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## **IMPACT OF LAND USE ACTIVITIES ON THE HYDROLOGICAL REGIME IN THE JUNJUNG RIVER BASIN, PENANG ISLAND, MALAYSIA**

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### **Abstract**

Land use activities in the river basin have a very significant negative impact on the hydrological regime, especially surface runoff. The study of the impact of land use activities on the hydrological regime in the Junjung river basin aims to analyse changes in the rate of surface runoff due to current land use changes and land use planning in 2030. To achieve the goal of this study, curve number analysis was used as a determinant of hydrological parameters in the development of HEC HMS modelling in the study basin area. The results of the study found that the current land use in 2020 recorded an average curve number value of 85.77 and then increased to 86.36 in 2030 due to land use changes in 2030. The change in the value of the curve number has had an impact on the hydrological regime that is surface runoff because there is an increase in the percentage of impervious areas from 22.84 percent in 2020 to 31.14 percent by 2030. The rate of change in runoff is shown through the simulation of the peak flow rate that occurs according to the frequency of the event, which is between 0.7 to 4.9 percent. The results obtained from this study can be used as fundamental data for advanced studies of flood control and management for better sustainable flood risk management.

**Keywords:** Land use, Runoff, hydrological regime, Curve Number, HEC-HMS

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## **INTRODUCTION**

Land use activities are anthropogenic factors that directly impact changes in the hydraulic regime of rivers, especially surface runoff. To date, changes in land use activities continue to occur to meet human needs and demands. Land use change is a continuous process, which includes all types of development on land such as agriculture, commercial, industrial, residential, urban and others. Changes in land use activities occur as a result of the changing needs of residents to carry out specific activities driven by physical, economic and social factors. Uncontrolled and excessive land use activities will have serious impacts on global warming, sea level rise, carbon cycle and changes in the hydrological regime. Land use activities create open or exposed surface areas without any canopy cover that can contribute to the increase in surface runoff entering the drainage system (Ismail, 2013; Felix Tongkul, 2000; Mustaffa et al., 2023). The increase in surface runoff is seen as significant with changes in land use activities that occur in a river basin area. For example, an increase in the area of impermeable surfaces can result in an increase in surface runoff capable of carrying various pollutants into the river system, as well as causing changes in the river's capacity to handle floodwaters, which can have an impact on the balance of the river system, especially during rainfall (Azid et al., 2015; Toriman et al., 2015; Saad et al. 2023). The imbalance of the river system can lead to various negative implications such as pollution, property damage, sedimentation, and flooding. Therefore, this study was conducted to identify the impact of land use activities on changes in the hydrological regime, i.e., surface runoff in the Junjung River Basin, and to propose mitigation measures that need to be taken to ensure that the increased surface runoff does not harm the residents around the Junjung River Basin area.

## **LITERATURE REVIEW**

### **Land Use**

Land use is often associated with human actions directly or indirectly in determining the landscape pattern on the land (Meyer et al., 1994). The spatial aspect of land use refers to changes in land size or area, whether it undergoes any changes or not. Meanwhile, from a temporal aspect, land use is viewed through a period of time (Wolman and Fournier, 1987). Land use activities refer to human determination, management and transformation of land based on human needs including basic needs, socio-economic development and so on (Bajocco et al., 2012; Pijanowski & Robinson, 2011; Pourebrahim et al., 2015; Zhao et al., 2017). Determining land use activities is a complex and dynamic process, but it can be controlled through certain management practices (Pei & Pan, 2010). Optimal land use, multiple objectives and maximum output are the basis for land use activities in an area (Putman, 1975). Land use change is a result of human influence on the landscape that occurs due to significant modifications in the ecosystem (La Mela Veca et al., 2016). In general, the developmental zones in the Junjung River area

in Penang mainly concern the existing built-up areas that have amenities such as transportation, infrastructure, and utilities, as well as urban sectors with a population growth rate of 2%.

