Flood Risk Vulnerability Using 3d Visual Models And Swat In Terengganu River Catchment

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Abstract- Flood is the natural occurrance penomena that affects many areas around the wolrd. The flood risk is predominantly found in area where rainfall exceeds 3000mm per annum. The Terengganu river cachment has one of this chacrateristics. It falls within the tropical equitorial monsoon climate. Generally, the vulnerability of the flood is more in Peninsular Malaysia. The use of 3D simulation has identified flood risk zones. the use of sub-basins parameters to calculated areas flooded is done in ArcGIS 10.3-ArcSWAT2012 extension. The outcome is the modeling of highly flooded zones. The individual impacts of flood risk have been monitored and the results display the modeling of flood risk zones in the catchment area of Terengganu.

Keywords: Flood, Modeling, Vulnerability, GIS, SWAT, Impact, Risk

1. Introduction

Flood risk is treated as a function of hazard, vulnerability, and exposure. All the three elements are directly influenced by climate change and they are represented as a geospatial data layer in the geographic information system (GIS) in order to provide a sequential framework to assist in management as well as planning purposes. There is need to create awareness and to highlight communities for sustainable resilient to face climate change. Flood has to occur all over the world [1] also stressed the influence of external hazard on the environment exposed to urban areas and cities or villages that affect its surrounding topography.

According to [2], GIS applications are applied because of the versatility of the resource over of time and space. Geographic Information systems are databases with a spatial component and ability to store and process data. However, the technology has potential to produce a map-like product for decision making. Data are stored in multiple files. Each file contains data in a coordinate system that identifies a position for each data point or entry. Most of the point data are characteristically stored as "attribute". A database of individual files is developed and can be combined as an attribute such as topography, stream location, water or soil sampling, management practice ownership, biota and point source. All the following data collected in GIS home meaning for analysis. All applications of interest can be imputed into GIS database as a variable or "layer" supporting the applications with data on the characteristics of water resource or watershed. Many of the project goals can better solve using advanced application of GIS, remote sensing, and Global Positioning System (GPS) technologies. Those advanced approached has made it necessary to use complex models through GIS technologies and collection of field data with GPS, [3].

[4] incorporated remotely sensed data collection used in the recent trend in GIS application to watershed research as improved the concurrency of collected data as compared to the manual entries which are subject to errors. Improved database organization and storage had help in determining watershed segmentation; identification of drainage divides and channels networks. [2] are of the view that making use of satellite data are essential on watershed over large land cover areas in the different ecosystem in Florida, Great Lakes, Washington, and Africa.

With very few inputs data the model can run almost entirely on available and free data. Therefore, the steps establish the processes to dominate hydrologic activity in the model [5]. According to [6], validated a crack flow model for SWAT, it simulates soil moisture condition in dry weather. Simulating crack volume was in agreement with seasonal trends, and also can predict daily surface runoff level consistently with measured runoff data.

The hydrodynamic model just like in SWAT, when compared, was proven to be of economic and ecological safe method for planning water resource development. 1D and 2D modeling were done in several river systems, although it depended on what kind of requirement is needed in the study [7]. The applications of SWAT in Lhasa Nadi tributary joining Parvati River in the state of Rajasthan was successfully done. The river was used to generate thermal energy and flood can be a serious problem to the thermal plan. Therefore, structures like reservoir and Levees were constructed from the non-perennial stream. The thermal plan was found suitable for flood mitigation through modeling. The input data used are Digital Elevation Model (DEM) from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) [8]. The DEM ASTER has a spatial resolution of 30 meters.

Another advantage of SWAT is its capability to incorporate numerous tools for analysis (calibration and sensitivity analysis) that provide room for model comparison result with actual data [9].

The 30m resolution of ASTER DEM was converted into ArcScene using ArcGIS 3D software. During the ancient times, people developed ways of monitoring flood level and this enables them to predict the water flow and the risk or hazard involved. The 3D visualization techniques include the remote sensing, such as satellite imageries, aerial photogrammetric, Geographic Information System (GIS) and LiDAR modeling. The recent application of 3D GIS had provided clear presentation and visualization of flood hazard event than the previously used of 2D maps [10]. Geographic modeling and simulation are now considered to be fundamental in process and mining as well as dam- break flood. The dam is of benefit to people but there is a tendency to be broken due to flood hazard event [11]; [12].

