MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
DEPARTMENT OF IRRIGATION AND DRAINAGE MALAYSIA

RIVER SAND MINING MANAGEMENT GUIDELINE

MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
DEPARTMENT OF IRRIGATION AND DRAINAGE
MALAYSIA

RIVER SAND MINING MANAGEMENT GUIDELINE

September 2009

Published by
Department of Irrigation and Drainage (DID)
Jalan Sultan Salahuddin
50626 Kuala Lumpur, MALAYSIA

Consultant
USAINS HOLDING SDN BHD
River Engineering and Urban Drainage Research Centre (REDAC)
Engineering Campus , Universiti Sains Malaysia
Seri Ampangan, 14300 Nibong Tebal, Pulau Pinang, Malaysia

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data
A catalogue record of this book is available from the Perpustakaan Negara Malaysia

RIVER SAND MINING MANAGEMENT GUIDELINE

ISBN 978-983-41867-2-2

RIVER SAND MINING MANAGEMENT GUIDELINE

TABLE OF CONTENTS

Page

FOREWORD **v**

ACKNOWLEDGEMENT **vii**

1.0 INTRODUCTION **1**

1.1 Objectives of the Guideline 1
1.2 Background 1
1.3 Sand and Gravel Mining Policy and Guidelines 2
1.4 Sand and Gravel Mining Management 5
  1.4.1 In-Stream Mining 5
  1.4.2 Off-Channel Mining 6
  1.4.3 Appropriate Extraction Methods and Monitoring Plan 7
1.5 Processing Applications at State Level 7

2.0 SEDIMENT TRANSPORT AND IMPACTS OF SAND MINING **9**

2.1 Sediment Transport in Rivers 9
2.2 Impact of Sand Mining 15
  2.2.1 River Morphology 15
  2.2.2 Aquatic and Riparian Habitat 20
2.3 HEC-RAS Modelling 20
2.4 Stable Channel Analysis 20

3.0 MANAGEMENT PLAN **25**

3.1 Long-Term Management Guidelines 25
  3.1.1 In-Stream Mining Recommendations 25
  3.1.2 Off-Channel or Floodplain Extraction Recommendations 27
  3.1.3 Reclamation Plans 29
3.2 Appropriate Extraction Methods 36
3.3 Appropriate Extraction Sites 44

RIVER SAND MINING MANAGEMENT GUIDELINE

TABLE OF CONTENTS

Page

4.0 MONITORING PLAN **45**

4.1 Sand Replenishment, Geomorphology and Hydrology 45
  4.1.1 Cross-sections 45
  4.1.2 Longitudinal Profile 46
  4.1.3 Geomorphic Maps 47
  4.1.4 Photodocumentation 47
  4.1.5 Hydrology and Sediment Transport 47
  4.1.6 Groundwater Level 47
4.2 Riparian Habitat 47
  4.2.1 Extent and Quality of Riparian Vegetation 47
  4.2.2 Riparian Vegetation Maps 47

REFERENCES 49

APPENDICES

Appendix A – Volume Extraction Determination
Appendix B – General Description of River Modelling Using HEC-RAS
Appendix C – Stable Channel Determination

FOREWORD

In recent years, rapid development has led to an increased demand for river sand as a source of construction material. This has resulted in a mushrooming of river sand mining activities which have given rise to various problems that require urgent action by the authorities. These include river bank erosion, river bed degradation, river buffer zone encroachment and deterioration of river water quality. Very often, over-mining occurs which jeopardises the health of the river and the environment in general.

There is a need for the Department of Irrigation and Drainage (DID) to be equipped with the necessary planning and management tools to deal with the problems that arise from river sand mining and the preparation of this guideline is an effort in this direction. This guideline consists of four chapters providing criteria for both in-stream and off-channel extraction of sand. The background on the theory of sediment transport in rivers, an important topic in determination of sand replenishment rate, is also included together with a discussion of the impacts of river sand mining. Recommendations for long-term management of sand extraction are also provided. Emphasis is also given to the setting up of monitoring plans that will provide data on profile changes and sediment transport capacity to enable the authorities to evaluate the long-term effect of the mining activities both upstream and downstream of sand extraction sites.

This guideline will enable DID engineers and sand-mining operators to acquire a good understanding of the theory of sediment transport process that determines the sand replenishment rate and hence the volume of sand that can be extracted from the reach of the river channel. The application of annual replenishment concept is key to ensuring long-term river channel stability as well the health of the aquatic and riparian habitats by allowing only a sustainable volume of sand based on the natural sediment transport process to be extracted.

I wish to record my appreciation to all parties who were involved in preparing this guideline and I am confident that their contributions in producing a scientific and systematic approach to effectively manage and control river sand mining will be appreciated by the users for many years to come.

Dato' Ir. Hj. Ahmad Husaini bin Sulaiman,

Director General,

Department of Irrigation and Drainage Malaysia

ACKNOWLEDGEMENT

Steering Committee:

Dato’ Ir. Hj. Ahmad Husaini bin Sulaiman, Dato’ Nordin bin Hamdan, Dato’ Ir. K. J. Abraham, Dato’ Ong Siew Heng, En. Mohd Abdul Nassir bin Bidin, Ir. Zainor Rahim bin Ibrahim, Kapt. Ir. Anuar bin Yahya, Ir. Hj Hanapi bin Mohamad Noor, Dato' Ir. Abdul Razak bin Dahalan, Ir. Hj. Baharuddin bin Ahmad Nasir, Hj Abd. Qahar bin Osman

Coordination Committee:

Dato’ Ong Siew Heng, Dr. Mohamed Roseli Zainal Abidin, En. Tan Teow Soon, En. Mohd Said Dikon, En. Ahmad Darus, En. Ng Kim Hoy, Pn. Bibi Zarina Che Omar, Pn. Azaitulnora Shamsudin, En. Mohd Hazri Moh Khambali, En. Shahar Md. Salleh, En. Mohd Idrus Amir, Cik Lily Azyyati Johar, En. Ahmad Fauzan Mohd Sabri, En. Azman Mat Jusoh, En. Khairulnizam Md Yasin

Consultant:

Professor Dr. Nor Azazi Zakaria, Professor Dr. Aminuddin Ab. Ghani, Ir Alias Hashim, Hj. Zorkeflee Abu Hasan, En. Chang Chun Kiat, Dr. Lai Sai Hin, Dr. H Md Azamathulla

1.0 INTRODUCTION

1.1 Objectives of the Guideline

This guideline is intended for use by relevant authorities and updates the existing sand and gravel permitting policies or guidelines to achieve the following regulatory and management objectives:

- to ensure that sand and gravel extraction is carried out in a sustainable way
- to maintain the river equilibrium with the application of sediment transport principles in determining the locations, period and quantity to be extracted
- to apply river model such as HEC-RAS in identifying the suitable locations, period and quantity that can be extracted

1.2 Background

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 (Kondolf et al., 2001).

Collins et al. (1990) summarised the effects of sand and gravel mining as listed below:

a) Extraction of bed material in excess of replenishment by transport from upstream causes the bed to lower (degrade) upstream and downstream of the site of removal.
b) Bed degradation can undermine bridge supports, pipe lines or other structures.
c) Degradation may change the morphology of the river bed, which constitutes one aspect of the aquatic habitat.
d) Degradation can deplete the entire depth of gravelly bed material, exposing other substrates that may underlie the gravel, which could in turn affect the quality of aquatic habitat.
e) If a floodplain aquifer drains to the stream, groundwater levels can be lowered as a result of bed degradation.
f) Lowering of the water table can destroy riparian vegetation.
g) Flooding is reduced as bed elevations and flood heights decrease, reducing hazard for human occupancy of floodplains and the possibility of damage to engineering works.
h) The supply of overbank sediments to floodplains is reduced as flood heights decrease.

i) Rapid bed degradation may induce bank collapse and erosion by increasing the heights of banks.
j) In rivers in which sediments are accumulating on the bed (aggrading) in undisturbed condition, gravel extraction can slow or stop aggradation, thereby maintaining the channel's capacity to convey flood waters.
k) The reduction in size or height of bars can cause adjacent banks to erode more rapidly or to stabilise, depending on the amount of sand and gravel removed, the distribution of removal, and on the geometry of the particular bend.
l) Removal of gravel from bars may cause downstream bars to erode if they subsequently receive less bed material than is carried downstream from them by fluvial transport.

An introduction to the principles of sediment transport in rivers and the effects of sand and gravel extraction on river morphology and biodiversity is further discussed in Chapter 2 of this guideline.

1.3 Sand and Gravel Mining Policy and Guideline

The following policies should be taken into consideration before approving sand and gravel mining permits:-

a) Ensure conservation of the river equilibrium and its natural environment.
b) Avoid aggradation at the downstream reach especially those with hydraulic structures such as jetties, water intakes etc.
c) Ensure the rivers are protected from bank and bed erosion beyond its stable profile.
d) Avoid interfering the river maintenance work by Department of Irrigation and Drainage (DID) or other agencies.
e) No obstruction to the river flow and water transport.
f) Avoid pollution of river water leading to water quality deterioration.

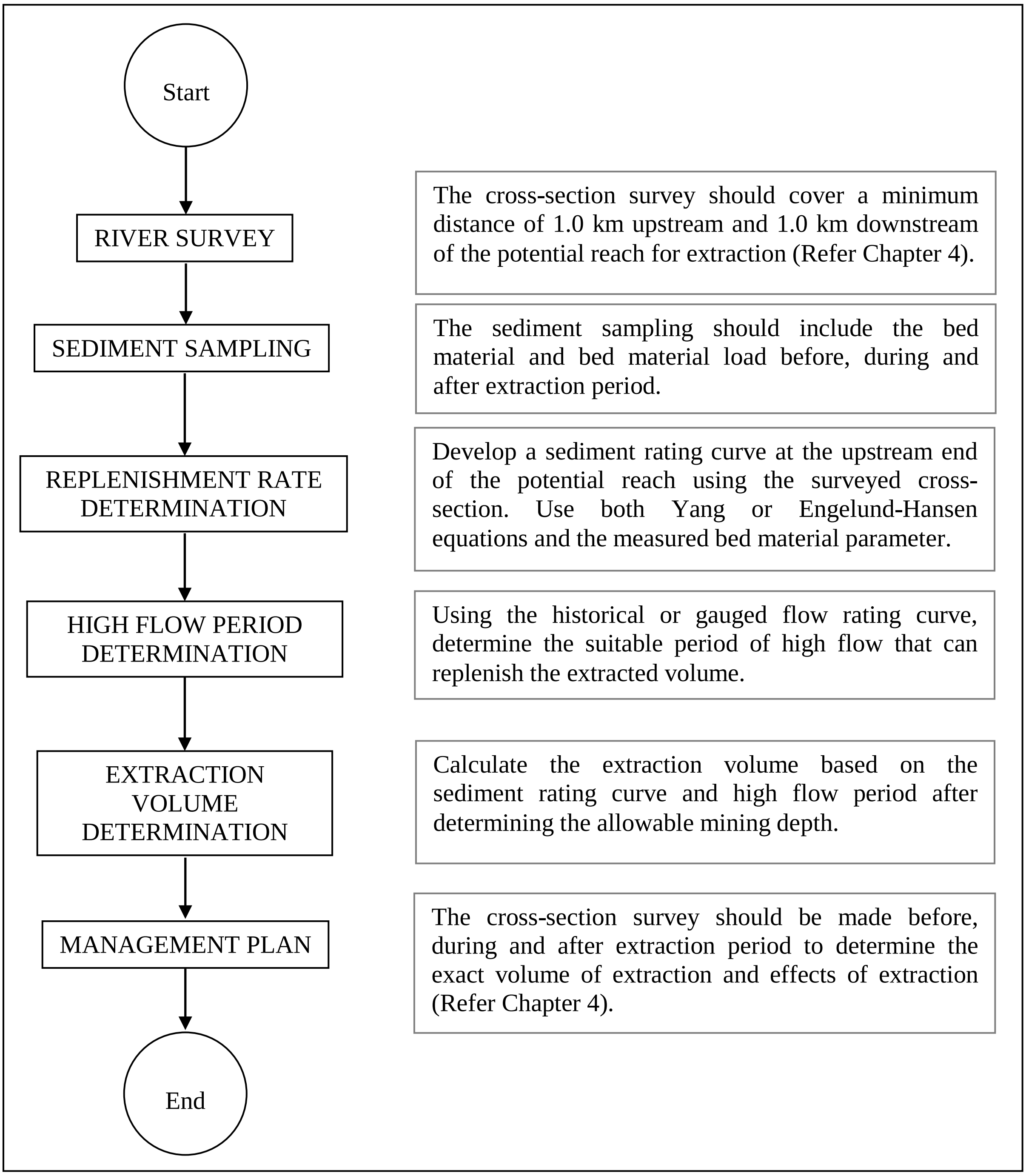
Figure 1.1 outline the process required in determining the locations, periods and quantity for sand and gravel mining. The general guidelines for sand and gravel mining are as follows:-

a) Parts of the river reaches that experience deposition or aggradation shall be identified first. Operators may be allowed to extract the sand and gravel deposit in these locations to lessen aggradation problem.
b) The distance between sites for sand and gravel mining shall depend on the replenishment rate of the river. Sediment rating curve for the potential sites shall be developed and checked against the extracted volumes of sand and gravel.
c) Sand and gravel may be extracted across the entire active channel (refer Figure 1.2) during the dry season (May to September).
d) Layers of sand and gravel which could be removed from the river bed shall depend on the width of the river and replenishment rate of the river (refer Figure 1.1).
e) Sand and gravel shall not be allowed to be extracted where erosion may occur, such as at the concave bank.
f) Sand and gravel shall not be extracted within 1,000 meter from any crucial hydraulic structure such as pumping station, water intakes, bridges, buildings and such structures.

g) Sand and gravel mining could be extracted from the downstream of the sand bar at river bends. Retaining the upstream one to two thirds of the bar and riparian vegetation is accepted as a method to promote channel stability.

h) Flood discharge capacity of the river could be maintained in areas where there are significant flood hazard to existing structures or infrastructure. Sand and gravel mining may be allowed to maintain the natural flow capacity based on surveyed cross-section history.

i) Alternatively, off-channel or floodplain extraction (see Figure 1.3) is recommended to allow rivers to replenish the quantity taken out during in-stream mining.



The cross-section survey should cover a minimum distance of 1.0 km upstream and 1.0 km downstream of the potential reach for extraction (Refer Chapter 4).

The sediment sampling should include the bed material and bed material load before, during and after extraction period.

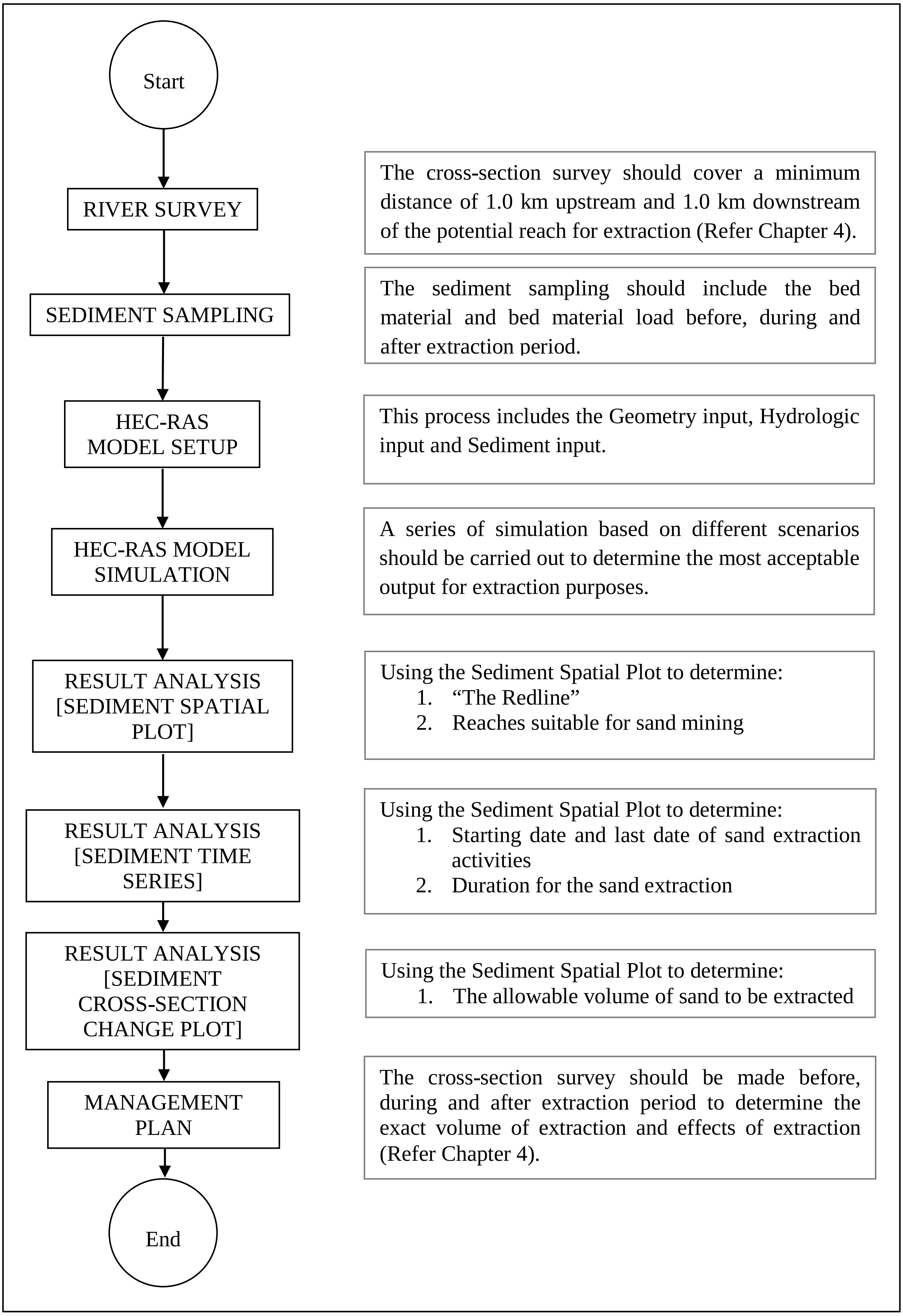
Develop a sediment rating curve at the upstream end of the potential reach using the surveyed cross-section. Use both Yang or Engelund-Hansen equations and the measured bed material parameter.

Using the historical or gauged flow rating curve, determine the suitable period of high flow that can replenish the extracted volume.

Calculate the extraction volume based on the sediment rating curve and high flow period after determining the allowable mining depth.

The cross-section survey should be made before, during and after extraction period to determine the exact volume of extraction and effects of extraction (Refer Chapter 4).

Figure 1.1(a): Volume Extraction Determination using Sediment Rating Curve (Refer Appendix A)



The cross-section survey should cover a minimum distance of 1.0 km upstream and 1.0 km downstream of the potential reach for extraction (Refer Chapter 4).

The sediment sampling should include the bed material and bed material load before, during and after extraction period.

This process includes the Geometry input, Hydrologic input and Sediment input.

A series of simulation based on different scenarios should be carried out to determine the most acceptable output for extraction purposes.

Using the Sediment Spatial Plot to determine:
1. “The Redline”
2. Reaches suitable for sand mining

Using the Sediment Spatial Plot to determine:
1. Starting date and last date of sand extraction activities
2. Duration for the sand extraction

Using the Sediment Spatial Plot to determine:
1. The allowable volume of sand to be extracted

The cross-section survey should be made before, during and after extraction period to determine the exact volume of extraction and effects of extraction (Refer Chapter 4).

Figure 1.1 (b): Volume Extraction Determination using HEC-RAS Modelling (Refer Appendix B)

1.4 Sand and Gravel Mining Management

Details of the criteria needed to ensure that sand and gravel extraction is carried out in a sustainable way are given in Chapter 3 of this guideline. A summary of recommendations for the management of sand and gravel mining is given herein.

1.4.1 In-Stream Mining

In-stream mining recommendations are based on the following concepts (see Section 3.1.1):

a) Permit mining volume based on measured annual replenishment;
b) Establish an absolute elevation below which no extraction may occur;
c) Limit in-stream mining methods to bar skimming;
d) Extract sand and gravel from the downstream portion of the bar;
e) Concentrate in-stream extraction activities to minimise area of disturbance;
f) Review cumulative effects of sand and gravel extraction;
g) Maintain river channel flood discharge capacity;
h) Establish a long-term monitoring program;
i) Minimise activities that release fine sediment to the river;
j) Retain riparian buffer at edge of water and against river bank;
k) Limit in-stream operation to the period between May and September and during dry season only;
l) An annual status and trends report should be produced by DID.

Setbacks and Mining Envelope Levels for In-Stream Mining

The excavation must be setback for distance a minimum of 10 m from the main channel bank toward the flow channel (Figure 1.2).

The stockpile must be located beyond 30 m to the left or right of the main channel bank (Figure 1.2).

The minimum depth of the excavation or redline must be at 1 m deposition above natural channel thalweg elevation (Figure 1.2), as determined by the survey approved by DID.

The maximum allowable mining depth is 1.5 m as shown in Figure 1.2.

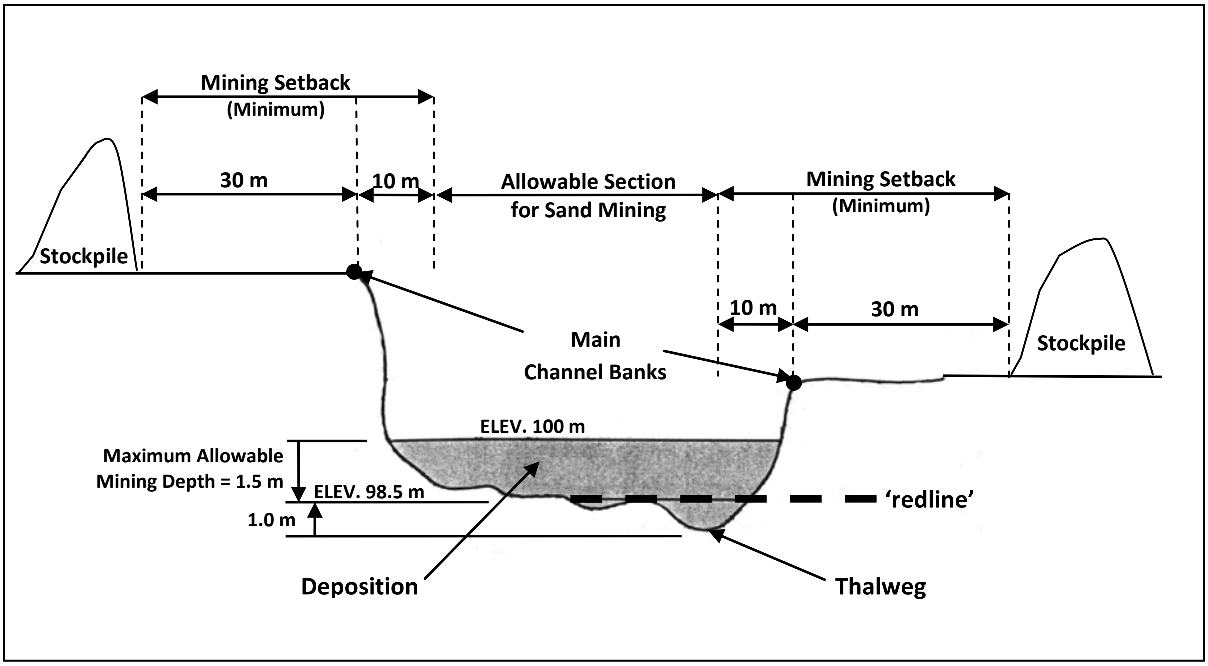


Figure 1.2: Setback, "redline" and Maximum Allowable Mining Depth for In-Stream Mining

1.4.2 Off-Channel Mining

Floodplain or terrace (off-channel) mining recommendations are based on the following concepts (see Section 3.1.2):

a) Floodplain extraction should be set back from the main channel;
b) The maximum depth of floodplain extraction should remain above the channel thalweg;
c) Side slopes of floodplain excavation should range from 3:1 to 10:1;
d) Place stockpiled topsoil above the 25-year return period or ARI level;
e) Floodplain pits should be restored to wetland habitat or reclaimed for agriculture;
f) A plan must be submitted that accounts for long-term liability;
g) Establish a long-term monitoring program;
h) An annual status and trends report should be produced by DID.

Setbacks and Excavation Depth for Floodplain Mining

The excavation must be setback a minimum of 50 m from the main channel bank (Figure 1.3).

The maximum depth of excavation is determined by a 10:1 line drawn from the elevation of the toe of the main channel bank, as shown in Figure 1.3.

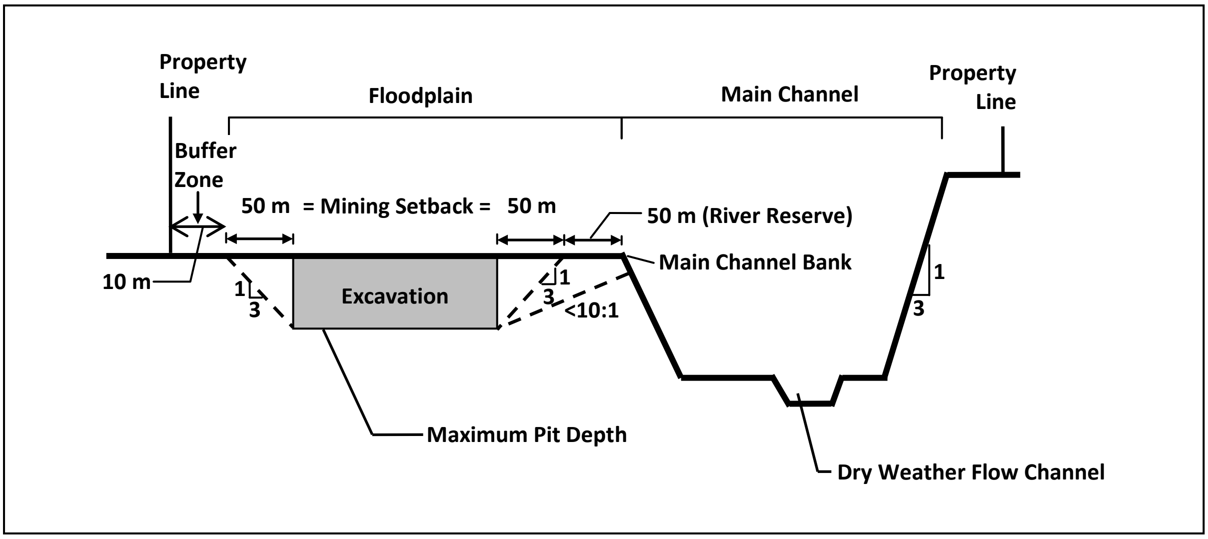


Figure 1.3: Floodplain Excavation Pit Geometry for Streamlined Floodplain Use Permit

1.4.3 Appropriate Extraction Methods and Monitoring Plan

A review of several methods of sand mining operations is given in Section 3.2. A monitoring plan to evaluate the upstream and downstream effects of extraction activities and long-term changes is given in Chapter 4.