### **Runoff**

Generally, stormwater runoff is defined as surface water flow resulting from storm events, and can contribute to large volumes of water that can lead to disasters for both life and water resources if not managed properly (Amatya et al., 2022; Ismail, 2013). The process of stormwater runoff is essentially the same as the water cycle in hydrology. However, the term "stormwater runoff" is used when surface water runoff, which should be absorbed by plants and infiltrate into the ground or return to the atmosphere, is diverted through impermeable surfaces, causing an increase in river discharge. Surface runoff is defined as water that runs off in areas that lack vegetation, have thin soil cover for infiltration processes, and semi-arid areas with high rainfall (Jones, 1997; Ranjan & Singh, 2022; Jaafar et al., 2010). Furthermore, the rate of urbanization has altered the hydrograph entity in terms of peak flow frequency (Hashim & Ahmad, 2007).

## **RESEARCH METHODOLOGY**

### **Research Location**

The state of Penang is located in the northern part of Peninsular Malaysia. It is divided into two areas, the island and the mainland, and has five main zones. For the island area, there are two main zones, namely the Southwest Zone and the Northeast Zone. As for the mainland area, Seberang Perai is divided into three main zones, namely the North Seberang Perai Zone, Central Seberang Perai Zone, and South Seberang Perai Zone. Generally, the study was conducted in the Junjung Basin in the Central Seberang Perai Zone, Penang Island. Junjung River is a sub-catchment of Jawi River, which flows through the southern part of Seberang Perai through the town of Simpang Ampat. Junjung River is also used for irrigation canals for rice cultivation. The main river of Junjung River is in Kampung Jawi, near the border of Kedah State. The area of the basin is approximately 154.8 km<sup>2</sup> and it consists of the main river and several sub-channels such as Cempedak, Junjung Mati, Batu Tiga, Perangin, and Tok Subuh. Over the past 20 years, the Junjung River Basin has undergone rapid development, converting agricultural land into industrial and residential estates. Junjung River is the main river of Jawi River, which originates from Bukit Batu Belah in the eastern part of Penang Island. The length of the main flow of Junjung River is 18.2 km. Figure 1 shows the extent of the basin and the main branch rivers. The average annual rainfall depth in the study area is approximately 2400 mm, ranging from 1800 to 3000 mm.

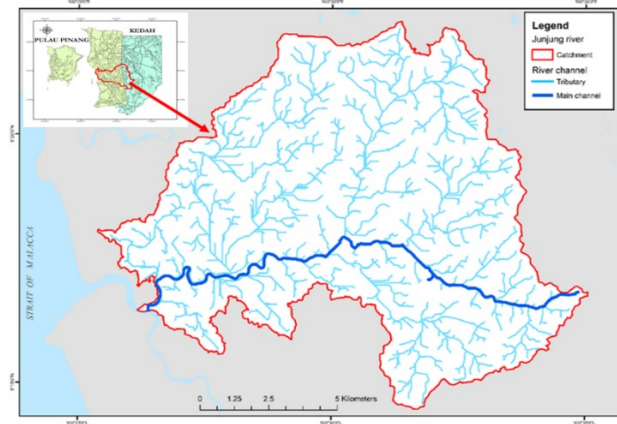


Figure 1: Main River Junjung, Malaysia

### Land Use Analysis

The analysis of land use change data involves various GIS technical applications used to assess the trend of land use change in the Sungai Junjung Basins. A map overlay approach is used to analyse changes that occur throughout the years, including relative percentage changes from 2010 to 2020, and from 2020 to 2030. ArcGIS software simplify the analysis process to determine changes according to various land use categories. The land use map for the year 2020 in JPEG format was first recorded in the Rectified Skew Orthomorphic (RSO) projection format, and then digitized according to the land use category of the studied area. The 2030 land use map from the Penang RSN report in PDF format which was then converted to file format using ArcGIS software to facilitate the map overlay technique. Figure 2 shows the overlay process performed using functions provided by ArcGIS software.

