A Study on Submerged Breakwater Length, Offshore Distance and Crest Width Affecting the Shoreline Response

by

LEE JIA LIANG

13104

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

JANUARY 2014

University Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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(CIVIL ENGINEERING)

Approved by,

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Supervisor
(AP Ahmad Mustafa B Hashim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JANUARY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(LEE JIA LIANG)

ABSTRACT

Submerged breakwater widely perceived to be able to protect shoreline from erosion by leaving no aesthetic issue to the beach comparing to conventional design such as groynes and revetments. There are also multi-functional submerged breakwaters which are excellent in enhancing surfing condition in local beach. However, several literature reviews revealed submerged breakwater built are most likely have erosion than accretion in the lee of the structure. The rare adoption of submerged breakwater often related to its inconsistency in combating erosion problem as the shoreline response to these structures are not well understood at present. Therefore, this study is aimed to identify the shoreline response behind SBW in Kerteh and Niigata. The geometrical ratio of crest width, breakwater length and offshore distance of SBW is then investigated by taking shoreline movement into account. The images are first extracted with Landsat Toolbox and corrected with tidal correction model. Then, DSAS is used to compute the shoreline changes from early 1980s – 2009. The shoreline changes are discussed and the geometrical ratio of submerged breakwater is investigated by relating it to the shoreline response in the leeside of the structure. Result showed that shoreline of Kerteh are generally eroded while accretion is seen behind the Niigata shoreline.

ACKNOWLEDGMENTS

The success and final outcome of this research project required a lot of involvements and participations from many parties and individuals and I am extremely fortunate to have got them all along the completion of my project work. Thus, I would like to take this opportunity to extend my appreciation to them.

First and foremost, thank God for the wisdom and perseverance that He has been bestowed upon me during this research project. Deepest gratitude goes to **AP Ahmad Mustafa B Hashim**, this dissertation could not have been done without him, who not only served as my project supervisor but also encouraged and challenged me throughout my academic program. I have been extremely lucky to have a supervisor who cared so much about my work, and responded to my questions and queries so promptly. Advice given by him has been a great help and I am particularly grateful for his valuable and constructive suggestions during the development of this research work.

Apart from that, I would also like to extend my thanks to the FYP coordinator, **Ir Idris** for conducting informative seminars and briefings to assist all the FYP students as well as helping in arranging the schedule for Pre-Sedex and Viva for students by sending invitations to the internal and external examiners.

I would also like to acknowledge with much appreciation the crucial role of **Mr Tunji Lawal**, for the constant guidance in the midst of confusion and doubts. The extensive teaching on the software has made the project meeting its original Gantt Chart.

Last but not least, I wish to thank my mother for her love and undivided support, both financially and emotionally throughout my years of study. Not to forget, my fellow colleagues and friends for their generous support.

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CHAPTER 1 - INTORUDCTION

1.1 Background of Study

Fast pace development disturbing dynamic equilibrium in the vicinity of coastal area caused coastal erosion, which is a severe problem worldwide menacing coastal properties, degrading valuable land resources, interfering fishing, shipping and tourism activities (Rambabu, 2005). Coastal erosion is a global problem; at least 70% of sandy beaches around the world are recessional (Bird, 1985). Domestically, approximately 86% of U.S. East Coast barrier beaches have experienced erosion during past 100 years (Galgano, 2004). Half of the valuable wetland of US has been lost mainly due to the combination of natural processes and human engineering within 200 years (Williams, 2001).

Further uncontrolled erosion is likely to bring damage to 87,000 homes and structures located along U.S.'s 10,000 miles of coastline which will cost owners $530 million per year and $80 million per year by National Flood Insurance Program (NFIP) for erosion related damage over the next 60 years. Widespread erosion is also well documented in California and in the Gulf of Mexico (Ranasinghe, 2004).

Besides, coastal erosion is equally challenging in Asia region as India faced erosion in 23% of its 7517 km coastline which composed of 43% of sandy beaches, 11% rocky coast and 46% of muddy area (Kumar et al, 2006). Thampanya (2006) reported obvious erosion had been observed at southern Thailand coastline for past decade by relating it to reduction of mangrove area to about 50% of its original coverage. According to Othman (1994), 30% of Malaysia coastline is eroding while a maximum coastal retreat of 300 m year^{-1} has been projected at the Luanhe River mouth in China (Feng Cai, 2009). The general coastal erosion reason is due to the climate changes, sediment transport, climate and human activities that lead to altered coastal processes.

Rock revetments are widely used in area subjected to ongoing coastal erosion whenever seawalls are not cost effective or environmentally acceptable to provide full protection. It is able to reduce erosion by dissipating wave energy when wave passing through the narrow space between them. On top of that, groynes are wooden barrier built perpendicular to the sea which capable of trapping sand from littoral drift. The performance of groynes are measured by the littoral drift they block. As these conventional beach protection structures affecting on beach amenity and becoming aesthetic considerations, the popularity of groynes and revetments went down. In contrast, submerged structures are widely perceived to be capable of providing the necessary beach protection without any loss of beach amenity or negative aesthetic impact. (Evans, 2001). Dick and Brebner (n.d.) supported this statement by reporting solid and permeable type submerged breakwater with near zero submergence able to reduce incident wave energy by 50%. This is supported by recent study conducted by Young (2011) which indicates that submerged breakwater with zero submergence has the maximum effect in reflecting wave with a coefficient of 0.53. Multi-functional submerged breakwaters are design to protect shoreline and enhance surfing conditions by optimizing local bathymetry, generating surfable waves (Black, 2001) and (Jackson, 2002).

There are frequent adoption of emergent offshore breakwater around the world such as US, Europe and Japan reported by (Dean & Dalrmple, 2001). The latter reported there are 4000 existing emergent breakwater by mid of 1980s showing the popularity of this type of breakwater. Submerged breakwater construction for shoreline protection is uncommon although Black (2001) suggesting submerged structures may provide beach protection as few reported investigations showed that shoreline response to submerged breakwaters are unreliable. Calabresea (2008) further reinforced the statement saying that despite submerged breakwaters up to date have been employed with different design philosophies, uncertainties remained in forecasting shoreline response. In contrast, erosion is almost never reported in the lee of emergent breakwater. Therefore, the fundamental principal that used for emergent breakwater to anticipate shoreline response may not be feasible to predict shoreline response to submerged breakwaters.

1.2 Problem Statement

Generally submerged breakwater is acknowledged to be able to provide coastal protection without sacrificing the amenity of the beach. However, shoreline response at the lee of the structure is not well understood at the moment as it is rarely adopted. Despite that, some submerged breakwaters are constructed even it has not incorporate the entire structural and environmental parameter in the design has made erosion of the beach gone from bad to worst. More specifically, there is more erosion than accretion where submerged breakwaters built as results of the prototype data often conflicting with the actual situation as it is hard to foresee every parameter at the site.

Globally, numerous researches confirmed the inconsistency in submerged breakwater's performance indicating that most submerged breakwaters not able to perform in expected manner in coastal protection. In Italy, there is a case whereby two submerged breakwater constructed near to each other whereby salient is observed behind one submerged breakwater while erosion is seen in the other structure. It is clearly seen that appropriately chosen structural parameter of submerged breakwater is a key to succession of coastal protection.

1.3 Objectives

This project is aimed to

- Identify the mode of shoreline formation in the leeside of SBW
- Investigate the effect of crest width, breakwater length and its offshore distance from shoreline of offshore breakwater of SBW to the shoreline response in Kerteh and Niigata

1.4 Scope of Study

This study involve the acquiring of satellite images of Kerteh and Niigata from USGS of a range of 2 decades. Landsat toolbox then responsible for the extraction of shorelines from satellite images in ArcGIS by differentiating the interface of land and sea. These shorelines extracted then undergo tidal correction process which require another image of nearly the same date to be obtained based on tidal correction model. Next, corrected shoreline changes are appended into the same layer through appending function which then allow the shoreline to be analyzed with DSAS (Digital Shoreline Analysis System) by transect projected from the baseline. Ultimately, the effectiveness of SBW is assessed by based on the shoreline responses of the investigated beach.

1.5 Relevancy of the Project

Basically, the project is aimed to investigate the structure parameter of breakwater length, offshore distance and crest width of coastal protection structure in Kerteh and Niigata in affecting the shoreline response. SBWs are constructed all around the world as coastal protection structure which aim to strive for both accretion and beach amenity. However, the implementation of this particular protection scheme is not as convincing as the analysis of the structure before construction as their performance are inconsistent whereby erosion is often observed in the leeside of the structure. Thus, this project wish to bridge the knowledge gap in SBW design by relating the shoreline responses to its breakwater length, offshore distance and crest width.

1.6 Feasibility of the Project

The feasibility of the project is discussed in term of time and economy aspect. For this project, a total time of 28 weeks are allocated from initial stage to finalization of project. The project's objectives is achievable if schedule of Gantt Chart is strictly followed whereby reasonable period are allocated for self learning and reporting of the results.

The project is as well achievable within the RM 500 budget allocated for FYP development. Firstly, the main software, ArcGIS is available for the public under the trial version. Then USGS has made the satellite images accessible by the public all day by registering as a valid user in its website. Thus, the project is an extremely low cost project whereby cost of achieving the objective are nearly negligible and definitely fall within budget allocated.

CHAPTER 2 – LITERATURE REVIEW

2.1 Case Studies

2.1.1 Conventional submerged breakwater

2.1.1.1 Italy

Due to shoreline erosion, most beaches in northern sector of Italy are under protection of shore structures. In vicinity of Rome, there are two submerged structures having contrasting shoreline responses near Tiber River entrance to preserve the amenity of the beach while favoring tourism industry. First structure is a shore parallel submerged breakwater, 3000 m long submerged 1.5 m below mean sea level (MSL), having crest width of 15 m located 100 m from shoreline in 4 m water depth. This project included beach nourishment of 502000 m^3 of fine sand and 888000 m^3 of gravel and coarse sand mix. Aerial photographs analysis revealed that erosion rate remained and an annual sand supply of 15000 m^3/km required to counter the erosion attributed to the structure (Tomassicchio, 1996). The result indicates the erosion remains unchanged and concluded submerged breakwater provides no measurable benefit to the shoreline.

The second structure constructed one year after completion of first structure reported by (Tomassicchio, 1996) in nearby coastline succeeding in protecting coastline. Without any beach nourishment program, widening of the beach was observed in the lee of the structure which is a 700 m long detached submerged breakwater was located 0.5 m below MSL having crest length of 15 m placed in 3-4 m water depth located about 50 m from shoreline after construction even though it is much more smaller than first structure. The failure occurs most probably related to high submergence of first structure compared to the second one as the submerged breakwater unlikely to reflect wave and reduce incident wave height in this condition Young, 2011.

A submerged breakwater constructed in Lido di Dante was aimed to replace revetments which was reported to be ineffective in preventing erosion problem in the nearby coastal area (Lamberti & Mancinelli., 1996). The particular structure is a 770 m long detached submerged breakwater, 150 m from shoreline, located in 3m depth and having crest width of 12 m and crest level of 0.5 m below MSL. The latest monitoring program reported that a maximum of 30 m beach widening was observed as soon as the project completed.

In Marche region, submerged breakwater was constructed along several beaches with groynes (Lamberti & Mancinelli., 1996). The structure was located 100 m – 200 m from shoreline, placed in 3 m water depth. The breakwater was constructed at a gap of 30 m with its crest level submerged 0.9 m below MSL. The initial structure was modified as heavy erosion indicated between the gap of the submerged breakwater during storm event which lead to low wave attenuation as the breakwater has a high submergence level during the event.

