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Impact of Malaysia major flood to river geomorphology changes and total suspended solid using GIS technique

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ABSTRACT

Flood is the most common type of disaster in Peninsular Malaysia. In December 2014, a major flood event occurred in Pahang River that recorded the worst flood ever hit Pahang River Basin and Malaysia generally. Twelve sampling station has been chosen which covered of upstream, middle stream and downstream parts of Pahang River. This study focuses on scrutinizing the processes of the river geomorphology changes using geographic information system and other techniques. Those stations are Jerantut Feri, JPS Tembeling, Chenor and Pekan. The 3D modelling surface showed that the bathymetric shape of Pahang River bed was severely affected by the flood due to collapse of river banks, land use changes and anthropogenic activities. However, other stations are also affected by the flood but it is not significant according to cluster group constructed. Total suspended solid was classified into three group using cluster analysis. The contributors of sedimentation problems in Pahang River are from unsustainable land use such as urbanization, agricultural activities, industrialization which are trapping the bed sediments and river band erosion caused by flood phenomenon. Sinuosity index (SI) of Pahang River shows that high percentage of changes occurred in the upstream at Tembeling River and Jelai River with the highest percentage recorded at 45%. SI recorded at middle stream shows a significant change with the percentage of 20.7%. While at downstream, the SI recorded three significant changes from 16.0% to 20.3%. Based on statistical analysis, significant changes with moderate correlation in R squared value at $R^2 = 0.6669$ was obtained between SI changes and water level that occurred from 2010 to 2015. Pahang River geomorphology change analysis and river bed geometric analysis are very important in order to decide the best mitigating measure and management plan that will overcome the biggest problem of Pahang River, that is, flood – that occurs every year. Generally, this study is very important to gather information on the effect of 2014 major flood in Pahang River in order to manage the Basin of Tropical River. In future, for mitigation measure, alternative management is proposed for Pahang River Maintenance such as service of natural flood ponds and flood mitigation projects.

Keywords: River geomorphology changes; Total suspended solid (TSS); 3D modelling; bathymetric; Pahang River basin

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1. Introduction

Flood is the most common natural disaster that occurs in Malaysia. Approximately every year, flood event will occur in some places in Malaysia whether it is huge flood or only flash flood. The land use cover due to deforestation and massive development of the areas has become a perception to the researcher that it is the main reason that contributed to the increased results in flood frequency and severity [1–5]. Stream flow of rivers is basically can be studied to be used as an indicator for the flood event [6]. Pahang River Basin is one of the areas that received highest total rainfall during north east monsoon period about 40% of the total rainfall annually [7,8]. According to Adnan and Atkinson [9], climate changes and weather play an important role in various fields such as hydrology, epidemiology, hydrogeology, and environment sustainability. Water level of rivers and intensity of rainfall in the areas basically can be studied to be used as an indicator for the flood event [8,10]. According to Lun et al. [10] and Kamarudin et al. [11], the heavy and extreme precipitation will increase as mean of total precipitation increase. During December 2014, a major flood event occurred that was classified as the worst flood that ever occurred in Pahang and several others states including Kelantan, Terengganu and Perak. The major flood event started in 17 December 2014 where heavy rainfall took place and water level increased at certain places in Pahang and led to a flood started from 22 December 2014 that flooded major districts such as Temerloh, Kuantan, Pekan, Bera, Jerantut, Maran and Lipis and evacuation of the victims has been performed [1,12].

Pahang has been surged by major flood events that caused a lot of damage to the state started in 1926 that recorded as the worst flood event in history. On 2014, one of the worst flood event that hit Pahang and the entire east coast of Peninsular Malaysia. The flood victims that evacuated were increased dramatically from time period due to the flood that spread to other districts. Pahang major flood event in 2014 has left a lot of damage especially on the domestic wealth and changes of hydrological system of Pahang River also being altered such as the depth, stream flow, river planform and bathymetry [13–16].

Almost every year, flood hit-Peninsular Malaysia at East Coast, Northern, and Southern region is affected. East coast of Peninsular Malaysia is being hit by flood that cost the most of economic and domestic loss to the country. Kelantan State also was hit by major flood in December 2014 that caused huge effect on Kelantan state generally. Most of the part of Kelantan areas such as Kuala Krai, Machang, and Kota Bharu are heavily affected by the flood. Pahang River Basin has been affected by massive flood event in December 2014 that caused huge loss of economic, agriculture, and properties. The investigation of river planform using geographic information system (GIS) and statistical analysis is one of the best methods that can be used to identify the sources that contributed to the flood problems. The analysis was created using GIS and satellite images were focused on the drainage capacity and the dynamics of river morphology. With the information from GIS analysis and statistical techniques, the alternative flood management system can be recommended for Pahang River to improve the mitigation programs and alternative efficient methods to overcome the flood event and impact of the flood from the source based on the historical river planform changes [4–5,17,18].

The issues of river quality and availability of water resources are being questioned because of the degradation of environmental health and dramatically increased pollution in Malaysia. Something has to be done before the situation becomes worse and affects our water resources. According to Sulaiman et al. [19], there are possibilities that the land use and intensive development of a certain area will alter the river systems near to the development and also the alteration of the river itself such as flood control and power generation will increase the degradation of river systems in Malaysia. Due to exploitation of natural resources in Malaysia such as massive land reclamation, development of livestock production, energy development project and uncontrolled discharge of pollution, this disturbance may result in flood event, stream degradation, and erosion [20]. The control and plan of a river can be done through identifying and evaluating the types of river [21], the evaluations of other aspects such as discharge, erosion process, sedimentation, and changes of land use can be used to identify the cause and factor that lead to the problems. The river geomorphology, river meander and geometric shape of river bed studies are also very important to overcome the problems in order to apply more sustainable controlling and planning for the river [18,22]. River geometry constitutes the shape and measurement of a river from vertical and horizontal of the river. It consists of river bed, river bank, stream flow, and flood plain of the river [23,24]. Therefore, the geometric shape of a river can be defined as shape or profile of the river for its physical characteristics and measurement of the river such as the river bank profile, river bed profile, and also the entire cross-section of the river [25].

The purpose of this study is to identify the changes of river bed geometry due to major flood 2014 based on the previous data from 2013 Pahang river geometric data. In addition, the effect of major flood 2014 on total suspended solid (TSS) and river discharge due to changes in river geometry characteristics. In statistical tools, non-parametric test is considered better and it displays much insensitivity to outlier unlike parametric test [12,19]. The application of environmetric, a branch of environmental analytical chemistry and the use of multivariate statistical modelling and data treatment was reported to be the best method in analyzing a large complex environmental monitoring data [26–28].

The scope of this study was to study about the effect of flood specifically in Pahang River during major flood in 2014. This study also has its own limitation that only focused on the effect of major flood 2014 on Pahang River changes in planform and geometry changes of Pahang river. These studies were focused on the use of GIS and statistical analysis to conduct an investigation on the changes in river planform at Pahang River mainstream from upstream of Jelai River, Tembeling River, and Pahang River mainstream from Kuala Tahan to Pekan and recommendation for the alternative flood management in Pahang River Basin, Malaysia.

2. Study area and research methodology

2.1. Area of study

Pahang river is also one of the largest river basins in Peninsular Malaysia and is located at longitude 1010 30′E to 1030 30′E and latitude 30 00′ N to 40 45′ N [1,29,30]. Pahang

River is the major river system in Pahang state that started from the Titiwangsa mountain range to the South China Sea. There are 12 sampling stations that involved in this research that represent the upstream, middle stream, and downstream of Pahang River (Table 1; Fig. 1).

According to the Department of Irrigation and Drainage [31], the big event has been accrued in 2014 where the rainfall intensity increased in December 2014 especially during mid-December and several areas such as Jerantut, Maran, Temerloh, Gua Musang, and Nenggiri (Fig. 2). Based on the isohyet map, the high rainfall intensity in December 2014 was focused at the Terengganu and Kelantan border with the range of rainfall intensity of 2,300 to 1,600 mm. The rainfall cumulative intensity still pouring down in few areas that were heavily affected by flood are National Park, Jerantut, Temerloh, Cameron highland especially in Brinchang and Chini in capacity range about 120 mm to 60 mm. Based on the isohyet map in January 2015, high intensity if rain was poured at Kuala Rompin area at the range of 800 to 700 mm. Other places such as central area of Pahang state and upstream area of Pahang River, the rainfall intensity has dropped to the range of 120 mm to 40 mm in the blue area.

