UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

The Role Of Paddy Field In Flood Control: Case Study Of Muda Irrigation Scheme (Region 3)

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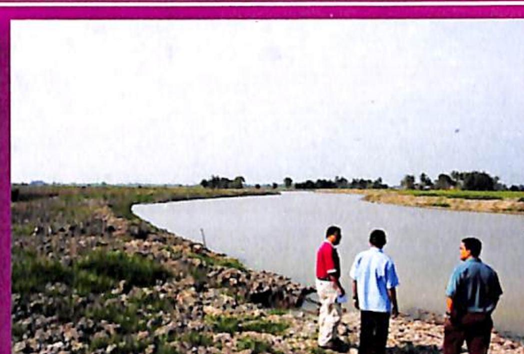
APEX

THE ROLE OF PADDY FIELD IN FLOOD CONTROL: CASE STUDY OF MUDA IRRIGATION SCHEME (REGION 3)

Short Term Research Project Report
(Grant No.: 304 / PREDAC / 60312036)



By

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THE ROLE OF PADDY FIELD IN FLOOD CONTROL: CASE STUDY OF MUDA IRRIGATION SCHEME (REGION 3)

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CHAPTER 1
INTRODUCTION

1.1 Background

Paddy fields are found majority in the Asian regions where it contributes staple food i.e. rice which are consumed by almost half of the world's population in this region. Generally, paddy fields have multiple roles. However, one of the roles of paddy fields is flood control, which is important to stakeholder.

Recent situation have emerged in Malaysia as well in the Asian regions in and around the paddy fields such as urbanization (rapid development and land conversions) leading to flood and dam age to property as well as inconvenience and disruption to social activities. This situation is aggravated by climatic change so called global warming. Necessary actions are needed to eradicate these issues to maintain and enhancing both the environment and culture in a sustainable matter for the paddy fields.

Traditional paddy field of Peninsular Malaysia yield crops once a year for centuries. Through the establishment of Muda Agricultural Development Authority or MADA, paddy plant was successfully cultivated twice a year. State of Kedah receives high rainfall throughout the year. This can cause problems to farmers and their paddy field due to heavy rain could potentially cause flood and losses to the farmers. In addition, this can also affects the paddy production target set by MADA

MADA is divided into four regional offices for the smooth administration, namely Region I (Kangar, Perlis), Region II (Jitra, Kedah), Region III (Pendang, Kedah), and Region IV (Kota Sarang Semut, Kedah), as show in Figure 1.1. Region III that cover almost the entire Pendang District in Kedah is selected as the study area upon recommendation by MADA office. It should be noted that the actual study area involved in this study only consists of a portion from the Region III, which was found to be suitable in achieving the scope of study.

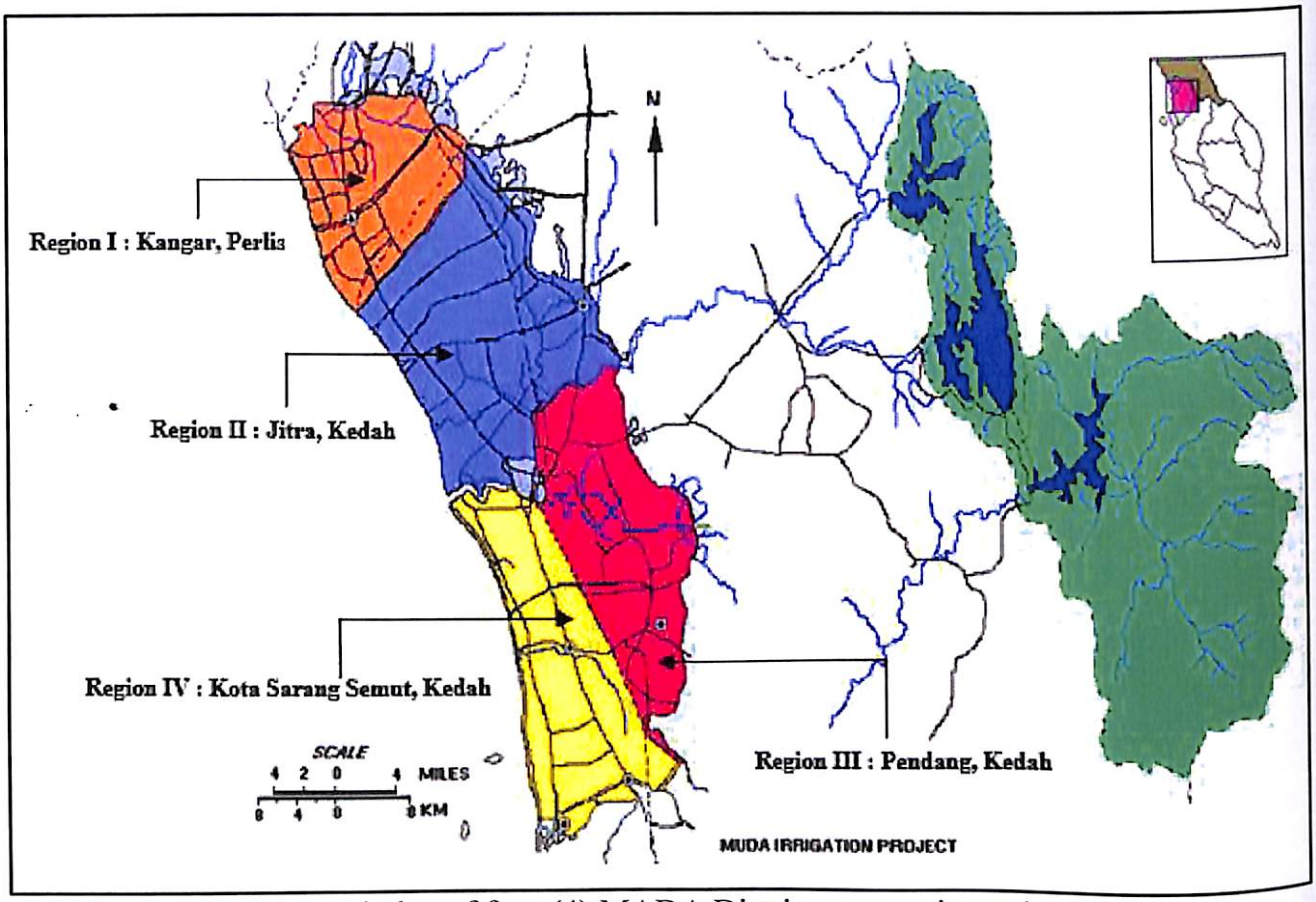

Figure 1.1. General plan of four (4) MADA District, reservoirs and catchment area

Topographically, most of the area in the Region III is flat. The landscape is dominated by paddy fields and sparse farm houses. Several towns are situated within the region, most notably is the Pendang town. The region is furnished with series of irrigation supply and drainage networks serving the paddy cultivation industry, which is the major economic contributor for the area. Sungai Pendang is the only main river flowing through the study area.

The river flow northwards, through Pendang town before passing Titi Haji Idris and eventually discharge into Sungai Anak Bukit in the Kota Setar District. Due to the flat terrain, the river frequently overspill its bank, flooding vast paddy fields located on both sides of the banks. It is especially so during monsoon that brings heavy rains. Flooding causes a lot of damage, especially for the paddy fields and paddy crops.

Figure 1.2 shows the study area that has been identified through site visits and discussion with MADA technical personnel. The stretch of river selected is bounded by route K135 (at Titi Haji Idris) and K133 (Pekan Pendang). Sungai Pendang flows northwards, from Pekan Pendang heading to Titi Haji Idris. The stretch involves a length of roughly 17.5 km of Sungai Pendang, with a general river width of about 30 m and depth of 5 m. Figure 1.3 shows the site condition of the river.

The site was proposed for several reasons, as given below:

a) The study site consists of frequently flooded paddy fields. This criterion is important as the study concentrates on examining flood control capacity of paddy fields.
b) The flood condition in this study area is properly recorded. River water levels are recorded at two locations namely, Titi Haji Idris (Station C) and Pekan Pendang (Station B), (MADA, 2008). This information is important to correctly carry out river hydraulic model, which will be used to study flooding.
c) Geometrical data for river stretch is available.
d) Strategic location and easy accessibility. The site is bounded by major state roads, which make it accessible for field works such as simple survey work.

Figure 1.2: Study area at Pendang, Kedah

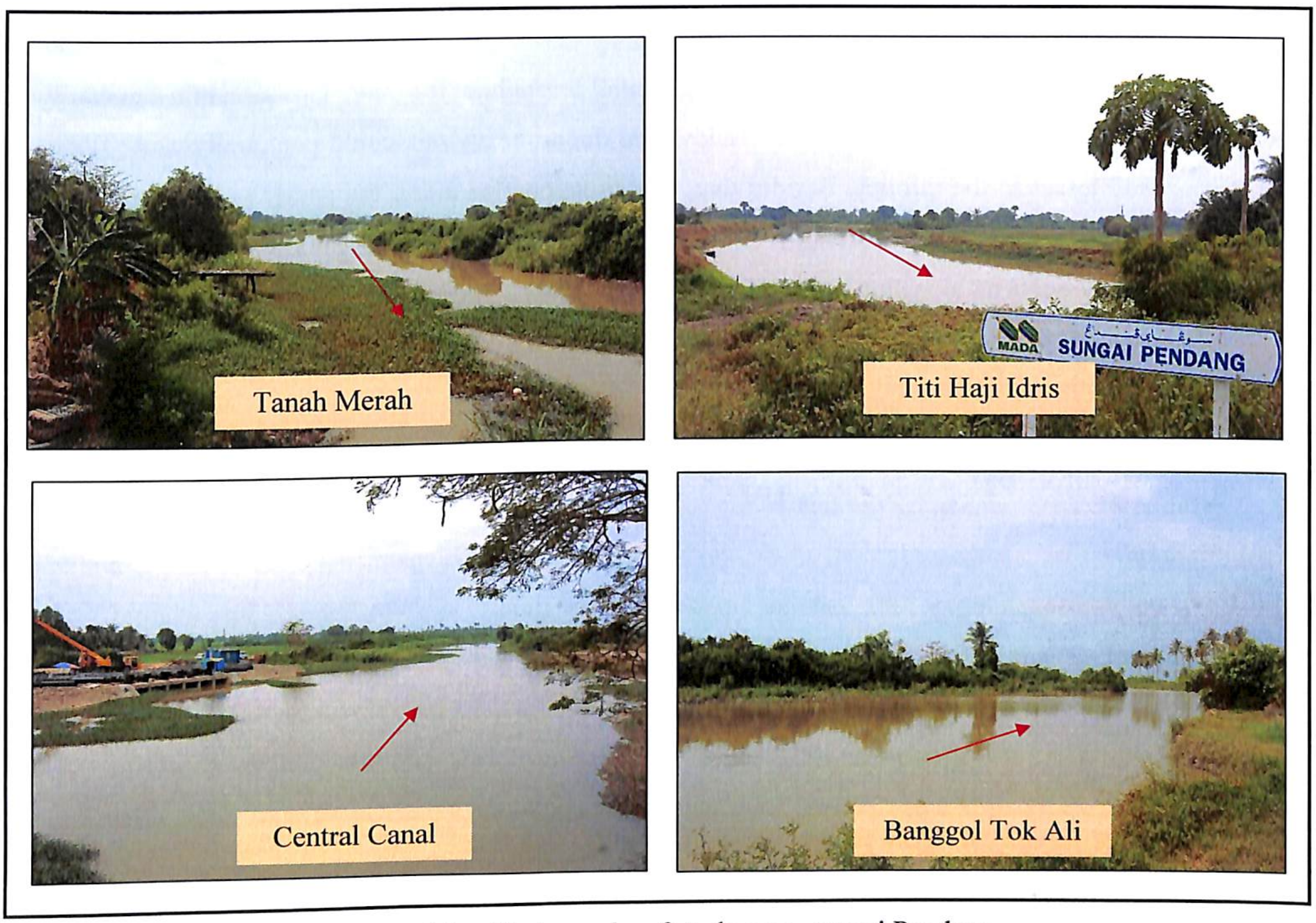

Figure 1.3: Photographs of study area, sungai Pendang

1.2 Research Objective

Specific objectives of this study are:

i) To model floodplain overflow.

ii) To determine the flood control capacity of paddy fields.

