

The Assessment of Rip Current at Kerachut Beach Using Hydrodynamic Modelling

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Abstract. Kerachut Beach is a beautiful beach in Penang National Park (PNP). However this beach is categorised as one of dangerous beach for swimming activities in Malaysia due to the drowning incidents reported almost every year. The steep beach slope and rip current were among the factors that lead to this incident. Using bathymetry profile, current, tidal and sediment data collected at site incorporated with UKMO wave data analysis, the hydrodynamic pattern was simulated using Mike 21 modelling software. Result from the model showed the evidence of rip current existence along the coastline. It showed that this rip current event occurred during spring tide phase when the flow change from Flood to Ebb. During this period, the current tend to move parallel to the shoreline with maximum speed of 0.3m/s which is capable to swipe away a swimmer. The bathymetry profile at Kerachut is very steep and dangerous to swimmers since there is a 4 meter sudden plunge just meters away from the shoreline.

Keywords: Malaysia, drowning, rip current, bathymetry, hydrodynamic.

1. Introduction

Rip currents occur as a result of interaction between waves, current, water level and near shore bathymetry. According to [1], rip currents flow faster near the water surface. This current are ubiquitous along wave dominated sandy beaches that exhibit three-dimensional surf zone sandbars [2]. Rip currents most typically form at low spots or breaks in sandbars, and also near structures such as groins, jetties and piers. It can be very narrow or extend in widths to hundreds of yards. The seaward pull of rip currents varies: sometimes it ends just beyond the line of breaking waves, but sometimes it continue to push hundreds of meters offshore. The illustration for rip currents is shown in Figure-1.



Figure 1. Rip current formation along the shoreline.



According to [3], most of the fatal drowning each year in US were associated by the effect of rip currents. These rip currents are identified as being responsible for more than 100 deaths annually in US [4]. Breaking waves generate narrow currents sometimes directed seaward through the surfzone because of an excess of momentum flux [5]. Swimmers being caught in a rip current are easily transported off their feet to deeper waters seaward.

It is reported that drowning incident occur every year at this beach stretch. The Kerachut beach is among the most dangerous stretches in Malaysia. The latest mishap occurred in January 2014 when five of team building members were swept away by strong waves with three of them were found dead. The drowning incident is also reported almost every year at Kerachut Beach. The objectives of this study are to identify the occurrences of rip current along shoreline of Kerachut and investigate the other factors that lead to these drowning incidents. Collection of raw data at site and computer modelling are used for analysis purpose.

2. Materials and methods

2.1 Study Area

Kerachut is located on the north-western tip of Penang Island, Malaysia at $5^{\circ}27'3.36''$ N and $100^{\circ}10'57.52''$ E. It is among the beaches managed by PNP including Monkey Beach, Teluk Aling, Teluk Duyung and Teluk Kampi. PNP is governed under the Department of Wildlife and National Parks of Malaysia (Perhilitan). This park is famous among the tourist for its rainforest and beautiful beaches. It is a great place to go trekking, camping, fishing, wildlife spotting and beach activities. The total length of Kerachut beach is 558 m with the slope gradient of 15° [6]. The main transport to Kerachut is either by boat which takes 15 minutes ride from PNP jetty or by one and half hour trekking from PNP entrance. The sand colour ranges from white to dark brown and formation of sandbar tend to change prior to the monsoon season.



Figure 2. Location of Kerachut Beach in PNP.

Kerachut is also known for its two layers of lake or lagoon of salty sea water and fresh water known as Meromictic Lake. This lake has two layers of water with different density that do not mix with each other [7]. According to [8], it is one of the few Meromictic Lakes in Asian Region and covers 10 hectares of PNP. During high tide, sea water could be seen on the top of the layer and fresh water would replace when the low tide occurs due to lower density of fresh water.

The Kerachut Turtle Conservation Centre represents the centre for sea turtles research study in Penang Island. The beach was identified as the most preferred landing area for Green Turtle in Malaysia. According to [6], a total of 43 Green Turtle nests were recorded at Kerachut and Telok Kampi from December 2009 to December 2010. The hatchery at Kerachut is the only hatchery in Penang which purposes to incubate turtle eggs and produce hatchlings to be released into the sea.