Pahang River is one of the tropical river streams that can be representing the tropical river generally in Peninsular Malaysia. Pahang River Basin is also the biggest river basin in Peninsular Malaysia. For a basin that is as big as Pahang River Basin, there are a lot of problems and issues involving the river planform and river geometry. Besides that, Pahang River Basin is also one of the areas that have tolerated a worst flood event in 2014. Due to the disaster, this research has been

Table 1
Sampling stations involved in Pahang River Basin, Pahang, Malaysia

Sampling station	Coordinates	Place
B1	3.50468, 103.389	Jambatan Pekan
B2	3.54842, 103.213	Kg.Temai Hulu
B3	3.5035, 103.14069	Paloh Hinai
B5	3.45189, 102.89143	Kg.Melayu
B6	3.5009, 102.74895	Lubuk Paku
B8	3.47997, 102.59414	Chenor
B12	3.45583, 102.42549	Temerloh
B13	3.5557, 102.41484	Lipat Kajang
B14	3.82545, 102.4078	Jeransang
B15	3.95704, 102.42703	Jerantut Feri
B17	4.07008, 102.32201	Kuala Tahan
B20	4.24225, 101.99693	Padang Tengku
B21	4.18328, 102.05836	Bndr Kuala Lipis
B24	4.23715, 102.38368	Jps Tembeling

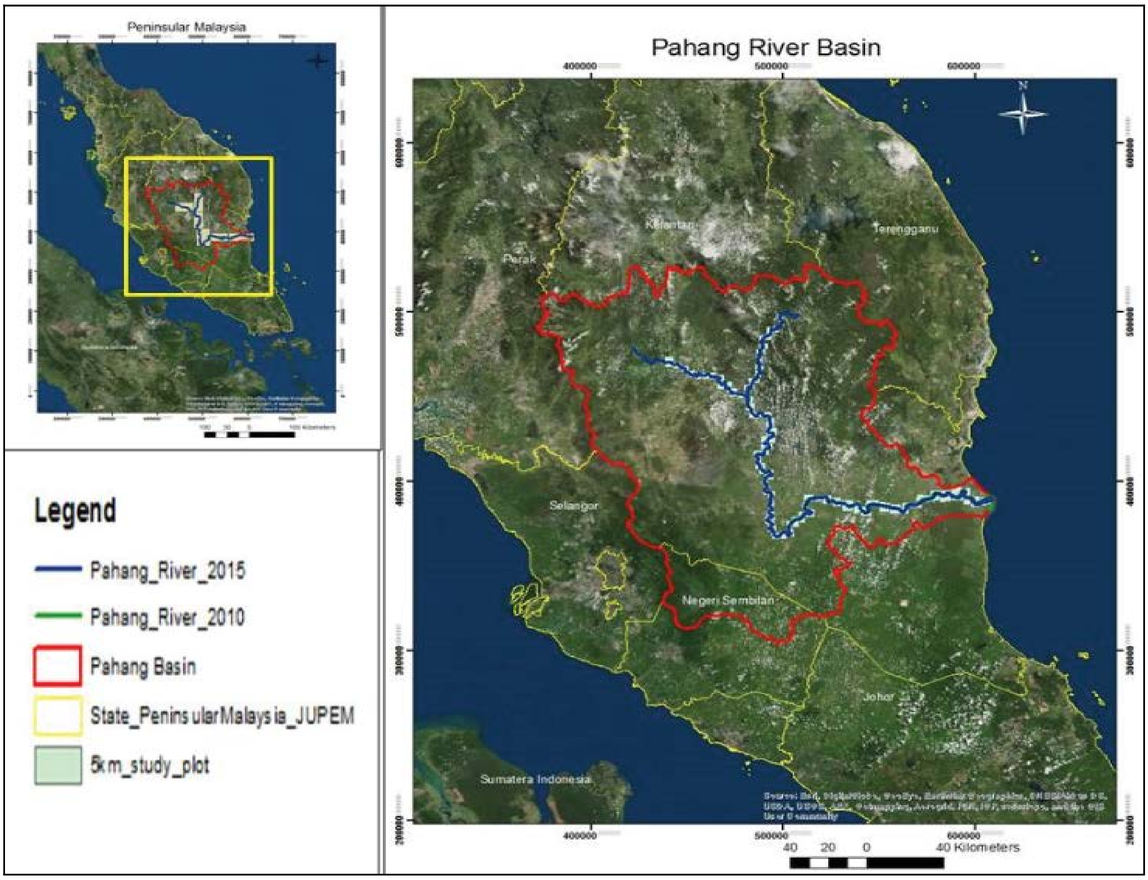


Fig. 1. Map of sampling stations involved in Pahang River Basin, Pahang, Malaysia.

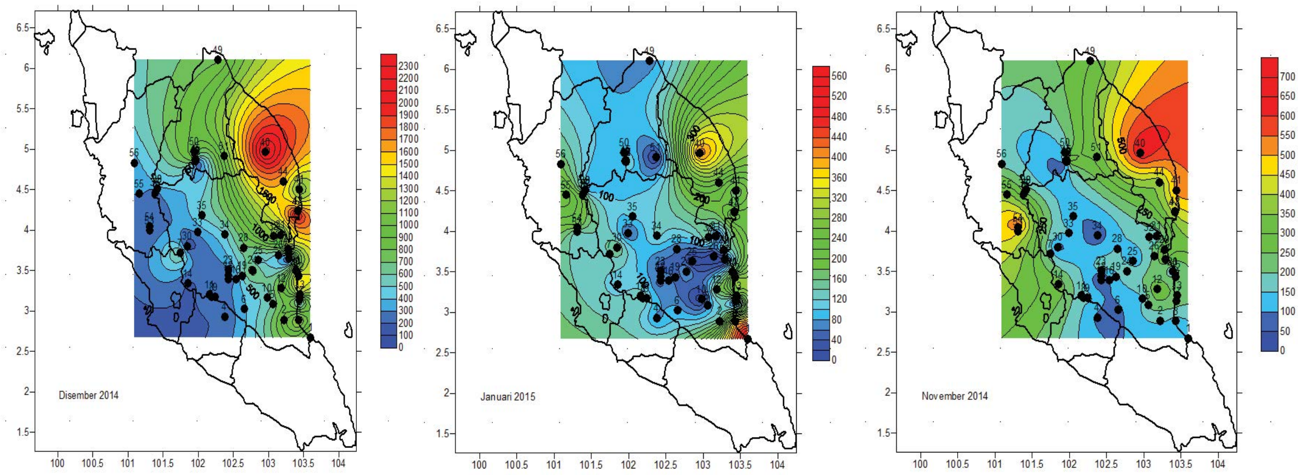


Fig. 2. Cumulative rainfall distribution of from (a) November of Pahang River Basin border for 2014, (b) December 2014, and (c) January 2015.

proposed to indicate the changes and solve the issues that rise in the study area.

Flood event that occurred effected several aspects of the basin especially Pahang River mainstream that became the main river stream in Pahang and act as indicator for flood disaster event. The river stream data such as changes in river planform and geometry are very important in order to minimize the risk of flood in the future. Pahang is one of the areas that received high total rainfall during North East monsoon period in mid of October to mid of January about 40% of total rainfall annually between 1,750 and 3,250 mm [7].

During the monsoon period, this high total rainfall usually increases the stream flow and water level of the river. Heavy and long duration rainfall intends to maximize the possibilities of flood occurrence. Pahang River Basin that is located directly in the pathway of North East monsoon has the same fate similar to Terengganu and Kelantan states that also experience major flood every year.

This problem is one of the most important aspects that the mitigating measure of flood and proper integrated management of irrigation in Pahang River is very necessary. Generally, the rainfall intensity in Pahang River Basin can be briefly explained with the isohyets map of Pahang in 2010 that is constructed by Department of Irrigation and Drainage (DID), Malaysia. The isohyets map of Pahang in Fig. 3 is based on 22 rainfall stations that are scattered all around Pahang. By using the rainfall data logging, the total rainfall intensity of Pahang has been determined by using this technique. Using isohyets map, the areas that receive high intensity of rainfall can be determined and the sources of high surface water can be indicated. High rate of rainfall in the upstream area increased the rate of stream flow that lead to the flood and will affect the planform of the river.

2.2. Research methodology

2.2.1. River measurement

There are several parameters that are being finalized by in-situ measurement of a river such as stream flow, river width and depth, and river datum view based on mean sea level (MSL). All of these data are very important in order to calculate and measure the cross section of a river and datum for the classification of the river, river planform evaluation and river geometry survey [33,34].

There are a number of equipments that are being used extensively during the measurement of river such as levelling meter, depth meter, range finder, mini diver that calculate the increment of the water level automatically and global positioning system (GPS). The accuracy of the data measured is very important, so the depth data that also being known as Z value supported using MSL of each station and DGPS data. MSL values are obtained from the DID stations along the side of river.

