

UNIVERSITY TEKNOLOGI MARA

**A STUDY ON BEACH PROTECTION USING NAHRIM
COASTAL PROTECTION AND EXPANSION (NEXC)
BLOCKS SYSTEM FOR PANTAI BATU 5,
PORT DICKSON, NEGERI SEMBILAN**

NOOR HISHAM BIN AB GHANI

MSc

July 2017

UNIVERSITY TEKNOLOGI MARA

**A STUDY ON BEACH PROTECTION
USING NAHRIM COASTAL
PROTECTION AND EXPANSION
(NEXC) BLOCKS SYSTEM
FOR PANTAI BATU 5,
PORT DICKSON,
NEGERI SEMBILAN**

NOOR HISHAM BIN AB GHANI

Dissertation submitted to in partial fullfilment
of the requirements for the degree of
Master of Science

Faculty of Civil Engineering

July 2017

AUTHOR'S DECLARATION

I declare that the work in this thesis/dissertation was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	:	Noor Hisham Bin Ab Ghani
Student I.D. No.	:	2015657582
Programme	:	Master of Science (Water Resources)
Faculty	:	Civil Engineering
Dissertation Title	:	A Study On Beach Protection Using NAHRIM Coastal Protection And Expansion (NEXC) Blocks System For Pantai Batu 5, Port Dickson, Negeri Sembilan
Signature of Student	:	
Date	:	July 2017

ABSTRACT

Coastal erosion is a natural phenomenon, resulting from the interactions of natural processes, human interventions and Mother Nature systems. Among the negative impact of coastal erosion is like the loss of land, property and human lives. There are two methods to combat the coastal erosion problem, either by using hard engineering approach or soft engineering approach or combination of both. The study was conducted to combine these two approach by introducing NEXC (NAHRIM Coastal Protection and Expansion) Blocks System as a dual function innovation product. The purpose of the study is to examine the performance of NEXC Block System in terms of stability, effectiveness and its ability to function well in reducing coastal erosion as well as naturally re-nourish the sandy beach. This study involves product development and design, laboratory physical modelling, deployment and installation of the products on site at Pantai Batu 5, Port Dickson, Negeri Sembilan which has suffered serious erosion (Category 1). The results show that NEXC Blocks product have promising performance and has the potential of being commercialized. In laboratory testing, the NEXC blocks is proven to be stable, and effective in reducing erosion. However, scouring problem is identified at the toe without affecting the structural integrity. Hence, toe protection for the structure is crucial and should be enhanced. Observation and analysis of the NEXC Blocks System performance onsite found that the blocks function well in controlling erosion and re-nourish the beach through the accretion process. Installation of this product have managed to safeguard the assets of the hotel.

ACKNOWLEDGEMENT

Firstly, I wish to thank God for giving me the opportunity to embark on my MSc and for completing this tough and challenging journey of successful. My gratitude and thanks go to my supervisor Dr. Lee Wei Koon and my research team. Thank you for the support, comments and ideas in assisting me with this project. I also would like to express my gratitude to the staff of the National Hydraulic Research Institute of Malaysia (NAHRIM), especially Ir. Hj. Mohd Radzi Abdul Hamid, Mr. Ahmad Hadi Mohamed Rashidi, Ir. Hj. Mohd Fauzi bin Mohamad and Mr. Mohd Kamarul Huda Samion for providing the facilities, knowledge and assistance.

My appreciation goes to the research team members of Coastal & Oceanography Research Division as well as the crew members of Hydraulic & Instrumentation Laboratory who provided the experimental facilities and assistance during my research activities. Special thanks to my colleagues and friends for helping me with this project.

Finally, this dissertation is dedicated to the loving memory of my very dear mother, wife and family for supporting me with prayer and patience. This piece of victory is dedicated to all of you. Alhamdulillah.

TABLE OF CONTENTS

	Page
AUTHOR'S DECLARATION	i
ABSTRACT	ii
ACKNOWLEDGEMENT	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF SYMBOLS	xvii
LIST OF ABBREVIATION/NOMENCLATURE	xix
CHAPTER ONE: INTRODUCTION	1
1.1 Research Background	1
1.1.1 Coastal Erosion in Malaysia	3
1.1.2 Coastal Protection in Malaysia	7
1.2 Problem Statement	10
1.3 Study Area	11
1.4 Objectives of Study	13
1.5 Scope of Study	13
1.6 Limitation of Study	13
1.7 Significance of Study	14
CHAPTER TWO: LITERATURE REVIEW	15
2.1 Introduction	15
2.2 Causes of Coastal Erosion and Accretion	17
2.2.1 Natural Factor	17
2.2.2 Human Factor	20
2.3 Coastal Erosion and Deposition on Sandy Beaches	24
2.4 General Impact of Coastal Erosion	26
2.4.1 Economic Consequences	28

2.4.2	Demographic Consequences	29
2.5	Coastal Erosion Control Measures (Coastal Defence)	30
2.5.1	Coastal Defence Structures in Malaysia	32
2.5.1.1	Rock Armour Revetments	33
2.5.1.2	Concrete Armour Revetments	35
2.5.1.3	SAUH Revetment	37
2.5.1.4	Groynes/Groins	38
2.5.1.5	Breakwaters	41
2.5.1.6	WABCORE (Wave Breaker and Coral Restorer)	44
2.5.1.7	Labuan Blocks	46
2.5.1.8	Seawalls	50
2.5.1.9	Beach nourishment	51
2.5.1.10	Mangrove Replanting	54
2.5.1.11	Geotextile Tubes	55
2.5.1.12	Beach Dewatering	59
2.6	NEXC Development	63
CHAPTER THREE: METHODOLOGY		64
3.1	Introduction	64
3.2	Product Development and General Design Criteria of NEXC Block	66
3.2.1	Prototype of NEXC Block	68
3.2.2	Final Design Option (Prototype B)	70
3.3	Data Collection and Acquisition	73
3.3.1	Primary Field Data Collection	73
3.3.1.1	Beach Profile Survey	74
3.3.1.2	Water Level	77
3.3.1.3	Sediment Data	78
3.3.2	Secondary Data	79
3.4	Physical modelling	81
3.4.1	Apparatus for Physical Modelling	81
3.4.2	Scaled Down Test Model of NEXC Block	82

3.4.3	Experimental Set-up	84
3.4.4	Product/model test/option or scenario	85
3.4.5	Calibration and Validation	87
3.5	Product Deployment on Site	87
3.5.1	Site Condition	88
3.5.2	Fabrication of Mould's Framework	90
3.5.3	Deployment of the NEXC Blocks System	93
3.6	Periodic Surveillance and Monitoring	99
3.6.1	Periodic Beach Profile Survey	100
3.6.2	Real Time Video Camera Monitoring	102
CHAPTER FOUR: RESULTS AND DISCUSSIONS		104
4.1	Introduction	104
4.2	Imagery Shoreline Change Analysis	104
4.3	NEXC Block Structure Stability Analysis	108
4.4	Physical Modelling Experiment Result and Analysis	111
4.4.1	Result of Scenario 1	112
4.4.2	Result of Scenario 2	121
4.4.3	Result of Scenario 3	128
4.5	Beach Profile Change Monitoring Programme	138
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS		152
5.1	Conclusion	152
5.2	Limitation	153
5.3	Recommendations	154
REFERENCES		156
APPENDICES		162

LIST OF TABLES

Tables	Title	Page
Table 2.1	Some of The Coastal Protection Strategy Approach	31
Table 3.1	Summary of Primary Field Data Collection	72
Table 3.2	The RTK Survey Points Value of The Transect Cross Section 1	74
Table 3.3	Analyzed Data from All Transect Cross Section (CS1 to CS24) to Derived The Average of Beach Gradient	76
Table 3.4	Tide Levels at Port Dickson Water Level Station	78
Table 3.5	The Summary of The Scale Factor For NEXC Block Physical Modelling	82
Table 4.1	Overturning Check on Seablock Structure at Point 0	108
Table 4.2	Sliding Check on NEXC Block Structure at Point 0	109
Table 4.3	The Summary and Option Analysis of Prototype A, B And C of NEXC Block Prototype Product	110
Table 4.4	The Summary of Physical Modelling Experiment and Scenarios Involved	111
Table 4.5	Sediment amount changes in the study site	144

LIST OF FIGURES

Figures	Title	Page
Figure 1.1	Some of the Local News Regarding to the Coastal Erosion Problem	1
Figure 1.2	Overall Length of Malaysian Coastline Including Sabah and Sarawak	3
Figure 1.3	Coastal Sediment along the Peninsular Malaysia Shoreline	4
Figure 1.4	Hard Protection Structures as Coastal Defense Built By DID along the Shoreline in Malaysia for Protection and Mitigation Measures	8
Figure 1.5	Soft Protection Approach also as Known as Eco-Engineering Method for Coastal Protection and Mitigation Measures in Malaysia	9
Figure 1.6	Shore-Connected Breakwaters Caused the Accretion at the Up Drift Side and Also Caused the Local Erosion at the Down Drift Side	9
Figure 1.7	Coastal Erosion Problem Just Behind the Building of Regency Hotel, Tanjung Tuan, Batu 5, Port Dickson	10
Figure 1.8	Location Map for Port Dickson Beaches	12
Figure 1.9	Study Area for Pilot Research Project Lead by Coastal and Oceanography Research Centre, NAHRIM at The Regency Hotel, Tanjung Tuan Beach Resort, Pantai Batu 5, Port Dickson, Negeri Sembilan	12
Figure 2.1	Definition of Coastal Terms	15
Figure 2.2	The Complex Processes of Coastal Erosion and Accretion	17
Figure 2.3	Severe Coastal Erosion Occurred in Teluk Lipat, Dungun, Terengganu Just After the North-East Monsoon due to the Destructive Wave Action.	18
Figure 2.4	The Extension of Runway of Sultan Mahmud Airport in Kuala Terengganu Lead a Serious Coastal Erosion for Adjacent Coastline	21

Figures	Title	Page
Figure 2.5	Coastal erosion at Pantai Tok Jembal and Pantai Kampung Tanjung Gelam Mengabang Telipot, Kuala Terengganu, Terengganu	21
Figure 2.6	The mangrove erosion in Tanjung Piai Wrought by Wave Action Brought on by Increased Shipping Traffic due to the Function of a New International Sea Port Nearby.	23
Figure 2.7	Reduction of Sediment Supply due to Uncontrolled Sand Mining Activity Will Caused Erosion to the Shoreline	23
Figure 2.8	The Differences Between Rough Weather (Monsoon Season) and Calm Weather (Off-Monsoon Season) on Beaches.	25
Figure 2.9	Cross-Section of a Sandy Beach Showing the Significant Difference in the Volume of Sediment Eroded in High-Magnitude Storms (1:100 Year) Compared to Seasonal Erosional Events	26
Figure 2.10	Some Example of Damaging Coastal Earth Bunds in Agricultural Area Caused by Wave Attack	27
Figure 2.11	Alternatives for Coastal Protection Strategy	32
Figure 2.12	Typical Cross-Section of Quarry Stone Revetment	33
Figure 2.13	Basalton Revetment in Melaka and Quarry Stone Revetment in Kedah	34
Figure 2.14	Four Types of Armor Units That Usually Used as Concrete Revetment	36
Figure 2.15	The Failure Condition of Interlocking Flex-Slab Revetment after Being Hit by Big Waves at Pantai Teluk Lipat, Dungun, Terengganu	37
Figure 2.16	SAUH Revetment That Was Constructed in Selangor Coastline	37
Figure 2.17	Various Types of Groynes Materials	38
Figure 2.18	Typical Design of Rubble Mound Groyne	39
Figure 2.19	Schematic Diagram of the Groyne's Function	40
Figure 2.20	Groyne Field at Tak Bai, Thailand	40
Figure 2.21	Typical Cross Section of Emerged Rubble Mound Breakwaters	41
Figure 2.22	Breakwaters at Sungai Marang River Mouth, Terengganu	42
Figure 2.23	Offshore Breakwater at Kerteh, Terengganu	43
Figure 2.24	Deposition of Sediment in front of Merang Breakwaters and Jetty	44

Figures	Title	Page
Figure 2.25	Submerged 3-layered WABCORE Breakwater and Artificial Reef With Narrow Hat Arrangement at Panuba Bay, Tioman Island, Pahang	45
Figure 2.26	First Generation Labuan Blocks as Vertical Cubic Blocks at Pancur Hitam, Wilayah Persekutuan Labuan	46
Figure 2.27	Second Generation of Labuan Blocks as Sloping “Mattresses” at Taman Robina, Seberang Perai Utara, Pulau Pinang	46
Figure 2.28	Drawing of Labuan Block Arrangement	47
Figure 2.29	Initial Beach Condition in Year 2000 and Stabilized Beach Condition in Year 2005 after Placement of Labuan Blocks as a Coastal Protection Control Measures at Kiamsam Beach, Wilayah Persekutuan Labuan	49
Figure 2.30	Example of Typical Section of Seawall	49
Figure 2.31	Seawall with Run-Up Deflector Made to Blend as Part of the Landscape at Gurney Drive, Penang	50
Figure 2.32	Beach Nourishment Project in Port Dickson. Left Figure is the View of Shoreline before the Project Started while the Right Figure Shown That the View of the New Beach Formed Just After the Project Completed	52
Figure 2.33	Example of Mangrove Replanting View in Malaysia	54
Figure 2.34	Geotube at Tanjung Piai, Pontian, Johor	55
Figure 2.35	Sand Bags at Pantai Penggorak, Kuantan	56
Figure 2.36	Typical Cross Section of Sand Bag’s Placement and Arrangement	57
Figure 2.37	Schematic Diagram of Beach Management System (BMS)	59
Figure 2.38	Schematic diagram of Pressure Equalization Modules (PEM) and Placement of Vertical Pipes Buried (50 to 100m at 10m interval)	60
Figure 2.39	Design of Pressure Equalisation Module Pipes	61
Figure 2.40	The Holes of NEXC Block Allow the Movement of the Sediment to the Rear of the Structure	63

Figures	Title	Page
Figure 3.1	NAHRIM Coastal Protection and Expansion (NEXC) Blocks	64
Figure 3.2	Flow Process for Overall Research's Activities	65
Figure 3.3	NEXC Block System at Pantai Batu 5, Port Dickson	66
Figure 3.4	The Holes on the NEXC Block Unit	68
Figure 3.5	Side View and Front View of the 30° NEXC Block Unit or Prototype A	69
Figure 3.6	Side View and Front View of the 45° NEXC Block Unit or Prototype B	69
Figure 3.7	Side View and Front View of the 60° NEXC Block Unit or Prototype C	70
Figure 3.8	Side View and Front View of the 45° NEXC Block Unit (Prototype B) as the final design option	70
Figure 3.9	The Arrow Shows Slotted (Male Connector) and Grooved (Female Connector) Interlocking Designed for NEXC Blocks System	72
Figure 3.10	Beach Profiling Survey by Using RTK Method and Instrumentation The RTK Device : Trimble R6 (High Resolution) GPS Receiver	74
Figure 3.11	Transect Line of Beach Profiling Survey at Study Site, Pantai Batu 5, Port Dickson, Negeri Sembilan	75
Figure 3.12	Plotted Graph of Transect Cross Section 1 (CS 1) of Beach Profiling on Test Site	76
Figure 3.13	The Sample Result and Graph of Sieve Analysis in Test Site, Pantai Batu 5 Port Dickson	78
Figure 3.14	Tidal Levels Plot for Port Dickson Water Level Station	80
Figure 3.15	The View of Flume 2D Basin Inside the MHI	82
Figure 3.16	Scaled Down Model Sample of NEXC Block	82
Figure 3.17	Flume Set-up for Physical Modelling Experiment	84
Figure 3.18	The View of Completed Experimental Design Set-Up in 2D Flume Basin	85
Figure 3.19	Physical Model Testing Flow Chart	86

Figures	Title	Page
Figure 3.20	The Key Map, the Location of Test Site and Google Earth Satellite View for the Development of NEXC Block Product at Pantai Batu 5, Port Dickson, Negeri Sembilan	88
Figure 3.21	The Test Site Location at Pantai Batu 5, Port Dickson (Backside of The Regency Beach Resort)	89
Figure 3.22	The Placement of Sandbags System to Prevent Erosion on The Beach	89
Figure 3.23	Flow Chart of Fabrication Process of NEXC Block	90
Figure 3.24	The Fabrication of Mould's Framework for NEXC Block	91
Figure 3.25	Some of the Installation Works of Mainframe Mould's Structure of NEXC Block at Site	91
Figure 3.26	Concrete Casting Works at Site	92
Figure 3.27	Two Types of Concrete Testing was Conducted during Concrete Casting Works for Quality Control of the NEXC Blocks	92
Figure 3.28	Final Touch-up of NEXC Block Surface	92
Figure 3.29	The Deployment Flow Process of NEXC Blocks System at the Test site	93
Figure 3.30	Tidal Level Analysis for Determination of Specific Locations of NEXC Blocks System Installation	94
Figure 3.31	Side View of NEXC Block System, the Installation Arrangement on Site	94
Figure 3.32	Excavation and Levelling Works at Test Site	95
Figure 3.33	Geotextiles Applications and Foundation Works on Site	96
Figure 3.34	Transportation and Handling of NEXC Blocks to Construction Sites	97
Figure 3.35	Site Preparation and Clearing for the Construction Project of NEXC Blocks System	97
Figure 3.36	Lifting of NEXC Block on Site by Using Safety Cable	97
Figure 3.37	The Deployment of the NEXC Blocks System on Test Site	98
Figure 3.38	Armour Rock is Stacked Nicely to Form a Layer of Mini Revetment System for the NEXC Blocks Structure	98

Figures	Title	Page
Figure 3.39	Straight Fine Tune Alignment of NEXC Blocks Structure on Test Site	98
Figure 3.40	The View on the test Project Site after the Completion of Site Finishing Works	99
Figure 3.41	Severe Erosion Occurred at the end of the Chainage 108m of NEXC Blocks System and Afterwards after the Southwest Monsoon Season	100
Figure 3.42	Survey Works with RTK Method and Instrumentation during the Monitoring Programme	101
Figure 3.43	Transect Line of Beach Profiling Survey	101
Figure 3.44	The location of the CCTV On-site Installation for Online Monitoring Program	102
Figure 4.1	Satellite Image of the Test Site Dated on 20 August 2003	105
Figure 4.2	Satellite Image of the Test Site Dated on 4 October 2009	105
Figure 4.3	Satellite Image of the Test Site Dated on 27 November 2010	106
Figure 4.4	Satellite Image of the Test Site Dated on 17 June 2014	106
Figure 4.5	Satellite Image of the Test Site Dated on 5 August 2015	107
Figure 4.6	Satellite Image of the Test Site Dated on 24 January 2016. The Small Picture in the Red Box Also Shows the Site That Already Deployed with NEXC Blocks System	107
Figure 4.7	Diagram of Wave Force on NEXC Block Structure	108
Figure 4.8	Sliding Along the Base	110
Figure 4.9	The Initial Condition of the Model Setup at the Beginning of the Experiment for Scenario 1 Of 1	112
Figure 4.10	The Condition of the Test Model in the 2D Flume after the Experiment for Scenario 1 Of 1	113
Figure 4.11	Side View & Plan View of the Survey Alignment Position and References Coordinates in the Flume	113
Figure 4.12	The 3D Graph of Beach Profile Measurements in 2D Flume for Scenario 1 of 1	114

Figures	Title	Page
Figure 4.13	Result of Scenario 1 of 1	115
Figure 4.14	Testing Condition of Scenario 1 of 2	115
Figure 4.15	Result of Scenario 1 of 2	116
Figure 4.16	Comparison Graph of the Result of Both Scenario 1 of 1 and Scenario 1 of 2.	117
Figure 4.17	Testing Condition of Scenario 1 of 3	117
Figure 4.18	Testing Condition of Scenario 1 of 4	118
Figure 4.19	Result of Scenario 1 of 3 (green line) and Scenario 1 of 4 (red line)	118
Figure 4.20	Testing Condition of Scenario 1 of 5	119
Figure 4.21	Testing Condition of Scenario 1 of 6	120
Figure 4.22	Result of Scenario 1 of 5 (green line) and Scenario 1 of 6 (red line)	120
Figure 4.23	Testing Condition of Scenario 2 of 1	122
Figure 4.24	Result of Scenario 2 of 1	122
Figure 4.25	Testing Condition of Scenario 2 of 2	123
Figure 4.26	Result of Scenario 2 of 2	124
Figure 4.27	Testing Condition of Scenario 2 of 3	124
Figure 4.28	Testing Condition of Scenario 2 of 4	125
Figure 4.29	Result of Scenario 2 of 3 (green lines) and Scenario 2 of 4 (red lines)	126
Figure 4.30	Testing Condition of Scenario 2 of 5	126
Figure 4.31	Testing Condition of Scenario 2 of 6	127
Figure 4.32	Result of Scenario 2 of 5 (green lines) and Scenario 2 of 6 (red lines)	128
Figure 4.33	Testing Condition of Scenario 3 of 1	129
Figure 4.34	Comparison Results between Scenario 3 of 1 and Scenario 2 of 1	129
Figure 4.35	Testing Condition of Scenario 3 of 2	130
Figure 4.36	Comparison Results between Scenario 3 of 2 and Scenario 2 of 2	131
Figure 4.37	Testing Condition of Scenario 3 of 3	131
Figure 4.38	Comparison Results between Scenario 3 of 3 and Scenario 2 of 3	132
Figure 4.39	Testing Condition of Scenario 3 of 4	133

Figures	Title	Page
Figure 4.40	Comparison Results between Scenario 3 of 4 and Scenario 2 of 4	134
Figure 4.41	Testing Condition of Scenario 3 of 5	134
Figure 4.42	Comparison Results between Scenario 3 of 5 and Scenario 2 of 5	135
Figure 4.43	Testing Condition of Scenario 3 of 6	136
Figure 4.44	Comparison Results between Scenario 3 of 6 and Scenario 2 of 6	137
Figure 4.45	Transect Lines for Survey Works with 10m Interval for Every Cross Section	138
Figure 4.46	Beach Profile for Cross-Section 1 (CS1) at Chainage 0	138
Figure 4.47	Beach Profile for Cross-Section 2 (CS2) at Chainage 10	139
Figure 4.48	Beach Profile for Cross-Section 3 (CS3) at Chainage 20	139
Figure 4.49	Beach Profile for Cross-Section 4 (CS4) at Chainage 30	139
Figure 4.50	Beach Profile for Cross-Section 5 (CS5) at Chainage 40	140
Figure 4.51	Beach Profile for Cross-Section 6 (CS6) at Chainage 50	140
Figure 4.52	Beach Profile for Cross-Section 7 (CS7) at Chainage 60	140
Figure 4.53	Beach Profile for Cross-Section 8 (CS8) at Chainage 70	141
Figure 4.54	Beach Profile for Cross-Section 9 (CS9) at Chainage 80	141
Figure 4.55	Beach Profile for Cross-Section 10 (CS10) at Chainage 90	141
Figure 4.56	Beach Profile for Cross-Section 11 (CS11) at Chainage 100	142
Figure 4.57	Beach Profile for Cross-Section 12 (CS12) at Chainage 110	142
Figure 4.58	Beach Profile for Cross-Section 13 (CS13) at Chainage 120	142
Figure 4.59	Beach Profile for Cross-Section 14 (CS14) at Chainage 130	143
Figure 4.60	Beach Profile for Cross-Section 15 (CS15) at Chainage 140	143
Figure 4.61	Wave Simulation Study for Port Dickson	145
Figure 4.62	Mean Velocities for the Inter-monsoon and NE and SW Monsoon Conditions at Tg. Tuan Area	146
Figure 4.63	Test site on 27 May 2015, First Site Visit and before Product Deployment	148
Figure 4.64	Test Site on 6 November 2015, Post Construction	149

Figures	Title	Page
Figure 4.65	Test Site on 21 November 2015, Additional Scour Protection at Toe	149
Figure 4.66	Test Site on 20 July 2016, Erosion Problem Occurred at the End of the Product Alignment	150
Figure 4.67	Test Site on 14 October 2016, a few Blocks of the Product Collapsed Due To Scouring of Old Piping Structure Underneath. Severe Erosion Problem Occurred at the End of the Product Alignment and Afterwards	150

LIST OF SYMBOLS

Symbols

B	Bottom length of structure
c	Cohesion of soil
d_{50}	Average particle size of beach material (sand)
d_s or h	Depth of sea water
δ	Angle of friction between the soil and base slab
e or Θ	Structure face slope angle
Σ	Sum
FOS	Factor of safety
h_c	Wave height
H_s	Maximum wave height
k	The coefficient value (range between 1/3 to 2/3)
L_r	Geometric scale
m	Beach slope
M	Model
M	Moment
M_0	Overturning moment about toe
M_R	Resisting moment about toe
N	Refractive index
$^\circ$	Degree of angle
$\emptyset$	Angle of friction
P	Prototype
$P1\&P2$	The wave pressure on the NEXC Block structure
$P4$	The uplift pressure due to hydrostatic force
R	Resistance force
RH	The horizontal resisting forces
RV	The vertical resisting forces

Symbols

T	Wave period
γ	Unit weight of soil
λ	Scale ratio in physical modelling

LIST OF ABBREVIATIONS / NOMENCLATURE

Abbreviations

1D/1-D	One dimensional
2D/2-D	Two dimensional
3D/3-D	Three dimensional
AR4	Fourth Assessment Report
BEM	Board of Engineers Malaysia
BM	Bench Mark
BMS	Beach Management System
CCTV	Closed-circuit Television
CD	Chart Datum
Ch	Chainage
CS	Cross Section
COSMO	National Seminar on Coastal Morphology
DID	Department of Drainage and Irrigation
DTGSM	Geodetic Vertical Datum of Peninsular Malaysia
EPU	Economy Planning Unit
ERP	Eco-friendly Raft Pile
FAO	Food and Agricultural Organization U.S.
FHWA	Federal Highway Administration U.S.
FKA	Fakulti Kejuruteraan Awam
FOS	Factor of Safety
GPS	Global Positioning System
HAT	Highest Astronomical Tide
ICZM	Integrated Coastal Zone Management
ISMP	Integrated Shoreline Management Plan
IPCC	Intergovernmental Panel on Climate Change
JPM	Jabatan Perdana Menteri
JPS	Jabatan Pengairan Dan Saliran

Abbreviations

JUPEM	Jabatan Ukur dan Pemetaan Malaysia
KLIA	Kuala Lumpur International Airport
LAT	Lowest Astronomical Tide
MHHW	Mean High High Water
MHI	Makmal Hidraulik dan Instrumentasi
MHW	Mean High Water
MHWL	Mean High Water Line
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLW	Mean Low Water
MLLW	Mean Low Low Water
MLWL	Mean Low Water Line
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MPPD	Majlis Perbandaran Port Dickson
MSL	Mean Sea Level
NAHRIM	National Hydraulic Research Institute of Malaysia
NCES	National Coastal Erosion Study
NE	North East
NEXC	NAHRIM Coastal Protection and Expansion
NHRI	Nanjing Hydraulics Research Institute
NRE	Natural Resource and Environment
PEM	Pressure Equalisation Module
PHN	Pusat Hidrografi Nasional
PKPO	Pusat Kajian Pantai dan Oseanografi
PVC	Polyvinyl Chloride
R,D&C	Research, Development and Commercialization
RTK	Real-Time Kinematic
SAUH	Simplified Armor Unit ‘H’
SNH	Scottish Natural Heritage

Abbreviations

SW	South West
TBM	Temporary Bench Mark
UN	United Nation
USACE	US Army Corps of Engineers
U.S.	United States
UTM	Universiti Teknologi Malaysia
UV	Ultraviolet
WABCORE	Wave Breaker and Coral Restorer
WL	Water Level

CHAPTER 1

INTRODUCTION

1.1. RESEARCH BACKGROUND

Coastal cities or towns located all around the world are in high risk of having a natural disaster comes from the ocean like tsunami, coastal flooding and are vulnerable to coastal erosion problem. Coastal erosion is a natural phenomenon, resulting from the interactions of natural processes and systems. Man's actions sometimes interfere with these processes and systems and alter erosion and accretion patterns. Coastal erosion is a major threat to all structures built near the coastal area which must be protected to prevent the destruction of life and property. Examples of coastal erosion report all over the country are as shown in Figure 1.1.

Samples of newspaper cutting on coastal erosion problem



Figure 1.1 : Some of the local news regarding to the coastal erosion problem

According to the Manual of Department of Drainage and Irrigation (DID), Malaysia (also known as DID Manual) Volume 3 on Coastal Management, it was state that coastal erosion refers to the eroded part of the shorelines that normally occur in the beach profile. The sign of erosion can be seen by scouring in the foot of the cliffs, dunes or at the escarpment. Coastal erosion always occur during the events of strong winds, high waves, high tides and storm surge conditions, normally during monsoon period.

The rate of erosion is can be expressed in $\text{m}^3/\text{m}/\text{year}$, but erosion rate is widely used synonymously with coastline retreat, and thus expressed in m/year . Coastal erosion usually occur when the monsoon winds which generate large waves hit the coastal areas that are exposed to this phenomenon. In Malaysia, during South West Monsoon normally starting from the end of May to September, coastlines along the Malacca Straits experiences coastal erosion. During North East Monsoon starting from November to March, the east coast coastlines along the South China Sea will experience similar erosion.

There are several factors that causes coastal erosion. The biggest factor affecting coastal erosion rate is the strength of the waves breaking along the coastline (Jackson, 2011). Jackson in explaining the factors affecting the rate of erosion states that is dominantly controlled by the wave action. The strength of ocean waves is dependent on the fetch distance and the wind speed. Longer fetches and stronger winds will generate larger and stronger waves that have more erosive power. This condition will definitely causing severe erosion. When the waves approaching the shore, its strength decreases due to frictional resistance of the increasing of seabed surface. This underwater elevation also called bathymetry actually will impacts the strength of waves. Flat beaches and coral reefs are naturally reduce wave's erosive power by increase the distance a wave travels before it reaches the coastline's and dissipate the wave energy through the corals structures. Headlands refract waves around them and reducing their erosive power at one location while increasing it at another. Weathering also plays a role in the rate of erosion by creating weaknesses in rocks that are exploited by the processes of erosion. Freeze-thaw weathering, for example, creates cracks in rocks, increasing the rock's susceptibility to hydraulic action (Jackson, 2011). Apart from that, human intervention is also a contributing factor to the coastal erosion problem. Human activities have a variety of complex effects on coastal erosion but most commonly the activities increase the strength of waves (Jackson, 2011). Coastal defence structures or beach nourishment project sometimes give a direct impact to the adjacent coastline especially disturbing the sediment transport activity to that particular area. Dredging activity is commonly carried out to improve shipping capacities but it reduces the amount of energy dissipated from incoming waves and so increases erosion (Jackson, 2011).

Another factor of coastal erosion is sea level rise phenomenon due to global warming. The earth temperature has been increasing and this warmer condition causes the melting of polar ice and glaciers. Sea level rise is a global effect. Which causes increased mean sea level, greater risk of storm surge, inundation, coastal flooding and wave damage to coastlines. Current predicted changes in sea level estimate a rise of up to 0.6 m by the year of 2100 (IPCC, 2007). Higher sea levels will raise extreme water levels, allowing waves to break nearer to the coast and transmit more wave energy to the shoreline. This will promote erosion and coastal retreat at sediment starved locations. Sea-level rise is therefore likely to cause an inland migration of beaches and the loss of up to 20% of coastal wetlands (IPCC, 2007).

1.1.1 Coastal Erosion in Malaysia

Coastal zones are particularly vulnerable to coastal erosion and dynamic changes due to wave action. In Malaysia, there are about 4,809 kilometres (km) coastlines including Sabah and Sarawak (DID, 2009). Figure 1.2 shows the coast line of Malaysia. The total length for Peninsular of Malaysia is about 2031 km, coastal length of Sabah State is 1743 km and coastal length of Sarawak State is 1035 km.

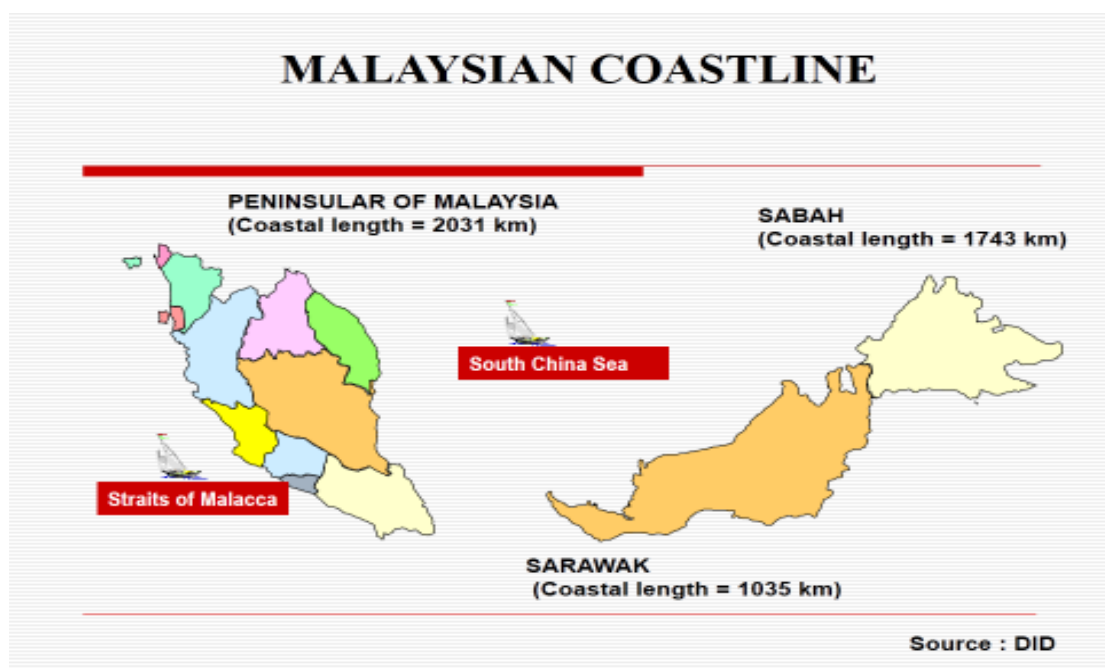


Figure 1.2 : Overall length of Malaysian coastline including Sabah and Sarawak (source : DID, 2009)

Realising the increasing threat of coastal erosion to the coastal population and loss of properties along the coastlines, Malaysian Government through Economy Planning Unit (EPU) and Department of Irrigation and Drainage (DID) has carried out the National Coastal Erosion Study (NCES) from November 1984 to January 1986 to look into the details on this particular issue. The study results indicate that out of the country's coastline, about 29% or 1,380 km was facing erosion. Most erosion in Malaysia occurs quite independently of man (EPU, 1985). By far the most important factors of coastal erosion in Malaysia are storm waves and long shore sediment transport. Structures that interrupt sediment transport or concentrate wave energy are the major man-induced causes of erosion.

As the wind waves near the shore travel through increasingly shallow water, they steepen and increase in height. When the water depth is about 1.3 times the wave height, the wave becomes unstable and collapses or breaks. Because the incoming waves are in a variety of sizes, they break in various depths and the band of breaking waves, known as the surf zone, changes width as the wave height range changes. During storms, the surf zone along the South China Sea Coast can be several hundred meters wide. The surf zone is a violent arena. Breaking waves dissipate their energy in turbulence, by generating intense local currents, and in a final uprush on the beach or shore. The turbulence lifts sediments off the sea bottom and the local currents transport them. Similarly, the uprush mobilizes sediments from the beach and the backrush transports them back into the surf zone. Figure 1.3 shows the types of coastal sediment in Peninsular Malaysia consist of mud, sand and stone.

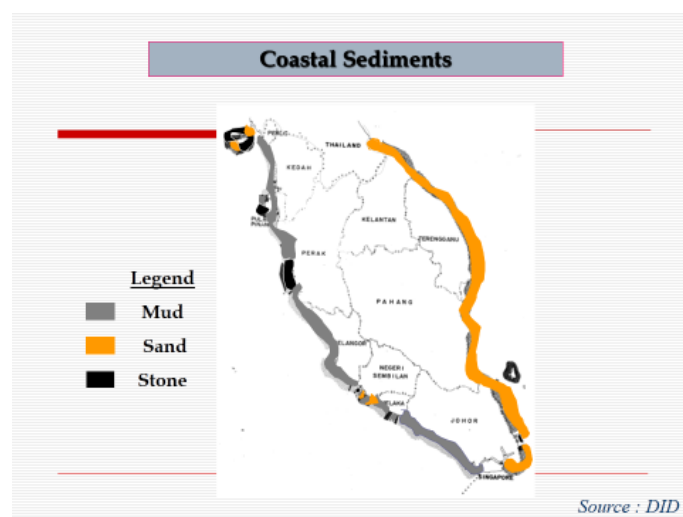


Figure 1.3 : Coastal sediment along the Peninsular Malaysia Shoreline
(source : DID)

When breaking waves approach the shoreline at an angle other than 90 degrees with the shoreline, a component of the wave energy is directed parallel to the shoreline and the generated current is similarly directed. This long shore current causes sediments lifted by the breaking waves to move along the shore, a process called long shore sediment transport. The backrush current normal to the shore also transports sediments. As the backrush loses velocity, the sediments are deposited a short distance from the shore and often form a bar which eventually grows large enough to cause the larger incoming waves to break on it. These breaking waves mobilize sediments from the bar making them available for transport alongshore and toward shore. Sediment is almost always in motion in the surf zone. Some sediments are transported along the shore (long shore transport) and some are transported normal to the shore (onshore - offshore transport).

This movement of sediments in near shore water under the influence of waves and currents, both in an onshore-offshore manner and along the shore, is called littoral transport. In most coastal areas in Malaysia, long shore transport is the more important activity. Long shore transport is in the direction of the wave-induced long shore current which is determined by breaking wave direction. During the northeast monsoon, the breaking wave direction is southerly and during the southwest monsoon, it is northerly (EPU, 1985).

The clay-silt soils and the sandy soils that form most of the Malaysian coasts respond quite differently to the wind wave driven mechanisms that mould and remould these coasts. Mobilization of the clay and silt sediments requires more energy than the mobilization of the sand sediments. Once mobilized, the clay and silt particles are suspended in the water column and are more easily transported by long shore and other currents than the heavier sand particles. Clay and silt sediments are dispersed throughout the water column, otherwise sand sediments are concentrated near the bottom. At present the transport of sand sediments is better understood than the transport of clay and silt sediments because coastal engineering research has generally concentrated on sandy beach protection.

Erosion results when the volume of sediments transported out of an area is greater than the volume transported into the area over time. Conversely, accretion occurs when the volume of sediments transported into an area is greater than the volume transported out of the area over time. The major cause of erosion and accretion in

Malaysia is long shore transport but offshore transport may be important in some areas, particularly during storms.

Meanwhile according to the NCES report, human intervention is a more dominant factors to cause the rapid rate of coastal erosion compare to the natural processes. Several common causes of human-induced shoreline are:

- Dredging works for navigational purposes
- Construction of harbours with breakwaters built in near shore region
- Construction of structures like jetty, groyne or structures that block the sediment movement and littoral drift current
- Reclamation of lands toward the seashore
- Sand mining activities
- Construction of dams on rivers with steep gradient (reduced sediment supply to shoreline area)

The rate of erosion varies widely from year to year at any given location and from location to location at any given time. Over long terms of 25 years or more, the average rate is usually less than 10 meters per year. In the short term the erosion rate is often as much as 20 meters per year (EPU, 1985). Based on National Coastal Erosion Study (NCES), Malaysia's shoreline are classified into three categories of erosion depending to the threat it caused to the existing shore-based facilities of substantial economic value and defined as follows:

- Category 1 : Shorelines currently in a state of erosion and where shore-based facilities or infrastructure are in immediate danger collapse or damage.
- Category 2 : Shoreline eroding at a rate whereby public property and agriculture land of value will become threatened within 5 to 10 years unless remedial action is taken.
- Category 3 : Undeveloped shoreline experiencing erosion but with no or minor consequent economic loss if left unchecked.

Government will identify and evaluate the priority of the coastal defence project based on these categories to overcome all the issue of coastal erosion problem by introducing the appropriate protection and mitigation measures.

1.1.2 Coastal Protection in Malaysia

In order to cope with continued coastal erosion problem, the Government has set up the Coastal Engineering Centre in the Department of Irrigation and Drainage (DID) in 1987 to implement coastal erosion control program throughout the country. There are few types of coastal defence structures that was built by DID along the shoreline in Malaysia for protection and mitigation measures.

Coastal protection can be divided into two categories, hard protection and soft protection (eco-engineering) methods. Hard protection structures normally prevent retreat of shoreline, prevent loss of sediments or trap sediments, wave attenuation and wave energy dissipation. This type of structures that was built by DID recently consist of hard engineering structures like rock revetment, groyne, seawall, interlocking flex-slab revetment, earth bunds, sauh revetment, Labuan block, segmented offshore breakwater and shore connected breakwater (refer to Figure 1.4).



(a) Rock revetment and groyne



(b) Interlocking flex-slab revetment and Seawall structures



(c) Earth bund and sauh revetment



(d) Labuan block



(e) Segmented offshore breakwater



(f) shore connected breakwater

Figure 1.4 : Hard protection structures as coastal defence built by DID along the shoreline in Malaysia for protection and mitigation measures
(source : DID, 2009)

Soft protection method, also well known as eco-engineering system based on green and soft technology approach are such as Geotube, soft rock (geo/sand bags), beach nourishment, mangrove replanting, artificial sea grass, Pressure Equalisation Module (PEM) and Beach Management System (BMS) (refer to Figure 1.5).



(a) Geotube



(b) soft rock (geo/sand bags)



(c) beach nourishment



(d) mangrove replanting

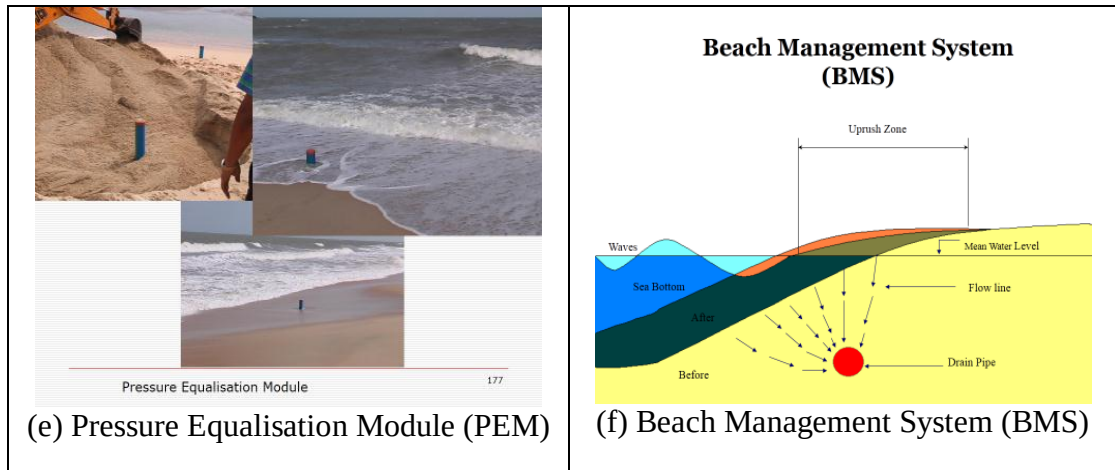


Figure 1.5: Soft protection approach also as known as eco-engineering method for coastal protection and mitigation measures in Malaysia (source : DID, 2009)

However hard structures can interrupt sediment transport and induce imbalances in transport. In some places, seawalls and revetments armour immobilize sediments at their source and thereby reduce the supply available to the transport system. In some places, groins, piers, breakwaters and fills project into the sea from the shore and physically block the movement of sediments along the shore thereby causing accretion on one side of the structure and erosion on the other. In some places, breakwaters and similar structures in the sea intercept and attenuate waves thereby denying energy to the transport system, and causing accretion nearby and erosion elsewhere (refer to Figure 1.6). In some places, seawalls and similar structures concentrate and deflect wave energy to their bases thereby accelerating erosion of the areas in front of them.



Figure 1.6 : Shore-connected breakwaters caused the accretion at the up drift side and also caused the local erosion at the down drift side (source : DID, 2009)

Apart from that, to improve and streamline the efforts towards best management practise in coastal protection strategies, DID introduced and implemented the concept of Integrated Shoreline Management Plan (ISMP) throughout the country. The ISMP programs carried out by the DID is tailored along the principles of Integrated Coastal Zone Management (ICZM) to address the major issues and problems facing our shoreline. It is an integrated approach that takes into account all the sectoral activities that affect the coastal areas and gives due consideration to economic, social, environmental and ecological issues. The goal is to develop a management tool to harmonise all the activities in the coastal area to support a broader set of management objectives for the coastal area. Objectives of ISMP are appraisal and selection of coastal development management strategies so that the development in the coastal area can be carried out in a sustainable manner, appraisal and selection of defence options for the coastline and formulation of specific guidelines and policies for development activities/proposals in the coastal area.

1.2. PROBLEM STATEMENT

Severe coastal erosion problem has occurred just behind the building of Regency Hotel, Tanjung Tuan, Batu 5, Port Dickson after the storm wave event in early October 2013. The event can be classified as Category 1 critical beach erosion that is close to the property just 15 meters from the hotel building (refer to Figure 1.7).



Figure 1.7 : Coastal erosion problem just behind the building of Regency Hotel, Tanjung Tuan, Batu 5, Port Dickson (source : Sinar Harian, 2013)

The erosion could threaten the safety and stability of the building structure. The length of the eroded shoreline is about 100 metres. The immediate remedial action conducted by the hotel's management was to carry out temporary protection works with sand bags which costs RM200,000. Unfortunately, erosion still happen. It is thus suggested that hard structures be considered and to reclaim back the beach. Hence in collaboration with National Hydraulic Research Institute of Malaysia (NAHRIM) and Negeri Sembilan state DID, Regency Hotel Port Dickson has considered the use of NAHRIM Coastal Protection And Expansion (NEXC) blocks system for coastal protection along Pantai Batu 5, Port Dickson, Negeri Sembilan.

1.3. STUDY AREA

Port Dickson is well known as a tourism town. Port Dickson Municipal Council has been proclaimed as Municipal Council on 2 February 2002 to manage the rapid development of this tourism area (MPPD, 2006). The municipal covers 140.32 km square. It is located at 2.54 latitude and 101.81 longitude and is situated 10 meters above sea level (World Atlas, 1996). Port Dickson is the second biggest city in Negeri Sembilan. The total population of Port Dickson in year 2010 is 111,910 and is expected to reach more than 120,000 by year 2016 based on Department of Statistics, Malaysia. Port Dickson has modernized town resort, urbanized farming activities, trading and industrial activities. There are several sandy beaches along Port Dickson coastlines that are very suitable for tourism activities like Pantai Tanjung Gemok, Pantai Bagan Pinang, Pantai Saujana, Pantai Cahaya Negeri, Pantai Telok Kemang, Pantai Sri Purnama, Pantai Cermin and Pantai Blue Lagoon as shown in Figure 1.8.

Port Dickson sandy beaches area have medium beach gradient and that is not too steep. Even though these sandy beaches seldom experienced of big storm wave event from the Strait of Malacca, some of the beaches had experienced a series of coastal erosion incidents in the past. Referring to the NCES report in 1985, the study had found that there is a history of significant coastal erosion (Category 1) in Pantai Batu 4, Port Dickson.

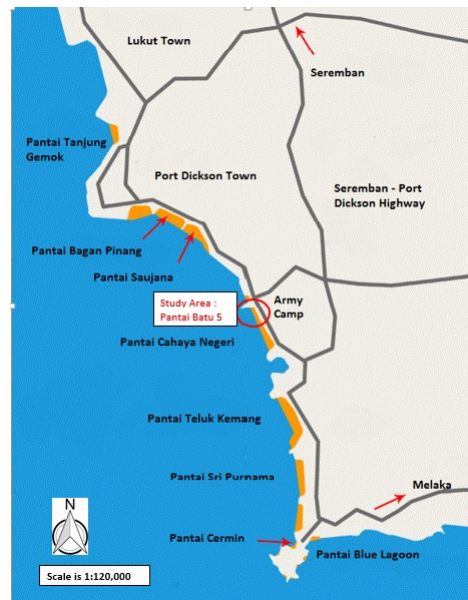


Figure 1.8 : Location map for Port Dickson beaches
(source : <http://www.pd.com.my/Beaches.htm>)

The Regency Tanjung Tuan Beach Resort is an idyllic seaside hotel apartment located about five miles from the township of Port Dickson. Situated approximately 45 minutes' drive from the Kuala Lumpur International Airport (KLIA) and about one and half hours' drive from the capital Kuala Lumpur. The Regency Tanjung Tuan Beach Resort sits snugly along one of the finest white sandy beaches of Port Dickson. Because of this reason, the hotel management stressed that it was very necessary to protect and maintain the beach as it is a main attraction for tourists to stay there (Figure 1.9).

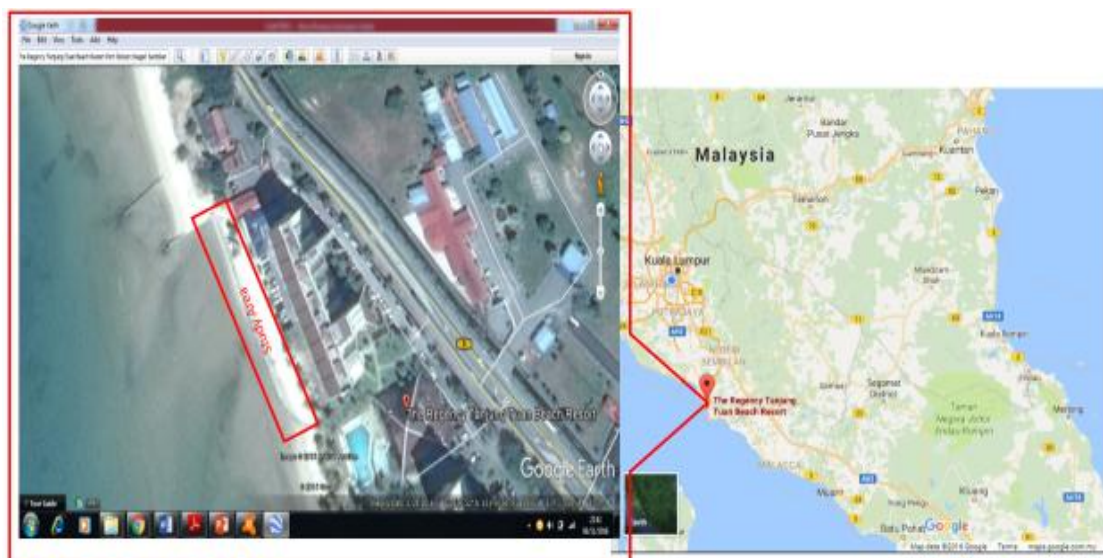


Figure 1.9 : Study area for pilot research project lead by Coastal and Oceanography Research Centre, NAHRIM at the Regency Hotel, Tanjung Tuan Beach Resort, Pantai Batu 5, Port Dickson, Negeri Sembilan (source : Google Earth and Google Maps)

1.4. OBJECTIVES OF STUDY

The objectives of the study are as follows:-

- a) to examine the stability of NEXC Block System;
- b) to examine the effectiveness of NAHRIM Coastal Protection And Expansion (NEXC) Block System in reducing coastal erosion;
- c) to determine the ability of NEXC structure functioning as beach accretion trap for sediment (sandy beach material).

1.5. SCOPE OF STUDY

Scopes of study are listed as follow to meet all the objectives of the study:

- a) Primary and secondary data collection on beach profile, coastal bathymetry, sediment, tidal level, wave height and direction;
- b) Analysis of historical beach profile changes ;
- c) Product development including product design, mould fabrication and construction of the NEXC blocks system (model and prototype);
- d) Conduct 2-dimensional (2-D) physical modelling test (flume) for downscale model of NEXC blocks system in Hydraulic and Instrumentation Laboratory, NAHRIM;
- e) Construction of the NEXC blocks system prototypes at Pantai Batu 5, Port Dickson, Negeri Sembilan;
- f) Monitoring programme : conduct a monthly beach profiling survey;
- g) Analyse beach profile changes;
- h) Assessment of the effectiveness, stability and ability of NEXC Block System in protecting coastal erosion as well as functioning as beach accretion trap for sediment.

1.6. LIMITATION OF STUDY

The following scopes are exclude in the study:-

- a) Numerical modelling for hydrodynamic and sediment transport model;
- b) Three dimensional (3-D) physical modelling (wave basin with two directions angle of wave generators);

- c) Effects of future land use and human intervention induced coastal erosion in the study area.

1.7. SIGNIFICANCE OF STUDY

In Malaysia, there is not much coastal defence products that have been produced and we still rely on some existing products. However, some of these products are quite effective and serves to protect the coastline in our country from the threat of critical erosion. Even if there is some kind of new products which are produced by manufacturers in our country, it's still lacking in terms of a detailed study on the effectiveness of the products that have been produced. DID has experiencing a few structural failure cases of these some coastal defence products that have been installed at the construction site. This scenario has caused losses to the government due to the additional costs for repair and rehabilitation works.

Coastal and Oceanographic Research Centre, NAHRIM, is one of the national excellence centre in this field has taken the initiative to produce the coastal protection product that is expected to resolve the endless problem of coastal erosion and loss of land as a result of this natural disasters. However, there a few challenges that we have to face in this pilot project. The biggest challenge is to make sure that the NEXC Block System could withstand during big wave or storm event to avoid structure failure due to scouring effect. The research team also should take into consideration with a proper design of the product in order to perform the dual function (protection and expansion of the beach sediment) at the same time. Accordingly, a detailed study of the effectiveness, stability, reliability and suitability of this product is very important to ensure that these products can work better in controlling coastal erosion.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Coastal processes comprise sediment transport that is driven by iteration of tidal currents, waves, river flows and vegetation, which continuously shape and reshape the coastline. Figure 2.1 shows that coastal area can be divided into three zones that are shore face or littoral zone, shore or beach zone and coast zone.

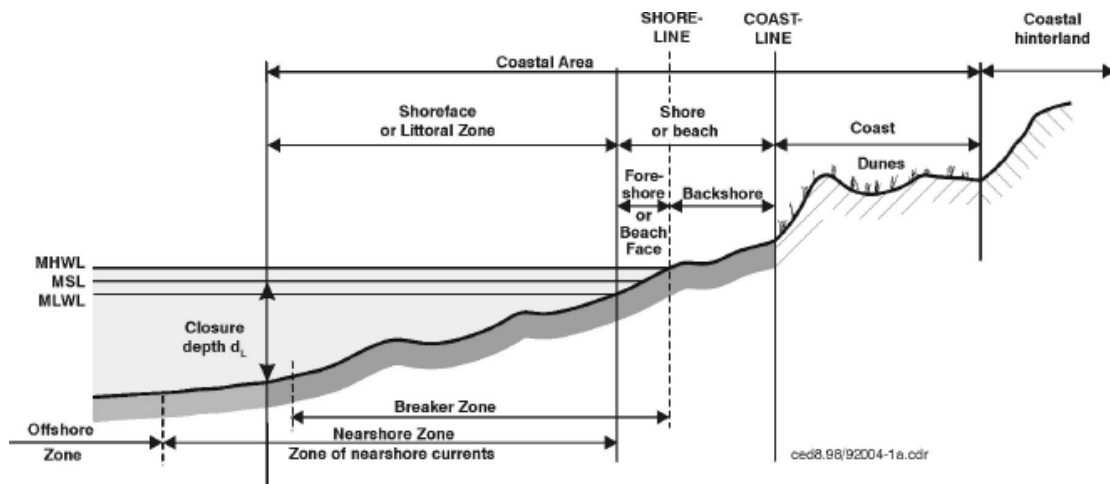


Figure 2.1 : Definition of coastal terms (Source: Shore Protection Manual, United States Army Coastal Engineering Research Centre, 1984).

Shore face or littoral zone can be defined as the active littoral zone off the low water line (DID, 2009). This zone extends seaward from the foreshore to some distance beyond the breaker-zone. The littoral zone is the zone in which the littoral processes take place, these are mainly the long-shore transport, also referred to as the littoral drift and the cross-shore transport. The beach or shore zone is the zone of unconsolidated material that extends from the Mean Low Water Line (MLWL) to the place where there is a marked change in material or physiographic form, or to the line of permanent vegetation (the effective limit of storm waves and storm surge) to the coastline. The beach or shore can be divided in the foreshore or beach face and the backshore. The backyard of the coastal area zone or as known as coast zone can be defined as the strip

of land that extends from the coastline inland to the first major change in the terrain features, which are not influenced by the coastal processes. The main types of coastal features are dunes, cliffs and low lying areas, possibly protected by dikes or seawalls.

Behind the coastal area, there is a coastal hinterland zone and can be defined as the land that extends landward of the coast and which is not influenced by coastal processes (DID, 2009). Shorelines is the intersection line between the Mean High Water Line (MHWL) and the shore. The line delineating the shoreline on Nautical Charts (Sea Maps) approximates this MHWL. The shoreline is not easy to identify in the nature in contrast to the coastline, which is based on a clear morphological shift between the shore and the coast. Coastline can be defined technically as the line that forms the boundary between the coast and the shore. Commonly, the coastline is the line that forms the boundary between the land and the water.

Coastal erosion happens in breaker zone due to the action of breaking waves and cross-currents. There is no clear definition of the breaker-zone or surf-zone, but it can be defined as the zone extending seaward from the shoreline that is exposed to depth-limited breaking waves. The closure depth can thus be defined as the depth at the seaward boundary of the littoral zone. Near shore zone can be defined as the zone extending seaward from the low water line well beyond the breaker-zone. It defines the area influenced by the near shore currents. The near shore zone extends somewhat further seawards than the littoral zone. Otherwise, the offshore zone is not well defined. In the present context, the offshore zone is defined as the zone off the near shore zone.

Understanding of dynamics wave action towards the impacts of coastal processes, is important to identify the location where erosion or accretion is expected to happen and thus to choose a suitable type of the coastal defence structure.

Coastal defence structures are very important to protect the coastline from wave action especially during monsoon seasons. In the State of Perlis for example, almost all of their coastline has already covered with coastal defence structure (rock revetments and groynes) that was constructed by DID. This was done to protect their granary areas (paddy cultivation), plantations and buildings.

