Trend Analysis of Sea Level Rise for Kukup (Johor), West Coast of Peninsular Malaysia

Azura Binti Ahmad Radzi, and Prof. Hadibah Binti Ismail

***Abstract*—** Future sea level rise would be expected to have a number of impacts, particularly on Malaysia coastal systems such as flooding and inundation, coastal erosion and salt water intrusion. This study analyzes the trend variation of sea level rise for selected locations along the West Coast of Peninsular Malaysia. Furthermore, rate of future SLR at those selected stations will be predicted in the year 2050 and 2100. This study also examines the trend of sea level rise in Kukup, Johor (Straits of Malacca). The historical mean sea level data from the selected stations were used in the trend analysis. In this study, the non-parametric Mann Kendal test was carried out to determine trends in sea level rise. From the analysis, the result shows that it is on upward trend of sea level rise based on 95% Confidence Interval. The rate of SLR lies between 0.829 mm/yr to 2.021 mm/yr. The trend analysis and the future projection also proven that the Straits of Malacca will experience a rise in sea level in 2050 and 2100.

***Keywords*---** Sea level rise, trend analysis, prediction, Straits of Malacca

I. Introduction

SEA level can change, both globally and locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass of water and (iii) changes in water density. Global mean sea level (MSL) has been rising since the end of the last ice age almost 18,000 years ago. Factors leading to sea level rise (SLR) under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes [1],[2],[5] and [6].

The global mean surface air temperature has increased by 0.5°C in the 20th century and is projected to increase further in this century [2], i.e. between 1.5 to 4.5°C. As the world's oceans rise, low-lying coastal areas will disappear.

Azura Ahmad Radzi is with Technical Foundation/Applied Science Technology Section at Universiti Kuala Lumpur, Malaysian Institute of Marine Engineering Technology, Jalan Pantai Remis, 32200, Lumut, Perak, Malaysia (corresponding author's phone: +6056909000; e-mail: azuraradzi@mimet.unikl.edu.my).

Prof. Hadibah binti Ismai, [2]Lecturer, Coastal and Offshore Engineering Institute, Faculty of Civil Engineering, Universiti Teknologi Malaysia (2nd author).

Flooding of coastal areas will become more common and more severe as storm surges have easier access to these lower-lying areas. The occurrence of extreme high water events related to storm surges, high tides, surface waves, and flooding rivers will also increase. Flooding and loss of land will have significant impacts on humans, wildlife, and entire ecosystems. According to [7] there is good geological evidence that showed over the last 5,000 or so years, sea level around Malaysian coast has been falling at a mean rate of about 1 mm/yr and the global tidal level is dropping at 2.4 ± 0.9 mm/yr. Meanwhile, the sedimentation rate which appears to be playing a critical role in relative sea level change in Malaysia is in the region of a few millimeters per year. In more recent finding, Malaysia sea level has risen at an average rate of 1.25 mm/yr over 1986 to 2006 [3] All of the above findings are signals to show that Malaysia coastal system might be vulnerable to SLR. Both South China Sea and Malacca Strait depicted that the rise of Mean Sea Level was clearly visible [8], [9] and [10]. The rate of sea level rise obtained using five satellites combination was about 1.64 and 1.42 mm/year respectively. As well as Sea levels off the west coast of Peninsular Malaysia will rise by 10cm to 13cm in the next 100 years mentioned by [11].

Therefore, there is indication of the urgency for Malaysia as one of the coastal nations to begin the progression of adapting to sea level rise not because there is an awaiting catastrophe, but because there are opportunities to avoid unpleasant impacts by acting now, opportunities that may be lost if the process is delayed. Unfortunately, there is lack of official indication or measurement has been done in Malaysia on SLR. Hence, how should Malaysians prepare for sea level rise? Thus, this particular study is required to analyze the trend variation of SLR for selected locations along West Coast of Peninsular Malaysia and to predict SLR in the year 2050 & 2100 so that the consequences of SLR can be reduced through a proper management and implementation of adaptation and mitigation measures.