2.2.2. Geographical information system

This study will be using GIS to identify the changes in river plan and meander evolution. GIS method used in geospatial data management which is the quantitative analysis of channel migration and meander evolution implemented effectively [35]. The data received similar to satellite imagery will be processed and digitization of the image will be done to establish the GIS. By using GIS method, the study also can include the areas that are affected by flood with quite precise radius. GIS also have been recognized as a powerful tool to integrate and analyze data from various sources in the context of floodplain management (Fig. 4). Its adequate information and prediction capability is vital to evaluate alternative scenarios for flood mitigation policies and can be used as a tool in order to help in the decision making process associated with flood management [36,37]. This study is used to overlay the method that indicates the significant changes of Pahang River Plan by comparing the river plan between year 2010 and year 2015.

2.2.3. Bathymetric survey

In this research, primary data are being used that were obtained from site sampling. Bathymetric data that are being

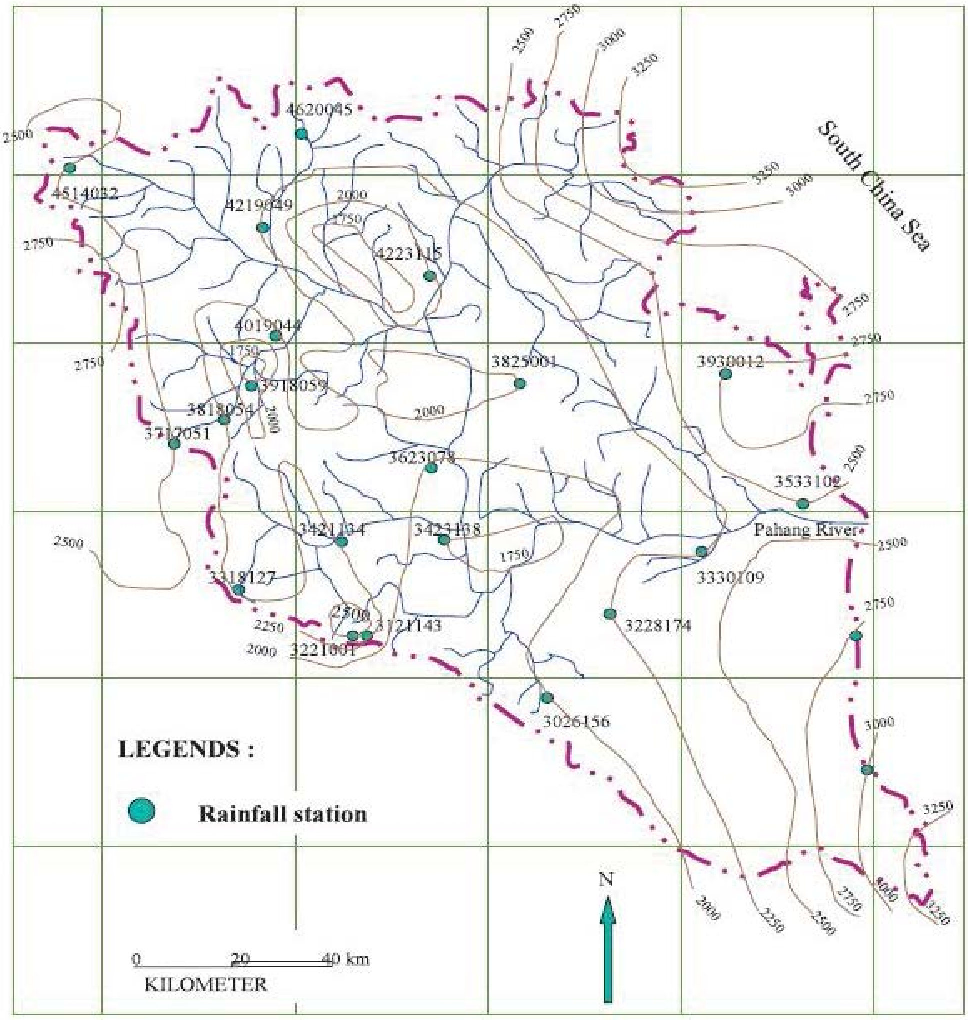


Fig. 3. Isohyet map of rainfall in 2007.
Source: Department of Irrigation and Drainage [32].

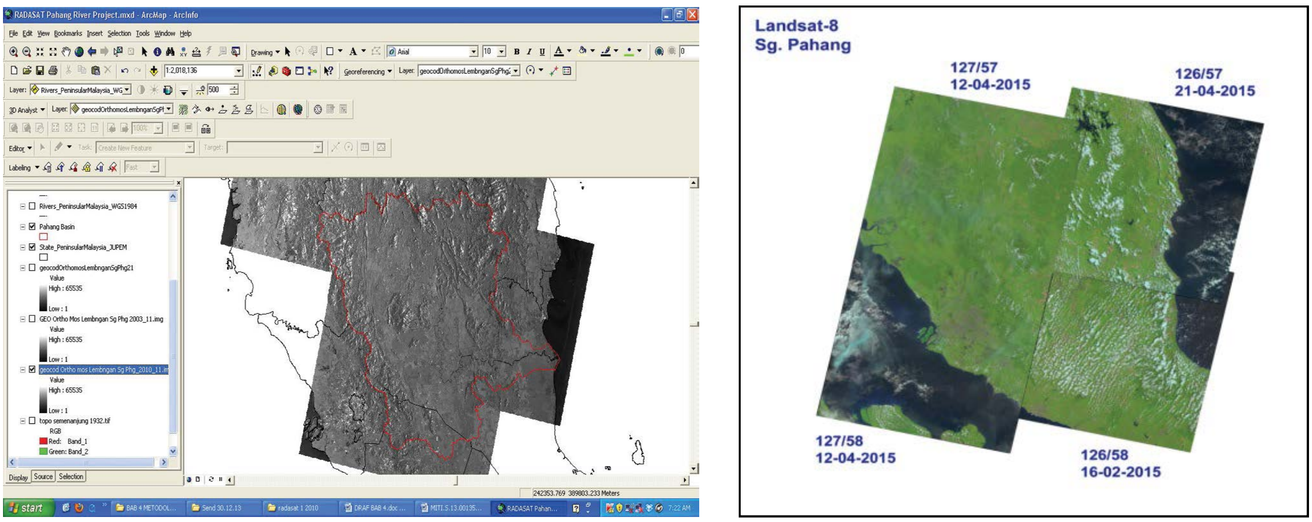


Fig. 4. Geographic information system (GIS) method to identified the changes in river plan and meander evolution using satellite image of Pahang River Basin, Pahang, Malaysia on 2015.

used to construct the river bed geometry were obtained from site survey by using SyQwest HydroBox Echo-sounder and Hypack Survey. SyQwest HydroBox Echo-sounder is used to identify and as data collection tools for river depth. Data collected using echo-sounder are being transmitted to Hypack Survey software as an application to record the water depth, GPS coordinates of each depth recorded and the pathway of the boat. By using Hypack software application, data were converted to xyz data and will be used for further investigation (Fig. 5(a)). For Surfer 8 application method, few more criteria must be confirmed that are the height of the river bank and its coordinates must be marked. The xyz data from echo-sounder instrument must be converted to Microsoft Excel format and being put in the right column (Fig. 5(b)). According to Hoffman et al. [38], each frequency that is being detected by the instrument is different between each object whether it is river bed, sediment, planforms or animals. The differences can be noticed when observing the reading of the echo-sounder in the notebook that shows the hollow image of object; also the colour of the reading is different with each other.

2.2.4. Sinuosity index calculation analysis

Sinuosity index (SI) is the main indicator for the determination of river planform changes in the evaluation that is being used [36,39]. Based on the results that are obtained from this study, this analysis classified the SI into three different categories, namely stable, unstable, and very unstable as shown in Table 2 [21]. The calculation of SI in Pahang River used the river bank as the channel length and straight line of two points for valley length. The reason of using river bank for the channel length and not in the middle of the stream was because the investigations were focused on the erosion and sedimentation that focus occurred at the river banks [40].