The 3D model display information uses in Google Earth. The KML files will be read in ArcGIS. Google Earth Pro is more advanced than the standard version which allows high image resolution to be overlaid with other information included in GIS data. It is necessary to analyze water flow direction within 2 meters that can allow flood monitoring [13]. The DEM was used to develop mesh in the system and the water mask was generated for simulation of flood and produce flood models. This can be successfully visualized in the realistic 3D environment.

The visualization of flood simulation result has been achieved in the propagation of flood water flow in 17th Street Canal levee breaching during the Hurricane Katrina using CCHE2D flood models which are similar to ArcScene simulation [14]; [15]. The result of the simulation was then translated into GIS and visualized it in realistic 3D animation environment in ArcGIS software ArcScene. For a better view of the image scenario, the 3D animation was made to show the possible level of simulation base on the elevation of the area [16]. The Three-dimensional (3D) visualization becomes an interesting method for GIS representation of model outcome. The land use scanner is a GIS-base method of modeling that simulate land cover pattern. The simulation of future land use follows categorically different scenarios, [17]. River level and rainfall level data was used in assessing fluid movement in River Klang Dam and Batu Dam [18] The study of flood simulation become necessary in other to evaluate and provide information for decision making and flood control planning. [19]; [20] at present two-dimensional visualizations are not sufficient in presenting real scene and therefore cannot make a full representation of data available. Today geographical simulation and modeling are regarded as a fundamental approach to solving complex geographic problems [21]. Virtual geographic environments (VGEs) provides a new generation of geographic analysis tools both on the web and computer-based environment that are developed to help in solving problems in geographic processes [22]. Internet services nowadays are more ubiquitous and 3D graphics are increasing in web technology domain.

1.1 Impacts of Flood

[23] concluded that in Malaysia, converting land use from agriculture to the urban area increase the runoff rate. The general perceptions of the flood were seemed to have negative impacts. Despite flood negative impacts, it has some positive influence. Flood is a natural disaster and phenomenon, it is important to figure out that for sustainable development food helps in enriching and rejuvenating most of the biodiversity found in the floodplains. Flood also play tremendous contribution in replenishes the lands with nutrient-rich soil supply. Certain flood clear debris for the removal of sediment from the flooded areas. Flood also recharges groundwater storage. In many parts of Malaysia, such a Kota Bharu and Kelantan flood have been taken to be a positive occasion for water festival that has not much disturb daily activities. In high populated and developed areas, the negative impacts of the flood are prominent. These include disrupt social and economic activities, threaten human and animal lives, flood maintenance is costly, destroy the building, spread epidemics, and deterred investment.

2. Materials and Methods

The flood mapping generally considered the geographical references for the much-needed data as it occurs in different formats. For the purpose of this study, we are giving emphasis on the required and optional data input from both Geographic Information System (GIS) and Remote Sensing. The ground survey was conducted in other to obtain recent and up-to-date information about the land cover pattern, soil types and the slope classes. The output data must have been expected to produce predictable results for simulation in ArcScene. The 3D simulation is conducted in other to visualize the flood event in Kuala Terengganu catchment. This study also focused on the specific methods so that each stage of the processing and analysis of the data can produce result independently based on the criteria assigned to it. The flood assessment prediction can be done by monitoring the flood events and water flow within the catchment area of Terengganu River. The amount of land cover and land used will adversely affect the flow of water and hence resulted in the flood risk in the lowland areas. The soil types and the slope are the determinant factors that course for concern in influencing flood in the catchment area of Terengganu.