1.5 Processing Applications at State Level

A complementary guideline for processing application may be attached depending on requirement of each state.

2.0 SEDIMENT TRANSPORT AND IMPACTS OF SAND MINING

2.1 Sediment Transport in Rivers

The loose boundary (consisting of movable material) of an alluvial channel deforms under the action of flowing water and the deformed bed with its changing roughness (bed forms) interacts with the flow. A dynamic equilibrium state of the boundary may be expected when a steady and uniform flow has developed (Nalluri & Featherstone, 2001).

The resulting movement of the bed material (sediment) in the direction of flow is called sediment transport and a critical bed shear stress (τ_c) must be exceeded to start the particle movement. Such a critical shear stress is referred as incipient (threshold) motion condition, below which the particles will be at rest and the flow is similar to that on a rigid boundary.

Shield (see Yang, 1996) introduced the concept of the dimensionless entrainment function, F_{rd}^2 (= τ_o/ $\rho g \Delta d$) as a function of shear Reynolds number, R_{e*} (= $U_* d/\nu$) where is ρ density of the fluid and Δ is the relative density of sediment in the fluid, d the diameter of sediment, g the acceleration due to gravity, U_* is the shear velocity ($\sqrt{\tau_o/\rho}$) and ν the kinematic viscosity of the fluid, and published a curve defining the threshold or incipient motion condition (Figure 2.1).

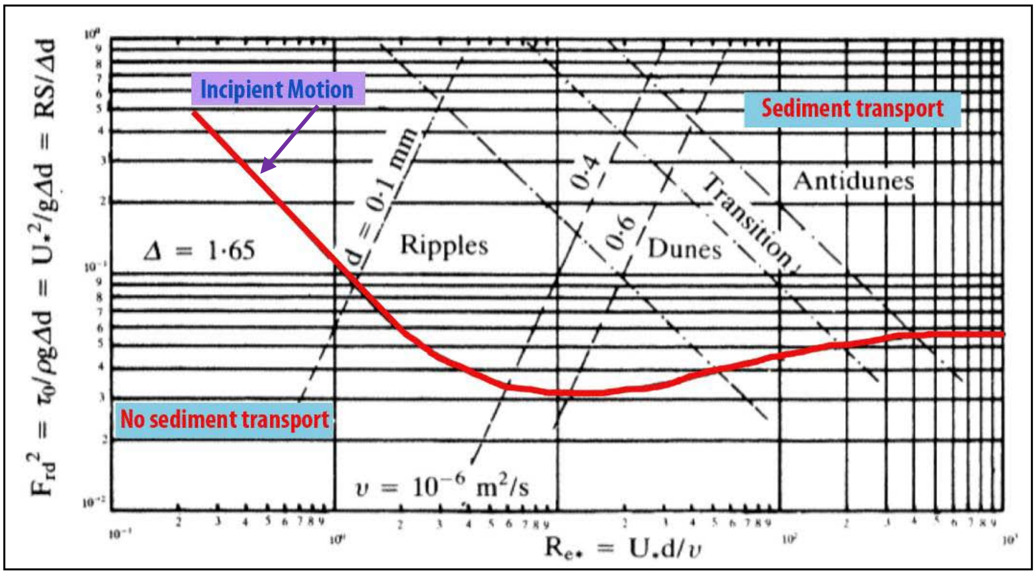


Figure 2.1: Shields Diagram (Nalluri and Featherstone, 2001)

When flow characteristics (velocity, average shear stress etc.) in an alluvial channel exceed the threshold condition for the bed material (Figure 2.2) the particles move in different modes along the flow direction. The mode of transport of the material depends on the sediment characteristics such as its size and shape, density ρ_s and movability parameter U_*/W_s where W_s is the fall velocity of the sediment particle. Figure 2.3 may be used to establish fall velocities of sediment particles of different shape factors.

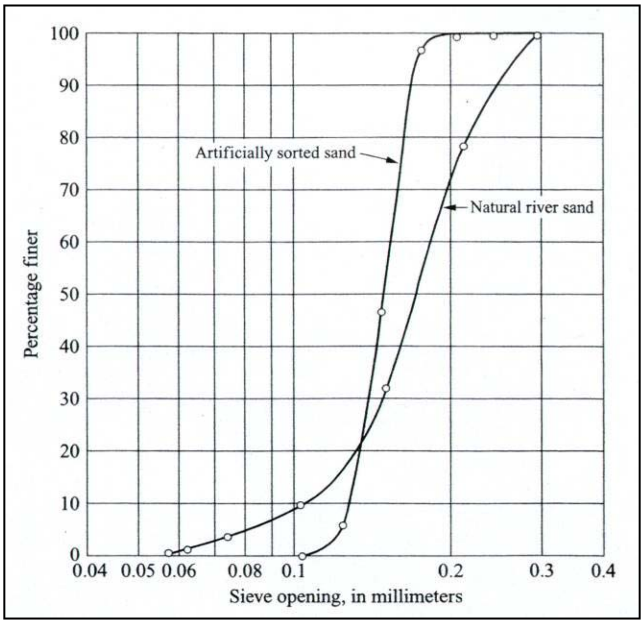


Figure 2.2: Cumulative Semi Logarithmic Size-frequency Graphs for Two Sands (Vanoni, 2006)

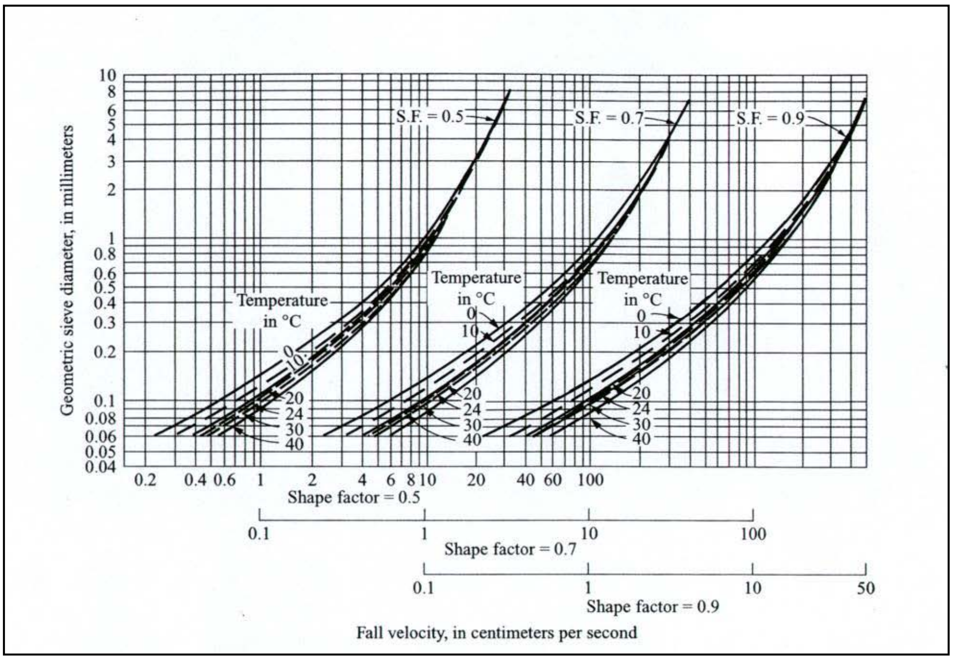


Figure 2.3: Fall Velocities of Sediment Particles (Vanoni, 2006)

Some sediment particles roll or slide along the bed intermittently and some others saltate (hopping or bouncing along the bed). The material transported in one or both of these modes is called ‘bed load’. Finer particles (with low fall velocities) are entrained in suspension by the fluid turbulence and transported along the channel in suspension. This mode of transport is called ‘suspended load’. Sometimes finer particles from upland catchment (sizes which are not present in the bed material), called ‘wash load’, are also transported in suspension. The combined bed material and wash load is called ‘total load’. A summary of mode of sediment transport is given in Figure 2.4 (Nalluri & Featherstone, 2001).

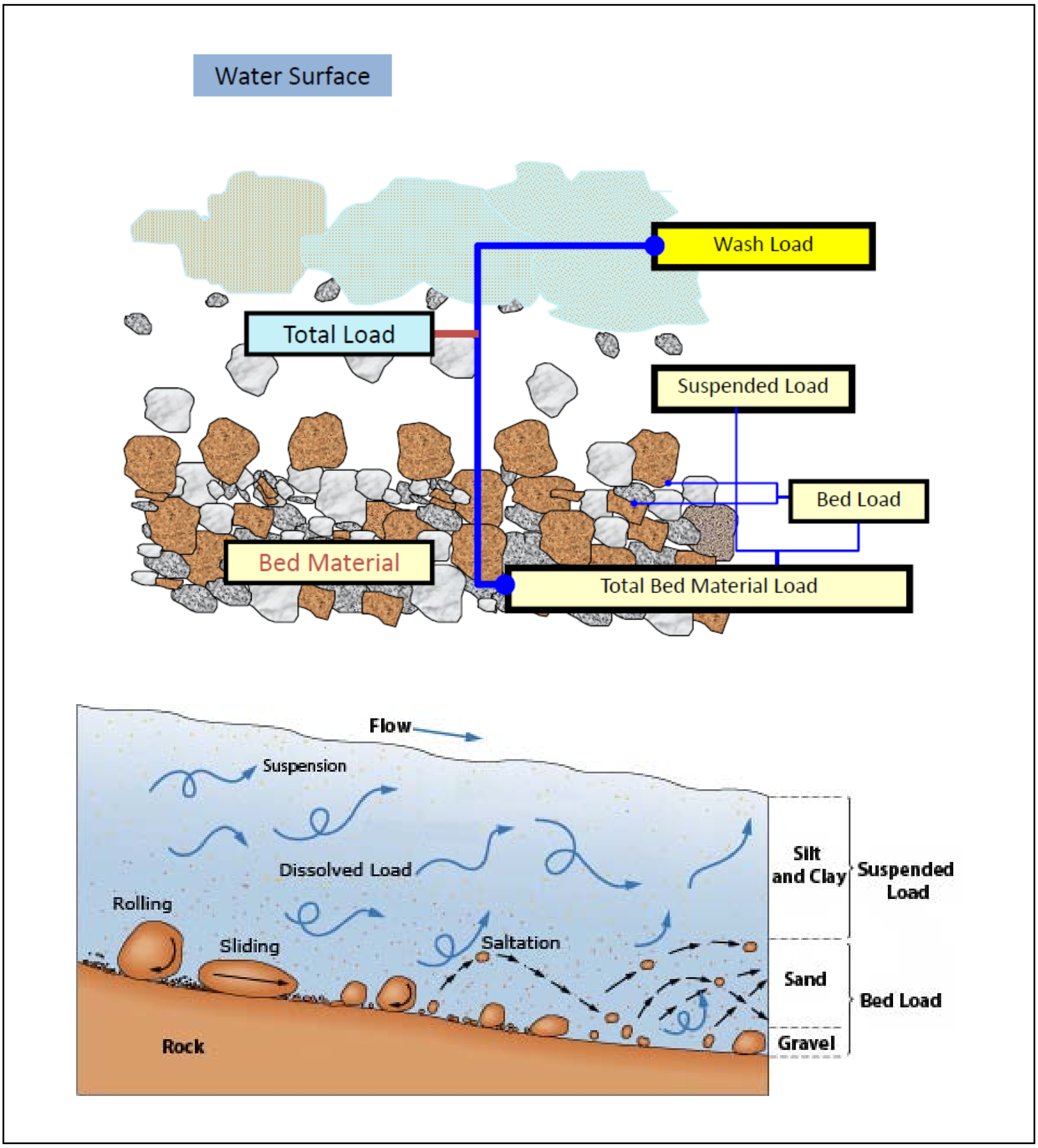


Figure 2.4: Modes of Sediment Transport in Rivers

Bed load ranges from a few percent of total load in lowland rivers to perhaps 15% in mountain rivers to over 60% in some arid catchments. Although a relatively small part of the total sediment load, the arrangement of bed load sediment constitutes the architecture of sand- and gravel-bed channels. The rate of sediment transport typically increases as a power function of flow; that is, a doubling of flow typically produces more than a doubling in sediment transport and most sediment transport occurs during floods (Kondolf, 1997).

Two existing sediment transport equations have been identified to be suitable for use in the prediction of the replenishment rate of rivers in Malaysia i.e. Yang and Engelund-Hansen equations:

Yang (1973)

Yang (1972) related the bed material load to the rate of energy dissipation of the flow as an agent for sediment transport. The theory of minimum rate of energy dissipation states that when a dynamic system reaches its equilibrium condition, its rate of energy dissipation is at a minimum. The minimum value depends on the constraints applied to the system. For a uniform flow of energy dissipation due to the sediment transport can be neglected. Yang equation for sand transport is:

$$\log C_T = 5.435 - 0.286\log\frac{W_S d_{50}}{\upsilon} - 0.457\log\frac{U_*}{W_S}$$

$$+\left\{\left(1.799 - 0.409\log\frac{W_S d_{50}}{\upsilon} - 0.314\log\frac{U_*}{W_S}\right)\times\log\left(\frac{VS_O}{W_S} - \frac{V_C S_O}{W_S}\right)\right\} \tag{2.1}$$

where

$$C_v(ppm) = \frac{C_t(ppm)}{S_S}$$

Critical velocity, V_C is given by:

$$\frac{V_C}{W_S} = \frac{2.5}{\log\frac{U_*}{V} - 0.06} + 0.06$$

$$for\ R_{e*} = \frac{U_* d_{50}}{V} = 1.2 \text{ to } 70$$

$$\frac{V_{cr}}{W_S} = 2.05 \qquad for\ R_{e*} \geq 70$$

C_t - Total sand concentration (ppm by weight)

W_S - Terminal fall velocity (m/s)

d_{50} - Average particle diameter of granular material (m)

υ - Kinematic viscosity (m^2/s)

U_* - Shear velocity (m/s)

VS - Unit stream power (m-kg/kg)/s)

$V_C S$ - Critical unit stream power required at incipient motion ((m-kg/kg)/s)

C_v - Sediment concentration by volume (ppm by volume)

Engelund-Hansen (1967)

Engelund-Hansen (1967) applied Bagnold's stream power concept and the similarity principle to obtain a sediment transport equation as below.

$$\phi = \frac{0.1}{f}(\psi)^{5/2} \tag{2.2}$$

$$f = \frac{2gRS_o}{V^2} \tag{2.3}$$

$$\phi = q_s\left[\rho_s\left(\frac{\rho_s - \rho}{\rho}\right)gd^3\right]^{-1/2} \tag{2.4}$$

$$\psi = \frac{\tau}{(\rho_s - \rho)d} \tag{2.5}$$

Substituting Equations 2.3 to 2.5 into 2.2,

$$q_s = 0.05\rho_s V^2\left[\frac{d_{50}}{g(S_s - 1)}\right]^{1/2}\left[\frac{\tau}{(\rho_s - \rho)d_{50}}\right]^{3/2} \tag{2.6}$$

$$Q_s = Bq_s$$

where

$$\tau = \rho gRS_o$$

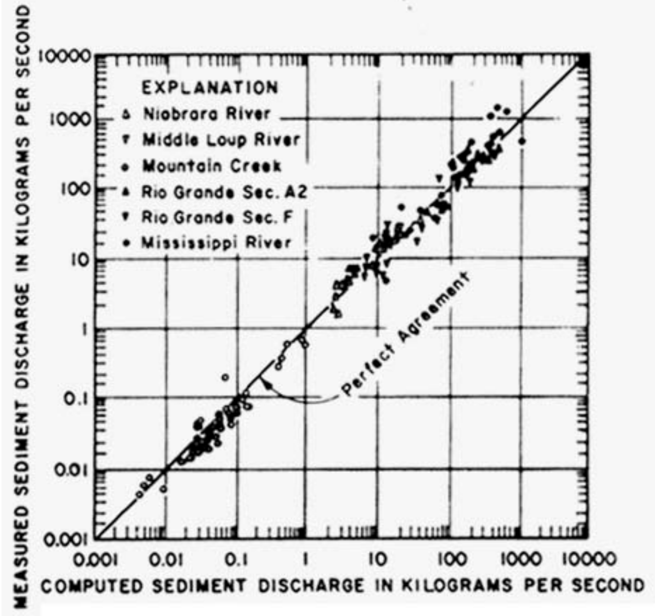
$$C_t = Q_s / G_w$$

$$G_w = \rho BRV$$

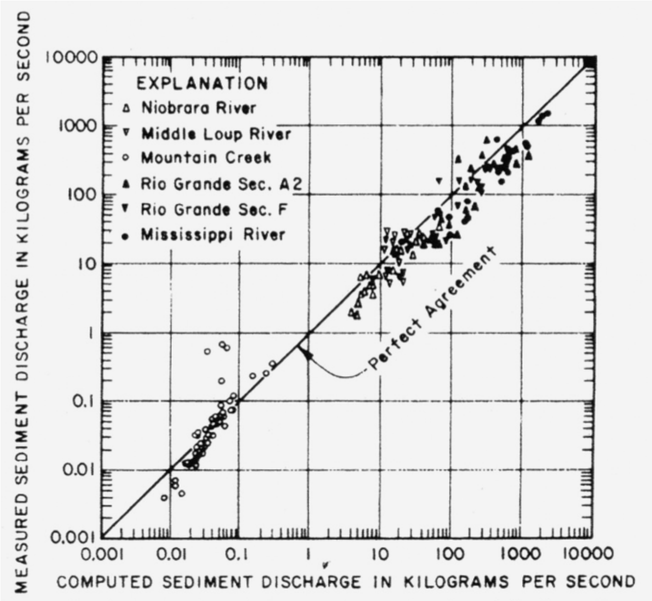
$$C_v(ppm) = \frac{C_t(ppm)}{S_S}$$

ϕ - Sediment transport parameter
ψ - Flow parameter
f - Sediment coefficient
g - Gravitational acceleration (m/s^2)
R - Hydraulic Radius (m)
q_s - Total sediment discharge by weight per unit width ((kg/s)/m)
Q_s - Total sediment discharge (kg/s)
V - Flow velocity (m/s)
G_w - Water discharge by weight (kg/s)
S_O - Slope of flow
τ - Shear stress along the bed (kg/m^2)
ρ - Density of water (kg/m^3)
ρ_S - Density of sediment (kg/m^3)
C_t - Sediment concentration by weight (ppm by weight)
C_v - Sediment concentration by volume (ppm by volume)

A comparison between measured total bed material loads from six river stations and the computed results using Yang and Engelund-Hansen Equation is shown in Figure 2.5.



(a) Yang equation



b) Engelund-Hansen equation

Figure 2.5: Assessment of Yang and Engelund-Hansen Equations using Data from Six River Stations (Yang & Molinas, 1982)

Examples of calculations using these two equations are given in Appendix A. More information on sediment transport theory and existing equations can be found in textbooks or manual such as Chang (1988), Yang (1996), Julien (2002) and Vanoni (2006). Examples of sediment rating curves computed using several existing sediment transport equations are shown in Figure 2.6.

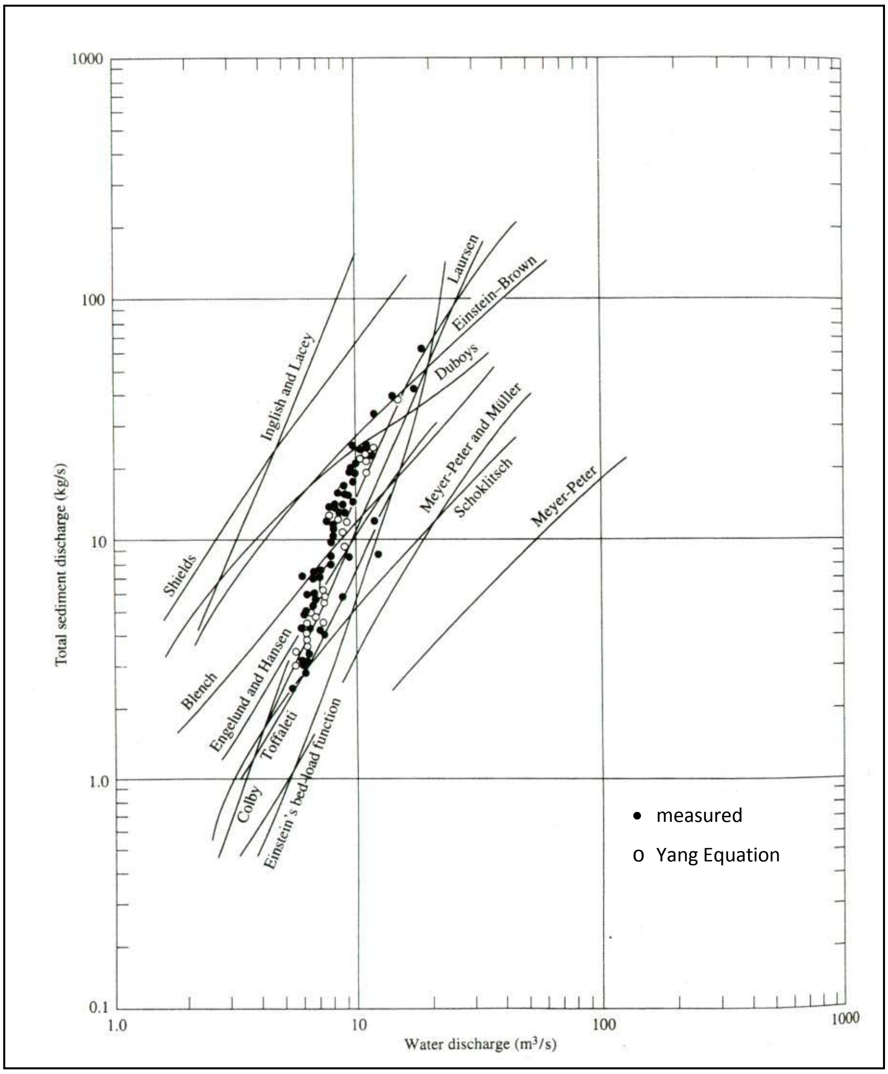


Figure 2.6: Sediment Rating Curve using Various Sediment Transport Equations (Yang, 1996)

2.2 Impacts of Sand Mining

2.2.1 River Morphology

There are a number of engineering techniques that can be employed to reduce the environmental impacts (Figures 2.7 to 2.10) from excavation of sand and gravel from stream channels, floodplains, and terraces. The specific techniques employed should be designed within the parameters of the natural hydrologic system (Langer, 2003).

One of the principal causes of environmental impacts from in-stream mining is the removal of more sediment than the system can replenish. Coarse material transported by a river (bed load) commonly is moved by rolling, sliding, or bouncing along the channel bed. Some researchers believe that environmental impacts from in-stream mining can be avoided if the annual bed load is calculated and aggregate extraction is restricted to that value or some portion of it. To accurately limit extraction to some portion of bed load, the amount of sediment that passes the in-stream mining site during a given period of time must be calculated. There is a large amount of uncertainty in the process of calculating annual rates of bed load transport (National Research Council, 1983). How much coarse material is moved, how long it remains in motion and how far it moves depends on the size, shape, and packing of the material and the flow characteristics of the river. Downstream movement commonly occurs as irregular bursts of short-distance movement separated by longer periods when the particles remain at rest. Because bed load changes from hour to hour, day to day, and year to year, estimating annual bed load rates is a dynamic process involving careful examination.

Figure 2.7: Extensive Modification to Stream Channel Caused by Gravel Extraction (Langer, 2003)

The problem can be addressed empirically by observing channel changes that result from various rates of gravel extraction. Channel changes can be determined from a series of aerial photographs, or from ground-based surveys. This technique may be an acceptable approach, even if the bed load calculations are bypassed.

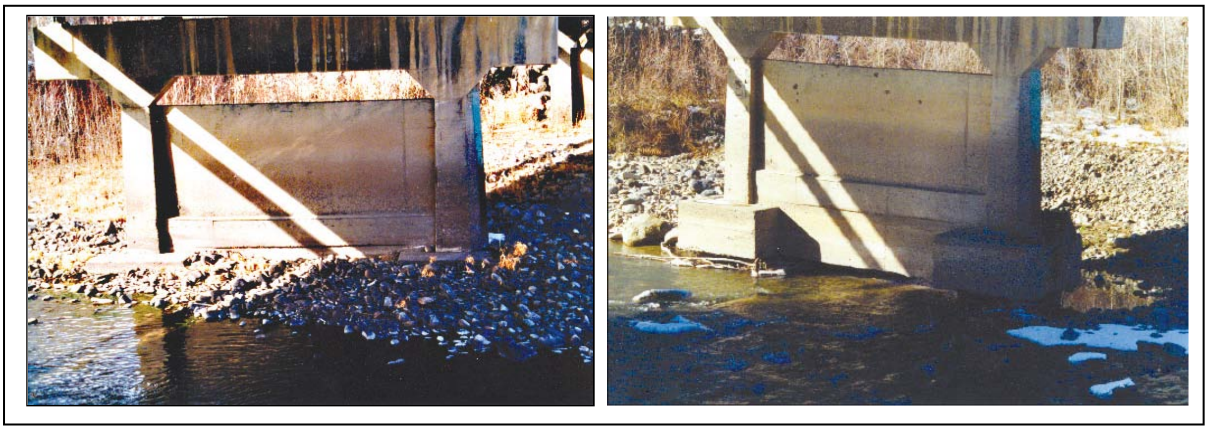


Figure 2.8: The left photograph shows a bridge abutment in 1992. The right photograph shows the same abutment during 1995. The bridge scour (erosion of river beds at bridge foundations) is due in part to in-stream mining and in part to channelisation of the river (Langer, 2003)

Figure 2.9: The left photograph, taken during 1988, is located about 8 kilometers upstream from a 32-kilometer stretch of river heavily impacted by illegal sand extraction. The right photograph, taken at the same location about 5 years later demonstrates the effects of headcutting (Langer, 2003)

Some sections of a stream are more conducive to aggregate extraction than others. Most stream erosion takes place during high-flow events. Constant variations in the flow of the river make the channel floor and riverbanks a dynamic interface where some materials are being eroded while others are being deposited. The net balance of this activity, on a short-term basis, is referred to as scour or fill. On a long-term basis, continued scour results in erosion (degradation), while continued fill results in deposition (aggradation). Removal of gravel from some aggrading sections of a river may be preferable to removing it from eroding sections. A general indicator of the stability of a stream relates to the amount of vegetation present. Gravel bars that are vegetated, or where the gravel is tightly packed, generally indicate streams where the gravel supply is in balance. Streams with excessive gravel generally have gravel bars with little or no vegetation, and are surfaced with loosely packed gravel.

