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Real-Time Flood Risk Simulation in the River Catchment of Terengganu Using Gis and Swat

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Abstract: *It is important to figure out the relevance of terrain model in ascertaining the water flow in steeplands and sloppy catchment or watershed. If the slope is undulating then the digital elevation model DEM can be determined through the satellite images data. The resolutions depend upon the type of satellite image used. For the purpose of this study, ASTER DEM with 30 meters resolution was used. The SWAT extension of ArcGIS has been applied to develop the model from the mask to produce animated flood risk model in the catchment area of Kuala Terengganu Malaysia. ArcSWAT software is used to determine the Hydrologic Respond Units (HRUs) and the total delineated watershed. The output is the model of areas liable to be occupied by flood especially if the river flow increases with certain meters above sea-level or water volume rises within the catchment for obvious reasons of climatic changes and monsoonal rainfall. The model validation can display different flood risk zones for planning and mitigation.*

Keywords: *3d, Simulation, Swat, Model, Catchment*

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I. Introduction

Flood is hazardous natural phenomena taking most all part of the world. Generally, rainfall triggered flow accumulation upstream to downstream overflow the river banks inundated causing damages on the surface of the earth including human lives (Bronstert, 2003).The use of Geographic Information System GIS has for long been proven by many authors and government to be an efficient tool applicable to all environmental science, the socio-economic and political point of views. Today marine geography was developed through the applications of GIS. Among the various natural hazards, the flood is considered to be the devastating disaster with a large account of damages (Youssef, Pradhan, & Hassan, 2011). The fundament factor in marine technology is the assessment of water quality simulation of water flow monitory coastal erosion for planning, conservation and management and better decision making. The conservation of water resources is a wise idea toward achieving sustainability. The world is now tending toward sustaining our environment for greater tomorrow control pollution, increase water quality mitigate flood for human safety. Nerus River is the largest tributary follow Strahler's order number 6 with drainage density of 2.64 (Strahler et al., 2006). The continuous precipitation due to climate change is in effect considered susceptible in flood-prone areas in the region (Bubeck, Botzen, & Aerts, 2012). According to (Dawson, Abrahart, Shamseldin, & Wilby, 2006), another detailed work using multi-criteria analysis in GIS for the estimation of the vulnerability of flood was presented in (Y. Wang, Li, Tang, & Zeng, 2011). (Kourgialas & Karatzas, 2016) explained vividly on flood hazard areas by superimposing GIS layers that visualize spatial and climate information. (Sanyal & Lu, 2006) The Department of Irrigation and Drainage Malaysia (DID) are responsible for providing flood forecast and warning services to the public (Chan, 2012).

The designed model will be relevant for planning, management and decision making to government and other related agencies. The application of SWAT into flood study is relevant; the model output can be best used for flood mitigation and decision making on how to control flood events at a premature stage to save lives and properties. The SWAT model (Arnold, Srinivasan, Muttiah, & Williams, 1998). According to (Blake, Khanbilvardi, & Rosenzweig, 2000), the issue of global warming and climate change is one of the driving forces that affect river flows pattern. The drainage basin (catchment) according to (Schumann, Funke, & Schultz, 2000) is the area that contributes water and sediment to the river system. According to (Lyon, Lopez, Lyon, & Lopez, 2001), GIS applications are applied because of the versatility of the resource over of time and space. The soil and water assessment tool (SWAT) is a continuous and deterministic watershed model that can operate on daily and hourly time steps (Penna, Tromp-van Meerveld, Gobbi, Borga, & Dalla Fontana, 2011). The figure below describes the influence of climate in the hydrological model. According to (Correia, Da Silva, & Ramos, 1999), GIS is recognized as a powerful tool in regulating and analyzing data from different sources and flood risk mapping was presented for different platforms of urban growths simulating and consequences of alternative cases (Zerger, 2002). Provision of warning or alert is expected to facilitate argument response and decrease the impact of possible future flood events Kia et al (2012)(Kia et al., 2012). The recent application of 3D GIS had provided clear presentation and visualization of flood hazard event than the previously used of 2D map (F. Wang & Xu, 2008).