Table 2
Sinuosity stabilization categories

Sinuosity index	Sinuosity stabilization categories	Acronym
<1.2	Stable	S
>1.2	Unstable	US
>1.5	Very unstable	VUS

2.2.5. Gravimetric method TSS analysis

Water sample is collected to identify the TSS production at all the point that represent upstream, middle stream, and downstream. TSS was measured using filtration methods with membrane filter 45 mm and vacuum pump (gravimetric method; Fig. 6) which was measured in mg L^{-1}. TSS is described as the concentration of solid-phase material suspended in a water sediment mixture which is usually expressed in milligrams per litre (mg L^{-1}). 250 mL water sample were needed for each study area (each station). The readings of TSS were taken and calculated using Eq. (1) [34].

$$\text{TSS} = \frac{\left(\left[\text{WBF} + \text{DR}\right] - \text{WBF}\right)\left(\text{mg}\right)}{\text{VFW}\left(\text{mL}\right)} \times 1{,}000 = \text{mg L}^{-1} \quad (1)$$

where WBF is the weight of membrane filter; DR is the dry residue; VFW is the volume of filtered water.

3. Result and discussion

3.1. Pahang River Planform change analysis

River planform change analysis for Pahang River mainstream was conducted based on two basic data that were satellite images from two-time period on 2010 and 2015. The basic data were taken from the time period of pre-flood event and post-flood event of major flood 2014. The overlay technique was applied using GIS application software to conduct the analysis and assessment of Pahang River planform changes. Thus, to ensure the explanformation and understanding of the research, this analysis is explained and elaborated based on a few plots that have been classified according to the classification made by Kamarudin et al. [1] in their study. There are three main plots that are discussed in this research; they are upstream, middle stream, and

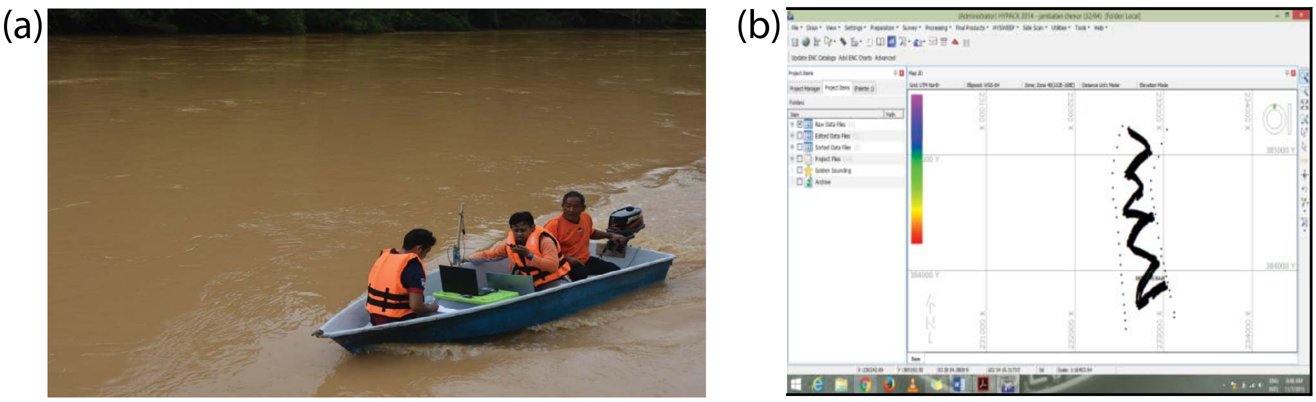


Fig. 5. (a) Bathymetric data sampling at Pahang River Basin, and (b) Surfer 8 application method illustration.

Fig. 6. Gravimetric method to analyse the total suspended solid (TSS).

downstream. The analysis of Pahang River planform changes has been conducted based on every 10 km^2 for Pahang river mainstream.

Major flood event in 2014 has caused a lot of damage and altered meander and planform for Pahang River mainstream. The outcomes of this study using ArcGIS 10.1 software and satellite imagery from two different time period in 5 years has shown quite significant changes of Pahang River mainstream planform and meander in the upstream compared with middle stream and downstream. Based on [1,11,17] the previous study conducted with the time period of 7 years, there is a significant difference between the river channel and the outcome from that study are quite similar with the outcomes of this study after the major flood 2014 but it is increased in high amount in a short period of time. Due to the changes, major flood event in 2014 is being identified to have played a major role in Pahang River planform changes based on the outcomes of this study. The erosion and sedimentation process were usual factors of river channel lateral movement and meander evolution [40]. Figs. 7–9 show the changes of river planform analysis of upstream and middle stream. The domination of braiding type of evolution seem to increase where several new sediment islands formed after the major flood in 2014 due to sedimentation process.

3.2. Bathymetric analysis

The section coming up shows the modelling of 3D views of bathymetric data on 12 points at Pahang River that indicate the changes of river bed and its bathymetric shape. The 3D surface view constructed by using Surfer 8 application show significant changes of river depth due to major flood 2014. Table 3 shows the changes of river bathymetric before and after the major flood in 2014. Jambatan Pekan point show quite significant changes between bathymetric data in 2013 and 2015 that were collected after the flood event. For Jambatan Pekan station, bathymetric data for year 2013 show that the depth of Jambatan Pekan station was at High depth (HD) compared with its bathymetric data in 2015 that class in Moderate Depth (MD). Lubuk Paku stations show the Very High Depth (VHD) clustered group similar to the previous bathymetric data from year 2013. This shows that the depth of Pahang River at Lubuk Paku station is not significantly affected by the major flood in 2014. Lubuk Paku station is mostly affected by high stream flow of the river during the flood event. River bank near the JPS station at Lubuk Paku was collapsed due to erosion by flood. Paloh Hinai station is located at the middle stream of Pahang River. It is also shown that Paloh Hinai station is not significantly affected by the major flood in terms of its depth but the river bank at Paloh Hinai station was collapsed due to the major flood and maybe affected the meander and river plan of Pahang River. Chenor station is a middle stream sampling station. The 3D surface view of Chenor station shows that the difference between the bathymetric depth in 2013 and 2015 (Fig. 10).

According to Fig. 10, the bathymetric depth of Pahang River at Chenor Station in same class and still as Very Shallow Depth (VSD) but the 3D surface view of bathymetric data indicates that the depth of Chenor Station was decreasing and shallower in 2015 after the flood event compared with 2013 bathymetric data. Bathymetric data of Jerantut Feri station indicate that the depth of the river was shallower after the flood in 2014. The river bed of Pahang River at Jerantut Feri station became unorganized due to the flood that brought the sediment and sand further down the stream. Jerantut Feri station shows that its group changes from VSD to HD.

Jerantut Feri station is located in the upstream of Pahang River after Kuala Tahan sampling station. JPS Tembeling station is the upstream station located in Tembeling River that is Pahang River source. The 3D surface bathymetric data of JPS Tembeling show that the depth and shape of the river bed was altered by the flood event. The river bed at JPS Tembeling station became shallower. JPS Tembeling station class changed from Middle Depth (MD) to VSD. This may be due to surface run-off that brought the sediment and sand into the river that resulted the river bed to become shallower and will lead to future flood. Other station also indicates the changes in depth cluster due to major flood event in Pahang December 2014 but the differences between pre-flood 2013 and post-flood 2015 do not leave significant differences between the depths of the river. All these stations included Kuala Tahan, Padang Tengku, Kuala Lipis, Lipat Kajang, and

