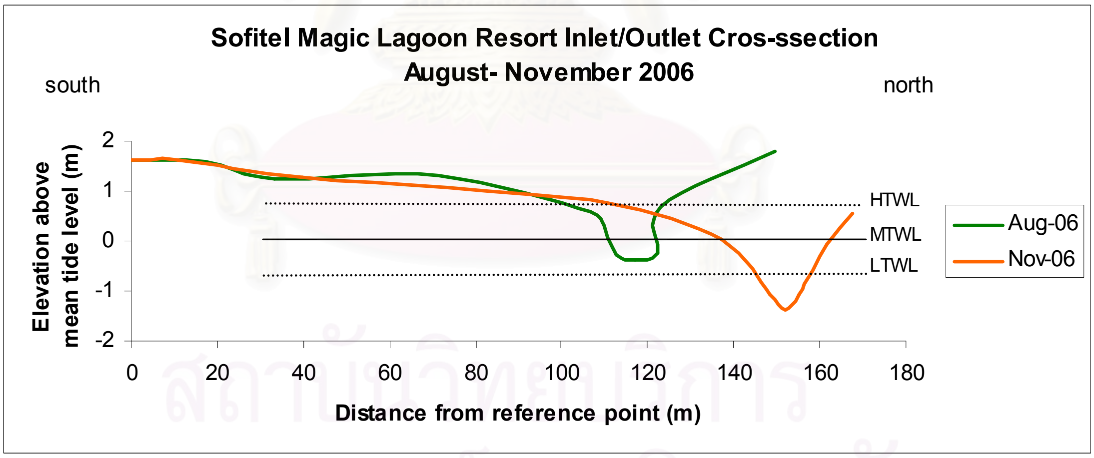

Figure 4.56 Inlet/outlet cross-section of Sofitel Magic Lagoon Resort area in period of August to November 2006 showing movement of channel to the north and erosion of channel bed which marked by V-shaped as a result of meandering of channel.

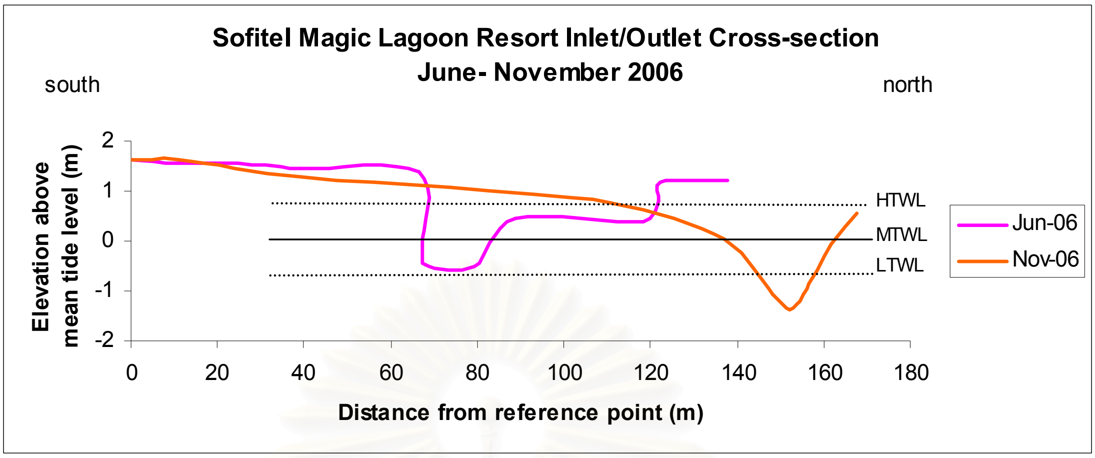

Figure 4.57 Inlet/outlet cross-section of Sofitel Magic Lagoon Resort area in period of January to November 2006 showing movement of channel to the north and erosion in channel bed that had changed channel shape from U-shaped to V-shaped.

In analyzing beach profile changes through time, between the initial surveys in January to June 2006, profiles showed reshape of foreshore as a result of changing in season from summer to rainy. Foreshore was retreated inland and beach ridge was higher due to steep slope of foreshore (Figure 4.50). After that during June to August 2006, continuity of erosion at foreshore still occurred and also beach ridge was slightly higher (Figure 4.51). Then, the August to November 2006, foreshore was suffered from erosion in monsoon season led to landward retreat of shoreline, and also runnel behind backshore become deeper and wider compared to the August (Figure 4.52). Finally, in periods of January to November 2006, beach profile shows erosion both in vertical and horizontal distances in foreshore and backshore zone (Figure 4.53). Therefore, it appears to be a trend for erosion of shoreline in this area. In term of horizontal change of shoreline, beach profile of Sofitel Magic Lagoon Resort area shows erosional trend which rate of erosion in 2006 was 10 m (Table 4.18 and Table 4.19). However, this result was carried out only one year for monitoring beach behavior. The more detail measurement, in term of identifies erosional beach type long term monitoring is required, for instance, at least ten years.

Table 4.18 Changing in horizontal and vertical distance of beach profile at Sofitel Magic Lagoon Resort (SF) in 2006.

Period / Area	**SF**	
	Horizontal* (m)	**Vertical** (m)**
January	43	1.675
June	40	2.075
August	37	2.075
November	33	1.825

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

Table 4.19 Comparing change of horizontal and vertical distances of beach profile at Sofitel Magic Lagoon Resort (SF) in 2006.

Period / Area	**SF**	
	Horizontal* (m)	**Vertical** (m)**
January	0	0
June	-3	+0.4
August	-3	0
November	-4	-0.25

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

+ = increase (compare to upper value)

- = decrease (compare to upper value)

4.2.2.2 Sedimentary analysis

A) **Grain size of surface beach sediments** Surficial grain size of beach sediments show majority of grain diameter of medium sand (Figure 4.58).

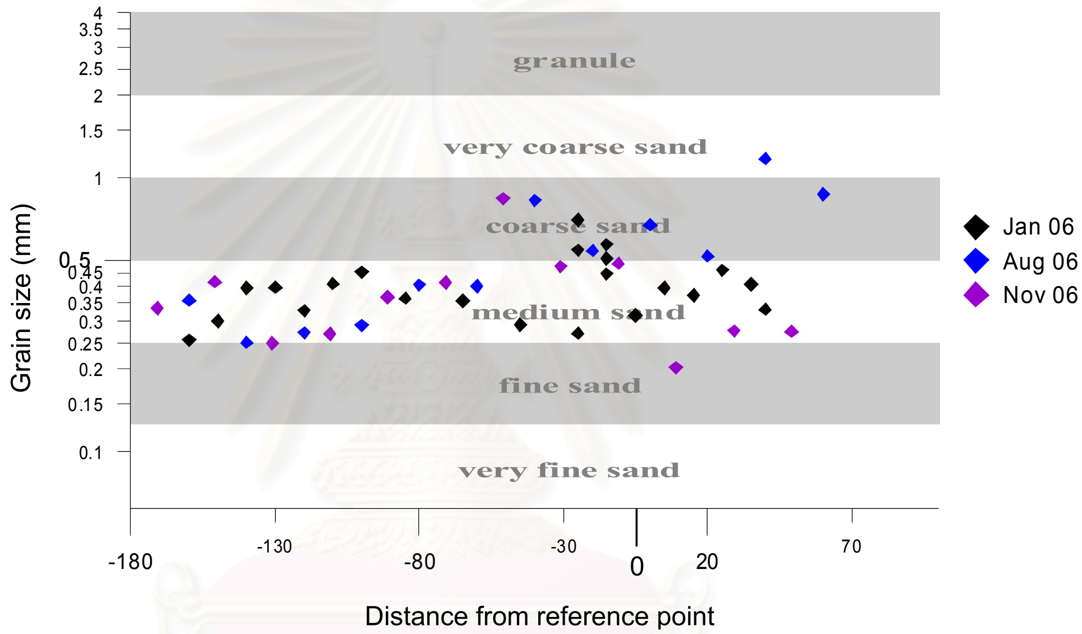

Figure 4.58 Grain size analysis of Sofitel Magic Lagoon Resort area in 2006.

Table 4.20 Changing in grain size of beach sediment at Sofitel Magic Lagoon Resort area in 2006.

Period	Size (mm)	Size comparable
January	0.403	medium sand
June	no data	no data
August	0.549	increase
November	0.384	decrease

Grain size analysis of Sofitel Magic Lagoon Resort area in 2006 exhibits some differences of grain size in each season (Figure 4.58 and Table 4.20). In January, grain size of beach sediment was characterized by medium sand with average diameter 0.403 mm. Between rainy season in August, grain size was increased to 0.549 mm and then decreased again in November about 0.384 mm after the beginning of winter season.

B) **Composition of beach sediment** Major compositions of surficial beach sediments are quartz about 60%, bioclasts about 35%, and others about 5% (Figures 4.59 to Figure 4.61). The Average percentage of quartz and bioclasts in surficial beach sediment exhibits some differences of compositions in each season of 2006 (Tables 4.21 and Table 4.22). Changing in percentage of quartz and bioclasts can obviously observe all of the year. In January quartz was 56.5% while bioclasts was 40% in percentage of surficial beach sediment. Then during monsoon season in August quartz percentage was increased about 4.92% while bioclasts was decreased about 4.17%. Finally, after the end of monsoon season in November quartz percent was increased about 3.58% while bioclasts was increased about 5.92 %.

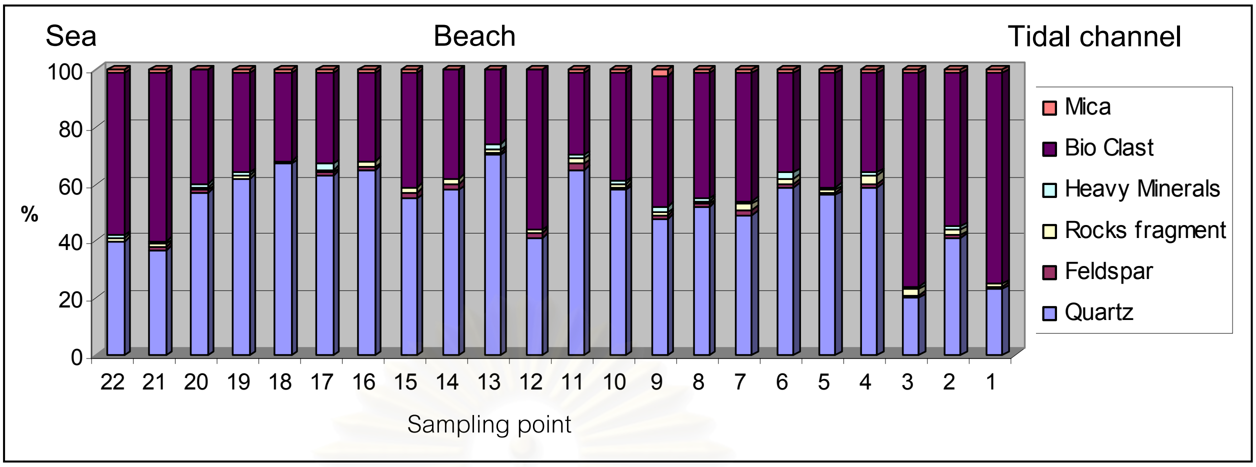

Figure 4.59 Graph of sediment compositions at Sofitel Magic Lagoon Resort area in January 2006. Major compositions are quartz and bioclasts. Quartz was decreased in percentage when far from beach zone. Samples were collected with 10 m. distance interval (Position of sampling point can be see in Appendix C).

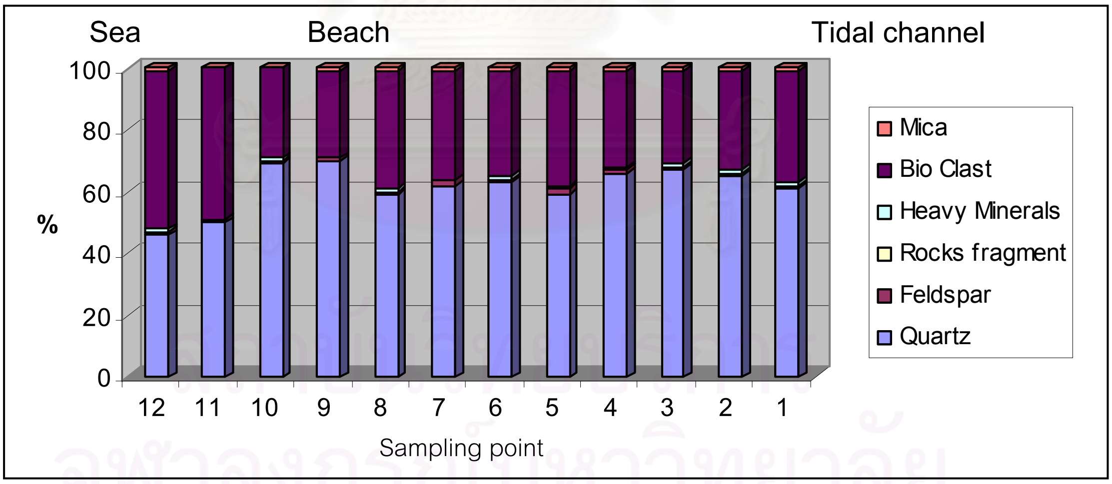

Figure 4.60 Graph of sediment compositions at Sofitel Magic Lagoon Resort area in August 2006. Major compositions are quartz and bioclasts. Quartz was decreased in percentage when far from beach zone. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

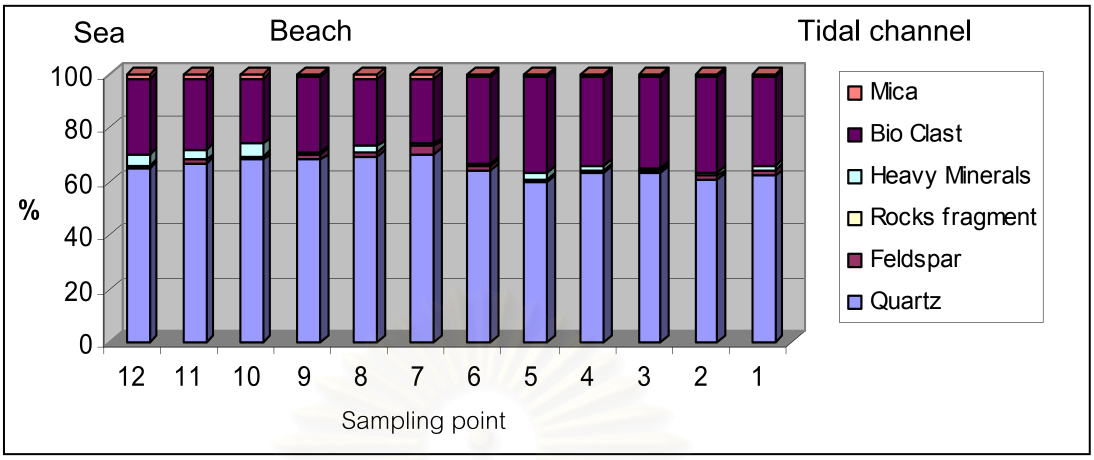

Figure 4.61 Graph of sediment compositions at Sofitel Magic Lagoon Resort area in November 2006. Major compositions are quartz and bioclasts. Heavy minerals were found increasing in percentage in seaward direction. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

Table 4.21 Average percentage of quartz and bio clasts in surficial beach sediment at Sofitel Magic Lagoon Resort area in 2006.

Month	Quartz %	Bioclast %
January	56.5	40
June	no data	no data
August	61.42	35.83
November	65	29.92

Table 4.22 Comparison increasing and decreasing in percentage of quartz and bio clasts in surficial beach sediment at Sofitel Magic Lagoon Resort area in 2006.

Month	Quartz %	Bioclast %
January	56.5	40
June	no data	no data
August	+4.92	-4.17
November	+3.58	-5.92

+ = increase (compare to upper value)

- = decrease (compare to upper value)

C) Physical properties Physical properties of surficial beach sediment at Sofitel Magic Lagoon Resort area in 2006 exhibits trend of roundness in sub-angular and also sphericity of sediment grain is presented in unit of high sphericity. Sediment grain with sub-angular in roundness present that it is new sediment which transport not far from their source. High sphericity of sediment grain also present that it was done by high energy of abrasion which usually occur in swash zone.

4.2.2.3 Field observation

Eroded shoreline at Sofitel Magic Lagoon Resort area was almost recovered after one year of the 2004 tsunami event. New sediment deposit was filled up in the eroded area at the mouth of inlet/outlet channel (Figures 4.62 and Figure 4.63). Accretion of sediment at mouth of inlet/outlet channel also found in this area (Figure 4.64), in January tidal delta was accumulated under low tide, then in June, August, and November tidal delta emerged and expanded itself in to the sea. Moreover, slope of foreshore was also changed which responded to the season change (Figure 4.65).

Figure 4.62 Photograph showing new sediment deposits at mouth of tidal channel. A is location where new beach sediment returned, and B shows new flood-tidal delta and washover deposits behind new beach ridge (looking west).

Figure 4.63 Photograph showing new backshore sediment indicate inclination of layer in landward direction (looking north) deposited where eroded channel back occurred.

Figure 4.64 Series of photographs at inlet/outlet channel mouth taken in 2006 at Sofitel Magic Lagoon Resort showing accretion of sediment at mouth of channel (looking north). Red arrows indicate expand of tidal delta in seaward direction.

Figure 4.65 Series of photographs of backshore and foreshore slope at Sofitel Magic Lagoon Resort area taken in different seasons of 2006 showing slope of foreshore became steeper during June to August in rainy season and decreased angle after end of rainy season in November (looking south).

4.2.3 Klong Khuek Khak

Figure 4.66 Beach profiling lines both perpendicular and parallel to the shoreline at Klong Khuek Khak. Green dot is a reference point. Red line is east-west beach profile and blue line is south-north inlet/outlet cross-section. Background image is from SPOT-5 satellite taken two year after the 2004 tsunami.

4.2.3.1 Beach profile

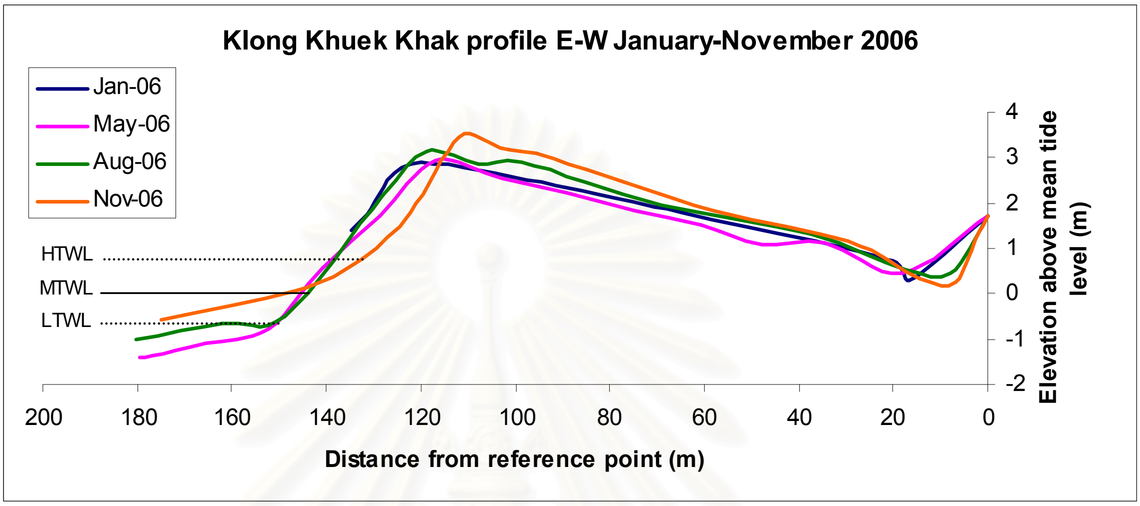

Figure 4.67 Beach profile of Klong Khuek Khak area showing configuration changed annually.

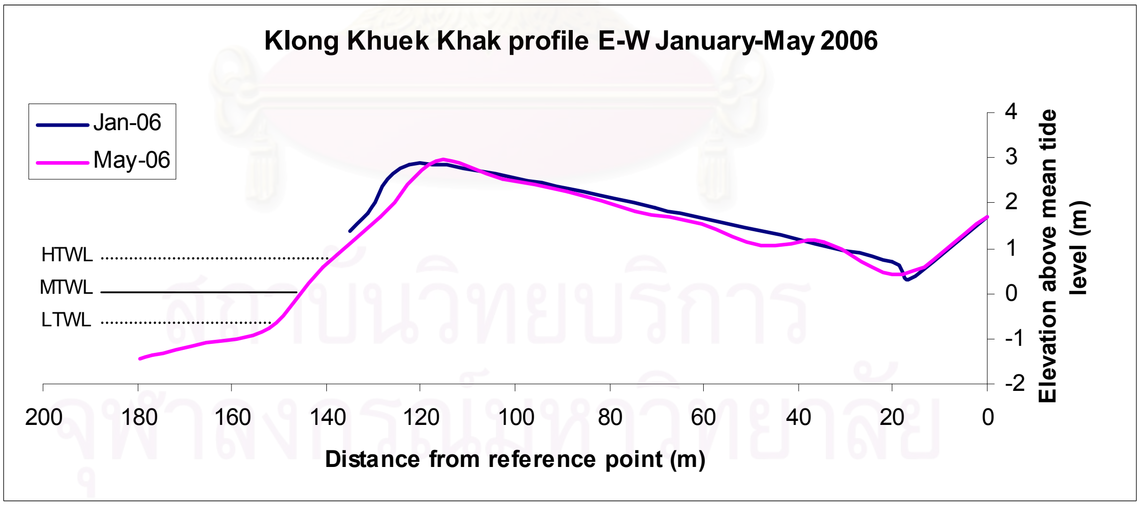

Figure 4.68 Beach profile of Klong Khuek Khak area in period of January to May 2006 beach ridge position was retreat from previous January due to erosion of foreshore during transition of summer and rainy season.

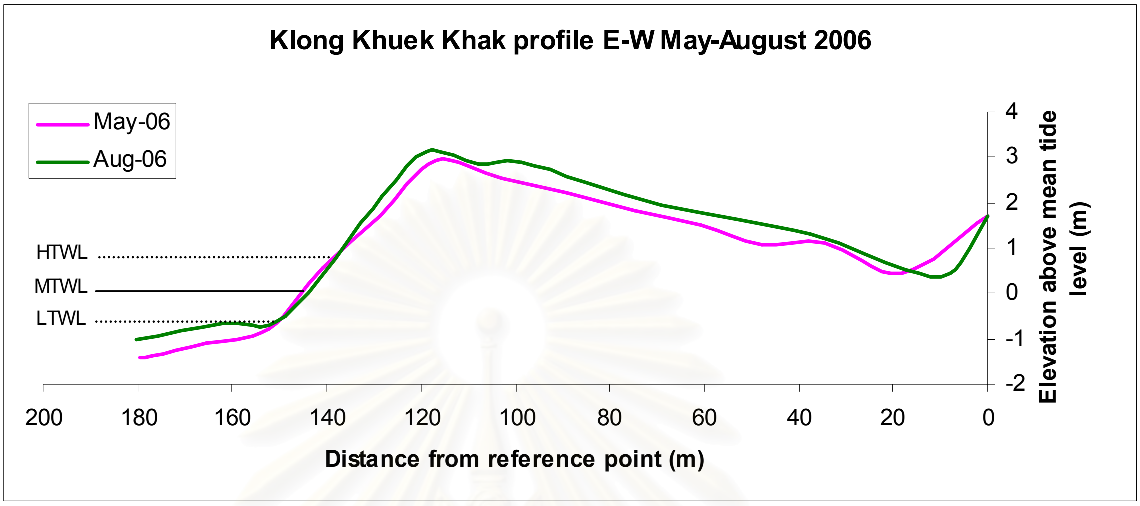

Figure 4.69 Beach profile of Klong Khuek Khak area in period of May to August 2006 beach ridge was higher and foreshore slope also steeper. Surface of backshore zone was also higher during monsoon season.

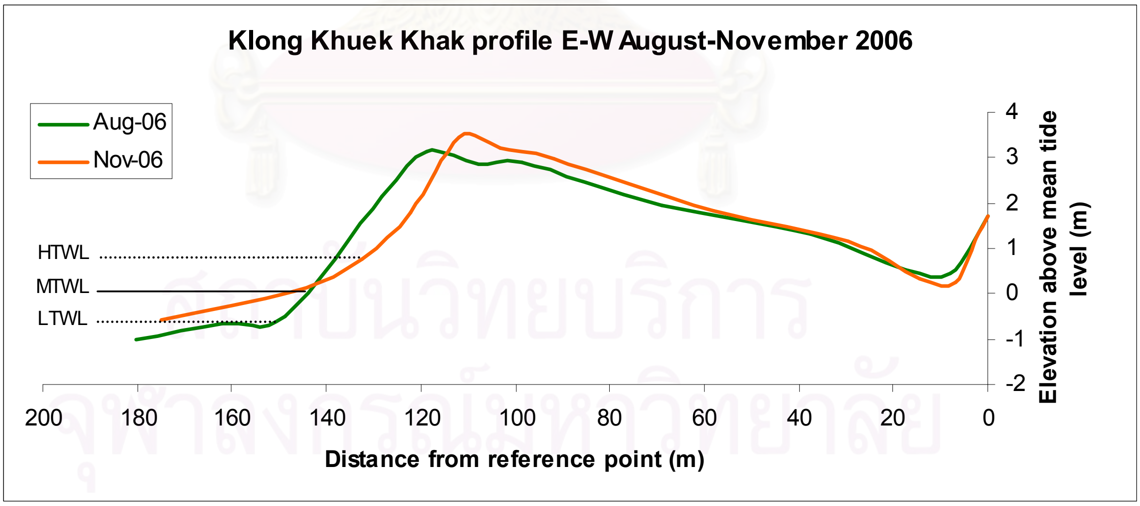

Figure 4.70 Beach profile of Klong Khuek Khak area in period of August to November 2006 showing suffered from monsoon season. Beach ridge was higher and foreshore slope also steeper with a concave shape. Surface of backshore zone was also higher during monsoon season.