II. Materials And Methods

New DEM from ASTER DEM with good resolution and quality images were used. While another author (Liu, Gebremeskel, De Smedt, Hoffmann, & Pfister, 2003) included several parameters in their rainfall-runoff model such as (land use, soil types, and DEM). This was to estimate spatial distinction between average flow and runoff in the river basin. ArcSWAT Software for watershed delineation has been installed. The Raster image from digital elevation model with 30 meters resolutions was added. Floodplains are the areas mostly the flatlands close to or adjacent to river formed by lateral migration (Acreman, Riddington, & Booker, 2003). Both of the land cover act as green infrastructure to migrate flooding by storing and flowing floodwater so that it arrives downstream gradually rather than in a single large pulse (Acreman et al., 2003). Wetlands are considered to be effective in lessening small frequent flood events, whereas floodplain can reduce downstream peak flow for more severe flood events (Opperman et al., 2009). Several climatic scenarios indicate an increase in high precipitation events (Min, Zhang, Zwiers, & Hegerl, 2011) which suggest the significance of both wetland and floodplain to human.

(Schanze, 2006) classified flood risk management categories into:

a. Flood risk mitigation

b. Flood risk assessment

The two distinctions take into cognizance the level of hazard and impact since it is difficult to eliminate risk possibly without design strategies to control the flood impact hazard at aerial or regional scale to identify prone areas (Tehrany, Pradhan, & Jebur, 2013).

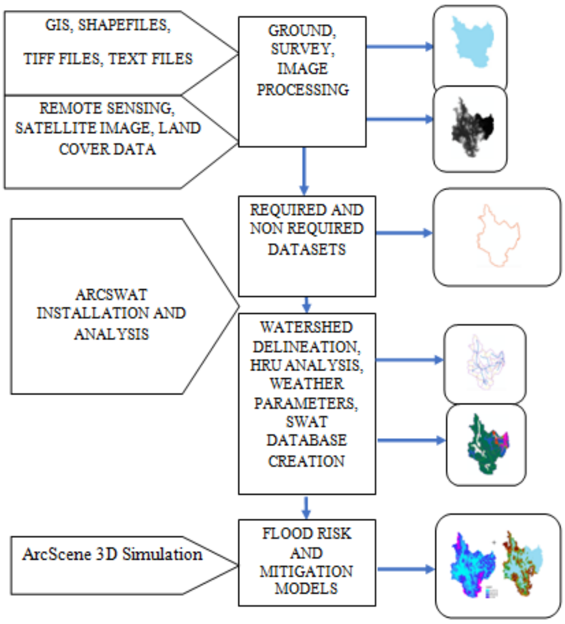


Figure 1 flow chart

III. Study Area

The study focuses on the flood mitigation in one of the flood-prone regions in the Eastern part of Peninsula Malaysia called Kuala Terengganu Catchment area. The Kuala Terengganu catchment has a total area of 441000 and the catchment lies within the wet tropical climate that exhibits vital roles in manipulating weather, soil, organic matter sediment yield that drained into the South China Sea. It is located at upper left corner 50305.407N, 10202315.536E and the lower right corner is 403924.251N, 103011 6.211E respectively. The bottom has gentle slope gradually deepening toward the open sea as cited in (Marghany, Ibrahim, & Van Genderen, 2002).