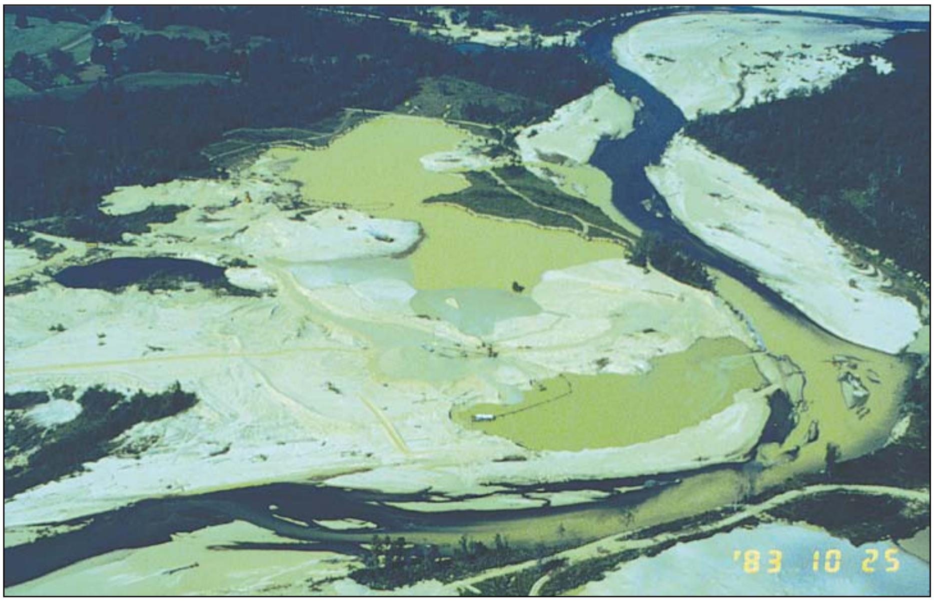


Figure 2.10: Dredging can Increase Turbidity of the Water in Rivers (Langer, 2003)

Even if a stream reach is eroding, aggregate mining may take place without causing environmental damage if the channel floor is, or becomes, armored by particles that are too large to be picked up by the moving water. For example, some sections of rivers underlain with large gravel layers deposited under higher flow rates than those prevailing at the current time may support gravel extraction with no serious environmental impacts. Jiongxin (1996) described such a situation on the *Hanjiang River* in China where downcutting stopped when coarse bed material was reached. A similar situation commonly occurs in modern stream valleys that are occupied by slow-flowing river, but were filled with sediment deposited thousands of years ago by torrential glacial melt water streams.

The impacts from stream avulsion and pit capture can be avoided by constructing a levee along the stream. The levee is designed with armored spillways that control where the levee will be “breached” by the stream during flooding. The spillway allows water to leave the channel and temporarily flow over the floodplain but keeps stream from creating a new channel and keeps the bed load in the stream.

There are some general relationships between environmental impacts, where the extraction site is located (Figure 2.11), whether or not the excavation penetrates the water table, how deep the excavation is, and the size and shape of the river or stream. These relationships can be used as a general guide for the design of in-stream and near-stream aggregate extraction. All other things being equal:

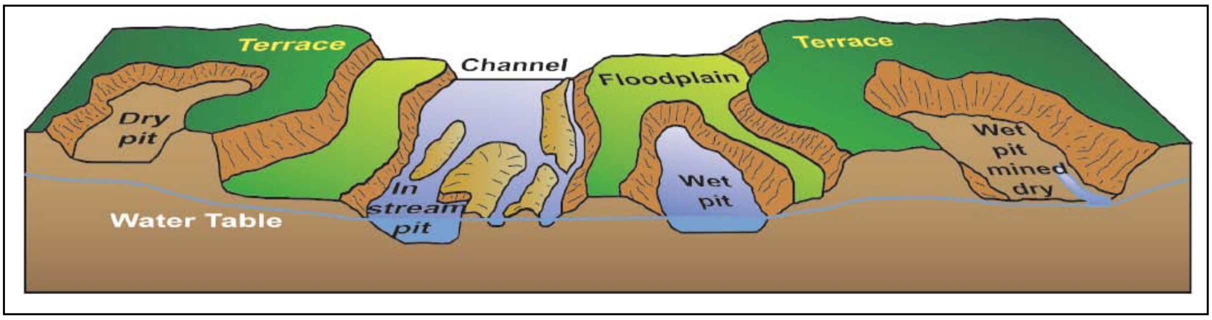


Figure 2.11: Aggregate extraction can take place in a number of in-stream or near-stream environments (Langer, 2003)

a) Extracting gravel from an excavation that does not penetrate the water table and is located away from an active stream channel should cause little or no change to the natural hydrologic processes unless the stream captures the pit during periods of flooding. The exception is that changes in evapotranspiration, recharge, and runoff may create minor changes to the ground-water system, which may in turn affect stream flow.
b) Limiting extraction of material in floodplains to an elevation above the water table generally disturbs more surface area than allowing extraction of material below the water table.
c) In-stream extraction of gravel from below the water level of a stream generally causes more changes to the natural hydrologic processes than limiting extraction to a reference point above the water level.

d) In-stream extraction of gravel below the deepest part of the channel (the thalweg) generally causes more changes to the natural hydrologic processes than limiting extraction to a reference point above the thalweg.
e) Excavating sand and gravel from a small straight channel with a narrow floodplain generally will have a greater impact on the natural hydrologic processes than excavations on a braided channel with a wide floodplain.
f) Extracting sand and gravel from a large river or stream will generally create less impact than extracting the same amount of material from a smaller river or stream.

Over-extraction of gravel can destabilise channels and banks, and/or affect the ecologic functioning of rivers particularly if undertaken at the wrong time, or in the wrong place, or in a way that damages the river bed or margins. For these reasons regional councils exercise controls on the amounts, and the process of extraction, to avoid or reduce adverse effects (Basher, 2006).

The potential impacts of gravel extraction are well known from literature (e.g., Kelly et al. 2005; Rinaldi et al. 2005) and include:

a) bed degradation and consequent effects on channel and bank stability (Figure 2.12);
b) increased sediment loads, decreased water clarity and sedimentation;
c) changes in channel morphology and disturbance of ecologically important roughness elements in the river bed;
d) ecological effects on bird nesting, fish migration, angling, etc.
e) modification of the riparian zone including bank erosion;
f) direct destruction from heavy equipment operation;
g) discharges from equipment and refuelling;
h) Reduction in groundwater elevations;
i) impacts on structures and access;
j) biosecurity and pest risks;
k) impacts on coastal processes.

Figure 2.12: Slumped/Exposed Bank of Pamba River Due to Unrestricted Mining Activities (Padmalal et al., 2008)

2.2.2 Aquatic and Riparian Habitat (NCAFS, 2002)

Effects directly related to extraction and to changes in geomorphology include increased sedimentation, turbidity, and bankfull widths (Rosgen, 1996), higher stream temperatures, reduced dissolved oxygen, lowered water table, decreased wetted periods in riparian wetlands, and degraded riparian habitat (see reviews by Nelson, 1993; NMFS, 1996; Meador and Layher, 1998; Bork, 1999; Roell, 1999; and original research by Kanehl and Lyons, 1992; Brown et al., 1998; and references therein). Channel geomorphology changes, such as a wider and shallower streambed (Kanehl and Lyons, 1992; Brown et al., 1998) may consequently result in increased stream temperature (Kondolf, 1997).

Although studies have shown differing results, chemical changes such as reduced dissolved oxygen and changes in pH levels have been reported downstream of in-stream mining areas (Nelson, 1993; Meador and Layher, 1998). Loss of riparian habitat may result from direct removal of vegetation along the stream bank to facilitate the use of a dragline or through the process of lowering the water table, bank undercutting, and channel incision (Kondolf, 1997; Brown et al., 1998).

The physical composition and stability of substrates are altered as a result of in-stream mining and most of these physical effects may exacerbate sediment entrainment in the channel. Furthermore, the process of in-stream mining and gravel washing produces fine sediments under all flow conditions, resulting in a deposition of fine sediment in riffles as well as other habitats at low discharge (Nelson, 1993).

Excess sediment is considered the greatest pollutant in U.S. waters and constitutes one of the major environmental factors in the degradation of stream fisheries (Waters, 1995). Much of the excess sediment is a result of poor watershed and riparian land use. However, in-stream mining may contribute additional sediment to downstream reaches due to the disruption of substrate stability. Once sediment enters the stream, it is best to let natural geomorphological and hydrological processes reach a dynamic equilibrium, rather than further exacerbating the situation by additional disturbance.

2.3 HEC-RAS Modelling

The Hydrologic Engineering Centers River Analysis System (HEC-RAS) is an integrated system of software designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels and provide input and output information in tabular and graphical formats. This system is capable of performing Steady and Unsteady Flow water surface profile calculations. The details of modelling methodology are given in Appendix B.

2.4 Stable Channel Analysis

For stable sand-bed channels, a rational design method was developed by Chang (1988) based on the physical relations of sediment transport, flow resistance and dynamic equilibrium.

A typical design chart (Figures 2.13 and 2.14) is provided, in which the width, depth, slope, water discharge, bed material size, and bed load (or sediment concentration) are interrelated. To design a channel using this method, the water discharge, sand size, and sediment concentration admitted into the channel need to be specified and the side slope needs to be estimated on the basis of the bank material. Then, stable width, depth, and slope of the channel are obtained within the limit of application.

For a set of independent variables Q, Q_s, and d together with assumed bank slope z reflecting the bank stability, the dependent variables B, D, and S are obtained following the computing steps given in Figure 2.13.

Results of the numerical example shown in Figure 2.13 are used as the basis of discussion for the variation of power expenditure with channel width. For the specified values of Q, Q_s, d, and z, the variation of S or γQS with B has a minimum under certain counteractive factors. For this sample case, the stable width which corresponds to the minimum slope is determined to be 26.5 m (87 ft) using 0.3048 m (1-ft) width increments (Figure 2.14).

An example of stable channel analysis for Sungai Muda and Sungai Langat is given in Appendix C.

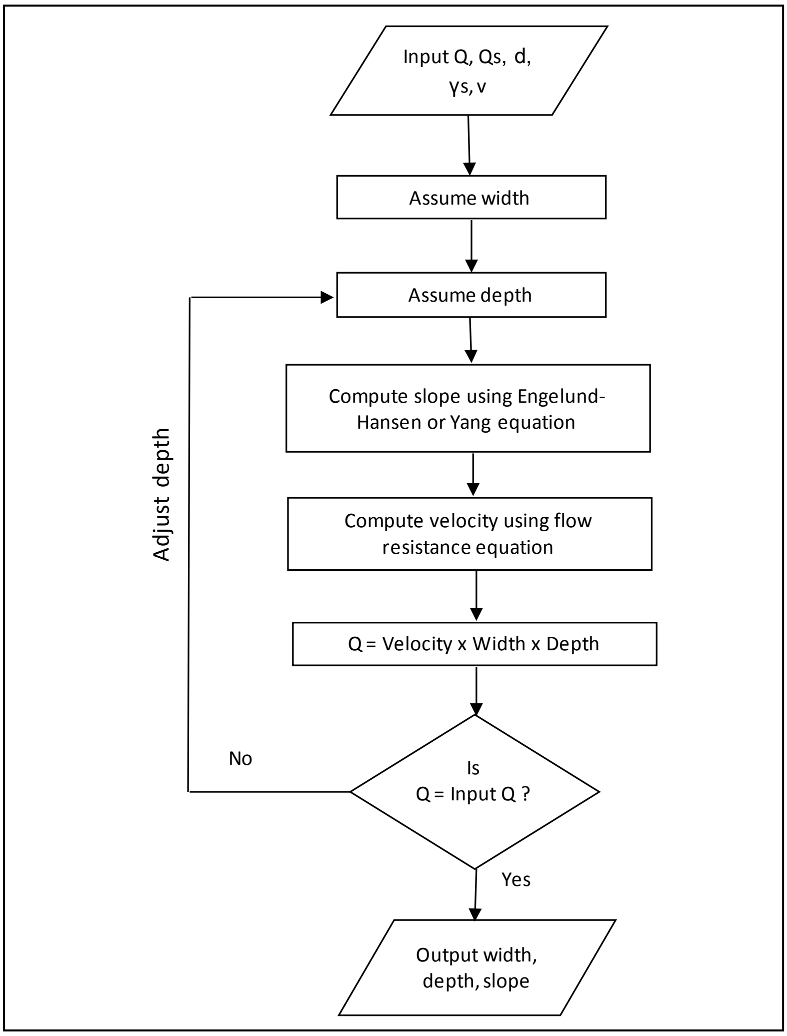


Figure 2.13: Flow Chart Showing Major Steps of Computation (Chang, 1988)

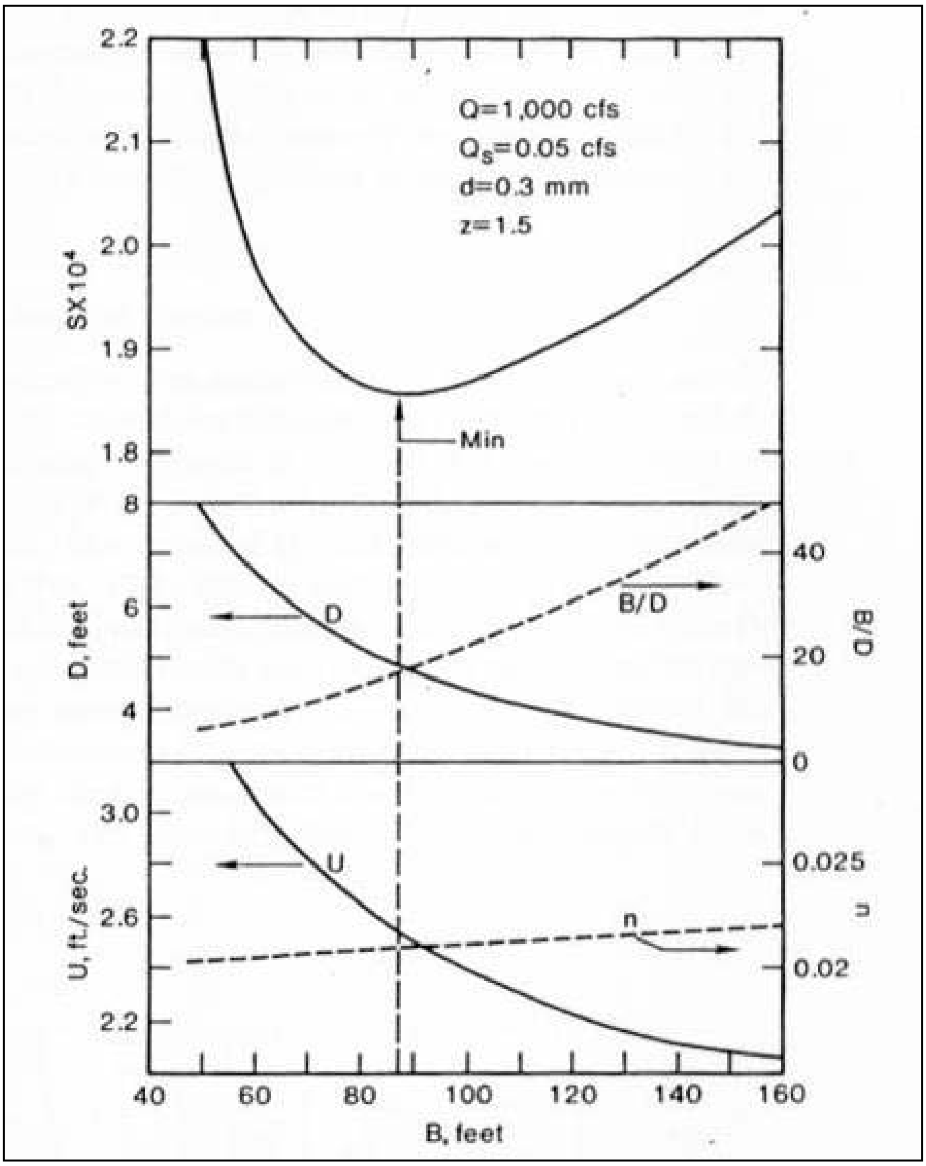


Figure 2.14: Variations of Computed Parameters with Channel Width (Chang, 1988)

The foregoing computing procedure was employed to compute different sets of channel width *B*, depth *D*, and slope *S* for different input sets of *Q*, Q_s, and *d*. The *z* value of 1.5 for the side slope was used in this case. The resulting values of *B* and *D* are shown as functions of *Q*, *S*, and *d* in Figure 2.15, which is the design chart for stable alluvial channels. The values of Q_s (bed load) and *U* are shown as functions of *Q*, *S*, and *d* in Figure 2.16. For the information given in Figure 2.15, concentrations of bed-material load computed using the Engelund-Hansen formula are shown in Figure 2.17. The computed results indicate that, at the same *S*, the values of *B, D,* Q_s, and *U* vary approximately in proportion to $d^{1/2}$; therefore, the two variables S and *d* can be combined into one variable $S/d^{1/2}$ in these figures.

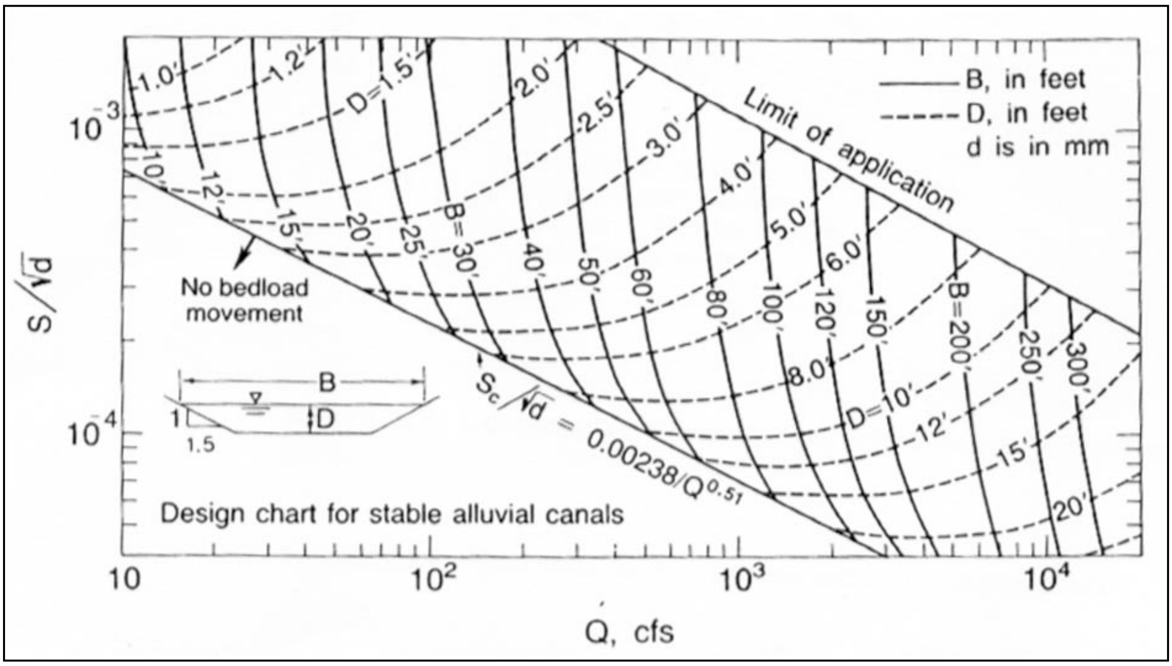


Figure 2.15: Design Chart of Stable Alluvial Canals for Specified Side Slope (Chang, 1988)

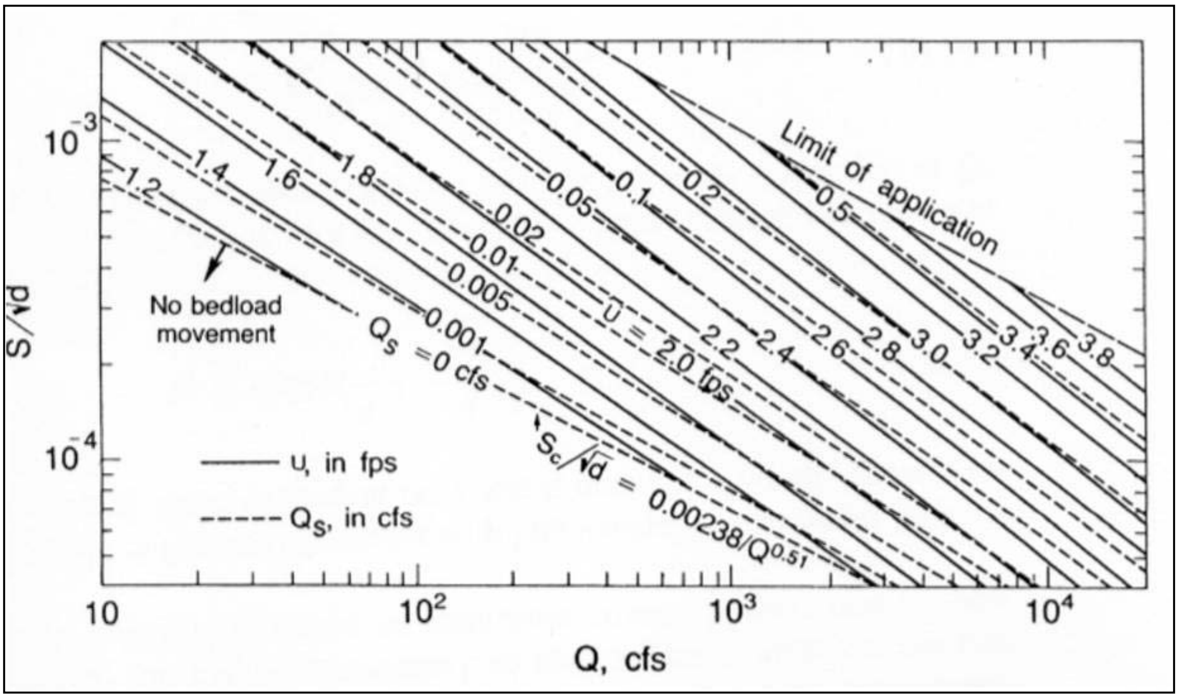


Figure 2.16: Bed Load and Velocity as Functions of Water Discharge, Slope and Sediment Size (Chang, 1988)

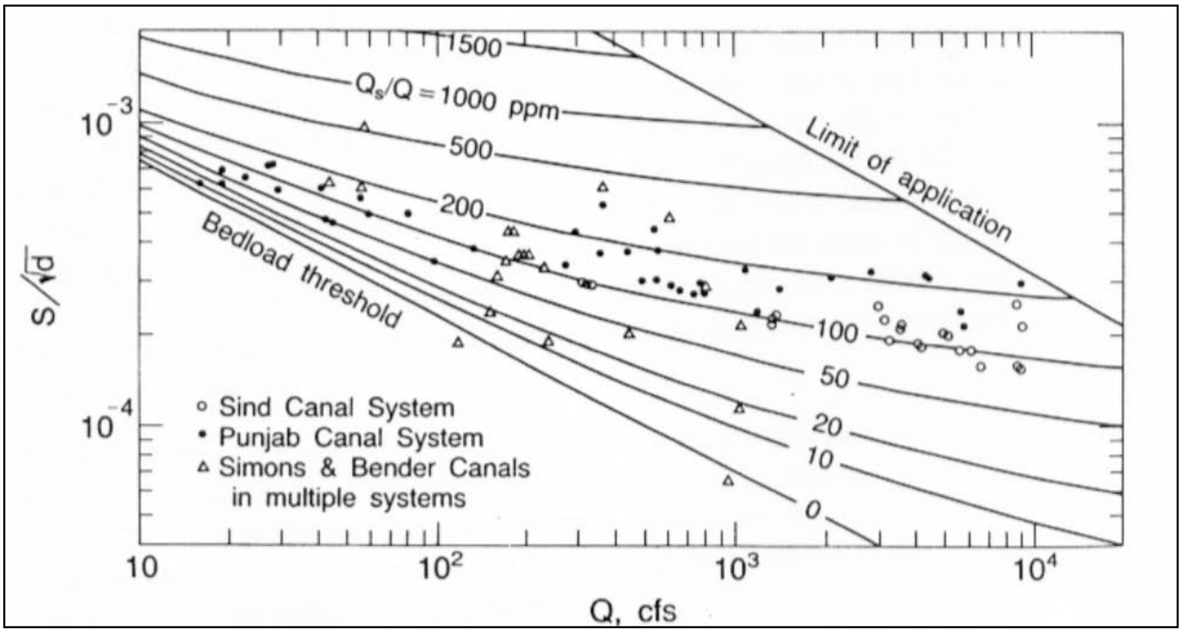


Figure 2.17: Concentration of Bed-Material Load as Function of Discharge, Slope and Sediment (Chang, 1988)

3.0 MANAGEMENT PLAN

3.1 Long-Term Management Guidelines

The following recommendations are adopted from a study on Garcia River Gravel Management Plan by Philip Williams & Associates, Ltd or PWA (1996).

3.1.1 In-Stream Mining Recommendations

a) *Permit Mining Volume Based on Measured Annual Replenishment*

In the first year following adoption of the management plan, a volume equal to the estimated annual replenishment could be extracted from the reach of channel. Replenishment (up to the elevation of the selected channel configuration) would need to occur before subsequent extraction could take place.