1.3 Research Scope and Hypothesis

Generally, State of Kedah receives high rainfall throughout the year. This situation can cause problems to the farmers and their paddy field due to heavy rain could potentially cause flood and losses to the farmers. Besides that, this situation also affect the paddy production target set by MADA. From this study, it can identify factors influencing flood control capacity of paddy fields include physical condition, crop growing stages and farmer's practices.

Hypothesis of this study are:

i) Floodplains temporarily can store floodwater and therefore attenuate flood wave.

ii) Paddy field also can serves as floodplain for adjacent rivers.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

A paddy field is a flooded parcel of arable land used for growing rice and other semi-aquatic crops. Apart from rice production, there are multiple outputs from agriculture, most of which have non-market values. The term 'multi-functionality' refers to an agricultural activity that could have multiple outputs besides providing food and fibres and, therefore, may contribute to several objectives at once. The multiple roles of agriculture include food security, maintaining and ensuring viability of rural communities and environmental protection, such as land conservation, sustainable management of renewable natural resources, preservation of biodiversity, landscape, etc. Being an agricultural activity that generates economy for countries, multi-functionality has been extensively studied in paddy field management and operation. Several researches have been carried out to determine the non-commodity output of paddy field operations. Matsumoto et al. (2003) had systematically categorized the multiple roles of paddy fields into 4 categories, namely:

- Water cycle control functions
- Environmental load control functions
- Nature formation functions
- Social culture formation functions

The multifunction of paddy field can be concluded as Table 2.1, based on category as stated above. It has been found that the literatures are very consistent in identifying the multiple roles of paddy fields; hence the fact that the paddy fields have become such integrated part of environment and culture in many Asian countries is inalienable. Matsuno et al. (2006) summarized brilliantly from rich set of literatures, comprising of over 200 documents on major external functions of paddy fields. The summary is given in Table 2.2. The table presented clearly on the commonly applied method for estimation and measurement, and also the subsequent management to enhance each function. In effort to quantify the worth of multi-functionality of paddy field, researchers has come up with many conceptual estimations of how each function contributes to 'profit' in terms of currency.

Using Replacement Cost Method (RCM), Huang et al. (2006) estimated that water cycle control function for the whole of Taiwan is worth about 1.323 billion USD (Table 2.3). Kim et al. (2006) reviewed several literatures on economic evaluation on multi-functionality for paddy field in Korea. Even though the reviewed researches adopts different approach towards estimating the economic value of each multi-function, Kim et al. (2006) concluded that the 'economic values are recognized as generally high'. It is also highlighted that methods used for evaluation by researches are different from one another, and is hard to be compared on an international level.

Table 2.1 Summary of functions put forward by literatures for paddy fields

Function:	Masumoto (2003)	Matsuno et al. (2006)	Huang et al. (2006)	Kim et al. (2006)
Water Cycle Control	• Flood prevention • Groundwater recharge • Prevention of soil erosion	• Flood control • Groundwater recharge • Soil erosion prevention	• Flood mitigation • Fostering water resources • Reducing soil erosion	• Flood alleviation • Groundwater recharge
Environmental Load Control	• Water purification • Processing of organic waste • Climate modification	• Landslide prevention • Water purification • Decomposition of organic waste • Climate mitigation	• Reducing land subsidence • Water purification • Cooling summer temperature • Air purification	• Water purification • Soil erosion control • Air purification • Climate change mitigation
Nature Formation	• Biodiversity • Landscape	• Conservation of biodiversity • Landscape formation		• Biodiversity conservation • Recreation and amenity
Social and Cultural Formation	• Health and recreation • Participatory learning	• Local community formation	• Health and recreation	
Negative Impact		• Water contamination • Methane emission • Pesticide contamination		• Methane gas emission • Disturbance and extinction of ecosystem • Excessive use of fertilizers and pesticides • Over withdrawal of surface and groundwater.
Flood Control	• Water control in paddy fields. • Decrease in function by abandonment of cultivation. • Additional economic benefits.	• Water storage capacity in paddy fields, irrigation canals, reservoirs, and ponds. • Decrease of peak discharge.	• Rainfall-runoff modelling • Estimation of water storage capacity. • Catchment scale analysis.	• Integrated river management at excessive flooding. • Cost burden by citizens in urban areas.

Table 2.1 Summary of functions put forward by literatures for paddy fields (continued)

Function:	Masumoto (2003)	Matsuno et al. (2006)	Huang et al. (2006)	Kim et al. (2006)
Groundwater Recharge	• Recycling water use system in paddy areas. • Mitigation of land subsidence. • Decrease in groundwater recharge by decreasing of paddy area.	• Infiltration from the irrigated paddy fields. • Part of water cycle structure in region. • Effect of pumping ground-water and precipitation.	• Monitoring of groundwater level. • Groundwater flow modelling. • Estimation using tracer. • Wider-area groundwater budget structure model.	• Flowing water in canals and ponding at paddy fields during non-irrigation period.
Soil Erosion Prevention	• Outflow of soil particles by puddling. • Soil erosion acceleration by abandonment of cultivation.	• Capture of soil particles from upstream area. • Formation of water-resistant soil aggregates by organic materials.	• USLE model including effects of rainfall soil, slope length, slope, vegetation, management as variables.	• Levee management. • Mulching. • Application of organic materials. • Non-puddling management. • Slope protection.
Landslide Prevention	• Landslide prevention by paddy fields in hilly and mountainous rural areas. • Landslide by abandonment of cultivation.	• Existence of terrace. • Dependence on precipitation, landscape, geology, soil, vegetation, earthquake, and snow.	• Estimation by score of valley density, slope, soil depth, tree age, tree species, agricultural land use.	• Hillside works. • Levee management.

Function:	Masumoto (2003)	Matsuno et al. (2006)	Huang et al. (2006)	Kim et al. (2006)
Water Purification	• Water purification by paddy fields and irrigation ponds. • Recycling-oriented society. Excess application of organic resources to soil. • Shortage of amount demanded.	• Denitrification in paddy soil. • Absorption of phosphorous in soil. • Uptake by rice. • Production, collection and transportation of organic resources. • Techniques of conversion to resources from organic waste. • Mineralization in soil.	• Material balance model. • Nitrogen removal equation. • Ecological model. • Catchment scale model. • Diagnostic model of biomass resources circulation. • Model decomposition of organic resources including temperature, rainfall, soil, slope and landuse.	• Constraint of abandonment of cultivation. • Sustainable paddy field management. • Drawing up and compliance of guideline of organic resources application. • Quality and safety of organic resources.

Table 2.1 Summary of functions put forward by literatures for paddy fields (continued)

Function:	Masumoto (2003)	Matsuno et al. (2006)	Huang et al. (2006)	Kim et al. (2006)
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Climate Mitigation	• Mitigation of heat island by paddy fields, ponds, and canals. • Sprawl of agricultural fields	• Increase of latent heat flux. • Area index and mixing index of paddy fields.	• Heat balance model.	• Constrain of scattering and isolating of paddy fields. • Utilization of fallow fields as biotope.
Conservation of Biodiversity	• Formation of landscape. • Decrease of biodiversity by farmland consolidation, acreage reduction, concrete channels, and decoupling of network across species.	• Bio-behaviour corresponding to paddy water management. • Continuousness of water between paddy and channel.	• Bio-behavioural model. • Estimation of inhabitable channels for fishes. • Estimation of biodiversity level.	• Utilization of fallow fields as biotope. • Improvement of canals and fish path for fishes. • Reducing pesticide conservation of hotspots.

Table 2.1 Summary of functions put forward by literatures for paddy fields (continued)

Function:	Masumoto (2003)	Matsuno et al. (2006)	Huang et al. (2006)	Kim et al. (2006)
Landscape Formation	• Disappearance of landscape value. • Landscape law.	• Repose, beauty, affectivity, and familiarity of paddy.	• Psychological measurement CVM, travel cost method.	• Elimination of artificial structures. • Conservation of traditional landscape • Zoning.
Local Community Formation	• Cooperative management of irrigation water. • Coexistence of agricultural and urban areas. • Harmonization of agriculture and nature	• Water use for rural life and environments. • Tradition of agricultural facilities and rice culture. • Recreation and amenity	• Predicting profit population of waterside CVM, travel cost method.	• Cooperative management with non-agricultural sector. • Environmental education.

Table 2.3: Non-commodity profit from multi-functions of paddy field (Kim et al., 2006)

Items of Multi-functionality	Eom et al. (1993)	RDA (1994)	Oh et al. (1995)	Yoon (1996)	KREI (2001)	Park and Chung (2003)
Flood alleviation	15,824	16,000	8,655	-	13,305	14,057
Water Storage	-	-	9,839	10,073	11,427	23,857
Improvement of water quality	59,615	59,611	12,325	-	11,946	3,887
Soil erosion control	667-2,061	2,173	-	19,047	4,532	1,648
Waste disposal	-	-	391	-	882	-
Atmosphere purification	27,979 – 56,869	56,773	46,246	3,076	22,118	113,705
Reduction of temperature	-	2,208	-	-	-	2,062
Maintenance of nature scenery	-	3,000	-	-	-	-
Total	104,086-134,370	139,765	78,446	32,196	64,210	159,216

2.2 Paddy Field for Flood Control

Flood control is one of the functions of paddy field that is widely recognized. The land parcels of paddy field are surrounded by ridges. Ridges serve as earth embankments to hold water for culturing rice crops, to provide access routes, and to divide crops for management purpose. When additional water flows into paddy fields, they are stored within, bounded by the ridges, thus creating impoundment effect. The large amount of water stored in the paddy fields might functions as many small reservoirs or dam. They hold rainfall in the fields, thus reducing peak flow and preventing flood (Huang et al., 2006).

Masumoto et al. (2006) developed an index for evaluating flood prevention function of paddies in a macro (regional or river basin) scale perspective. The index relates storage capacity of the storage depth in paddy field and the maximum drainage capacity of area downstream. This relation was said to be able to help river basin manager and agricultural planner to correctly utilize the flood control capacity of paddy field in catchment wide flood management. The expression is given in Equation 2.1 below.

$$\frac{S}{S_o} = \left[\frac{(D_o - D)}{D_o}\right]^u \qquad \text{(Equation 2.1)}$$

Where S_o and D_o are the maximum storage and drainage capacities respectively, and u is the curve parameter, determined by regression method. If the downstream drainage capacity exceeds the maximum drainage capacity of the basin, no additional storage will be required for flood alleviation; If the drainage capacity is limited, then storage will be required to be allocated to cater the flood volume.

