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____

(Supervisor's Signature)

Full Name : MR. NORASMAN BIN OTHMAN

Position : LECTURER

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____

(Co-supervisor's Signature)

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Full Name : NIK MOHAMED ZAKI BIN NIK MOHD NASIR

ID Number : AA14255

Date : 8 JANUARY 2018

SEDIMENT TRANSPORT MODELLING IN THE UPSTREAM OF SUNGAI KUANTAN BY USING HEC-RAS

NIK MOHAMED ZAKI BIN NIK MOHD NASIR

Thesis submitted in fulfillment of the requirements
for the award of the
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ABSTRAK

Stesen Bukit Kenau terletak di hulu Sungai Kuantan di negeri Pahang di mana terdapat banyak hujan semasa musim monsun yang membawa proses pengangkutan sedimen yang tinggi. Tanggapan sungai dengan meningkatkan atau mengurangkan kapasiti penyimpanan sedimen, berubah dalam bahagian rentas saluran, hakisan dan pemendapan sepanjang saluran, yang memberi kesan kepada kestabilan saluran sepanjang tempoh masa. Kajian ini adalah untuk mensimulasikan pengangkutan sedimen di sekitar Sungai Kuantan (Stesen Kenau) dengan menggunakan satu dimensi (1D) aliran tak mantap HEC RAS. Terdapat beberapa data yang diperlukan seperti data geometri, data hidrologi, data suhu dan data sedimen. Analisis ini dilakukan dengan menggunakan kaedah Tofaletti (kaedah yang sesuai) untuk pelbagai analisis tahunan iaitu satu (1), tiga (3), lima (5) dan sepuluh (10) tahun analisis. Dari simulasi dan hasilnya, morfologi sungai di dasar sungai dapat diramal. Hasilnya juga menunjukkan lokasi hakisan dan pemendapan berlaku. Untuk analisis simulasi sepuluh (10) tahun, hakisan maksimum berlaku pada kedalaman 1.47 m pada seksyen 44200 (4000 m dari hiliran). Sementara itu, pemendapan maksimum kira-kira ketinggian 2.39 m berlaku di seksyen 40800 (600 m dari hiliran). Oleh itu, lokasi yang sesuai untuk aktiviti perlombongan adalah di seksyen 40800 (600 m dari hiliran) kerana lokasi ini mempunyai nilai pemendapan yang tinggi. Kelebihan utama kajian ini ialah pengangkutan sedimen boleh diramalkan yang dapat memberikan kesan yang tinggi terhadap kestabilan saluran sungai dan isu-isu alam sekitar di sekitar sungai dapat dipelihara.

ABSTRACT

Bukit Kenau Station is located in the upstream of Sungai Kuantan the state of Pahang where subjected to huge amount of rainfall during monsoon season that bring high impact sediment transport process. The river responses by increased or decreased sediment carrying capacity, changing in channel cross section, erosion and deposition along the channel, which impact on channel stability over a period of time. The study is to simulate the sediment transport around Sungai Kuantan (Kenau Station) by using one dimensional (1D) quasi unsteady flow HEC-RAS. There is few data required such as geometric data, hydrological data, temperature data and sediment data. The analysis is done by using Tofaletti method (suitable method) for various year of analysis which are one (1), three (3), five (5), and ten (10) year analysis. From the simulation and results, the river morphology of the riverbed can be forecast. The result also shows the location of erosion and deposition occurs. After ten (10) year simulation analysis, the maximum erosion occurs at the depth of 1.47 m at cross section of 44200 (4000 m from the downstream). Meanwhile, the maximum deposition about of 2.39 m height occurred at cross section of 40800 (600 m from the downstream). Therefore, the suitable location for mining activities is at cross section of 40800 (600 m from the downstream) since this location has high value of deposition. The main advantages of this study is the sediment transport can be forecast which it can give high impact to river channel stability and environmental issues around the river can be preserved.

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LIST OF SYMBOLS

A	Cross section area
Q	Discharge
R	Hydraulic radius
P	Wetted perimeter
W	Top width

LIST OF ABBREVIATIONS

HEC-RAS	Hydrologic Engineering Centers River Analysis System
DID	Department of Irrigation and Drainage
ARC-GIS	Aeronautical Reconnaissance Coverage Geographic Information System

CHAPTER 1

INTRODUCTION

1.1 General

Malaysia today has been many changes in term of rapid urbanization. This development causes the changes of river catchment area since the surface run-off is increase due to increase in impervious area and resulting the flood is easy to occur. Numerous logging activities as shown in Figure 1.1 also makes serious issue because the effect of it activities can produce a high erosion to land surface and the volume of sediment will increase. The other effect that change the pattern of sediment transport in the stream is sand mining activity around the stream channel area (in-stream sand mining) (Department of Irrigation and Drainage, DID, 2009).

Figure 1.1: Logging activity around river catchment area

Sources: www.bharian.com.my/node/39349

Sediment transport is serious issue that need to consider since its lead to damage of the hydraulic structures along the river. Sediment transport also will affect the river morphology and channel capacity to convey or carry the flood water from upstream to downstream and can cause flooding.

Basically the sediment is divided into two which is bed load and wash load. For Sungai Kuantan, this two types of sediment is both existed since the colour of Sungai Kuantan is appear “muddy”. Sungai Kuantan also have large impact during event especially during monsoon season (November to March). During flood, the river water level will increase and thus increase the flow rate of river channel. When the flow rate is increase, the amount of sediment transport expected to be increase.

Besides, during wet season in Kuantan, the colour of the river will become murky than before which means the wash load (part of sediment total load) is increase. This occur when erosion occur around the channel bank that happen from surface run-off increase during flood event. The aim of this study is to model sediment transport in upstream of Sungai Kuantan during wet season by using 1d quasi unsteady flow HEC-RAS. So that the real pattern of sediment transport and bed profile evolution at Bukit Kenau Station can be determined.

1.2 Problem Statement

Movement of sediment during flood event will increase and also will cause the several problems to the stream channel especially for stream bed. The sediment transport as bed load and wash load basically depend on the physical properties of the sediment such as grain size, density, and shape. The higher the velocity of flow of water also will affect the sediment transport. During wet season, the velocity of flow of water will increase and the amount of the sediment transport also will increase. The sediment transport also depends on in-stream sand mining. The sedimentation process is important to cover back the mining area so that the stream bad will balance. The increase in mining deep will need more sediment to cover the mining area and will cause the amount of sediment transport increase.

1.3 Objective of Study

The main objectives to be achieves in this study can be write down as follow:

i. To determine the suitable method to simulate the sediment transport of Sungai Kuantan.

ii. To simulate the water surface and river bed profile by using several method of transport function in 1D Quasi-Unsteady Flow HEC-RAS.

iii. To propose the suitable location for mining activities.

1.4 Scope of Study

The scope of this study is simulating the sediment transport by using 1D quasi unsteady flow HEC-RAS software. The simulation are using the data that collected from DID Kuantan. The simulation of sediment transport can be achieves after the collection of sample of sediment from Kampung Bayas at Sungai Kuantan. By determine the particle size distribution, the sieve graph can be plotted and put that data into HEC-RAS software so that the sediment transport modelling can be performed or simulated.

1.5 Significance of Study

After simulating the sediment transport modelling during wet season, the river morphology in the study area can be determined and simulated. By collecting a real data from DID Kuantan, a real situation about what will happens to the river morphology can be understood so that the sediment transport can be manages perfectly. Then, the suitable location of future sand mining activities can be proposed.

CHAPTER 2

LITERATURE REVIEW

2.1 Open Channel

The learning of the physics of fluids flow in conveyances in which the following fluids forms a free surface and is driven by gravity. There are two types of open channel, natural open channel (river, creek) and artificial open channel (human construction; canals and flumes). The forms of flow in open channel are categorized with respect to time, space, viscosity, density and gravity.

2.1.1 Unsteady Flow in river

The depth varies with both time and space is unsteady flow involves the solution of the energy momentum and friction equations with time. It can be analysed as gradually varied steady flow because the flow is sufficiently close to steady flow. Figure 2.1 shows the unsteady flow of the river.

Figure 2.1: Unsteady flow in River (www.pexels.com/search/river/)

2.1.2 One Dimensional River Continuity Equation

Figure 2.2 below defines a river reach with cross section area, A, top width W, wetted perimeter P, hydraulic radius Rh = A/P, and mean flow depth h = A/W. Product of the area A and mean flow velocity V, produce the total discharge Q; the unit discharge of the lateral flow is ql. The rainfall intensity is i, and the infiltration rate through the wetted perimeter is ib. The net volumetric flux leaving the control volume is (∂Q/∂x) dx + ib P dx. The net volumetric flux entering the control volume is ql dx + iW dx. The difference between entering and leaving volumetric fluxes corresponds to volumetric storage ∂A dx = ∂(Wh)dx per unit time ∂t.

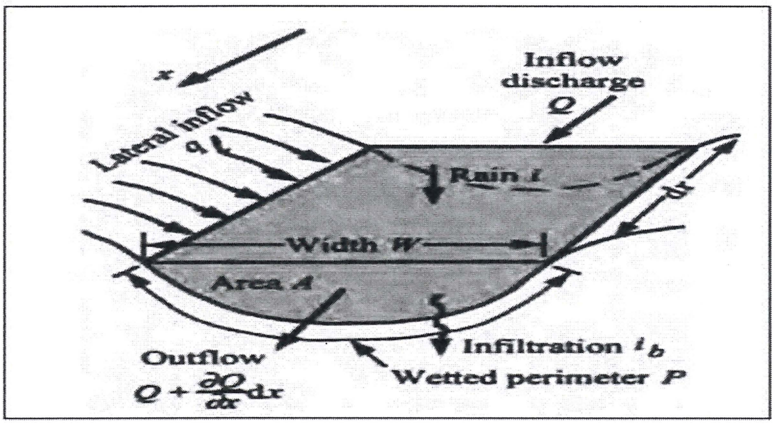

Figure 2.2: Continuity of river reach

Sources: Julien P.Y. (2002)

After dividing by dx, we easily demonstrate that

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} + \text{ib} - \text{iw} - \text{ql} = 0 \qquad (2.1)$$

Where ib is the rate of infiltration through the wetted perimeter P, i is the rainfall intensity through the reach-averaged river width W, A is the reach-averaged cross- sectional area, and q is the unit discharge of lateral inflow. For an impervious channel (ib=0) without rainfall (i =0) and without lateral inflow (ql = 0), the1D equation of continuity simply reduces to

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 \quad (2.2)$$

This simple differential equation that expresses conservation of mass is widely used in the analysis of flood-wave propagation.

2.1.3 One (1) Dimensional Momentum of River

However, for most practical purposes, the spatial variations in lateral and transverse directions can be neglected and the flow in a river system can be approximated as a one-dimensional process along the longitudinal direction (i.e., in the direction of flow). The Saint Venant equations that were derived in the early 1870s by Barre de Saint-Venant, may be obtained through the application of control volume theory to a differential element of a river reach. The Navier-Stokes equations can be simplified for one-dimensional flow. Assumption made in Saint Venant equations as:

a) The flow is one-dimensional. The water depth and flow velocity vary only in the direction of flow. Therefore, the flow velocity is constant and the water surface is horizontal across velocity is constant and the water surface is horizontal across any section perpendicular to the direction of flow.

b) The flow is assumed to vary gradually along the channel so that the hydrostatic pressure distribution prevails and vertical accelerations can be neglected. The channel bottom slope is small and the channel bed is stable such that there is no change in bed elevations in time. The fluid is incompressible and of constant density throughout the flow.

c) The Manning and Chezy equations, which are used in the definition of channel resistance factor in steady, uniform flow conditions, are also used to describe the resistance to flow in unsteady, non-uniform flow applications.

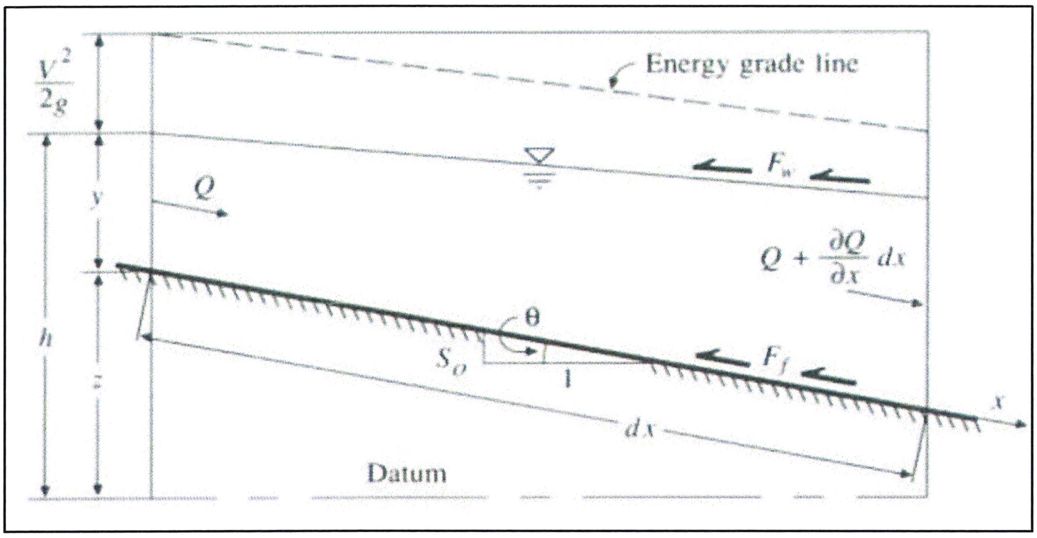

Figure 2.3: Cross section view for 1 Dimension flow

These equations are the governing equations of one dimensional unsteady flow in open channels and were originally developed by the French scientist Barre de Saint-Venant in 1872.

$$\frac{\partial A}{\partial t} + \frac{\partial(\beta Q^2)}{\partial x} + gA + (\frac{\partial h}{\partial x} + Sf + Se) - \beta qvx + WfB = 0 \qquad (2.3)$$

2.2 Sediment

Sediment is hard or loose material found mainly on the bottom of the river. There are many forms and sizes of sediment. It transported by fluid flow and which eventually is deposited as a layer of solid particles on the bed.

2.2.1 Sediment Transport

No sediment was moved at very low velocities but sediment will transport along the bed at some higher velocity. Motions of sediment in different modes which exist in a stream are defined as follow. Individual grain on the channel bed will roll and slide intermittently along the streambed in the direction of the flow. The sediment so moved is defined as the contact load of the stream. Some grain may also move above the bed surface by saltation. Movement in this mode is describe as saltation load of the stream that occurs when one grain, causing it to jump upward and the fall back toward the bed. Some of the grain transported as suspension if the flow velocity is increasing and the jumps executed by the grain will occur more frequently.

These rolling, sliding, suspension and saltation motions move sediment in a streambed and characterize the transport as bed load. The weight of the sediment related to flow velocity in a stream. In stream channel the transport of sediment as the bed load has been widely studied and a number of empirical equations have been proposed (Einstein, 1942; Meyer-Peter and Muller, 1948; Van Rijn, 1984; Ackers and White et al, 1978).

Motion of sediment in suspension by turbulent eddies are mostly finer-grained. Suspended load is the particles transport within the water column call. If the turbulent is present, there may be continues exchange of sediment between the bed loads of the river. Part of the suspended load may be colloidal clays, which remain in suspension for a very long period of time, depending on the type of clay and water chemistry.

Finest sediment particles in transport are wash load. An inflow of fine sediment in suspension which remain in suspension describe as wash load. The concentration of wash load in suspension is fundamentally independent of hydraulic condition in the stream. Thus, it cannot be calculated using hydraulic parameters such as velocity or discharge. The concentration of wash load is usually a function of supply. As the watershed and banks can transport, the stream can take as much wash load. Figure 2.4 shows various loads within a stream and motion of sediment transport.

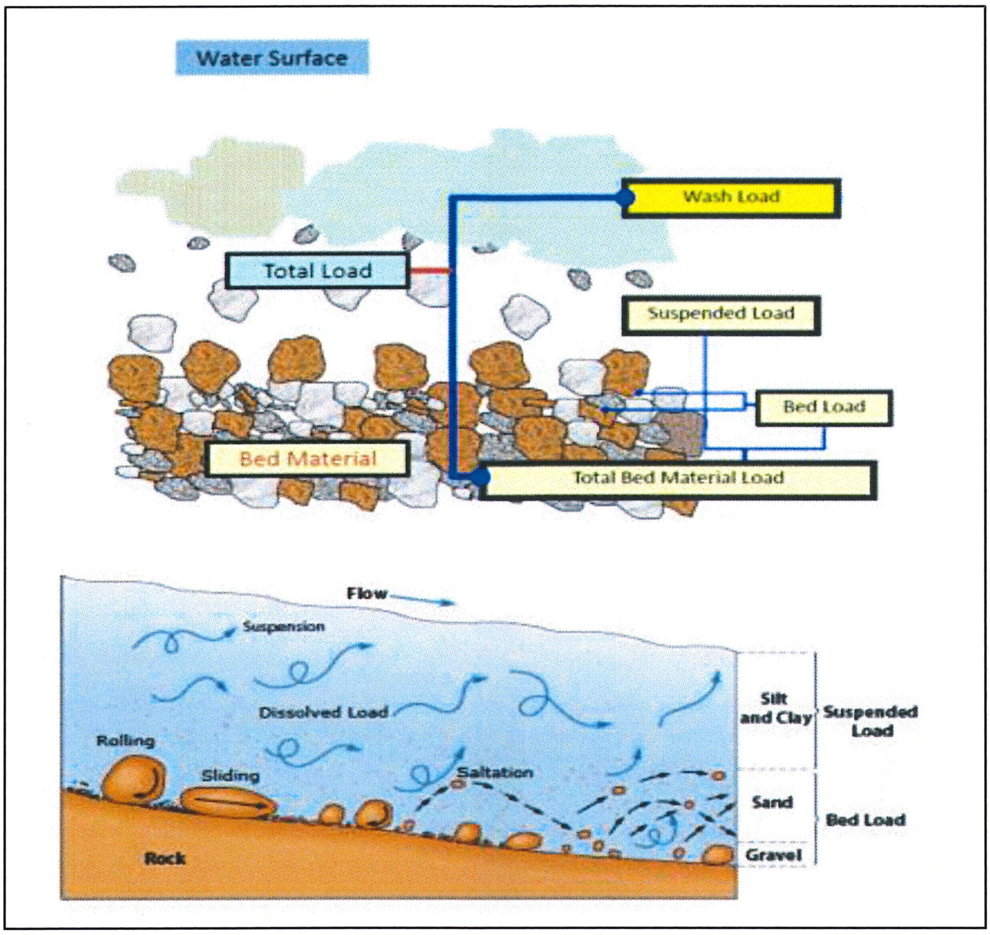

Figure 2.4: Modes and various types of Sediment Transport in Rivers

Sources: DID (2009)

2.2.2 Cohesive and Non-cohesive Sediment Cohesive

Cohesive and non-cohesive sediment have differences in the natural characteristic. The major discrepancies between suspended cohesive sediment and suspended non cohesive sediment depend on calculation of the settling velocity or fall velocity of sediment, the interchange across the sediment water interface and bed compaction consideration (Van Rijn, 1984). Particles size of cohesive sediment that are smaller than 62 μm. In the case, the effect of the flocculation makes settling velocity a function of sediment concentration (Van Leussen, 1994).