The concept of annual replenishment accounts for the episodic nature of sediment transport. For example, during wet periods with high stream flows, and a high contribution of sediment from hillslopes and tributaries, monitoring data would show that sand and gravel bars are replenished quickly. During drought periods with low streamflow, and little sediment supply or transport, monitoring data would likely show that bars were replenished at a slower rate. The use of monitoring data is essential in measuring when actual replenishment occurs. The use of the concept of annual replenishment protects long-term channel stability as well as aquatic and riparian habitat by extracting a volume sustainable by watershed processes.

It is important to develop a system to allocate the total estimated annual replenishment between all of the operators.

b) *Establish an Absolute Elevation below Which No Extraction May Occur (Minimum Enveloped Level or Redline)*

The absolute elevation below which no mining could occur or “redline” would be surveyed on a site-specific basis in order to avoid impacts to structures such as bridges and to avoid vegetation impacts associated with downcutting due to excessive removal of sediment.

An extraction site can be determined after setting the deposition level at 1 m above natural channel thalweg elevation, as determined by the survey approved by DID.

c) *Limit In-stream Extraction Methods to Bar Skimming*

If mining is limited to the downstream end of the bar with a riparian buffer on both the channel and hillslope (or floodplain) side, bar skimming would minimise impacts. Other methods such as excavation of trenches or pools in the low flow channel lower the local base level, and maximise upstream (headcutting and incision) and downstream (widening and braiding) impacts. In addition, direct disturbance of the substrate in the low flow channel should be avoided.

Trenching on bars may be beneficial in the future if the river becomes severely aggraded, flat, shallow and braided.

Trenching of bars may initially impact a smaller area of riparian habitat than skimming - as a result of excavating deeper rather than shallow skimming of a large area. However, over the long-term, the upstream and downstream effects of a trench on the bar or in the channel may offset any short-term benefit derived from this method.

d) Extract Sand and Gravel from the Downstream Portion of the Bar

Retaining the upstream one to two thirds of the bar and riparian vegetation while excavating from the downstream third of the bar is accepted as a method to promote channel stability and protect the narrow width of the low flow channel necessary for fish. Sand and gravel would be redeposited in the excavated downstream one to two thirds of the bar (or downstream of the widest point of the bar) where an eddy would form during sediment transporting flows. In contrast, if excavation occurs on the entire bar after removing existing riparian vegetation, there is a greater potential for widening and braiding of the low flow channel.

e) Concentrate Activities to Minimise Disturbance

In-stream extraction activities should be concentrated or localised to a few bars rather than spread out over many bars. This localisation of extraction will minimise the area of disturbance of upstream and downstream effects. Skimming decreases habitat and species diversity - these effects should not be expanded over a large portion of the study area.

f) Review Cumulative Effects of Sand and Gravel Extraction

The cumulative impact of all mining proposals should be reviewed on an annual basis to determine if cumulative riverine effects or effects to the estuary are likely and to ensure that permits are distributed in a manner that minimises long-term impacts and inequities in permits between adjacent mining operations.

g) Maintain Flood Capacity

Flood capacity in the river should be maintained in areas where there are significant flood hazards to existing structures or infrastructure.

h) Establish a Long-term Monitoring Program

Monitoring of changes in bed elevation and channel morphology, and aquatic and riparian habitat upstream and downstream of the extraction would identify any impacts of sand and gravel extraction to biologic resources. Long-term data collected over a period of decades as sand and gravel extraction occurs will provide data to use in determining trends.

i) *Minimise Activities That Release Fine Sediment to the River*

No washing, crushing, screening, stockpiling, or plant operations should occur at or below the streams "average high water elevation," or the dominant discharge. These and similar activities have the potential to release fine sediments into the stream, providing habitat conditions harmful to local fish.

j) *Retain Vegetation Buffer at Edge of Water and Against River Bank*

Riparian vegetation performs several functions essential to the proper maintenance of geomorphic and biological processes in rivers. It shields river banks and bars from erosion.

Additionally, riparian vegetation, including roots and downed trees, serves as cover for fish, provides food source, works as a filter against sediment inputs, and aids in nutrient cycling. More broadly, the riparian zone is necessary to the integrity of the ecosystem providing habitat for invertebrates, birds and other wildlife.

k) *Limit In-stream Operations to the Period Between May and September*

The in-stream mining should only be allowed during the dry season.

l) *An Annual Status and Trends Report*

This report should review permitted extraction quantities in light of results of the monitoring program, or as improved estimates of replenishment become available. The report should document changes in bed elevation, channel morphology, and aquatic and riparian habitat. The report should also include a record of extraction volumes permitted, and excavation location. Finally, recommendations for reclamation, if needed should be documented.

3.1.2 Off-Channel or Floodplain Extraction Recommendations

a) *Floodplain Extraction Should Be Set Back from the Main Channel*

In a dynamic alluvial system, it is not uncommon for meanders to migrate across a floodplain. In areas where sand and gravel occurs on floodplains or terraces, there is a potential for the river channel to migrate toward the pit. If the river erodes through the area left between the excavated pit and the river, there is a potential for "river capture," a situation where the low flow channel is diverted though the pit.

In order to avoid river capture, excavation pits should set back from the river to provide a buffer, and should be designed to withstand the 100-year flood (100-year

ARI). Adequate buffer widths and reduced pit slope gradients are preferred over engineered structures which require maintenance in perpetuity. Hydraulic, geomorphic, and geotechnical studies should be conducted prior to design and construction of the pit and bund.

In addition to river capture, extraction pits create the possibility of stranding fish. To avoid this impact, all off-channel mining should be conducted above the 25-year ARI level.

b) The Maximum Depth of Floodplain Extraction Should Remain above the Channel Thalweg

Floodplain pits should not be excavated below the elevation of the thalweg in the adjacent channel. This will minimise the impacts of potential river capture by limiting the potential for headcutting and the potential of the pit to trap sediment. A shallow excavation (above the water table) would provide a depression that would fill with water part of the year, and develop seasonal wetland habitat. An excavation below the water table would provide deep water habitat.

c) Side Slopes of Floodplain Excavation Should Range from 3:1 to 10:1

Side slopes of a floodplain pit should be graded to a slope that ranges from 3:1 to 10:1. This will allow for a range of vegetation from wetland to upland. Steep side slopes excavated in floodplain pits on other systems have not been successfully reclaimed, since it is difficult for vegetation to become stabilised. Terrace pits should be designed with a large percentage of edge habitat with a low gradient which will naturally sustain vegetation at a variety of water levels.

d) Place Stockpiled Topsoil above the 25-year Return Period or ARI Level

Stockpiled topsoil can introduce a large supply of fines to the river during a flood event and degrade fish habitat. Storage above the 25-year flood (25-year ARI) inundation level is sufficient to minimise this risk.

e) Floodplain Pits Should Be Restored to Wetland Habitat or Reclaimed for Agriculture

There are very few examples of successfully restored or reclaimed extraction pits on river systems. The key to successful restoration or reclamation is to conserve or import adequate material to re-fill the pit, while ensuring that pit margins are graded to allow for development of significant wetland and emergent vegetation (Figures 3.1 to 3.6).

f) Establish a Long-term Monitoring Program

A long-term monitoring program should provide data illustrating any impacts to river stability, groundwater, fisheries, and riparian vegetation. The monitoring program should assess the success of any reclamation or restoration attempted.

g) *An Annual Status and Trends Report*

The status and trends report described previously should include a section on the hydrologic and biologic components of floodplain pit reclamation.

3.1.3 Reclamation Plans

In-stream reclamation plans should include:

a) a baseline survey consisting of existing condition cross-section data. Cross-sections must be surveyed between two monumented endpoints set back from the top of bank, and elevations should be referenced to JUPEM's bench mark;
b) the proposed mining cross-section data should be plotted over the baseline data to illustrate the vertical extent of the proposed excavation;
c) the cross-section of the replenished bar should be the same as the baseline data. This illustrates that the bar elevation after the bar is replenished will be the same as the bar before extraction;
d) a planimetric map showing the aerial extent of the excavation and extent of the riparian buffers;
e) a planting plan developed by a plant ecologist familiar with the flora of the river for any areas such as roads that need to be restored;
f) a monitoring plan (See Chapter 4).

The appropriate reclamation plans can turn in-stream and floodplain sand and gravel mining operations into something perceived by the public as desirable as shown in Figure 3.1 to 3.6 (Langer, 2003).

The following forms (CIR-1, CIR-2 and CIR-3) can be used to monitor the on-going sand mining activities:

a) CIR-1: Compliance Inspection Report
b) CIR-2: District Inspector's Checklist
c) CIR-3: Assurance of Compliance

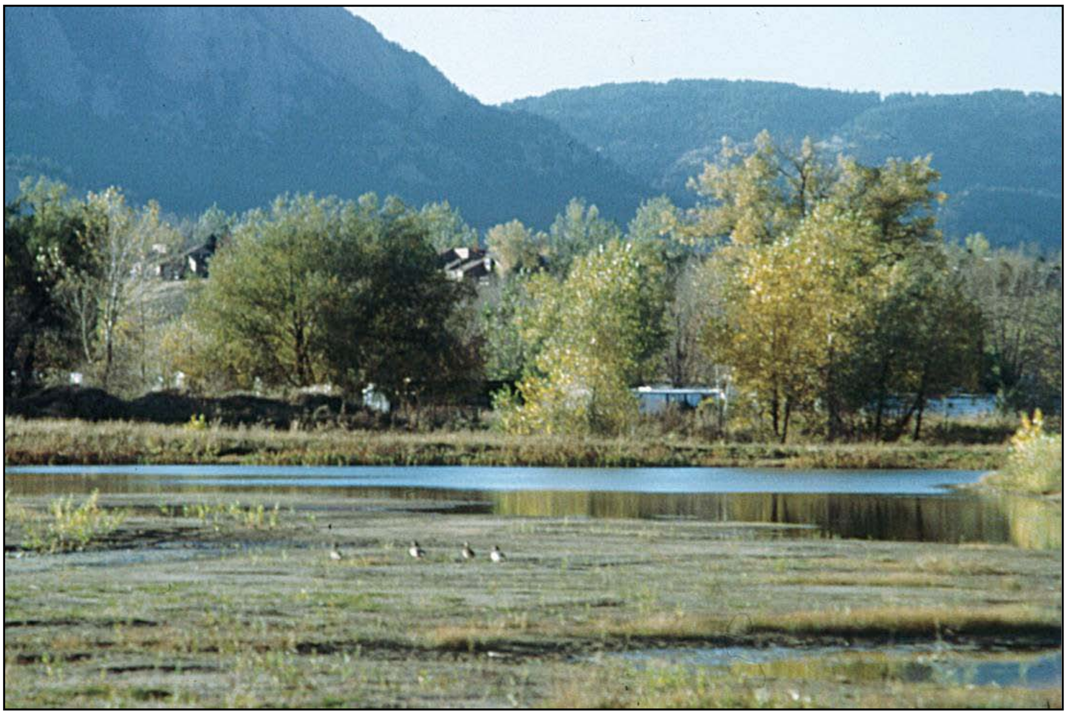


Figure 3.1: Wildlife Habitat (Langer, 2003)

Figure 3.2: Wetlands and Suburban Nature Park (Langer, 2003)

Figure 3.3: Residential Lakefront Property (Langer, 2003)

Figure 3.4: Recreation (Langer, 2003)

Figure 3.5: Residential Lakefront Property (Langer, 2003)

Figure 3.6: Municipal Water Storage (Langer, 2003)

CIR-1

Department of Irrigation and Drainage Malaysia

COMPLIANCE INSPECTION REPORT

Permittee: ______________________________

Location: ______________________________

Accompanied By
Name: ________________
Title: ________________
Affiliation: ______________
Phone No.: ______________

Permit Number: ___________

Date/Time: ______________

Inspector: ________________

State DID: ________________

____

____

Synopsis:

1. Activity:

2. Mining Setbacks:

3. Depth and Extent of Excavation/Operation:

4. Adverse Affects to Banks:

5. Structures in Channel/Floodway:

6. Maintenance of Drainage and Silting Pond:

7. Pit Slopes (Floodplain):

8. Other:

Inspector’s Signature: _____________________ Date of Report: ______________

JPS Negeri: ____________________________

CIR-2

DISTRICT INSPECTOR’S CHECKLIST

Project Name ____ Permit # _____________

Inspector Name ______________________________________ State DID ___________

Date of Current Inspection ______________Date of Last Inspection ___________________

Follow-Up on Previous Non-Compliance Items

Watercourse Condition Documentation – describe changes
_____ Attach recent aerial photograph (note changes from previous inspection)
_____ Attach ground photographs (match photo location and aspect from previous inspection if possible)

Mining Operation Conditions
_____ Excavation depth
_____ Excavation limits
_____ Property setbacks
_____ Condition of flood control structures
_____ Reclamation – progress vs. schedule

CIR-3

ASSURANCE OF COMPLIANCE

Permit Number ______________________________ Date __________________________

I/we ______________________________________ (permitee), certify that the operation conducted on this site during the previous three (3) months has been in accordance with the approved plan of development.

Signed: ____________________________

Date: ______________________________

Notary Seal: _______________________________

Required Attachments: Documents of current excavation depth and limits sealed by a registered professional engineer or surveyor (Refer to para 5.8, *Syarat-syarat Teknikal* in *Prosedur Permohonan Pengambilan Pasir Sungai*).

Note: This form is to be submitted every three (3) months.

3.2 Appropriate Extraction Methods

Kondolf et al. (2001) summarised several methods of sand and gravel mining operations as below:

a) *Bar scalping or skimming*

Bar scalping or skimming is extraction of sand and gravel from the surface of bars. Historical scalping commonly removed most of the bar above the low flow water level, leaving an irregular topography (Figure 3.7). Present method generally requires that surface irregularities be smoothed out and that the extracted material be limited to what could be taken above an imaginary line sloping upwards and away from the water from a specified level above the river's water surface at the time of extraction (typically 0.3 - 0.6 m (1-2 ft)).

Bar scalping is commonly repeated year after year (Figure 3.8). To maintain the hydraulic control provided to upstream by the riffle head, the preferred method of bar scalping is now generally to leave the top one-third (approximately) of the bar undisturbed, mining only from the downstream two-thirds.

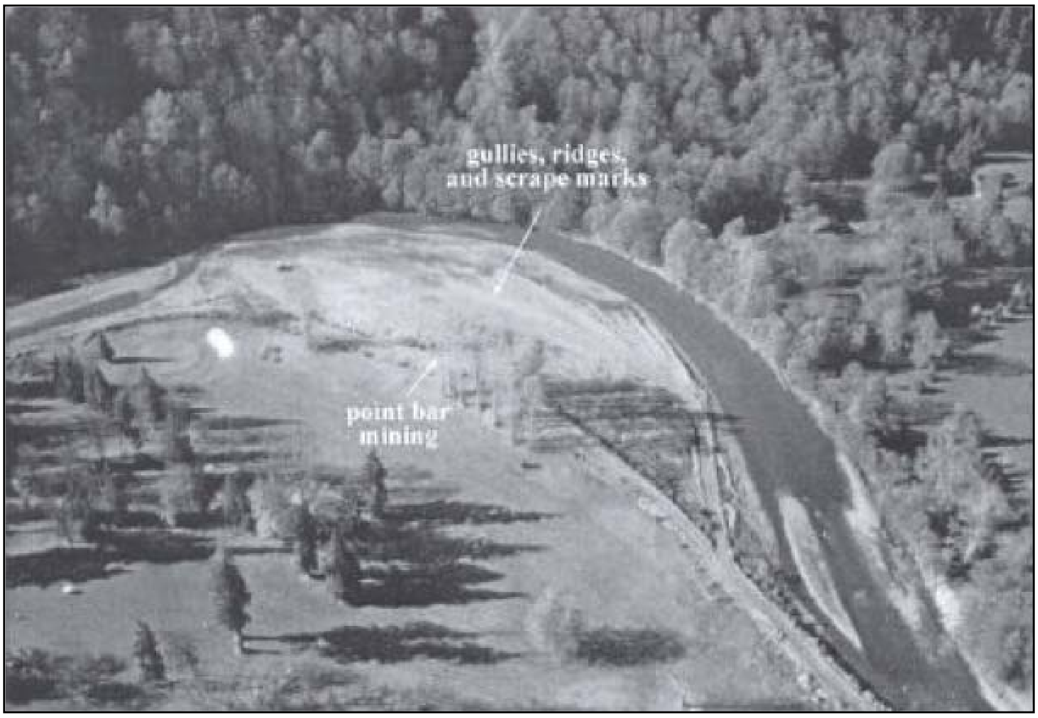


Figure 3.7: Oblique Aerial View of Freshly Scalped Point Bar in the Wynoochee River, California. Appx 1965 (Kondolf et al., 2001)

Figure 3.8: Aggregate being “skimmed” off the surface of a bar (Langer, 2003)

b) *<u>Dry-Pit Channel Mining</u>*

Dry-pit channel mines are pits excavated within the active channel on dry intermittent or ephemeral stream beds with conventional bulldozers, scrapers and loaders (Figure 3.9). Dry pits are often left with abrupt upstream margins, from which headcuts are likely to propagate upstream.

Figure 3.9: Dry pit excavation, Stony Creek, California (Kondolf et al., 2001)

c) *Wet-Pit Channel Mining*

Wet-pit mining (Figures 3.10 to 3.15) involves excavation of a pit in the active channel below the surface water in a perennial stream or below the alluvial groundwater table, requiring the use of a dragline or hydraulic excavator to extract sand and gravel from below the water surface.

In some areas, such as low terraces, some glaciofluvial deposits, and some ephemeral streambeds, sand and gravel mining may penetrate the water table and may be mined wet or dry. In some geologic settings, wet pits can be made dry by collecting the groundwater in drains in the floor of the pit and pumping the water out of the pit.

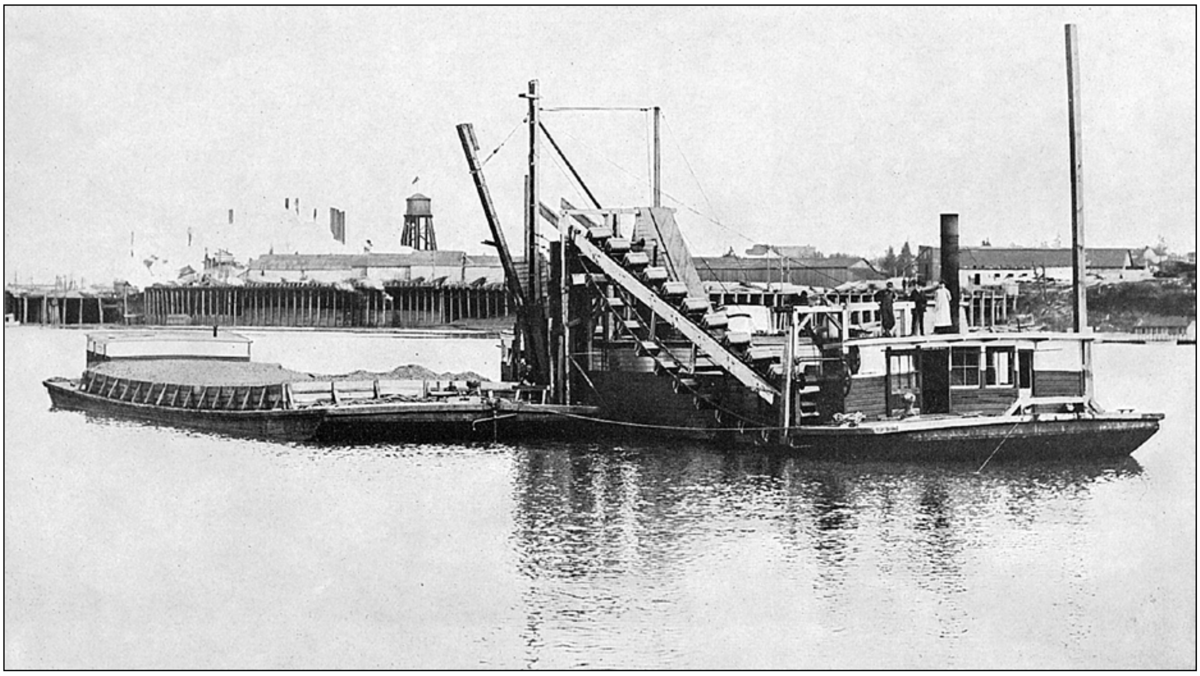


Figure 3.10: Dredge for raising sand and gravel from the bed of the Willamette River near Portland, Oregon, Circa 1909 (Langer, 2003)

Figure 3.11: Wet-pit Mining at Sungai Langat

Figure 3.12: Wet-pit Mining at Sungai Kulim

Figure 3.13: Wet-pit Mining at Sungai Kelantan

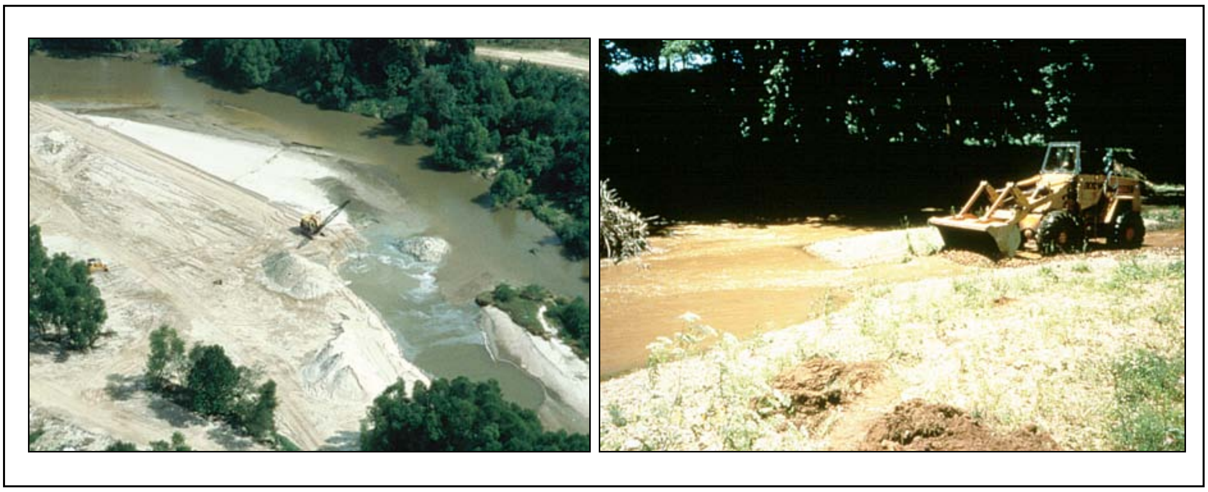


Figure 3.14: Excavating Sand and Gravel from Stream Channels Using Conventional Earth Moving Equipment (Langer, 2003)

Figure 3.15: Draglines can be used to excavate sand and gravel from a stream channel (Langer, 2003)

d) *Bar Excavation*

A pit is excavated at the downstream end of the bar as a source of aggregate and as a site to trap sand and gravel. Upon completion, the pit may be connected to the channel at its downstream end to provide side channel habitat. On the Russian River, California, recent proposals for bar mining include leaving the bar margins untouched and excavating from the interior of the downstream part of the bar, but above the water surface elevation, a variant intermediate between bar scalping and bar excavation.

e) *In-stream Gravel Traps*

Sand or “bed load traps” have been used to reduce sand in downstream channels for habitat enhancement in Michigan. Such traps can also be potential sources of commercial aggregate, provided the amounts so collected are sufficient to be economically exploited. One advantage of the traps as a method for harvesting sand and gravel are the concentration of mining impacts at one site, where heavy equipment can remove sand and gravel without impacting riparian vegetation or natural channel features. Sand and gravel can be removed year after year from the bed load trap.

An idealized trap shown in Figure 3.16 has short dikes to create a constriction downstream and to hold the resultant higher stages. Sand and gravel are removed from the downstream end of the deposit, and a grade control structure at the upstream end of the trap prevents headcutting upstream from the extraction. There is no hydraulic impact upstream due to the extraction, because the engineered constriction is the hydraulic control during high flows. The concentrated flow scours a deep pool immediately downstream from the constriction, which may be important habitat in aggrading reaches where pool formation is limited by deposition.

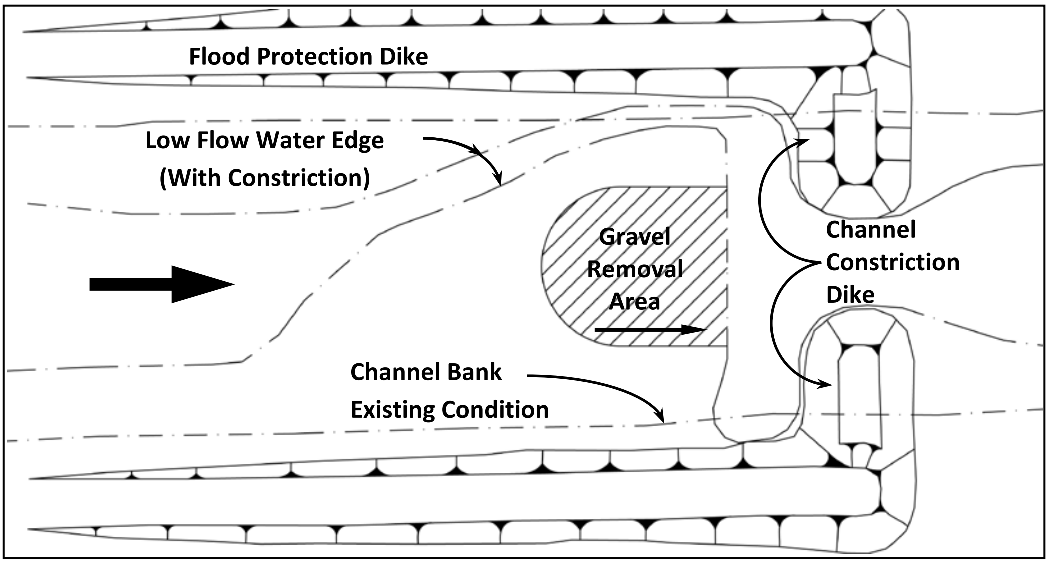


Figure 3.16: Idealized Sand and Gravel Trap (Kondolf et al., 2001)

f) *Channel-wide In-Stream Mining*

In rivers with a highly variable flow regime, sand and gravel are commonly extracted across the entire active channel during the dry season. The bed is evened out and uniformly (or nearly so) lowered.

Table 3.1 highlights commonly used sand and gravel mining methods and their consequences (PWA, 1996).

