DESIGN OF FIXED OFFSHORE PLATFORM TO MARINE GROWTH THICKNESS IN MALAYSIAN WATER

by

Math Romly

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

MAY 2013

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

DESIGN OF FIXED OFFSHORE PLATFORM TO MARINE GROWTH THICKNESS IN MALAYSIAN WATER

By

MATH ROMLY

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
CIVIL ENGINEEERING

Approved by,

____
Assoc. Prof. Ir. Dr. Mohd Shahir Liew

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2014

CERTIFICATION OF ORIGINALITY

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

____

MATH ROMLY

ABSTRACT

Marine growth is one of the main parameters to be considered for the design of fixed offshore platform; because it affects the wave and current force calculation, which is used for the design of sub structure. The thickness and type of marine growth depends on location, weather, the age of the structure and the maintenance regime. For Malaysian region, there is a guideline in PETRONAS Technical Standard, PTS, for marine growth thickness in the design. However, there is a recommendation to study on the updated real data measurement in order to redefine the marine growth thickness design standard. Therefore, the primary purpose of this research is to compare the current marine growth thickness in the PTS to the prediction thickness of real data measurement obtained from the three operational regions in Malaysia. Statistical method of extreme value analysis is used for this research in order to find the extreme value of marine growth thickness for every 5 m water depth interval. The result of the study have shown that there are quite differences between the values of the marine growth thickness in PTS to the prediction values of measured data.

ACKNOWLEDGEMENT

Foremost, I would like to extend my gratitude to my supervisor, Assoc. Prof. Ir. Dr. Mohd Shahir Liew, for his acceptance as my supervisor, his continuous support, time patience, guidance, motivation, and immense knowledge.

Second, I would also like to express my deep appreciation to Mr. Idwan Mohamad Selamat and other post graduate students of Universiti Teknologi PETRONAS for their support, time and guidance from the beginning until the end of this project.

Third, I would never forget the encouragement, motivation and assistance from my beloved family, seniors and friends.

Special thanks to PETRONAS for granting me the opportunity to study in Malaysia. It has been an invaluable and unforgettable experience for me.

Last, no words can express my gratitude to all staffs of Universiti Teknologi PETRONAS for support and helpfulness.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The first fixed offshore oil platform was constructed in 1947 in Louisiana to stand in 6 meter water depth in Gulf of Mexico (Chakrabarti, 1987).Whereas in Malaysia, the first offshore oil filed was discovered in two areas of Sarawak in 1962. Then in 1974, national petroleum company, PETRONAS, was established with exclusive rights of ownership, exploration and production of all oil and gas whether onshore or offshore the country. In collaboration with other experienced international petroleum companies through production sharing contract (PSC), there are about 200 oil platforms operating in three operational regions in Malaysia under PETRONAS. Majority of the platforms are fixed offshore platforms and some of them are standing over 40 years more than its design period of 30 years (Potty & Mohd Akram, 2009).

The design of fixed offshore structures should satisfy the complicated and, in most cases, combined environmental phenomenon of extremely uncertain magnitude of transient loading (eg. Wind, wave, current, operational loads etc.) (Kolios, 2000). According to PETRONAS Technical Standard 2012 (PTS), there are many design criteria for designing substructure of fixed offshore platform. One of the criteria is wave and current force calculation on the jacket of the structure. In section 4.5 (a) of PTS recommends that the computation of global wave and current exerted on the cylindrical or non-cylindrical objects is based on Morison equation when the ratio of wave length to the member diameter is greater than five (L/D > 5) as per American Petroleum Institute Recommended Practice 2A-WSD, API code requirement.

Morison equation: $F = F_D + F_I = \frac{1}{2} C_D \rho D U|U| + \rho C_M \frac{\pi D^2}{4} \dot{U}$

Where: F_D is the drag force

F_I is the inertia force

From the above equation, it is shown that diameter of the tubular member, D, is one of the main parameters that give change in wave and current force calculation. Diameter of tubular member, D increases when the tube is fouled by marine growth; this increases structural diameter of the jacket that cause volume to increase and hence result in increasing hydrodynamic loading. Furthermore, it increases the force coefficient which gives rise to change in both drag and inertia force in Morison equation (Jusoh & FRINA, 1996). An increase of 50mm marine growth thickness leads to a load increase of 5.5 percent (Heaf N.J, 1979).

The value of inertia and drag force coefficient in PTS for the wave and current force calculation are taken based on the experience and the study of the Gulf of Mexico and the North Sea environmental conditions. However, the environmental condition of Malaysian sea is quite different from the Gulf of Mexico and the North Sea. Instead of following the value from Gulf of Mexico and the North Sea platforms, the study of marine growth in Malaysian sea water is required in order to optimize the design of fixed offshore platform in three operational regions in Malaysia as well as in South China Sea region.

One more, marine growth is one of the ten risk criteria for the development of an integrated Structural Integrity Management (SIM) system for the Malaysian fixed offshore platform (M Akram & Sambu Potty, 2013).

Therefore, marine growth is one of the significant factors for the substructure design and maintenance as marine growth gives change on wave and current force calculation.

For this research, only marine growth thickness is studied using statistical method of extreme value analysis based on the obtained site data measurement.

1.2 Problem Statement

PETRONAS Technical Standard (PTS) is used as the standard design for fixed offshore platform in Malaysian region, which is based on American Petroleum Institute Recommended Practice 2A-WSD (API RP-WSD). API RP-WSD standard is based on the study and experiences from the Gulf of Mexico and the North Sea, which their environmental and metocean criteria are different from Malaysian operational regions as well as the South China Sea; they are rougher than Malaysian sea's. As a result, majority of the platforms in Malaysia are still standing in very good condition after operating more than 40 years, which is longer than the required design period of 30 years. Therefore, environmental and metocean criteria of the local sea region have to be redefined in order to enhance the design; one of them is marine growth thickness.

The major task of this research is to study and propose marine growth thickness design standard based on the prediction on measured data using extreme value analysis.

1.3 Objective of Study

The objectives of this study are:

- To compare the current marine growth thickness in the PTS to the prediction of real data measurement using extreme value analysis method.
- To redefine the marine growth thickness to reflect the actual condition of the South China Sea region.
- To optimize the design of jacket due to marine growth affecting the hydrodynamics of the jacket.

1.4 Scope of Study

In this project, the focuses are on:

- Analysis of extreme value (EVA) of marine growth thickness to the depth of the platform leg of the three operational regions in Malaysia
- Estimation through EVA on the maximum thickness and zero growth zone of marine growth.
- Provides design criteria due to marine growth in three operational regions, i.e., PMO, SKO, SBO.

CHAPTER 2

LITERATURE REVIEW

2.1 Jacket Platform

Fixed offshore structure that extend to the seabed are divided into four types which are jacket, gravity base structure (GBS), compliant structure, and jack up. Jacket is the most popular type of platforms operating in the world as well as in Malaysia; 95 percent of offshore platforms are jacket supported. These jacket platforms generally support a superstructure having 2 or 3 decks with drilling and production equipment, and work over rigs.

The jacket, normally used for moderate water depth up to 400 meter, is a space frame structure comprise of tubular steel members (typically 8 in to 48 in diameter) interconnected to form a three dimensional truss (Chakrabarti, 1987). These structures usually consist of four to eight legs with the outside leg battered to achieve better stability against toppling. Jackets with three legs are known as tripods. Jackets with a single caisson type leg also exist which is known as monopods. Environmental and topsides loads are transmitted into the piles and subsequently into the seabed by the jacket legs and braces. Piles made of tubular steel are installed through the legs of the jacket or through the pile sleeves connected to the jacket legs at its base.

There are many parameters for designing jacket platform, such as required strength, fatigue, load and life cycle which come from topside load and environmental load, accidental load and many more. Jacket platform in Malaysia is designed based on the American Petroleum Institute Recommended Practice 2A-WSD (RP 2A-WSD), which environmental data of the sea condition such as wave, current, wind, marine

growth are derived from the Gulf of Mexico and the North Sea. The sea condition of these both regions are rougher than Malaysian sea condition.
Hydrodynamics force, wave and current force, is one of the major contribution to the design of sub structure. The study of hydrodynamic force of the local sea regions has to be done in order to optimize the design.

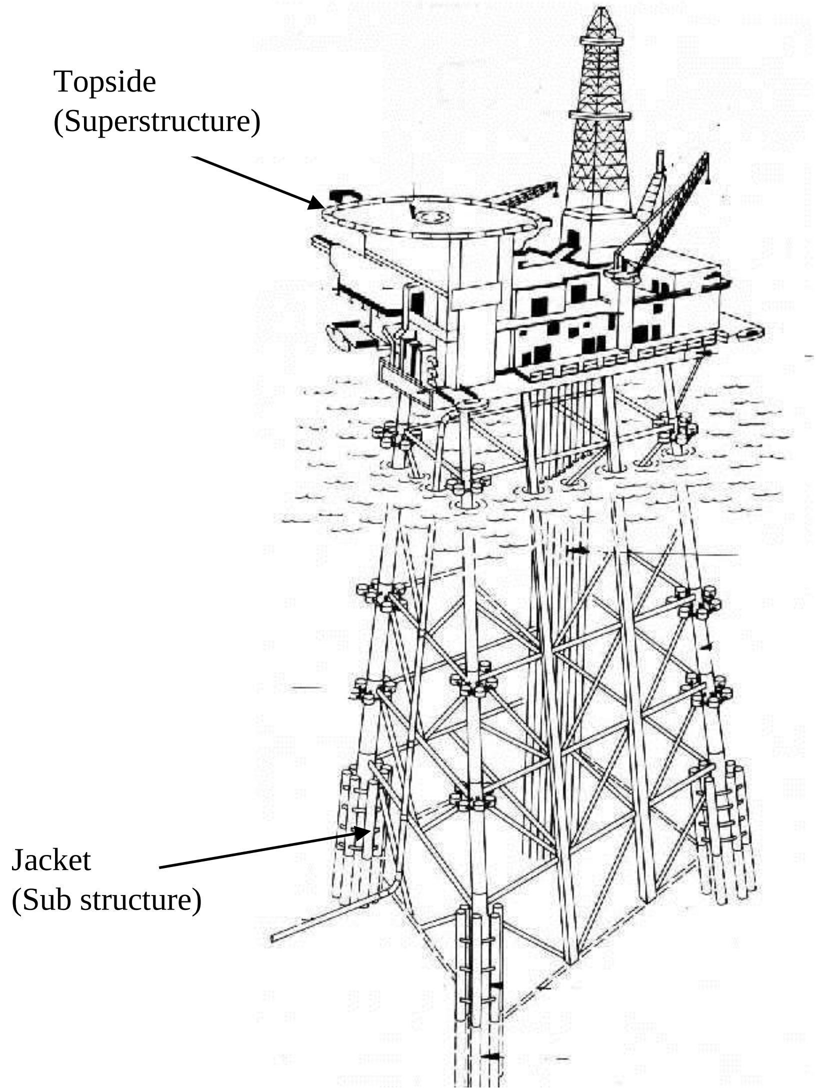


Figure 1: Jacket platform. (Steel Jacket Structure, n.d.)

2.2 Hydrodynamic Loads

Hydrodynamic loads result from the interaction of waves and current with structural members. It is known as a primary factor in the design of offshore structure. It is also one of the most challenging study since it involves the complexity of the interaction of waves with structure. Furthermore, the study of the random nature of the ocean waves, and the inadequacy of even some of the highly nonlinear wave theories are done to describe it, its effect on the offshore structure is noticeably even more difficult. Nonetheless, some of the current theories available paired with our understanding of the interaction phenomenon through analytical studies, laboratory experiments and at-sea measurements are randomly accurate in predicting wave loads on a variety of offshore structure (Chakrabarti, 1987).

API Recommended Practice 2A-WSD (2005) recommends to use Morison equation to calculate the force exerted by waves and current on a cylindrical or non-cylindrical object if the ratio of the wave length to the member diameter is more than 5 (L/D >5).

Morison equation: $F = F_D + F_I = \frac{1}{2} C_D \rho D U|U| + \rho C_M \frac{\pi D^2}{4} \dot{U}$

Where F_D: is drag force

F_I: is the inertia force

The Morison equation consists of drag force and inertia force. These two components are the function of tubular member diameter, inertia coefficient and drag coefficient, whose values are changed when the members are fouled by marine growth.

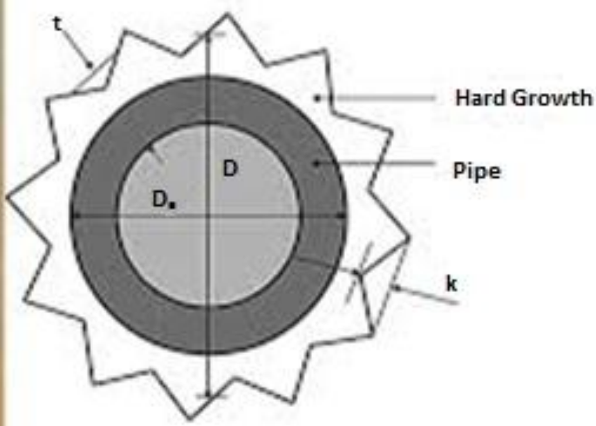


Figure 2: Marine growth on the member of the jacket. (Wei Shi, Park, Han, Na, & Kim, 2013)

2.3 Marine Growth

On any offshore structure, numerous type of marine fouling organism can be founded on the surface of its submerged member to certain water depth after a certain time. The varied distributions of the marine growth on the structural members cause by geographical location, water temperature, water depth, current, tide, platform design and operation (Jusoh & FRINA, 1996). Generally, all marine growth species are competing directly for space, food, and light. There is a certain type of the fouling, which is found to grow not only on the clean member but also on other types of fouling for the sake of space and food. Thus, marine growth thickness is higher near to the mean sea level compare to the deeper water depth.

Marine growth are categorized into three main groups, which are hard growth, soft growth and long and flapping weed. Hard growth comprises of barnacles, oysters, mussels, bivalves, and tubeworms. Barnacles are commonly founded on the structural member in Malaysian water. Soft growth consist of seaweeds, soft corals, sponges, anemone, hydroid, sea grass, and algae. Soft corals, hydroids, and sea grass are commonly founded in Malaysian water. Long flapping weed is kelp that could be soft growth, but it is single out with much larger size.

According to (Heaf N.J, 1979) marine growth is found to affect the loading of an offshore structure in at least five ways:

1. It causes member diameter to increase, leading to increase projected area and displace volume and hence to increase hydrodynamic loading
2. It causes drag force coefficient to increase, leading to increase hydrodynamic loading.
3. It causes mass and hydrodynamic added mass to increase, leading to reduce natural frequency and hence to an increased dynamic amplification factor.
4. It causes structural weight to increase, both in the water and above the water level in air.

5. It gives effect upon hydrodynamic instabilities, such as vortex shedding.

The first two above points affect the wave force calculation using Morison equation. The coefficient of drag force, coefficient of inertia force, and thickness of the marine growth, shown in table 01, 02, and 03 below, are recommended in the PTS 2012 in order to overcome the effect of marine growth to the offshore structure. However these values are based on the API RP2A-WSD whose criteria are derived from the Gulf of Mexico and The North Sea's environmental condition.