2.2 Field Data Collection

The field data collection works were carried out from 27th May 2014 until 20th June 2014. The information forms the basis for the required modelling and assessment purpose.

2.3 Bathymetry

Hydrographic survey is the science of marine surveying that determines the position of points on the earth's surface and also depths of the sea [9]. An Odom Hydrotrac II Single Frequency precision. echo sounder was utilized in the survey. Bathymetric survey at the site covers an area of 4000 meters by 1500 meters with 50 meters line spacing and 250 meters check lines (Figure-3). The objective of the survey is to produce an accurate bathymetric profile at Kerachut and nearby beach.



Figure 3. Transect line for bathymetry survey.

2.4 Current Measurement

The currents are measured with Acoustic Doppler Current Profiler (ADCP), a device that utilizes sonar to measure the velocity of moving water particles. The ADCP records water velocities with respect to the depth. Therefore, it can produce a profile of water currents over a range of depths. The current measurements were conducted at two locations for three weeks deployment period as DID Guidelines covering both spring and neap tide. The ADCP positions were indicated in Figure-3 and Table- 1. The data obtained from the measurement during both tidal periods are depicted in Figure-4 and Figure-5.

Table 1. Location of ADCP Deployment.

Location	Latitude (N)	Longitude (E)
ADCP 1	5.46219°	100.16867°
ADCP 2	5.44586°	100.15699°

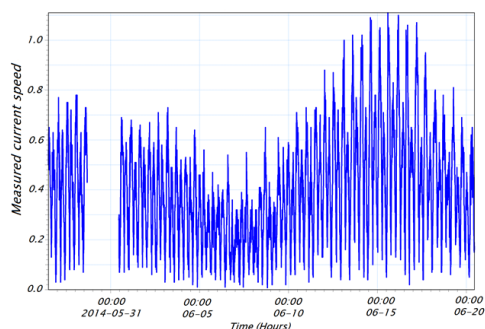


Figure 4(a). Measured current speed at ADCP 1.

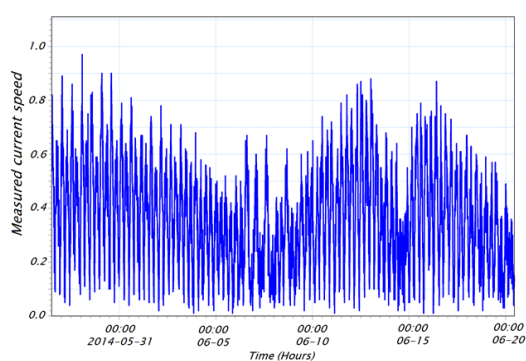


Figure 4(b). Measured current speed at ADCP 2.

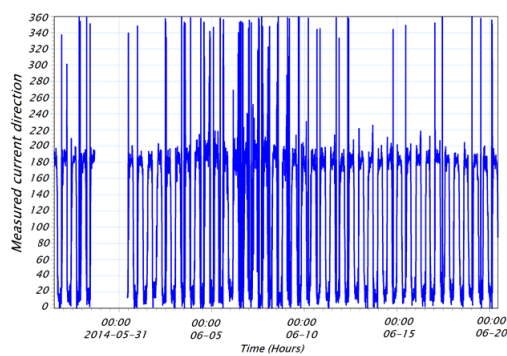


Figure 5(a). Measured current direction at ADCP 1.

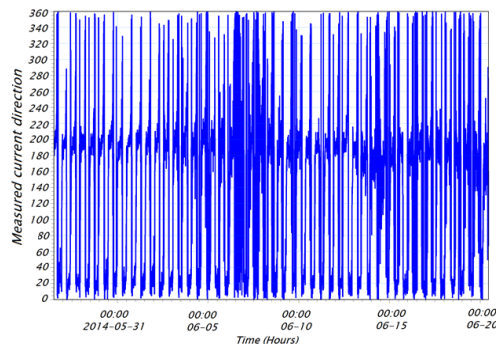


Figure 5(b). Measured current direction at ADCP 2.