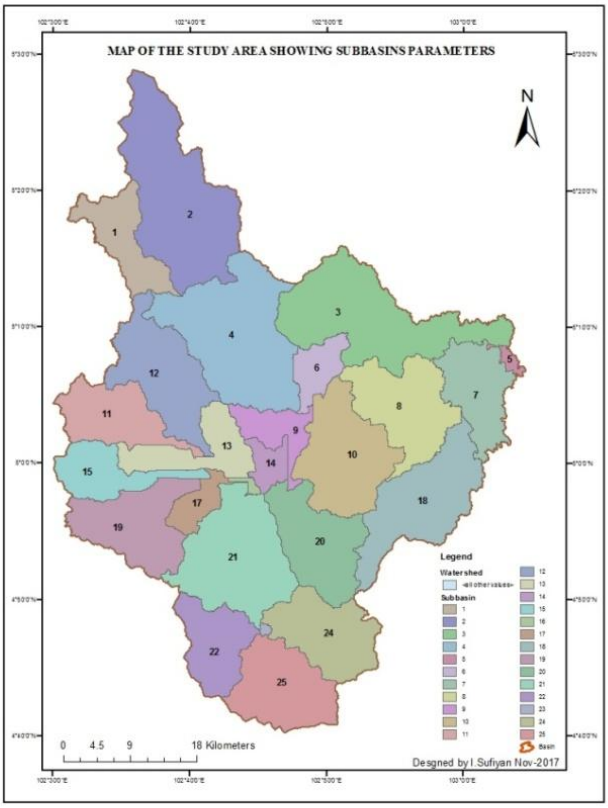


Figure 2: study area map

The SWAT software will automatically export all the characteristics of subbasins parameters into the database for further in hydrological analyses.

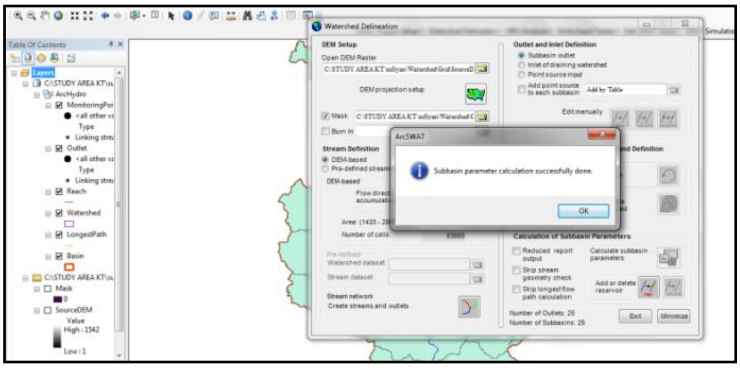


Figure 3: SWAT data processing

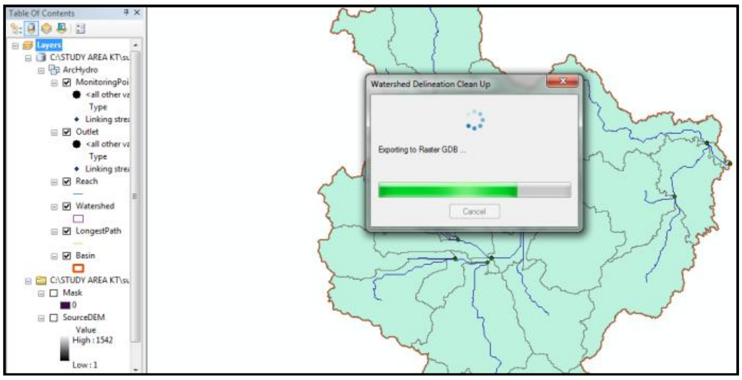


Figure 4: data exported to Geodatabase

IV. Result

The results from SWAT displays the highest land use is water body with 73.2% followed by forest evergreen with 14.8% and the other as shown in Table below.

Table 2: land use/cover result

Land Use Type	Area²	Area%
Forest Evergreen	47,7359	14.77
Water Body	2,367,210	73.245
Oil Palm	16,3033	5.045
Rubber	42,352	1.31
Urban High Density	13,9700	4.323
Paddy	39,349	1.218
Open Land	2,144	0.066
Reserve Land	619	0.019
Grassland	122	0.004

The soil in Kuala Terengganu, the predominant local soils found in the Terengganu catchment are the water with 68.7%, Kuala Brang with 12.7% Marang with 9.2% and the rest as shown in the Table below.

Table 2: Local Soil from the Terengganu catchment

Soil Type	Area²	Area%
Marang	297,122	9.19
Water	2,221,972	68.726
Kuala Brang	409,400	12.663
Tok Yong	88,200	2.728
Peat	52,541	1.625
Telemong	145,720	4.507
Rudau	18,112	0.56

Slope in Kuala Terengganu; the slope characteristic where flood usually occurs is between slope ranges of 0-10 with maximum flood hazard risk of the 5-meter water level. The rest of the slope ranges depend upon the water volume and climate change which can enhance flood. If the water level reaches 10 meters or above, the flood will be at risk level and move on to more dangerous level.