Table 1: Drag force coefficient and inertia force coefficient in PTS 2012

	Tubular Member		**Non-Tubular Member**
	Clean Member	**Fouled member**	**Fouled member**
Drag coefficient, C_D	0.65	1.05	2
Inertia coefficient, C_M	1.6	1.2	2

Table 2: Offshore Sabah/Sarawak

Elevation	**Layer Thickness mm**	**Surface Roughness, mm**
At MSL	80	20
1/3 WD from MSL	80	20
Mudline	25	6.25

Table 3: Offshore East Peninsular Malaysia

Elevation	**Layer Thickness, mm**	**Surface Roughness, mm**
MSL	127	64
-30	127	64
Mudline	25	13

Source: (Technical Specification: Design of Fixed Offshore Structures, 2012)

Thickness and type of marine growth depends on location of the sea, the age and type of the structure and its operational function, and the maintenance service. Experience in one area of the world cannot certainly be applied to another. Where necessary, site-specific studies shall be conducted to produce the likely thickness and its depth dependence. (ISO 19901-1:2005- Part 1: Metocean Design and Operating Conditions.)

The study of marine growth thickness and roughness height on 19 structures on the Louisiana continental shelf was started in 1981 in order to compare with the thickness of the North Sea fouling. The result showed that marine growth thickness and roughness height are lesser than the North Sea's (Heidemant & George, 1981).

Therefore, the thickness of marine growth of local area has to be studied and redefined for the design.

In this study, marine growth thickness is analyzed by using extreme value analysis method in order to find the suitable thickness for the design in the local sea regions in Malaysia.

2.4 Extreme Value Analysis

Extreme-value analysis is the field of statistics particularly concerned with the systematic study of extreme values, which modelling and measuring events occur with very small probability. This implies its helpfulness in risk modelling as risky events per definition occur with low probability (Alves & Neves).

It is well known to engineers that design values of engineering works (e.g., dams, buildings, bridges, etc.) are obtained based on a compromise between safety and cost, that is between guaranteeing that they survive when subject to extreme operating conditions and reasonable costs (Castillo, Hadi, Balakrishnan, & Sarabia, 2005).

Its application varies from engineering, risk management, insurance, telecommunication, economics hydrology, hydraulics, environment, finance, structure, corrosion, and many others industries dealing with extreme events.

The class of Extreme Value Distributions (EVD) are divided into three types of extreme value distributions, type I, II, and III, and it is defined as below:

- Type I : Gumbel Distribution

  $G(x) = \exp(-\exp(-x))$

- Type II: Fréchet Distribution

$$G(x) = \begin{cases} 0 & , x \leq 0 \\ exp(-x^{-\alpha}) , & x > 0, \ \ \alpha > 0 \end{cases}$$

- Type III: Weibull Distribution

$$G(x) = \begin{cases} \exp(-(-x)^{\alpha}) , x < 0, \alpha > 0 \\ 1, \ \ x \geq 0 \end{cases}$$

2.4.1 Gumbel Distribution

Gumbel Distribution appears very often in any practical problems for the study of observed data that represent maxima values and it is perhaps the most widely applied statistical distribution for problems in engineering. It is generally used in hydrology to predict maximum rainfall, river discharge volume, river flood and draught. It is also commonly used in predicting metocean data such as wave and wind.

2.4.1.1 Gumbel Probability Distibution Function

The Gumbel probability distribution is expressed as:

$$f(x) = \exp(-x - \exp(-x))$$

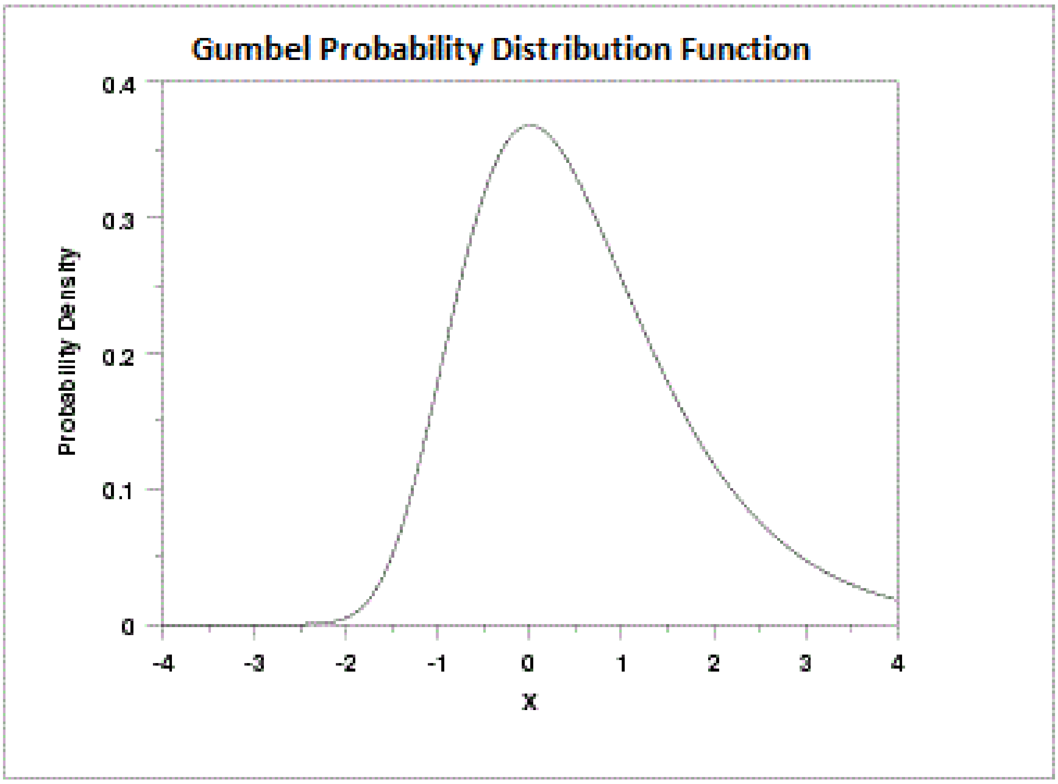


Figure 3: Graph of Gumbel Probability Distribution Function

2.4.1.2 Cumulative Distribution Function

$$F(x) = \exp\left(-\exp\left(-\frac{x-\lambda}{\alpha}\right)\right), -\infty < x < \infty,$$

Where f(x) is the probability distribution function of x.

λ *and* α are the location and scale parameter.

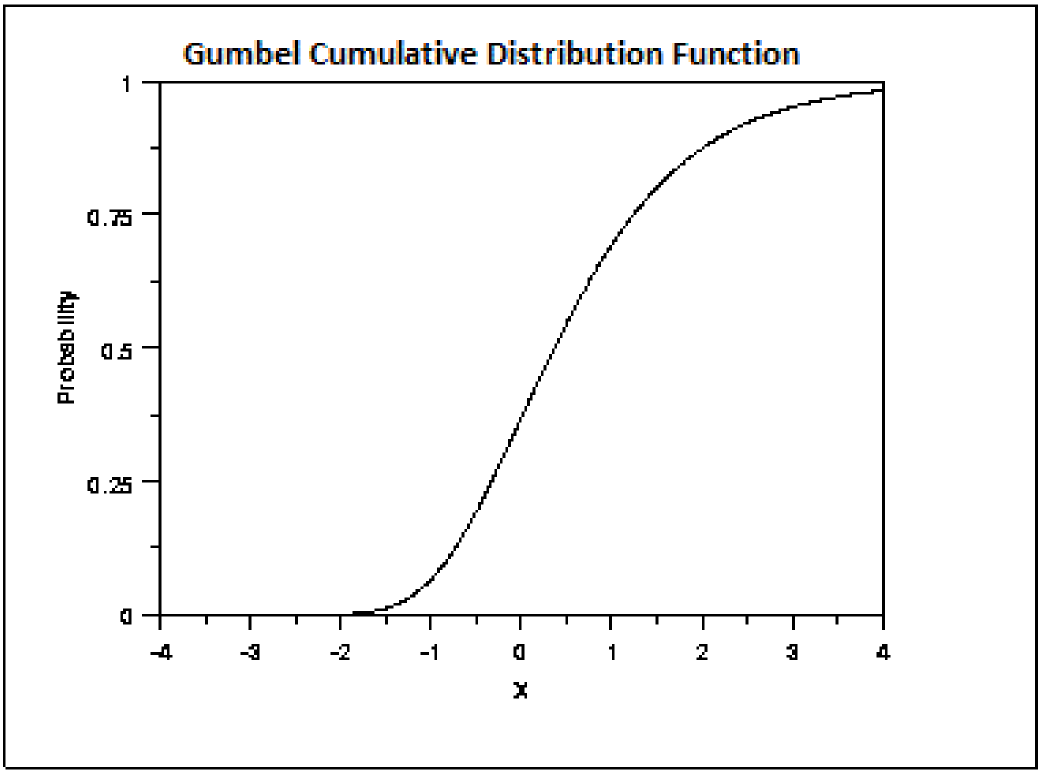


Figure 4: Graph of Gumbel Cumulative Distribution Function

2.4.1.3 Probability Plot

When the interest of extreme values is needed, graphical presentation of the relationship between values x and cumulative distribution function *F(x)* in arithmetic scale is not commonly proper to use. The probabilities of extreme value are quite small, and it is hard to interpret them from a plot. A special type of graph is created to present the relationship between the probability and data values, which is known as probability plot. Probability plots are created for specific theoretical distributions by transforming the scale of the probability axis so that a given distribution is represented by straight line. The reduced variable y = (x-λ)/α, which is a transform of F(x) and is linearly related to x, is used for this probability plot. F(y) can be calculated as:

F(y) = i/(1+N)

Where i is the *ith* of the ordered value, x, in descending order and N is the total number of sample. Plotting y as a function of x obtains a best-fitting straight line; its slope provides 1/a and its intercept at y = 0 obtains λ.

Transformation of Gumbel Distribution Function:

$$y = -\ln(-\ln(F(y)))$$

$$y = x$$

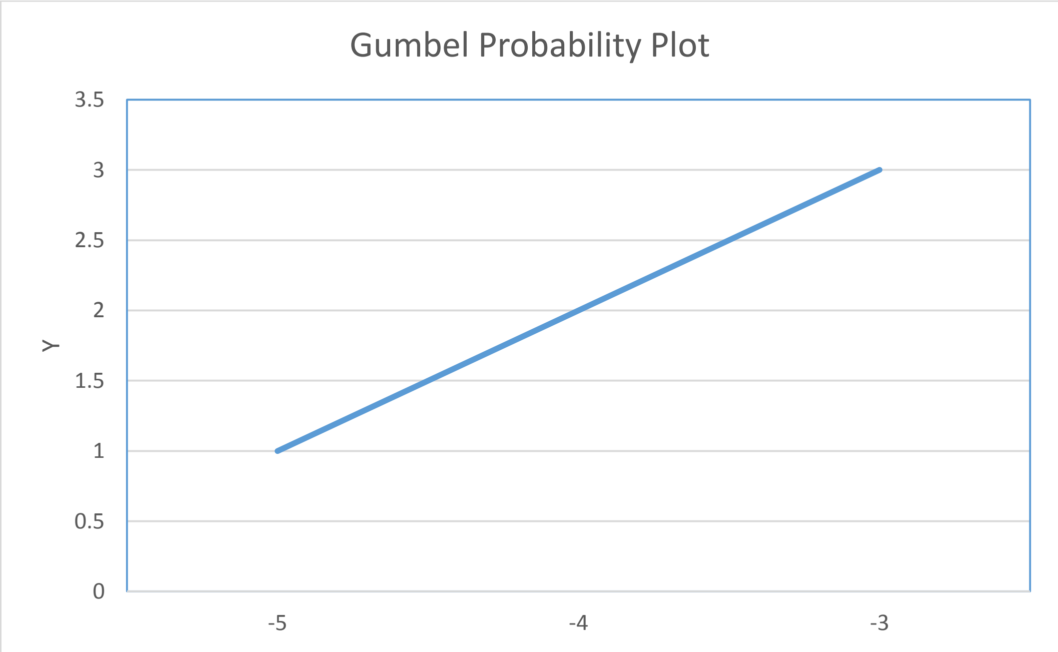


Figure 5: Graph of Transformation of Gumbel Probability Plot

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The methodology of this study consists of three main parts. First part is data preparation. Second part is data analysis. In this part, extreme value analysis is used to analyze the extreme thickness of the marine growth. Microsoft Excel will be used in aiding the extreme value analysis. Last part is result and discussion.

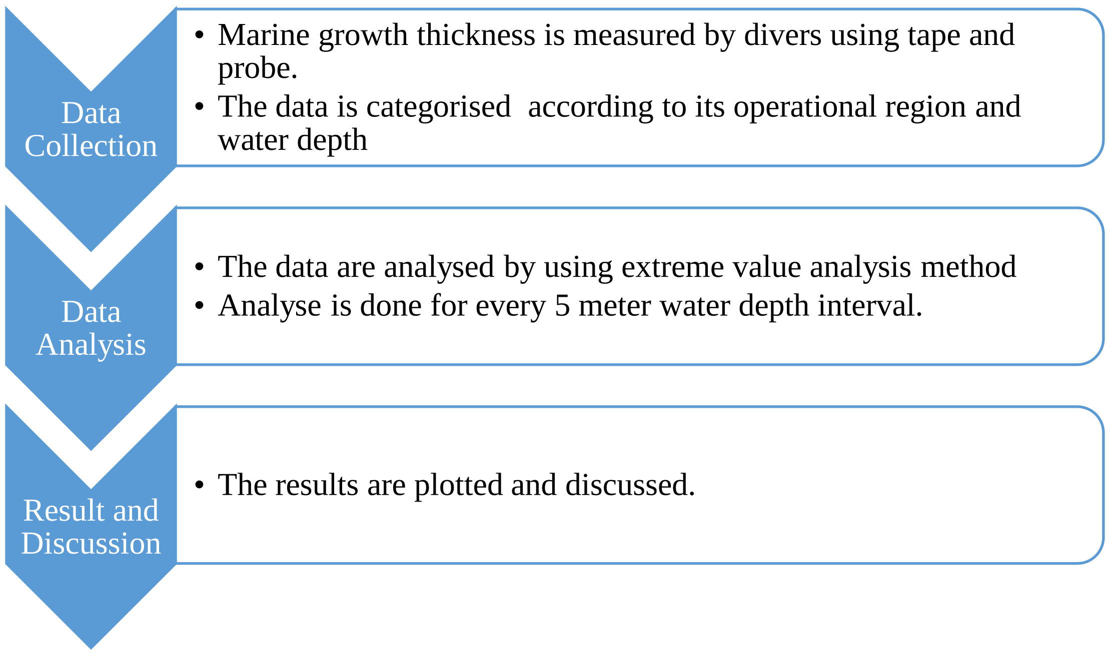


Figure 6: Flow chart of the project methodology.

3.1.1 Data Preparation

The data of marine growth thickness for this project are obtained from PETRONAS Carigali Sdn Bhd. These data are obtained from the measurement of the three operational regions in Malaysia, Sabah Opertion (SBO), Sarawak Operation (SKO), and Peninsular Operation (PMO) by using probe method and tape measurement. There are 19 platforms from SBO, 43 platforms from SKO, and 29 platforms from PMO from which marine growth thickness are measured.