Based on ADCP 1 data, the range of current speed is 0 - 1.10 m/s with the dominant current coming from 0° - 30° and 170° - 200° direction. There were missing data from 29th -31st May 2014 due to disturbance of the sensor during deployment period. For ADCP 2, the range of current speed is 0 - 0.95 m/s with the dominant direction coming from 0° - 30° and 170° - 220° .

2.5 Water Level

Water levels are produced by a combination of two major force components - gravitation forces and centrifugal forces. These forces induce a variation of the tidal levels due the shear effect of the winds and regional barometric pressure fields (in many cases producing an elevation due to a low or a reduction due to a high pressure field). The variation of the water levels due to climatic conditions is usually described as residual levels. One unit of tide gauge was installed at PNP jetty for two weeks duration for model calibration purpose.

2.6 Bed Samples

A total of 20 bed samples were collected within Kerachut and TelukKampi shore. These samples provide information on the type and distribution of bed materials present within the study area. A mechanical grabber was used to obtain seabed samples. The location of each sample was determined using a handheld GPS device. Since the position was marked, the grabber was released and retrieved after touching bed. Each sample was stored in a clear plastic bag which was then placed in another plastic bag before being tied and labelled. All samples were kept in a cool dry place before being sent to a laboratory for Particle Size Distribution (PSD) analysis. It can be inferred from the bed sampling exercise and analysis that the bed material within the study area primarily consists of clay and silt which particle size is $<63 \mu\text{m}$.

2.7 Wave Analysis

The meteorological conditions at Kerachut are governed by the Northeast (NE) and Southwest (SW) monsoon. The NE monsoon occurs between November to March while SW monsoon occurs between May to September [10]. Thus, April and October are inter-monsoon periods.

To derive the wave conditions at Kerachut, offshore wind and wave data were purchased from the United Kingdom Meteorological Office (UKMO). Figure-6 shows the location of the UKMO station and data covered from 28th May 1999 to 30th June 2014. The wave climate at the offshore of Kerachut is composed of locally generated wind waves and swell waves approaching from Indian Ocean and Andaman Sea.

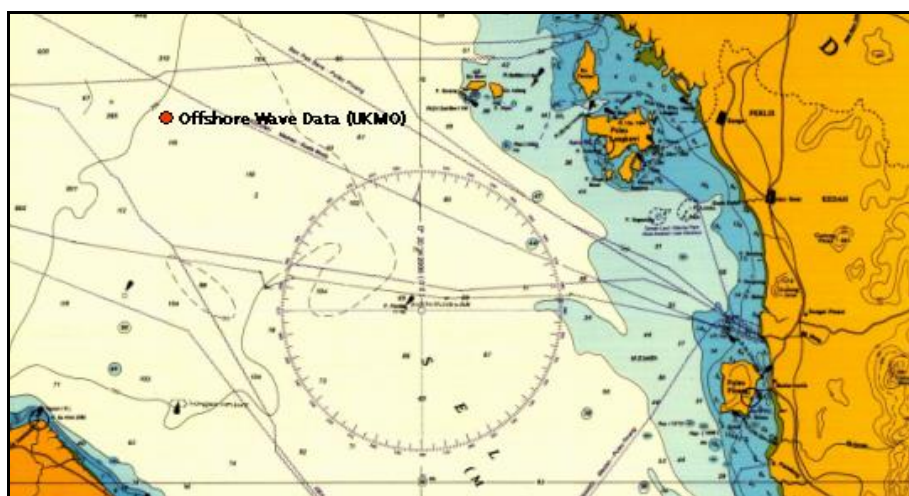


Figure 6. Location of wave data point (UKMO).

Figure-7 shows the time series of Significant Wave Height (H_s) of the purchased UKMO data while Figure-8 shows the wave rose of the same Hmo-parameters. From the wave rose, it is clearly seen that the long period swell waves are approaching mainly from westerly directions during SW monsoon.

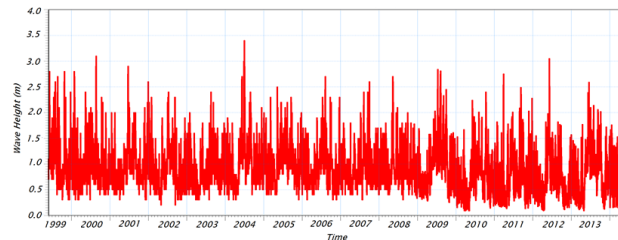


Figure 7. Time Series of Significant Wave Height (Hmo) Data (1999-2014).

