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STUDY ON WATER RESOURCES IN TIOMAN ISLAND

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Abstract. Tioman Island which is situated in the southeast of Pahang State is one of the small islands in Malaysia that have been promoted as a tourism destination. Based on the previous study, the island requires more than 2000 m^3/day of water for domestic and tourism industry consumption, and the demand is expected to rise due to the increasing population and tourism activities. Study on surface water and groundwater indicate a good potential for water resources to meet the demand of the future water needs. An intensive study is being carried out to investigate the quantity of water resource that is available in this island. In this study, the amount of surface water flow was estimated by using MIKE 11 NAM Model, and for groundwater extraction ASM (Aquifer Simulation Model) was used. This paper reports the preliminary findings of the amount of the water resources available in Kg. Tekek, Tioman Island, i.e. the daily average of surface runoff is 3024 m^3/day and the groundwater extraction is 5003 m^3/day, that was calculated for the period of February 1999.

Key words: surface water, groundwater and small island

Abstrak. Pulau Tioman terletak di sebelah tenggara Negeri Pahang merupakan salah satu dari pulau-pulau kecil di Malaysia yang sudah dimajukan sebagai destinasi pelancong. Berdasarkan penyelidikan terdahulu, pulau ini memerlukan bekalan air bersih melebihi 2000 m^3/hari untuk keperluan penduduk tempatan dan pelancong, dan keperluan ini akan meningkat dengan peningkatan jumlah penduduk dan pelancong. Penyelidikan terhadap air larian permukaan dan air bumi menunjukkan bahawa keduanya berpotensi sebagai sumber air yang baik untuk memenuhi keperluan air pada masa hadapan. Suatu kajian yang intensif dilaksanakan untuk mengkaji keupayaan sumber air yang sedia ada bagi pulau ini. Untuk menentukan berapa banyaknya air larian permukaan, perisian model MIKE 11 NAM digunakan, dan untuk menentukan keupayaan air bumi yang boleh dipam, ia berpandukan kepada perisian Aquifer Simulation Model (ASM). Kertas kerja ini membentangkan penemuan permulaan bagi jumlah sumber air yang sedia ada di Kg. Tekek Pulau Tioman, purata air larian permukaan harian adalah 3024 m^3/hari dan air bawah tanah yang boleh dipam adalah sebanyak 5003 m^3/hari, yang dikira untuk tempoh bulan Februari 1999.

Kata kunci: Air larian permukaan, air bumi dan pulau kecil

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1.0 INTRODUCTION

1.1 General

Based on the previous study by Nazan Awang and Loganathan [1], in Tioman Island have been investigated, two areas namely, Kampung Tekek and Kampung Juara, which have a good potential for exploitation of surface water and groundwater. The current study is concentrated in Kampung Tekek, and intend to assess the maximum annual water yield from surface water and groundwater. For this purpose, available models were used to calculate and simulate the hydrological and hydrogeological data.

In hydrological analysis, long term data are required for any decision. Unfortunately, in the present study such long term data are not available. However, the present study uses the rainfall data of 14 years (1986–1999) during which the data in 1993 and 1995 are not available. Also there are many missing rainfall data from 1991 to 1997.

The evaporation data taken from Mersing (1986-1999) were used because there is no evaporation station in Tioman Island. The evaporation station in Mersing is the nearest station to Kampung Tekek.

The runoff data are available one month only. Precipitation, evaporation and runoff data are not complete. Simple Arithmetic Average Method were used for filling up the missing data.

The main river in the catchment area of Kampung Tekek is Ayer Besar River, which does not have a stream flow gauge. In the case of groundwater level fluctuation, long term data are also required but only a 10 month-data record is available.

After treating all of the data properly, the magnitudes of surface water runoff and the maximum extraction of groundwater can be predicted by simulation using existing models, namely MIKE 11 NAM Model and ASM (Aquifer Simulation Model) for surface water and groundwater, respectively. The results of the water simulation are compared with the observed data, and the potential of surface water and groundwater resources are then examined.

1.2 Brief Description of the Study Area

Tioman Island situated in the State of Pahang is one of the islands in Malaysia that have been promoted as a tourist destination. It is located east of Peninsular Malaysia at 2° 43' 00" to 2° 54' 00" N latitude and 104° 6' 00" to 104° 12' 30" E longitude (see Appendix A). The area of the island is about 131 km^2, with a maximum width of about 11 km (west to east) and a maximum length of about 20 km (north to south). It is the largest small island among a group of 64 volcanic islands. The coast of Tioman Island is predominantly featured with rocky hills with green flora on the top.