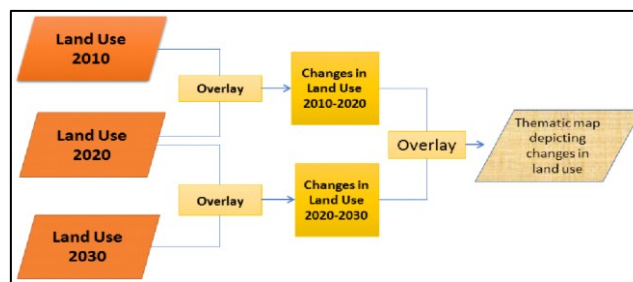


Figure 2: Process of Land Use Map Overlay for 2010 – 2030

## Hydrological Data Analysis

### *Development of Thiessen Polygon*

Rainfall data is the fundamental data used in this study to determine changes in hydrological regime, especially changes in discharge rates that occur in the Junjung River Basin. However, in this study, there is only one rainfall station located within the basin area, namely the Simpang Ampat River station. Therefore, to continue this study, seven rainfall stations closest to the basin area were used to determine the annual rainfall amount in the Junjung River Basin. Table 1 show the selected rainfall station locations to represent the Junjung River Basin. Furthermore, the Thiessen polygon method and the availability of data were used to estimate the amount of rainfall that influences the Junjung River Basin area according to the selected rainfall stations. The Thiessen polygon method is a better method than the arithmetic computation of rainfall in an area based on rainfall stations (Chow et al., 1988; Abdul Maulud et al., 2021). This method uses the GIS-Thiessen polygon command found in the CWRW Vector Extension. The polygons formed are based on lines that have the same distance between the climate observation stations. The total rainfall for the entire Junjung River Basin area is calculated using equation [1]:

$$P = [Ps1 * A1 + Ps2 * A2 + \dots + Ps8 * A8] / At [1]$$

where:

P = Total rainfall of the area (areal precipitation), At = Area, Ps1, Ps2...Ps8 = Rainfall for each station, A1, A2...A8 = Area of each Thiessen Polygon.

**Table 1:** List of Rainfall Stations and Data in Junjung River Basin

No.	Station Name	Longitude	Latitude	Data Availability
1	Sungai Simpang Ampat	100°28'50.00"E	5°17'38.00"N	1989-2019
2	Ladang Batu Kawan	100°25'50.00"E	5°15'25.00"N	2000-2019
3	Sungai Bakap	100°29'48.00"E	5°12'57.00"N	2000-2019
4	Terap at Kedah	100°37'45.00"E	5°16'55.00"N	2011-2019
5	Komplek Prai	100°23'30.00"E	5°22'55.00"N	2000-2019
6	Kolam Air Cheruk To' Kun	100°28'27.00"E	5°20'59.00"N	2000-2019
7	Kampung Dusun at Kedah	100°33'35.00"E	5°23'5.00"N	2009-2019
8	Kolam Air Bukit Berapit	100°28'32.00"E	5°22'32.00"N	2000-2019

### *Development of Intensity-Duration-Frequency Curve (IDF)*

The development of IDF frequency curve is a graph that shows the variable intensity of rainfall against the probability of possible events. The IDF curve is constructed with the aim of estimating rainfall conditions in the past to make projections for the future (Mukhtar et al. 2020; Suhaimi et al., 2020). The IDF curve was developed using the annual maximum rainfall collected (Ariff, Jemain & Abu, 2015). The IDF curve considered a generalized extreme value (GEV)-

Max (kappa specified, L-Moments) distribution using Hydrognomon software (Houessou-Dossou et al., 2019). The development of the frequency curve (IDF) for rainfall was carried out for the return period of ARI 2-, 5-, 10-, 20-, 50-, 100- and 1000- years. Furthermore, the intensity of rainfall in the Junjung River Basin is calculated using the Thiessen weight method (Thiessen, 1911) using equation [2].