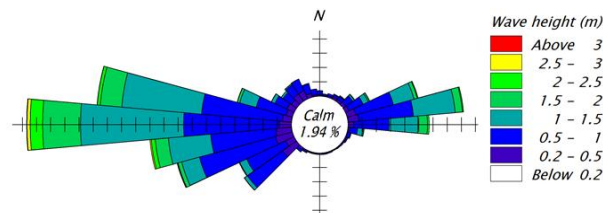


Figure 8. Offshore wave rose for the UKMO data.

The wave data used was from the offshore waves and far away from study area. Hence, numerical modelling of MIKE 21 NSW was used to transform this waves into the near shore 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.

The model parameters include bottom roughness (Nikuradse roughness parameter), $k_N = 2$ mm; and wave breaking parameters, $\gamma_1 = 1.0$, $\gamma_2 = 0.8$ and $\alpha = 1.0$. The bottom roughness and wave breaking parameters are very important in the surf zone. Parameters related to the discretisation of the wave spectra in the model are maintained at well-proven default values. Input for bathymetry, wave properties along the boundary, wind condition, bottom roughness, tidal elevation and wave breaking parameters were used to setup the hydrodynamic model.

2.8 Hydrodynamic Modelling

The modelling is carried out using the hydrodynamic module in MIKE 21 modelling system, MIKE 21 HD. This is a basic module of the entire MIKE 21 software. It provides the hydrodynamic basis for the computations performed in most of the other modules. The objectives of the modelling is to establish the existing hydraulic regime for the study area and to assess the rip current occurrences along the Kerachut shoreline. The water levels and flows are resolved on a rectangular grid covering the area of interest when provided with the bathymetry, bed resistance coefficients, wind and wave field and hydrographic boundary conditions.

This study adhere the 'Guidelines for Preparation of Coastal Engineering Hydraulic Study Reports' prepared by Department of Irrigation and Drainage (DID), Malaysia. This guidelines were introduced to ensure that all the hydraulic and coastal modellings comply with the Malaysian's standard requirements.

The important criteria in modelling work is to define the model area that needs to be set up. The hydrodynamic model extends from Goh Don, Thailand to Bagan Datoh, Malaysia, which covers

approximately 378 km x 351 km. The model contains four layers with an outer 270 m grid (coarse grid) down to 10 m grid (local grid) in order to enhance the resolution in the vicinity of the site. All nested grids are dynamically linked and solved simultaneously. The bathymetry data for the model setup is based on the Admiralty Charts from Royal Malaysian Navy, digital C-Map data from Mike 21 and NAHRIM bathymetry survey. The bathymetry profile for the model is shown as Figure-9.

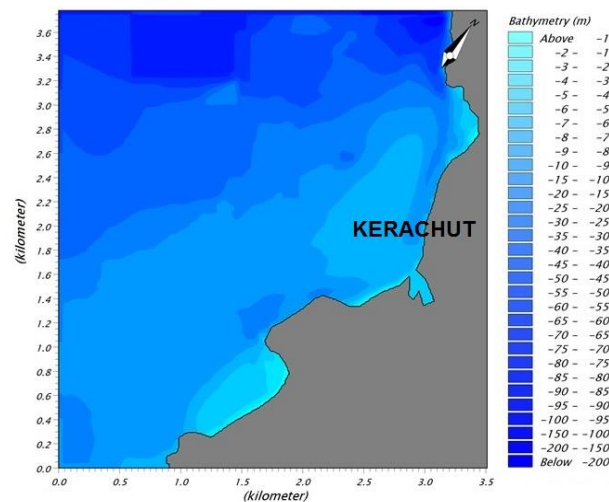


Figure 9. Bathymetry for Nested Hydrodynamic model: local grid.

The bed roughness is prepared based on the waves with ripples height of 4 m to 7 m and lengths of 250 m to 450 m exist in the Malacca Strait. The Manning number can be expected to vary between 17 and 61 over the entire study area. In the calibration, Manning numbers of 25 to 55 was used based on Different Range Of Water Depth.

