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Hydraulic Characteristics of Penang's Main River

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Abstract The water supply in Penang has been severely depleted. Due to a lack of drinking water, Penang inhabitants are experiencing a shortage of both human and animal populations. Humans need water to survive. Governments at all levels must find a solution. Higher-ups will likely be asked to hire workers for dams, reservoirs, and water treatment facilities. Examine the river before starting the construction. When it comes to providing water to homes and businesses, the river's flow is critical. Therefore, determining the river's hydraulic qualities are essential. To validate or determine the flow rate of Penang's key rivers, this study is critical. Higher river flow rates, as it is known, equate to greater efficiency and, as a result, lower costs. Using this method, the large flow coordinates can be found. In order to verify the river's length, the data is collected with the aid of AutoCAD. In order to get more accurate results, Google Earth is needed to pinpoint the river's position. The 8 main rivers at Penang are Sungai Air Itam, Sungai Ara, Sungai Jawi, Sungai Dua, Sungai Junjung, Sungai Dondang, Sungai Juru and Sungai Muda. These rivers had an area of 54.60m^2, 151.80m^2, 231.10m^2, 21.56m^2, 54.30m^2, 36.25m^2, 54.21$m^2$and 136.21m^2 and a wetted perimeter of 24.20 m, 56.60 m, 54.32 m, 20.24 m, 24.70 m, 19.50 m, 49.05 m and 48.41 m respectively. Moreover, these rivers were also measured a hydraulic radius of 2.30 m, 2.68 m, 4.25 m, 1.10 m, 2.20 m, 1.86 m, 1.11 m and 2.81 m and the flow rate of 90.91m^3/s, 229.40m^3/s, 220.69 m^3/s, 27.74 m^3/s, 42.26m^3/s, 101.11m^3/s, 63.08m^3/s and 95.17m^3/s. Based on these 8 main rivers data, the highest flow rate for Penang's main rivers is Sungai Ara with the flow rate of 229.4 m^3/s. Hence, Sungai Ara is Penang's river system's highest peak flow with the value of 229.4m^3/s. This is the most suitable river to construct a dams, reservoirs, or treatment plants.

Keywords: Flow rate, Area, Wetted perimeter, Hydraulic radius, Manning Roughness Equation, Bed Slope

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1. Introduction

Rivers are vital for the sustainability of all natural systems and are the major supply of water for aquatic life. Rivers not only provide water for drinking, irrigation, and industry, but also absorb and direct industrial and municipal effluent, sewage disposal, and farmland runoff fields and streets. With a vast water supply, it is safe to assume that each and every Malaysian citizen or client will have access to water. Penang's water supply looks to be inadequate when compared to other Malaysian states. Penang's water system would be public relations. Privatization of water distribution could lead to difficulties such as insufficient access to clean water, water quality being compromised or lowered, and private finance being more expensive than public funding. Local governments should therefore, establish a strategy to solve these issues in order to prevent the drawbacks of continuing to use privatised water supply. As a response, the government should devise a strategy to construct or enhance dam, reservoirs, or water treatment plants. However, before building or making huge structures, one must also grasp how to choose an acceptable place or location. As a result, knowing a river's feature is promptly crucial because it leads to choose where to build dams, reservoirs, or water treatment plants. One way to overcome this obstacle is to understand better the river's qualities. One can only examine the downstream and upstream of streams by examining their features. After determining the stream's type, flow statistics can be collected. As seen, increased flow rate means increased reservoir altitude. Likely cutting costs and increasing efficiency, higher flow rates require less pump power. This data would be used to decide which river should be placed on new dams or water treatment facilities. This emphasises the need of defining a main river's characteristics before designing water systems.

2. Methods for calculating the river flow

The manning's equation was used in order to gain the flow rate of each selected river. There are 8 main rivers that will proceed with this formulae in order to verify the flow rate of the river. Those rivers are Sungai Air Itam, Sungai Ara, Sungai Jawi, Sungai Dua, Sungai Junjung, Sungai Dondang, Sungai Juru and Sungai Muda.

2.1 Manning's method

Known as the Manning law, this equation shows the link between channel shape, slopes, and rough coefficient and the velocity of a pipe running through it. In its most basic form, depicts the energy balance between gravitational and frictional forces in a channel. An empirical equation is one that is not derived using basic science and physical ideas, but rather by estimating the parameters to actual data. By using such method in engineering is fine, as long as it is keep in note that it was obtained subjectively and has a very limited application.

2.2 Collecting the data for each equation of the Manning's equation

The technique section details the methods utilised to accomplish the study's objectives. The streams information must have been obtained through a site that uses AutoCAD to analyse and modify the entire map structure. Additionally, the objective of using AutoCAD for water is to find length as well as widths of the river in situations when precise information at the water's width is unknown. The river's water level was then determined by visiting the website of https://publicinfobanjir.water.gov.my/aras-air/data-paras-air/?state=PNG&lang=en. The river water level check is intended to provide information on rivers that lack depth data. After determining the river's water level, the river's depths, widths, and bed slopes are determined. Following the collecting of pertinent data, the Manning's approach was applied to determine the river's water flow rate.