The figure 1 below is the flow chart illustrating how the study was conducted

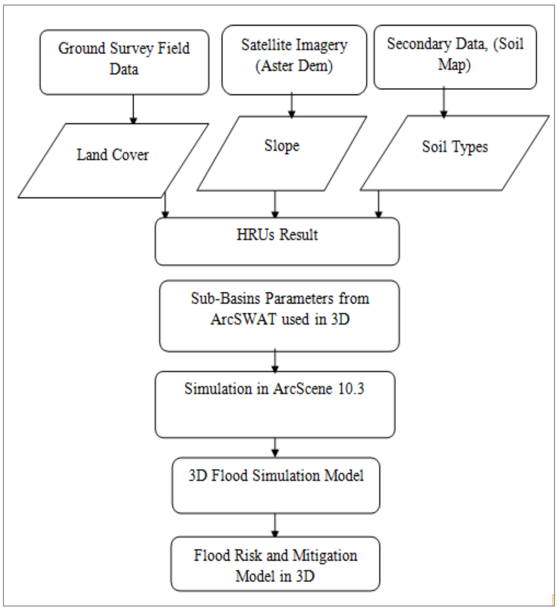

Figure 1: General flow diagram

2.2 Swat Data Sources

1. Department of Irrigation and Drainage (DID)
   a. Data of flood event in the study area (previously)
   b. Stream flows data
      These are obtainable base on different location of the stations
2. Climate data from Malaysian Meteorological Department (MET Malaysia) from 2000-2015
3. Land cover images from Malaysian Remote Sensing Agency (MRSA)
4. Malaysian soil map was obtainable from online source European Digital Archives of soil maps (EuDASM) named Reconnaissance soil map Peninsular Malaysia 1968.

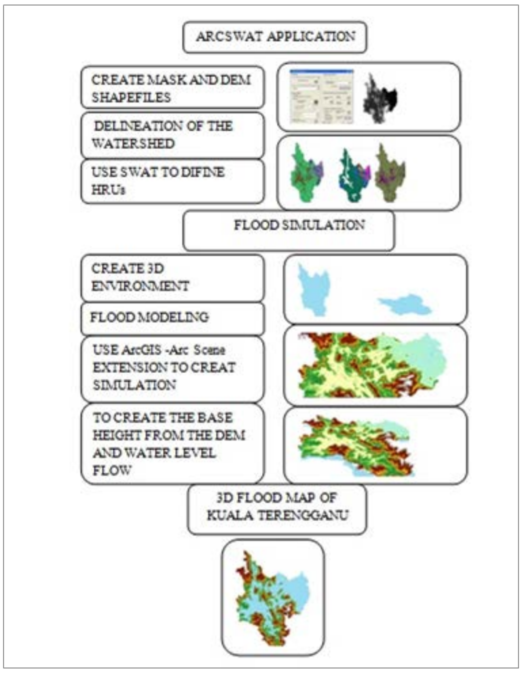

Figure 2: description of how the flood model was developed for Terengganu catchment area.

The input data for ArcSWAT includes the following:

Required spatial datasets and Optional spatial datasets

The required spatial datasets entails the following;

i. DEM
ii. Land Cover
iii. Soil map/data

The optional spatial datasets includes

i. Weather parameters
ii. Daily rainfall data
iii. Daily stream flow
iv. Daily suspended-sediment

Reconnaissance Survey The acquisition of field data started with the introduction of the study area along the Kuala Terengganu catchment. The main data collection commences on 2nd Week of February 2016. For the purpose of this study, there are two basic data to be obtained; this includes the land cover information and the flood frequency and months of highest rainfall and temperature.

2.3 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 River Catchment. The Terengganu catchment has a total area of stream definition of 5,730.1452 [Ha] about 14,159.497acres or 57.401km^2 with cells value of 63,668 as shown in figure 3.14 and the catchment lies within the wet tropical climate that exhibits vital roles in manipulating weather, soil, organic matter and sediment yield that drained into the South China Sea. It is located at upper left corner 50^0 30^I.40^{II} N, 102^0 23^I 15^{II} E and the lower right corner is 40^0 39^I 25^{II} N, 103^0 11^I 62^{II} E respectively. The bottom has gentle slope gradually deepening toward the open sea as cited in [24].