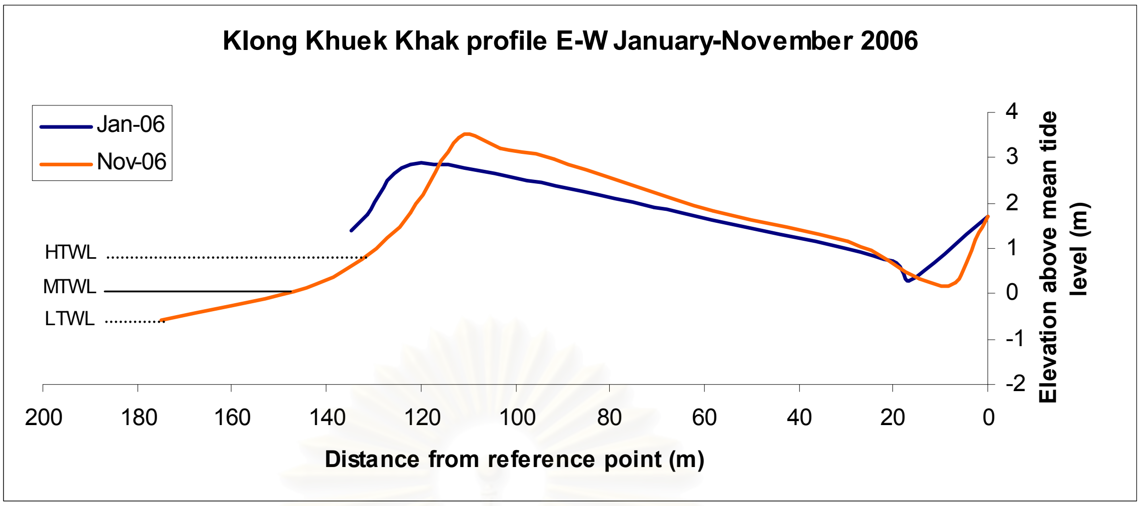

Figure 4.71 Beach profiles of Klong Khuek Khak area in period of January to November 2006 showing adjustment of beach shape in vertical and horizontal distances which response to the season change.

In analyzing beach profile changes through time, between the initial surveys in January to June 2006, erosion of foreshore was recognized by retreat of beach ridge in landward direction that was the signal for beginning of rainy season (Figure 4.68). After that during May to August 2006, beach ridge was higher and foreshore slope also steeper. Surface of backshore zone was also higher from washover deposit left by storm surge during monsoon season (Figure 4.69). Overwash process produced by storm surge along these areas flooded over beach zone with distance less than 100 m inland from shoreline. Then, the August to November 2006, foreshore shows suffered from erosion in monsoon season. Beach ridge was higher and foreshore slope also steeper with a concave shape. Surface of backshore zone was higher from washover deposit left by storm surge during monsoon season (Figure 4.70). Finally, in periods of January to November 2006, beach profile shows adjustment of beach shape in vertical and horizontal distance which response to the season change (Figure 4.71). Therefore, it appears to be a normal cycle of beach state in this area. In term of horizontal change of shoreline, beach profile of Klong Khuek Khak area shows erosion of shoreline in landward direction in which rate of erosion in year 2006 was 8 m. (Tables

4.23 and Table 4.24). However, while foreshore was eroded beach ridge was higher by deposition of eroded sediment from foreshore. These seem like a balance in beach state which adjusts itself response to the seasonal change. After the monsoon season, wave energy will decrease and foreshore slope will be gentle again as seen on a result of beach profile in January 2006.

Table 4.23 Changing in horizontal and vertical distance of beach profile at Klong Khuek Khak (KK) in 2006.

Period / Area	**KK**	
	Horizontal* (m)	**Vertical** (m)**
January	140	2.075
May	139	2.155
August	138	2.375
November	132	2.925

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

Table 4.24 Comparing change of horizontal and vertical distances of beach profile at Klong Khuek Khak (KK) in 2006.

Period / Area	KK	
	Horizontal* (m)	**Vertical** (m)**
January	0	0
May	-1	+0.08
August	-1	+0.22
November	-6	+0.55

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

+ = increase (compare to upper value)

- = decrease (compare to upper value)

4.2.3.2 Sedimentary analysis

A) Grain size of surface beach sediments Grain size of surface beach sediments shows majority of grain diameter of coarse sand (Figure 4.72). Grain size analysis of Klong Khuek Khak area in 2006 year exhibits some differences of grain size in each season of the 2006 year (Figure 4.73 and Table 4.25). In January, grain size of beach sediment was characterized by coarse sand with average diameter 0.682 mm, and then in May, grain size was slightly decreased to 0.669 mm. Between rainy season in August, grain size was increased to 0.751 mm and then decreased again in November about 0.561 mm after the beginning of winter season.

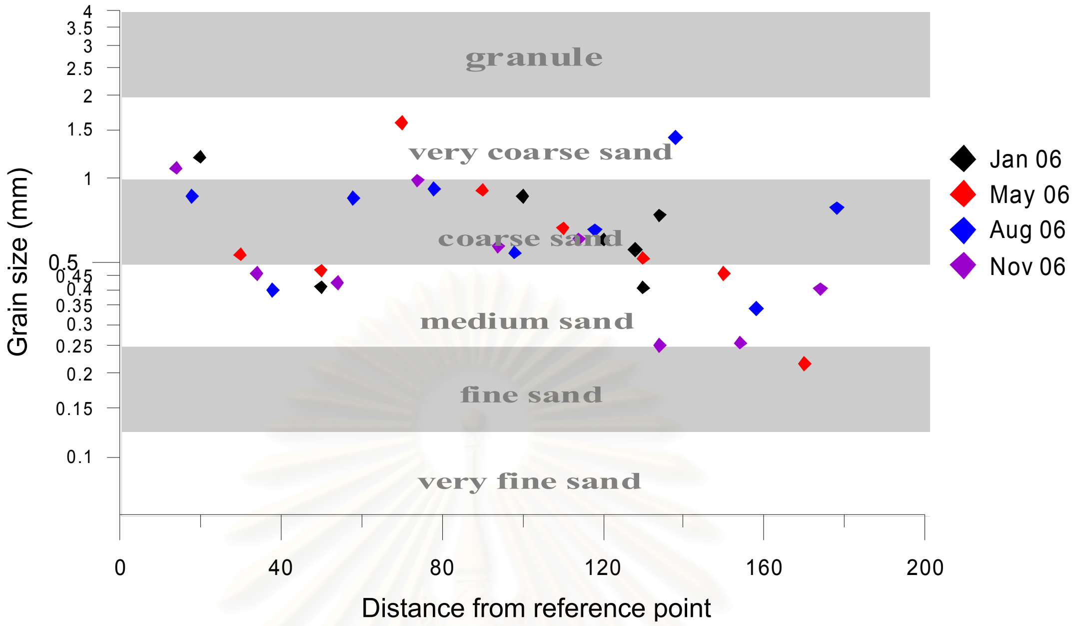

Figure 4.72 Grain size analysis of Klong Khuek Khak area in annual year 2006.

Table 4.25 Changing in grain size of beach sediment at Klong Khuek Khak area in 2006.

Period	Size (mm)	Size comparable
January	0.682	coarse sand
May	0.669	decrease
August	0.751	increase
November	0.561	decrease

B) Composition of beach sediment Major compositions of surficial beach sediments are quartz about 60%, bioclasts about 35%, and others about 5% (Figures 4.73 to Figure 4.76). The Average percentage of quartz and bioclasts in surficial beach sediment exhibits some differences of compositions in each season of the 2006 year (Tables 4.26 and Table 4.27). Quartz was slightly changed in percentage whereas bioclasts can obviously observe in the May as beginning of rainy season. In January quartz was 62.86% while bioclasts was 23.57% in percentage of surficial beach sediment. After that, in May quartz percentage was decreased about 1.61 % whereas bioclast was increased about 12.80%. Then in August quartz percentage was increased about 3.57% while bioclasts was decreased about 2.26%. Finally, after the end of monsoon season in November quartz percent was increased about 2% while bioclasts was decreased about 3.33 %.

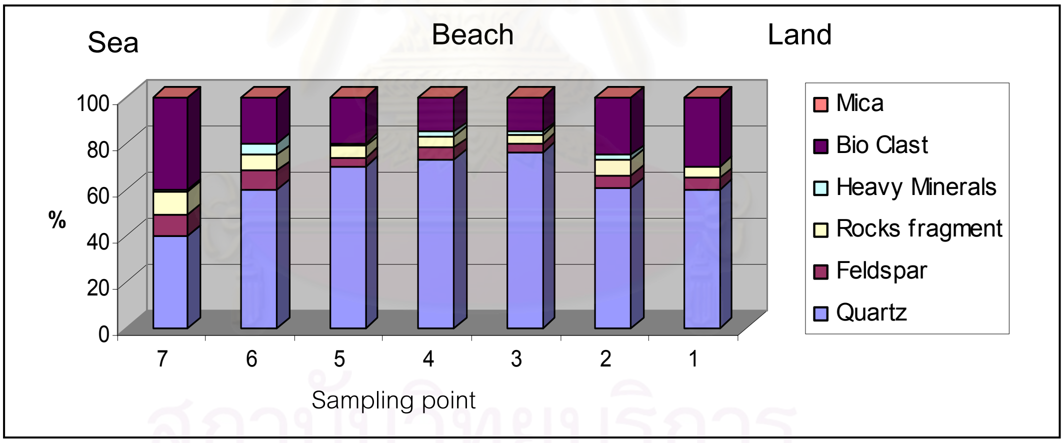

Figure 4.73 Graph of sediment compositions at Klong Khuek Khak area in January 2006. Major compositions are quartz and bioclasts. Quartz was decreased in percentage when far from beach zone. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

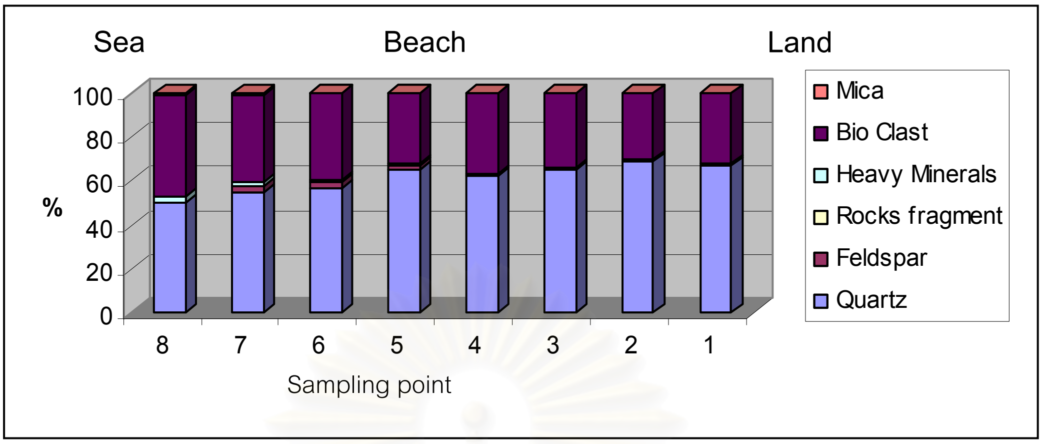

Figure 4.74 Graph of sediment compositions at Klong Khuek Khak area in May 2006. Major compositions are quartz and bioclasts. Quartz was decreased in percentage when far from beach zone. Heavy minerals were found increasing in percentage in seaward direction. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

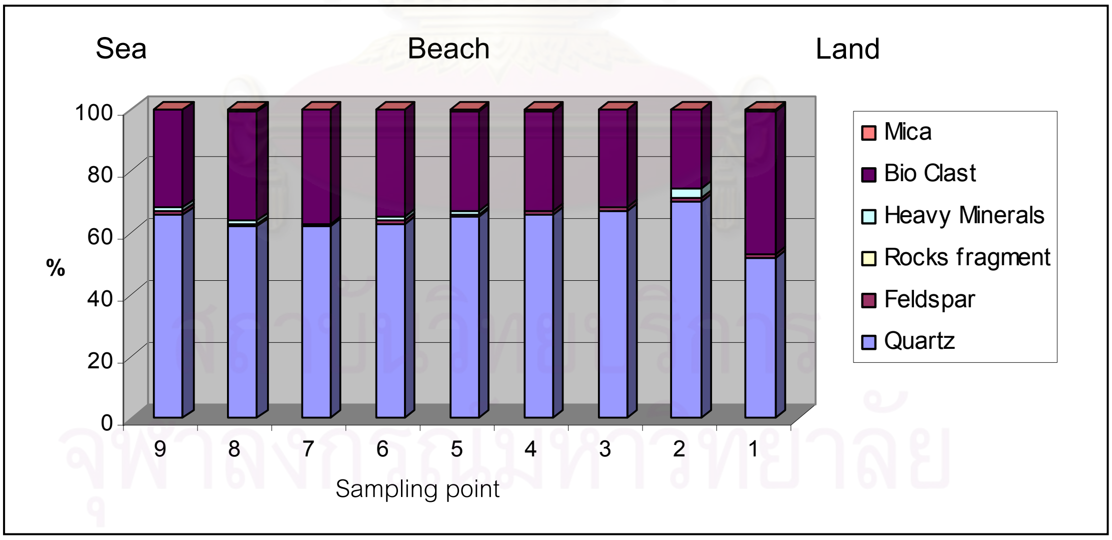

Figure 4.75 Graph of sediment compositions at Klong Khuek Khak area in August 2006. Major compositions are quartz and bioclasts. In this period quartz was increased in percentage at seaward direction compare to January and May. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

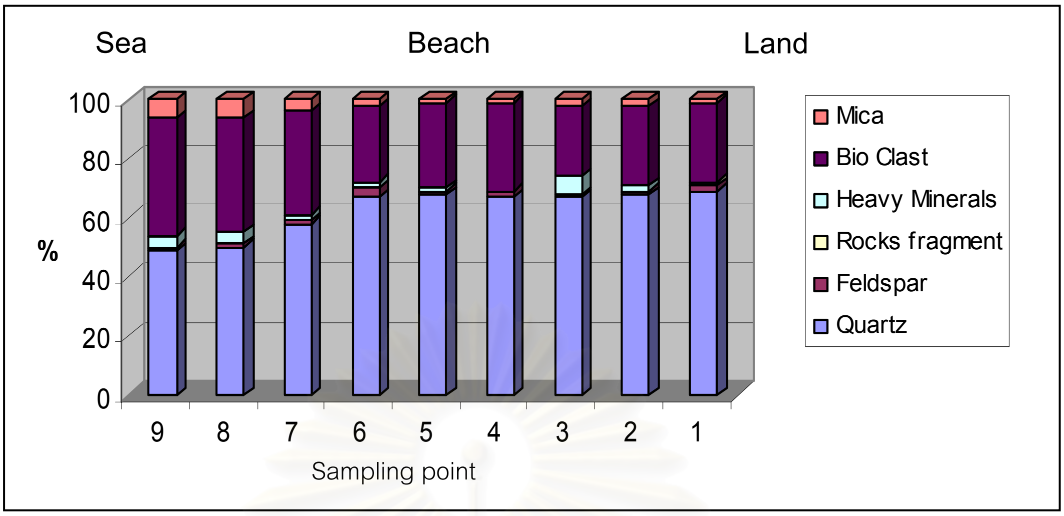

Figure 4.76 Graph of sediment compositions at Klong Khuek Khak area in November 2006. Major compositions are quartz and bioclasts. Quartz was decreased in percentage when far from beach zone while heavy minerals were increased. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

Table 4.26 Average percentage of quartz and bioclasts in surficial beach sediment at Klong Khuek Khak area in 2006.

Month	Quartz %	Bioclast %
January	62.86	23.57
May	61.25	36.38
August	65.00	34.11
November	67.00	30.78

Table 4.27 Comparison of increasing and decreasing in percentage of quartz and bioclasts in surficial beach sediment at Klong Khuek Khak area in 2006.

Month	Quartz %	Bioclast %
January	62.86	23.57
May	-1.61	+12.80
August	+3.57	-2.26
November	+2.00	-3.33

\+ = increase (compare to upper value)

\- = decrease (compare to upper value)

C) Physical properties Physical properties of surficial beach sediment at Klong Khuek Khak area in 2006 exhibits trend of roundness in sub-angular and also sphericity of sediment grain is presented in unit of high sphericity. Sediment grain with sub-angular in roundness present that it is new sediment which transport not far from their source. High sphericity of sediment grain also present that it was done by high energy of abrasion which usually occur in swash zone.

4.2.3.3 Field observation

Eroded shoreline at Klong Khuek Khak area was almost recovered after one year of the 2004 tsunami event. New sediment deposit was filled up in the eroded area at the mouth of inlet/outlet channel. New sand spit was found at the mouth of inlet/outlet channel in January 2007 which approximately high 3 meters above the present mean sea level (Figure 4.77). Sand spit was accumulated in northward direction response to the longshore current in this area. In November sand spit was growth exceeds the mouth of inlet/outlet channel and extends itself into the sea (Figure 4.79 C). After that, from field observation in March 2007, sand spit closed the mouth of inlet/outlet channel led channel meandered to find new drainage outlet. The middle part of sand spit which close to the main channel was destroyed by erosion of meandering stream behind sand spit (Figure 4.78 C) and new outlet was opened at the middle part of sand spit (Figure 4.78 E).

Slope of foreshore also changes response to the annual seasonal changes (Figure 4.80). In January 2006, foreshore slope was gently (Figure 4.80 A), then steeper in August (Figure 4.80 B), and much steeper in November (Figure 4.80 C). Finally, in March 2007 slope of foreshore was decreased and turned to gentle again (Figure 4.80 D). Evidence of high energy of wave in monsoon season was also observed. In May, washover fan and slump of sand spit was found behind sand spit (Figure 4.81).

Figure 4.77 Photograph showing new sand spit at mouth of inlet/outlet channel at Klong Khuek Khak area (looking north). Height of sand spit from water level in channel at high tide time is approximately 3 meters.

Figure 4.78 Series of photographs taken from January 2006 to March 2007 showing the change in shape of sand spit (looking south).

Figure 4.79 Series of photographs of inlet/outlet channel mouth at Klong Khuek Khak area taken in different seasons of 2006 showing accretion of sediment at mouth of channel as arrow indicated (looking north).

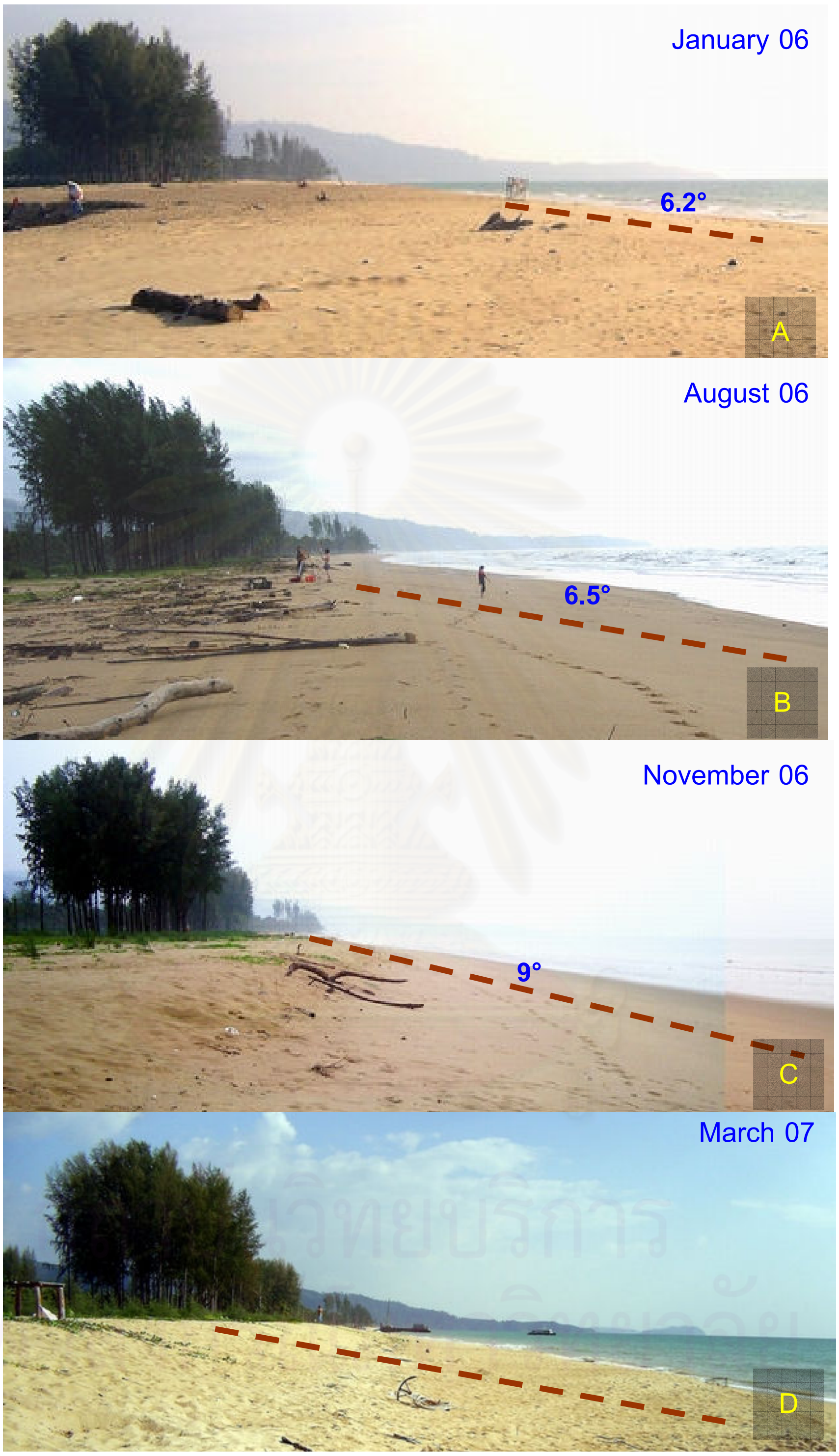

Figure 4.80 Series of photographs of foreshore slope at Klong Khuek Khak area comparing in different seasons since January 2006 to March 2007 showing steep slope in August to November 2006, and gentle slope in January 2006 and March 2007(looking south).

Figure 4.81 Photographs showing washover sand deposits and slump of sand behind sand spit has left by seasonal storm surge (picture A looking north, picture B looking south).

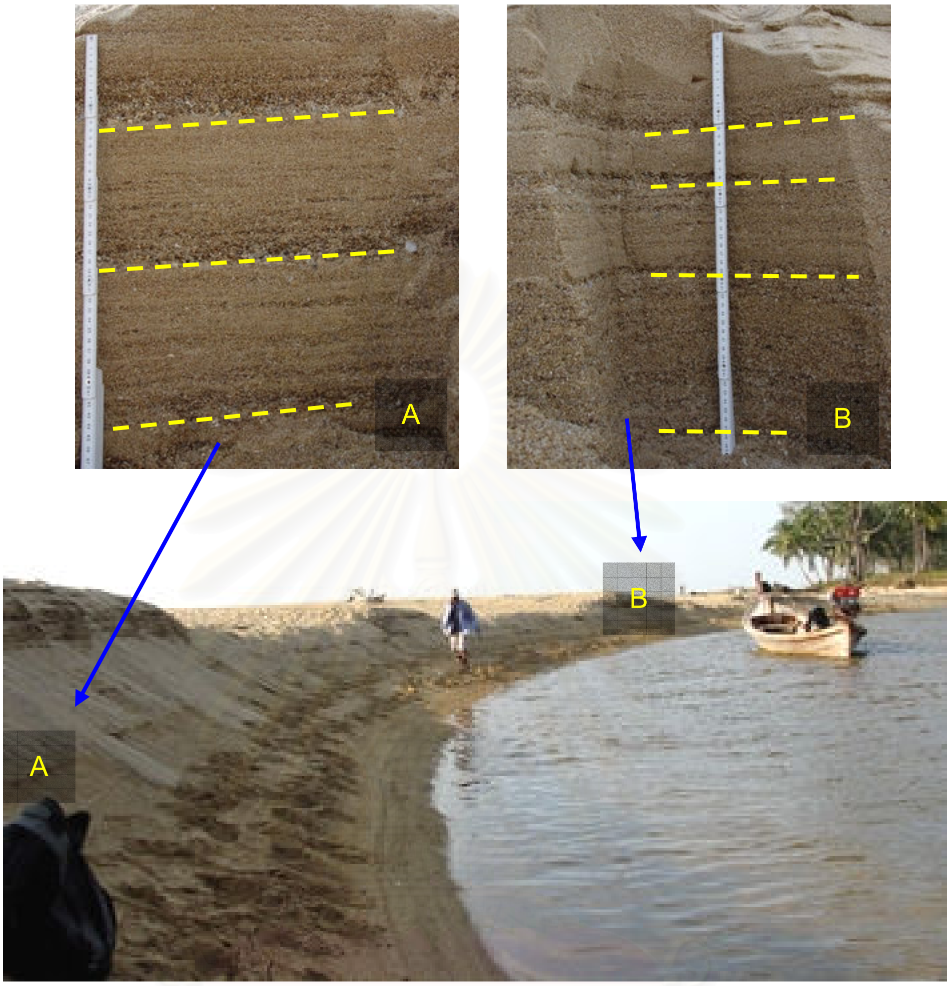

Figure 4.82 Photographs showing several layers of new sand in fining upward sequence of very coarse sand to fine sand showing normal depositional events in one year since January 2005 to January 2006.

4.2.4 Ban Bang Niang

Figure 4.83 Profiling position at Ban Bang Niang. Green dot is a reference point. Red line is east-west beach profile and blue line is south-north inlet/outlet cross-section. Background image is from SPOT-5 satellite taken two year after the 2004 tsunami.

4.2.4.1 Beach profile

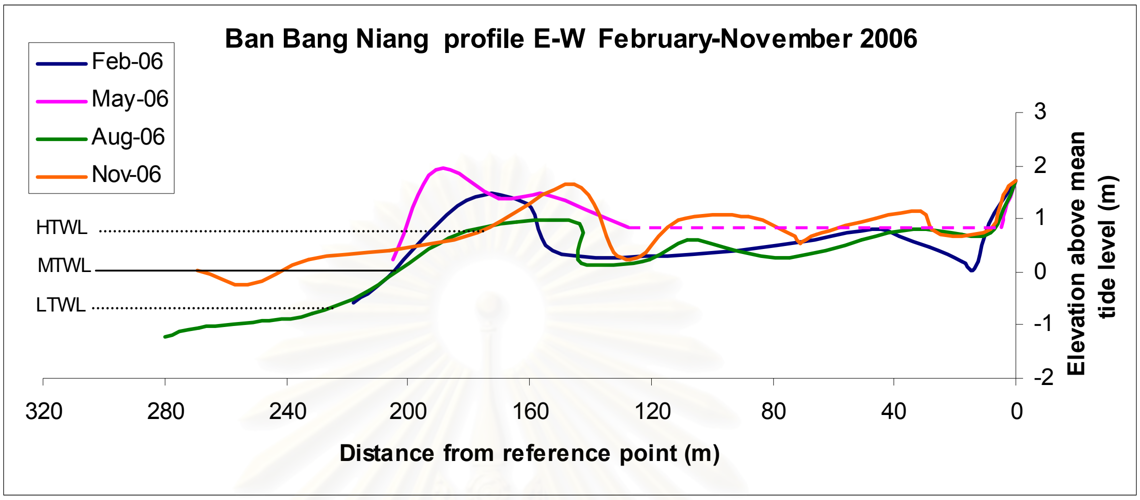

Figure 4.84 Beach profile of Ban Bang Niang area showing configuration changed annually.