Table 3.1: Summary of Commonly Used Sand and Gravel Mining Methods and Their Consequences (PWA, 1996)

Method	Dimensions	Advantages	Disadvantages
Trenches	Length to 500 m Width: 12 to 15 m Depth: 3 to 5 m	1. Can create efficient channel. 2. Less disturbance on bar. 3. Smaller impact on riparian vegetation. 4. Can create pool habitat. 5. Can remedy channel braiding. 6. Useful for aggraded channels.	1. Potential introduction of fines. 2. Potential low flow channel diversion. 3. Potential fish stranding. 4. Poor fish habitat value. 5. Potential bed load sink. 6. In non-aggraded channels, can result in head cutting, bank erosion, turbidity.

Table 3.1: Summary of Commonly Used Sand and Gravel Mining Methods and Their Consequences (Continued)

Method	**Dimensions**	**Advantages**	**Disadvantages**
Skimming		Ideally, self replenishing	If extended replenishment deficit: 1. Loss of channel confinement. 2. Channel widening and shallowing. 3. Potential braiding. 4. High summer water temperatures. 5. Potential channel degradation. 6. Increased bank heights. 7. Lowering of groundwater table. 8. Loss of riparian vegetation.
Pit mining (bar)	122 m	With proper design, can be used to create wetland habitat	1. Stream capture. 2. Fish stranding.
Channel holes			
Suction dredges and drag lines			
Extraction from meander scars, high terraces		If above floodplain, potentially limited direct impacts on fish	1. Channel shifts may result in stream capture. 2. Potential fish stranding. 3. "Permanent" land use change.

3.3 Appropriate Extraction Sites (PWA, 1996)

a) Appropriate extraction sites are locations chosen based on knowledge of the local rate of aggradation or scour, a site-specific determination of channel stability and bank erosion and evaluation of riparian resources.
b) Site-specific evaluation is needed to evaluate each proposed operation to minimize disturbance and maximise stability of channel.
c) In-stream extraction sites should be located where the channel loses gradient or increases in width, and deposition occurs unrelated to regular bar-pool spacing in channel. Particular sites may include sites upstream of a bedrock constriction or backwater, or at deltas created near confluences.

4.0 MONITORING PLAN

Monitoring will provide data to evaluate the upstream and downstream effects of sand and gravel extraction activities, and long-term changes. A brief report summarizing the annual results of the physical and biological monitoring should document the evolution of the sites over time, and the cumulative effects of sand and gravel extraction. The summary should also recommend any maintenance or modification of extraction rates needed to minimize impacts of extraction (PWA, 1996).

4.1 Sand Replenishment, Geomorphology and Hydrology

Physical monitoring requirements of sand and gravel extraction activities should include surveyed channel cross-sections, longitudinal profiles, bed material measurements, geomorphic maps, and discharge and sediment transport measurements. The physical data will illustrate bar replenishment and any changes in channel morphology, bank erosion, or particle size.

In addition to local monitoring for replenishment at specific mining sites, monitoring of the entire reach through the estuary will provide information on the cumulative response of the system to sand and gravel extraction. For example, it is important for downstream bars and the estuary to receive sufficient sand and gravel to maintain estuarine structure and function. Because the elevation of the bed of the channel is variable from year to year, a reach-based approach to monitoring will provide a larger context for site-specific changes.

If long-term monitoring data show that there is a reach-scale trend of bed lowering (on bars or in the thalweg), the extraction could be limited.

4.1.1 Cross-sections

Surveyed channel cross-sections should be located at permanently monumented sites upstream, downstream and within the extraction area. Cross-sections intended to show reach-scale changes should be consistently located over geomorphic features such as at the head of riffles, across the deepest part of pools, or across particular types of channel bars.

Cross-section spacing should be close enough to define the morphology of the river channel. Cross-section data should be surveyed in March or April to evaluate changes that may occur during the flooding season. Cross-section data should be collected over the reach to the estuary, and locally upstream, downstream, and within each mining site.

<u>Reach Scale Cross-sections</u>

a) One long-term monitoring set to include the existing cross-sections to illustrate long-term changes over the scale of the reach to the estuary.
b) Cross-sections surveyed by other government agencies should be incorporated into this program.

c) Additional cross-sections could be added to the set to aid in answering specific questions that arise.
d) Cross-section spacing should range from about 100 m to 250 m depending on the local channel morphology.
e) At least 10 survey points to be measured for each cross-section.
f) It is advantageous to locate new cross-sections at the head (upstream end) of riffles, where changes in bed elevation are most likely representative of larger scale trends.
g) This long-term monitoring data should be collected and analyzed even if no mining occurs in order to understand the trends of the river.

Mining Site Cross-sections

a) One set of cross-sections at each extraction site to illustrate local changes related to specific in-stream extraction activities.
b) At least 10 survey points to be measured for each cross-section at 20 to 30 m interval.
c) Cross-sections should illustrate the upstream, mid-, and downstream portion of the channel bar being excavated, and at least one cross-section upstream and one cross-section downstream of the bar.
d) Thus, at least five cross-sections should be located at every extraction site to illustrate local changes. Cross-sections should be oriented perpendicular to the channel, extend from the top of bank to the opposite top of bank, and show the morphology of the channel (including the portion below the water surface).
e) Survey notes should describe geomorphic features including top and base of bank, edges of bars, thalweg (the deepest part of the channel) and sediment characteristics.
f) All cross-section elevations should be tied into a benchmark referenced to Department Survey and Mapping Malaysia (JUPEM)’s bench mark.
g) By standardizing the horizontal and vertical reference datum, data can be used in a watershed data base, or GIS which could be used to address issues related to river stability, flood control, bed load transport, and the cumulative effects of sand and gravel extraction.
h) A standard format for recording cross-section data should be provided to operators by DID to ensure that cross-section data is repeatable, and usable as part of the long-term record.
i) Scour chains (Nawa and Frissell, 1993) may be used in addition to cross-sections to document changes in bed elevation.
j) Scour chains should be placed on a bar, and the location should be mapped and described in field notes, to aid in data recovery.

4.1.2 Longitudinal Profile

A longitudinal profile should extend through a reach extending from upstream of the project area to downstream of the project area. Profile points should be surveyed in the thalweg and be detailed enough to illustrate the channel morphology (riffle-pool sequences). Profile elevations should reference to JUPEM’s bench mark.

4.1.3 Geomorphic Maps

Geomorphic maps may be constructed using a tape and compass for the project reaches to illustrate channel morphology. Maps should illustrate bed and bank characteristics of the channel and particle size.

4.1.4 Photodocumentation

Photographs of the project sites should be taken prior to excavation to document the baseline conditions, and again during each monitoring session. Aerial photos should be taken twice a year (spring and fall) at a scale of 1:6,000 (1" = 500') or larger. Local field photographic station locations should be mapped on the geomorphic map and staked in the field in order to establish permanent photo stations.

4.1.5 Hydrology and Sediment Transport

Discharge and bed material measurements including suspended and bed load transport measurements taken by DID should continue in order to provide a statistically significant data base. Long-term data taken over a range of flows will add to our knowledge of river processes and aid in objectively evaluating the long-term trends in the river.

4.1.6 Groundwater Level

Monitoring wells should be established adjacent to each off-channel floodplain excavation to record changes in ground water levels. Measurements should be taken monthly.

4.2 Riparian Habitat

4.2.1 Extent and Quality of Riparian Vegetation

Document the extent and quality of riparian vegetation, including successional status, and any increase in disturbance indicators (non-native plants). The extent of riparian habitat can be determined utilising aerial photos. Habitat quality data, i.e., successional status and species composition, must be determined through field reconnaissance. The data gathering methodology employed for the development of this plan should be utilised, as it incorporates accepted statewide protocols.

4.2.2 Riparian Vegetation Maps

Develop yearly maps of the sensitive habitat areas and document their aerial extent over time. These maps may be combined with the geomorphic maps. Monitor sites identified as sensitive for disturbance in excess of expected geomorphic trends - i.e., massive bank wasting up or downstream from an active mine site. Monitor sand and gravel mining impacts which may translate up and downstream, causing accelerated erosion of sensitive zones and impacting the ability of new habitat to form due to excessive scour or sedimentation.

REFERENCES

Chang, H.H. (1988). *Fluvial Processes in River Engineering*. John Wiley & Sons, USA.

Collins, B. and Dunne, T. (1990). *Fluvial Geomorphology and River-Gravel Mining: A Guide for Planners*, Case Studies Included. Special Publication 98, California Department of Conservation, Division of Mines and Geology.

Department of Irrigation and Drainage or DID. (2008). *Garis Panduan untuk Memproses Permohonan dan Menetapkan Syarat-Syarat Pengambilan Pasir Sungai*. <http://www.water.gov.my/images/river_section/pengambilan%20pasir%20sungai.pdf> (Nov. 20, 2008).

Flood Control District of Maricopa County or FCDMC. (2004). *Sand and Gravel Mining Floodplain Use Permit Application Guidelines.* Arizona. JE Fuller/Hydrology & Geomorphology, Inc.

Japan International Corporation Agency or JICA, (1995). *Comprehensive Management Plan for Muda River Basin*, Final Report.

Julien, P.Y. (2002). *River Mechanics,* Cambridge Universiti Press, UK.

Kondolf, G.M. (1997). *Hungry Water: Effects of Dams and Gravel Mining on River Channels.* Environmental Management 21:533–551.

Kondolf, G.M., Smeltzer, M. and Kimball, L. (2001). *Freshwater Gravel Mining and Dredging Issues.* Washington Departments of Fish and Wildlife, Ecology, and Transportation, Olympia.

Langer, W.H. (2003). *A General Overview of the Technology of In-Stream Mining of Sand and Gravel Resources, Associated Potential Environmental Impacts, and Methods to Control Potential Impacts*: U.S. Geological Survey Open-File Report 02-0153, 44 p.

Nalluri, C. & Featherstone, R.E. (2001). *Civil Engineering Hydraulics.* Blackwell Sceince, Oxford, UK.

Nawa, R.K. and Frissell, C.A. (1993). Measuring Scour and Fill of Gravel Streambeds with Scour Chains and Sliding-Bead Monitors. *North American Journal of Fisheries Management,* Vol. 13, pp. 634-639.

North Carolina Chapter of the American Fisheries Society or NCAFS, (2002). Position paper on *Instream Sand and Gravel Mining Activities in North Carolina*. February 6, 2002.

Philip Williams & Associates, Ltd or PWA, (1996). *Garcia River Gravel Management Plan*. San Francisco.

Vanoni, V.A., (ed). (1975) *Sedimentation Engineering. ASCE Manuals and Reports on Engineering Practice No.54*. American Society of Civil Engineers, New York.

Yang, C.T. (1996). *Sediment Transport Theory and Practice*. The McGraw-Hill Companies, Inc., NewYork.

Yang, C.T. & Molinas, A. (1982). Rate of Energy Dissipation and Sediment Transport, *Proceedings of Applying Research to Practice Conference*, ASCE, Jackson, Mississippi, August 17-20.

APPENDIX A

Volume Extraction Determination

A1. Application of Sediment Transport Equations

Yang Equation:

Sungai Muda @ Jambatan Ladang Victoria (30 October 2008, 1.45 pm) :

Q = 193.820 m^3/s

V = 0.700 m/s

B = 90.0 m

y_o = 6.87 m

S_o = 0.00024

d_{50} = 0.60 mm

w_s = 0.090 m/s

A = 276.810 m^2

P = 71.29 m

R = 3.883 m

$T_{b\ (Measured)}$ = 0.0882 kg/s

$T_{t\ (Measured)}$ = 13.4791 kg/s

$T_{j\ (Measured)}$ = 13.5673 kg/s

$w_s d_{50}/\nu$ = $(0.090) \times (0.60 \times 10^{-3}) / (1\times10^{-6})$ = 54

U_* = $(gRS_o)^{1/2}$ = $(9.81\times3.883\times0.00024)^{1/2}$ = 0.0956 m/s

U_*/w_s = 0.0956 / 0.090 = 1.062

R_e = $U_* d_{50}/\nu$ = $0.0956 \times (0.60\times10^{-3}) / 10^{-6}$ = 57.37

VS_o/w_s = 0.700 x 0.00024 / 0.090 = 0.0019

If : R_e < 70, V_c / w_s = $\dfrac{2.5}{\left(\log \dfrac{U_* d_{50}}{\upsilon} - 0.06\right)} + 0.66$

R_e > 70, V_c / w_s = 2.05

$$V_c/w_s = \frac{2.5}{(\log 59.44) - 0.06} + 0.66 = 1.53174$$

Therefore, $V_c S_o/w_s$ = 1.53174 x 0.00024 = 0.0004

$$\log C_T = 5.435 - 0.286 \log \frac{w_s d_{50}}{\upsilon} - 0.457 \log \frac{U_*}{w_s} + \left(1.799 - 0.409 \log \frac{w_s d_{50}}{\upsilon} - 0.314 \log \frac{U_*}{w_s}\right) \times \log \left(\frac{VS_o}{w_s} - \frac{V_c S_o}{w_s}\right)$$

= 1.871

$C_{T\ (ppm)}$ = 7.43E-05

$C_{v\ (ppm)}$ = $C_{T\ (ppm)}$ / 2.65 = 2.81E-05

T_j = $C_{v\ (ppm)} \times Q \times \rho_s$ = (0.0000281)x(193.82)x(2650)
= 14.4077 kg/s

Discripency ratio (DR) = $\dfrac{T_{j-computed}}{T_{j-measured}}$ = $\dfrac{14.7077}{13.5673}$
= 1.06

0.5 < DR < 2.0, Yang Equation is **suitable** to predict sediment tranport

Engelund-Hansen Equation:

Sungai Muda @ Jambatan Ladang Victoria (30 October 2008, 1.45 pm) :

Q = 193.820 m^3/s

V = 0.700 m/s

B = 90.0 m

y_o = 6.87 m

S_o = 0.00024

d_{50} = 0.60 mm

A = 276.810 m^2

P = 71.29 m

R = 3.883 m

$T_{b\ (Measured}$ = 0.0882 kg/s

$T_{t\ (Measured)}$ = 13.4791 kg/s

$T_{j\ (Measured)}$ = 13.5673 kg/s

τ = $\rho g R S_o$ = (1000)(9.81)(3.883)(0.00024 = 9.142 N/m^2

$\tau^{3/2}$ = $(9.142)^{3/2}$ = 27.642 N/m^2

V^2 = $(0.700)^2$ = 0.4900

$$q_s = 0.05\gamma_s V^2\left[\frac{d_{50}}{g(\gamma_s/\gamma-1)}\right]^{1/2}\left[\frac{\tau_o}{(\gamma_s/\gamma)d_{50}}\right]^{3/2}$$

$$= 0.05 \times \gamma_s \times (\gamma_s/\gamma - 1)^{-1/2} \times (\gamma_s/\gamma)^{3/2} \times \tau^{3/2} \times V^2\ /\ d_{50}$$

$$= 0.05\ (2650 \times 9.81)\ (0.5625)^{-1/2}\ (2650 \times 9.81 - 1000 \times 9.81)^{-3/2}\ .\tau^{3/2}.V^2\ /\ d_{50}$$

$$= 1.569 \times 10^{-4} \times \tau^{3/2} \times V^2\ /\ d_{50}\ \ (kg/s)/m$$

Q_s = B x 1.569 x 0.0001 x $\tau^{3/2}$ x V^2 / d_{50} = 318.773 N/s

Q_s = 318.773 / 9.81 = 32.4947 kg/s

G_w = 1000 x B x R x V = 1000 x 90 x 3.883 x 0.700
= 244629 kg/s

C_T = Q_s / G_w = 32.4947 / 244629 = 0.00013

C_v = C_T / 2.65 = 0.00013 / 2.65 = 5E-05

Q_{st} = C_v x Q = 0.00005 x 293.82 = 0.0097 m^3/s

T_j = Q_{st} x ρ_s = 0.0097 x 2650 = 25.7456 kg/s

Discripency ratio (DR) $= \dfrac{T_{j-computed}}{T_{j-measured}}$

$$= \frac{25.7456}{13.5673}$$

$$= 1.90$$

0.5 < DR < 2.0, Engelund-Hansen is **suitable** to predict sediment tranport

A2. Sediment Rating Curve Determination

Sungai Muda @ Jambatan Nami (MU6)

(i) Flow Discharge based on Surveyed Cross Section

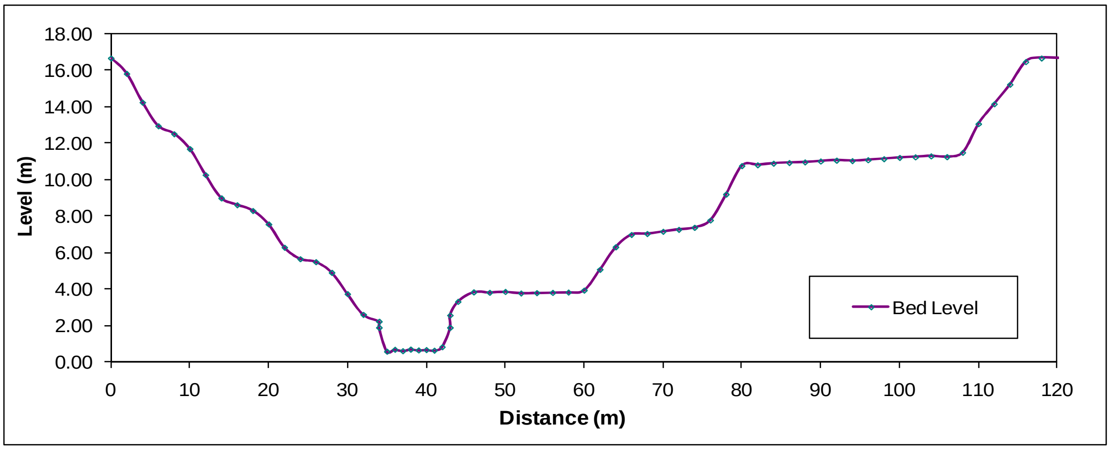


Figure 1: Surveyed Cross Section at MU6, Sungai Muda

Table 1: Flow Discharge Computation

y_o (m)	B (m)	A (m^2)	P (m)	R (m)	S_o	n	V (m/s)	Q (m^3/s)
0.50	7.54	3.03	7.96	0.381	0.00075	0.034	0.42	1.28
1.00	8.32	6.96	9.23	0.754	0.00075	0.034	0.67	4.64
1.65	9.24	12.65	10.83	1.168	0.00075	0.034	0.89	11.30
3.26	16.18	33.11	18.77	1.764	0.00075	0.034	1.18	38.94
4.50	34.61	73.21	37.81	1.936	0.00075	0.034	1.25	91.61
5.50	40.98	111.12	44.60	2.491	0.00075	0.034	1.48	164.49
6.41	45.10	150.08	49.13	3.055	0.00075	0.034	1.70	254.50
7.50	57.85	209.19	62.27	3.359	0.00075	0.034	1.81	377.95
8.50	64.23	273.65	69.16	3.957	0.00075	0.034	2.02	551.41
10.18	68.70	381.27	74.64	5.108	0.00075	0.034	2.39	910.87
11.50	99.72	502.22	106.27	4.726	0.00075	0.034	2.27	1139.20
12.50	104.27	604.06	111.36	5.424	0.00075	0.034	2.49	1502.10

Note:

- Determine water surface slope, S_o at site over 200 m distance
- Assume Manning's n value based on site characteristics
- Compute average velocity, V from Manning's equation for different flow depth, y_o

(ii) Sediment Distribution Curve

- Obtain bed material distribution from site sampling

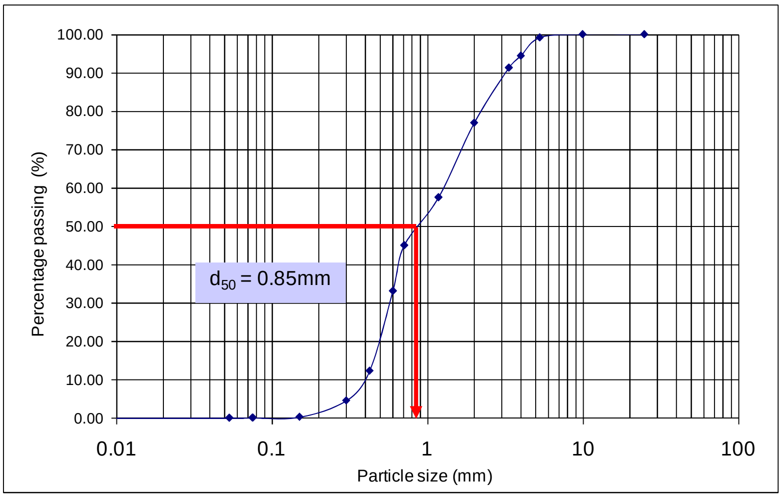


Figure 2: Sediment Distribution Curve on 13 August 2008

(iii) Total Bed Material Load Computation using Yang Equation

Table 2: Total Bed Material Load Computation

y_o (m)	d_{50} (mm)	Ws (m/s)	Wsd_{50}/ν	U* = $(gRS_o)^{1/2}$	U*/Ws	Re*= U^*d_{50}/ν	VS/Ws	Vc/Ws	VcS/Ws
0.50	0.85	0.12	102	0.0529	0.4410	44.983	0.0026	1.6293	0.001222
1.00	0.85	0.12	102	0.0745	0.6207	63.312	0.0042	1.4956	0.0011217
1.65	0.85	0.12	102	0.0927	0.7725	78.798	0.0056	2.05	0.0015375
3.26	0.85	0.12	102	0.1139	0.9494	96.835	0.0073	2.05	0.0015375
4.50	0.85	0.12	102	0.1194	0.9946	101.453	0.0078	2.05	0.0015375
5.50	0.85	0.12	102	0.1354	1.1283	115.083	0.0093	2.05	0.0015375
6.41	0.85	0.12	102	0.1499	1.2493	127.430	0.0106	2.05	0.0015375
7.50	0.85	0.12	102	0.1572	1.3101	133.633	0.0113	2.05	0.0015375
8.50	0.85	0.12	102	0.1706	1.4219	145.029	0.0126	2.05	0.0015375
10.18	0.85	0.12	102	0.1939	1.6155	164.784	0.0149	2.05	0.0015375
11.50	0.85	0.12	102	0.1865	1.5539	158.499	0.0142	2.05	0.0015375
12.50	0.85	0.12	102	0.1998	1.6648	169.809	0.0155	2.05	0.0015375

y_o (m)	Log Ct	C_T (ppm)	C_v (ppm)	Q_j (m^3/s)	T_j (kg/s)
0.50	1.92223	0.00008	0.00003	4.0E-05	0.1072
1.00	2.33238	0.00021	0.00008	0.0004	0.9984
1.65	2.48845	0.00031	0.00012	0.0013	3.4799
3.26	2.66968	0.00047	0.00018	0.0069	18.1980
4.50	2.70775	0.00051	0.00019	0.0176	46.7390
5.50	2.80624	0.00064	0.00024	0.0397	105.290
6.41	2.88155	0.00076	0.00029	0.0731	193.751
7.50	2.91548	0.00082	0.00031	0.1174	311.113
8.50	2.97225	0.00094	0.00035	0.1952	517.278
10.18	3.05695	0.00114	0.00043	0.3919	1038.51
11.50	3.03164	0.00108	0.00041	0.4624	1225.29
12.50	3.07623	0.00119	0.00045	0.6756	1790.30

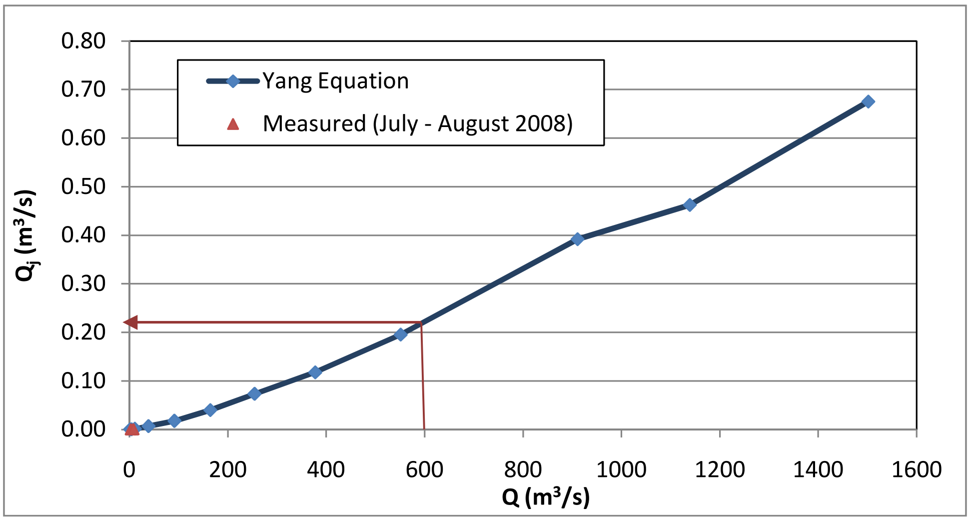
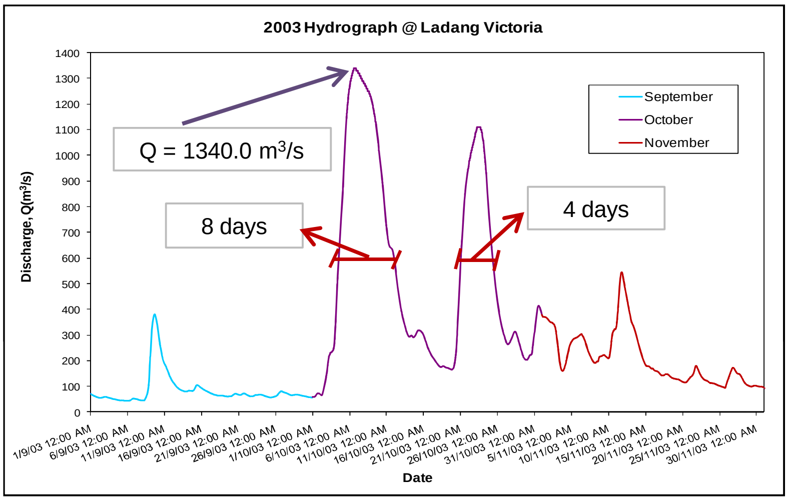


Figure 3: Sediment Rating Curve at Jambatan Nami (MU6), Sungai Muda

(iv) Historical Flood Hydrograph (September - November 2003)

- Choose the most recent event with 50-year ARI

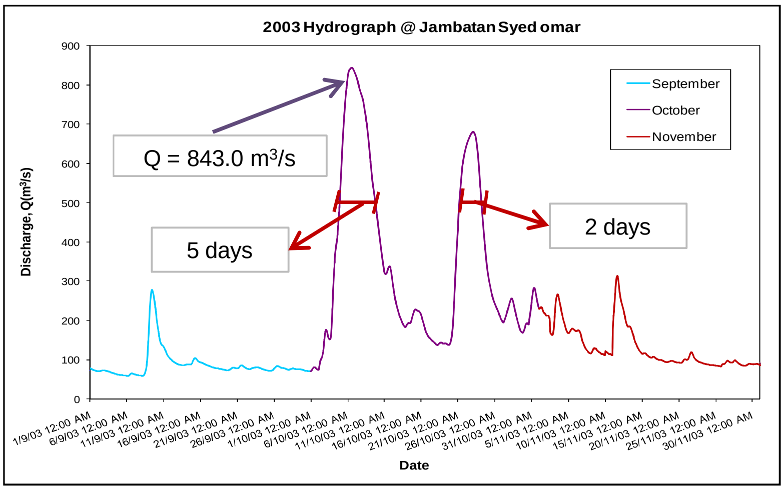


Q = 1340.0 m³/s

8 days

4 days

Figure 4a: Historical Flood hydrograph @ Ladang Victoria



Q = 843.0 m³/s

5 days

2 days

Figure 4b: Historical Flood hydrograph @ Jambatan Syed omar

- Determine period of highflow at 600 m³/s: 10 days

(v) Extraction Volume Determination

For flow discharge = 600.00 m^3/s

Q_j = 0.22 m^3/s

Assuming a 10-day flood,

Total replenishment volume = 0.22 x 10 x 24 x 60 x 60

= 190,080 m^3

This volume is to be spread out at several sites having aggradation and apply the minimum and maximum envelope level requirements.