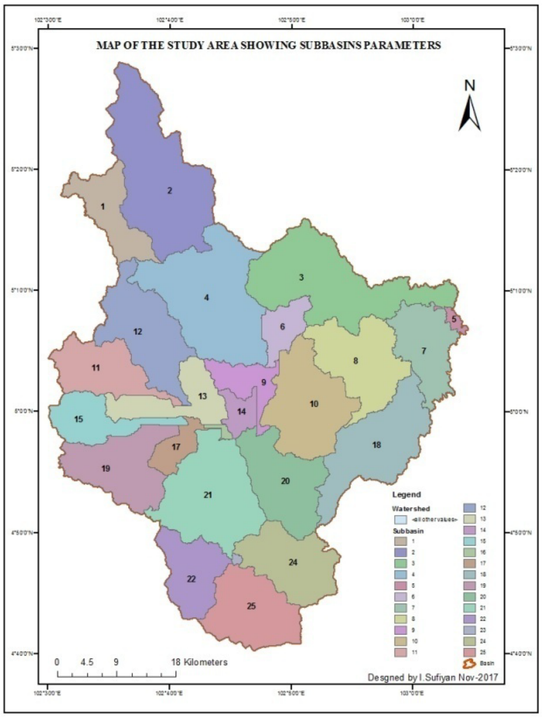

Figure 3: study area map of Terengganu

river catcment, Malaysia

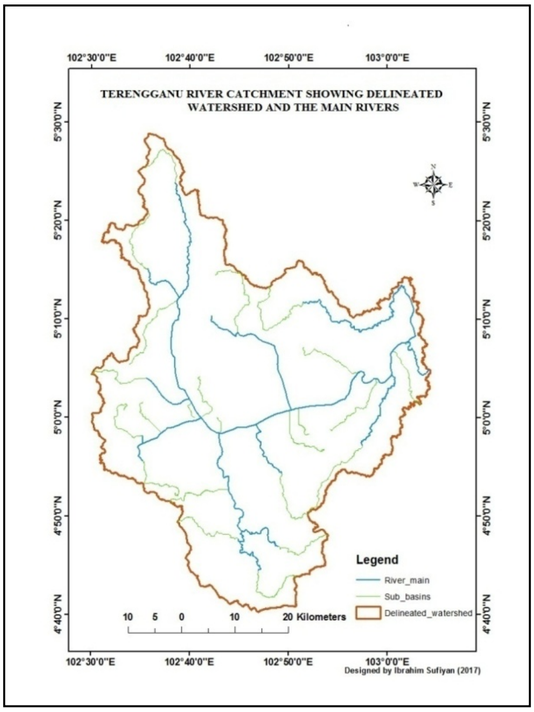

Figure 4: Delineation of the watershed and the main Rivers of Terengganu catchment.

3. Result and Discussion

figure 4 is the demarcation of the delineated watershed of the study area. The blue color is the main Rivers that flow toward the South China Sea. The minor streams are attached to the sub-basins.

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 sub-basin. There are also 3 major reservoirs confirned within the watershed as shown in figure 5.