II. Trend Analysis And Methodology

Trend analysis is a forecasting technique in which (1) a baseline scenario is constructed using trend extrapolation, (2) future events that may affect this scenario are identified and evaluated on the basis of their probability of occurrence and degree of impact, (3) the combined effect of these events is applied to the baseline scenario to create future scenarios. Trend studies are valuable in describing long-term changes in

a population. They can establish a pattern over time to detect shifts and changes in some event. In this study, Kukup, Johor is selected based on the existing tidal gauge stations along the West Coast of Peninsular Malaysia. Figure 1 below shows the selected locations, while Figure 2, briefly explain the methodology process.

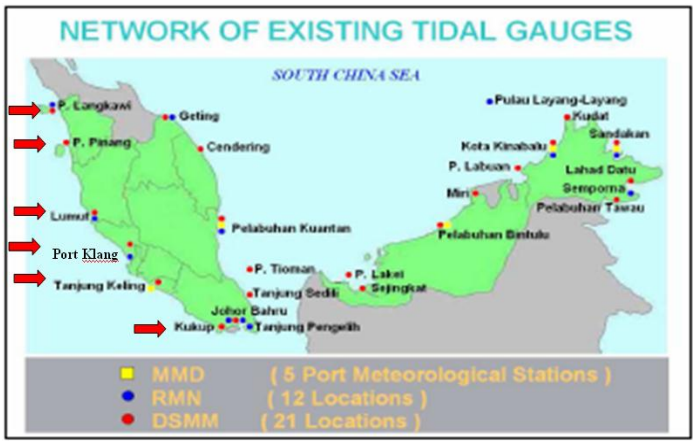

Fig. 1 Study area location

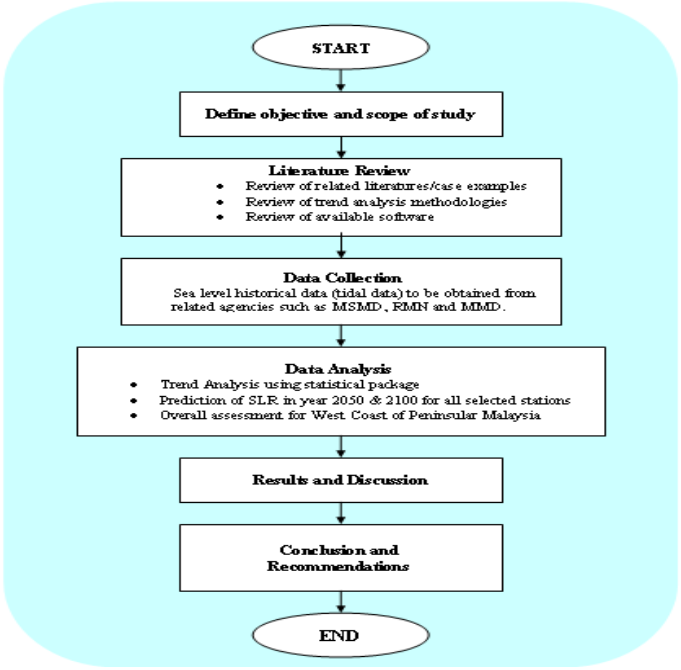

Fig. 2 Research flow chart

The data collection is an important element in this study. In order to do the trend analysis of sea level rise, the mean sea level historical data (tidal data) is necessary. The data for all the selected locations was obtained from the Malaysia Survey and Mapping Department (MSMD). The station information is as in Table 1. Basically an analysis process will be conducted on the collected data. The data analysis part consists of two types of analysis, that is trend analysis and statistical analysis.

TABLE I
STATION INFORMATION

Station	KOD STN	LAT	LONG	Data Period	Length
Kukup	KUK	01 19 31	103 26 34	1986 - 2005	20 years

Mann Kendall test is a specific tool for seasonal data that able to compare all pairs of observations, counts the number where values are increasing, subtracts the number decreasing and calculates a probability. The robust macro function that does not required specific distribution, less sensitive to extreme values, less sensitive to missing values and able to validate data for further investigation and analysis. In the trend analysis, raw data were transfered into Minitab Software, which is a statistics package. It was developed at the Pennsylvania State University by researchers Barbara F. Ryan, Thomas A. Ryan, Jr. and Brian L. Joiner in 1972.