(vi) Visits to extraction site annually, reviews cross section survey data & estimates the actual amount of replenishment over the flood season.

APPENDIX B

General Description of River Modelling Using HEC-RAS

GENERAL DESCRIPTION OF RIVER MODELLING USING HEC-RAS

HEC-RAS is an integrated package of hydraulic analysis programs in which the user interacts with the system through the use of a graphical user interface (GUI). The current system is capable of performing steady and unsteady flow water surface profile calculations, and sediment transport.

In HEC-RAS terminology, a project is a set of data files associated with a particular river system. The modeler can perform any or all of the various types of analyses included in the HEC-RAS package as part of the project. The data files for a project are categorized as follows: plan data, geometric data, steady flow data, unsteady flow data, sediment data, and hydraulic design data. In this study, HEC-RAS will be utilized as one of the mathematical models to simulate the scour and deposition in Sungai Muda. This general description uses Sungai Muda as an example and other projects to give reader a better explanation on HEC-RAS modelling. Detail description and for user instruction, the reader can also read manual HEC-RAS that available on the web.

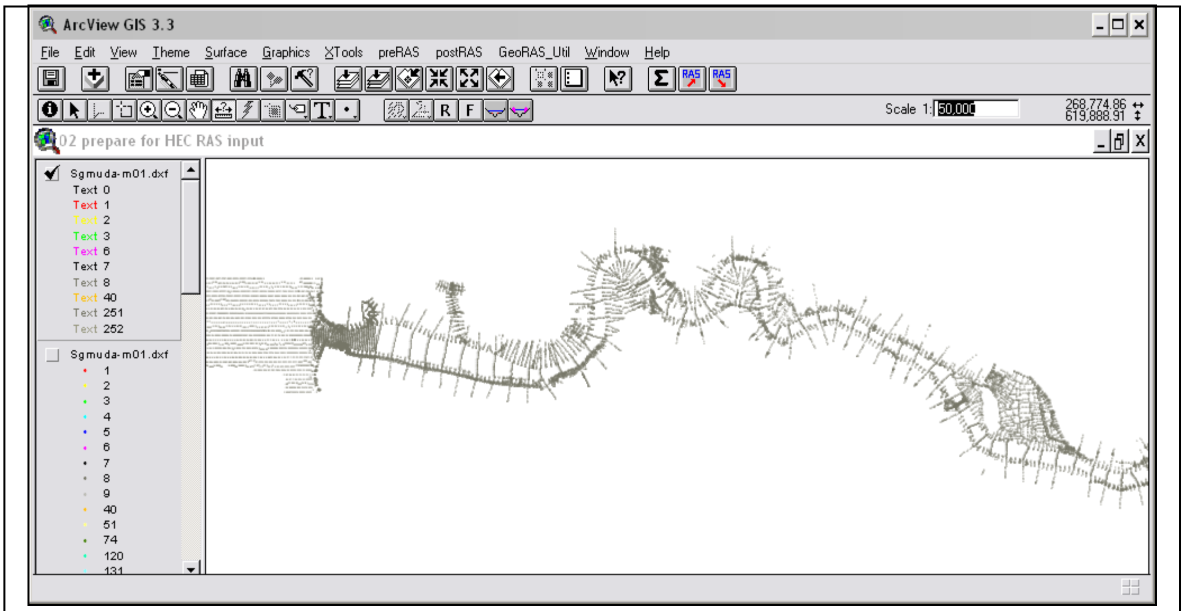
HARDWARE AND SOFTWARE REQUIREMENTS

Intel based PC or compatible, Pentium III or higher
Hard disk – 40 Mb of free space (100Mb is recommended)
RAM – 32 Mb for Windows 95, 98, ME, or 64 Mb for Windows NT, 2000 or XP (128 Mb is recommended)
Color Video Display – Super VGA and large monitor screen is recommended

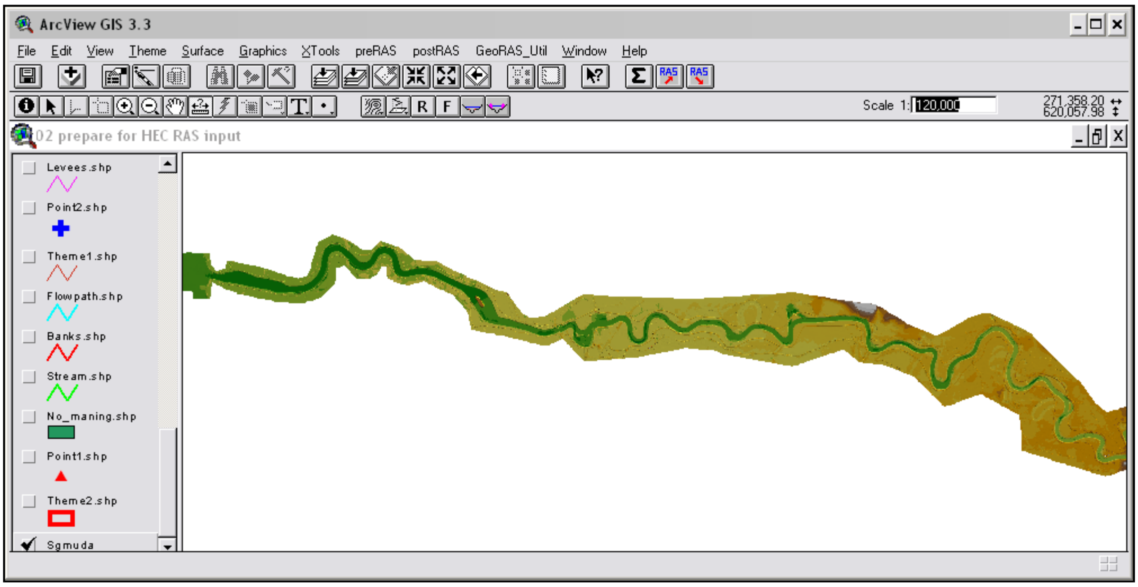
I. INPUT DESCRIPTION

1. GEOMETRIC DATA

HEC-RAS has the ability to import three-dimensional (3D) river schematic and cross section data created in a GIS or CADD system. The geometric input for was derived from the 2001 surveyed plan for the Proposed Sungai Muda Flood Mitigation Project provided by the DID in the CAD format. The modeler develops the geometric data by either first drawing in the river system schematic on the Geometric Data window or by importing geometric data from a GIS. The study stretch is approximately 40 km from the upstream most at Ladang Victoria to the river mouth. The survey data reasonably dense with the distance between detail cross-section (river and floodplain) is about 200 to 250 m. Interpolation using GIS system was applied to transform the CAD survey plans to GIS format as shown in Figure 1.



(a) CAD of Sungai Muda (downstream reach) system (scale 1:500000)



(b) TIN of entire study reach of Sungai Muda (scale 1:500000)

Figure 1: Plan View of Sungai Muda in CAD and GIS Formats

2. BOUNDARY CONDITIONS FOR FLOW OR WATER SURFACE ELEVATION

Boundary conditions are necessary to establish the starting water surface at the ends of the river system (upstream and downstream). A starting water surface is necessary in order for the program to begin the calculations. In a subcritical flow regime, boundary conditions are only necessary at the downstream ends of the river system. If a supercritical flow regime is going to be calculated, boundary conditions are only necessary at the upstream ends of the river system. If a mixed flow regime calculation is going to be made, then boundary conditions must be entered at all ends of the river system.

Inflow hydrograph of year 2003 for station at Ladang Victoria (Figure 2) was used for the upstream boundary condition and tide record for the year 2003 (Figure 3) as the downstream boundary condition.

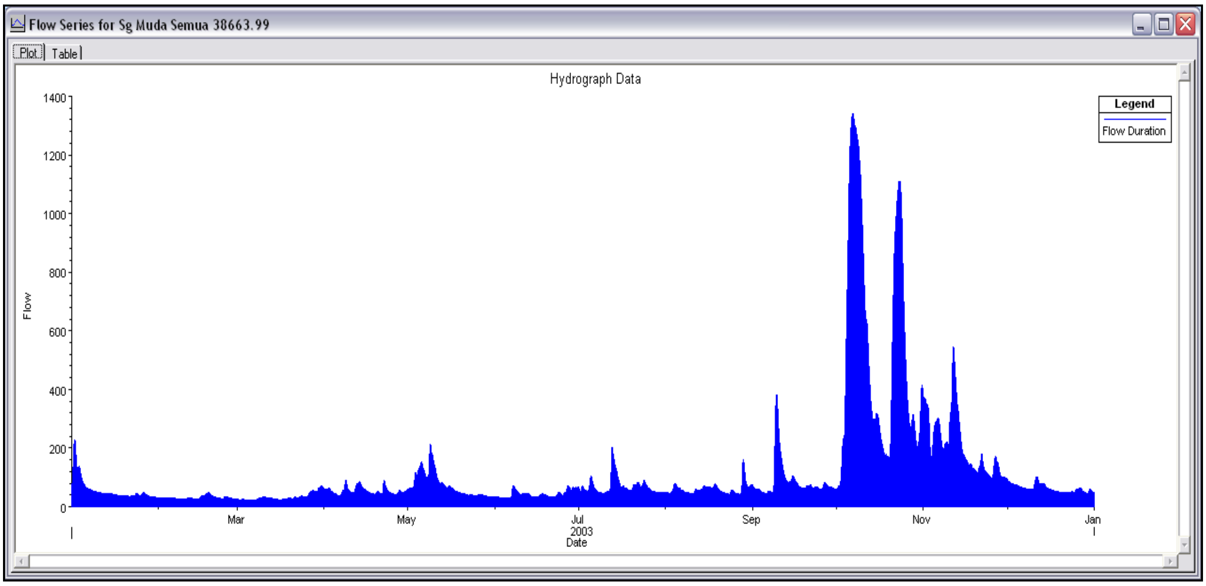


Figure 2: Inflow Hydrograph Used for the Sediment Transport Modelling of Sungai Muda

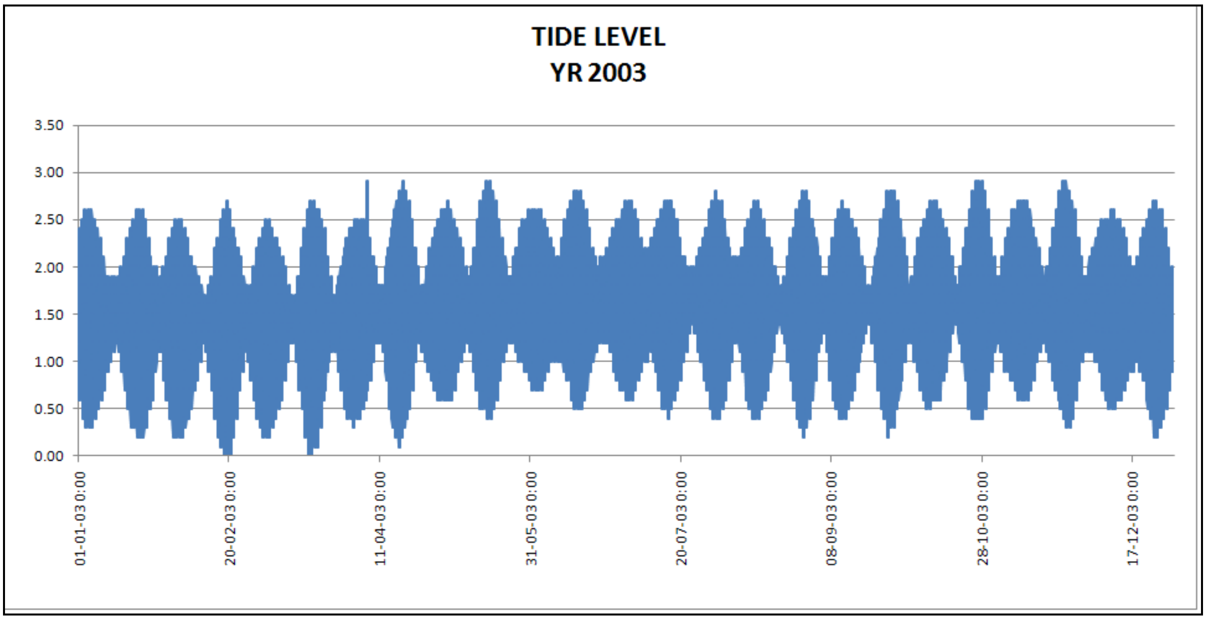
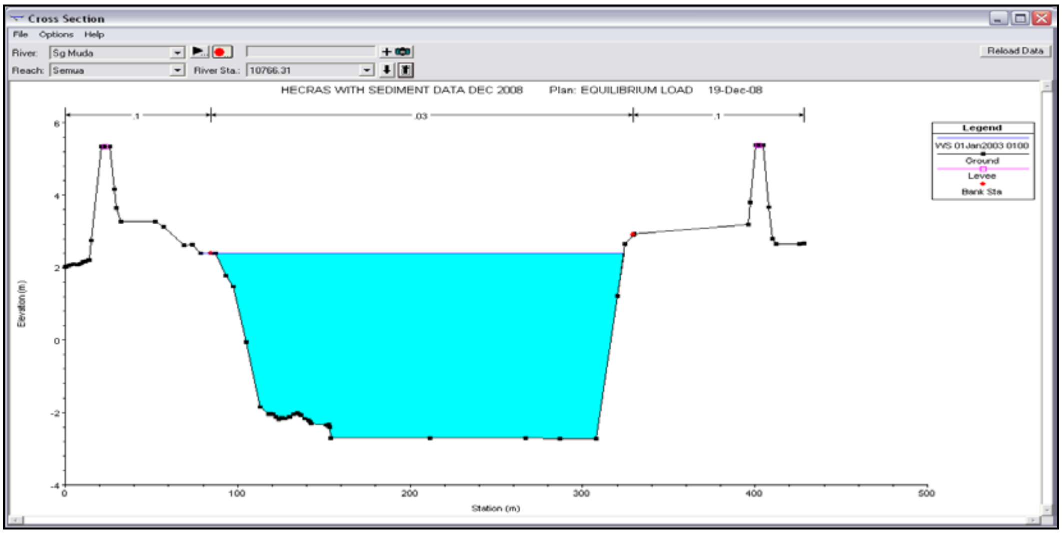


Figure 3: Stage Hydrograph as Downstream Boundary Condition used for Sungai Muda Sediment Transport Modeling

3. CROSS SECTION AND CHANNEL BED ROUGHNESS COEFFICIENT

Cross section data represent the geometric boundary of the stream. Cross sections are located at relatively short intervals along the stream to characterize the flow carrying capacity of the stream and its adjacent floodplain. Cross sections are required at representative locations throughout the stream and at locations where changes occur in discharge, slope, shape, roughness, at locations where levees begin and end, and at hydraulic structures. Manning's *n* of 0.03 was used for the stream and 0.08 for the floodplain in Sungai Muda HEC-RAS as shown in Figure 4.


River: Sg Muda
Reach: Semua
River Sta.: 10766.31

HECRAS WITH SEDIMENT DATA DEC 2008 Plan: EQUILIBRIUM LOAD 19-Dec-08

Figure 4: Cross-sections and Manning Coefficient

4. SEDIMENT INPUT

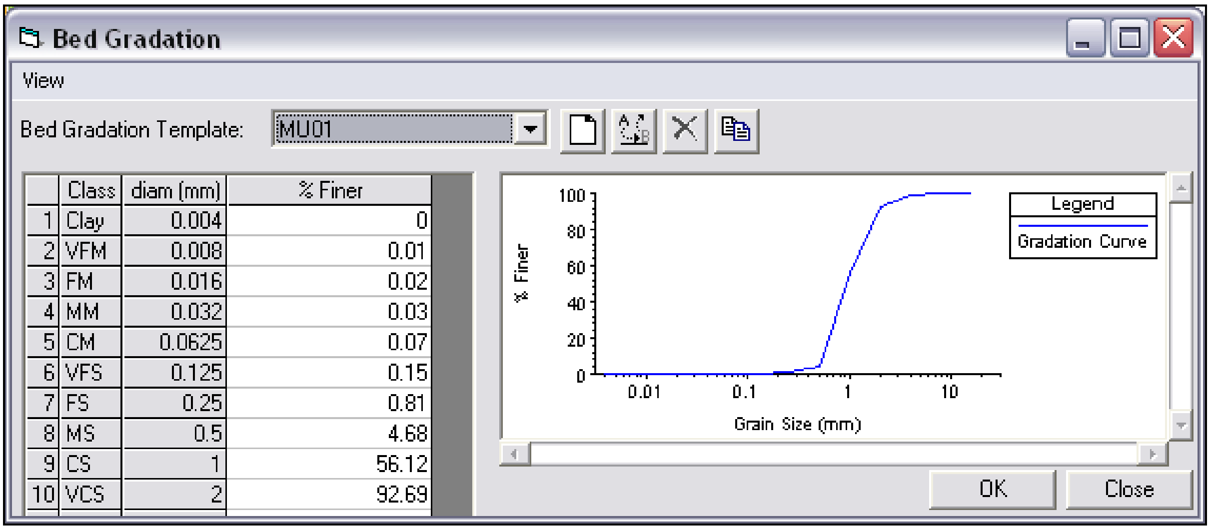
Once the geometric data are entered, the modeler can enter the sediment data required to develop a mobile bed sediment transport model. However, it is suggested that the modeler first run a series of profiles using the Steady Flow Analysis option. This will allow the modeler to work out any problems with the river hydraulics calculations, and to develop a robust hydraulic model before attempting the mobile bed calculations.

To access the sediment data editor, select Sediment Data from the Edit menu or press the sediment data icon. Inputs for sediment transport model are:

(i) Bed gradations: Each cross section must have an associated bed gradation. HEC-RAS first requires the creation of bed material gradation templates. Then the bed gradations templates can be associated with the appropriate range of cross sections using pick and drag functionalities. These information are from the sediment data collected during the study period as shown in Figure 5

(ii) Transport function: Yang equation was used for the simulation. Sediment transport results are strongly dependent on which transport function is selected. Carefully review the range of assumptions, hydraulic conditions and grain sizes for which each method was developed, and select the method developed under conditions that most closely represent the system of interest.

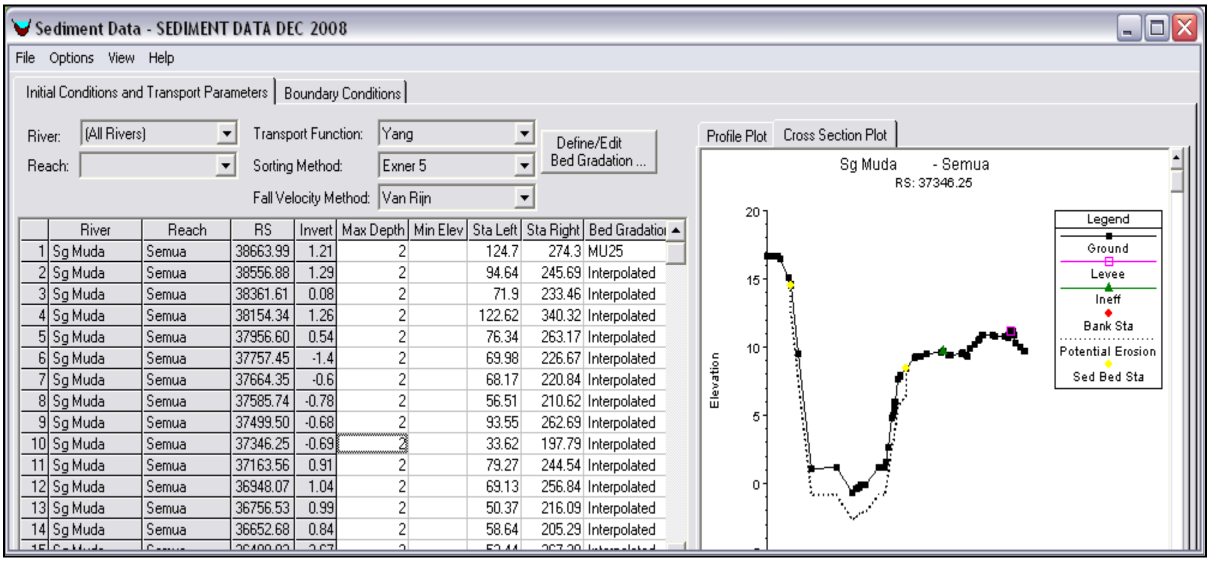
(iii) Sediment boundary condition: Equivalent load as shown in Figure 6. On the boundary conditions tab, sediment loads can be specified in a variety of locations and formats. The form will automatically list external boundaries of the model. Sediment boundary conditions must be specified for all external boundary conditions. Lateral boundary conditions can be added as appropriate.



Bed Gradation Template: MU01

	Class	diam (mm)	% Finer
1	Clay	0.004	0
2	VFM	0.008	0.01
3	FM	0.016	0.02
4	MM	0.032	0.03
5	CM	0.0625	0.07
6	VFS	0.125	0.15
7	FS	0.25	0.81
8	MS	0.5	4.68
9	CS	1	56.12
10	VCS	2	92.69

Figure 5: Bed Gradations of Sungai Muda



River: (All Rivers)
Reach:
Transport Function: Yang
Sorting Method: Exner 5
Fall Velocity Method: Van Rijn

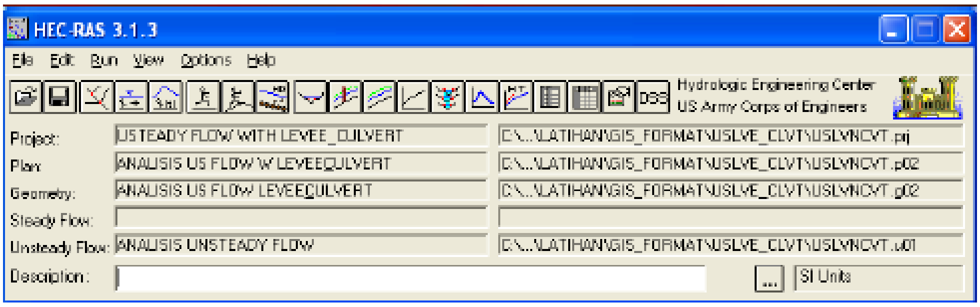
	River	Reach	RS	Invert	Max Depth	Min Elev	Sta Left	Sta Right	Bed Gradatio
1	Sg Muda	Semua	38663.99	1.21	2		124.7	274.3	MU25
2	Sg Muda	Semua	38556.88	1.29	2		94.64	245.69	Interpolated
3	Sg Muda	Semua	38361.61	0.08	2		71.9	233.46	Interpolated
4	Sg Muda	Semua	38154.34	1.26	2		122.62	340.32	Interpolated
5	Sg Muda	Semua	37956.60	0.54	2		76.34	263.17	Interpolated
6	Sg Muda	Semua	37757.45	-1.4	2		69.98	226.67	Interpolated
7	Sg Muda	Semua	37664.35	-0.6	2		68.17	220.84	Interpolated
8	Sg Muda	Semua	37585.74	-0.78	2		56.51	210.62	Interpolated
9	Sg Muda	Semua	37499.50	-0.68	2		93.55	262.69	Interpolated
10	Sg Muda	Semua	37346.25	-0.69	2		33.62	197.79	Interpolated
11	Sg Muda	Semua	37163.56	0.91	2		79.27	244.54	Interpolated
12	Sg Muda	Semua	36948.07	1.04	2		69.13	256.84	Interpolated
13	Sg Muda	Semua	36756.53	0.99	2		50.37	216.09	Interpolated
14	Sg Muda	Semua	36652.68	0.84	2		58.64	205.29	Interpolated

Figure 6: Yang Equations and Equivalent Load were used for Sungai Muda HEC-RAS Input

II. RUNNING THE MODEL

Four files are required to run a HEC-RAS project (Figure 7).
Project File - acts as a file management tool and identifies which files are used in the model;
Plan File - sets the model conditions as subcritical, supercritical, or mixed flow and runs the simulation;
Geometry File - contains all the geometric attributes for the model; and
Steady/Unsteady Flow File - establishes the flow and boundary conditions at numerous points in time for the model.

On the HEC-RAS interface, the project plan, geometry, and unsteady flow information should now be filled with the names of those respective files as shown below.