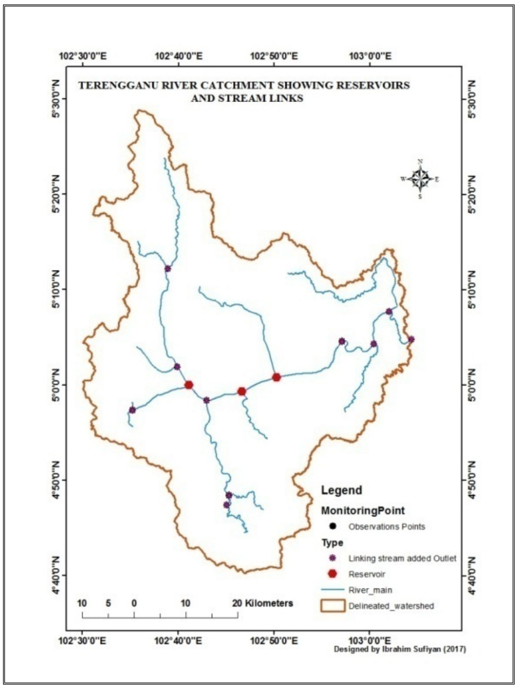

Figure 5: Stream Links and Reservoirs

3.1 Land Cover Types of Terengganu River Catchment

The results obtained from the hydrologic response units (HRUs) were used to define the land covers, soils and slope of the Terengganu River catchment. There are about 9 categories of land cover found within the Terengganu catchment. The land use/covers in table 1 present the portion each of the land covers occupies. The highest land cover found in Terengganu catchment is Forest-Evergreen with 73.93% occupying about 211,809.14 Ha; Waterbody has 14.90%, to 42,684.65 Ha; Rubber Trees 4.18% with 11,981.45%; Residential-High Density area occupies 1.17%, about 3,346.7332 Ha; Oil Palm 4.63% with about 13, 251.0778 Ha; Residential –Low Density has 0.06% with 167.2060 Ha; Paddy land has 1.12% with 3,209.3467 Ha; Orchard 0.02% occupies 46.8465 Ha. Finally, the Grassland has 0%. This indicates that that the geographical location of the study area lays within the forest zones with highest percent and the Grassland virtually little or no grass cover. Table 1 summarizes the land cover found in Terengganu catchment. Figure 6 presents the model of land cover types in the Terengganu watershed.

Table 1: Land Use/Cover (LULC)

Land use	**%wat. Area**
Water Body	14.90
Residential-High Density	1.17
Orchard	0.02
Rubber Trees	4.18
Residential –Low Density	0.06
Oil Palm	4.63
Paddy	1.12
Grassland	0.00
Forest-Evergreen	73.93

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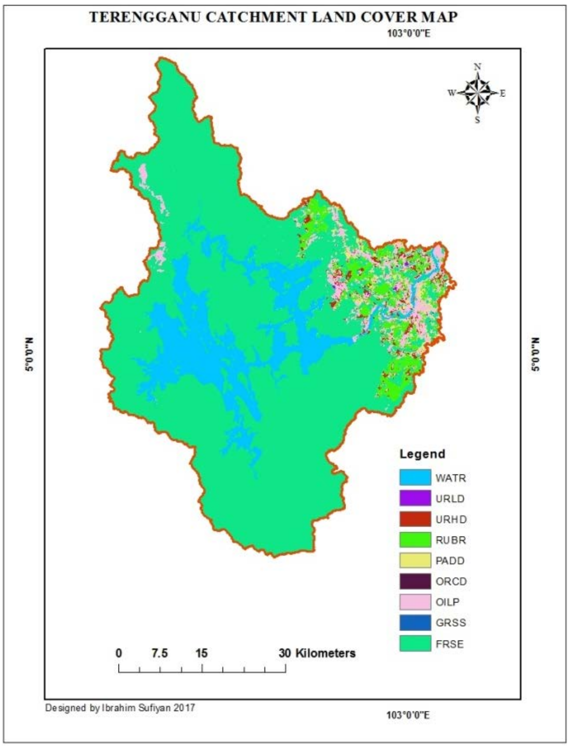

Figure 6: Land Use classification of Terengganu River catchment

3.2 Soil Types of Terengganu River Catchment

There are about 7 classifications of soil types in the catchment area of Terengganu. These are presented in table 2. The present of soils in the catchment determine the large extent the porosity, structure, moisture content and its ability to hold water. The 7 local soils identified includes Kuala Brang occupy 12.43%, with about 35,605.88 Ha; Marang has 9.34%, with about 26,762.6042 Ha; Peat Soil has 1.65%, with well over 4732.3090 Ha; Rudua has 0.47% has about 1357.6481; Steepland has 69.85% occupies about 200,117.6886 Ha; Telemong has 3.58% 10,250.0178 Ha; and Tok Yong has 2.68%, with 7682.1981 Ha. According to this result presented the typical soil class occupying the Terengganu catchment is Steepland and Kuala Brang, the fewer soil types are Rudua and Peat soils. The steepland are mountainous soil formed from the product of weathering of rocks. The soils are rich in nutrient being mixed with humus formed during humification process of soil formation that causes rapid decay of organic matter due to high humidity. The dominant present of forest and Oil Palm land cover in Table 2 explained more about the local soils present in percents within the catchment area of Kuala Terengganu. Figure 7 below is the model of the local soils.