There are many big stones arrangement like a stronghold on the foothills at the seaside. In some places there are beautiful sandy beaches and the narrow plains, such as Kampung Tekek, Kampung Salang, Kampung Juara, Kampung Mukut, Kampung Pasir, Kampung Nipah, Kampung Genting, Kampung Paya and Kampung Lalang. Each of them has a sandy beach as a recreation area which attracts visitors. In general, the island is still in pristine condition with a crystal clear azure sea and rich marine life.

2.0 TIOMAN ISLAND'S CONDITION

2.1 Topography

The terrain of the island is quite steep, rising from 75 m to 1,040 m above mean sea level, resulting in short and steep river profiles. About 12 km^2 of the island's area falls in the range of slope between 0^9 to 30°' while about 119 km^2 is having slope greater than 30°. Approximately 90% of the land is occupied by slope greater than 30° [4]. In the hinterland, there are hills, mounts, and plateau, covered by flora of tropical forest, namely Gunung Kajang (1,038 m), Gunung Rombin Tioman (976 m), Gunung Seperak (958 m), and Bukit Nenek Semukut (766 m). There are many small rivers, and the largest river is Sungai Mentawak (about 5.5 km). Ayer Besar River basin lies in Tekek Area. Keliling River basin and Baharu/Air Dalam River basin lie in Juara Area. The down stream area of the basins are coastal plains.

2.2 Geology and Hydrogeology

Tioman Island is made up mainly of Triassic granite with Permian volcanic at the eastern part of the island. In low lying areas such as Kampung Tekek, they are generally made up of thin layers of alluvium consisting silt, sand and gravel with some clays and corals. The study area is classified as an unconfined aquifer comprising mainly of about 14-m thick medium to coarse sand with coral along the coast. Geophysical investigation using gravity method showed that the overall coral thickness is most likely within 7 to 20 m [2].

Hydro-geological factors have a major influence on the distribution of groundwater on an island. These factors include the permeability and porosity of the rocks and sediments, and the presence and distribution of karstic features such as small cave systems and solution cavities. Surface water resources prevail only on islands with relatively low permeability. Groundwater resources are most abundant on small islands with moderate to high permeability and porosity. Size, shape and topography of a small island are major influences on the occurrence of both surface and groundwater resources [3].

The geology of Tioman Island was well described by Bean [1972]. This island is underline mainly by granite rock/hard rocks which mean has least groundwater potential, and a thin narrow belt of metamorphosed volcanic and sedimentary rocks along the north and east coast of the island. Meanwhile the alluvium which has a better prospect for groundwater development were found only on the limited areas, patches along coastline at low lying area such as Kampung Tekek, Salang, Juara, Paya, Genting and Mukut. Most of those areas except in Kampung Tekek and Juara, the alluvium were confined to limited area along coastline and it does not form extensive aquifers.

2.3 Climate

The study area has a tropical climate characterized by uniformly high temperature and high relative humidity. It can be said that, tropical islands exhibit little variation in temperature [Falkland, 1992] yet, on a regional scale. The most important factors that control the annual variation of tropical convection are the annually varying thermal contrast between land and ocean and the annual cycle of sea surface temperature [Wang, 1994] with mean temperatures in January and July of about 25°C compared to 28°C during the 1982 Elnino [*see*, e.g., Ooi, 1999], [4].

The highest monthly temperature varying from 30.0°C to 38.1°C, the lowest monthly temperature ranging from 20.5°C to 26.8°C, and the mean monthly temperature ranging from 24.1°C to 31.7°C, from September 1998 to August 1999. The mean monthly relative humidity varying between 75% to 86%, depending on month from September 1998 to August 1999 [5].

The climate of an island has a very large influence on its environment, hydrological cycle and water resources. Among the climatic variables, rainfall contributes significantly to the local hydrology. It is the source of supply of all surface and subsurface water. The quantity of available water resources varies daily, monthly and yearly depending on prevailing wind flows with affect the rainfall pattern. The presence of large water body surrounding has great influence on the climate of the island. As Tioman Island in situated within the Asian monsoon regime, monsoon effects modify its climate.