Cohesive sediment is the clay-sized materials that are composed, which have strong inner particles forces due to their surface ionic charges. The behaviour of sediment dominant by inter particles forces. Its surface area per un*i*t volume (i.e. specific surface area) increases when particles size decrease. There is no clear boundary between cohesive sediment and non-cohesive sediment. The definition is usually site specific. In overall finer sized grains are more cohesive. Sediment sizes smaller than 2 μm (clay) are usually considered cohesive sediment. Silt (2 μm – 60 μm) is well-thought-out to be between cohesive and non-cohesive sediment. The cohesive properties of silt are predominantly due to the presence of clay. Coarse non-cohesive sediment is defined by sediment of size larger than 60 μm. Hence in engineering practice, silt and clay well known be cohesive sediment. (Van Leussen, 1994).

Cohesive sediment contains of organic minerals and inorganic minerals. The organic material is present as animal detritus and plant. There are two types of inorganic minerals such as clay mineral (e.g. illite, kaolinite, montmorrillonite, silica) and non-clay minerals (e.g quartz, mica, and carubonates, among others). Sediment especially cohesive sediment is associated to water quality in stream. Sediment concentration decrease the quality of the water in a stream makes pollutant. In addition, chemicals and wastes are adsorbed to the sediments, are sometimes a water quality concern. The increase in turbidity causes the sunlight evasion to penetrate and decrease the food availability, thus affecting aquatic life. Therefore from the environmental point of view sediment transport is important because there is a link between the presence of sediment and pollutant concentrations.

2.2.3 Properties of sediment

The discipline of sediment transport interrelated between flowing water and sediment. The study of sediment transport is essential for understanding of the physical properties of water and sediment or sediment is its size. Shape and roundness are vital to the diameter of the grain particles. Shapes define as form of particle whereas roundness defines as the sharpness or radius of its curvature of its edges. For example, a flat particle have a smaller fall velocity than a sphere, but hard for bed load to transport.

Sediment in a stream is naturally occurring material of many different sizes and shapes. The particle size distribution is usually represented by a plot weight percentage of the total sample which is smaller than a given size plotted as function of the particle size. The typical sediment size D_{50} is meant by the sediment size for which 50% by weight of the material is finer. D_{50} is generally used as the characteristic grain size. Due to environmental conditions, the size distribution of cohesive sediment (e.g. clay, silt) may vary to which the sediments have been exposed and also the measures that are used to determine their size distribution. Sediment are classify into two categories: cohesive sediment (e.g. clay and silt) and non-cohesive sediment (e.g. sand, gravel, cobbles and boulders). A typical sediment size classification is shown in table 2.1.

Table 2.1: Sediment size classification.

Class Name		Size Range (mm)
Clay	Very fine clay	0.00024-0.0005
	Fine clay	0.0005-0.0010
	Medium clay	0.0010-0.0020
	Coarse clay	0.0020-0.004
Silt	Very fine silt	0.004-0.008
	Fine silt	0.008-0.016
	Medium silt	0.016-0.031
	Coarse silt	0.031-0.062
Sand	Very fine sand	0.062-0.125
	Fine sand	0.125-0.250
	Medium sand	0.250-0.500
	Coarse sand	0.500-1.000
	Very coarse sand	1.000-2.000
Gravel	Very fine gravel	2-4
	Fine gravel	4-8
	Medium gravel	8-16
	Coarse gravel	16-32
	Very fine gravel	32-64
Cobbles	Small cobbles	64-128
	Large cobbles	128-256
Boulders	Medium boulders	256-512
	Coarse boulders	512-1024
	Very large boulders	1024-2048
	Small cobbles	2048-4096

Sources: Vanoni (1977)

2.2.4 Fall Velocity

Fall velocity is the velocity at which a sediment particle falls through a fluid. The velocity reflects the shape, particle size and weight as well as the fluid characteristic. In a quiescent fluid (water), we consider a sphere of diameter D that is released at zero velocity. Fluid resistance reduces the acceleration to equilibrium as the fall velocity W increases. At equilibrium, the gravity forces is in balance with the drag force and terminal velocity, Wt exist.

$$w_t = \left(\frac{D^2 g}{18v}\right)\left(\frac{\rho_s}{\rho} - 1\right) \tag{2.4}$$

Sediment particles are somewhat smaller than spherical, and for a given diameter, based on a sieve analysis; they usually have a fall velocity a little smaller than that of a sphere of the same diameter. In general, stroke lay is applicable to gravity particles in the silt and clay-size range falling in fluid. They are obviously referred to as wash load because these fine materials tend to wash on through the system. Form drag and surface drag are two types of drag.

2.2.5 Bed Forms and Flow Resistance

Free surface flow over erodible sand beds produces a range of different bed forms and bed configuration. The type and dimension of a bed form depends on the properties of the flow, fluid and bed material. Table 2.2 shows summary description of bed forms arranged in increasing order of sediment transport rate. Because there is a hard connection among the flow resistance, the bed and configuration and the rate of the sediment, it is vital to know the circumstance under which different bed forms exist.

Table 2.2: Bed form classification

Bed form	Dimensions	Shape	Behaviour and occurrence
Ripples	Wavelength less than approximate 1 ft; height less than approximate 0.1 ft	Roughly triangular in profile, with gentle, slightly convex upstream slopes and downstream slopes nearly equal to the angle of the repose. Generally short-creasted and three dimensional	Move downstream with velocity much less than that of the flow. Generally do not occur in sediments coarser than 0.6 mm
Bars	Length comparable to the channel width height comparable to mean flow depth	Profile similar to ripples plan form variable	Four types of bats are distinguished: 1) Point 2) Alternating 3) Transverse 4) Tributary. Ripples may occur on upstream slopes
Dunes	Wavelength and high greater than ripples but less than bars	Similar to ripples	Upstream slopes of dunes may be covered with ripples. Dunes migrate downstream in manner similar to ripples.
Transition	Vary widely	Vary widely	A configuration consisting of a heterogeneous arry of bed forms, primarily low amplitude ripples and dunes interspersed with flat regions
Flat bed	-	-	A bed surface devoid of bed forms. May not occur for some ranges of depth and sand size
Anti-dune	Wave length = $2\pi v^2/g$ (approx..)[a] Height depends on depth and velocity of flow	Nearly sinusoidal in profile. Crest length comparable to wavelength	In phase with and strongly interact with gravity water surface waves. May move upstream, downstream or remain stationary depending on properties of flow and sediment.

Sources: Vanoni(1977)

Figure 2.5 shows bed form charts for flow depths up to 10 ft (3m) and also between 100μm and 600μm from (Vanoni, 1974). Bed form is typically classified into a lower regime for subcritical flow, and an upper regime for supercritical flow, with a transition zone close to critical flow.

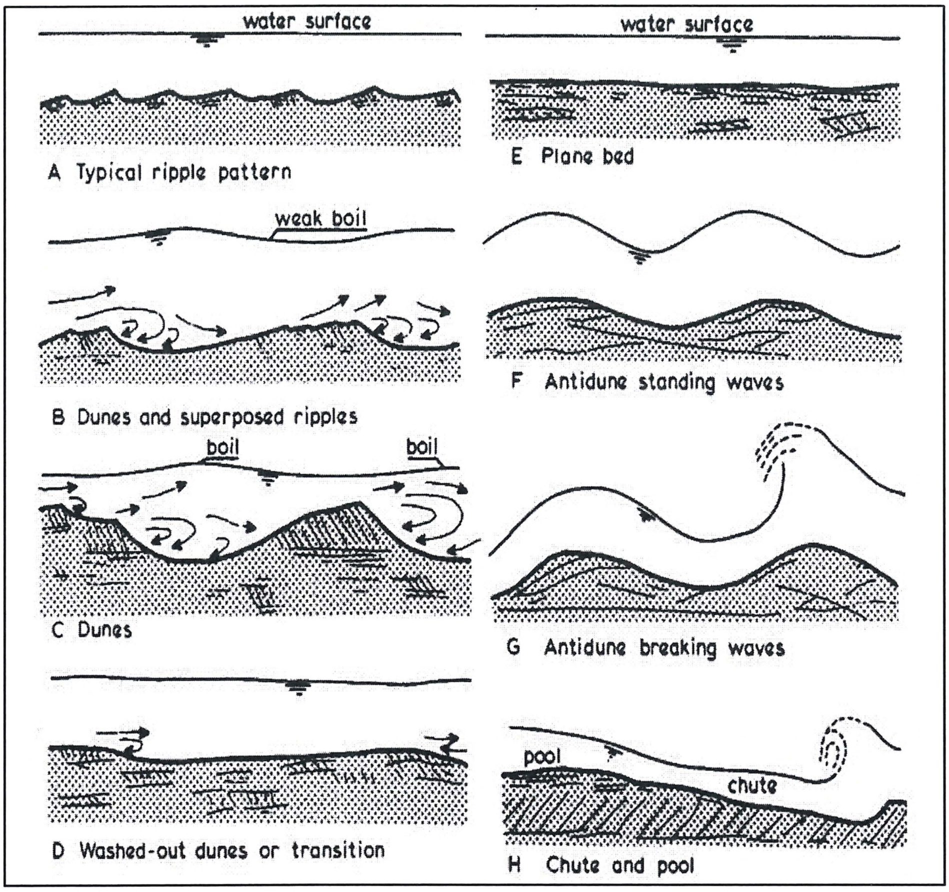

Figure 2.5: Bed form charts

Sources: Vanoni (1974)

2.2.6 Sediment transport function

Table 2.3 shows summary description of sediment transport function used in to analysed sediment transport analysis.

Table 2.3: Sediment transport function

Function name	type	Sediment size range (mm)	Develop form	comments
Ackers-White	Total load	0.04 – 2.5	Flume data	Provides good description of movement for lightweight sediments in laboratory flumes and natural rivers
Yang	Total load	0.015 – 1.71	Stream data	The function is effective for sediments with specific gravity of 2.65. Yang's sand formula is adaptable for sand-bed laboratory flumes and natural rivers-wash load excluded. Yang's gravel formula is for bed material between 2 and 10 mm.
Meyer-peter Muller	Bed load	0.40 – 30	Flume data	Not valid for flows with appreciable suspended loads. The function was calibrated for coarse sands and gravels. It is recommended for rivers when the bed material is coarser than 5mm. depth range is from 1 to 1.2 m.
Toffaleti	Total load	0.062 – 16	Stream data	The bed load portion may be calculated by a load function (for example, Schoklitsch, or Meyer-Peter and Muller). It should not be used for lightweight and coarser material but is adaptable for large sand-bed rivers with specific gravity of 2.65.
Laursen	Total load	0.01 – 4.08	Flume data	Intended to be applied only to natural sediments with specific gravity of 2.65. It is adaptable for shallow rivers with fine sand and coarse silt.
Engelund-Hansen	Total load	Size in excess of 0.15 mm	Large flume data	Appears to satisfactory predict sediment discharge in sand-bed rivers
wilcock	Bed load	2 – 64	Stream data	-

Sources: Vanoni (1977)

2.2.7 Suspended load transport

Sediment along a stream bed will move when the flow condition satisfy or at higher shear stress. Bed load transport classify as sediment is rolling, sliding or jumping along the bed. Bed load transport rate of a river is about 5 % - 25 % of suspension. The motion of the sediment when it is surrounded by fluid describe as sediment suspension. Suspended sediment is defined by the amount of sediment transported by suspension.

Advencive turbulent diffusion and convective causes the movement of suspended matter. The diffusion characterizes the random motion and mixing of sediment through the water depth superimposed to the longitudinal flow motion. When the turbulent mixing length is greater, sediment motion by convection occurs compared with the sediment distribution length scale.

The sediment diffusivity may be assumed to be nearly equal to the turbulent diffusion coefficient (i.e the eddy viscosity). The eddy viscosity is a coefficient of momentum transfer. It expresses the transfer of momentum from points where the momentum per unit volume is high to points where it is lower. Combination of convection and diffusion are one of an alternative approach, thus dealing explicitly with the upward transport of sediment in traveling vortices (Nielsen 1995). The integration of the continuity equation for sediment gives the distribution of sediment gives the distribution of sediment concentration across flow depth:

$$\frac{c}{C_a} = \left(\frac{h-z}{z} \times \frac{a}{h-a}\right)^{\frac{w_a}{KU_o}} \tag{2.5}$$

Where Ca is the reference concentration (g/L0 at the distance above the bed (m), h is water depth (m) and w_0/KU_o is the Rouse number of supended sediment, which determines the degree of uniformity of suspension). The smaller the Rouse number, the more uniform the suspension is. Equation was develop by Rouse (1937) and it was successful examines with laboratory and field data (e.g Vanoni1946). Figure 2.6 shows Rouse solution for vertical distribution of suspended sediment concentration.

2.2.8 Deposition

When the critical shear stress,τc is greater than the bottom shear stress,τ deposition of sediment occurs. Depositions take place when a stream lack of energy to carry its loads. For bed load materials, deposition occurs when material settle out of suspension for suspended load. In still water, a particle will settle out a rate dependent on its terminal velocity, (Briggs, 1977) discusses three major processes which lead to deposition sediment:

a) The placement of the sediment in flow changes, increasing resistance. The lift and drag on a non-spherical sediment will change with placement. The force acting on the sediment will also affect its placement on the bed.

b) The capability of the stream decrease. It was meaning that the energy available for transporting sediment is decrease. Suspended sands and gravels settle out when stream flow drops, and when a local velocity decreases such in river.

c) The quantity or size of the sediment load suddenly increases. This type of deposition may occur if a stream suddenly receives an influx of sediment from a landslide or collapsing stream bank.

2.3 Sand Mining

Sand mining is the removal of sand from their natural configuration and can be shown in Figure 2.6 below. Sand is used for all kinds of projects like land reclamations, the construction of artificial islands and coastline stabilization. These projects have economical and social benefits, but sand mining can also have environmental problems. Environmental problems occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials. The morphologies of the mining areas have demonstrated the impact of mining with the prowess to destroy the cycle of ecosystems.

Figure 2.6: River sand mining (www.thestar.com.my)

Sand mining bring a great effect to ecosystem of the river and also effect the water quality of the river. Figure 2.7 shows illegal river sand mining in the Perak State that occurred on December 2017.

Figure 2.7: Illegal sand mining in Perak State (www.nst.com.my)

Sand mining is a great importance to the Malaysian economy. It should however, be recognised that the processes of prospecting, extracting, concentrating, refining and transporting minerals have great potential for disrupting the natural environment. Many Selangor streams, rivers and their floodplains have abundant quantities of sand and gravel that are mined conveniently and economically for a variety of uses. Often the conditions imposed on the approval for sand mining activities are expressed in administrative terms, without technical consideration of their potential impact on the ecosystem.

Physical impacts of sand mining include reduction of water quality and destabilization of the stream bed and banks. Mining can also disrupts sediment supply and channel form, which can result in a deepening of the channel (incision) as well as sedimentation of habitats downstream. Channel instability and sedimentation from sand mining also can damage

2.4 River Morphology

The terms river morphology and its synonym fluvial geomorphology are used to describe the shapes of river channels and how they change in shape and direction over time. The morphology of a river channel is a function of a number of processes and environmental conditions, including the composition and erodibility of the bed and banks (e.g., sand, clay, bedrock); erosion comes from the power and consistency of the current, and can affect the formation of the river's path. Also, vegetation and the rate of plant growth; the availability of sediment; the size and composition of the sediment moving through the channel; the rate of sediment transport through the channel and the rate of deposition on the floodplain, banks, bars, and bed; and regional aggradation or degradation due to subsidence or uplift. River morphology can also be effected by human interaction, which is a way the river responds to a new factor in how the river can change its course. An example of human induced change in river morphology is dam construction, which alters the ebb flow of fluvial water and sediment, therefore creating or shrinking estuarine channels. During flood and in-stream mining, it will affect the riverbed degradation and aggradation.

2.4.1 Riverbed Degradation

Channel degradation refers to the general lowering of the bed elevation that is due to erosion. In some cases, the bed material is fine and degradation will result in channel incision. In other cases, the material is sufficiently coarse to form an armour layer that prevents further degradation.

Slope adjustments refer to streams that would require either a steeper or a milder slope for reaching equilibrium between incoming and outgoing water and sediment discharge. Stated in simple terms, when the outgoing exceeds the flowing sediment load, alluvial streams will scour bed material and degrade.