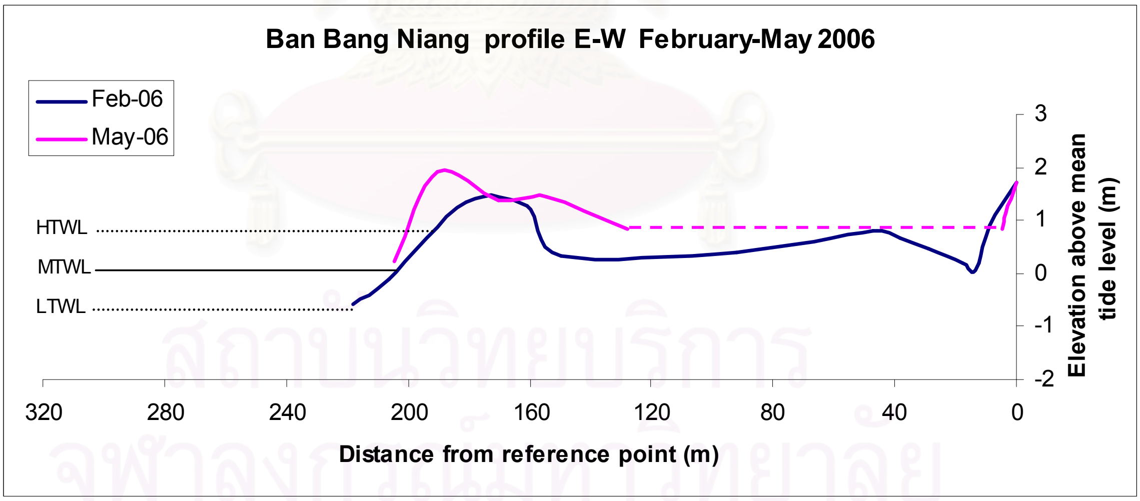

Figure 4.85 Beach profile of Ban Bang Niang area in period of February to May 2006 showing lagoon area as a result of closing of inlet/outlet mouth from higher beach ridge.

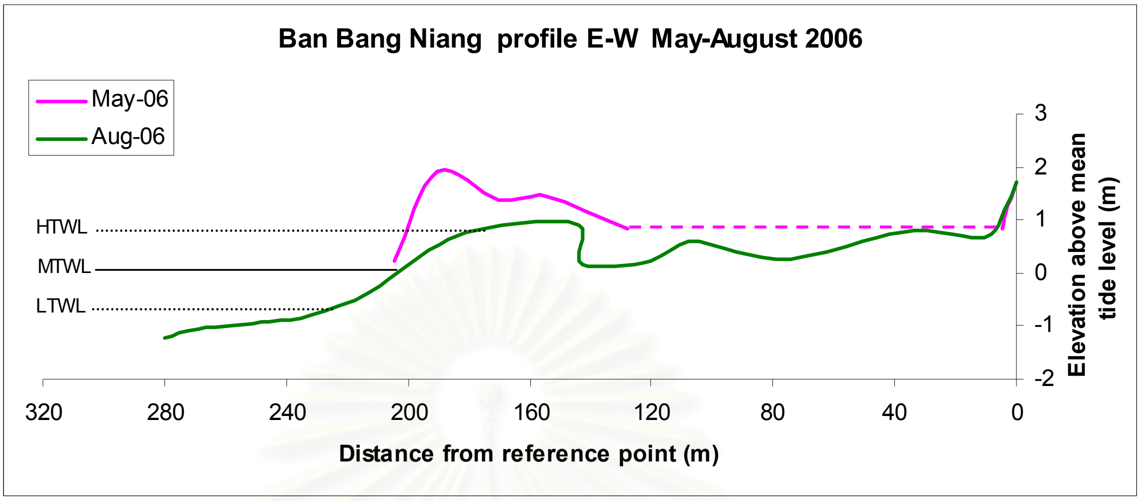

Figure 4.86 Beach profile of Ban Bang Niang area in period of May to August 2006 showing erosion of sediment deposit at mouth of inlet/outlet. Previous lagoon and higher beach ridge was disappeared and turned into gentle slope of foreshore and smaller beach ridge.

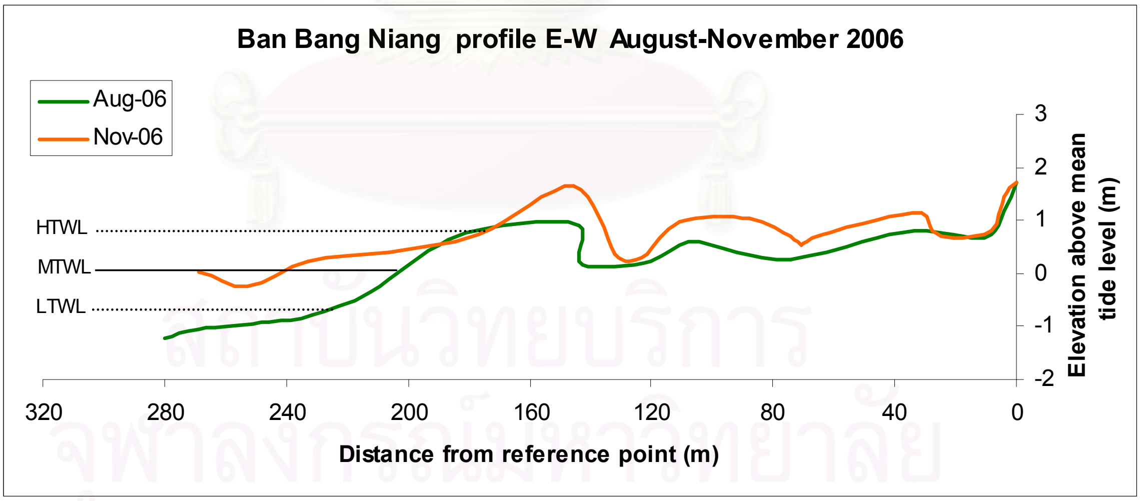

Figure 4.87 Beach profile of Ban Bang Niang area in period of August to November 2006 showing deposition of sediment deposit at mouth of inlet/outlet. Beach ridge was higher and changed in vertical distance. Channel flood plain behind backshore was clearly observed.

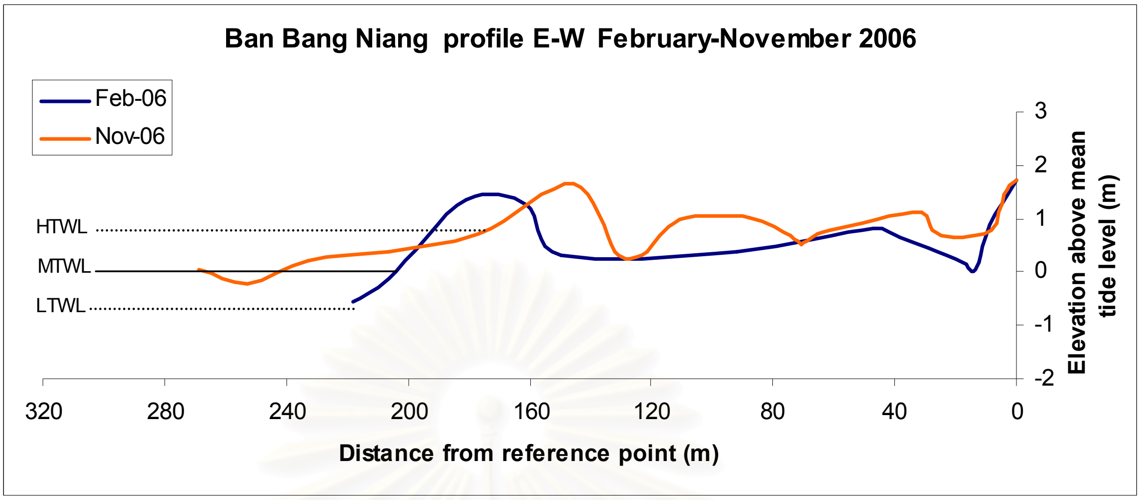

Figure 4.88 Beach profiles of Ban Bang Niang area in period of February to November 2006 showing balance of deposition and erosion of sediment deposit at inlet/outlet mouth. Flood plain behind backshore showed deposition of sediment from fluvial which recognized by higher flood plain surface.

In analyzing beach profile changes through time, between the initial surveys in February to May 2006, in the February, beach profile showed the steep slope of foreshore, and then in May, deposition was occurred at foreshore with a steeper slope and beach ridge was higher. Sediment deposit at inlet/outlet mouth was higher than HTWL (high tide water level) because water in channel cannot drain out to the sea and lagoon was occurred behind the backshore area (Figure 4.85). After that during May to August 2006, previous foreshore and beach ridge was eroded, so that water in channel be able to drain out to the sea and lagoon was disappeared (Figure 4.86). Then, the August to November 2006, beach ridge was higher as a result of deposition at foreshore and also floodplain surface behind backshore area was higher in vertical distance (Figure 4.87). Finally, in periods of February to November 2006, the balance of deposition and erosion of sediment deposit at inlet/outlet mouth was returned. Flood plain behind backshore area showed deposition of sediments from fluvial which recognized by higher flood plain surface (Figure 4.88). Therefore, beach behavior appeared to be a normal cycle of beach state in this area. In term of horizontal change of shoreline, beach profile of Ban Bang Niang area showed erosion of shoreline in landward direction which rate of erosion in 2006 year was 18 m. (Tables 4.28 and Table 4.29). However, while foreshore was eroded, beach ridge was higher by deposition of eroded sediment from foreshore. Moreover from the beach profile in November (Figure 4.87), it seems to be a deposition stage of foreshore in the next month that responsible to the low energy of wave in winter and summer seasons.

Table 4.28 Changing in horizontal and vertical distance of beach profile at Ban Bang Niang (BN) in 2006.

Period / Area	**BN**	
	Horizontal* (m)	**Vertical** (m)**
February	192	0.715
May	201	1.145
August	180	0.205
November	174	0.905

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

Table 4.29 Comparing change of horizontal and vertical distances of beach profile at Ban Bang Niang (BN) in 2006.

Period / Area	BN	
	Horizontal* (m)	**Vertical** (m)**
February	0	0
May	+9	+0.43
August	-21	-0.94
November	-6	+0.7

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

+ = increase (compare to upper value)

- = decrease (compare to upper value)

Inlet/outlet cross-section

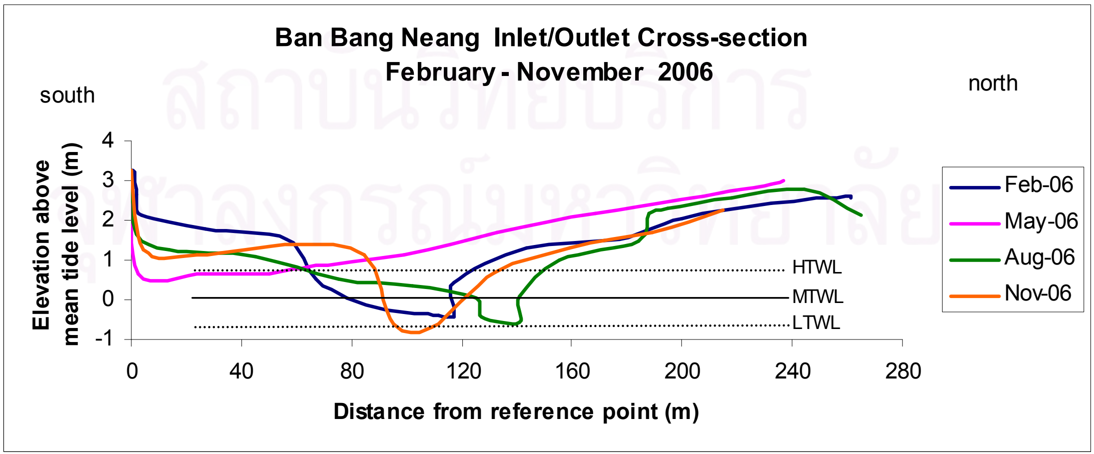

Figure 4.89 Inlet/outlet cross-section of Ban Bang Niang area showing configuration changed annually.

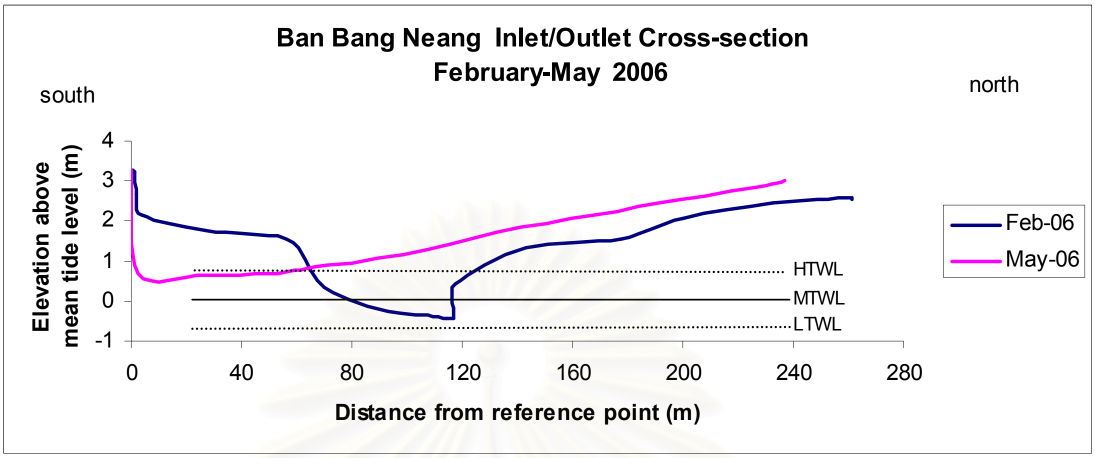

Figure 4.90 Inlet/outlet cross-section of Ban Bang Niang area in period of February to May 2006 showing movement of channel in southward direction. Deposition of sediment at inlet/outlet mouth is clearly observed in the northward whereas erosion was occurred in the southward of channel.

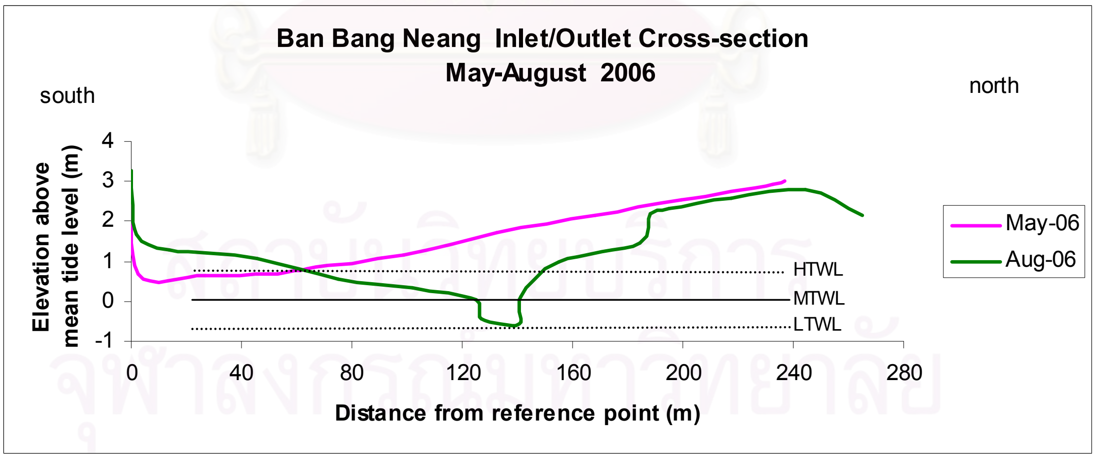

Figure 4.91 Inlet/outlet cross-section of Ban Bang Niang area in period of May to August 2006 showing movement of channel in northward direction. Erosion of sediment at inlet/outlet mouth is clearly observed in the northward whereas deposition was occurred in the southward of channel.

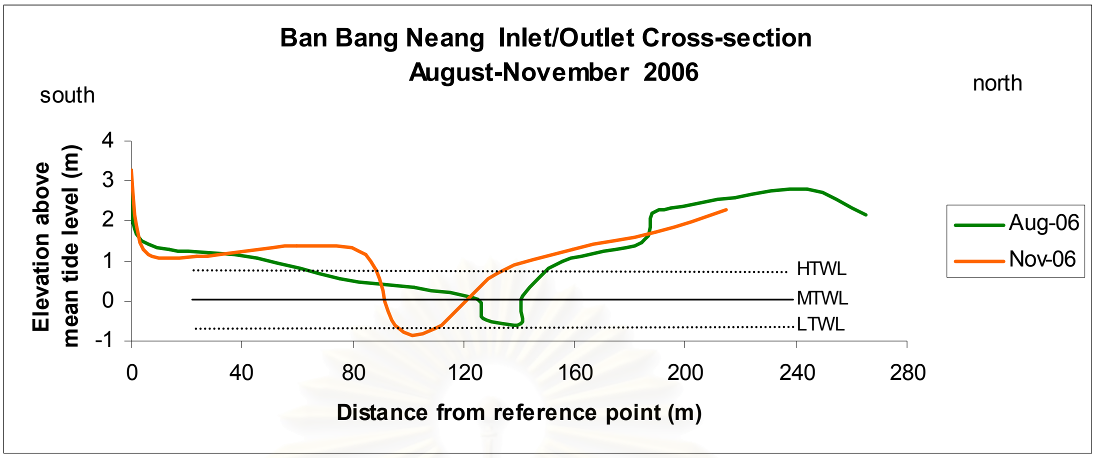

Figure 4.92 Inlet/outlet cross-section of Ban Bang Niang area in period of August to November 2006 showing movement of channel in northward direction. Deposition of sediment at inlet/outlet mouth is clearly observed in the northward whereas erosion was occurred in the southward of channel.

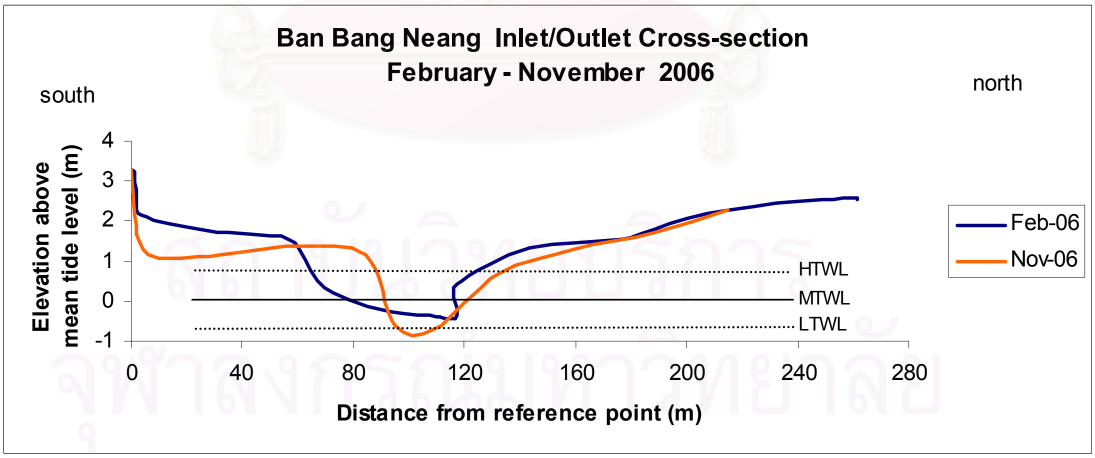

Figure 4.93 Inlet/outlet cross-section of Ban Bang Niang area in period of February to November 2006 showing meandering of channel in northward and southward direction. Inlet/outlet mouth was in the same position with February period but slightly differ in width of channel.

4.2.4.2 Sedimentary analysis

A) Grain size of surface beach sediments Grain size of surface beach sediments shows majority of grain diameter of coarse to very coarse sand (Figure 4.94).

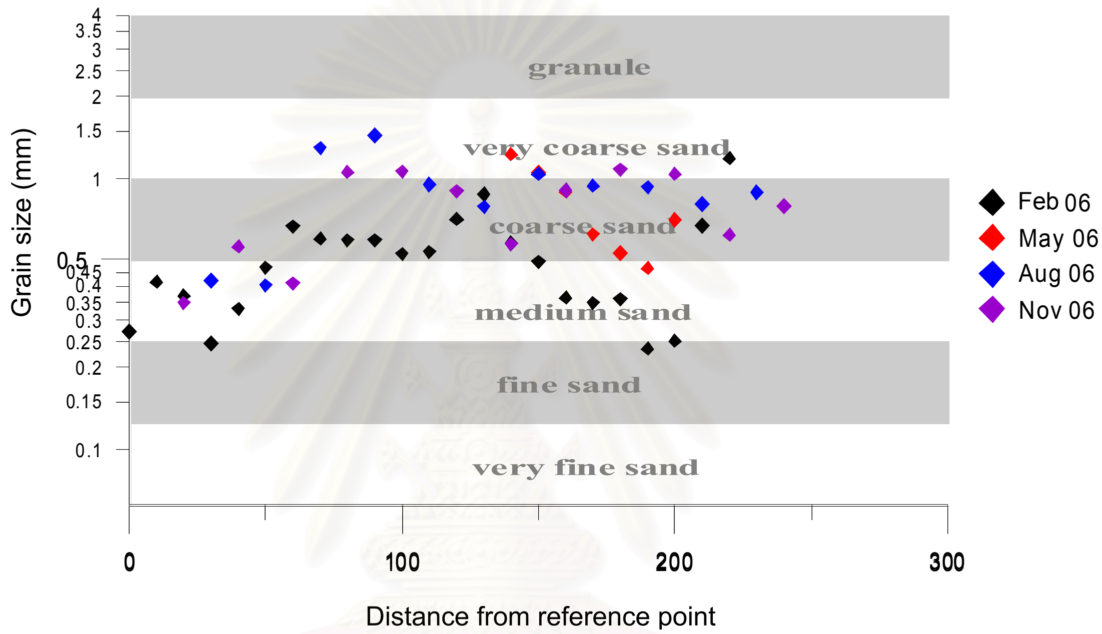

Figure 4.94 Grain size analysis of Ban Bang Niang area in annual year 2006.

Table 4.30 Changing in grain size of beach sediment at Ban Bang Niang area in 2006.

Period	Size (mm)	Size comparable
February	0.507	coarse sand
May	0.783	increase
August	0.899	increase
November	0.777	decrease

Grain size analysis of Ban Bang Niang area in 2006 year exhibits some differences of grain size in each season of the 2006 year (Figure 4.94 and Table 4.30). In February, grain size of beach sediment was characterized by coarse sand with average diameter 0.507 mm, and then in May, grain size increased to 0.783 mm. Between rainy season in August, grain size was increased to 0.899 mm and then decreased again in November about 0.777 mm after the beginning of winter season.

C) Composition of beach sediment Majority of compositions of surficial beach sediments are quartz about 60%, bioclasts about 35%, and others about 5 % (Figures 4.95 to Figure 4.98). The Average percentage of quartz and bioclasts in surficial beach sediment exhibits some differences of compositions in each season of the 2006 (Tables 4.31 and Table 4.32). In February quartz was 63.48% while bioclasts was 32.48% in percentage of surficial beach sediment. After that, in May quartz percentage was increased about 3.24 % whereas bioclasts was decreased about 0.91%. Then in August quartz percentage was decreased about 6.17% while bioclasts was increased about 4.90%. Finally, after the end of monsoon season in November quartz percent was increased about 7.37% while bioclasts was decreased about 8.93 %.

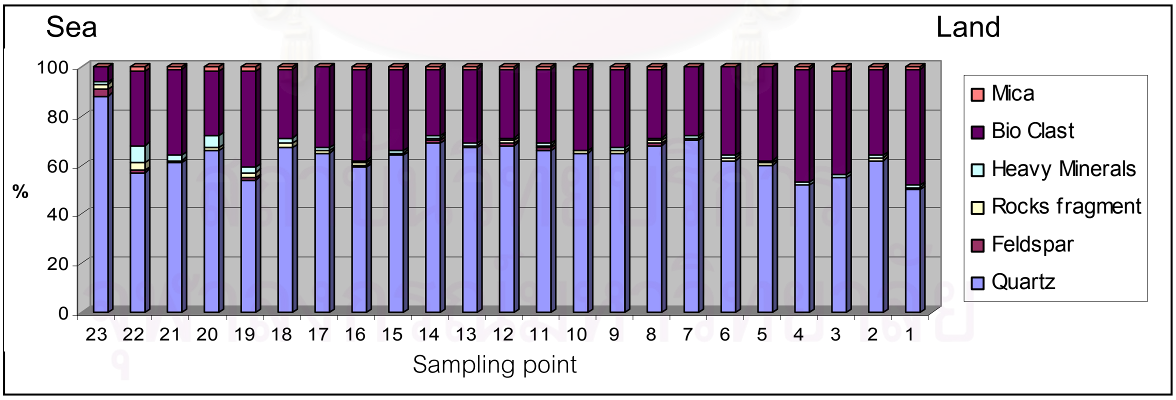

Figure 4.95 Graph of sediment compositions at Ban Bang Niang area in February 2006. Major compositions are quartz and bioclasts. Heavy minerals were found increasing in percentage in seaward direction. Samples were collected with 10 m. distance interval (Position of sampling point can be see in Appendix C).