The rainy season in Tekek from July to January and in Juara from August to January are affected by the northeast monsoon whereas the dry season in Tekek occurs from February to June and in Juara from February to July.

3.0 WATER RESOURCES OF STUDY AREA

The main factors influencing hydrological processes and the nature of surface and groundwater resources on small tropical islands are physiography, climate and hydrology, geology and hydrogeology, soil and vegetation, and human impacts, including abstraction and pollution from a variety of sources. For low islands and low lying areas of high islands, sea level movements due to tides, pressure changes and longer term influences are also important factors [3].

Water resources for this study area can be divided into surface water resource and groundwater resource. At present, surface water is used for domestic and tourism industries purposes, as untreated water by direct supply from small collecting dam.

3.1 Surface Water

Surface water for Tekek Village is obtained mainly from Ayer Besar River whereas for Juara Village is obtained from Baharu River and Keliling River. But there is no streamflow gauge on these rivers.

The value of streamflow can be measured directly and calculated or predict by using MIKE 11 NAM Model (Nedb⊥r-Afstr∅mnings-Model means preci pitation-runoff-model). The results of the simulation of the Mike 11 NAM model are shown in Figure 1, 2 and 3. These results are tentative results, because collecting flow data are not finish yet. Until now the observed flow data is only in July 1987.

The rainfall data for 1993 and 1995 are not available. And there are many missing rainfall data in 1991 to 1997. Therefore, Simple Arithmetic Average Method were used to fill up the missing data.

The average and the maximum value of the runoff were calculated from the runoff prediction for 1986 to 1999 as much as 0.035 m^3/sec and 1914 m^3/sec, respectively.

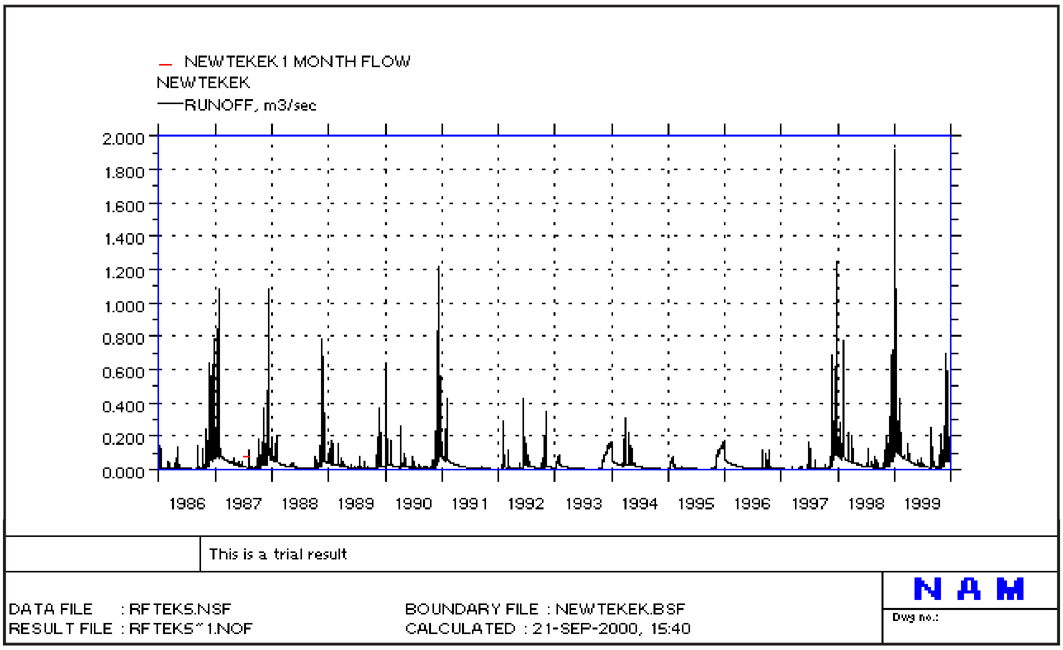


Figure 1 Runoff prediction of Tekek Basin from 1986 to 1999 and the observed flow data in July 1987