Flood control capacity of paddy field was estimated by studying the major hydrological processes of paddy field and other land use type by Wu et al. (2001). Evapotranspiration, deep percolation (assumed to be groundwater recharge capability) and runoff were examined by comparing the estimations of these processes on paddy field, fallow and dry land in response to same rainfall event.

It was found that paddy field has superior evapotranspiration (Figure 2.1), lower runoff (Figure 2.2), and higher percolation rate (Figure 2.3). It was thus concluded that paddy fields were better in runoff control and ground water recharge compared to dry land and fallow on the same plot of land.

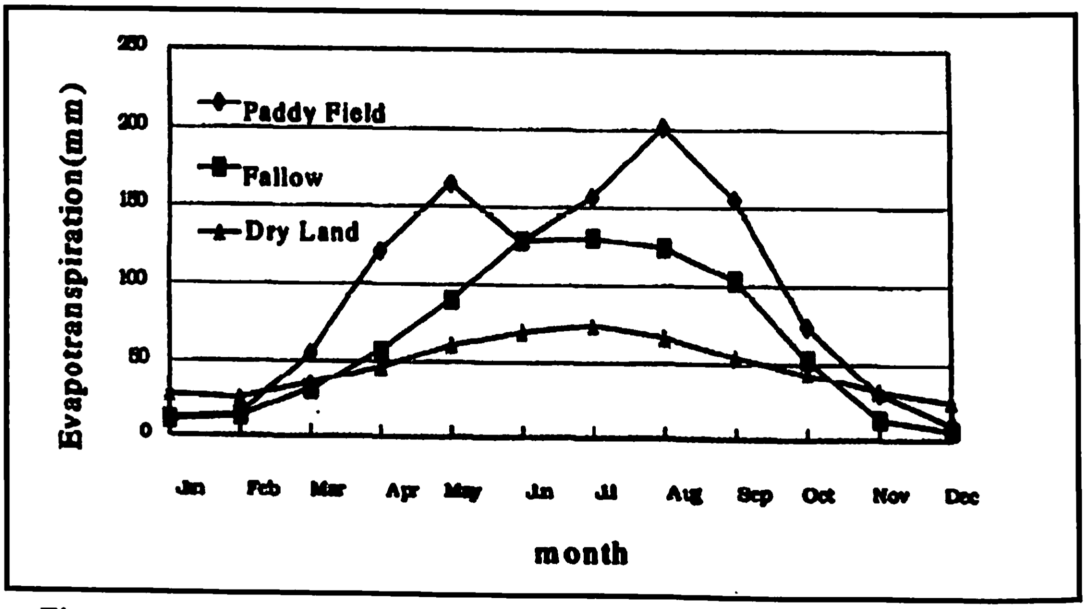


Figure 2.1: Evapotranspiration rate for various landuse (Wu et al., 2001)

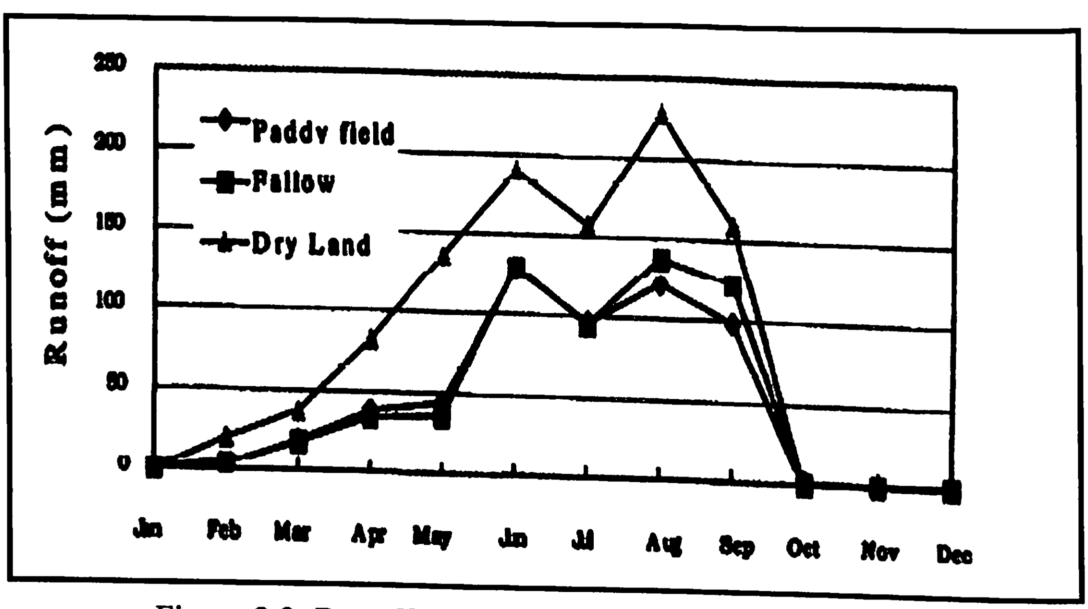


Figure 2.2: Runoff for various landuse (Wu et al., 2001)

Flood control in paddy field can also be interpreted as the flow attenuation effect of wetlands. Paddy fields are normally found near to river, both in flat floodplain and also deltas. In most of the years, paddy field with shallow water ponding resembles the same hydraulic characteristic of wetlands or reed riparian. These semi-aquatic zones acted as floodplains for the main channel and thus are part of the natural conveyance system. Floodplain (wetlands, mangrove swamp, and grassland) is an important part of river as it shares the flood load by dispersing it over a wide and flat land. Studies have shown that floodplain plays important role of slowing down flow and dispersing the flood volume.

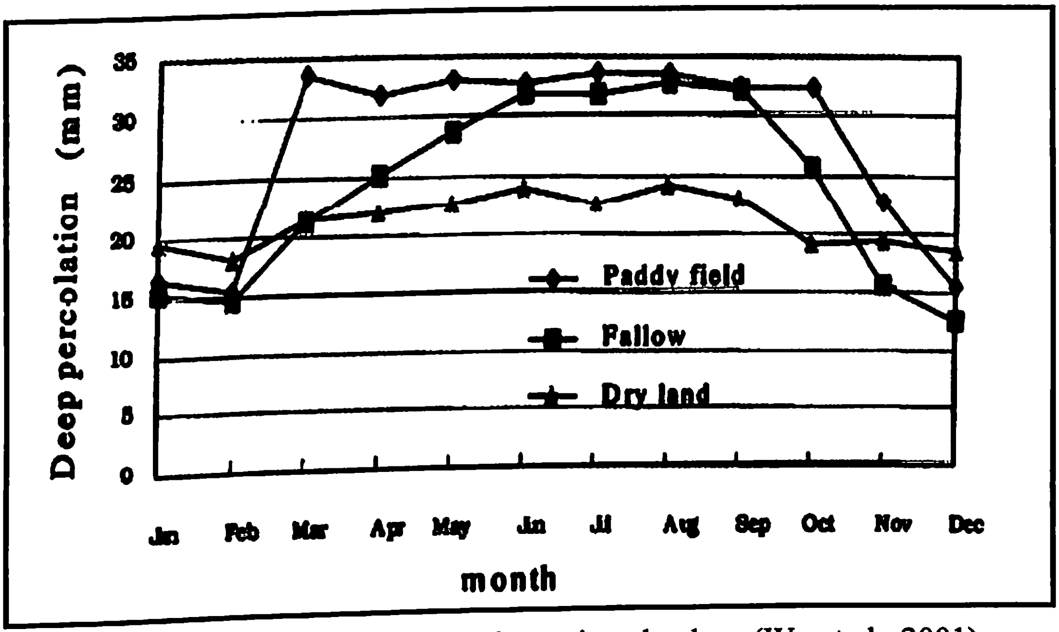


Figure 2.3: Percolation rate for various landuse (Wu et al., 2001)

Reduced velocity helps to reduce flow force hence decrease the risk of life and property damage. Lai et al. (2008) proved that flat floodplain has the capability of slowing down velocity by inducing higher boundary sheer. Figure 2.4 shows wide floodplain has lowered the velocity on both flanks of the channel. Riparian reed also proved to have contributed to flow attenuation by obvious reduction of velocity in channel with and without riparian reed, as shown in Figure 2.5 (Wang and Wang, 2007). Based on these examples, it can be rationalized that paddy field would be able to achieve such hydraulic impact to a certain degree.

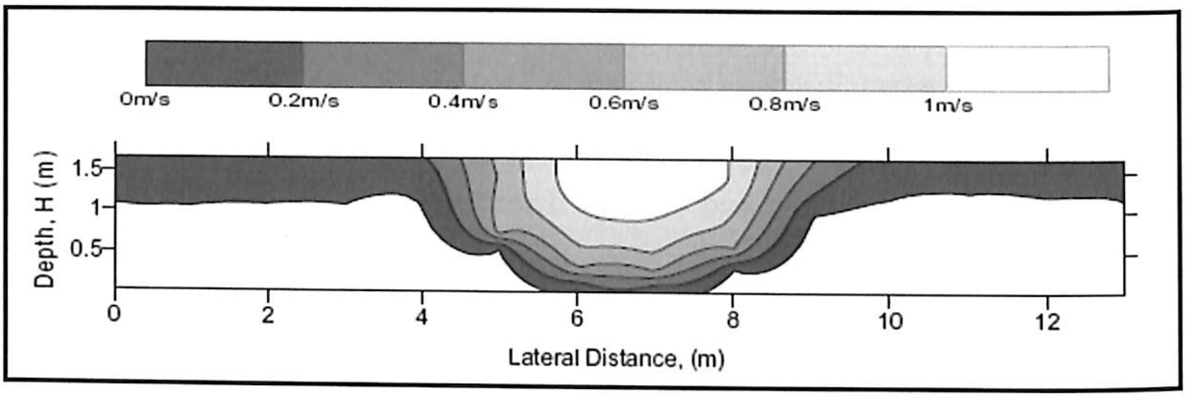


Figure 2.4: Variation of flow velocity over the river cross section (Lai et al., 2008)