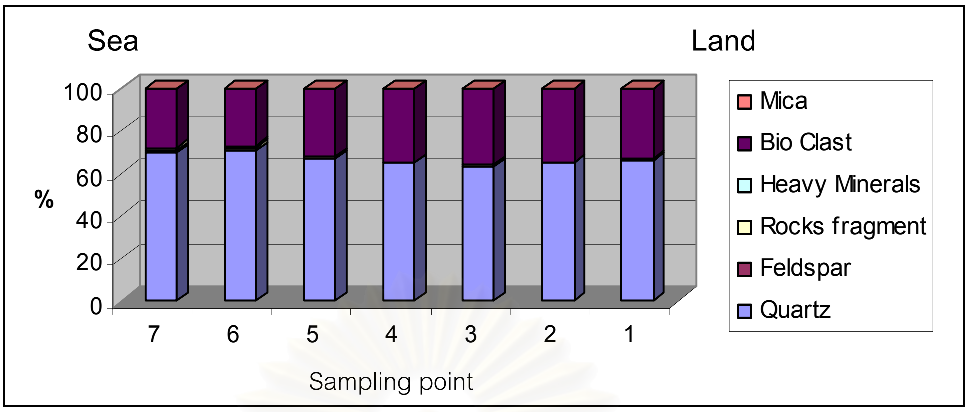

Figure 4.96 Graph of sediment compositions at Ban Bang Niang area in May 2006. Major compositions are quartz and bioclasts. Percentage of bioclasts was decreased in seaward direction. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

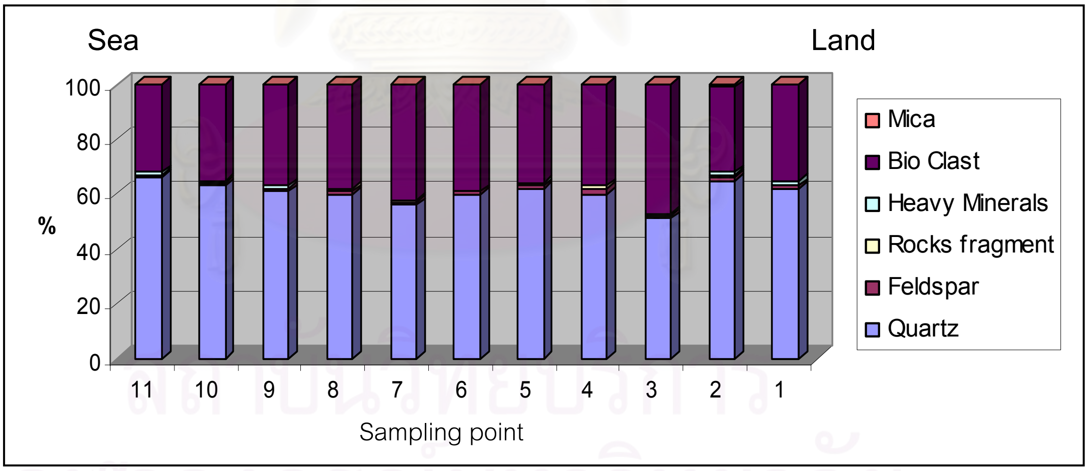

Figure 4.97 Graph of sediment compositions at Ban Bang Niang area in August 2006. Major compositions are quartz and bioclasts. Quartz was decreased in percentage while bioclasts was increased compare to May 2006. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

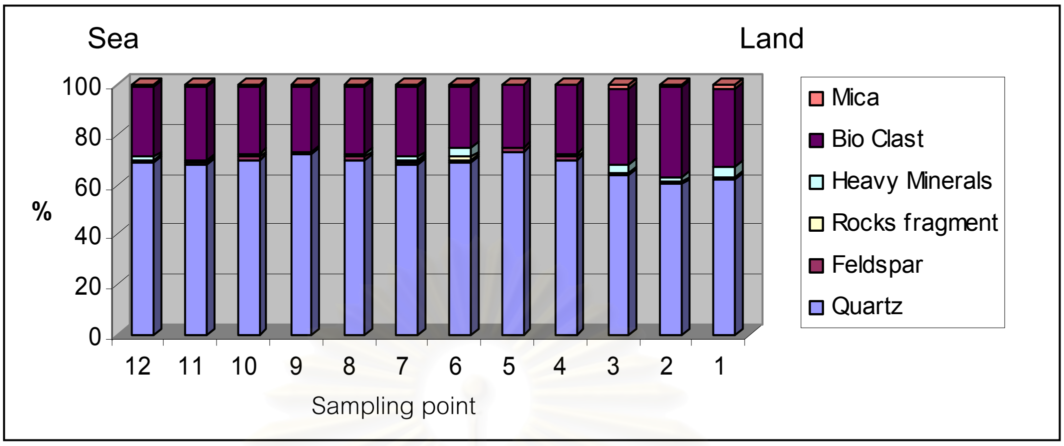

Figure 4.98 Graph of sediment compositions at Ban Bang Niang area in November 2006. Major compositions are quartz and bioclasts. Quartz was increased in percentage while bioclasts was decreased compare to August 2006. Samples were collected with 20 m. distance interval (Position of sampling point can be see in Appendix C).

Table 4.31 Average percentage of quartz and bioclasts in surficial beach sediment at Ban Bang Niang area in 2006.

Month	**Quartz %**	**Bioclast %**
February	63.48	32.48
May	66.71	32.29
August	60.55	37.18
November	67.92	28.25

Table 4.32 Comparison of increasing and decreasing in percentage of quartz and bioclasts in surficial beach sediment at Ban Bang Niang area in 2006.

Month	Quartz %	Bioclast %
January	63.48	32.48
May	+3.24	-0.19
August	-6.17	+4.90
November	+7.37	-8.93

+ = increase (compare to upper value)

- = decrease (compare to upper value)

C) Physical properties Physical properties of surficial beach sediment at Ban Bang Niang area in 2006 exhibits trend of roundness in sub-angular and also sphericity of sediment grain is presented in unit of high sphericity. Sediment grain with sub-angular in roundness present that it is new sediment which transport not far from their source. High sphericity of sediment grain also present that it was done by high energy of abrasion which usually occur in swash zone.

4.2.4.3 Field observation

Eroded shoreline at Ban Bang Niang area was almost recovered after one year of the 2004 tsunami event. New sediment deposit was filled up in the eroded area which height approximately 2.5 meters from ground surface (Figure 4.99 C). Stream cut outcrop near the mouth of inlet/outlet channel in February 2006 also shows development of shoreline that indicating successions of backshore and foreshore layer (Figure 4.100). Instability of mouth channel area was recorded from field investigation since February to November 2006 as mentioned in inlet/outlet cross-section which shows erosion and deposition of channel bank at mouth of inlet/outlet area (Figure 4.101). In February, tidal channel became small and slightly meandered (Figure 4.101 A). Then, in May, channel had changed outlet to the left of previous one due to erosion of stream cut outcrop near inlet/outlet (Figure 4.101 B). Sediment deposit at the mouth of inlet/outlet channel was accumulated higher than high tide water level leading water cannot drain out to the sea (Figure 4.101 B). Three months later, in August, (Figure 4.101 C), tidal channel eroded sand barrier and new outlet opened on the right of previous one with more meandered channel shape. Finally, in November, (Figure 4.101 D) new sediment deposit occurred again near inlet/outlet mouth at the same place that stream cut outcrop was observed. Channel shape was wider, bigger and meandered into the entire area.

Figure 4.99 Photographs showing new sediment filled up in the eroded area of Ban Bang Niang in February 2006. Picture A shows sediment deposit at mouth of inlet/outlet channel (looks west), picture B shows new beach deposits in the south side of inlet/outlet channel (looking south) and picture C shows new sediments deposit near inlet/outlet channel, height of deposition is 2.5 from ground surface.

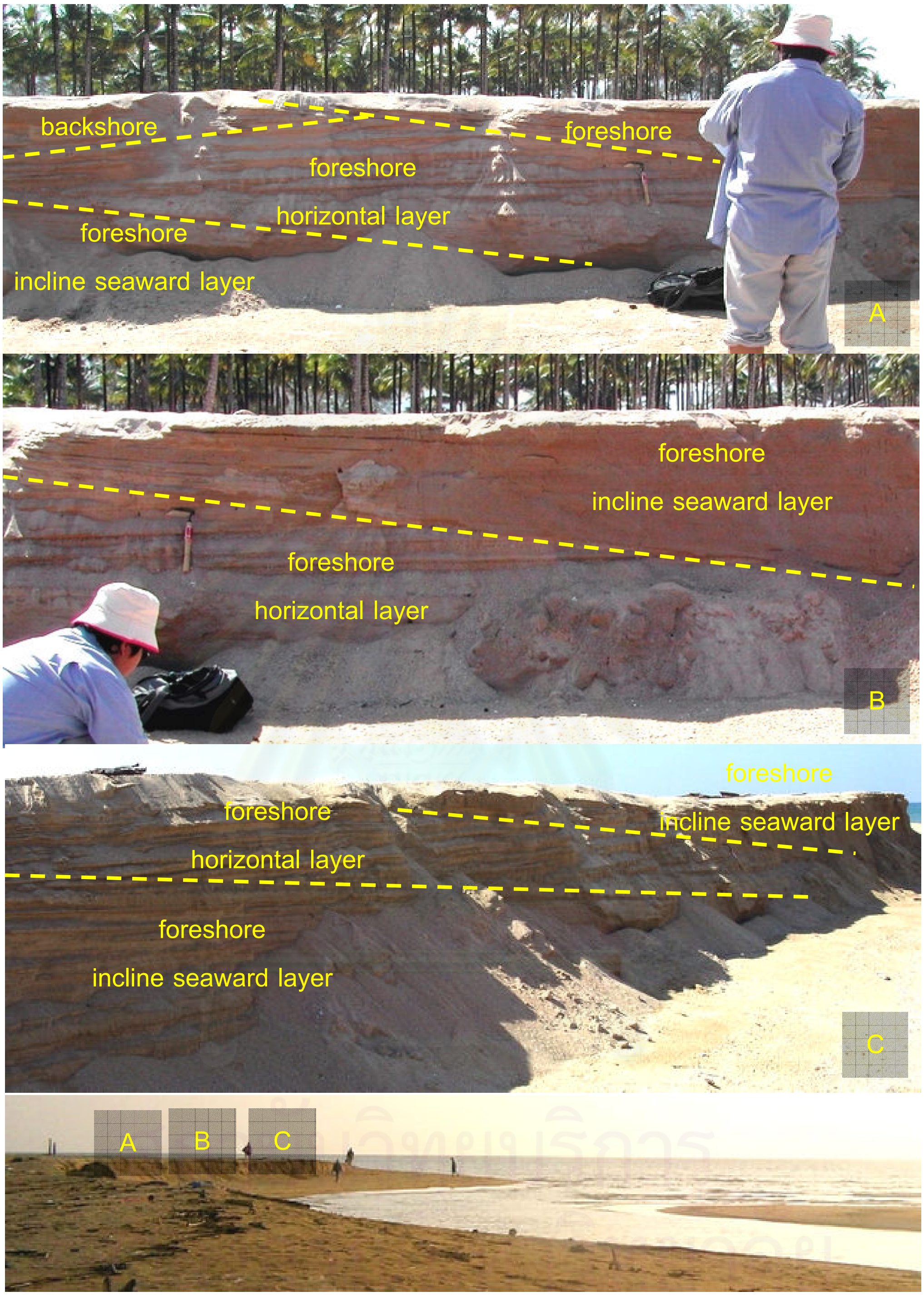

Figure 4.100 Photographs showing stream-cut outcrop illustrating new succession of shoreline developing which indicated by several successions of foreshore deposits including horizontal layers and incline in seaward direction layers of sand that show progradation of shoreline.

Figure 4.101 Photographs showing a small meandering stream that was clearly observed at Ban Bang Niang from February to November 2006 (looking west).

Figure 4.102 Photographs showing inlet/outlet channel at Ban Bang Niang area showing meandering stream inside tidal channel and also land use change from June to November 2006 (looking south).

CHAPTER V

DISCUSSION AND CONCLUSION

The purposes of this study are aimed to monitor recovering process in beach area after shoreline was changed by the 24 December 2004 tsunami and to understand beach behavior including characteristics of beach sediment and accretion and erosion of shoreline in 2006 after shoreline was recovered. In this chapter, the recovering processes of shoreline that suffered from the 2004 tsunami events and annual coastal change in each area will be discussed. This chapter also provides the characteristics of beach sediment in study area, sediment transportation direction, sediment source zone, and the discussion on coastal type before and after tsunami. In addition, the factors controlling coastal changes and the benefits of this study are also suggested for land use.

5.1 Discussion

5.1.1 Recovery process of eroded area

Result of analysis in shoreline change and beach area change after the 2004 Indian Ocean tsunami shows the different rate of recovered among four sub areas that can be divided into two periods (Figure 5.1). The first period of extensive recovery was started just after the event; from January to June 2005 (purple dashed line). High depositional rate in eroded beach area approximately 60 % recovered was evaluated. The second period of gradual recovery was, then, followed from August 2005 to November 2006 (green dashed line). Rate of deposition was decreased and beach zone seemed to get more stability.

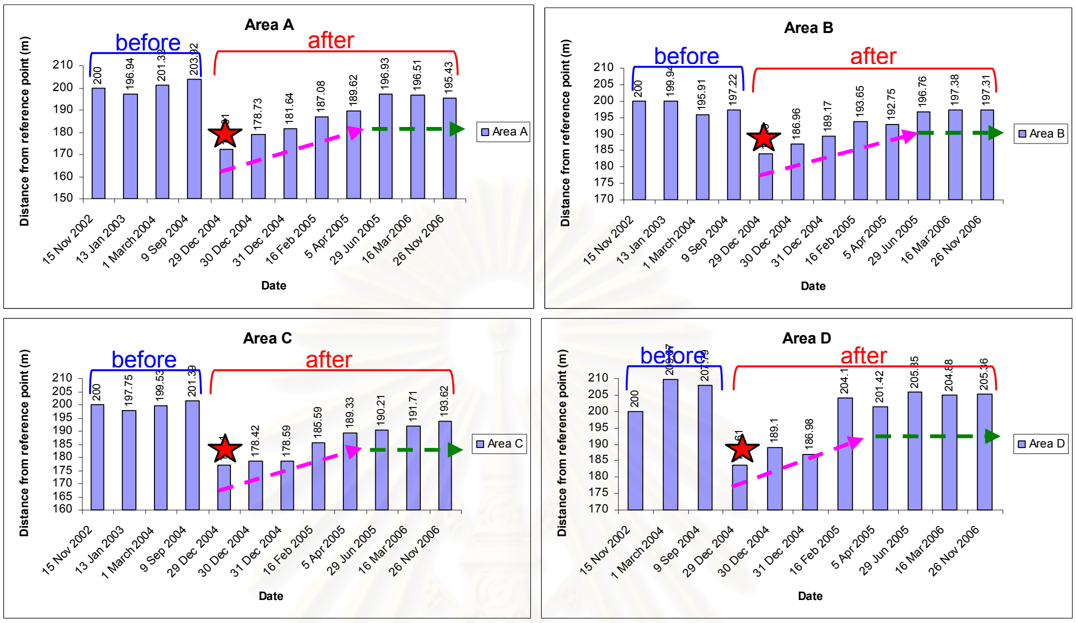

Figure 5.1 Graph of shoreline change shows two periods in different rate of recovered in four sub areas. Red star is three day after tsunami attacked, purple dashed line is first period of recovery and green dashed line is second period of recovery.

5.1.1.1 Accommodation space

Difference in rate of deposition at eroded area was also confirmed by sediment accommodation space. Accommodation space is a place where sediment can deposit. If there is zero accommodation space available, the sediment will be transported to an area of (positive) accommodation space where they can be deposited. Thus, areas of zero accommodation space are sites of sediment by-pass. If there is a negative amount of accommodation space, the previously deposited sediments will be eroded and transported to an area of (positive) accommodation space. This is because all sedimentary systems are trying to achieve and then preserve the equilibrium profile (or depositional profile) where the available accommodation space is balanced by the amount of sediment supplied as previously suggested by Coe et al. (2003). In this study, before the 2004 Indian Ocean tsunami event, shoreline showed stability in the equilibrium cycle and only seasonal change was recognized because accommodation space in the area was almost zero (Figure 5.2). Then after tsunami attacked in the 26 December 2004, shoreline and beach area was eroded approximately 75 % leading to extensive increase of accommodation space (Figure 5.3). Thus, sediments from whatever source either offshore or onshore can deposit at the eroded area as much of accommodation space available. This is why rate of deposition in first period (2005) is higher than second period (2006). After sediments were filled up in the eroded area (new positive accommodation space), accommodation space was decreased corresponding to decrease of deposition rate (Figure 5.4).

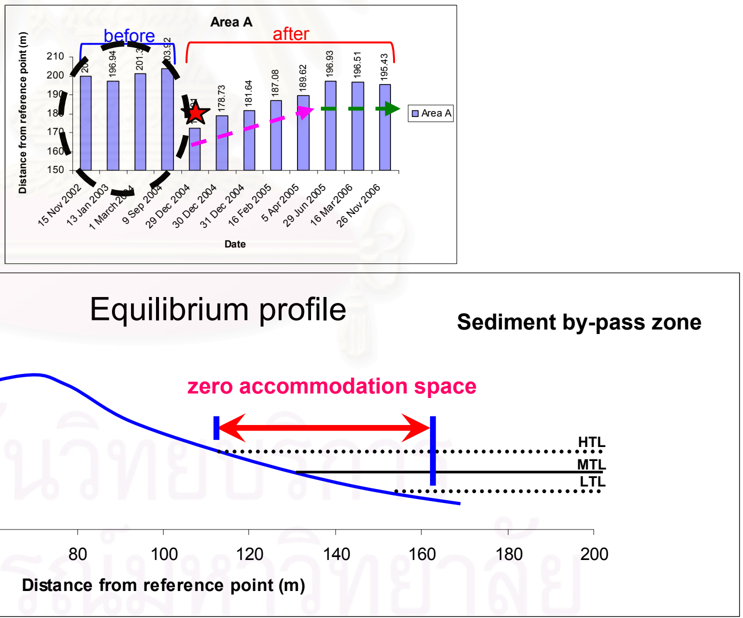

Figure 5.2 Profile of beach in equilibrium stage before the 2004 Indian Ocean tsunami with accommodation space was almost zero. This is a stage before tsunami 2004 attacked shoreline which has a change of shoreline in an equilibrium cycle like a stable coastline as drawn in a black dashed polyline.

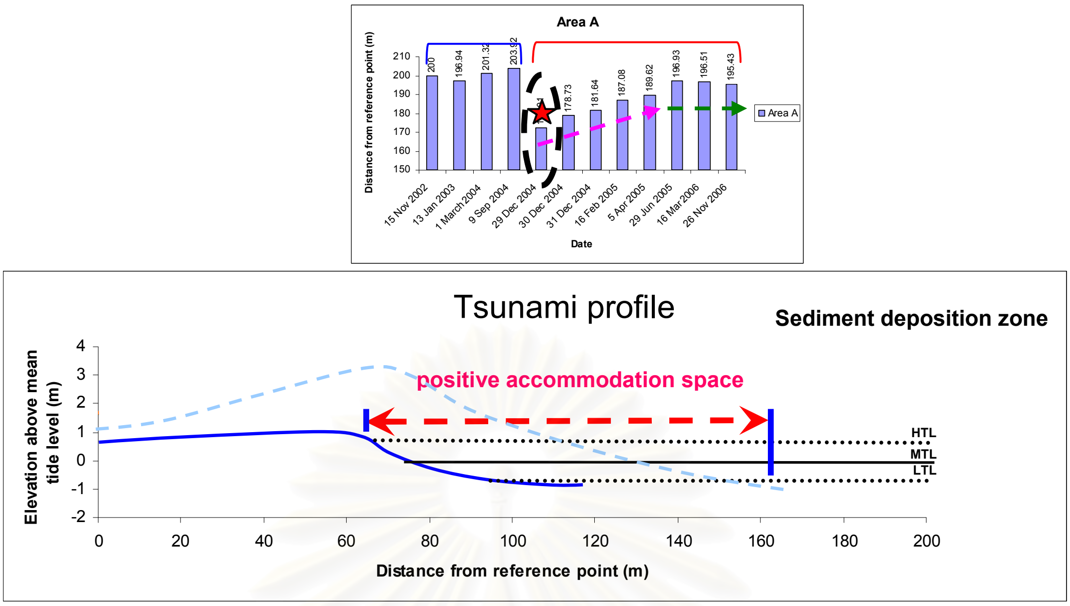

Figure 5.3 Profile of beach erosion after the 2004 tsunami shows increasing in positive accommodation space. Therefore, numerous sediments can deposit in a large accommodation space due to rapidly recovered of beach area.

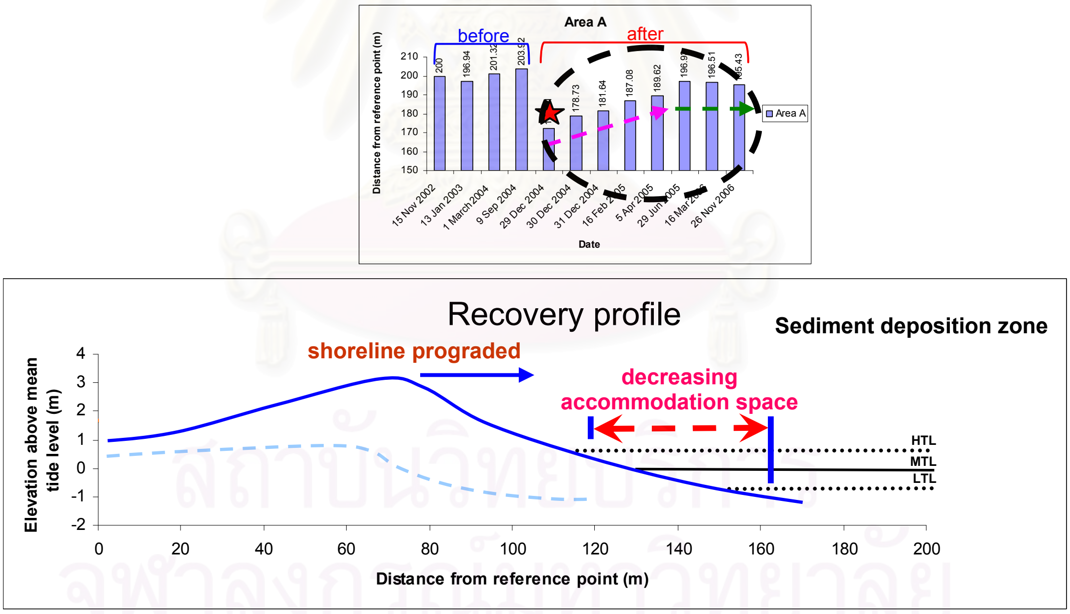

Figure 5.4 Profile of recovered beach show recovered of erosional area. The first period was recovered with high rate (purple dashed line) as a result of high accommodation space. While recovery process was running the accommodation space was decreasing. Then the second period, recovery rate was decreased (green dashed line) corresponded to a smaller accommodation space.

Furthermore, from the series of satellite images during 2002-2006, recovery processes was recognized extensively only at beach area and mouth of inlet/outlet area, whereas in the eroded tidal channel were not recovered. Tidal channel showed little recovery because of small amount of sediment supplies from inland channel itself. Thus, controlling factor in recovery process in this study area is dominated by marine process led to the more sediment supply and the more energy comparison to fluvial process in this area.

5.1.2 Annual coastal change in 2006

Result of beach profile measurement as mentioned in chapter IV shows changing in profile due to seasonal changes which can observed from foreshore configuration (Table 5.1). At Blue Village Pakarang Resort (BV), beach cycle seemed to be equilibrium in erosion and deposition, while at Sofitel Magic Lagoon Resort (SF) exhibits much of erosion within foreshore area in horizontal distance through the year 2006. The deposition in vertical scale can be observed at beach ridge which higher deposition was recognized in monsoon season comparing to non-monsoon season. At Klong Khuek Khak (KK), erosion of foreshore in horizontal distance shows similar patterns to SF area. In the same time, while erosion occurred in horizontal, deposition was occurred vertically at beach ridge and continued to slightly higher rate of deposition since January 2006 until November 2006. Finally, at Ban Bang Niang (BN) area, erosion in horizontal distance was seriously induced during monsoon season in August with rate of erosion about 21 meters, but after end of monsoon season rate of erosion was decreased. Then, there was deposition of beach ridge in vertical distance about 0.7 meters.

In conclusion, measurement of beach profile in 2006 shows erosion in monsoon season and after the end of monsoon season beach still suffered from erosion. Evidence of high energy wave in monsoon season was left by steep slope of foreshore (Table 5.2) and retreat of shoreline. Deposition usually occurs in the period of fair-weather climate in non monsoon season which is confirmed by result of beach profile in January to February and from field investigation in March 2007. Slope of foreshore at KK area was gentler than last November 2006 as mentioned in chapter IV. However, this result was carried out only one year for monitoring beach behavior. The more detail measurement, in term of identifies erosional beach type long term monitoring is required.

Table 5.1 Changing in horizontal and vertical distances of beach profile in 2006.

Period / Area	**BV**		**SF**		**KK**		**BN**	
	H* (m)	V** (m)	H* (m)	V** (m)	H* (m)	V** (m)	H* (m)	V** (m)
First	37	1.825	43	1.675	140	2.075	192	0.715
Second	+9	0	-3	+0.4	-1	+0.08	9	+0.43
Third	-7	+0.1	-3	0	-1	+0.22	-21	-0.94
Fourth	+1	+0.1	-4	-0.25	-6	+0.55	-6	+0.7

*Horizontal = distance from Reference point to Mean High Tide Level

**Vertical = elevation of Beach ridge above Mean High Tide Level

+ = increasing (compare to upper value)

- = decreasing (compare to upper value)

Table 5.2 Changing in foreshore slope in 2006

Period / Area	**Slope angle** (degree)			
	BV	**SF**	**KK**	**BN**
First	4.5	2.5	6.2	3
Second	-2	+2	-0.7	+3
Third	+1.5	+0.5	+1	-5
Fourth	-1	-1	+2.5	+0.5

+ = increasing (compare to upper value)

- = decreasing (compare to upper value)

5.1.3 Sedimentary analysis

Result of sedimentary analysis of total 288 beach sediment samples collected in this study area in 2006 can be summarized as follows.

A) Grain size analysis

Result of grain size analysis of surficial beach sediments in the study area as mentioned in chapter IV show trend of grain size finer to the north (Table 5.3 and Figure 5.5), from Ban Bang Niang (BN) to Blue Village Pakarang Resort (BV). At BV area grain size is fine to medium sand, at Sofitel Magic Lagoon Resort (SF) grain size is medium sand, at Klong Khuek Khak (KK) grain size is coarse sand, and at Ban Bang Niang grain size is coarse to very coarse sand. Changing of grain size in difference season is also observed (Table 5.4). It is clearly observed that in monsoon season grain size is bigger than non monsoon season and after end of monsoon season grain size is decrease in size again.

