# Simulation Model to Assess Tidal Potential Energy in East Coast of Malaysia using GIS

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**Abstract**. This article studies the GIS simulation of yearly power generation in five different tidal stations in the East Coast region of Malaysia. The tidal stations are Geting, Tanjung Gelang, Tioman, Tanjung Sedili and Cendering. The tidal station in Geting is not analysed in this study because the tidal range is insignificant. After analysing the lagoons nearby to the four tidal stations, Tanjung Gelang and Tanjung Sedili are chosen in this study based on their natural characteristics and geomorphology of lagoons. The simulation model is based on yearly power generation using tidal barrage. This article also looks into the model in terms of mapping using GIS software to obtain bathymetry and tidal range data. Bathymetry data in GIS format is obtained from NOAA (National Oceanic and Atmospheric Administration) and tidal range data is obtained from 'Jabatan Ukur dan Pemetaan Malaysia'. The latest tidal data up to date is the year 2011. The minimum depth of tidal basin should be 3.0 meter. Using GIS software to analyse bathymetry and tidal range data, the results are then combined to find yearly generation power output in the two tidal stations and are plotted in one map for each tidal station. The area of basin in Tanjung Gelang and Tanjung Sedili are 17.736 $km^2$ and 27.919 $km^2$. The calculation includes the important parameters such as area of basin, tidal range, number of tide cycles per year, and number of hours per tide. From the results and analysis, it is concluded that Tanjung Sedili and Tanjung Gelang produce 25.0 GWh and 21.6 GWh as their yearly power generation in 2011.

## 1. INTRODUCTION

A tidal phenomenon is a sea water movement in sequence due to natural entity [1]. Tidal and its wave are different as their relationship is hard to determine. A tidal involves sea water increment and decrement, while its waves show the movement of its flow horizontally. The occurrences of tidal are because of gravitational force from solar system. Hence, tidal energy depends on the rise and fall of sea water level which forms tidal range and this leads to the creation of hydroelectricity [2].

To control the flood and ebb of the tides to drive the turbines and generate electricity, tidal barrage is used. The primary functions include to increase the depth of river, to separate fresh water from salt water, and to reduce the risk of tidal flowing up the river. Still, the usage of tidal barrage to generate electricity is the main reason for it to be built along lagoons that are suitable for tidal power generation [3].

Tidal energy is the subset of hydropower that produces electricity when tidal energy is converted.

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Future energy generation depends on the potential of tidal energy because it is more predictable than any other renewable energy sources likes solar and wind. But it is limited for some places due to the tidal range that is not sufficient and hence the availability of sites is one of the limits besides high cost [4].

## 2. TIDAL BASIN POWER GENERATION

Tidal barrage works like a dam which is built across an estuary. Electricity generation from tidal barrage uses same method as generation of hydroelectric. The difference is that tide current flows in both directions in a tidal barrage. The turbine used in a tidal barrage can be single-flow or bi-directional [5].

### 2.1 Single-basin tidal barrage

Single basin system consists of one tidal basin with barrage built across an estuary [5].

### 2.2 Double-basin tidal barrage

Double-basin system consists of two basins. The main basin of a double-basin tidal barrage is the same as the basin of a single-basin system. During the ebb-generation phase, a portion of energy is used to pump water into the second basin. The second basin acts like a storage where the electricity power generation is generated according to demand [5].

### 2.3 Ebb generation

When high tide happens, seawater enters through sluice gates to fill the tidal basin. The filling sluice gates are closed when the basin is filled completely. The operation will continue when it passes the point of low tide or until the head on the turbines has reached the minimum value where they can operate efficiently. The distributor gates are then closed. Seawater will fill into the basin again when it rises to the basin level, making the sluice gate being opened [6].

### 2.4 Flood generation

When seawater level rises and an amount of hydrostatic head is achieved across the barrage, the sluice gate will open. The turbine gates are then also opened for seawater to flow in thus generating electricity [7].