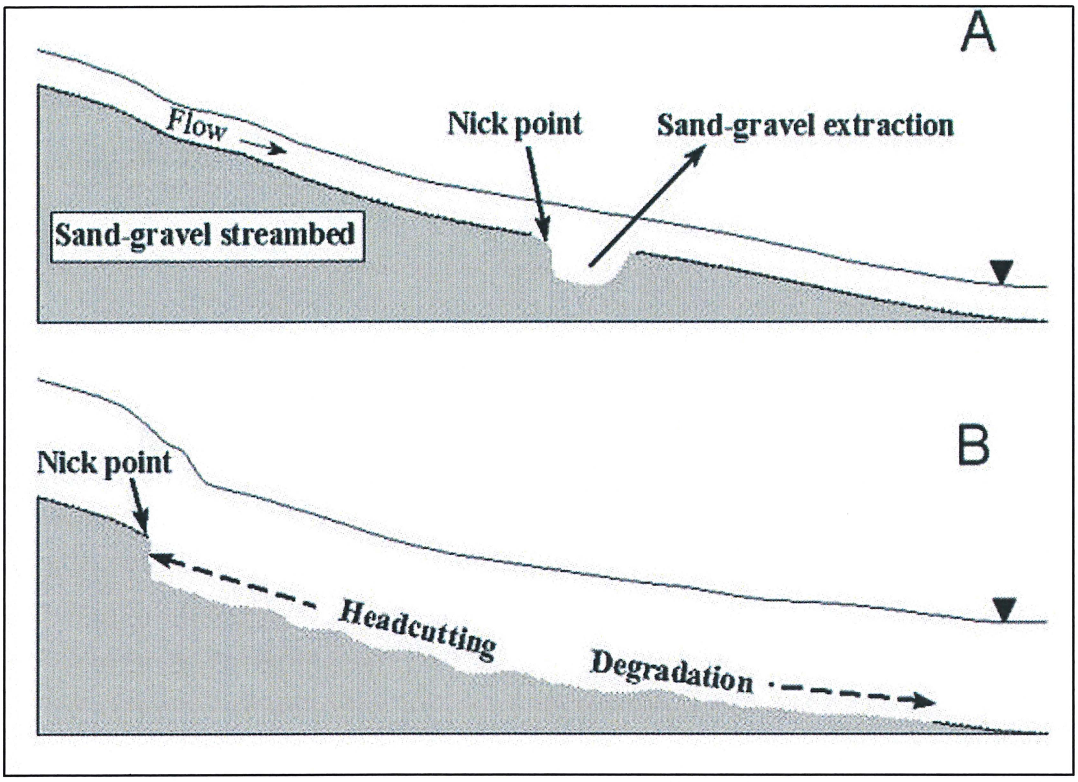

Figure 2.8: Schematic of riverbed degradation

Sources: http://threeissues.sdsu.edu

Channel degradation also causes the banks to become unstable and subject to failure. Gully-like incised channels become very unstable, and bank erosion may become a significant source of sediment to the channel. Incised channels often can be found where the stream slope increases in the downstream direction. Knickpoints indicate points with a sudden change in bed slope. Headcuts refer to sudden drops in bed elevation. Headcuts start downstream, and their upstream migration is a characteristic cause headcutting and degradation in the tributaries. Figure 2.8 above also show the headcut propagates upstream from the confluence cause severe stability problems in structures on shallow foundations such as bridges and some grade-control structures. The ensuing gullying in a tributary affects significant bank instabilities and channel widening.

Armouring of bed layer refers to coarsening of the bed-material size as a result of degradation of well-graded sediment mixtures. The selective erosion of finer particles of the bed material leaves the coarser fractions of the mixture on the bed to induce coarsening of the bed material. When the applied bed shear stress is sufficiently large to mobilize the larger bed particles, degradation continues; when the applied bed shear stress cannot mobilize the coarse bed particles, an armour layer forms on the bed surface. The armour layer becomes coarser and thicker as the bed degrades until it is sufficiently thick to prevent any further degradation. The armour layer is representative of stable bed conditions and can be mobilized only during large floods. A riverbed is sometimes said to be paved when the armour layer can be mobilized only during exceptional floods. Three conditions need to be satisfied to form armour layers; (1) the stream must be degrading, (2) the bed material must be sufficiently coarse, and (3) there must be a sufficient quantity of coarse bed material. Figure 2.9 shows the schematic diagram for armouring the bed layer.

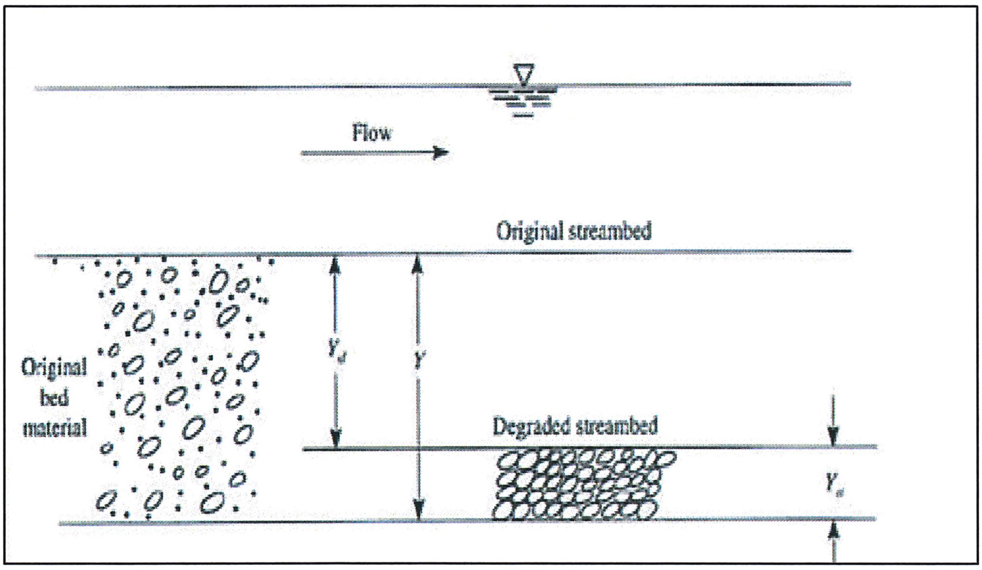

Figure 2.9: Armouring a bed layer

Sources: https://harbisoncreek.weebly.com

2.4.2 Riverbed Aggradation

Channel aggradation refers to a gradual bed-elevation increase that is due to bed load sedimentation. When the inflowing sediment discharge exceeds the outgoing sediment capacity, alluvial channels tend to deposit their sediment load throughout the reach. Streams carrying mostly wash load will not change their morphology because the sediment overload will be carried downstream to settle in lakes, reservoirs, or estuaries. Streams carrying most of their sediment load suspension change their morphology gradually as the excess sediment load settles in downstream direction. From Lane's relationship, downstream fining is usually accompanied by a downstream decrease in bed slope. On the other hand, streams that carry predominantly bed load material will respond quite rapidly to a change in sediment-transport capacity. A decrease in transport capacity induces direct settling on the bed of alluvial channels. Figure 2.8 below shows the phenomenon of riverbed aggradation.

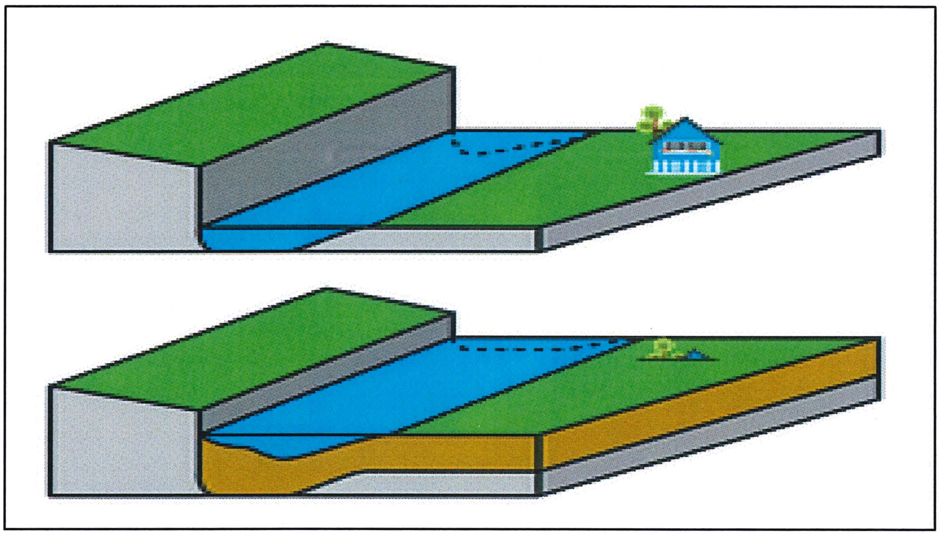

Figure 2.10: Schematic of riverbed aggradation

2.5 HEC-RAS

HEC-RAS is one-dimensional hydraulic analysis software produced by US Army Corps of Engineers (USACE, 1991). The software consists of four elements for steady flow water surface calculation, unsteady flow simulation that use hydraulic computation routines and geometric data. Basic water surface profiles can be generate using several hydraulic design features. In addition, HEC-RAS can forecast the changes in channel bed and river profiles from troubles such as flood plain. It is capable to analysis sediment transport.

2.5.1 Quasi-Unsteady Flow

The quasi-unsteady flow model simplifies hydrodynamics, representing a continuous hydrograph with a series of discrete steady flow profiles. HEC-RAS keeps flow constant for each flow record, computing transport over flow record duration. The steady flow profiles are more stable than the matrix solution of the unsteady Saint-Venant equations, but approximating a hydrograph with a series of steady flows does not conserve flow or explicitly account for volume.

The quasi-unsteady flow model has divides time into three time step. HEC-RAS divides each discrete steady flow profile (Flow Duration), over which HEC-RAS holds flow constant, into Computational Increments, which are the hydraulic and sediment transport time step. HEC-RAS updates the hydraulics and cross sections every Computational Increment, but further subdivides this time step into Bed Mixing Time Steps, updated bed gradation accounting for each bed layer several times each Computational Increment. Figure 2.10 shows quasi unsteady flow series with time step.

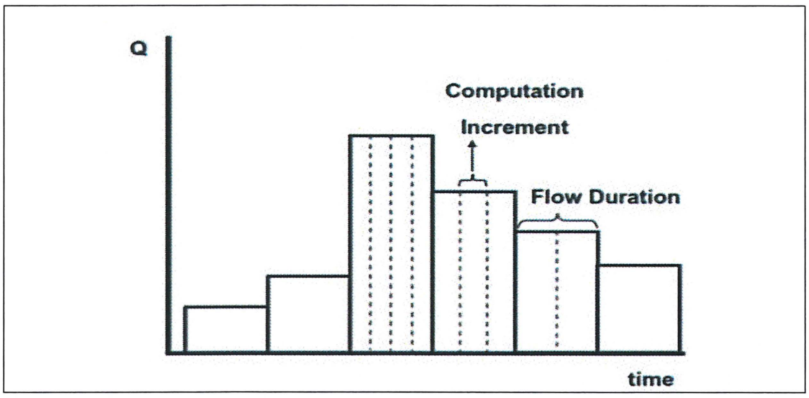

Figure 2.11: A quasi unsteady flow series with time step.

Sources: HEC-RAS (2016)

2.5.2 Sediment Continuity

The HEC-RAS sediment routing routines solve the sediment continuity equation also known as the Exner equation:

$$(1 - \lambda p)B\frac{\partial \eta}{\partial t} = -\frac{\partial Qs}{\partial x} \qquad (2.6)$$

Like most continuity equations, the Exner equation simply states that the difference between sediment entering and leaving a control volume must be stored or removed from storage. The unique feature of the Exner equation is that sediment storage is stored in the bed in a multi- phase mixture with water, requiring porosity to translate mass change into volume change. The Exner equation translates the difference between inflowing and outflowing loads into bed change, eroding or depositing sediment.

HEC-RAS solves the sediment continuity equation by computing a sediment transport capacity for control volume (Qs-out) associated with each cross section, comparing it to the sediment supply (Qs-in) entering the control volume from the upstream control volume or loacal sources (e.g. lateral sediment loads). If capacity is greater than supply, HEC-RAS satisfies the deficit by eroding bed sediments. If supply exceeds capacity, HEC-RAS deposits the sediment surplus.

2.5.3 Compute Transport Capacity

The right hand side of the continuity equation, the sediment gradient across the control volume, compares the sediment inflow with the sediment outflow. Sediment inflow is simply the sediment entering the control volume from the upstream control volume(s) and any local sources (lateral sediment inflows). Computing the sediment leaving the control volume is more difficult, a measure of the sediment mass the water can move, which is a complex function of the hydrodynamics and sediment properties. Sediment transport capacity is a measure of the control volume competence to pass sediment, computing the maximum sediment it can transport by grain class.

2.5.3.1 Ackers-White

The general transport equation for the Ackers-White function for a single grain size is represented by:

$$Ggr = C\left(\frac{Fgr}{A} - 1\right) \tag{2.7}$$

$$X = \frac{Ggr s d_s}{D\left(\frac{u*}{V}\right)^n} \tag{2.8}$$

Where X is Sediment concentration, in parts per part, s is Specific gravity of sediments, Ggr is sediment transport parameter, ds is mean particle diameter, D is Effective depth, u* is shear velocity, V is average channel velocity, n is transition exponent, depending on sediment size, C is coefficient, Fgr is sediment mobility parameter, A is critical sediment mobility parameter

2.5.3.2 Engelund-Hansen

The general transport equation for the Engelund-Hansen function is represented by:

$$g_s = 0.05\gamma_s V^2 \sqrt{\frac{d_{50}}{g\left(\frac{\gamma_s}{\gamma}-1\right)}} \left[\frac{\tau o}{(\gamma s-\gamma) d50}\right]^{3/2} \tag{2.9}$$

Where gs is unit sediment transport, γ is unit weight of water, γs is unit weight of solid particles, V is average channel velocity, τo is bed level shear stress, d50 is particle size of which 50% is smaller.

2.5.3.3 Laursen

The general transport equation for the Laursen (Copeland) function for a single grain size is represented by:

$$Cm = 0.01\gamma\left(\frac{ds}{D}\right)^{7/6}\left(\frac{\tau o}{\tau} - 1\right)f\left(\frac{u*}{\omega}\right) \tag{2.10}$$

Where Cm is sediment discharge concentration, in weight/volume, G is unit weight of water, ds is mean particle diameter, D is effective depth of flow, τo is bed shear stress due to grain resistance, τc is critical bed shear stress, f($\frac{u*}{\omega}$) is Function of the ratio of shear velocity to fall velocity as defined in Laursen's Figure 14 (Laursen, 1958)

2.5.3.4 Meyer-Peter Müller

The general transport equation for the Meyer-Peter Müller function is represented by:

$$\left(\frac{kr}{k\prime r}\right)^{3/2} \gamma RS = 0.047(\gamma s - \gamma)d\mathrm{m} + 0.25\left(\frac{\gamma}{g}\right)^{1/3} \left(\frac{\gamma s-\gamma}{\gamma s}\right)^{2/3} gs^{2/3} \quad (2.11)$$

Where gs is unit sediment transport rate in weight/time/unit width, kr is a roughness coefficient, kr' is a roughness coefficient based on grains, γ is unit weight of water, γs is unit weight of the sediment, g is acceleration of gravity, dm is median particle diameter, R is hydraulic radius, S is energy gradient.

2.5.3.5 Toffaleti

The general transport equations for the Toffaleti function for a single grain size is represented by:

$$g\mathrm{ssu} = M \frac{\left(\frac{R}{11.24}\right)^{0.244z} \left(\frac{R}{2.5}\right)^{0.5z} \left[R^{1+nv-1.5z} - \left(\frac{R}{2.5}\right)^{1+nv-1.5z}\right]}{1+nv-1.5z} \quad (2.12)$$

$$g\mathrm{sb} = M(2dm)^{1+nv-0.756z} \quad (2.13)$$

$$g\mathrm{ssL} = M \frac{\left(\frac{R}{11.24}\right)^{1+nv-0.756z} - (2dm)^{1+nv-0.756z}}{1+nv-0.756z} \quad (2.14)$$

$$gssM = M\frac{\left(\frac{R}{11.24}\right)^{0.244z}\left[\left(\frac{R}{2.5}\right)^{1+nv-z}\left(\frac{R}{11.24}\right)^{1+nv-z}\right]}{1+nv-z} \tag{2.15}$$

$$M = 43.2CL(1+nv)VR^{0.756Z-nv} \tag{2.16}$$

$$gs = gssL + gssM + gssU + gsb \tag{2.17}$$

Where gssL is suspended sediment transport in the lower zone, in tons/day/ft, Where gssU is suspended sediment transport in the upper zone, in tons/day/ft gssM is suspended sediment transport in the middle zone, in tons/day/ft, gsb is bed load sediment transport in tons/day/ft, gs is total sediment transport in tons/day/ft, M is sediment concentration parameter, CL is sediment concentration in the lower zone, R is hydraulic radius, dm is median particle diameter, z is exponent describing the relationship between the sediment and hydraulic characteristics, nv is temperature exponent.

2.5.3.6 Yang

The general transport equations for sand and gravel using the Yang function for a single grain size is represented by:

$$logCt = 6.681 - 0.633log\frac{\omega dm}{v} - 4.816log\frac{u*}{\omega} +$$

$$\left(2.784 - 0.305log\frac{\omega d_m}{v} - 0.282log\frac{u*}{\omega}\right)log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \tag{2.18}$$

for sand dm < 2 mm

$$logCt = 5.435 - 0.286log\frac{\omega dm}{v} - 0.457log\frac{u*}{\omega} +$$

$$\left(1.799 - 0.409log\frac{\omega d_m}{v} - 0.314log\frac{u*}{\omega}\right) log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \quad (2.19)$$

for gravel dm ≥ 2 mm

Where Ct is total sediment concentration, ω is particle fall velocity, dm is median particle diameter, ν is kinematic viscosity, u* is shear velocity, V is average channel velocity.

2.6 Previous Study on River Sedimentation Modelling

2.6.1 Sand Mining Effects, causes and concerns in Bestari Jaya, Selangor, Peninsular Malaysia (Ashraf et al, 2011)

The mining of sand resources from rivers and ex-mining areas in Selangor state is a common practice and may lead to destruction of public assets as well as impacts or increase stress on commercial and non-commercial living resources that utilize these areas. Hydraulic and sediment transport modelling study were carried out to determine possible sand deposition and their flow towards Selangor River. The Hydrologic Engineering Centers River Analysis System (HEC-RAS) software were used to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels and to get input and output information in tabular and graphical formats. The resulting vertical and horizontal distributions of sediment show encouraging agreement with the field data, demonstrating markedly different dispersal patterns due largely to the differential settling of the various sand classes. The assessment of water quality shows that water has been highly polluted immediately downstream of station at Selangor River due to high concentrations of suspended particles. Transport modelling and water quality analyses performed have identified major physical environmental impacts. The issue poses a number of policy questions that are worth to be implemented by the government. From the results, it shows the where the location of deposition occurred. The deposition occurred normally occurred at location with low velocity.

2.6.2 River Sand Mining Management Guideline on Sungai Muda, Selangor (DID, 2009)

Sand and gravel have long been used as aggregate for construction of roads and building. Today, the demand for these materials continues to rise. In Malaysia, the main source of sand is from in-stream mining. In-stream sand mining is a common practice because the mining locations are usually near the "markets" or along the transportation route, hence reducing transportation costs.

In-stream sand mining can damage private and public properties as well as aquatic habitats. Excessive removal of sand may significantly distort the natural equilibrium of a stream channel. By removing sediment from the active channel bed, in-stream mines interrupt the continuity of sediment transport through the river system, disrupting the sediment mass balance in the river downstream and inducing channel adjustments (usually incision) extending considerable distances (commonly 1 km or more) beyond the extraction site itself. The magnitude of the impact basically depends on the magnitudes of the extraction relative to bed load sediment supply and transport through the reach. From the simulation, the suitable location for mining activities can be propose so that the river channel can maintain its stability. In order to determine the location of mining area, the location for highest deposition occurred need to be determined.