Grain size change is also observed in relationship with beach morphology as the degree of difference in grain size at foreshore in each season is greater than backshore (Figure 5.6).

Table 5.3 Mean grain size of surficial beach sediment in 2006.

Area	**Mean Grain size** (Udden-Wenworth size class)
BV	fine - medium sand
SF	medium sand
KK	coarse sand
BN	coarse - very coarse sand

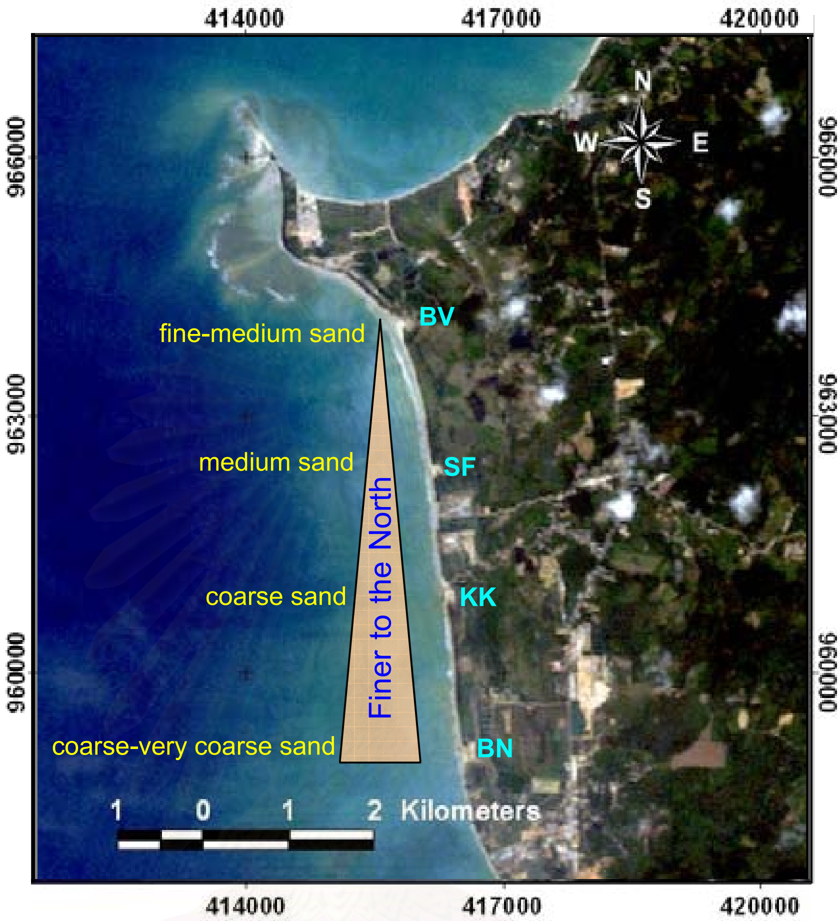

Figure 5.5 Trend of grain size distribution showing finer of diameter to the north.

Table 5.4 Changing in grain size of the study area in 2006.

Period / Area	Grain size (mm)			
	BV	SF	KK	BN
First	0.26	0.40	0.68	0.50
Second	-0.01	no data	-0.01	+0.28
Third	+0.16	+0.15	+0.08	+0.11
Fourth	-0.07	-0.16	-0.19	-0.12

+ = increasing (compare to upper value)

- = decreasing (compare to upper value)

For example, at Klong Khuek Khak (KK), grain size analysis graph plotted with the beach profile exhibit relationship of grain size changed in correspondence well with beach morphology. At backshore zone, grain size seemed to be in the same trend all of the year, whereas in the foreshore at swash zone changing in grain size is clearly observed. In general, foreshore, in swash zone, is a dynamic area because wave hitting this part all the time and sediment also moves in and out both in horizontal and vertical direction. In contrast, at backshore effect from wave usually occur only from storm surge so sediments in this zone are more stable than foreshore zone.

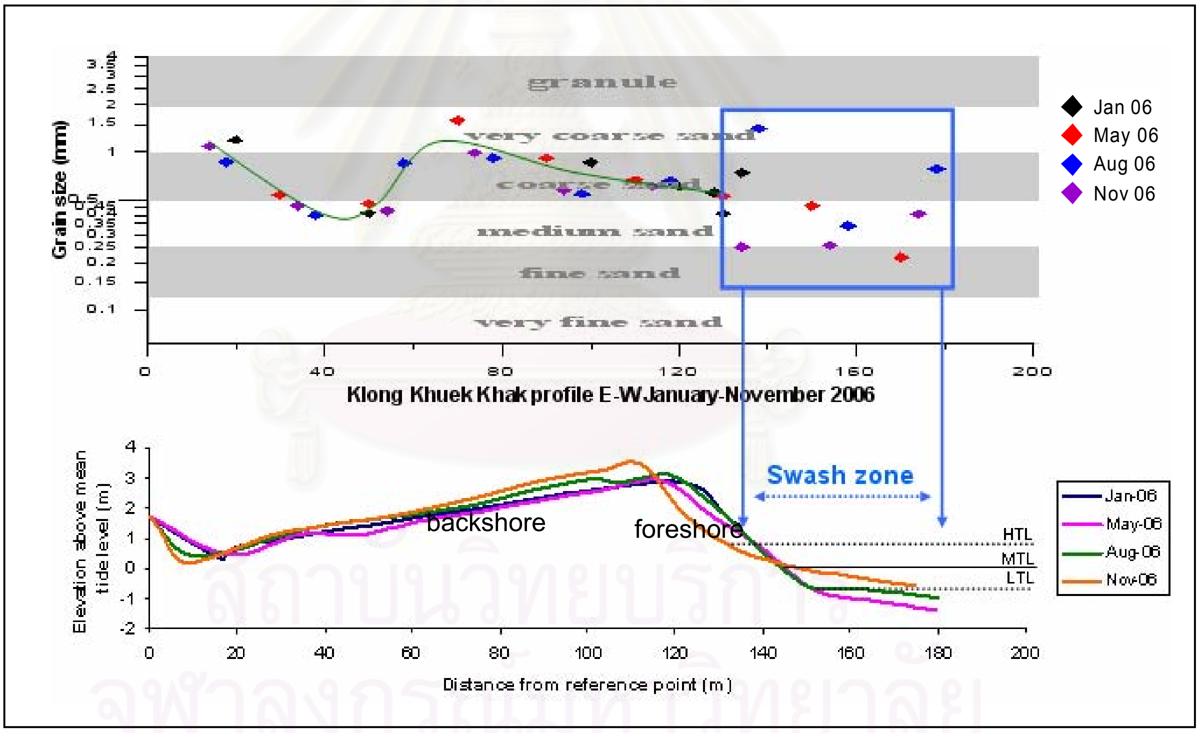

Figure 5.6 Relationship between grain size of surficial beach sediment and beach morphology at Klong Khuek Khak area from January to November 2006 (looking south). Much of grain size variation is recognized only in swash zone.

B) Composition of surficial beach sediment

The composition of surficial beach sediment in year 2006 in the study area can be divided into three major compositions. Quartz was found in average 60% of the whole sediment samples. Bioclasts were recognized at 35%, and the rest 5% was unidentified rock fragments. Thus, analysis in composition of surficial beach sediment in the study area will be focused only for the two major compositions, quartz and bioclasts (Tables 5.5 and 5.6). Changing in percentage of bioclasts showed some significant that can help to identify relationship with the seasonal change. After monsoon season, bioclasts percentage was decreased in every observed area (Figure 5.5), which can be implied that after monsoon season wave energy was decreased, then bioclasts from offshore and nearshore zones cannot transport much to deposit at beach area.

Table 5.5 Changing in percentage of quartz in surficial beach sediment in 2006.

Period / Area	Quartz (%)			
	BV	**SF**	**KK**	**BN**
First	58.13	56.50	62.86	63.48
Second	65.20	no data	61.25	66.71
Third	55.17	61.42	65.00	60.55
Fourth	54.86	65.00	67.00	67.92

Table 5.6 Changing in percentage of bioclasts in surficial beach sedimentin 2006.

Period / Area	Bioclasts (%)			
	BV	**SF**	**KK**	**BN**
First	34.38	40.00	23.57	32.48
Second	29.00	no data	36.38	32.29
Third	42.00	35.83	34.11	37.18
Fourth	36.43	29.92	30.78	28.25

C) Physical properties of surficial beach sediment

Result of laboratory analysis in physical properties of surficial beach sediment shows that roundness of sediment in the study area is sub-angular and sphericity of sediment show high sphericity in the whole study area. Sediment grain with sub-angular in roundness present that it is new sediment which transport not far from their source. High sphericity of sediment grain also present that it was done by high energy of abrasion which usually occur in swash zone.

5.1.4 Sedimentary transportation

Result of grain size analysis, composition, and physical properties helps to analyze direction of current, recovery process of eroded area by sediment transported pathway and sediment source zone. In the study area from Lame Pakarang to Khao Lak, granite outcrop was found at beach area as headland. Offshore granite was also observed from the southern part of Ban Bang Niang to Khao Lak. Granite headland is thought to provide abundant quartz into beach zone in this study area (Figure 5.7). From the grain size analysis, size of sediment in the study area showed trend of diameter finer to the north from coarse to very coarse sand at Ban Bang Niang to fine sand at Blue Village Pakarang Resort. This sediment characteristic present that source rock should be located in short distance, possibly at the southern part of Ban Bang Niang. Large amount of weathered rock exposure was eroded and then transported to the north by longshore current, leading to coarse grain quartz can be observed near source rock and fine grain quartz can deposit far away from its source (Figure 5.8). Mica, feldspar, and hornblende as a common composition of granite rock, was also found extensively in beach sediment (see Appendix C). Moreover, sub-angular and high sphericity of sediment grain indicated immaturity of sediment which source of sediment should located not far from this area. Thus, it is possible that beach sediments were derived from granitic source rocks at the Khao Lak headland in this study area.

Nearshore and offshore sediments were alternatively the minor sources for beach sediment in this area which can be proved by composition of sediment. Bioclasts were found about 35% in beach sediment and they showed some significant to indicate their locations by decreasing in percentage after monsoon season. In monsoon season bioclasts from nearshore and offshore zone were transported and deposited at beach by high energy of wave. When monsoon season was passed, bioclasts that were in nearshore and offshore zones cannot transported and deposited at beach area in the same quantity as in monsoon season because of decreasing in wave energy.

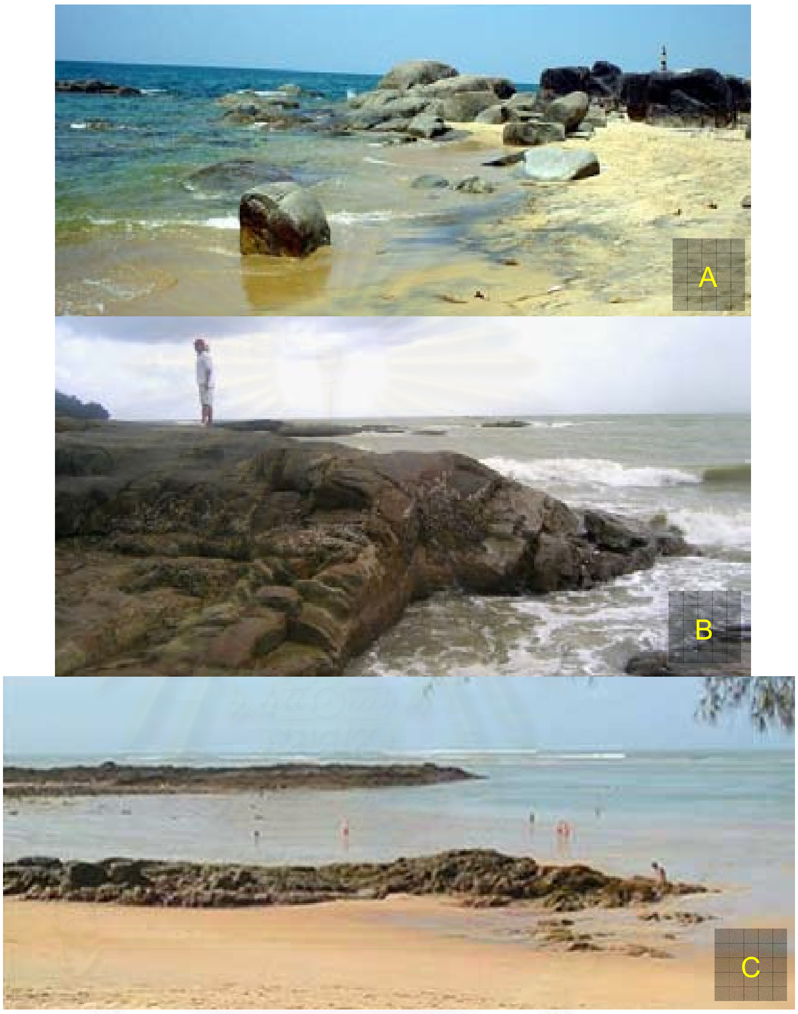

Figure 5.7 Picture of granite outcrop at southern part of Ban Bang Niang to Khao Lak mountain, Picture C granite outcrop at nearshore zone emerged when sea water was drawn down before tsunami attacked.

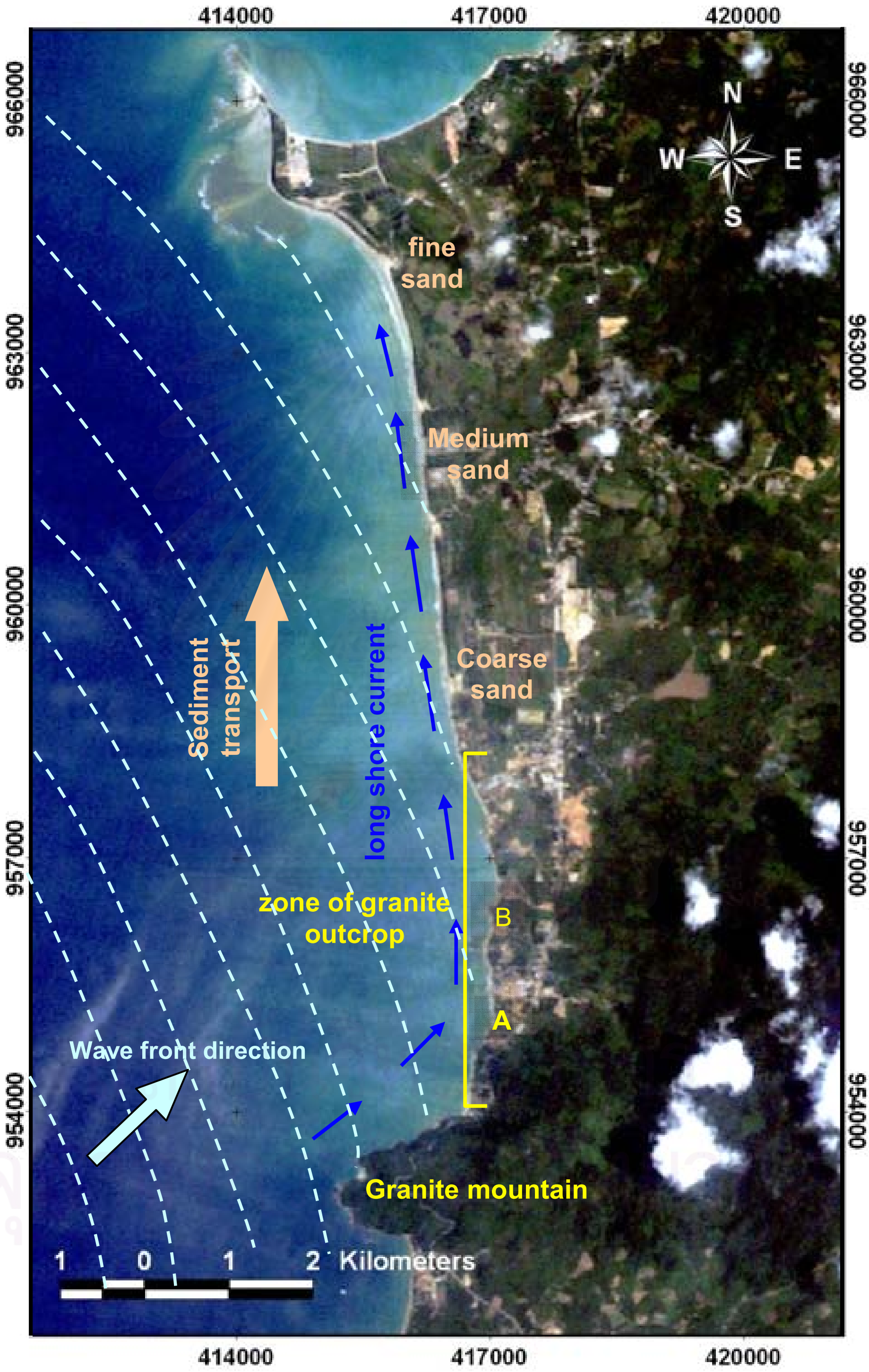

Figure 5.8 Relationship of beach sediment grain size and candidate source rock in this study area. A and B located granite outcrop in Figure 5.7.

5.1.5 Coastal type before and after tsunami

After one year of tsunami event which shoreline was almost recovered the characteristic of coastal type in the study area did not change from the day before tsunami event. Before 2004 tsunami event, Sinsakul et al (2003) documented the rate of coastal erosion along Lame Pakarang to Khao Lak area and classified the characteristic of coastal behavior in this area into three types (also see Figure 3.3). Firstly, coastal area from the southern part of Lame Pakarang to the south tidal channel where Blue Village Pakarang Resort located was characterized as a depositional coast with the accretion rate of 1-5 m/year. Secondly, from the Blue Village Pakarang Resort down south to Ban Bang Niang, this zone was defined as a stable coast with depositional rate of ±1 m/year. Lastly, the area extending from Ban Bang Niang to Khao Lak was identified as a moderately eroded coast with erosional rate of 1-5 m/year. After the tsunami event the characteristic of coastal behavior in this area is still the same. Results of remote sensing and GIS analysis in shoreline change and beach area recovery as mentioned in chapter IV show that the recovery of shoreline in the northern part of the study area from Blue Village Pakarang Resort down south to Klong Khuek Khak (area A, B, C, and D) was 98 percent recovered whereas at Ban Bang Niang (area E) recovery of shoreline was 96 percent. Recovery of beach area is also similar. For example, recovery of beach area in the northern part from Blue Village Pakarang Resort down south to Klong Khuek Khak (area A, B, C, and D) was approximately 100 percent recovered whereas at Ban Bang Niang (area E) beach area was recovered 71 percent. From the result of this study its show that in the northern part of the study area the recovery process performs faster than the southern part. Therefore the question is arisen on why the recovery rate at Ban Bang Niang is slowest? One of the several factors that control recovery process of shoreline is a difference in coastal type. From the study of Sinsakul et al (2003) Ban Bang Niang (area E) was located in a moderately eroded coast with erosional rate of 1-5 m/year due to slowing in recovery process. In contrast, in the northern part at Blue Village Pakarang Resort down south to

Klong Khuek Khak (area A, B, C, and D) was located in a stable coast with depositional rate of ±1 m/year so rate of shoreline recovery is faster. In conclusion, the characteristic of coastal behavior in this study area is still the same as time before tsunami attacked.

5.1.6 Suggestion for land use

Land lost - results of shoreline and beach area recovery process after 2004 tsunami show that in the five months after the disaster event shoreline and beach area was recovered approximately 60 percent by itself with natural recovery process without helping from human activity. This means in this area an anthropogenic activity in helping recovery of eroded shoreline is not necessary. Shoreline can recover itself by natural processes so the landlords can keep their money to rehabilitate their foundations without caring about recovery of land lost.

Living with risk – Two years after tsunami event, rehabilitation of foundations was done in the affected area. Resort and luxury hotel usually located closer to the beach which is in the 2004 tsunami maximum water depth zone. Most of them were rebuilding in the same shape and same structure similar to two years ago. There are no protections for people and no guarantee for saving of their life from destructive wave that can occur in the future. However, this area is an economical area for people in this city, moving zone of economic is not a good idea. Furthermore, building dam or wall for protect people from the tsunami wave can destroy beautiful scene of the sea in this area. Therefore, when people choose to live in the same place which has severely suffered from 2004 tsunami event they should take care and prepare themselves for the next disaster that can occur in the future. Education about tsunami is necessary for people in this area when they known and understood the nature of tsunami they can live fearless with this hazard.

5.2 Conclusion

Lame Pakarang-Khao Lak area, Phang-Nga province is one of the most damaged areas from the 26 December 2004 tsunami. Severely erosion of shoreline in this area can observed clearly both from the field and from high resolution remote sensing data. Beach area was eroded approximately 80 percent and tidal channel were wider approximately 300 percent. Most of unconsolidated sediments at beach area and tidal channel's mouth was eroded and moved inland by tsunami inflow which some were deposits in landward direction and some in seaward direction at outflow time. Seriously erosion usually occur at mouth of tidal channel as it is a weak zone that tsunami can penetrate easily. Five months after tsunami event, shoreline was recovered itself approximately 60 percent by natural processes without inducing from human recovery activity. Large accommodation space as a result of seriously erosion of shoreline induced recovery rate of eroded area can perform very fast. After that when shoreline recovered itself reach to 60 percent, the accommodation space was decreased so rate of deposition was reduced too. Recovery rate of shoreline was decreased from the first period of five months after the event and seem to be stable in deposition at 2006 year. Finally, from the result of remote sensing and GIS analysis, shoreline was recovered approximately 90 percent until 2006.

One year after tsunami attacked beach behavior in the study area shows balance in deposition and erosion corresponds to the seasonal change. From the result of beach profile measurement erosion of beach occurred in the period of rainy season and beach ridge also higher. Slope of foreshore in rainy season is also greater than summer season. Grain size of beach sediments at Ban Bang Niang is characterized by coarse to very coarse sand and finer to the north as fine to medium sand at Blue Village Pakarang Resort.

Grain size also change corresponds to the difference of season. In rainy season grain size of beach sediment are bigger than summer season as a result of different energy of wave in each season. Beach sediments in the study area are composed of quartz (60%), bioclasts (35%), and others (5%) which bioclast shows clearly change in decreasing quantity during end of rainy season.

In conclusion, after two year of tsunami event suffered shoreline was recovered approximately 90 percent and shoreline was shows an equilibrium in beach cycle. Furthermore, coastal type is not change from the past before tsunami event, deposition and erosion zone is still at the same area.