Firstly, the data are categorized based on the operational regions. Secondly, they are grouped according to the depth of water. Lastly, the data are ready for the second step which is data analysis using statistical analysis of extreme value.

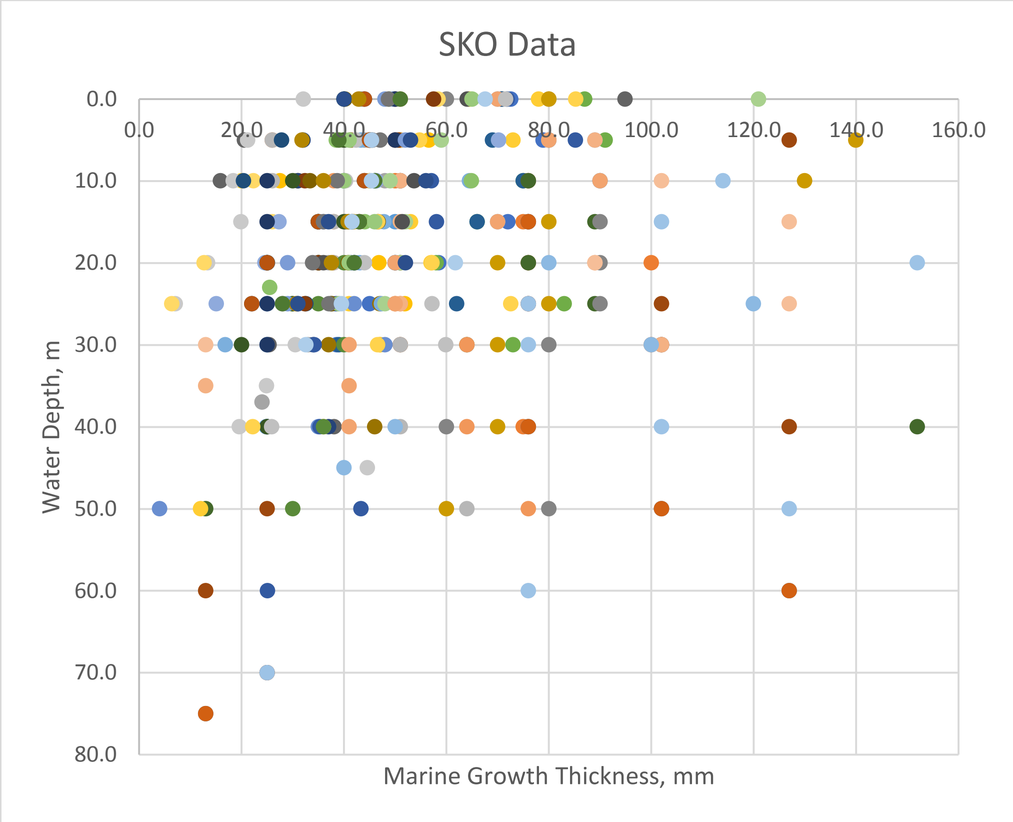


Figure 7: SKO's marine growth thickness data

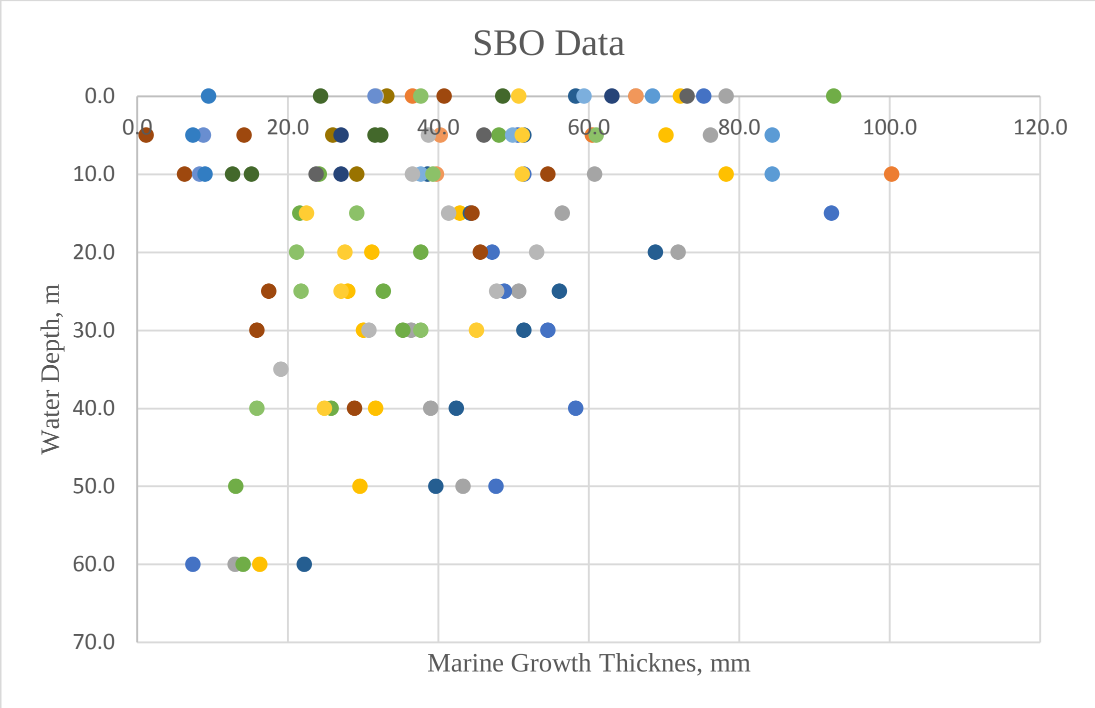


Figure 8: SBO's marine growth thickness data

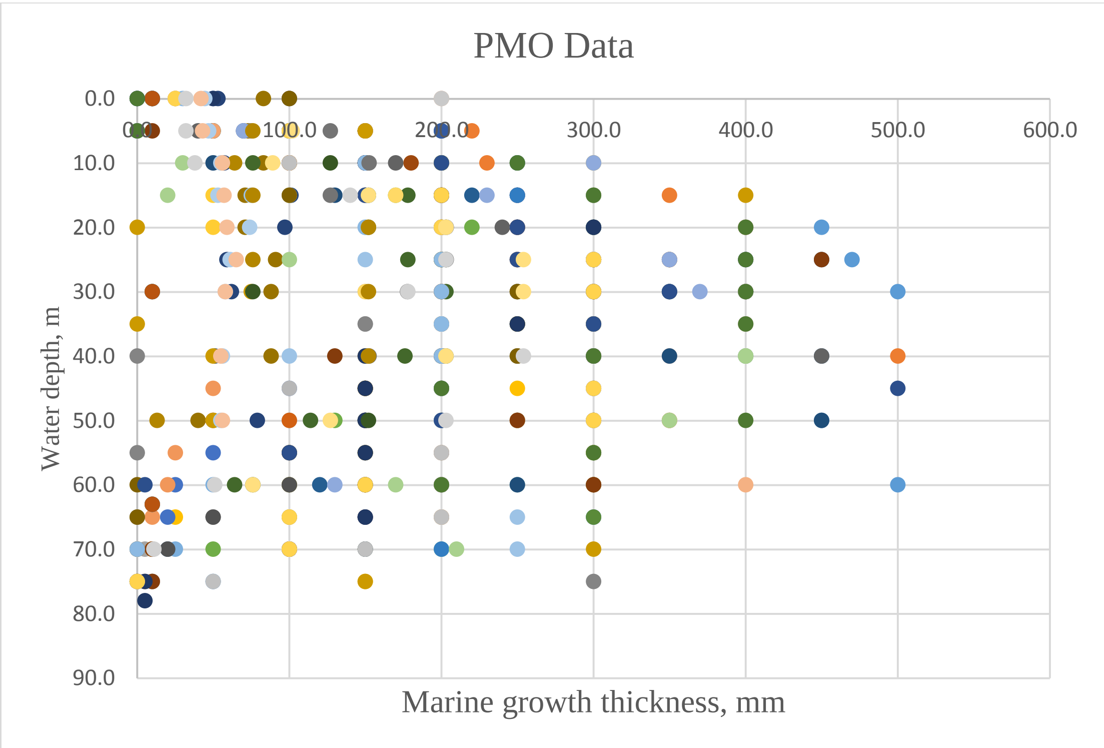


Figure 9: PMO's marine growth thickness data

3.1.2 Data Analysis

The maximum data of every duration of every water depth interval is selected for forecasting the extreme value of the marine growth thickness. Below here is the table of the maximum marine growth thickness at 5m water depth of SKO region. There are 22 data from different platforms.

Table 4: Maximum marine growth thickness of each duration at 5m depth below MSL of SKO region.

At 5m depth below MSL				
Platform	**Year Installed**	**Year Inspection.**	**Duration, n (year)**	**Thickness, (mm)**
D35PG-A/Leg A1	1994	2001	7	21.2
BOP-A/Leg A	1982	1990	8	85.2
BNDP-I/Leg B3	1991	2000	9	43.3
BNG-B/Leg A2	1992	2002	10	73.0
BAP-AA/Leg A3	1993	2005	12	91.0
BAK-B/Leg B1	1992	2005	13	78.9
TEJT-C/Leg B1	1989	2005	16	50.6
TEJT-T/Leg B1	1988	2005	17	45.5
D18V-A/Leg C	1986	2005	19	89.0
BODP-B/Leg A4	1984	2005	21	140.0
BOV-A/Leg A1	1982	2005	23	89.0
TEDP-E/Leg B3	1981	2005	24	27.8
TEDP-B/Leg B1	1979	2005	26	59.0
TKJT-D/Leg A1	1977	2004	27	80.0
BNV-B/Leg C	1977	2005	28	51.0
BKJT-A/Leg B2	1974	2003	29	20.6
WLP-A/Leg A1	1968	1998	30	47.1
BAV-B/Leg B	1973	2005	32	127.0
WLP-C/Leg B2	1972	2005	33	45.4
BA-18/Leg A	1971	2005	34	50.0
WLDP-A/Leg B1	1970	2005	35	52.0
WLP-A/Leg B1	1968	2005	37	53

Based on the above data, the Probability Distribution Function (PDF) is plotted using Easyfit software in order to find the suitable extreme value distribution for the forecasting. From the PDF graph, it is found that Gumbel Distribution is the suitable one. Below here are PDF graph and Cumulative Distribution Function, (CDF).

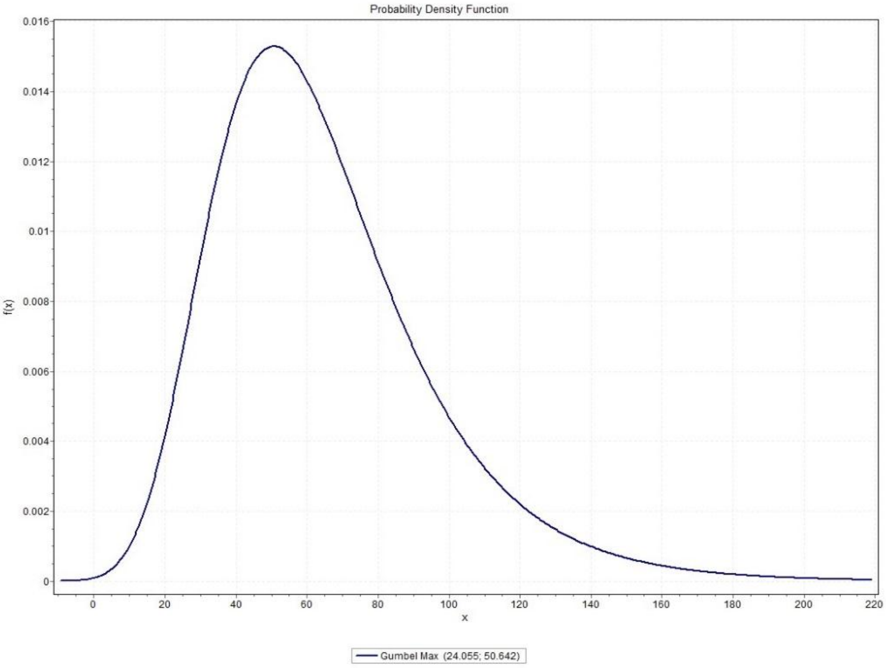


Figure 10: Probability density function of marine growth thickness at 5m water depth below MSL of SKO region.

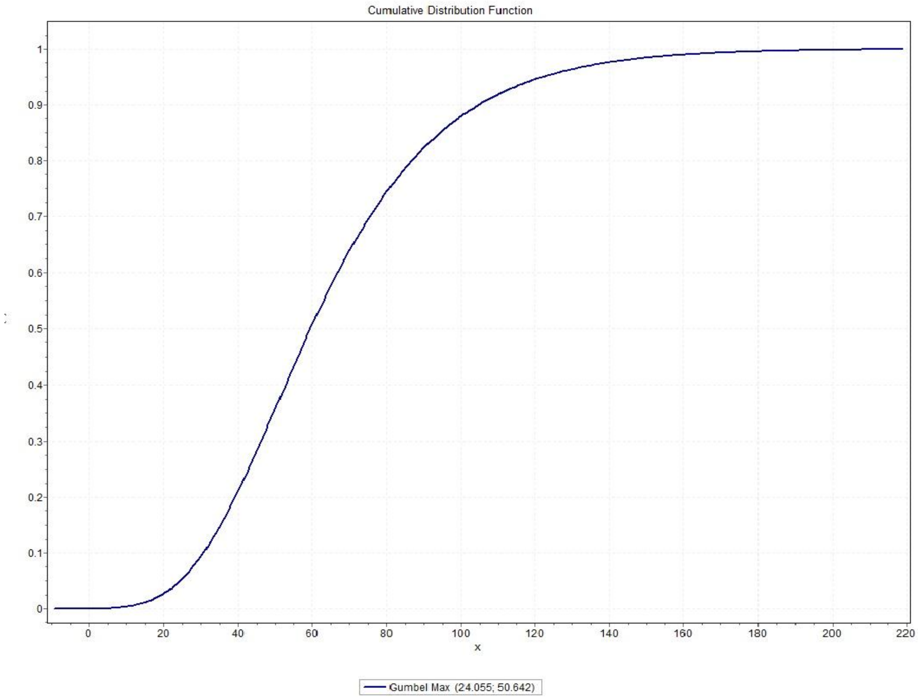


Figure 11: Cumulative distribution function of marine growth thickness at 5m water depth below MSL of SKO region.

Then, all the data are forecasted based on Gumbel distribution method in order to obtain extreme value of the marine growth thickness. Gumbel method sorts the maximum value of each year duration from the lowest to the highest value with a set of rank. Next, the probability graph is plotted based on the ranked probability to the marine growth thickness. The graph provides the value of R square, intercept and slope. These values help the calculation of the predicted mean return interval and its predicted extreme value. The calculation result is presented through the logarithmic scale graph of yearly return period to predicted maximum marine growth of each interval depth.

Table 5: Table of data calculation for probability plot using Gumbel method.