2.3 The equation for Manning's formulae

The manning formula will be utilised to validate the river's flow rate in this investigation. Thus, the roughness coefficient, area, wetted perimeter, hydraulic radius, and bed slope are necessary to create this formula. The equations for Manning's equation are shown in Eq.1.

$$Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \ (Eq. 1)$$

2.4 Verifying the roughness coefficient for Manning's equation

The roughness coefficient is one of the main parameter that is needed in Manning's formula. That is used to verify the lost of energy by the flowing water as a result of pipe or channel of the wall roughness. This data is obtained directly after observing the condition of the river and also by taking the average between the three roughness coefficients in the upstream, midstream, and downstream directions. These streams obtain their values from an observation of the environment with Manning's roughness coefficient table.

Table 1: The section of natural streams coefficient in Manning's roughness coefficient table

Type of the channel and descriptions	Minimum	Normal	Maximum
D. Natural Streams			
D-1. Minor streams (top, width at flood stage < 100ft)			
a. Streams on plain			
1. Clean, straight, full stage no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel,			

banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High Grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crops	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few done trees, little undergrowth flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage > 100ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistances			
a. Regular section with no boulders or brush	0.025	-	0.060
b. Irregular and rough section	0.035	-	0.100

3. Results and discussions

In this investigation, the lengths of all Penang's main river will be determined. In addition, the results of this study suggests that additional research into the water depth of the 8 river systems will be examined, that includes Air Itam river, Ara river, Dua river, Jawi river, Junjung river, Dondang river, Juru river, and Muda river. It was also necessary to identify river streams by using the Google Maps image in order to verify locations and Manning's rough coefficient. If internet is not used, a prediction will be done to verify the bed slope, width and depth of the trench. Lastly, the outcomes of every stream flow should be evaluated to see if rivers are suitable for the building of a dam or reservoir. The findings of the study are summarised in the following paragraphs.

3.1 Gathering the parameter of each rivers for Manning's equation

By gathering all the information, the flow rate is determined. Considering the fact that the rivers were arranged in such a way, by obtaining dimensions such as lengths, widths, depths, slopes, roughness coefficients, areas, wetted perimeters, and hydraulic radius are required before the computation begins. It is possible to obtain the widths through the internet or by using Autodesk to manually calculate them. Finding the width through internet is also accessible. Although the average water level was used to estimate some streams, including Junjung river, Jawi river, Juru river, Dua river, and Muda river. The river's datum is expected to be at the river's bottom in this case scenario. In addition, journals were used to collect bed slope datas. If the bed slope of a river is not available in a nearby river, the bed slope may be taken from a neighbouring or close by stream that is nearer to the river in question. Since the Manning roughness coefficient was previously determined, it is used as a reference. The formula for all rivers will be calculated and assumed as a rectangular channel.

3.2 Results of each rivers using Manning's equation

The findings of the research on flow rate have been compiled after most of the data has been analysed. Due to the rivers shaped like rectangles, collecting information for widths, depths, bed slopes, manning roughness coefficients, areas, wetted perimeters, and also hydraulic radius are essential for the calculation to operate. An Autodesk software programme may be used to compute the widths. For more information, related websites can be visited. The average level of water was used to determine the volume of Junjung river as well as its tributaries. At the riverbed, this river's datum should be present. To gather bed slope data, journals are employed. A stream that is closer to the river may be used to estimate the bed slope in rivers when no information is available. In order to calculate the Manning roughness coefficient, the means of Manning coefficients from prior studies are used. The hydraulic radius, wetted perimeter, and area are all calculated using the rectangular channel approach. Table 1 displays the flow rate data.

Table 2: The data results for each of the 8 rivers

River Number	Name of the river	Manning's roughness coefficient	Area (m^2)	Wetted Perimeter (m)	Hydraulic Radius (m)	Flow rate (m^3/s)
1	River Air Itam	0.037	54.6	24.2	2.3	90.91
2	River Ara	0.037	151.8	56.6	2.68	229.4
3	River Jawi	0.08	231.1	54.3	4.25	220.69
4	River Dua	0.024	21.56	20.2	1.1	27.74

5	River Junjung	0.063	54.3	24.7	2.2	42.26
6	River Dondang	0.021	36.25	19.5	1.86	101.11
7	River Juru	0.027	54.21	49.05	1.11	63.08
8	River Muda	0.057	136.21	48.41	2.81	95.17

3.3 Discussion of the results

Ara river has the highest flowrate at 229.4 m^3/s. Despite the fact that Ara's river Manning's roughness coefficient is the fourth lowest in the world, Ara river has a high area value of 151.8m^2. This is one of the primary reasons for Ara's river high flow rate. As it has been established, that a lower Manning's roughness coefficient results in a larger flow rate in the Ara River example. This is due to the vast quantity of area.

4. Conclusions

The flow rate of 8 rivers in Penang, that includes Air Itam river, Ara river, Jawi river, Dua river, Junjung river, Dondang river, Juru river and Muda river, were effectively determined in this study. According to the data gathered, Ara River has the highest flowrate at 229.4 m^3/s. As a result of the high flow rate, Ara river is an excellent and suitable location for opening or constructing a dam, reservoir, or water treatment plant. In addition, a higher flow rate indicates a smaller pump is required to pump to the user and an additional cost savings are possibly done. Ara river has promised due to its elevated location. Even with all of the acquired data, numerous unanswered questions remain. That is one of the reasons that site visits are highly advised, in means of as site surveillance.

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