Project: USTEADY FLOW WITH LEVEE_CULVERT C:\...\LATIHAN\GIS_FORMAT\USLVE_CLVT\USLVNCVT.prj
Plan: ANALISIS US FLOW W LEVEECULVERT C:\...\LATIHAN\GIS_FORMAT\USLVE_CLVT\USLVNCVT.p02
Geometry: ANALISIS US FLOW LEVEECULVERT C:\...\LATIHAN\GIS_FORMAT\USLVE_CLVT\USLVNCVT.g02
Steady Flow:
Unsteady Flow: ANALISIS UNSTEADY FLOW C:\...\LATIHAN\GIS_FORMAT\USLVE_CLVT\USLVNCVT.u01
Description:
SI Units

Figure 7: Files Required to be fill in HEC-RAS Interface

To start HEC-RAS, double click the **HEC-RAS** icon in Windows as shown in Figure 8. The HEC-RAS interface will show up unit system need to be set before starting a new project as shown in Figure 9.

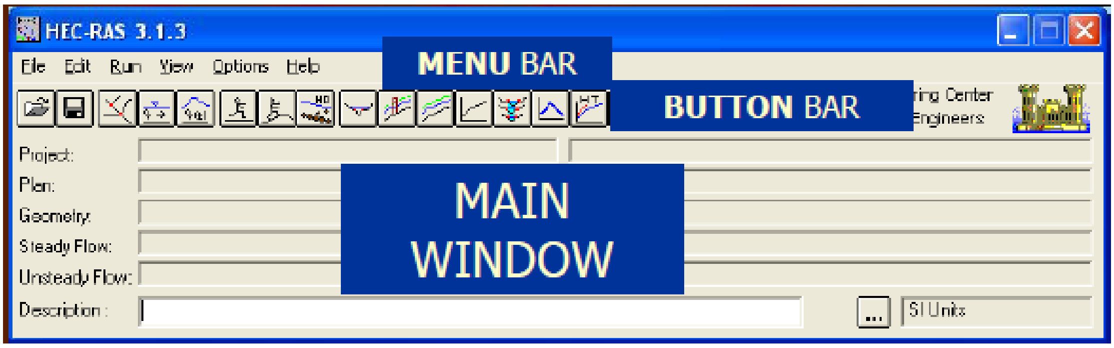


Figure 8: HEC-RAS Main Interface

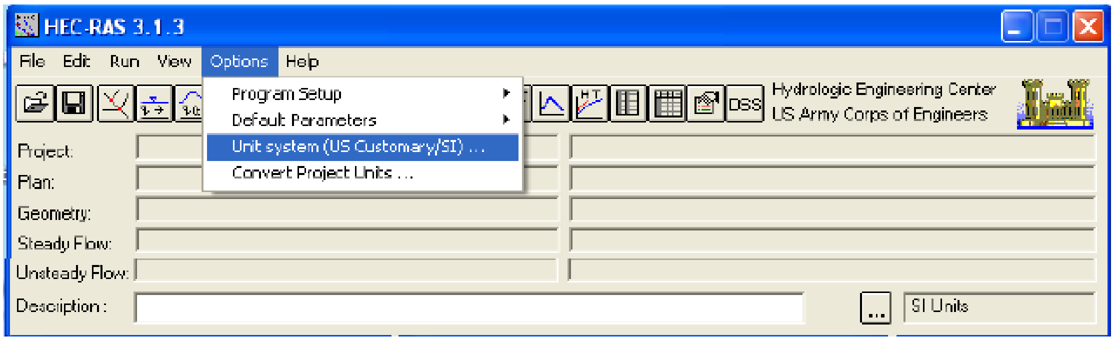


Figure 9: Setting Unit Systems for HEC-RAS

Entering and Editing Geometric Data

The modeler develops the geometric data by either first drawing in the river system schematic on the **Geometric Data** window (Figure 10). The River System Schematic is a diagram of how the stream system is connected together. The river system is drawn on a reach-by-reach basis, by pressing the **River Reach** button and then drawing in a reach from upstream to downstream (in the positive flow direction). Each reach is identified with a **River Name** and a **Reach Name**. The **River Name** should be the actual name of the stream, while the reach name is an additional qualifier for each hydraulic reach within that river. A river can be comprised of one or more reaches. Reaches start or end at locations where two or more streams join together or spilt apart. Reaches also start or end at the open ends of the river system being modeled.

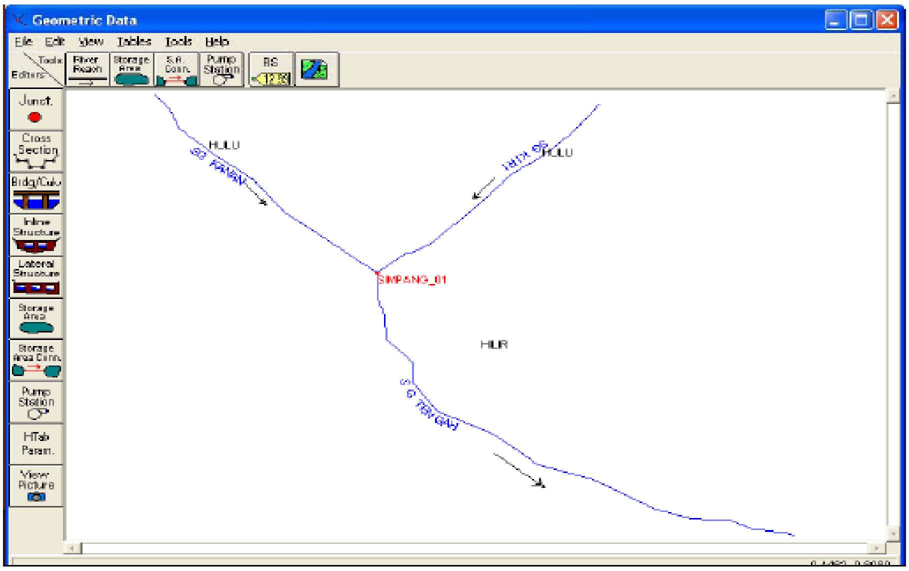
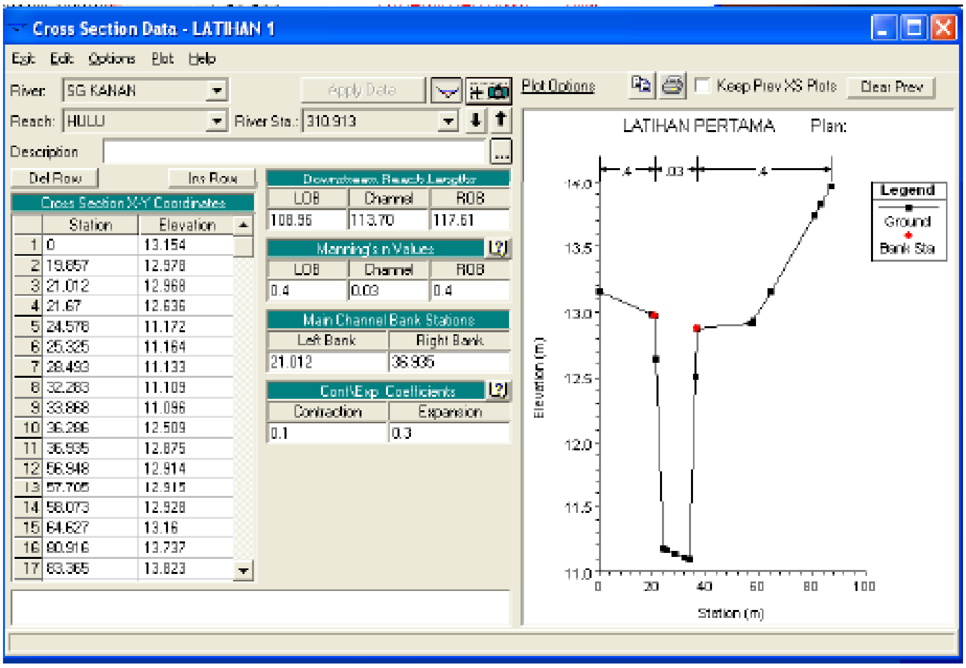


Figure 10: Geometric Data Editor Window

After the river system schematic is completed, the next step for the modeler is to enter the cross section data. Cross section data represent the geometric boundary of the stream. Cross sections are located at relatively short intervals along the stream to characterize the flow carrying capacity of the stream and its adjacent floodplain. Cross sections are required at representative locations throughout the stream and at locations where changes occur in discharge, slope, shape, roughness, at locations where levees begin and end, and at hydraulic (Figure 11).



River: SG KANAN

Reach: HULU

River Sta.: 310.913

Description:

Cross Section X-Y Coordinates

	Station	Elevation
1	0	13.154
2	19.657	12.978
3	21.012	12.968
4	21.67	12.636
5	24.578	11.172
6	25.325	11.164
7	28.493	11.133
8	32.283	11.109
9	33.868	11.096
10	36.286	12.509
11	36.935	12.875
12	56.948	12.914
13	57.705	12.915
14	58.073	12.928
15	64.627	13.16
16	80.916	13.737
17	83.365	13.823

Downstream Reach Lengths

LOB	Channel	ROB
108.96	113.70	117.61

Manning's n Values

LOB	Channel	ROB
0.4	0.03	0.4

Main Channel Bank Stations

Left Bank	Right Bank
21.012	36.935

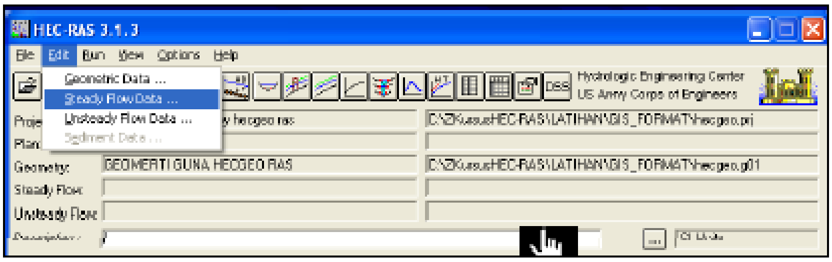
Cont\Exp Coefficients

Contraction	Expansion
0.1	0.3

Figure 11: Cross Section Data Editor

Performing a Steady Flow Analysis

The next step in developing the required data to perform steady flow water surface profile calculations is to enter the steady flow data. To bring up the steady flow data editor, select Steady Flow Data from the **Edit** menu on the HEC-RAS main window. The Steady Flow Data editor should appear as shown in Figure 12.

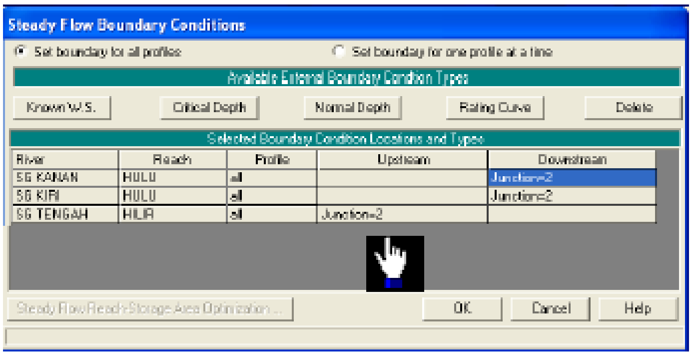


Project: ...y hecgeo ras C:\ZKursusHEC-RAS\LATIHAN\GIS_FORMAT\hecgeo.prj

Geometry: GEOMERTI GUNA HECGEO RAS C:\ZKursusHEC-RAS\LATIHAN\GIS_FORMAT\hecgeo.g01

Figure 12: Steady Flow Data editor

The next step is to enter any required boundary conditions. To enter boundary conditions, press the Enter Boundary Conditions button at the top of the **Steady Flow Data** editor (Figure 13). Boundary conditions are necessary to establish the starting water surface at the ends of the river system. A starting water surface is necessary in order for the program to begin the calculations. In a subcritical flow regime, boundary conditions are only required at the downstream ends of the river system. If a supercritical flow regime is going to be calculated, boundary conditions are only necessary at the upstream ends of the river system. If a mixed flow regime calculation is going to be made, then boundary conditions must be entered at all open ends of the river system.

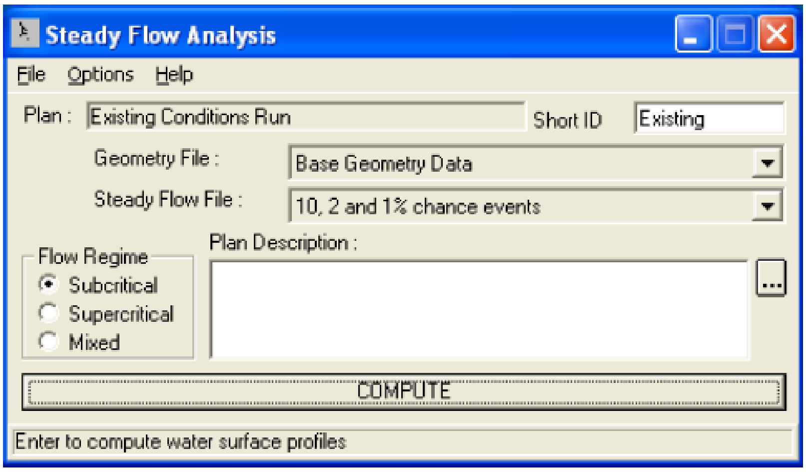


● Set boundary for all profiles ○ Set boundary for one profile at a time

River	Reach	Profile	Upstream	Downstream
SG KANAN	HULU	all		Junction=2
SG KIRI	HULU	all		Junction=2
SG TENGAH	HILIR	all	Junction=2	

Figure 13: Steady Flow Boundary Conditions Editor

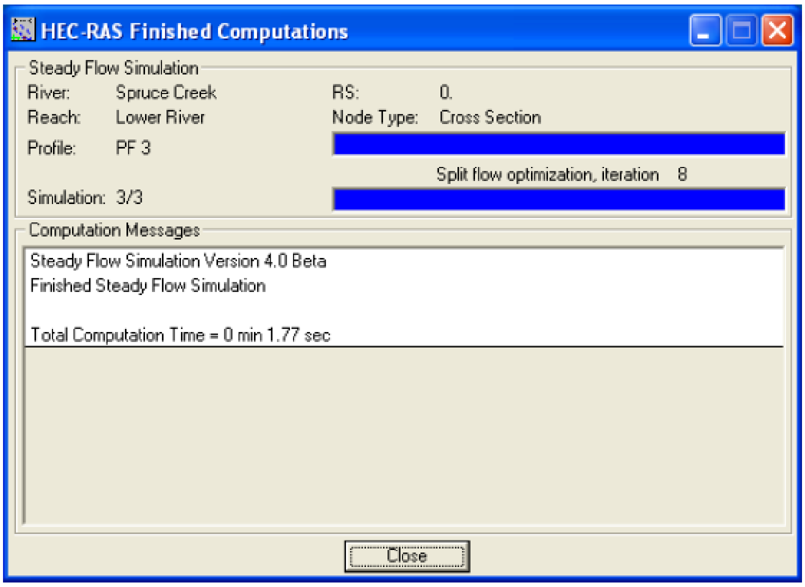
Now that all of the data have been entered, we can calculate the steady water surface profiles. To perform the simulations, go to the HEC-RAS main window and select **Steady Flow Analysis** from the **Run** menu (Figure 14).



Plan : Existing Conditions Run
Short ID: Existing
Geometry File : Base Geometry Data
Steady Flow File : 10, 2 and 1% chance events
Flow Regime
● Subcritical
○ Supercritical
○ Mixed
Plan Description :
Enter to compute water surface profiles

Figure 14: Steady Flow Analysis Simulation Windows

Once all of the data have been entered, and a Plan has been defined, the steady flow computations can be performed by pressing the **Compute** button at the bottom of the steady flow simulation window. Once the compute button is pressed, a separate window will appear showing you the progress of the computations (Figure 15). If the computations ended with a message stating "**Finished Steady Flow Simulation,"** the user can then begin to review the output.



Steady Flow Simulation
River: Spruce Creek
Reach: Lower River
Profile: PF 3
RS: 0.
Node Type: Cross Section
Split flow optimization, iteration 8
Simulation: 3/3

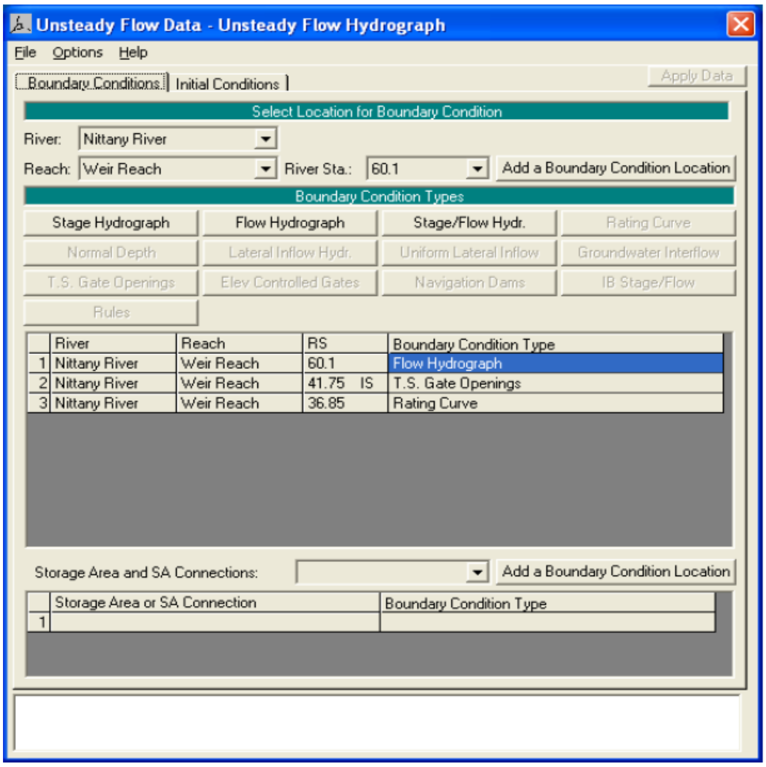
Computation Messages
```
Steady Flow Simulation Version 4.0 Beta
Finished Steady Flow Simulation

Total Computation Time = 0 min 1.77 sec
```

Figure 15: HEC-RAS Steady Flow Computation Progress Window.

Performing an Unsteady Flow Analysis

Once all of the geometric data are entered, the modeler can then enter any unsteady flow data that are required. To bring up the unsteady flow data editor, select **Unsteady Flow Data** from the **Edit** menu on the HEC-RAS main window. The Unsteady flow data editor should appear as shown in Figure 16.



River: Nittany River

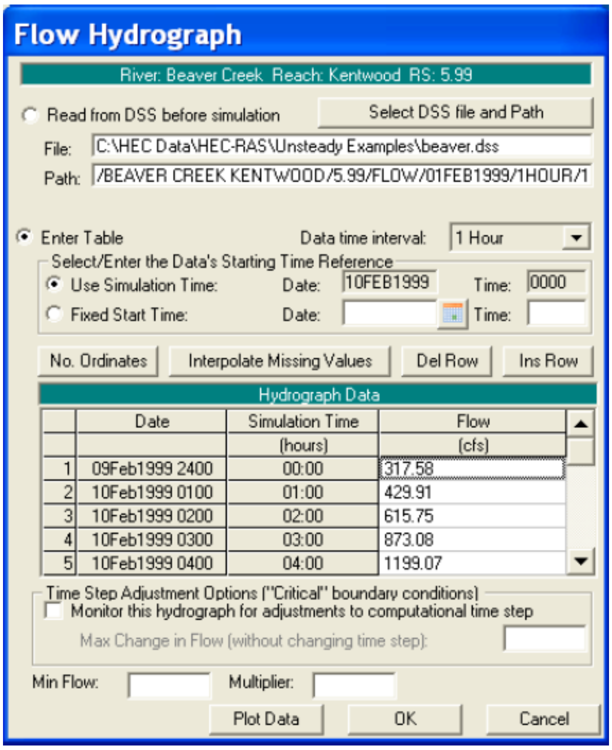
Reach: Weir Reach River Sta.: 60.1

	River	Reach	RS	Boundary Condition Type
1	Nittany River	Weir Reach	60.1	Flow Hydrograph
2	Nittany River	Weir Reach	41.75 IS	T.S. Gate Openings
3	Nittany River	Weir Reach	36.85	Rating Curve

	Storage Area or SA Connection	Boundary Condition Type
1		

Figure 16: Unsteady Flow Data Editor

A flow hydrograph can be used as either an upstream boundary or downstream boundary condition, but is most commonly used as an upstream boundary condition. When the flow hydrograph button is pressed, the window shown in Figure 17 will appear.



River: Beaver Creek Reach: Kentwood RS: 5.99

○ Read from DSS before simulation

File: C:\HEC Data\HEC-RAS\Unsteady Examples\beaver.dss

Path: /BEAVER CREEK KENTWOOD/5.99/FLOW/01FEB1999/1HOUR/1

● Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

● Use Simulation Time: Date: 10FEB1999 Time: 0000

○ Fixed Start Time: Date: Time:

	Date	Simulation Time (hours)	Flow (cfs)
1	09Feb1999 2400	00:00	317.58
2	10Feb1999 0100	01:00	429.91
3	10Feb1999 0200	02:00	615.75
4	10Feb1999 0300	03:00	873.08
5	10Feb1999 0400	04:00	1199.07

Time Step Adjustment Options ("Critical" boundary conditions)

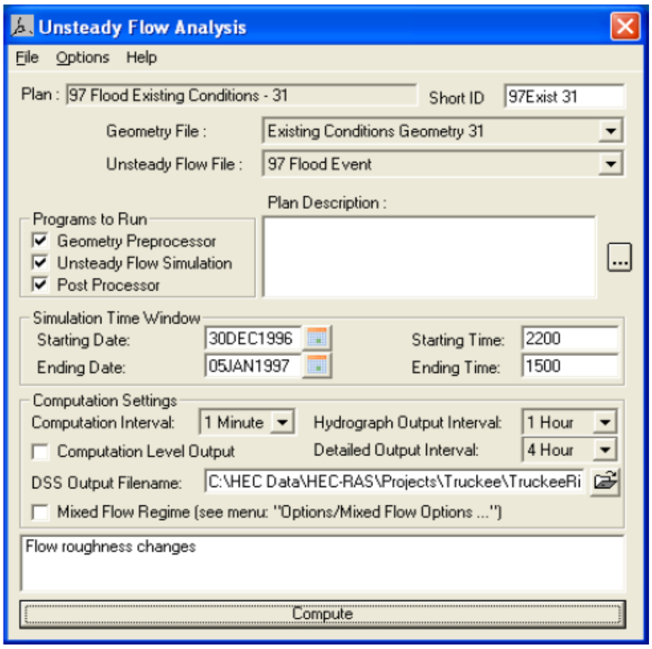
☐ Monitor this hydrograph for adjustments to computational time step

Max Change in Flow (without changing time step):

Min Flow: Multiplier:

Figure 17: Example Flow Hydrograph Boundary Condition

Once all of the geometry and unsteady flow data have been entered, the user can begin performing the unsteady flow calculations. To run the simulation, go to the HEC-RAS main window and select **Unsteady Flow Analysis** from the Run menu. The Unsteady Flow Analysis window will appear as in Figure 18.



Plan : 97 Flood Existing Conditions - 31
Short ID 97Exist 31
Geometry File : Existing Conditions Geometry 31
Unsteady Flow File : 97 Flood Event
Plan Description :

Programs to Run
☑ Geometry Preprocessor
☑ Unsteady Flow Simulation
☑ Post Processor

Simulation Time Window
Starting Date: 30DEC1996
Ending Date: 05JAN1997
Starting Time: 2200
Ending Time: 1500

Computation Settings
Computation Interval: 1 Minute
Hydrograph Output Interval: 1 Hour
☐ Computation Level Output
Detailed Output Interval: 4 Hour
DSS Output Filename: C:\HEC Data\HEC-RAS\Projects\Truckee\TruckeeRi
☐ Mixed Flow Regime (see menu: "Options/Mixed Flow Options ...")

Flow roughness changes

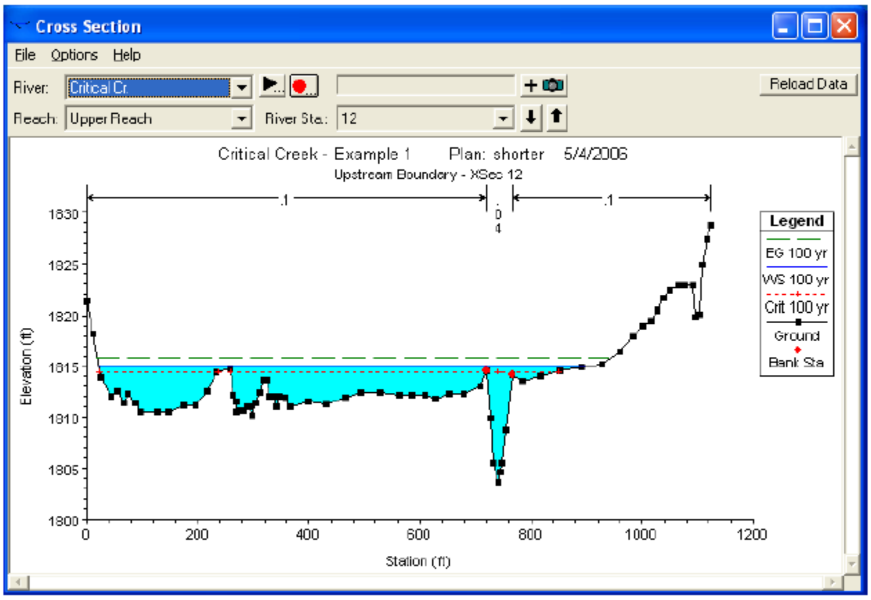
Figure 18: Unsteady Flow Analysis Windows

III. OUTPUT DESCRIPTION

After the model has finished the steady or unsteady flow computations the user can begin to view the output. Output is available in a graphical and tabular format. The current version of the program allows the user to view cross sections, water surface profiles, general profiles, rating curves, hydrographs, X-Y-Z perspective plots, detailed tabular output at a single location, and summary tabular output at many cross sections.

1. Cross Sections, Profiles, and Rating Curves

To view a graphic on the screen, select Cross Sections, Water Surface Profiles, or Rating Curves from the **View** menu on the HEC-RAS main window. Once you have selected one of these options, a window will appear with the graphic plotted in the viewing area. An example cross-section plot is shown in Figure 19. The user can plot any cross section by simply selecting the appropriate reach and river station from the list boxes at the top of the plot. The user can also step through the cross section plots by using the up and down arrows.