Table 3: Slope variable result

Slope Range	Slope In Meters
O-10	5
10-20	10
20-30	20
30-40	30
40-100	40

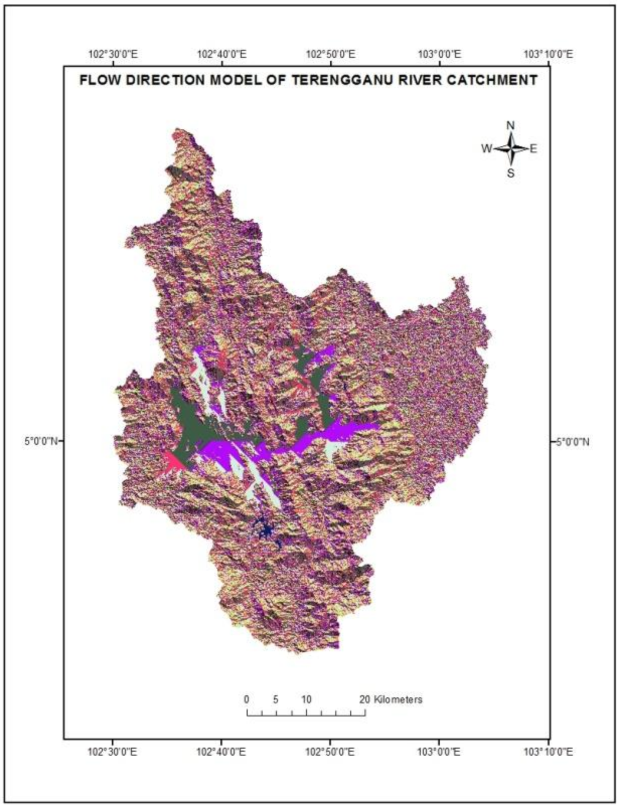


Figure 5: slope model of the study area

The flood events are selected from 15 districts of Kuala Terengganu to show the areas affected by the flood. Table 4.6 shows the highest area flooded in Terengganu around Universiti Malaysia Terengganu with 42 % and Gong Badak having 23%.

Table 4: Flooded areas during 2016 flood events

Valid	Frequency	Percentage	Valid Percentage	Cumulative Percent
Bukit Tunggal	1	1.0	1.0	1.0
Gong Badak	23	23.0	23.0	24.0
Kermaman	7	7.0	7.0	31.0
Kuala Brang	1	1.0	1.0	32.0
Kuala Ibai	2	2.0	2.0	34.0
Kula Nerus	2	2.0	2.0	36.0
Kuala Telemong	1	1.0	1.0	37.0
Kuala Terengganu	11	11.0	11.0	48.0
Manir	2	2.0	2.0	50.0
Marang	1	1.0	1.0	51.0
Mengabang Telipot	1	1.0	1.0	52.0
Padang Kemunting	1	1.0	1.0	53.0
Setiu	4	4.0	4.0	57.0
Unisza	1.0	1.0	1.0	58.0
University Malaysia Terengganu	42	420.	42.0	100.0
Total	100	100.0	100.0	

Source: field data 2017

The chard in figure 4.13 presents the highest flood areas in the study area.

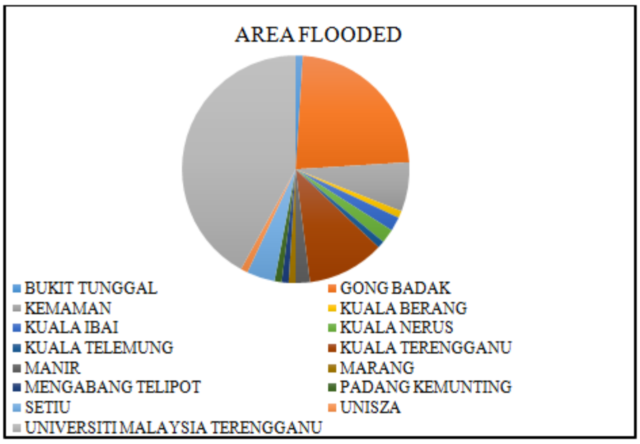


Figure 6: portion of flooded areas

The figure 7 the line graph indicating the flood areas during the 2016 flood event in Kuala Terengganu.