2.2 CAUSES OF COASTAL EROSION AND ACCRETION

In general, both coastal erosion and accretion process mainly driven by two factors, natural factor and human activities. Figure 2.2 lists the complex processes of coastal erosion and accretion, as well as natural factors and human activities.

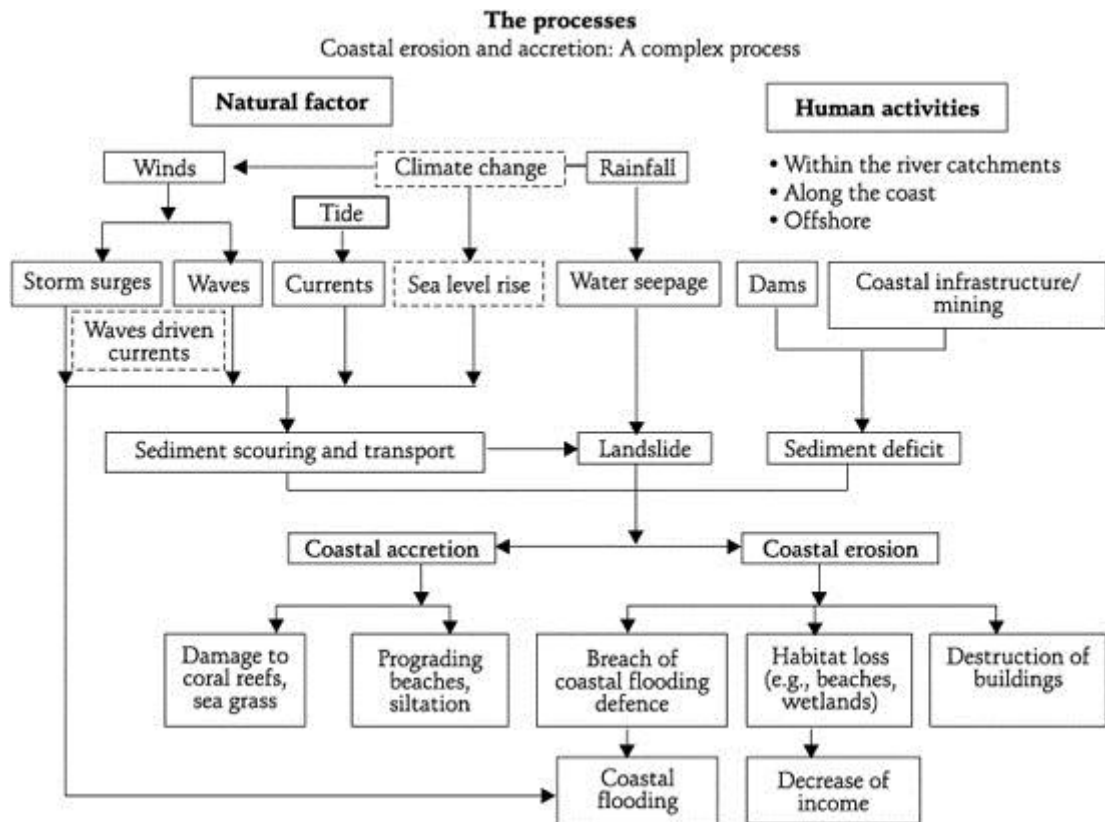


Figure 2.2 : The complex processes of coastal erosion and accretion
(source : EuroSION, 2004)

2.2.1 Natural Factor

The natural processes primarily responsible for Malaysian coastal erosion are driven by wind waves (EPU, 1985). In the ocean condition, winds will generate waves. Wind is the main force in wave generation. Winds is the most important factor that caused a complexity of this phenomena by the actions of storm surges and waves that lashed coastal areas. According to Wikipedia, “wind-generated waves are surface waves that occur on the free surface of oceans or seas generated from the wind blowing over an area of fluid surface. Waves in the oceans can travel thousands of miles before reaching land. Wind waves range in size from small ripples, to waves over 30 metre high. When directly generated and affected by local winds, a wind wave system is called

a wind sea. After the wind ceases to blow, wind waves are called swells. Wind waves in the ocean are called ocean surface waves”. Waves are the most important forces for sediment erosion and transport to the coastal zone (Gegar, 2009). They introduce energy to the coast and also a series of currents that move sediment along the shore (long shore drift) and normal to the shore (cross-shore transport). It is important to understand the movement of wave forms as well as water particles and their interaction with seabed material, also how the waves determine whether the coasts are erosive or accretion. During monsoon season, strong winds blow will generate a series of storms, hurricanes or typhoons. Big waves generated during these major storms coupled with high tide as frequently happened during monsoon season exacerbate coastal erosion problem (refer to Figure 2.3).



Figure 2.3 : Severe coastal erosion occurred in Teluk Lipat, Dungun, Terengganu just after the North-East Monsoon due to the destructive wave action.

(source : <http://marinahunny.blogspot.my/2011/12/hakisan-di-pantai-teluk-lipat-dekatdgn.html>)

Under the right environmental conditions, wind may transfer sediment from the beach environment landward on all open coastlines (Gegar, 2009). This is the case where sand is predominant which can be blown landward from the beach or towards the seashore. Strong wind blow towards hinterland will form a bulk of dunes rising many meters above from the berm level, a similar scenario that always happen in dessert. This phenomenon also can cause berm erosion if the wind direction blow toward the sea and

also known as wind drift condition. This condition is typically occur on sandy beaches that have a relatively fine sediment size.

Tides are influential in beach morphodynamics. Peninsular Malaysia consists of three types of tides namely, diurnal, semi-diurnal and mixed tide (Lee and Fauzi, 2010). They modulate wave action, controlling energy arriving on the coast and drive groundwater fluctuation and tidal currents. Tidal range also play an important role in coastal erosion and deposition. Tidal range is the differential of tidal elevations between the highest and lowest tidal elevations which occur at a particular point in the ocean. This periodic change in water level results in different parts of the foreshore being exposed to wave energy throughout the day. In regions with large tidal ranges, the water may rise and fall a few meters, and the shoreline may move laterally several kilometres between high and low water (USACE, 2016). So the tidal currents themselves can erode and transport sediment to the near shore and offshore. Because of this scenario, we found that, various parts of the intertidal zone are exposed to erosion and deposition.

Sea level rise is one of the main consequences of global warming. Sea level rise poses new threat to coastal and estuarine environment which may cause increase of extent, duration of flooding in the coastal area, loss of land, changes the physical characteristics of tidal rivers, increase salinization and consequences on the livelihoods and socio-economic (Md Khairi, 2014). There are very strong relationship exists between sea level rise and sandy beach erosion. For example, a sustained rise of 10 cm in sea level could result in 10 m of shoreline erosion. There is good agreement between sea level rise and average long-term shoreline change for eroding beaches by rationing both the shoreline retreat rate and sea level rise rate. The ratio of shoreline retreat rate to sea level rise rate ranges from 110 to 181 for undisturbed beach segments, confirming that there is indeed an association between long-term sea level rise and shoreline retreat (Stephen et al., 2000). IPCC Fourth Assessment Report (AR4) has predicted that the global sea level rise for the period of 1990 to 2100 will be 18 to 59 cm and for Peninsular Malaysia, coastlines is predicted to rise with a mean in between 25 to 52 cm (NAHRIM, 2010). As mentioned in Chapter 1, higher sea levels will raise extreme water levels, allowing waves to break nearer to the coast and transmit more wave energy to the shoreline. This will promote erosion and coastal retreat at sediment starved locations. Generally, the most common experience of acute coastal erosion has been associated with transient erosion due to storm events involving large

waves and abnormally high water levels, especially when storm surges coincide with spring tides (Stewart, 2010).

2.2.2 Human Factor

In Malaysia, human intervention is more dominant factors to cause the rapid rate of coastal erosion compare to the natural processes (EPU, 1985). But most of the time, the combination of both factors are contributing to the severe cases of coastal erosion and all these scenario can be modelled by using numerical modelling and physical modelling approach. Several common causes of human-induced shoreline are:

- Construction of structures like jetty, groyne or structures that block the sediment movement and littoral drift current
- Reclamation of lands toward the seashore
- Coastal forest clearing (especially mangrove) along the coastline
- Construction of dams on rivers with steep gradient (reduced sediment supply to shoreline area)
- Construction of harbours with breakwaters built in near shore region
- Dredging works for navigational purposes and sand mining activities

Activities along the coastline will give a great impact to human and coastline interaction. Development within or too close to dynamic zone with minimum set back will worsen the situation. Construction of protective seawalls lead to erosion at the end of the structures, generate beach scouring at the toe of seawall and shorten the beach face (Gegar, 2009). This can occur in the short term (less than five years) or the long term (more than five years). Other structures such as groynes and jetties typically cause erosion down-drift of the structure within a short period of time (between five and ten years). Building houses, airport or structures via land reclamation or within sand dune areas has a long-term impact on shoreline change (Gegar, 2009). For example, the extension of runway of Sultan Mahmud Airport in Kuala Terengganu lead a serious coastal erosion for adjacent coastlines like Pantai Tok Jembal and Pantai Kampung Tanjung Gelam (refer to Figure 2.4 and 2.5). It is also found that the reclamation of sand for runway platform contributes severe erosion on an average of 21.3 m at the north side (down drift of the runaway) and accretion on an average of 24.8 m at the south sides (up drift of the runway) between in year 2010-2013 (Mohammad et al., 2014).

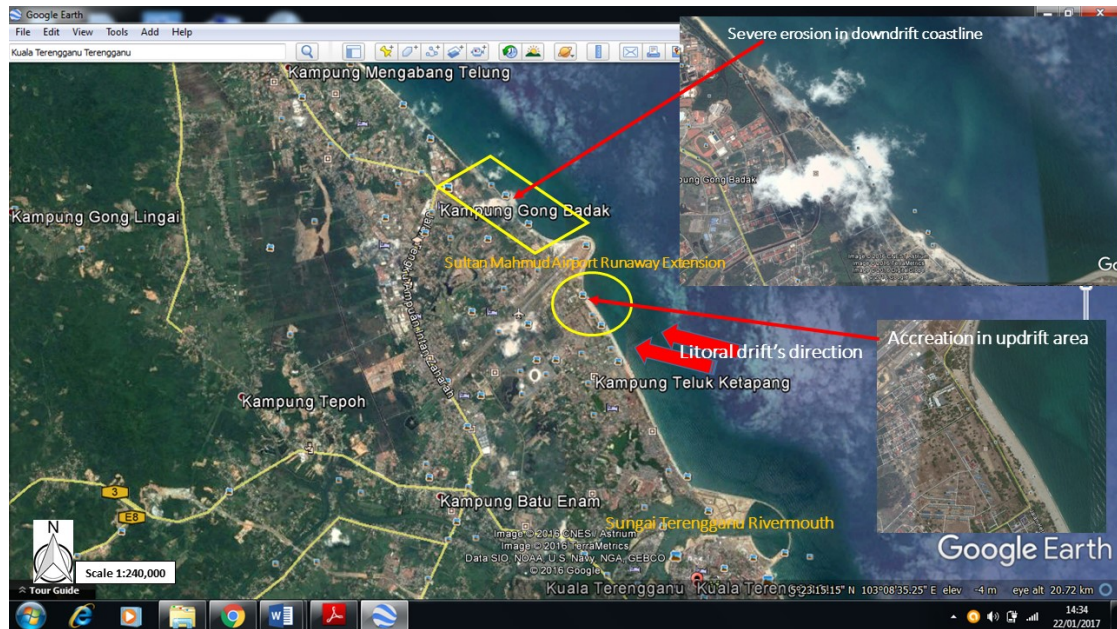


Figure 2.4 : The extension of runway of Sultan Mahmud Airport in Kuala Terengganu lead a serious coastal erosion for adjacent coastline (source : Google Earth)



Figure 2.5 : Coastal erosion at Pantai Tok Jembal (left) and Pantai Kampung Tanjung Gelam (right), Mengabang Telipot, Kuala Terengganu, Terengganu (source : <https://ainanatasha94.wordpress.com/2014/11/11/hakisan-pantai-tok-jembal/> and <http://www.hmetro.com.my/node/104335>)

The interaction of groundwater with tides in the coastal forest environment is crucial in understanding why coastal forest clearance causes intensive coastal erosion in particular environments (Gegar, 2009). Removal of dune vegetation and mangroves will expose low energy shorelines to increased energy and reduced sediment stability, causing erosion. Thinning of mangrove forests results in greater wave energy impact on shoreline and cause a rate of shoreline retreat may accelerate. Over clearing of mangroves and under providing setbacks led to greater wave impact especially on mud coast. Aquaculture has been identified as one of the thrusts of the fisheries industry but in direct conflict with mangrove preservation. Mangrove actually act as a buffer

zone by reduce wave energy, provide protection and reduce the damage to the backshore (Hideaki, 2008). By clearing them to give way for aquaculture activities may cause a severe coastal erosion as seen in our country.

Activities within river catchments/watersheds will directly affect to the sediment supply. Dam construction and river diversion cause reduction of sediment supply to the coast that contributes to coastal erosion. The effects of dam and river diversion in terms of coastal erosion are not straightforward, but there are mid-term to long-term impacts (20 to 100 years) with spatial scales approximately from one to 100 kilometres (Gegar, 2009). For example Kenyir dam was horrible effect to the sand supply for Sungai Terengganu. Construction of the Kenyir Dam has decreased fluvial sediment supply to the coast and resulted in erosion on both sides of the river mouth, necessitating the relocation of several villages (Teh and Yap, 2003). By retaining the sediment into the dam, less supply to the river and sea lead to increase a series of coastal erosion to the Kuala Terengganu coastline such Pantai Batu Buruk and Psurrounding area. Port and harbour activities and development also will create a problem to the coastal area especially from the ship's operational and maintenance. Waves generated from a big ship (as known as ship wakes) multiple with natural waves action will make the magnitude of erosion worsen than the previous event. Additional with the increasing of the maritime traffic, ship wakes generate more frequency and intensity of waves that cause a coastal erosion and accretion to the coastlines. Tanjung Piai Coast in Johor experienced a severe coastal erosion due to heavy maritime traffic. Tanjung Piai is the Southern Most Tip of the Asian Mainland that was declared as a Ramsar Site by United Nation (UN), located at the southwest of Johor and just opposite site with Singapore's busy ports site. From the total 526 hectares (ha) of mangrove forests, about 164 ha of them had been lost due to the erosion and accretion problems (Wan Hasliza et al., 2013) as shown in Figure 2.6. From the result of this study also show that severe erosion occurred around east coast of Tanjung Piai at rate ranging from -2.8m/year to -14m/year while accretion occurred around the west coast at a rate which can reach up to 7m/year.



Figure 2.6 : The mangrove erosion in Tanjung Piai wrought by wave action brought on by increased shipping traffic due to the function of a new international sea port nearby. (Source : http://ramsar.rgis.ch/cda/en/ramsar-news-archives-2003-ramsar-visit-to-new/main/ramsar/1-26-45-86%5E16294_4000_0__)

Onshore and offshore Dredging activities will resulted a great impact to the sediment transport to the coastal area. These activities will directly disturb the equilibrium of the sediment transport process in that particular coastline. Interception of sediment movement by dredged pit due to uncontrolled sand mining activity will reduce the supply of sediment to the coastal zone and will caused erosion to the down coast area (refer to figure 2.7).

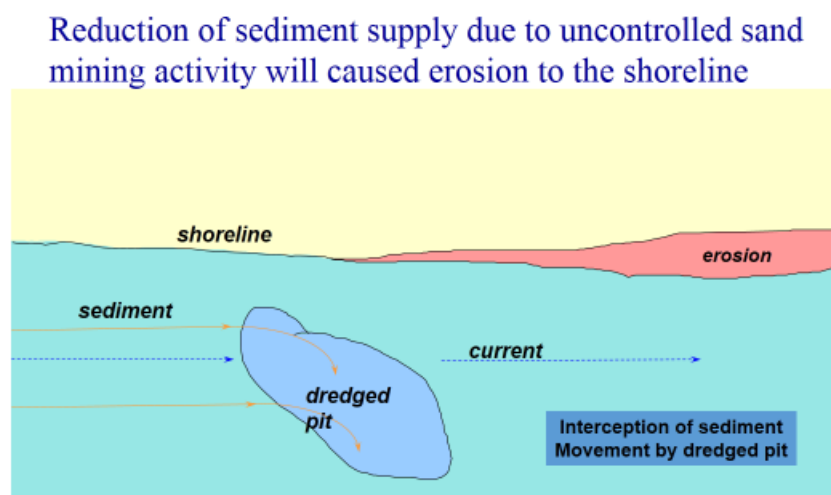


Figure 2.7 : Reduction of sediment supply due to uncontrolled sand mining activity will caused erosion to the shoreline (source : DID, 2009)

Sand mining and dredging works for navigational purpose may affect coastal processes in various ways such as contributing to sediment deficit in the coastal system and modifying water depth that leads to altered wave refraction and long shore drift. The impact of these activities will be obvious within a short period of time within one to ten years (Gegar, 2009). For example, river improvement works for Sungai Terengganu River mouth for navigational purpose will cause the rate of erosion to be more severe due to the lack of sediment supply from Sungai Terengganu and changes in the wave height (NAHRIM, 2001). Maintenance dredging also will effects on morphological changes to the coastal environment as happened in Penang Port Harbour due to the deepening of navigation channel by port authority. Due to the current speed and surface elevation changes, the siltation and erosion of the sediment will occur in the navigation channel and port berthing basin with the siltation rates between 3m/year to 4m/year and the erosion rates ranging from 1.5m/year to 2m/year (Lee and Othman, 2010).

2.3 COASTAL EROSION AND DEPOSITION ON SANDY BEACHES

Coastal erosion and accretion occurs daily by wave and tidal currents. Most of the coastlines in the world are in a dynamic equilibrium. The total volume of sediments lost normally equals to the volume gained by it. Erosion excessively happen during the monsoon vice versa accretion will happen in the post-monsoon months. On almost all coasts, both deposition and erosion happen to varying degrees most of the time, although in different places. Beach deposits predominantly consist of sand particles that can be easily eroded by waves. These deposits comprise terrestrial sediment delivered to the coast by rivers, sediment produced by the erosion of coastal landforms by waves, and marine sediment that has been reworked from offshore deposits onto the coast. Sand derived from a terrestrial source is usually dominated by resistant minerals such as quartz. Marine sediments, however, comprise resistant minerals and biogenically-produced calcium carbonate (OzCoasts, 2012).

In Malaysia, most beaches go through a seasonal cycle because conditions change from monsoon to inter-monsoon season. Monsoon season are referring to the both North-East (NE) Monsoon and South-West (SW) Monsoon. During inter-monsoon season, sea conditions are relatively calm with long-wavelength, low-amplitude waves generated by distant winds. In monsoon season, the sea conditions are rougher, with

shorter-wavelength, higher-amplitude waves caused by strong winds. As shown in Figure 2.8, the heavy seas of monsoon season (rough weather) gradually erode sand from beaches, moving it to an underwater sandbar offshore from the beach. This condition of wave action is namely as destructive wave action. The gentler waves of inter-monsoon season (calm weather) gradually push this sand back toward the shore, creating a wider and flatter beach. Instead of that, this condition of wave action is namely as constructive wave action. The differences between rough weather (monsoon season) and calm weather (inter-monsoon season) on beaches in areas where the monsoon conditions are rougher and waves have a shorter wavelength but higher energy. In this condition also, sand from the beach is stored offshore (Steven, 2016).

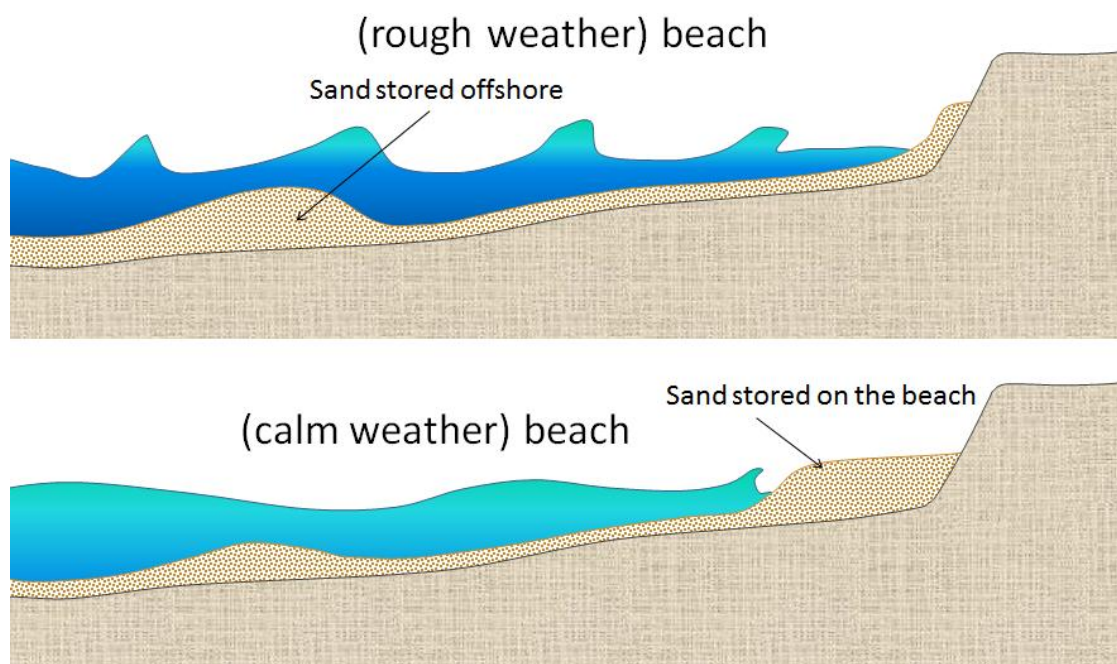


Figure 2.8 : The differences between rough weather (monsoon season) and calm weather (inter-monsoon season) on beaches. (source : Steven, 2016).

Sandy beaches are dynamic sedimentary systems that naturally experience phases of erosion and accretion that operate over a range of time intervals (Thom and Hall, 1991). Frequent short-term changes are seasonal, erosion mostly occurs in seasons when storms that generate erosional wave regimes are more frequent. Rapid erosional episodes may also be produced by high-magnitude storms, such as tropical cyclones or intense low pressure systems in temperate regions. The degree of erosion that occurs within a particular erosional phase can be highly variable, and this likewise is linked to the magnitude and frequency of storms that impact on the coast. For example, during a

1 in 100 year high magnitude storm, waves may erode several metres into the fore dune that sits well behind the normally active zone of accretion and erosion (refer to Figure 2.9). Also, several lower-magnitude storms that occur in quick succession can produce a similar degree of erosion because the intervening periods are too short for constructive swell waves to push a significant amount of sediment back to the shoreline (OzCoasts, 2012).

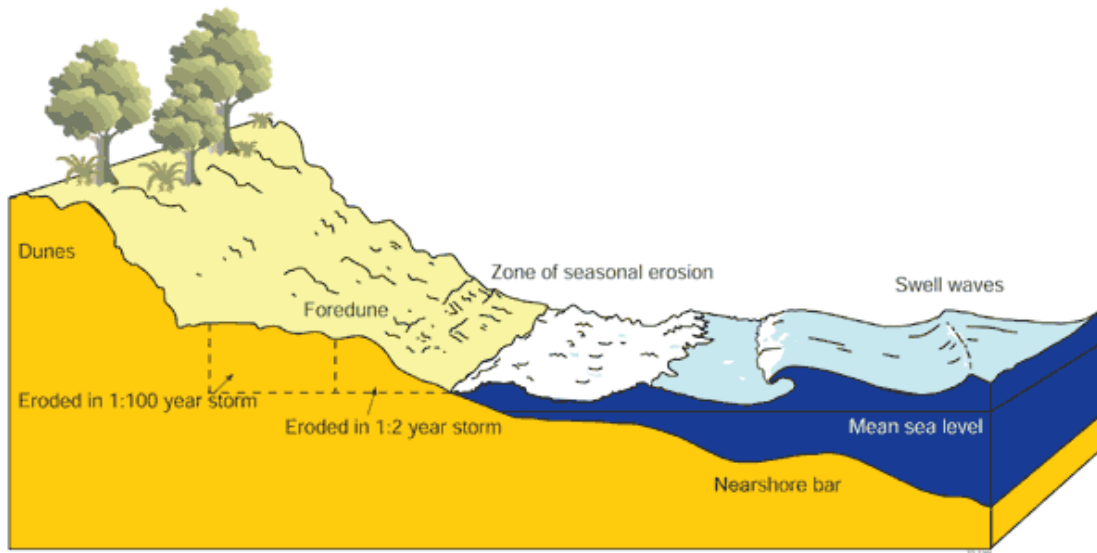


Figure 2.9 : Cross-section of a sandy beach showing the significant difference in the volume of sediment eroded in high-magnitude storms (1:100 year) compared to seasonal erosional events (OzCoasts, 2012).

The accretion of sand on beaches occurs during the more quiescent seasons when average swell waves deliver sediment back to the shoreline. Beach accretion, however, is generally a much slower process than beach erosion. For example, it may take several years for a beach to return to its pre-storm condition after one major storm or several smaller storms in quick succession (Thom and Hall, 1991).

2.4 GENERAL IMPACT OF COASTAL EROSION

Coastal erosion has been already known will caused a significant impact on the coastal environment, damage and loss of property and affect all activities involved. Community life, agriculture, transportation, recreation and tourism activities are seriously affected by coastal erosion. Housing, coastal bunds, roads and beaches

important to those activities have been damaged and more damage is imminent. This continuous natural disaster will ruin all the properties along the affected coastlines within overnight. The rate of erosion varies widely from year to year at any given location and from location to location at any given time. According to NCES, over long terms of 25 years or more, the average rate is usually less than 10 meters per year. In the short term the erosion rate is often as much as 20 meters per year.

Erosion directly affects those who own and use the eroding land, those employed by the users, those who transport and market the products of the users and those who sell goods and services to these. Erosion indirectly and to a lesser extent affects many others because it retards economic growth, reduces the output of goods and services, and reduces tax revenues. The measureable economic and social consequences of coastal erosion and the concern generated has increased rapidly as the use of coastal land has intensified. Many varied activities suffer when developed land erodes. The important general activities most often affected are agriculture, housing, transportation and recreation.

Agriculture, particularly in areas along the Melaka Straits, is seriously threatened. Bunds which are important features of large agricultural drainage area projects have been breached by wave attack and more breaches are threatened (refer to Figure 2.10).



Figure 2.10 : Some example of damaging coastal earth bunds in agricultural area caused by wave attack (source : DID, 2009)

The bunds were generally built 400 meters or more behind seaward edges of mangrove swamps and depended on the mangrove buffers for protection from waves. Erosion has since removed the protecting buffer. The tidal flooding that follows breaching of the bunds can penetrate as far as 2 kilometres or more and damaging the existing crops such

as palm oil, coconuts, cocoa, or rice and reducing the capability of the land for future crops.

Coastal towns, villages and larger communities along the coast are the bases on which fishermen and others working in and near the sea depend. In some settlements, residences and commercial housing have been, or soon will be, damaged or destroyed because of coastal erosion. These structures were sited behind sandy beaches or tidal mud flats which provided protection from waves. As the mud flats and beaches eroded, the building foundations were undermined and the structures destroyed or endangered.

Transportation is disrupted or impaired when coastal erosion damages or severs roads along and near the shore. In some areas, main or principal roads are affected. In other areas, secondary roads connecting kampongs and scattered homes with primary roads are damaged. Travel is either delayed or interrupted and the affected communities are seriously inconvenienced when either is damaged.

Beaches are perhaps Malaysia's most important recreational assets. Coastal erosion has nearly destroyed some beaches and has drastically reduced the useable area at many others. Many of the impacted beaches are only lightly used now and the consequences of their erosion are not as yet fully recognized. But this is certain to change. As Malaysia's development and economic growth continue, increased leisure time and disposable income will encourage greater local use of beaches. Apart from that, as Malaysia attracts more tourists, additional tourist centres and resorts dependent on beaches will develop. The resultant intensification of beach use and demand for more beaches will make beach erosion a greater concern.

2.4.1 Economic Consequences

Economic analyses quantify the monetary impacts of the physical consequences of erosion (EPU, 1985). There are four direct costs to the economic consequences of coastal erosion in Malaysia regarding to the NCES. They are income losses, reduced market value of existing improvements, cost of relocating and re-routing, and reduced willingness to pay for recreational experiences.

Income losses are a particularly important indicator of the economic consequences of erosion induced damage to agricultural land and to recreational beaches. When agricultural drainage area project areas are flooded with salt water

because of bund failures, the income from annual crops is completely eliminated and the income from tree crops is substantially reduced. When beaches on, which resorts and tourist centres depend are destroyed or drastically reduced in size, occupancy rates in associated hotels and lodging houses decline.

Housing in agricultural structurally damaged by access is maintained and areas is quite often not destroyed or erosion induced tidal flooding because the structures are elevated. The market value of, and demand for, the housing is nonetheless reduced because the land is cultivated less intensively, or not at all. Housing and transportation based activities are sometimes forced to relocate because the land on which facilities are sited is lost to coastal erosion. In the case of housing, the economic consequence is the cost of a new site and replacement housing. In the case of transportation, when a road is severed, traffic must be re-routed to an alternate road or the severed road must be relocated further inland. The economic consequences are the increased trip cost because of changed route and the cost of relocating the road.

The economic consequences of beach erosion are not fully measured by market indicators because there are no user fees. Consumer willingness to pay is the best measure of the economic value of these free facilities. Willingness to pay is indicated by the historic expenditures of users. When the useable area of a beach is reduced, the number of users is reduced and the economic consequence is the amount these lost users would have paid for recreation experiences.

2.4.2 Demographic Consequences

Economic consequences are quantifiable and facilitate objective comparison of erosion protection investments with other investment opportunities. But coastal erosion has costs which are not measured in monetary terms and which are not quantifiable. These other costs are important. They are the social costs and are the consequences of the effects of erosion on individual and community ways of life, and on the interactions of individuals, groups, and social organizations. Collectively, these costs are the demographic costs. Demographic costs are highest where impacts of erosion disrupt general community life styles and patterns and lowest where only isolated individuals are affected (EPU, 1985).

2.5 COASTAL EROSION CONTROL MEASURES (COASTAL DEFENCE)

Management of coastal areas vulnerable to coastal erosion is complex due to varying land tenure, high recreational demands and values, competing interests in the land and irreversible coastal processes. Coastal erosion control measures or coastal defence is one of the adaptation strategy to combat this problem. Selection of appropriate methods of coastal defence strategy is the most important things and it will determine the success of that particular project's goals or objectives. Coastal defence strategy can be divided into two, curative measures and preventive measures. For curative measures, normally stakeholders will implement erosion control works on critical areas and for preventive measures, government or authorities will control the development in coastal zone with a minimum set back and identify optimum usage of coastline such as acting as a buffer zone. The combination of both curative and preventive measures is the worldwide recent approach by the authorities in coastal protection. In Malaysia, our government now introducing integrated approach concept in coastal management. They are combining a few components including best practice management, sustainability engineering, environmental friendly and more viable concepts to strengthen the coastal defence strategy and approach. For example, Integrated Coastal Zone Management (ICZM) and Integrated Shoreline Management Plan (ISMP) are the two models of management plan that now implementing in our country, under jurisdiction of DID and Ministry of Natural Resource and Environment (NRE).

In general, coastal erosion control measures or coastal defence can be categorised into two, hard engineering protection method and soft engineering protection method. However, in the case of coastal erosion mitigation strategy, we still need to consider the implementation of hard and soft engineering protection methods based on urgency, current conditions and needs (short/middle/long term curative measures). As discussed in Chapter 1, hard engineering protection method normally prevent retreat of shoreline, prevent loss of sediments or trap sediments, wave attenuation and wave energy dissipation. However, soft engineering protection options aim to dissipate wave energy by mirroring natural forces and maintaining the natural coast topography (Chiwan, 2016). Some of the coastal protection strategy approach that

can be considered by the stakeholders and authorities are summarized in Table 2.1 and illustrated in Figure 2.11.

Table 2.1 : Some of the coastal protection strategy approach (source : DID, 2009)

	Type	Description	Method
1	Do nothing	Allow the beach to change without intervention (usually applied to areas with insignificant or no economic importance)	Allow natural changes
2	Adaptation and retreat	Modify current usage or relocation of existing population or activities	houses on stilts, floating houses and resettlement
3	Beach nourishment (soft engineering)	Fill up the beach with similar material	Beach nourishment, new technologies
4	Combination and new technologies (hard and soft engineering)	Combination of above methods or innovative methods	Nourishment and groynes, geotextile bags, eco-engineering techniques
5	Stabilization	Reducing the erosion rate by slowing down the loss of sediments	Groynes, breakwaters
6	Armouring	Defending the shoreline at its current position	Revetments

They need to plan and choose the right strategy in implementing this approach based on the categories outlined in NCES as described in previous chapter (under topic 1.1.1). Advantages and disadvantages of these engineering protection methods can be evaluated based upon their function, safety, durability, economy, constructability, environment impacts, landscape condition, recreation function and ecological impact (Chiwan, 2016).

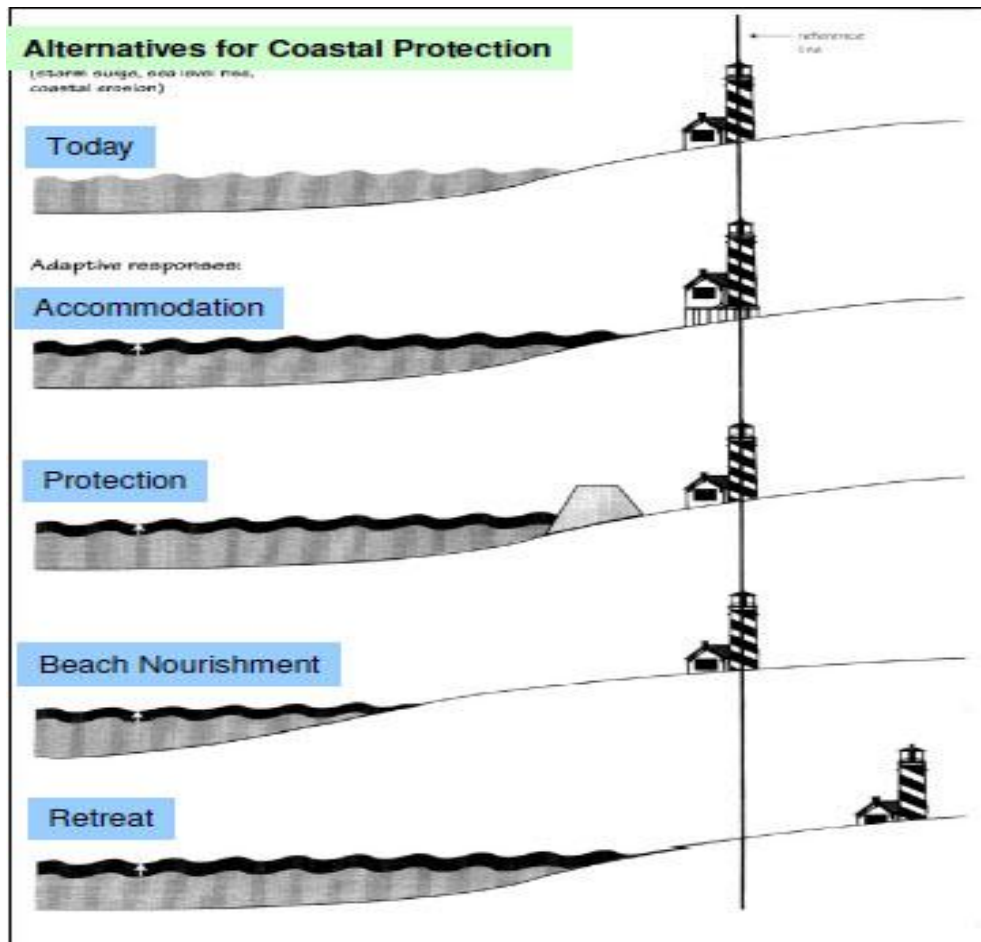


Figure 2.11 : Alternatives for coastal protection strategy (source : DID, 2009)

2.5.1 Coastal Defence Structures in Malaysia

In Malaysia, DID is the only custodian agency that tasked by the government to implement the coastal erosion control projects. The Government has set up the Coastal Engineering Technical Centre (now it is known as the Coastal Zone Management Division) within the Department of Irrigation and Drainage (DID) in 1987 to implement coastal erosion control program for the whole country. Since that, there are so many coastal erosion control programs including the coastal erosion mitigation measures projects that have been taken by DID. The program involves two strategies, long-term and short-term strategies. The short-term strategy involves construction of erosion control projects and the long-term strategy involves improving coastal zone management in an integrated manner so that incidences of coastal erosion will not increase.

As explained before, there are two methods used in the implementation of coastal defence engineering projects by DID, through hard engineering and soft engineering protection methods. Among the coastal erosion mitigation measures projects that have been undertaken via hard engineering protection methods are revetments (i.e. rock armour revetment and concrete revetment such as Sauh, Tetrapods, Core-Loc and Accropods), groynes, breakwaters and concrete blocks (i.e. Labuan Blocks,) while for soft engineering protection methods that commonly implemented include beach nourishment, mangrove replanting, sediment filled geotextile breakwaters (i.e. geotube and soft rock) and beach drainage system (i.e. Beach Management System (BMS) and Pressure Equalization Module (PEM)). Most of these structures will be described in more detail in the next sub-topics.

Revetments are onshore structures constructed with the principal function of protecting the shoreline from erosion (DID, 2009). Since 1987, this structure is the most widely used by DID in addressing the coastal erosion problem in our country and so can maintain our shoreline. Revetments are normally constructed parallel to the beach to limit or halt landward erosion by receiving the impact of waves and to prevent coastal flooding due to storm surge (Silverster and Hsu, 1997). Revetment structures are flexible and typically consist of armour rock or cast concrete blocks. Revetments rest on the surface being protected and depend on it for support. A typical cross-section of rock (quarry stone) revetment are shown in Figures 2.12 while Figure 2.13 illustrate two types of the rock armour revetments built by the DID.

Figure 2.12 : Typical cross-section of quarry stone revetment (source : DID, 2009)



Figure 2.13 : Basalt revetment in Melaka (left) and quarry stone revetment in Kedah (right) (source : DID, 2009)

The design of the structures is intended to create wave breaking and loss of energy during the run-up process, limiting the reflection of wave energy from the beach (Robert and Robert, 2004). They are relatively light structures and are well suited to locations free of heavy wave attack. The design of a stone revetment may consist of two or more layers of stone with the upper, larger stones providing stability against wave attack (Robert and Robert, 2004). According to The Shore Protection Manual by U.S. Army Corps of Engineer (1984), the stone sizes must be graded to ensure that the lower, smaller stone does not wash out through the upper layers. Voids within the revetment permit quick drainage over the surface of the slope and hence reduces wave run-up. Properly designed and constructed revetments are long life structures and require little maintenance. The stone size of armour layer is relatively bigger and heavier than under layer stone, approximately 1 tonne. More weighted stone should be used in order to protect the shoreline and structure from collapse for long term protection (Amri, 2010) especially for toe and scour protection. Typically, the stone is underlain by a geotextile fabric to prevent the base sand on which structure is built from washing out (Robert and Robert, 2004).

There are five typical failure mechanisms for coastal revetments; inadequate armour layer design for wave action, inadequate under layer, flanking, toe scour, and overtopping splash (FHWA, 2014). A revetment's strength depends on the underlying soil. If wave action can remove that soil via any mechanism, the revetment will collapse. Each of the four typical failure mechanisms involves failure to protect that underlying soil. During construction, several cases of structure failure always occur in muddy coast area due to the low bearing capacity and settlement problem. But to overcome these problems, DID come out with the solution of constructing a basal reinforcement

underneath the revetment structure by using some sorts like bakau piles, coconut piles, bamboo foundation and Eco-friendly Raft Pile Foundation System (ERP System).

However, it has been observed in recent years by the DID that when revetments are built on sandy shorelines, the fronting beach gradually reduces in width. According to R. G. Dean (1986), this scenario happened because coastal armouring is designed to protect the upland, but does not prevent erosion of the beach profile seaward of the armouring. Thus an eroding beach will continue to erode. If the armouring had not been placed, the width of the beach would have remained approximately the same, but with increasing time, would have been located progressively landward. According to DID Manual, hardening the stretch of the shoreline, it can cause increased erosion along the shoreline down drift to the erosion. This is because the stretch of shoreline that is protected is no longer contributing sediment to littoral drift. This deficit needs to be made up by erosion of the adjacent shoreline. This has been observed in Miri where the hardening of the shoreline by revetment to the north of the Miri refinery has resulted in an increased rate of erosion along the shoreline from another facility (DID, 2009). Sea level rise is another factor that potentially give severely impact to the stability of this structure which caused the overtopping problem. It was suggested by Amri (2010) that the height of the structure should be design higher (i.e. projected sea level rise value should be considered in the design criteria accordingly with the life span of the revetment structure) and by introducing wave wall on the top of crest structure can be solved and prevent the over topping problem. It was suggested by Robert and Robert (2004) that, in designing revetment, the crest elevation should be sufficiently high to prevent excessive overtopping during high waves, and the toe elevation should be low enough to prevent undermining by scour action.

2.5.1.2 Concrete Armour Revetments

Concrete armour revetments have a quite same functions with the rock revetments, but the difference is the armour units itself was produce by concrete products with a special design like a Flex-Slabs, Tetrapods, Core-Locs and Accropods (refer to the Figure 2.14) or others product that available in the market. These types of concrete revetment also usually used as the armour layer for breakwater and groyne, especially in areas that are difficult to get a source of quarry stone.

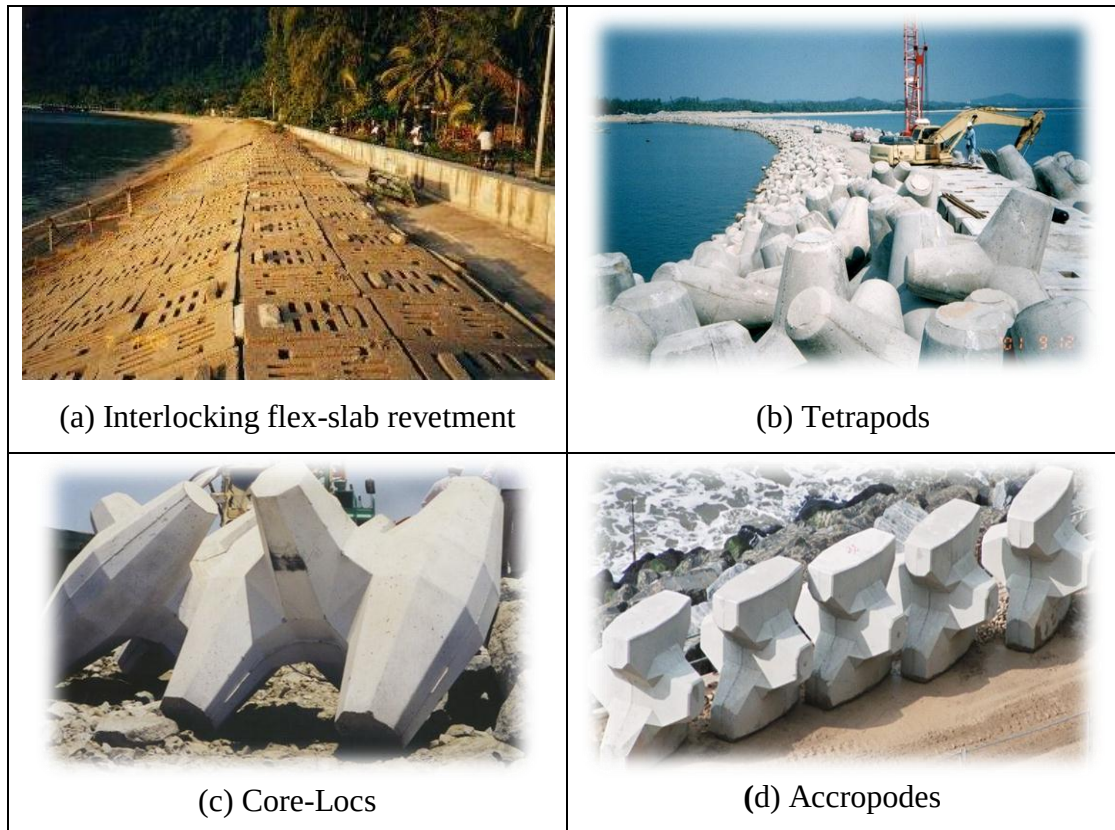


Figure 2.14 : Four types of Armour units that usually used as concrete revetment (source : DID, 2009)

Almost all concrete armour units revetment rely on their physical interlocking (between individual blocks) design for stability. The performance of interlocking blocks in severe coastal environments has not been good. According to d'Angremond, ven der Meer and van Nes (1994), in the late seventies, eighties a number of large breakwaters (consisted of slender concrete armour units like tetrapods) in European Countries was severely damaged due to the breakage of the amour units. A minor damage can lead to failure of a large portion of the revetment. One case of the interlocking flex-slab revetment structure failure has been reported after being hit by large waves at Pantai Teluk Lipat, Dungun, Terengganu during northeast monsoon in 2015 ago (refer to Figure 2.15). Problems with concrete block revetments in coastal situations often develop at the ends of the revetment where the blocks abut a more rigid structure and even a small amount of settlement can affect the aesthetics of block revetments (FHWA, 2014).



Figure 2.15 : The failure condition of interlocking flex-slab revetment after being hit by big waves at Pantai Teluk Lipat, Dungun, Terengganu (source : DID, 2009)

2.5.1.3 SAUH Revetment

In 1987, the DID produced the simplified armour unit ‘H’ or SAUH as an experimental concrete revetment for escarpment and bund protection. SAUH revetment is also classified as interlocking concrete armour units (refer to Figure 2.16).



Figure 2.16 : SAUH Revetment that was constructed in Selangor Coastline (source : DID, 2009)

Light but well interlocked, the SAUH performed well on the weak soils of the Selangor coastline. At Sungai Burung, SAUH was used in combination with mangrove replanting in what was arguably the first attempt at combining a biological component with a structural coastal protection measure. This was one of the recorded successes of mangrove replanting on an eroding shoreline and highlighted the significant role played by a protective hard structure in the process (Nor Hisham, 2005). Without protection from the waves, the roots of young mangrove saplings are unable to hold on to the substrate.

2.5.1.4 Groynes/Groins

Groynes or groins are narrow structures, usually straight and perpendicular to the preproject shoreline with the aim of interrupting the littoral drift (DID, 2009). It have served traditionally to prevent shoreline erosion and still being used until now in many places over the world. Groynes normally constructed by using rock, concrete, steel pile, wood, gabion or whatever structure including soft engineering method like a geotextile mattress such as geotube or geobag sand mattress, as long as it's built as a vertical barrier extending directly offshore (Robert and Robert, 2004), (refer to Figure 2.17).



Figure 2.17 : Various types of groynes materials (source : internet)

The most popular material is still rock as the material is flexible. According to DID Manual, the important features of a rock groyne are as follows (refer to Figure 2.18):

(i) Tail

The tail of the groyne must be constructed beyond the level of the wave uprush. This is to prevent groyne from being eroded from behind and eventually being detached from the shoreline.

(ii) Trunk

The trunk should be sufficiently high from the existing beach level to trap the sand. However, the trunk should not be too high or else it will obstruct the view and affect the aesthetics of the beach. Normally the crest of the trunk should not be more than 1 to 2 meters above the existing beach level. The base of the trunk should be sufficiently deep to prevent loss of material from underneath the groyne.

(iii) Head

The head of the groyne should be massive and strong enough to withstand the impact of the waves as most of the wave energy will be concentrated at this point. The structure must also be flexible as there will be a lot of beach movement at this location.

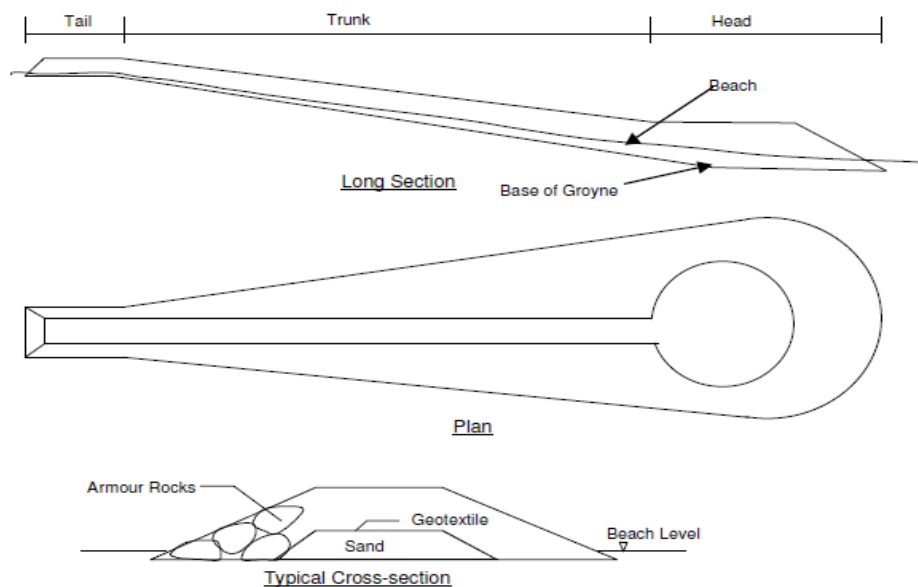


Figure 2.18 : Typical design of rubble mound groyne (source : DID, 2009)

Groynes are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due to primarily to a net long shore loss of beach material. Groynes function only when long shore transport occurs. The effect of a single groyne is accretion of beach material on the up drift side and erosion on the down drift side;

both effects extend some distance from the structure. The impact is very much dependent on the magnitude of the littoral drift and the direction of the predominant waves (DID, 2009).

Groynes are usually constructed in a series or simultaneously (DID, 2009), namely a groyne system. Consequently, a groyne system results in a saw-tooth-shaped shoreline within the groyne field and a differential in beach level on either side of the groynes (refer to Figure 2.19 & 2.20). There are various types of groyne's shape could be designed by coastal engineers like a I-shape, T-shape, L-shape, bending shape or curve shape, depends to the site condition.

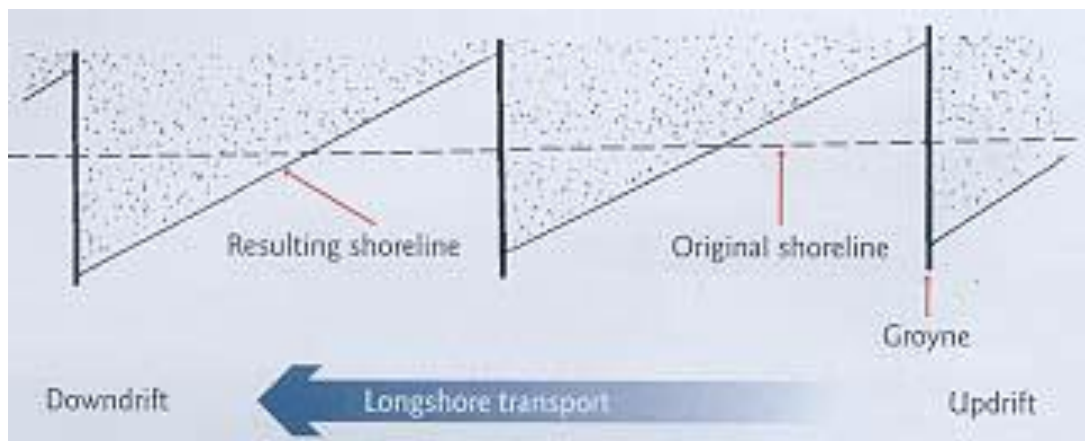


Figure 2.19 : Schematic diagram of the groyne's function (source : USACE, 1984)



Figure 2.20 : Groyne Field at Tak Bai, Thailand (source : DID, 2009)

Construction of groynes along shore to control erosion help to trap the long shore sediment and stabilised the beach requires understanding of the local sediment transport condition. Like the other hard engineering structures such as revetments or breakwaters, groynes construction also will have a direct impact on morphology changes to the adjacent coastline. It is very important for implementing agency like DID to conduct a comprehensive study before starting a project. Usually, initial stage of the coastal defence project, they will do a proper study and analysis such as feasibility study, hydraulic study and sediment transport analysis before they start a design and construct the groyne. The detail study of these all kind of coastal defence structures like groynes, revetments and breakwaters (in term of stability, integrity, effectiveness, option and etc.) could be conducted either by using a numerical modelling study (software application) or physical modelling study in the coastal basin facilities or combination of both numerical and physical modelling.

2.5.1.5 Breakwaters

Breakwaters are structures placed on the foreshore or offshore to create calm areas landward of the structures (DID, 2009). It has features similar to revetments, but being placed away from the shoreline. Breakwaters are built to reduce wave action in an area in the lee of the structure. Wave action is reduced through a combination of reflection and dissipation of incoming wave energy.

Breakwaters can be classified into two main types, sloping-front and vertical-front structures. Sloping-front structures are in most cases rubble-mound structures armoured with rock or concrete armour units, with or without wave wall superstructures. Vertical-front structures are in most cases constructed of either sand filled concrete caissons or stacked massive concrete blocks placed on a rubble stone bedding layer. In deep water, concrete caissons are often placed on a high mound of quarry rock for economic reasons. Figure 2.21 show us a typical cross section of emerged rubble mound breakwaters.

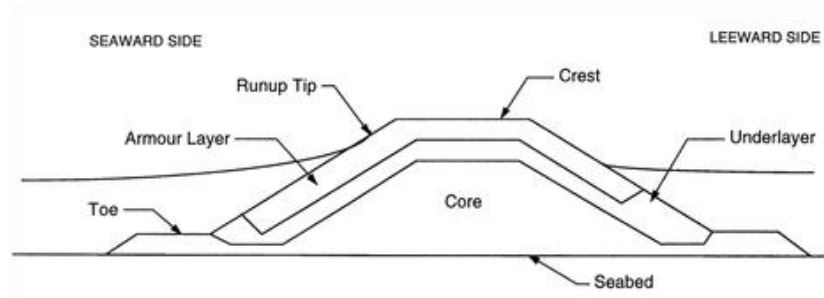


Figure 2.21 : Typical cross section of emerged rubble mound breakwaters (source : Palmer and Christian, 1998)

Since breakwaters are used to create calm areas landward of the structures, they are mainly used to create harbour areas. When used for harbours, breakwaters are constructed to create sufficiently calm waters for safe mooring and loading operations, handling of ships, and protection of harbour facilities (DID, 2009). Breakwaters also built to improve maneuvering conditions at river mouth entrances and to help regulate sedimentation by directing currents and by creating areas with different levels of wave disturbance (refer to Figure 2.22).



Figure 2.22 : Breakwaters at Sungai Marang river mouth, Terengganu (Source : DID, 2009)

According to DID Manual, the wave heights that break on the structure will normally be bigger, resulting in much larger armour sizes. The size of the armouring at the toe may be smaller if waves are not expected to break on the toe. Some breakwaters may be designed to allow for wave overtopping, in which case, the back slopes of the breakwater will also be armoured to prevent damage due to the flow of the water over

the crest. If the waves are expected to break on the crest, the crest may be strengthened with large armour units. In some cases, the crest may also be widened to prevent armour units from being dislodged. The ends of the breakwater are particularly vulnerable to damage as the degree of the interlocking of the armour units are not high as if the units are placed on the trunk of the structure. Furthermore, wave energy, due to the action of refraction and diffraction, tends to concentrate at this point. Thus the armour units are usually larger at the ends of the breakwater or the slope of the breakwater at the ends are usually made gentler.

Breakwaters can also be used to protect the shoreline by reducing the wave energy arriving on the shoreline (DID, 2009). The reduction in wave energy reduces the long shore drift and onshore-offshore sediment movement, resulting in deposition in the calm areas. This deposition is called a tombolo. Figure 2.23 shows an example of offshore breakwater at Kertih constructed to create a calm area for ships to anchor.



Figure 2.23 : Offshore breakwater at Kertih, Terengganu (source : DID, 2009)

The tombolo was created along the shoreline. The effect of this tombolo is the erosion occurred to the south (down drift) of the tombolo. In order to prevent this erosion, a series of groynes were constructed.

As shown in Figure 2.22, at Sungai Marang river mouth, a pair of shore-connected breakwaters was built to keep the river mouth open for navigation and flood mitigation. The effect of this construction was to create deposition to the south (up drift) of the breakwater and erosion to the north (down drift). This is a classic example of the impact of a shore connected breakwater interrupting the littoral drift. Deposition in the calm areas landward of breakwaters can also cause problems. This situation occurred at Merang, Terengganu (refer to Figure 2.24). A pair of breakwaters was constructed to create a calm area for ferries to berth. However, the calm area promoted deposition of sediments that was moving in the littoral drift. This situation has caused Merang jetty cannot be used and utilized since it was completed until now. This abandoned structures also become a burden and caused losses to the government as well as tourism industry.



Figure 2.24 : Deposition of sediment in front of Merang Breakwaters and jetty
(source : DID, 2009)

2.5.1.6 WABCORE

Breakwaters can also be designed as a submerge wave breaker instead of emerge structure, but very rare being used in Malaysia. Submerged, or reef breakwaters are design on the concept that shallow depth over the structure will induce wave reflection, breaking and turbulent energy dissipation within the structure, leading to reduction in

wave height shoreward of it (Robert and Robert, 2004). NAHRIM has produced one product of submerge breakwater with dual function, namely WABCORE (wave breaker and coral restorer). WABCORE is a concrete artificial reef and submerge breakwater with a simple trapezoidal design of narrow crest structure block (refer to Figure 2.25). Several studies have been conducted by NAHRIM to evaluate the performance and effectiveness of this product. According to Safari, Othman and Melini (2016), WABCORE shows tremendous performance for wave transmission, the wave energy dissipated up to 65% in the physical modelling test. The attenuation of wave energy has given promising potential of submerged breakwater to protect vulnerable coastlines from erosion, and thus protect infrastructure and residents in the shoreline settlement without destroying beach aesthetics.