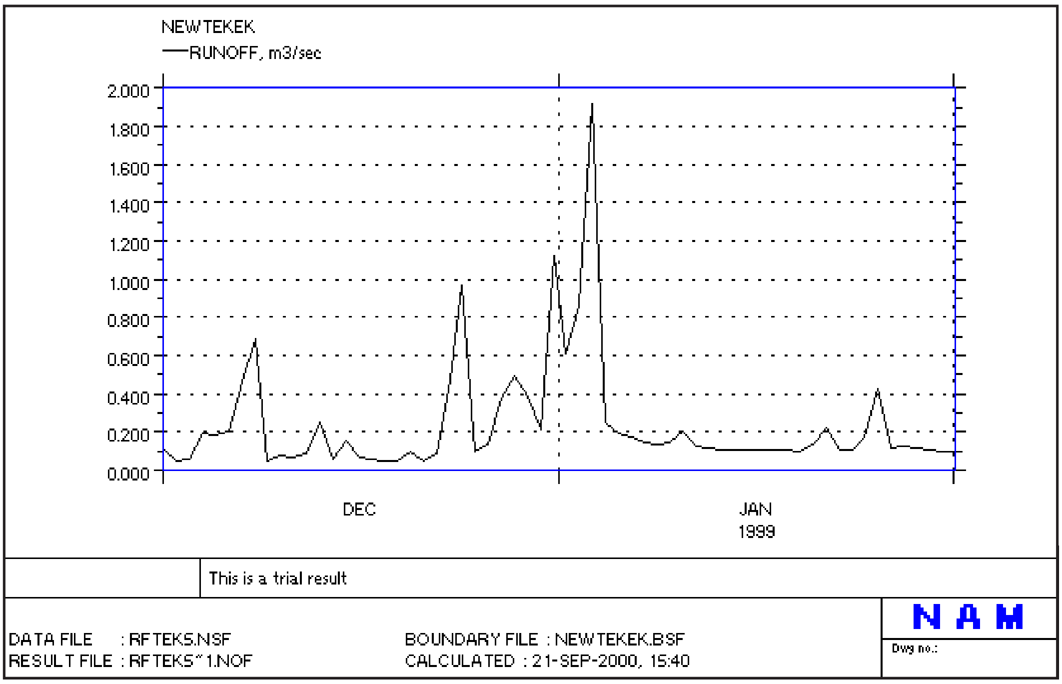
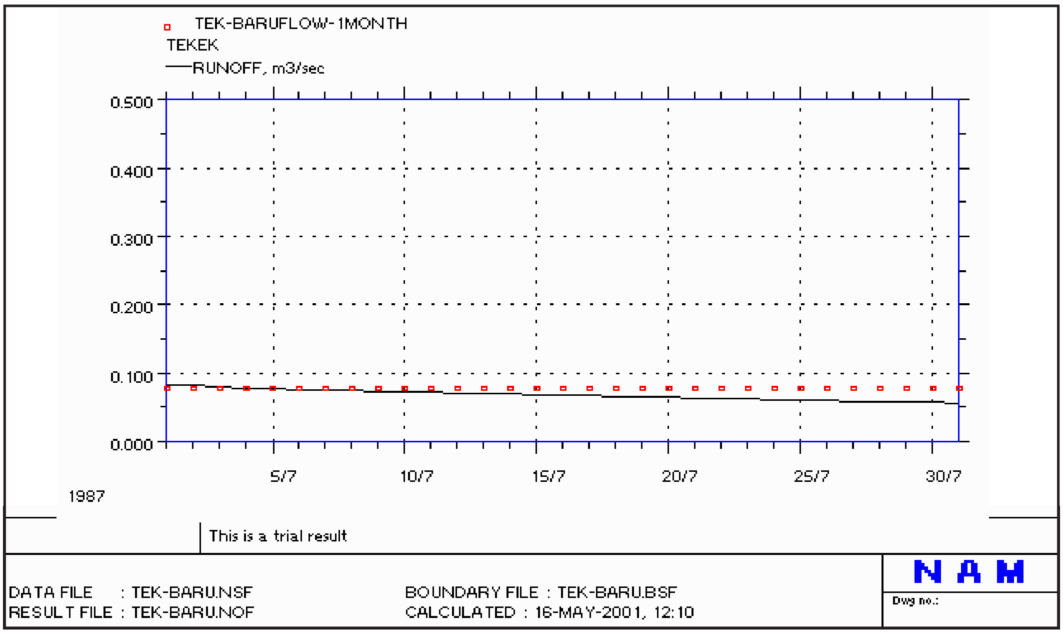


Figure 2 The maximum runoff prediction from 1986 to 1999



+++++++ = Observed Flow
——— = Calculated Flow

Figure 3 The runoff prediction and the observed flow in July, 1987

3.2 Groundwater

Tekek Aquifer has good potential of groundwater resource. The study shows that Tekek area can produce water of 1,368 m^3/day [1]. Generally, groundwater on high island like Tioman Island, occurs in form of elevated (high level) or basal (low-level) aquifer. Basal aquifer, which usually takes form of fresh water lens, is more important as groundwater resource. Assessment of water resources and their sustainable yields are paramount importance for small islands where demands for clean water supply are seasonally fluctuated in nature.