2.6.3 Sediment Transport Modelling Around Bridge at SUNGAI TUI Using 1D Quasi Unsteady Flow HEC-RAS (Krishnamuthi, 2015)

Sungai Tui is located in the state of Pahang where huge amount of rainfall during monsoon season subjected to sediment transport process. The river responses by increased or decreased sediment carrying capacity, changing in channel cross section, erosion and deposition along the channel, which impact on river bank stability over a period of time. The research is to model sediment transport around bridge at Sungai Tui by using one dimensional (1D) quasi unsteady flow Hydrologic Engineering Centers River Analysis System (HEC-RAS). There is few data required such as catchment area, precipitation data, geometric data and sediment data. The analysis is done using various method of transport function found in HEC-RAS. For 5 years analysis of sediment transport, maximum erosion and deposition occurs at the depth 0.49m and 0.64m using Ackers-White; 0.50m and 0.76m using England-Hansen; 0.50m and 1.18m using Laursen; 0.50m and 1.12m using Meyer Peter Muller; 0.49m and 0.48m using Toffaleti; 0.50m and 0.76m using Yang and 0.50m and 1.18m using Wilcock. Erosion and deposition of sediment along the channel is not similar using various methods of transport function. In conclusion, sediment pattern can be predicted and analyzed using several methods in HEC-RAS software. Figure 2.14 and 2.15 shows the HEC-RAS model of Sungai Tui, and bed profile before and after 5 year analysis by using Yang transport function.

2.6.4 Sediment transport modelling for Kulim River (Kiat et al, 2008)

Rapid urbanization has accelerated impact on the catchment hydrology and geomorphology. This rapid development which takes place in river catchment will result in higher sediment yield and affect river morphology and river channel stability; it also becomes the main cause for serious flooding in urban areas. Therefore, it is necessary to predict and evaluate the river channel stability due to the existing and future developments. This study proceeds at Kulim River in Kedah state, a natural stream in Kedah, Malaysia. The FLUVIAL-12 model, an erodible-boundary model which simulates inter-related changes in channel-bed profile, width variation and changes in bed topography was selected for this study. Engelund-Hansen formula and roughness coefficient n = 0.030 were found to be the best combination to represent the sediment transport activity in the study reach, where good agreements were obtained for both water level and bed profiles between the measured data and predicted results by FLUVIAL-12 model. The model simulation results for existing conditions, future conditions and long-term modeling show that the sediment size and channel geometry in Kulim River changed significantly. However, modeled results show that future changes in cross sectional geometry will be limited and erosion along the reach will slow down from 2006 to 2016, thus Kulim River was predicted to be stable at most locations.

2.6.5 Simulation for Sedimentation assessment a case study of Kunar River in Afghanistan (W. Safi, 2017)

Rivers are easily accessible resources of water for miscellaneous uses but the erosion and sedimentation in rivers are unique and great deal of importance. The analysis of flow and sediment in river under different conditions is a base for rivers' behaviour and decision making on engineering aspects. Kunar River is an important river of Afghanistan has considerable interest because of strategic and environmental condition regarding water resources project planning, agriculture, forests, hydropower and industrial scope. This study is carried out to simulate the process of erosion and sedimentation using HEC-RAS model to assess hydraulic parameters and sedimentation processes in 250 Km stretch of Kunar River from Nari district of Kunar province to Pule-Kama of Nangarhar Province. The model was calibrated manually for hydraulic parameters of river flow and then sediment transport model was simulated. The changes in transverse and longitudinal profile, velocity and shear stress variation along the river, mass inflow and outflow, bed level change of river and suspended sediment concentration is studied for the modelled length. The sediment transport from river tributaries and gullies joining the river from two sides of narrow valley is also assessed. The model was first calibrated manually using excel sheet for flow hydraulics and then simulating for sediment transport was carried out. The results showed that Kunar river experience erosion in upstream half-length (150 – 250 Km) reach and sedimentation happens in half-length of downstream (0 – 150 Km) reach. There are many pools in upstream length which causing sediments trapping.

2.6.6 1D Sediment Transport Modelling in Langat River by Using Quasi Unsteady HEC-RAS (Badri, 2014)

The main purpose of the study is to study sediment transport characteristics at Langat River. Langat River is located in the state of Selangor and it is subjected to regular flooding. Sediment transport capabilities can be known by using HEC-RAS. The appropriate data required to create the model. The data needed to use in HEC-RAS is cross sectional data and elevation data. HEC-RAS can create the sediment transport and hydraulic models. The sediment transport model will calculates sediment transport capacity with a number of available methodologies. In this research, HEC-RAS can show sediment transport. The HEC-RAS model can calibrate and gives the values of Manning's coefficients of roughness for the Langat River. HEC-RAS also can predict the changes of bed elevation. The model will conclude that there is a significant increase in river bed depth due to development, which means there is no change in flooding behaviour was detected in the short term. This paper will be focused only on bed load sediment. The result of 6 years stream flow shows there are some area had faced sediment transport and erosion of the river. By using the England Hansen function in HEC-RAS had shown a little change in the river. From the simulation, the result shows the section that experienced sediment transport at station 943 (1.45km from the upstream part at Bangi) and station 959 (1.05km from the upstream part at Bangi), and station 972 (725rn from the upstream part at Bangi) that experienced the erosion of river.

2.6.7 1D Quasi Unsteady Flow Sediment Transport in Galing River by Using HEC-RAS (Hanif, 2014)

Sedimentation comes from the sediment transport, which involved the rock, gravel, sand, silt, clay and other natural sources where it is caused by the erosion in the river. In my study, it is essential to make a research about the physical of the Galing River that can influence the simulating of sediment transport rate where can effect of Urban Land Uses and Stream-water. River bed changes, prediction in this study leans post uses 1 D modelling sediment provided by HEC-RAS. This software allows performing one-dimensional quasi unsteady flow and sediment transport calculations. The data of cross section, flow discharge and sediment data are collected to run this software (HEC-RAS 4.1). Through this software we can the simulation the sediment transport pattern. There are 3 total bedload data that are used which is 0.1777 tonnes/m-day, 2.275 tonnes/m-day and 7.760 tonnes/m-day while the slope is 0.0001383. The result are predicting about a year and half with computation increment is 1 hour. The result shows that there are many sediment transport occur and it is compared to others method. The result of each approach, Meyer-Peter Muller method shows that there many locations that occur the erosion and sedimentation. The erosion occurs at the 150 m, 700 m and 1800 m from the downstream while the sedimentation formed at station 7 and 16 where 600 m and 1100 m from downstream. The Toffaleti method show that the erosion that occurs same with Meyer-Peter Muller method which is 150 m, 700 m and 1800 m from downstream. The sedimentation that formed only at 1 location which is at station 7 where 600 m from downstream. The Laursen method shows that the erosion has occurred in many locations which is 150 m, 700 m, 1150 m and 1800 m from downstream while the sedimentation that formed are same with Meyer-Peter Muller method.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In order to perform sediment the transport simulation, there are few boundary conditions that need to take account such as location and condition of study area, primary data analysis, and secondary data analysis.

3.2 Study Area

The study area to perform the sediment transport modelling is took about 5 km long from [upstream (3.932805, 103.051265) to downstream (3.928848, 103.078232)] and the average width of the Sungai Kuantan at Bukit Kenau Station, Kuantan Pahang is about 70 m. The condition and location of the study area is at (3.931806, 103.057527) and can be shown as figure 3.1 and 3.2.

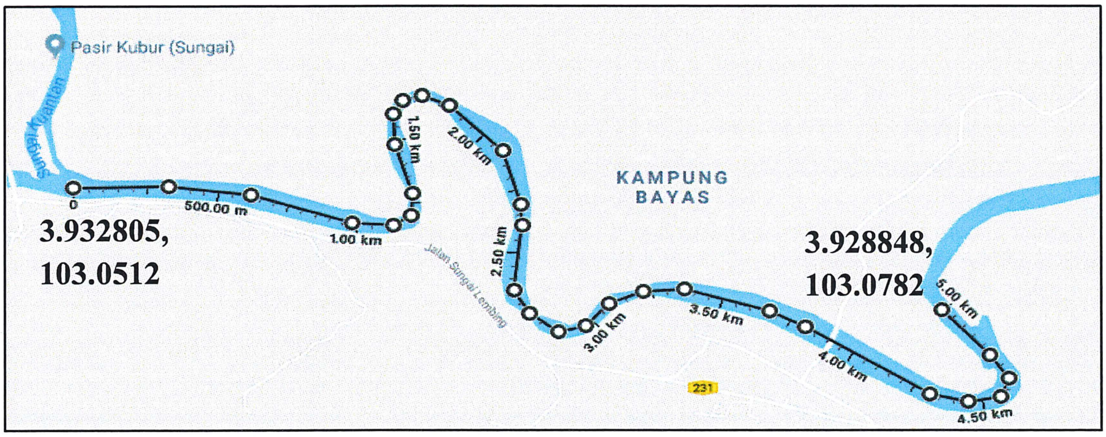

Figure 3.1: Length of the river profile at the study area (Google Map)

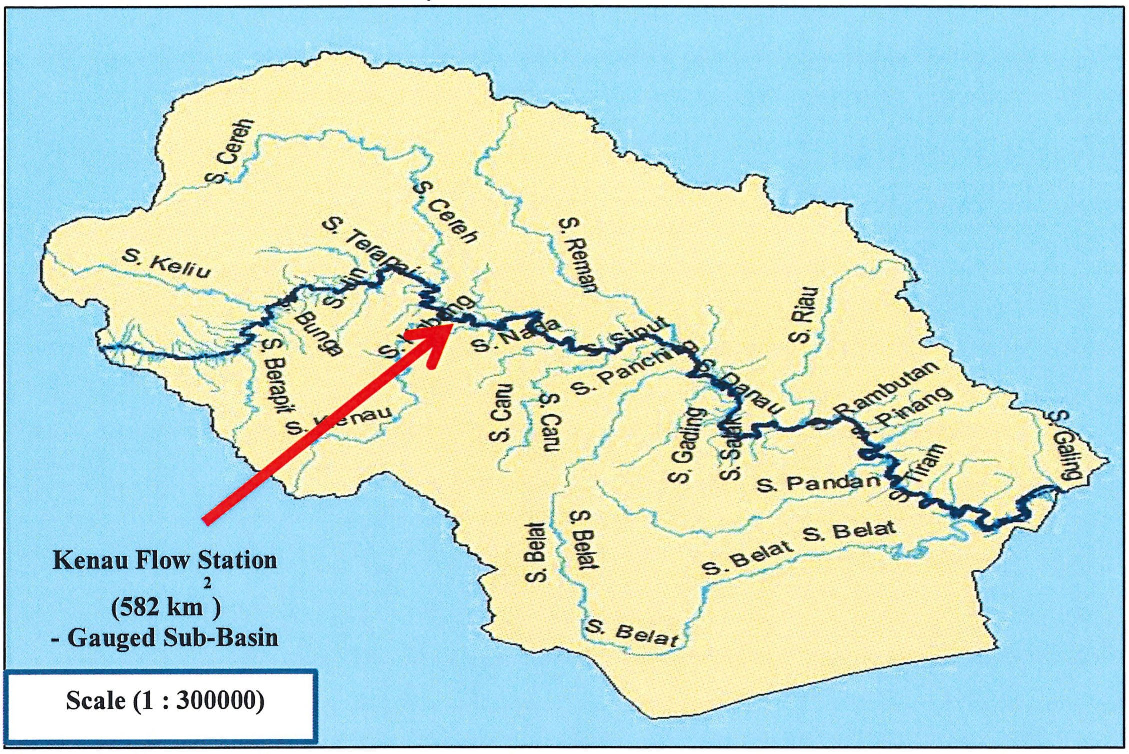

Figure 3.2: Location of the study area (Google Map)

3.3 Primary Data Analysis

Primary data is a type of information that is obtained directly from first-hand sources by means of surveys, observation or experimentation. In this study, the sieve analysis experiment was conducted in Geotechnical Laboratory UMP using a sample which is collected from Kampung Bayas. After the sieve analysis is done, the particles size distribution of the sample can be determined.

3.4 Secondary Data Analysis

In order to model the sediment transport by using HEC-RAS software, there are few data that are importantly needed such as discharge rate during specific time, catchment area details, and also hydrological data that is collected from DID. The River cross-section information for selected section of Kuantan River was collected from the land surveyor. Basically to simulate the sediment transport, the information of initial condition of the site and transport parameters need to gather first.

3.5 Flow Chart of Sediment Transport Simulation

In order to perform the sediment transport simulation, there are few steps that need to be follows and can be shown in Figure 3.3 below.

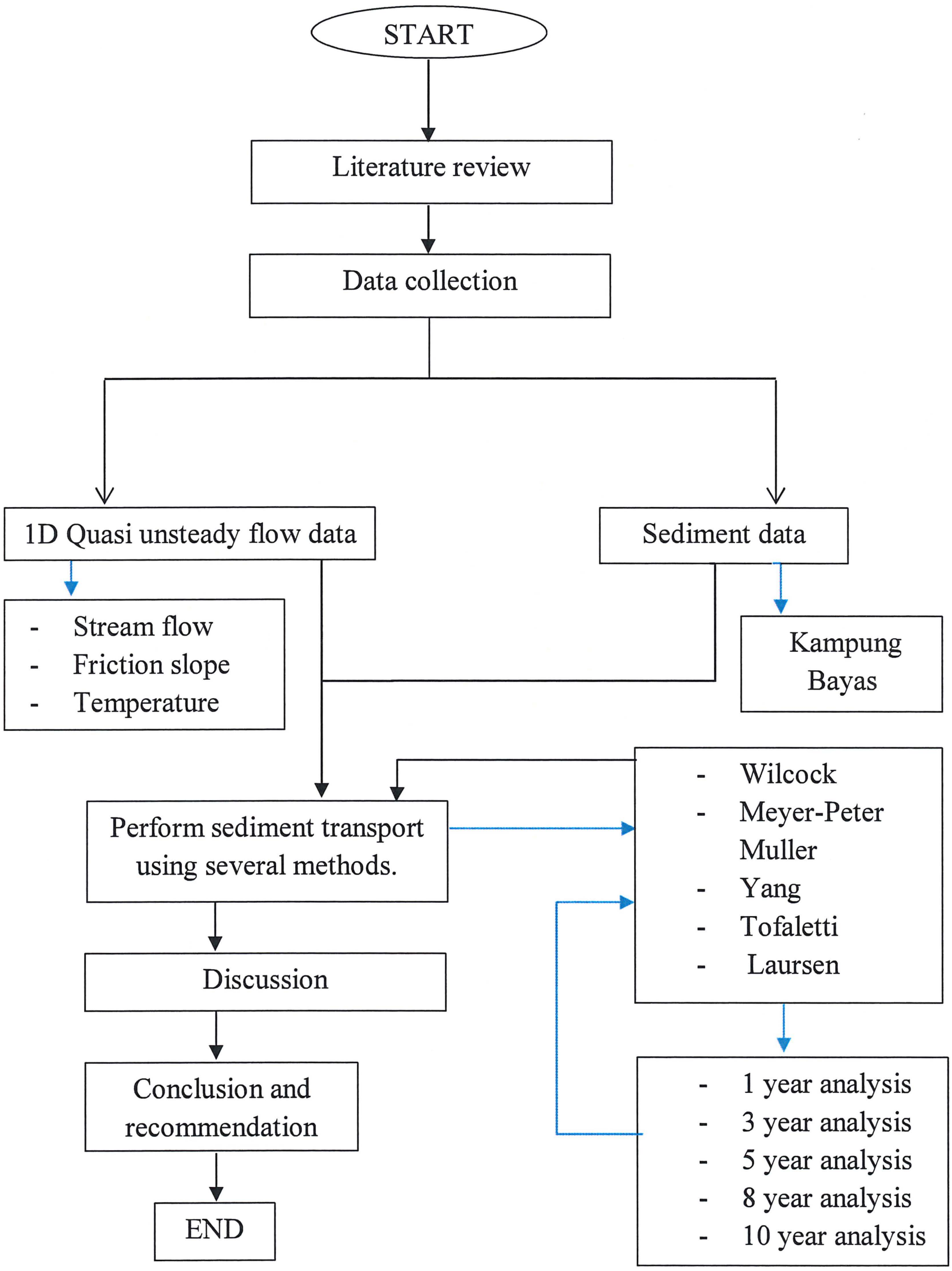

Figure 3.3: Flow chart of sediment transport

3.6 Type of Data

There are several types of data required to simulate the sediment transport around Sungai Kuantan during wet season by using 1D quasi unsteady flow which is river geometric, temperature, and hydrological data.

3.6.1 Geometric Data of River Cross Section

Geometric is very important data that need to take into account. The data are taken for every 200 m interval. From this data, the shape and cross section of the river for chainage can be determined. From the geometric data, the river bed and river bank profile can be determined and can be shown as Figure 3.4 below

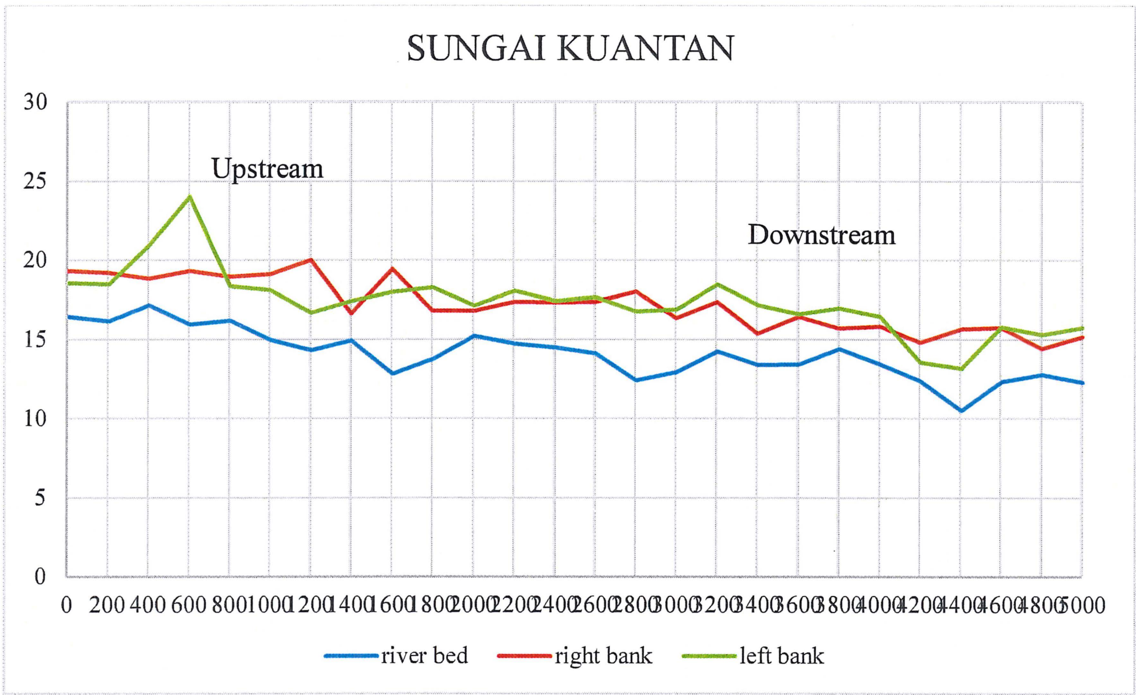

Figure 3.4: River bed and river bank profile

3.6.2 Temperature data

Temperature data is very important parameter for the sediment transport simulation. The temperature will affect the size of the sediment and then will affect the sediment transport pattern in the river.