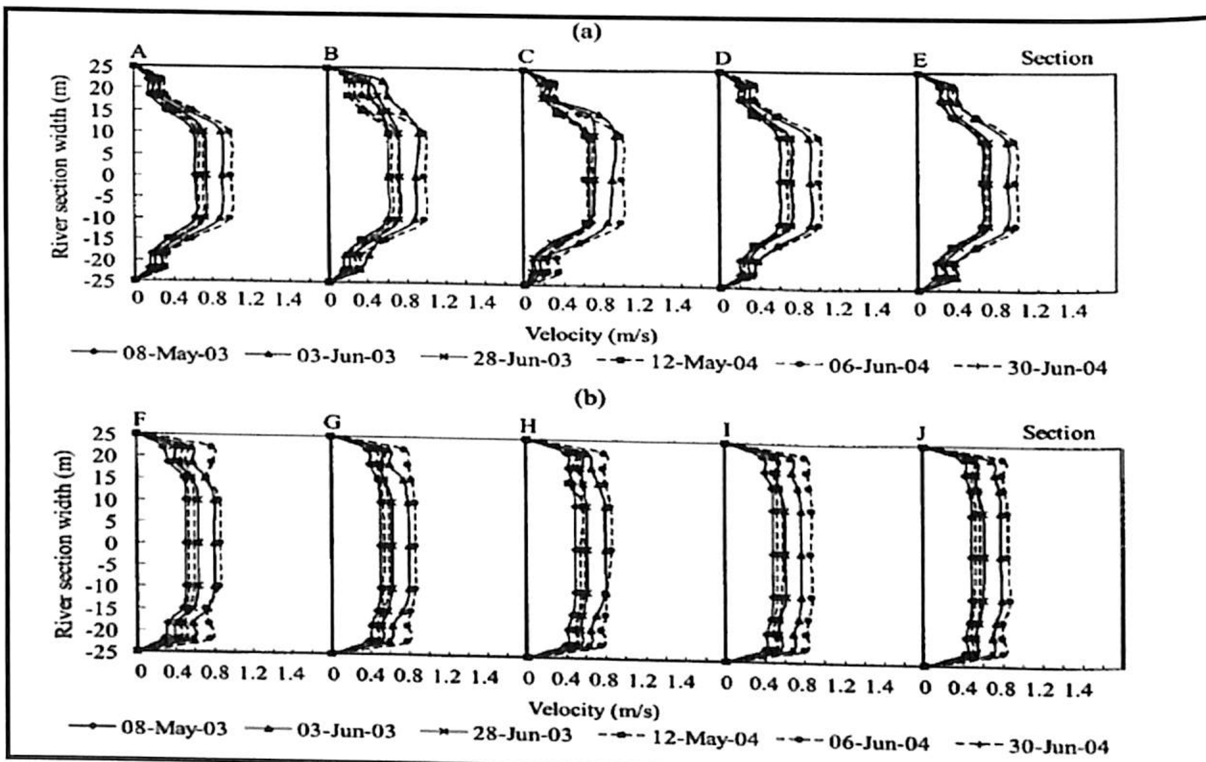


Figure 2.5: Flow variation of (a) Non-vegetated floodplain and (b) Vegetated floodplain

Establish Guidelines for Flood Control

CHAPTER 3
METHODOLOGY

3.1 Introduction

The study will be conducted to examine the flood control capacities of paddy fields. In this part, the functions will be examined in two scales, namely micro (local) and macro (regional) scales. Finally, the flood control capacity will be determined. Figure 3.1 shows the methodology and sequence of work in this study.

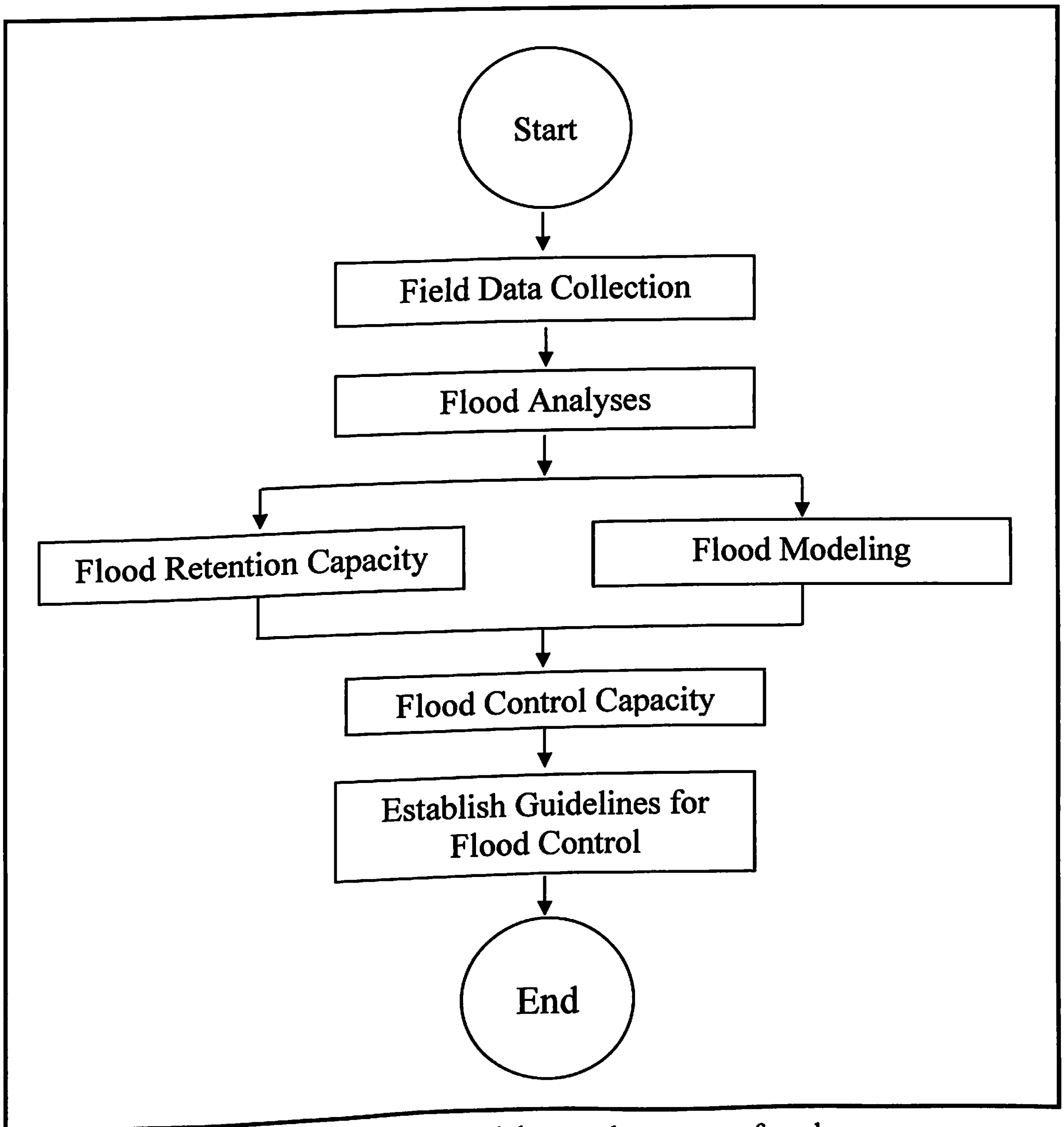


Figure 3.1: Methodology and sequence of work

3.2 Data Collection

Data collection will be carried out to gather all relevant information available. This information will be cleaned, processed, and formatted to produce useful data for modeling purposes.

Generally, two types of data are required. Desk study provides published data and information for the study area. The data includes rainfall and river water level records provided by relevant authorities. On top of that, field works will be carried out to obtain necessary data not available through desk studies. The field works will also serves as verification for available published data in relevant cases. The field works included simple cross sectional survey of river.

3.2.1 Cross Section Survey Using Doppler

Titi Haji Idris (Figure 3.2 to Figure 3.5) is the selected location to apply Doppler river gauging technique due to easy accessibility. As a result, river cross section at selected location is obtained as shown in Figure 3.6.

Figure 3.2: Titi Haji Idris (selected location using Doppler)