Groundwater resources are most abundant on islands with moderate to high permeability and porosity. Generally, the hard rock aquifers do not have very high primary porosity or permeability compares to alluvial aquifers. The water yielding properties in hard rocks aquifer are largely dependent on the occurrence of secondary features such as fracture, cavities, joint and fault zones. The hard rocks aquifer will only yield limited water compare to alluvial aquifers. Therefore groundwater from alluvial aquifers is more favored than hard rock aquifers.

The ASM model (Aquifer Simulation Model) was used to predict the maximum extraction from the Tekek aquifer by giving the certain amount of pumping rates and in a certain time that causes the groundwater level to be same with or little higher than mean sea level, in order to protect saline intrusion.

3.2.1 Aquifer Simulation Model for the Tekek Aquifer

The whole data of the Aquifer Simulation Model can be found in Table 1 and boundary condition of the aquifer is described in Figure 4.

Table 1 The Data of Aquifer Simulation Model

No.	Item	Descriptions		Number (pcs)	Size (m)
1.	Mesh Size	Initial:	Columns	20	145
			Rows	20	102
		After Refin:	Columns	84	–
			Rows	100	–
			elements	8400	–
2.	Aquifer Type	Unconfined Anisotropy for homogen ous Tx = Ty or kx = ky		–	–
3.	Boundary Condition	Fixed Head: South China Sea, Sg.Air Besar, Sg. Air Hantu, and Sg. Air Sabut			

(*cont.*)

(*cont.*)

		Variable Head: Other Cells No Flow: Granite		
4.	Elevation of Aquifer	Aquifer Top Aquifer Bottom	 –	4.50 – 14.00
5.	Initial Hydraulic Heads	a. Bore holes: TK1 TK2 TK3 TK4 TK5 TK6 TK7 TK8 TK9 TK10 TK11 TK12 TK13 b. Well: PTP3 c. River: Sg. Air Besar Sg. Air Hantu Sg. Air Sabut	– – – – – – – – – – – – –	2.30 2.36 2.47 4.08 2.34 2.14 2.05 2.74 2.19 3.72 4.35 4.20 2.43 2.43 0.1 – 1.9 0.1 – 1.0 0.1 – 1.8
6.	Hydraulic Conductivity	0.0005 m/sec.	–	–
7.	Effective Porosity	0.15	–	–
8.	Simulation	Steady State	–	–
9.	Pumping from Well PTP3	1. 0.0185 m^3/sec (1598 m^3/day) 2. 0.035 m^3/sec (3024 m^3/day) 3. 0.038 m^3/sec (3283 m^3/day) 4. 0.0554 m^3/sec (3599 m^3/day) 5. 0.0579 m^3/sec (5003 m^3/day	– – – – –	– – – – –

The result of simulations can be seen in Figure 5, 6, 7, 8 and 9.

Figure 4 Boundary condition of Tekek Aquifer

Figure 5 The result of the first pumping (1598 m^3/day) of Tekek Aquifer

Figure 6 The result of the second pumping (3024 m^3/day)

Figure 7 The result of the third pumping (3283 m^3/day)

Figure 8 The result of the fourth pumping (3599 m^3/day) of Tekek Aquifer

Figure 9 The result of the fifth pumping (5003 m^3/day) of Tekek Aquifer

Table 2 The results of pumping simulation from the PTP3 Well (54,55)

No.	Extraction by Pump	Initial Head of Water in Well (m)	Water Head after Pumping (m)	Draw down (m)
1.	Pumping I (0.0185 m^3/sec = 1598 m^3/day)	2.48	–0.695	3.175
2.	Pumping II (0.035 m^3/sec = 3024 m^3/day)	2.48	–2.127	4.607
3.	Pumping III (0.038 m^3/sec = 3283 m^3/day)	2.48	–2.749	5.229
4.	Pumping IV (0.0554 m^3/sec = 3599 m^3/day)	2.48	–4.296	6.776
5.	Pumping V (0.0579 m^3/sec = **5003 m^3/day**)	2.48	–5.058	7.538

According to the simulation graph, the suitable result of the maximum extraction in Feb. 1999 is the fifth pumping as much as 5000 m^3/day, because sea water still does not enter to the aquifer area, and water head in the well (–5.058 m) is still higher than aquifer bottom (–14.00 m). After running all the available initial head data in one year, the daily average extraction can be determined.