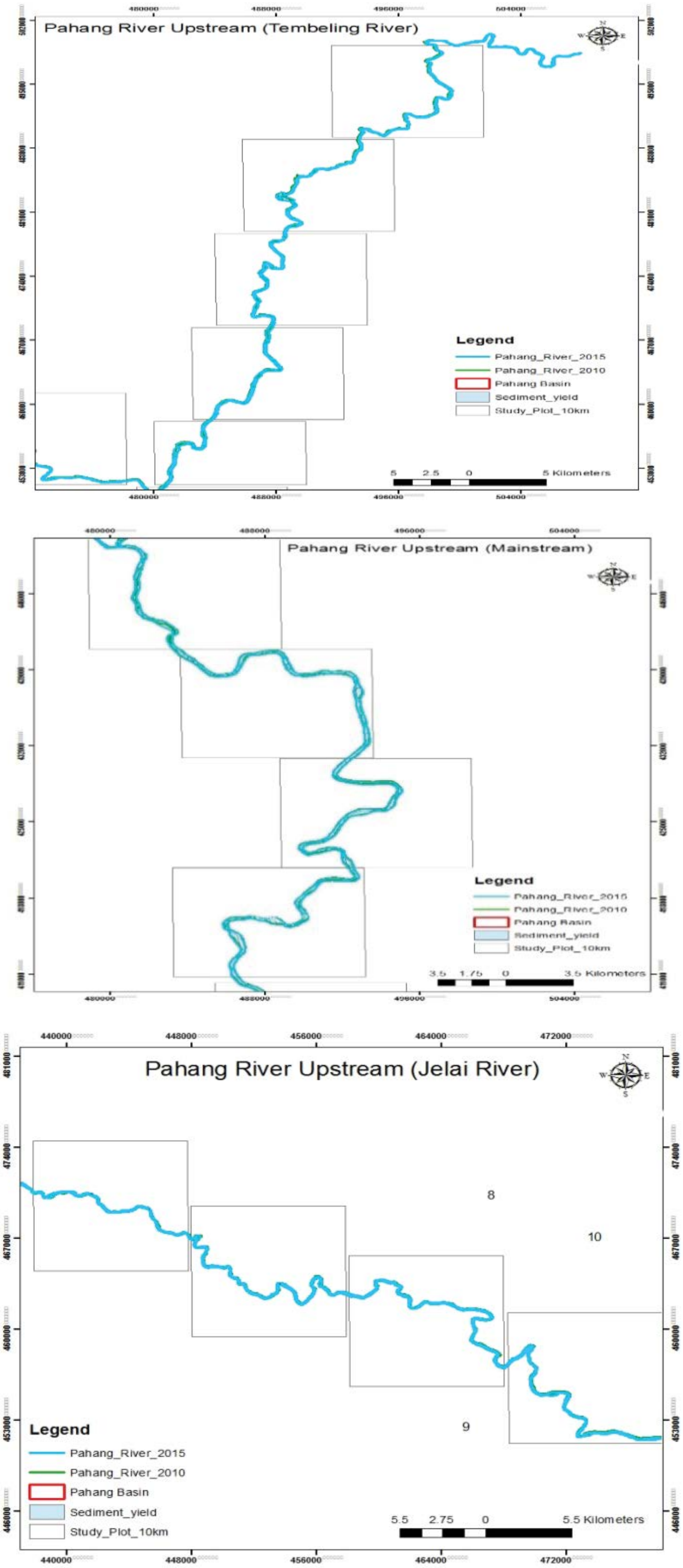


Fig. 7. Pahang River upstream change analysis of Jelai River, Tembeling River, and upstream Pahang River.

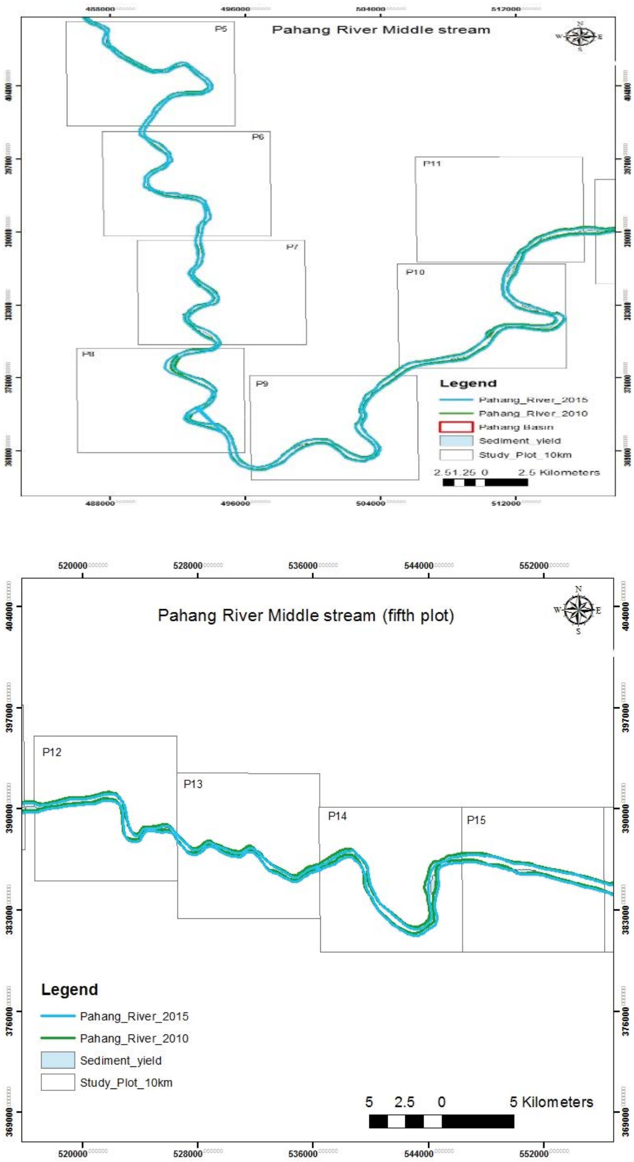


Fig. 8. Pahang River middle stream change analysis of Pahang River mainstream plot 4 and mainstream plot 5.