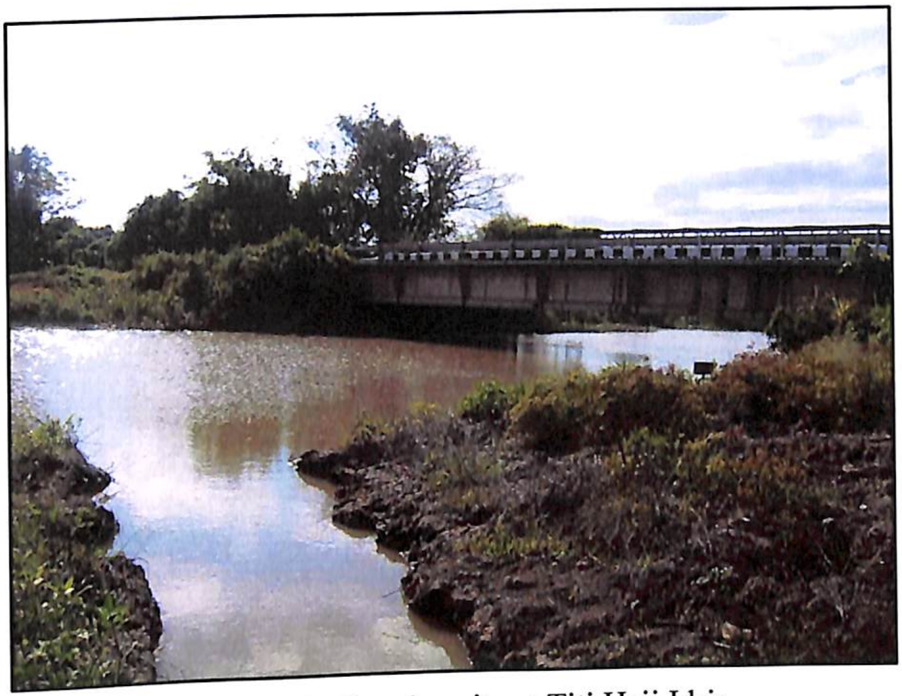


Figure 3.3: Gauging site at Titi Haji Idris

Figure 3.4: Installation work

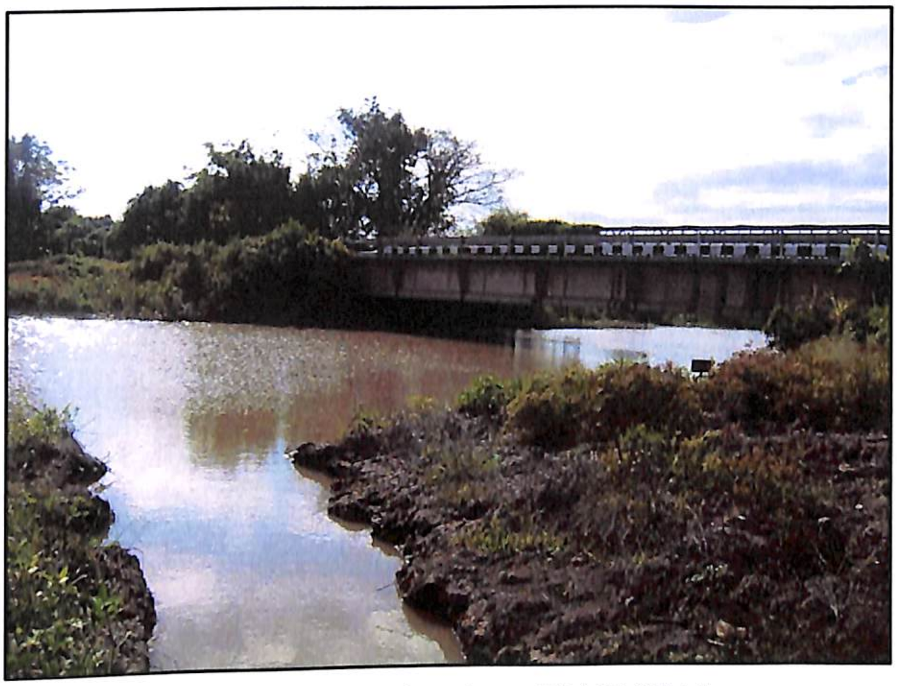


Figure 3.3: Gauging site at Titi Haji Idris

Figure 3.4: Installation work

Figure 3.5: Pulling across the river

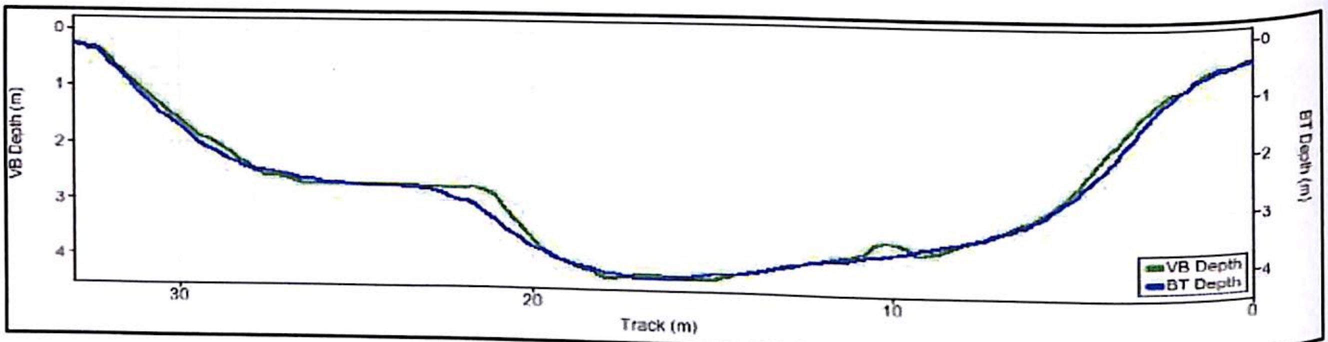


Figure 3.6: River cross section at Titi Haji Idris using Doppler

3.2.2 Plot Survey

In order to study flood retention capacity in plot, the terrain structure of the 3 study plots needs to be identified. This will allow more realistic hydrologic routing. However, due to lack of terrain information in study area, initiative was taken to carry out simple engineering survey to record important terrain features such as bund heights along the perimeter of the paddy plots, inlet and outlet structures, and level of plot basin.

The survey was carried out using Electronic Distance Measurement (EDM) theodolite. First, the Global Positioning System (GPS) unit was used to ascertain the corners of the plots. Then after the EDM was setup, the distance and angled of the corners are recorded, which will later on being used to correctly position the location of the EDM unit. As the survey began, a first point is measured to be used as datum for reduced level (a reference height of 10m was set). Normally a hard structure such as inlet structure is selected as the datum. From there, EDM was used to make a horizontal 360° sweep to pick up important features of the paddy plot. For each feature, distance, height and angle readings were recorded. Additional information not picked up by survey such as width of bund, details of hydraulic structures, and water depth are manually recorded to supplement digital terrain building task in later stage of study.

Figure 3.7 shows the recorded GPS position for Plot 1 (Alor Berala), from which the surveyed spot heights are tied to (Figure 3.8). For Plot 2 (Banggol Tok Ali), the GPS positions are given in Figure 3.9 while Figure 3.10 shows the corrected spots heights collected from the survey exercise. Figure 3.11 presents the GPS positions recorded for Plot 3 (Alor Punti) and Figure 3.12 shows the spot heights for this particular plots.

It should be noted that GPS positions contains an error of ±5m. The EDM position derived from these GPS points naturally inherit such errors. However, satellite image is used to ensure the position error is not significant and that the final spot height position matches the satellite image to a satisfactory degree.

Figure 3.7 GPS records for Plot 1 (Alor Berala)

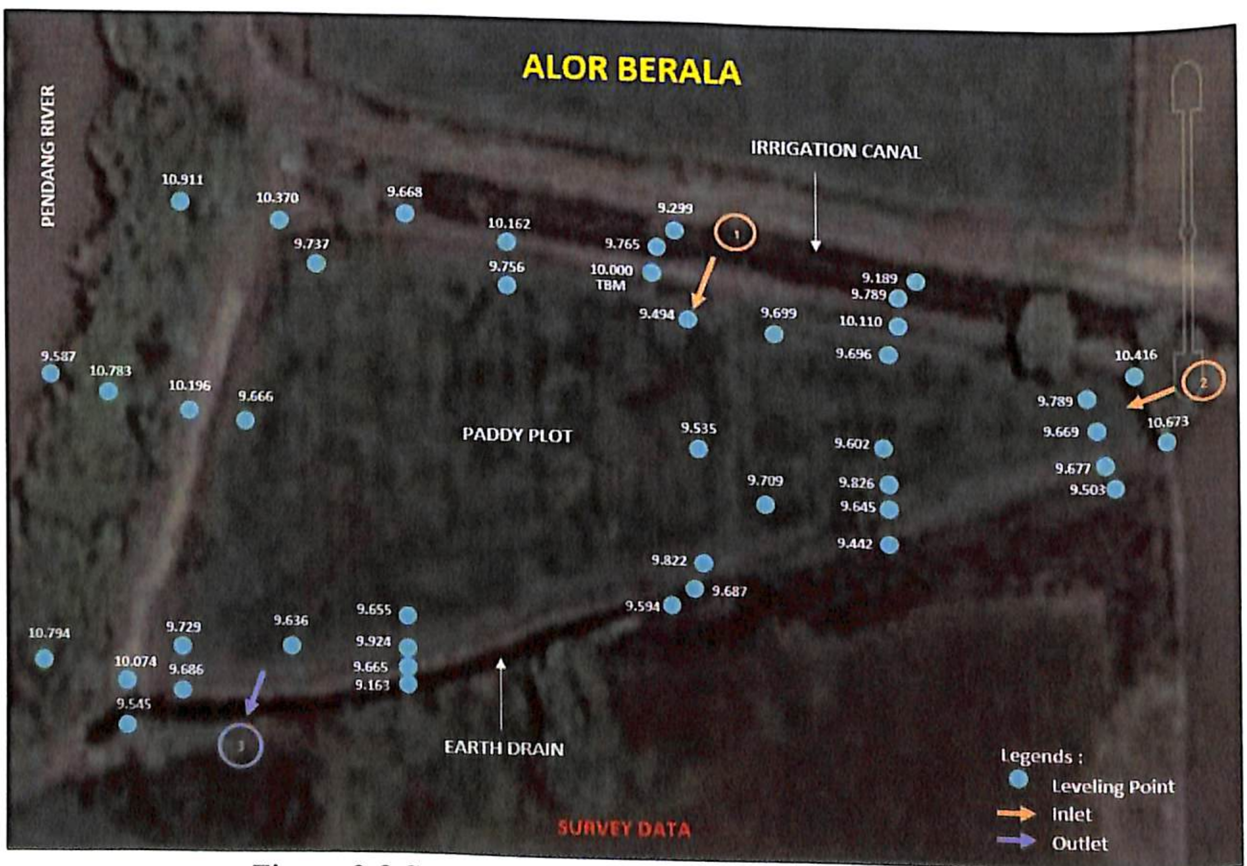


Figure 3.8 Survey spot heights for Plot 1 (Alor Berala)

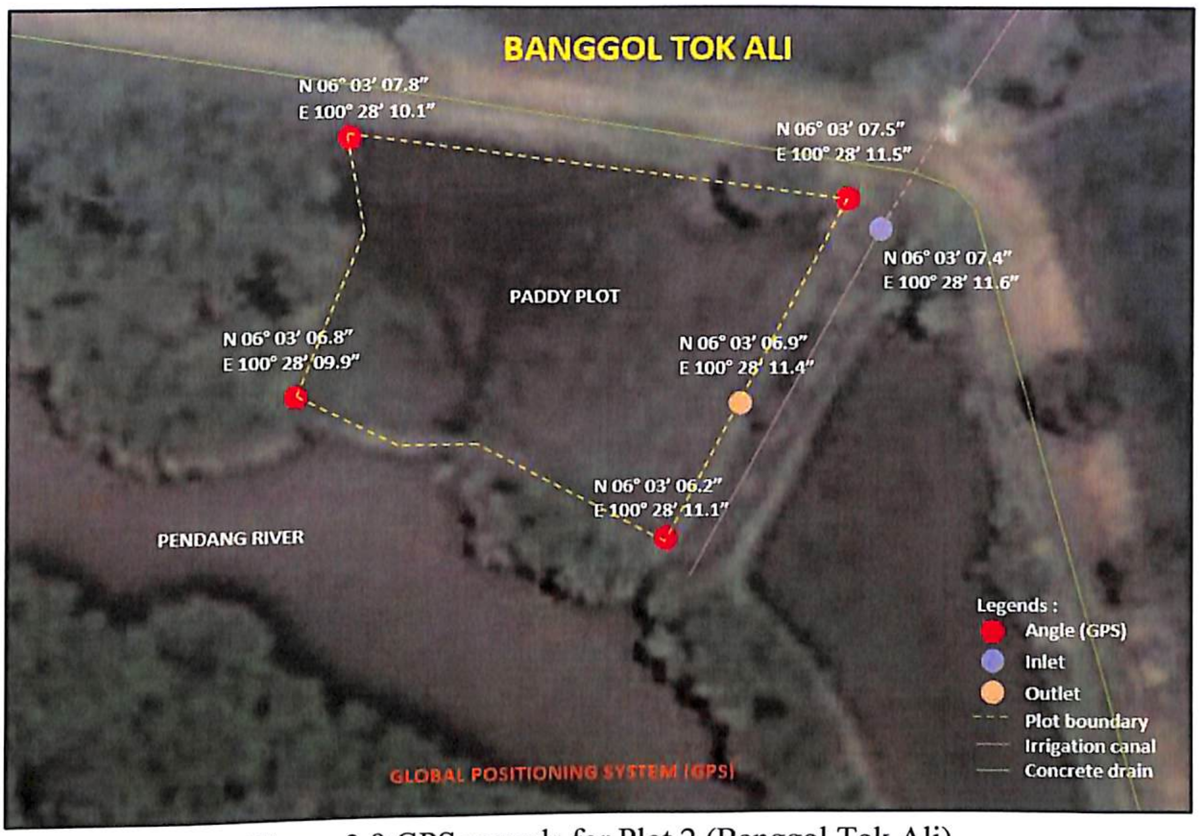


Figure 3.9 GPS records for Plot 2 (Banggol Tok Ali)