Table 2: Local Soil Types

Soils	**%wat. Area**
Kuala Brang	12.43
Marang	9.34
Peat	1.65
Rudua	0.47
Steepland	69.85
Telemong	3.58
Tok Yong	2.68

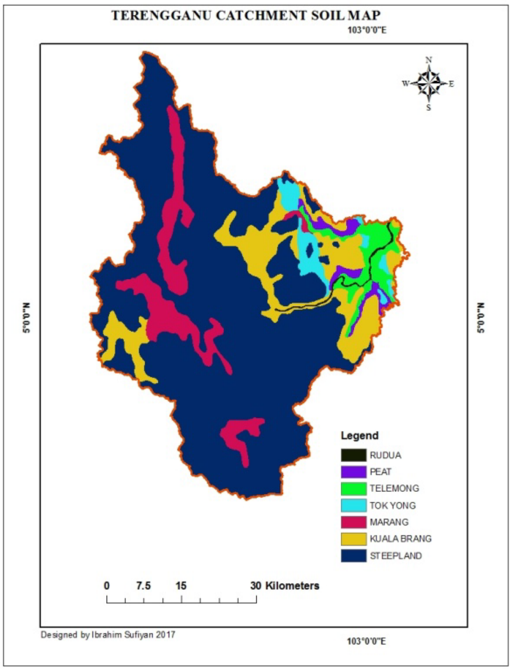

Figure 7: Soil map of Kuala Terengganu Catchment Area.

3.3 Slope Classes of Terengganu River Catchment

The slope class chosen is adjusted from the SWAT database base on the terrain and the threshold. If the basin is large enough then we increase the threshold, for instance, the previous work on sediment yield and deposit in the catchment area of Kuala Terengganu suing SWAT has few stream outlets and they considered the threshold of 5/5/5%. But for this study, the threshold was increased to 10/10/10% due to the coverage and to have all the features represented. The major slope class where the flood events frequently occur between 0-1 m and 1-2m has occupied about 21.70%. According to the flood simulation model in figure 9 the elevation data reaches up to 1-2m where the flood events mostly occurred. Therefore, all areas in Kuala Terengganu catchment might be liable to flood at the surface water level of 1, 2 or rarely 3m. The slope data clearly demonstrates the gradient with 0 to 1m and 1 to 2m as the zones of the flood. Table 3 is the summary of the slope in Terengganu watershed that falls within 0-10m with 21.70 percent.

Table 3: Slope Classes

Slope	% wat. Area
0-10	21.70
10-20	20.93
20-30	18.98
30-40	15.30
40-9999	23.08

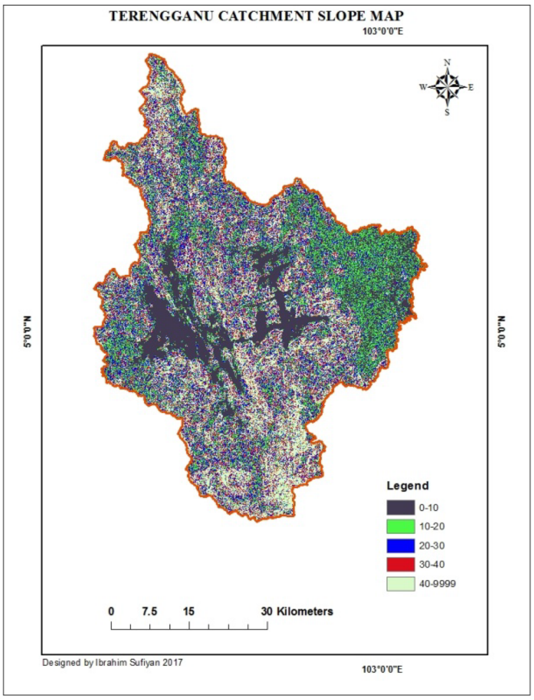

Figure 8: Slope map of Kuala Terengganu River Catchment

The river flow direction indicates the water flow toward the lower slope or elevation zones where the major Terengganu River catchment has an outlet into the South China Sea. The rivers that formed sub-basins from the artificial Kenyir Lake are all drained into the other adjacent outlets as indicated in figure 8. Above.

3.4 Impact of Flood Risk zones vulnerability on Subbasins in Terengganu River Catchment

The figure 9 displays the flood risk zones in Terengganu River catchment. The classification is base on the slope gradient and the simulations carried out in the 3D environment. These classes are divided into high, moderate, low, very low and free flood risk zones.