Figure 2.25 : Submerged 3-layered WABCORE breakwater and artificial reef with narrow crest arrangement at Panuba Bay, Tioman Island, Pahang (source : Mohd, 2013)

This narrow crest submerged breakwater also acts as artificial reef to protect and conserve marine biology as well as enhance the marine ecological environment (Safari, Othman, Melini, Azuhan, Fauzi and Icahri, 2016). Additionally, WABCORE artificial reefs deployed at Panuba Bay, Tioman Island exhibit the potential of establishing new habitat for corals and other sessile organisms (Fauzi, Ang, Saiful and Kamarul, 2013). Apart from that, according to Fauzi et al. (2013), WABCORE have also depicted a positive and encouraging potential in the conservation of natural marine resources as the artificial reefs site has various population of corals, ascidian, anemone, coral reef fishes and invertebrates. One more advantage of the submerged breakwater is that the structure is not visible and thus does not disturb the view of the sea but it may create a navigational hazard unless well marked (Robert and Robert, 2004).

2.5.1.7 Labuan Blocks

Apart from the SAUH described earlier, the Labuan Blocks is another innovative form of coastal protection structure produced by the DID in recent years. Labuan blocks is not really a sea wall or concrete revetment structure, but this kind of coastal protection blocks can be categorized in between both of them. The first generation of Labuan Blocks, coined after their first installation site, are simple mass concrete blocks designed in-house based on basic principles of material retention, scarp and toe protection (Tan, Hisham and Ong, 2006). Essentially designed to protect scarps on the backshore (which occasionally occur after major storms), the blocks can be arranged as a low stepped- wall or in the form of slope-faced seawall (refer to Figure 2.26).



Figure 2.26 : First generation Labuan Blocks as vertical cubic blocks-Pancur Hitam, Wilayah Persekutuan Labuan (source : DID, 2009)

Additional modifications in the form of trapezoidal buttons have been introduced to the original smooth-faced design to reduce run-up for the second generation (refer to Figure 2.27).



Figure 2.27 : Second Generation of Labuan Blocks as sloping “mattresses” at Taman Robina, Seberang Perai Utara, Pulau Pinang (source : DID, 2009)

The purpose of Labuan Blocks is to provide short term (3-15 years) protection from backshore erosion by absorbing wave energy along the dune face (Tan et al., 2006). Their application is restricted to the upper part of sandy beaches, since they are not sufficiently durable to withstand regular direct wave action. As they are concrete structures placed at backshore, they will tend to trap windblown sand and sediment transport and allow the growth of vegetation under favourable conditions. This only applies to sloping structures.

According to Tan et al. (2006), Labuan Blocks can be placed as sloping “mattresses” or as near vertical cubic blocks. The latter are intended for bank or cliff stabilisation and are not normally suitable for use in shoreline situations. Labuan Blocks (backshore) are generally preferred to rock revetment (foreshore) in coastal environments being less reflective of wave energy and more stable. Sand is also better able to accumulate on Labuan Blocks, potentially softening their appearance.

Concrete Blocks should be placed as a sloping revetment as shown in Figure 2.28. Near vertical walls are more likely to suffer toe scour and structural collapse as they are less able to dissipate wave energy during storm wave attack.

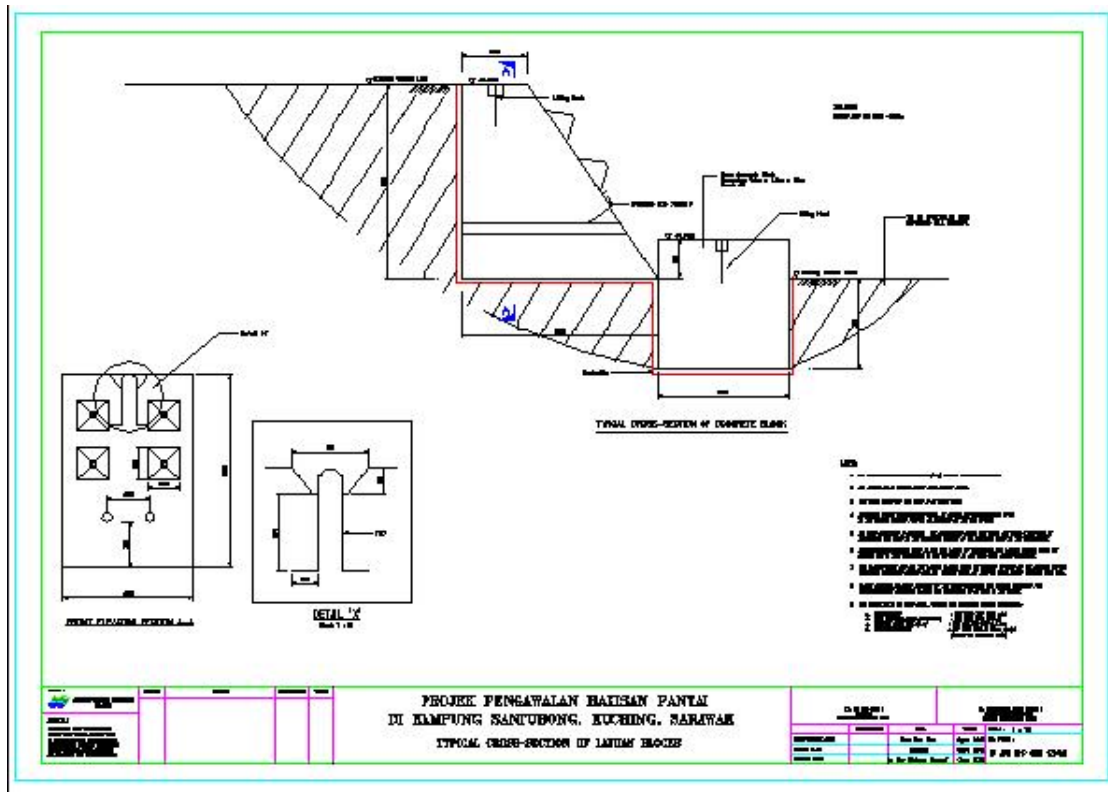


Figure 2.28 : Drawing of Labuan Block arrangement (source : DID, 2009)

Nadia (2012), suggested for suitable height arrangement and improvement on existing bed protection for this structure in order to become more effective and able to last longer. They are also much more obtrusive to the dune landscape and will not become buried by new fore dunes. Structure face slopes are a compromise between flatter faces that absorb more wave energy, and therefore suffer less toe scour, and steeper faces that give the structure a smaller footprint. A slope of 1:1.5 is a reasonable compromise, and is in keeping with natural dune slopes (Tan et al., 2006).

According to Tan et al. (2006), the approximate limits of wave run-up can be established by observing and recording the location of the strand line over Spring tide periods during both monsoon and more normal wave conditions. The toe of a freshly eroded dune face is normally just below the run-up limit of the most recent severe sea. During placement, regarding of the beach/dunes may have to be carried out so as to adequately bed the blocks. A suitable geotextile should be used to prevent the underlying sand from being washed out through the blocks. Edge details should be carefully addressed to prevent exposure of unsightly lengths of textile. Landward edges can be buried to fix the geotextile during Labuan Blocks placement. Seaward edges should be trimmed or firmly secured. The placing device for all the concrete blocks

shall be lowered to rest on the ground before releasing the concrete blocks and no blocks shall be dropped from height greater than 0.5 m (Tan et al., 2006).

Labuan Blocks are concrete mass blocks, cast in-situ, often with locally available material and therefore have a relatively low capital cost (approximately RM1,500 per meter run). Labuan Blocks provide a short term alternative to rock armour structures in areas where large rocks are not available at an acceptable cost, or where long term protection is not appropriate and there is no space to build huge coastal protection structure (like an island). Because they are portable and removable, they can be easily transported to any places, reducing the cost of coastal erosion control project. Sandy beach sites suffering periodic moderate to severe erosion where backshore assets are at risk is the appropriate locations to install this product. They are very useful and quite effective for backshore protection (refer to Figure 2.29). Well placed Labuan Blocks provide reasonable fixed defences, but have a limited life of 3-15 years due to deterioration of the concrete. It is also useful solution where armour rock is considered inappropriate or too costly. It can be buried by sand and vegetation with permeable face absorbs wave energy and encourages upper beach stability. However, same like other hard engineering structures, Labuan Blocks will also impair the aesthetic and scenic beach area with the appearance of these bulky concrete blocks.



Figure 2.29 : Initial beach condition in year 2000 (left) and stabilized beach condition in year 2005 (right) after placement of Labuan Blocks as a coastal protection control measures at Kiamsam Beach, Wilayah Persekutuan Labuan (source : Jurutera Bulletin April 2006, BEM)

2.5.1.8 Seawalls

Seawalls are vertical structures built along the shoreline to prevent erosion of the shoreline (DID, 2009). The walls are usually made of sheet piles, concrete, timber or rubble pitching and usually designed as retaining walls (refer to Figure 2.30 and 2.31). We can easily find this type of structure along the beaches in coastal towns worldwide because it is widely used as a coastal protection a long time ago. Seawalls protect the upland by preventing wave attack (Robert and Robert, 2004). According to Robert and Robert (2004) also, seawalls are most often vertical walls fronting a bluff or other highland with the beach or water on the opposite side.

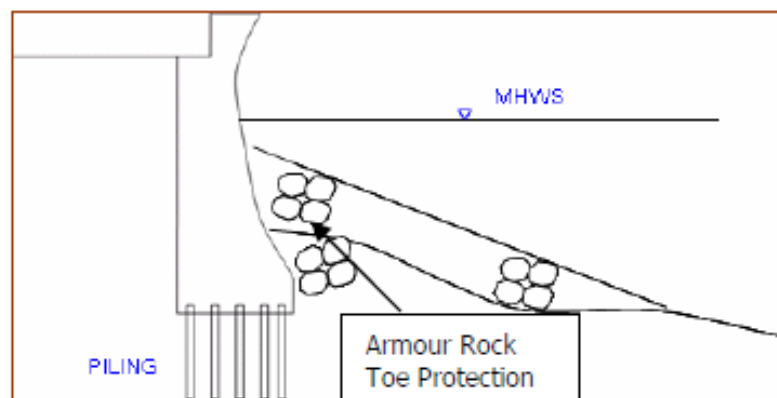


Figure 2.30 : Example of typical section of seawall (source : DID, 2009)



Figure 2.31 : Seawall with run-up deflector made to blend as part of the landscape at Gurney Drive, Penang (source : DID, 2009)

However, a vertical or near vertical wall can cause extremely high wave run-ups. Vertical walls can also cause wave reflection, causing a nearly doubling of the wave height where the crest of the incident wave coincides with the reflected waves (DID, 2009). Seawalls can cause erosion of the foreshore due to the incident waves that

are reflected from the walls. This increase in the wave height due to the meeting of the crests of the incident and reflected waves can cause agitation of the foreshore material, resulting in the erosion of the foreshore. This will in turn cause undermining of the toe of the seawall, resulting in overturning of the wall. Many seawalls have failed this way. Thus, where possible, this type of construction should be avoided. It is therefore important to provide toe scour protection and deep foundation for stability in the design of seawall. Other seawall designs, usually constructed of concrete, have curved shapes to deflect the incident waves and reducing scour at the toe of the wall (Robert and Robert, 2004).

2.5.1.9 Beach Nourishment

Beach nourishment is a soft structure solution used for prevention of shoreline erosion. The placement of sand on beach to restore (or to build) it is referred to as beach nourishment or beach fill (Robert and Robert, 2004) and need a good sand source. Beach nourishment is also known as beach replenishment, beach feeding or beach recharge. Beach nourishment is a popular method in rehabilitating sandy beaches especially for additional recreational area purpose. This method however does not stop the process of erosion.

The design of beach nourishment projects takes into consideration the local rate of erosion, alongshore and cross-shore sediment transport, the natural beach slope, native and imported sediment grain sizes, wave climate and tidal levels (Nor Hisham, 2011). Material of preferably the same, or larger, grain size and density as the natural beach material is artificially placed on the eroded part of the beach to compensate for the lack of natural supply of beach material (DID, 2009). Typically, sand from offshore or onshore sources is placed on the eroding beach (Robert and Robert, 2004). It entails finding a suitable source of material that is compatible with, but not necessarily identical to the material on the beach to be nourished. It is often the most satisfactory means of protecting a shoreline as it provided the necessary reservoir of material that allows a beach to respond to wave and achieved equilibrium. It is not a permanent solution but the period for replenishment or re-nourishment of the beach is about 5 to 10 years (DID, 2009).

According to DID Manual, since beach nourishment works by replacing the sand that has been lost to the system, the coastal processes will eventually erode the

nourished beach to the line before the nourishment exercise. In some situations, this occurs at a rate faster than expected. The reasons for this can be several, as listed below:

- i. The beach line is at a more seaward position than before the nourishment, resulting in stronger littoral drift and stronger onshore-offshore movement than expected.
- ii. The wave climate may vary from year to year and there may be certain years where the wave climate is stronger than normal, resulting in a faster rate of erosion.
- iii. The sand used as the nourishment material is finer than the original beach sand, resulting in faster erosion rate.

Since the nourished beach is expected to be eroded away, it is clear that periodic re-nourishment of the beach is required. In areas where the littoral drift is causing loss of the beach material, replacing the lost material with sand is one option in coastal protection (DID, 2009). According Robert and Robert (2004), widening profile of beach nourishment will reduce the wave energy to the near shore and creating a sacrificial beach to be eroded during a storm. The beach fill might protect not only the beach where it is placed, but also down drift stretches by providing an up drift point source of sand (DID, 2009). This method is preferred if the beach is to maintain its natural characteristics and the movement of sediments along the shoreline is not to be interrupted.

Beach nourishment material is usually placed such that the beach is extended seaward and the initial underwater slope is substantially steeper than would be associated with an equilibrium beach profile (DID, 2009). Upon the completion of placement of beach nourishment, the profile will commence to spread out laterally to the adjacent beaches. Since the waves are the mobilizing factor which cause the spreading out of the nourishment, the performance of beach nourishment is quite sensitive to the wave energy level at the project site as well as the alongshore length of the project. The nourishment material grain size relative to the native is an important determinant in the performance of beach nourishment as well. Specifically, because coarse sands are naturally associated with steeper slopes than fine sands, if the nourishment sand is coarser than the native, the additional dry beach width after equilibration will be substantially greater than if the nourishment sands were finer than the native.

Beach nourishment is usually more expensive than revetments (approximately RM5 million per km). However, if access to the beach and its aesthetic quality is more important and with the increasing commercial, residential, recreational and environmental values and investments along the shoreline, beach nourishment may become a much preferred options (DID, 2009). Important tourist beaches such as Port Dickson and Pantai Cahaya Bulan, Kota Baru, Kelantan have been protected using beach nourishment regarding to this reason (refer to Figure 2.32).



Figure 2.32 : Beach nourishment project in Port Dickson. Left figure is the view of shoreline before the project started while the right figure shown that the view of the new beach formed just after the project completed. (source : DID, 2009)

The primary environmental considerations for beach nourishment are the nourishment sand characteristics relative to the native (DID, 2009). The nourishment sand, if poorly sorted than the native sand, may thus contain a greater proportion of fine material which can cause two adverse effects to the environment. The first is during placement when silt and clay size particles remain suspended, it will increase a turbidity and can reduce light penetration, interfere with respiration of fish, and benthic flora and fauna including coral. Thus silt curtain, sand washing and close monitoring of the timing of placement with the tide condition are some of the measures that can be considered to mitigate the adverse impact. The second is through a partial weak cementation of sand grains together, resulting in a beach that is less suitable for sea turtle nesting. This can usually be improved by tilling the beach surface with normal agricultural equipment.

2.5.1.10 Mangrove Replanting

Mangrove forest act as buffer zone to the coastline and can be considered as natural coastal defence. Behind the mangroves are usually agricultural areas that are protected by bunds from tidal inundation (Akhir, 1991). In Malaysia, coastal bunds have been built since the 1930's to protect agriculture land. Mangrove will attenuate and dissipate wave energy before it reaches the coastal bund and the agriculture land within. Wave energy reaching typically flat mangrove-fringed coasts is usually low allowing silt sized material to remain at or near the shore. Short fetches and depth limited wave approach directions of mangrove-fringed coasts limit wave energy reaching the shore. We have a good experience in the effectiveness of the mangrove forests to reduce the wave run up and disaster impact during tsunami event. In some areas of Indonesia, Thailand and Malaysia, mangrove forests saved lives and properties by acting like a giant dampener (Fogharty, 2005).

However, recently the acreage of mangrove forest is getting lesser due to logging as well as land clearing for development of residential, roads, townships, agricultural and aquaculture activities. Because of this reason, our government are very emphasize about mangrove replanting and become one of the national agenda to move forward (refer to Figure 2.33). The objective of mangrove replanting is to maintain or restored the mangrove line and prevent it from retreat especially in critical areas that will be affected by tsunamis such as West Coast of Langkawi and Penang, Kuala Kedah to Butterworth Coast and Tanjung Piandang, Perak (Aslinda, Lee, Azuan and Tayalan, 2010). It will also encourage the mangrove line to advance. This can be accomplished by forcing a reduction in wave and current scour in front of the existing mangrove line, and forcing an increase in the sedimentation rate. The main challenge in mangrove replanting is low survival rate due to the exposure of young bakau trees to the big waves, drift away by strong current, unsuitable species with local sediment and few others thing. According to Aslinda et al. (2010), mangrove survive well in areas where the significant wave height is less than 1 metre, yearly calm condition (more than 30% of the time) and mean suspended sediment is more than 300mg/litre. Mangrove replanting in areas that exposed to severe wave actions is not recommended unless some sort of temporary protection is installed in front of the planting area and all factors such as the climatic condition during the planting activities, wave actions, tidal levels, sea water

pollution and pest attacks be remedied so that the number of survival can be increased (Nor Aslinda et al., 2004).



Figure 2.33 : Example of mangrove replanting view in Malaysia
(source : www.themalaysiantimes.com.my/penanaman-pokok-bakau-mampu-tangani-fenomena-air-pasang/)

2.5.1.11 Geotextile Tubes

In recent decades, another method of soft engineering solution adopted in addressing the problem of coastal erosion is by using geotextile tubes. There a few product available in the market can be used as a geotextile tubes namely as geotube, sandbags, geobags, soft rocks and many more. Applications of geotextile tubes in sandy beaches were mainly to prevent coastline from further erosion and to encourage beach nourishment, however for the muddy coasts, it were used to assist mangrove rehabilitation and conservation (Siew et al., 2014). Other than that, geotextile tubes also can be used in the construction of other type's sea defence structures such as dune reconstruction, soft revetments, emerge or submerge breakwaters and groynes.

In Malaysia, the famous one is geotube that are always being used in coastal engineering works. Geotube is a sausage shape of large tube (greater than 2.5m in circumference) fabricated from high strength woven geotextile and typically filled hydraulically with a slurry of sand and water (refer to Figure 2.34).



Figure 2.34 : Geotube at Tanjung Piai, Pontian, Johor (source : DID, 2009)

An apron of geotextile is also designed together with geotube to protect the foundation of the main geotube from the undermining effects of scour (Tan et al., 2006). Scour can be present at the base of the geotube due to wave and current action. Scour aprons are typically anchored by a small tube at the water's edge or by sandbags attached to the apron.

Geotube breakwaters are widely use in mangrove replanting project in Malaysia. Geotube breakwaters are very helpful to help the establishment of the seedlings by protecting the young mangrove forest environment from wave attack (Aslinda et al., 2004). In the unlikely event that some small boats hitting the Geotube, it would be like running aground on a sandbar thereby posing no dangers to the boat.

In sandy coast area, sand bags are commonly as a temporary protection to combat the coastal erosion problem (refer to Figure 2.35). They are potentially most useful as a buried revetment under the dune face, where they will form a final line of protection after the overlaying sand has been eroded by storm waves (SNH, 2005).



Figure 2.35 : Sand bags at Pantai Penggorak, Kuantan (source : DID, 2009)

The placement of these impermeable sand bags is suitable for low to moderate energy sandy shorelines but this kind of geotextile tubes only provides for short term (less than 5 years) fixed line of defence. They are filled in-situ with local beach sand and therefore have a relatively low cost and burial of them may extend life. Sand bag structure can be placed without the need for costly equipment or skilled labour. It also can be used to shape any form of shoreline structure but will have a short life expectancy due to lack of resistance to physical damage like wave borne debris impacts, rapid deterioration of geotextiles caused by ultraviolet (UV) sunlight, exposed to the vandalism and public pressure. Even a single tear will affect the whole tube, so that damaged sand bags should be repaired rapidly to avoid failure of the structure.

The important design consideration about these geotextile tubes is the failures factor because of scouring effects at the toe of the structures. As structures are effectively impermeable they will not absorb wave energy and may cause local beach scour to accelerate (SNH, 2005). Proper design, methods of filling and methods of placing of these geotextile tubes during construction that recommended by the designer/manufacturer should be followed carefully to avoid the failures problem (refer to Figure 2.36).

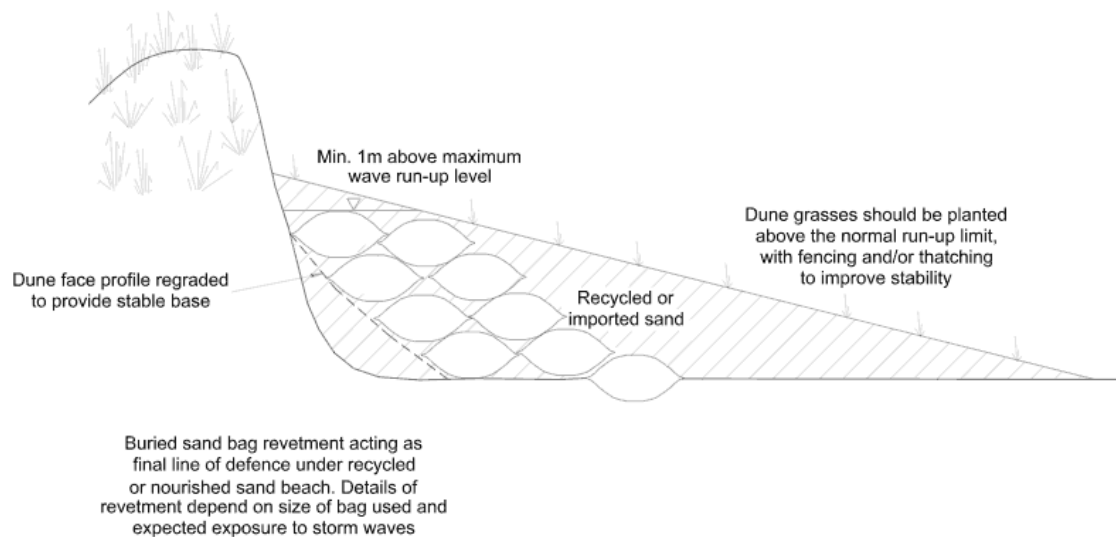


Figure 2.36 : Typical cross section of sand bag's placement and arrangement
(source : Scottish National Heritage (SNH, 2005))

According to SNH (2005), a few things should be taken into consideration during the construction of these sand bags as follow:

- i. The tubes should be fully filled with in-situ sand (by hand or by pumping in a slurry of sand and water) and closed properly
- ii. Prior to construction the dune face will need to be dressed to form a plane of slope (not be steeper than 1:1.5) on which bags can be laid evenly
- iii. Sand bags should be stacked against the dune face
- iv. The bags should be placed with their long axes parallel to the beach line
- v. A minimum thickness of 2 bag widths is recommended, with a thickness of 3 bag widths for the lowest course to reduce scour. The seaward line of bags should be treated as sacrificial
- vi. The toe of the completed revetment should be landward of the limit of normal wave run-up to avoid scour problems
- vii. The crest should be about 1 metre above the limit of run-up during storms to avoid overtopping damage to the dune face.

Bags intended to provide a buried revetment as a final line of defence should be covered by recycled or imported sand, stabilised by transplanted vegetation cover and fencing/thatching. If a good quality geotextile is used to make the bags and if regular recycling programme is maintained to make good seasonal erosion, then a life expectancy of 10 years might be assumed (SNH, 2005).

2.5.1.12 Beach Dewatering

Beach dewatering is another soft engineering method in coastal protection. It can be classified between a soft approach and a beach management one and has no environmental impact (L. Damiani et al., 2003). A significant difference in some of the newer innovations is that, rather than creating an energy dissipating barrier to waves, they instead improve the drainage capacity of the beach which then leads to more compact beach sediments (Nor Hisham, 2005). According to Grant (1984), on swash zone processes revealed that high water table under a beach accelerates its erosion and that low water table may lead to accretion. With this concept of saturated beach is more erodible than an unsaturated beach, so we need to create the condition of unsaturated beach all the way. This lead to the design of beach dewatering techniques to stabilise beaches (Nor Hisham, 2005).

The beach dewatering system works by locally lowering the groundwater table in the uprush zone of the sandy beach, making it more difficult for the down rush water to dislodge the sand from the beach as a higher fraction of down rush water percolates into the beach (DID, 2009). Furthermore the physical properties of the beach sand is strengthened due to decreasing in pore water pressure by the lowering of water table thereby making the beach more resistant against erosion. The extent of the effectiveness of this method is depends on various factors such as beach sand properties, waves condition, tide, groundwater table, erosion rate etc. In Malaysia, two innovations based on improving the beach drainage systems were installed by DID, the first one is Beach Management System (BMS) and the second one is Pressure Equalization Modules (PEM).

i. Beach Management System (BMS)

The Beach Management System (BMS) works on the principle that a saturated beach is more erodible than an unsaturated beach (Nor Hisham, 2005). When saturated, the density of individual grains of sand is less and there is also less inter-particle contact which makes the beach material prone to movement by up-rush and down-rush forces. Thus, if a beach is well-drained, particles are more closely packed and the beach sand is better consolidated.

The BMS is a system which combines drainage pipes and pumps to drain a beach as shown in Figure 2.37.

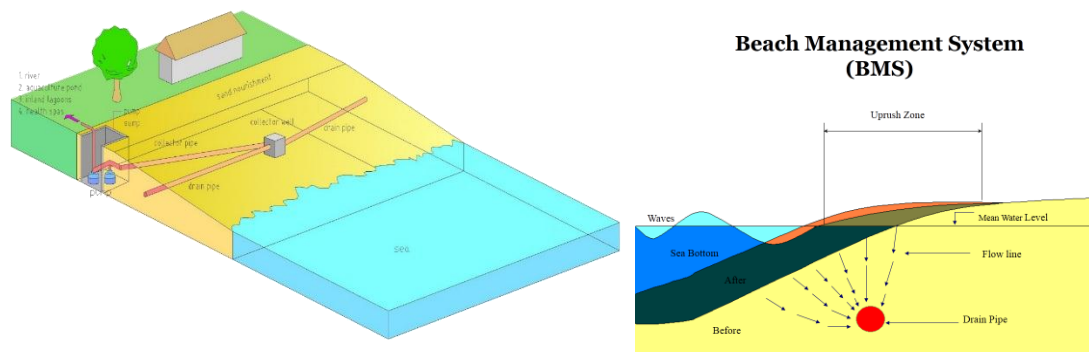


Figure 2.37 : Schematic Diagram of Beach Management System (BMS)
(source : DID, 2009)

A drainage system is installed under the beach face and parallel to the coastline to enhance beach accretion by artificially lowering the groundwater table (L. Damiani et al., 2003). Lowering of ground water table is achieved by pumping the water out of the beach through pipes laid in the beach. The buried shore-parallel drains of the BMS are in the form of perforated pipes wrapped in geotextile (Nor Hisham, 2005). Pumps, usually powered by electricity, are used to achieve this. The drains channel that collected water into a sump which flows into the pumping chamber built further to the backshore. Sensor-activated submersible pumps will start to pump the drained water out and away from the beach as soon as the water level in the chamber reaches a pre-set level. Hence is the drawback of this system, whereby the pump requires regular maintenance and the electricity used adds to the operation costs.

ii. Pressure Equalization Modules (PEM)

Pressure Equalization Modules (PEM) are hollow permeable tubes inserted vertically into the beach, resulting in a well-drained beach (Kenneth, 2006). The tubes and the modules are placed under the beach surface and each row extending from the dune to shoreline. The modules are not connected and no energy is used to operate the system. The PEM functions in the uprush zone of the beach where wave runs up the beach face and, upon reaching its limit, runs down and at the same time infiltrates into the bed (Nor Hisham, 2005) as shown in Figure 2.38.

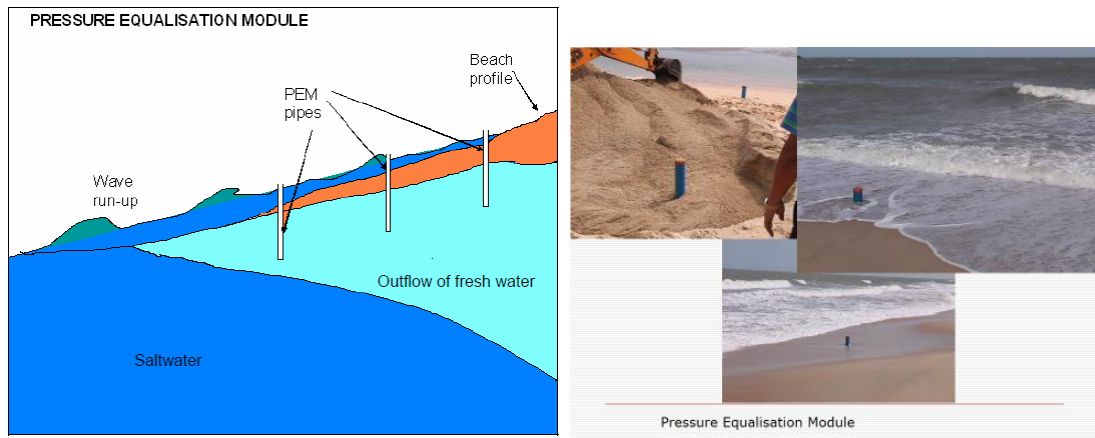


Figure 2.38 : Schematic diagram of Pressure Equalization Modules (PEM) and placement of vertical pipes buried (50 to 100m at 10m interval) (source : DID, 2009)

According to Nor Hisham (2005), the infiltration of seawater into the bed is limited by the existing level of groundwater. Hence, if the groundwater can be lowered, more water from the run-up can percolate into the bed and less will run down the surface dragging sediments with the flow. The lowering of the local groundwater table can be achieved with the PEM system which relieves the pressure within the beach by physically ‘connecting’ it with the atmosphere. In summary, the PEM increases vertical infiltration of uprush in the swash zone. Rows of perforated PVC pipes about 15 cm in diameter are installed normal to the shoreline in the area between the upper shore limit of the swash zone (area influenced by wave run-up) and the mean low water line with the distance of 50 to 100m at 10m interval. The pipes behave as a vertical filter which equalises groundwater pressure within the beach allowing increased circulation of seawater within the beach profile. The PEM pipe design is illustrated in Figure 2.39. Each PEM pipe is 2.0 m long with perforations measuring 400 to 900 microns (1 micron = 0.001 mm) and are placed vertically into the beach with the bottom end penetrating the phreatic line. Any water pressure build-up within the beach will be transferred into the pipes.

The PEM system is suited for littoral coastlines with a natural supply of sand from the coast (Nor Hisham, 2005). In cases where the natural sand supply has been depleted, beach nourishment is necessary. The presence of the PEM system causes the beach to retain more material on the foreshore area (between the low water line and the high water line) and form a more erosion-resistant beach. Its immediate affect will be in lowering the sediment transport capacity of wave down-rush. In the medium term,

the shoreline undergoes a change whereby sediment mounds will form normal to the shore along the position of the PEM pipes.

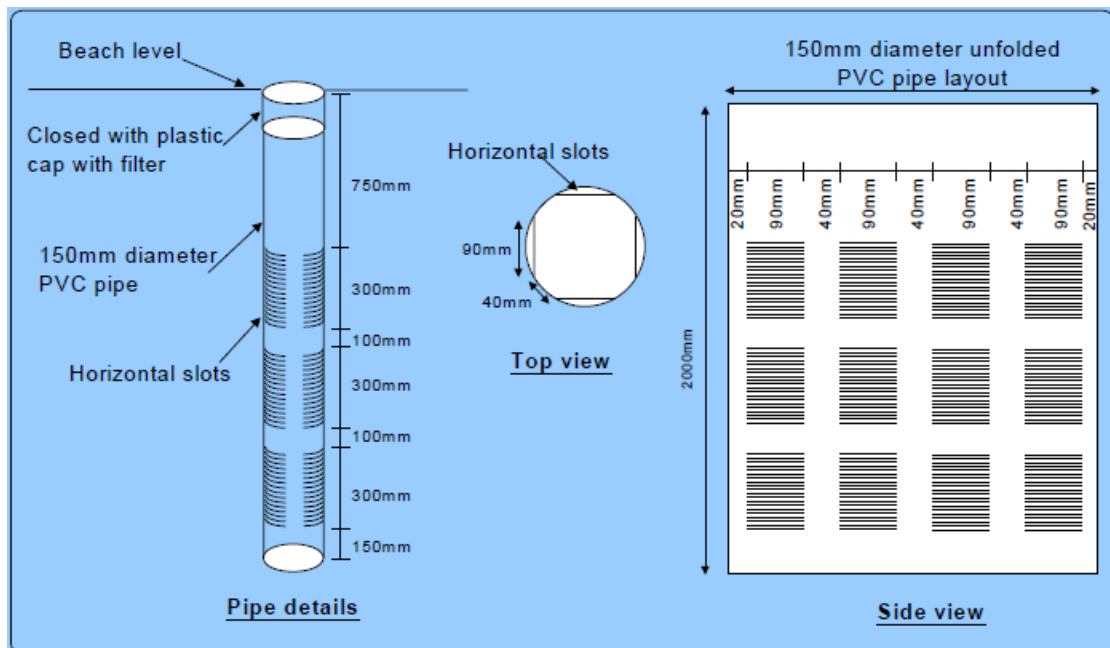


Figure 2.39 : Design of Pressure Equalisation Module Pipes (source : Ghazali, 2005)

The PEM systems can be also applied as a stabilisation system for artificial beach nourishment. This system is able to reduce water pressure in the beach which reduce erosion and prolongs the lives of nourished beaches (Kenneth, 2006). If enough sediment is available, significant accretion can be obtained in a few months. With a more erosion-resistant beach, beach nourishment replenishment intervals is expected to increase. For example, The PEM System that was used to drain a beach in a pocket bay in combination with beach nourishment in front of Hyatt Resort Hotel, Teluk Chempedak, Kuantan, Pahang has remain stable over a period of 2 years (Kenneth, 2006). It was observed that, the beach elevation has been raised a few metres from the nourishment line due to the natural accretion process since the PEM System has been installed. Another notable benefit is that the PEM System creates minimal disruption to the shoreline both in the physical and ecological sense (Nor Hisham, 2005). The construction phase of a PEM project, unless beach nourishment is required, uses very little machinery causing minimal disturbance to beach activities (Ghazali, 2005).

2.6 NEXC DEVELOPMENT

NEXC block is the coastal block for erosion and sedimentation control that was design and developed by NAHRIM since 2015. It will be used as the model and prototype in this study. This product is suitable to be used on sandy beach type condition as a coastal protection structure. Due to this reason, the severe eroded sandy beach at Pantai Batu 5, Port Dickson is chosen as the test site in this study.

There are few products similar like NEXC coastal block such as Labuan Block produced by DID. Although the shape of the NEXC product is similar to Labuan Block, NEXC block has dual function purpose with the introduction of holes at the body of NEXC block. The holes was designed with to allow the movement of the sediment or sand to the rear of the structure in order to promote natural reclamation of sediment as a result of dynamic wave action (Figure 2.40).

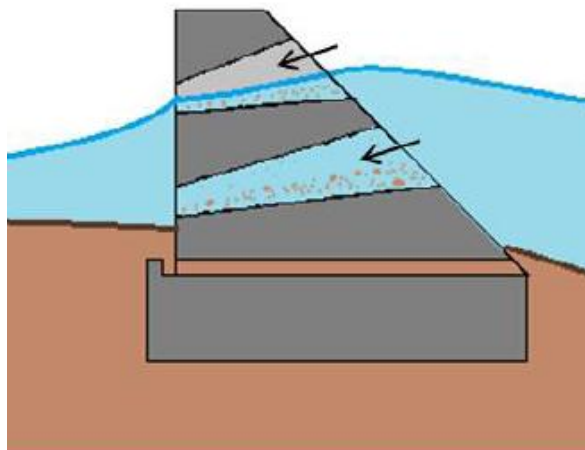


Figure 2.40 : The holes of NEXC block allow the movement of the sediment to the rear of the structure (source : NAHRIM)

This study will examine the potential of a coastal block structure that can be used as a coastal protection for coastal defence purpose in terms of hard engineering approach. The study will examine the stability and the effectiveness of NEXC Block System in reducing coastal erosion and also will identify the ability of the product to promote the sediment accretion in order to renourish the beach naturally.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

National Hydraulic Research Institute of Malaysia (NAHRIM) under the research, development and commercialisation (R,D&C) programme through Coastal and Oceanography Research Centre initiated the development of one innovative product for coastal protection and natural beach expansion. This product is known as NAHRIM Coastal Protection and Expansion (NEXC) Blocks (Figure 3.1) and are used as subjects in this study.



Figure 3.1 : NAHRIM Coastal Protection and Expansion (NEXC) Blocks
(source : NAHRIM)

This study focused on the evaluation of a few design options for this new coastal protection invention, experiments in the physical modelling laboratory as well as site deployment for the prototypes of this product. The overall activities of research methodology is shown in Figure 3.2.

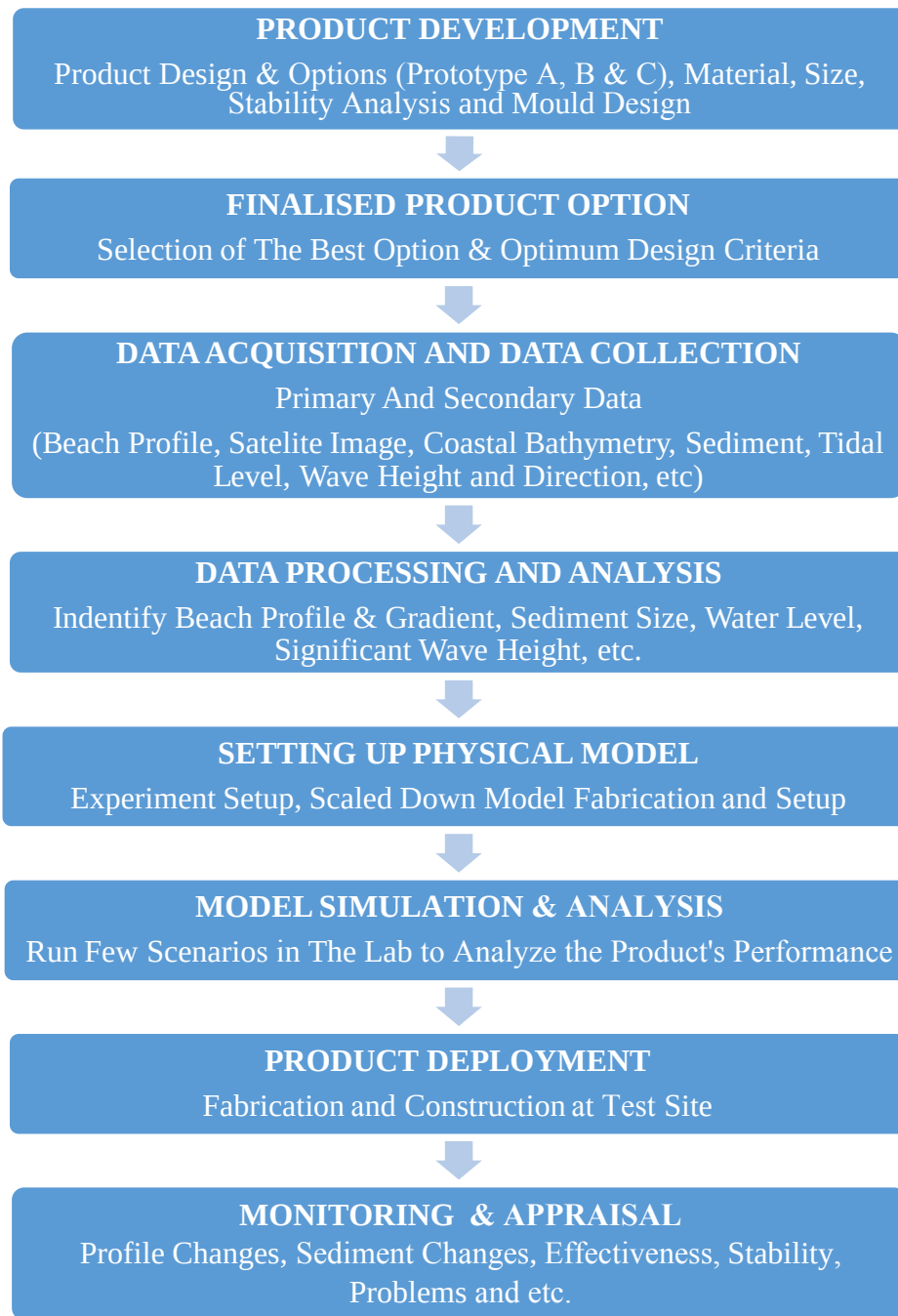


Figure 3.2 : Flow process for overall research's activities

The main objective of this study is to examine the effectiveness of NEXC Block System in reducing coastal erosion. It is called NEXC Blocks System because the deployment of these structure at sites are made in series and connected each other, parallels to the shoreline as shown in Figure 3.3. The other objective is to examine the stability of NEXC Block System especially due to overturning and sliding failures. This study also will identify the wave and sediment interaction with the NEXC blocks

structure in sandy beach condition whether it could help to stop or reduce the erosion during high tide and storm event especially in monsoon season.



Figure 3.3 : NEXC Block System at Pantai Batu 5, Port Dickson (source : NAHRIM)

During inter-monsoon season, beach accretion will happen due to net sediment supply from cross-shore current and long-shore current (littoral drift). With this constructive wave action scenario, the deployment of NEXC blocks system at site would be expected to help formation of beach landform by trapping the sediment (in front of and at the back of the blocks).

In this study, laboratory testing is carried at the Hydraulic and Instrumentation Laboratory (NAHRIM), whereas the deployment of NEXC blocks system is carried out at Pantai Batu 5, Port Dickson. Field data is collected through regular monitoring program on a monthly basis or as required (such as immediately after the monsoons). All these results are then observed and analysed.

3.2 PRODUCT DEVELOPMENT AND GENERAL DESIGN CRITERIA OF NEXC BLOCK

NEXC block is a semi-trapezoidal shape structure made of reinforced concrete, designed for coastal protection against the erosion as shown in Figure 3.1. It is purposely designed to tackle the Category 2 of coastal erosion problem. According to NCES, Category 2 erosion means shoreline is eroding at a rate whereby public property and agriculture land of value will become threatened within 5 to 10 years

unless remedial action is taken. In this study, the aim was to highlight the concept of combination both of the hard and soft engineering protection measures through the application of NEXC blocks system as coastal defence product.

NEXC block is quite similar to the Labuan block that was also designed by DID. NEXC block is the second coastal protection product that was invented by NAHRIM after WABCORE, the submerge and reef breakwater as discussed in Chapter 2. Same like Labuan block, NEXC block also was designed for short term or intermediate term of coastal defence and protection. The 15 years return period of big wave event is consider enough for the design purpose.

According to PKPO NAHRIM (2016), the special features of NEXC Block are as follows:

- Heavy and solid block
- Allow water penetration to dissipate wave energy
- Surface with holes, purposely design to help natural beach accretion
- toe/scour protection

Similar like Labuan Block, the NEXC block is quite heavy, about 2.5 tonnes per unit and solid structure because it is made by concrete. In coastal protection structures, this criteria is very important in order to deal with the strong wave action and hydraulic force.

NEXC block was designed to dissipate wave energy by introducing the holes on the block unit as shown in Figure 2.40. These holes actually plays an important role as energy dissipater by allowing the water flow in and out through it. So that it will reduce the wave run up impact on the surface of the NEXC block structure during big wave events. At the same time, all these holes also will help the process of beach accretion at the back as well as in front of the structure especially during constructive wave action. The wave or water that carry the sand particles can penetrate to the rear side of the structure through the holes on the NEXC block and naturally it will help the accumulation process of the sand at the back side. There are 8 main holes that arranged parallel in two row on the structure of NEXC block unit as shown in Figure 3.4.



Figure 3.4 : The holes on the NEXC block unit (source : NAHRIM)

The size of the holes is larger at the front than at the back and slopes backward. It is designed so that it can trap the sediment (sand) that carried with the flow of water through the hole to the back of NEXC blocks especially during the incident of big waves and high tides. Small weep holes also was provided at the bottom of the structure to drain the water as well as to reduce the pore pressure.

Toe and scour protection also is very important to avoid failure as well as to make sure the stability and integrity of the structure. Suitable quarry stone (armour rock) size are used as a toe protection from scouring effect. The placement of these armour rock in front of the toe of the NEXC block structure also dissipate wave energy and reduce the wave run up. For basal reinforcement, a flat and compacted layer of aggregates (crusher run) and covers with geotextile as a blanket separator is used as a foundation of NEXC block structure. The combination of these two armour rocks and basal reinforcement foundation also will help to reduce the effect of scouring due to destructive wave action. With all these features, it is expected that these products can help in protecting the beach from severe erosion problems and nourish the beach naturally.

3.2.1 Prototype of NEXC Block

In the process of developing a prototype of NEXC block, there are 3 design options that was considered, named Prototype A, Prototype B and Prototype C. The final design prototype option is determined based on several criteria such as structural

stability, fitness for purpose, safety and reliability, economy, suitability and ease of handling at the construction site as well as maintainability. To ensure the stability of the structure against wave's action, the gradient of the surface structure is very important in order to reduce wave run up. Accordingly, three different gradient angles are considered, i.e. 30° for prototype A, 45° for prototype B and 60° for prototype C. The width and the height of the prototypes remain the same at 1.2 m each but the length is varies to suit with the design. The dimension of all these three prototypes are used as a basis for the calculation of structural stability analysis for NEXC block and is described in more details in Chapter 4. Engineering drawings and dimension for all Prototype A, B and C are as shown in Figure 3.5 to Figure 3.7.

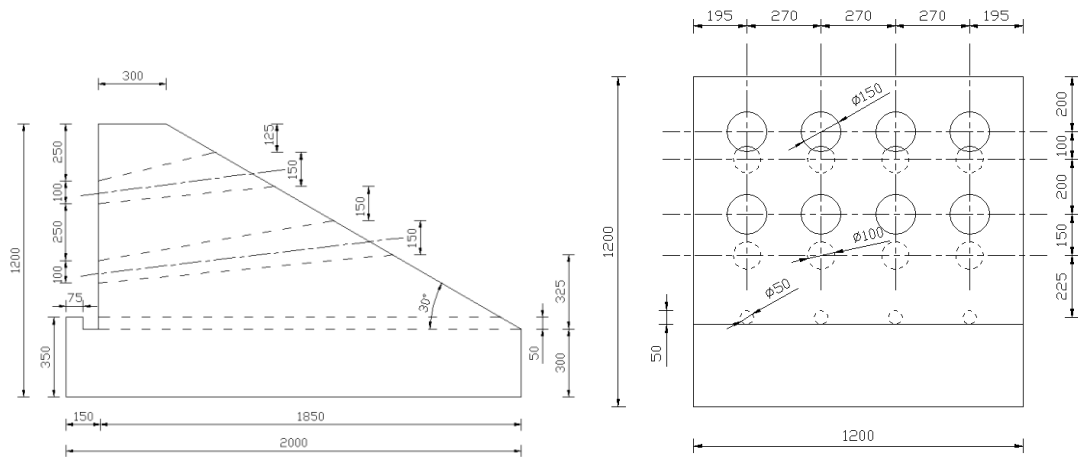


Figure 3.5 : Side view (left) and front view (right) of the 30° NEXC block unit or Prototype A (source : NAHRIM)

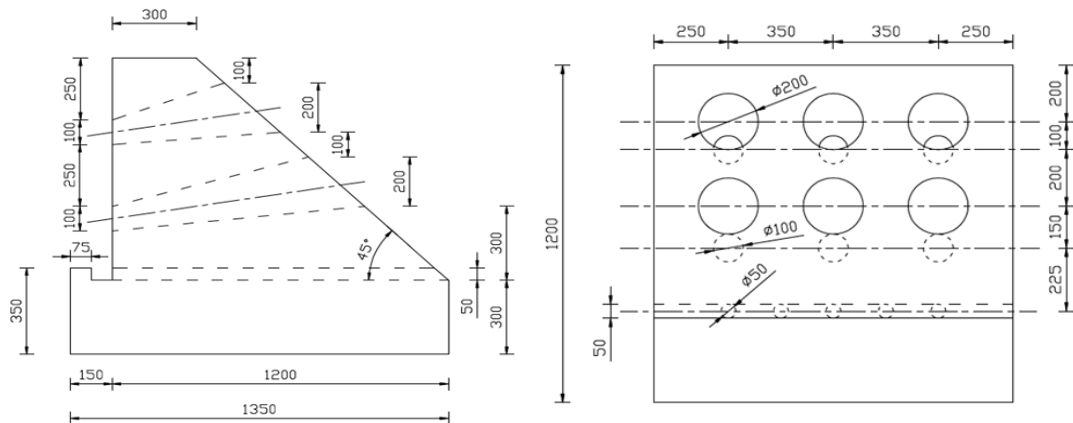


Figure 3.6 : Side view (left) and front view (right) of the 45° NEXC block unit or Prototype B (source : NAHRIM)

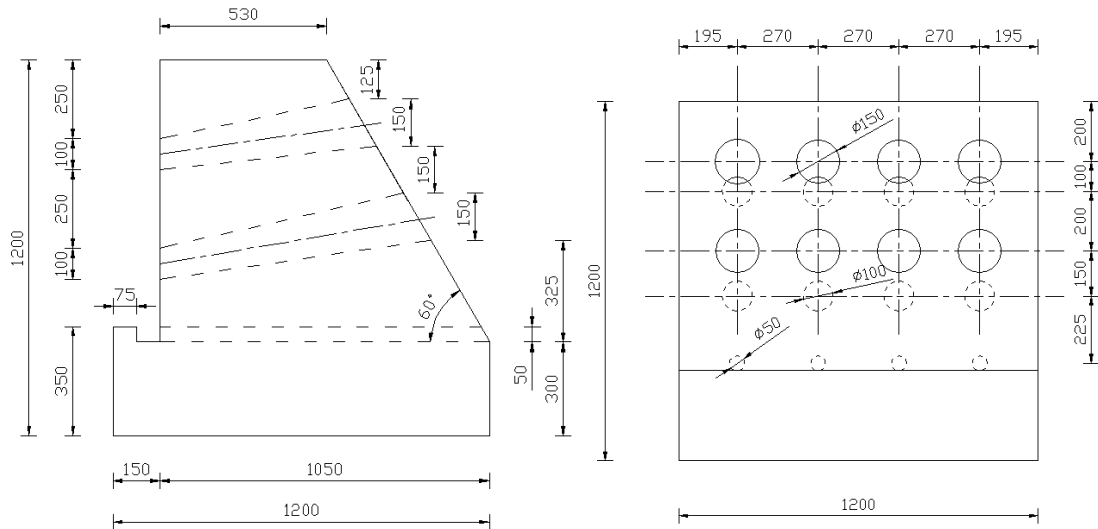


Figure 3.7 : Side view (left) and front view (right) of the 60° NEXC block unit or Prototype C (source : NAHRIM)

3.2.2 Final Design Option (Prototype B)

The final design option was decided based on the results of stability analysis for all Prototype A, B and C. There is no prototype testing in the laboratory for this initial stage. The decision takes into account failure caused by overturning and sliding as well as factor of safety (FOS). Prototype B (refer to Figure 3.8) was selected as a final design option based on the result and analysis in Chapter 4. However the detail discussion about the result and analysis will discuss further in Chapter 4.

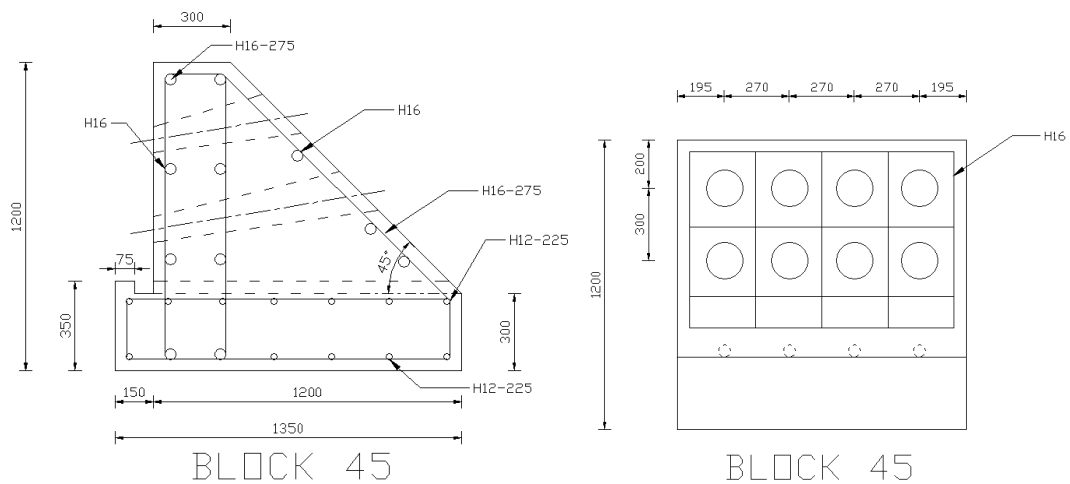


Figure 3.8 : Side view (left) and front view (right) of the 45° NEXC block unit (Prototype B) as the final design option (source : NAHRIM)

Summary of engineering design for Prototype B is given as follows:

- Surface block angle = 45°
- FOS = 2.4
- Dimension of NEXC block : 1.2m height x 1.2m width x 1.35m length
- Approximate weight: 2,500kg @ 2.5 tonnes
- Concrete Grade : 40 kN/m²
- Reinforcement bar : H and Y type
- Concrete cover : 50 mm
- Interlocking system with male and female lock design

Additional factors that make Prototype B the best design option include it is easier to fabricate the product with surface gradient of 45° compared to 30° or 60° . This angle facilitates the work of making moulds and fabricating products as it is not too steep and not too flat. FOS value of 2.4 is very adequate to avoid overdesign. Having ideal weight (2.5 tonnes) and moderate dimension made them easy to transport to the site and no difficulties to handle by standard crane and hoist during placement. The holes on the NEXC block structure can be utilised to lift the block by using appropriate cable in the handling and deployment process.

For concrete mix design, Grade 40 is adopted. Referring to BS EN 1992, for concrete exposed to tidal, splash and spray zone (marine structure), concrete mix with design strength of 45 N/mm². However, NEXC block structure does not carry any other loads except its own weight, the design strength of concrete mix was thus reduced to 40 N/mm². Another reason is because this structure is not constantly exposed to saltwater but dry most of the time except during high tide or storm events. Concrete cover of 50mm thickness is consider enough to protect the rebar from risk of exposure to salt water and rust problem.

To facilitate the connection between each unit of NEXC block with the others, special interlocking system is designed on both sides of the structure. These slotted and grooved interlocking designed are in the form of male and female connectors (refer to figure 3.9).



Figure 3.9 : The arrow shows slotted (male connector) and grooved (female connector) interlocking designed for NEXC Blocks System (source : NAHRIM)

The arrangement and connection of this NEXC blocks system will form a robust shoreline defence structure especially in dissipating the energy of strong waves. The application of NEXC blocks system as a coastal defence structure is also very preferable for sandy beaches because the bearing capacity is relatively high compared to the muddy coast which have low bearing capacity that will lead to settlement problem. It can also be removed or use elsewhere (removable) after the beach has reach a stabilized condition (erosion and accretion rate is almost equal) to give way for natural beach scenery. In conclusion, the design of the prototype B will be used as the basis design for the development of models and prototypes of the NEXC Block for the next level, either in the laboratory testing or on site deployment.

3.3 DATA COLLECTION AND ACQUISITION

Data collection and acquisition for this study involves primary and secondary data. Primary data will be obtained directly from the test site, Pantai Batu 5, Port Dickson (the location of prototype product deployment). Secondary data obtained from desk study includes all the data from past studies and additional data obtained from other sources such as authority department (e.g. NCES by EPU, ISMP of Negeri Sembilan by DID and Tide Tables by National Hydrographic Centre, PHN). The primary data and secondary data will be used for the experimental setup and deployment setup for the prototype product on a test site.

3.3.1 Primary Field Data Collection

In this study, the primary data was collected on test site at Pantai Batu 5, Port Dickson, Negeri Sembilan. The primary data collection that was conducted in the test sites are beach profiling (before, during and after the deployment of the NEXC Block product), water level and sediment sample. All the data collection exercises was carried out by NAHRIM in-house research and survey team. Table 3.1 presents the summary of primary data collection that was conducted in this study.

Table 3.1 : Summary of Primary Field Data Collection

Data obtained	Method	Instrumentation used	Application
Beach profiling	Real Time Kinematic (RTK) survey	Trimble R6 (High Resolution) GPS Receiver	Baseline condition, determination of beach gradient
Water level	Direct measurement	Mobile tide gauge recorder	Datum
Sediment sample	In-situ grab sampler	Shovel	Sediment size, D_{50} for physical modelling scaled down sediment

3.3.1.1 Beach Profile Survey

Site survey works was conducted at the test site to obtain preliminary information on the physical condition of the study site, especially beach profile and gradient. The site survey works involves the beach profile survey and sea bed profile or bathymetry survey. Beach profile survey was carried out by using the apparatus and method of Real Time Kinematic (RTK) as shown in Figure 3.10.



Figure 3.10 : Beach profiling survey by using RTK Method and instrumentation (left picture). The RTK Device : Trimble R6 (High Resolution) GPS Receiver (right picture) (source : NAHRIM)

The development and advancement of GPS technology nowadays has enabled survey works performed more accurately, quickly and efficiently through this RTK method (JUPEM, 2005).

Beach profile survey was conducted at test site to get the cross section along the existing shoreline. This survey works was carried out during low tide to facilitate the measurement in the seaward direction. In this study, there are 24 transect of beach cross section survey to be used as the baseline condition (Figure 3.11).

Transect 1 to Transect 22 is along the shoreline where the test product is deployed, with 10m interval. Transect 23 and 24 are extra profiling further south which are used for references. From the survey result of all these transect line, the beach profile is plotted, and the beach gradient determined based on the mean gradient of each transect.



Figure 3.11 : Transect Line of Beach Profiling Survey at Study Site, Pantai Batu 5, Port Dickson, Negeri Sembilan. (source : NAHRIM)

Table 3.2 shows the final processed data of RTK survey point's value of Transect 1 (CS1). In this survey, z value is refer to the height of the measured ground level, which 0 value is referred to MSL as a reference point. However, 0 value for cumulative distance is referred to the starting point of the cross section during the survey works at landward side of the beach profile.