3.3 Problems Faced

In this study some problems are faced that must be overcome. The problem are

(a) hydrological missing data. Rainfall data are not available for some months in a year or in a series of years, and there is no evaporation data in Tioman Island, because of there is not at all the evaporation station.
(b) the greater parts of topography are hilly. This causes difficulty to build surface storage. But, subsurface storage can be built if needed.
(c) Not enough availability of socioeconomic data.

4.0 CONCLUSIONS

Based on the previous study, Tioman Island requires more than 2000 m^3/day of water for domestic and tourism industry consumption, and the demand is expected to rise due to increasing population and tourism activities. This study shows that Tioman Island has a good potential of surface water and groundwater resources. From this study, it was found that the daily average of surface runoff is 3024 m^3/day and of groundwater extraction is 5003 m^3/day, calculated for the period of February 1999.

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REFERENCES

[1] Mohd. Nazan Awang and P. Loganathan, P.J.K. 1991. *Prospek Sumber Air Tanah Pulau Tioman Pahang*. Jabatan Penyiasatan Kajibumi, Malaysia. Projek Kajian Sumber Air Tanah, Semenanjung Malaysia, Lampiran 2.

[2] Mohammad Hatta A. K, B. B Abdul Rashid and B. A. Mohd. Nazan. 1993. *Hydrology and Model Analysis of Kg. Tekek Aquifer System, Tioman Island, Pahang*. Jabatan Penyiasatan Kaji Bumi Malaysia.

[3] Falkland, T. 1997. *Research in Humid Tropics Island Hydrology:Curren Knowledge and Future*. Direction Workshop on local scale hydrological processes in island, highlands, and urban environments in Malaysia. Kuala Lumpur Malaysia.

[4] Mohd.Nor Mohd.Desa, HTC. 1999. The Prospect of Tropical Island Water Resources And A Case of Tioman Island, Malaysia. First Workshop on Tioman Island Hydrological Study, 3 – 4 June 1999.

[5] Mohd. Rosaidi C. A. 2000. *Climatological Study of Tioman Island*, The Regional Conference on Hydrology and Environment of Small Islands, 29th – 31st May 2000, Berjaya Tioman Beach Resort Tioman Island, Malaysia.

[6] Amir Hashim Mohd.Kassim, Norhan Abd. Rahman, Kamarul Azlan Hasan Basyri Daulay, Anuar Mohmood and Azmi Aris. 1999. *Preliminary Study For Tioman Island Water Resources and Hydrological Processes*, Research Seminar On: CONSTRUCTION, MATERIALS AND ENVIRONMENTAL TECHNOLOGY, 3 – 4 February 1999' UTM, Johor Bahru.

[7] Ahmad Fauzi Abd. Majid, Lembaga Pembangunan Tioman Pahang Darul Makmur. 1999. Future Development of Tioman Island. First Workshop On Tioman Island Hydrological Study, 3 – 4 June 1999.

[8] Hashim Amir, and Daulay, Hasan B. 2000. *Conjunctive use of surface andground water resources in Tioman Island*. The Regional Conference on Hydrology and Environment of Small Islands, 29 – 31 May 2000, Berjaya Tioman Beach Resort, Tioman Island, Malaysia.

[9] Mohd. Nazan Awang. 1988. *Kajian Keseimbangan Air di Kampung Tekek dan Kampung Juara, Pulau Tioman*. Laporan Persidangan Geologi Tahunan yang ke-19, 1988, jilid 2, JPK, Malaysia.

[10] Norhan Abd. Rahman, Amir Hashim, Hasan Basyri Daulay, and Kamarul Azlan. 1999. Hydrological and Water Resources Study for Tioman Island, FRIM Seminar, March, 1999, Kuala Lumpur.

Appendix A: Tioman Island map