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APPENDICES

APPENDIX A

DATA SHEETS FOR BEACH PROFILE MEASUREMENT

Area Blue Village Pakarang Resort

Location 08° 43' 07" N, 98° 14' 08" E

Profile 1

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
20-21 January 2006	1	-47.044	1.220
	2	-42.229	1.145
	3	-40.251	1.586
	4	-23.381	2.051
	5	-8.672	2.531
	6	0.000	2.643
	7	9.945	2.491
	8	20.054	1.631
	9	29.870	1.073
	10	39.898	0.686
	11	52.718	0.360
	12	71.391	0.079
	13	89.075	-0.123
	14	105.488	-0.318
	15	118.910	-0.578
11 May 2006	1	97.967	-0.407
	2	77.812	-0.053
	3	57.644	0.422
	4	49.596	0.657
	5	28.934	1.498
	6	23.152	1.799
	7	14.816	2.231
	8	7.559	2.570
	9	0.000	2.643
	10	-9.169	2.552
	11	-28.767	1.960
	12	-40.727	1.272
12 August 2006	1	-61.516	1.505
	2	-48.994	1.637
	3	-40.950	1.211
	4	-39.168	1.620
	5	-26.093	1.964
	6	-17.591	2.380
	7	-8.180	2.557
	8	0.000	2.643
	9	9.925	2.639
	10	21.920	1.668
	11	37.482	0.871
	12	49.766	0.522
	13	69.849	-0.108
	14	89.412	-0.461
	15	114.784	-0.663
	16	140.702	-0.948

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
7 November 2006	1	-65.046	1.547
	2	-55.756	1.619
	3	-38.754	1.486
	4	-25.318	1.939
	5	-8.473	2.545
	6	0.000	2.643
	7	10.138	2.745
	8	26.603	1.757
	9	40.648	0.718
	10	72.239	-0.175
	11	97.971	-0.423
	12	128.756	-0.880
	13	151.151	-1.268

Profile 2

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
20-21 January 2006	1	0.000	2.440
	2	6.500	2.025
	3	51.900	0.467
	4	80.500	0.397
	5	111.400	-0.041
	6	130.200	-0.464
11 May 2006	1	0.000	2.512
	2	13.275	1.980
	3	31.983	1.010
	4	49.186	0.327
	5	68.772	-0.128
	6	93.195	-0.611
12 August 2006	1	0.000	2.520
	2	21.070	1.144
	3	40.282	0.230
	4	60.485	-0.359
	5	80.085	-0.603
	6	106.068	-0.899
	7	129.517	-1.456
	8	162.030	-1.917

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
7 November 2006	1	0.000	3.019
	2	18.603	1.867
	3	32.489	1.004
	4	51.546	0.415
	5	69.783	0.289
	6	82.425	0.107
	7	103.679	-0.168
	8	142.984	-0.868

Profile 3

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
20-21 January 2006	1	0.000	3.274
	2	4.500	3.248
	3	21.000	2.410
	4	31.500	1.786
	5	41.800	1.388
	6	52.000	1.107
	7	61.500	0.901
	8	72.000	0.819
	9	82.000	0.712
	10	91.700	0.610
	11	103.000	0.499
	12	110.500	0.394
11 May 2006	1	0.000	2.058
	2	15.927	1.922
	3	23.382	1.571
	4	45.134	0.561
	5	60.144	0.037
	6	79.620	-0.415
	7	113.665	-1.158
12 August 2006	1	0.000	2.235
	2	20.439	1.189
	3	40.132	0.401
	4	59.476	-0.060
	5	81.123	-0.329
	6	110.234	-0.679
	7	169.430	-1.692

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
7 November 2006	1	0.000	3.157
	2	13.075	2.596
	3	27.159	1.729
	4	40.499	1.201
	5	69.216	0.728
	6	99.021	0.547
	7	134.171	-0.115
	8	149.856	-0.484

Profile 4

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
20-21 January 2006	1	0.000	3.224
	2	4.000	3.250
	3	10.800	2.955
	4	29.100	2.114
	5	42.800	1.742
	6	58.300	1.489
	7	64.000	1.327
	8	76.000	1.211
	9	87.000	1.194
	10	94.900	1.233
	11	103.900	1.010
	12	120.500	0.824
11 May 2006	1	0.000	1.397
	2	7.917	1.238
	3	21.348	0.897
	4	46.595	-0.096
	5	73.257	-0.803
	6	96.326	-1.293
	7	125.421	-1.857
12 August 2006	1	0.000	2.098
	2	40.803	0.760
	3	61.258	0.310
	4	81.147	-0.032
	5	112.380	-0.276
	6	182.995	-1.610
7 November 2006	1	0.000	3.154
	2	13.847	2.738
	3	25.608	2.023
	4	47.694	1.278
	5	72.370	1.066
	6	98.442	1.143
	7	126.313	0.818
	8	169.172	-0.048

Profile 5

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
12 August 2006	1	0.000	1.210
	2	21.396	0.740
	3	40.281	0.356
	4	60.254	0.109
	5	79.184	-0.009
	6	116.509	-0.381
	7	190.062	-1.616
7 November 2006	1	0.000	2.213
	2	19.163	1.320
	3	35.969	0.834
	4	58.224	0.665
	5	77.803	0.273
	6	99.748	0.220
	7	121.649	-0.057
	8	151.712	-0.033
	9	169.213	-0.123
	10	202.075	-0.537

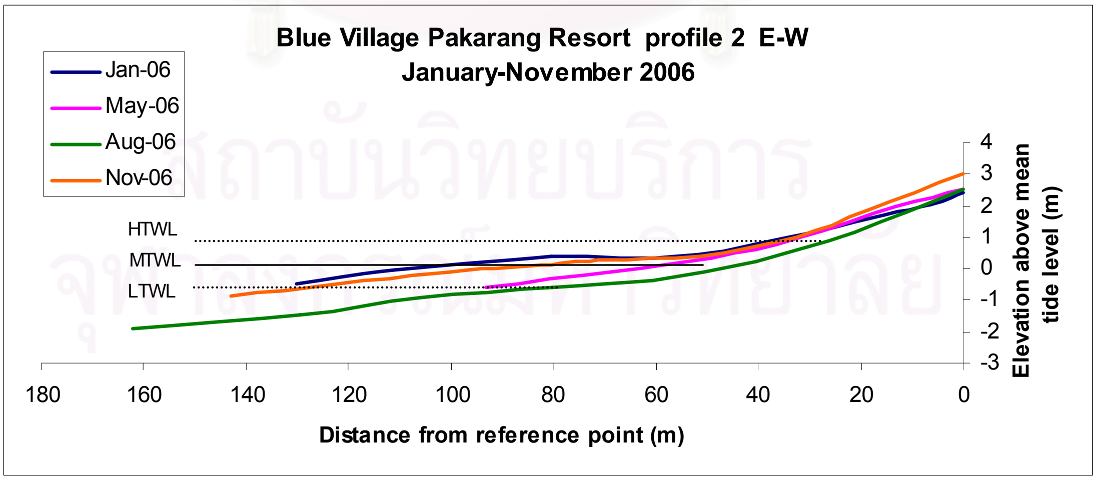
Inlet/outlet cross-section

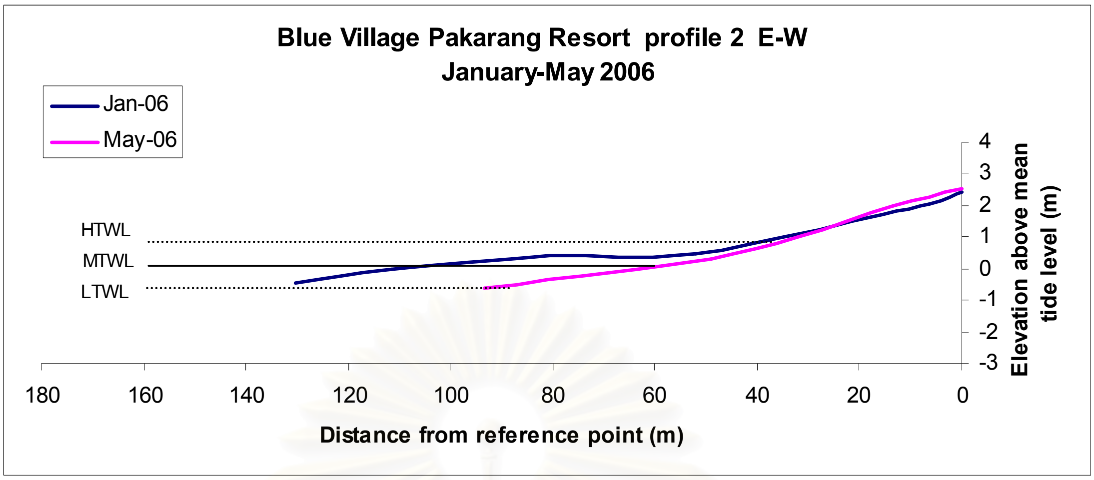
Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
20-21 January 2006	1	222.182	1.024
	2	238.258	0.097
	3	255.137	-0.737
	4	267.433	-0.860
	5	273.553	-0.809
	6	283.045	-0.231
	7	295.097	-0.069
11 May 2006	1	220.227	1.727
	2	229.035	1.351
	3	243.583	0.047
	4	247.205	-0.103
	5	251.332	-0.032
	6	290.231	0.433
	7	297.544	0.744
	8	297.773	1.688

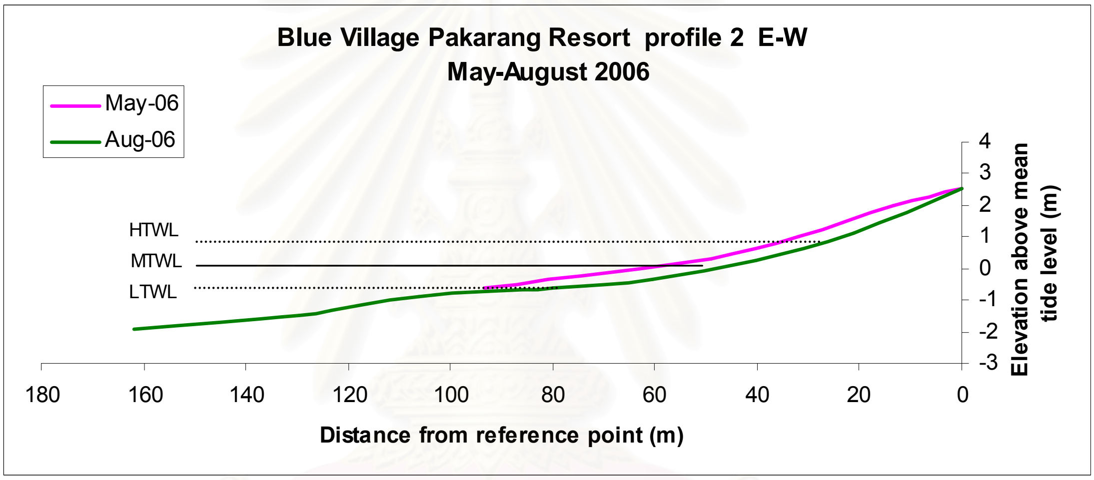
Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
12 August 2006	1	297.773	1.688
	2	297.031	0.140
	3	277.661	-0.731
	4	267.670	-1.713
	5	252.942	-0.656
	6	204.271	0.704
7 November 2006	1	298.833	1.838
	2	297.423	-0.153
	3	290.225	-1.046
	4	284.822	-1.305
	5	280.472	-1.001
	6	246.973	0.391
	7	226.453	0.901

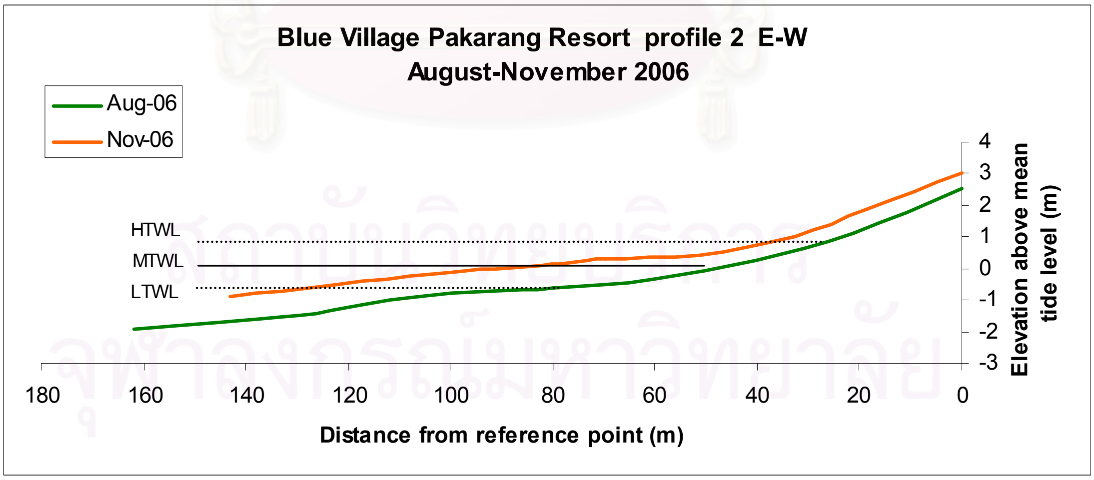
Beach profile of Blue Village Pakarang Resort

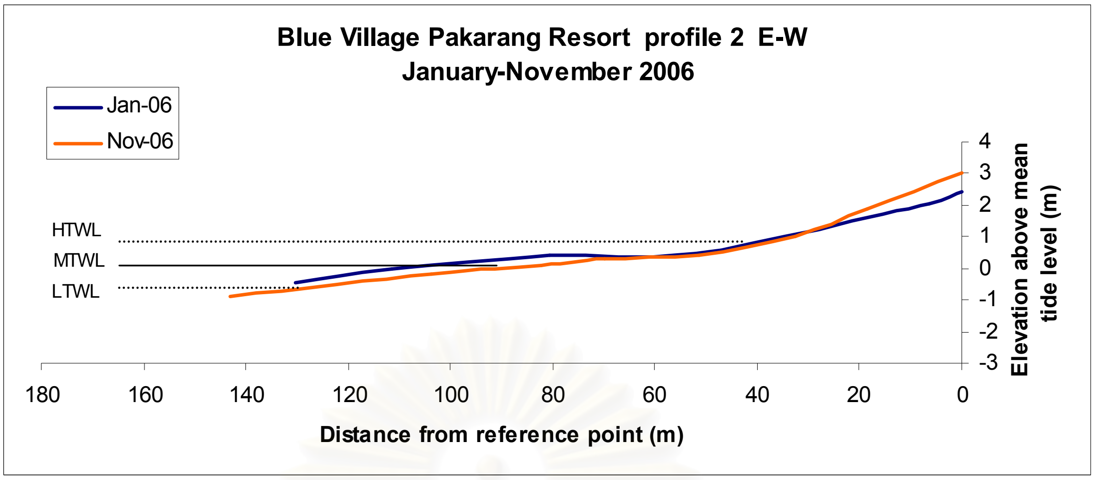
Profile 2




Blue Village Pakarang Resort profile 2 E-W
January-May 2006
Jan-06
May-06
HTWL
MTWL
LTWL
Elevation above mean tide level (m)
Distance from reference point (m)

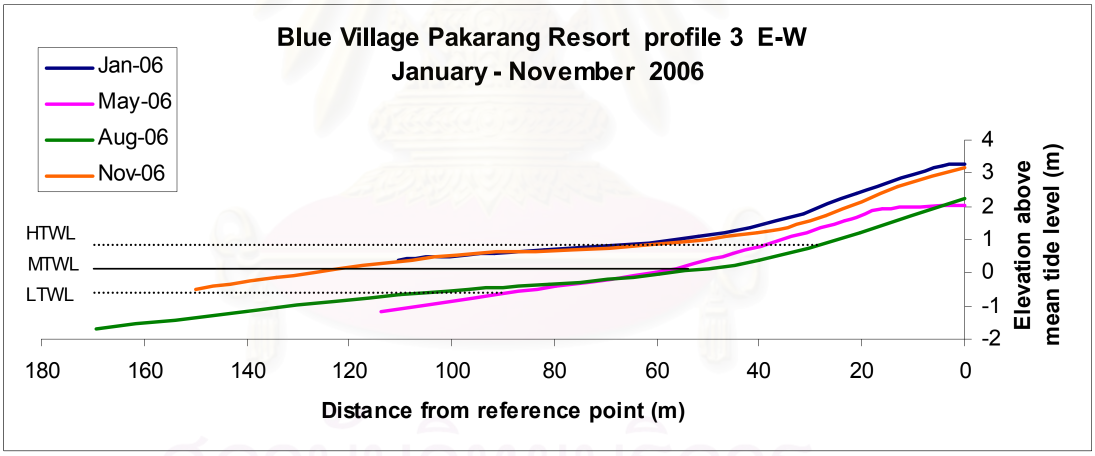

Blue Village Pakarang Resort profile 2 E-W
May-August 2006
May-06
Aug-06
HTWL
MTWL
LTWL
Elevation above mean tide level (m)
Distance from reference point (m)


Blue Village Pakarang Resort profile 2 E-W
August-November 2006
Aug-06
Nov-06
HTWL
MTWL
LTWL
Elevation above mean tide level (m)
Distance from reference point (m)

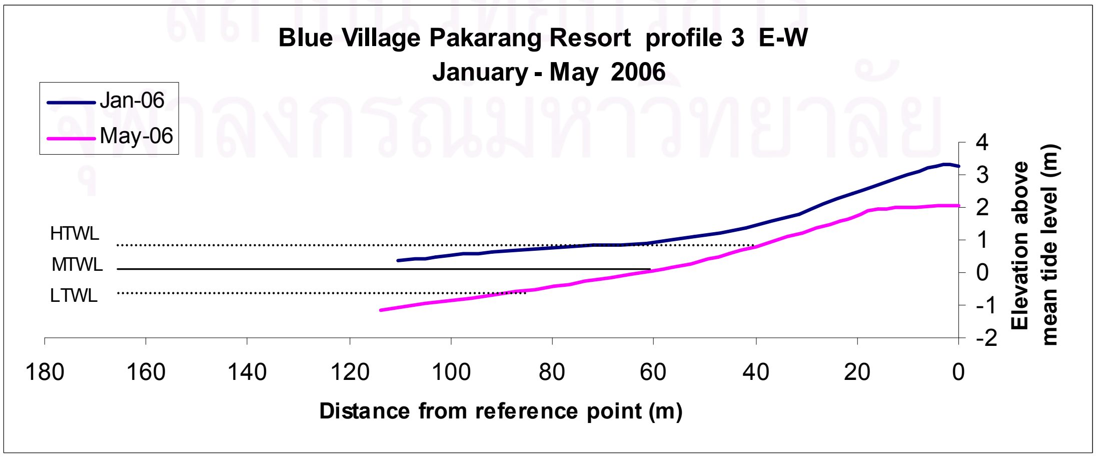


Blue Village Pakarang Resort profile 2 E-W
January-November 2006
Jan-06
Nov-06
HTWL
MTWL
LTWL
Elevation above mean tide level (m)
Distance from reference point (m)

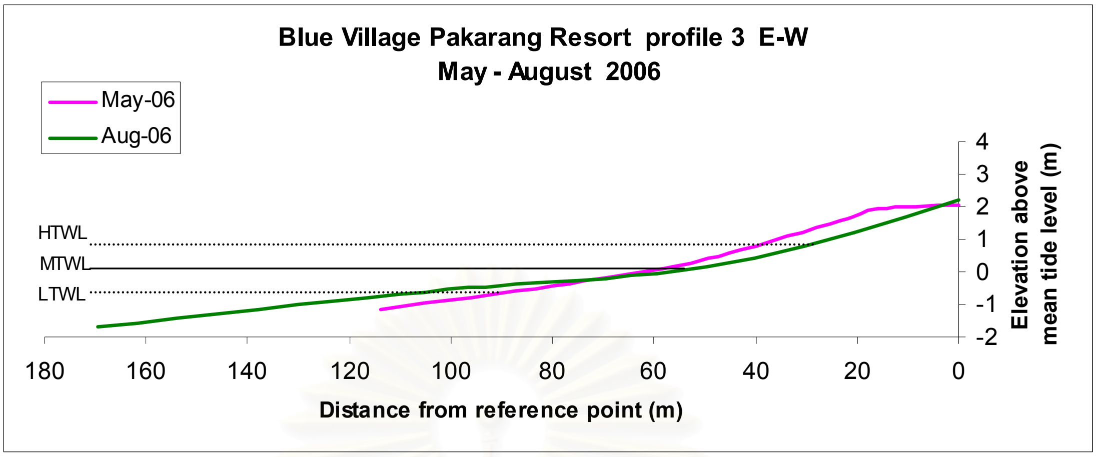
Profile 3

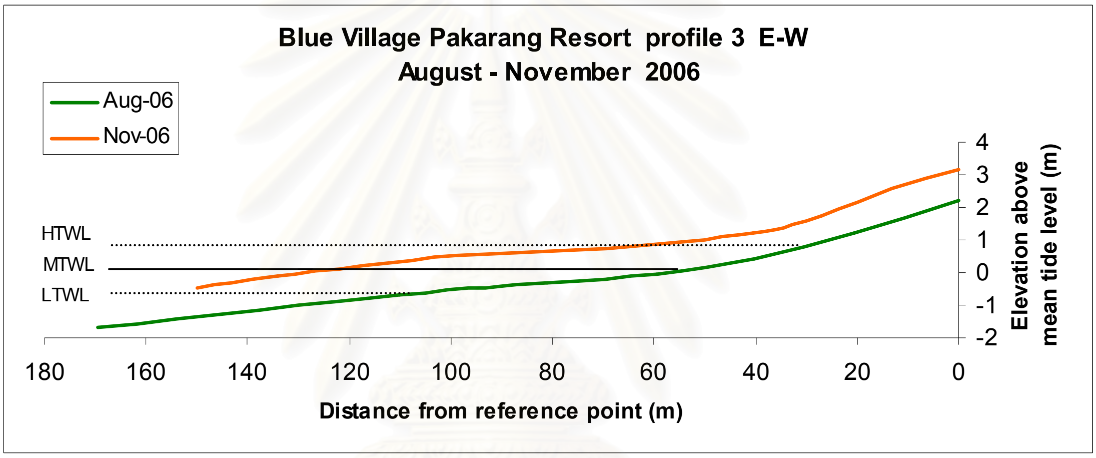


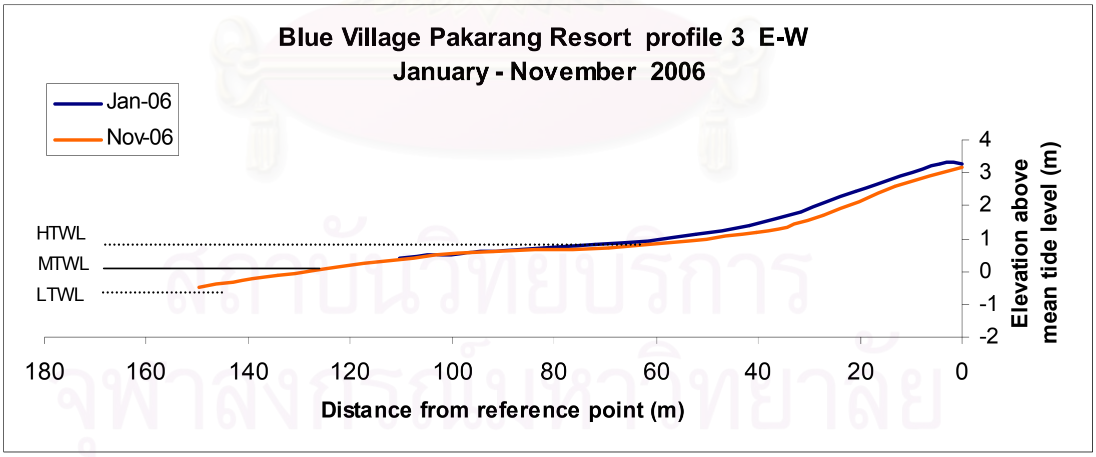
Blue Village Pakarang Resort profile 3 E-W
January - November 2006
Jan-06
May-06
Aug-06
Nov-06
HTWL
MTWL
LTWL
Elevation above mean tide level (m)
Distance from reference point (m)



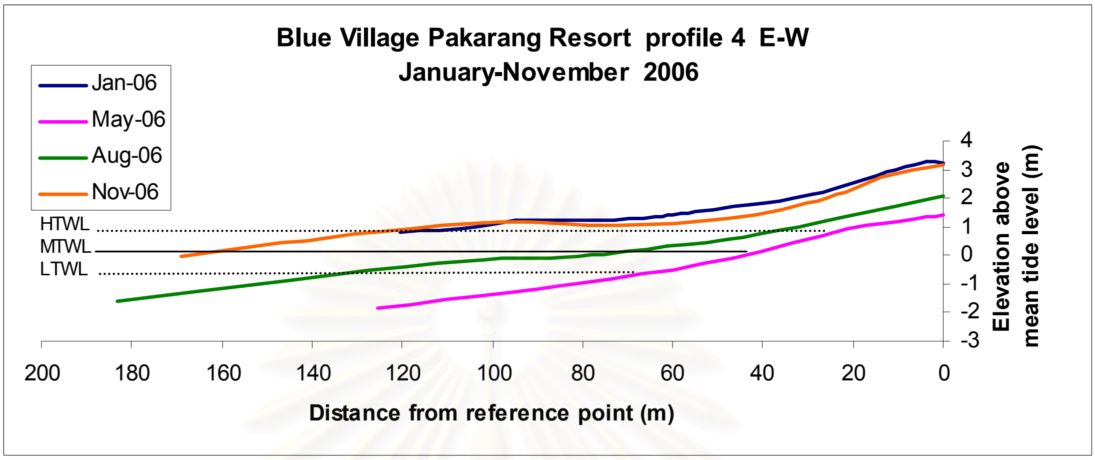
Blue Village Pakarang Resort profile 3 E-W
January - May 2006
Jan-06
May-06
HTWL
MTWL
LTWL
Elevation above mean tide level (m)
Distance from reference point (m)

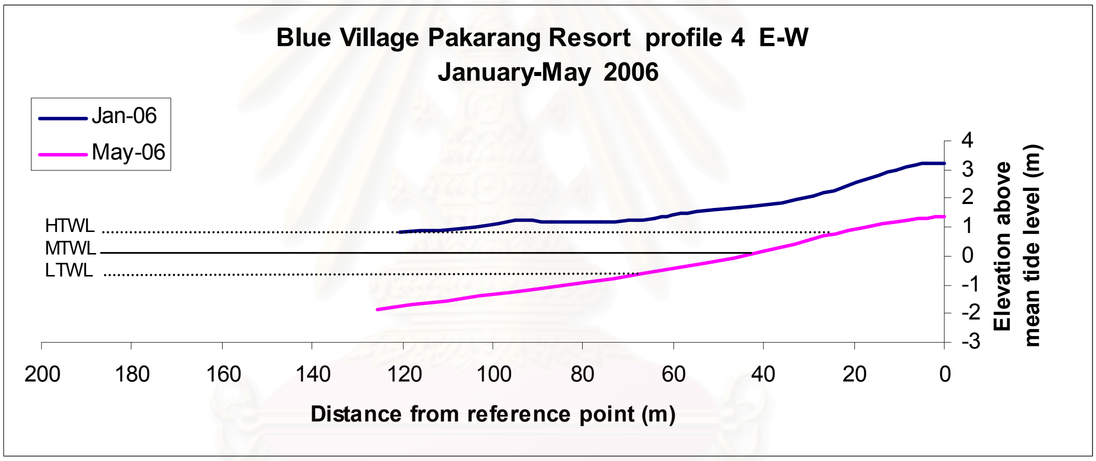

Blue Village Pakarang Resort profile 3 E-W
May - August 2006
May-06
Aug-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
Elevation above mean tide level (m)
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)

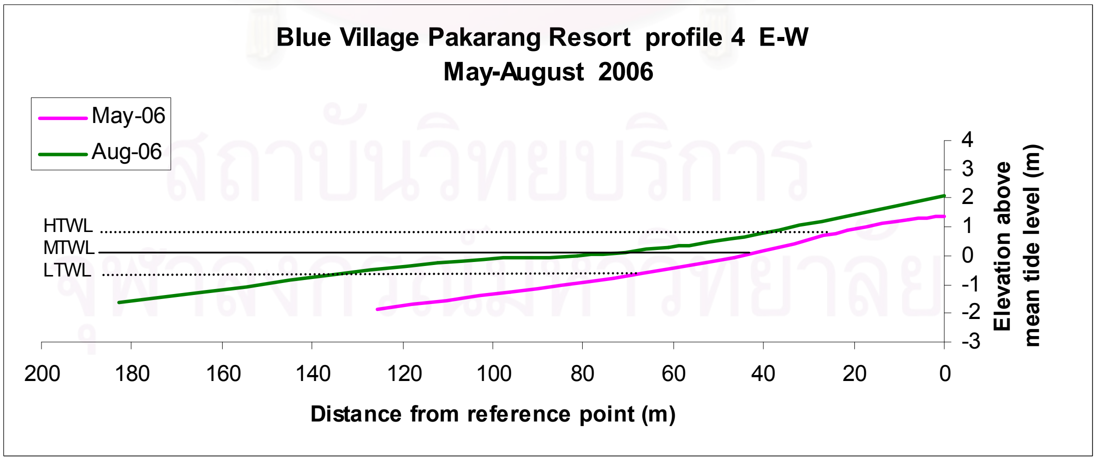

Blue Village Pakarang Resort profile 3 E-W
August - November 2006
Aug-06
Nov-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
Elevation above mean tide level (m)
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)