Table 3.2 : The RTK survey points value of the transect cross section 1 (CS1)

Easting	Northing	Cumulative Distance From Starting Point (m)	Ground Level, z (m)
816528.048	274941.272	0.00	1.617
816527.160	274940.719	1.04	1.546
816526.128	274940.150	2.22	1.507
816525.367	274940.314	2.84	1.401
816524.534	274939.864	3.78	1.254
816523.433	274939.386	4.98	1.080
816522.534	274939.002	5.96	0.955
816521.364	274938.543	7.21	0.815
816520.437	274937.871	8.33	0.691
816520.137	274937.379	8.81	0.732
816519.216	274936.860	9.87	0.570
816518.014	274936.287	11.20	0.395
816516.632	274935.906	12.61	0.210
816515.370	274935.252	14.03	0.106
816514.557	274934.529	15.08	0.075
816513.542	274934.220	16.12	0.075

The plotted graph of beach profile transect is shown in Figure 3.12.

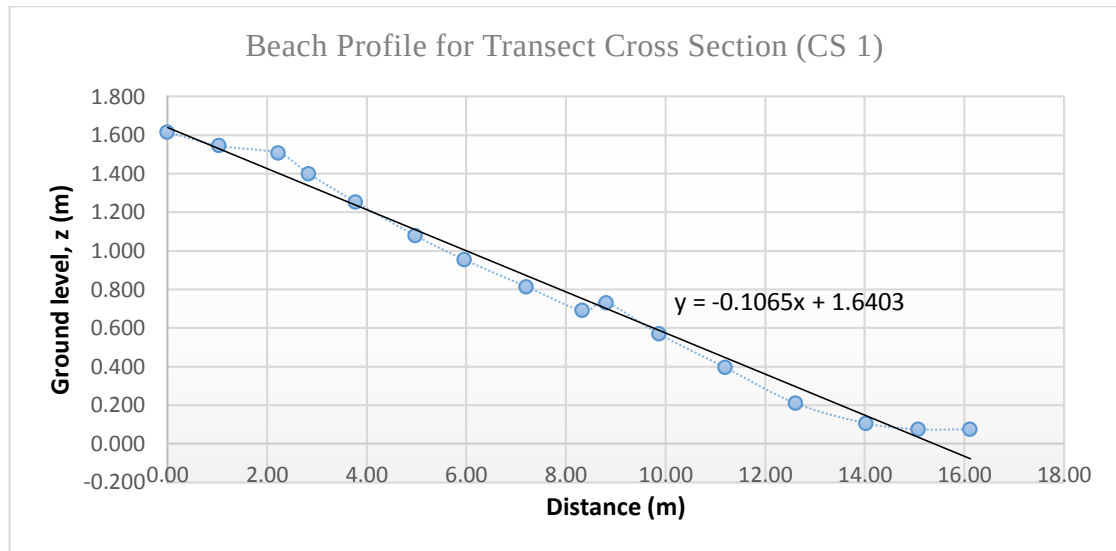


Figure 3.12 : Plotted Graph of Transect Cross Section 1 (CS 1) of Beach Profiling on Test Site (source : NAHRIM)

Refer to the graph in Figure 3.12, the beach gradient m , given by the linearly fitted curve, is 0.1065 and is equivalent to a slope of 1:9.4.

Details of all transect data and plots are attached in Appendix 1A. The values of the beach gradient for all transect lines CS1 to CS24 are calculated and summarized as shown in Table 3.2. The average gradient of Batu 5, Port Dickson is 1:10.8. However, to facilitate the construction works of experiments model in the laboratory, the beach slope 1:15 used in this study.

The present results of the beach slope is used as a baseline data. After completion of the product deployment, the beach profile will be surveyed again to establish the condition after the construction stage. Finally, periodic or monthly beach profiling survey works will carried out under the monitoring programme to observe the profile changes, erosion and accretion rates due to the dynamic process of sediment movement.

Table 3.3 : Analysed data from all transect cross section (CS1 to CS24) to derived the average of beach gradient

Transect Line	<i>m</i> Value	1/<i>m</i>	Beach Gradient
CS 1	0.1065	9.3897	1 : 9.4
CS 2	0.0902	11.0865	1 : 11.1
CS 3	0.0956	10.4603	1 : 10.5
CS 4	0.1102	9.0744	1 : 9.1
CS 5	0.1002	9.9800	1 : 10
CS 6	0.1033	9.6805	1 : 9.7
CS 7	0.1097	9.1158	1 : 9.1
CS 8	0.0943	10.6045	1 : 10.6
CS 9	0.1089	9.1827	1 : 9.2
CS 10	0.1087	9.1996	1 : 9.2
CS 11	0.1091	9.1659	1 : 9.2
CS 12	0.1098	9.1075	1 : 9.1
CS 13	0.1141	8.7642	1 : 8.8
CS 14	0.1063	9.4073	1 : 9.4
CS 15	0.1010	9.9010	1 : 9.9
CS 16	0.1165	8.5837	1 : 8.6
CS 17	0.0971	10.2987	1 : 10.3
CS 18	0.1152	8.6806	1 : 8.7
CS 19	0.1204	8.3056	1 : 8.3
CS 20	0.1192	8.3893	1 : 8.4
CS 21	0.0948	10.5485	1 : 10.5
CS 22	0.1180	8.4746	1 : 8.5
CS 23	0.0438	22.8311	1 : 22.8
CS 24	0.0338	29.5858	1 : 29.6
	Average	10.8257	1 : 10.8

3.3.1.2 Water Level

Measurements of water level is important to obtained tidal data in the study area. Mobile tide gauge was installed temporary in the study site as a water level recorder in order to obtain these data. The deployment of the tide gauges have to be made before the beach profile and bathymetry surveying work commences. It is also used as a datum for this study, namely zero tide gauge level.

3.3.1.3 Sediment Data

The sediment data collection on test site is carried out to determine the size distribution of the sediment. Samples were obtained from several locations, seaward and leeward to the shoreline and along the alignment of the test model. Sediment sampling is carried out using in-situ grab sample by hand shovel. Generally, the existing local sediment in the test site is sandy material.

Sieve analysis was carried out to get the sediment particle distribution. The mean value of the sediment size were used as a basis for determination of downscale sediment size in the laboratory. In this study, it was found that the average size of the sandy sediment diameter (D_{50}) on site is approximately 1 mm (refer to Figure 3.13).

Sieve Size (mm)	Weight of Sieve (gm)	Weight of Seive + Soil (gm)	Weight of Soil (gm)	Cummulative Weight (gm)	% Cummulative Weight Retained	% Cummulative Weight Passing
20	1501.1	1501.1	0	0	0.0	100.0
10	1366.4	1378.7	12.3	12.3	2.5	97.5
4.75	1464.4	1528.7	64.3	76.6	15.4	84.6
2.36	1169.8	1236.3	66.5	143.1	28.7	71.3
1.18	1095.2	1169.6	74.4	217.5	43.7	56.3
0.6	1024.8	1251.0	226.2	443.7	89.1	10.9
0.3	963.5	1016.6	53.1	496.8	99.8	0.2
0.15	1014.1	1014.7	0.6	497.4	99.9	0.1
pan	733.7	734.1	0.4	497.8	100.0	0.0

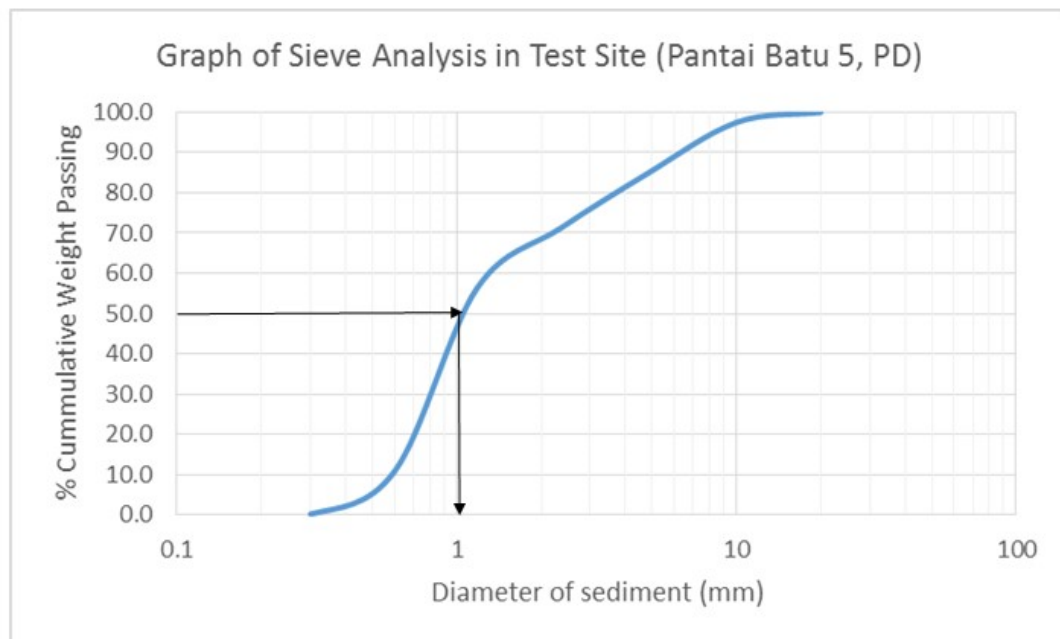


Figure 3.13 : The Sample Result and Graph of Sieve Analysis in Test Site, Pantai Batu 5 Port Dickson (source : NAHRIM)

3.3.2 Secondary Data

Secondary data on the water levels, such as MSL, MHWS, MLWS and maximum wave height was applied to the determination of the water level in physical modelling.

These data is obtained from the formal reports such as Integrated Shoreline Management Plan (ISMP) for Negeri Sembilan by DID, NCES by EPU and several information from Tide Tables by National Hydrographic Centre (PHN). The relevant data required include tide levels, wind and wave data, current data (i.e. current speed, current direction, dominant current direction and littoral drift direction), as well as sediment data (i.e. erosion rate, sediment rate, sediment budget and sediment sources). Imagery data from Google earth for beach morphology changes history is used as past historical references for this study.

Tide levels for Port Dickson (semidiurnal type) is shown in Table 3.4 and Figure 3.14 and all this value is referred to chart datum (CD) by PHN.

Table 3.4 : Tide Levels at Port Dickson Water Level Station (source : PHN)

Remarks	Level (m CD)
Zero of tide gauge	0.00
Lowest Astronomical Tide (LAT)	0.00
Mean Lower Water Spring (MLWS)	0.31
Bench Mark (BM) JUPEM	1.30
Temporary Bench Mark (TBM) NAHRIM	1.30
Mean Low Water Neap (MLWN)	1.14
Mean Sea Level (MSL)	1.55
Mean High Water Neap (MHWN)	1.96
Mean High Water Spring (MHWS)	2.79
Highest Astronomical Tide (HAT)	3.51

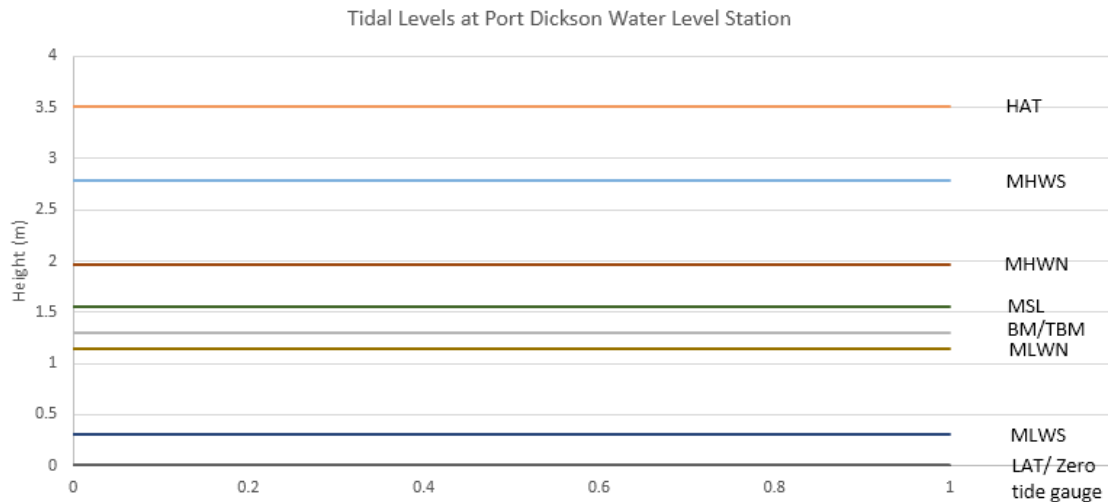


Figure 3.14 : Tidal Levels Plot for Port Dickson Water Level Station

Wind wave interaction normally are used in the wind generated wave analysis in numerical modelling. According to NCES, the Southwest (SW) Monsoon winds rarely exceed 15m/s, but gusts of up to 30m/s have been recorded. Prevailing wind direction are south to west with average wind speed of about 4m/s. Due to this wind condition, the average near shore maximum wave height generated in Malacca Strait during the Southwest Monsoon is approximately 2m. This value will be used as a maximum wave height in the flume setup for experiment.

The detailed study of ISMP Negeri Sembilan also reported that the flow current conditions in this area are very strong, with values exceeding 1.5m/s especially in the southern section adjacent to Tanjung Tuan. Following the shape of the near shore profile, in the northern areas the strong currents are located away from the shoreline with weaker currents near shore. In the southern end the currents are strong and very close to the beach. The overall flow pattern is characterised by preferential flow directions induced by the rocky headland at Tanjung Tuan that tend to accelerate the flow. Due to this current flow direction, the sediment movement drifting southwards and accretion has formed a beach ridge plain

The beaches sediment in this study area are generally sandy material. Most of these sediment source of sand is coming from offshore sand bar. There are no major rivers discharging in this stretch, however sediment concentration levels can increase during monsoon conditions that allow fine sediments to be transported from the nearby coastlines. According ISMP report of Negeri Sembilan, for this study area the sediment samples show sizes of d_{50} ranging from 0.07 to 0.35mm. This indicates that

these are exposed beaches with significant current velocities (tidal, wind and waves induced) and turbulent wave action that does not allow fine sediments to settle.

The study also reported that the littoral transport during inter-monsoon conditions occurs only offshore and is almost negligible in the near shore areas. However during the monsoon seasons when wind and wave driven currents are more dominants, the littoral transport becomes more significant both in the near shore and offshore areas, with the largest transport occurring offshore. As expected the Northeast (NE) monsoon induce transport towards south-southeast while during the Southwest monsoon the transport reverses. The annual average sediment transport in this area is about $500\text{m}^3/\text{year}/\text{m}$. The sediment transport analysis also indicates that erosion rates of 0.25 to 0.5m/year should be expected in this study area. The coastline is also dynamic due to the seasonal variability of the littoral transport induced by the variation of wave conditions during the NE and SW monsoons.

3.4 PHYSICAL MODELLING

Physical modelling or laboratory testing for scaled down model of this product was carried out in Hydraulic and Instrumentation Laboratory (MHI) NAHRIM, in Seri Kembangan, Selangor, assuming that the aspects of interest within the model will behave similarly to the prototype (real world scale) within the prescribed range of applicable conditions (NAHRIM, 2006). Data from the experimental results include measurements of beach profiling (erosion and accretion), scour pattern and deformation or failure pattern of the structure.

3.4.1 Apparatus for Physical Modelling

Physical modelling and product testing setup was carried out in two dimensional (2D) flume basin inside the MHI (refer to Figure 3.15). The flume dimension is 50m length, 1.5m width and 2m height. One wave board pedal at the end of the flume functions as a wave generator according to the input data (wave high, amplitude and velocity) in the software. This wave maker software and hardware is developed by Nanjing Hydraulics Research Institute (NHRI), China.



Figure 3.15 : The View of Flume 2D Basin inside the MHI (source : NAHRIM)

It also can generate regular and irregular wave types. Maximum design specification for this basin 2D Flume is as follows:

- Maximum amplitude : $\pm 300\text{mm}$
- Maximum velocity : 0.75m/s
- Maximum wave height : 0.5m
- Maximum water depth : 1.5m

3.4.2 Scaled Down Test Model of NEXC Block

Scaled down model is derived using geometrical scaling ratio for model and prototype at 1:10 (Figure 3.16).



Figure 3.16 : Scaled Down Model Sample of NEXC Block (source : NAHRIM)

Dynamic scale factor between prototype and model is based on Froude similitude criteria (NAHRIM, 2006) as follows:

Let scale = λ , model = M and prototype = P,

- M Length = P Length / λ (cm)
- M Time = P Time / $\lambda^{0.5}$ (s)
- M Weight = P Weight / λ^3 (g)

The scale ratio, λ for this study is 10 and the prototype, P length is 1200cm. So, the model length in the laboratory testing is:

$$\text{M length} = \text{P} / \lambda \text{ (cm)} = 1200\text{cm}/10 = 120\text{cm}.$$

For model length of 120cm. The approximate dimension of the NEXC Block prototype is 1200cm high, 1200cm long and 1200cm wide. The laboratory scaled down model was not fabricated as a single split unit like the prototype block but was fabricated as a NEXC Block System with 500cm overall width as shown in Figure 3.16 to accommodate to the flume width (1.5m).

Table 3.5 shows the summary of the scale factor for NEXC Block physical modelling in this study.

Table 3.5 : The summary of the scale factor for NEXC Block physical modelling

NEXC BLOCK PHYSICAL MODEL		
Geometric Scale, L_r	10	
Time scale	3.2	
Parameter	Prototype	Model Scale
Length, (m)	1.2	0.12
Height, (m)	1.2	0.12
Width, (m)	1.2	0.5 x 3 unit
Maximum Wave Height, H_s (m)	1.0 & 2.0	0.1 & 0.2
Wave Period, T (s)	6.4	2
Water Level Maximum (m)	2.79 (MHWS)	1.1
Water Level Average (m)	1.55 (MSL)	1.0
Water Level Minimum (m)	0.31 (MLWS)	0.9
Beach Material size (Sand), d_{50} (mm)	1.0	0.1

3.4.3 Experimental Set-up

In real situation on coastal environment, the wave will approach at various incidence angle towards the shoreline. However, the experimental design set-up uses 1D flume with regular wave type at normal incidence to the model product.

The first step of the test set-up is to construct the beach profile with 1:15 slope as shown in Figure 3.17.

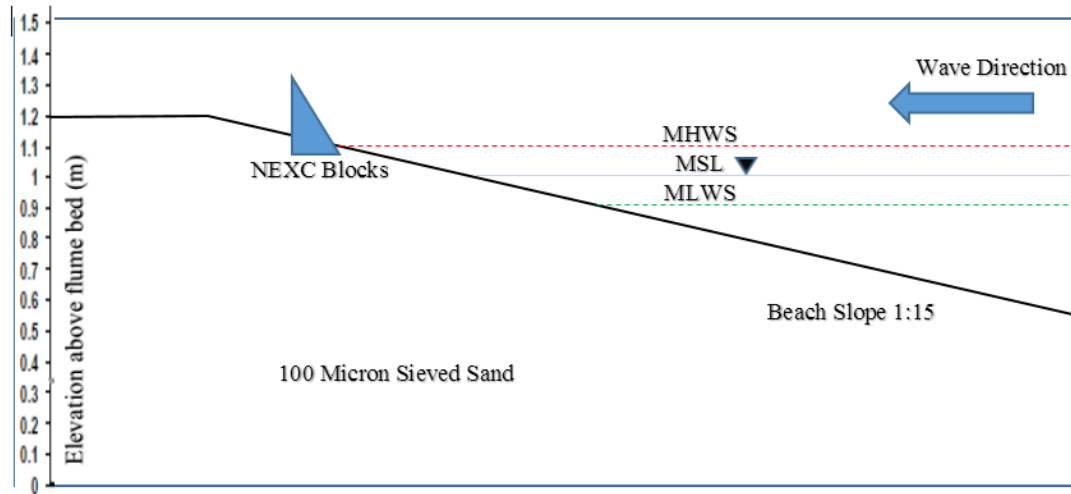


Figure 3.17 : Flume set-up for physical modelling experiment

The 100 micron or 0.1mm sieved sand material was used as a beach material. Approximately 10 tons of sand was used to construct this experiment model. After the initial formation of beach profile is completed, the flume is filled up with water up to the design (Figure 3.18). Measuring markers and rulers was used to mark the constructed shoreline and profile line changes after the test run. At this stage, the experiment model is ready to run the simulation. During the experiment, wave probes was used to measure the wave height and video camera was used to record the dynamic processes during the experiment. There a few scenarios of simulation in this experiment and the measurement of beach profile changes will be carried out just after the test run.



Figure 3.18 : The view of completed experimental design set-up in 2D Flume Basin
(source : NAHRIM)

3.4.4 Product/model test/option or scenario

In this study, the simulation in laboratory testing involves three main scenarios as follows:

- i. Scenario 1 : Simulation without NEXC block structure with three (3) different water level (0.9m, 1.0m and 1.1m) and two (2) different wave height (0.1m and 0.2m) as control measures
- ii. Scenario 2 : Simulation with NEXC block structure with three (3) different water level (0.9m, 1.0m and 1.1m) and two (2) different wave height (0.1m and 0.2m)
- iii. Scenario 3 : Simulation with NEXC block structure and toe protection with three (3) different water level (0.9m, 1.0m and 1.1m) and two (2) different wave height (0.1m and 0.2m)

Every scenario involves 6 test runs and thus a total of 18 tests were carried out in this study. Every test run took about 60 minutes which is equivalent to 192 minutes in the field. All of the physical modelling simulation cycle in the laboratory is summarized by Figure 3.19.

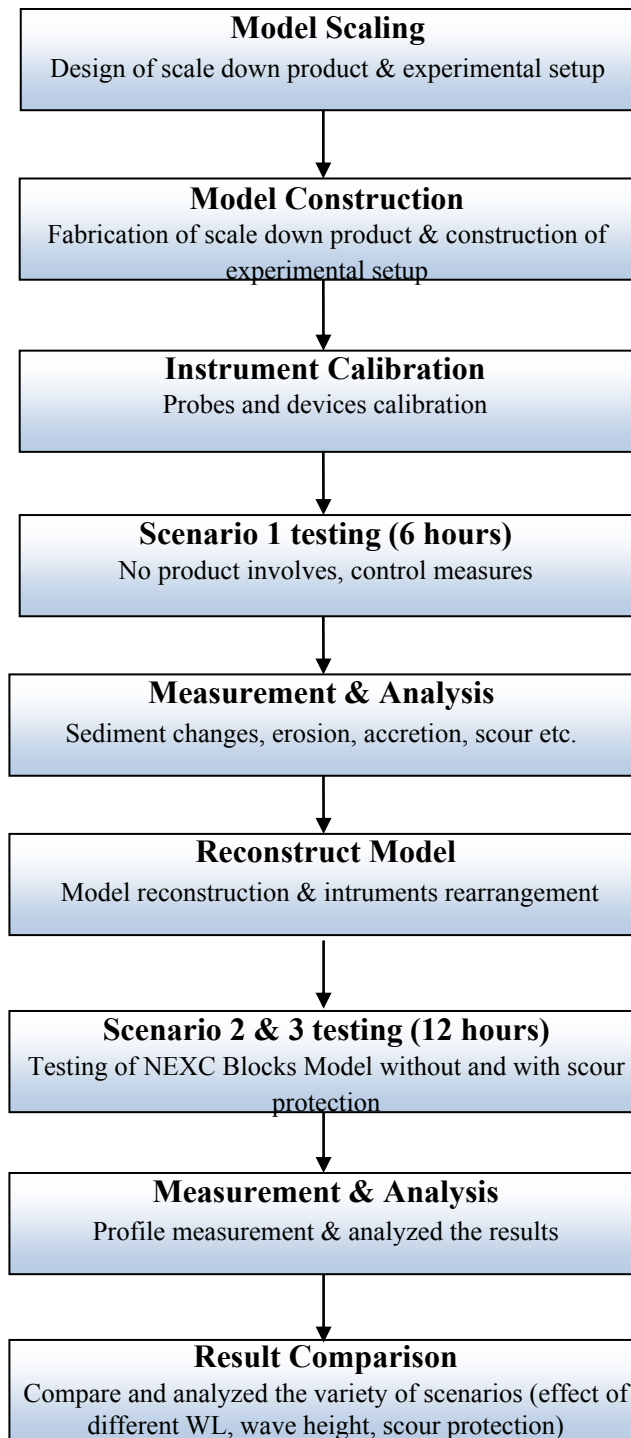


Figure 3.19 : Physical Model Testing Flow Chart

The three different water levels set in the laboratory test runs represent the 3 specific conditions. The 1.0m water level in the flume represents MSL; 0.9m water level represents MLWS and 1.1m water level represents MHWS. The 2 options of wave heights represent the maximum wave height with 2 different return period. According to the NCES, 1.0m and 2.0m maximum wave height represents 25 and 50

years return period respectively for coastal structural design. In the laboratory testing, these translate to 0.1 and 0.2 wave heights in the flume respectively.

The erosion condition for scenario 1 is expected to be the most severe compared to the others because it was a control measures experiment without any structure. This condition is representative of the field condition on the test site. Scenario 2 focused on product testing without toe protection; Scenario 3 with additional option of toe protection.

3.4.5 Calibration and Validation

In this experiment, the wave probe was used to measure the wave heights generated in the flume. Calibration procedure was carried out according to the manufacture manual prior to its use.

In addition, validation procedure of the correct wave height and water level was carried out during this experiment. Both the wave height and water level were measured manually using ruler inside and outside the flume to validate the measurement. It was found that both of the wave probe and manual measurement recorded almost the same value.

3.5 PRODUCT DEPLOYMENT ON SITE

However there is a few significant limitation during testing in a laboratory. In this case the simulation of sediment transport cannot be modelled due to lack of appropriate equipment. This test should be carried out by taking into account the simulation of sediment supply. However, it is quite difficult to model this type of physical modelling simulation due to not enough instrumentation, expertise and experience in NAHRIM's laboratory. This experiment only based on the static and unchanged amount of sediments. While the situation on site, the process of sediment transport in the coastal area is very dynamic. Normally, the littoral drift of sediment movement will affect the shoreline morphology changes either erosion or accretion.

The fact is we cannot model everything in the laboratory, but we can run the real condition of test at site. There is no doubt that how important the real condition of test is carried out on site to assess the ability of these products can work and function as expected. Apart from this, the comparison of the results obtained by on site testing

and in the laboratory is also very important for this research to analyse quantitatively and qualitatively.

3.5.1 Site Condition

Pantai Batu Lima, Port Dickson, Negeri Sembilan was selected as the test site because this area is often threatened by coastal erosion each year due to strong winds, huge waves and high tides over the past five years (Hadi et al., 2016). The exact location of the test site is just behind the compound of The Regency Beach Resort. Figure 3.20 shows the key map, the location of test site and Google Earth satellite view for the development of NEXC Block product at Pantai Batu 5, Port Dickson.

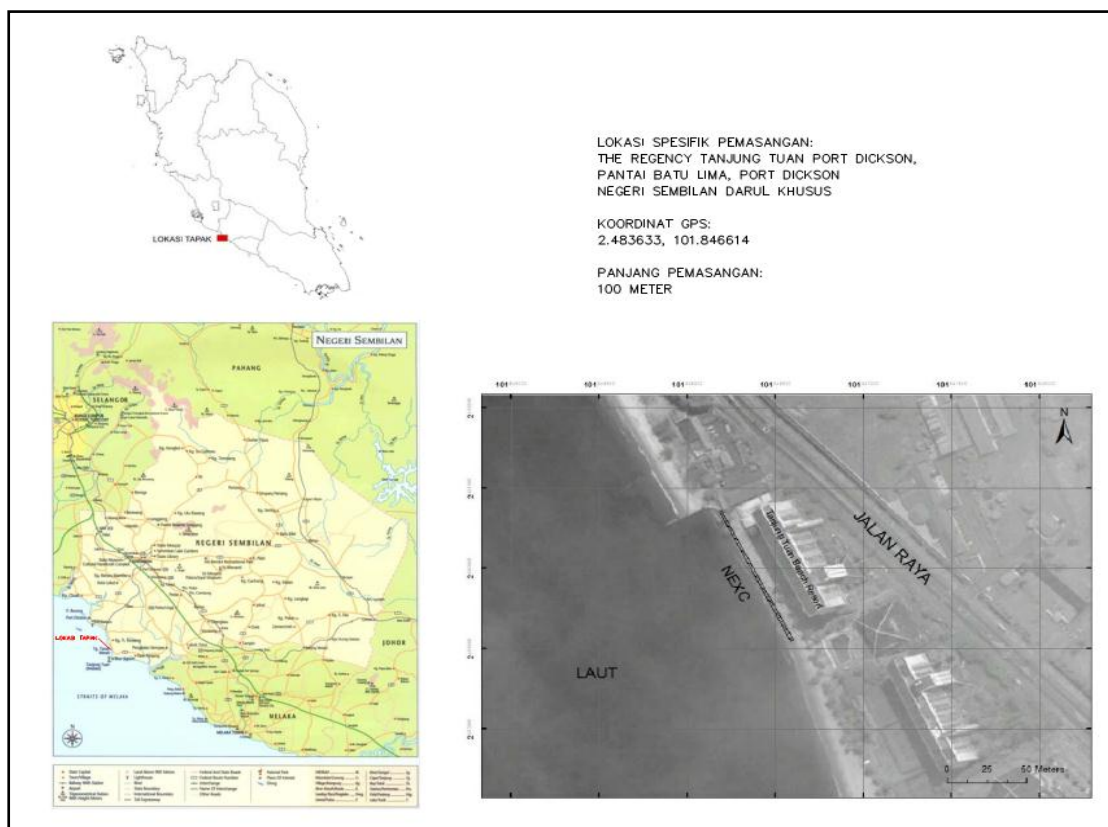


Figure 3.20 : The key map, the location of test site and Google Earth satellite view for the development of NEXC Block product at Pantai Batu 5, Port Dickson, Negeri Sembilan (source : NAHRIM & Google Earth)

Pantai Batu Lima, Port Dickson is selected as the test site location based on several criteria that are appropriate to the design and function of NEXC blocks (refer to Figure 3.21).



Figure 3.21 : The Test Site Location at Pantai Batu 5, Port Dickson (Backside of The Regency Beach Resort) (source : NAHRIM)

The selection of the test site location was also expected to provide a qualitative and quantitative comparison of shoreline protection system. The main criterion includes sandy beaches environment, moderate beach slope gradient, and relatively significant non-critical (category II) erosion rate. In addition, McIntosh Probes test analysis at the site showed that the bearing capacity on the site is able to accommodate the loads of the NEXC Blok system (FKA UTM, 2015).

Before this project started, the condition of eroded part of the beach is covered by the temporary mitigation measures. The hotel management had already installed the sandbags system in 2011 as a temporary protection to combat this problem (see Figure 3.22). However this sandbags system cannot fully prevent the erosion problem in the shoreline areas of the hotel. The sandbags were starting to tear and expose, look loses its ability to function properly. There are several units of these sandbags have been torn, causing loss of sand as filling material inside and subsequently no longer to protect the shoreline. In addition, due to the interaction of sea and sunlight, the sand bag systems have begun to deteriorate, turn black, mouldy and spoiling the beautiful scenery of the beach. Furthermore the hydraulic reaction and interaction among the sandbags structure, sediment, sea water and waves cause the formation of uneven and deterioration of sandbags system (Hadi et al., 2016).



Figure 3.22 : The Placement of Sandbags System to Prevent Erosion on The Beach (source : NAHRIM)

3.5.2 Fabrication of Mould's Framework

The NEXC block was fabricated and installed onsite by a third-party contractor under the supervision of NAHRIM's technical and research team. The overall process of this fabrication methodology is shown in the flow chart in Figure 3.23.

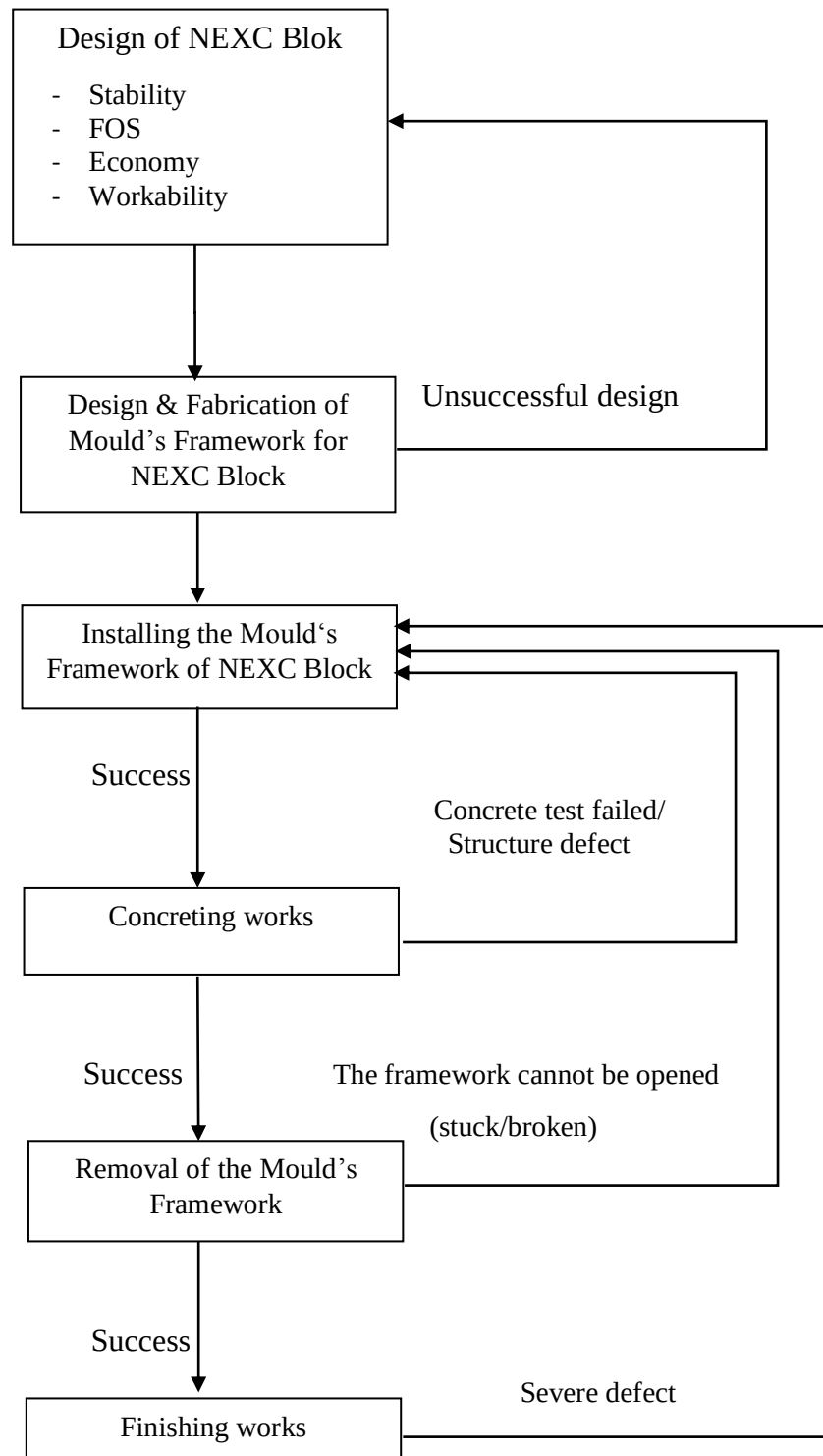


Figure 3.23: Flow Chart of Fabrication Process of NEXC Block (source : NAHRIM)

Figure 3.24 to Figure 3.28 show a series of fabrication processes of NEXC Block on site.



Figure 3.24 : The Fabrication of Mould's framework for NEXC Block
(source : NAHRIM)



(a) Steel bar that used as a reinforcement



(b) Steel plates and plywood are used in the installation works



(c) Cone shape steel plate of mould's frame is used to form the holes



(d) Complete mainframe of mould structure is ready to use

Figure 3.25 : Some of the installation works of Mainframe Mould's Structure of NEXC Block at site (source : NAHRIM)



Figure 3.26 : Concrete Casting Works at Site (source : NAHRIM)

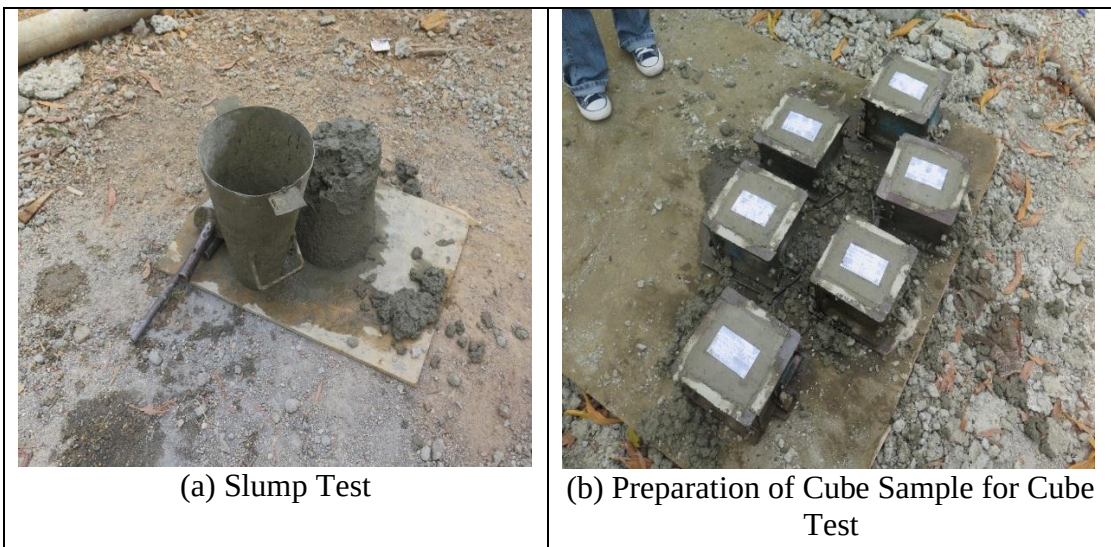


Figure 3.27 : Two types of concrete testing was conducted during concrete casting works for quality control of the NEXC Blocks product (source : NAHRIM)



Figure 3.28 : Final Touch-up of NEXC Block Surface (source : NAHRIM)

3.5.3 Deployment of the NEXC Blocks System

Deployment of the NEXC blocks system covers about 108 m length of shoreline at Pantai Batu 5, Port Dickson. Ninety (90) unit of NEXC blocks was used in the construction of this test site. NEXC blocks are installed in parallel with the shoreline. The deployment of this structure at site can be done within short construction time because it is designed with a simple interlocking method and involves minimum construction works and machineries. The deployment process of NEXC Blocks System at the test site is summarised as shown in Figure 3.29.



Figure 3.29 : The deployment flow process of NEXC Blocks System at the test site

Installation of these structure should not be too high to landward, causing sea water does not reach to it or too low to seaward, causing the structures constantly submerged. The installation of NEXC Blocks System also is not suitable or inappropriate in the area of shoreline with too steep and unstable gradient. The data from station Port Dickson Standard Port is used as a reference, analysed and determination of the location for the onsite installation (refer to Figure 3.30).

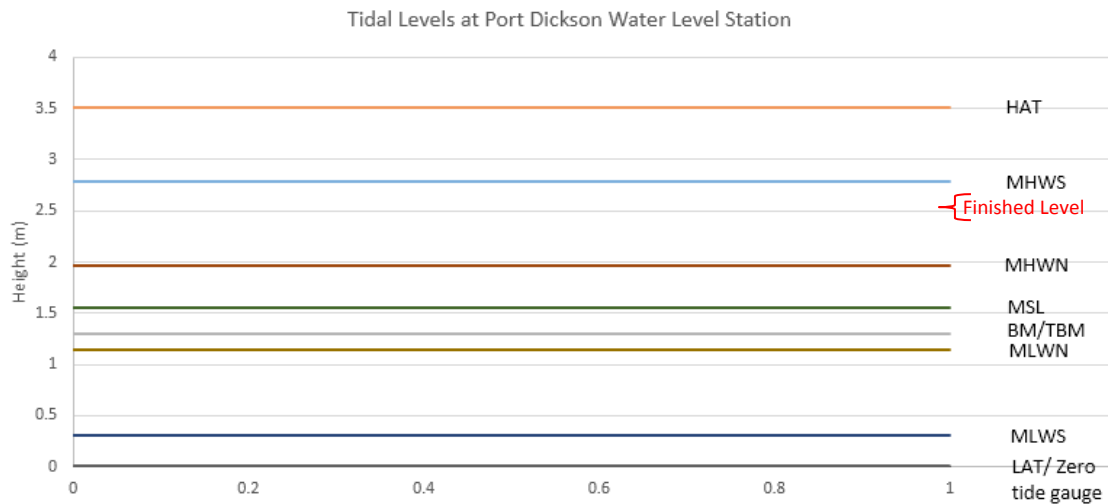


Figure 3.30 : Tidal Level Analysis for Determination of Specific Locations of NEXC Blocks System Installation (source : NAHRIM)

The standard dimensions of each unit NEXC block structure are 1.2 m length, 1.2 m width and 1.2 m height, with an estimated weight of 2,500 kg. During the placement of the NEXC block product at site, 0.3m of the block is installed below the ground level, or the ‘finished level’ (Figure 3.31).

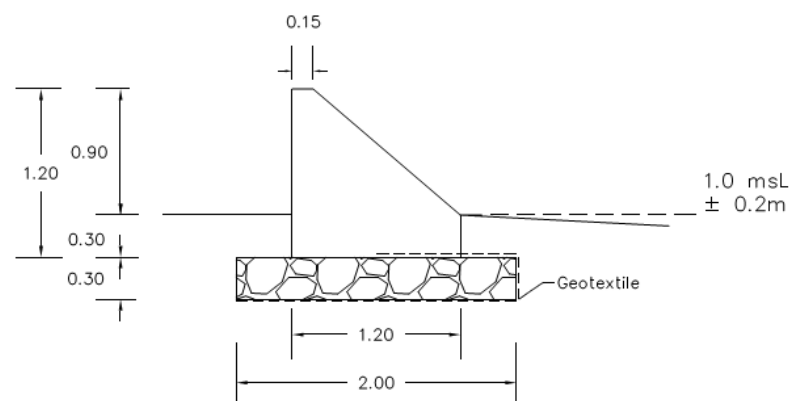


Figure 3.31 : Side view of NEXC Block System, the installation arrangement on site (source : NAHRIM)

Practically, the finish level is approximately $1.0\text{m} \pm 0.2\text{m}$ above the mean sea level (MSL). The finished level is chosen to give sufficient support for structural stability against wave action as well as to provide protection from scour problem at the toe .

Even though giving more protection to the beach, this structure's positioning will cause them flooded just only during the storm events and high tides. This position will also cause the NEXC Blocks System seem quite far from the shoreline during low tides due to high tidal range and flat beach slope. A natural process of sediment accumulation is expected to remain in place at the front of the structure during low tide through constructive wave action or by a gust of wind. Whereas during the high tide, the sediment (sand) will penetrate through the holes of the NEXC blocks and gets trapped at the rear of the structure.

Excavation and levelling works of existing local sandy material is carried out in order to set the finished level base on the MSL (refer to Figure 3.32).



Figure 3.32 : Excavation and levelling works at test site (source : NAHRIM)

This works also done to set the vertical and horizontal alignments for the installation of the NEXC Blocks System. The overall dimension of excavation is 0.6m depth, 2.0m width and an overall length of $108\text{m} \pm 5\text{m}$ parallel to the shoreline. The finished level is set to be a referral point for this excavation works. The excavated soil surface should be compacted and levelled properly, then to be aligned as the foundation of NEXC Blocks System.

The applications of the geotextiles are also used in the installation of the structure of NEXC Blocks System. It serves as a separator between the sand and crusher run that have been used as a foundation for this structure. In addition, it also

serves as a filter to the interaction of water and sand, especially during the wave action. The type of geotextile that was used in this project is non-woven fabric with grade TS50. A layer of geotextile is lay down on the excavated ground and left over on the front of the toe structure to be used as a cover layer for the foundation (refer to Figure 3.33).

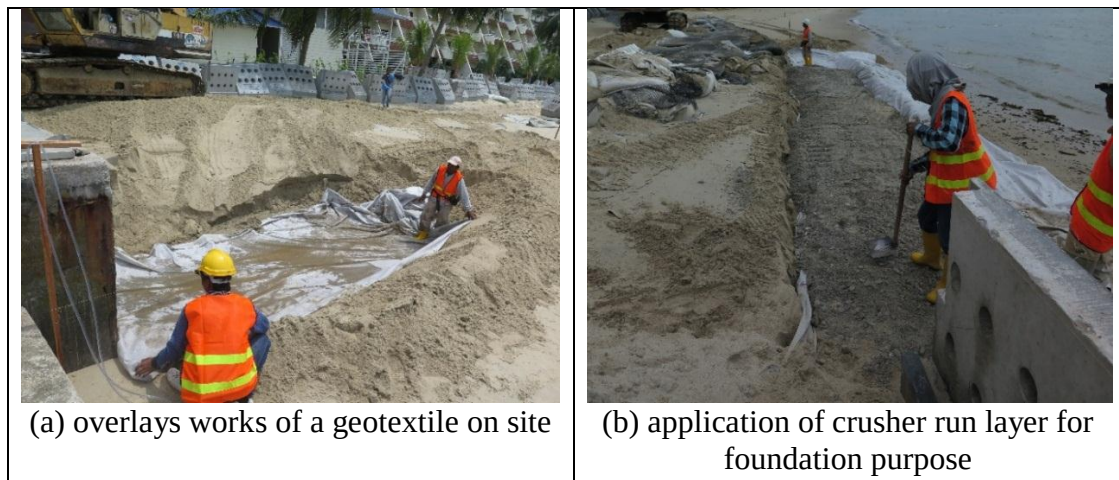


Figure 3.33 : Geotextiles Applications and Foundation Works on Site
(source : NAHRIM)

Crusher run material with thickness of 0.3m and 2.0m wide, covered with geotextile was used as a foundation for NEXC Blocks System. The foundation is levelled and compacted. The geotextile does not cover the entire rear sections of the structure to allow water and sand to get in.

The existing local sand was used to level and cover the surface layer of the NEXC blocks foundation. After that, this layer of sand cover will be compacted properly with hand held compacter. To provide more protection from scouring problems, medium-size (average size of 0.3m – 0.5m) rock armour revetment is placed in front of the toe structures.

Figure 3.34 to Figure 3.38 show some photos during the installation process of NEXC Blocks System at the construction site.



Figure 3.34 : Transportation and Handling of NEXC Blocks to Construction Sites
(source : NAHRIM)



Figure 3.35 : Site Preparation and Clearing for the Construction Project of NEXC Blocks System (source : NAHRIM)



Figure 3.36 : Lifting of NEXC Block on Site by Using Safety Cable
(source : NAHRIM)



Figure 3.37 : The deployment of the NEXC Blocks System on test Site
(source : NAHRIM)



Figure 3.38 : Armour rock is stacked nicely to form a layer of mini revetment system for the NEXC blocks structure (source : NAHRIM)

The alignment of NEXC Blocks System is ascertained in straight line and uniform by using laser scanner and fluorescent wire rope as shown in Figure 3.39.



Figure 3.39 : Straight Fine Tune Alignment of NEXC Blocks Structure on Test Site
(source : NAHRIM)

However, at the end of the alignment, there are curved shape of the structure in order to anchor the NEXC Blocks System closed up to the beach as shown in Figure 3.40.



Figure 3.40 : The view on the test project site after the completion of site finishing works (source : NAHRIM)

3.6. PERIODIC SURVEILLIANCE AND MONITORING

After completion of the product installation, inspection and monitoring programme were carried out regularly to make sure the integrity of the structure in good condition. Any failure that occurs to the structure will necessarily threaten the integrity and stability of the whole system.

Site inspection and monitoring visits to the test site at Pantai Batu 5, Port Dickson is carried out by NAHRIM research team periodically, either monthly or bimonthly. Any formation of failure, distortions, instability or deformation occurs to these structures were recorded, marked and measured for analysis. If the damage is critical, repair and recovery action must be taken immediately.

Apart from that, site surveillance for special inspection is carried out just after the monsoon event. Storm event normally will generate a strong wave action and will caused severe erosion to the shoreline. The height of the waves run up that lashed the beach in the range of 2 to 3 meters in coastal areas will certainly affect the integrity of the structure and its environment. So the special visit and inspection is undertaken to assess the integrity and stability of the structure of NEXC Blocks System just after the end of the monsoon season.

For example, a site visit was conducted by NAHRIM research team to the test site shortly after the SW monsoon season that hit in 2016. Investigation and observation on site has been found that at the end of chainage 108m of NEXC Blocks

System, the occurrence of severe erosion as a result of destructive wave action during SW monsoon at Batu 5, Port Dickson as shown in Figure 3.41. However, the integrity of the structure is still in good condition.



Figure 3.41 : Severe erosion occurred at the end of the chainage 108m of NEXC Blocks System and afterwards after the Southwest Monsoon season
(source : NAHRIM)

3.6.1 Periodic Beach Profile Survey

Periodic beach profile survey is carried out to appraise any changes to the shoreline on a monthly basis and in any case within 7 days after the full moon high tide for a period of at least one to two years from the date of product deployment. The beach profile survey is an analytical method for quantitative comparison to determine the coastline changes after onsite installation of the NEXC Block System. Usually this survey works was carried out simultaneously with the site inspection for periodic surveillance and monitoring.

During the survey works, the coordinates of each point of measurement and transect line is recorded using the reference datum DTGSM (Geodetic Vertical Datum

of Peninsular Malaysia) for monitoring purposes. This survey work were performed by the NAHRIM research team internally using RTK surveying tool set (refer to Figure 3.42).



Figure 3.42 : Survey Works with RTK Method and Instrumentation during the Monitoring Programme (source : NAHRIM)

This detail survey was carried out just after the completion of the deployment of the NEXC Block System and each transect line marked as Transect 1,2,3... then up to Transect n as shown in Figure 3.43.



Figure 3.43 : Transect Line of Beach Profiling Survey (source : NAHRIM)

Any changes to the vertical or horizontal of the shoreline profile will be analysed and determined based on that measured changes, whether it is undergoing a process of erosion or accretion. The position and height of some distorted units of NEXC Block structure has also been identified and marked properly in order to determine any movement or change occur either vertically or horizontally.

3.6.2 Real Time Video Camera Monitoring

Real time video camera monitoring or CCTV (closed-circuit television) is another option for the monitoring programme. This method requires the installation of outdoor video cameras in test site and real time connected with the internet network to view live from the office. The advantage of this method is monitoring can be carried out 24 hours in real time condition or at least with a lag of one hour delay time depending on the speed and capacity of internet access by the service provider. On site and office installation of the devices is also easy to implement and in affordable price. However, it should take into account the state of its strategic location and equipment safety after it is installed. In this study, the location of the video camera installation have been specified and installed on the manhole outlet structure which is positioned before the chainage 0 of the NEXC Blocks structure alignment as shown in Figure 3.44.

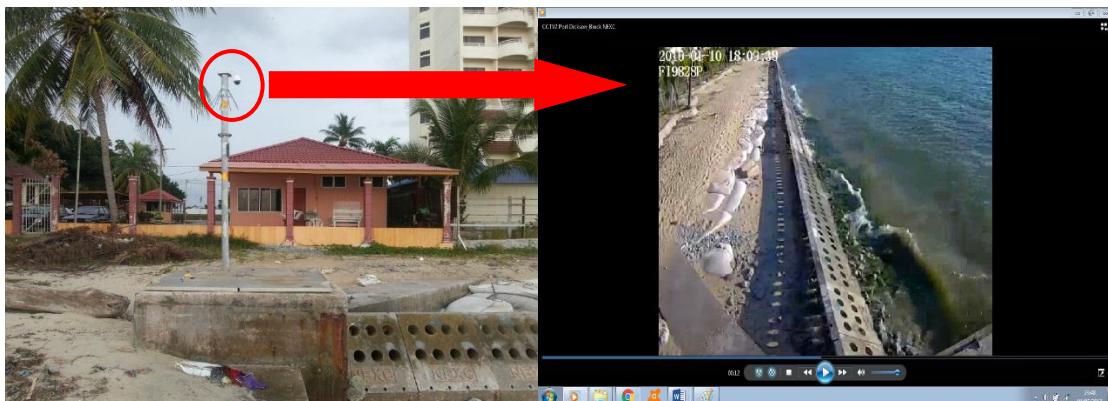


Figure 3.44 : The location of the CCTV on-site installation for online monitoring program (source : NAHRIM)

However there are several threats to the safety of that equipment such as the risk of theft and damage due to lightning strike. Fortunately, the hotel management

also has provided good cooperation in ensuring the safety of this equipment and keep them in order to prevent stolen by irresponsible parties.

Other than that, the hotel management also has helped in monitoring the structure at the test site. They are supposed to make an immediate complaint to NAHRIM in case of any problems happen associated with the NEXC Blocks System. Bilateral cooperation with the hotel management developed through technical meetings, reports and complaints can also directly assist the monitoring program in this study.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this study, the result and analysis will be presented or highlighted in four section. Firstly, morphological process at the test site over a few years is analysed based on shoreline changes as observed in satellite image. Secondly, stability analysis of Prototypes A, B and C are discussed. Next, results and discussions of physical modelling under different scenario was carried out. Finally, beach profile changes obtained from onsite monitoring programme at Pantai Batu 5, Port Dickson is analysed and discussed.

4.2 IMAGERY SHORELINE CHANGE ANALYSIS

Shoreline change monitoring is very important to analyse the dynamic morphological changes in a particular area. In this study, historical satellite imagery is used to identify the changes over several years. These archive pictures were extracted from Google Earth Pro, ranging in dates from 20 August 2003 to 24 January 2016 as shown in Figure 4.1 to Figure 4.6.

According to NCES, the dominant littoral drift direction in the study area is in the south east direction as shown in Figure 4.1. The Regency Tanjung Tuan Beach Resort is located quite closed to the beach and very vulnerable to coastal erosion problem. The man-made marina was constructed at the down drift side of the resort. This man-made structure formed a head land that potentially block the sediment supply to the down drift side and will lead to erosion and accretion process to the adjacent shoreline.

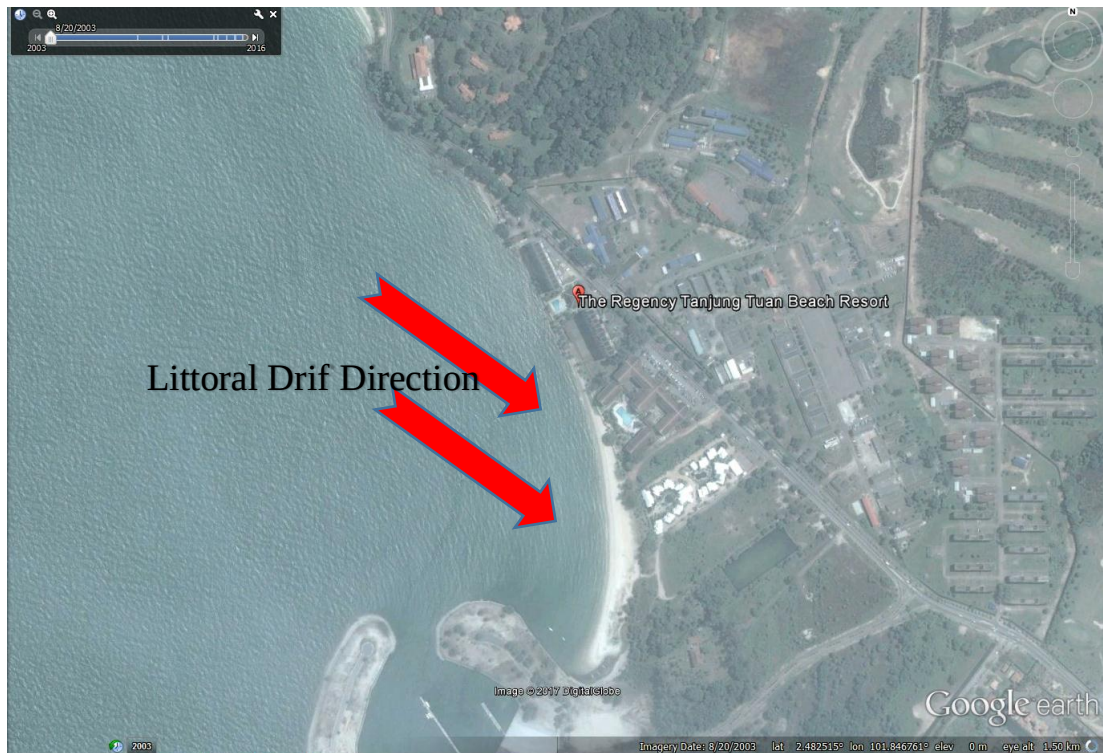


Figure 4.1 : Satellite image of the test site dated on 20 August 2003
(source : Google Earth)



Figure 4.2 : Satellite image of the test site dated on 4 October 2009
(source : Google Earth)

From Figure 4.2, we can see the rapid accretion process at the upper part of the marina head land structure over a period of 6 years. This sandy beach formation

occurred quite significantly in that particular area compare to previous image. DID also was carried out beach nourishment project in 2005 and expected that some of the sediment source already moved to the accreted part.



Figure 4.3 : Satellite image of the test site dated on 27 November 2010
(source : Google Earth)



Figure 4.4: Satellite image of the test site dated on 17 June 2014
(source : Google Earth)



Figure 4.5 : Satellite image of the test site dated on 5 August 2015
(source : Google Earth)



Figure 4.6 : Satellite image of the test site dated on 24 January 2016. The small picture in the red box also shows the site that already deployed with NEXC Blocks System
(source : Google Earth)

Overall, the images show little changes from year 2009 to 2016. However, comparison of image dated on 2003 with 2009 shows appreciable accretion at the down side of the headland of the man-made marina. This may be attributed to sediment intercept at that particular area due to the structure.

Figure 4.6 shows the latest image dated 24 January 2016, which reflects the site condition after the NEXC Blocks System is deployed. The image shows severe erosion had occurred at the up drift due to the lack of sediment supply. The two pipe outfalls located up drift of the NEXC Blocks System acts like groynes that block the sediment from moving to the down drift direction. This condition had led to the severe erosion problem to this shoreline.