2.1.1.2 Japan

Coastal protection in Japan is relatively important and improvement need to be made as only 35% of total coastline that needs protective measures has been somehow protected (Irie, 1990). In Niigata, Japan erosion in the lee of a submerged breakwater 1.5 m below MSL of crest width 20 m and length of 540 m due to storm event which result in strong divergent currents was reported by Funakoshi (1994). Erosion was indicated in Keino-Matsubara Beach when half of sandy material (5000 m^3) used for beach nourishment program was depleted within 2 months after completion of submerged breakwater construction which contrast with the capability of submerged breakwater in retaining shore-side sediment and have minimum impact on the surrounding environment and able to reduce 30-70% of wave height (Pillarczyk, 1996).

2.1.1.3 United State

In Delaware Bay, a submerged breakwater constructed in a different way whereby the submerged breakwater is connected to groynes which built onshore (Douglass & Weggel, 1987). The 300 m long breakwater placed at 1 m water depth, 75 m away from shoreline was supplemented with beach nourishment material of 1500 m^3. Survey indicated that salient is formed behind lee of the submerged breakwater. However, beach nourishment material was depleted within 4 years monitoring period. Author relates the erosion to oblique wave incident which develop caused the longshore sediment transport.

In Florida, a long submerged breakwater of 1260 m which comprised of 330 precast locking units; each having 1.8 m high, 3.7 m long and 4.6 m wide at the crest. It is submerged 0.7 m below mean low low water (MLLW). Monitoring program pointed out that the erosion after construction is twice as much as background erosion (Dean, 1997). The author relating the failure to submerged structure's low crest level which result in low wave attenuation. This high degree of wave energy transmission was expected to have resulted in significant onshore flow over the reef, which then deflected in the nearshore, resulting in strong longshore currents.

A precast submerged breakwater was built in Vero Beach, Florida having 217 precast units and 11 segments forming 915 m long detached structure. Erosion was seen in the lee of the structure. Worst still, the settlement experienced after construction further reduced the ability to attenuate wave which ultimately led to greater erosion rate.

2.1.1.4 Malaysia

Coastal area of Kerteh, Terengganu is experiencing coastal erosion. The beach is a series of and small hook shaped bay, making it susceptible to direct wave attack especially during NE monsoon (Tunji et al., 2011). The erosion rate is too high that it exceeded the acceptable risk level of Petronas Complex building nearby where it possessed the probability of damaging the building in any near future. The main reason behind this erosion is because of the complete cutting off of the upcoast sediment supply to the beach, leading to bay indentation. Thus, construction of three submerged breakwater and sediment supply are taken as erosion mitigation measure at the affected area. The breakwaters are approximately 200 m offshore and 1000 m long accompanied by 400,000 m^3 beach nourishment material. However, no monitoring program carried out to measure the effectiveness of the submerged breakwater installed.

2.1.2 Multi-functional submerged reef

2.1.2.1 Australia

Jackson et al. (2002) reported performance of multi-functional artificial reef in Gold Coast, Australia. This submerged structure is designed to protect coastal erosion and enhance surfing experience at the same time. Thus this dual function submerged structure by configuration is a much complex design in order to facilitate surfable wave. The structure was constructed of large sand filled geotextile bags (up to 350 ton) and extends from about 100 m to 600 m offshore and 350 m alongshore (Jackson & Corbett, 2007). The apex of the structure was located at a water depth of about 10 m while the inshore extremity was at a depth of 2 m. The ambient bed slope was 0.02. Although the original design for the crest level of the structure was 0.25 m below MLW, this was lowered to 1 m below MLW, principally due to surfer safety considerations. The project also included a major beach nourishment program of approximately 1.2 million m^3. During the first 6 months after construction seabed erosion (up to 2 m) in the vicinity of the structure resulted in a significant lowering of the crest level. Two further construction phases were undertaken in late 2001 and again in November 2002 to raise the crest level up to the design level of 1 m below MLW. The analysis of the time-series of weekly shorelines extracted from the video images indicated that the structure promoted accretion during the first 12 months (January 2001–January 2002) after the first phase construction was completed.

2.1.2.2 New Zealand

A relatively tiny yet unique submerged breakwater, Mount Reef is constructed in Bay of Plenty in New Zealand for coastal protection in moderate wave climate. Mount Reef is differ from conventional design as it is not constructed in a rectangular shape and have several adjustments made such as widening crest, longer breaking zone length and its depth is altered at where focus zone intersect with breaking zone (Black & Mead, 2005). It has a crest level of 0.5

m below MSL and placed in seabed of 3.5 m. The geometry of breakwater is shown in Figure 2-1 below.

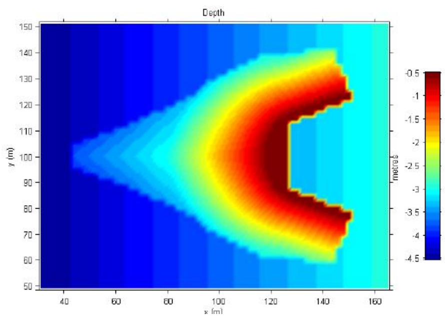


Figure 2-1 Numerical model representation of Mount Reef (Black & Mead, 2005)

The reef is predicted to be able to interfere with normal wave propagation by dissipating wave energy in its lee side. The capability of wave attenuation is verified when salient is formed in the shoreline behind the structure.

2.1.2.3 England

Boscombo Reef is located at place it named after which situated in the vicinity of south coast of England. This reef is built primarily to surfing activities than coastal protection, constructed with geotextile containers of diameter 1 m to 4 m and length of 15 m to 40 m placed 200 m offshore (Mead et al., 2011). The design incorporate the dual level reef with a focus section which aim for wave breaking along crest for pleasant surfing condition as shown in Figure 2-2.

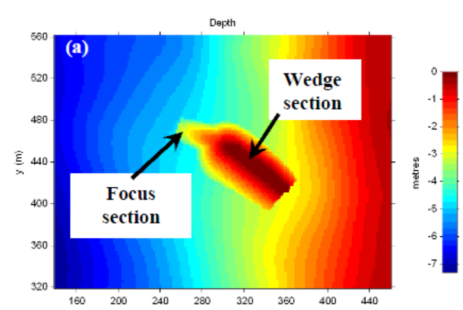


Figure 2-2 Numerical model of Boscombe Reef (Meat et al., 2011)

A total of 17 bathymetry survey and 3 beach profile survey are conducted in assessing its effect to shoreline. Through these surveys, significant salient formation is seen in the lee of the structure throughout the survey years as shown in Figure 2-3.

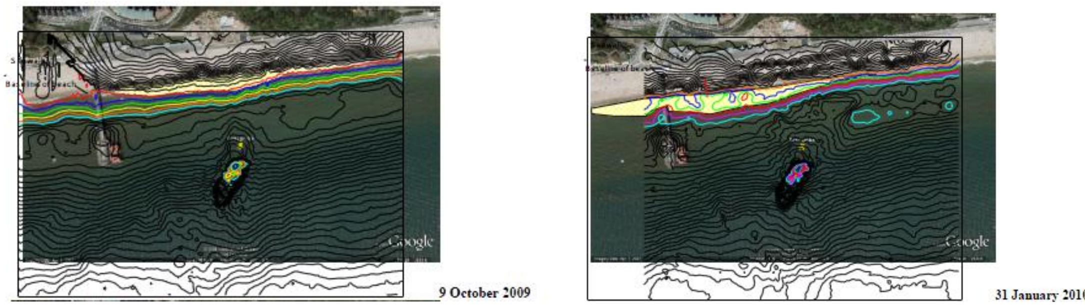


Figure 2-3 Shoreline comparison behind Boscombe Reef (Mead et al., 2011)

However, the salient formed at slightly west of Boscombe Reef as sediment transport has a predominant direction of west to east.

Table 2-1 Summary of case studies

Location	Reference	Crest Width (m)	Length (m)	Submerged Level below MSL (m)	Distance from Shoreline (m)	Accretion/ Erosion
Tiber River Entrance #1, Italy	Tomassicchio (1996)	15	3000	1.5	100	Erosion
Tiber River Entrance #2, Italy	Tomassicchio (1996)	15	700	0.5	50	Accretion
Lido di Dante, Italy	Lamberti & Mancinelli (1996)	12	770	0.5	150	Accretion
Niigata	Funakoshi (1994)	20	540	1.5	400	Erosion
Delaware Bay	Douglass & Weggel (1987)	-	300	MLW	75	Erosion
Vero Beach, Florida	Stauble et al. (2000)	4.6	915	0.25	85	Erosion
Palm Beach, Flo Rida	Dean (1997)	4.6	1260	0.7	-	Erosion
Gold Coast, Australia	Jackson & Corbett (2007)	-	350	0.25	100-600	Accretion
Kerteh, Terengganu, Malaysia	Tunji et al (2011)	-	1000	-	200	Erosion
Bay of Plenty, New Zealand	Black & Mead (2005)	-	90	0.5	-	Accretion
Boscombe, England	Mead et al (2011)	-	100	-	-	Accretion

— no clear description provided

The above case studies showed that factors governing accretion or erosion of the shoreline are not govern solely by the length or size of the structure only as most large submerged breakwater has not succeeding in protecting the coastline. These submerged structures most likely to achieve their objectives when it takes not only structural parameter but environmental factors into consideration in designing phase.

2.2 Shoreline Responses Assessment

2.2.1 Numerical Modelling

Numerical modeling is widely used in analyzing shoreline response behind submerged breakwater. Among these numerical modeling, DHI Water & Environment's Mike seems to be a popular method in doing the complex task.

Figure 2-4 Numercial Modelling module

In a research investigating shoreline response behind multi-functional reef, MIKE 21 HD (hydrodynamic module), MIKE 21 ST (sediment transport module) and MIKE 21PMS (wave module) were used in stages to compute the shoreline response (Ranasinghe, 2006). In this model, morphological elements, initial wave and current fields correspond to boundary condition are first set up. The model used is a V-shaped structure superimposed on a plane sloping beach with a gradient of 0.02. (Ranasinghe et al., 2006) reported that it is not feasible to consider large environmental and structural parameter toward the shoreline response. However, the author is able to predict the shoreline response relating it to circulation pattern in the lee of the structure. The circulation patterns are shown in Figure 2-5.