3.6.3 Hydrological data

In order to simulate the model, the Quasi-unsteady flow data need to fill in HEC-RAS. One of the data that is needed in river modelling is streamflow data at Bukit Kenau Station is collected form Department of Irrigation (DID). The streamflow data for every 24 hour interval were selected inserted into HEC-RAS software for plotting streamflow hydrograph.

3.6.4 Friction Slope data

Friction slope are determine by calculating the slope of the river from upstream to downstream. The difference in elevation between upstream and downstream is 4.16 m, and the distance from upstream to downstream is 5000 m which gives the value of slope is 0.000832.

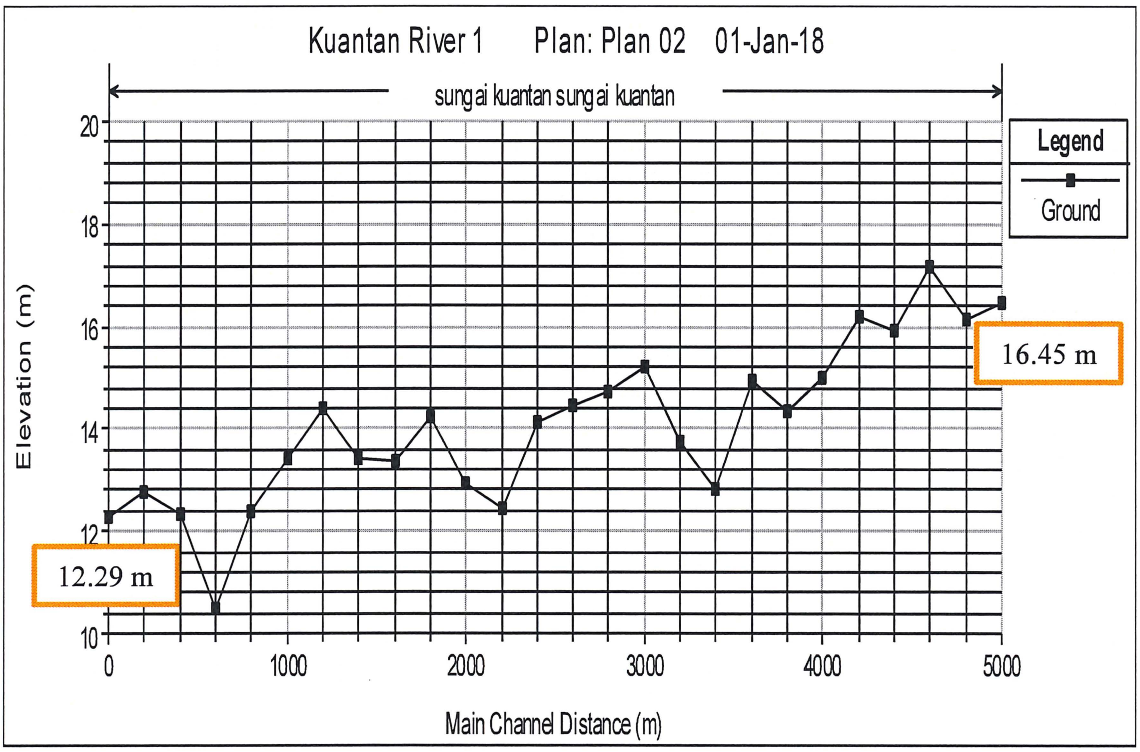

Figure 3.5: Bed profile for Sungai Kuantan

3.6.5 Sediment data

The sediment data are very important in order to determine the particle size distribution. This sediment data are used to determine the fall velocity for the sedimentation process in the river. The sediment sample was collected at Kampung Bayas. The detail of the sampling location can be shown in Figure 3.5 below.

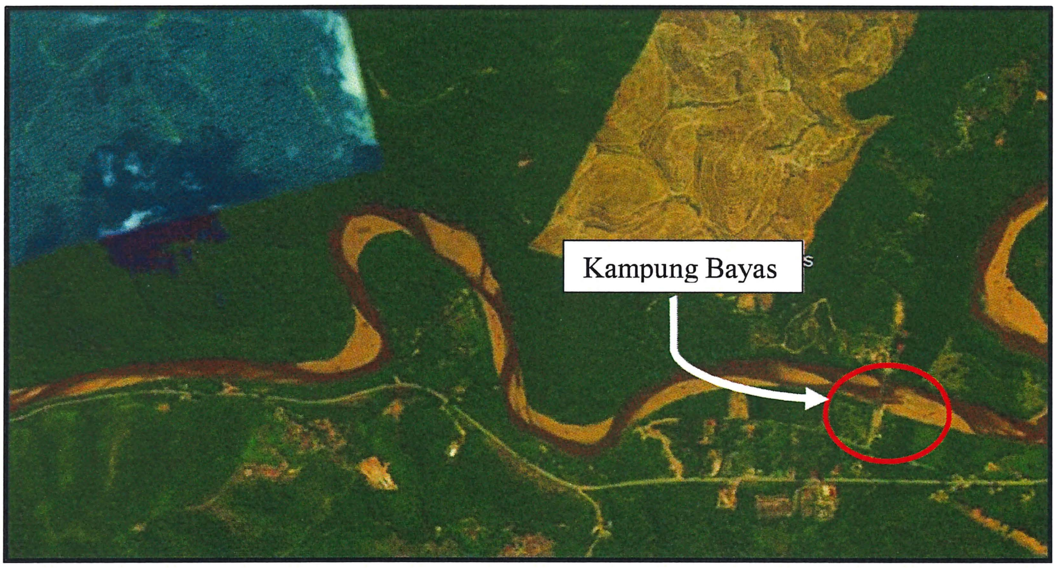

Figure 3.6: Location of sediment collection at Kampung Bayas.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Streamflow Hydrograph

The stream flow streamflow gauging station at Bukit Kenau station. The stream flow hydrograph shows the flow of the water in Kuantan River starting from 2002 until 2012 and can be shown as figure 4.1 below.

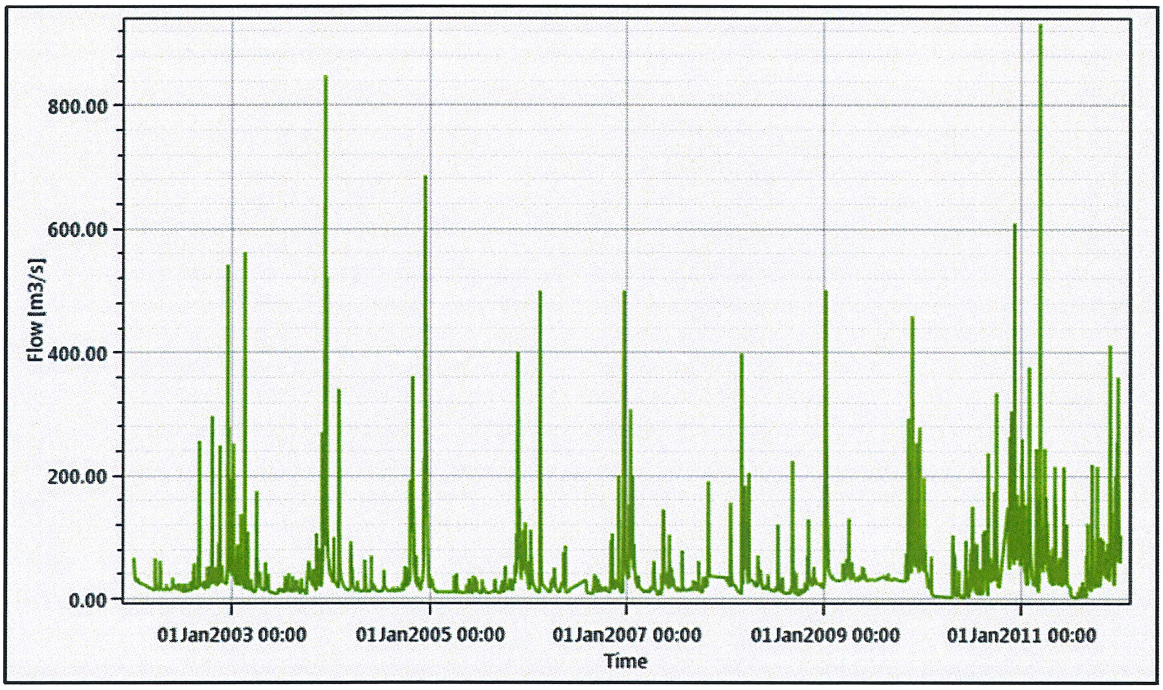

Figure 4.1: Streamflow hydrograph at Bukit Kenau Station (2002-2012)

4.2 Particle Size Distribution of Sediment

Particle size distribution are used in order to determine the mean diameter, D_{50} for sediment. The function of the data are used to determine fall velocity for the sediment in water. Figure 4.2 below shows the particle size distribution for sediment at Kampung Bayas.

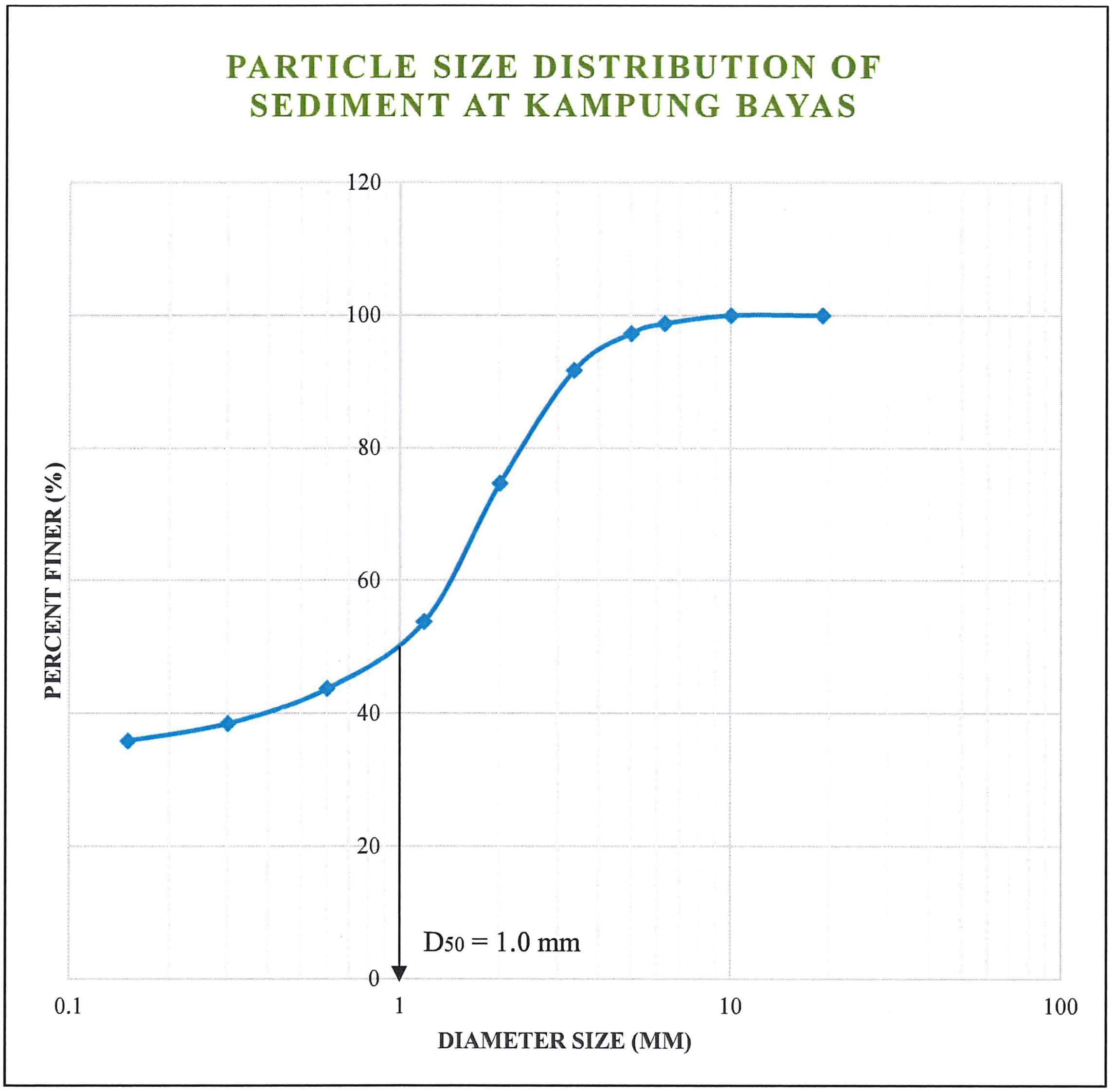

Figure 4.2: Particle size distribution of sediment at Kampung Bayas

4.3 Sediment Transport Simulation by several method

Sediment transport modelling were performed by using several method in order to identify which method can be used in order to perform the sediment transport computation completely without produce any error. Section 4.3.1 until 4.3.5 explain about the error occur during computation in HEC-RAS, and also explain whether the method can be use or not in order to perform sediment transport simulation.

4.3.1 Computation Result by Wilcock

Figure 4.3 shows when using Wilcock method in order to perform sediment transport simulation, the model cannot be run or error occur. The error occurred because of the unrealistic vertical adjustment at 4800 m from the downstream. Furthermore, this situation happen when the cross section suddenly subjected to erosion after deposition at this cross section.

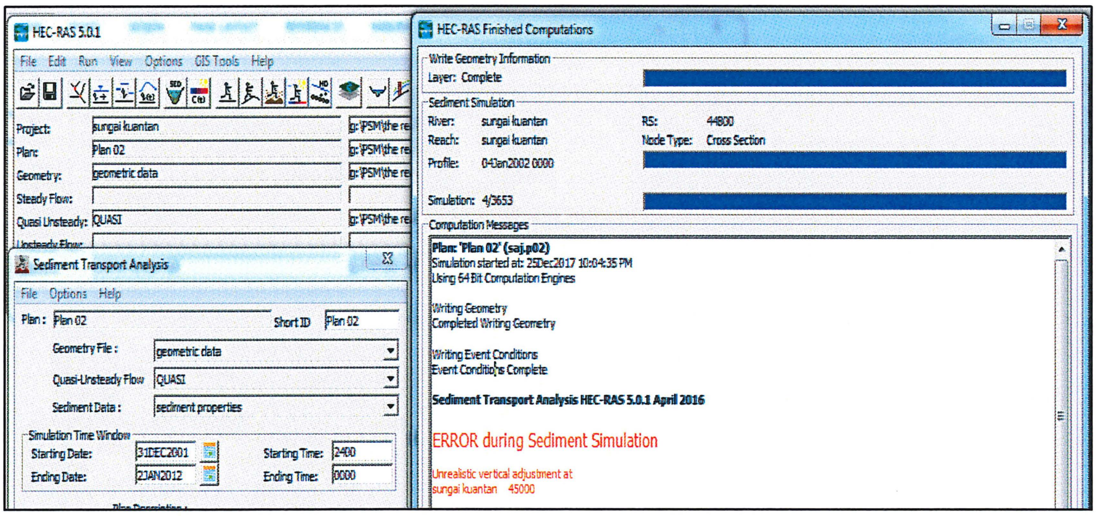

Figure 4.3: Computation result by using Wilcock method

Figure 4.4 and 4.5 illustrate the erosion suddenly happen after deposition at cross section of 4800 m from the downstream

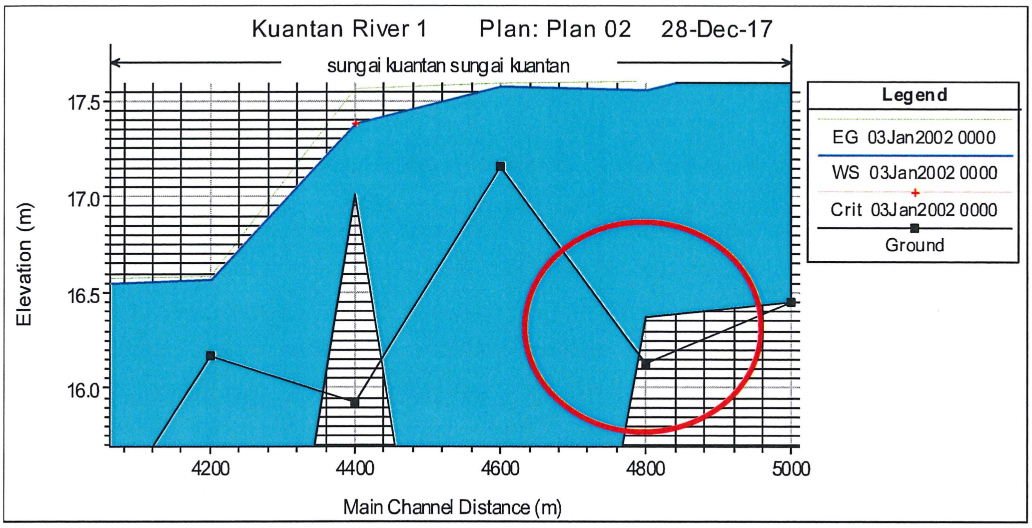

Figure 4.4: Location of deposition in 3 Jan 2002 by Wilcock

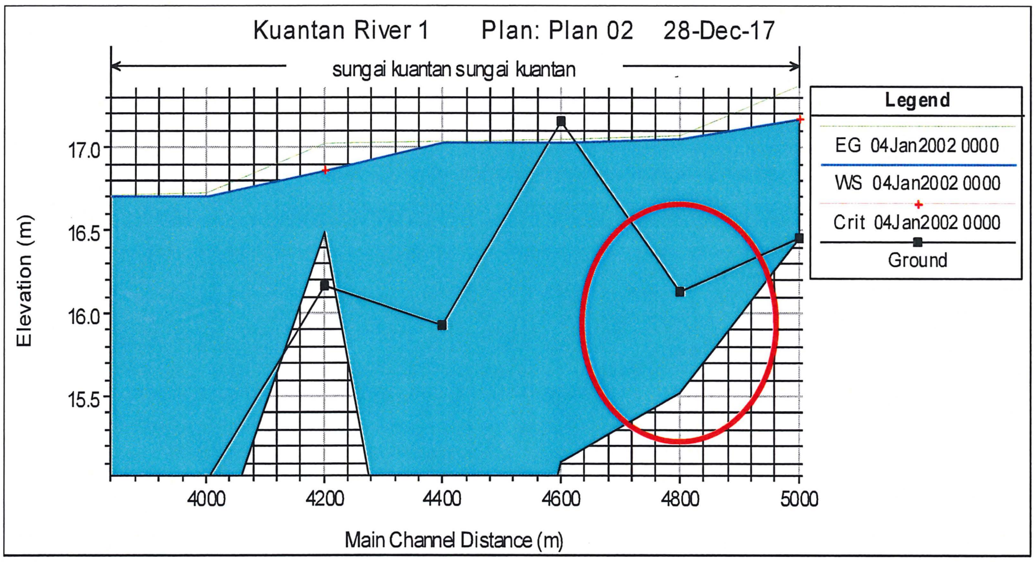

Figure 4.5: Location of erosion in 4 Jan 2002 by Wilcock

From the computation result, the Wilcock method cannot be used for sediment transport simulation of Sungai Kuantan. As a recommendation, in order to run this model without error, more cross section are required with less value of interval between the river cross section.