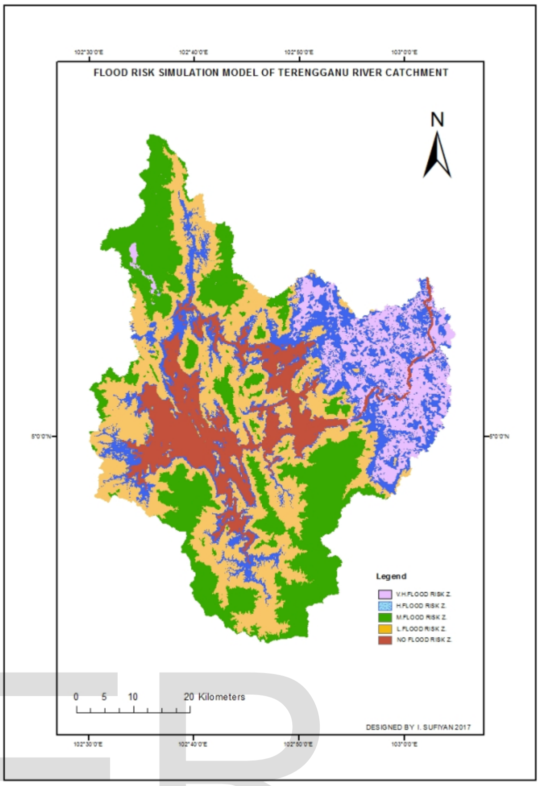

Figure 9: Impacts of flood risk vulnerability

The 25 subbasins in Terengganu River catchment were influenced by the 3 major factors from the HRUs and variable effects in the flood zones. Depending on the locations, functions and impacts each subbasin performed, the flood reflects the magnitude of vulnerability. Base on the subbasins within the catchment model, it clearly portrays the subbasins vulnerable to flood risk and hazard events.

The number of subbasins that are vulnerable to very high flood risk zones includes subbasins number 3, 7, 8 and 18. Subbasins number 1, 2, 16 and 22 are located at high flood risk zones. Subbassins number 11, 20, 25 are in moderate flood risk zones while the rest are either on low or free flood risk zones as shown in figure 10 below.

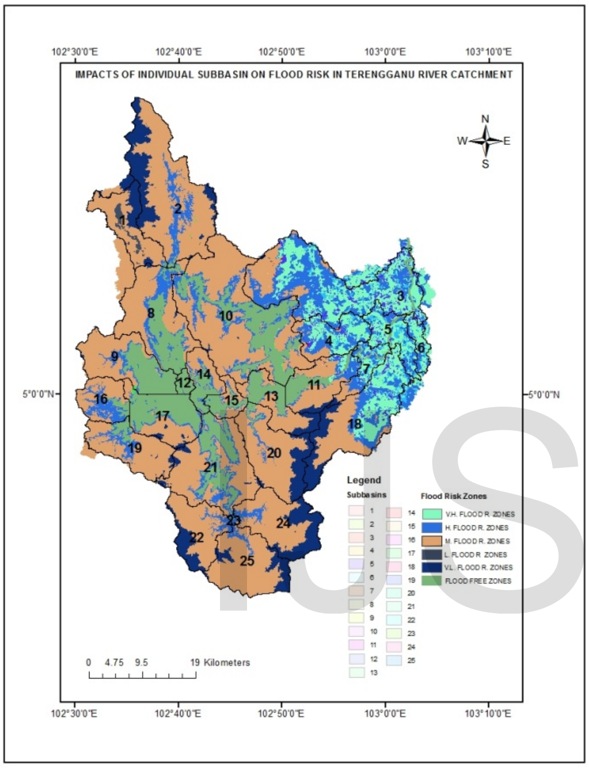

Figure 10: impact of flood risk zones on subbasins

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4. Conclusion

Most of the flood events occur during the monsoon season in almost all part of Peninsular Malaysia. The Terengganu river catchment has been delineated with the results showing the significant impacts of hydrologic response units on individual subbasins parameters. The simulated model had categorised the flood risk base on the simulation of high to low flood risk zones. The importance attached to the modeling is for management, planning and mitigation for the purpose future flood occurrence in the Terengganu river catchment.

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