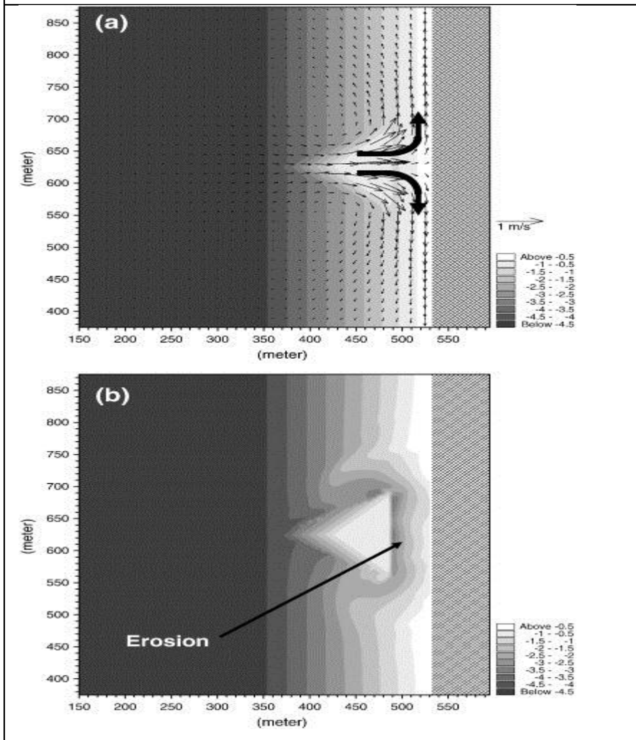
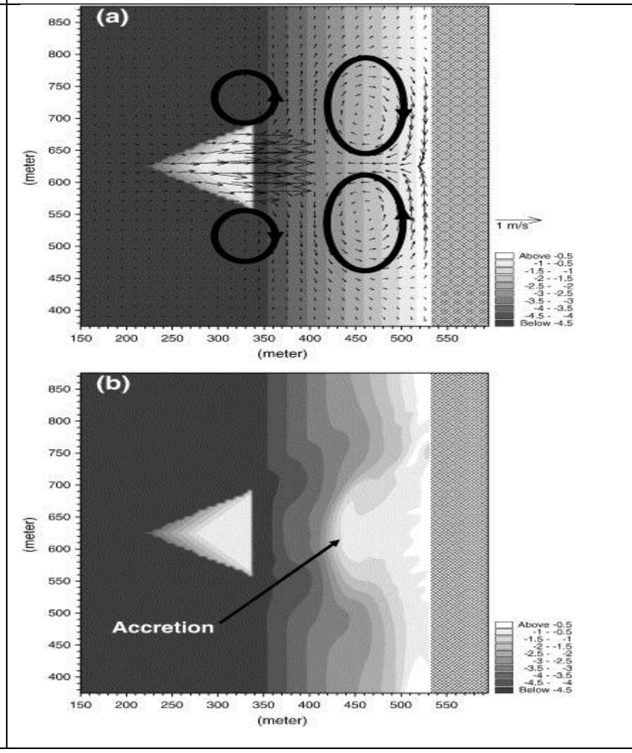
2-cell circulation pattern	4-cell circulation patten
	

Figure 2-5 Circulation patterns in the lee of multi-functional artificial reef (Ranasinghe, 2006)

It is concluded that mode of shoreline response behind submerged breakwater can vary between accretion and erosion. The critical parameter determines the mode of shoreline response is the distance of submerged breakwater from shoreline. It is seen that near shore submerged breakwater generate 2-cell circulation pattern with divergent flow is leading to erosion while convergent 4-cell circulation pattern created by submerged breakwater further from shoreline contribute to accretion in the shoreline. As the same structure move offshore, 2-cell circulation pattern tend to switch to 4-cell circulation pattern under shore normal wave and accretion is observed. Accretion occurs as longshore current decelerate as it venture into deeper water, causing release of sediment.

2.2.2 Physical Modelling

The result of numerical modeling is usually verified by series of lab experiment in scale as no suitable field data is available for validation of model simulation. Generally, qualitative physical model validation is provided by 3D wave basin experiments using the numerical model scale down to experimental size (Ranasinghe, 2004).

A physical modelling study about artificial reef structure in Gold Coast, Australia is conducted to investigate hydrodynamic and morphological effect on the breakwater. The experiment model of scale 1:50 is conducted in a basin of 24.5 m long and 16 m wide to monitor shoreline changes behind it. The actual wave with wave height of 1 m – 4 m and wave period of 6s – 13 s is represent with monochromatic waves of wave height 2 cm – 8 cm and wave period of 0.85s – 1.84 s. Nominal wave direction at the actual site (95^o – 115^o) is examined in this experiment. Hence, the nominal wave direction is actually oblique wave to the shoreline.

The general nearshore circulation pattern is shown in Figure 2-6 indicating a weakened longshore current at up-drift section of the shoreline while higher magnitude longshore current is present at down-drift of the shoreline. Salient formation is expected behind the artificial reef judging from the longshore current gradient along shoreline line. The model is then examined under oblique wave with 7^o incident wave and salient formed is smaller compare to the former condition. Salient size is reduced significantly when the model is tested under storm condition where it is worst weather in Gold Coast as the wave attenuation capability is reduced and shoreline is impact by larger wave.

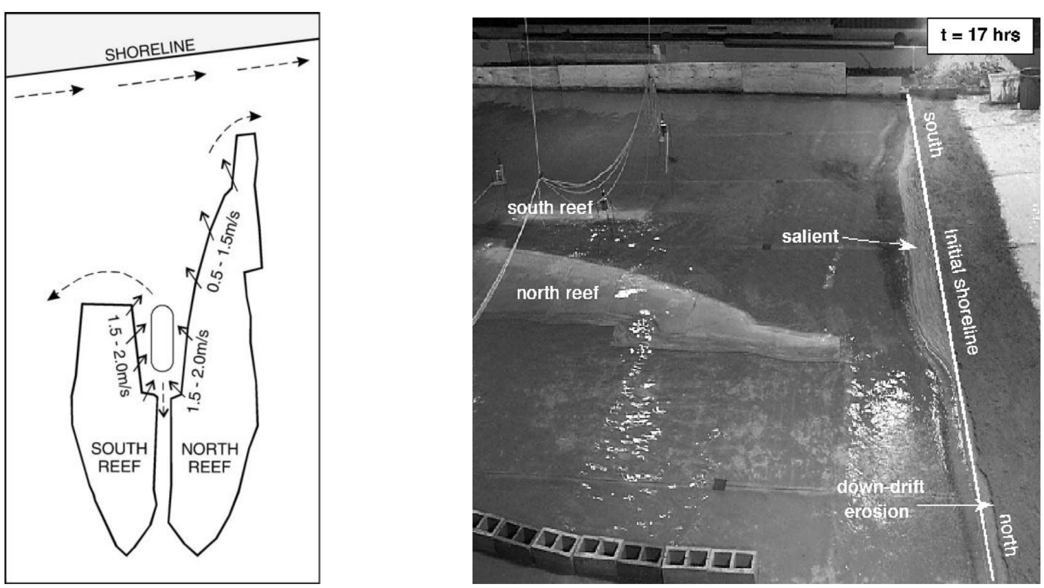


Figure 2-6 General nearshore circulation pattern predicted by physical modelling method (Ranasinghe, 2004).

Physical modelling is able to assimilate physical mechanism governing shoreline response without any simplified assumptions; economically viable as data collections can be done within the laboratory; experimental conditions is highly manipulative are the advantages using physical modelling as verification process.

2.3 Wave behavior behind the lee of submerged breakwater

Submerged breakwater dissipates wave energy through three mechanisms which attenuate wave height (Young, 2011). Firstly, energy is dissipated when wave breaks due to sudden change in water depth as it meets submerged breakwater. Upon impact with submerged breakwater, wave is reflected back to open sea. . On the other hand, energy dispersion occurs on the surface and permeable layer of submerged breakwater. The energy lost in permeable layer is given by

$$D_p = \frac{1}{T}\int_0^T (\omega p)_{z=-h} dt$$

Where T=wave period,

ω, ρ = vertical water particle velocity and pressure at the surface of the permeable layer

h = depth on the permeable layer

Pillarczyk (1996) found out that in an experiment to investigate the breakwater length L_B and Y_B, distance from shoreline where incident wave approaching at 150^0, the velocity of longshore current is halved when L_B is less than two times the incident wave length within breaker zone (YB/Y_b=0.57, where Y_b is width of breaker zone).

Besides, experiments on wave-induced flow patterns around submerged breakwater with length, L_B and gap width, G_B and Y_B, which is the distance from shoreline.G_B must be $< L_B/4$ if the leeside of the structure is designed to be swimming area which uniform wave decay is anticipated. G_B should be greater than ¼ L_B and length of breakwater L_B should be less than $4Y_B$ when deposition of sediment on the shore-side of breakwater is desired (Pillarczyk, 1996).

2.4 Design of Low Crest Structures

Low crest structures are usually preferred mainly due to aesthetic concerns. This type of structures are generally environmentally friendly whereby it does not harm or alter the ecosystem of the local environment but high construction cost and the difficulty in predicting the response of the leeside of SBW has become the main reason of the inhibit use of SBW.

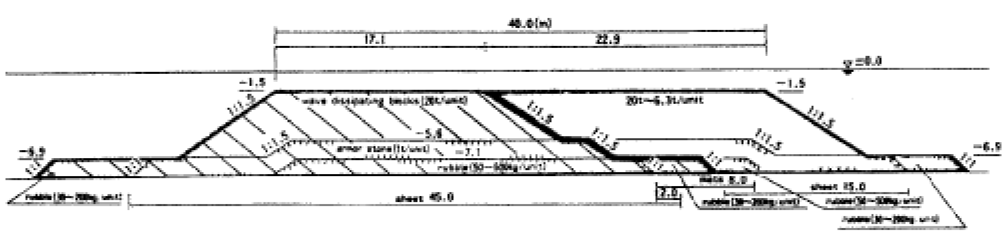


Figure 2-7 Typical cross section of SBW (Pilarczyk, 2003)

Shoreline response in the leeside of the SBW is governed by a total of 14 variables, of which eight are considered primary (Pilarczyk, 2003). They are offshore distance, length of the structure, transmission characteristics, beach slope, mean wave height, mean wave period, orientation of the structure and predominant wave direction. Meanwhile, detached breakwater should considered the extra factor, gap between the SBW as its primary variables. By altering these variables, the SBWs are able to change the wave climate in its leeside to a smaller magnitude and therefore reduce the capacity of wave in transporting sediment.

A simple formula proposed by Harris & Herbich (1986) has a simple geometrical empirical criteria in predicting the formation of salient/tombolo is shown below.

- For tombolo formation : Length/offshore distance > (1.0 – 1.5)
- For salient formation : Length/offshore distance > 0.5

More extensive study is done to assess the parameters governing salient formation based on SBW longshore length, L_s and offshore distance, X. The data summarized that tombolo formed when L_s/X has a ratio of 0.65 while salient form when $L_s/X < 1.0$.

CHAPTER 3 – METHODOLOGY

3.1 Satellite Image

Satellite imagery method has been widely used for past few decades to obtain variety of information ranging from agriculture, global weather pattern, tectonic activity, landscaping, education and military purposes which interpreted and analyzed using specialized remote sensing. The ability of satellite imagery to detect even slightest changes to the subject in high accuracy has extend the uses to oceanography in detecting landscape of beaches, water depth and bathymetry. Hence it is suitable in observing shoreline responses behind breakwater in this study.

Satellite images of submerged breakwater in Kerteh and Niigata of over 20 years are obtained from U.S. Geological Survey (USGS) online website, http://www.usgs.gov/. Satellite images downloaded revolved around coordinate of Kerteh, Niigata and Lido di Osita as shown in Table 3-1.

Table 3-1 Coordinate of Point of Interest

Address/ Place	Lattitude	Longitude
Kerteh, Malaysia	4.5247	103.4561
Niigata, Japan	37.9162	139.0364

Landsat 5 is a satellite launched on March 1st, 1984 in order to collect imagery by scanning the entire Earth in every 16 days at an altitude of 705.3 km with its Thematic Mapper and Multi-Spectral Scanner. These images are taken by LANDSAT since early 1980 where approximately 400 scenes were captured each day and archived, having smallest pixel of 30 m X 30 m. The processed satellite image, level 1 satellite image are processed by USGS so that these processed satellite images come in as seven different bands whereby each of them are captured with different wavelength. However, not much images are good enough to process as sometime the point of interest are covered by cloud which blur its shoreline. Plus, there are incomplete images 2009 onward whereby there are missing pixel which forms stripes that make them somewhat not reliable in processing. Therefore, satellite images from 1984 - 2009 with least cloud coverage are downloaded for further analysis.