4.3.2 Computation Result by Meyer-Peter Muller

Figure 4.6 shows when using Meyer-Peter Muller method in order to perform sediment transport simulation, the model cannot be run or error occur. The error occurred because of the unrealistic vertical adjustment at 4600 m from the downstream. Furthermore, this situation happen when the cross section suddenly subjected to deposition after erosion at this cross section.

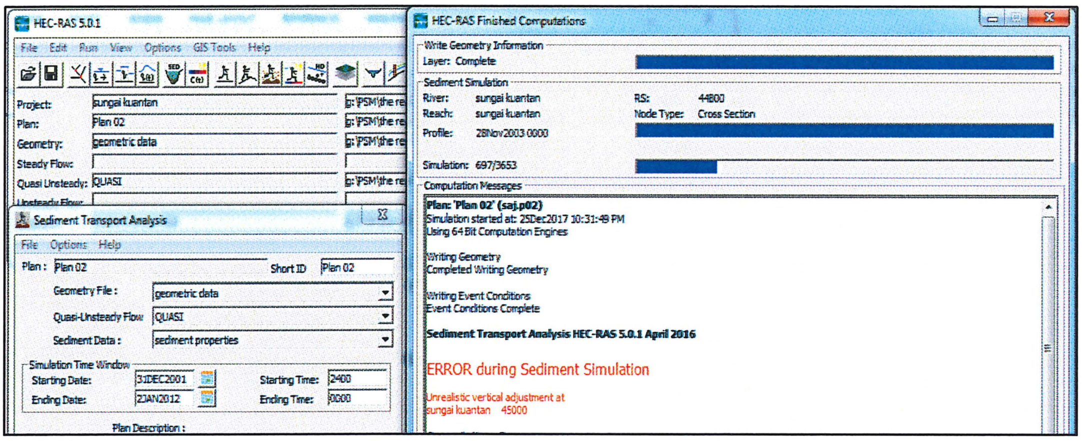

Figure 4.6: Computation result by Meyer-Peter Muller

Figure 4.7 and 4.8 illustrate the deposition suddenly happen after erosion at cross section of 4600 m from the downstream

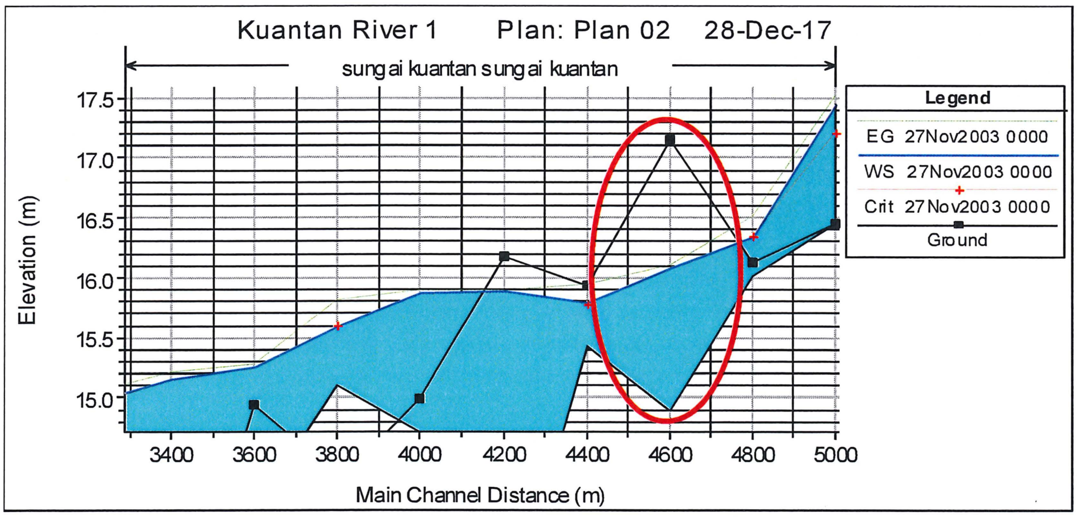

Figure 4.7: Location of erosion in 27 Nov 2003 by Meyer-Peter Muller

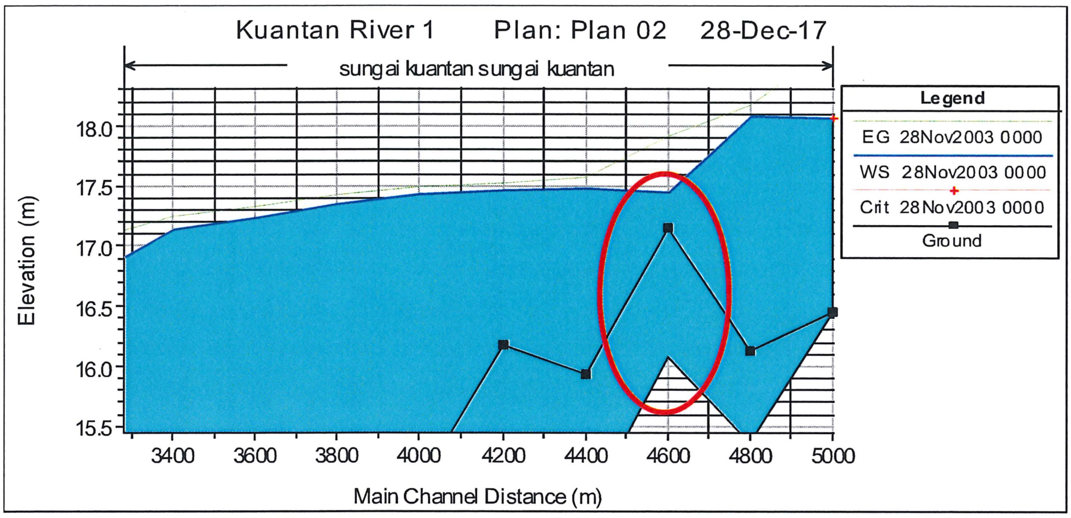

Figure 4.8: Location of deposition in 28 Nov 2003 by Meyer-Peter Muller

From the computation result, the Meyer-Peter Muller method cannot be used for sediment transport simulation of Sungai Kuantan. As a recommendation, in order to run this model without error, more cross section are required with less value of interval between the river cross section.

4.3.3 Computation Result by Yang's Method

Figure 4.9 shows when using Yang method in order to perform sediment transport simulation, the model cannot be run or error occur. The error occurred because of the unrealistic vertical adjustment at 4600 m from the downstream. Furthermore, this situation happen when the cross section suddenly subjected to erosion after deposition at this cross section.

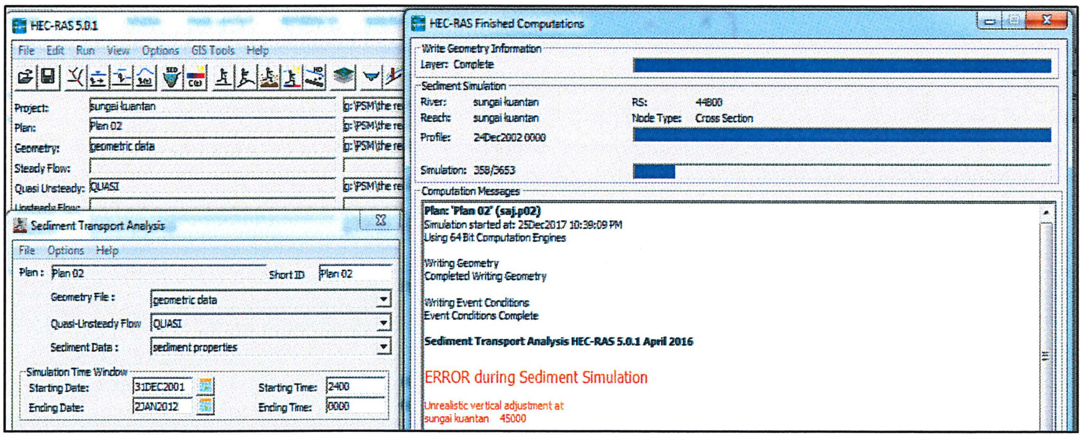

Figure 4.9: Run analysis Yang method

Figure 4.10 and 4.11 illustrate the erosion suddenly happen after deposition at cross section of 4600 m from the downstream

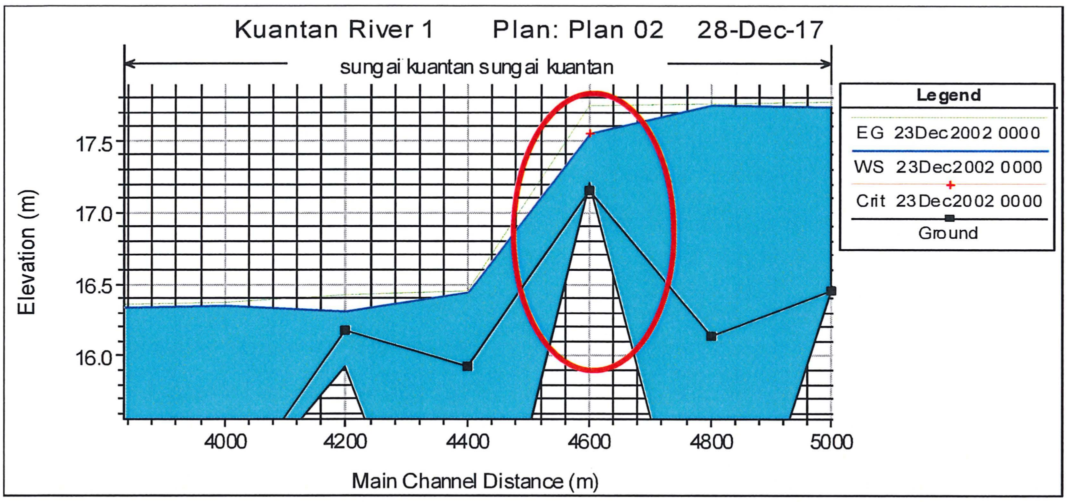

Figure 4.10: Location of deposition in 23 Dec 2002 by Yang

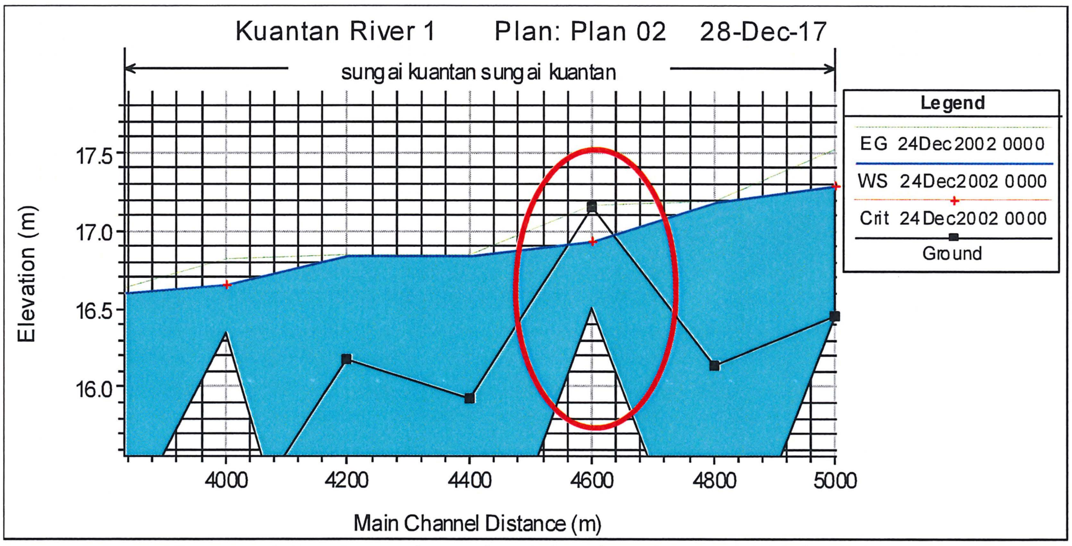

Figure 4.11: Location of erosion in 24 Dec 2002 by Yang

From the computation result, the Yang method cannot be used for sediment transport simulation of Sungai Kuantan. As a recommendation, in order to run this model without error, more cross section are required with less value of interval between the river cross section.

4.3.4 Computation Result by Laursen

Figure 4.12 shows when using Laursen method in order to perform sediment transport simulation, the model cannot be run or error occur. The error occurred because of the unrealistic vertical adjustment at 4600 m from the downstream. Furthermore, this situation happen when the cross section suddenly subjected to erosion after deposition at this cross section.

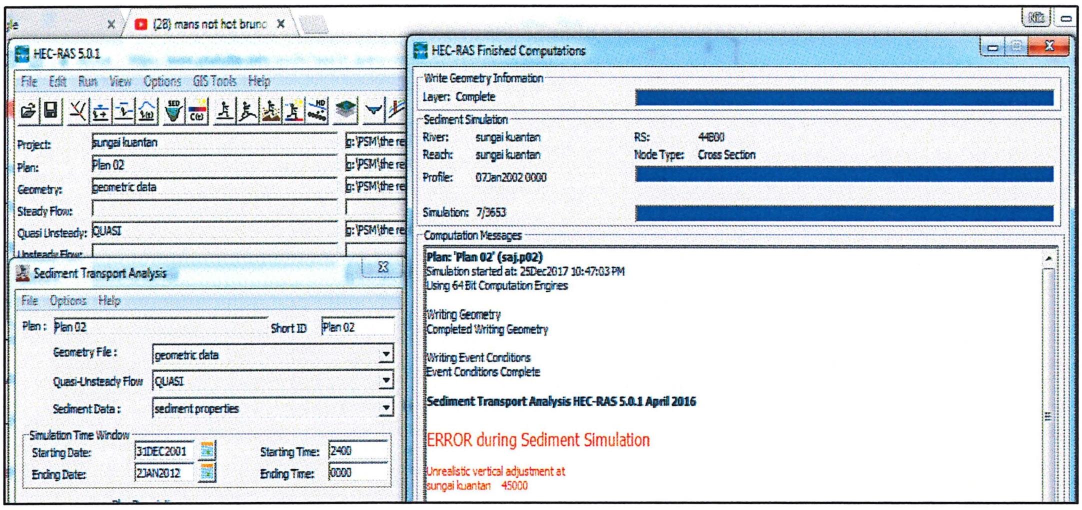

Figure 4.12: Run analysis Laursen method

Figure 4.13 and 4.14 illustrate the erosion suddenly happen after deposition at cross section of 4600 m from the downstream

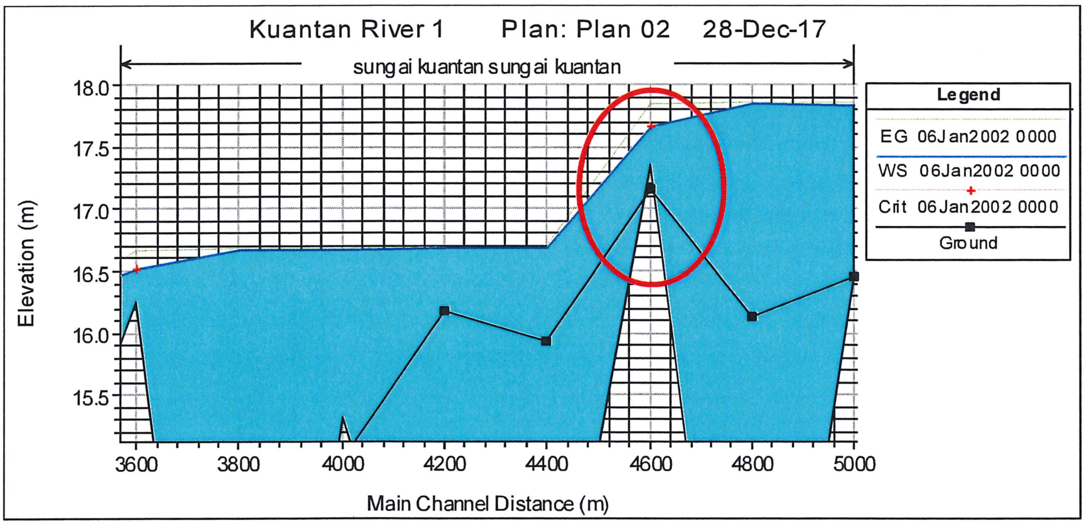

Figure 4.13: Location of deposition in 06 Jan 2002 by Laursen

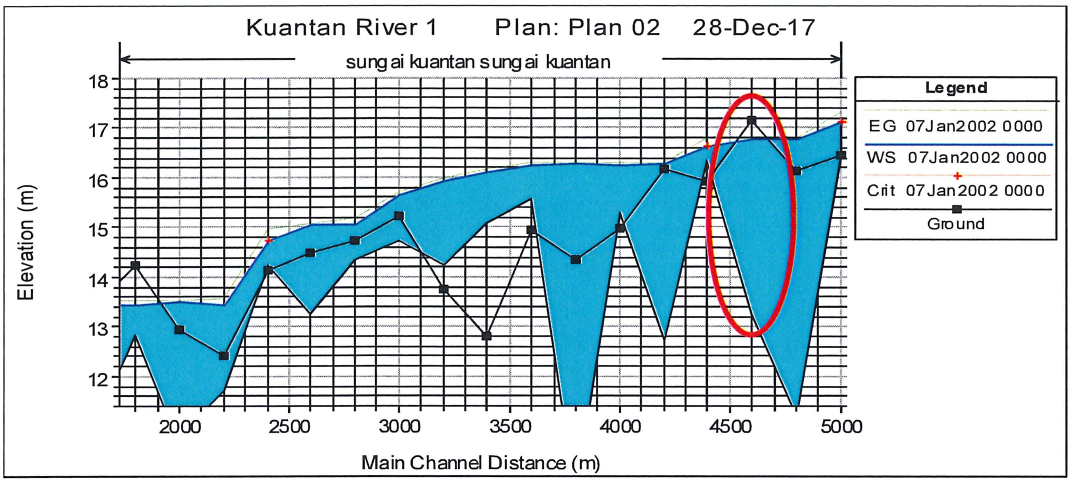

Figure 4.14: Location of erosion in 07 Jan 2002 by Laursen

From the computation result, the Laursen method cannot be used for sediment transport simulation of Sungai Kuantan. As a recommendation, in order to run this model without error, more cross section are required with less value of interval between the river cross section.