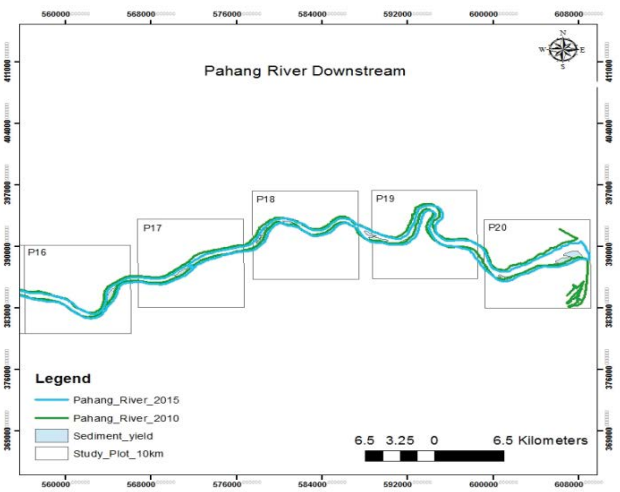
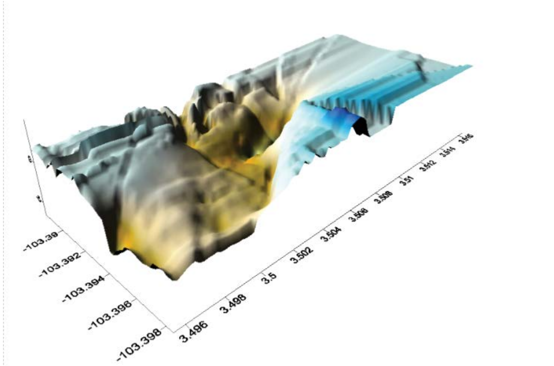
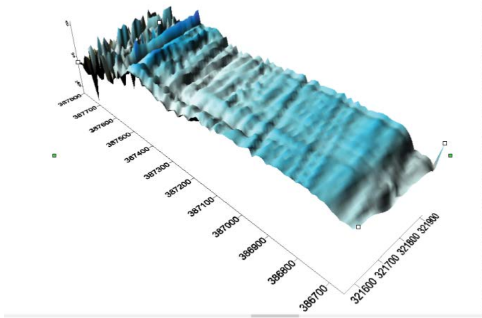
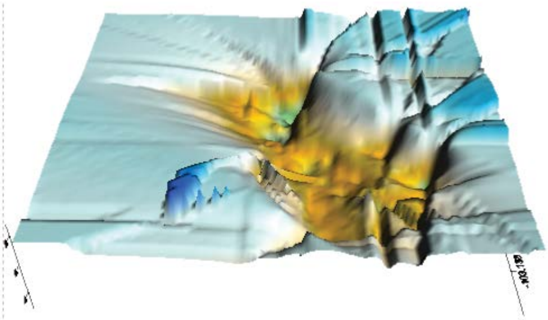
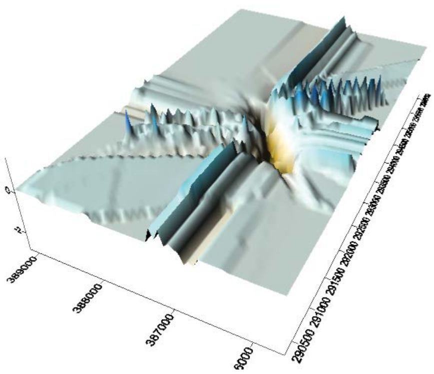
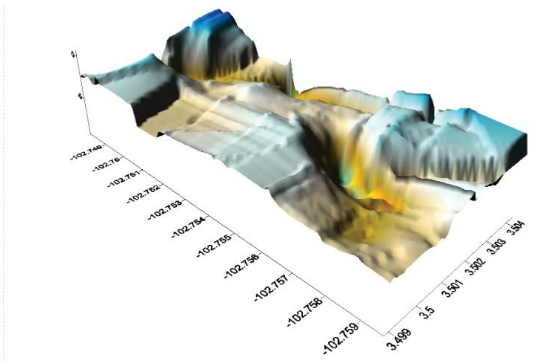
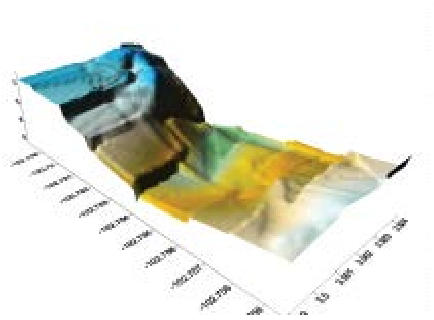
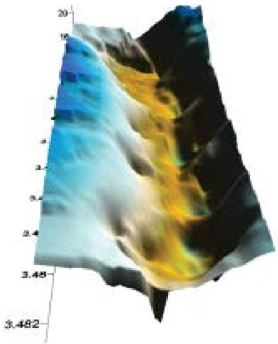
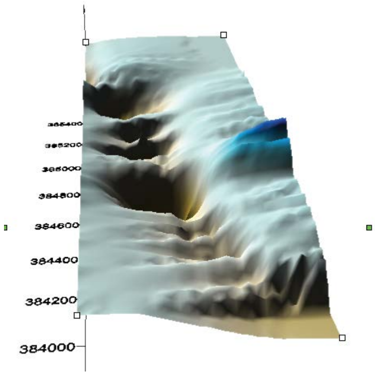
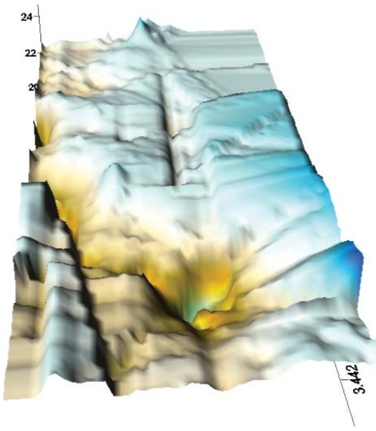
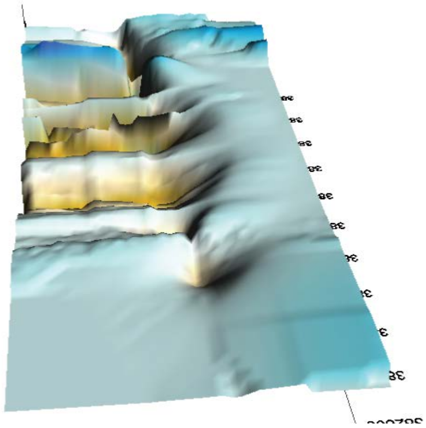
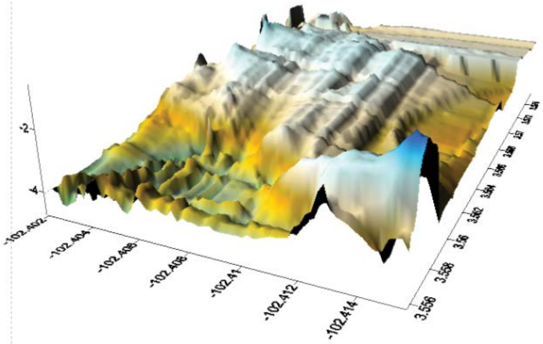
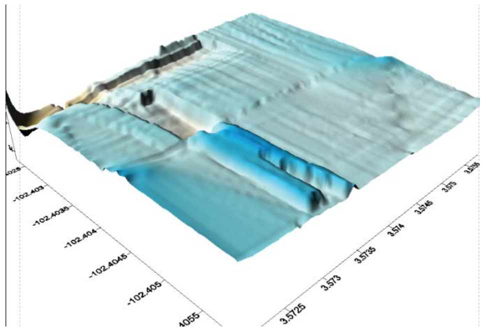
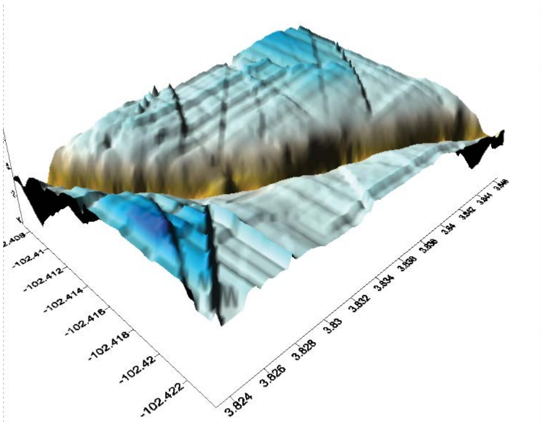
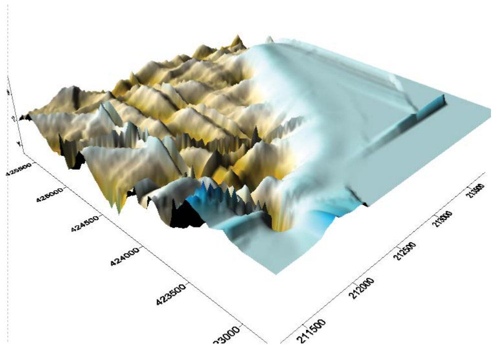
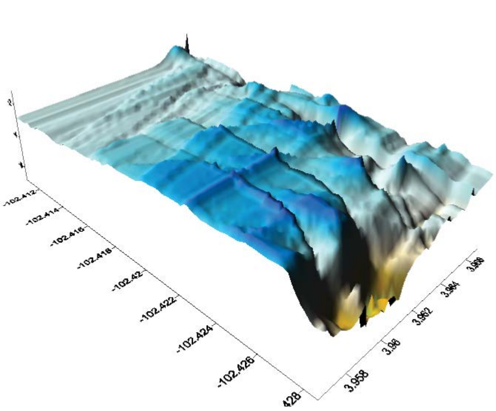
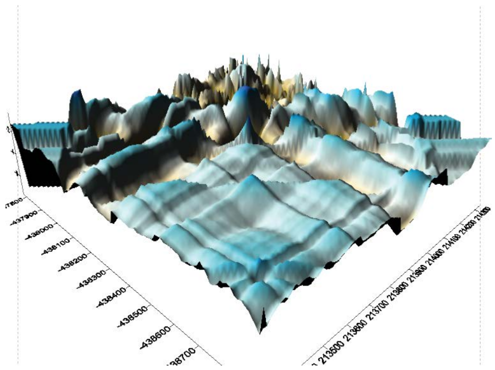