3.2 Shoreline Generation

Shoreline generation technique using the Landsat Toolbox which combined the Tasseled Cap and NDVI (Normalized Difference Vegetation Index) method was found to be reliable enough to generate shoreline as it was used to derived ocean shoreline of Southwest Washington and Northwest Orgeon for years 1989, 1995, 1999, 2010, 2011, 2012. The validation test was conducted against a high accuracy air photography and a high correlation value of 0.79 obtained indicated that shorelines extracted from Landsat images are close to the actual change in beach profile (Richard, n.d.).

Obtaining satellite images of different years of a certain location are normally huge in size and time consuming. In order to cut down the processing time and undesired part, the images are broken down into smaller pieces with 'clip' function. The boundary of clip is determined by the shapefile created. Then, a smaller images is crop out and the same process is repeated for other images of different bands. The clipping process is shown in Figure 3-1.

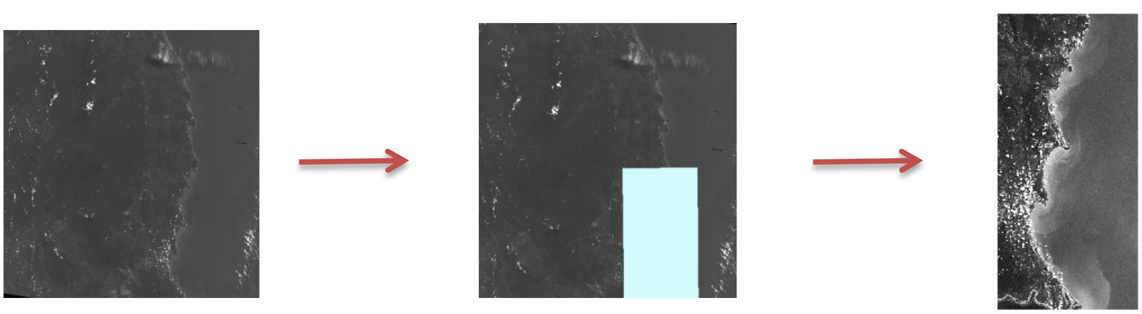


Figure 3-1 Clipping process

'Landsat Toolbox', an extra plugin for ArcGIS is installed to specifically process the Landsat 5 satellite images as shown in Figure 3-2.

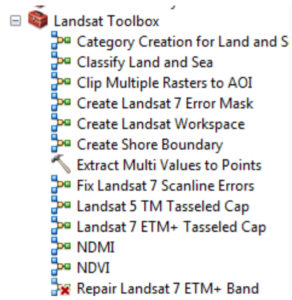


Figure 3-2 Landsat Toolbox interface

It is able to extract shoreline out of satellite images through several steps. Firstly, the clipped images of band 1,2,3,4,5 and 7 are processed in Landsat Toolbox's Landsat 5 Tasseled Cap which is able to execute the shoreline extraction function given that disadvantage is difficult in differentiating clouds from shoreline (Richard, n.d.). The tasseled cap function has output of 'brightness', 'wetness' and 'greenness'. Then, images of IR (infrared) and near IR(NIR) band which are band 3 and 4 are processed under NDVI function which is suitable for water delineation in "slicing" the band to identify water, soil and vegetated land. However, due to instability in normal wave environment in near shore zone and high variability in reflectance value in red and IR red band, solely NDVI is not effective in separating land and sea. Eventually, Richard (n.d.) found out that the combination of both NDVI and Tasseled Cap tools give the better overall result by omitting band 6.

Output of both Tasseled Cap and NDVI allowed the 'Category of Land and Sea Classification' function which used to classify objects seen in satellite images into a total of 10 different categories with each one of them painted with their own respective colours. These 10 categories are further simplified into just two which are land and sea through 'classify land and sea' function. The land and sea boundary can now be separated by the 'shore boundary generation' which gives the clear boundary between land and sea by creating shoreline. The process is as shown in Figure 3-3.

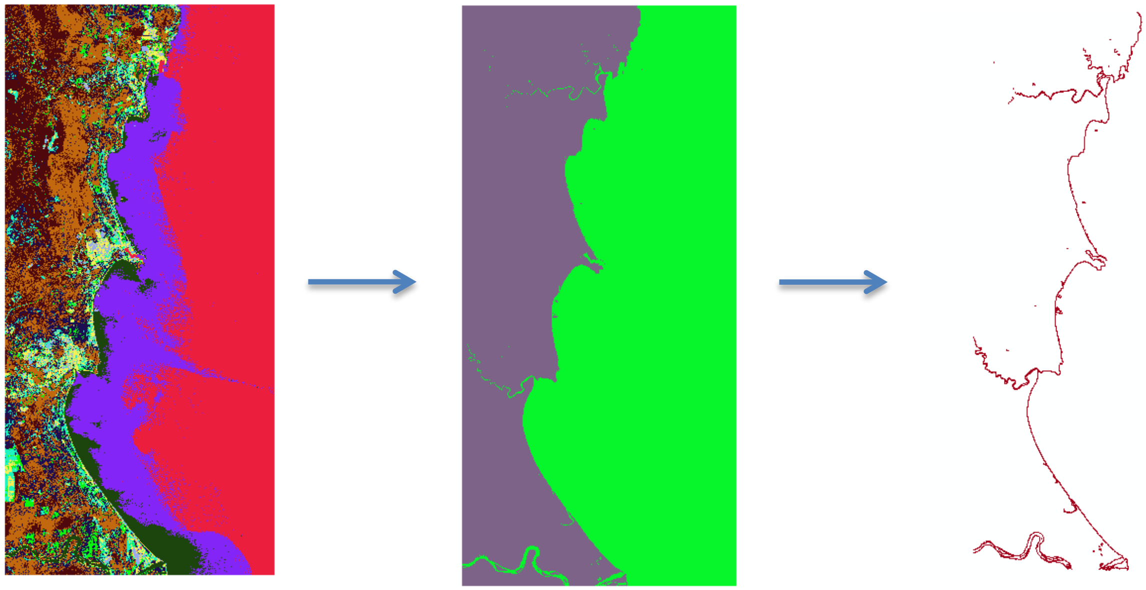


Figure 3-3 Typical result of class 10 to class 2 which give a clear shoreline with shore boundary generation

3.3 Tidal correction

It is found out that shoreline extracted from USGS satellite images are inconsistent when compare it to shoreline of same location in the subsequent period (within 6 months). This happens as same shoreline subjected to different tidal height when they were taken throughout the monitoring period. Thus, it is essential to include tidal correction in the analysis to ensure shoreline examined correctly.

To include tidal correction, two satellite images of nearly the same date, better if satellite images within 6 months are compared as shoreline is assumed to stay unchange for a period of 6 months. By assuming they are the same, tidal correction would be made possible following the model shown in Figure 3-4.

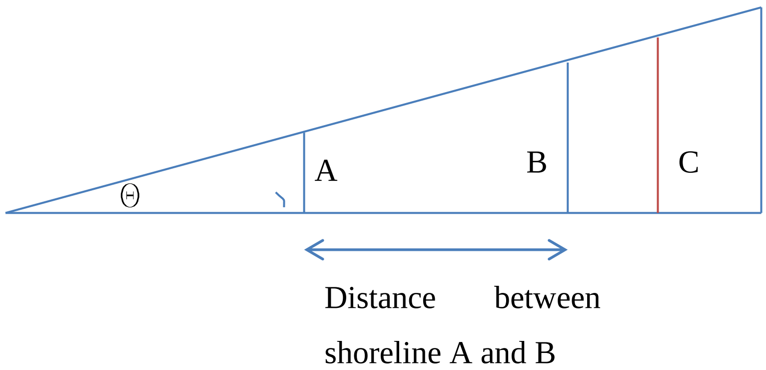


Figure 3-4 Tidal correction model

Model shown is a beach profile whereby A and B are shorelines experiencing different tidal condition at the same beach. Thus, date of A and B should be close enough so that they resemble almost same beach profile (within 6 months). To avoid any tidal interference for other shoreline, they are adjusted to C where it is high enough to be free from any tide.

3.4 DSAS (Digital Shoreline Analysis System)

DSAS is a freeware that work within ESRI (Environmental System Research Institute) Geographic Information System (ArcGIS) software in computing shoreline changes over years and even decades (Thieler et al., 2009). It is a comprehensive plugin whereby it is able to compute rate of change statistics for a time series of shoreline vector data. The data is calculated based on the distance projected by transect from the baseline. The baseline is flexible whereby it can be cast from offshore or onshore as shown in Figure 3-5.

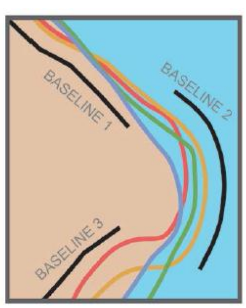


Figure 3-5 Combination of offshore and onshore baseline

If a baseline is projected from the offshore distance, the negative movements are indicated as accretion and vice versa. The DSAS has general workflow as shown in Figure 3-6.

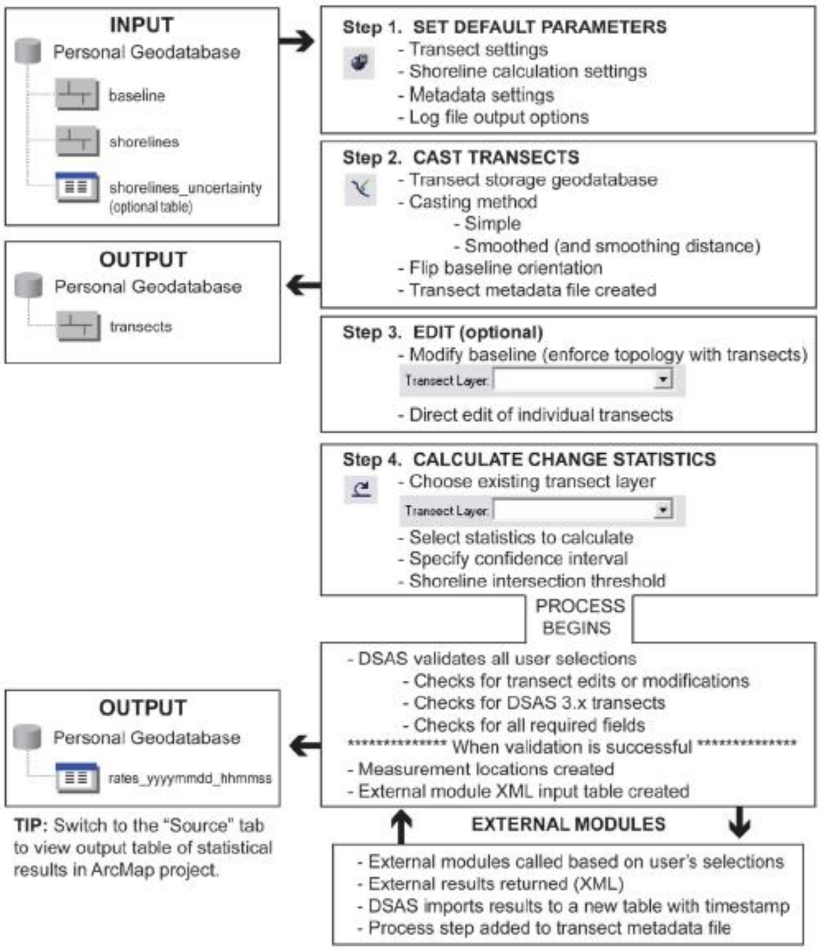


Figure 3-6 General workflow of DSAS

Rate calculations are performed by MATLAB executables embedded within DSAS installation which require installation of MATLAB Component Runtime (MCR) library utility. The final calculation of the shoreline changes is then compiled in XML formatted file in the Calculate Change Statistics Window. Apart from that, DSAS provides extra calculation such as SCE (shoreline change envelope) and NSM (net shoreline movement) which simplify computation of data. SCE and NSM concepts are graphically explained in Figure 3-7.