4.3.5 Computation Result by Tofaletti

Figure 4.15 it shows when using Tofaletti method in order to perform sediment transport simulation, the model is completely run the sediment transport simulation.

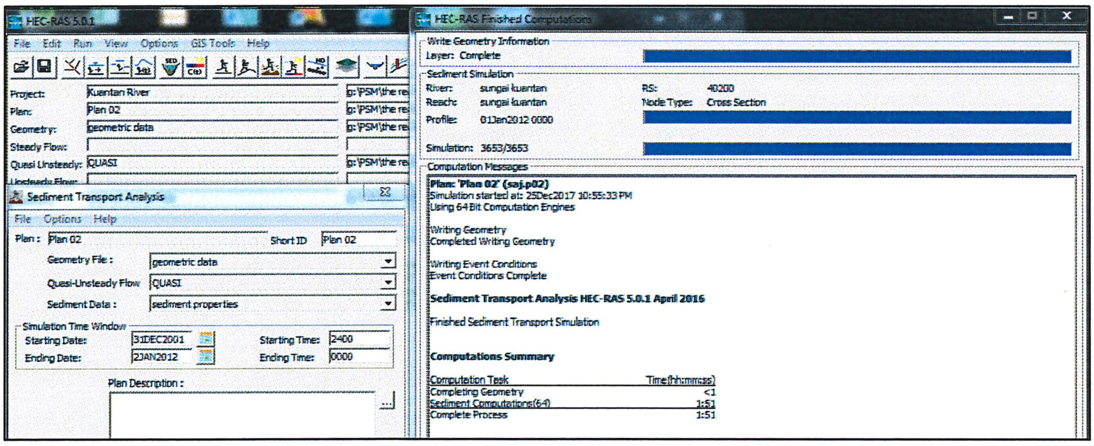

Figure 4.15: Run analysis Tofaletti method

From the computation result, Tofaletti method is selected for sediment transport simulation of Sungai Kuantan.

4.4 Sediment Transport Simulation of Sungai Kuantan for Various Year Analysis

4.4.1 One (1) Year Duration Analysis

The elevation of the riverbed changes from 13.44 m to 12.63 m at the cross section of 41200 (1000 m from downstream). Erosion occurs at the depth of 0.81 m. The elevation of riverbed changes from 12.94 m to 13.16 m at the cross section of 42200 (2000 m from downstream). Deposition occurs at the height of 0.22 m. The elevation of riverbed changes from 15.21 m to 14.95 m at the cross section of 43200 (3000 m from downstream). Erosion occurs at the depth of 0.22 m. The elevation of riverbed changes from 14.98 m to 14.88 m at the cross section of 44200 (4000 m from downstream). Deposition occurs at the height of 0.10 m. Figure 4.16 shows the riverbed changes for 1 year duration analysis. The maximum erosion occur at the depth of 1.18 m at cross section of 41400 (1200 m from downstream. Meanwhile the maximum deposition occur at the height of 1.86 m at cross section of 40800 (600 m from downstream).

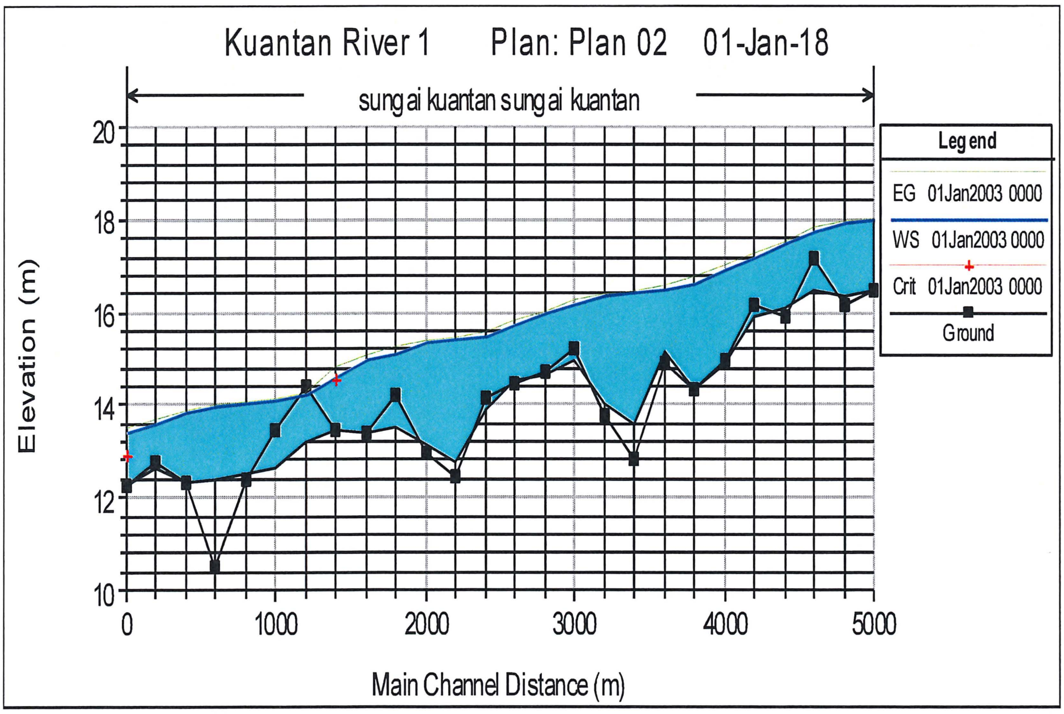

Figure 4.16: Water surface and riverbed profile for 1 year analysis by Tofaletti

4.4.2 Three (3) Year Duration Analysis

The elevation of the riverbed changes from 13.44 m to 12.76 m at the cross section of 41200 (1000 m from downstream). Erosion occurs at the depth of 0.68 m. The elevation of riverbed changes from 12.94 m to 13.29 m at the cross section of 42200 (2000 m from downstream). Deposition occurs at the height of 0.35 m. The elevation of riverbed changes from 15.21 m to 14.92 m at the cross section of 43200 (3000 m from downstream). Erosion occurs at the depth of 0.29 m. The elevation of riverbed changes from 14.98 m to 15.01 m at the cross section of 44200 (4000 m from downstream). Deposition occurs at the height of 0.03 m. Figure 4.17 shows the riverbed changes for 3 year duration analysis. The maximum erosion occur at the depth of 1.15 m at cross section of 41400 (1200 m from downstream. Meanwhile the maximum deposition occur at the height of 2.01 m at cross section of 40800 (600 m from downstream).

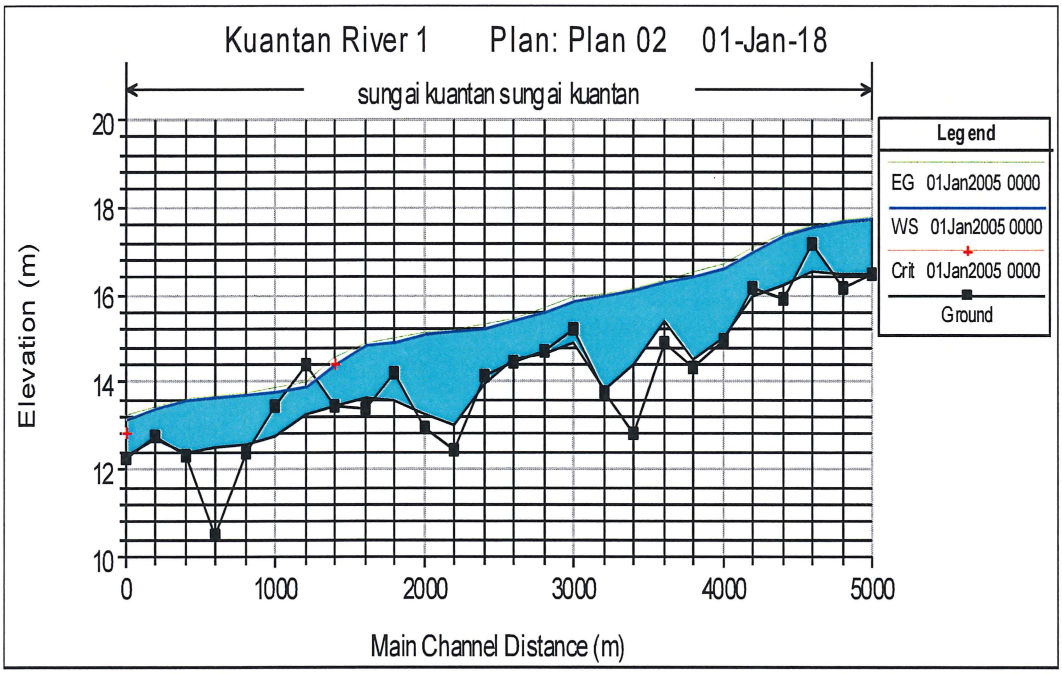

Figure 4.17: Water surface and riverbed profile for 3 year analysis by Tofaletti

4.4.3 Five (5) Year Duration Analysis

The elevation of the riverbed changes from 13.44 m to 12.87 m at the cross section of 41200 (1000 m from downstream). Erosion occurs at the depth of 0.57 m. The elevation of riverbed changes from 12.94 m to 13.52 m at the cross section of

42200 (2000 m from downstream). Deposition occurs at the height of 0.58 m. The elevation of riverbed changes from 15.21 m to 14.94 m at the cross section of 43200 (3000 m from downstream). Erosion occurs at the depth of 0.27 m. The elevation of riverbed changes from 14.98 m to 15.02 m at the cross section of 44200 (4000 m from downstream). Deposition occurs at the height of 0.04 m. Figure 4.18 shows the riverbed changes for 5 year duration analysis. The maximum erosion occur at the depth of 1.15 m at cross section of 41400 (1200 m from downstream. Meanwhile the maximum deposition occur at the height of 2.34 m at cross section of 40800 (600 m from downstream).

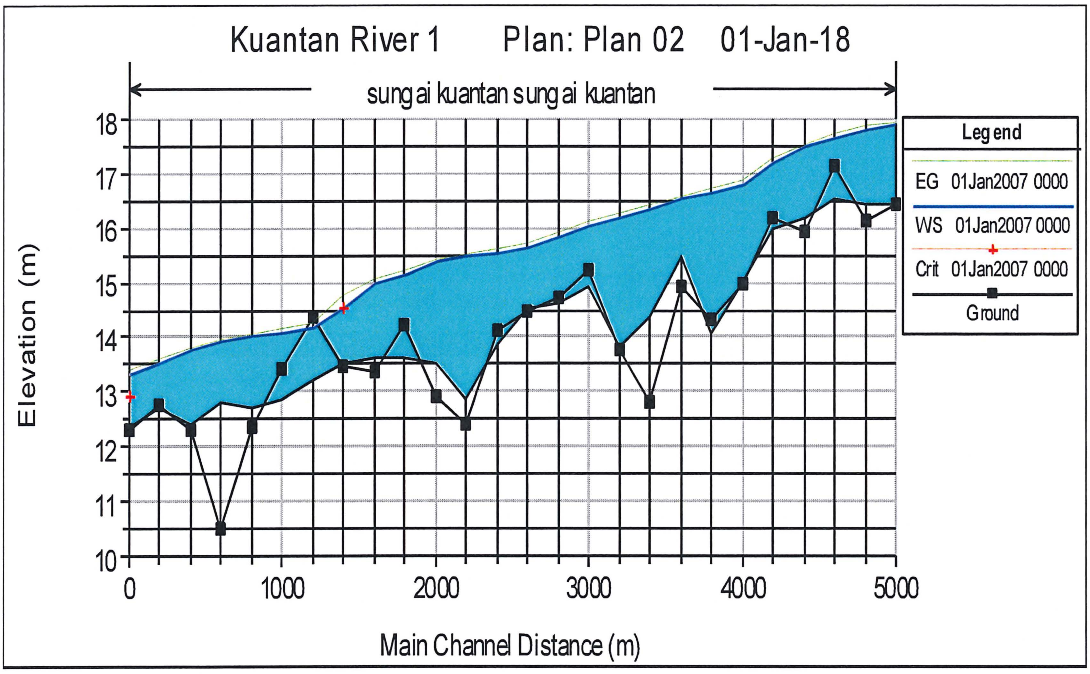

Figure 4.18: Water surface and riverbed profile for 5 year analysis by Tofaletti

4.4.4 Eight (8) Year Duration Analysis

The elevation of the riverbed changes from 13.44 m to 13.08 m at the cross section of 41200 (1000 m from downstream). Erosion occurs at the depth of 0.36 m. The elevation of riverbed changes from 12.94 m to 13.51 m at the cross section of 42200 (2000 m from downstream). Deposition occurs at the height of 0.57 m. The elevation of riverbed changes from 15.21 m to 15.06 m at the cross section of 43200 (3000 m from downstream). Erosion occurs at the depth of 0.15 m. The elevation of riverbed changes from 14.98 m to 14.89 m at the cross section of 44200 (4000 m from downstream). Erosion occurs at the depth of 0.09 m. Figure 4.19 shows the riverbed changes for 8 year duration analysis. The maximum erosion occur at the depth of 1.04 m at cross section of 41400 (1200 m from downstream. Meanwhile the maximum deposition occur at the height of 2.27 m at cross section of 40800 (600 m from downstream).

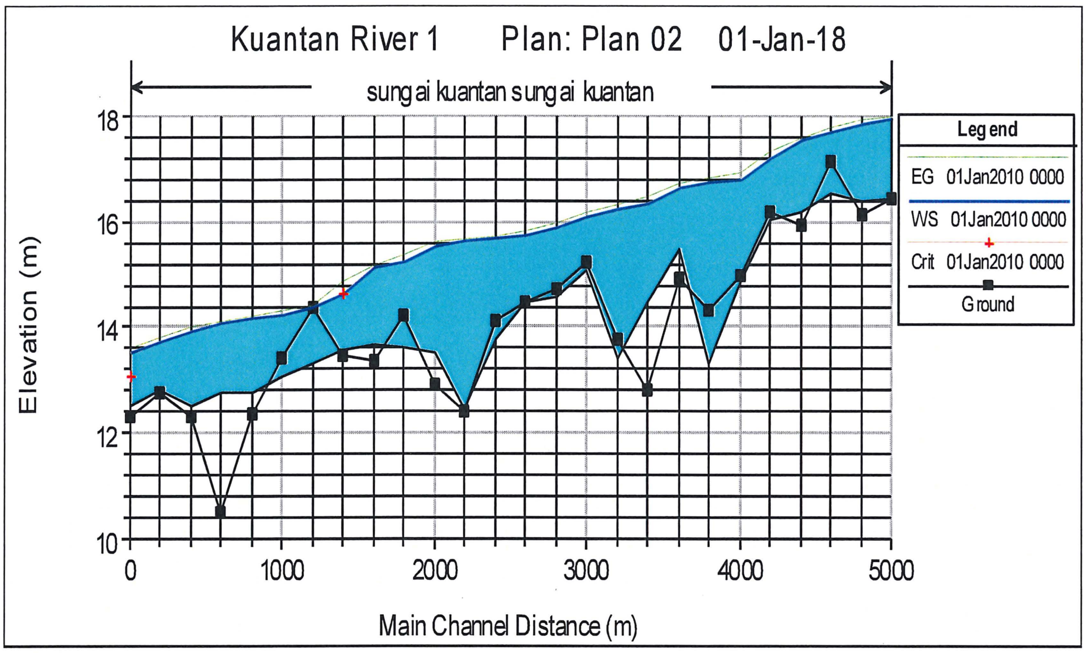

Figure 4.19: Water surface and riverbed profile for 8 year analysis by Tofaletti

4.4.5 Ten (10) Year Duration Analysis

The elevation of the riverbed changes from 13.44 m to 13.22 m at the cross section of 41200 (1000 m from downstream). Erosion occurs at the depth of 0.22 m. The elevation of riverbed changes from 12.94 m to 13.19 m at the cross section of 42200 (2000 m from downstream). Deposition occurs at the height of 0.25 m. The elevation of riverbed changes from 15.21 m to 14.25 m at the cross section of 43200 (3000 m from downstream). Erosion occurs at the depth of 0.96 m. The elevation of riverbed changes from 14.98 m to 14.97 m at the cross section of 44200 (4000 m from downstream). Erosion occurs at the depth of 0.01 m. Figure 4.20 shows the riverbed changes for 8 year duration analysis. The maximum erosion occur at the depth of 1.47 m at cross section of 44200 (4000 m from downstream. Meanwhile the maximum deposition occur at the height of 2.39 m at cross section of 40800 (600 m from downstream).