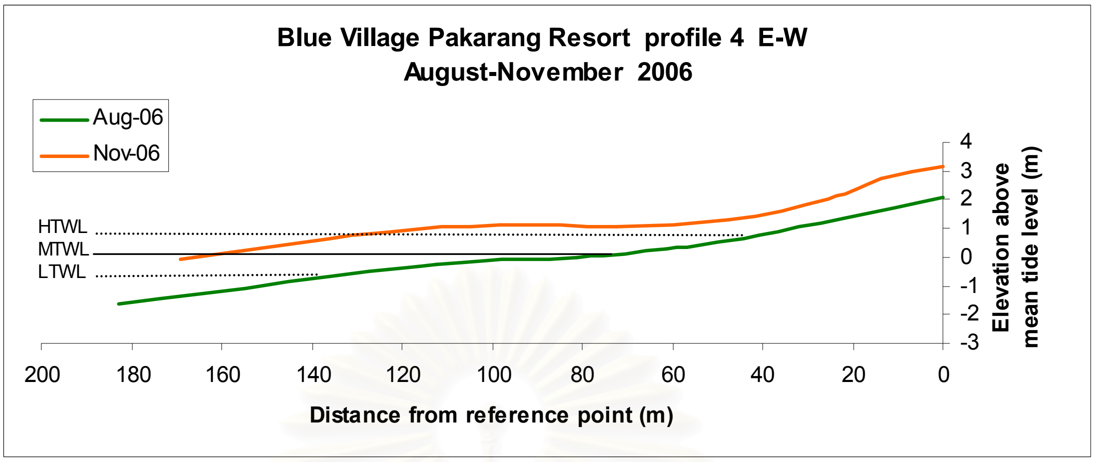

Blue Village Pakarang Resort profile 3 E-W
January - November 2006
Jan-06
Nov-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
Elevation above mean tide level (m)
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)

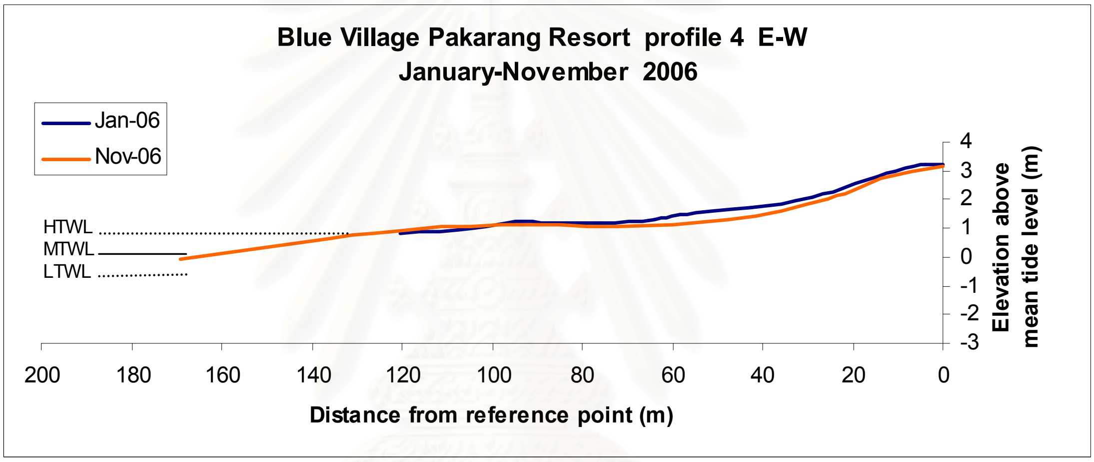
Profile 4


Blue Village Pakarang Resort profile 4 E-W
January-November 2006
Jan-06
May-06
Aug-06
Nov-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
-3
Elevation above mean tide level (m)
200
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)

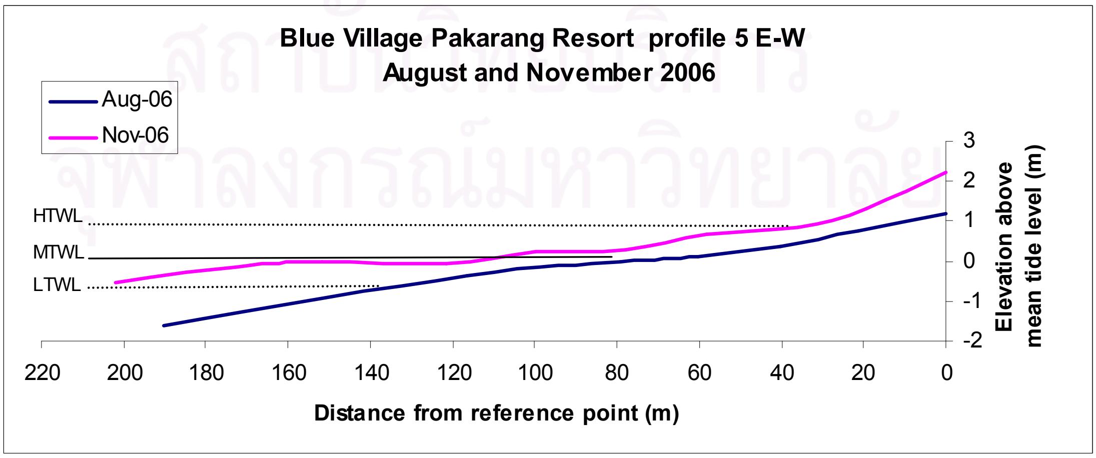

Blue Village Pakarang Resort profile 4 E-W
January-May 2006
Jan-06
May-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
-3
Elevation above mean tide level (m)
200
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)


Blue Village Pakarang Resort profile 4 E-W
May-August 2006
May-06
Aug-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
-3
Elevation above mean tide level (m)
200
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)


Blue Village Pakarang Resort profile 4 E-W
August-November 2006
Aug-06
Nov-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
-3
Elevation above mean tide level (m)
200
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)


Blue Village Pakarang Resort profile 4 E-W
January-November 2006
Jan-06
Nov-06
HTWL
MTWL
LTWL
4
3
2
1
0
-1
-2
-3
Elevation above mean tide level (m)
200
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)

Profile 5


Blue Village Pakarang Resort profile 5 E-W
August and November 2006
Aug-06
Nov-06
HTWL
MTWL
LTWL
3
2
1
0
-1
-2
Elevation above mean tide level (m)
220
200
180
160
140
120
100
80
60
40
20
0
Distance from reference point (m)

Area Sofitel Magic Lagoon Resort

Location 08° 42' 18" N, 98° 14' 18" E

Beach profile

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
20 January 2006	1	46.061	0.432
	2	43.338	0.690
	3	27.669	2.116
	4	22.022	2.454
	5	16.199	2.389
	6	7.172	2.186
	7	0.000	2.180
	8	-16.495	2.093
	9	-32.492	1.643
	10	-47.276	1.050
	11	-48.140	0.664
	12	-54.841	0.557
	13	-56.616	0.675
	14	-57.410	0.905
	15	-69.511	0.981
	16	-82.873	0.877
	17	-99.264	0.839
	18	-115.068	0.899
	19	-133.124	0.832
	20	-134.570	0.474
	21	-143.022	0.425
	22	-147.302	0.631
	23	-159.915	0.513
3 June 2006	1	-158.065	0.347
	2	-157.124	0.586
	3	-149.314	0.679
	4	-136.668	0.612
	5	-122.879	0.554
	6	-111.171	0.938
	7	-101.304	0.927
	8	-88.798	0.900
	9	-77.803	0.933
	10	-64.899	0.972
	11	-52.565	0.749
	12	-49.925	0.601
	13	-44.079	1.102
	14	-32.062	1.556
	15	-19.280	1.991
	16	0.000	2.180
	17	8.330	2.332
	18	23.124	2.847
	19	31.163	1.849
	20	40.389	0.727
	21	59.022	-0.283

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
14 August 2006	1	72.150	-0.745
	2	59.094	-0.250
	3	41.352	0.526
	4	30.371	1.413
	5	20.061	2.813
	6	10.111	2.435
	7	0.000	2.180
	8	-19.545	1.943
	9	-42.924	1.033
	10	-44.565	0.606
	11	-51.913	0.756
	12	-59.705	0.933
	13	-79.721	0.842
	14	-99.643	0.834
	15	-119.263	0.584
	16	-139.684	0.590
	17	-159.674	0.395
9 November 2006	1	-171.473	0.046
	2	-132.427	0.408
	3	-101.802	0.482
	4	-82.025	0.431
	5	-61.923	0.186
	6	-40.796	1.079
	7	-20.360	1.645
	8	-6.281	2.104
	9	0.000	2.180
	10	15.135	2.565
	11	26.508	1.435
	12	47.667	-0.357
	13	81.666	-1.216

Inlet/outlet cross-section

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
3 June 2006	1	0.000	1.633
	2	10.791	1.568
	3	24.835	1.543
	4	39.137	1.455
	5	66.394	1.374
	6	67.154	-0.107
	7	68.058	-0.475
	8	79.391	-0.526
	9	88.815	0.443
	10	118.442	0.385
	11	121.940	0.780
	12	122.286	1.167
	13	137.613	1.195
14 August 2006	1	0.000	1.633
	2	17.080	1.590
	3	33.272	1.255
	4	71.500	1.316
	5	106.624	0.572
	6	109.067	0.459
	7	112.678	-0.268
	8	117.217	-0.372
	9	122.345	-0.230
	10	123.027	0.695
	11	149.461	1.792
9 November 2006	1	167.535	0.538
	2	161.636	-0.056
	3	155.125	-1.058
	4	152.117	-1.372
	5	148.211	-1.078
	6	137.118	0.029
	7	110.807	0.747
	8	73.498	1.053
	9	39.494	1.293
	10	11.023	1.624
	11	0.000	1.633

Area Klong Khuek Khak

Location 08° 41' 34" N, 98° 14' 26" E

Beach profile

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
21 January 2006	1	0.000	1.701
	2	16.587	0.300
	3	20.180	0.708
	4	70.511	1.894
	5	97.527	2.509
	6	122.351	2.843
	7	131.292	1.764
	8	134.829	1.383
10 May 2006	1	0.000	1.701
	2	18.035	0.435
	3	34.428	1.125
	4	47.932	1.070
	5	60.582	1.524
	6	74.682	1.820
	7	89.139	2.236
	8	102.778	2.540
	9	116.810	2.923
	10	128.650	1.705
	11	140.693	0.578
	12	152.088	-0.771
	13	165.500	-1.105
	14	176.941	-1.368
	15	179.649	-1.426
13 August 2006	1	0.000	1.701
	2	7.785	0.467
	3	17.473	0.531
	4	37.411	1.332
	5	69.123	1.966
	6	98.715	2.911
	7	107.591	2.839
	8	118.765	3.117
	9	128.437	2.125
	10	148.786	-0.516
	11	161.969	-0.671
	12	180.185	-1.009

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
8 November 2006	1	174.923	-0.588
	2	146.894	0.043
	3	132.407	0.756
	4	122.125	1.808
	5	112.116	3.449
	6	103.053	3.214
	7	91.738	2.956
	8	58.222	1.811
	9	29.746	1.144
	10	14.307	0.340
	11	6.935	0.231
	12	2.500	1.201
	13	0.000	1.701

Area Ban Bang Niang

Location 08° 40' 32" N, 98° 14' 36" E

Beach profile

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
7 February 2006	1	218.138	-0.570
	2	206.512	-0.121
	3	180.956	1.352
	4	160.881	1.266
	5	149.576	0.318
	6	91.688	0.387
	7	47.296	0.821
	8	38.228	0.659
	9	28.633	0.458
	10	17.629	0.181
	11	14.885	0.010
	12	12.317	0.195
	13	9.010	0.898
	14	0.000	1.713
10 May 2006	1	204.694	0.243
	2	190.457	1.912
	3	170.242	1.391
	4	154.256	1.430
	5	127.661	0.842
	6	4.500	0.842
	7	3.300	1.142
	8	0.000	1.713

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
14 August 2006	1	0.000	1.713
	2	8.324	0.727
	3	17.722	0.704
	4	33.750	0.808
	5	50.903	0.591
	6	74.297	0.249
	7	92.010	0.388
	8	107.876	0.600
	9	120.273	0.226
	10	142.904	0.170
	11	143.712	0.900
	12	164.023	0.933
	13	186.731	0.633
	14	212.410	-0.350
	15	231.565	-0.785
	16	245.671	-0.933
	17	268.586	-1.053
	18	279.674	-1.238
10 November 2006	1	268.935	0.042
	2	252.537	-0.229
	3	232.492	0.228
	4	206.007	0.394
	5	176.893	0.721
	6	145.503	1.660
	7	132.171	0.373
	8	127.173	0.235
	9	121.592	0.380
	10	110.974	0.978
	12	88.062	1.033
	13	74.003	0.691
	14	70.703	0.521
	15	65.548	0.711
	16	45.956	0.994
	17	31.103	1.136
	18	27.732	0.796
	19	20.400	0.667
	20	8.036	0.792
	21	4.151	1.455
	22	0.000	1.713

Inlet/outlet cross-section

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
7 February 2006	1	0.000	3.261
	2	1.516	3.216
	3	2.116	2.660
	4	3.813	2.133
	5	27.167	1.763
	6	56.257	1.541
	7	67.333	0.524
	8	78.479	0.043
	9	92.931	-0.249
	10	111.321	-0.387
	11	114.490	-0.446
	12	116.858	-0.426
	13	117.091	-0.164
	14	117.362	0.430
	15	143.142	1.317
	16	177.245	1.527
	17	200.032	2.050
	18	232.240	2.428
	19	261.074	2.597
	20	261.208	2.555
10 May 2006	1	0.000	3.261
	2	2.794	0.665
	3	26.833	0.652
	4	49.929	0.660
	5	64.006	0.805
	6	98.940	1.150
	7	132.615	1.703
	8	168.303	2.161
	9	199.462	2.541
	10	232.354	2.923
	11	237.083	2.998

Date	Instrument station (m)	Horizontal distance (m)	Height above mean tide level (m)
14 August 2006	1	0.000	3.261
	2	1.574	1.653
	3	13.519	1.272
	4	45.358	1.068
	5	74.993	0.531
	6	101.998	0.348
	7	125.296	0.041
	8	127.012	-0.438
	9	140.702	-0.553
	10	141.199	0.102
	11	155.253	0.983
	12	184.115	1.469
	13	187.919	2.182
	14	194.951	2.301
	15	217.804	2.586
	16	244.117	2.787
	17	264.930	2.141
10 November 2006	1	214.682	2.260
	2	188.872	1.707
	3	159.194	1.298
	4	132.026	0.682
	5	109.301	-0.701
	6	95.299	-0.626
	7	84.634	1.145
	8	59.642	1.383
	9	23.915	1.115
	10	4.112	1.272
	11	0.000	3.261

APPENDIX B

DATA SHEETS FOR GRAIN SIZE ANALYSIS

Grain size analysis

Area Blue Village Pakarang Resort

Location 08° 43' 07" N, 98° 14' 08" E

First period: 20-21/01/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bv1 1	-40	0.320	0.420
bv1 2	-30	0.386	0.304
bv1 3	-20	0.457	0.223
bv1 4	-10	0.331	0.477
bv1 5	0	0.402	0.206
bv1 6	10	0.419	0.223
bv1 7	20	0.338	0.196
bv1 8	30	0.189	0.041
bv1 9	40	0.193	0.066
bv1 10	50	0.197	0.079
bv1 11	60	0.212	0.170
bv1 12	70	0.210	0.156
bv1 13	80	0.206	0.128
bv1 14	90	0.212	0.125
bv1 15	100	0.219	0.119
bv1 16	110	0.229	0.152
bv2 1	120	0.232	0.153
bv2 2	105	0.199	0.152
bv2 3	90	0.196	0.144
bv2 4	75	0.206	0.151
bv2 5	60	0.205	0.216
bv2 6	45	0.196	0.137
bv2 7	30	0.198	0.087
bv2 8	15	0.310	0.285
bv2 8 wet	15	0.192	0.055
bv2 9	0	0.415	0.202
bv3 1	110	0.249	0.217
bv3 2	95	0.221	0.142
bv3 3	80	0.237	0.198
bv3 4	65	0.235	0.230
bv3 5	50	0.222	0.174
bv3 6-1	35	0.292	0.388
bv3 6-2	35	0.212	0.147
bv3 7	20	0.199	0.058
bv3 8	10	0.321	0.197
bv3 9	0	0.363	0.164

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bv4 1	120	0.209	0.195
bv4 2	105	0.197	0.117
bv4 3	90	0.230	0.190
bv4 4	75	0.242	0.215
bv4 5	60	0.238	0.252
bv4 6-1	45	0.221	0.289
bv4 6-2	45	0.184	0.119
bv4 7	30	0.208	0.153
bv4 7-1	30	0.793	0.662
bv4 7-2	30	0.193	0.085
bv4 8	15	0.257	0.196
bv4 9	0	0.331	0.365
bv5 1	120	0.233	0.211
bv5 2	105	0.242	0.189
bv5 3	90	0.326	0.311
bv5 4	75	0.284	0.243
bv5 5	60	0.341	0.348
bv5 6-1	45	0.251	0.207
bv5 6-2	45	0.322	0.363
bv5 7	30	0.319	0.383
bv5 7-1	30	0.834	0.490
bv5 7-2	30	0.211	0.110
bv5 8	15	0.303	0.220
bv5 9	0	0.245	0.110

Second period: 11/05/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bv1 1	88	0.408	0.330
bv1 2	68	0.197	0.103
bv1 3	48	0.209	0.101
bv1 4	28	0.208	0.088
bv1 5	8	0.214	0.091
bv2 1	90	0.204	0.147
bv2 2	70	0.217	0.102
bv2 3	50	0.209	0.092
bv2 4	30	0.228	0.090
bv2 5	10	0.225	0.095
bv2 6	0	0.414	0.219
bv3 1	108	0.216	0.114
bv3 2	88	0.209	0.113
bv3 3	68	0.205	0.072
bv3 4	48	0.215	0.071
bv3 5	28	0.203	0.060
bv3 6	8	0.489	0.206

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bv4 1	108	0.210	0.078
bv4 2	88	0.241	0.166
bv4 3	68	0.243	0.090
bv4 4	48	0.214	0.079
bv4 5	28	0.229	0.079
bv4 6	8	0.399	0.132
bv5 1	108	0.266	0.122
bv5 2	88	0.306	0.213
bv5 3	68	0.255	0.094
bv5 4	48	0.268	0.114
bv5 5	28	0.280	0.097
bv5 6	8	0.371	0.190

Third Period: 12/08/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bv1 0	0	0.255	0.128
bv1 1	10	0.534	0.233
bv1 2	30	0.792	0.483
bv1 3	50	0.398	0.391
bv1 4	70	0.203	0.092
bv1 5	90	0.242	0.157
bv2 0	0	0.308	0.156
bv2 1	20	0.796	0.302
bv2 2	40	0.306	0.256
bv2 3	60	0.401	0.376
bv2 4	80	0.210	0.108
bv2 5	100	0.245	0.155
bv3 0	0	0.343	0.166
bv3 1	20	0.738	0.315
bv3 2	40	0.353	0.282
bv3 3	60	0.258	0.183
bv3 4	80	0.313	0.231
bv3 5	100	0.270	0.191
bv4 0	0	0.410	0.212
bv4 1	20	0.791	0.293
bv4 2	40	0.326	0.242
bv4 3	60	0.390	0.360
bv4 4	80	0.232	0.161
bv4 5	100	0.246	0.163
bv5 0	0	0.452	0.252
bv5 1	20	0.490	0.327
bv5 2	40	0.314	0.235
bv5 3	60	0.250	0.160
bv5 4	80	0.300	0.203
bv5 5	100	0.275	0.167

Fourth period: 07/11/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bv1 1	10	0.471	0.185
bv1 2	30	0.412	0.390
bv1 3	50	0.328	0.150
bv1 4	70	0.405	0.417
bv1 5	90	0.220	0.214
bv1 6	110	0.240	0.206
bv1 7	130	0.256	0.228
bv2 1	10	0.483	0.219
bv2 2	30	0.423	0.355
bv2 3	50	0.223	0.150
bv2 4	70	0.388	0.294
bv2 5	90	0.260	0.179
bv2 6	110	0.280	0.174
bv2 7	130	0.320	0.273
bv3 1	10	0.441	0.226
bv3 2	30	0.370	0.272
bv3 3	50	0.231	0.177
bv3 4	70	0.301	0.238
bv3 5	90	0.262	0.141
bv3 6	110	0.306	0.189
bv3 7	130	0.426	0.297
bv3 8	150	0.368	0.204
bv4 1	10	0.404	0.143
bv4 2	30	0.312	0.146
bv4 3	50	0.384	0.265
bv4 4	70	0.385	0.132
bv4 5	90	0.399	0.156
bv4 6	110	0.381	0.119
bv4 7	130	0.434	0.181
bv4 8	150	0.416	0.191
bv4 9	170	0.425	0.174
bv5 1	10	0.352	0.094
bv5 2	30	0.464	0.258
bv5 3	50	0.516	0.323
bv5 4	70	0.385	0.134
bv5 5	90	0.417	0.162
bv5 6	110	0.263	0.176

Area Sofitel Magic Lagoon Resort

Location 08° 42' 18" N, 98° 14' 18" E

First period: 20/01/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
SF1	-160	0.255	0.258
SF2	-150	0.300	0.253
SF3	-140	0.398	0.397
SF4	-130	0.398	0.267
SF5	-120	0.328	0.251
SF6	-110	0.411	0.303
SF7	-100	0.453	0.367
SF8	-85	0.364	0.268
SF9	-65	0.355	0.220
SF10	-45	0.292	0.202
SF11	-25	0.547	0.422
SF11-1	-25	0.702	0.442
SF11-2	-25	0.270	0.139
SF12	-15	0.572	0.430
SF12-1	-15	0.508	0.300
SF12-2	-15	0.447	0.308
SF13	-5	0.314	0.159
SF14	5	0.397	0.201
SF15	15	0.372	0.253
SF16	25	0.460	0.275
SF17	35	0.409	0.297
SF18	40	0.332	0.241

Third period: 14/08/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
sf1	60	0.873	0.588
sf2	40	1.173	0.633
sf3	20	0.519	0.235
sf4	0	0.676	0.352
sf5	-20	0.542	0.324
sf6	-40	0.831	0.656
sf7	-60	0.403	0.206
sf8	-80	0.408	0.221
sf9	-100	0.290	0.217
sf10	-120	0.273	0.205
sf11	-140	0.250	0.194
sf12	-160	0.358	0.305

Fourth period: 09/11/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
sf1	-171	0.335	0.110
sf2	-151	0.418	0.200
sf3	-131	0.250	0.218
sf4	-111	0.270	0.191
sf5	-91	0.367	0.245
sf6	-71	0.415	0.267
sf7	-51	0.842	0.565
sf8	-31	0.475	0.309
sf9	-11	0.487	0.274
sf10	9	0.203	0.117
sf11	29	0.277	0.279
sf12	49	0.276	0.170

Area Klong Khuek Khak

Location 08° 41' 34" N, 98° 14' 26" E

First period: 21/01/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
kk1	20	1.199	0.891
kk2	50	0.408	0.261
kk3	100	0.865	0.585
kk4	120	0.604	0.335
kk5	128	0.557	0.335
kk6	130	0.406	0.292
kk7	134	0.740	0.770

Second period: 10/05/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
kk1	170	0.216	0.114
kk2	150	0.456	0.293
kk3	130	0.517	0.272
kk4	110	0.663	0.348
kk5	90	0.910	0.652
kk6	70	1.593	0.986
kk7	50	0.467	0.359
kk8	30	0.533	0.326

Third period: 13/08/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
kk1	18	0.866	0.612
kk2	38	0.397	0.281
kk3	58	0.854	0.705
kk4	78	0.917	0.677
kk5	98	0.542	0.318
kk6	118	0.653	0.427
kk7	138	1.408	0.978
kk8	158	0.342	0.308
kk9	178	0.784	0.650

Fourth period: 08/11/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
kk1	14	1.093	0.759
kk2	34	0.457	0.336
kk3	54	0.423	0.246
kk4	74	0.989	0.712
kk5	94	0.569	0.233
kk6	114	0.607	0.298
kk7	134	0.252	0.255
kk8	154	0.257	0.343
kk9	174	0.402	0.463

Area Ban Bang Niang

Location 08° 40' 32" N, 98° 14' 36" E

First period: 07/02/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bn1	0	0.272	0.209
bn2	10	0.416	0.272
bn3	20	0.369	0.277
bn4	30	0.247	0.177
bn5	40	0.330	0.200
bn6	50	0.469	0.319
bn7	60	0.665	0.432
bn8	70	0.599	0.398
bn9	80	0.594	0.431
bn10	90	0.591	0.397
bn11	100	0.526	0.348
bn12	110	0.535	0.341
bn13	120	0.709	0.537
bn14	130	0.871	0.631
bn15	140	0.575	0.404
bn16	150	0.492	0.317
bn17	160	0.363	0.217
bn18	170	0.348	0.242
bn19	180	0.359	0.301
bn20	190	0.236	0.152
bn21	200	0.252	0.171
bn22	210	0.670	0.587
bn23	220	1.184	0.873

Second period: 10/05/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bn1	200	0.703	0.589
bn2	190	0.466	0.249
bn3	180	0.531	0.322
bn4	170	0.621	0.331
bn5	160	0.891	0.631
bn6	150	1.049	0.908
bn7	140	1.224	0.745

Third period: 14/08/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bn00	30	0.420	0.210
bn0	50	0.403	0.190
bn1	70	1.296	0.634
bn2	90	1.439	0.496
bn3	110	0.951	0.705
bn4	130	0.785	0.488
bn5	150	1.037	0.644
bn6	170	0.940	0.576
bn7	190	0.929	0.613
bn8	210	0.804	0.575
bn9	230	0.887	0.580

Fourth period: 10/11/2006

Sample	Distance from reference point (m)	Mean (mm)	Standard deviation (mm)
bn1	20	0.348	0.195
bn2	40	0.559	0.312
bn3	60	0.410	0.267
bn4	80	1.052	0.629
bn5	100	1.064	0.636
bn6	120	0.898	0.656
bn7	140	0.573	0.347
bn8	160	0.905	0.633
bn9	180	1.079	0.655
bn10	200	1.038	0.705
bn11	220	0.620	0.427
bn12	240	0.790	0.616

Table 1 Locations, time of beach measurement and surface sand sample collection for this research.