5m MSL			
Thickness	**Ranking**	**Gumbel**	**y=-ln(-ln(p))**
20.6	1	0.043478	-1.14279
21.2	2	0.086957	-0.89296
27.8	3	0.130435	-0.71142
43.3	4	0.173913	-0.55916
45.4	5	0.217391	-0.42269
45.5	6	0.26087	-0.29545
47.1	7	0.304348	-0.17360
50	8	0.347826	-0.05454
50.6	9	0.391304	0.06372
51	10	0.434783	0.18283
52	11	0.478261	0.30436
53	12	0.521739	0.42988
59	13	0.565217	0.56116
73	14	0.608696	0.70030
78.9	15	0.652174	0.84993
80	16	0.695652	1.01361
85.2	17	0.73913	1.19640
89	18	0.782609	1.40600
89	19	0.826087	1.65519
91	20	0.869565	1.96781
127	21	0.913043	2.39721
140	22	0.956522	3.11335

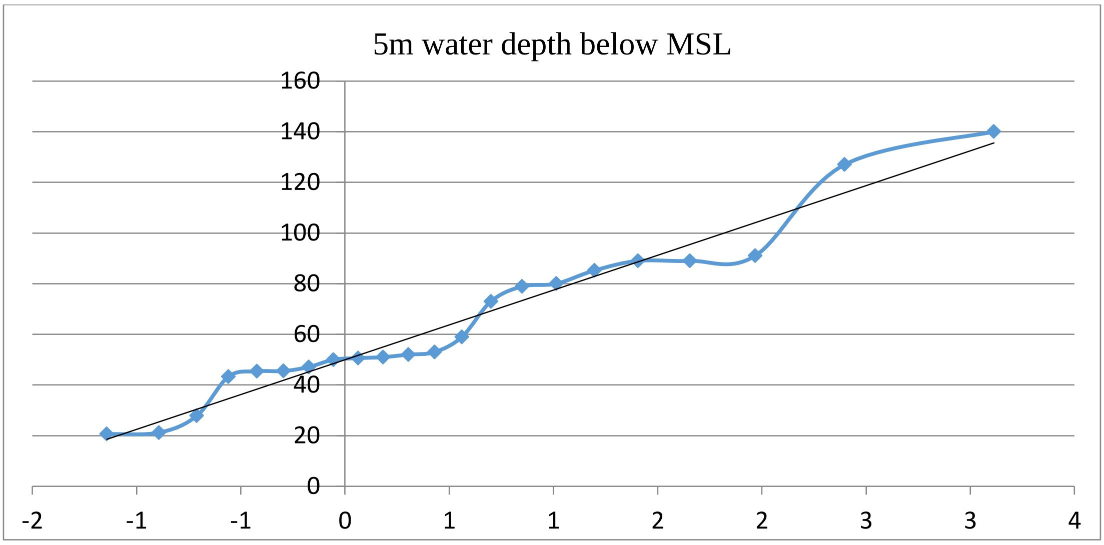


Figure 12: Probability plot of 5m water depth below MSL

Based on the above graph, value of R square, interception, and slope are obtained. Then the forecasting marine growth can be calculated using below equation:

$$t = u + \frac{1}{a}(-\ln\left(-\ln\left(1-\frac{1}{R}\right)\right))$$

Table 6: Marine growth thickness forecasting calculation table

Return Period, R	Intercept ,u	Slope, 1/a	(-ln(-ln(1-(1/R))))	1-(1/R)	t(m)
10	50.04657	27.48913	2.250367	0.9	111.907
20	50.04657	27.48913	2.970195	0.95	131.694
30	50.04657	27.48913	3.384294	0.9666	143.077
50	50.04657	27.48913	3.901939	0.98	157.307
100	50.04657	27.48913	4.600149	0.99	176.5
200	50.04657	27.48913	5.295812	0.995	195.624
300	50.04657	27.48913	5.702113	0.9966	206.793
500	50.04657	27.48913	6.213607	0.998	220.853
1000	50.04657	27.48913	6.907255	0.999	239.921

3.2 Gantt Chart and Key Milestone

Table 7: Gantt chart and key milestone for FYP 1

N⁰	Activities	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of project topic														
2	Preliminary research works: search and read related article														
	Draft project methodology														
3	Preparation of extended proposal														
	Submission of extended project proposal defense														
4	Analysis of the data														
5	Proposal defence														
6	Project work continues														
	Preparation of draft interim report														
	Edition of draft interim report														
Project Milestone															
1	Submission of extended project proposal defence														
2	Submission of draft interim report														
3	Submission of interim report														

N⁰	Activities	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continue															
2	Analyze the Data															
3	Discussion the Result															
4	Prepare for SEDEX															
5	Prepare for Draft Report															
6	Prepare Technical Paper															
7	Prepare for Oral Presentation															
8	Prepare for Hand bound Dissertation Submission															
Project Milestone																
1	Submission of Progress Report															
2	Pre-SEDEX															
3	Submission of Draft Report															
4	Submission of Dissertation (soft bound)															
5	Submission of Technical Paper															
6	Oral Presentation															
7	Submission of Project Dissertation (hard bound)															

Table 8: Gantt chart and key milestone for FYP 2

CHAPTER 4

RESULT AND DISCUSSION

4.1 Marine Growth Thickness Forecasting Result of Sarawak Operation

Table 09 is the result summary of the first forecasting marine growth thickness using Gumbel method based on the measuring data obtained. The missing predicted result from 60 m to 75m water depth is due to insufficient data required for forecasting. The graphs are plotted in the figure 13 based on the table 09 in order to displays how the data vary from each water depth interval compared to PTS. All the forecasting results of each water depth interval and region are attached in the appendix.

Table 9: First marine growth thickness calculation result

Depth, m	Marine Growth Thickness, mm			
	PTS 10	PTS 12	30 year return period	50 year return period
0.0	100	80	119	128
5.0	100	80	143	157
10.0	100	80	130	143
15.0	100	80	123	134
20.0	50	80	135	148
25.0	0	80	130	143
30.0	0	25	138	153
40.0	0	25	161	179
50.0	0	25	184	205
60.0	0	25		
70.0	0	25		
75.0	0	25		

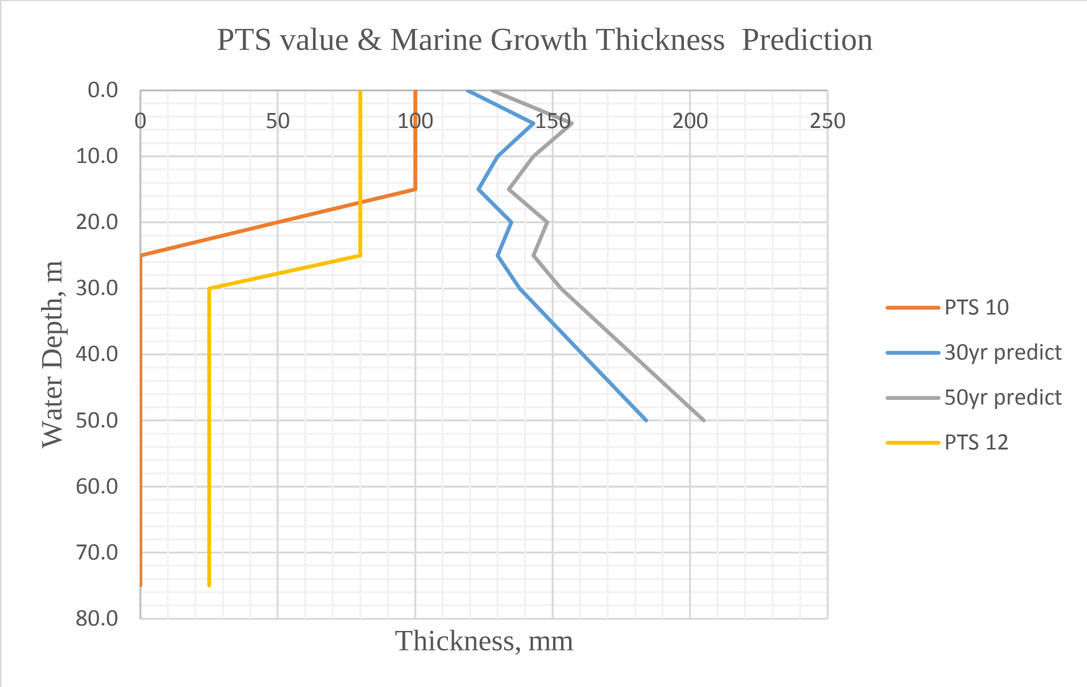


Figure 13: Graph of first predicted marine growth thickness

From the graph above, it shows that marine growth thickness keeps increasing after 20m water depth, which is contrast to the fact that marine growth thickness is getting lesser when the water depth is getting deeper. Therefore, the measuring data is not reliable after 20 m water depth and it has to be corrected. For this data, from 25m below water depth, the value of the marine growth thickness is interpolated by mirroring the data along 25m water depth value. This equation, 2*t25-ti, is used to calculate the new value of 30m water depth to 50m water depth.

Table 10: Interpolated result and proposed design data of marine growth thickness.

Depth, m	Thickness, mm							
	PTS 10	PTS 12	30 Years	50 Years	Interpolated 30 Year	Interpolated 50 Year	Proposed Design, 30 Year	Proposed Design, 50 Year
0.0	100	80	119	128	119	128	130	142
5.0	100	80	143	157	143	157	130	142
10.0	100	80	130	143	130	143	130	142
15.0	100	80	123	134	123	134	130	142
20.0	50	80	135	148	135	148	130	142
25.0	0	80	130	143	130	143	130	142
30.0	0	25	138	153	122	133	100	107
40.0	0	25	161	179	99	107	100	107
50.0	0	25	184	205	76	81	100	107
60.0	0	25						
65.0	0	25						
70.0	0	25						
75.0	0	25						

The new graphs of the marine growth thickness after interpolation are plotted as shown below:

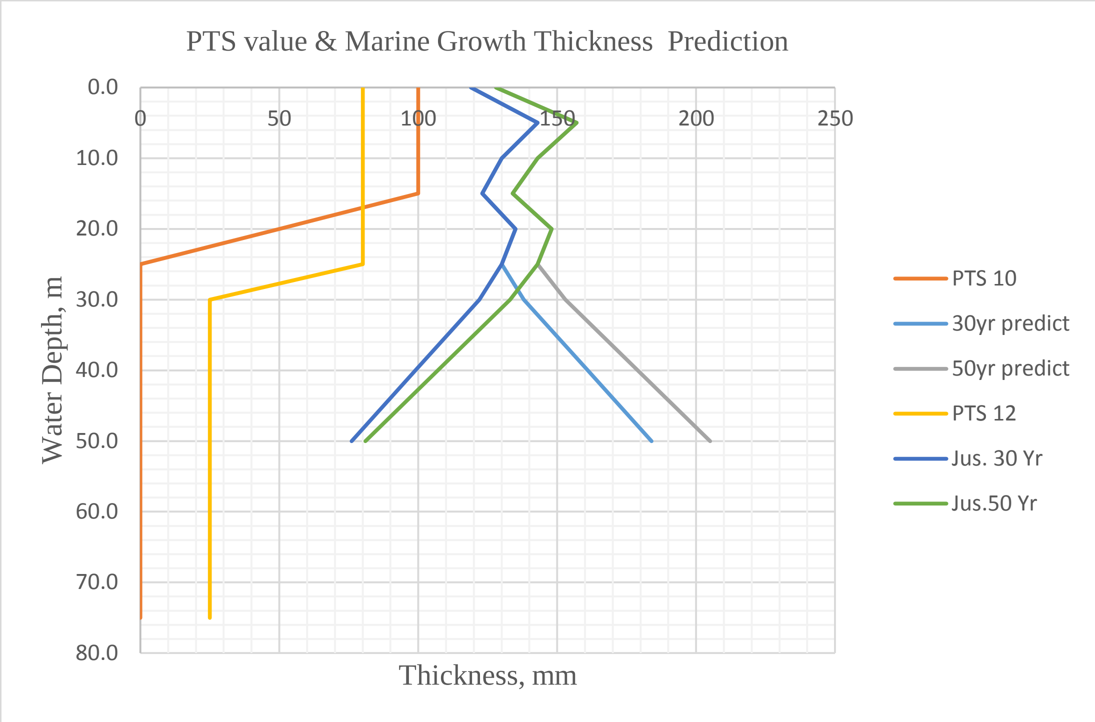


Figure 14: Marine growth thickness prediction of SKO region after interpolation

In order to present the predicted result in the better way, the new graphs are plotted as shown in the figure 15 below. The calculation is based on the average value of 25m water depth interval.

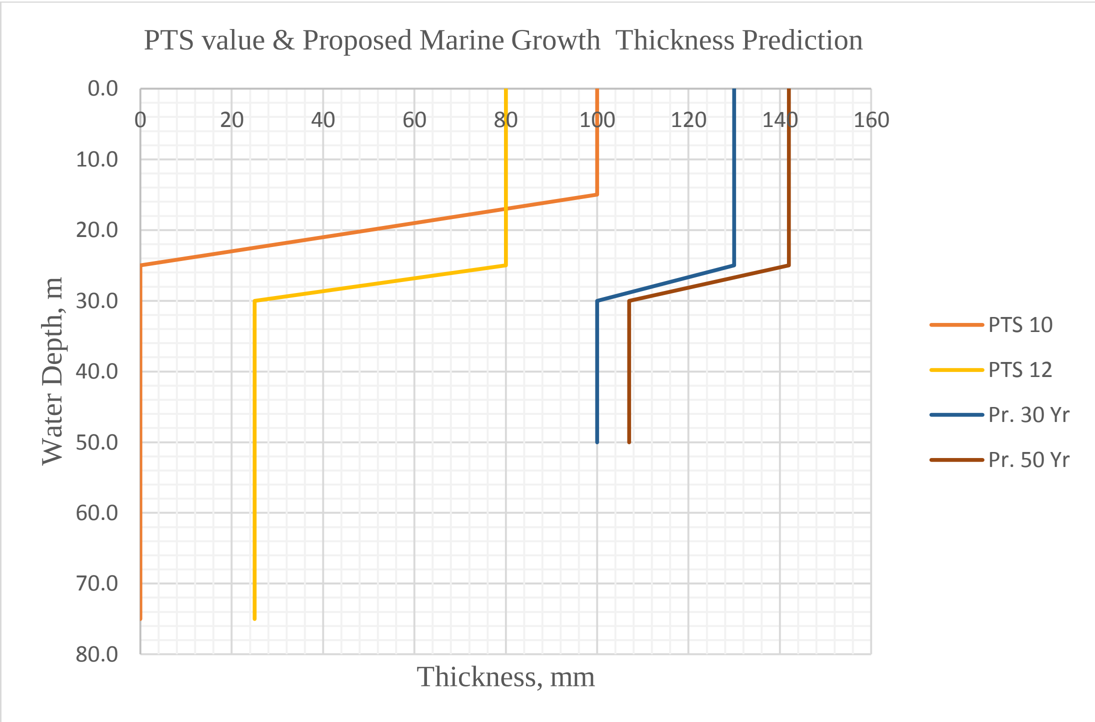


Figure 15: Proposed marine growth thickness for design in SKO region

4.2 Marine Growth Thickness Forecasting Result of Sabah Operation

Table 11 illustrates the result summary of the forecasting marine growth thickness from first prediction until proposed designed value after discussion. The Gumbel method is used for forecasting based on the measuring data obtained.