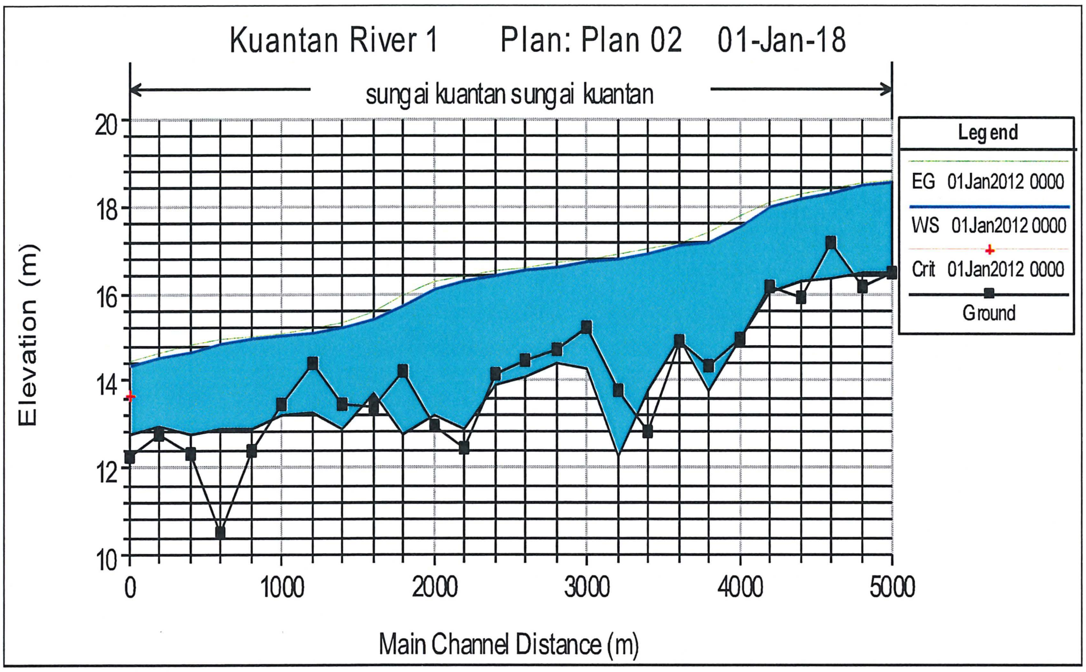

Figure 4.20: Water surface and riverbed profile for 10 year analysis by Tofaletti

4.5 Comparison of Riverbed Profile for Before and After Simulation between Various Years of Analysis

After the sediment transport simulation were completely compute, the difference between riverbed profiles can be determine. Besides, the value of erosion and/or deposition at every cross section can be determined. Section 4.5.1 until 4.5.2 shows the detail of difference between riverbed profile for before and after simulation for every year duration analysis, and the value of erosion and/or deposition at every cross section.

4.5.1 One (1) Year Analysis

After one (1) year analysis of simulation, the riverbed profile for before and after simulation can be determined. Besides, the value and location of erosion and deposition can be determined. Table 4.1 shows the comparison between riverbed for before after simulation, and the value of erosion or deposition for every 200 m of cross section.

Table 4.1: Comparison between riverbed profiles for one (1) year analysis

Distance from downstream (m)	Riverbed before simulation (m)	Riverbed after simulation (m)	Erosion depth (m)	Deposition height (m)
5000	16.45	16.45	0	
4800	16.13	16.38		0.25
4600	17.16	16.49	0.67	
4400	15.93	16.09		0.16
4200	16.17	15.9	0.27	
4000	14.98	14.88	0.1	
3800	14.33	14.33	0	
3600	14.94	15.17		0.23
3400	12.82	13.59		0.77
3200	13.76	14.03		0.27
3000	15.21	14.95	0.26	
2800	14.72	14.64	0.08	
2600	14.48	14.5		0.02
2400	14.12	13.88	0.24	
2200	12.42	12.75		0.33
2000	12.94	13.16		0.22
1800	14.24	13.53	0.71	
1600	13.39	13.39	0	
1400	13.45	13.45	0	
1200	14.39	13.21	1.18	
1000	13.44	12.63	0.81	
800	12.37	12.54		0.17
600	10.50	12.36		1.86
400	12.34	12.33	0.01	
200	12.78	12.67	0.11	
0	12.29	12.28	0.01	

4.5.2 Three (3) Year Analysis

After three (3) year analysis of simulation, the riverbed profile for before and after simulation can be determined. Besides, the value and location of erosion and deposition can be determined. Table 4.2 shows the comparison between riverbed for before after simulation, and the value of erosion or deposition for every 200 m of cross section.

Table 4.2: Comparison between riverbed profiles for three (3) year analysis

Distance from downstream (m)	Riverbed before simulation (m)	Riverbed after simulation (m)	Erosion depth (m)	Deposition height (m)
5000	16.45	16.45	0	
4800	16.13	16.46		0.33
4600	17.16	16.51	0.65	
4400	15.93	16.23		0.3
4200	16.17	15.96	0.21	
4000	14.98	15.01		0.03
3800	14.33	14.51		0.18
3600	14.94	15.38		0.44
3400	12.82	14.39		1.57
3200	13.76	13.85		0.09
3000	15.21	14.92	0.29	
2800	14.72	14.66	0.06	
2600	14.48	14.51		0.03
2400	14.12	13.95	0.17	
2200	12.42	13		0.58
2000	12.94	13.29		0.35
1800	14.24	13.58	0.66	
1600	13.39	13.62		0.23
1400	13.45	13.47		0.02
1200	14.39	13.24	1.15	
1000	13.44	12.76	0.68	
800	12.37	12.61		0.24
600	10.50	12.51		2.01
400	12.34	12.38		0.04
200	12.78	12.68	0.1	
0	12.29	12.33		0.04

4.5.3 Five (5) Year Analysis

After five (5) year analysis of simulation, the riverbed profile for before and after simulation can be determined. Besides, the value and location of erosion and deposition can be determined. Table 4.3 shows the comparison between riverbed for before after simulation, and the value of erosion or deposition for every 200 m of cross section.

Table 4.3: Comparison between riverbed profiles for five (5) year analysis

Distance from downstream (m)	Riverbed before simulation (m)	Riverbed after simulation (m)	Erosion depth (m)	Deposition height (m)
5000	16.45	16.45	0	
4800	16.13	16.45		0.32
4600	17.16	16.52	0.64	
4400	15.93	16.21		0.28
4200	16.17	15.98	0.19	
4000	14.98	15.02		0.04
3800	14.33	14.06	0.27	
3600	14.94	15.5		0.56
3400	12.82	14.36		1.54
3200	13.76	13.82		0.06
3000	15.21	14.94	0.27	
2800	14.72	14.64	0.08	
2600	14.48	14.53		0.05
2400	14.12	13.89	0.23	
2200	12.42	12.89		0.47
2000	12.94	13.52		0.58
1800	14.24	13.6	0.64	
1600	13.39	13.63		0.24
1400	13.45	13.5		0.05
1200	14.39	13.24	1.15	
1000	13.44	12.87	0.57	
800	12.37	12.72		0.35
600	10.50	12.84		2.34
400	12.34	12.43		0.09
200	12.78	12.73	0.05	
0	12.29	12.36		0.07

4.5.4 Eight (8) Year Analysis

After eight (8) year analysis of simulation, the riverbed profile for before and after simulation can be determined. Besides, the value and location of erosion and deposition can be determined. Table 4.4 shows the comparison between riverbed for before after simulation, and the value of erosion or deposition for every 200 m of cross section.

Table 4.4: Comparison between riverbed profiles for eight (8) year analysis

Distance from downstream (m)	Riverbed before simulation (m)	Riverbed after simulation (m)	Erosion depth (m)	Deposition height (m)
5000	16.45	16.45	0	
4800	16.13	16.4		0.27
4600	17.16	16.54	0.62	
4400	15.93	16.18		0.25
4200	16.17	16.02	0.15	
4000	14.98	14.89	0.09	
3800	14.33	13.3	1.03	
3600	14.94	15.49		0.55
3400	12.82	14.46		1.64
3200	13.76	13.44	0.32	
3000	15.21	15.06	0.15	
2800	14.72	14.57	0.15	
2600	14.48	14.47	0.01	
2400	14.12	13.76	0.36	
2200	12.42	12.48		0.06
2000	12.94	13.51		0.57
1800	14.24	13.64	0.6	
1600	13.39	13.65		0.26
1400	13.45	13.57		0.12
1200	14.39	13.35	1.04	
1000	13.44	13.08	0.36	
800	12.37	12.75		0.38
600	10.50	12.77		2.27
400	12.34	12.54		0.2
200	12.78	12.84		0.06
0	12.29	12.51		0.22

4.5.5 Ten (10) Year Analysis

After ten (10) year analysis of simulation, the riverbed profile for before and after simulation can be determined. Besides, the value and location of erosion and deposition can be determined. Table 4.5 shows the comparison between riverbed for before after simulation, and the value of erosion or deposition for every 200 m of cross section.

Table 4.5: Comparison between riverbed profiles for ten (10) year analysis

Distance from downstream (m)	Riverbed before simulation (m)	Riverbed after simulation (m)	Erosion depth (m)	Deposition height (m)
5000	16.45	16.45	0	
4800	16.13	16.47		0.34
4600	17.16	16.38	0.78	
4400	15.93	16.27		0.34
4200	16.17	16.07	0.1	
4000	14.98	14.97	0.01	
3800	14.33	13.79	0.54	
3600	14.94	14.94	0	
3400	12.82	13.74		0.92
3200	13.76	12.29	1.47	
3000	15.21	14.25	0.96	
2800	14.72	14.39	0.33	
2600	14.48	14.08	0.4	
2400	14.12	13.88	0.24	
2200	12.42	12.87		0.45
2000	12.94	13.19		0.25
1800	14.24	12.78	1.46	
1600	13.39	13.71		0.32
1400	13.45	12.9	0.55	
1200	14.39	13.27	1.12	
1000	13.44	13.22	0.22	
800	12.37	12.92		0.55
600	10.50	12.89		2.39
400	12.34	12.79		0.45
200	12.78	12.94		0.16
0	12.29	12.8		0.51

4.6 Proposed Suitable Location for Mining Activity at Study Area

In order to determine the suitable location for mining activities, the location of deposition and erosion need to be identified. It is stated in River Sand Mining Guideline by DID Malaysia that the suitable location for mining activities is the location that is subjected to the deposition. As a conclusion after ten year analysis of sediment transport simulation, the location of deposition (suitable for mining activities) can be forecast. Figure 4.21 shows the location of deposition occurred.

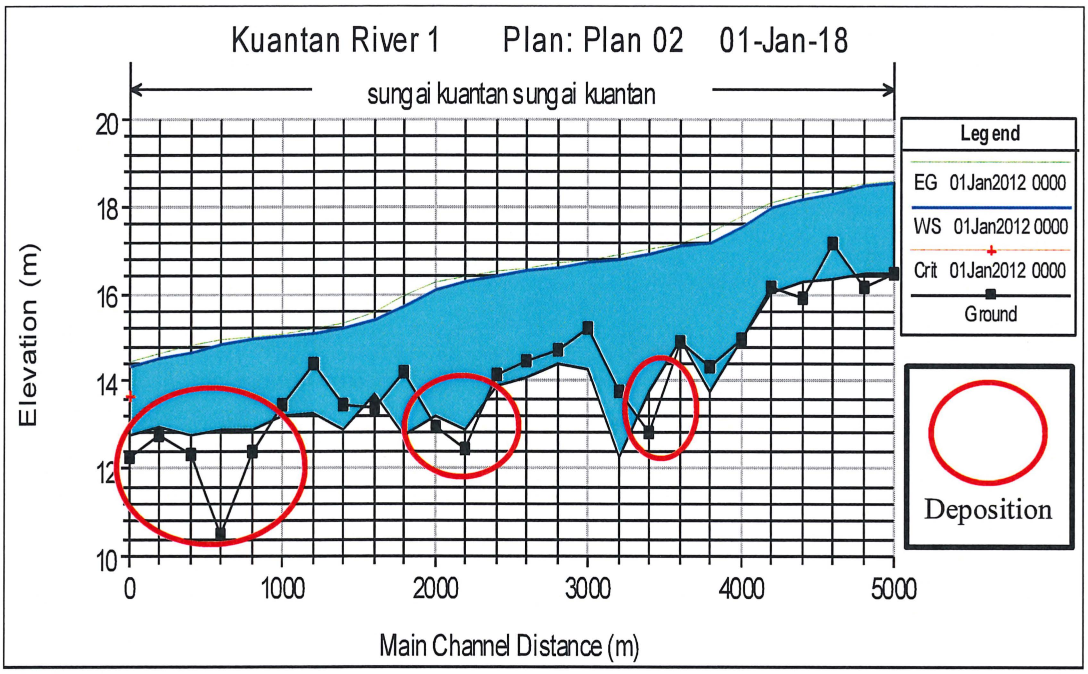

Figure 4.21: Water surface and riverbed profile after ten (10) year analysis

From figure 4.21, it shows the location of deposition are around 0 m until 800 m from the downstream, 2000 m and 2200 m from the downstream, and 3400 m from the downstream. Figure 4.22 below shows the location in google earth for the location of deposition occurred.

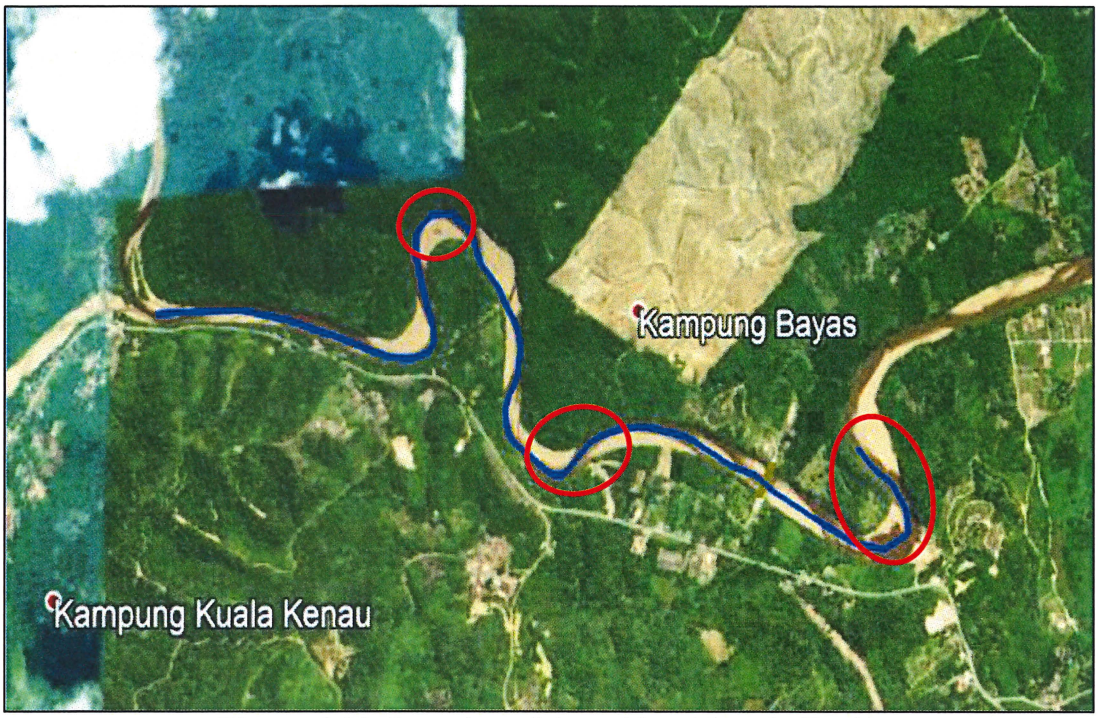

Figure 4.22: Location of deposition (Google Earth)

The deposition occurs at those location because of the limitation of energy to transport the sediment. Energy losses occur due to water that are flowing in the river meet the cornering part of the river. This situation may reduce the flow energy and also the velocity of the river, and may cause deposition of sediment to occur. More energy losses, more deposition may occur.

The location with the red mark shows the location where the deposition occur. After ten (10) year analysis (Figure 4.21), the maximum deposition is occurs at the height of 2.39 m which is at cross section of 40800 (600 m from the downstream). As a conclusion, the suitable location for mining activities is at 600 from the downstream since this location has high value of replenishment volume (maximum deposition) to balance the riverbed after mining. Figure 4.23 shows the location for mining activities which is where the maximum deposition occur.

Figure 4.23: Location for mining (Google Earth)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, the objectives of this study were accomplished through the stimulation and analysis the pattern of sediment transport around Sungai Kuantan at Bukit Kenau station, Pahang. The sediment transport pattern can be predicted and analyse using several method in HEC-RAS software. From the run analysis, it shows not all the method can run the model which means the right method need to be determine in order to perform sediment transport simulation. The error may occurs since all the sediment transport function has their own assumption. This can be look in Table 2.3 (Chapter 2, 2.2.6) e.g. Meyer Peter Muller transport function only valid for Flume data and not valid for fine material which is less than 5 mm. It is shows that in Chapter 4, that the suitable method to use in sediment transport modelling for Sungai Kuantan is Tofaletti method. Moreover, erosion and deposition of riverbed profile can be evaluated from the sediment analysis. Flow condition is depending on historical data of year 2001 until 2012.

From the analysis and simulation, the location of erosion and deposition occurred can be predicted for by using the suitable method. After ten (10) year analysis, the maximum erosion occurs at the depth of 1.47 m which is at cross section of 44200 (4000 m from the downstream). Meanwhile the maximum deposition occurs at the height of 2.39 m which is at cross section of 40800 (600 m from the downstream).

Besides, the simulation and analysis of sediment transport can give very high impact on in-stream mining activities. The in-stream mining can be manage properly after the model of sediment transport are produced. From the model produced, the right location (subjected to deposition) for in-stream mining activities can be predicted so that the environment and stability of the stream channel will not disturb.

Based on the results and discussion in Chapter 4, the location for mining activities is at cross section of 40800 (600 m from the downstream), as shown in Figure 4.23. Since this location has highest deposition which is at the height of 2.39 m.

5.2 Recommendation

In forthcoming, it is recommended that, more study should carry out in sedimentation as the key to understand the fundamental sedimentation process and principles comprehend. The damages create by sediment are wide-ranging depend on the amount of sediment is influenced by the process of erosion, transport and deposition. Significant knowledge is desirable comparative to the different aspects of erosion, transport and deposition of sediment before accurate foresights of causes and effects can be determined.

Furthermore, the warning occur during simulate the sediment transport simulation since the distance between two (2) cross section are really far, e.g. 200m. Hence, it is really recommended to construct the river model with less value of interval between the cross section to prevent the warning occur.

Lastly, The sediment transport simulation should be carry out for all river in Malaysia in managing the stability of the river structures, environmental problem, and the flood can be managed properly.

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