$$I_{basin} = \frac{\sum_{i=1}^n l_i w_i}{\sum_{i=1}^n w_i} \quad [2]$$

Where  $I_{Basin}$  = Intensity,  $l_i$  = Interval value and  $W_i$  = Area

### **Development of the HEC-HMS Model**

The HEC-HMS model was used in the Junjung River Basin to simulate rainfall design for various frequencies and durations. The basin consists of five main sub-basins: Machang Bubok, Junjung hulu, Chempedak, Junjung Mati, and Junjung Downstream. The HEC-HMS modelling was used to generate synthetic hydrographs for the ARI 2-, 5-, 10-, 20-, 50-, 100-, and 1000-year recurrence intervals for the effects of land use changes in 2020 and projected changes in 2030. The Hydrologic Modelling System (HEC-HMS) is designed to simulate hydrological processes in dendritic river modelling systems. This software considers various hydrological elements such as infiltration, unit hydrograph, and hydrologic routing and is developed for various geographical conditions to solve hydrology problems. In this study, the SCS-CN method was used to simulate rainfall losses due to its simplicity, applicability, and wide usage for various basin conditions. The SCS-CN method is represented by CN, which consists of a combination of hydrological soil group, land use types, and type of land cover. Soil structure is an important spatial data in determining Curve Number (CN), and each soil type has a different infiltration rate. The cumulative CN value with the weightage area factor equation [3] and CN value for land use soil and land use type refer to United States Department of Agriculture (USDA, 1986).

$$CN_{aw} = \frac{\sum_{i=1}^n (CN_i \times A_i)}{\sum_{i=1}^n A_i} \quad [3]$$

where;

$CN_{aw}$  = Cumulative Curve Number,  $CN_i$  = Curve Number for Area  $A_i$  and  $\sum A_i$  = Basin Area

Conversion of rainfall into runoff is using Unit Hydrograph SCS-CN. It needs to have main parameters; time of concentration ( $T_c$ ), storage constant (R) and baseflow. Formulae for each parameter are shown as in Table 2. Many

methods can be used to determine the time of concentration,  $T_c$  based on basin condition such as forest, rural and urbanized. Initial estimation of concentration time is based on HP27. Storage constant calculated based on hydrograph where the inflection points of falling limb hydrograph divided with derivative of discharge,  $Q$  of the time. Baseflow estimation that needs to calculate the whole hydrograph design using Hydrological Procedure No. 27 (2010) by DID, Malaysia.

**Table 2:** Equation Used for Hydrology Model

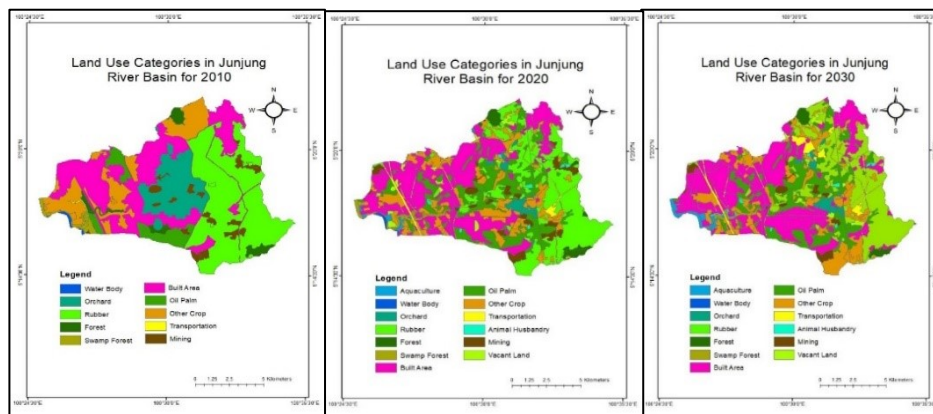
Equation	Formulae	Description
(1) Time of concentration, $T_c$	$T_c = 2.32A^{-0.1188}L^{0.9573}S^{-0.5074}$	$A$ = basin area ( $\text{km}^2$ ); $L$ = length of flowpath (km);
(2) Storage constant, $R$	$R = 2.976A^{-0.1943}L^{0.9995}S^{-0.4588}$	$S$ = basin slope (m/km); $R$ = storage constant;
(3) Basin baseflow, $Q_b$	$Q_b = 0.11A^{0.85889}$	$A$ = basin area ( $\text{km}^2$ ); $L$ = longest flow path in river basin (km); $S$ = basin slope (m/km); $Q_b$ = basin baseflow;