3. Result and Discussion

The model was analysed for spring and neap tidal cycle of 27th May 2014 until 20th June 2014 covering a total of 25 days period. This period was sufficient enough to cover one completed tidal cycle and can be assumed to represent a hydrodynamic condition for the whole study area. The acceptance criteria for the calibration is based on. For the calibration parameters to be acceptable, the average absolute difference between the models calculated and observed should be less than the percentage stated in Table-2.

Table 2. Root Mean Square (RMS) acceptance for hydrodynamic model.

Parameter	Acceptance Criteria
Tidal range	RMS Error 10%
Current speeds	RMS Error 20%
Current direction	RMS Error 20°

The model was calibrated and verified using the NAHRIM measured water level. The extracted water levels from the model simulation suit very well with the observed data (an average difference of less than 10%). The current patterns in the Malacca Straits flow to the South during flood and went North during Ebb with the acceptance criteria was less than 20% in speed and 20° in direction.

Based on modelling result, it can be said that KerachutBeach is having semi-diurnal tides with two high waters and two low waters in a day with maximum tidal range of 2.90 meters during spring tides. It was within the Highest Astronomical Tide (HAT) predicted by [11] using Kedah Pier Station which predicted 3.09meters range of water height.

The Significant Wave Height (H_s) show relatively small during the 30 years return period simulations. Analysis of wave model showed the maximum of 1.0 meter height along the Kerachut. Wave plays major role in sediment transport based on its frequencies. The sediment transport may actively occurs during May to September when the wave direction coming from 270°(West). This large reduction in wave height is caused by sheltering effect of the Langkawi Island and the dissipation of wave energy in the shallow coast of Penang Island.

The current pattern of Kerachut shoreline were plotted to determine the presence of rip current along the shoreline. Based on the analysis, it clearly showed the evidence that Kerachut is having rip current during the period of flood to ebb flow of spring tide. Typical plot of current pattern during this period is shown in Figure-10.

During this period, the rip current at Kerachut will flow to the NE and SW direction which parallel to the shoreline. The changes of bathymetric profile along the surf zone created the rip current to these directions as the sea water flow is influenced by tidal fluctuation. However, the mean current speed at Kerachut is generally moderate which in the range of 0.1 to 0.3 m/s and rip current will only occurred during spring tide when the flow change from Flood to Ebb. During other periods, the rip current effect can be considered as safe.