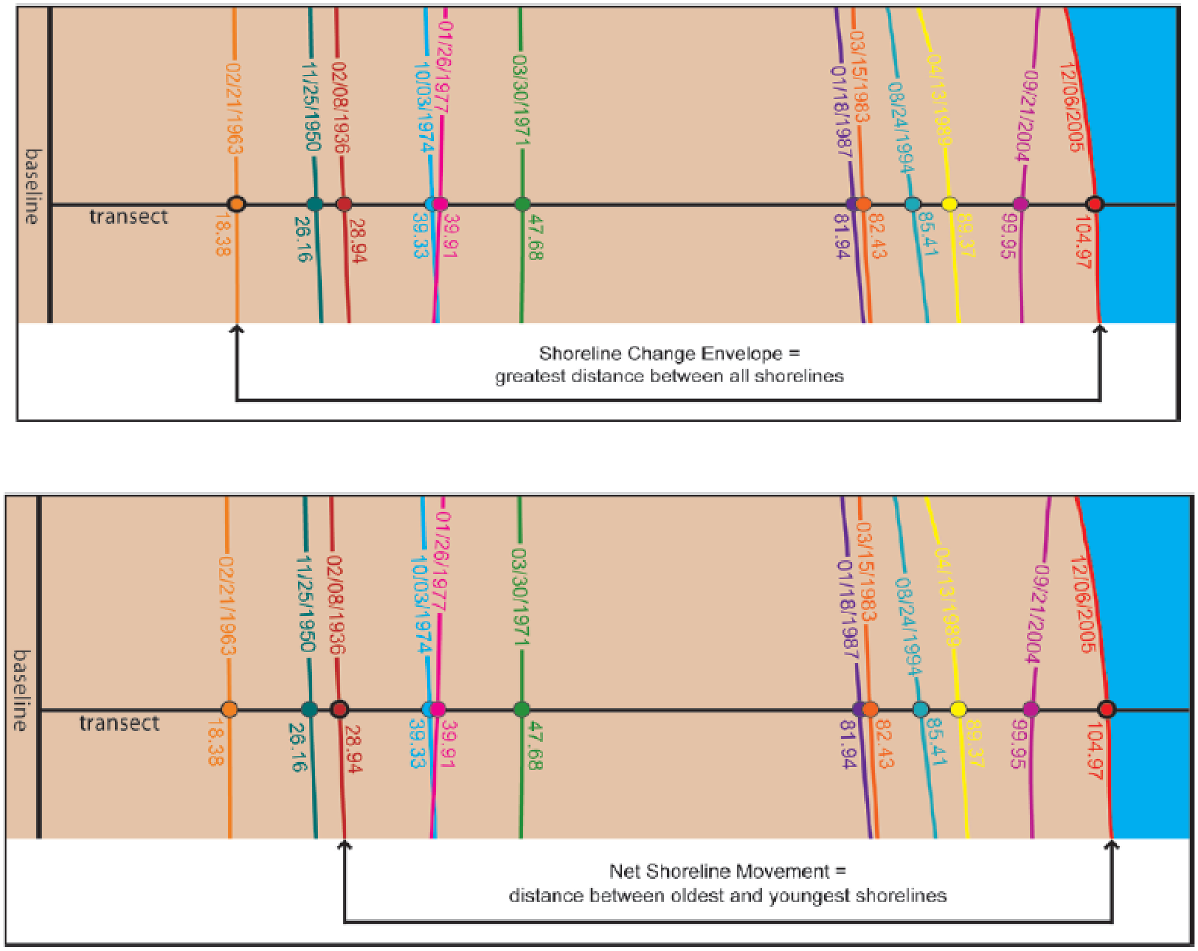


Figure 3-7 SCE and NSM

In this study, shorelines extracted are appended into only one layer in ArcGIS as shown in Figure 3-8.

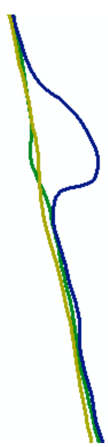


Figure 3-8 Appended shorelines

In order to be able to differentiate each shoreline from one another, 'Date' attribute is added and filled by user. Then baseline, a polyline layer drawn onshore and parallel to the shoreline is set up. 'ID' attribute of text category is added to the baseline feature class so that DSAS could identify the sequence of baseline if it is constructed as fragmented baseline with some onshore while some offshore.

Next, transect of certain spacing and length from baseline is projected seaward across all appended shorelines. Simple projection method is chosen to calculate the shoreline as the point of interest is generally made up of smooth shoreline. Results are then obtained by selecting desired output such as SCE (shoreline change envelope) and NSM (net shoreline movement) values besides shoreline distance from baseline. The same process is repeated for location of interest.

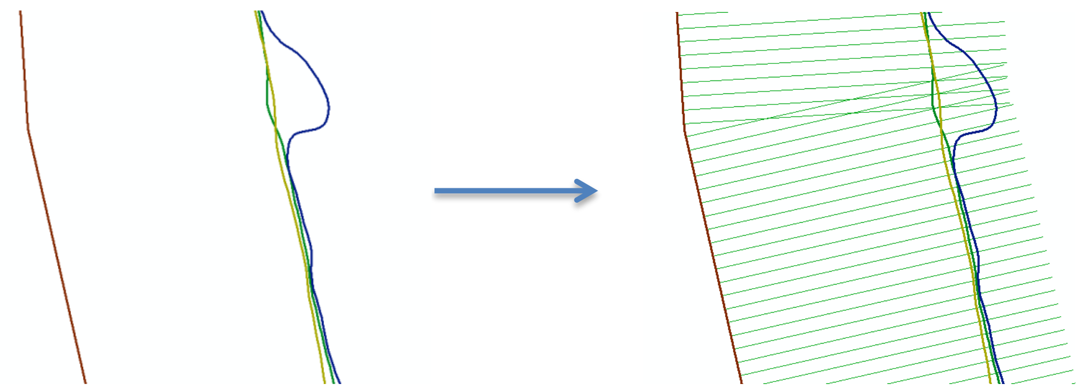


Figure 3-9 Creation of baseline and projection of transect

The summary of overall methodology is represented by Figure 3-10.

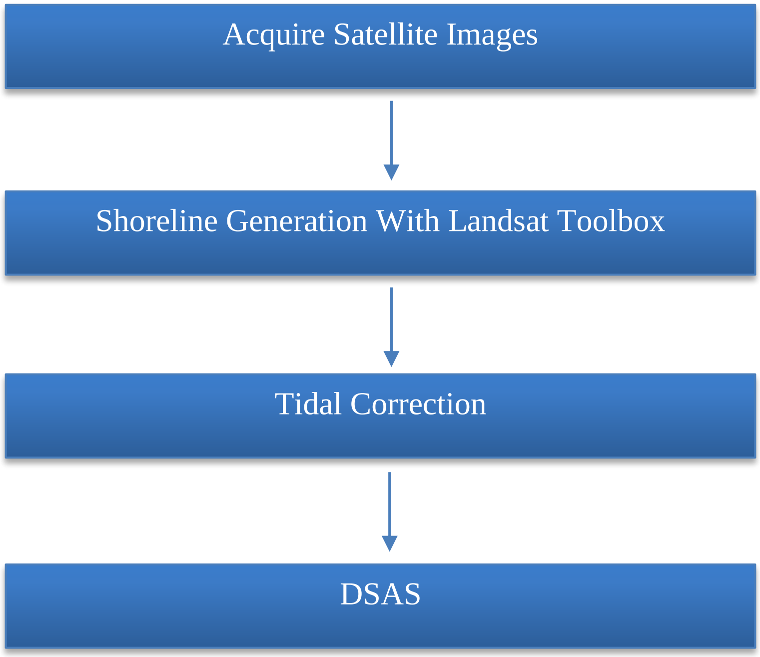


Figure 3-10 Summary of Methodology

3.5 Tools and Equipment

Tools and equipment used are tabulated with function elaborated.

Table 3-2 Functions of various tools and equipment

Tools/Equipment	**Function**
ArcGIS	To create shapefile, baseline, adjusting and correcting shoreline
Landsat Toolbox	Generate shoreline from satellite images
DSAS	Compute shoreline changes
Microsoft office	report writing and data tabulation

3.6 Key Milestone

Table 3-3 Key Milestones

Milestones	Description
Proposal Defend	Present project proposal to supervisor and internal examiner
Project Work	Acquiring Satellite Images of Kerteh, and Niigata
	Generate shoreline with Landsat Toolbox
	Generate tidal corrected shoreline
	Compute the shoreline changes with DSAS
Project Finalization	Relate submerged breakwater structural parameter in defending shoreline of Kerteh and Niigata
	Preparation of full report

3.7 Project Gantt Chart

Table 3-4 Project Gantt Chart

Activity/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Acquire FYP title																												
Literature Review																												
Extended Proposal Submission																												
Proposal defense																												
Interim Report Submission																												
Acquire Satellite Images																												
Data Processing																												
Data Analysis																												
Report Submission																												

CHAPTER 4 RESULT AND DISCUSSION

4.1 Shoreline Response

4.1.1 Kerteh

Submerged breakwaters built along Kerteh shoreline are mainly aimed to protect the beach along the coastline because of its residential and recreational functions. The beach of residential area, golf field and school are given more detail analysis as submerged breakwater existed in front of them. Transect ID with respect to the submerged breakwater and gap are as tabulated in Table 4-1.

Table 4-1 Breakwater Structure with respect to transect ID

Breakwater Structure	Area behind SBW	Transect ID
Northern Breakwater	Living quarters	77 – 85
Gap A	Golf course	86 – 92
Middle Breakwater	Golf course + school	93 – 104
Gap B	School	105 – 108
Southern Breakwater	-	109 - 119

The overall shoreline responses of Kerteh is plotted in Figure 4-1.

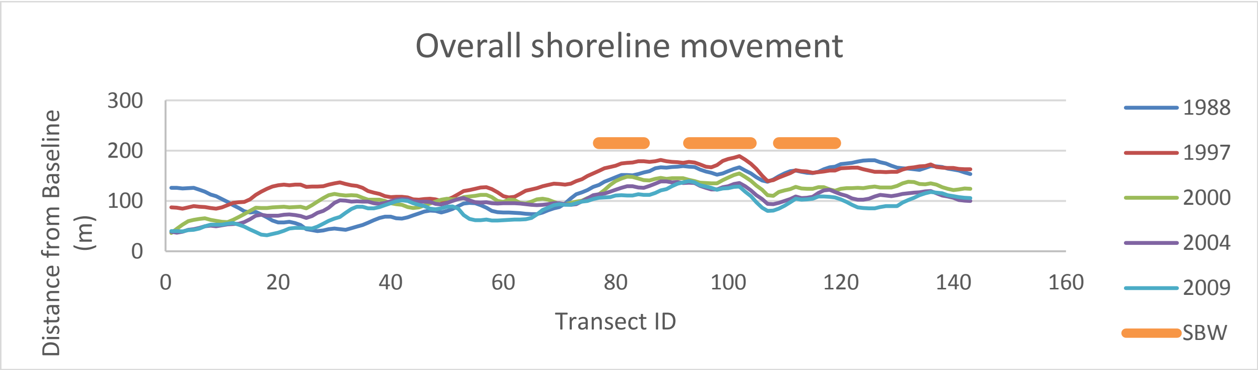


Figure 4-1 Overall shoreline

It is difficult to analyze the movement of shoreline by plotting all the shorelines in one particular graph. Hence, the movement of shoreline is further breakdown and plotted.