## RESULT AND DISCUSSION

### Analysis of Land Use Changes

The land use analysis in this study covers changes in land use classification from 2010 to 2030 for two river basins, and considers the classifications adopted by various government departments such as the Department of Agriculture Malaysian, PLANMalaysia@Penang, Penang Town, and Rural Planning Department. Thirteen land use categories were identified, including aquaculture, water bodies, orchards, rubber, forest, swamp forest, built areas, oil palm, other crops, transportation, animal husbandry, mining, and vacant land. More detailed classification results for land use category and the percentage of area they cover are presented in Figure 3. The Figure 3 illustrates the land use trends in the Junjung River Basin area from 2010 to 2030. The study identifies 13 land use categories, namely aquaculture, water bodies, orchards, rubber, forests, swamp forests, built areas, oil palm, other crops, transportation, animal husbandry, mining, and vacant land. In 2010, rubber was the largest land use category occupying  $44.39 \text{ km}^2$  (28.67%) of the area, followed by built areas covering  $34.67 \text{ km}^2$  or 22.4% of the studied area. Forests, swamp forests, and other crops came next with  $15.13 \text{ km}^2$  (9.77%),  $13.17 \text{ km}^2$  (8.51%), and  $10.21 \text{ km}^2$  (6.6%), respectively. The remaining categories were oil palm, transportation, orchards, mining, and water bodies. The land use in the region started to change in 2020 as construction activities expanded, and built-up areas began to dominate, occupying  $45.33 \text{ km}^2$  or 29.28% of the land area. The area under rubber decreased by 11.71%, from  $44.39 \text{ km}^2$  in 2010 to  $26.26 \text{ km}^2$  in 2020. Other crops rose in

importance, taking up 15.51 km<sup>2</sup> (16.6%) by 2020. Land use for transportation and oil palm cultivation also increased, accounting for 13.1 km<sup>2</sup> (8.46%) and 10.82 km<sup>2</sup> (6.99%), respectively, in 2020. The area under forests and swamp forests declined to 13.86 km<sup>2</sup> (8.95%) and 10.63 km<sup>2</sup> (6.87%), respectively. Water bodies, orchards, and mining also decreased in 2020, occupying 5.82 km<sup>2</sup> (3.76%), 3.87 km<sup>2</sup> (2.5%), and 3.29 km<sup>2</sup> (2.13%), respectively. On the other hand, aquaculture, animal husbandry, and vacant land categories increased in land use, occupying 1.06 km<sup>2</sup> (0.68%), 2.85 km<sup>2</sup> (1.84%), and 1.41 km<sup>2</sup> (0.91%), respectively.