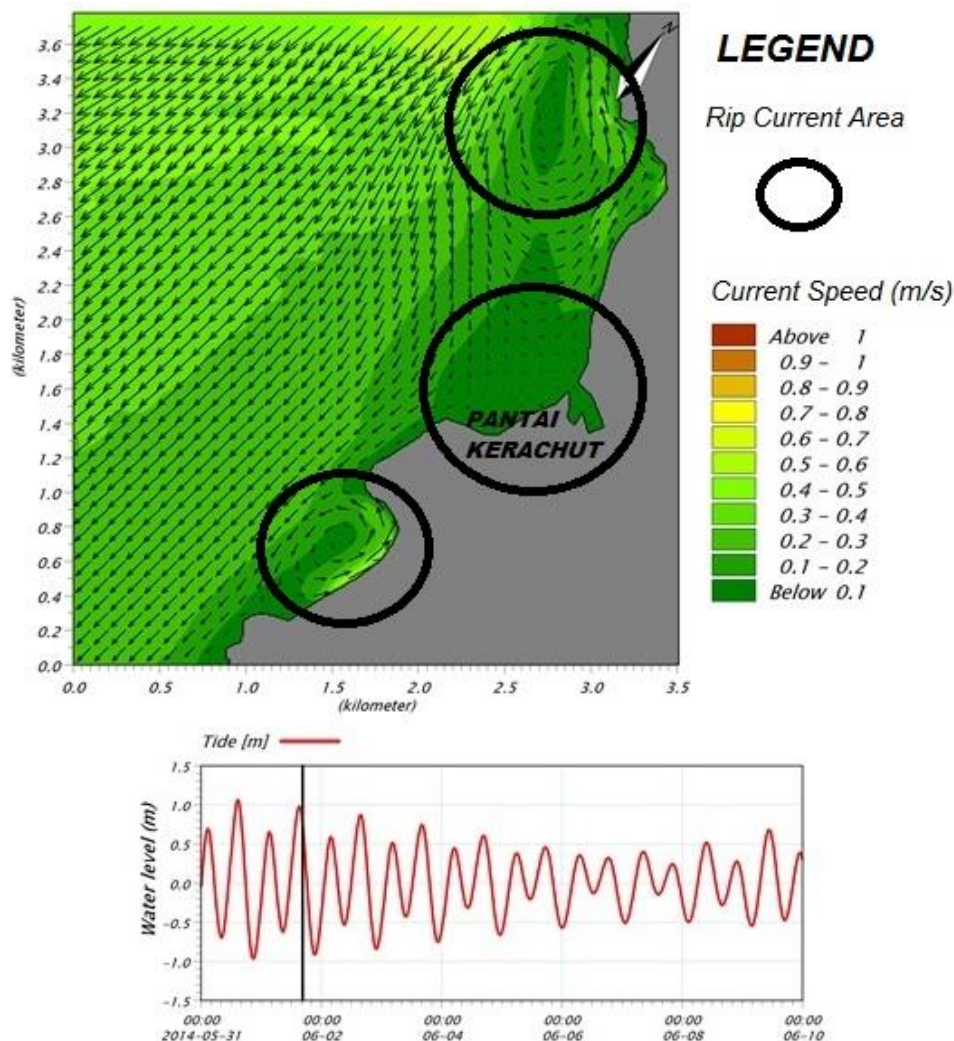


Figure 10. The rip current area during Flood and Ebb flow at Kerachut shore.

The bathymetry and beach profile transect for Kerachut Beach and TelukKampi Beach is shown in Figure-11.

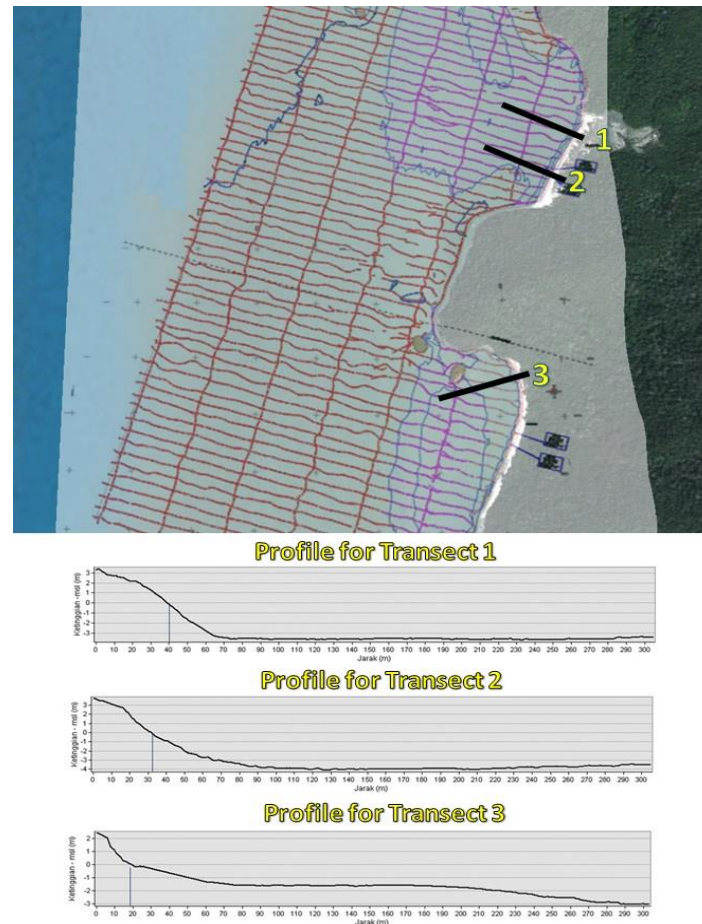


Figure 11. Shoreline profile at Kerachut and Teluk Kampi.