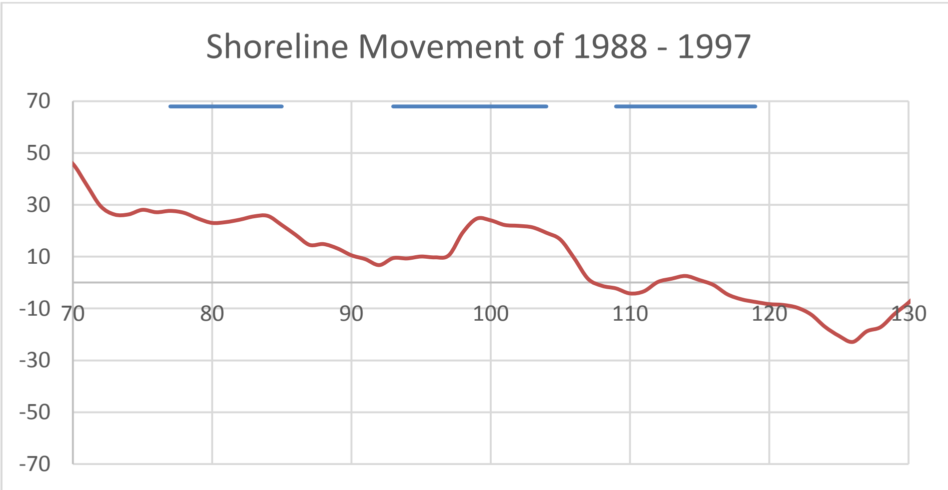


Figure 4-2 Shoreline movement from 1988 – 1997

Majority of the shoreline showed accretion with maximum beach widening of 46 m at the site after the implementation of SBW at Kerteh while a small part of school area showed a minor erosion compare to its accretion. The area of school has an erosion of nearly 10 m.

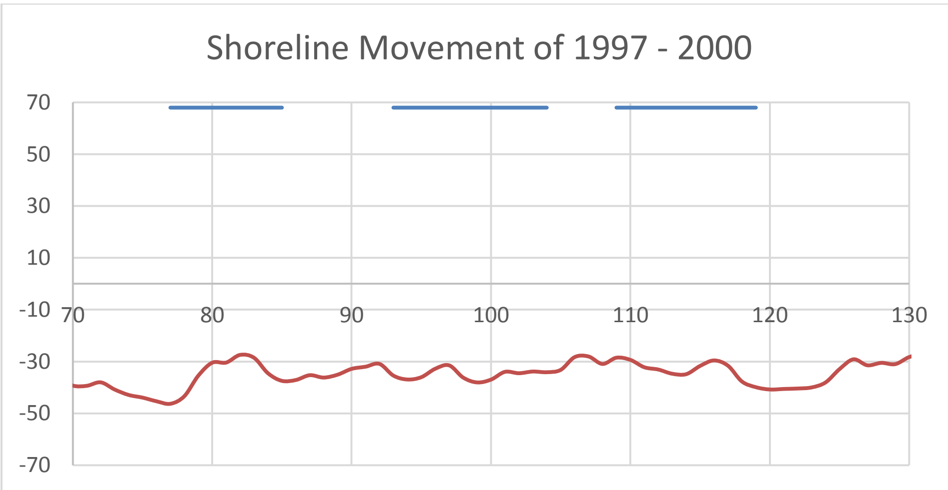


Figure 4-3 Shoreline movement from 1997 – 2000

Controversial to the previous shoreline movement, shoreline of 2000 started to eroded since 1997 within the range from 28 m to 48 m which endanger the coastline of the living quarters, golf course and school. The maximum erosion observed occur right before the living quater at nearly 50 while no accretion is seen at the leeside.

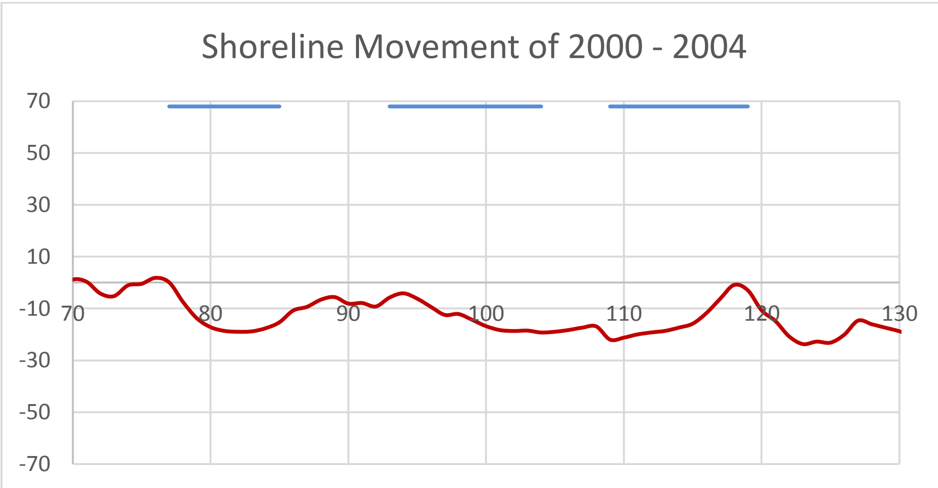


Figure 4-4Shoreline movement from 2000 – 2004

The beach is still under erosion for most section of the beach except beach in front of the living quarter experiencing a minor accretion of 1 – 3 m. The erosion rate is common in front of the golf course and school with an erosion rate of 7 m to 23 m. The highest erosion occur after the school where a magnitude of 25 m is seen.

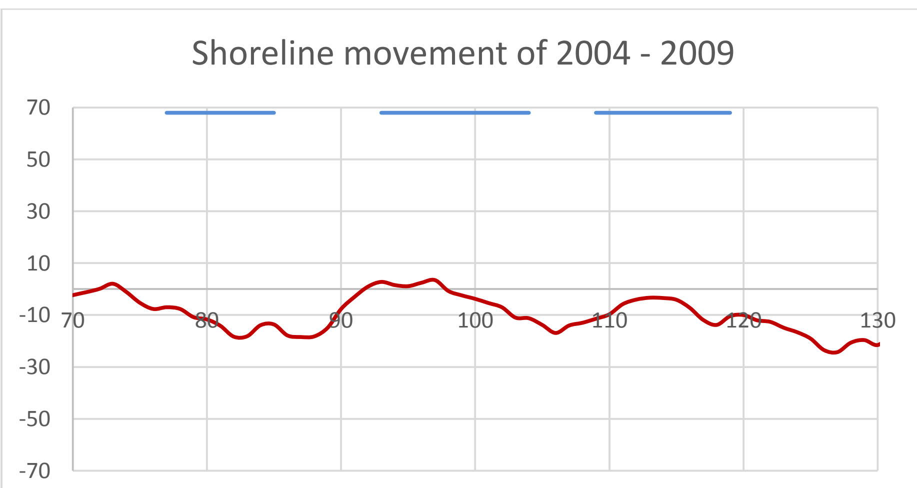


Figure 4-5 Shoreline movement from 2004 -2009

The overall shoreline are experiencing erosion which the erosion rate goes as high as 28 m after the school. Besides, the living quarter is retreating at a rate of roughly 10 m. In contrast to this, shoreline in front of golf course are experiencing accretion of less than 10 m.

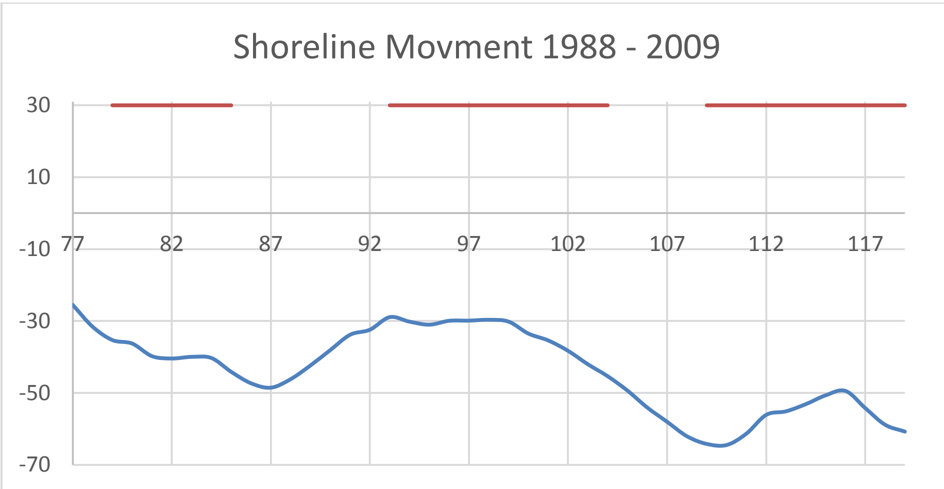


Figure 4-6 Shoreline movement from 1988 – 2009

Earliest and latest shoreline movement are summarized in Figure 4-6 in the place of interest where living quarters, golf course and school are situated. The graph informed an erosion happened across the beach behind the SBW where an erosion range from -25 m to 67 m is observed. The erosion rate are seen to be of lesser magnitude behind the structure while more erosion is seen in between the gaps of the breakwaters.

4.1.2 Niigata, Japan

Shoreline from 1984, 1988, 1997, 2000, 2003 and 2009 are analyzed and plotted in Figure 4-7. These shoreline movement will be breakdown for more detail analysis based on SBW lies within transect.