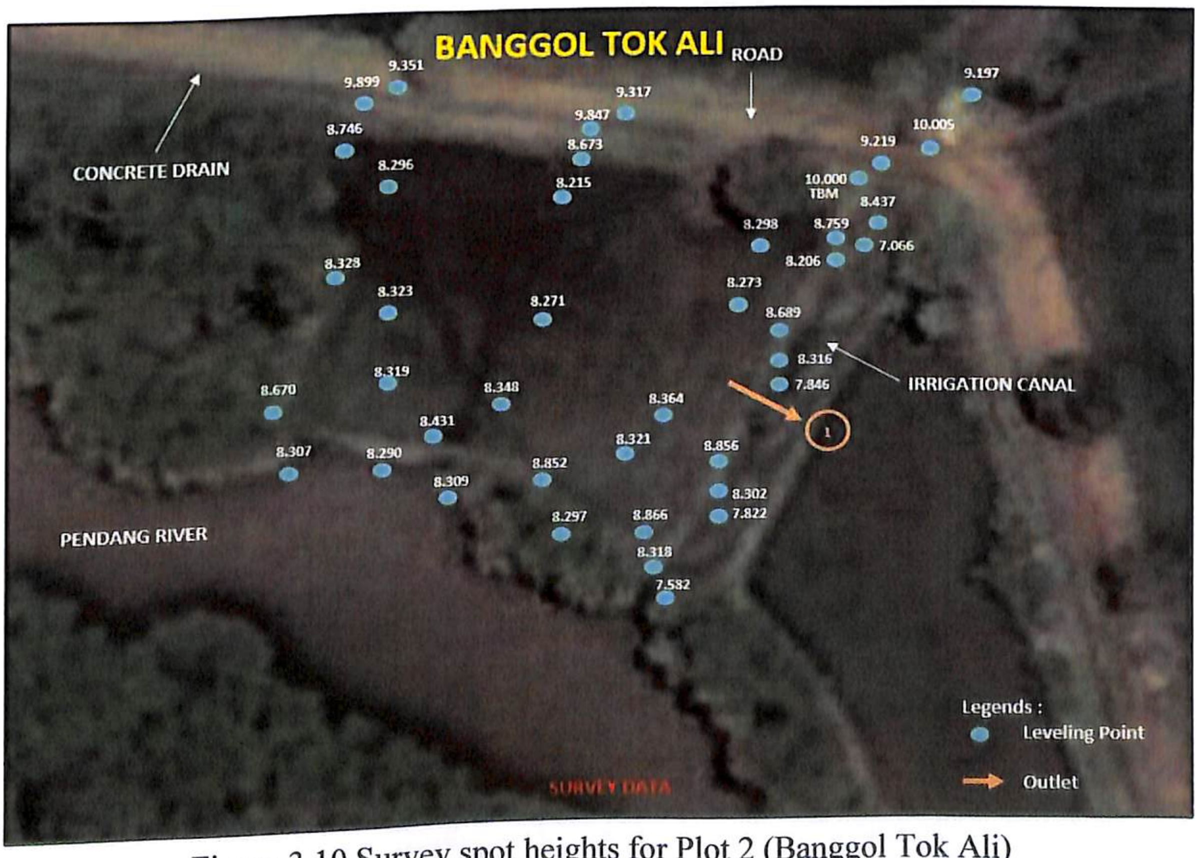


Figure 3.10 Survey spot heights for Plot 2 (Banggol Tok Ali)

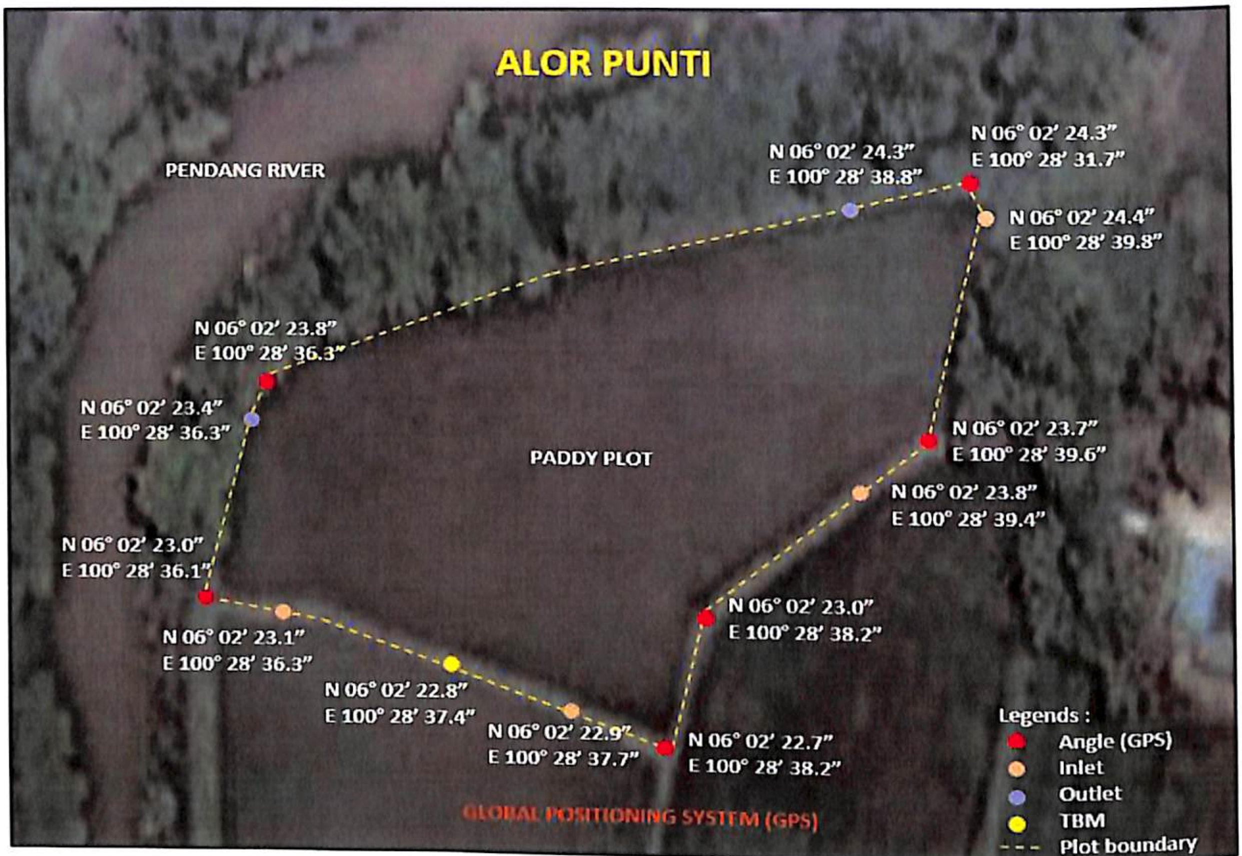


Figure 3.11 GPS records for Plot 3 (Alor Punti)

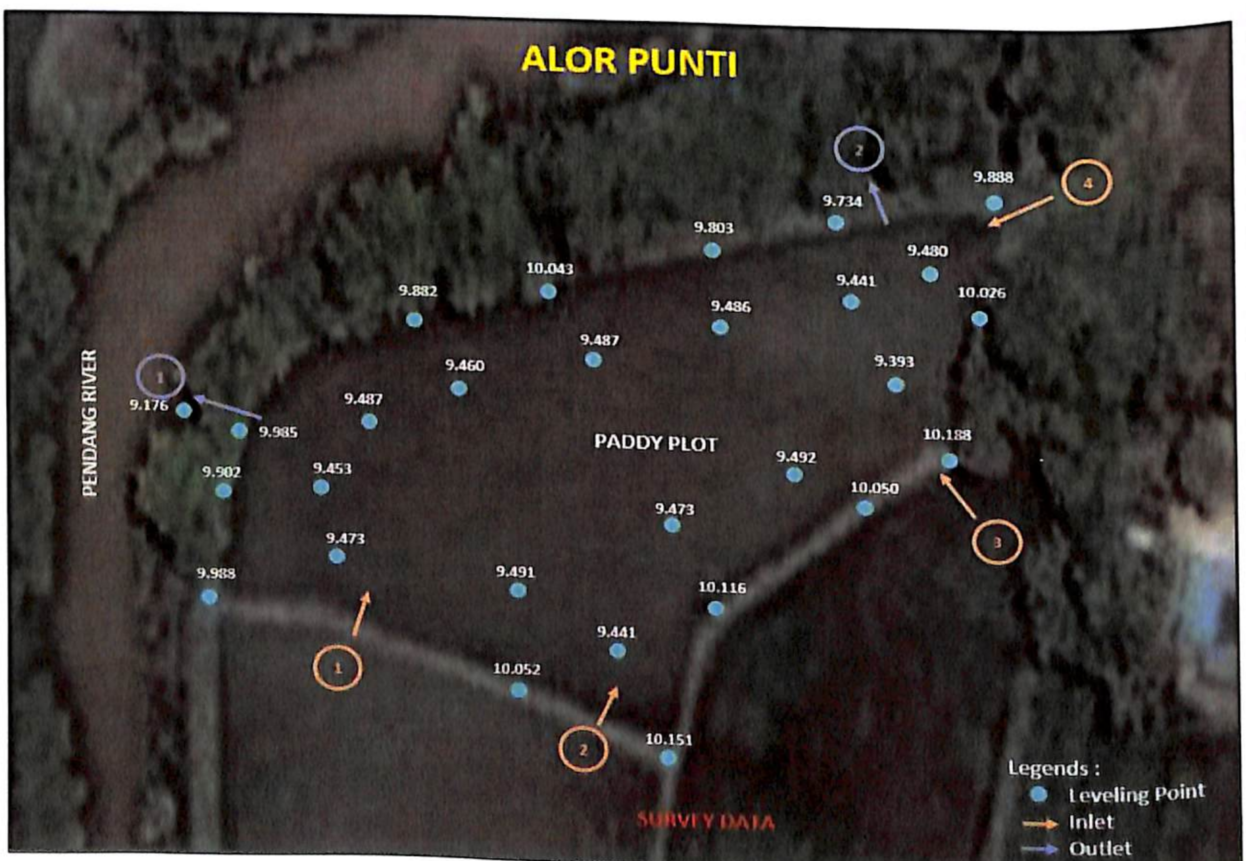


Figure 3.12 Survey spot heights for Plot 3 (Alor Punti)

3.2.3 Floodplain Cross Section Survey

Floodplain is an important part of river as it shares the flood load by dispersing it over a wide and flat land. Studies have shown that floodplain plays important role of slowing down flow and dispersing the flood volume. Spot height survey for the floodplain was conducted by survey team using structures as shown in Figure 3.13 (small picture) within study area as datum and Figure 3.14 shows the cross section for flood plain in Pendang. A gradient profile of 1 to 5000 is observed in this sample survey. These structures have fixed elevation which is made known by MADA office. The elevation is tied to the mean sea level, which made it compatible to be used with the engineering survey data.