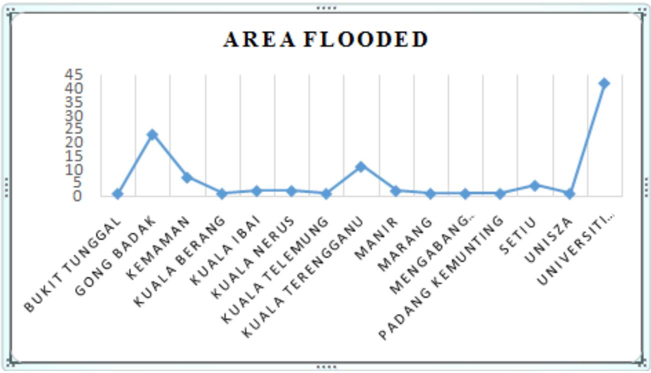


Figure 7 Line graph showing flooded area

Real-Time Simulation Using Flood Map is analyzed in mosaic in other to capture the flood event as it occurs. The simulation is at best prediction during the monsoon period between Novembers to early January in most part of the coastal areas of Peninsular Malaysia. The flood event in the diagrams below depicted from 1-meter simulation (a) to 10 meters (g).

Flood Map Water Level Elevation

Simulation set at 1 meter showing the spots of the flooded near the South China Sea

a

Simulation set at 2 meters the Estuary located in Kuala Terengganu Catchment (low risk)

b

Simulation set at 4 meters, the flood is shown in dotted blue color.

c

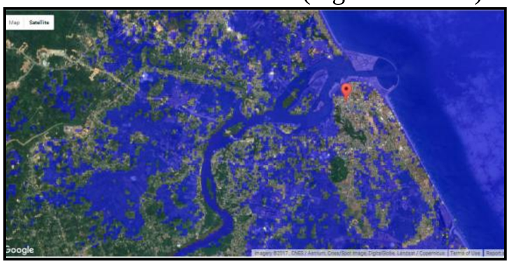
Flood event At 5 meters (risk zones)

d

Flood event At 6 meters (moderate risk zones)

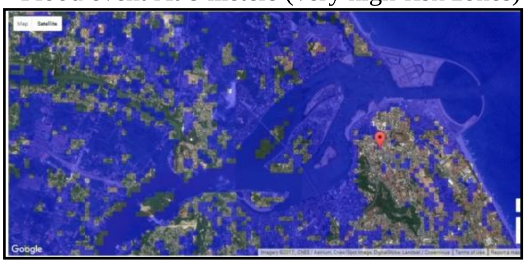
e

Flood event At 7 meters (high-risk zones)



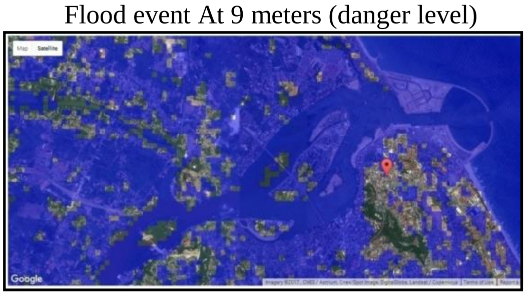
f

Flood event At 8 meters (very high-risk zones)



g

Flood event At 9 meters (danger level)



h

At 10 meters (more dangerous level)

g

V. Discussion

Watershed is also known as a basin or catchment, or simply an area delineated with a specified outlet point that emptied into a large body of water. The figure below represents the delineated watershed of Kuala Terengganu River Catchment. The boundary with brown color in figure 8 is the demarcation of the delineated watershed of the study area.