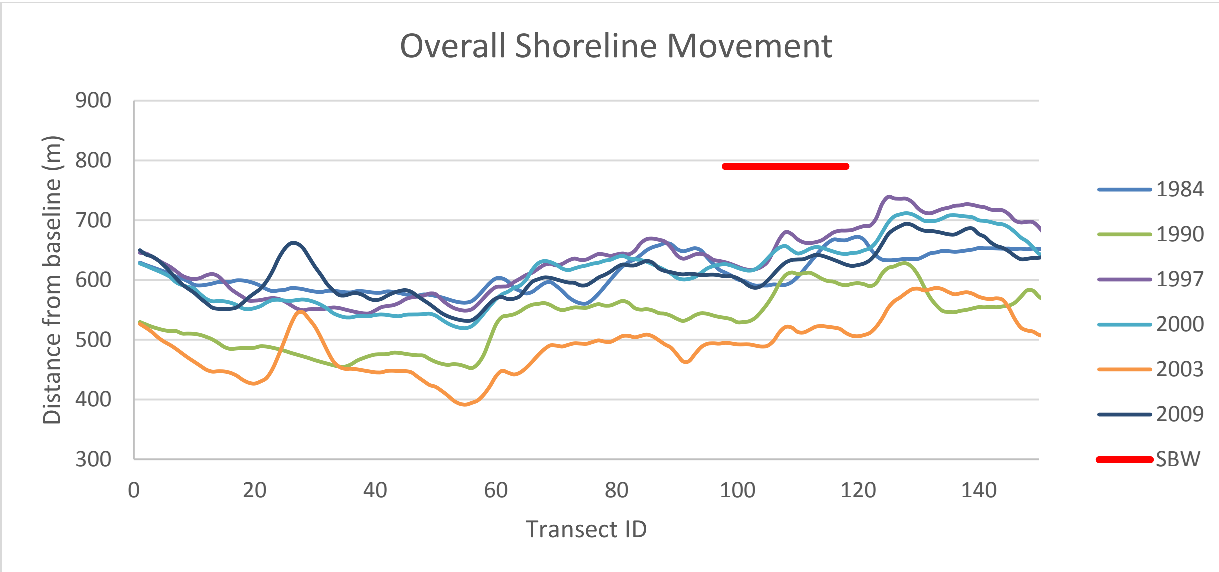


Figure 4-7 Overall shoreline movement

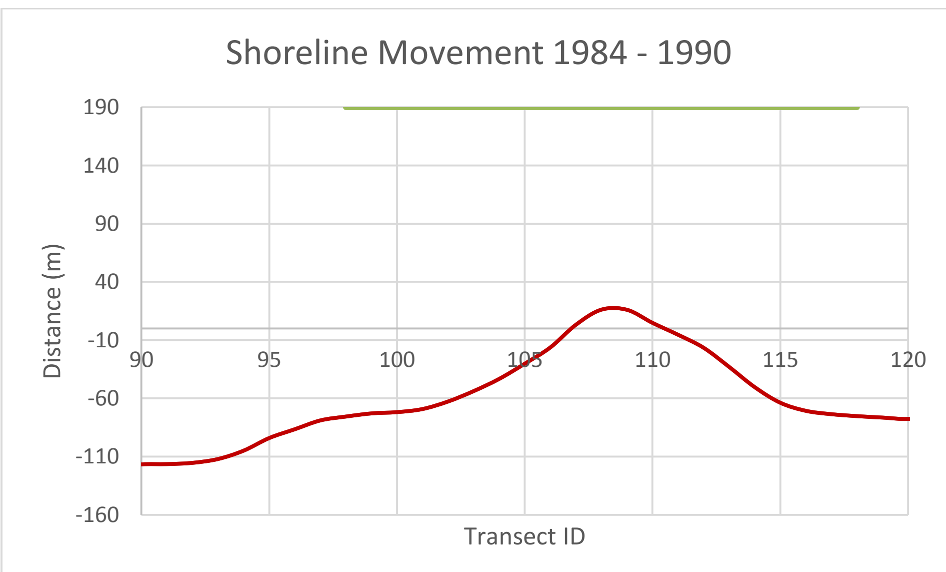


Figure 4-8 Shoreline movement from 1984 – 1990

Shoreline are generally experienced erosion where major part of it are eroding and the highest value reads 115 m while only a 19 m accretion is recorded. This most probably become one of the main reason SBW constructed two years later.

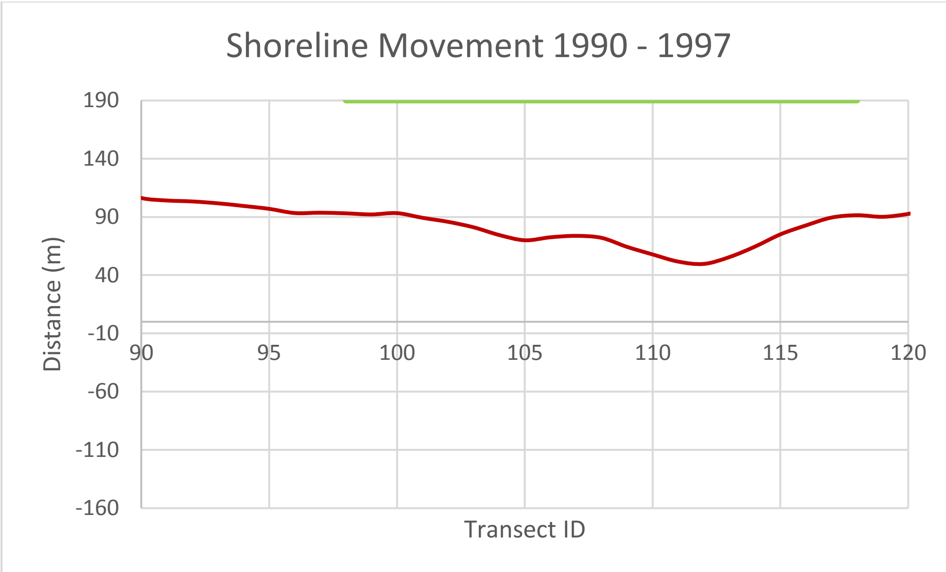


Figure 4-9 Shoreline movement from 1990 – 1997

All section of the shoreline generally experience accretion at a higher rate of erosion happened between 1984 – 1990 where highest erosion rate of nearly 110 m is observed. The accretion magnitude is 40 m and above.

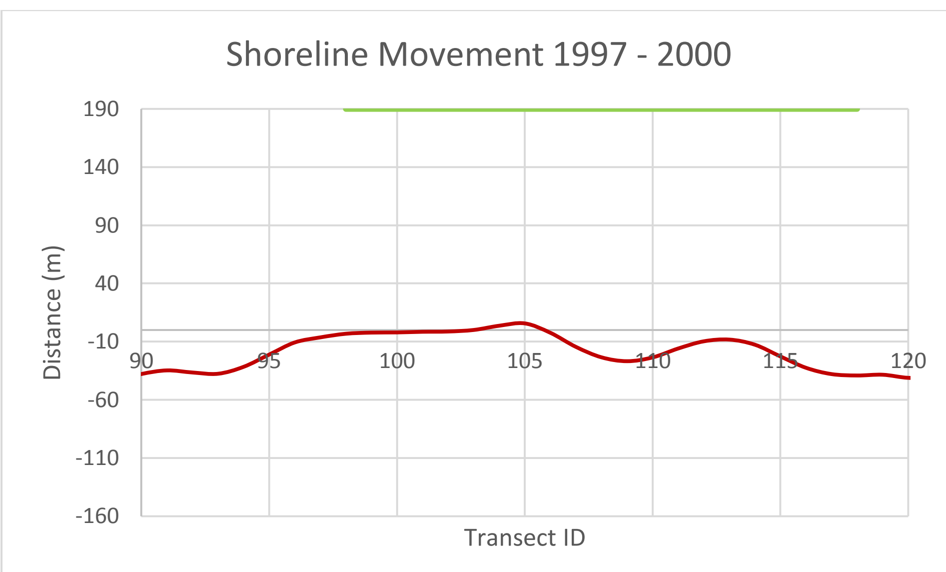


Figure 4-10 Shoreline movement from 1997 – 2000

During 1997 – 2000, generally shoreline experience erosion of highest magnitude at 50 m and a maximum accretion at 18 m. Although erosion is seen at most section of the shoreline, the leeside of the submerged breakwater has lesser erosion compare to other section of the shoreline.

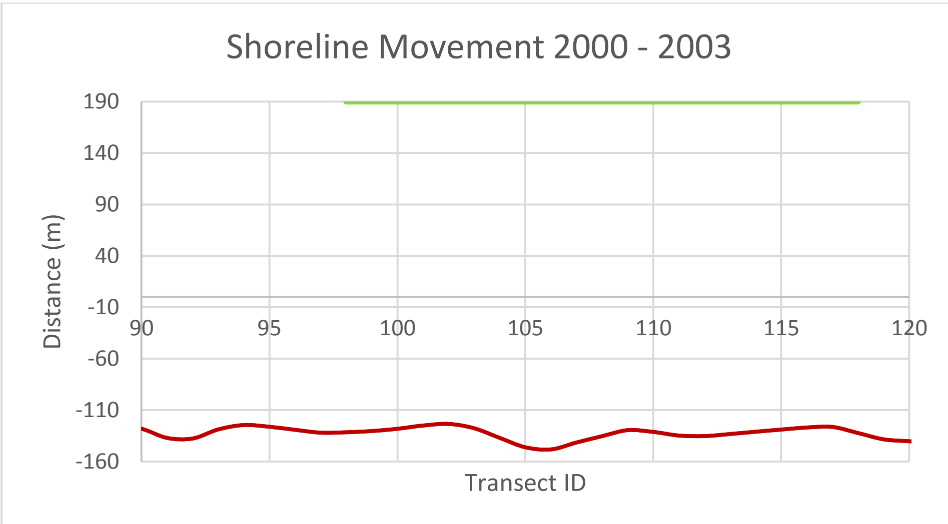


Figure 4-11 Shoreline movement from 2000 – 2003

In the 3 years period, the shoreline retreat at a very high magnitude whereby majority of the shoreline has erosion rate of more than 110 m and and reach almost up to 160 m.

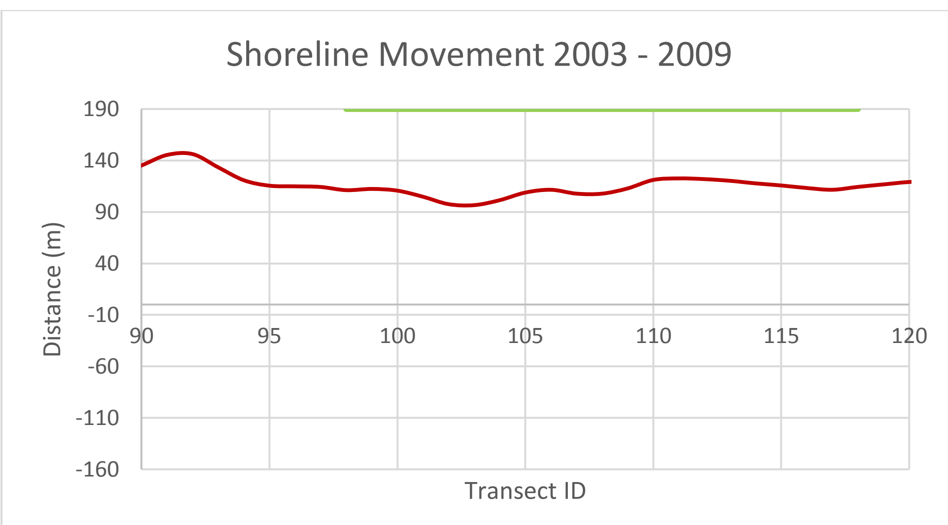


Figure 4-12 Shoreline movement from 2003 – 2009

A major shoreline accretion of more than 90 m is seen at all section of the beach where highest accretion achieve 165 m while the least accretion occur behind SBW has a magnitude of 93 m.

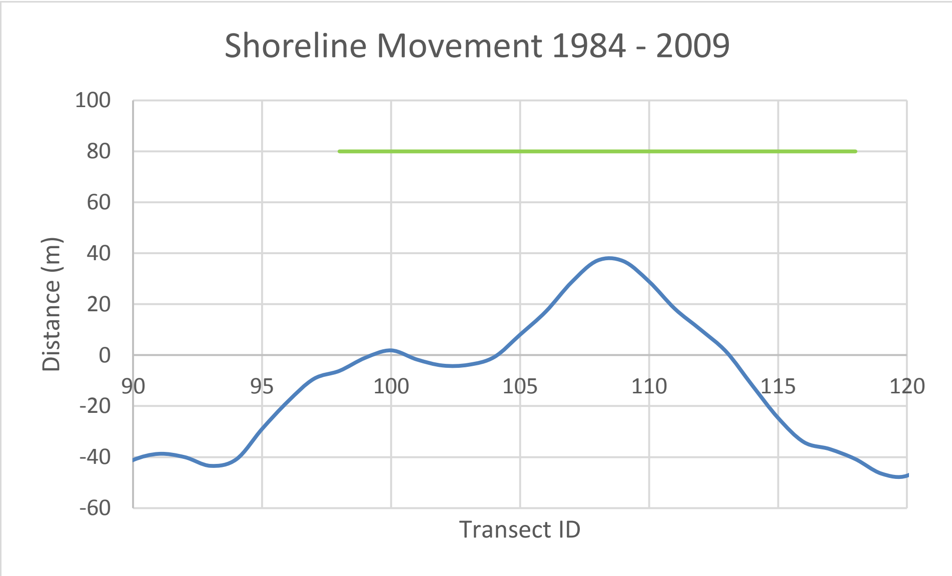


Figure 4-13 Shoreline movement from 1984 – 2009

The net shoreline movement from the earliest to latest shoreline is plotted in Figure 4-13. Shoreline retreat and accretion are both observed whereby most erosion happen outside the SBW while all shoreline accretion happened in the leeside of the submerged breakwater.