Figure 3.13: Survey work by survey team

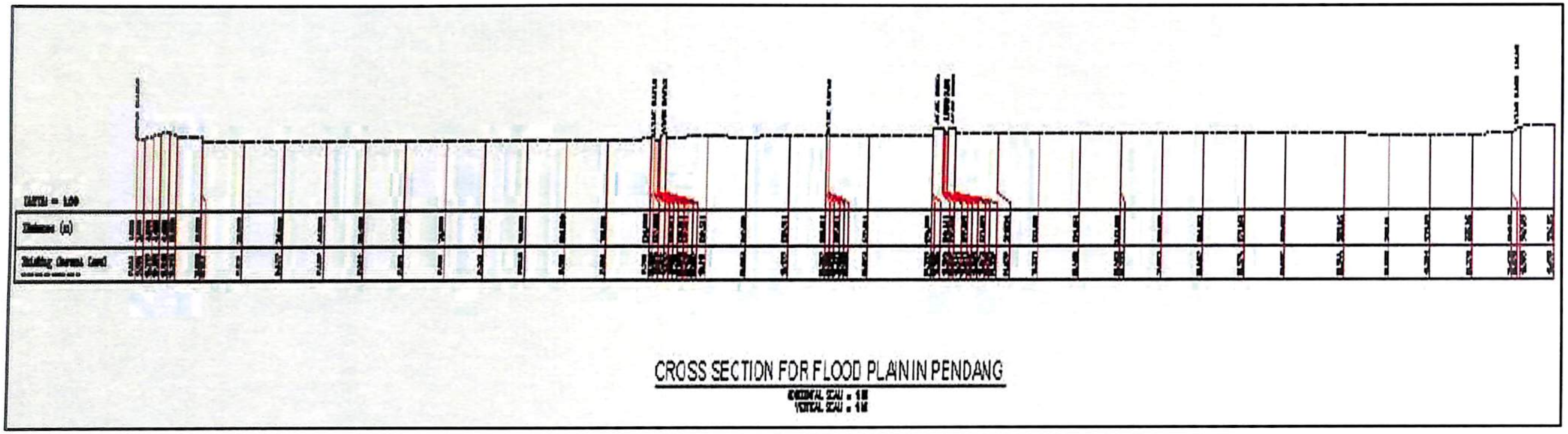


Figure 3.14: Cross section for floodplain in Pendang

3.3 Flood Analysis

In a regional aspect, paddy field also serves as floodplain for adjacent rivers. The flat and wide terrain of paddy fields acts collectives as a huge detention storage area. The storage area temporarily store flood water, therefore reducing flood risk on other lands such as towns or villages. In order to investigate flood control potential, 1-D hydraulic model was used to simulate flood condition within selected river reach and adjacent paddy fields.

1-D hydraulic modelling was used to study the function of paddy fields as part of the river system. In general, paddy plots are situated within the floodplain of rivers. Floodplains are normally low and frequently flooded to cater for excessive flood waters. Floodplains temporarily store floodwater and therefore attenuate flood wave. This is very crucial as it helps to reduce flood level, hence reducing flood extent and damage particularly in the downstream area.

Hydrologic Engineering Center-River Analysis System or HEC-RAS was developed to study the hydraulics behaviour of river system, including floodplains. The current version of HEC-RAS supports steady and unsteady flow water surface profile calculations; sediment transport/moveable boundary sediment computations; and water temperature analysis.

The main objective of HEC-RAS is to produce hydraulic properties (particularly water level) at cross section of interest. The profile computation begins at a cross section with known or assumed starting conditions, and proceeds upstream for subcritical flow or downstream for supercritical flow. HEC-RAS is capable of simulating both steady and unsteady flow conditions.

Flood volume is water volume stored by paddy fields i.e. calculated by area of paddies and level of height of bund or levee in average.

3.4 Flood Retention Capacity

The structure of paddy fields with raised embankment to divide plots as well as to store water needed for paddy cultivation forms pockets of storage compartments, capable of providing huge amount of depression storage. In order to study the relationship as well as factors affecting the potential flood retention capacity of paddy plots, site data will be collected, which include water level in paddy plot, inflow from canal, outflow to drainage and infiltration rate.

- ***Concept***

The rainfall will eventually from surface runoff that flows into streams and in occasion of major rain, can cause overflow or flooding. As rain falls, a small fraction is intercepted and absorbed by plants (in this case paddy), while other are absorbed by the soil.

The structures of paddy fields with raised embankment to divide plots as well as to store water needed for paddy cultivation forms pockets of storage compartments, capable of providing huge amount of depression storage.

In order to study the relationship as well as factors affecting the potential flood retention capacity of paddy plots, site data were collected, which include:

(a) Water level in paddy plot
(b) Inflow from canal
(c) Outflow to drainage
(d) Average perimeter height bund

These data was collected on selected paddy plot and covered different planting season as well as plant growth stages. The variations have different implications on the retention capacity of paddy fields.

For example, during growing season, water is retained in paddy field to aid growth, therefore reduces the depression storage depth available for detention of excess rainfall but during harvesting, the ground maybe drier, allowing more excess rainfall to be retained.

The capacity of paddy field in resuming this function however can be affected by several factors. In a micro scale, i.e. within the field itself, paddy cultivation helps to reduce runoff generation. Depending on type and seasonal different, paddy is able to reduce runoff generation through interception and infiltration. The structure of paddy plot is also expected to significantly increase the capacity of paddy field to reduce flood risk.

- ***Analysis Approach***

A water balance model is setup to study the mass balance between various forms of water within the selected paddy plot. In any hydrologic system, a water budget can be developed to account for various forms of water that exists in the system at a period of time. In general, the hydrologic continuity equation 3.1for any system is given as:

$$\bar{I} - \bar{O} = \frac{dS}{dt} \qquad \text{(Equation 3.1)}$$

Where

$\bar{I}$ = inflow in m^3/s,

$\bar{O}$ = outflow in m^3/s, and

dS/dt = change in storage per time in, m^3/s

Inflow for a system can come from several sources including precipitation, irrigation supply, natural flow, or stormwater discharge received from catchment area. Water mass leaves a system through several means including, infiltration, seepage, evapotranspiration, surface runoff and water supply intake. It can include or exclude any of the hydrologic processes to the importance of the system analyzed.

For example, in cases where groundwater was to be incorporated, infiltration can be omitted, as the outflow of the surface system becomes the inflow for groundwater system. Also, assuming infiltration is so insignificant mostly due to soil property (clay), the process can be omitted from the system.

The first aspect will be performed using a level pool routing method, a procedure normally performed to check the effectiveness of a pond/ storage unit to contain/ control water. This concept calculation steps are given in is described by Chow et al. (1988). Figure 3.15 illustrates how the change of storage (water level) is influenced by the difference between inflow and outflow of a system, as presented by Equation 3.1. The current study applies a standard procedure for the method as recommended by the Urban Stormwater Management Manual for Malaysia, or MSMA (DID, 2000).

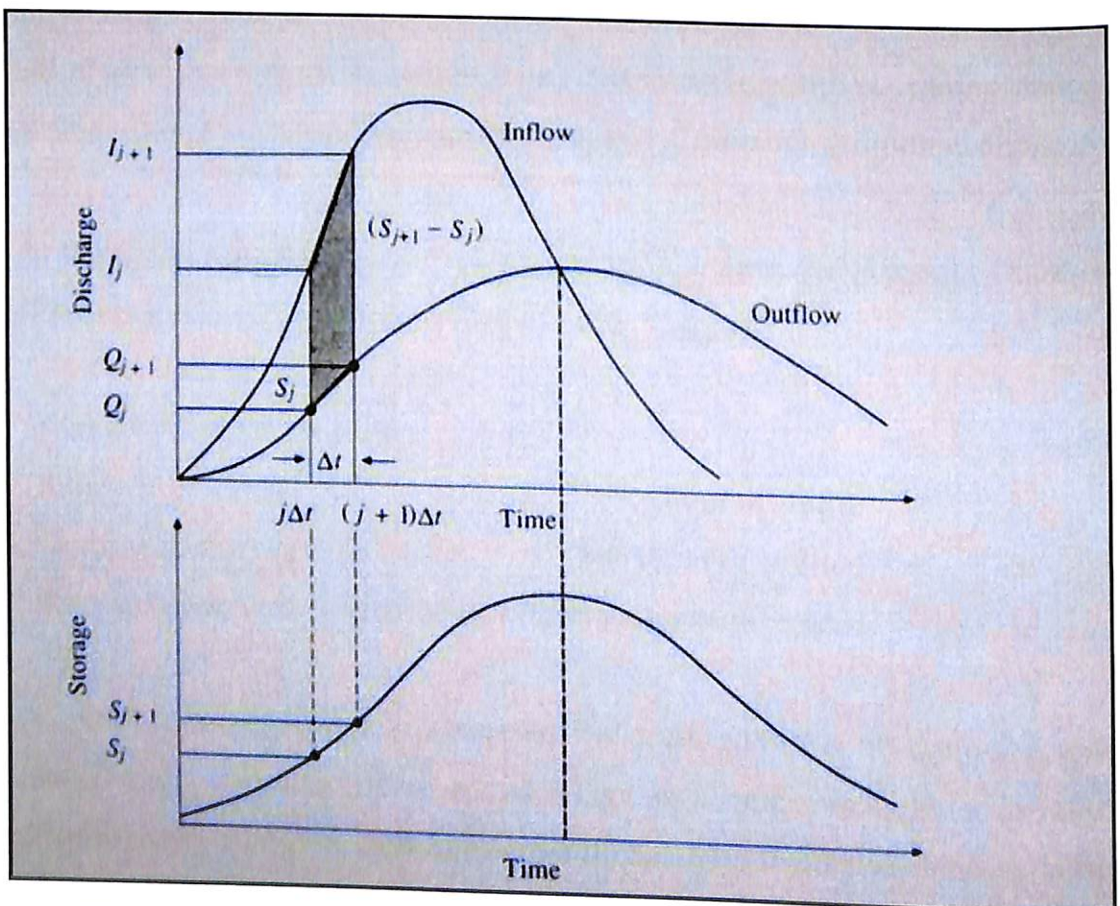


Figure 3.15: Concept of level pool routing (After Chow et al, 1988)

Time, t	Inflow, I	I_j+I_{j-1}	$(2S_j/\Delta_t)-Q_j$	$(2S_{j+1}/\Delta_t)+Q_{j+1}$	Outflow	Water Level
0	0.000000	0.017676	0	0.000000	0.0000	9.5
14400	0.017676	0.017676	0.02	0.017676	0.0000	9.58
28800	0.012190	0.029866	0.05	0.047542	0.0006	9.66
43200	0.009752	0.021942	0.06	0.068246	0.0042	9.70
57600	0.007314	0.017066	0.06	0.076816	0.0065	9.72
72000	0.008533	0.015847	0.07	0.079605	0.0073	9.72
86400	0.005486	0.014019	0.06	0.079080	0.0071	9.72
100800	0.000000	0.005486	0.06	0.070301	0.0048	9.71
115200	0.000000	0.000000	0.06	0.060711	0.0028	9.69
129600	0.000000	0.000000	0.05	0.055174	0.0019	9.68
144000	0.000000	0.000000	0.05	0.051444	0.0013	9.67
158400	0.000000	0.000000	0.05	0.048932	0.0008	9.66
172800	0.000000	0.000000	0.05	0.047239	0.0006	9.66
187200	0.000000	0.000000	0.05	0.046099	0.0004	9.66
201600	0.000000	0.000000	0.04	0.045331	0.0003	9.65
216000	0.000000	0.000000	0.04	0.044814	0.0002	9.65
230400	0.000000	0.000000	0.04	0.044465	0.0001	9.65
244800	0.000000	0.000000	0.04	0.044231	0.0001	9.65
259200	0.000000	0.000000	0.04	0.044072	0.0001	9.65
273600	0.000000	0.000000	0.04	0.043966	0.0000	9.65
288000	0.000000	0.000000	0.04	0.043894	0.0000	9.65
302400	0.000000	0.000000	0.04	0.043846	0.0000	9.65
316800	0.000000	0.000000	0.04	0.043813	0.0000	9.65
331200	0.000000	0.000000	0.04	0.043791	0.0000	9.65
[illegible]	[illegible]	0.000000	0.04	0.043776	0.0000	9.65

As the procedure of level pool routing requires repetitive computation of several parameters, it is performed using a Microsoft® EXCEL™ spread sheet. Several relationships that described the study plot including storage, discharge and inflow should be prepared beforehand. Upon completing data input, the spreadsheet automatically performs the level pool routing and the result of flow attenuation and water level fluctuation are presented in graphical format.