From this simple imagery monitoring analysis, it can be concluded that, the morphology changes in the study area occurred due to the natural sediment process as well as the intervention of man-made structures such as marina and pipe outfall.

4.3 NEXC BLOCK STRUCTURE STABILITY ANALYSIS

The stability of NEXC Block Structure Prototype A, B and C are determined considering overturning and sliding. Figure 4.7 shows all relevant forces that are considered with reference to point 0, P_1 and P_2 are the wave pressure on the NEXC Block structure; P_4 is the uplift pressure due to hydrostatic force. Other parameters include wave height h_c , structure face slope e (or $\theta = 30^\circ, 45^\circ \text{ \& } 60^\circ$), depth of sea water $d_s (= h)$ and beach slope $m (= 1:15)$.

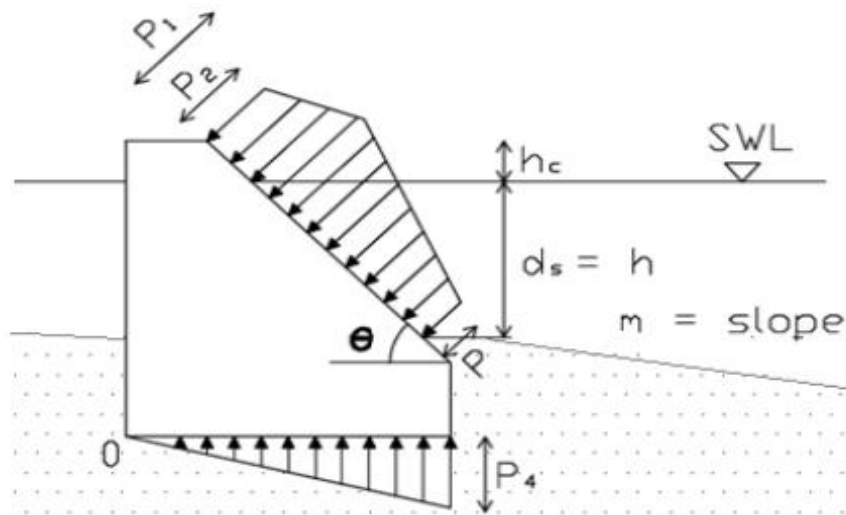


Figure 4.7: Diagram of wave force on NEXC Block Structure (FKA UTM, 2016).

All of the overturning failure is rotation of wall about its toe due to exceeding of moment caused due overturning forces to resisting forces (FKA UTM, 2016). Equation (1) show the factor of safety against (FOS) overturning is given by:

$$FOS = \frac{\sum M_R}{\sum M_0} > 1.5 \quad (1)$$

where,

$\sum M_R$ = sum of resisting moment about toe

$\sum M_0$ = sum of overturning moment about toe

Table 4.1 shows the moment acting on the sea block structure at point 0 (refer to the Figure 4.7). The stability analysis on overturning is checked and the factor of safety for overturning must be more than exceeds 1.5 for all cases, and are thus acceptable.

Table 4.1: Overturning check on sea block structure at point 0

Prototype	Θ	Moment at 0		$\frac{\sum M +}{\sum M -}$	Remark
		$\sum M +$ (kNm)	$\sum M -$ (kNm)		
A	30°	58.2	18.88	3.1	Ok
B	45°	18.1	7.58	2.4	Ok
C	60°	14.71	7.64	1.9	Ok

(source : FKA UTM, 2016)

However, Prototype A may be overdesigned (FOS = 3.1). Prototype B (FOS = 2.4) presents an economical option. On the other hand, Prototype C (FOS = 1.9) is on the lower side.

Figure 4.8 indicates the illustration of sliding along the base. The factor of safety sliding may be expressed by Equation (2) below:

$$FS = \frac{\sum R_V \tan \delta + k c_2 B}{\sum R_H} \quad (2)$$

where,

$\sum R_V$ = sum of the vertical resisting forces

$\sum R_H$ = sum of the horizontal resisting forces

δ = angle of friction between the soil and base slab

k = the range between 1/3 to 2/3

c = cohesion of soil

R = resistance force

B = bottom length of structure

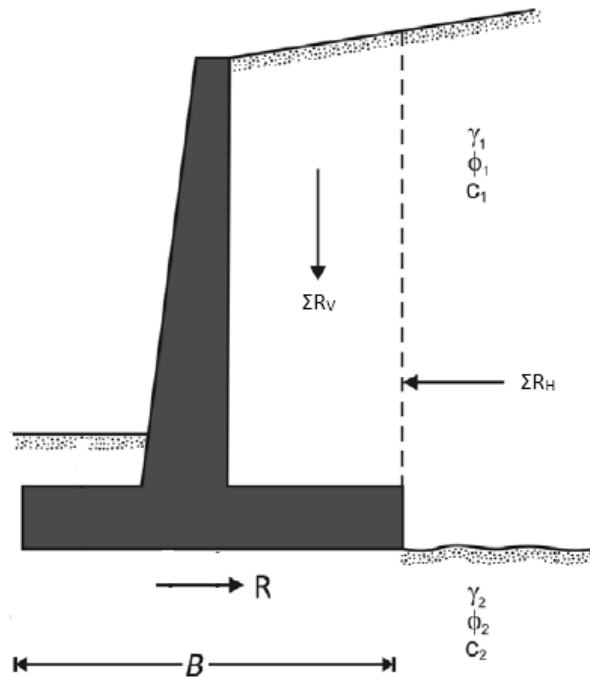


Figure 4.8: Sliding along the base (source : FKA UTM, 2016)

The result of sliding check is shown in Table 4.2. The results show that all 3 options full fill the minimum FOS of 1.5.

Table 4.2: Sliding check on NEXC Block Structure at point 0

Prototype	Angle (°)	ΣR_v (kN)	ΣR_H (kN)	B (m)	FOS	Remark
A	30	68	18.45	1.85	3.7	Ok
B	45	40.2	15.36	1.2	2.8	Ok
C	60	31.75	12.34	1.05	2.9	Ok

(source : FKA UTM, 2016)

The summary and option analysis of all these three prototypes (Prototype A, B and C) is given in the Table 4.3. It is deduced that the best design option for NEXC Block is Prototype B.

Table 4.3 : The summary and option analysis of Prototype A, B and C of NEXC Block Prototype Product.

Item	Prototype A	Prototype B	Prototype C
FOS for overturning check must > 1.5	3.1 (ok but can consider as overdesign)	2.4 (just nice)	1.9 (ok but not enough for precaution measure)
FOS for sliding check must > 1.5	3.7 (ok but can consider as overdesign)	2.8 (ok)	2.9 (ok)
Approximate Weight (tonnes)	3.7 (heavy)	2.5 (moderate)	2.2 (light)
Shape	too steep	average	too vertical
On-site handling	quite difficult to handle	easy to handle	easy to handle
Selection :	Not recommend	Best option	Not recommend

4.4 PHYSICAL MODELLING EXPERIMENT RESULT AND ANALYSIS

The result of the physical modelling experiment simulation in laboratory based on three main scenarios as discussed in Chapter 3, as follows (Table 4.4):

- i. Scenario 1 : Simulation without NEXC block structure with three (3) different water level (0.9m, 1.0m and 1.1m) and two (2) different wave height (0.1m and 0.2m) as control measures
- ii. Scenario 2 : Simulation with NEXC block structure with three (3) different water level (0.9m, 1.0m and 1.1m) and two (2) different wave height (0.1m and 0.2m)
- iii. Scenario 3 : Simulation with NEXC block structure and toe protection with three (3) different water level (0.9m, 1.0m and 1.1m) and two (2) different wave height (0.1m and 0.2m)

Table 4.4 : The Summary of Physical Modelling Experiment and Scenarios Involved

Scenario	Water Level (m)	Wave Height (m)	
Scenario 1 (without structure), no. of experiment = 6	0.9	0.1	0.2
	1.0	0.1	0.2
	1.1	0.1	0.2
Scenario 2 (with NEXC Block Structure), no. of experiment = 6	0.9	0.1	0.2
	1.0	0.1	0.2
	1.1	0.1	0.2
Scenario 3 (with NEXC block structure and toe protection, no. of experiment = 6	0.9	0.1	0.2
	1.0	0.1	0.2
	1.1	0.1	0.2

4.4.1 Result of Scenario 1

Scenario 1 of 1 : experimental setup without NEXC Block Structure, water level (WL) 0.9m and wave height (Hs) 0.1m.

The initial condition of the model setup at the beginning of the experiment is shown in Figure 4.9 and the condition of the test model in the 2D flume after the experiment completed is shown in Figure 4.10.



Figure 4.9 : The initial condition of the model setup at the beginning of the experiment for scenario 1 of 1 (source : NAHRIM)

Yellow line marker was used as a marking line for initial beach slope and geometry shape for the model construction.

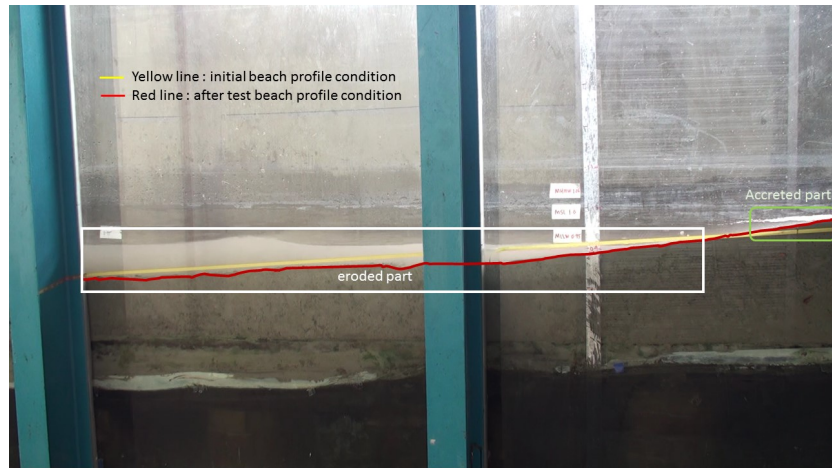


Figure 4.10 : The condition of the test model in the 2D flume after the experiment for scenario 1 of 1 (source : NAHRIM)

From this experiment (refer to Figure 4.10), it can be observed that erosion occurred at the breaking zone and accretion occurred at the other part of the beach. Profiling survey was carried out to confirm the morphology changes due to the erosion and accretion processes. For the profile changes measurement, the survey alignment was carried out along the test model in the flume at the location of cross shore section of 0.4m (x coordinate at 40cm), 0.7m (x coordinate at 70cm) and 1.0m (x coordinate at 100cm) as shown in Figure 4.11.

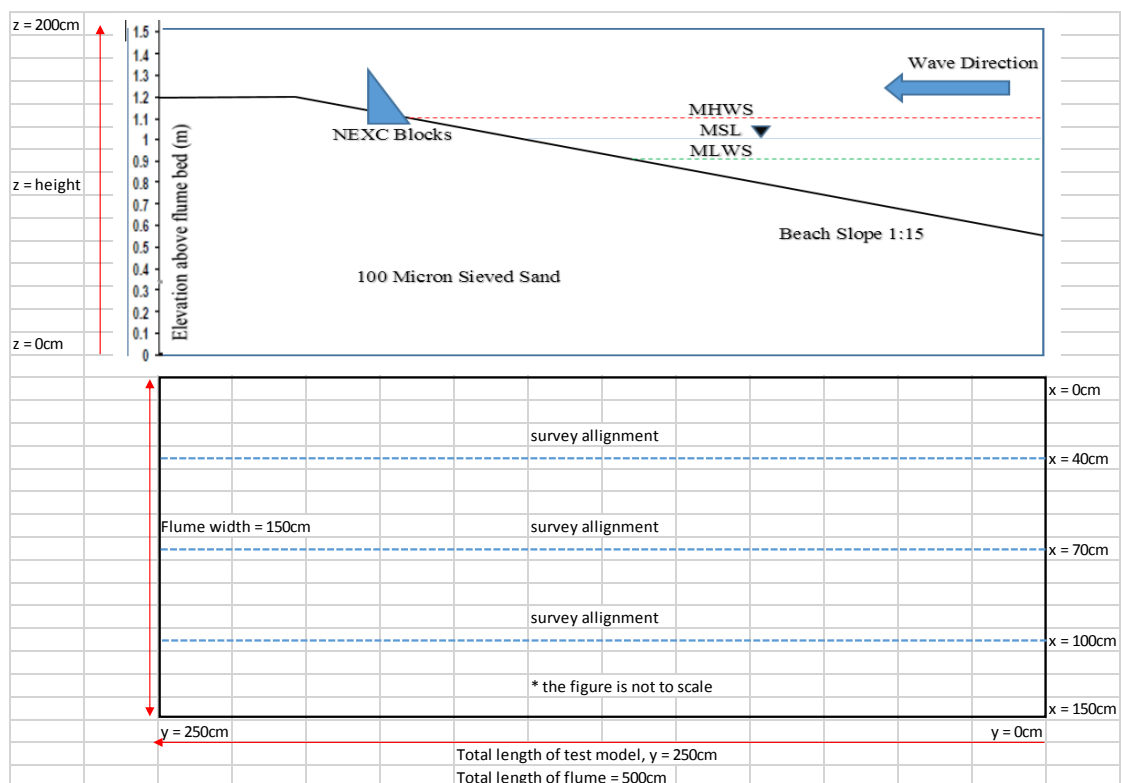


Figure 4.11 : Side view & plan view of the survey alignment position and reference coordinates in the flume

In plotting the graph, these survey alignment marked and referred as x40 for cross shore section at 0.4m, x70 for cross shore section at 0.7m and x100 for cross shore section at 1.0m. The survey result was plotted in the 3D graph as shown in Figure 4.12.

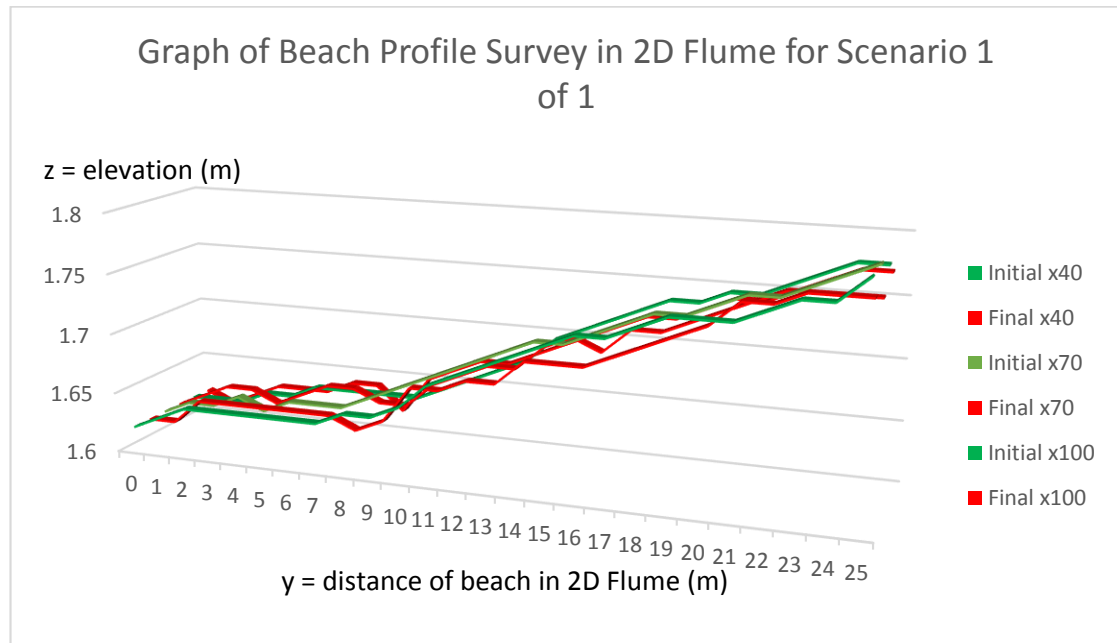


Figure 4.12 : The 3D Graph of Beach Profile Measurements in 2D Flume for Scenario 1 of 1

In Figure 4.12, the green lines represent the initial condition of beach profile or before test condition while the red lines represent the after test or final condition of beach profile. However, it is quite difficult to see any changes in morphology of the beach in the flume with 3D-graph.

To simplify the analysis and to show the relationship between the profile changes in the flume before and after test condition with the erosion and accretion value, we convert the graph to a simple way. So, the result of this survey is given in erosion value (m) as shown in the 3D graph in Figure 4.13. The positive (+) value of z represent the erosion and the negative (-) value represent the accretion in the test model. From the Figure 4.13, we found that, most of the beach profile experienced the erosion due to wave action and only minor part of the beach was accreted due to sediment movement from the eroded part. The erosion was actively occurred in the cross shore section area between 10 to 21 m of y value due to breaking wave zone.

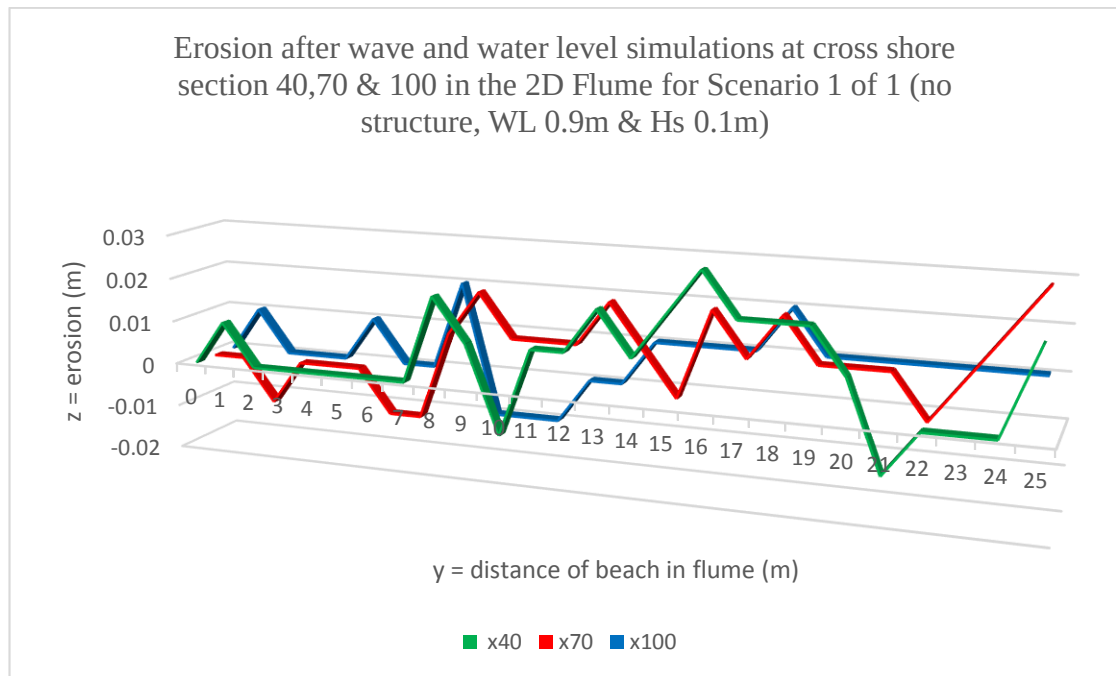


Figure 4.13 : Result of Scenario 1 of 1

Scenario 1 of 2 : experimental setup without NEXC Block Structure, water level 0.9m and wave height 0.2m.

The condition of the test model is shown in Figure 4.14 and the result of this experiment is shown in Figure 4.15.

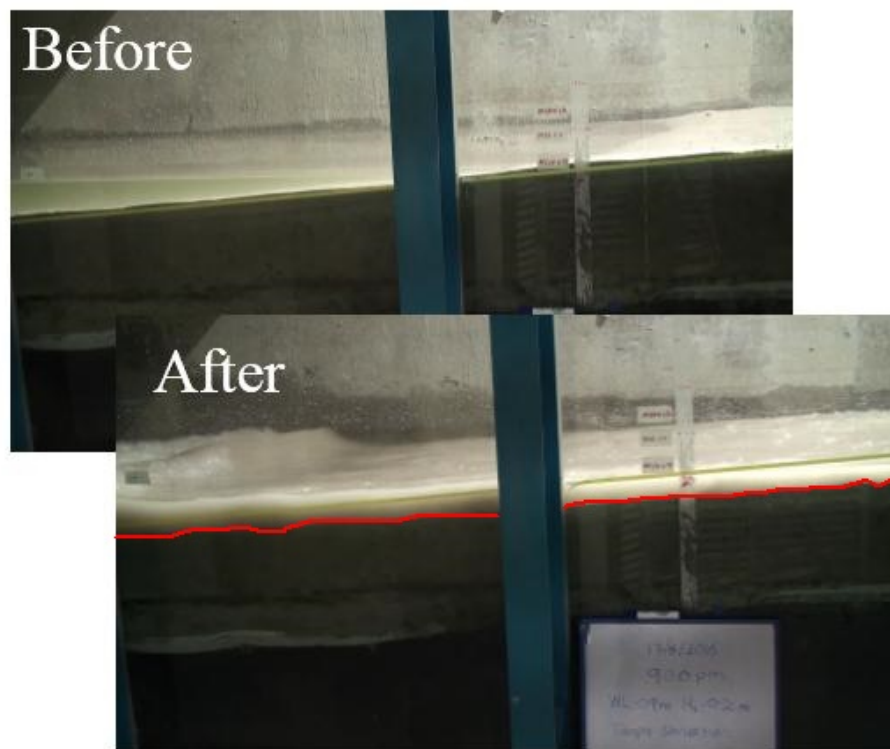


Figure 4.14 : Testing Condition of Scenario 1 of 2 (source : NAHRIM)

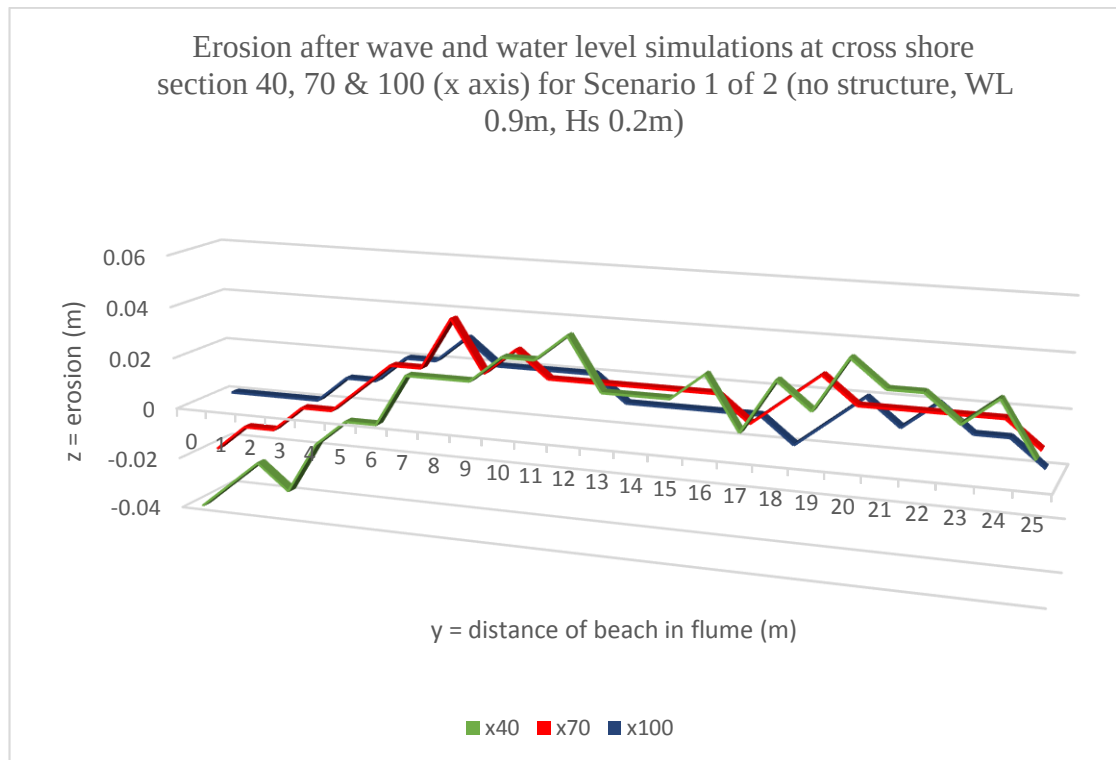


Figure 4.15 : Result of Scenario 1 of 2

In this experiment, same like scenario 1 of 1, most of the beach profile experienced the erosion due to wave action but the severity is more compare to the previous scenario. In scenario 2, the water level remain same with scenario 1 but the wave height is double while the erosion occurred more severe. The comparison of these two scenario's result is shown in 3D lines graph in Figure 4.16. From the graph, we can see the maximum value of erosion in Scenario 1 of 2 is more or exceed 0.03m or 3cm (red lines) compare to the Scenario 1 of 1, (green lines). So that both of these two scenario (mean low water condition) generally have proven the natural condition of beach erosion that the magnitude of erosion worsened by the increasing of wave height.

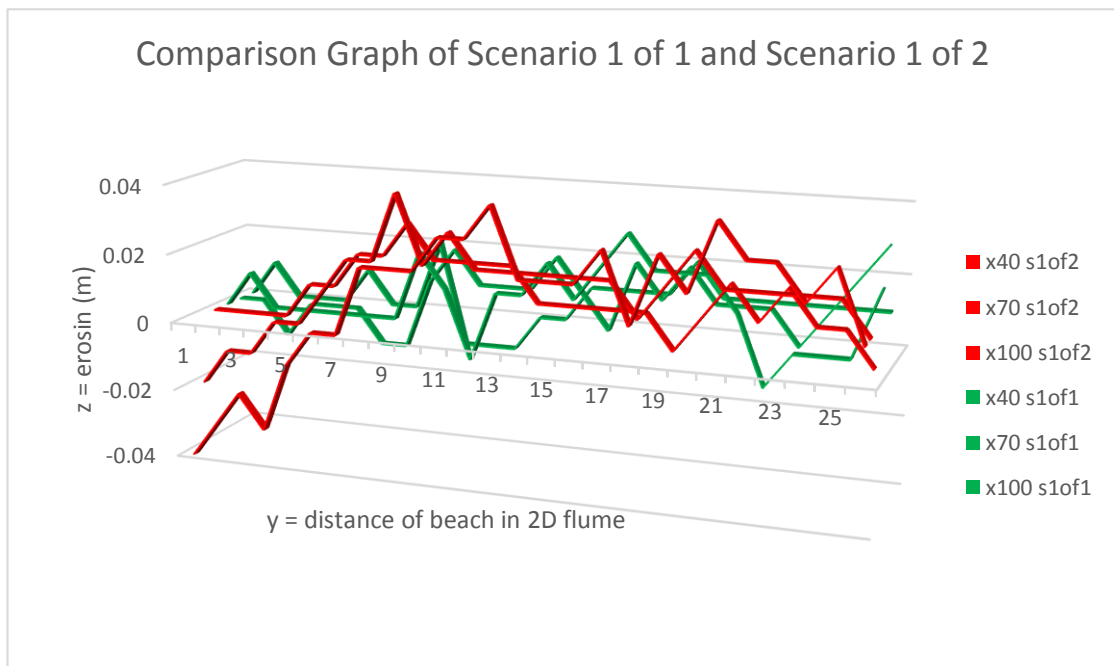


Figure 4.16 : Comparison Graph of the Result of Both Scenario 1 of 1 and Scenario 1 of 2.

Scenario 1 of 3 : experimental setup without NEXC Block Structure, water level 1.0m and wave height 0.1m.

The condition of the test model is shown in Figure 4.17.

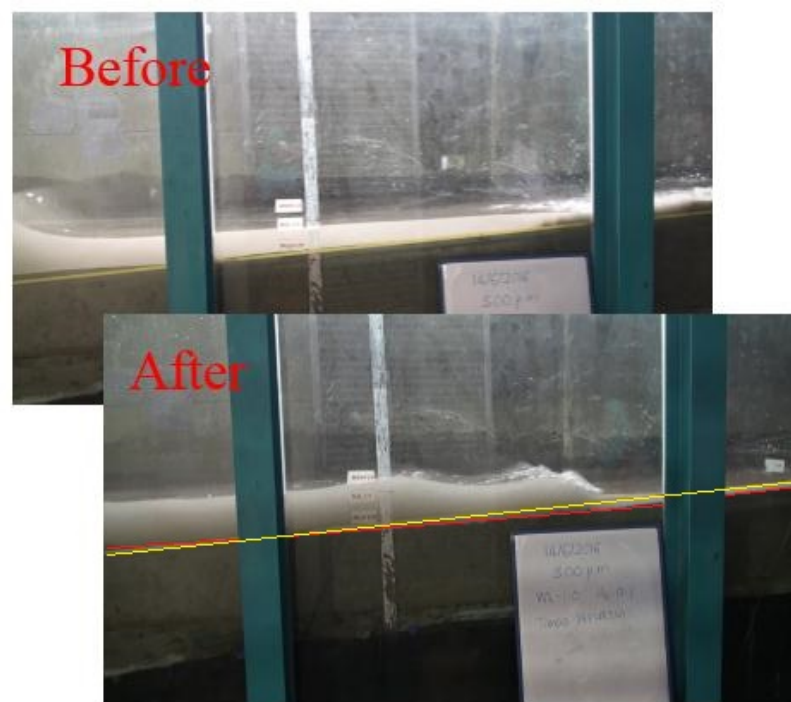


Figure 4.17 : Testing Condition of Scenario 1 of 3 (source : NAHRIM)

Scenario 1 of 4 : experimental setup without NEXC Block Structure, water level 1.0m and wave height 0.2m.

The condition of the test model is shown in Figure 4.18.

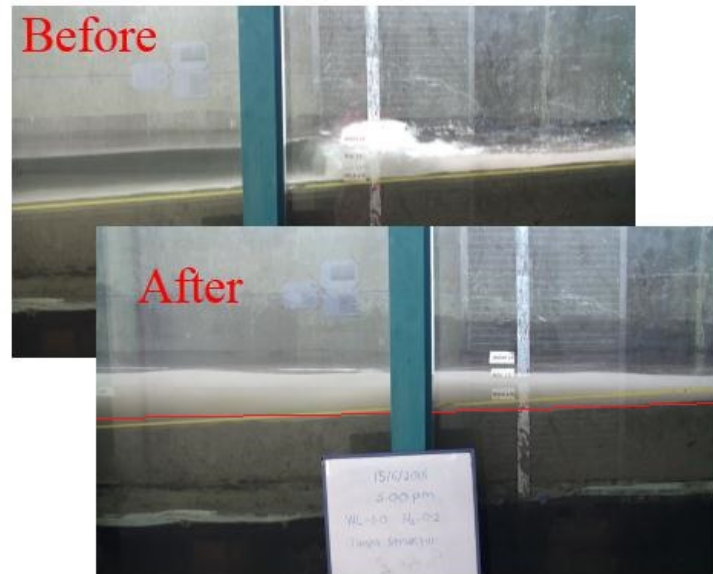


Figure 4.18 : Testing Condition of Scenario 1 of 4 (source : NAHRIM)

For scenario 1 of 3 and scenario 1 of 4, the comparison result is shown in the 3D line series graph in the Figure 4.19.

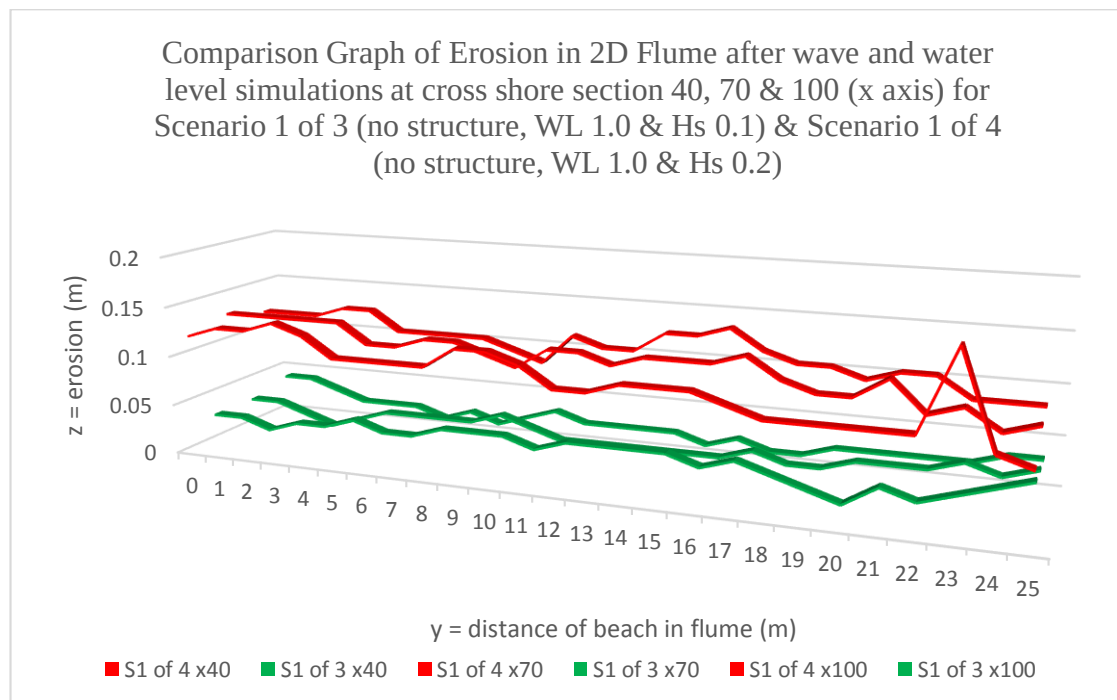


Figure 4.19 : Result of Scenario 1 of 3 (green line) and Scenario 1 of 4 (red line)

For these two scenario with the water level represent the MSL condition, also clearly prove that the magnitude of erosion worsened by the increasing of wave height and the maximum value of erosion is higher compare to the scenario for mean low water condition.

Scenario 1 of 5 : experimental setup without NEXC Block Structure, water level 1.1m and wave height 0.1m.

The condition of the test model is shown in Figure 4.20.

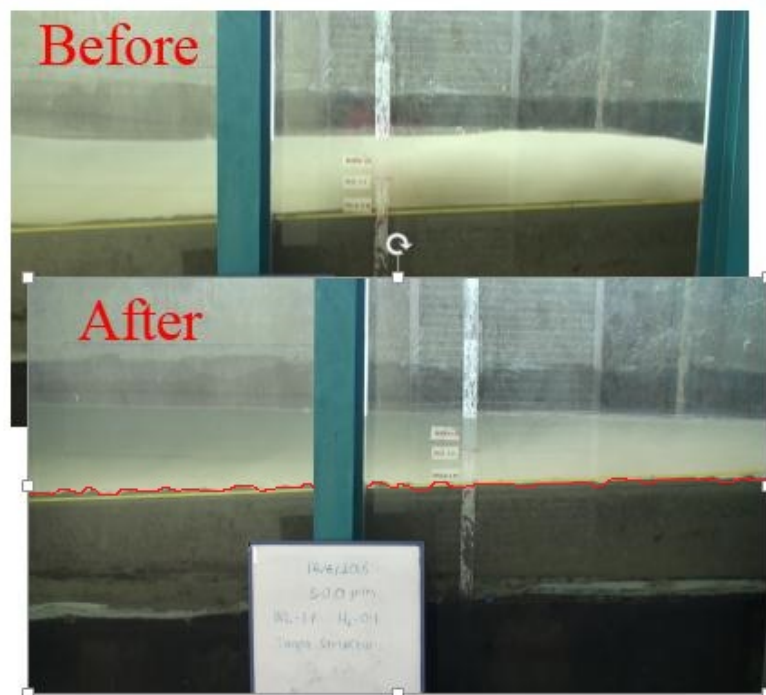


Figure 4.20 : Testing Condition of Scenario 1 of 5 (source : NAHRIM)

Scenario 1 of 6 : experimental setup without NEXC Block Structure, water level 1.1m and wave height 0.2m.

The condition of the test model is shown in Figure 4.21.

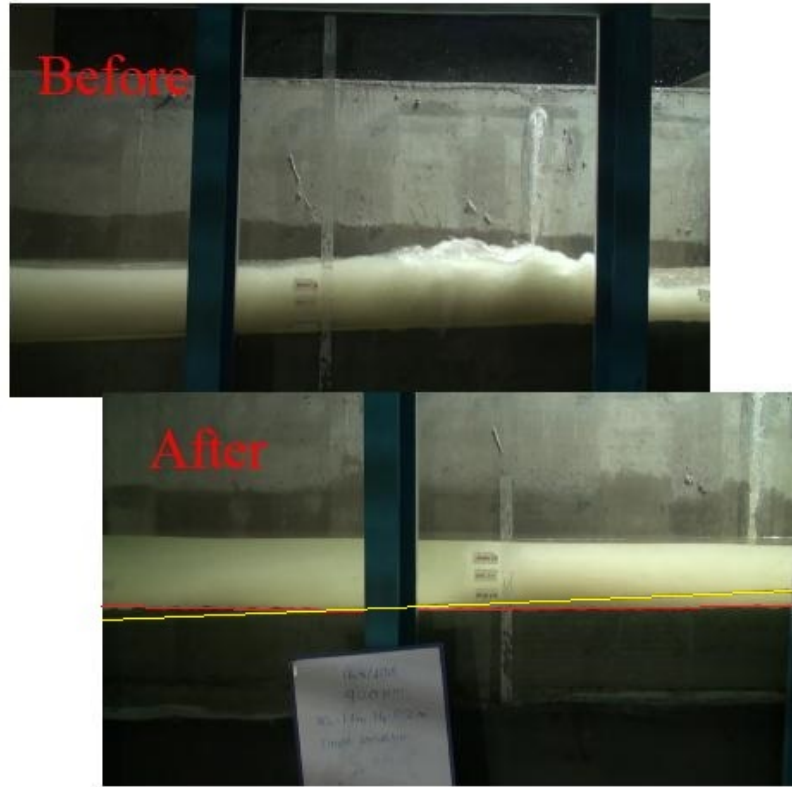


Figure 4.21 : Testing Condition of Scenario 1 of 6 (source : NAHRIM)

For scenario 1 of 5 and scenario 1 of 6, the comparison result is shown in the 3D line series graph in the Figure 4.22.

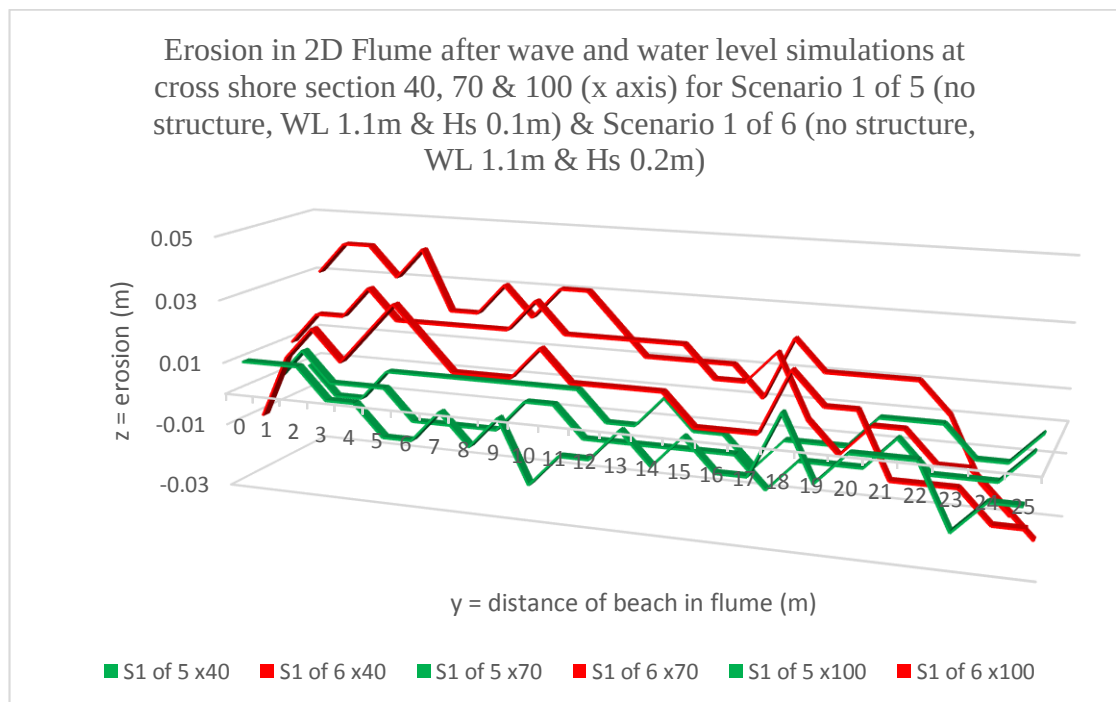


Figure 4.22 : Result of Scenario 1 of 5 (green line) and Scenario 1 of 6 (red line)

From the Figure 4.22, the erosion magnitude for scenario 1 of 6 (red lines) is bigger than the erosion magnitude for scenario 1 of 5 (green lines) due to bigger wave high.

For overall observation from Scenario 1 physical modelling experiment, we can conclude that:

- Bigger wave high (H_s) will cause the breaking condition occurred more towards leeward side of the beach for all cases of water level (MLW, MSL & MHW). Bigger wave high also will have more impact due to bigger force, more energy, higher wave run up and speed.
- Bigger wave high also will cause more impact to bed scour towards the beach and the erosion will occur far inland
- In these scenario, the erosion condition is dominant compare to accretion condition. However, behind the breaking wave and bed scour area, we observed that the accretion of sediment occurred in that particular area. More accretion of sand sediment occurred in the cases of higher water level and higher wave scenario.

4.4.2 Result of Scenario 2

In the scenario 2 experiments, a single layer of NEXC Blocks System was placed in the test model to study the performance of the product.

Scenario 2 of 1 : experimental setup with NEXC Block Structure (without toe protection), water level (WL) 0.9m and wave height (H_s) 0.1m.

The condition of the test model is shown in Figure 4.23. From the Figure 4.23, we can see that the potential of this product to protect the shoreline from erosion. After test condition, the product is still in the position and remain stabil. The sediment also accreted in front of the NEXC Blocks and some of the sediment penetrated to the back side of the product through the holes. However, a quite severe erosion also occurred seaward from the product due to wave action. The eroded sediment from this area actually pushed up to the accretion side in front of the product because of wave forces. The result of this survey is given in erosion (m) for positive (+) value and accretion in negative (-) value as shown in the 3D graph in Figure 4.24.

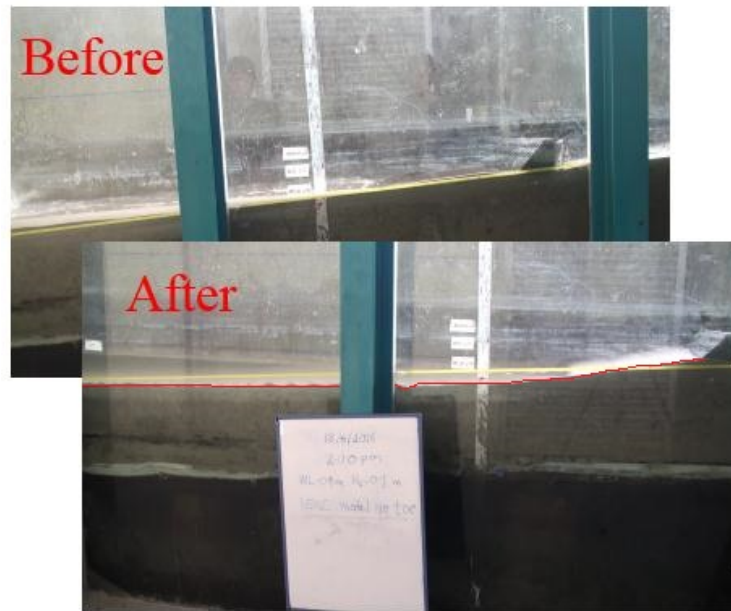


Figure 4.23 : Testing Condition of Scenario 2 of 1 (source : NAHRIM)

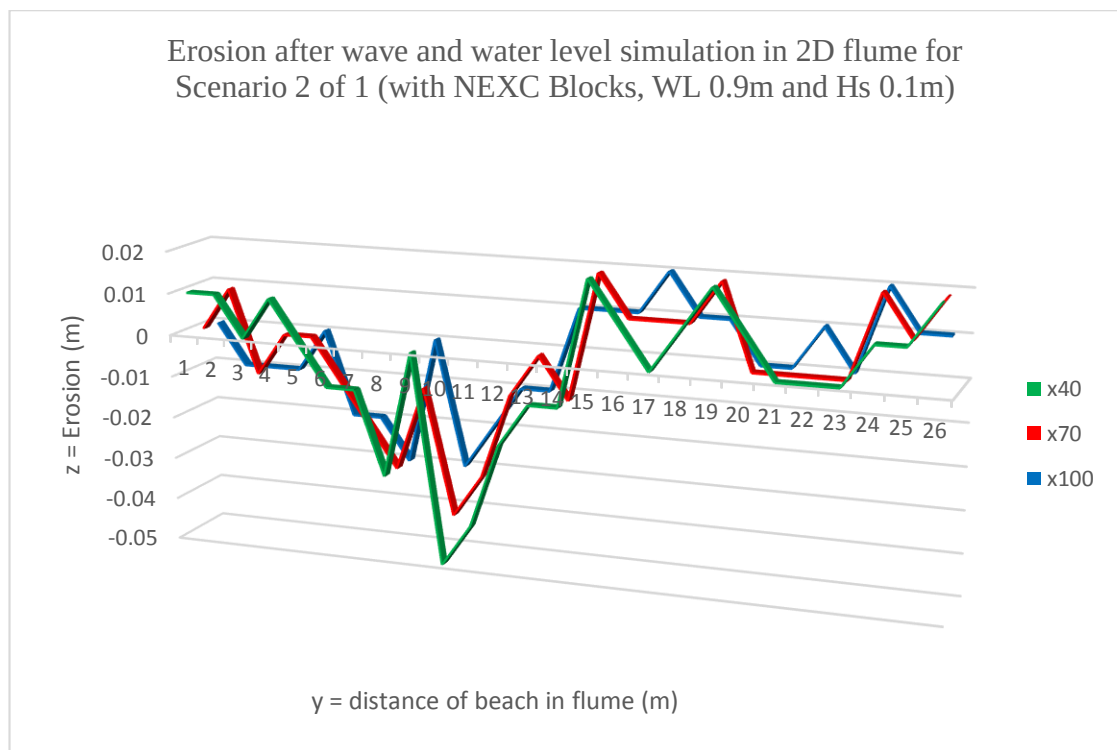


Figure 4.24 : Result of Scenario 2 of 1

From the graph in Figure 4.24, the accretion occurred in front of the NEXC Blocks (y distance between 9 to 13) with maximum value of -0.05m or -5cm. So we can say

that that the placement of this product had already reduced the magnitude of erosion to the shoreline.

Scenario 2 of 2 : experimental setup with NEXC Block Structure (without toe protection), water level (WL) 0.9m and wave height (Hs) 0.2m.

The condition of the test model is shown in Figure 4.25.



Figure 4.25 : Testing Condition of Scenario 2 of 2 (source : NAHRIM)

For scenario 2 of 2, higher wave height (0.2m) caused a severe erosion and minor scour problem was also detected in front of the toe of NEXC Blocks as shown in Figure 4.25. Even though in this case, the NEXC Blocks is still intact with the shoreline, but the integrity of the structures are in quite dangerous condition.

The result of this experiment is shown in the 3D graph in Figure 4.26. From the graph in Figure 4.26, erosion occurred dominantly towards the beach (y value from 9m to 25m in the flume) while accretion was taking place towards the offshore (y = 1m to 9m). Sediment from eroded part was moved to accreted part due to wave action. For this scenario, the maximum value of erosion is 4cm and for accretion is 2cm.

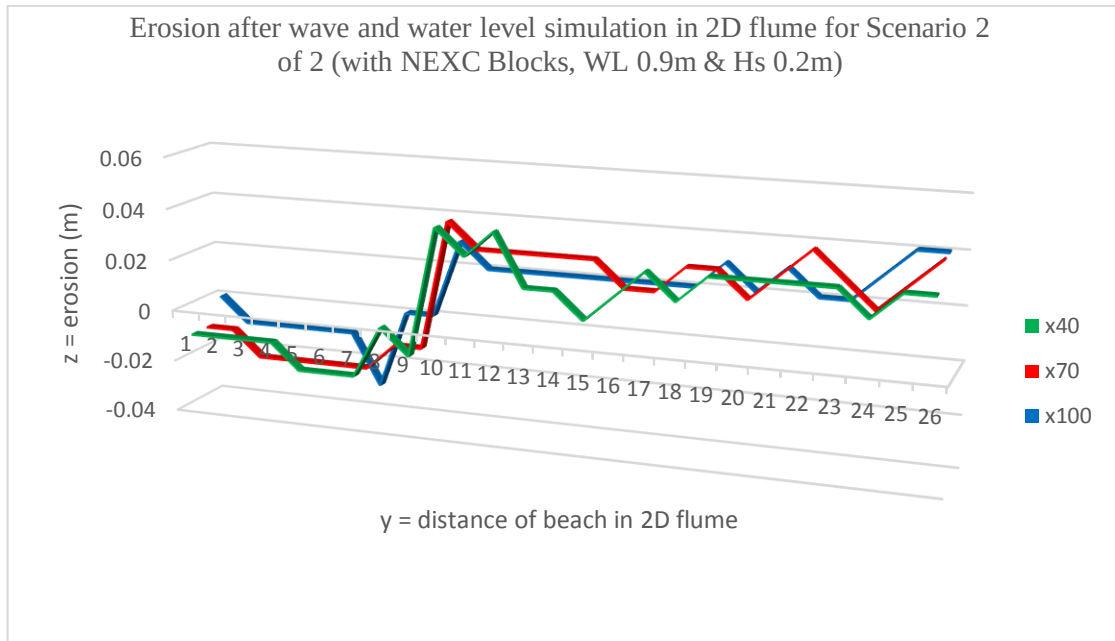


Figure 4.26 : Result of Scenario 2 of 2

Scenario 2 of 3 : experimental setup with NEXC Block Structure (without toe protection), water level (WL) 1.0m and wave height (Hs) 0.1m.

The condition of the test model is shown in Figure 4.27.

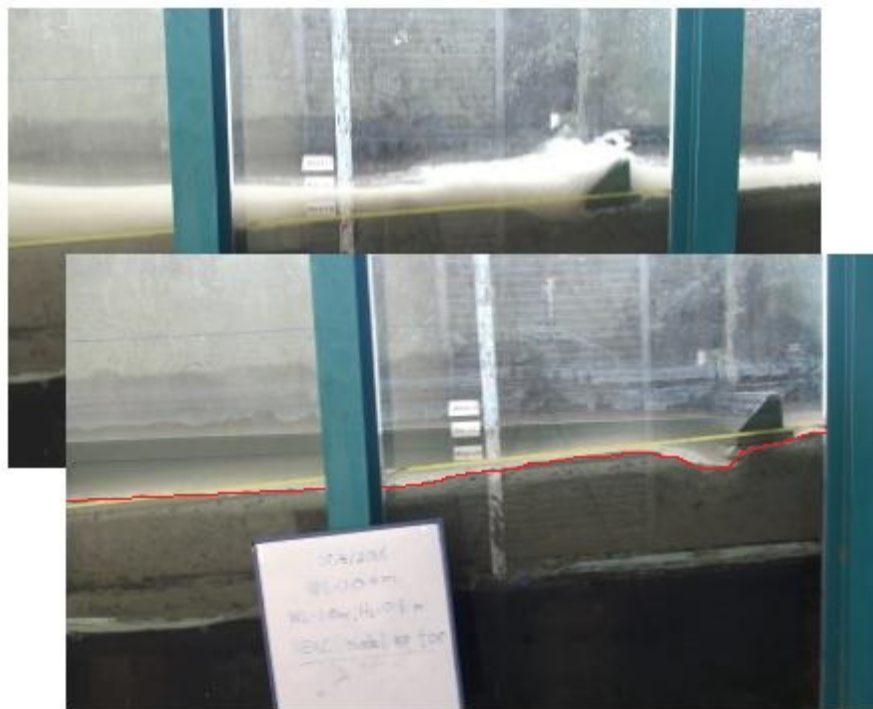


Figure 4.27 : Testing Condition of Scenario 2 of 3 (source : NAHRIM)

From the Figure 4.27, the increasing of 0.1m water level has caused severe scoring problem in front of the toe NEXC Blocks structure. The stability of this structure is in danger and it will lead to structure failure.

Scenario 2 of 4 : experimental setup with NEXC Block Structure (without toe protection), water level (WL) 1.0m and wave height (Hs) 0.2m.

The condition of the test model is shown in Figure 4.28.

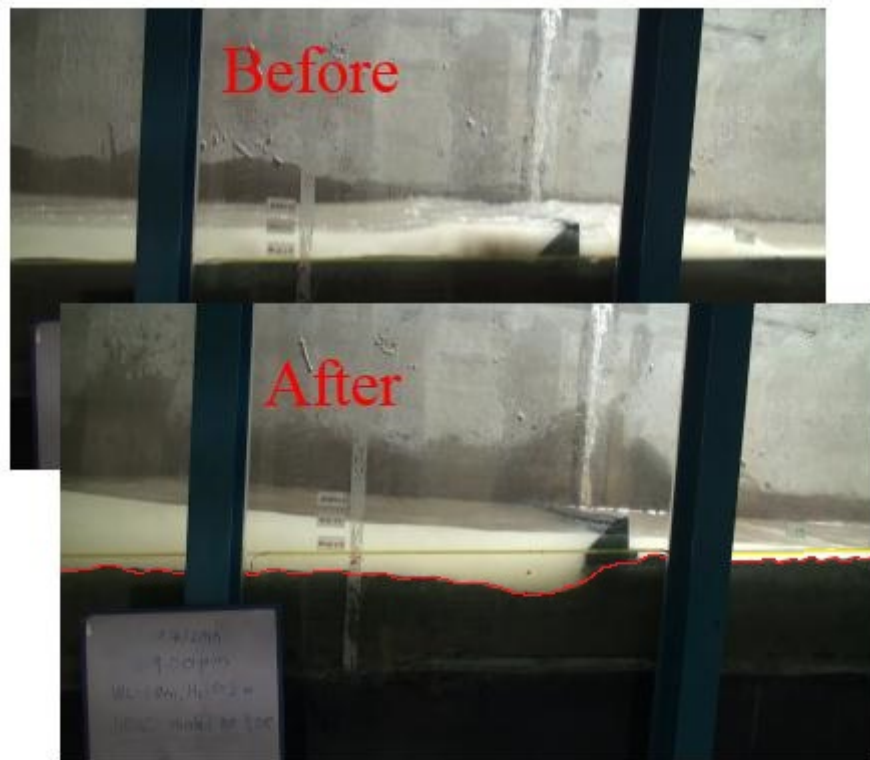


Figure 4.28 : Testing Condition of Scenario 2 of 4 (source : NAHRIM)

From the Figure 4.28, the scour and erosion magnitude are more especially in front of the toe structure compared to the previous scenario (2 of 3) due to the increasing of wave high (0.2m). Generally, the vertical structure have a great impact of scouring against the wave action as already occurred in this experiment. To compare the magnitude of erosion between these two scenario (2 of 3 and 2 of 4), it was illustrated in the 3D graph as shown in Figure 4.29.

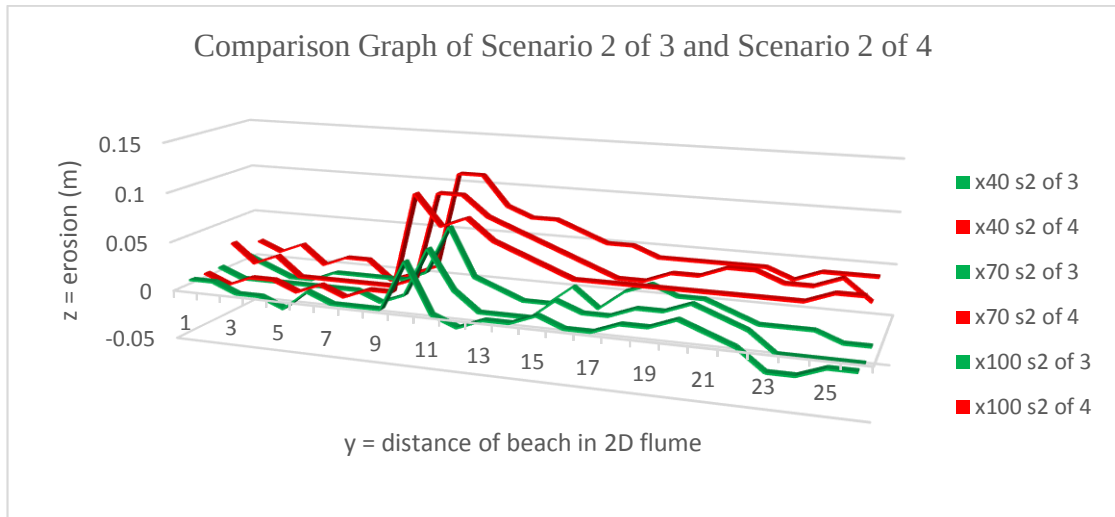


Figure 4.29 : Result of Scenario 2 of 3 (green lines) and Scenario 2 of 4 (red lines)

From the graph in Figure 4.29, the maximum value of erosion for scenario 2 of 4 is 11cm and 6cm for scenario 2 of 3 (at location $y=10\text{m}$). 5cm accretion also occurred at the back side of the structure (at location $y = 23$ and 24) for scenario 2 of 3 due to sediment passing through the holes of the structure.

Scenario 2 of 5 : experimental setup with NEXC Block Structure (without toe protection), water level (WL) 1.1m and wave height (H_s) 0.1m.

The condition of the test model is shown in Figure 4.30.



Figure 4.30 : Testing Condition of Scenario 2 of 5 (source : NAHRIM)

Scenario 2 of 6 : experimental setup with NEXC Block Structure (without toe protection), water level (WL) 1.1m and wave height (H_s) 0.2m.

The condition of the test model is shown in Figure 4.31.