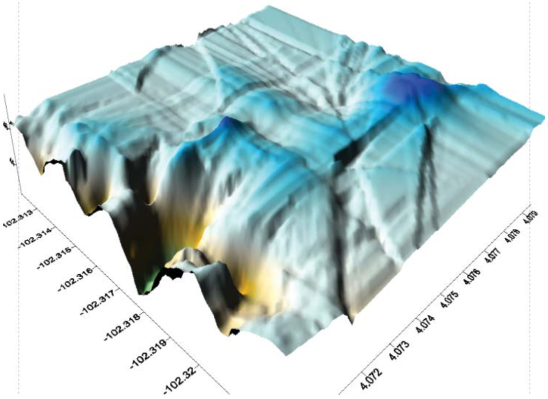
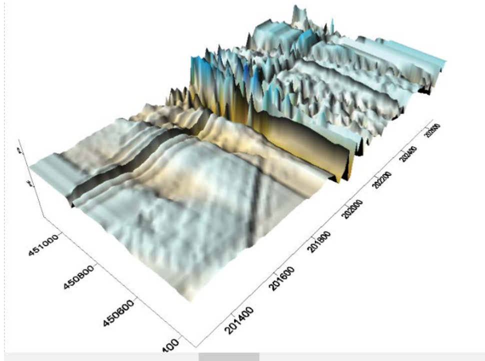
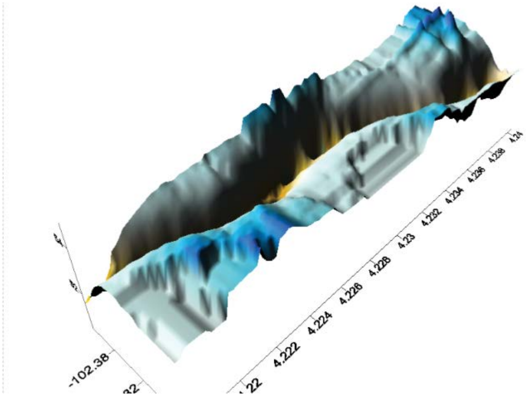
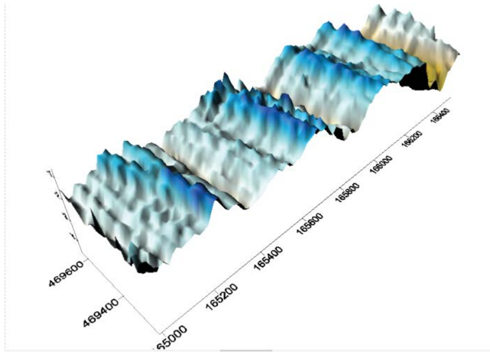
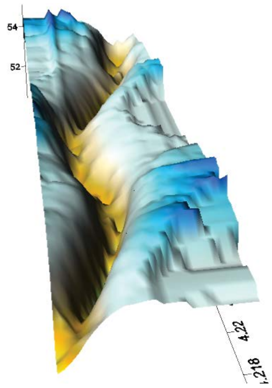
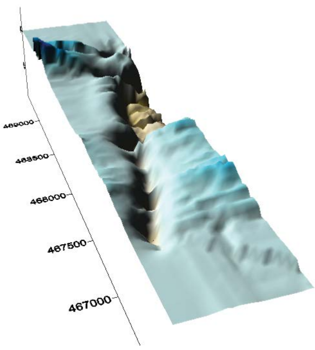
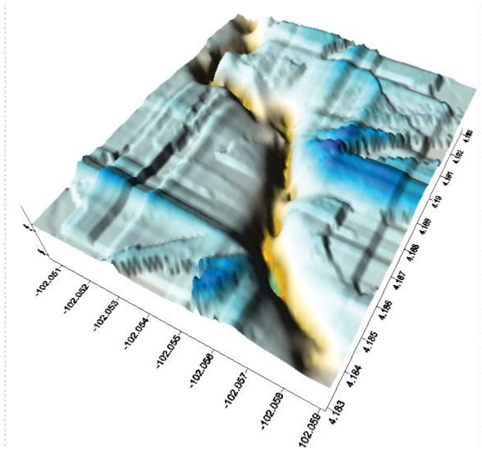
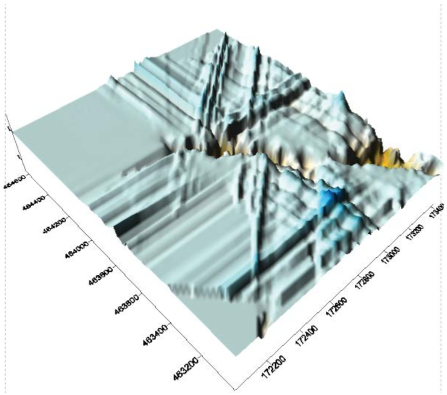
Fig. 9. Pahang River planform change analysis of downstream.

Table 3
Bathymetric data of Pahang River

Sampling station	Year 2013	Year 2015
Jambatan Pekan B1		
Paloh Hinai B3		
Lubuk Paku B6		
Jambatan Chenor B8		

Sampling station	Year 2013	Year 2015
Temerloh B12		
Kg.Lipat Kajang B13		
Kg.Jeransang B14		
Jerantut Feri B15		

(*Table 3 Continued*)

Sampling station	Year 2013	Year 2015
Kuala Tahan B17		
Padang Tengku B20		
Kuala Lipis B21		
JPS Tembeling B24		

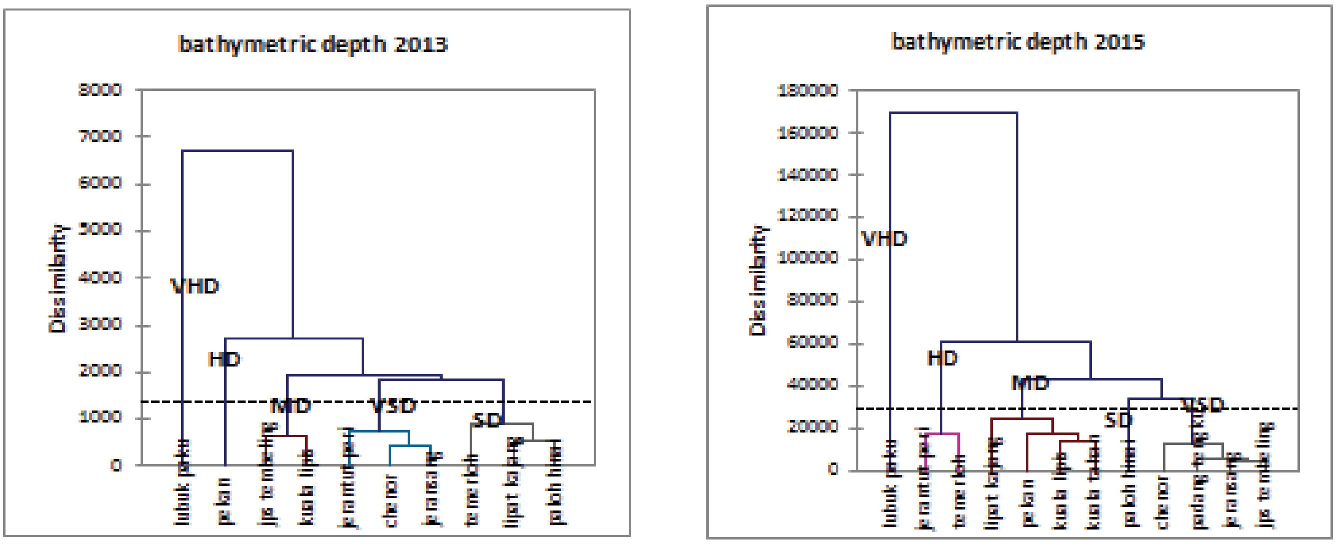


Fig. 10. 2013 and 2015 Pahang River depth cluster.

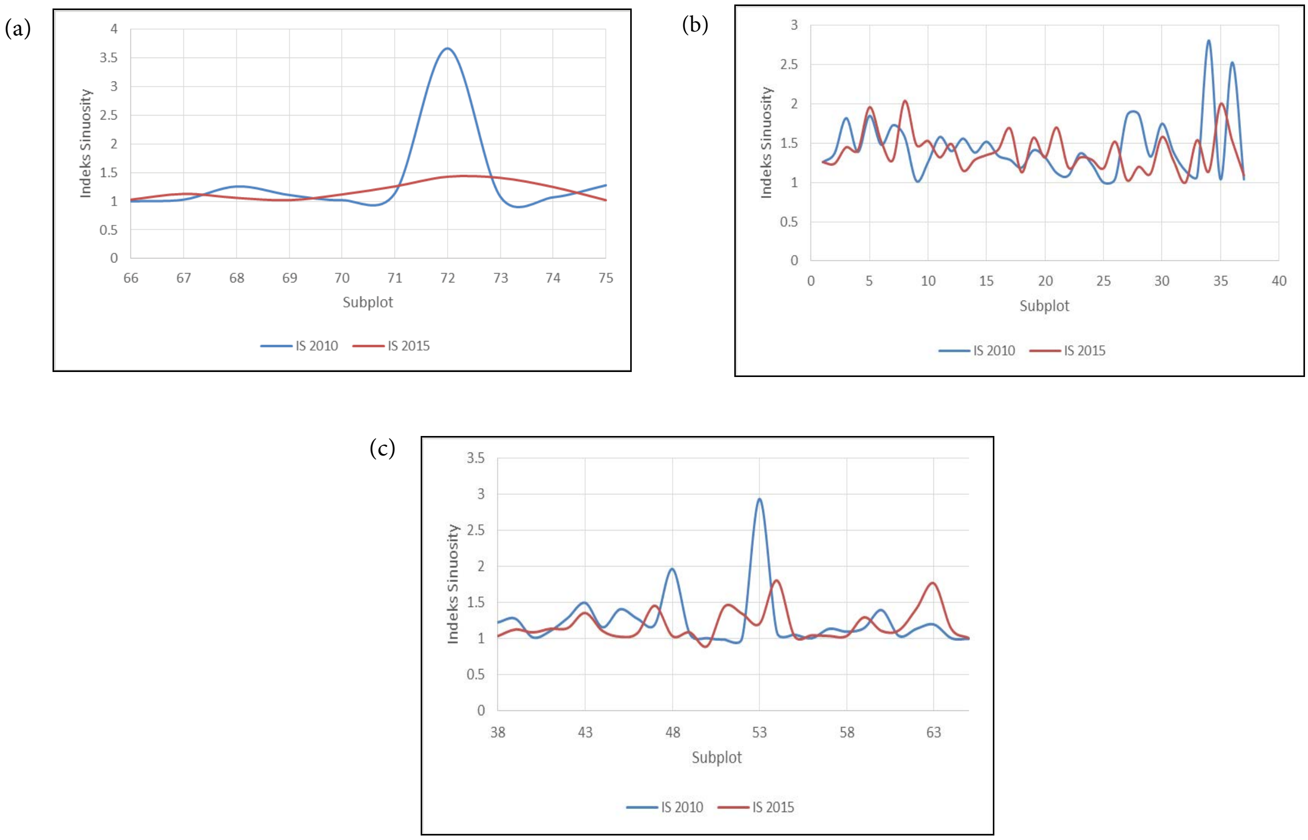


Fig. 11. Pahang River (a) downstream, (b) upstream, and (c) middle stream of sinuosity index trend.