**Figure 3:** Classification for Land Use Category at Junjung River Basin

In line with the vision of Penang for development into the future, the pattern of land use will be expected to change further towards the year 2030. From the results of this analysis, the area under agriculture can be expected to decrease. In particular, the area under rubber cultivation is expected to decline to 11.14 km<sup>2</sup>, accounting for only 7.2% of the land area in 2030. Nonetheless, some other aspects of agriculture will likely experience expansion. The area planted with oil palm could reach 12.3 km<sup>2</sup> (7.94%) in 2030, while aquaculture would take up 2.17 km<sup>2</sup> (1.4%) of the total land area, animal husbandry 3.59 km<sup>2</sup> (2.32%) and miscellaneous crops 17.81 km<sup>2</sup> (11.51%). According to the trend, land use for various other categories would decline by 2030. The area under forests would be reduced to 10.56 km<sup>2</sup> (6.82%), that of swamp forest to 7.08 km<sup>2</sup> (4.57%), water bodies to 4.81 km<sup>2</sup> (3.11%), orchards to 1.64 km<sup>2</sup> (1.06%), vacant land to 1.27 km<sup>2</sup> (0.82%) and mining areas to 1.05 km<sup>2</sup> (0.68%). The built-up area would continue to expand from 2020 to 2030 as the entire area develops as a whole, taking up 63.81 km<sup>2</sup>, representing 41.22% of the land area in 2030. In tandem with this development, infrastructure for transportation would increase, accounting for 17.57 km<sup>2</sup> or 11.35% of the land area in 2030.



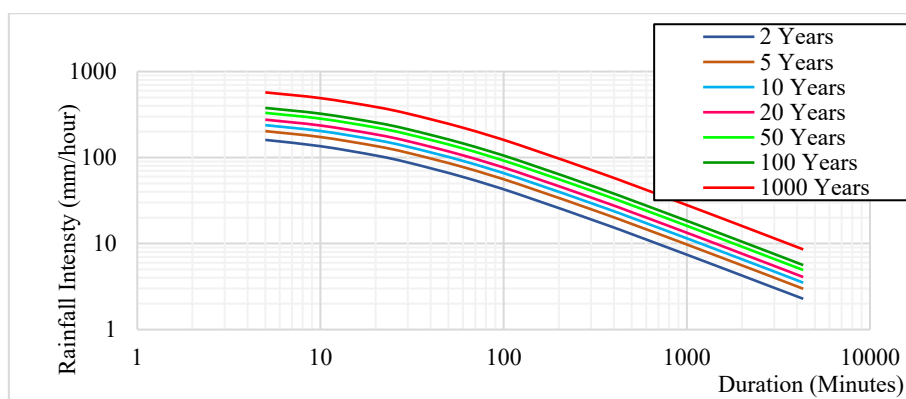
### Rainfall Analysis

Determining the annual rainfall amount in an area using the Thiessen polygon method requires information on the area's extent and rainfall data representing each formed polygon. This study used eight rainfall stations located within and around the Junjung River Basin area to obtain the annual rainfall amount in the basin area. Table 3 show the results of the rainfall influence area for each selected rainfall station, as well as the thematic map of Thiessen polygons for the Junjung River Basin.

**Table 3:** Thiessen Weightage Factor at Junjung River Basin

No	Station	Area (km <sup>2</sup> )	Thiessen Weightage Factor, w
1	Sungai Simpang Ampat	71.1	0.535
2	Ladang Batu Kawan	9.0	0.068
3	Kolam Air Bukit Berapit	0.6	0.005
4	Sungai Bakap	7.7	0.058
5	Terap at Kedah	8.4	0.063
6	Komplek Prai	0.9	0.007
7	Kolam Air Cheruk To' Kun	10.1	0.076
8	Kampung Dusun at Kedah	25.1	0.189

Next, the Intensity-Duration-Frequency (IDF) curve is the basis for designing any structure, especially those involving drainage systems. The IDF curve is plotted based on the recurrence interval of events of 2, 5, 10, 20, 50, 100, and 1000 years. The IDF curve is then plotted with rainfall duration (minutes) on the horizontal axis and rainfall intensity (mm/hour) on the vertical axis. Figure 4 IDF curve in the Junjung River Basin according to the recurrence interval of events that have been determined using the Thiessen polygon method.