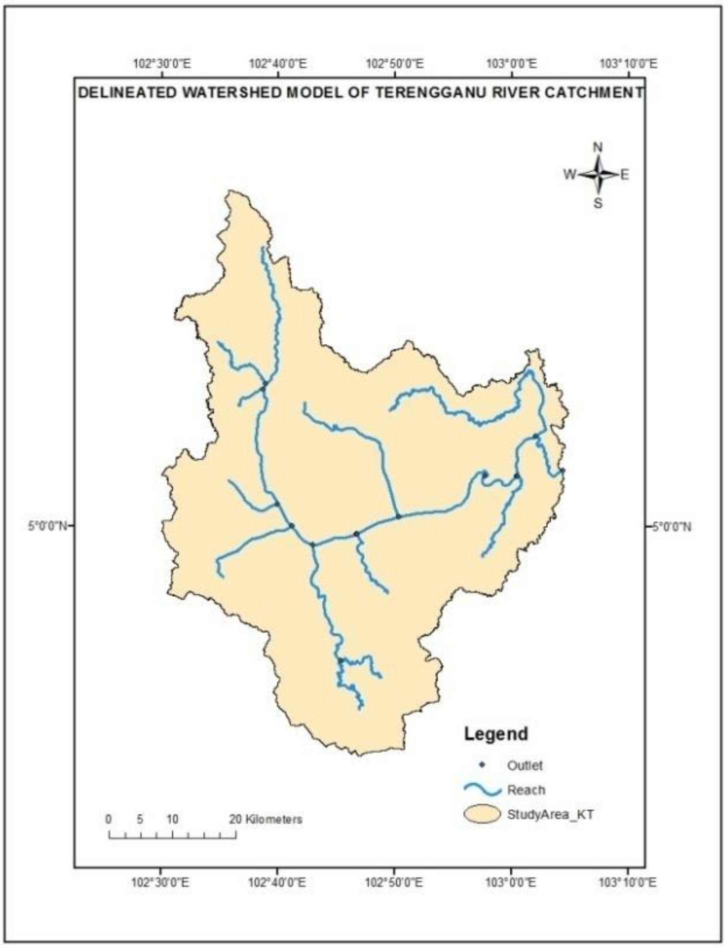


Figure 8: delineated watershed and streams of Terengganu river catchment

The stream links are developed through the stream network. 10 stream links are obtained from the Terengganu catchment. Each stream link had been connected with the defined subbasin. The 3 major reservoirs were identified within the watershed as shown in figure 9.

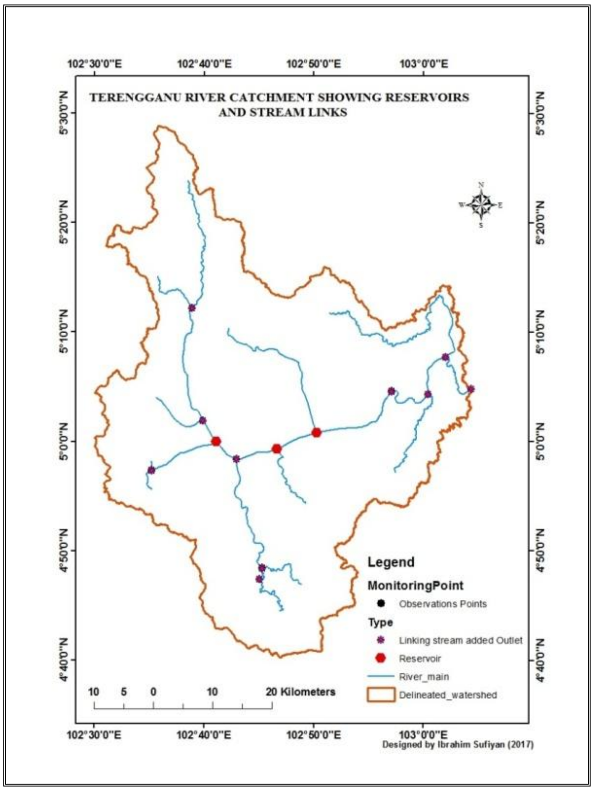


Figure 9: stream links and reservoirs

There are about 25 different sub-basins in the study area created by the SWAT. Each of the sub-basins was characterized by a distinct parameter for easy classification and hydrologic analyses. Figure 10 shows the classified sub-basins in Kuala Terengganu catchment. The major Terengganu Rivers as shown in figure 9 are added connected by the stream links to the watershed and the main rivers were appended to the whole catchment.