Table 11: Marine growth thickness prediction vs PTS 10 and PTS 12

Depth, m	Thickness, mm							
	PTS 10	PTS 12	30 years	50 years	Fit. Log 30 Year	Fit.Log 50 Year	Proposed Design, 30 Year	Proposed Design, 50 Year
0.0	100	80	122.52	133.88	122.52	133.88	112	123
5.0	100	80	111.43	122.69	111.43	122.69	112	123
10.0	100	80	118.82	131.48	118.82	131.48	112	123
15.0	100	80	110.69	121.67	110.46	122.15	112	123
20.0	50	80	96.36	104.47	94.47	103.67	112	123
25.0	50	25	75.85	81.94	80.79	87.99	65	69
30.0	0	25	70.11	75.38	69.09	74.68	65	69
35.0	0	25	38.60	39.23	59.08	63.38	65	69
40.0	0	25	38.60	39.23	50.53	53.79	65	69
45.0	0	25	76.43	83.81	43.21	45.65	35	36.5
50.0	0	25	76.43	83.81	36.95	38.75	35	36.5
55.0	0	25	31.95	35.02	31.60	32.88	35	36.5
60.0	0	25	31.95	35.02	27.03	27.91	35	36.5

At first the graphs of 30 year and 50 year return period versus PTS are plotted as shown in figure 16 in order to easily present the result for comparison and discussion. From the graphs, it shows that the marine growth thickness is getting lesser when the water depth is getting deeper, which is following the theory. However there are difference at water depth 45m and 50 m, because the thickness of these two depth interval are higher than the shallow water depth. This error may result from the measurement in mudline area. Fit logarithm trendlines are plotted, $y = 31.964\ln(x) - 165.38$ for 30 year return period and $y = 30.481\ln(x) - 161.47$ for 50 return period, in order to obtain the expected graphs. The new graphs with logarithm trendlines are plotted as shown in figure 17. The value of marine growth thickness obtained from logarithm trendlines are calculated and displayed in the table 11 above.

In order to present the predicted result in the convenient way that is easily taken for the design and comparison with the PTS, the new graphs are plotted as shown in figure 18 which is based on the average value of 20m water depth interval.

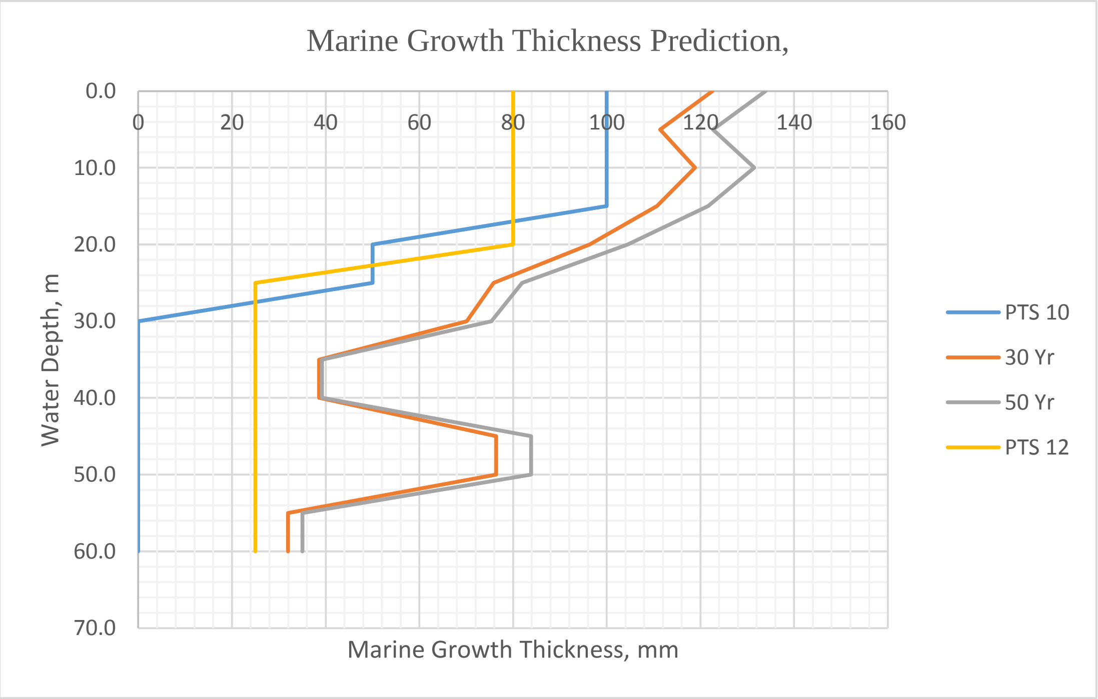


Figure 16: Graph of first predicted marine growth thickness of SBO region

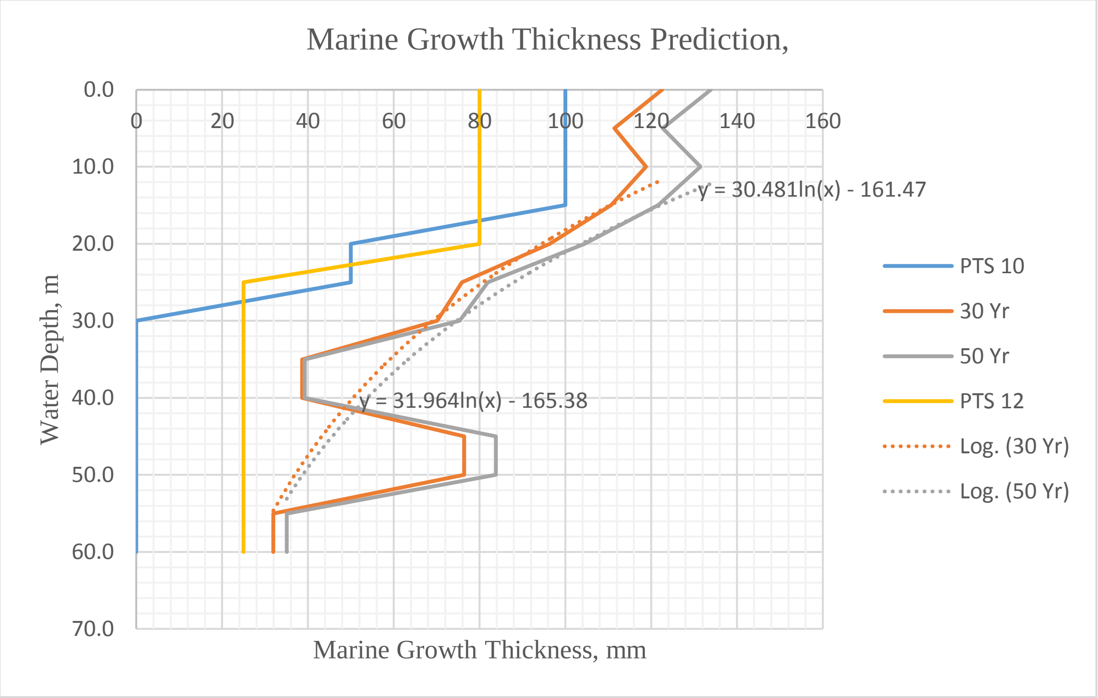


Figure 17: Graph of modified marine growth thickness prediction of SBO region

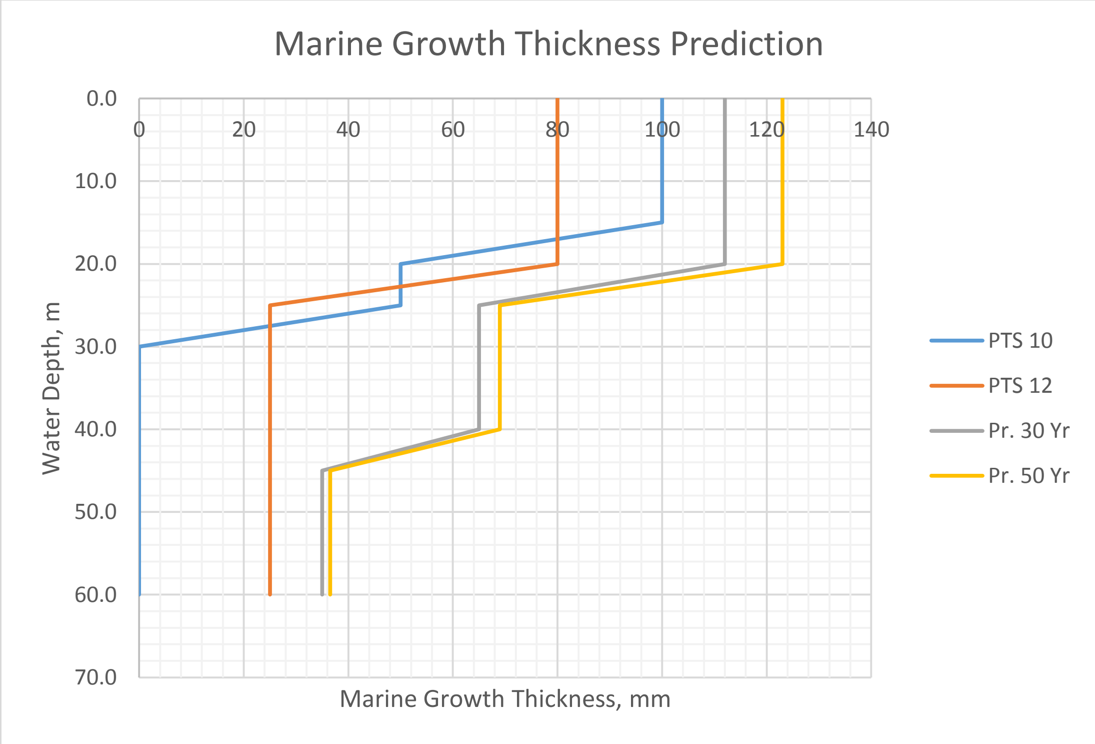


Figure 18: Graph of proposed marine growth thickness for design in SBO region

4.3 Marine Growth Thickness Forecasting Result of Peninsular Operation

Table 12: Predictive marine growth thickness of peninsular operation versus PTS

Depth, (m)	Thickness, mm			
	PTS 10	PTS 12	Analysed Data	Proposed Design
0.0	51	127	55.35	110.00
5.0	153	127	68.30	110.00
10.0	153	127	101.07	110.00
15.0	153	127	119.02	110.00
20.0	153	127	140.61	110.00
25.0	153	127	159.41	110.00
30.0	153	127	123.14	110.00
35.0	153	25	131.52	100.00
40.0	153	25	111.10	100.00
45.0	153	25	107.29	100.00
50.0	102	25	80.80	100.00
55.0	25	25	88.07	100.00
60.0	25	25	77.76	100.00
65.0	25	25	52.79	45.00
70.0	25	25	44.68	45.00

75.0	25	25	29.31	45.00

Table 12 shows the summary result of the analyzed marine growth thickness of peninsular region. The obtained measuring data is far higher than the PTS and other rough sea regions in the world. At first the average method is suggested and the value of the thickness are displayed as shown in the table 12 and figure 19. The result shows that the marine growth thickness is less than PTS for water depth between MSL to 30m water depth, but it is higher than PTS for water depth deeper than 30 m.

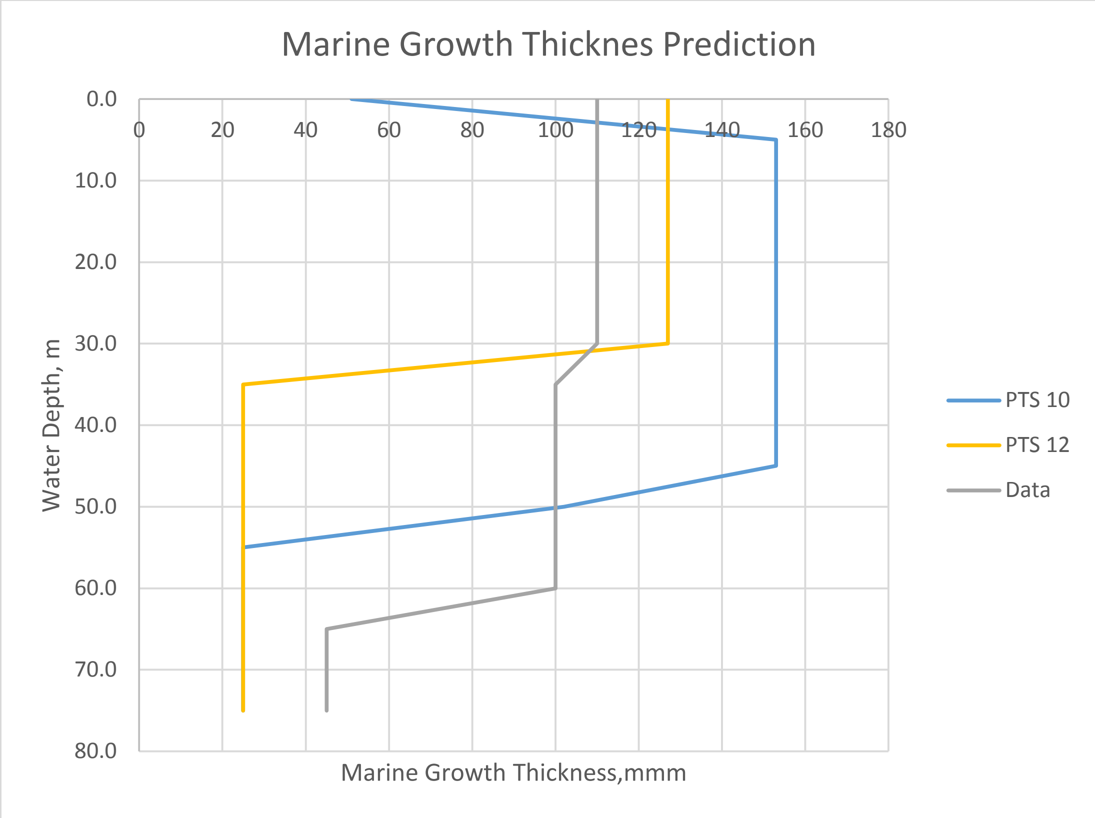


Figure 19: Marine growth thickness of peninsular region using average method

4.4 Percentage Differences between 30 and 50 Years for Marine Growth Thickness of Each Operation Region

The below table 13 shows the percentage differences between 30 year and 50 year predicted marine growth thickness of each operation region in Malaysia. For SKO, from MSL to 25m water depth, the difference percentage is 9.23% and from 25m to 50m, the percentage difference is 7%. For SBO, from MSL to 20m water depth, the percentage difference is about 9.82%, from 20m to 40m water depth, the percentage difference is 6.15%, and from 40m to 60m water depth, the percentage difference is only 4.28% difference. In short, the results show that there are slightly increase in predicted marine growth thickness between 30 year return and 50 year return period for all operation regions. Either 30 year return period or 50 year return period is chosen for the design, there is no much difference. However, according to the PTS (2012), "the requirement of the service life shall be 30 years, unless otherwise defined in the scope of work" (p.1). Therefore, the predicted value of 30 year return period is suggested for the design.

These value are quite large different compared to the PTS 2012. The comparison of 30 year design versus PTS 2012 is discussed in the next section.