### 2.5 Double-mode generation

Double mode generation uses flood and ebb generations to generate electricity. The turbines and sluice gates are closed and seawater is only allowed to pass through the sluice gate and turbines when near the end of the flood cycle. The sluice gates are opened once the minimum hydrostatic head for the rated turbine is achieved. The sluice gates are closed during high tide while trapping seawater to achieve a significant hydrostatic head. Seawater flows through the turbines to generate electricity in ebb mode [5].

### 2.6 Classification of Estuary

Figure 1: Bar built estuary

These estuaries are semi-isolated from ocean waters by barrier beaches (barrier islands and barrier spits). Formation of barrier beaches partially encloses the estuary, with only narrow inlets allowing contact with the ocean waters. They are extensive along the Atlantic and Gulf coasts of the U.S. in areas with active coastal deposition of sediments and where tidal ranges are less than 4 m. The average water depth is usually less than 5 m and rarely exceeds 10 m [8].

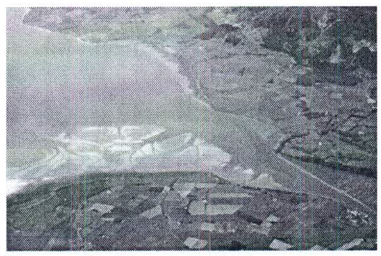

Figure 2: Drowned river valleys

Their width-to-depth ratio is typically large, appearing wedge-shaped in the inner part and broadening and deepening seaward. Water depths rarely exceed 30 m [9].

## 3. ANNUAL POWER GENERATION

### 3.1 Tidal stations

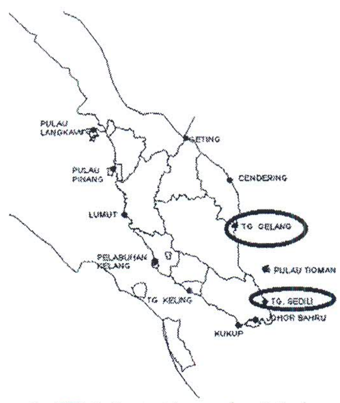


Figure 3: Tidal stations in Malaysia [10]

This study covers the East Coast region of Peninsular Malaysia. The tidal stations are Cendering, Tanjung Gelang, Pulau Tioman and Tanjung Sedili. But due to the natural structure of the nearby lagoons in the 4 tidal stations, among them, Tanjung Gelang and Tanjung Sedili have the best characteristics on their estuaries structure and hence these 2 areas are selected in this study, as highlighted in Figure 1. Geting is not covered in this study due to its insignificant tidal range value. The minimum depth for tidal basin is 3.0 meter [11].

### 3.2 Tidal range difference

In double mode tidal basin power generation, the equation to determine tidal range is shown as below.

$$\text{Tidal range} = \text{High tide} - \text{Low tide}$$

### 3.3 Tidal basin power generation

The equation below demonstrates the calculation of yearly power generation from tidal plants [5].

Potential energy contained in water volume impounded in basin

$$E_p = 0.5\,\rho g A_b \Delta h_b{}^2 \qquad \text{(Eq.1)}$$

$\rho$ = density of seawater, 1.025 $ton/m^3$
$g$ = 9.81 m/s$^2$
$A_b$= horizontal area enclosed by basin, km$^2$
$\Delta h_b$ = mean tidal range, m
$E_p$ = potential energy over a tide cycle, GJ

The tidal regime generally consists of two flood and two ebb tides, with a semi-diurnal period of 12.42 hours.

$$\textit{Total energy potential per day} = \frac{24}{12.42} E_p \text{ GJ}$$

$$\textit{Mean potential power, } \bar{P} = \frac{24}{12.42} x \frac{1}{24x60x60} E_p \text{ GW}$$

$$\bar{P} = 0.11244\, A_b\, \Delta h_b{}^2 \text{ MW} \qquad \text{(Eq. 2)}$$

The potential annual tidal energy output, $E_{yr}$ in GWh:

$$E_{yr} = 0.11244\, x\, 24\, x\, 365\, A_b\, \Delta h_b{}^2\, \eta$$

$$E_{yr} = 0.985\, A_b\, \Delta h_b{}^2\, \eta \qquad \text{(Eq. 3)}$$

$\eta$ = efficiency, include efficiency range of 20% - 40% with an average of 33%[6].