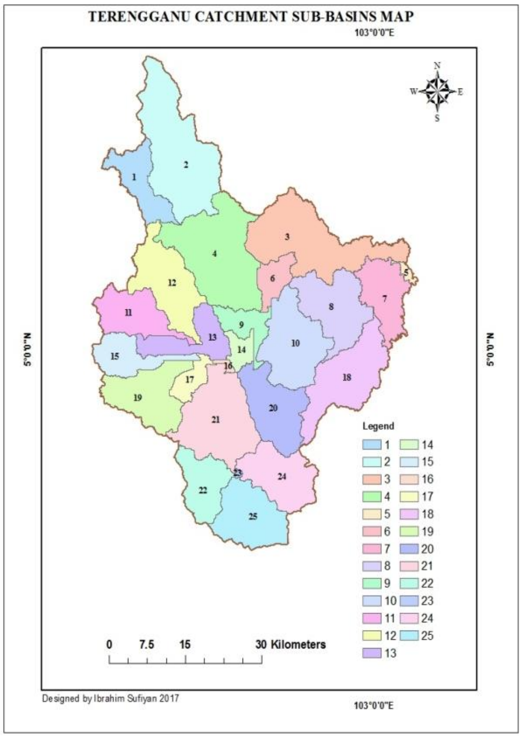


Figure 10: Subbasins Parameters

The area affected by the flood in Terengganu River catchment are presented in figure 11 below**:** the simulation in the 3D environment has developed into models of flood risk zones which are categorized by 5 distinct classes. These includes

1. Vey high flood risk zones
2. High flood risk zones
3. Moderate flood risk zones
4. Low flood risk zones
5. No flood risk zones

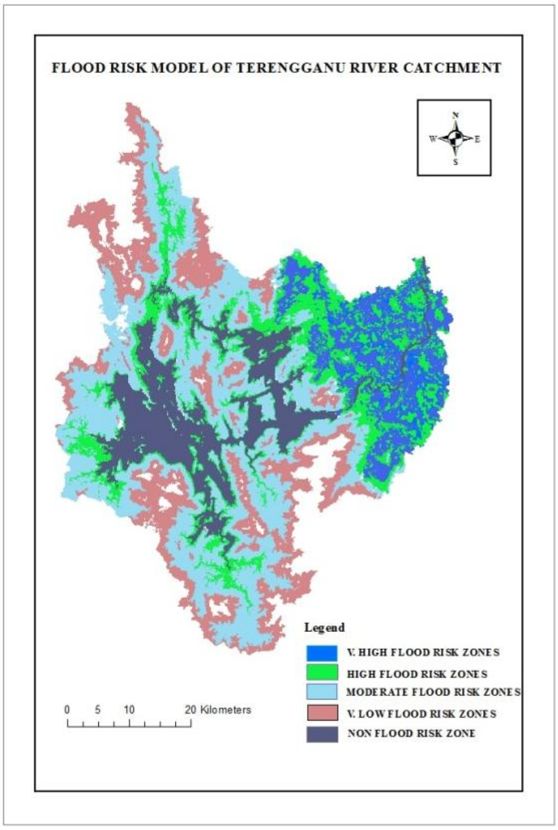


Figure 11: the flood risk mitigation model of Terengganu River catchment

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VI. Conclusion

The real-time flood simulation is a new technique developed from the satellite technology combined with the hydrological software known as soil and water assessment tool (SWAT). It is observed that every catchment area have different characteristics of land use, soil and slope. The uniqueness of the three variables changes the shape and influenced not only flood event but also predict a nutrient loss, plant growth as well as sediment yield within the River catchment. The result obtained from the simulated flood risk models of Terengganu River catchment had predicted about 5 different flood risk zones. We observed that when the water level reaches a certain level, the flood might be hazardous and risky perhaps to danger zones. People settling or occupying land at lower elevation near streams or rivers will be prompt to flooding. The flood simulations will serve as a warning and alert, the model is paramount to urban planners, Engineers, and other relevant agencies.

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