Table 13: Percentage differences between 30 year and 50 year predicted marine growth thickness

	Water Depth, m	30 year return period	50 year return period	Percentage Difference, %
SKO	0-25	130	142	9.23
	25-50	100	107	7
SBO	0-20	112	123	9.82
	20-40	65	69	6.15
	40-60	35	36.5	4.28

4.5 Comparative Study with the PTS 2012

Table 14 shows the percentage differences of each operation region versus PTS 2012. For SKO region, there is 38.46 percent difference for water depth from MSL to 25m and 75 percent difference for water depth from 25m to 50m. For SBO, there are 28.57 percent difference for water depth from MSL to 20 m, 40 percent difference for water depth from 20 m to 40m, and 28.57 percent difference for water depth from 40m to 60m. For East Peninsular, there is 15.45 percent difference for water depth from MSL to 30 m; the predicted data of marine growth for this water interval is less than the PTS. For water depth from 30 m to 60 m, there are 75 percent difference, and from water depth 60 m to 75 m, there is 44.44 percent difference.

These results show that there are large difference between predicted data to PTS 2012. The large difference results from analyzing data using Gumbel method, which project the data based on the available measuring data. These predicted results are suggested for the design because it considers the extreme value. The design will be safer than PTS, but the design will be more conservative, which results in higher cost.

Table 14: Percentage difference of each operational region versus PTS 2012

	Water Depth, m	Marine Growth Thickness, mm	PTS 2012 Marine Growth Thickness, mm	Percentage Difference, %
SKO	0-25	130	80	38.46
	25-50	100	25	75
SBO	0-20	112	80	28.57
	20-40	65	25	40
	40-60	35	25	28.57
PMO	0-30	110	127	-15.45
	30-60	100	25	75
	60-75	45	25	44.44

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

From the result, it is shown that the extreme value analysis performed has meet the objectives of the study. The analysis is performed based on every water depth interval of each jacket platform and the duration of the marine growth attached on the jacket.

Based on the discussion on the result of marine growth thickness, which obtained by using extreme value analysis method, it is concluded that predicted marine growth thickness for each operational region is higher than the marine growth thickness in PTS 2012 excluding the water depth interval between MSL to 30 m of East Peninsular. The percentage difference of each operational region is shown as following:

- For Sabah operation, from MSL to 20 m water depth, there is 28.57 percent difference, from 20 m to 40 m water depth, there is 40 percent difference, and from 40 m to 60 m water depth, there is 28.57 percent difference.
- For Sarawak operation, from MSL to 25 m water depth, there is 38.46 percent difference, from 25 m to 50 m water depth; there is 70 percent difference.
- For East Peninsular, from MSL to 30 m water depth, there is 15.45 percent difference, from 30 m to 60 m water depth; there is 75 percent difference, and from 60 m water depth; there is 44.44 percent difference.

4.2 Recommendation

4.2.1 Recommendation for future work

From this study, some suggestions are recommended to enhance the significance of the expected results towards marine growth thickness prediction of the offshore platform. The recommendations for future study are as the following:

- Marine growth data for every interval period of inspection of each platform must be available, so that it gives more reliability for the study
- Property of marine growth fouled on any member such as hard and soft should be highlighted.
- The operational function of the platform must be stated; whether it is an unmanned or a manned platform so that the data are grouped accordingly for analysis.

4.2.2 Recommendation for expansion work

Marine growth study is a wide area subject to be researched for redefining PTS. Beside marine growth thickness, there are several more areas to be studied such as:

- Surface roughness of marine growth; it also affect wave and current calculation of sub structure of fixed offshore structure.
- Drag and inertia coefficient of fouled member; this is one of most important research to be studied in the lab. This study is based on the surface roughness and marine growth thickness and wave theory. Until now, drag and inertia coefficient value is still the same as the value in API RP 2A-WSD.

REFERNCES

Alves, I. F., & Neves, C. (n.d.). *Extreme Value Distribution.*

Castillo, E., Hadi, A., Balakrishnan, N., & Sarabia, J. (2005). *Extreme Value and Related Models with Applicatios in Engineering and Science.* New Jersey: John Wiley & Sons, Inc.

Chakrabarti, S. K. (1987). *Hydrodynamics of Offshore Structures.* Illinois: WIT Press.

Heaf N.J. (1979). The Effect of Marine Growth on the Performance of Fixed Offshore Platfroms in the North Sea. *Offshore Technology*, (pp. 255-260). Houston.

Heidemant, J., & George, R. (1981). Biological and Engineering Parameters for Macrofouling Growth on Platforms Offshore Lousiana. 550-557.

Idzwan, M. S., Liew, M., Kurian, V. J., & Abdullah, M. N. (2013). Extreme Value Analysis and Joint Density of Metocean Loads for Malaysian Water. *Malaysian Journal of Civil Engineering*, 40-52.

ISO 19901-1:2005- Part 1: Metocean Design and Operating Conditions. (n.d.).

Jusoh, I., & FRINA, J. W. (1996). Effect of Marine Growth and Hydrodynamic Loading on Offshore Structure. *Journal Mechanical*, 87-91.

Kolios, A. I. (2000). *A multi-configuration approach to reliability based structural integrity assessment for ultimate strength.* United Kingdom: Cranfield University, Bedford, .

M Akram, M., & Sambu Potty, N. (2013). *Development of an Integrated Structural Integrity Management System for Malaysian Fixed Offshore Platforms.* Tronoh: UTP.

Potty, N. S., & Mohd Akram, M. (2009). Structural Integrity Management for fixed offshore platform in Malaysia. *World Academy of Science, Engineering, and Technology*.

Rcommend Practice for Planning, Designing, and Constructing Fixed Offshore Platfrom-Working Stress Design . (2005). Washinton, D.C: American Petroleum Institute.

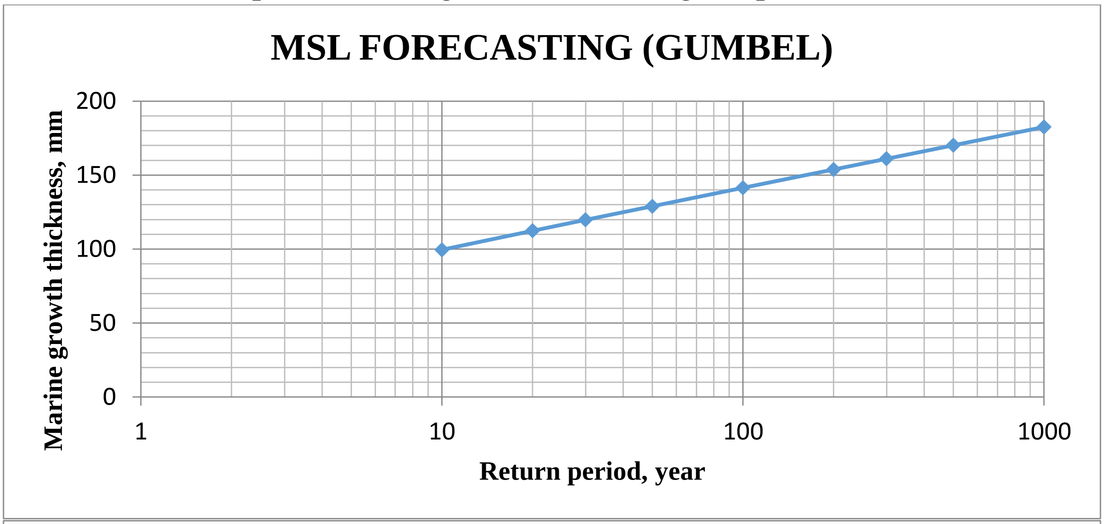
Steel Jacket Structure. (n.d.). Retrieved from Univesity of Stratchclyde: http://www.esru.strath.ac.uk/EandE/Web_sites/98-9/offshore/steel.htm

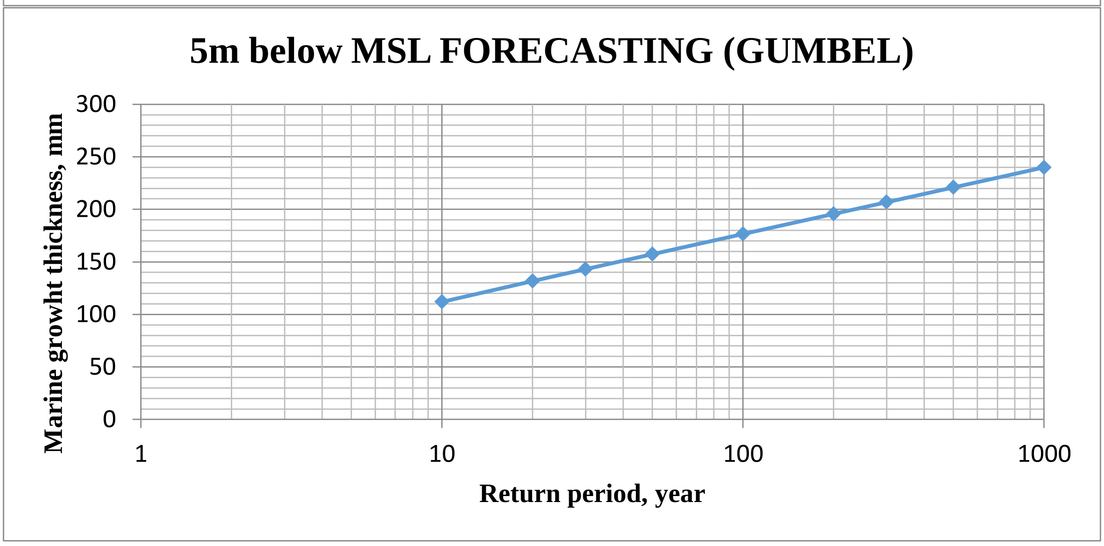
Technical Specification: Design of Fixed Offshore Structures. (2012). Kuala Lumpur.

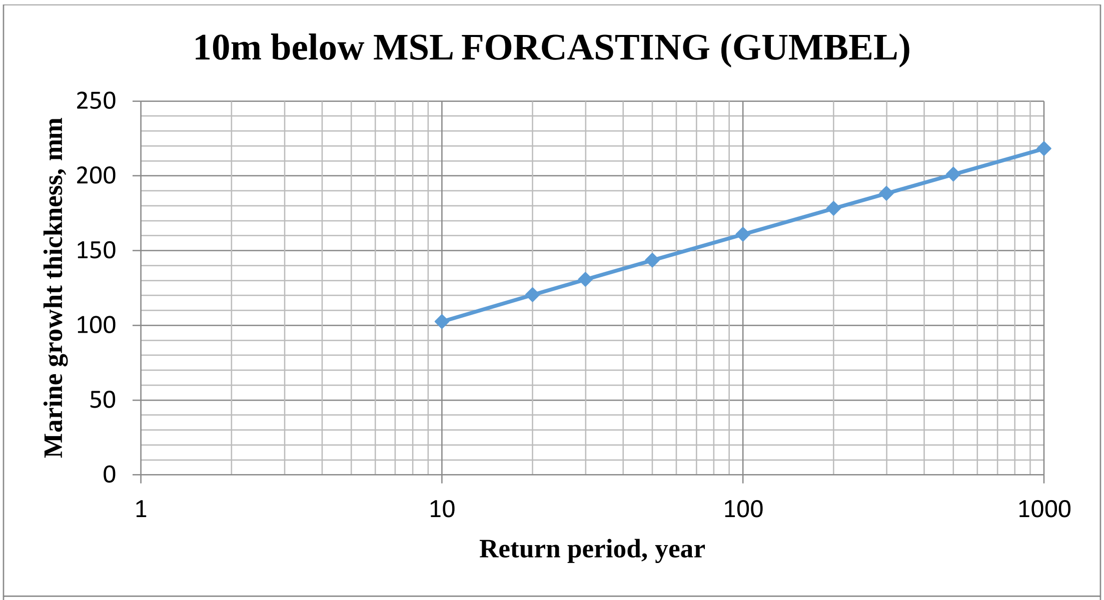
Wei Shi, Park, H., Han, J., Na, S., & Kim, C. (2013). A study on the effect of different modeling parameters on the dynamic response of a jacket-type offshore wind turbine in the Korean Southwest Sea. *Elseviar*, 54.

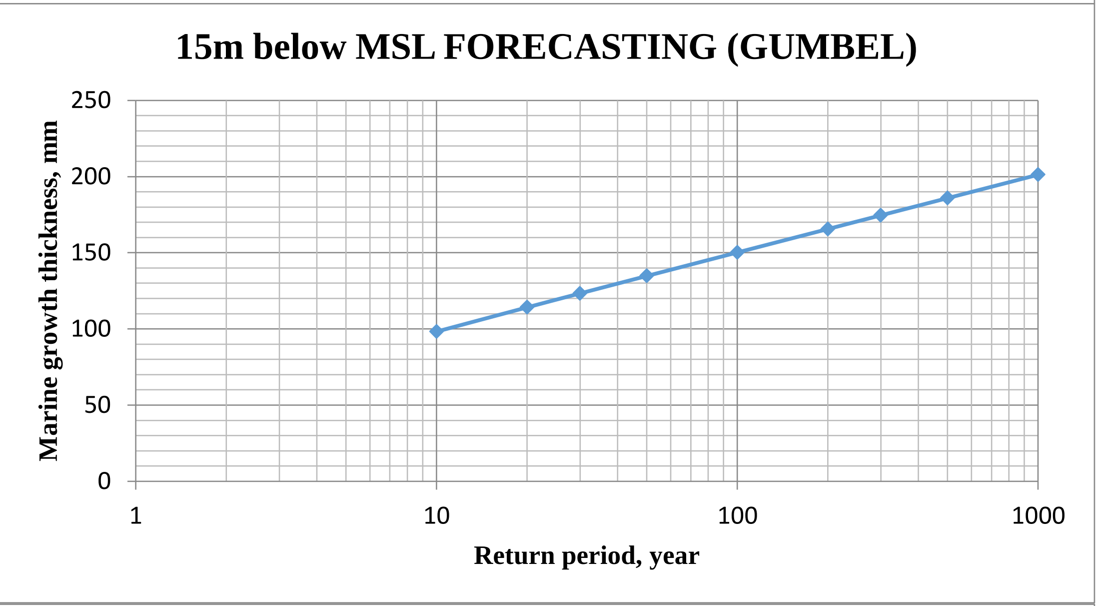
APPENDICES

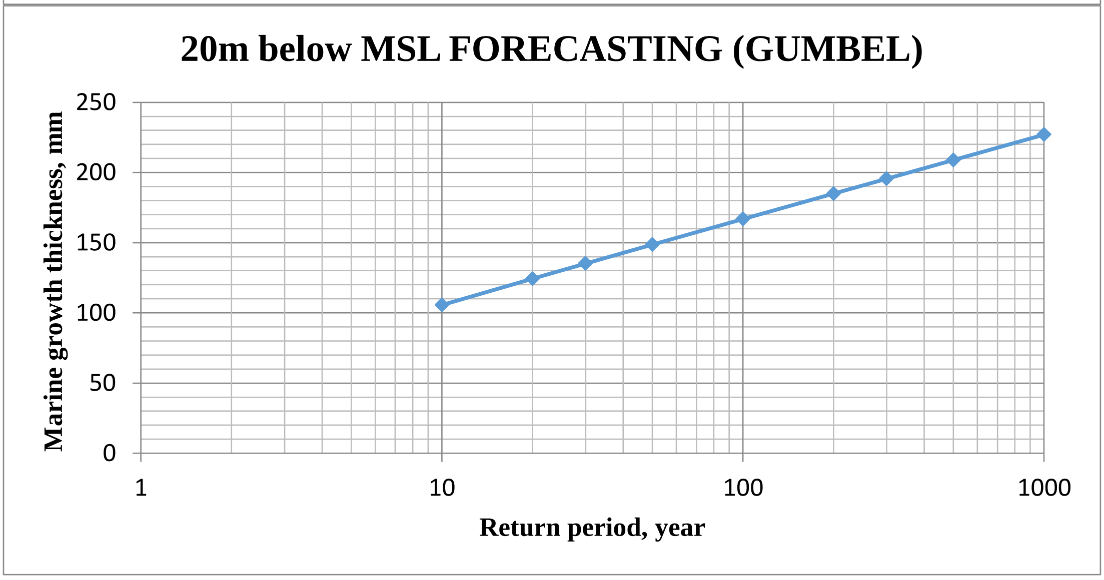
A. Sarawak Operational Region's Forecasting Graphs