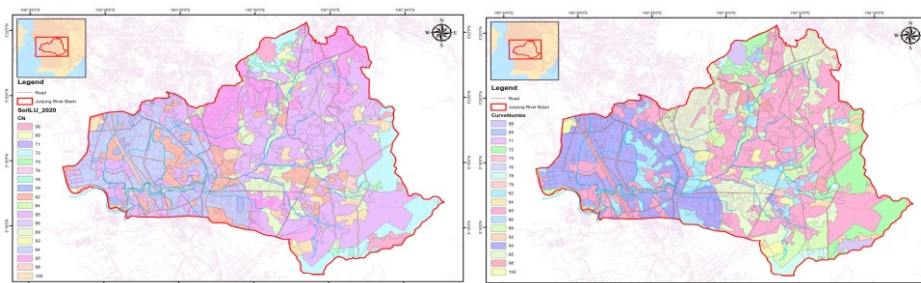
**Figure 4:** IDF Curve with Thiessen Polygon in Junjung River Basin, Malaysia

### **Soil Hydrology Groups**

Hydrological soil group has been identified through spatial land use data from the Department of Agriculture Malaysia. There are three groups of soil hydrology dominated at both of the basin which is B, C and D. Based on the information, the Junjung River Basin is dominated by soil hydrology class D (75,361 km<sup>2</sup>) which is a type of sand, clay-clay and concentrated in the upstream area of the basin. This type of soil has a low infiltration rate and has the potential to produce high runoff especially the maximum level of soil saturation especially during the rainy season. While the soil hydrology class C (40,949 km<sup>2</sup>) with its distribution is concentrated in the downstream area of the basin. This type of soil has the characteristics of clay-clay with usually high with a percentage of clay. It also has a moderately low infiltration rate. For hilly areas at the headwaters of the basin, the hydrology class of soil B (15,358 km<sup>2</sup>) is clearly visible where this type of soil has shallow-loess, sandy and easily eroded properties.

### **Curve Number Analysis**

The Curve Number analysis is based on Technical Release 55 (Soulis & Valiantzas, 2012). The CN value is produced after combining the land use data set in the river basin area. The curve number values in the river basin vary, and the estimated flow is usually identified through the curve number that can represent the entire basin area. Figures 5a and 5b show the gridded curve numbers for the Junjung River Basin in year 2020 and 2030. Figure 5a shows the cumulative curve number in 2020 is 87.15, while in 2030, due to land use changes (Figure 5b), the curve number increases to 87.71. This indicates the possibility of an increase in the magnitude of flow, especially for peak flow at each rainfall design for the next 10 years. Curve number analysis is essential to understand the future changes in land use. The increase in the impermeable area can be seen with the increase in the curve number value. The curve number is then used in the HEC-HMS model to represent the land use changes scenario. The rainfall design to be applied should cover the entire time of concentration (T<sub>c</sub>) calculated for the whole basin area. Therefore, designated rainfall events can be greater than the basin's time of concentration; some suggest using 3 to 4 times the time of concentration (County, 1990), while most of the design peak flows used 24 hours or the same as the time of concentration (Levy & McCuen, 2001). The results of the hydrological parameters for the model developed for the current land use scenario in 2020 and the land use scenario in 2030 are shown in Table 4.



**Figure 5a and 5b:** Curve Number for Year 2030 Junjung River Basin

**Table 4:** Hydrology Parameters at Junjung River Basin

Sub-basin	Losses				Transform		Baseflow
	Curve Number (CN)		Impermeable Area (%)		Conc. time (hr)	Storage constant (hr)	Initial discharge (m <sup>3</sup> /s)
	2020	2030	2020	2030			
<i>Machang Bubok</i>	86.07	86.51	19.05	25.93	8.86	10.19	2.0
<i>Junjung Upstream</i>	81.97	82.71	7.52	15.14	6.94	7.76	2.16
<i>Chempedak</i>	82.20	83.84	10.53	22.25	4.66	5.65	1.29
<i>Junjung Mati</i>	89.27	89.34	39.79	47.42	10.22	11.40	2.99
<i>Junjung Downstream</i>	89.34	89.38	37.29	44.96	23.14	26.06	0.97

### Model Calibration and Validation

According to received dataset, it was identified that there was no river discharge data available in Junjung River Basin. Hence, to validate the developed model, comparative analysis of peak flow conducted with the Hydrological Procedure No. 27 (DID, 2010).