4.2 Effectiveness of SBW based on structural geometrical ratio

Submerged breakwater in Kerteh is a detached breakwater scheme with three segments breakwater length of 400 m, 400 m and 200 m with 600 m and 400 m spacing in between. All of them generally have 200 m offshore distance from the shoreline as shown in Figure 4-14.

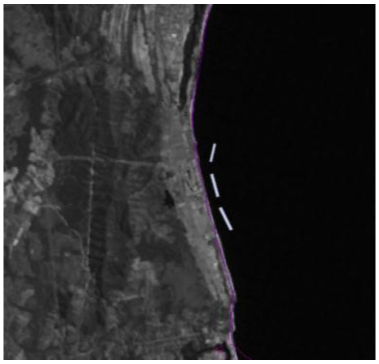


Figure 4-14 Kerteh beach and the location of SBW

The average shoreline movement rate is tabulated in with their breakwater length and offshore distance. On the other hand, SBW of Niigata has a breakwater length of 540 m and placed 400 m offshore parallel to the shoreline as shown in Figure 4-15.

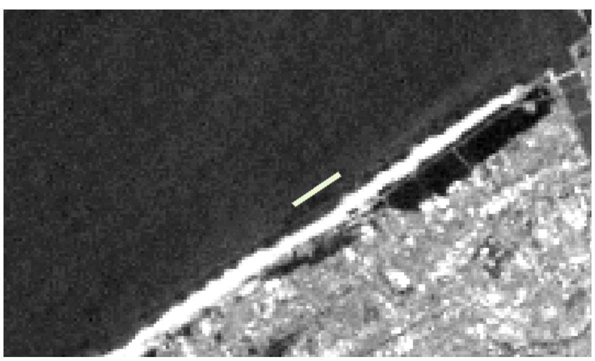


Figure 4-15 Niigata shoreline and location of SBW

Table 4-2 Comparison of erosion rate against structural parameters

Breakwater	Offshore Distance, X (m)	Breakwater Length, L(m)	Crest Width, W (m)	Average Shoreline Movement (m)
Kerteh 1	200	400	30	-37.0
Kerteh 2	200	400	30	-33.7
Kerteh 3	200	200	20	-57.1
Niigata	540	400	20	12.3

The known structural parameters of SBW are plotted against the shoreline movement in the leeside in Figure 4-16 Figure 4-17 and Figure 4-18.

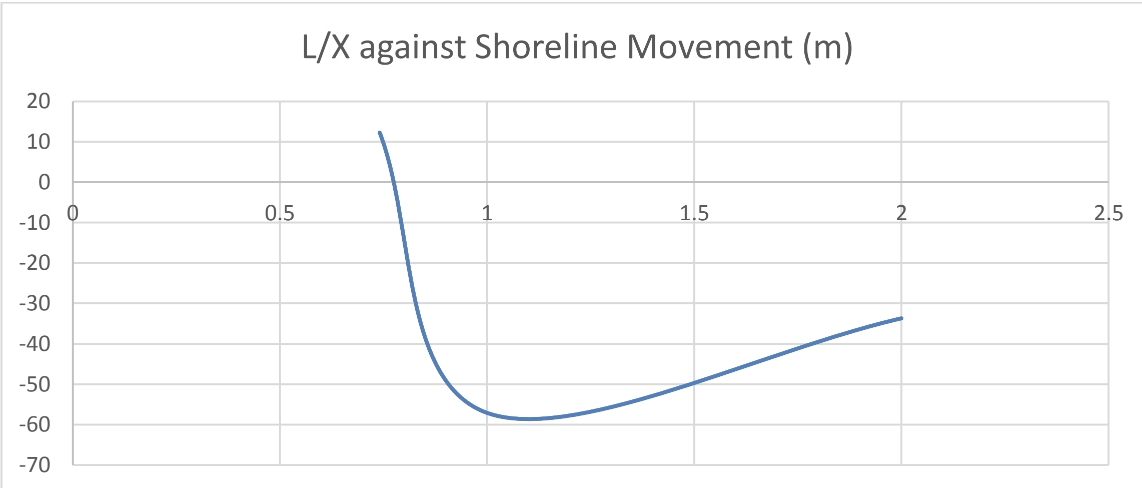


Figure 4-16 L/X against shoreline movement

Comparing its offshore distance and breakwater length against shoreline movement in Figure 4-16, it first showed a downward curve followed by an upward curve whereby if the ratio of length over offshore distance increases, it resulted in accretion in the leeside of the submerged breakwater. The major downward curve is observed as Kerteh 3 has a higher erosion rate in the leeside compare to the other two segments. Pilarczyk (2003) suggested that tombolo and salient are formed within the range of 0.65 – 1.0 for breakwater length over offshore distance which matched the result whereby Kerteh 1 and 2 have L/X of 2, Kerteh 3 has L/X of 1 while Niigata SBW has L/X of 0.74. Therefore, accretion is only seen in Niigata SBW.

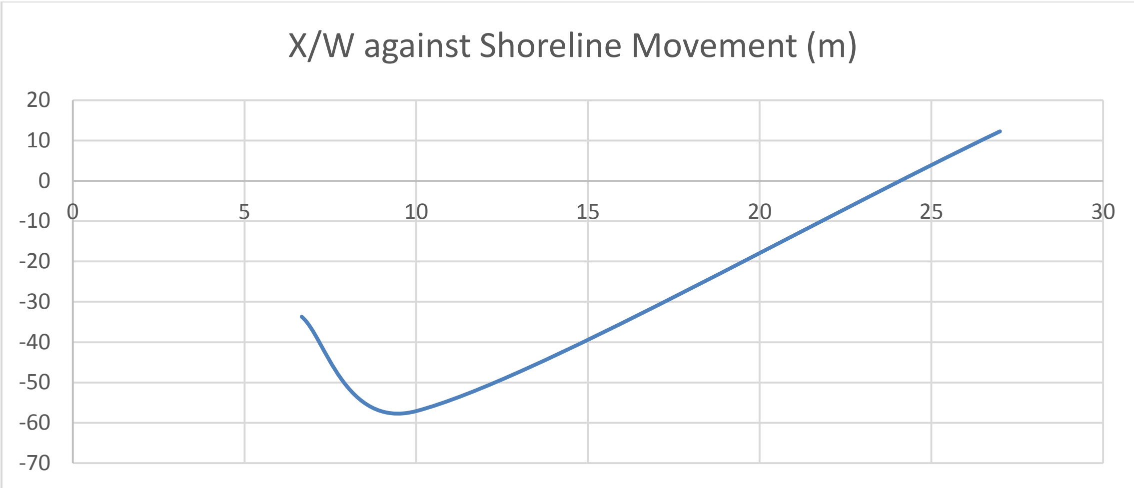


Figure 4-17 X/W against shoreline movement

In Figure 4-17, the shoreline movement is compared against crest width and the offshore distance. The accretion is likely to happen as the X/W ratio getting larger. However, there could be possibility accretion might as well happen when the structure's crest is wide enough whereby the X/W is lower as the beginning of the graph showed an upward trend as the width of crest increases.

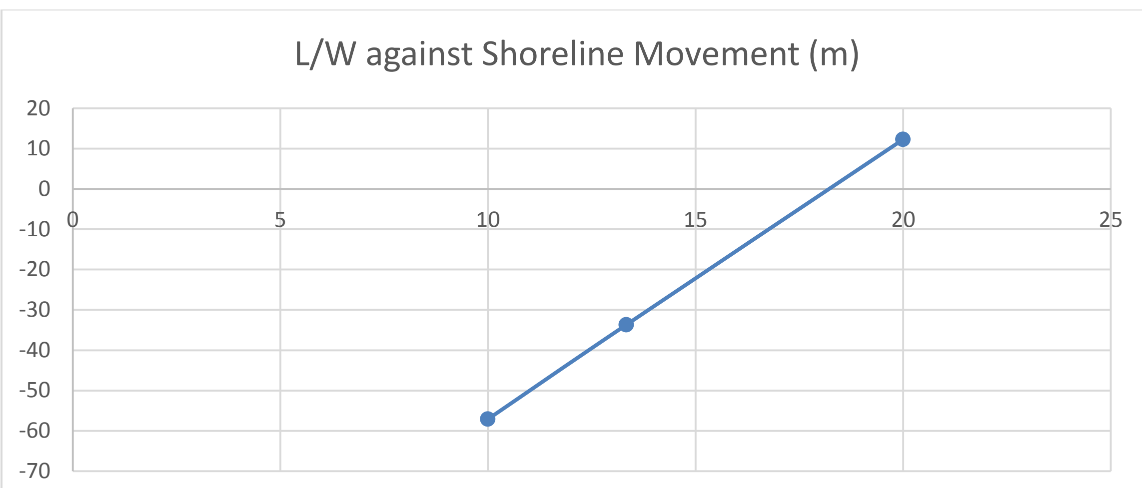


Figure 4-18 L/W against shoreline movement

Meanwhile in Figure 4-18, crest width and breakwater length against shoreline movement showed a straight line indicated that shoreline response is directly proportional to the crest width and breakwater length. As length of breakwater increase at a larger increment than its crest width, shoreline showed an accretion sign whereby salient are formed behind of the SBW. The accretion condition according to structural parameter is as tabulated Table 4-3.

Table 4-3 Condition for accretion according to structural parameter of submerged breakwater

Geometrical Ratio of Structural Parameter	Condition for accretion
L/X	< 0.75
X/W	> 24.5
L/W	>18

CHAPTER 5– CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The shoreline movement is identified at both Kerteh, Malaysia and Niigata, Japan whereby major part of Kerteh beach eroded while Niigata has more accretion site than erosion site. By comparing the shoreline movement of Kerteh from 1988 – 2009 which is the earliest to the latest shoreline, all section of beach between section 77 – 119 protected by submerged breakwater are eroded as time progresses despite some minor accretion happened in between the timeline. On the other hand, submerged breakwater constructed in Niigata has ability in reducing the sediment transport rate in the leeside of the submerged breakwater and an average accretion rate of 12 m is seen behind the submerged breakwater.

Submerged breakwater has a totally different performance in both cases and the differences in shoreline in the leeside of the submerged breakwater is related to the configuration of the structural parameter of the submerged breakwater. To assess that, graph of geometrical ratio of SBW is plotted against the shoreline movement behind them. It is found out that if L/X ratio < 0.75, accretion is observed behind the SBW. The graph of X/W, offshore distance and crest width against shoreline movement show accretion at a geometrical ratio of 24.5 while a directly proportional straight line is observed when L/W, length of breakwater and crest width is plotted against shoreline movement whereby the accretion happened at geometrical ratio of 18.

5.2 Recommendations

This study has come to an end but there are still room for improvement to increase the reliability of the project. First of all, a real site investigation, beach profile survey could be done to conduct a reliability check on accuracy of results obtained from 30 m resolution satellite images. Besides, high resolution satellite images could be purchased to improve the changes of shoreline at the sites and thus attain a better results.

Apart from that, more submerged breakwater with different designs worldwide should be assessed so that the relationship between geometrical ratio of the submerged breakwater and the shoreline responses in the leeside of the breakwater could be well understood.

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