Location	Field survey date			
	First	Second	Third	Fourth
Blue Village Pakarang Resort	20-21/01/2006	11/05/2006	12/08/2006	07/11/2006
Sofitel Magic Lagoon	20/01/2006	03/06/2006	14/08/2006	09/11/2006
Klong Khuek Khak	21/01/2006	10/05/2006	13/08/2006	08/11/2006
Ban Bang Niang	07/02/2006	10/05/2006	14/08/2006	10/11/2006

Mean grain size :Mean

Descriptive criteria

Grain size (mm)	Wenworth Classification
1.00 - 2.00	Very Coarse Sand
0.50 - 1.00	Coarse Sand
0.25 - 0.50	Medium Sand
0.125 - 0.25	Fine Sand
0.0625 - 0.125	Very Fine Sand

Moment Sorting : Standard deviation

Descriptive criteria

Sorting Range	Description of Sorting
< 0.35	Very well sorted
0.35 - 0.50	Well sorted
0.50 - 0.71	Moderately well sorted
0.71 - 1.00	Moderately sorted
1.00 - 2.00	Poorly sorted
2.00 - 4.00	Very poorly sorted
> 4.00	Extremely poorly sorted

APPENDIX C

COMPOSTITIONS OF SURFICIAL BEACH SEDIMENTS

First Period

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
KK1	60	5	5	0	30	0	100	Sub-Angular High Sphericity	20
KK2	61	5	7	2	25	0	100	Sub-Angular High Sphericity	50
KK3	76	4	4	1	15	0	100	Sub-Rounded High Sphericity	100
KK4	73	5	5	2	15	0	100	Sub-Rounded High Sphericity	120
KK5	70	4	5	1	20	0	100	Sub-Rounded High Sphericity	128
KK6	60	8	7	5	20	0	100	Sub-Angular High Sphericity	130
KK7	40	9	10	1	40	0	100	Sub-Angular High Sphericity	134
SF1	23	1	1	0	74	1	100	Sub-Angular High Sphericity	-160
SF2	41	1	2	1	54	1	100	Sub-Rounded High Sphericity	-150
SF3	20	1	2	1	75	1	100	Sub-Angular High Sphericity	-140
SF4	59	1	3	1	35	1	100	Sub-Angular High Sphericity	-130
SF5	56	1	1	1	40	1	100	Sub-Angular High Sphericity	-120
SF6	59	1	2	2	35	1	100	Sub-Angular High Sphericity	-110
SF7	49	2	2	1	45	1	100	Sub-Angular High Sphericity	-100
SF8	52	1	1	1	44	1	100	Sub-Angular High Sphericity	-85
SF9	48	1	1	2	46	2	100	Sub-Angular High Sphericity	-65
SF10	58	1	1	1	38	1	100	Sub-Angular High Sphericity	-45
SF11	65	2	2	1	29	1	100	Sub-Rounded High Sphericity	-25
SF11-1	41	2	1	0	56	0	100	Sub-Rounded High Sphericity	-25
SF11-2	70	1	1	2	26	0	100	Sub-Rounded High Sphericity	-25
SF12	58	2	2	0	38	0	100	Sub-Rounded High Sphericity	-15
SF12-1	55	2	2	0	40	1	100	Sub-Angular High Sphericity	-15
SF12-2	65	1	2	0	31	1	100	Sub-Angular High Sphericity	-15
SF13	63	1	1	2	32	1	100	Sub-Angular High Sphericity	-5
SF14	67	0	1	0	31	1	100	Sub-Angular High Sphericity	5
SF15	62	0	1	1	35	1	100	Sub-Angular High Sphericity	15
SF16	57	1	1	1	40	0	100	Sub-Angular High Sphericity	25
SF17	37	1	1	1	59	1	100	Sub-Angular High Sphericity	35
SF18	40	0	1	1	57	1	100	Sub-Angular High Sphericity	40
BN1	50	0	1	1	47	1	100	Sub-Angular High Sphericity	0
BN2	62	0	1	1	35	1	100	Sub-Angular High Sphericity	10
BN3	55	0	0	1	42	2	100	Sub-Angular High Sphericity	20
BN4	52	0	0	1	46	1	100	Sub-Angular High Sphericity	30
BN5	60	0	1	1	38	0	100	Sub-Angular High Sphericity	40
BN6	62	0	1	1	36	0	100	Sub-Rounded High Sphericity	50
BN7	70	0	1	1	28	0	100	Sub-Rounded High Sphericity	60
BN8	68	1	1	1	28	1	100	Sub-Angular High Sphericity	70
BN9	65	0	1	1	32	1	100	Sub-Angular High Sphericity	80
BN10	65	0	1	0	33	1	100	Sub-Angular High Sphericity	90
BN11	66	1	1	1	30	1	100	Sub-Angular High Sphericity	100
BN12	68	1	1	1	28	1	100	Sub-Angular High Sphericity	110
BN13	67	0	1	1	30	1	100	Sub-Angular High Sphericity	120
BN14	69	1	1	1	27	1	100	Sub-Angular High Sphericity	130
BN15	64	0	1	1	33	1	100	Sub-Angular High Sphericity	140
BN16	59	1	1	1	37	1	100	Sub-Angular High Sphericity	150
BN17	65	0	1	1	33	0	100	Sub-Angular High Sphericity	160
BN18	67	0	2	2	28	1	100	Sub-Angular High Sphericity	170
BN19	54	1	2	2	39	2	100	Sub-Angular High Sphericity	180
BN20	66	0	1	5	26	2	100	Sub-Angular High Sphericity	190
BN21	61	0	1	2	35	1	100	Sub-Angular High Sphericity	200
BN22	57	1	3	7	30	2	100	Sub-Angular High Sphericity	210
BN23	88	3	2	1	6	0	100	Sub-Angular High Sphericity	220

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
BV1-1	47	2	0	1	50	0	100	Sub-Angular High Sphericity	-40
BV1-2	40	4	1	1	53	1	100	Sub-Angular High Sphericity	-30
BV1-3	52	3	2	1	41	1	100	Sub-Angular High Sphericity	-20
BV1-4	46	1	0	2	50	1	100	Sub-Angular High Sphericity	-10
BV1-5	60	3	1	1	34	1	100	Sub-Angular High Sphericity	0
BV1-6	62	3	1	1	32	1	100	Sub-Angular High Sphericity	10
BV1-7	64	3	2	1	29	1	100	Sub-Angular High Sphericity	20
BV1-8	68	1	1	5	23	2	100	Sub-Angular High Sphericity	30
BV1-9	62	1	0	5	30	2	100	Sub-Angular High Sphericity	40
BV1-10	58	1	0	5	33	3	100	Sub-Angular High Sphericity	50
BV1-11	60	1	0	7	30	2	100	Sub-Angular High Sphericity	60
BV1-12	61	1	0	6	29	3	100	Sub-Angular High Sphericity	70
BV1-13	63	1	0	6	28	2	100	Sub-Angular High Sphericity	80
BV1-14	63	1	0	5	29	2	100	Sub-Angular High Sphericity	90
BV1-15	61	1	0	5	31	2	100	Sub-Angular High Sphericity	100
BV1-16	63	2	0	5	28	2	100	Sub-Angular High Sphericity	110
BV2-1	83	1	1	1	13	1	100	Sub-Angular High Sphericity	0
BV2-2	61	1	0	6	30	2	100	Sub-Angular High Sphericity	15
BV2-3	68	1	1	6	22	2	100	Sub-Angular High Sphericity	15
BV2-4	54	1	0	6	36	3	100	Sub-Angular High Sphericity	30
BV2-5	55	1	0	7	34	3	100	Sub-Angular High Sphericity	45
BV2-6	57	1	0	7	32	3	100	Sub-Angular High Sphericity	60
BV2-7	58	2	0	6	31	3	100	Sub-Angular High Sphericity	75
BV2-8	60	1	0	6	31	2	100	Sub-Angular High Sphericity	90
BV2-9	62	2	0	6	28	2	100	Sub-Angular High Sphericity	105
BV2-10	62	1	0	6	29	2	100	Sub-Angular High Sphericity	120
BV3-1	91	2	1	1	5	0	100	Sub-Angular High Sphericity	0
BV3-2	83	4	1	3	8	1	100	Sub-Angular High Sphericity	10
BV3-3	56	1	0	6	36	1	100	Sub-Angular High Sphericity	20
BV3-4	57	2	0	6	34	1	100	Sub-Angular High Sphericity	35
BV3-5	56	2	0	5	35	2	100	Sub-Angular High Sphericity	35
BV3-6	58	1	0	6	34	1	100	Sub-Angular High Sphericity	50
BV3-7	60	2	0	5	31	2	100	Sub-Angular High Sphericity	65
BV3-8	60	1	0	6	32	1	100	Sub-Angular High Sphericity	80
BV3-9	62	1	0	6	30	1	100	Sub-Angular High Sphericity	95
BV3-10	61	3	0	2	33	1	100	Sub-Angular High Sphericity	110
BV4-1	77	3	1	2	16	1	100	Sub-Angular High Sphericity	0
BV4-2	64	2	0	2	31	1	100	Sub-Angular High Sphericity	15
BV4-3	62	4	0	4	29	1	100	Sub-Angular High Sphericity	30
BV4-4	70	5	1	0	24	0	100	Sub-Angular High Sphericity	30
BV4-5	52	2	0	4	41	1	100	Sub-Angular High Sphericity	30
BV4-6	48	2	0	3	46	1	100	Sub-Angular High Sphericity	45
BV4-7	46	2	0	5	46	1	100	Sub-Angular High Sphericity	45
BV4-8	50	4	0	4	40	2	100	Sub-Angular High Sphericity	60
BV4-9	55	2	0	3	38	2	100	Sub-Angular High Sphericity	75
BV4-10	54	3	0	4	38	1	100	Sub-Angular High Sphericity	90
BV4-11	52	3	0	4	40	1	100	Sub-Angular High Sphericity	105
BV4-12	52	1	0	4	42	1	100	Sub-Angular High Sphericity	120

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
BV5-1	87	1	0	2	10	0	100	Sub-Angular High Sphericity	0
BV5-2	82	1	0	1	15	1	100	Sub-Angular High Sphericity	15
BV5-3	68	1	0	2	28	1	100	Sub-Angular High Sphericity	30
BV5-4	83	1	1	0	15	0	100	Sub-Angular High Sphericity	30
BV5-5	62	1	0	2	34	1	100	Sub-Angular High Sphericity	30
BV5-6	57	2	0	1	39	1	100	Sub-Angular High Sphericity	45
BV5-7	58	2	0	1	37	2	100	Sub-Angular High Sphericity	45
BV5-8	59	3	0	1	36	1	100	Sub-Angular High Sphericity	60
BV5-9	58	3	0	1	38	0	100	Sub-Angular High Sphericity	75
BV5-10	61	3	0	1	34	1	100	Sub-Angular High Sphericity	90
BV5-11	60	2	0	2	35	1	100	Sub-Angular High Sphericity	105
BV5-12	56	2	0	4	37	1	100	Sub-Angular High Sphericity	120

Second period

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
BN1	66	0	1	0	33	0	100	Sub-Angular High Sphericity	140
BN2	65	0	0	0	35	0	100	Sub-Angular High Sphericity	150
BN3	63	0	1	0	36	0	100	Sub-Angular High Sphericity	160
BN4	65	0	0	0	35	0	100	Sub-Angular High Sphericity	170
BN5	67	0	1	0	32	0	100	Sub-Angular High Sphericity	180
BN6	71	0	1	1	27	0	100	Sub-Angular High Sphericity	190
BN7	70	1	1	0	28	0	100	Sub-Angular High Sphericity	200
KK1	67	1	0	0	32	0	100	Sub-Angular High Sphericity	30
KK2	69	0	0	1	30	0	100	Sub-Angular High Sphericity	50
KK3	65	1	0	0	34	0	100	Sub-Angular High Sphericity	70
KK4	62	1	0	0	37	0	100	Sub-Rounded High Sphericity	90
KK5	65	2	1	0	32	0	100	Sub-Angular High Sphericity	110
KK6	57	2	0	1	40	0	100	Sub-Angular High Sphericity	130
KK7	55	3	0	1	40	1	100	Sub-Angular High Sphericity	150
KK8	50	0	0	3	46	1	100	Sub-Angular High Sphericity	170
BV1-1	70	2	0	3	24	1	100	Sub-Angular High Sphericity	8
BV1-2	62	2	0	3	32	1	100	Sub-Angular High Sphericity	28
BV1-3	66	2	0	3	28	1	100	Sub-Angular High Sphericity	48
BV1-4	65	2	0	3	29	1	100	Sub-Angular High Sphericity	68
BV1-5	63	3	0	1	32	1	100	Sub-Angular High Sphericity	88
BV2-1	72	8	1	0	19	0	100	Sub-Angular High Sphericity	0
BV2-2	64	5	0	1	29	1	100	Sub-Angular High Sphericity	10
BV2-3	65	2	0	2	30	1	100	Sub-Angular High Sphericity	30
BV2-4	62	1	0	2	34	1	100	Sub-Angular High Sphericity	50
BV2-5	60	2	0	2	35	1	100	Sub-Angular High Sphericity	70
BV2-6	50	0	0	2	46	2	100	Sub-Angular High Sphericity	90
BV3-1	78	5	1	0	15	1	100	Sub-Angular High Sphericity	8
BV3-2	80	1	0	1	17	1	100	Sub-Angular High Sphericity	28
BV3-3	78	1	0	2	18	1	100	Sub-Angular High Sphericity	48
BV3-4	61	2	0	2	33	2	100	Sub-Angular High Sphericity	68
BV3-5	60	0	0	1	38	1	100	Sub-Angular High Sphericity	88
BV3-6	62	1	0	1	35	1	100	Sub-Angular High Sphericity	108
BV4-1	87	4	1	0	7	1	100	Sub-Rounded High Sphericity	8
BV4-2	87	2	0	2	8	1	100	Sub-Angular High Sphericity	28
BV4-3	72	1	0	2	24	1	100	Sub-Angular High Sphericity	48
BV4-4	86	1	0	2	10	1	100	Sub-Angular High Sphericity	68
BV4-5	67	0	0	1	32	0	100	Sub-Angular High Sphericity	88
BV4-6	70	1	0	1	27	1	100	Sub-Angular High Sphericity	108
BV5-1	81	4	1	1	12	1	100	Sub-Angular High Sphericity	8
BV5-2	76	2	0	2	19	1	100	Sub-Angular High Sphericity	28
BV5-3	74	2	0	1	22	1	100	Sub-Angular High Sphericity	48
BV5-4	64	1	0	1	33	1	100	Sub-Angular High Sphericity	68
BV5-5	62	1	0	1	35	1	100	Sub-Angular High Sphericity	88
BV5-6	56	2	0	1	40	1	100	Sub-Angular High Sphericity	108

Third Period

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
SF1	61	1	0	1	36	1	100	Sub-Angular High Sphericity	-160
SF2	65	1	0	1	32	1	100	Sub-Angular High Sphericity	-140
SF3	67	1	0	1	30	1	100	Sub-Angular High Sphericity	-120
SF4	66	1	0	1	31	1	100	Sub-Angular High Sphericity	-100
SF5	59	2	0	1	37	1	100	Sub-Angular High Sphericity	-80
SF6	63	1	0	1	34	1	100	Sub-Angular High Sphericity	-60
SF7	62	2	0	0	35	1	100	Sub-Angular High Sphericity	-40
SF8	59	1	0	1	38	1	100	Sub-Angular High Sphericity	-20
SF9	70	1	0	0	28	1	100	Sub-Angular High Sphericity	0
SF10	69	1	0	1	29	0	100	Sub-Angular High Sphericity	20
SF11	50	1	0	0	49	0	100	Sub-Angular High Sphericity	40
SF12	46	1	0	1	51	1	100	Sub-Angular High Sphericity	60
KK1	52	1	0	0	46	1	100	Sub-Angular High Sphericity	18
KK2	70	1	0	3	26	0	100	Sub-Angular High Sphericity	38
KK3	67	1	0	0	32	0	100	Sub-Angular High Sphericity	58
KK4	66	1	0	0	32	1	100	Sub-Angular High Sphericity	78
KK5	65	1	0	1	32	1	100	Sub-Angular High Sphericity	98
KK6	63	1	0	1	35	0	100	Sub-Angular High Sphericity	118
KK7	62	1	0	0	37	0	100	Sub-Angular High Sphericity	138
KK8	62	1	0	1	35	1	100	Sub-Angular High Sphericity	158
KK9	66	1	0	1	32	0	100	Sub-Angular High Sphericity	178
BN1	62	1	0	2	35	0	100	Sub-Angular High Sphericity	30
BN2	65	1	1	1	31	1	100	Sub-Angular High Sphericity	50
BN3	51	1	1	0	47	0	100	Sub-Angular High Sphericity	70
BN4	60	2	1	0	37	0	100	Sub-Angular High Sphericity	90
BN5	62	1	0	1	36	0	100	Sub-Angular High Sphericity	110
BN6	60	1	0	0	39	0	100	Sub-Angular High Sphericity	130
BN7	56	1	1	0	42	0	100	Sub-Angular High Sphericity	150
BN8	60	1	1	0	38	0	100	Sub-Angular High Sphericity	170
BN9	61	1	0	1	37	0	100	Sub-Angular High Sphericity	190
BN10	63	1	0	1	35	0	100	Sub-Angular High Sphericity	210
BN11	66	1	0	1	32	0	100	Sub-Angular High Sphericity	230
BV1-1	70	1	0	2	27	0	100	Sub-Angular High Sphericity	0
BV1-2	39	1	0	1	59	0	100	Sub-Angular High Sphericity	10
BV1-3	57	1	0	0	42	0	100	Sub-Angular High Sphericity	30
BV1-4	52	1	0	1	45	1	100	Sub-Angular High Sphericity	50
BV1-5	56	0	0	3	40	1	100	Sub-Angular High Sphericity	70
BV1-6	57	1	0	3	39	0	100	Sub-Angular High Sphericity	90
BV2-1	55	1	0	1	43	0	100	Sub-Angular High Sphericity	0
BV2-2	28	2	1	0	69	0	100	Sub-Angular High Sphericity	20
BV2-3	27	1	0	1	70	1	100	Sub-Angular High Sphericity	40
BV2-4	36	1	0	1	61	1	100	Sub-Angular High Sphericity	60
BV2-5	65	1	0	1	32	1	100	Sub-Angular High Sphericity	80
BV2-6	62	1	0	2	34	1	100	Sub-Angular High Sphericity	100
BV3-1	66	1	0	1	32	0	100	Sub-Angular High Sphericity	0
BV3-2	54	1	0	0	44	1	100	Sub-Angular High Sphericity	20
BV3-3	41	1	0	1	56	1	100	Sub-Angular High Sphericity	40
BV3-4	40	1	0	3	55	1	100	Sub-Angular High Sphericity	60
BV3-5	44	1	0	2	52	1	100	Sub-Angular High Sphericity	80
BV3-6	49	1	0	1	48	1	100	Sub-Angular High Sphericity	100

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
BV4-1	41	2	0	1	55	1	100	Sub-Angular High Sphericity	0
BV4-2	48	2	0	0	49	1	100	Angular High Sphericity	20
BV4-3	52	1	0	1	45	1	100	Angular High Sphericity	40
BV4-4	51	2	0	2	44	1	100	Sub-Angular High Sphericity	60
BV4-5	55	2	0	3	39	1	100	Sub-Angular High Sphericity	80
BV4+6	57	2	0	3	37	1	100	Sub-Angular High Sphericity	100
BV5-1	52	3	0	1	43	1	100	Angular High Sphericity	0
BV5-2	50	3	0	2	44	1	100	Sub-Angular High Sphericity	20
BV5-3	53	1	0	3	42	1	100	Sub-Angular High Sphericity	40
BV5-4	57	1	0	3	38	1	100	Sub-Angular High Sphericity	60
BV5-5	52	2	0	2	43	1	100	Sub-Angular High Sphericity	80
BV5-6	54	1	0	2	42	1	100	Sub-Angular High Sphericity	100

Fourth period

Sampling Point	Estimated Percentages of Various Kinds of Particles						total	Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica			
SF1	62	2	0	2	33	1	100	Sub-Angular High Sphericity	-171
SF2	61	1	0	1	36	1	100	Sub-Angular High Sphericity	-151
SF3	63	1	0	1	34	1	100	Sub-Angular High Sphericity	-131
SF4	63	1	0	2	33	1	100	Sub-Angular High Sphericity	-111
SF5	60	1	0	2	36	1	100	Sub-Angular High Sphericity	-91
SF6	64	2	0	1	32	1	100	Sub-Angular High Sphericity	-71
SF7	70	3	0	1	24	2	100	Sub-Angular High Sphericity	-51
SF8	69	2	0	2	25	2	100	Sub-Angular High Sphericity	-31
SF9	68	2	0	1	28	1	100	Sub-Angular High Sphericity	-11
SF10	68	1	0	5	24	2	100	Angular High Sphericity	9
SF11	67	1	0	4	26	2	100	Sub-Angular High Sphericity	29
SF12	65	1	0	4	28	2	100	Sub-Angular High Sphericity	49
BN1	62	1	0	4	31	2	100	Sub-Angular High Sphericity	20
BN2	60	1	0	2	36	1	100	Sub-Angular High Sphericity	40
BN3	64	1	0	3	30	2	100	Sub-Angular High Sphericity	60
BN4	70	1	1	0	28	0	100	Sub-Angular High Sphericity	80
BN5	73	2	0	0	25	0	100	Sub-Angular High Sphericity	100
BN6	69	1	1	4	24	1	100	Sub-Angular High Sphericity	120
BN7	68	1	1	1	28	1	100	Sub-Angular High Sphericity	140
BN8	70	1	0	1	27	1	100	Sub-Angular High Sphericity	160
BN9	72	0	1	0	26	1	100	Sub-Angular High Sphericity	180
BN10	70	1	1	0	27	1	100	Sub-Angular High Sphericity	200
BN11	68	1	0	1	29	1	100	Sub-Angular High Sphericity	220
BN12	69	1	0	1	28	1	100	Sub-Angular High Sphericity	240
KK1	69	2	1	0	27	1	100	Sub-Angular High Sphericity	14
KK2	68	1	0	2	27	2	100	Sub-Angular High Sphericity	34
KK3	67	1	0	6	24	2	100	Sub-Angular High Sphericity	54
KK4	67	2	0	0	30	1	100	Sub-Angular High Sphericity	74
KK5	68	1	0	1	29	1	100	Sub-Angular High Sphericity	94
KK6	67	3	0	2	26	2	100	Sub-Angular High Sphericity	114
KK7	58	1	0	2	35	4	100	Angular High Sphericity	134
KK8	50	1	0	4	39	6	100	Angular High Sphericity	154
KK9	49	1	0	4	40	6	100	Sub-Angular High Sphericity	174
BV1-1	58	2	0	1	37	2	100	Sub-Angular High Sphericity	10
BV1-2	50	1	0	1	42	6	100	Angular High Sphericity	30
BV1-3	59	1	0	2	32	6	100	Angular High Sphericity	50
BV1-4	48	2	0	1	44	5	100	Angular High Sphericity	70
BV1-5	57	1	0	4	33	5	100	Angular High Sphericity	90
BV1-6	56	1	0	4	34	5	100	Angular High Sphericity	110
BV1-7	56	2	0	4	33	5	100	Angular High Sphericity	130
BV2-1	60	3	1	1	32	3	100	Sub-Angular High Sphericity	10
BV2-2	58	3	0	2	33	4	100	Sub-Angular High Sphericity	30
BV2-3	54	2	0	3	35	6	100	Angular High Sphericity	50
BV2-4	52	3	1	2	38	4	100	Sub-Angular High Sphericity	70
BV2-5	48	3	0	5	39	5	100	Sub-Angular High Sphericity	90
BV2-6	53	2	0	3	38	4	100	Sub-Angular High Sphericity	110
BV2-7	52	2	0	3	39	4	100	Sub-Angular High Sphericity	130
BV3-1	53	3	1	1	40	2	100	Sub-Angular High Sphericity	10
BV3-2	50	3	0	3	40	4	100	Sub-Angular High Sphericity	30
BV3-3	48	3	0	5	39	5	100	Angular High Sphericity	50
BV3-4	52	3	0	3	38	4	100	Sub-Angular High Sphericity	70
BV3-5	53	3	0	2	38	4	100	Sub-Angular High Sphericity	90
BV3-6	52	3	0	5	36	4	100	Sub-Angular High Sphericity	110
BV3-7	50	3	1	6	35	5	100	Sub-Angular High Sphericity	130
BV3-8	48	4	1	4	38	5	100	Sub-Angular High Sphericity	150

Sampling Point	Estimated Percentages of Various Kinds of Particles							Notes and Remarks	Distance from reference point(m)
	Quartz	Feldspar	Rocks fragment	Heavy Minerals	Bio Clasts	Mica	total		
BV4-1	59	3	1	6	28	3	100	Sub-Angular High Sphericity	10
BV4-2	51	4	0	6	35	4	100	Angular High Sphericity	30
BV4-3	44	4	0	5	41	6	100	Angular High Sphericity	50
BV4-4	46	5	0	5	40	4	100	Sub-Angular High Sphericity	70
BV4-5	49	4	0	3	40	4	100	Sub-Angular High Sphericity	90
BV4-6	53	3	0	3	38	3	100	Sub-Angular High Sphericity	110
BV4-7	55	4	0	2	37	2	100	Sub-Angular High Sphericity	130
BV4-8	55	5	0	4	32	4	100	Sub-Angular High Sphericity	150
BV4-9	48	4	0	3	41	4	100	Sub-Angular High Sphericity	170
BV5-1	59	4	0	3	31	3	100	Sub-Angular High Sphericity	10
BV5-2	52	4	1	3	37	3	100	Sub-Angular High Sphericity	30
BV5-3	52	4	0	2	39	3	100	Sub-Angular High Sphericity	50
BV5-4	52	4	0	3	37	4	100	Sub-Angular High Sphericity	70
BV5-5	53	4	0	3	36	4	100	Sub-Angular High Sphericity	90
BV5-6	54	4	0	4	34	4	100	Sub-Angular High Sphericity	110

Table 1 Locations, time of beach measurement and surface sand sample collection for this research.

Location	Field survey date			
	First	**Second**	**Third**	**Fourth**
Blue Village Pakarang Resort	20-21/01/2006	11/05/2006	12/08/2006	07/11/2006
Sofitel Magic Lagoon	20/01/2006	03/06/2006	14/08/2006	09/11/2006
Klong Khuek Khak	21/01/2006	10/05/2006	13/08/2006	08/11/2006
Ban Bang Niang	07/02/2006	10/05/2006	14/08/2006	10/11/2006

BIOGRAPHY

Mr. Sumet Phantuwongraj was born on June 19, 1980 in Bangkok. He has got Bachelor Degree in Geography with 2nd honor from Department of Geography, Faculty of Arts, Silpakorn University in 2002. Then he worked as a GIS/MIS administrator at Prima Techmark Co., Ltd. for two year. He carried out further study on Master program on Earth Sciences at Department of Geology, Faculty of Science, Chulalongkorn University, in 2004.