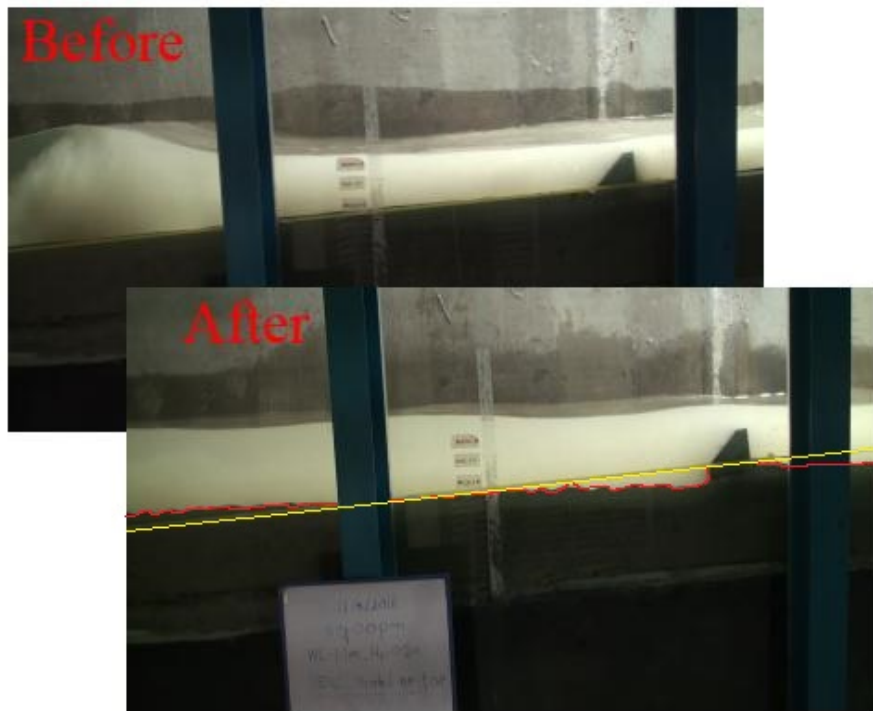


Figure 4.31 : Testing Condition of Scenario 2 of 6 (source : NAHRIM)

From both testing condition of scenario 2 of 5 and scenario 2 of 6 as shown in Figure 4.30 and 4.31, it was observed that the test model and product experienced the erosion, accretion and scouring processes. The morphology changes and behaviour are almost same like previous scenario but with different magnitude or value. To compare the magnitude of erosion between these two scenarios, it was illustrated in the 3D graph as shown in Figure 4.32.

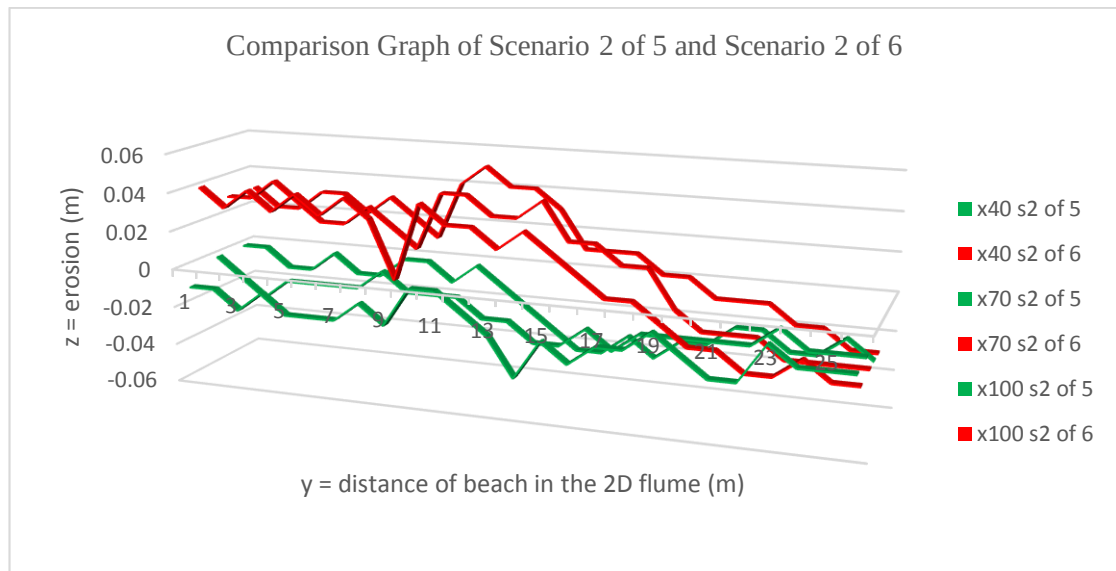


Figure 4.32 : Result of Scenario 2 of 5 (green lines) and Scenario 2 of 6 (red lines)

From the 3D graph in Figure 4.32, the 5cm maximum value of erosion was recorded for scenario 2 of 6 and maximum accretion value of 4cm for scenario 2 of 5. The magnitude of erosion is also more severe in the case of higher wave height condition.

For overall situation of scenario 2, we observed that the severe scour occurred in front of the toe area of the NEXC Blocks Structure. The structure actually could withstand with these kind of wave force and already help to reduce the erosion but the scour problem should be taking care in the design consideration. Accretion also occurred at the back side of the product especially during low water level. However, due to the limitation of no sediment supply adding to this test model, so the sediment transport element could not took into account in this experiment (static sediment condition).

4.4.3 Result of Scenario 3

In scenario 3, a layer of toe protection was placed at the toe area for scour protection. The plastic straws was used as a scour protection structure in this experiment in order to improve the performance of NEXC Blocks as a coastal protection product.

Scenario 3 of 1 : experimental setup with NEXC Block Structure with toe protection, water level (WL) 0.9m and wave height (Hs) 0.1m.

The condition of the test model is shown in Figure 4.33.

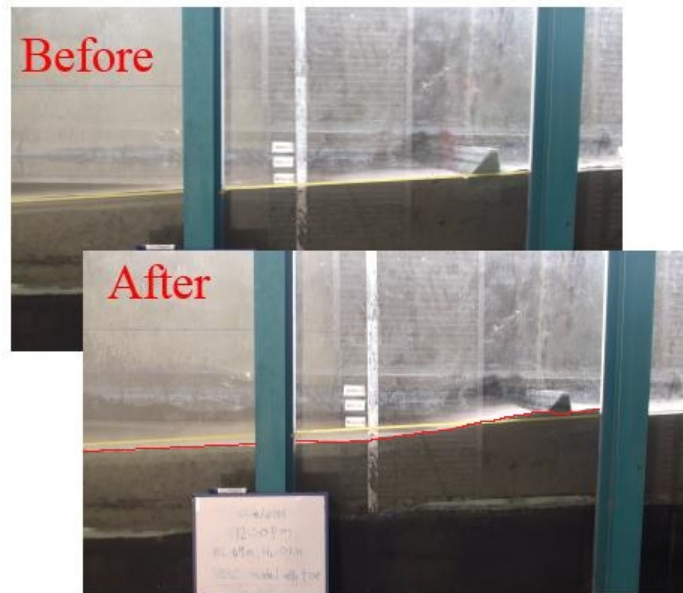


Figure 4.33 : Testing Condition of Scenario 3 of 1 (source : NAHRIM)

From the Figure 4.33, with the placement of the toe protection, eventhough the erosion still occured at the seaward side, the NEXC Blocks Structure was found performed well in combacting the erosion in this case. Therefore, the comparison results between scenario 3 of 1 (NEXC Blocks structure with scour protection) and scenario 2 of 1 (NEXC Blocks structure without protection) will be analyzed for better understanding (refer to Figure 4.34).

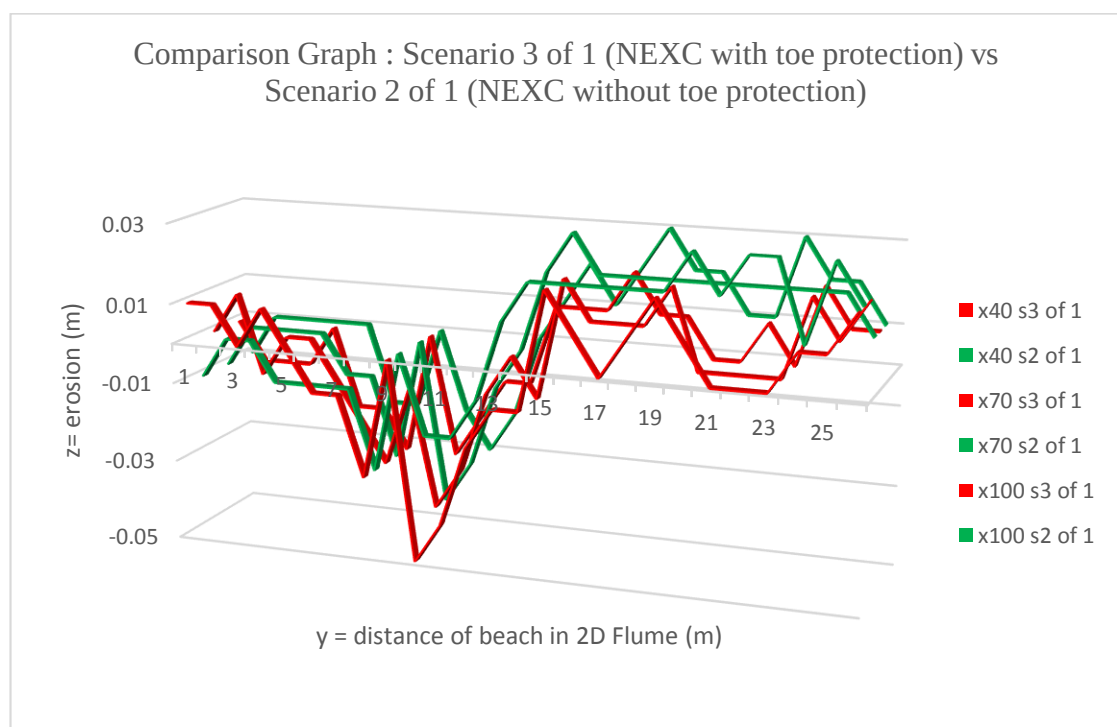


Figure 4.34 : Comparison results between scenario 3 of 1 and scenario 2 of 1

In Figure 4.34, the red lines of the graph represent the scenario 3 of 1 and the green lines represent the scenario 2 of 1. We can see from the graph, the value of erosion was successfully reduced towards the NEXC Blocks Structure and seaward side (y value between 15 to 25) due to the installment of the scour protection at the toe of the model product.

Scenario 3 of 2 : experimental setup with NEXC Block Structure with toe protection, water level (WL) 0.9m and wave height (Hs) 0.2m. The condition of the test model is shown in Figure 4.35.

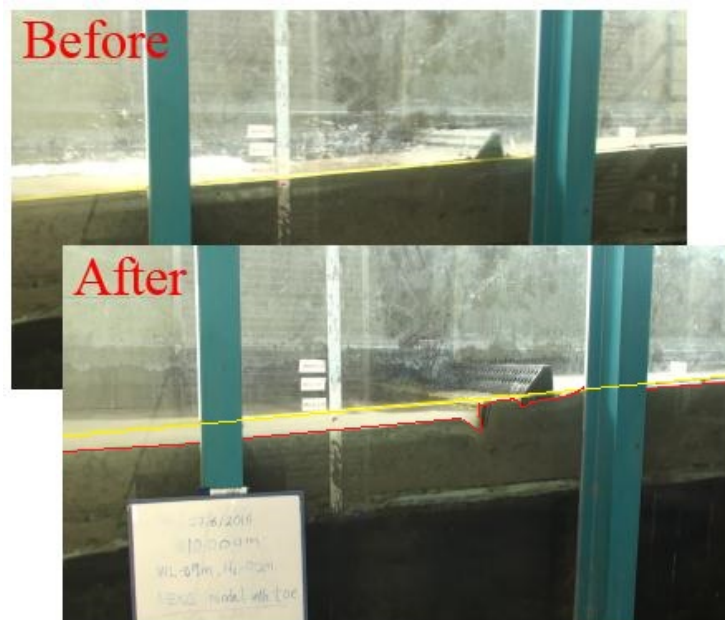


Figure 4.35 : Testing Condition of Scenario 3 of 2 (source : NAHRIM)

From the Figure 4.35, the severe scour problem occurred after the toe protection. This scour condition happened due to vertical shape of protection structure will increase the turbulence and wave run up. Severe erosion also occurred to the seaward of the product while the beach condition at the back side of the product is remain stable. Comparison analysis of the results between scenario 3 of 2 (NEXC Blocks structure with scour protection) and scenario 2 of 2 (NEXC Blocks structure without protection) is carried out to see the impact of toe protection (refer to Figure 4.36)

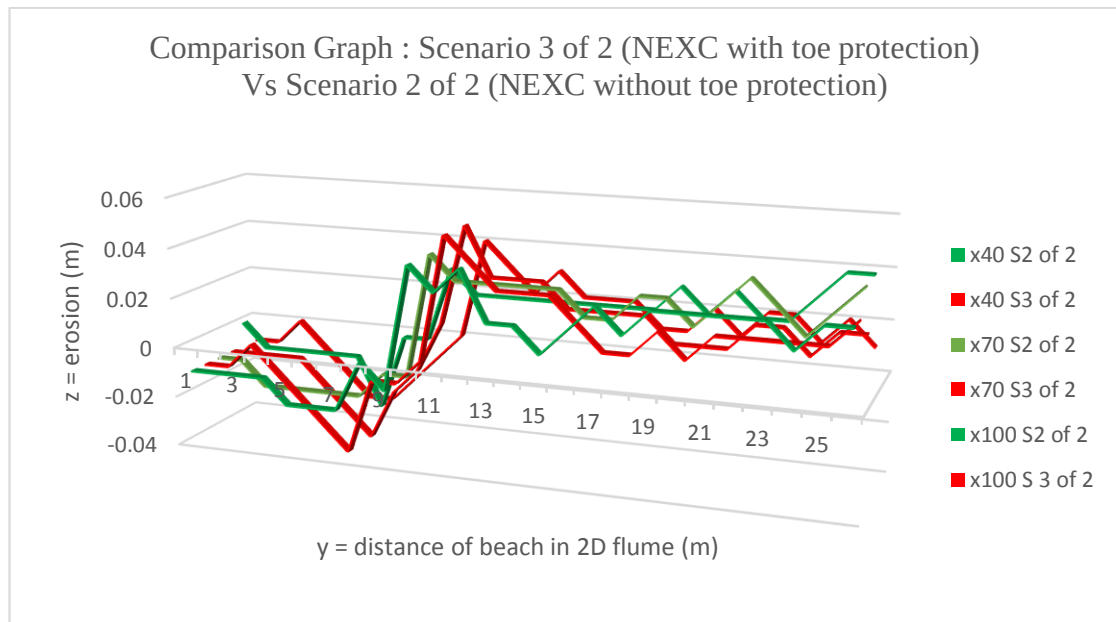


Figure 4.36 : Comparison results between scenario 3 of 2 and scenario 2 of 2

In Figure 4.36, the red lines of the graph represent the scenario 3 of 2 and the green lines represent the scenario 2 of 2. Same like previous analysis, the value of erosion also reduced towards the NEXC Blocks Structure and seaward side (y value between 17 to 25) due to the installment of scour protection at the toe of the model product.

Scenario 3 of 3 : experimental setup with NEXC Block Structure with toe protection, water level (WL) 1.0m and wave height (H_s) 0.1m.

The condition of the test model is shown in Figure 4.37.



Figure 4.37 : Testing Condition of Scenario 3 of 3 (source : NAHRIM)

From the Figure 4.37, in this case there is no severe impact of scour due to less wave height (0.1m) compare to previous scenario (3 of 2). The NEXC Blocks structure also in good condition eventhough a series of erosion occurred leeward and seaward side from the product. Comparison analysis of the results between scenario 3 of 3 (NEXC Blocks structure with scour protection) and scenario 2 of 3 (NEXC Blocks structure without protection) is carried out to see the impact of additional toe protection structure (refer to Figure 4.38).

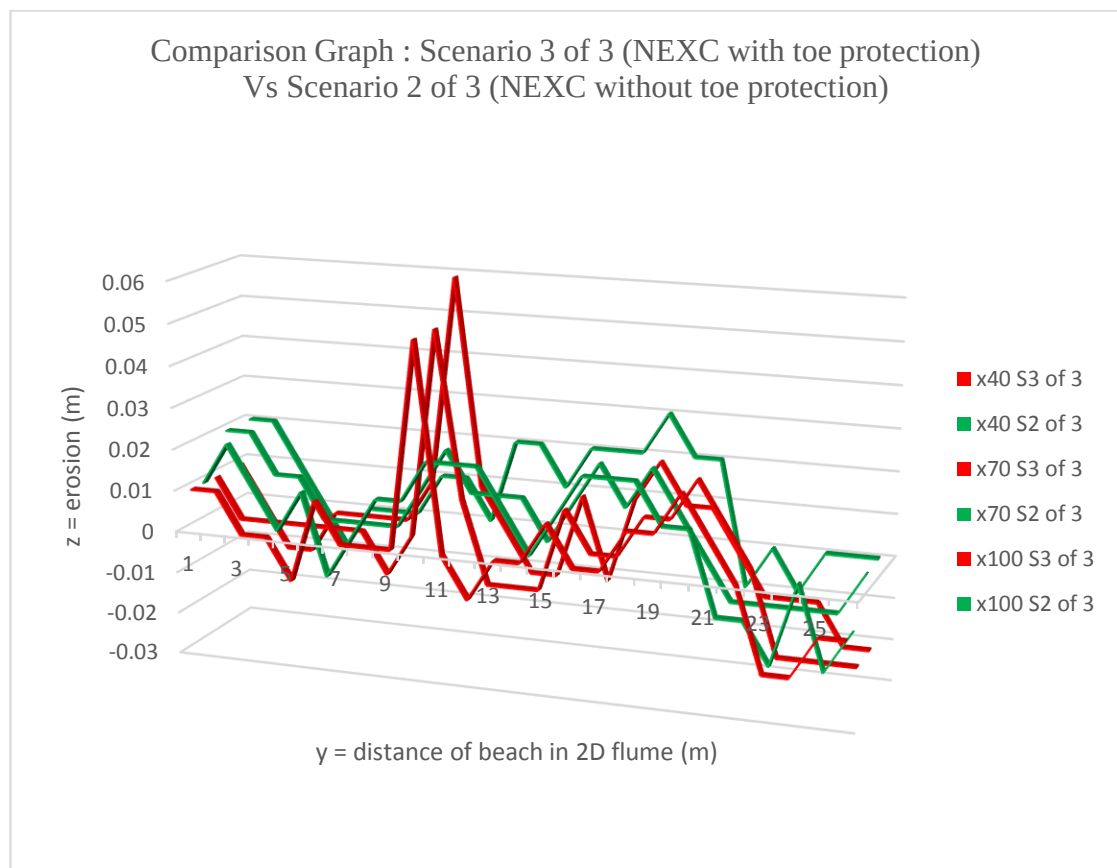


Figure 4.38 : Comparison results between scenario 3 of 3 and scenario 2 of 3

In Figure 4.38, the red lines of the graph represent the scenario 3 of 3 and the green lines represent the scenario 2 of 3. The magnitude of erosion for senario 3 of 3 slightly reduced towards the NEXC Blocks Structure (y value between 13 to 25) compared to the scenario 2 of 3 due to the installment of scour protection at the toe of the model product.

Scenario 3 of 4 : experimental setup with NEXC Block Structure with toe protection, water level (WL) 1.0m and wave height (Hs) 0.2m.

The condition of the test model is shown in Figure 4.39.

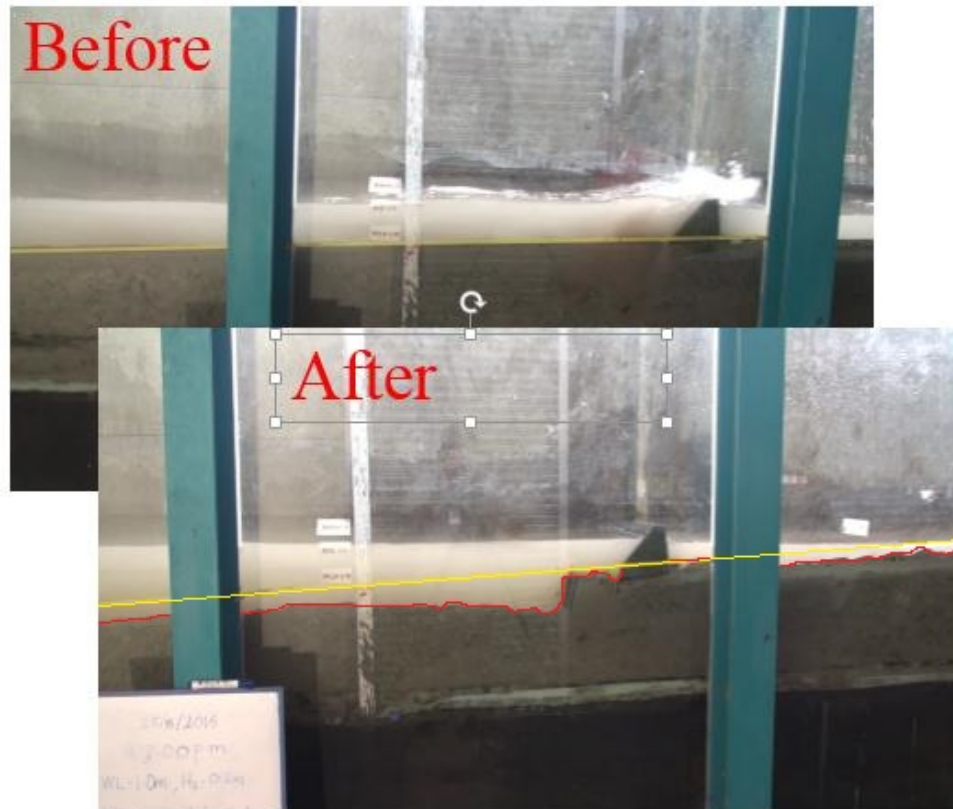


Figure 4.39 : Testing Condition of Scenario 3 of 4 (source : NAHRIM)

From the Figure 4.39, the severe scour problem occurred in front of the toe protection. Same case like scenario 3 of 2, but in this case the worse scour condition happened due to vertical shape of protection structure that increase the turbulence and wave run up at the toe area. Severe erosion also occurred to the seaward of the structure while the product is remain in stable condition. Comparison analysis of the results between scenario 3 of 4 (NEXC Blocks structure with scour protection) and scenario 2 of 4 (NEXC Blocks structure without protection) is carried out to see the impact of toe protection (refer to Figure 4.40).

In Figure 4.40, the red lines of the graph represent the scenario 3 of 4 and the green lines represent the scenario 2 of 4. The overall magnitude of scouring and erosion for scenario 3 of 4 is slightly reduced towards the NEXC Blocks Structure (y value between 11 to 25) compared to the scenario 2 of 4 due to the installment of scour protection at the toe of the model product.

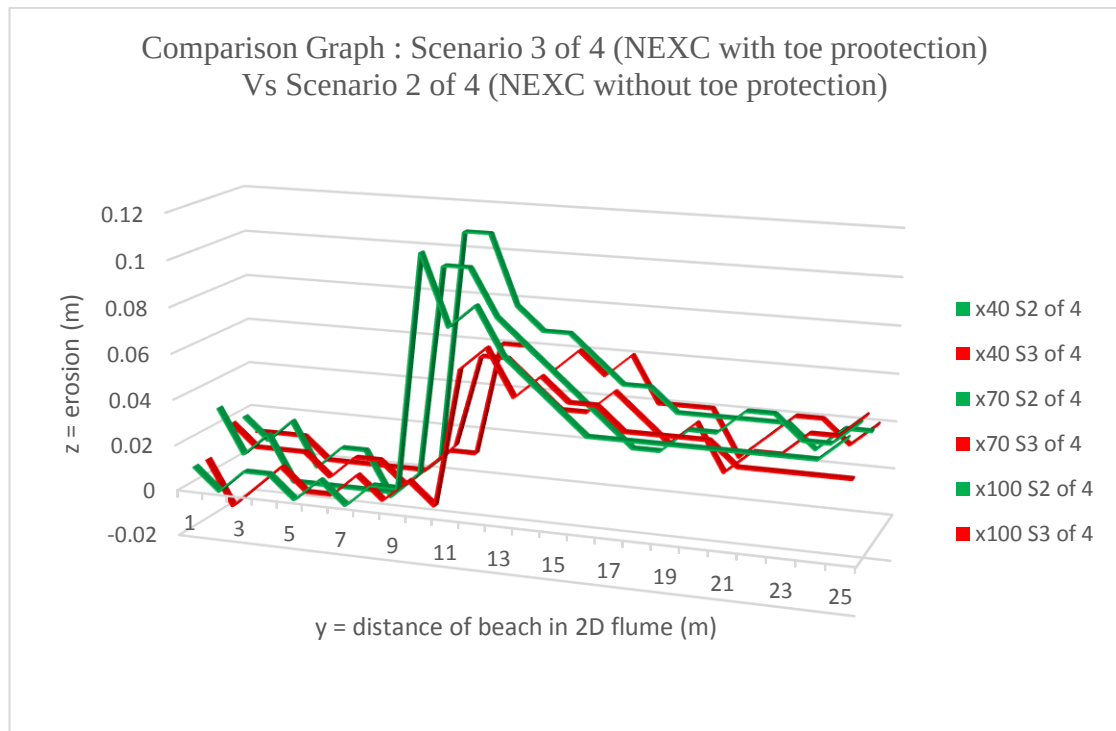


Figure 4.40 : Comparison results between scenario 3 of 4 and scenario 2 of 4

Scenario 3 of 5 : experimental setup with NEXC Block Structure with toe protection, water level (WL) 1.1m and wave height (H_s) 0.1m.

The condition of the test model is shown in Figure 4.41.



Figure 4.41 : Testing Condition of Scenario 3 of 5 (source : NAHRIM)

From the Figure 4.41, there is no severe impact of scour due to less wave height (0.1m), same situation like scenario 3 of 1 and scenario 3 of 3. The NEXC Blocks structure also in good condition and only low magnitude of erosion occurred in the test model. Comparison analysis of the results between scenario 3 of 5 (NEXC Blocks structure with scour protection) and scenario 2 of 5 (NEXC Blocks structure without protection) is carried out to see the impact of additional toe protection structure (refer to the graph in Figure 4.42).

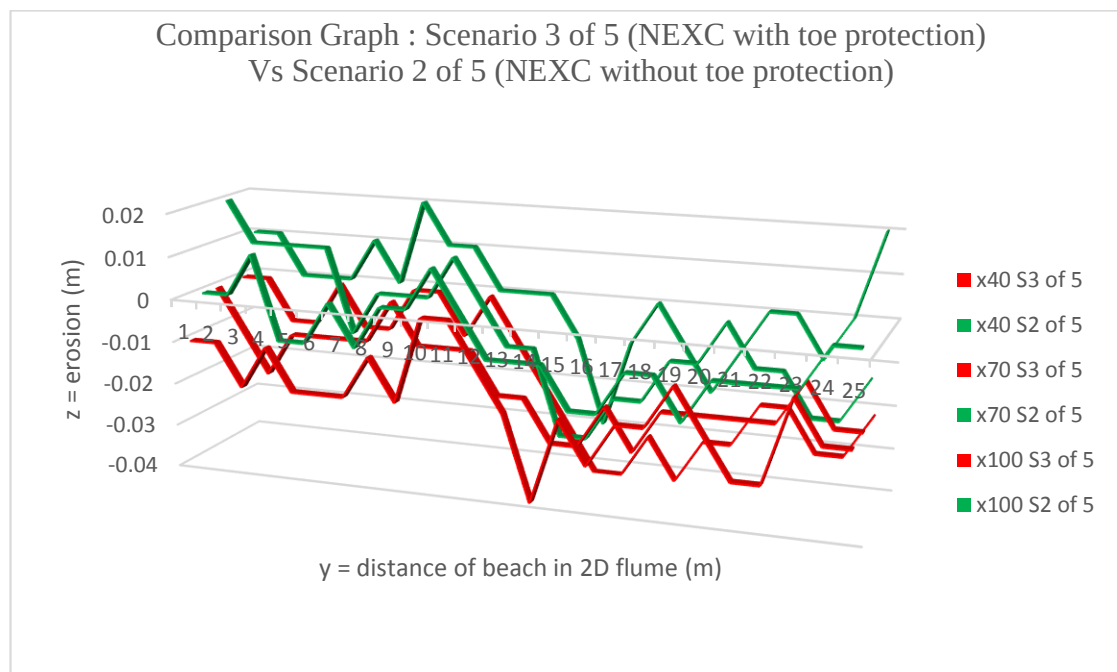


Figure 4.42 : Comparison results between scenario 3 of 5 and scenario 2 of 5

In Figure 4.42, the red lines of the graph represent the scenario 3 of 5 and the green lines represent the scenario 2 of 5. Almost all the accretion occurred for scenario 3 of 5 with the 4cm maximum value of accretion compared to the scenario 2 of 5 that experienced erosion with maximum value not more than 2 cm. From this result also, we found a good agreement about this product that really have a very high potential to function as coastal protection structure especially under the condition of scenario 3 of 5.

Scenario 3 of 6 : experimental setup with NEXC Block Structure with toe protection, water level (WL) 1.1m and wave height (Hs) 0.2m.

The condition of the test model is shown in Figure 4.43.

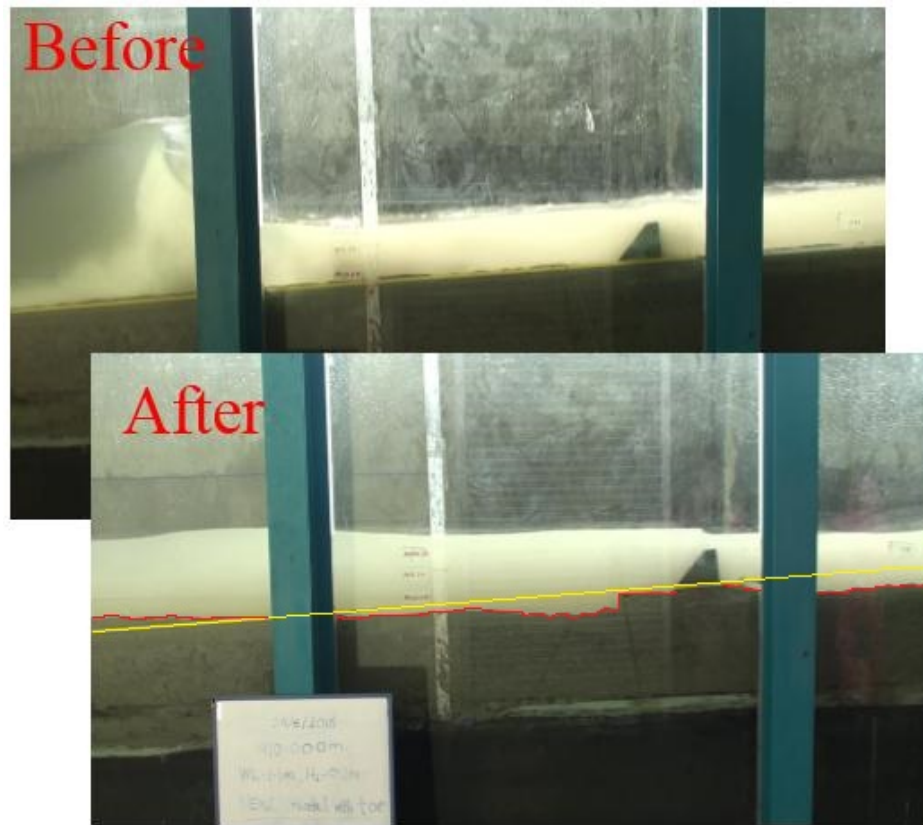


Figure 4.43 : Testing Condition of Scenario 3 of 6 (source : NAHRIM)

From the Figure 4.43, the scour problem still occurred in front of the toe protection due to the increasing of wave height (0.2m), turbulence and wave run up against the vertical shape of toe protection structure. Comparison analysis of the results between scenario 3 of 6 (NEXC Blocks structure with scour protection) and scenario 2 of 6 (NEXC Blocks structure without protection) is carried out to see the impact of the placement of toe protection (refer to Figure 4.44).

In Figure 4.44, the red lines of the graph represent the scenario 3 of 6 and the green lines represent the scenario 2 of 6. In this case, we found that the erosion and accretion pattern for both these two scenario is quite similar. However the magnitude of accretion for both scenario is vary with maximum value of 5 cm for senario 2 of 6 and 4cm for scenario 3 of 6. From the graph also, we can say the placement of toe protection did not give a significant impact to the scour problem due to the condition of high water level (1.1m) and high wave (0.2m).

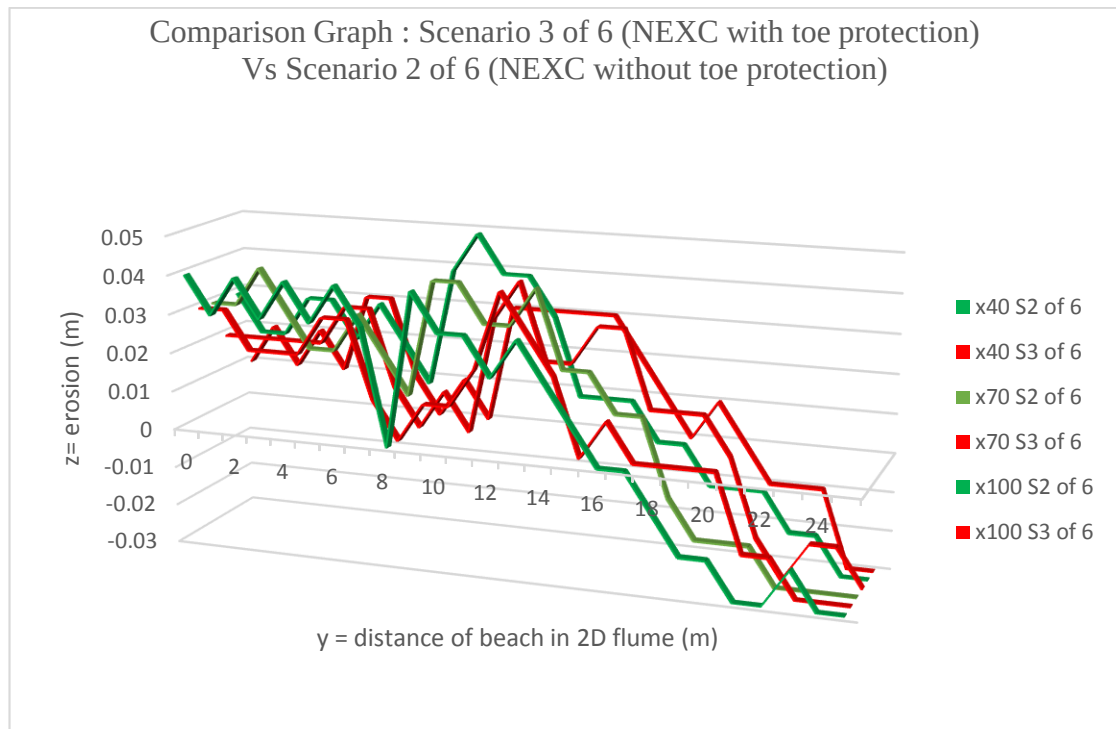


Figure 4.44 : Comparison results between scenario 3 of 6 and scenario 2 of 6

Generally, in the cases of scenario 3, we found that with the placement of scouring protection at the toe of NEXC Blocks Structure, are able to reduce the impact of scouring and the magnitude of erosion. From the experiment also, we agreed that the NEXC Blocks Structure with additional toe protection have a potential to serve as a coastal protection product.

4.5 BEACH PROFILE CHANGE MONITORING PROGRAMME

In this study, monitoring programme and survey works for beach profile change was carried out over 6 exercises November 2015 and December 2016. There are 15 transect lines in this study at approximately 10m interval as shown in Figure 4.45.

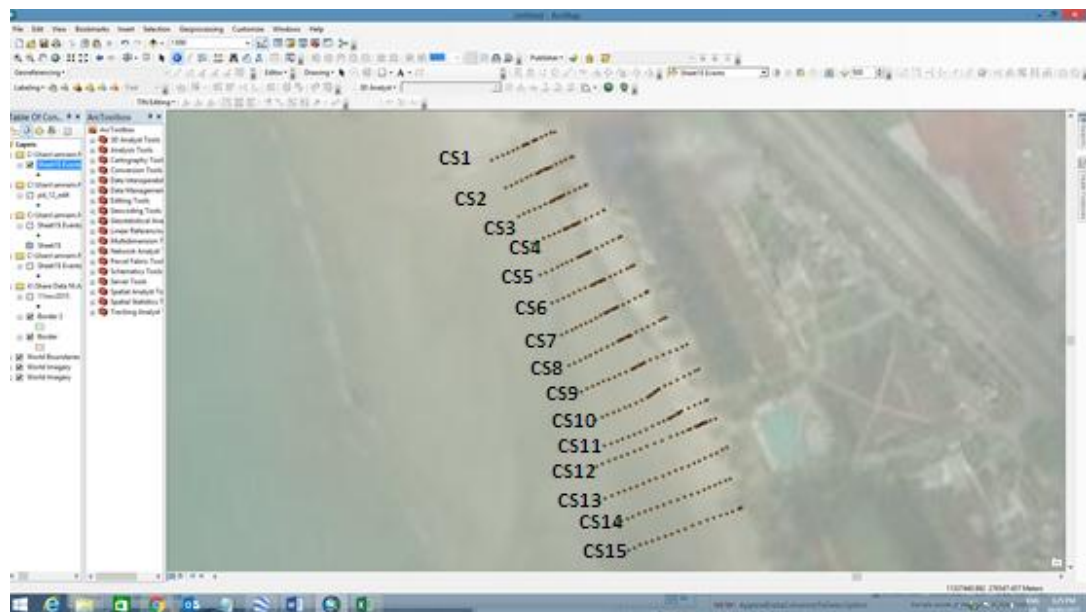


Figure 4.45 : Transect lines for survey works with 10m interval for every cross section (source : NAHRIM)

The result for all 15 transect lines of the beach profile survey is presented in line graph as shown in Figure 4.46 to Figure 4.60.

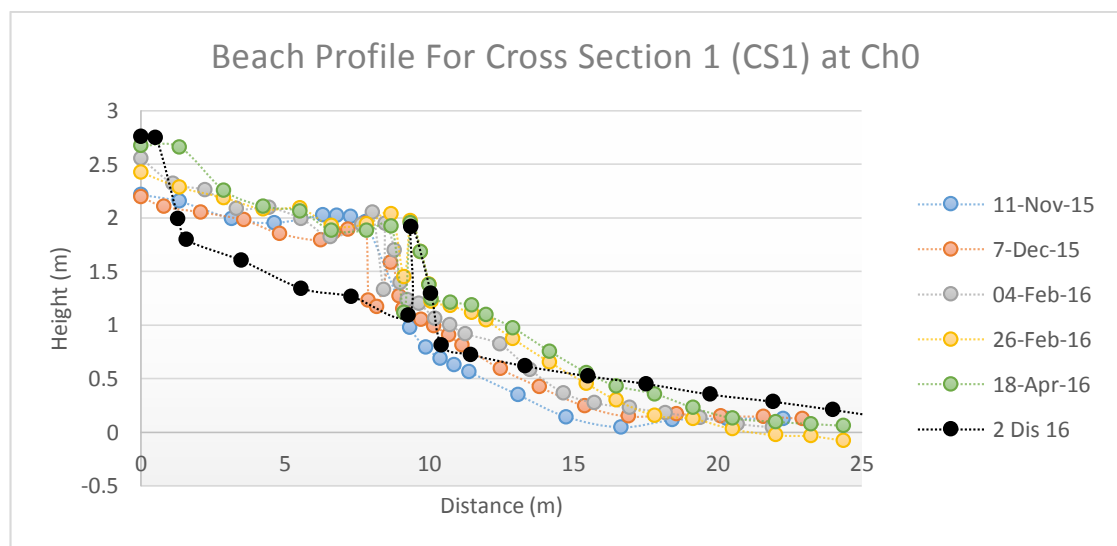


Figure 4.46 : Beach profile for cross-section 1 (CS1) at chainage 0

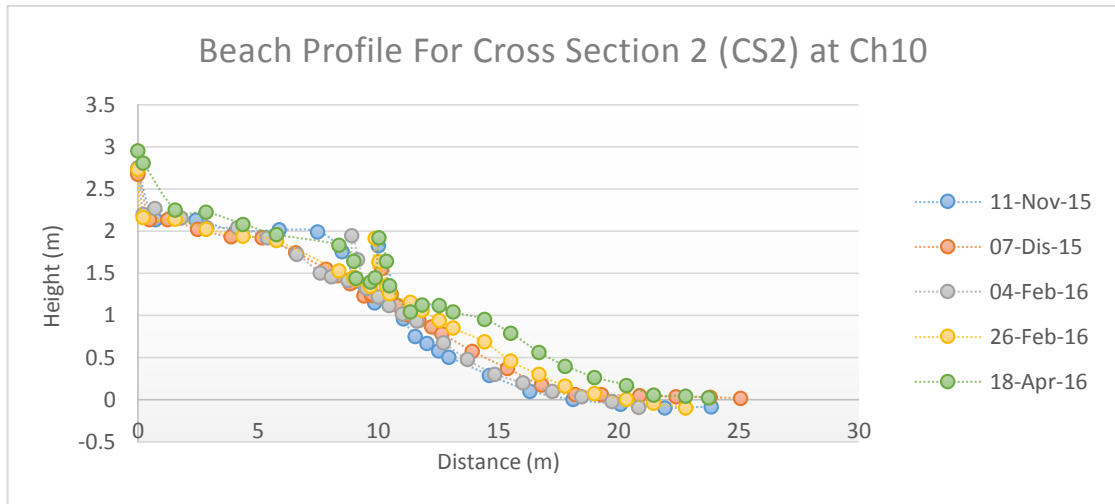


Figure 4.47 : Beach profile for cross-section 2 (CS2) at chainage 10

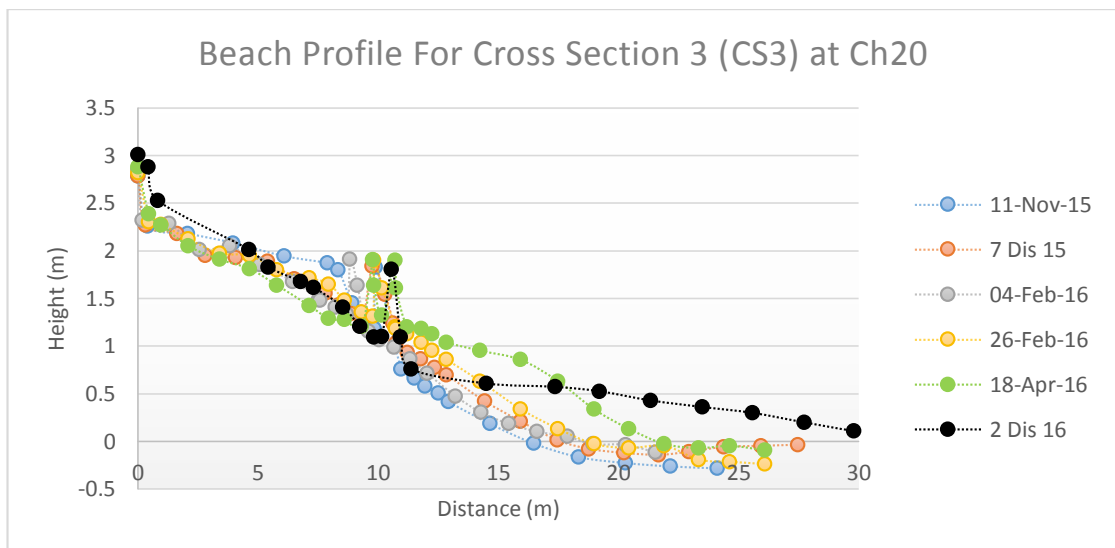


Figure 4.48 : Beach profile for cross-section 3 (CS3) at chainage 20

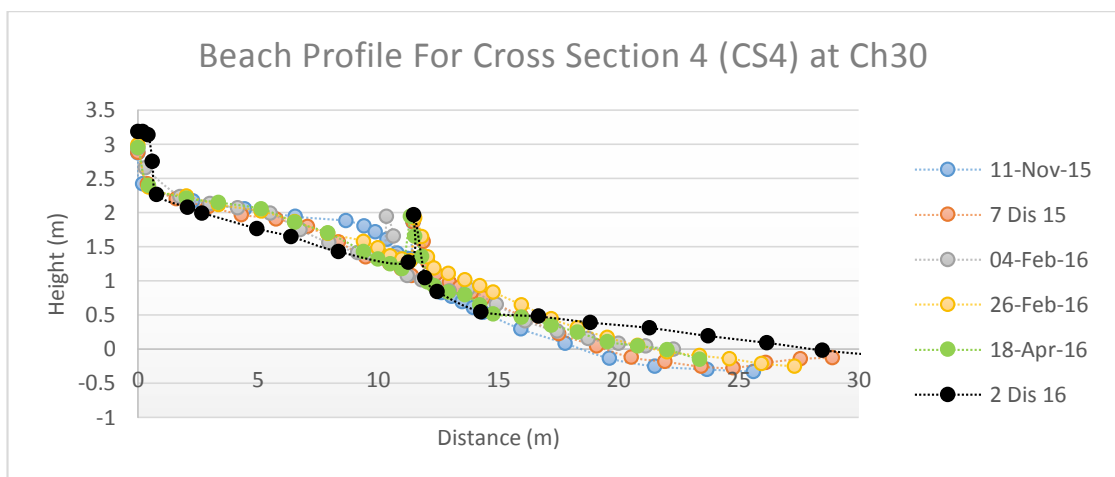


Figure 4.49 : Beach profile for cross-section 4 (CS4) at chainage 30

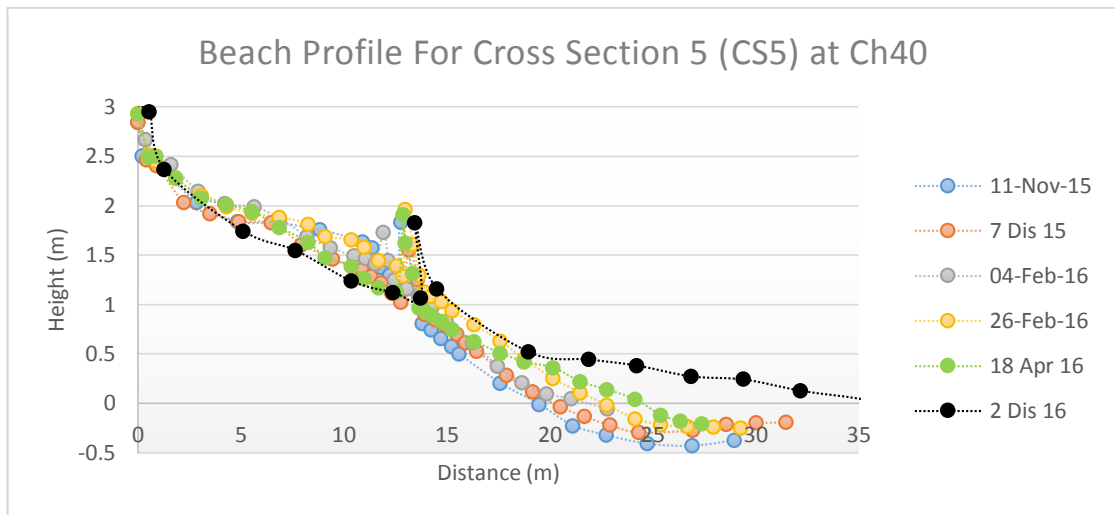


Figure 4.50 : Beach profile for cross-section 5 (CS5) at chainage 40

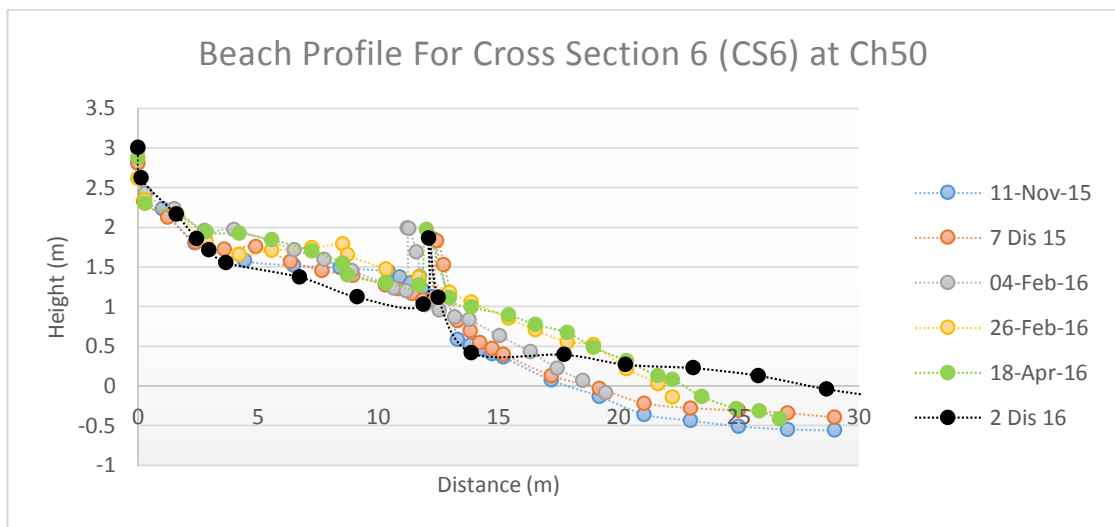


Figure 4.51 : Beach profile for cross-section 6 (CS6) at chainage 50

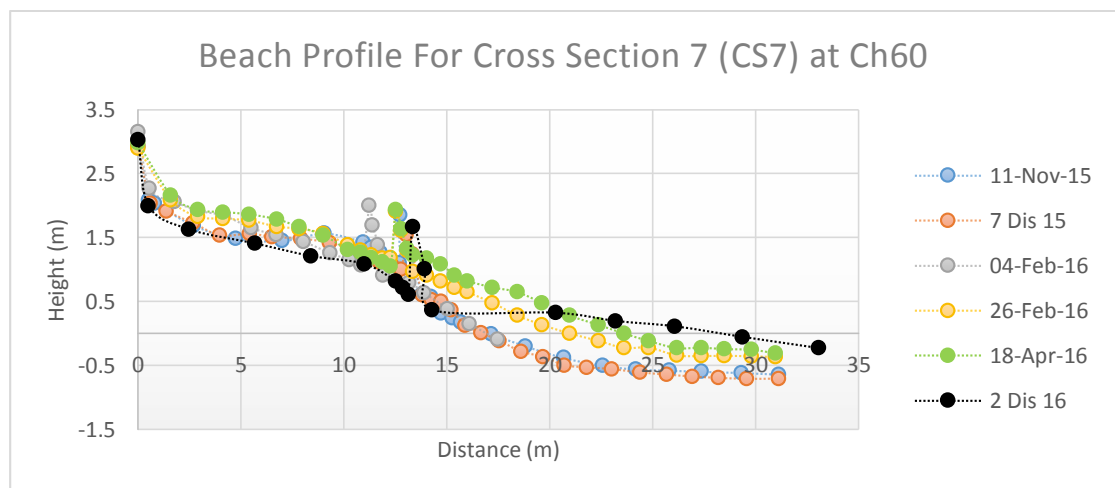


Figure 4.52 : Beach profile for cross-section 7 (CS7) at chainage 60

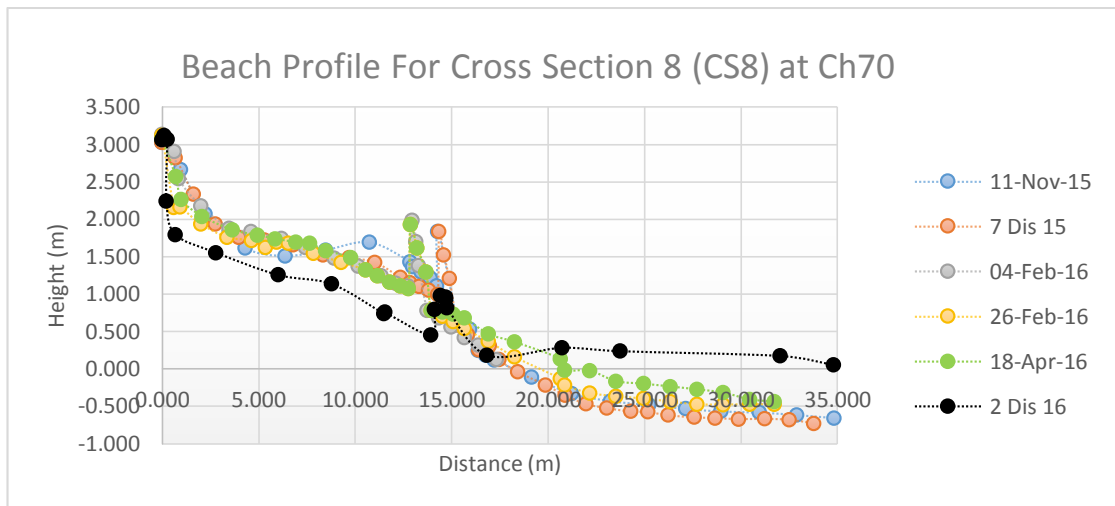


Figure 4.53 : Beach profile for cross-section 8 (CS8) at chainage 70

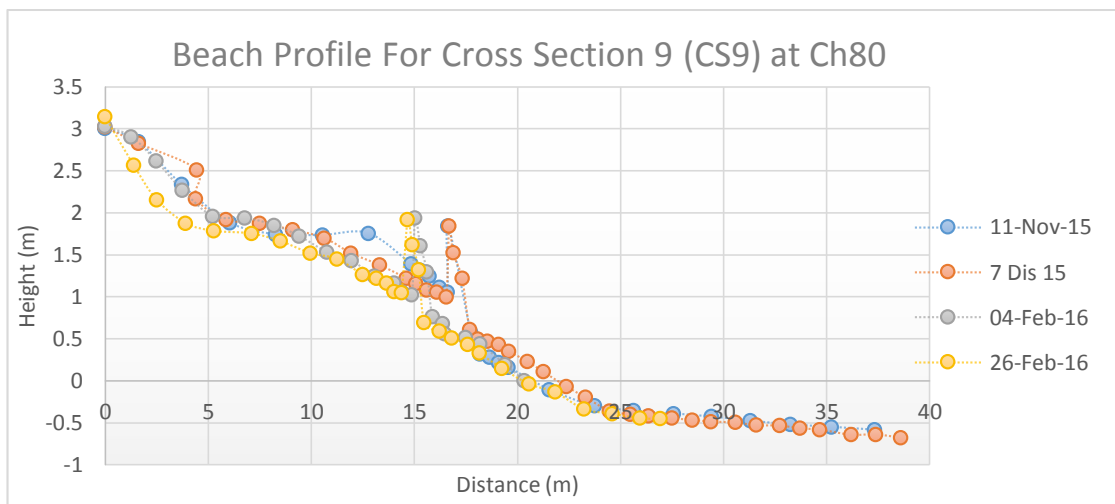


Figure 4.54 : Beach profile for cross-section 9 (CS9) at chainage 80

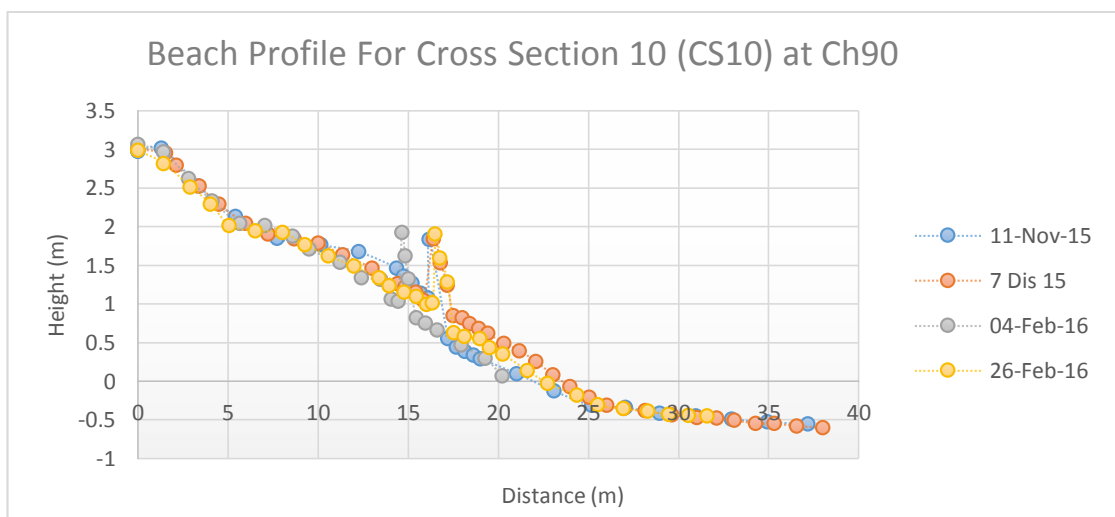


Figure 4.55 : Beach profile for cross-section 10 (CS10) at chainage 90

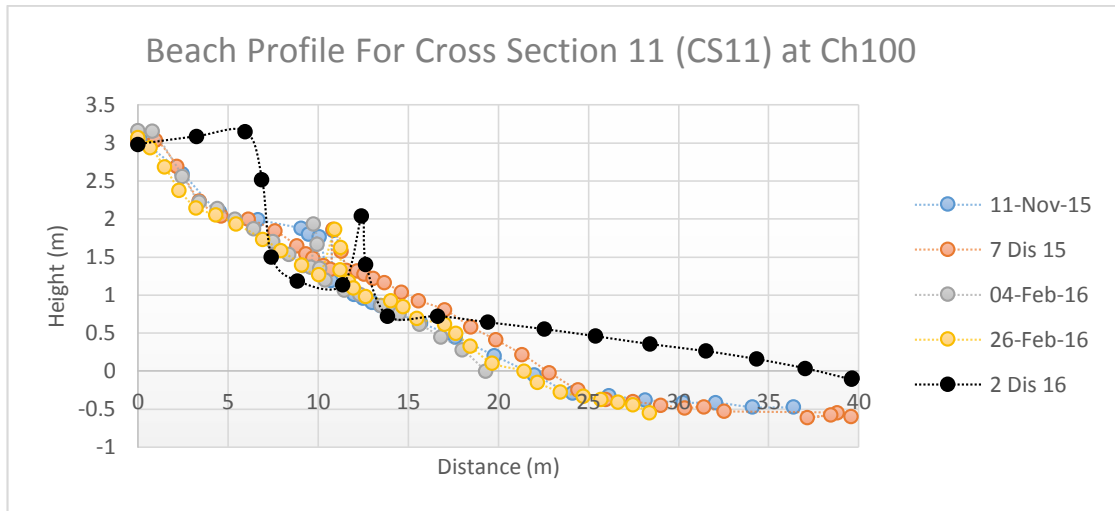


Figure 4.56 : Beach profile for cross-section 11 (CS11) at chainage 100

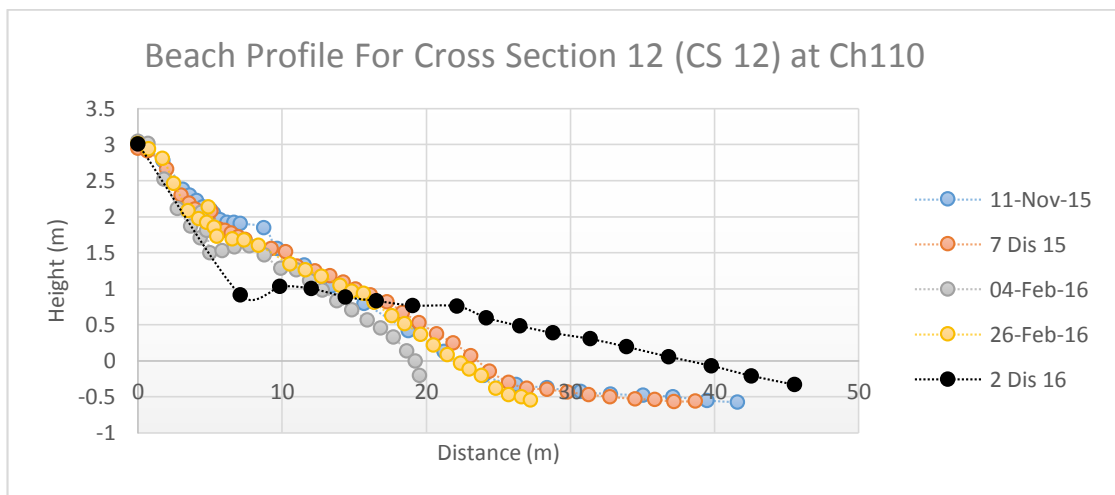


Figure 4.57 : Beach profile for cross-section 12 (CS12) at chainage 110

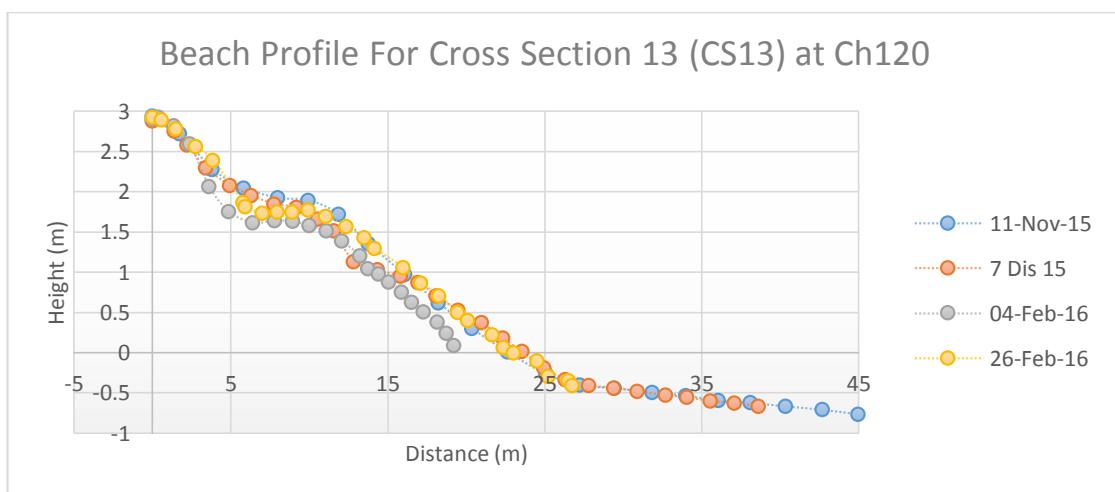


Figure 4.58 : Beach profile for cross-section 13 (CS13) at chainage 120

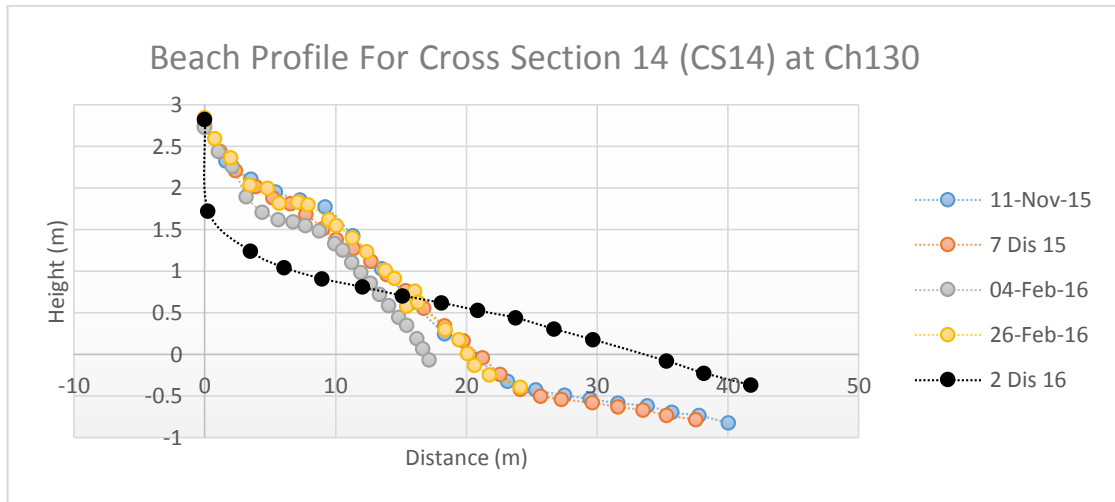


Figure 4.59 : Beach profile for cross-section 14 (CS14) at chainage 130

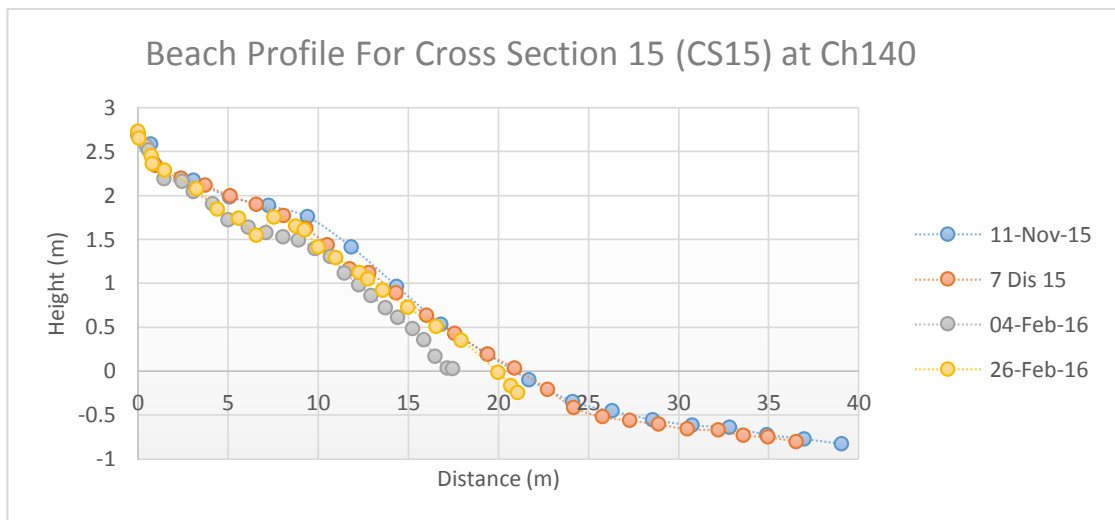


Figure 4.60 : Beach profile for cross-section 15 (CS15) at chainage 140

From the result, it is observed that the beach profile undergoes a very dynamic changes within a short period of time due to the wave action and sediment transport processes as well as monsoon driven factor. Wind condition in the Malacca Strait is the primary wave generating mechanism for waves incident to the study area. The winds are much stronger in magnitude during the two monsoon periods.