**Table 5:** Validated Peak Flow for Junjung River Basin

Sub-basin	Method	Validation date		
		22.11.2015	3.9.2017	14.4.2018
Muara Sungai	HP27	102.8	169.9	81.5
Junjung	HEC HMS	81.8	120.5	43.1
Junjung U/S	HP27	30.5	51.1	25
	HEC HMS	22	31.2	9.6
Junjung Mati	HP27	32.3	53	25.7
	HEC HMS	29.6	45	19.1
Junjung D/S	HP27	7.3	10	4.9
	HEC HMS	5.4	7.4	2.8
Chempedak	HP27	21.9	35.1	17.6
	HEC HMS	16.6	22.5	7.2

Sub-basin	Method	Validation date		
		22.11.2015	3.9.2017	14.4.2018
Machang Bubok	HP27	23	38.1	18.5
	HEC HMS	17.6	26.7	9.2

Assessment of peak flow showed as in Table 5. It was found that most of the data close to line of equality 1:1 and linear regression with intercept at 0 which indicates the consistency of equality in determine the peak flow. The value of linear correlation coefficient ( $R^2$ ) obtained from the comparison analysis was 0.9649.

### **Simulation Impact of land use changes on peak flow**

Two main scenarios were simulated to assess the effects of increased surface runoff in the Junjung River Basin, namely the current scenario and the land use impact scenario in 2030. The current scenario involves an analysis of land use changes over a ten-year period from 2010 to 2020. The second scenario refers to the land use planning impact in 2030 according to rainfall frequencies of 2, 5, 10, 20, 50, 100, and 1000-years ARI. The simulation was carried out for time periods of 3, 6, 12, and 24 hours. The analysis of peak flow in the Junjung River Basin shows a significant increase. This is demonstrated through simulations of rainfall events over periods of 3, 6, 12, and 24 hours, and with a return period of 2, 5, 10, 20, 50, 100, and 1000 years, which indicate that peak flow values are increasing due to land use changes in the Junjung River Basin. For a rainfall event lasting 3 hours, the land use changes that occur in 2030 result in an increase in peak flow rates of 1.5 to 4.9 percent for each return period. For a rainfall event lasting 6 hours, peak flow increases between 1.3 to 4.5 percent. For rainfall events lasting 12 to 24 hours, peak flow rates increase by 1.1 to 3.9 percent and 0.7 to 2.3 percent, respectively, for each return period. Surface runoff occurs when the land surface fails to absorb water into the ground during rainfall events.

The findings of the study on land use change from 2010 to 2030 show a moderate and not too drastic increase. However, it is expected that in the coming years after 2030, the land use in Junjung River, Penang, will face development pressure due to the increasing population and high demand for land use for housing and other purposes. Changes in land use activities in the Junjung River Basin, Penang, starting from 2010 and 2020, and development plans in 2030, found that the agricultural land use category has changed to the category of densely built-up land use. Densely built-up land use refers to developed areas that have impervious surfaces that prevent water from infiltrating into the soil through percolation to recharge groundwater storage (Ferguson, 1998).

## CONCLUSION

In conclusion, the study found that land use is an important factor that affects the quantity and quality of water in a river basin. Significant changes in land use can alter the rate of discharge and surface water flow in a river basin. Integrated river basin management should be implemented in the Junjung River Basin area so that the increase in surface runoff due to increased urbanization can be managed more sustainably. From such management, it will increase the potential for other sector to grow and contribute to the local economy. This is deemed as potential positive spillovers to the local community (see Azwar et al., 2022) and organic growth of other sectors such as tourism for instance in the sense that it is managed sustainably (see Azinuddin et al., 2022).

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## DISCLOSURE STATEMENT

Following international publication policy and our ethical obligation as a researcher, we report that we have no conflict of interest.

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