Based on the trend line plotted, the fitted linear regression model was determined. The equation demonstrates whether the trend has increased or decreased over time, and if it has, how quickly or slowly the increase or decrease has occurred. There after, by making future projection using the equation, an estimate of the SLR rate in the year 2050 and 2100 will be obtained.

III. DATA ANALYSIS AND RESULT

The analysis of sea level rise trend for West Coast of Peninsular Malaysia has exposed the actual trend of sea level rise according to the selected tidal stations. The results were obtained from the analysis of historical mean sea level data at Kukup (1986 -2005) was processed and analyzed accordingly using statistical package [4].

The Non-parametric tests of Mann-Kendall were carried out using Minitab as a statistical package on Kukup Johor MSL Data. From the non-parametric Mann-Kendall test, trend analysis, and prediction test Kukup exhibit of upward trend. The summary of the mean sea level trend is summarizing as in Table II and the trend plotted in Figure 3.

TABLE II
STATION TREND LINE

Station	Fitted Linear Regression Model	Intercept	Coefficient /Slope	Confidence Interval	Trend
Kukup (1986 – 2005)	Y(t) = 398.452 + 0.0123033 *t	398.452	0.0123033	95%	**Upward**

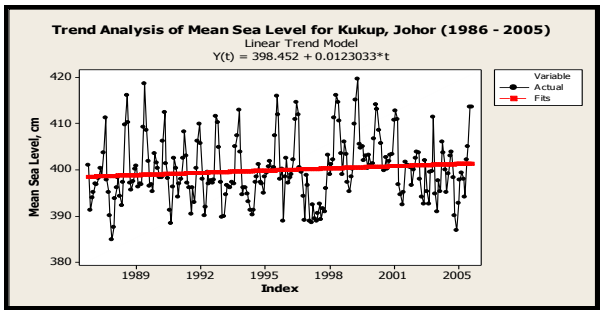

Fig. 3 Kukup Trend Analysis for 1986 to 2005

IV. Sea Level Rise (SLR) Prediction

Trend line of mean sea level for Kukup station was extrapolated for an estimate SLR in the year 2050 and 2100 as in Figure 4. Table 3 summarized the Predicted Sea Level Rise (SLR) in year 2050 and 2100 for Kukup station.

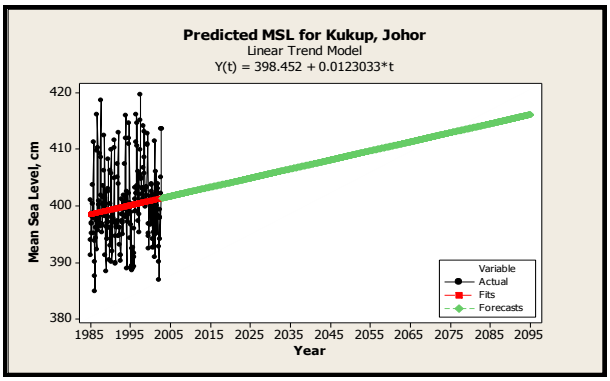

Fig. 4 Kukup Predicted MSL for 2050 and 2100

TABLE III
STATION TREND LINE

Rate of SLR (mm/yr)	MSL 2005 (cm)	Incremental SLR (cm)		Predicted SLR (cm)	
		2050	2100	2050	2100
1.469	401.158	7.247	14.900	408.405	416.058

V. Closing Remarks

From the analysis, the result shows that Kukup Johor have an upward trend of sea level rise based on 95% Confidence Interval. The rate of SLR lies between 0.829 mm/yr to 2.021 mm/yr. In 2050, Kukup, Johor is predicted to have additional mean sea level which at 7.247cm and 14.900cm in 2100. The trend analysis and the future projection also proved that the Straits of Malacca will experience a rise in sea level in year 2050 and 2100 as highlighted by [3] and [9]. As a closing remarks, the results of this study impose a strong signal of SLR threat to the West Coast of Peninsular Malaysia and will lead the Government to come out with a National Plan on adaptive measures to mitigate the SLR impacts.

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