After the product deployment, accretion occurred for short period of time (November 2015 to April 2016) in front and at the back of the NEXC Blocks System. Sediment supply moving towards the shoreline from offshore sand bar during inter-monsoon season but erosion takes place during monsoon event. However, towards the end of the year 2016, the severe erosion occurred due to South West Monsoon.

The sediment amount changes at the study site on the initial condition (11 November 2015) and final condition (2 December 2016) was calculated. The boundary condition of sediment calculated is above the MSL and 20m distance from the starting point of the survey transect (0m). The result is given in Table 4.5.

Table 4.5 : Sediment amount changes in the study site

Chainage (width for every chainage is 10m)	Amount of Sediment Within 20m Distance (m ³)		Remarks
	Initial Condition (11 November 2015)	Final Condition (2 December 2016)	
Ch0	213.75	201.35	decrease
Ch10	249.87	no data	262.54m ³ on 26 Februari 2016
Ch20	234.07	230.75	decrease
Ch30	233.98	289.63	increase
Ch40	278.75	287.56	increase
Ch50	246.51	221.57	decrease
Ch60	221.36	197.84	decrease
Ch70	272.57	203.48	decrease & structure settled
Ch80	331.46	no data	298.35m ³ on 26 Februari 2016
Ch90	351.28	no data	316.87m ³ on 26 Februari 2016
Ch100	275.56	316.25	increase
Ch110 (no structure)	337.52	275.86	decrease
Ch120 (no structure)	343.75	no data	326.56m ³ on 26 Februari 2016
Ch130 (no structure)	306.23	197.68	decrease
Ch140 (no structure)	393.25	326.39	decrease

The dynamic changes of beach sediment at study site is very closely related to the wind-wave action during monsoon season and sediment transport movement. The analysis of the hydrodynamic, wave simulation and sediment movement at the study site is based on the ISMP for the Coastline of Negeri Sembilan (2008) and hydraulic study for the Proposed Development of International Maritime Gateway, Port Dickson, done by HR Runding (2009). According to HR Runding (2009), it was stated that during the NE Monsoon, the winds tend to blow from the north and northeast directions. The NE Monsoon reaches maximum strength and steadiness in January. During the SW Monsoon,

winds blow mainly from the south to southwest directions. The SW Monsoon reaches maximum development in July and August. The wind-wave generation are dominant from the West to Northwest sectors during the NE monsoon and from the south west during SW monsoon. During the SW monsoon squalls (lines of thunderstorms) known as ‘sumatras’ may develop and this may result in localised strong winds and rough seas. Such squalls could result in waves of 2m to 3m in height with a maximum period of 9s (HR Runding, 2009).

Figure 4.61 shows the extracted wave simulation study from the report to relate with the study site. The annual wave rose offshore for Port Dickson in Figure 4.61 shows that the significant wave height is normally less than 0.5m (about 85% of the time) and from a dominant direction of 300°N.

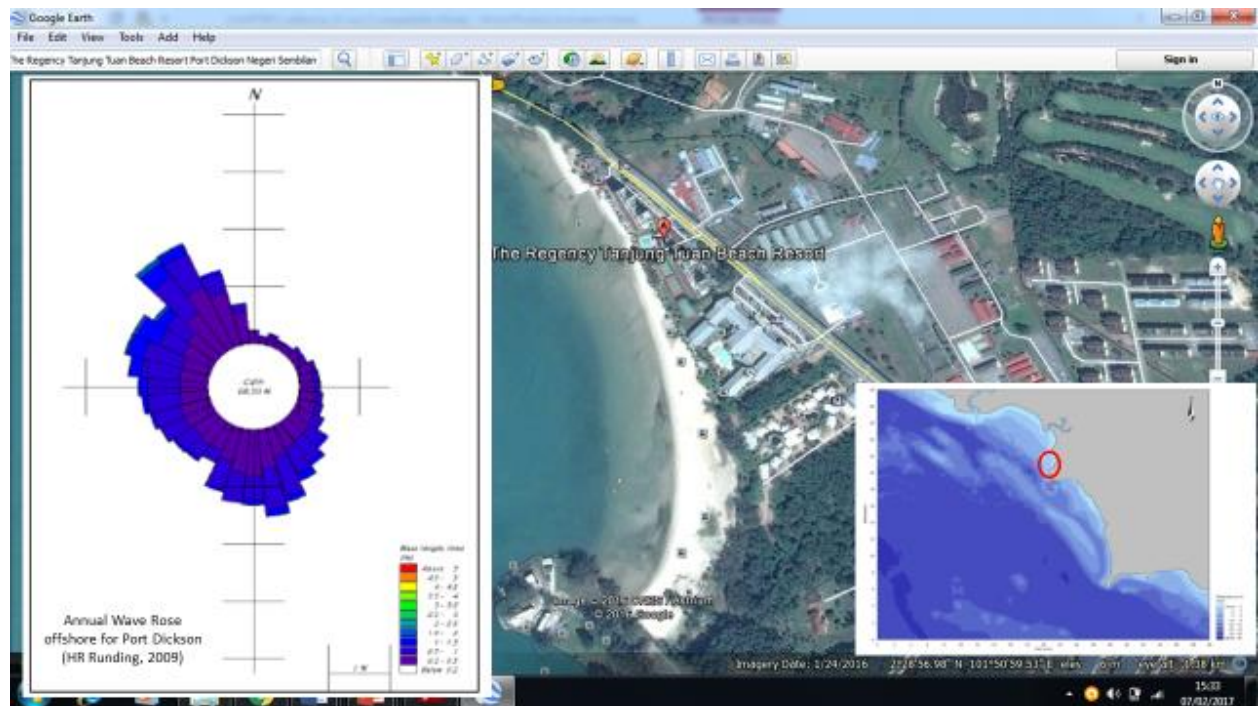


Figure 4.61: Wave Simulation Study for Port Dickson (source : HR Runding, 2009)

According to this wave simulation study also found that the maximum offshore significant wave height during the 21 years period is about 5.26m (wave time series data corresponding to the 20-year wave hindcast). Waves greater than 1.0m usually occur from the west-south west (WSW) to the west-north west (WNW) direction sector. MIKE 21 software was used to transform the offshore waves into the nearshore environment. The model takes into account the effects of refraction and shoaling due to varying depth, local

generation of wind waves, the influence of directional spreading and energy dissipation due to wave breaking and bottom friction. Simulations were carried out for dominant wave directions approaching the project location. Based on the onshore wave simulation, the dominant directions of wave propagation towards the beach are from the southwest (150° N) to North (300° N). This condition of wind-wave action influenced the sediment transport and resulting the severe erosion problem at the study site especially during monsoon seasons due to destructive wave action.

According to ISMP Negeri Sembilan (2008), currents are very strong in the study area. Large current flows are observed and predicted offshore, with values exceeding 1.5m/s especially in the southern section adjacent to Tg. Tuan. Following the shape of the nearshore profile, in the northern areas the strong currents are located away from the shoreline with weaker currents nearshore. In the southern end the currents are strong and very close to the beach. The overall flow pattern is characterised by preferential flow directions induced by the rocky headland at Tg. Tuan that tend to accelerate the flow. The mean current pattern is presented in Figure 4.62.

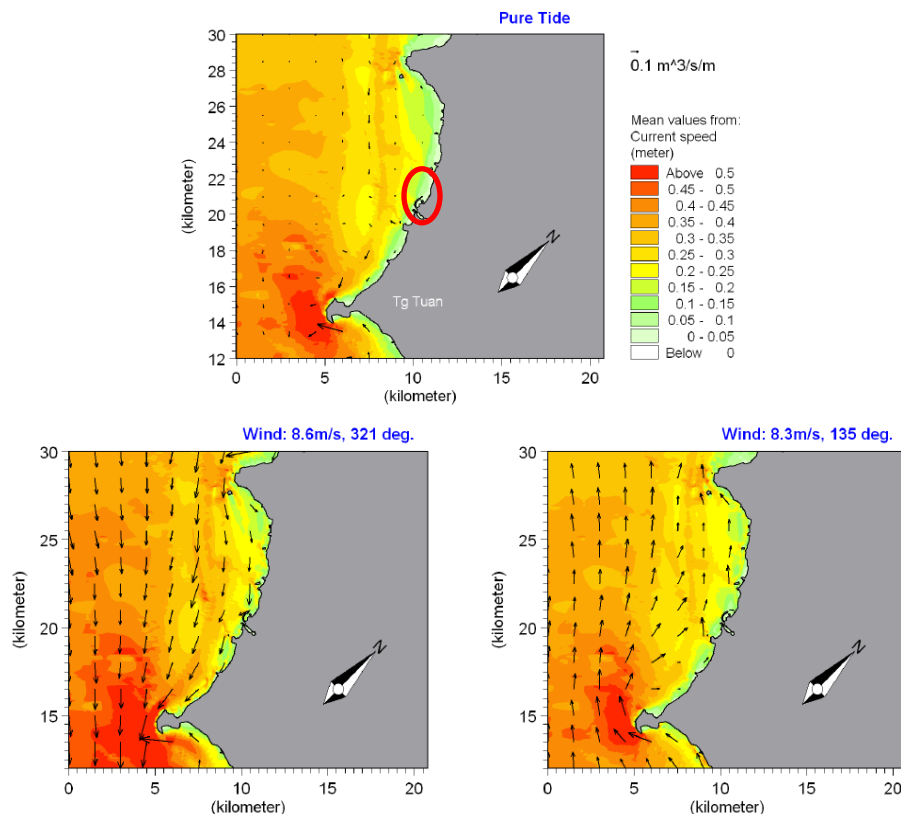


Figure 4.62: Mean velocities for the inter-monsoon and NE and SW monsoon conditions at Tg. Tuan area (source : ISMP Negeri Sembilan, 2008)

The littoral transport results indicate erosion along the central area (the study site) whereas the northern and southern stretches appear to be in equilibrium. The littoral transport occurs in the areas along the beach profile especially in the inner surf zone (close to the 0 MSL line) that is associated with the varying water level conditions so that during low water levels waves break offshore inducing offshore littoral currents and at high water levels waves are able to penetrate all the way into the inner part of the profile so that breaking occurs in landward part of the profile.

The results show also that the largest waves from the NW tend to break offshore while the smallest from the SE break close to the MSL line. This behaviour is typical of the northern areas where the beach profile extends far offshore, however for the southern beaches with narrower beach profiles the transport should concentrate along one area only.

The sediment transport pattern is complex in this cell since the nearshore tidal and wave-wind driven currents tend to interact with the coastal features (headlands, marinas and some developments that extend into nearshore areas), inducing a complex pattern. The overall littoral budget shows that in the central stretch, the sediment transport increases towards south therefore this area is under sand starving process which will induce a general trend of erosion along the shore.

The localised erosion/accretion occurs around some of the structures/natural features as already occurred in study/test site. The existing site condition shows accumulation on the northern part of the beach at test site and slight erosion on the southern side that required the construction of a short stretch of coastal protection structures like NEXC Blocks System to avoid recession of the coastline. The sediment transport analysis also indicates that erosion rates of 0.25 to 0.5m/year should be expected in this study area. However the rate of erosion that has taken place on the test site recently is higher, approximately 1 to 2m/year. The coastline morphology is also dynamic due to the seasonal variability of the littoral transport induced by the variation of wave conditions during the NE and SW monsoons.

The bulk of trapped sand (sediment) behind the NEXC Blocks System is washed away by the strong waves during storm events through the holes. However the holes already meet the design purpose for trapping the sand but need to be improvised.

One more issue should be highlighted in this study is about the scour problem. Vertical shape design of toe structure for NEXC Block will accelerate the process of scouring. According to the result from the graph dated on 2 December 2016, we can clearly see the scour depth in front of the toe structure. So the placement of scour protection in front of the structure seems not capable enough to overcome this problem. The sizing of the armour rock should be reconsider because in this study, we only use a medium size (average size of 0.3m to 0.5m) quarry stone for that purpose.

In this study, there a few series of data missing, dated on 18 April 2016 for CS9 to CS15 due to technical problem and for December 2016, available data is only for a few selected cross section due to human error. The lack of data since May to November 2016 is the weakness point in this analysis especially in monitoring the trend for beach profile changes of the study site. During this time, the shoreline experience the series of big wave and storm events due to Southwest Monsoon (May to September). Anyway, the last data set dated on 2 December 2016 is considered good to monitor the trend of post-monsoon shoreline changes and comparison purpose. Result from the graphs dated on 2 December 2016 (post-monsoon condition) clearly indicates that, the deployment of the NEXC Blocks System on test site indirectly helping to reduce the gradient of beach.

Apart from that, a few selected pictures was captured on different date at test site to see the historical view of beach changes and the post-deployment condition of NEXC Blocks System as shown in Figure 4.63 to Figure 4.67.



Figure 4.63 : Test site on 27 May 2015, first site visit and before product deployment (source : NAHRIM)

Figure 4.64 was captured during our first site visit to the test site. These pictures shows the initial condition of the beach which experienced severe erosion closed to the hotel building with temporary mitigation measure and outlet pipe located perpendicular to the beach.



Figure 4.64 : Test site on 6 November 2015, post construction (source : NAHRIM)

Figure 4.65 illustrate the post construction condition at the test site, just after the product deployment works completed. The sand was flatten properly in both side, behind and in front of the structures to create a stable beach condition.



Figure 4.65 : Test site on 21 November 2015, additional scour protection at toe (source : NAHRIM)

The placement of scour protection was placed in front of the toe structure to give an extra defence and protection to the NEXC Blocks System as shown in Figure 4.66. It was observed that, after sometimes the sediment (sand) start to erode by wave action especially at the toe area. So the placement of rock armour consist of a few layer of

medium size of quarry stone as a scouring protector will ensure the stability of the structures.



Figure 4.66 : Test site on 20 July 2016, erosion problem occurred at the end of the product alignment (source : NAHRIM)

The hotel management was reported that a quite severe erosion problem occurred at the end of the product alignment and the site visit was carried out on 20 July 2016 as shown in Figure 4.67. However the NEXC Blocks System still in good and stable condition. Immediate action of remedial works should be carried out to repair or extend the alignment of the structure by NAHRIM side in order to ensure the integrity of the structure. But due to budget constrain, the repair works cannot be executed on time and it will lead to the potential of structure failure.



Figure 4.67 : Test site on 14 October 2016, a few blocks of the product settled due to scouring of old piping structure underneath. Severe erosion problem occurred at the end of the product alignment and afterwards (source : NAHRIM)

Site visit to test site was carried out on 14 October 2016, so we found that a few blocks of the NEXC Blocks System settled due to scouring problem as shown in

Figure 4.67. At that particular alignment, there a located the old piping structure underneath and this weak point condition caused the failure due to strong wave action. Severe erosion problem also still occurred at the end of the product alignment and afterwards. Other part or alignment of the NEXC Blocks System are remain stable but experienced of minor distorted structure condition and scour problems. The remedial works with the extension of NEXC Blocks System will be carried out by NAHRIM as soon as possible in 2017.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Coastal erosion is a natural disaster which is a major threat to the coastal community. Mitigation measures using coastal defence, including both the applications of structural and non-structural methods that have been practiced in our country has managed to reduce the impact of coastal erosion.

The NEXC Blocks System developed by NAHRIM provide added value to coastal erosion structure by combining the concept of hard and soft protection engineering. In addition to reducing the impact of coastal erosion, it promotes the accumulation of sediment (sand) to assist the process of beach reconstruction after severe beach erosion due to a series of storm events.

This study involves the design, laboratory physical modelling and deployment and installation of the products on site at Pantai Batu 5, Port Dickson, Negeri Sembilan which has suffered serious erosion. The results obtained from experiments in the laboratory and on test site show a positive and encouraging results. It proves that NEXC Blocks product has been successfully performing its functions as coastal erosion control products.

The NEXC Blocks product is designed for structural stability against the wave force, including sliding and overturning failures with safety factor value of 1.5. Of the different prototypes (Prototype A, Prototype B and Prototype C) considered, Prototype B is selected considering criteria including fitness for purpose, safety, reliability, economy and maintainability.

For all scenarios tested in the laboratory, the NEXC blocks is proven to be stable, and effective in reducing erosion. However, scouring problem is identified at the toe without affecting the structural integrity. Hence, toe protection for the structure is crucial and should be enhanced.

Observation and analysis of the NEXC Blocks System performance onsite found that the blocks function well in controlling erosion and renourish the beach through the accretion process. Survey result of the beach profile changes found that almost all the

cross section experienced accretion process from November 2015 to April 2016 but experience the erosion process due to SW monsoon season during May 2016 towards the end of the season. The slope of the beach become more stable after the end of the monsoon season. The accreted sediment can be found in front and behind of the structure during inter monsoon season. Nevertheless, it was found that the accumulated sand behind the structure is loss again significantly during the big waves and monsoon due to the relatively large opening holes on the structure.

Installation of this product have managed to safeguard the assets of the hotel. However, the structure has undergone some settlement at the end of its alignment after the southwest monsoon season in 2016 as a result of foundation problem. Nonetheless, the blocks can be easily reorganized and realign in remedial works.

In summary, results show that NEXC Blocks product have promising performance and has the potential of being commercialized.

5.2 LIMITATION

The present laboratory test was conducted in 1D flume. It is better if the product is tested in two-dimensional (2D) wave basin which is more representative of actual site condition. 2D test can take into consideration of different oblique incidence angle.

Sediment transport process is not incorporated in this study because the facilities and instrumentation are not well equipped to generate sediment supply condition. However the experiments in 1D flume is still capable of providing the picture of the structural stability.

Numerical modelling should be included in this study to assess the hydraulic and morphology conditions of the test site before and after the deployment of the product. It will provide detailed physical understanding of the changes and behaviour of currents, tides, sediment transport, littoral drift, and various aspects of hydrodynamics at the study site. Although the data collection works was completely conducted, but numerical modelling assessment cannot be implemented due to the time constraints.

For field testing, the installation of the products is limited to a short stretch of coastline of approximately 108 m due to insufficient budget, and did not cover the entire stretch of the eroded shoreline measuring up to 200 m. Hence, the effectiveness of the product is only partially realized.

The test also suffers from the lack of data during the Southwest monsoon (May to September) of 2016, in particular, the shoreline profile changes during this particular time period. Nevertheless, the post monsoon (December 2016) data were very helpful in analysing the overall changes in the test site shoreline.

5.3 RECOMMENDATIONS

The following recommendations is proposed in order to enhance the related issues of this study, to improvise the product design as well as to combat the erosion problem:-

- i. Further research on the hydrodynamic and sediment transport study by using numerical modelling approach need to be conducted at study site;
- ii. Physical modelling for this test product should be carried out in coastal wave basin for further research finding;
- iii. More reliable beach profiling survey data should be obtained in order to enhance the beach profile monitoring programme;
- iv. Flap gate or valve structure should be installed at the back side of the holes on the NEXC block to trap sediment from being wiped out again especially during big wave and storm events;
- v. Additional toe protection using appropriately-sized armour rock or other new innovative structure (such as curved-shaped structure) should be considered to overcome the scour problem.;
- vi. Robust, innovative and environmental friendly material types should be used in fabricating the next new version of NEXC Blocks structure. Concrete material will deteriorate when exposed to sea environment, and the reinforcement bar can become rusted due to exposure to sea water. Alternative such as composite material with rice husk can be used to replace the concrete material.
- vii. For the erosion problem at the study area, groyne structure perpendicular to the NEXC Blocks System can be considered to trap sediment on the down drift side of the NEXC blocks section. This hybrid erosion control measures will more effectively block the sediment movement from the up drift side and will naturally reconstruct the beach as well as control the erosion problem at that particular area.

- viii. Proposed a control headland approach by introducing or constructing an artificial headland or near shore breakwater or detach breakwater. However both of these options (vii & viii) should be verified with detailed study using appropriate numerical or physical modelling method.
- xi. Any sediment movement in the test site compound either due to natural process like erosion from surface runoff or human intervention is not considered in this study. However, it should be considered especially in the sediment changes calculation as part of beach morphology study in order to improve the study result.

REFERENCES

- Ahmad Hadi Mohamed Rashidi, Sheikh Mohd Affan Sh. Ab. Rahim, Nor Aslinda Awang and Mohd Radzi Abd Hamid (2015). Pusat Kajian Pantai dan Oseanografi (KPO), NAHRIM. Laporan Rekabentuk Dan Fabrikasi Struktur Inovasi Sistem Blok Perlindungan Dan Perluasan Pantai (NAHRIM Coastal Protection & Expansion (NEXC) Block). NAHRIM Coastal and Oceanography Research Series No. 1/2015.
- Ahmad Hadi Mohamed Rashidi, Khairul Anuar Mohamad, Ahmad Tarmizi Alwi, Yannie Benson, Nor Aslinda Awang and Mohd Radzi Abd Hamid (Mac 2016). Pusat Kajian Pantai dan Oseanografi (PKPO), NAHRIM. Laporan Projek Perintis Pembangunan Dan Pemasangan Sistem Blok Perlindungan Dan Perluasan Pantai NAHRIM (Blok NEXC) Untuk Institut Penyelidikan Hidraulik Kebangsaan Malaysia Di Pantai Batu Lima, Port Dickson, Negeri Sembilan Darul Khusus. NAHRIM Coastal and Oceanography Research Series No. 2/2015.
- Alex Jackson (2011). Coastal Erosion. Retrieved from <http://geographyas.info/coasts/coastal-erosion/>
- Amri Md Shah (June 2010). A Case Study: Structure Testing on Slope Stability and Overtopping due to Sea Level Rise. Proceeding of The National Seminar on Coastal Morphology (COSMO), 17 June 2010 in NAHRIM, 184-192.
- Chiwan Hsieh (November 2016). Fundamental of Coastline Protection and the Role of Geosynthetics. National Pingtung University of Science and Technology, Taiwan. Retrieved from <http://www.geosyntheticsasia.in/ppts/7%20Nov%2016/Workshop/20161107%20Fundamental%20of%20coastline%20protection%20and%20the%20role%20of%20geosynthetics.pdf>
- Department of Irrigation and Drainage (DID) Malaysia (March 2009). DID Manual, Volume 3, Coastal Management.
- Department of Statistics, Malaysia (2010). Population and Housing Census of Malaysia.
- Economy Planning Unit (EPU) (1985). Jabatan Perdana Menteri (JPM) Malaysia. National Coastal Erosion Study (NCES).

- EuroSION (2004). Living with coastal erosion in Europe: Sediment and Space for Sustainability. A guide to coastal erosion management practices in Europe. Final version, June 2004. Retrieved from http://www.euroSION.org/shoreline/Shoreline_management_guide_FINAL.zip
- Federal Highway Administration (FHWA), U.S. Department of Transportation (2014). Chapter 6: Coastal Revetments for Wave Attack. Highways in the Coastal Environment: Second Edition by FHWA. Retrieved from <http://www.pilebuck.com/highways-coastal-environment-second-edition/chapter-6-coastal-revetments-wave-attack/>
- Faculty of Civil Engineering (FKA), Universiti Teknologi Malaysia (UTM) provided study for National Hydraulic Research Institute of Malaysia (NAHRIM) (2015). Report On Soil Investigation, Product Fabrication Services And Other Related Analysis Related To The Installation Of Beach Protection Structures. Final Report.
- Faculty of Civil Engineering (FKA), Universiti Teknologi Malaysia (UTM) provided study for National Hydraulic Research Institute of Malaysia (NAHRIM) (2016). Design of Innovative Seawall and Seablock Systems. Final Report.
- Fogarty, David (2005). Tsunami-Hit Nations Look to Save Mangroves. Reuters, 17 January 2005.
- G. Palmer, and C.D. Christian (1998). Design and Construction of Rubble Mound Breakwaters. IPENZ Transactions.
- Gegar Prasetya (2009). Protection from Coastal Erosion. FAO Corporate Document Repository. Retrieved from <http://www.fao.org/docrep/010/ag127e/AG127E09.htm>
- Ghazali NHM (2005). Coastal Protection Using Pressure Equalisation Modules; Proceedings of Seventh Annual Institution of Engineers Water Resources Colloquium, Petaling Jaya. June 2005; pp. 3-1 – 3-12
- Grant U.S. (1984). Influence of Water Table on Beach Aggradation and Degradation. Journal of Maritime Research, 7, 655-660.
- Hideaki Yanagisawa (2008). The Reduction Effects of Mangrove Forest on a Tsunami Based on Field Surveys at Pakarang Cape, Thailand and Numerical Analysis. Estuarine, Coastal and Shelf Science 81 (2009), 27–37.
- HR Runding (May 2009). Preliminary Environmental Impact Assessment (EIA) Study for the Proposed Development of International Maritime Gateway on Lot PT

- 7396 and PT 7397 Mukim Port Dickson, Daerah Port Dickson, Negeri Sembilan. Final Report.
- Intergovernmental Panel on Climate Change (IPCC) (2007). Fourth Assessment Report (AR4), Geneva, Switzerland.
- Jabatan Pengairan Dan Saliran (JPS) Malaysia, (September 2008). The Integrated Shoreline Management Plan (ISMP) for the Coastline of Negeri Sembilan. Final Report.
- Jabatan Ukur dan Pemetaan Malaysia (JUPEM) (September 2005). Pekeliling Ketua Pengarah Ukur Dan Pemetaan Bil. 9 Tahun 2005. Garis Panduan Mengenai Penggunaan Perkhidmatan Malaysian RTK GPS Network (MyRTKnet).
- K. Angremond, J.W. van der Meer and C.P. van Nes (1994). Stresses in Tetrapod Armour Units Induced by Wave Action. Retrieved from http://www.vandermeerconsulting.nl/downloads/stability_c/1994_dangremond_vandermeer.pdf
- Kenneth W. Christensen (September, 2006). Environmentally Friendly and Cost-effective Beach Erosion Control. Retrieved from http://ecoshore.com/PDF_and_Word_files/PEM%20Info%20Sep.%209,%202006.pdf
- L. Damiani, G. Ranieri and R. Rossetti (2003). Coastal Protection with BMS: The First Experience in Italy. Retrieved from <https://www.witpress.com/Secure/elibrary/papers/CE03/CE03036FU.pdf>
- Lee Hin Lee and Mohd. Fauzi Mohamad (June, 2010). Coastal Vulnerability Assessment for Peninsular Malaysia Coastline. Proceeding of The National Seminar on Coastal Morphology (COSMO), 17 June 2010 in NAHRIM, 18-29.
- Lee Hin Lee and Othman A. Karim (2010). Assessment on Morphological Changes Due to Deepening of Penang Port Harbour. Proceeding of The National Seminar on Coastal Morphology (COSMO), 17 June 2010 in NAHRIM, 172-182.
- Majlis Perbandaran Port Dickson (MPPD) (2006). Background. Retrieved from <http://www.mppd.gov.my/en/mppd/profile/background>
- Md Khairi Yaacob (July 2014). A Study on the Impact of Sea Level Rise on Flooding in Batu Pahat River, Johore, Malaysia (Master dissertation). University Putra Malaysia (UPM).
- Mohammad Fadhli Ahmad, Subiyanto, Rosnan Yaacob, Mustafa Mamat, Aidy M. Muslim and Mohd Lokman Husain (2014). Coastline Changes in Vicinity of

- Runway Platform of Sultan Mahmud Airport, Kuala Terengganu: Comparative Analysis of One-line Model Versus Satellite Data. *Journal of Applied Sciences*, 14: 2234-2245.
- Mohd Fauzi M., S.Y Ang, Saiful Bahri H. and Mohd Kamarul Huda S. (2013). Colonization of Marine Epibiota around WABCORE Artificial Reef at Panuba Bay, Tioman Island, Malaysia. ICESD 2013: January 19-20, Dubai, UAE.
- Muhammad Akhir Othman (1991). Value of Mangroves in Coastal Protection. Retrieved from <http://www.water.gov.my/images/stories/coastal/pdf/newpapers/Did0004.pdf>.
- National Hydraulic Research Institute of Malaysia (NAHRIM) (August 2001). Erosion and Accretion Study Due to the Proposed Rivermouth Improvement Works at Kuala Terengganu, Terengganu Darul Iman.
- National Hydraulic Research Institute of Malaysia (NAHRIM) (2006). Physical Model Study on Sg. Hj. Dorani Erosion Problem. Final Report.
- National Hydraulic Research Institute of Malaysia (NAHRIM) (2010). The study of the impact of climate change on sea level rise in Malaysia. Final Report.
- National Hydrographic Centre (PHN) (2015). Tide Tables Malaysian 2015.
- Nor Aslinda Awang, Khairul Azuan Adam and Shahrani Mamad (2004). Coastal Zone Stabilisation, Restoration and Enhancement through Mangrove Forest Establishment. National Hydraulic Research Institute of Malaysia (NAHRIM).
- Nor Aslinda Awang, Lee Hin Lee, Khairul Azuan Adam and M. Tayalan (2010). Identifying Mangrove Replanting Plots from Hydraulic Assessment. Proceeding of The National Seminar on Coastal Morphology (COSMO), 17 June 2010 in NAHRIM, 49-55.
- Nor Hisham Mohd. Ghazali (2011). Beach Nourishment and Its Impact on Holiday Beaches. Retrieved from http://www.water.gov.my/images/stories/coastal/pdf/newpapers/Beachnourishment_impact.pdf
- Nor Hisham M. Ghazali (November 2005). New Innovations and Technologies in Coastal Rehabilitation. International Conference on Innovations and Technologies in Oceanography for Sustainable Development, Kuala Lumpur 26-28 November 2005.
- OzCoasts Australian Online Coastal Information (2012). Beach Erosion. Retrieved from http://www.ozcoasts.gov.au/indicators/beach_erosion.jsp

- R. G. Dean (1986). Coastal Armoring: Effects, Principles and Mitigation. Retrieved from <http://floridalivingshorelines.com/wp-content/uploads/2015/05/Dean-1986-Coastal-Armoring-Effects-Principles-and-Mitigation.pdf>
- Robert G. Dean and Robert A. Dalrymple (2004). Coastal Processes with Engineering Applications. Cambridge, UK. Cambridge University Press.
- Richard Silvester and John R. C. Hsu (1997). Coastal Stabilization. Advanced Series on Ocean Engineering – Volume 14. Singapore : World Scientific Publishing Co. Pte. Ltd.
- Safari Mat Desa, Othman A. Karim and Wan Hanna Melini Wan Mohtar (2016). Physical Hydrodynamic Modeling To Study Wave Interaction Onto Submerged Breakwater, The National University of Malaysia (UKM), Engineering & Built Environment Research Bulletin Volume 09.2016.
- Safari Mat Desa, Othman A.Karim, Wan Hanna Melini, Azuhan Mohamed, Fauzi Mohamad and Iahri Chatta (2016). Wave Energy Dissipation Laboratory Modelling Of Submerged Breakwater for Shoreline Erosion Control. Science & Technology Research Institute for Defence (STRIDE). Defence Science and Technology Bulletin, Volume 9 No. 2 Year 2016.
- Scottish Natural Heritage (SNH) (2005). A Guide to Managing Coastal Erosion in Beach/Dune Systems. Retrieved from http://www.snh.org.uk/publications/online/heritagemanagement/erosion/appendix_1.6.shtml
- Sharifah Nadia Syed Ahmad (2012). Coastal Defence: A Study On The Performance Of Labuan Block (Degree Dissertation). Universiti Malaysia Pahang (UMP).
- Siew Cheng Lee, Roslan Hashim, Shervin Motamedi and Ki-Il Song (2014). Utilization of Geotextile Tube for Sandy and Muddy Coastal Management: A Review. Retrieved from <https://www.hindawi.com/journals/tswj/2014/494020/>
- Sinar Harian (October 2013). Hotel diancam hakisan pantai. Retrieved from <http://www.sinarharian.com.my/nasional/hotel-diancam-hakisan-pantai-1.210777>
- Stephen P. Leatherman, Keqi Zhang and Bruce C. Douglas (February 2000). Sea Level Rise Shown to Drive Coastal Erosion. EOS, Vol. 81, No. 6, February 8, 2000, 55-57. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1029/00EO00034/pdf>
- Steven Earle (2016). Landforms of Coastal Deposition. Retrieved from <https://opentextbc.ca/geology/chapter/17-3-landforms-of-coastal-deposition/>

- Stewart Smith (2010). Coastal Erosion & Sea Level Rise. New South Wales Parliamentary Library, Australia. Briefing Paper No 6/2010.
- Tan King Seng, Nor Hisham Mohd. Ghazali and Ong Hon Lim (2006). Innovation in Coastal Protection Works Using Labuan Blocks. Board of Engineers Malaysia (BEM). Jurutera Bulletin, April 2006.
- Tan King Seng, Nor Hisham Mohd. Ghazali and Ong Hon Lim (2006) Coastal Protection against Wave Energy Part 2. The Ingenieur, Board of Engineers Malaysia (BEM). Vol.30 Jun - Aug 2006, 50-55.
- Teh Tiong Sa and Yap Hui Boon (April 2003). Overview of Malaysia Coastline: Terengganu. The World's Coasts: Online, 19 South East Asia. Nanyang Technological University, Singapore
- Thom, B.G. and Hall, W. (1991). Behaviour of Beach Profiles during Accretion and Erosion Dominated Periods. Earth Surface Processes and Landforms 16, 113-127.
- US Army Corps of Engineers (USACE) (September 2016). Coastal Effects of Tides. Retrieved from <http://www.corpscoasts.us/coastdyn/cd-tidescoast.cfm>
- U.S. Army Corps of Engineer (USACE) (1984). Shore Protection Manual. Retrieved from <http://ft-sipil.unila.ac.id/dbooks/S%20P%20M%201984%20volume%201-1.pdf>.
- Wan Hasliza Wan Jusoh, Fredolin Tanggang, NorAslinda Awang and Mohd. Radzi Abdul Hamid (2013). Analysis of Coastal Changes and Hydrodynamic Simulation at Tanjung Piai Coast, Johor, Malaysia. Malaysia Water Research Journal, National Hydraulic Research Institute of Malaysia (NAHRIM), Vol.4, No.2 (2013): 40-49.
- Wikipedia. Wind wave. Retrieved from https://en.wikipedia.org/wiki/Wind_wave
- World Atlas (1996). Where is Port Dickson. Retrieved from <http://www.worldatlas.com/as/my/05/where-is-port-dickson.html>

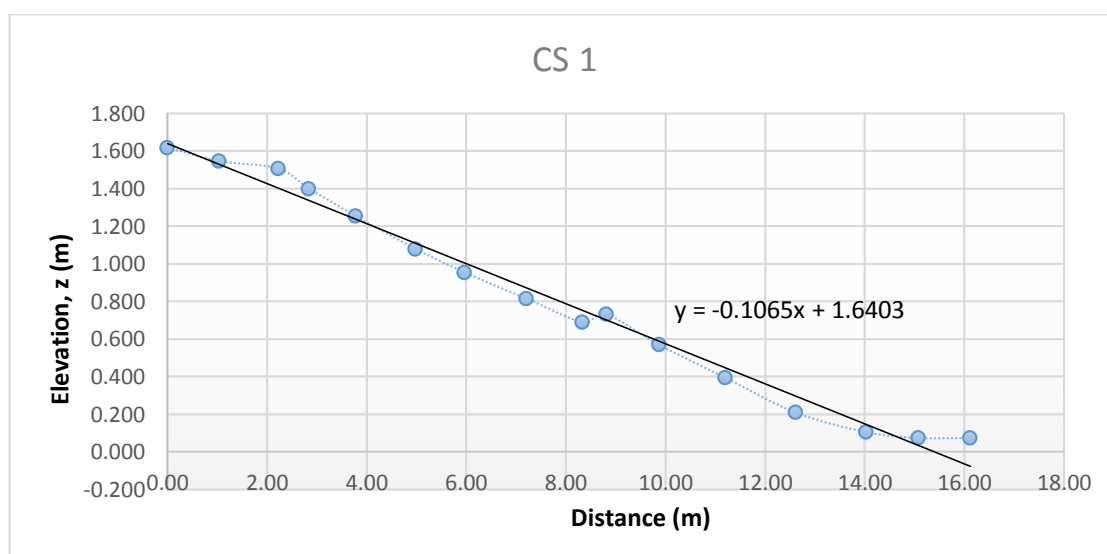
APPENDICES

APPENDIX 1A

The RTK Survey Points Value and Plotted Graph of the Transect Cross Section 1 (CS1) to Cross Section 24 (CS24) for Beach Profiling on Test Site

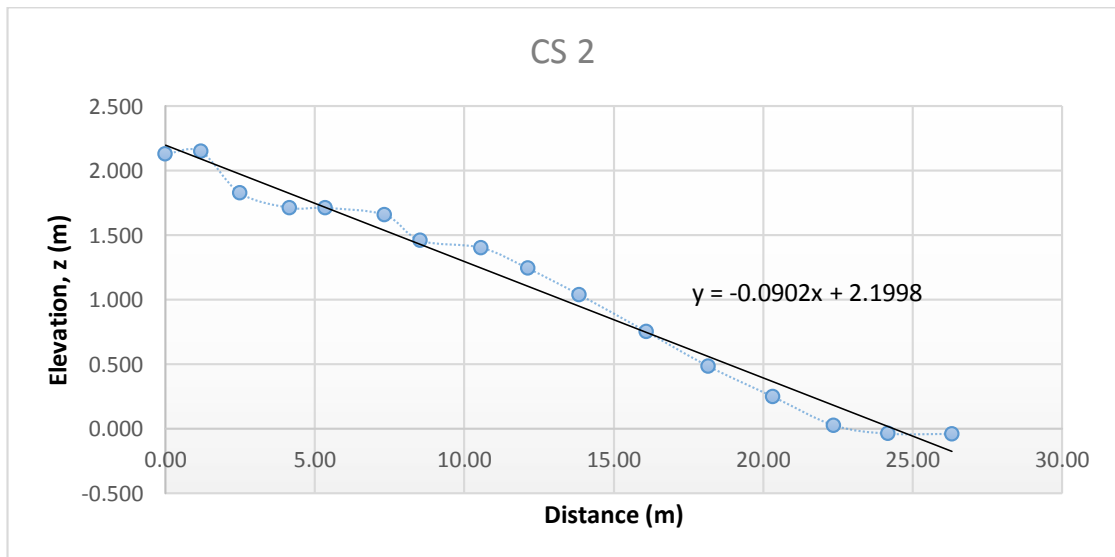
Cross Section 1

Easting	Northing	Cumulative Distance	z (m)	Transect
816528.048	274941.272	0.00	1.617	CS1
816527.160	274940.719	1.04	1.546	CS1
816526.128	274940.150	2.22	1.507	CS1
816525.367	274940.314	2.84	1.401	CS1
816524.534	274939.864	3.78	1.254	CS1
816523.433	274939.386	4.98	1.080	CS1
816522.534	274939.002	5.96	0.955	CS1
816521.364	274938.543	7.21	0.815	CS1
816520.437	274937.871	8.33	0.691	CS1
816520.137	274937.379	8.81	0.732	CS1
816519.216	274936.860	9.87	0.570	CS1
816518.014	274936.287	11.20	0.395	CS1
816516.632	274935.906	12.61	0.210	CS1
816515.370	274935.252	14.03	0.106	CS1
816514.557	274934.529	15.08	0.075	CS1
816513.542	274934.220	16.12	0.075	CS1



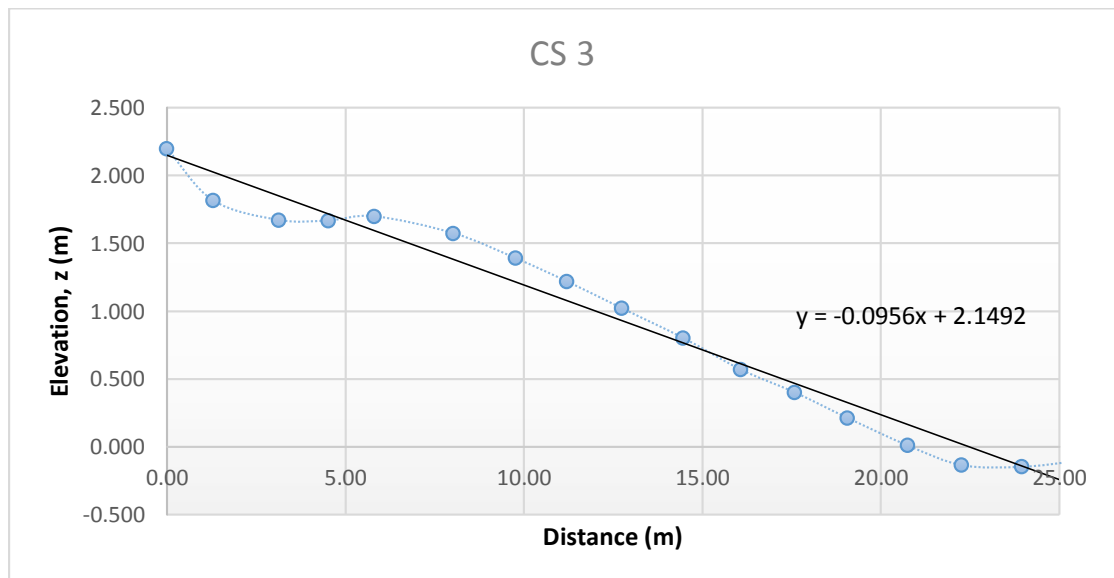
Cross Section 2

Easting	Northing	Cumulative Distance	z (m)	Transect
816540.798	274937.148	0.00	2.131	CS2
816539.795	274936.522	1.18	2.151	CS2
816538.572	274936.017	2.49	1.829	CS2
816537.152	274935.132	4.16	1.714	CS2
816536.078	274934.624	5.35	1.713	CS2
816534.313	274933.702	7.34	1.659	CS2
816533.310	274933.051	8.53	1.460	CS2
816531.638	274931.871	10.57	1.404	CS2
816530.184	274931.269	12.13	1.244	CS2
816528.673	274930.441	13.85	1.040	CS2
816526.761	274929.247	16.10	0.752	CS2
816525.056	274928.063	18.17	0.485	CS2
816523.185	274926.975	20.33	0.249	CS2
816521.528	274925.792	22.36	0.028	CS2
816519.889	274925.002	24.18	-0.037	CS2
816518.015	274923.953	26.32	-0.039	CS2



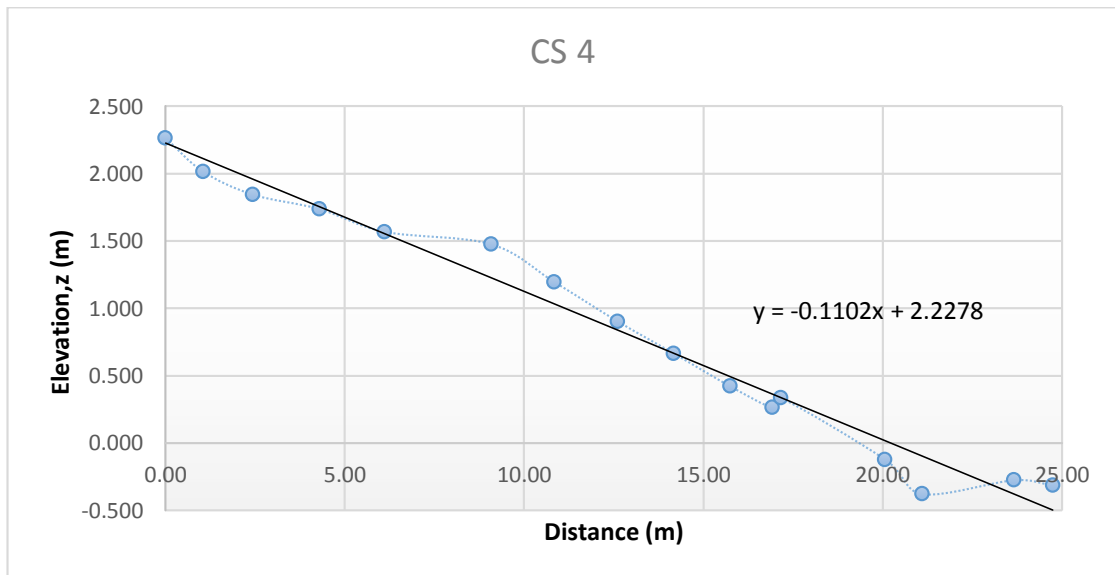
Cross Section 3

Easting	Northing	Cumulative Dinstance	z (m)	Transect
816544.692	274929.905	0.00	2.196	CS3
816543.588	274929.230	1.29	1.816	CS3
816541.945	274928.402	3.13	1.672	CS3
816540.785	274927.631	4.52	1.668	CS3
816539.674	274926.970	5.81	1.699	CS3
816537.769	274925.822	8.03	1.574	CS3
816536.318	274924.857	9.77	1.390	CS3
816535.065	274924.147	11.21	1.219	CS3
816533.765	274923.328	12.75	1.021	CS3
816532.353	274922.334	14.47	0.802	CS3
816530.989	274921.484	16.08	0.570	CS3
816529.766	274920.592	17.59	0.402	CS3
816528.473	274919.874	19.07	0.214	CS3
816527.041	274918.988	20.75	0.012	CS3
816525.729	274918.216	22.27	-0.133	CS3
816524.234	274917.434	23.95	-0.145	CS3
816522.906	274916.727	25.46	-0.104	CS3



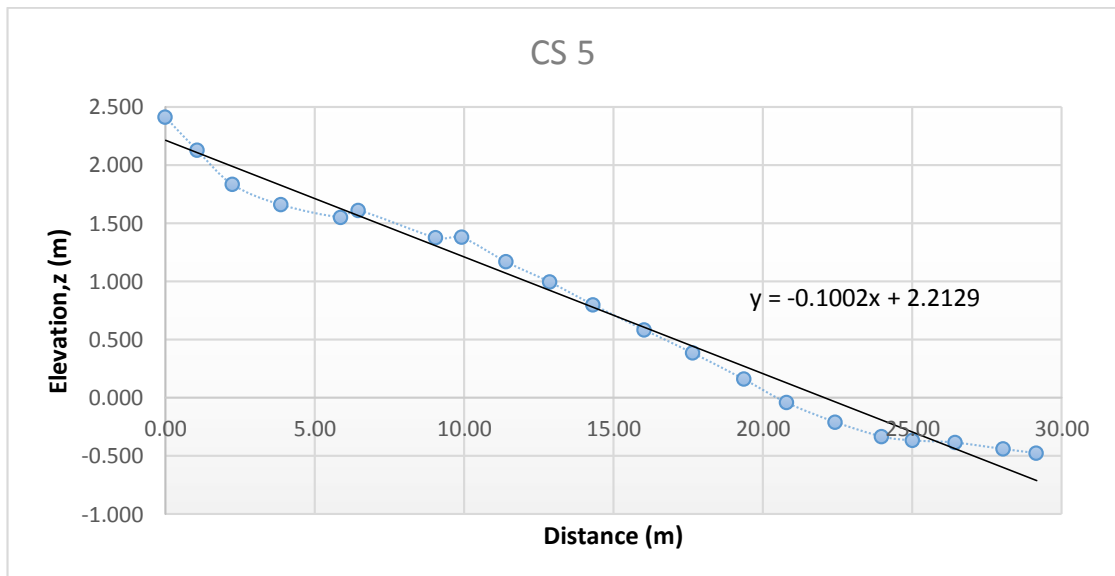
Cross Section 4

Easting	Northing	Cumulative Distance	z (m)	Transect
816548.778	274922.865	0.00	2.265	CS4
816547.835	274922.396	1.05	2.016	CS4
816546.705	274921.568	2.44	1.845	CS4
816545.160	274920.545	4.29	1.738	CS4
816543.594	274919.629	6.11	1.569	CS4
816541.178	274917.882	9.08	1.477	CS4
816539.632	274917.031	10.84	1.197	CS4
816538.088	274916.167	12.61	0.904	CS4
816536.750	274915.337	14.18	0.665	CS4
816535.454	274914.449	15.75	0.422	CS4
816534.387	274913.937	16.93	0.264	CS4
816534.259	274913.708	17.16	0.336	CS4
816531.731	274912.261	20.07	-0.122	CS4
816530.821	274911.750	21.11	-0.378	CS4
816528.691	274910.325	23.67	-0.275	CS4
816527.763	274909.785	24.75	-0.315	CS4



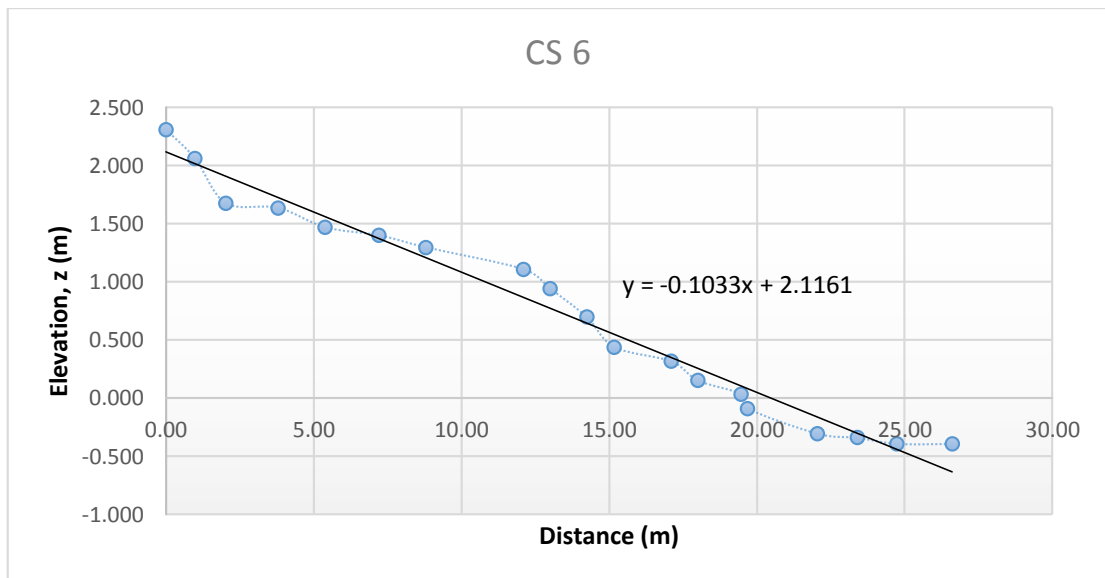
Cross Section 5

Easting	Northing	Cumulative Distance	z (m)	Transect
816555.397	274914.840	0.00	2.414	CS5
816554.489	274914.288	1.06	2.129	CS5
816553.503	274913.607	2.25	1.834	CS5
816552.088	274912.835	3.86	1.661	CS5
816550.434	274911.690	5.87	1.553	CS5
816549.965	274911.340	6.46	1.611	CS5
816547.758	274909.993	9.04	1.378	CS5
816546.927	274909.670	9.92	1.379	CS5
816545.719	274908.793	11.41	1.169	CS5
816544.400	274908.152	12.87	0.995	CS5
816543.052	274907.580	14.32	0.800	CS5
816541.585	274906.711	16.02	0.585	CS5
816540.205	274905.852	17.65	0.386	CS5
816538.642	274905.124	19.36	0.160	CS5
816537.399	274904.427	20.79	-0.041	CS5
816535.980	274903.626	22.42	-0.208	CS5
816534.706	274902.724	23.97	-0.332	CS5
816533.811	274902.206	25.01	-0.366	CS5
816532.633	274901.406	26.43	-0.385	CS5
816531.204	274900.629	28.05	-0.440	CS5
816530.325	274899.935	29.16	-0.476	CS5