Jeransang mostly focusing on the shape of the river bed that has been altered due to the flood.

3.3. SI analysis

The outcomes from SI analysis are then categorized to a several levels of stability such as stable (S), unstable (US), and very unstable (VUS) as the category of stabilization for the meander evolution in Pahang River mainstream (see Fig. 11). For the purpose of understanding of the analysis, this study displayed based on the plot that have been created and classified as before. There are six plots that have been divided as upstream, middle stream, and downstream of Pahang River. The classification of sinuosity stabilization of a river that has been applied in this research for Pahang River mainstream. The classification of sinuosity stabilization in Pahang River is important in order to differentiate between the parts of the river that need to focus on in the current and future times. Stream SI is usually derived from the tendency of a river channel to move toward its floodplain. It is calculated by dividing the length of a reach as measured along the channel with the length of a reach as measured along a valley.

Based on the analysis of the evolution of the Pahang River main planform shows the SI assessing the evolution of the river was slowly changed through the different aspects of GIS analysis stages where the error can be reduced because the SI analysis is carried out based on the river bank as channel length. According to the findings obtained, the analytical method SI conducted in every 5 km^2 found that indeed there is a change in the number of study plots in the upstream, midstream, and downstream Pahang River. According to the results obtained through studies conducted SI, there are a lot of changes to the planforms and Pahang River SI based on a change from 2010 before the major flood of 2014 and 2015 in the wake of the disaster. Strong flood runoff causes erosion of river banks and causes enlargement of river meander. Changes in river planform in some places resulted in significant changes seen through SI.

Table 4
Total suspended solid distribution in Pahang River Basin, Pahang

Station	Total suspended solid (TSS)			
	1	2	3	Average
Jambatan Pekan	74	74	73	73
B2	51	51	52	51
Paloh Hinai	51	50	52	51
Kg. Melayu	26	25	26	25
Lubuk Paku	23	21	24	22
Muara Chini	58	57	58	57
Chenor	25	24	25	24
Temerloh	75	74	75	74
Lipat Kajang	46	46	45	45
Jeransang	96	95	96	95
Jerantut Feri	127	127	125	126
Kuala Tahan	29	28	29	28
Jelai River (Tahan)	212	212	214	212
Pahang River(Tahan)	111	112	111	111
Kuala Lipis	145	145	144	144
Padang Tengku	98	99	98	98
Jps Tembeling	19	18	19	18

3.4. Total suspended solid

TSS was tested by using water sample that was collected at the stations. There are additional stations that are involved in this sampling. Those are B2 station, Kg. Melayu station, Muara Chini station, Sg. Jelai (Tahan) station and Sg. Pahang (Tahan) station (Table 4). From Fig. 11, TSS was divided into three different classes: high suspended solid (HSS), middle suspended solid (MSS), and low suspended solid (LSS). Compared with the bathymetric depth and shape of river bed, TSS of all stations involved in this study show that most of the VSD of Pahang river indicates that it contain high results of suspended solid such as Padang Tengku, Kuala

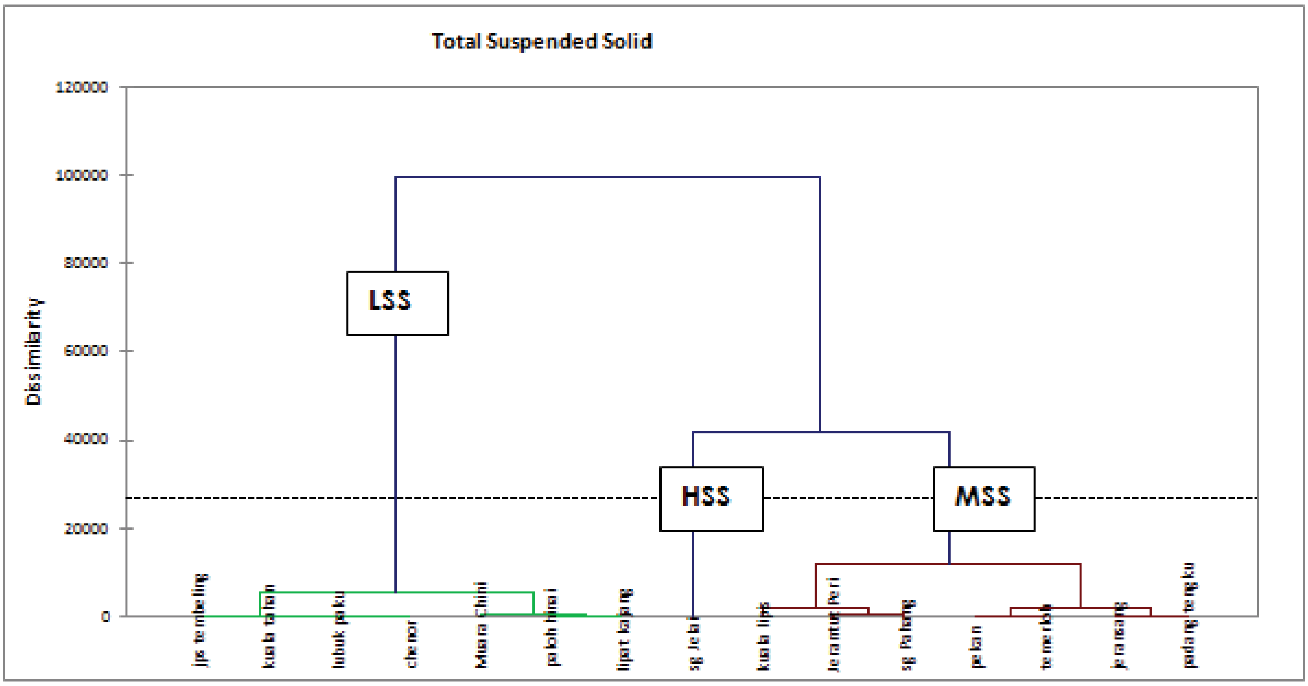


Fig. 12. Clustering Analysis (CA) of Total Suspended Solid (TSS) at Pahang River Basin, Pahang, Malaysia.

Lipis, Pahang River (Tembeling). The station that been classified in VHD and HD is classified in MSS. Jelai River showed very high in suspended solid results and it is classified into HSS. Other stations such as JPS Tembeling, Lubuk Paku, Chenor, Muara Chini, Paloh Hinai, and Lipat Kajang were classified into LSS.

3.5. Effect on Pahang River after flood 2014

A river changes complex process that undergone during flood event was being the causes of river planform changes [41,42]. These processes deliver a high impact to the environmental situation of the river. Besides that, the processes also deliver another problem for communities that lead to the development issues of the area alongside the Pahang River. During the research, there are several aspects of processes such as erosion, sedimentation, and the overflow of the river that have been found. Based on the observation during the sampling event, the river bank clearly shows the layer of the soil that differs due to the collapse of river bank after the high velocity flow of flood water. The results from Lubuk Paku where the in-situ river measurement obtained shows in 2013, there are big rocks and the river bank is near to the tree lines, but in 2015, there occurred a massive sedimentation after major flood 2014 when sediment yield as high as 5 m. However, the aerial views of Pekan that is the downstream of Pahang River and located nearby the delta of Pahang River in Pekan. The views clearly show the sediment yield that deposited in the middle of the river stream and later created braiding process in the river. The mitigation barrier also being constructed during the field sampling and it is affecting the sedimentation process of the river that encourages the sediment deposition.

4. Conclusion

The bathymetric data of Pahang River have been drastic changes due to major flood event during December 2014. The flood has affected the river bed and shape of the river bed. The composition of suspended solid also increases at the stations that classify in very shallow and shallow depth. Major flood Pahang in December 2014 have left a lot of damage and affected the entire hydrological system of Pahang River. The decrease in depth of Pahang River also indicates that flood water will rise and flood the area in a short period of time compared with previous flood due to its capabilities to carry flood water long enough before its flooded the area in Pahang. The mitigation measure must be strengthened to overcome and reduce the impact of flood in Pahang in the future. Dredging of Pahang River must be done to increase the depth and in that case the flood water can be held longer to make sure there is a reduction in flood impact to the communities.

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