Based on the analysis of bathymetric data in Figure-11, it shows that this beach is also dangerous for swimming activities due to its steepness and some large scale of rocky features spotted on the seabed. As enter a few meters to the beach, there will be a plunge at a very sharp angle with 4 to 5 meters in depth. The strong wave and monsoon impact may create such a dangerous morphology profile along the coastline as the bathymetry contour was constant along the shoreline. In addition, the muddy properties which dominated the seabed make it more dangerous to the swimmer. Only a small stretch area of PantaiTelukKampi (Transect 3) is identified safe for swimming activities due to its gentle and mild profile of the beach.

Conclusion

Based on the extensive data collection and hydrodynamic modelling that have been carried out, it proved that Kerachut Beach should be avoided for swimming activities. Modelling result shows that rip currents occurred during spring tide when the flow change from Flood to Ebb. This rip current tend to flow parallel to the shoreline in the direction of NE and SW with the magnitude of 0.3m/s. In addition, the coastal profile is very steep with sudden plunge of 4 to 5 meter by just meters away from the shoreline. The steepness of bathymetry profile, rip current occurrence and some rocky material scattered along the seabed makes this beach too dangerous for the swimmers. Swimming should be prohibited to all visitors except at the beach in front of PNP Guard Post at TelukKampi. According

[12], it is difficult to educate public on how to identify rip current. Hence, safety briefing related to current and wave pattern, tides and monsoon impact must be assigned to PNP officers and rangers on duty to enhance understanding about the hydrodynamic behaviour along the coastline and ensure the effective monitoring of the visitors.

References

- [1] Haas, K.A. and Svendsen, I.A. (2002). Laboratory measurements of the vertical structure of rip currents. *Journal of Geophysical Research*, 107: 3047; doi: 10.1029/2001JC000911
- [2] Castelle, B., Reniers, A., MacMahan, J. (2013). Numerical modelling of surfzone retention in rip current systems: on the impact of the surfzone sandbar morphology, *Journal of Coastal Dynamic*. p. 295-304
- [3] Gensini V. A., Ashley W. A. (2009). An examination of rip current fatalities in the United States. *Nat Hazards*: DOI 10.1007/s11069-009-9458-0
- [4] Alvarez-Ellacuria, A.; Orfila, A.; Olabarrieta, M.; Medina, R.; Vizoso, G., and Tintore., J. (2010). A Nearshore Wave and Current Operational Forecasting System. *Journal of Coastal Research*, 26(3), 503–509. West Palm Beach (Florida), ISSN 0749-0208
- [5] Bowen, A.J., 1969. Rip Currents, 1, Theoretical Investigations. *Journal of Geophysical Research*, 74(23), 5467–5478
- [6] Sarahaizad, M.S., Shahrul Anuar, M.S., Mansor, Y. (2012). Nest Site Selection and Digging Attempts of Green Turtles (*Chelonia Mydas*, Fam. *Cheloniidae*) at Pantai Kerachut and Telok Kampi, Penang Island, Peninsular Malaysia. *Malays. Appl. Biol.* (2012) 41(2): 31–39
- [7] Wetzel, R.G. (2001). *Limnology: Lake and river ecosystems*. 3rd Edition. New York: Academic Press.
- [8] Hong, C.W. & Chan, N.W. (2009). The Potentials, Threats and Challenges in Sustainable Development of Penang National Park. *Malaysian Journal of Environmental Management* 11(2) (2010):95-109
- [9] Aklima, C. A., Rusli, O. (2011). Hydrographic Survey using Real Time Kinematic Method for River Deepening. *Geoinformation Science Journal*, Vol. 11, No. 1, 2011, pp: 1-14
- [10] Ahmad, J.S., Mohd Zaki, M.A., & Zubaidi, J. (2011). Potential Climate Change Impact on Water Resources in Malaysia, *Malaysia Water Research Journal*, Vol 1(2011) : p.5-14
- [11] Hydrographic Directorate, Royal Malaysian Navy, Tide Tables for Malaysia, Volume 1 2015
- [12] Fletemeyer, J. and Leatherman, S. (2010). Rip current and beach safety education. *Journal of Coastal Researches*, 26: 1-3