River: Critical Cr

Reach: Upper Reach

River Sta.: 12

Figure 19: Example Cross Section Plot

An example profile plot is shown in Figure 20. The profile plot displays the water surface profile for the first reach in the river system. If there is more than one reach, additional reaches can be selected from the Options menu on or the reach button at the top of the window.

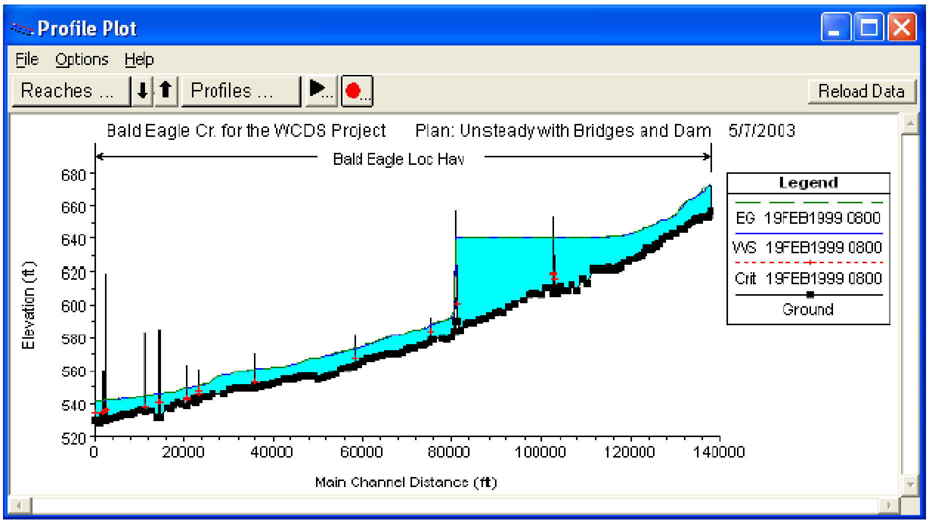
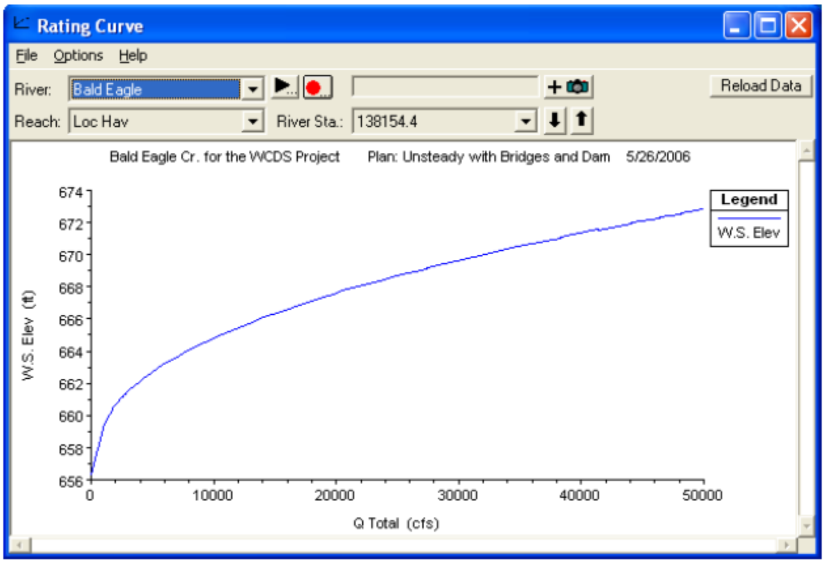


Figure 20: Example Profile Plot

An example rating curve plot is shown in Figure 21. The rating curve is a plot of the water surface elevation versus flow rate for the profiles that were computed. A rating curve can be plotted at any location by selecting the appropriate reach and river station from the list boxes at the top of the plot.



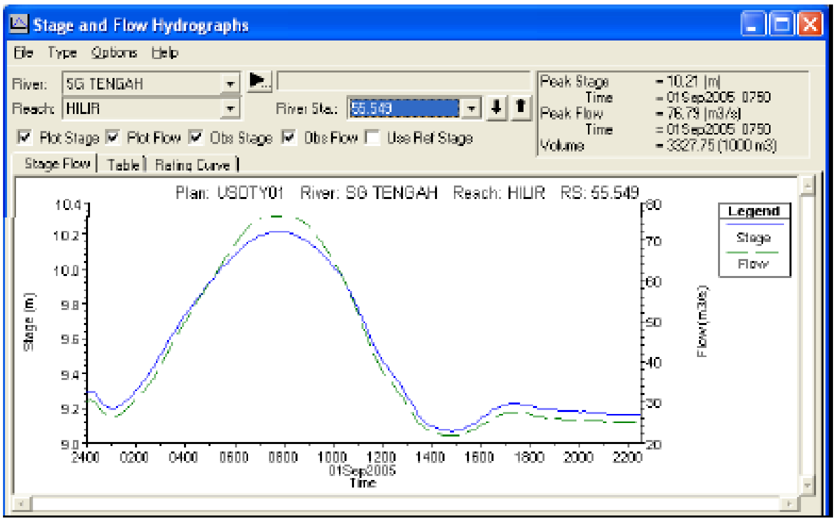
River: Bald Eagle
Reach: Loc Hav
River Sta.: 138154.4

Bald Eagle Cr. for the WCDS Project Plan: Unsteady with Bridges and Dam 5/26/2006

Figure 21: Example Rating Curve Plot

2. Stage and Flow Hydrographs

If the user has performed an unsteady flow analysis, then stage and flow hydrographs will be available for viewing. To view a stage and/or flow hydrograph, the user selects **Stage** and **Flow** from the **View** menu of the main HEC-RAS window. When this option is selected a plot will appear as shown in Figure 22.



River: SG TENGAH
Reach: HILIR
River Sta.: 55.549

☑ Plot Stage ☑ Plot Flow ☑ Obs Stage ☑ Obs Flow ☐ Use Ref Stage

Peak Stage = 10.21 (m)
Time = 01Sep2005 0750
Peak Flow = 76.79 (m3/s)
Time = 01Sep2005 0750
Volume = 3327.75 (1000 m3)

Plan: USDTY01 River: SG TENGAH Reach: HILIR RS: 55.549

Figure 22: Stages and Flow Hydrograph Plot

3. Sediment Spatial Plot

There are a wide array of variables that can be accessed either in plot or table form by selecting **Sediment Spatial Plot** from the **View** Menu of the main HEC-RAS dialog. These include: thalweg elevation, water surface elevation, velocity, bed change, and an array of weights and volumes tracked by layer and grain size. Figure 23 shows that Sungai Muda will experience deposition throughout the river reach. Rate of deposition is higher at the downstream reach as shown in Figure 24.

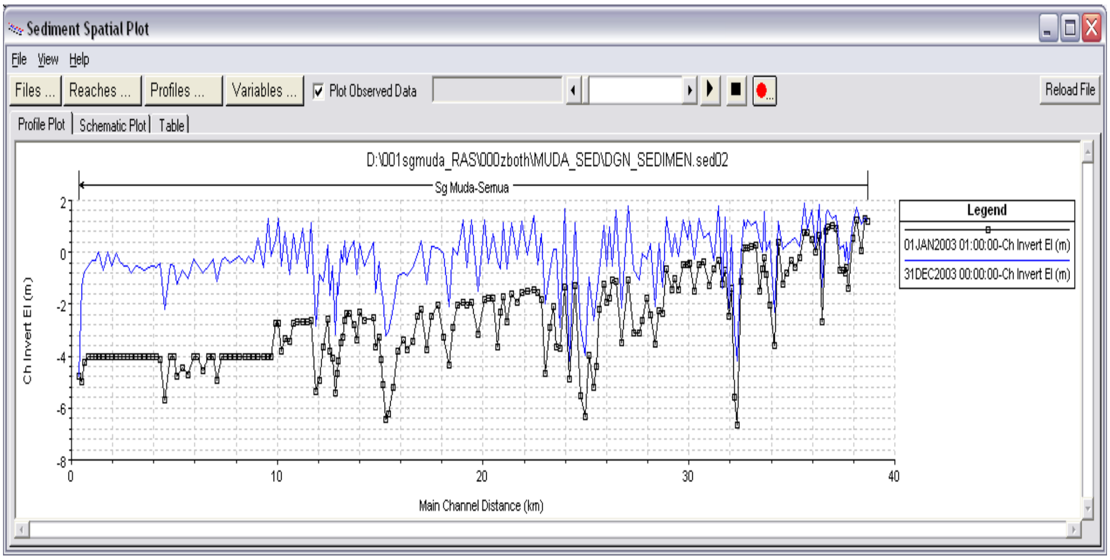


Figure 23: Bed Levels of Sungai Muda Before and After Simulation (1 year)

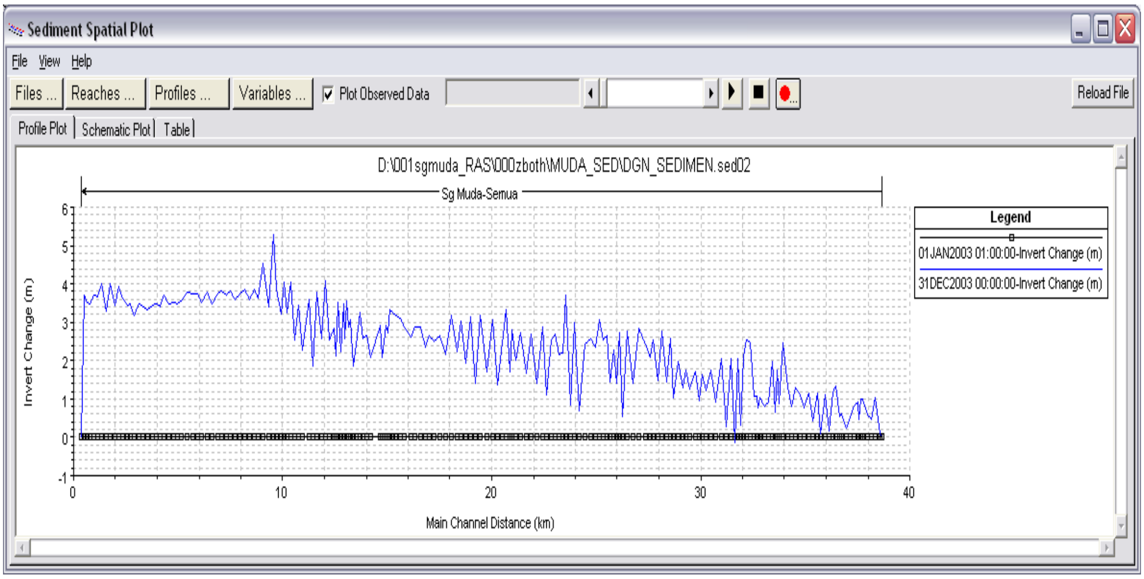


Figure 24: Invert Changes Before and After Simulation (1 year)

4. Sediment Time Series

Similarly, by selecting **Sediment Time Series** and **RC Plot** from the **View** Menu of the main HEC-RAS dialog a user can plot the change in the same variable(s) over time at a single cross section. Erosion or deposition does not necessarily follow the rate of flow. This is an important factor to determine the locations of suitable sand mining sites. Figure 25 shows the flow discharge example for Sungai Muda and Figure 26 shows erosion occur during high flow at the invert changes for STN 36948.07. Invert change for STN 31609.87 shows that the sedimentation for 2 months, where the rapid erosion occur from about 1 week and then stabilize at 0.15 m below proposed level as shown in Figure 27.

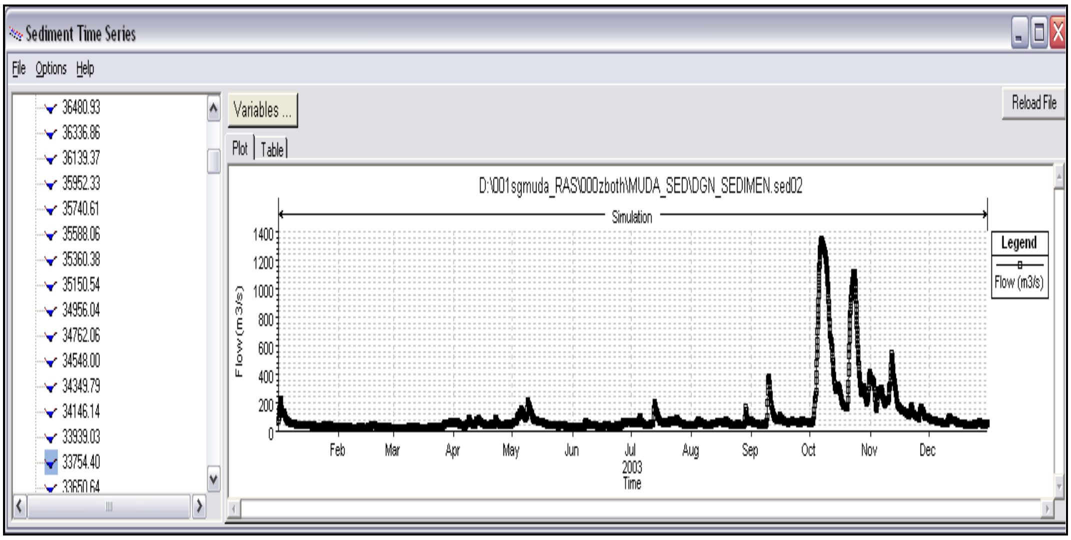


Figure 25: Flow Discharge

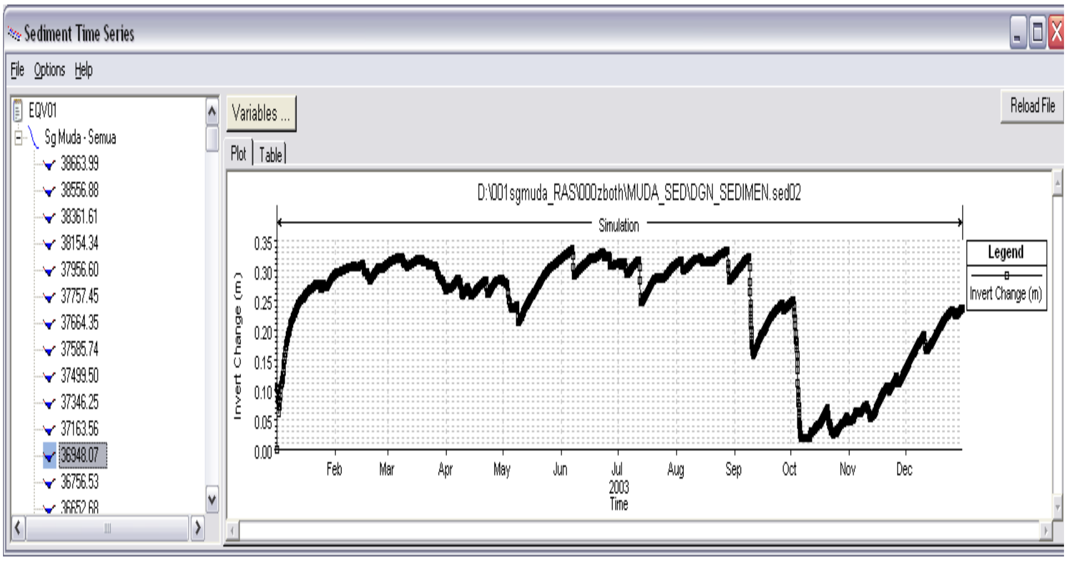


Figure 26: Invert Change for STN 36948.07 – Erosion during High Flow

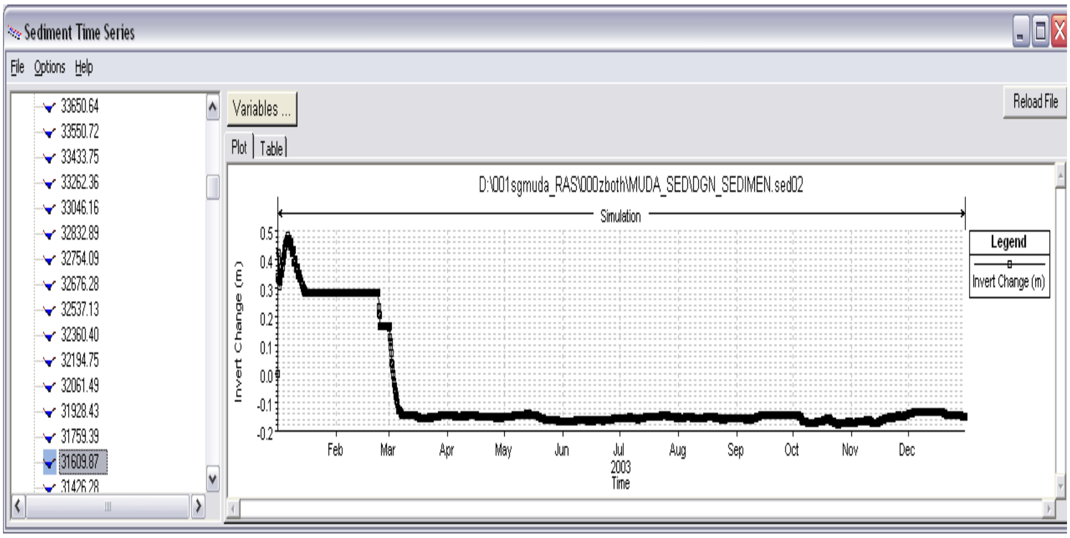


Figure 27: Invert Change for STN 31609.87

APPENDIX C

Stable Channel Determination

STABLE CHANNEL DIMENSIONS

The stable channel dimensions can be determined from existing sediment transport equations such as Engelund-Hansen and Yang using the flow chart suggested by Chang (1988) as shown in Figure 1. Table 1 gives an example of stable channel dimensions for Sungai Muda at the existing sand mining pit (CH 33.60) and Sungai Langat (CH 76715) at the upstream. For the selected sediment size, flow discharge and sediment transport rate, the stable channel dimensions can be determined. Table 1, Figure 2 and Figure 3 show that degradation or the lowering of the existing river bed might occur.

Table 1: River Stable Dimension

River	Input				Output		
	d_{50} (mm)	Q (m^3/s)	Q_s (m^3/s)	Z	B (m)	y_o (m)	S_o
Sungai Muda (CH 33.60)	1.00	1000	0.05	3	89.00	4.55	0.000046
Sungai Langat (CH 76715)	1.00	650	0.03	3	75.00	3.85	0.000046

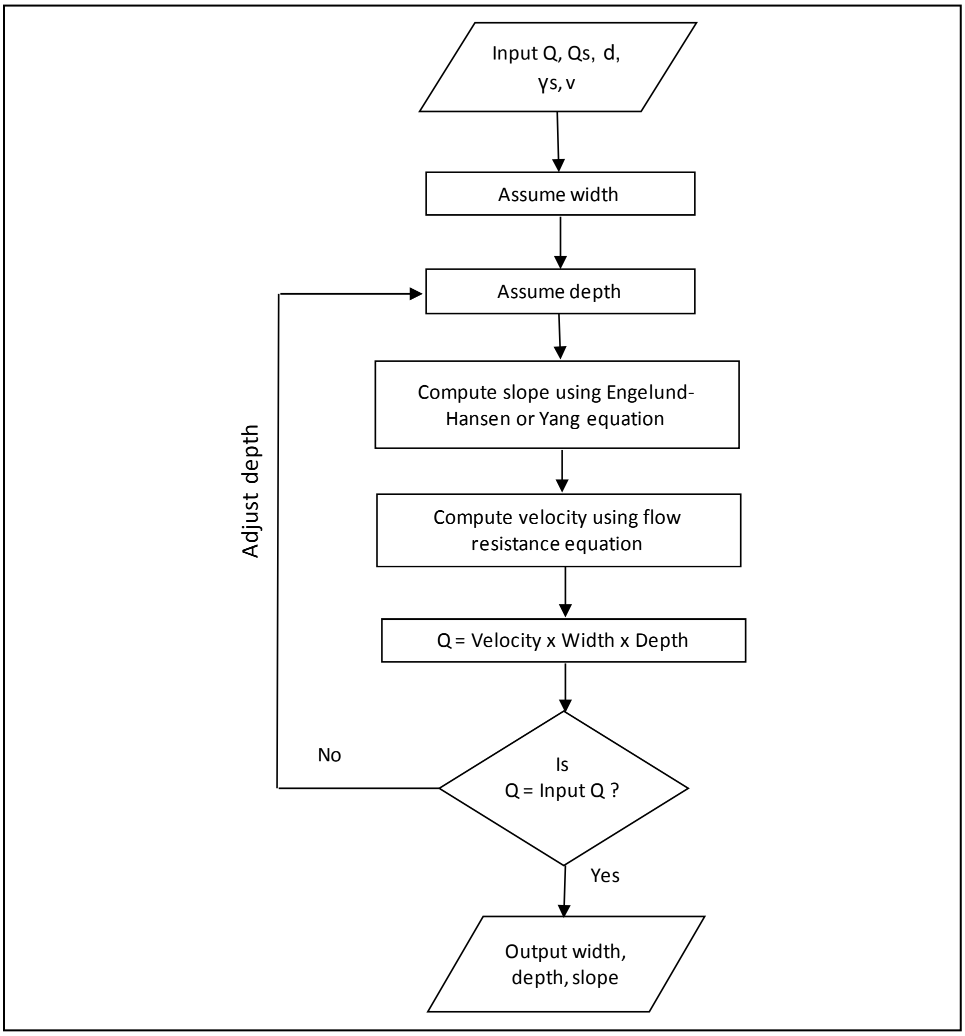


Figure 1: Determination of a Stable Channel Dimension

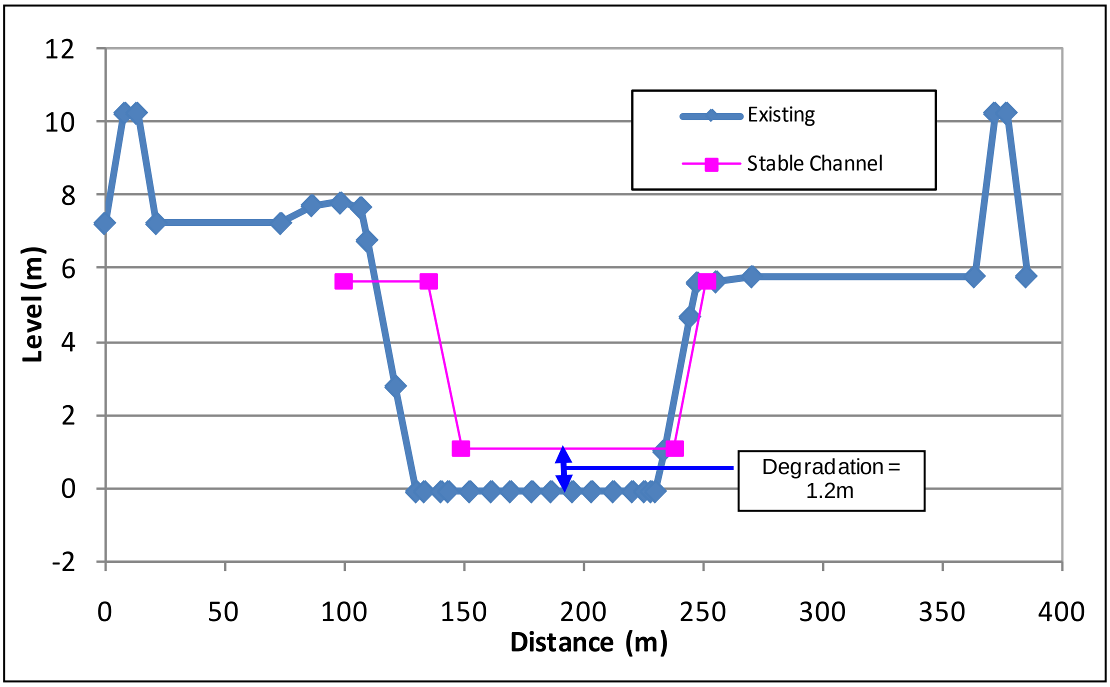


Figure 2: Existing and Stable Channel Cross Sections for an On-Going Sand Mining Pit at Sungai Muda (CH 33.60)

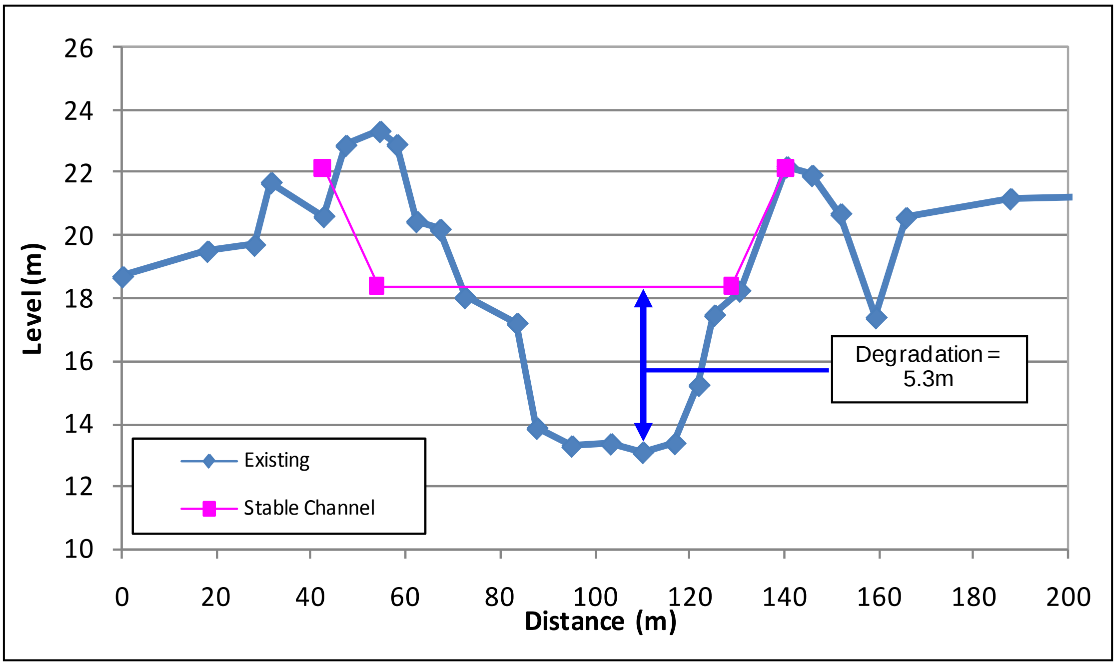


Figure 3: Existing and Stable Channel Cross Sections at Sungai Langat (CH 76715)