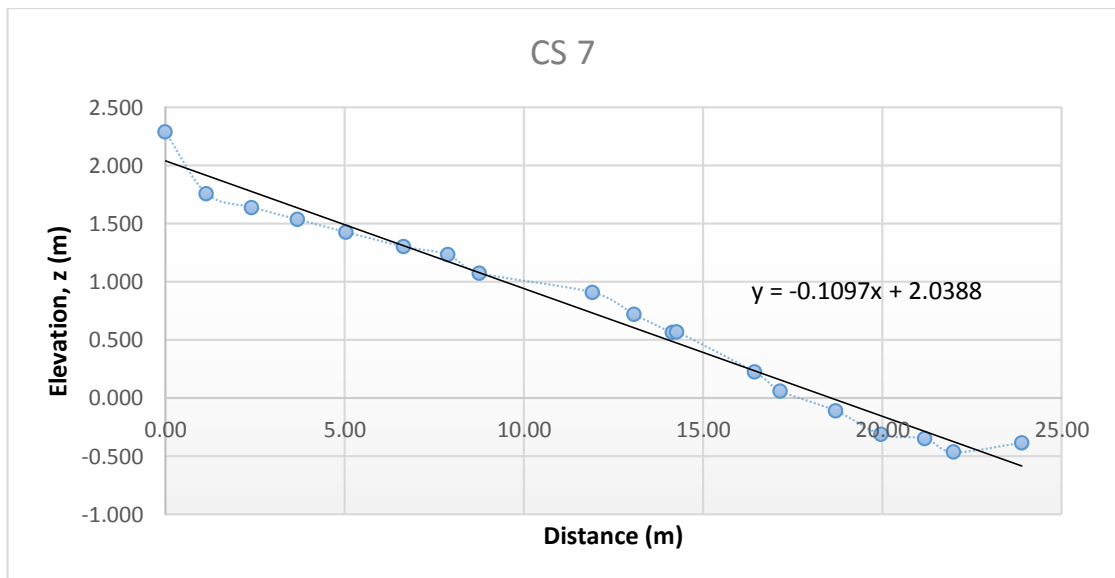
Cross Section 6

Easting	Northing	Cumulative Distance	z (m)	Transect
816560.078	274906.981	0.00	2.305	CS6
816559.237	274906.474	0.98	2.058	CS6
816558.343	274905.938	2.02	1.675	CS6
816556.885	274904.934	3.79	1.635	CS6
816555.471	274904.183	5.39	1.467	CS6
816553.826	274903.381	7.21	1.399	CS6
816552.446	274902.601	8.79	1.296	CS6
816549.590	274900.935	12.10	1.107	CS6
816548.847	274900.415	13.00	0.941	CS6
816547.698	274899.929	14.24	0.696	CS6
816546.890	274899.475	15.17	0.439	CS6
816545.237	274898.468	17.10	0.316	CS6
816544.476	274897.988	18.00	0.152	CS6
816543.213	274897.245	19.47	0.035	CS6
816543.111	274896.985	19.69	-0.090	CS6
816541.070	274895.786	22.05	-0.305	CS6
816539.904	274895.110	23.40	-0.340	CS6
816538.755	274894.422	24.74	-0.392	CS6
816537.089	274893.561	26.61	-0.393	CS6



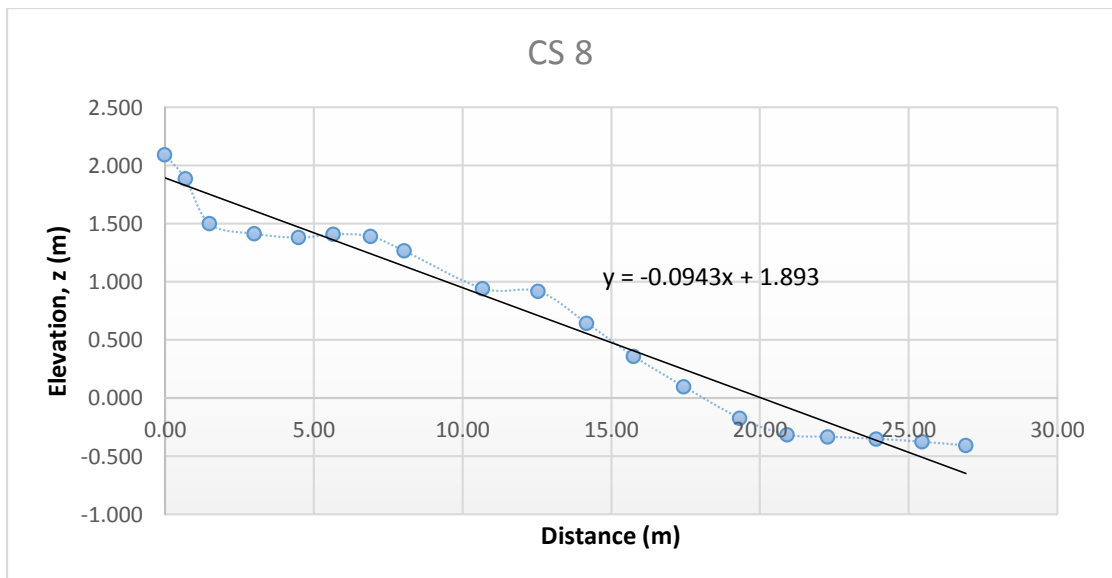
Cross Section 7

Easting	Northing	Cumulative Distance	z (m)	Transect
816564.542	274898.164	0.00	2.287	CS7
816563.524	274897.644	1.14	1.759	CS7
816562.374	274897.124	2.40	1.640	CS7
816561.293	274896.408	3.69	1.536	CS7
816560.038	274895.888	5.04	1.426	CS7
816558.600	274895.197	6.64	1.303	CS7
816557.482	274894.649	7.88	1.233	CS7
816556.817	274894.033	8.76	1.076	CS7
816554.283	274892.090	11.92	0.908	CS7
816553.270	274891.522	13.08	0.719	CS7
816552.356	274890.980	14.14	0.563	CS7
816552.240	274890.929	14.27	0.570	CS7
816550.400	274889.767	16.44	0.224	CS7
816549.859	274889.288	17.15	0.063	CS7
816548.533	274888.488	18.70	-0.108	CS7
816547.354	274887.979	19.97	-0.312	CS7
816546.347	274887.316	21.18	-0.345	CS7
816545.655	274886.885	21.99	-0.463	CS7
816543.968	274886.015	23.89	-0.382	CS7



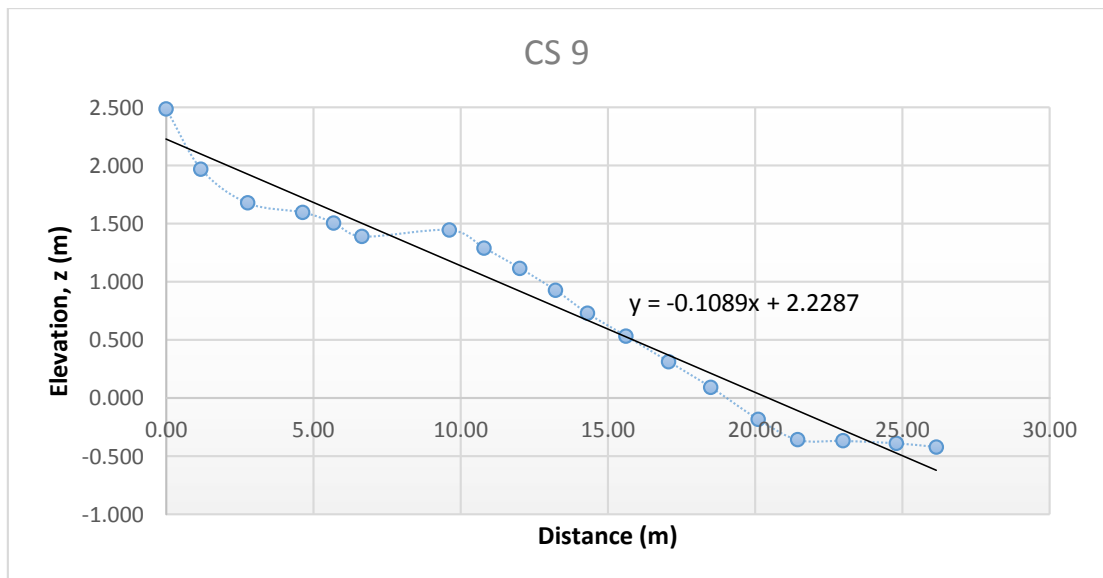
Cross Section 8

Easting	Northing	Cumulative Distance	z (m)	Transect
816569.987	274888.753	0.00	2.094	CS8
816569.395	274888.398	0.69	1.885	CS8
816568.632	274888.093	1.50	1.499	CS8
816567.312	274887.371	3.01	1.414	CS8
816566.024	274886.621	4.50	1.380	CS8
816565.018	274886.017	5.67	1.411	CS8
816563.967	274885.334	6.92	1.391	CS8
816562.966	274884.811	8.05	1.266	CS8
816560.862	274883.190	10.68	0.943	CS8
816559.057	274882.552	12.56	0.918	CS8
816557.512	274882.000	14.18	0.644	CS8
816556.039	274881.390	15.77	0.358	CS8
816554.508	274880.690	17.45	0.098	CS8
816552.907	274879.681	19.33	-0.173	CS8
816551.513	274878.919	20.92	-0.315	CS8
816550.147	274878.583	22.29	-0.333	CS8
816548.613	274878.008	23.92	-0.350	CS8
816547.245	274877.297	25.46	-0.376	CS8
816545.922	274876.644	26.93	-0.408	CS8



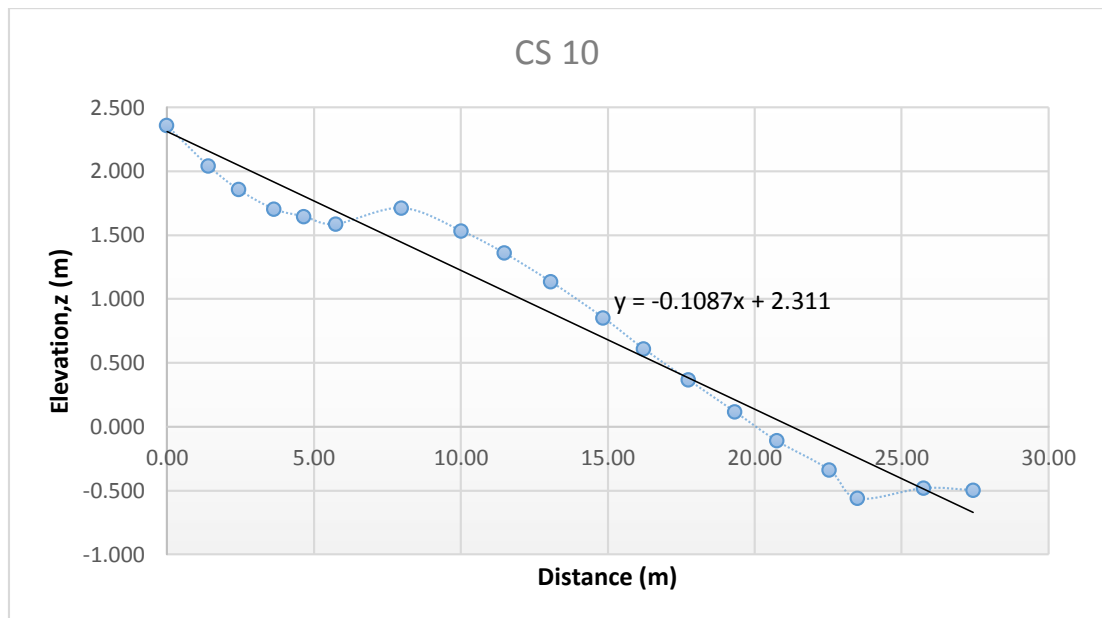
Cross Section 9

Easting	Northing	Cumulative Distance	z (m)	Transect
816574.351	274881.515	0.00	2.487	CS9
816573.279	274880.991	1.19	1.968	CS9
816571.851	274880.306	2.77	1.677	CS9
816570.268	274879.300	4.64	1.597	CS9
816569.358	274878.754	5.70	1.507	CS9
816568.569	274878.191	6.66	1.390	CS9
816566.157	274876.457	9.62	1.446	CS9
816565.144	274875.845	10.81	1.290	CS9
816564.046	274875.321	12.02	1.117	CS9
816562.945	274874.799	13.23	0.927	CS9
816561.965	274874.319	14.32	0.729	CS9
816560.818	274873.707	15.62	0.534	CS9
816559.526	274873.024	17.08	0.313	CS9
816558.218	274872.459	18.50	0.094	CS9
816556.693	274871.891	20.11	-0.182	CS9
816555.439	274871.365	21.46	-0.358	CS9
816554.093	274870.628	22.99	-0.366	CS9
816552.396	274869.945	24.81	-0.387	CS9
816551.193	274869.335	26.16	-0.419	CS9



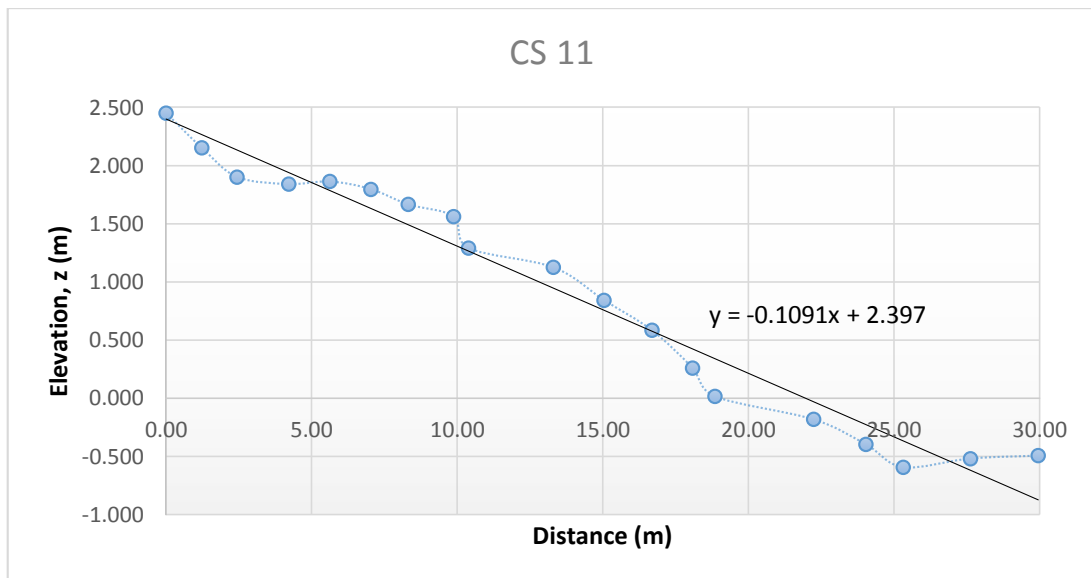
Cross Section 10

Easting	Northing	Cumulative Distance	z (m)	Transect
816579.124	274873.233	0.00	2.357	CS10
816577.891	274872.542	1.41	2.042	CS10
816576.980	274872.050	2.44	1.856	CS10
816576.103	274871.339	3.65	1.703	CS10
816575.012	274871.032	4.66	1.646	CS10
816574.069	274870.501	5.74	1.587	CS10
816572.311	274869.054	7.99	1.712	CS10
816570.524	274868.075	10.02	1.533	CS10
816569.272	274867.327	11.48	1.359	CS10
816567.868	274866.585	13.07	1.134	CS10
816566.309	274865.727	14.85	0.853	CS10
816565.016	274865.199	16.23	0.609	CS10
816563.569	274864.673	17.75	0.366	CS10
816562.094	274864.085	19.33	0.117	CS10
816560.703	274863.657	20.76	-0.111	CS10
816559.060	274862.942	22.54	-0.338	CS10
816558.186	274862.555	23.50	-0.561	CS10
816556.111	274861.647	25.76	-0.480	CS10
816554.546	274861.026	27.44	-0.496	CS10



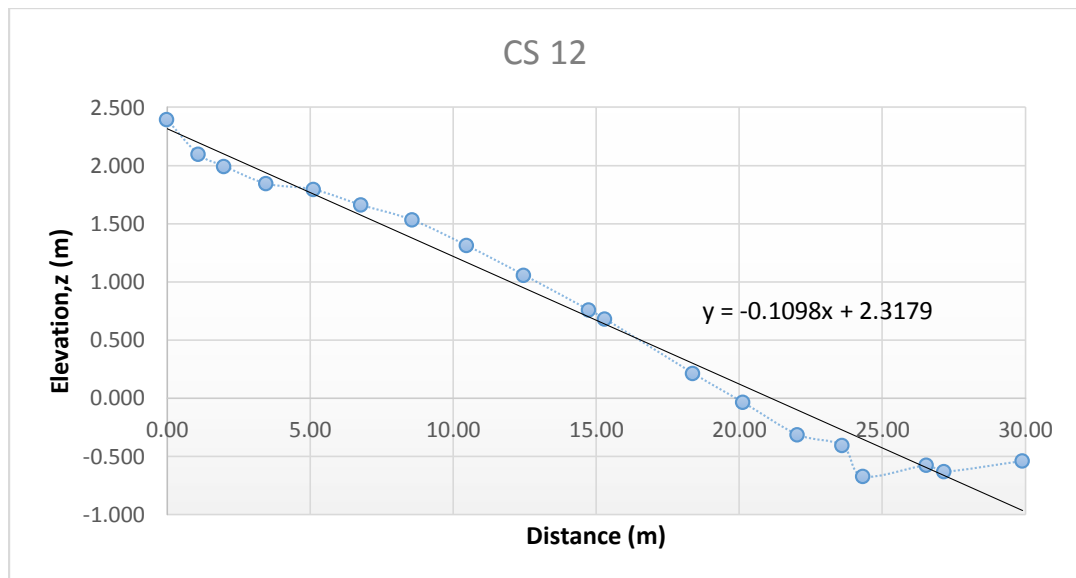
Cross Section 11

Easting	Northing	Cumulative Distance	z (m)	Transect
816582.492	274866.218	0.00	2.448	CS11
816581.290	274865.992	1.22	2.152	CS11
816580.183	274865.428	2.44	1.900	CS11
816578.529	274864.788	4.21	1.839	CS11
816577.280	274864.115	5.62	1.861	CS11
816576.012	274863.476	7.03	1.796	CS11
816574.797	274863.031	8.32	1.664	CS11
816573.372	274862.417	9.88	1.561	CS11
816572.931	274862.129	10.39	1.290	CS11
816570.282	274860.897	13.31	1.123	CS11
816568.680	274860.216	15.05	0.841	CS11
816567.167	274859.604	16.69	0.583	CS11
816565.819	274859.215	18.08	0.260	CS11
816565.089	274858.960	18.85	0.015	CS11
816561.839	274857.931	22.25	-0.184	CS11
816560.151	274857.295	24.05	-0.399	CS11
816558.939	274856.873	25.33	-0.594	CS11
816556.814	274855.972	27.64	-0.520	CS11
816554.674	274855.061	29.97	-0.495	CS11



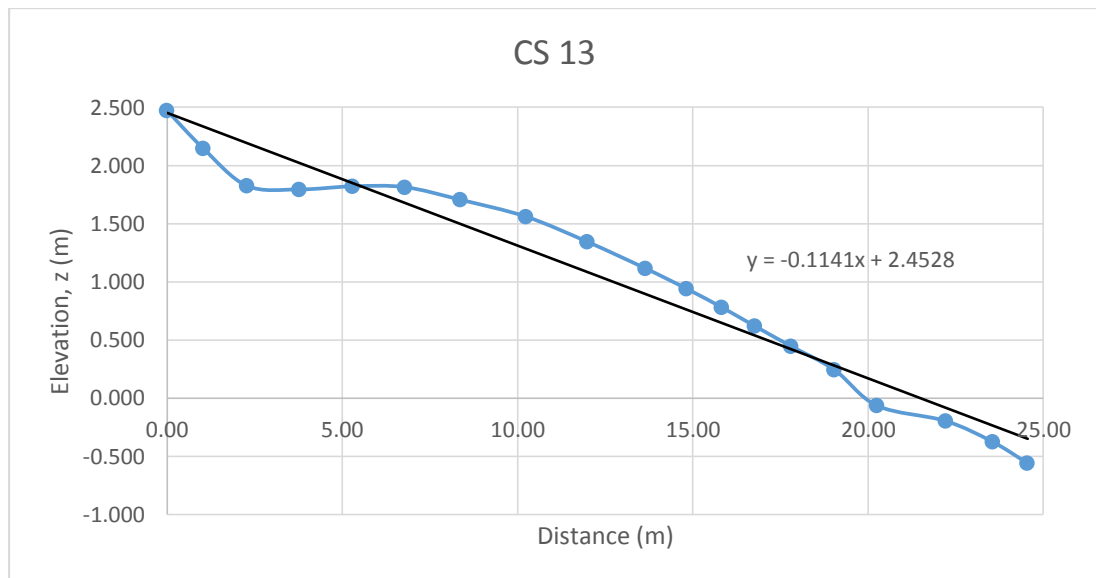
Cross Section 12

Easting	Northing	Cumulative Distance	z (m)	Transect
816584.458	274860.341	0.00	2.394	CS12
816583.397	274860.058	1.09	2.098	CS12
816582.542	274859.761	2.00	1.993	CS12
816581.152	274859.274	3.47	1.844	CS12
816579.603	274858.684	5.12	1.793	CS12
816578.127	274857.883	6.79	1.660	CS12
816576.488	274857.188	8.57	1.531	CS12
816574.726	274856.464	10.47	1.312	CS12
816572.913	274855.612	12.47	1.058	CS12
816570.858	274854.614	14.75	0.757	CS12
816570.374	274854.363	15.30	0.682	CS12
816567.498	274853.230	18.39	0.212	CS12
816565.856	274852.643	20.13	-0.037	CS12
816564.074	274851.964	22.03	-0.313	CS12
816562.670	274851.272	23.60	-0.408	CS12
816561.977	274851.019	24.33	-0.673	CS12
816559.905	274850.245	26.54	-0.578	CS12
816559.361	274849.909	27.17	-0.633	CS12
816556.935	274848.650	29.90	-0.541	CS12



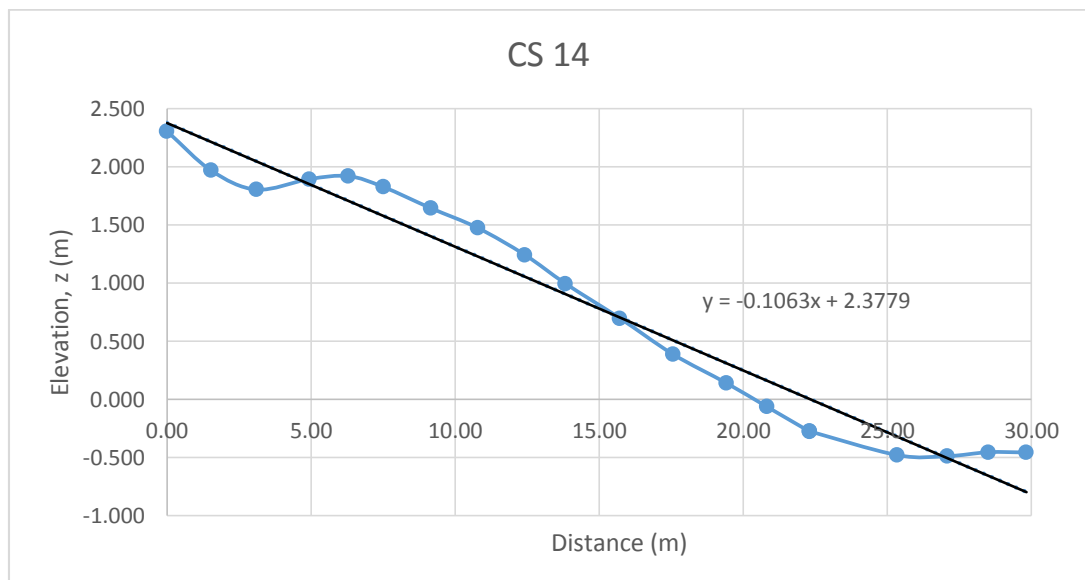
Cross Section 13

Easting	Northing	Cumulative Distance	z (m)	Transect
816588.947	274852.626	0.00	2.470	CS13
816587.963	274852.298	1.03	2.147	CS13
816586.765	274851.953	2.28	1.825	CS13
816585.349	274851.499	3.77	1.794	CS13
816583.961	274850.806	5.30	1.821	CS13
816582.541	274850.405	6.78	1.814	CS13
816581.124	274849.659	8.36	1.706	CS13
816579.374	274848.968	10.24	1.560	CS13
816577.758	274848.302	11.99	1.344	CS13
816576.191	274847.742	13.65	1.115	CS13
816575.110	274847.292	14.82	0.941	CS13
816574.153	274846.972	15.83	0.780	CS13
816573.293	274846.610	16.77	0.619	CS13
816572.351	274846.174	17.80	0.447	CS13
816571.176	274845.782	19.04	0.243	CS13
816570.076	274845.253	20.26	-0.065	CS13
816568.303	274844.410	22.21	-0.196	CS13
816567.149	274843.692	23.55	-0.375	CS13
816566.274	274843.211	24.55	-0.559	CS13



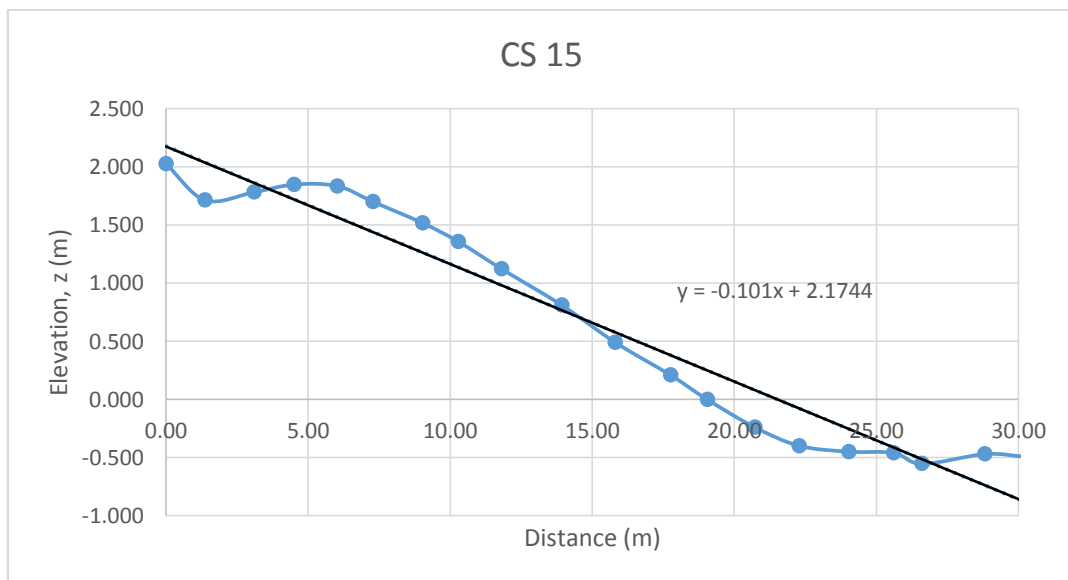
Cross Section 14

Easting	Northing	Cumulative Distance	z (m)	Transect
816591.099	274845.493	0.00	2.305	CS14
816589.647	274844.988	1.53	1.968	CS14
816588.216	274844.338	3.10	1.804	CS14
816586.490	274843.739	4.93	1.894	CS14
816585.240	274843.191	6.29	1.920	CS14
816584.072	274842.836	7.51	1.826	CS14
816582.578	274842.158	9.15	1.645	CS14
816581.081	274841.488	10.78	1.475	CS14
816579.535	274840.953	12.42	1.243	CS14
816578.172	274840.577	13.83	0.996	CS14
816576.433	274839.825	15.72	0.698	CS14
816574.682	274839.255	17.56	0.389	CS14
816572.922	274838.663	19.41	0.142	CS14
816571.574	274838.248	20.82	-0.062	CS14
816570.203	274837.700	22.30	-0.275	CS14
816570.206	274837.694	22.30	-0.273	CS14
816567.351	274836.604	25.35	-0.478	CS14
816565.808	274835.811	27.08	-0.487	CS14
816564.450	274835.385	28.50	-0.453	CS14
816563.168	274835.009	29.83	-0.455	CS14



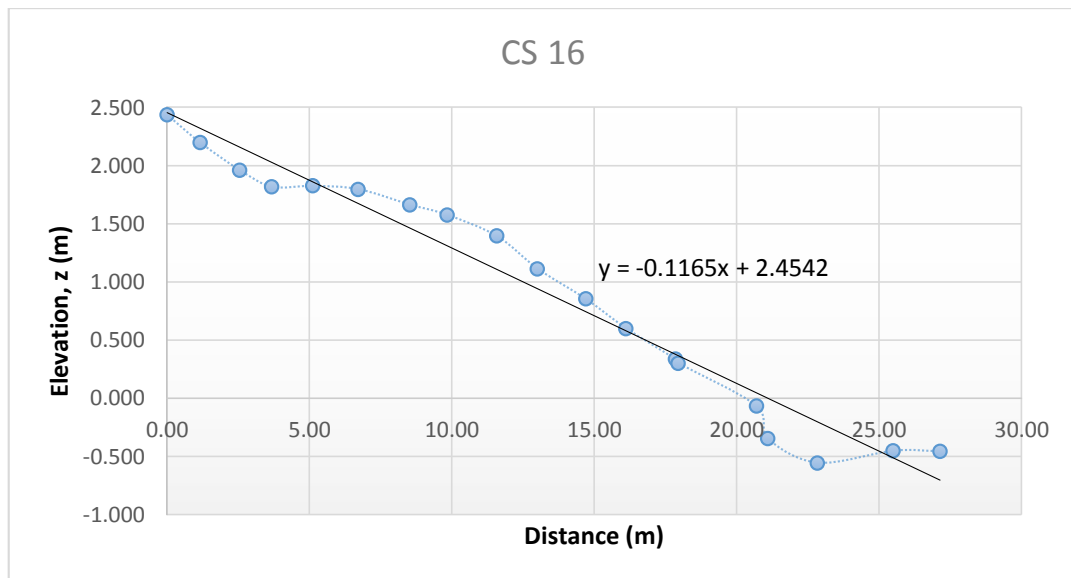
Cross Section 15

Easting	Northing	Cumulative Distance	z (m)	Transect
816592.284	274839.516	0.00	2.024	CS15
816591.045	274838.895	1.38	1.712	CS15
816589.392	274838.377	3.10	1.782	CS15
816588.098	274837.803	4.52	1.848	CS15
816586.684	274837.259	6.03	1.834	CS15
816585.596	274836.589	7.30	1.698	CS15
816583.948	274836.011	9.04	1.515	CS15
816582.830	274835.438	10.29	1.356	CS15
816581.438	274834.830	11.81	1.122	CS15
816579.380	274834.256	13.93	0.810	CS15
816577.581	274833.673	15.82	0.489	CS15
816575.746	274833.037	17.76	0.209	CS15
816574.537	274832.551	19.06	-0.002	CS15
816572.935	274832.035	20.74	-0.241	CS15
816571.467	274831.493	22.30	-0.399	CS15
816569.855	274830.813	24.05	-0.449	CS15
816568.454	274830.022	25.61	-0.458	CS15
816567.553	274829.649	26.62	-0.553	CS15
816565.535	274828.736	28.83	-0.469	CS15
816564.297	274828.071	30.23	-0.492	CS15



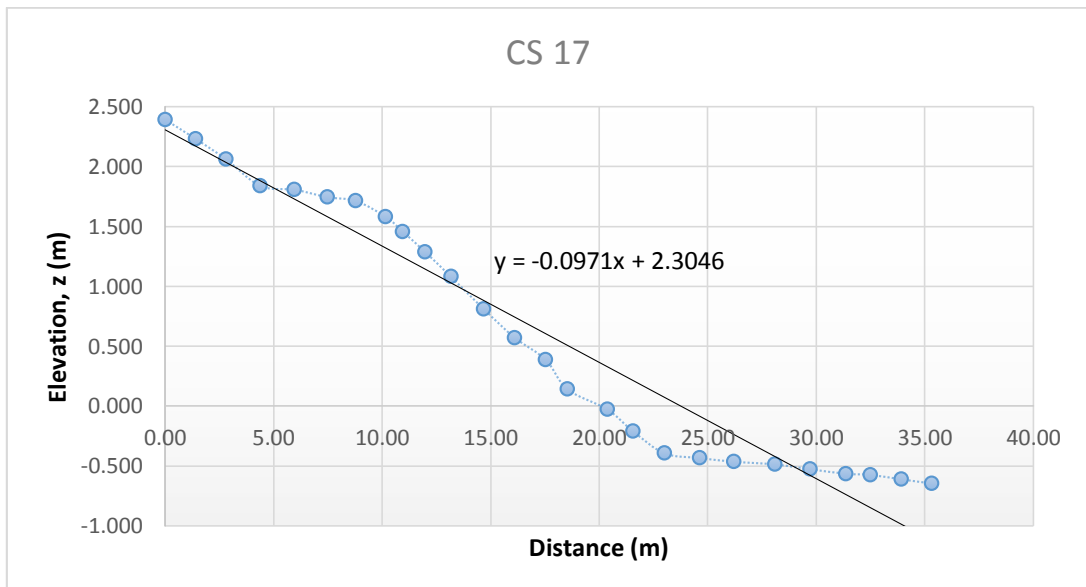
Cross Section 16

Easting	Northing	Cumulative Distance	z (m)	Transect
816595.965	274833.596	0.00	2.435	CS16
816594.882	274833.144	1.17	2.195	CS16
816593.640	274832.542	2.55	1.960	CS16
816592.541	274832.241	3.68	1.817	CS16
816591.234	274831.648	5.11	1.824	CS16
816589.800	274830.940	6.71	1.796	CS16
816588.182	274830.097	8.53	1.663	CS16
816586.924	274829.733	9.83	1.575	CS16
816585.304	274829.059	11.58	1.393	CS16
816584.035	274828.402	13.01	1.112	CS16
816582.499	274827.689	14.70	0.852	CS16
816581.219	274827.072	16.12	0.599	CS16
816579.642	274826.354	17.85	0.334	CS16
816579.588	274826.240	17.95	0.300	CS16
816577.047	274825.191	20.70	-0.068	CS16
816576.696	274825.001	21.09	-0.348	CS16
816575.077	274824.356	22.84	-0.556	CS16
816572.673	274823.194	25.50	-0.453	CS16
816571.196	274822.479	27.14	-0.458	CS16



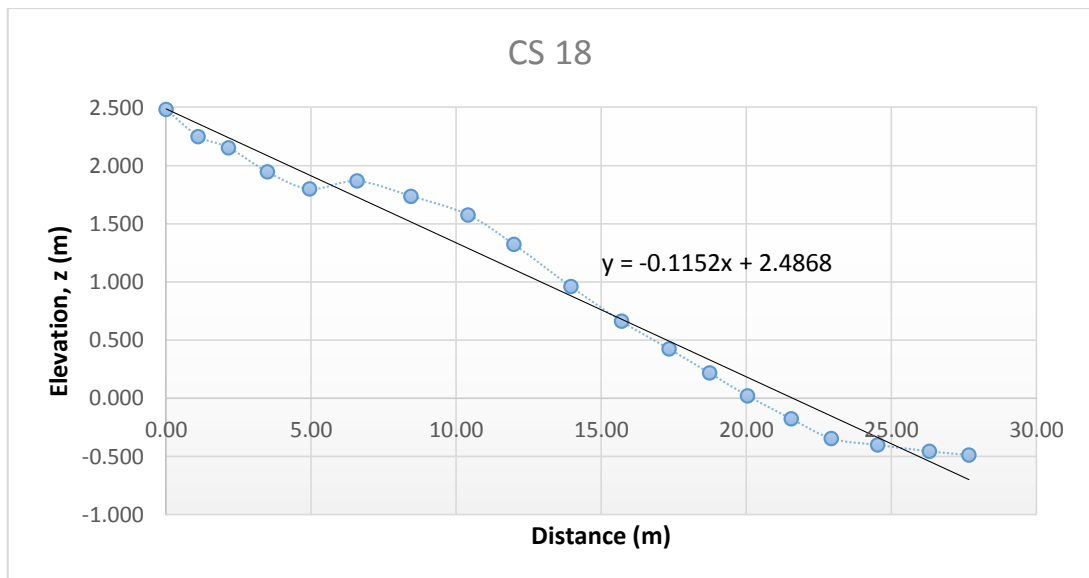
Cross Section 17

Easting	Northing	Cumulative Distance	z (m)	Transect
816599.447	274825.845	0.00	2.392	CS17
816598.116	274825.404	1.40	2.232	CS17
816596.842	274824.799	2.80	2.062	CS17
816595.359	274824.252	4.38	1.839	CS17
816593.846	274823.803	5.96	1.807	CS17
816592.436	274823.208	7.49	1.745	CS17
816591.156	274822.908	8.79	1.713	CS17
816589.867	274822.460	10.16	1.581	CS17
816589.170	274822.064	10.95	1.457	CS17
816588.200	274821.690	11.98	1.287	CS17
816587.104	274821.248	13.17	1.080	CS17
816585.711	274820.610	14.69	0.808	CS17
816584.416	274820.022	16.11	0.571	CS17
816583.082	274819.535	17.53	0.388	CS17
816582.173	274819.130	18.53	0.141	CS17
816580.482	274818.394	20.37	-0.027	CS17
816579.389	274817.965	21.55	-0.209	CS17
816578.047	274817.401	23.00	-0.393	CS17
816576.545	274816.780	24.63	-0.433	CS17
816575.095	274816.168	26.20	-0.463	CS17
816573.395	274815.335	28.09	-0.486	CS17
816571.901	274814.686	29.72	-0.526	CS17
816570.317	274814.184	31.37	-0.564	CS17
816569.338	274813.624	32.49	-0.573	CS17
816568.011	274813.074	33.93	-0.611	CS17
816566.775	274812.416	35.32	-0.645	CS17



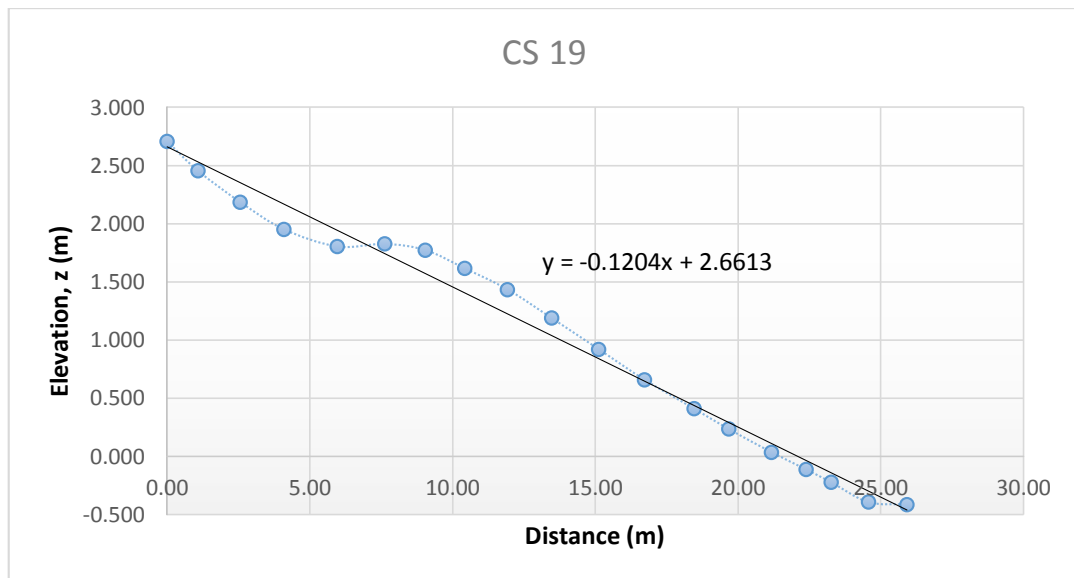
Cross Section 18

Easting	Northing	Cumulative Distance	z (m)	Transect
816601.830	274819.316	0.00	2.480	CS18
816600.802	274818.893	1.11	2.249	CS18
816599.841	274818.488	2.15	2.153	CS18
816598.532	274818.136	3.50	1.943	CS18
816597.149	274817.727	4.94	1.797	CS18
816595.605	274817.158	6.58	1.865	CS18
816593.855	274816.517	8.45	1.736	CS18
816592.054	274815.760	10.40	1.576	CS18
816590.582	274815.159	11.99	1.321	CS18
816588.723	274814.522	13.95	0.960	CS18
816587.038	274814.005	15.71	0.660	CS18
816585.484	274813.491	17.35	0.422	CS18
816584.151	274813.092	18.74	0.216	CS18
816582.846	274812.868	20.04	0.022	CS18
816581.405	274812.424	21.55	-0.176	CS18
816580.045	274812.118	22.94	-0.346	CS18
816578.497	274811.698	24.54	-0.401	CS18
816576.829	274811.059	26.32	-0.455	CS18
816575.550	274810.639	27.67	-0.487	CS18



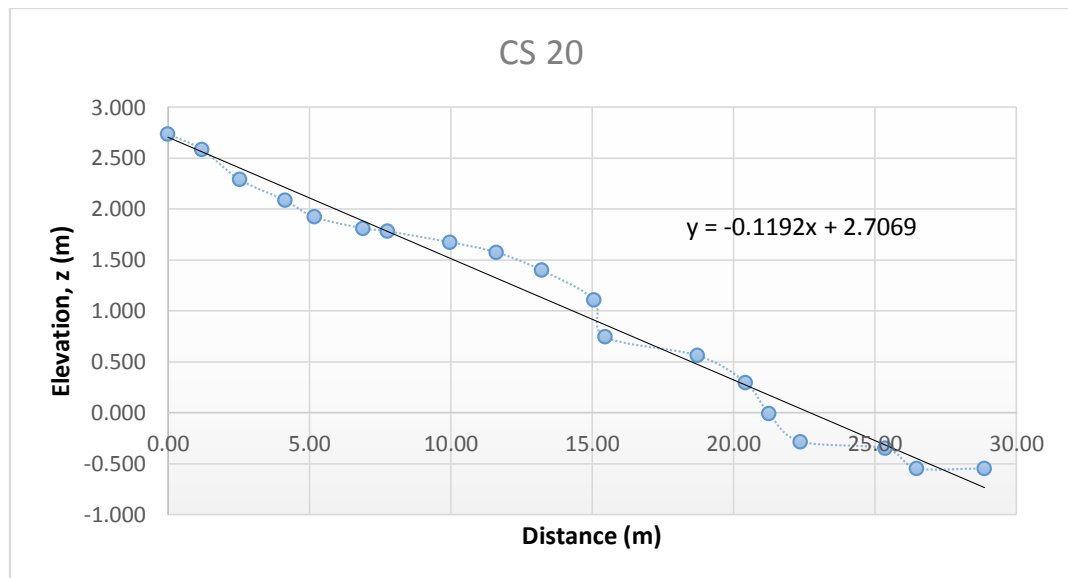
Cross Section 19

Easting	Northing	Cumulative Distance	z (m)	Transect
816605.034	274811.834	0.00	2.706	CS19
816603.993	274811.509	1.09	2.452	CS19
816602.554	274811.154	2.57	2.184	CS19
816601.115	274810.633	4.09	1.951	CS19
816599.311	274810.125	5.97	1.803	CS19
816597.758	274809.552	7.62	1.825	CS19
816596.429	274809.020	9.05	1.772	CS19
816595.163	274808.458	10.43	1.615	CS19
816593.780	274807.870	11.93	1.434	CS19
816592.339	274807.293	13.48	1.187	CS19
816590.750	274806.817	15.13	0.919	CS19
816589.247	274806.292	16.73	0.658	CS19
816587.589	274805.783	18.46	0.410	CS19
816586.450	274805.358	19.68	0.234	CS19
816585.024	274804.900	21.17	0.036	CS19
816583.916	274804.389	22.39	-0.113	CS19
816583.027	274804.245	23.27	-0.224	CS19
816581.809	274803.790	24.57	-0.394	CS19
816580.519	274803.378	25.93	-0.415	CS19



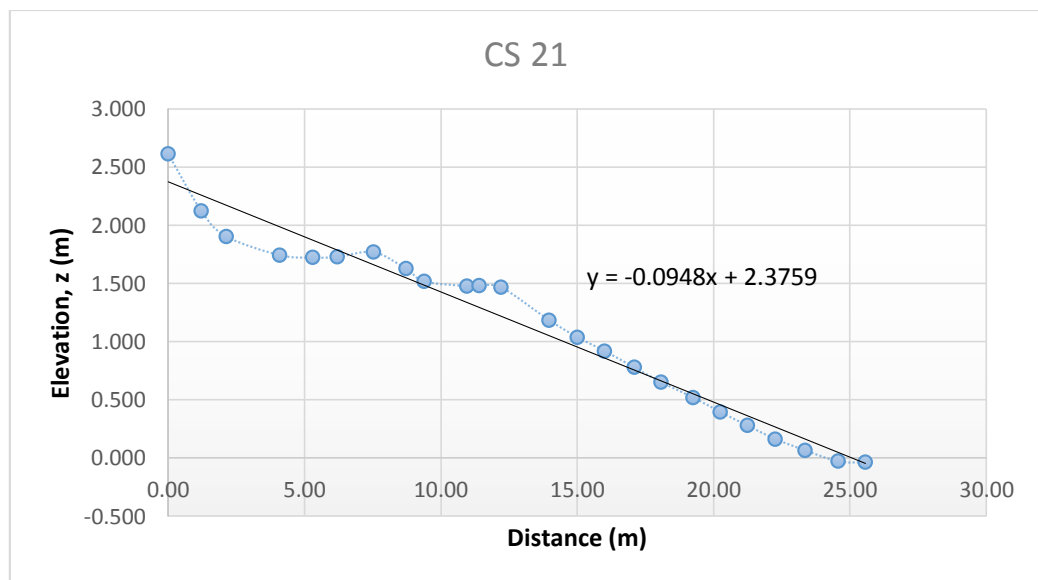
Cross Section 20

Easting	Northing	Cumulative Distance	z (m)	Transect
816607.790	274806.802	0.00	2.740	CS20
816606.715	274806.261	1.20	2.588	CS20
816605.503	274805.713	2.53	2.293	CS20
816604.002	274805.089	4.15	2.087	CS20
816602.818	274804.411	5.17	1.924	CS20
816601.491	274803.981	6.90	1.813	CS20
816600.757	274803.507	7.76	1.784	CS20
816598.695	274802.697	9.97	1.676	CS20
816597.175	274802.079	11.61	1.577	CS20
816595.639	274801.605	13.21	1.401	CS20
816593.842	274801.120	15.06	1.111	CS20
816593.464	274800.941	15.47	0.745	CS20
816590.302	274800.090	18.73	0.562	CS20
816588.741	274799.436	20.42	0.298	CS20
816587.954	274799.142	21.26	-0.010	CS20
816586.919	274798.746	22.37	-0.283	CS20
816584.105	274797.721	25.36	-0.350	CS20
816583.099	274797.234	26.48	-0.546	CS20
816580.864	274796.332	28.88	-0.547	CS20



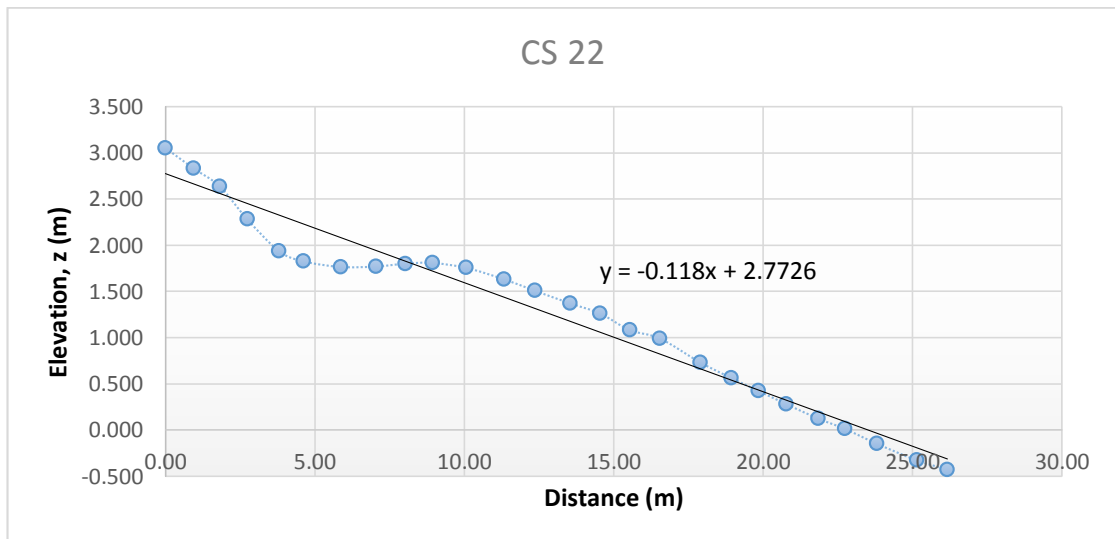
Cross Section 21

Easting	Northing	Cumulative Distance	z (m)	Transect
816540.674	274939.731	0.00	2.611	CS21
816539.744	274938.934	1.22	2.120	CS21
816538.891	274938.553	2.13	1.903	CS21
816537.072	274937.788	4.09	1.742	CS21
816535.967	274937.288	5.30	1.721	CS21
816535.173	274936.833	6.21	1.727	CS21
816533.931	274936.375	7.53	1.768	CS21
816532.831	274935.909	8.72	1.626	CS21
816531.651	274935.487	9.40	1.516	CS21
816530.755	274935.049	10.96	1.477	CS21
816530.332	274934.890	11.41	1.478	CS21
816529.688	274934.391	12.21	1.466	CS21
816528.177	274933.478	13.97	1.184	CS21
816527.289	274932.930	15.01	1.037	CS21
816526.382	274932.501	16.01	0.918	CS21
816525.455	274931.946	17.09	0.778	CS21
816524.613	274931.430	18.07	0.652	CS21
816523.589	274930.832	19.26	0.518	CS21
816522.721	274930.374	20.24	0.396	CS21
816521.940	274929.776	21.24	0.278	CS21
816521.059	274929.184	22.27	0.162	CS21
816520.100	274928.657	23.36	0.065	CS21
816519.125	274927.920	24.57	-0.030	CS21
816518.231	274927.472	25.57	-0.039	CS21



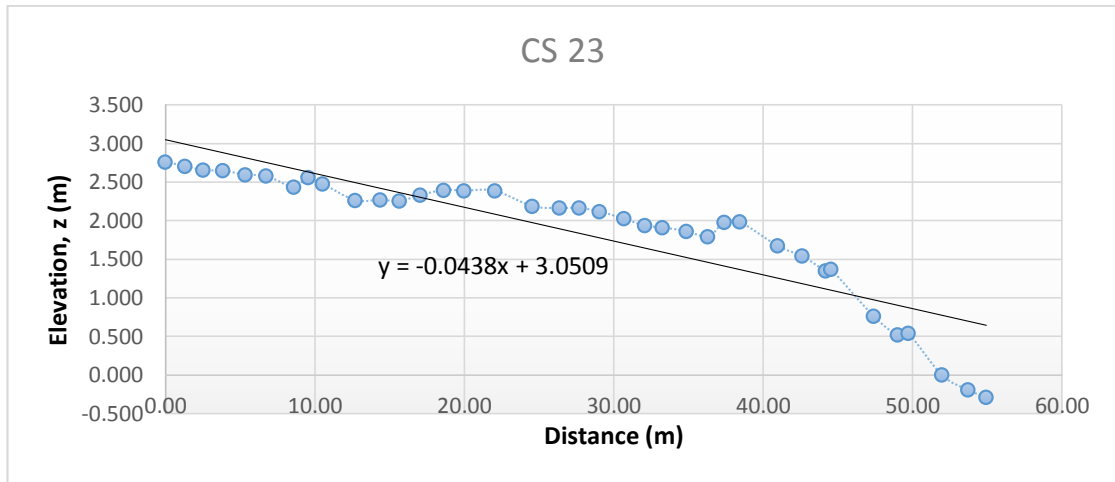
Cross Section 22

Easting	Northing	Cumulative Distance	z (m)	Transect
816589.781	274855.636	0.00	3.054	CS22
816588.915	274855.249	0.94	2.834	CS22
816588.146	274854.830	1.82	2.638	CS22
816587.265	274854.527	2.74	2.282	CS22
816586.342	274854.002	3.80	1.938	CS22
816585.640	274853.592	4.61	1.828	CS22
816584.503	274853.069	5.86	1.767	CS22
816583.463	274852.521	7.04	1.771	CS22
816582.623	274851.992	8.03	1.802	CS22
816581.825	274851.561	8.93	1.810	CS22
816580.743	274851.191	10.07	1.756	CS22
816579.578	274850.707	11.33	1.633	CS22
816578.592	274850.360	12.37	1.508	CS22
816577.527	274849.872	13.54	1.373	CS22
816576.539	274849.586	14.55	1.262	CS22
816575.630	274849.207	15.54	1.083	CS22
816574.687	274848.848	16.55	0.992	CS22
816573.367	274848.489	17.90	0.733	CS22
816572.451	274847.987	18.94	0.564	CS22
816571.641	274847.579	19.84	0.426	CS22
816570.784	274847.222	20.77	0.283	CS22
816569.769	274846.840	21.85	0.125	CS22
816568.992	274846.429	22.73	0.015	CS22
816568.038	274845.918	23.81	-0.147	CS22
816566.845	274845.331	25.14	-0.326	CS22
816565.929	274844.860	26.17	-0.427	CS22



Cross Section 23

Easting	Northing	Cumulative Distance	z (m)	Transect
816693.262	274605.653	0.00	2.758	CS23
816691.986	274605.321	1.318	2.708	CS23
816690.740	274605.104	2.518	2.653	CS23
816689.551	274604.704	3.830	2.650	CS23
816688.080	274604.332	5.347	2.595	CS23
816686.716	274604.039	6.742	2.579	CS23
816684.930	274603.530	8.598	2.437	CS23
816683.984	274603.330	9.564	2.558	CS23
816683.057	274603.064	10.528	2.477	CS23
816680.946	274602.522	12.707	2.264	CS23
816679.326	274602.133	14.373	2.271	CS23
816678.089	274601.805	15.653	2.253	CS23
816676.752	274601.397	17.049	2.330	CS23
816675.228	274600.998	18.625	2.397	CS23
816673.917	274600.685	19.972	2.388	CS23
816671.867	274600.343	22.044	2.387	CS23
816669.412	274599.823	24.552	2.188	CS23
816667.671	274599.233	26.384	2.164	CS23
816666.409	274598.884	27.693	2.165	CS23
816665.115	274598.505	29.040	2.120	CS23
816663.517	274598.040	30.703	2.025	CS23
816662.173	274597.679	32.095	1.934	CS23
816661.013	274597.461	33.273	1.912	CS23
816659.395	274597.286	34.885	1.864	CS23
816658.003	274596.970	36.312	1.795	CS23
816656.952	274596.647	37.410	1.976	CS23
816655.997	274596.217	38.441	1.985	CS23
816653.557	274595.475	40.988	1.673	CS23
816651.992	274594.999	42.623	1.541	CS23
816650.453	274594.665	44.196	1.350	CS23
816650.144	274594.503	44.536	1.373	CS23
816647.277	274594.097	47.414	0.762	CS23
816645.724	274593.687	49.020	0.517	CS23
816645.027	274593.565	49.726	0.542	CS23
816642.843	274593.066	51.966	0.003	CS23
816641.088	274592.805	53.732	-0.194	CS23
816639.928	274592.394	54.957	-0.289	CS23



Cross Section 24

Easting	Northing	Cumulative Distance	z (m)	Transect
816668.599	274370.474	0.000	1.571	CS24
816667.670	274370.656	0.946	1.586	CS24
816667.659	274370.676	0.961	1.583	CS24
816665.787	274371.419	2.966	1.604	CS24
816664.783	274371.571	3.970	1.623	CS24
816663.912	274371.953	4.914	1.645	CS24
816662.858	274372.108	5.969	1.660	CS24
816661.823	274372.321	7.024	1.650	CS24
816660.668	274372.749	8.250	1.631	CS24
816659.603	274372.964	9.334	1.639	CS24
816658.410	274373.213	10.550	1.682	CS24
816657.049	274373.483	11.935	1.742	CS24
816655.718	274373.722	13.284	1.810	CS24
816655.314	274373.718	13.675	1.955	CS24
816653.801	274373.937	15.197	1.971	CS24
816652.304	274374.304	16.739	1.963	CS24
816650.396	274374.782	18.705	1.906	CS24
816649.737	274374.838	19.360	2.063	CS24
816647.432	274375.546	21.766	1.931	CS24
816645.712	274375.709	23.478	1.867	CS24
816644.320	274376.135	24.930	1.764	CS24
816642.736	274376.702	26.602	1.630	CS24
816641.443	274377.085	27.949	1.455	CS24
816640.825	274377.331	28.607	1.575	CS24
816638.213	274378.394	31.401	1.067	CS24
816637.637	274378.570	32.002	1.064	CS24
816634.672	274379.524	35.113	0.438	CS24
816634.341	274379.621	35.458	0.526	CS24

816632.470	274380.052	37.377	0.245	CS24
816630.383	274380.788	39.583	-0.172	CS24
816629.302	274381.319	40.766	-0.232	CS24