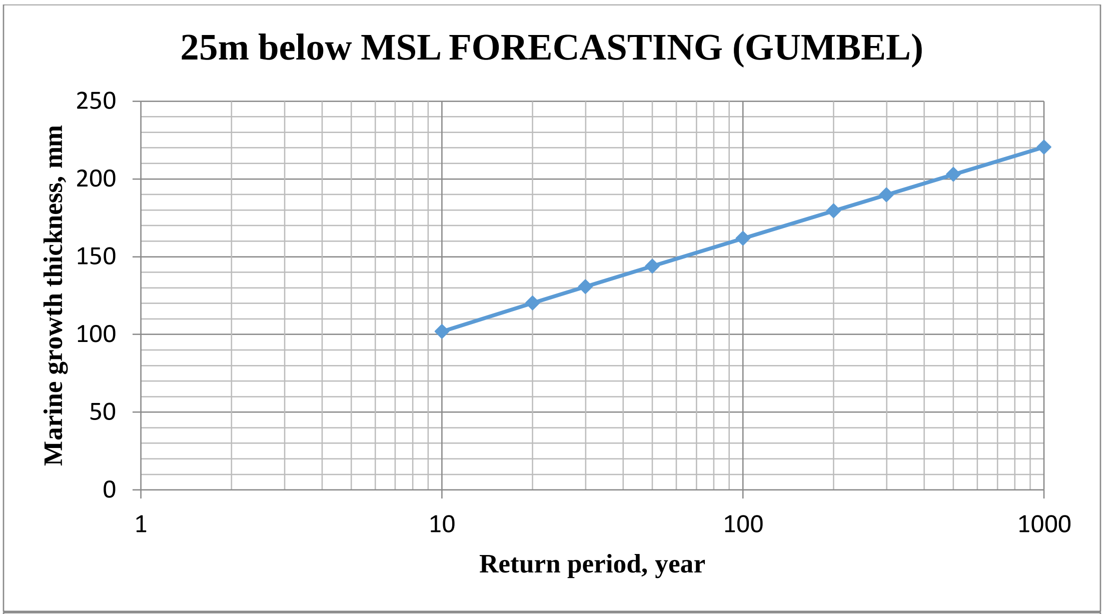


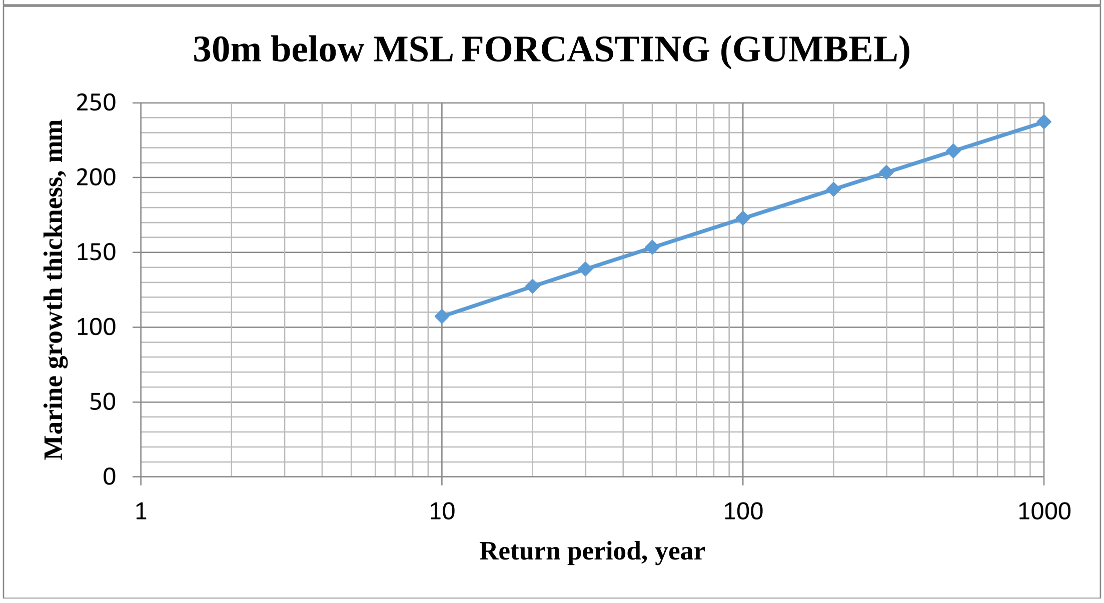


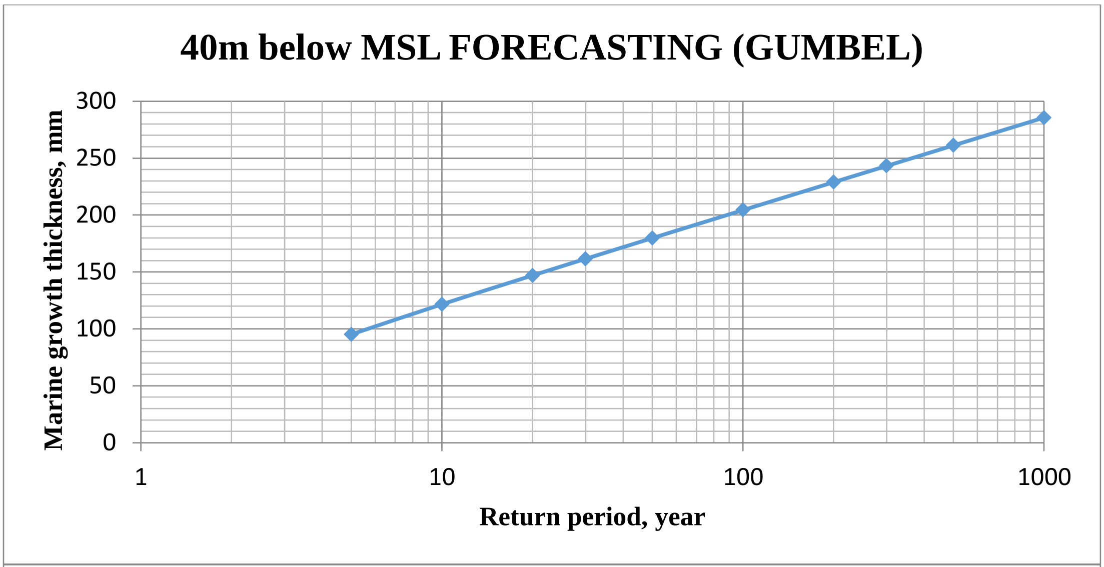

10m below MSL FORCASTING (GUMBEL)
Marine growht thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year

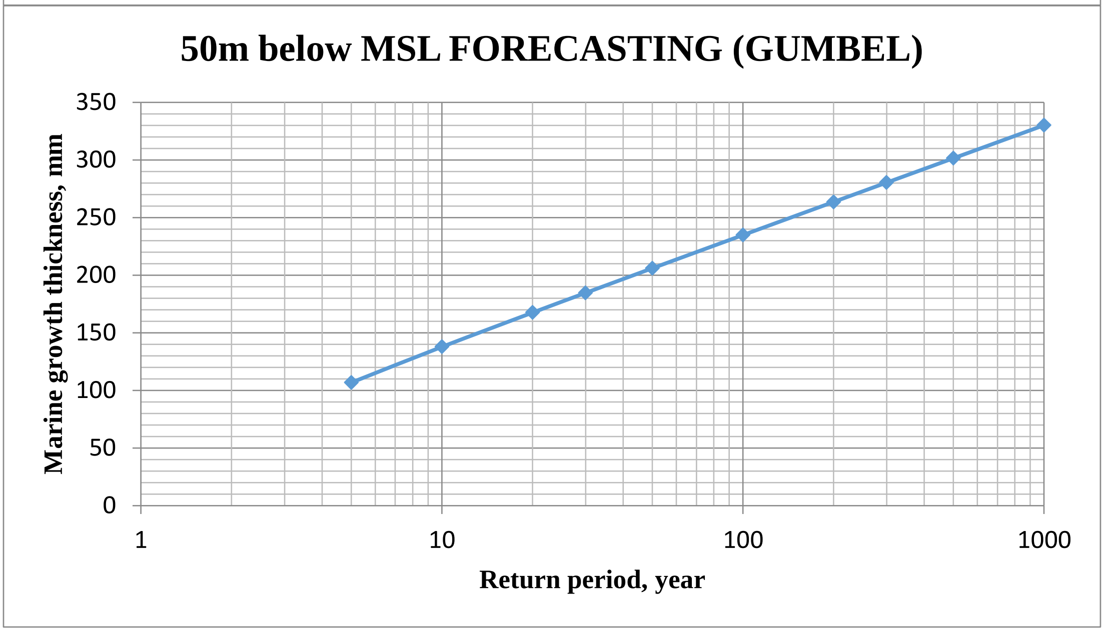

15m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year


20m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year

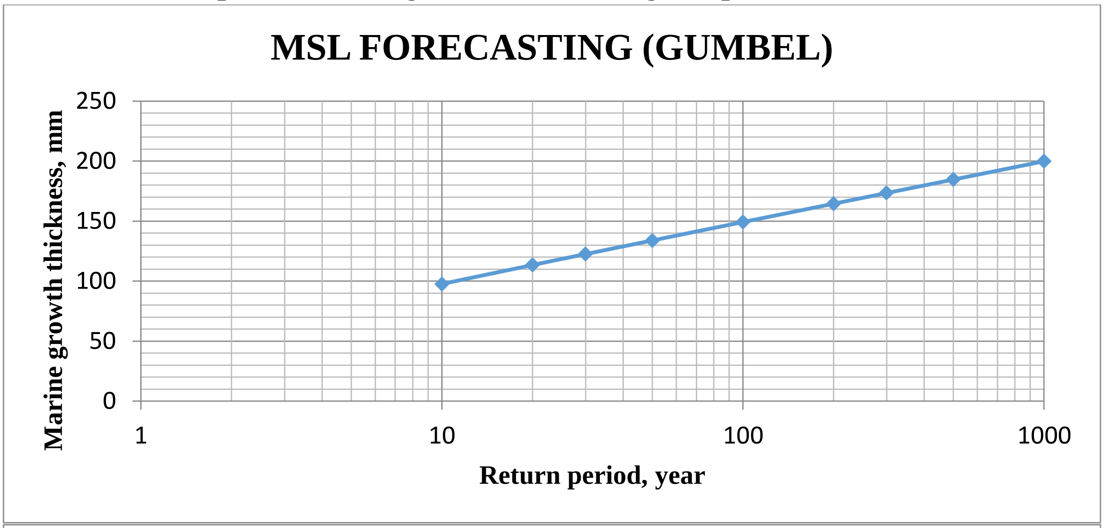

25m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year

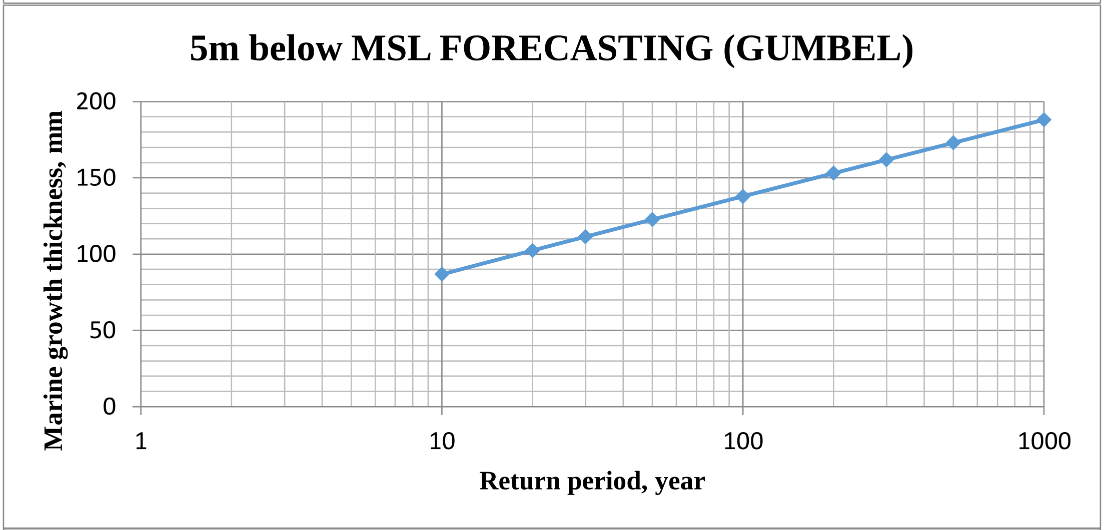

30m below MSL FORCASTING (GUMBEL)
Marine growth thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year

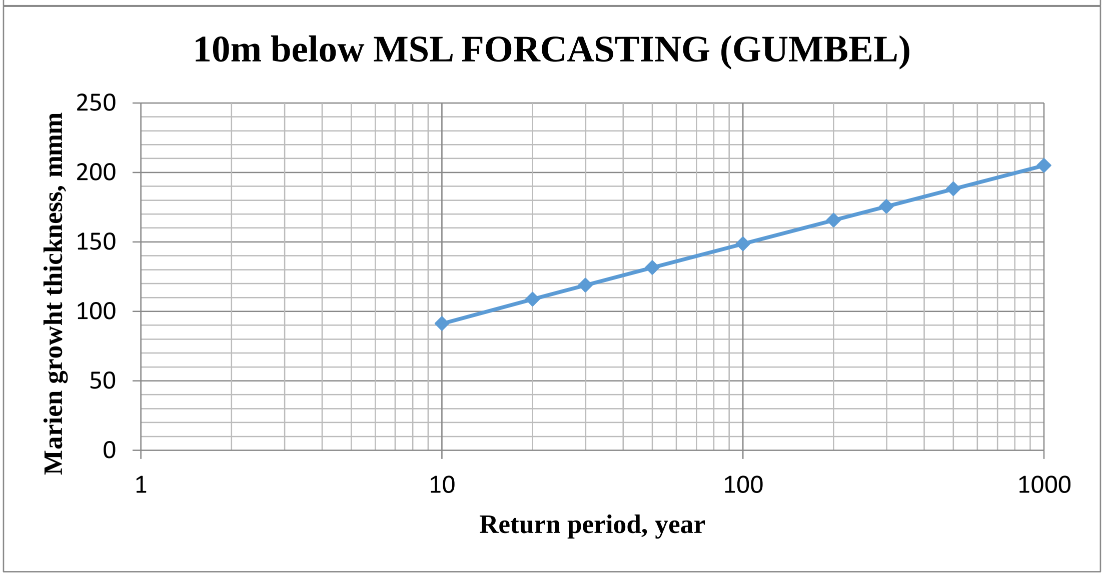

40m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
300
250
200
150
100
50
0
1
10
100
1000
Return period, year