### 3.4 Mode of generation

In this study, double-mode generation is studied. Electricity is produced over a longer period of around 8 hours per tide.

To harness tidal energy, for maximum efficiency, a double cycle system is the most suitable. For filling seawater into the basin, it gains potential energy due to lunar gravitational pull while for the emptying stage, the basin water flows out due to gravity action of the earth. The energy available from a tidal plant depends on two factors, namely the tidal range and the volume of water in the basin.

### 3.5 GIS usage

GIS software is used to evaluate the suitable lagoons for building of barrage. In this study, we use Quantum GIS or QGIS software which an open free software. QGIS is used to identify the natural characteristics of lagoons. Besides that, it is also used to analyse the bathymetry data obtained from NOAA and to plot the tidal range nearby the lagoons too. Tidal range data is obtained from 'Jabatan Ukur dan Pemetaan Malaysia' published hardcopy book and the data is integrated into GIS data format. The latest tidal range data obtained is from 2011. Finally, a map will be drawn using QGIS using all the data obtained.

## 4. RESULTS AND ANALYSIS

### 4.1 Results

Table 1: Comparison between annual tidal energy output of selected tidal stations in 2011, 2010 and 2009

| Year | Site | Basin area | Tidal range | $E_{yr}(\eta)$ |
|---|---|---|---|---|
| | | [km²] | [m] | [GWh] |
| 2011 | Tanjung Sedili | 27.9 | 1.66 | 25.0 (33%) |
| | Tanjung Gelang | 17.7 | 1.93 | 21.6 (33%) |
| 2010 | Tanjung Sedili | 27.9 | 1.76 | 28.2 (33%) |
| | Tanjung Gelang | 17.7 | 2.01 | 23.3 (33%) |
| 2009 | Tanjung Sedili | 27.9 | 1.73 | 27.0 (33%) |
| | Tanjung Gelang | 17.7 | 2.00 | 23.6 (33%) |

The result is based on an assumption of 33% overall efficiency.

Figure 2 and 3 show the map plotted using QGIS and the parameters involved in calculating the annual generation for each location in the year of 2011.