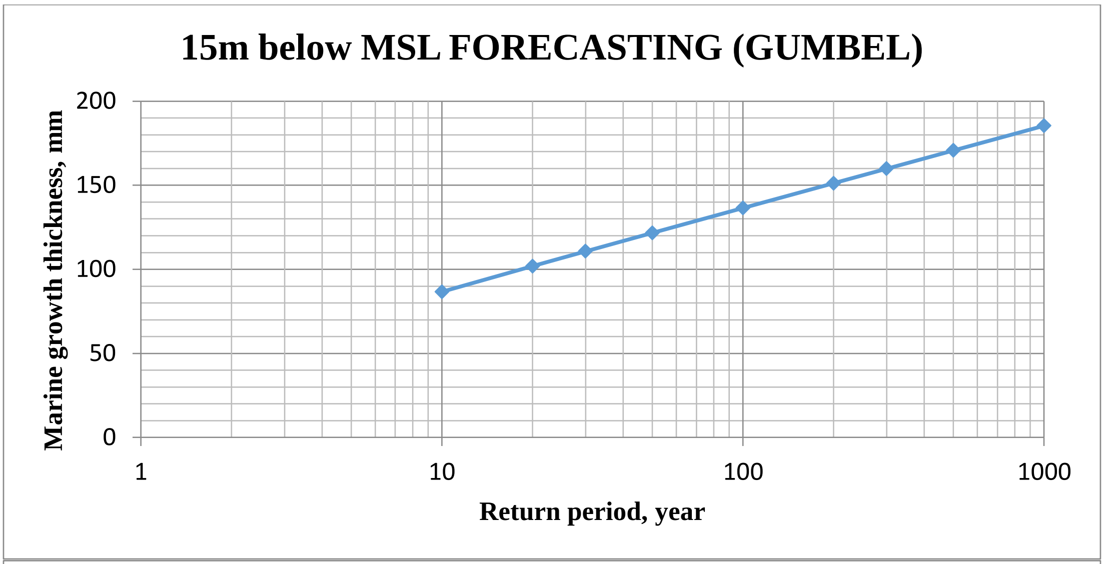

50m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
350
300
250
200
150
100
50
0
1
10
100
1000
Return period, year

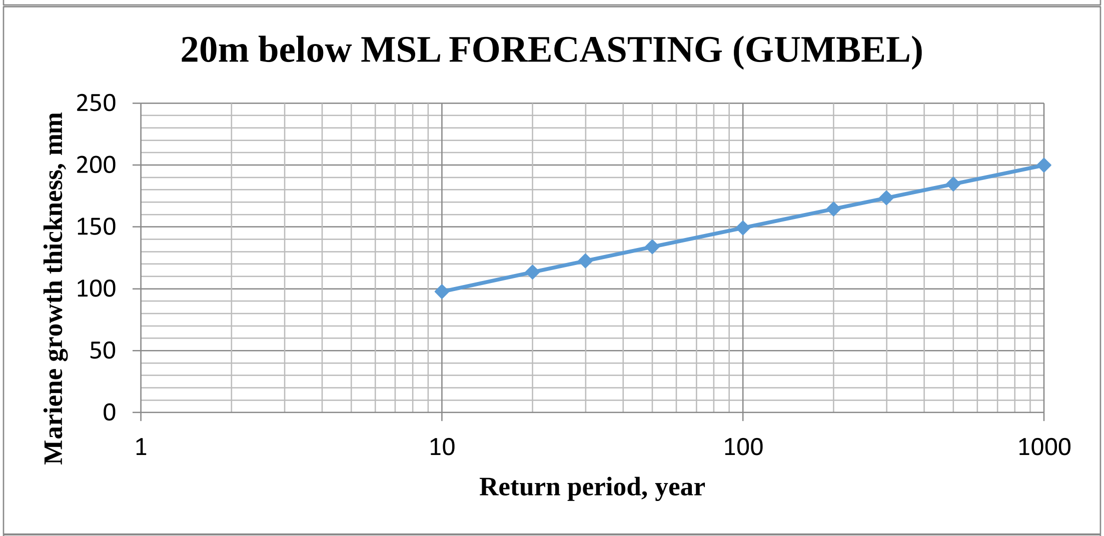
B. Sabah Operational Region's Forecasting Graphs

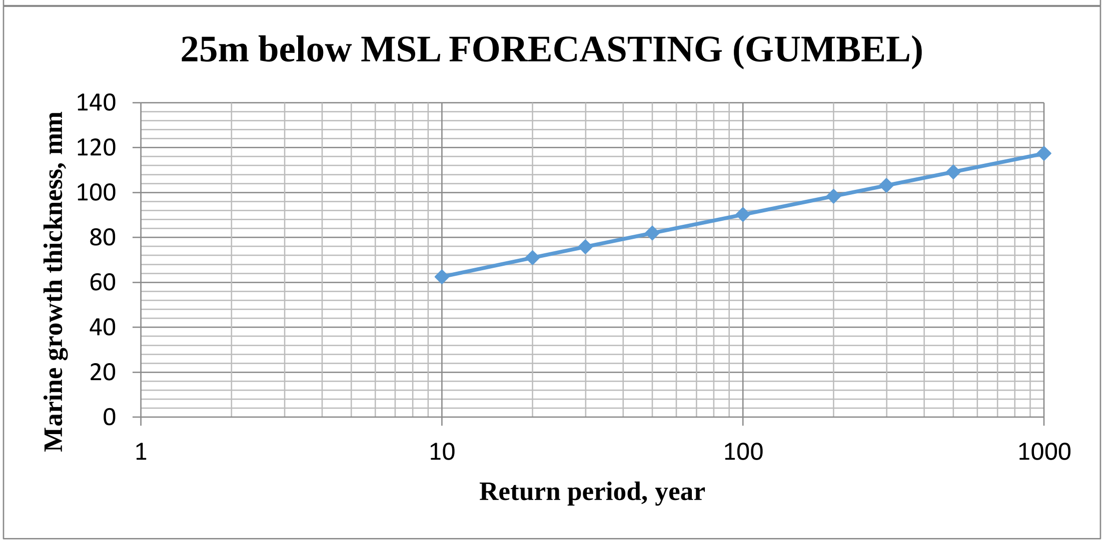


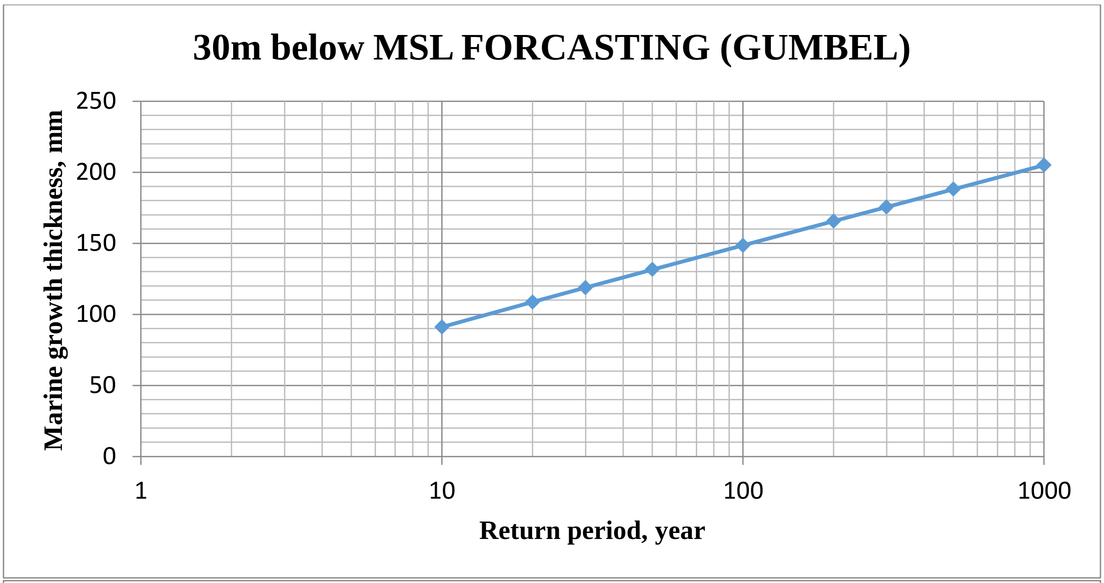


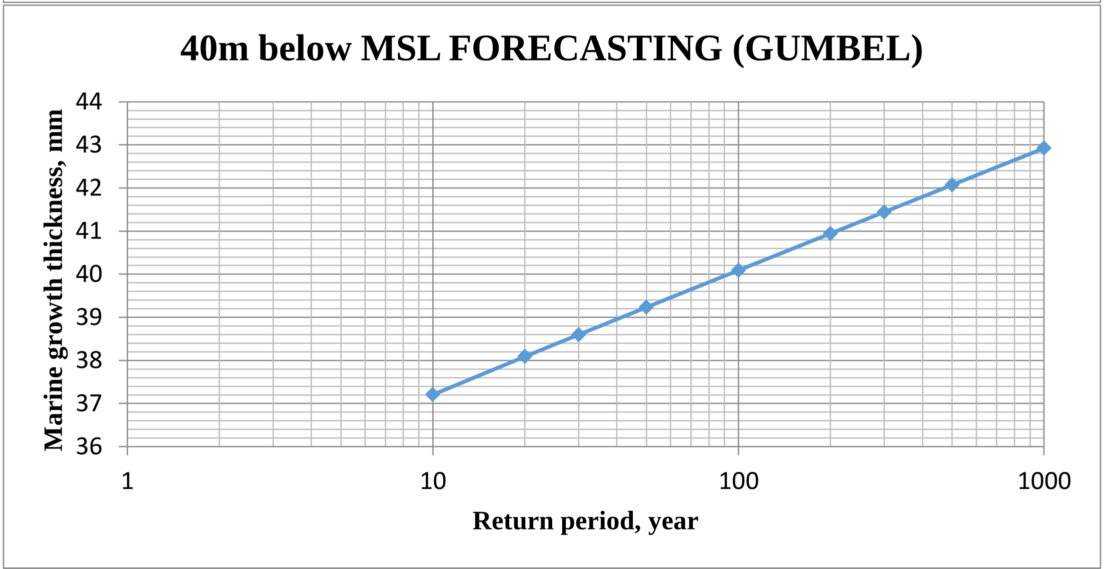


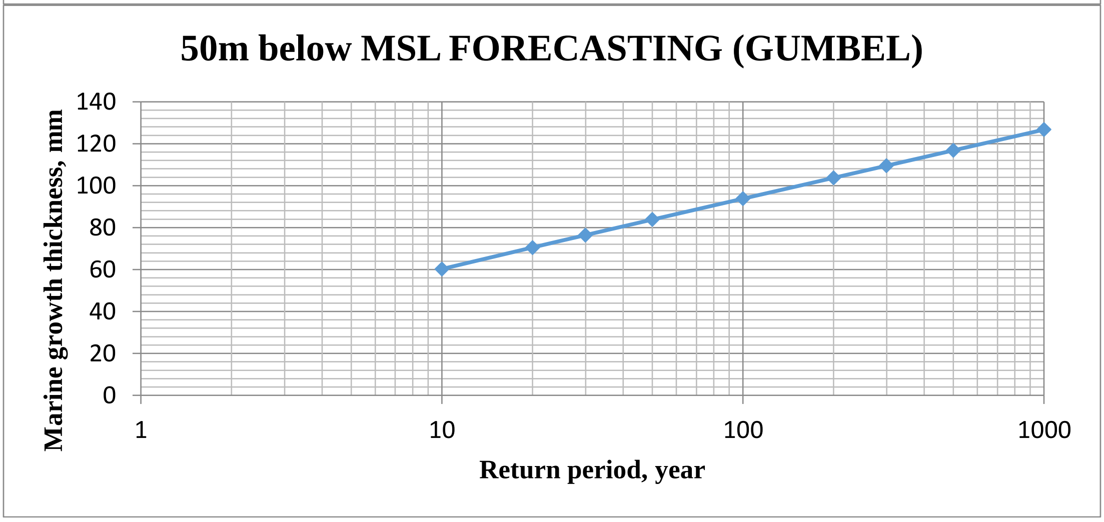

15m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
200
150
100
50
0
1
10
100
1000
Return period, year

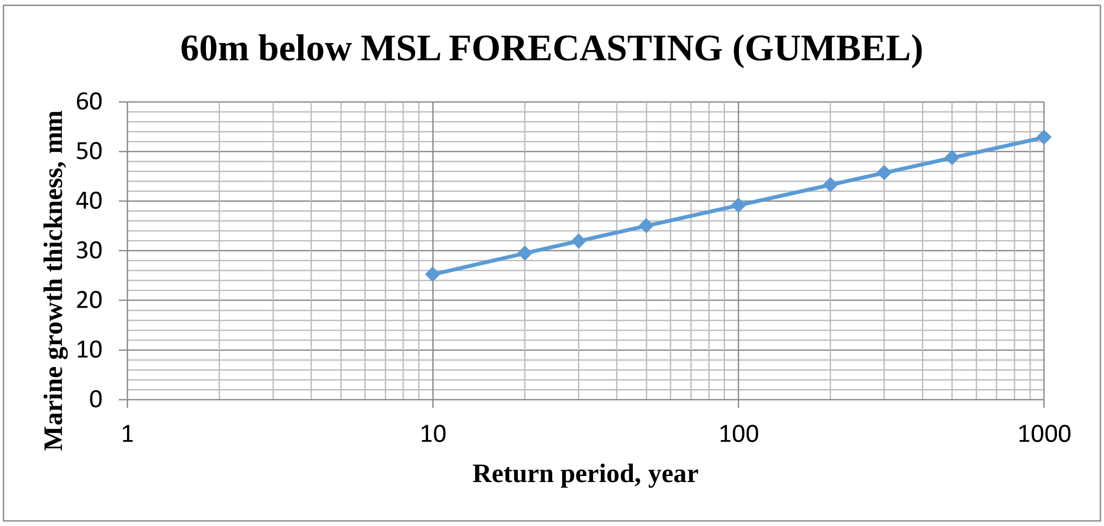

20m below MSL FORECASTING (GUMBEL)
Mariene growth thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year


25m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
140
120
100
80
60
40
20
0
1
10
100
1000
Return period, year


30m below MSL FORCASTING (GUMBEL)
Marine growth thickness, mm
250
200
150
100
50
0
1
10
100
1000
Return period, year


40m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
44
43
42
41
40
39
38
37
36
1
10
100
1000
Return period, year


50m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
140
120
100
80
60
40
20
0
1
10
100
1000
Return period, year


60m below MSL FORECASTING (GUMBEL)
Marine growth thickness, mm
60
50
40
30
20
10
0
1
10
100
1000
Return period, year

C. Peninsular Operational Region's Forecasting Graphs