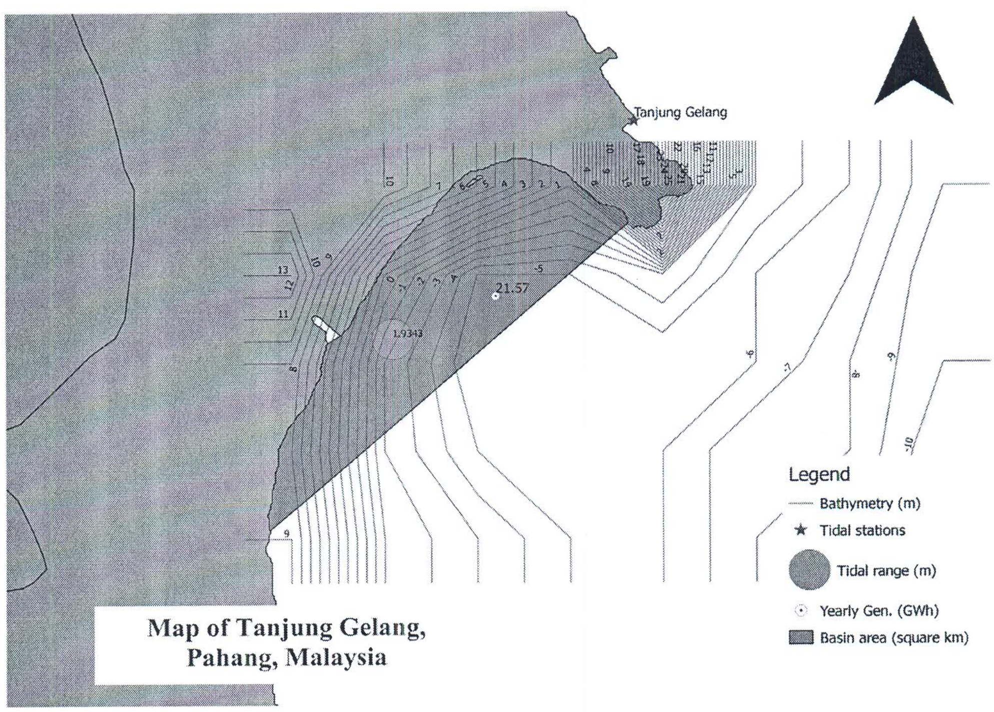


Figure 4: QGIS map of Tanjung Gelang, Pahang, Malaysia in 2011

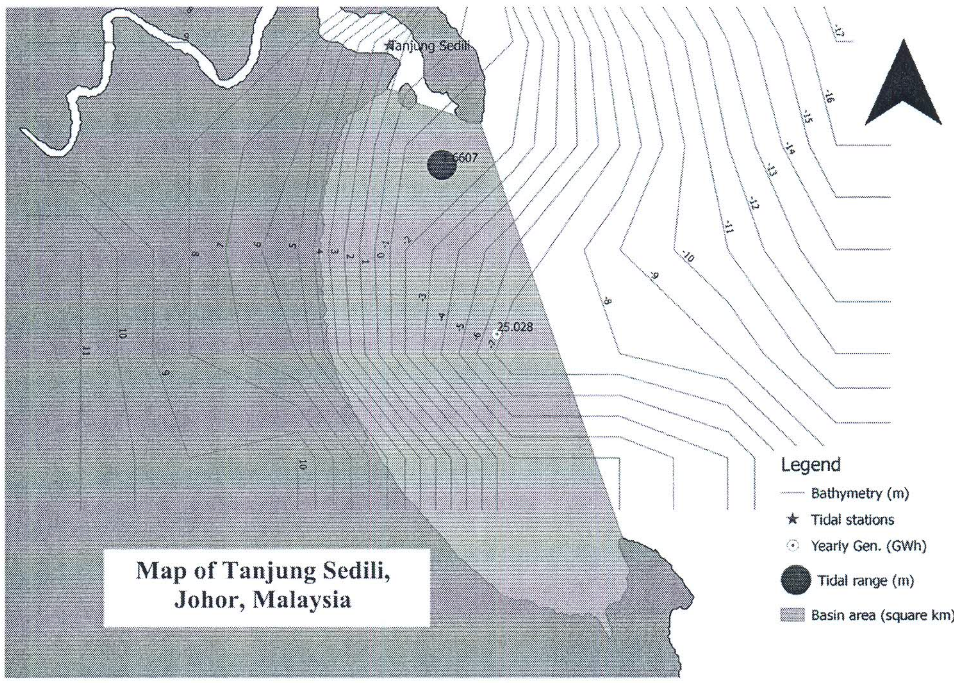


Figure 5: QGIS map of Tanjung Sedili, Johor, Malaysia in 2011

## 5. CONCLUSION

Tanjung Sedili has the highest yearly generation of power among the two tidal stations in East Coast region of Malaysia in year 2011, 2010 and 2009. This is due to the larger area covered by the barrage compared to Tanjung Gelang although the tidal range in Tanjung Gelang is higher. From the analysis, it is possible to harness tidal energy in the East Coast region of Malaysia to generate electricity due to the nature characteristics of the lagoons that contribute to the large areas for building a dam.

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