Figure 3.16 below shows a snapshot of the spreadsheet used for level pool routing. From the same spreadsheet, the final output can be plotted into graphs as shown in Figure 3.17.

Time, t	Inflow, I	I_j+I_{j-1}	$(2S_j/\Delta_t)-Q_j$	$(2S_{j+1}/\Delta_t)+Q_{j+1}$	Outflow	Water Level
0	0.000000	0.017676	0	0.000000	0.0000	9.5
14400	0.017676	0.017676	0.02	0.017676	0.0000	9.58
28800	0.012190	0.029866	0.05	0.047542	0.0006	9.66
43200	0.009752	0.021942	0.06	0.068246	0.0042	9.70
57600	0.007314	0.017066	0.06	0.076816	0.0065	9.72
72000	0.008533	0.015847	0.07	0.079605	0.0073	9.72
86400	0.005486	0.014019	0.06	0.079080	0.0071	9.72
100800	0.000000	0.005486	0.06	0.070301	0.0048	9.71
115200	0.000000	0.000000	0.06	0.060711	0.0028	9.69
129600	0.000000	0.000000	0.05	0.055174	0.0019	9.68
144000	0.000000	0.000000	0.05	0.051444	0.0013	9.67
158400	0.000000	0.000000	0.05	0.048932	0.0008	9.66
172800	0.000000	0.000000	0.05	0.047239	0.0006	9.66
187200	0.000000	0.000000	0.04	0.046099	0.0004	9.66
201600	0.000000	0.000000	0.04	0.045331	0.0003	9.65
216000	0.000000	0.000000	0.04	0.044814	0.0002	9.65
230400	0.000000	0.000000	0.04	0.044465	0.0001	9.65
244800	0.000000	0.000000	0.04	0.044231	0.0001	9.65
259200	0.000000	0.000000	0.04	0.044072	0.0001	9.65
273600	0.000000	0.000000	0.04	0.043966	0.0000	9.65
288000	0.000000	0.000000	0.04	0.043894	0.0000	9.65
302400	0.000000	0.000000	0.04	0.043846	0.0000	9.65
316800	0.000000	0.000000	0.04	0.043813	0.0000	9.65
331200	0.000000	0.000000	0.04	0.043791	0.0000	9.65
345600	0.000000	0.000000		0.043776	0.0000	9.65

Stage	Discharge, Q	Storage, S	$(2S/\Delta_t)+Q$
9.50	0.000000	104.584	0.00
9.55	0.000000	200.185	0.03
9.60	0.000000	314.971	0.04
9.65	0.003602	447.964	0.07
9.70	0.010958	593.953	0.09
9.75	0.021865	747.197	0.13
9.80	0.039407	906.368	0.17
9.85	0.062346	1070.621	0.21
9.90	0.103045	1239.55	0.28

Time Step: 240 min @ 14400 seconds

Initial Water Level: 9.5 m A.D.

Stage Interval: 0.05 m

Figure 3.16: Example of level pool routing in spreadsheet environment

As the procedure of level pool routing requires repetitive computation of several parameters, it is performed using a Microsoft® EXCEL™ spread sheet. Several relationships that described the study plot including storage, discharge and inflow should be prepared beforehand. Upon completing data input, the spreadsheet automatically performs the level pool routing and the result of flow attenuation and water level fluctuation are presented in graphical format.

Figure 3.16 below shows a snapshot of the spreadsheet used for level pool routing. From the same spreadsheet, the final output can be plotted into graphs as shown in Figure 3.17.

Time, t	Inflow, I	I_j+I_{j-1}	$(2S_j/\Delta_t)-Q_j$	$(2S_{j+1}/\Delta_t)+Q_{j+1}$	Outflow	Water Level	Stage	Discharge, Q	Storage, S	$(2S/\Delta_t)+Q$
0	0.000000	0.017676	0	0.000000	0.0000	9.5	9.50	0.000000	104.584	0.00
14400	0.017676	0.017676	0.02	0.017676	0.0000	9.58	9.55	0.000000	200.185	0.03
28800	0.012190	0.029866	0.05	0.047542	0.0006	9.66	9.60	0.000000	314.971	0.04
43200	0.009752	0.021942	0.06	0.068246	0.0042	9.70	9.65	0.003602	447.964	0.07
57600	0.007314	0.017066	0.06	0.076816	0.0065	9.72	9.70	0.010958	593.953	0.09
72000	0.008533	0.015847	0.07	0.079605	0.0073	9.72	9.75	0.021865	747.197	0.13
86400	0.005486	0.014019	0.06	0.079080	0.0071	9.72	9.80	0.039407	906.368	0.17
100800	0.000000	0.005486	0.06	0.070301	0.0048	9.71	9.85	0.062346	1070.621	0.21
115200	0.000000	0.000000	0.06	0.060711	0.0028	9.69	9.90	0.103045	1239.55	0.28
129600	0.000000	0.000000	0.05	0.055174	0.0019	9.68				
144000	0.000000	0.000000	0.05	0.051444	0.0013	9.67				
158400	0.000000	0.000000	0.05	0.048932	0.0008	9.66				
172800	0.000000	0.000000	0.05	0.047239	0.0006	9.66				
187200	0.000000	0.000000	0.05	0.046099	0.0004	9.66				
201600	0.000000	0.000000	0.04	0.045331	0.0003	9.65				
216000	0.000000	0.000000	0.04	0.044814	0.0002	9.65				
230400	0.000000	0.000000	0.04	0.044465	0.0001	9.65				
244800	0.000000	0.000000	0.04	0.044231	0.0001	9.65				
259200	0.000000	0.000000	0.04	0.044072	0.0001	9.65				
273600	0.000000	0.000000	0.04	0.043966	0.0000	9.65				
288000	0.000000	0.000000	0.04	0.043894	0.0000	9.65				
302400	0.000000	0.000000	0.04	0.043846	0.0000	9.65				
316800	0.000000	0.000000	0.04	0.043813	0.0000	9.65				
331200	0.000000	0.000000	0.04	0.043791	0.0000	9.65				
345600	0.000000	0.000000	0.04	0.043776	0.0000	9.65				

Time Step:	240 min @		14400 seconds
Initial Water Level:		9.5 m A.D.	
Stage Interval:		0.05 m	

Figure 3.16: Example of level pool routing in spreadsheet environment

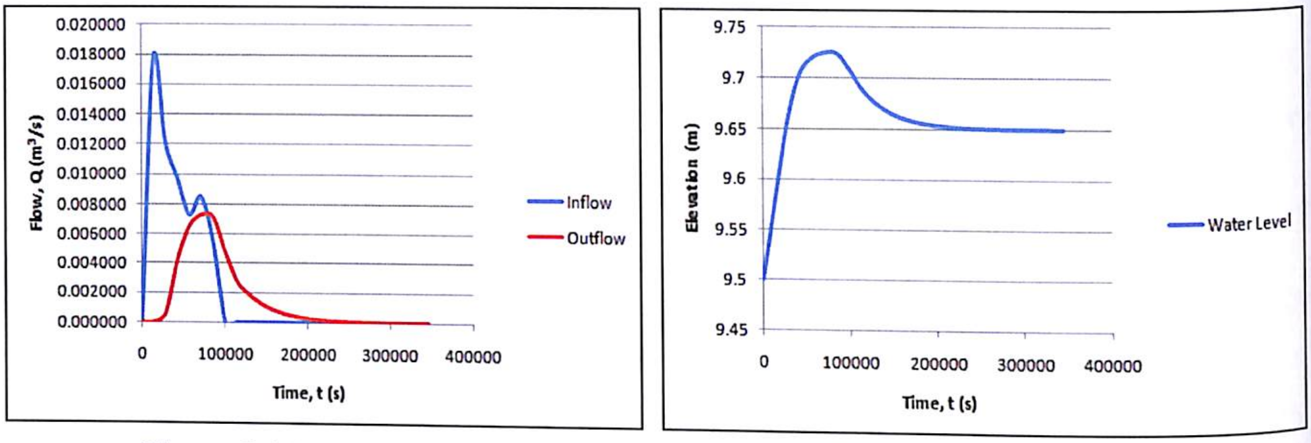


Figure 3.17: Example of result output from level pool routing spreadsheet

3.5 Flood Control Capacity

After all analyses are carried out, it will able to determine the flood control facility based on the case study carried out. The capacity of flood control will be determined by:

- The attenuation effect on hydrograph.
- The volume of detention the paddy field is able to provide.
- The overall performance of paddy field compared to other land use in flood control.

3.6 Establish Guideline for Flood Control

This study will ultimately produce an example of how flood capacity of paddy field can be assess. The study will also produce a guideline on the design of better paddy field in terms of flood control capacity. A set of criteria will be stated in respect to hydraulic and hydrology design to release the full potential of flood control of paddy field.

The guidelines consists of proposed standard procedures to evaluate the capacity of flood and sediment control functions in paddy field. Such preliminary procedures will provide the paddy field management authorities with standard evaluation methodology in rating flood and sediment control functions of paddy fields.

Monetary Assessment

Multiple functions of irrigation services provide huge benefit to many beneficiaries in addition to farmers. It is include flood mitigation, ground water recharge, preventing soil from erosion, reducing soil erosion, reducing land subsidence, water purification, sediment control, health and recreation. In a word, to share the broadened concept of Multiple Uses and Functions (MUFs) of irrigation water by policy makers and tax payers, monetary assessment can be a tool to make its value virtually visible.

- **Cost Replacement Method**

The cost replacement method is commonly used to quantify monetarily the value of indirect services/products provided by ecosystem. In the case of paddy field and particularly flood control by paddy field, the cost replacement method represents the best option for evaluation due to simplicity and lack of other more directly related valuation mechanism.

The cost replacement method evaluates a service/product that could not be quantified monetarily with a substitute product/ services available on the market. Many human activities can be equated with monetary values. Therefore, by equating services/products provided by ecosystem with manmade services/products at a similar magnitude/quantity which offers the similar functions, there is a possibility to allocate a value for the services/ products offered by ecosystem.

The monetary evaluation using cost replacement method requires two components. First, the volume function of the services/products under study must be known. Various methods can be used to quantify the services/products based on the type and nature. Secondly, a unit cost (cost per quantity) of the product should be estimated using the substituted manmade services/products. Multiplying both will reveal the monetary value of a service/product provided by an ecosystem.

- **Determining Monetary Value of Flood Control Capacity**

Flood control value of a paddy field can be equated to the flood control provided by a dam with same flood control capacity. In other words, the value of paddy field flood control capacity is equals to the cost of constructing and maintaining a dam structure to store the same amount of water. Figure 3.18 illustrates further the concept of flood control value replacement by a dam.

The unit cost for the substituted flood control dam was determined based on an actual flood control dam proposal in 2009. The unit cost is determined through the unit cost involved for dam construction and maintenance. Finally, the monetary value of flood capacity can be determined by multiplying the volume function and unit cost of a dam project.

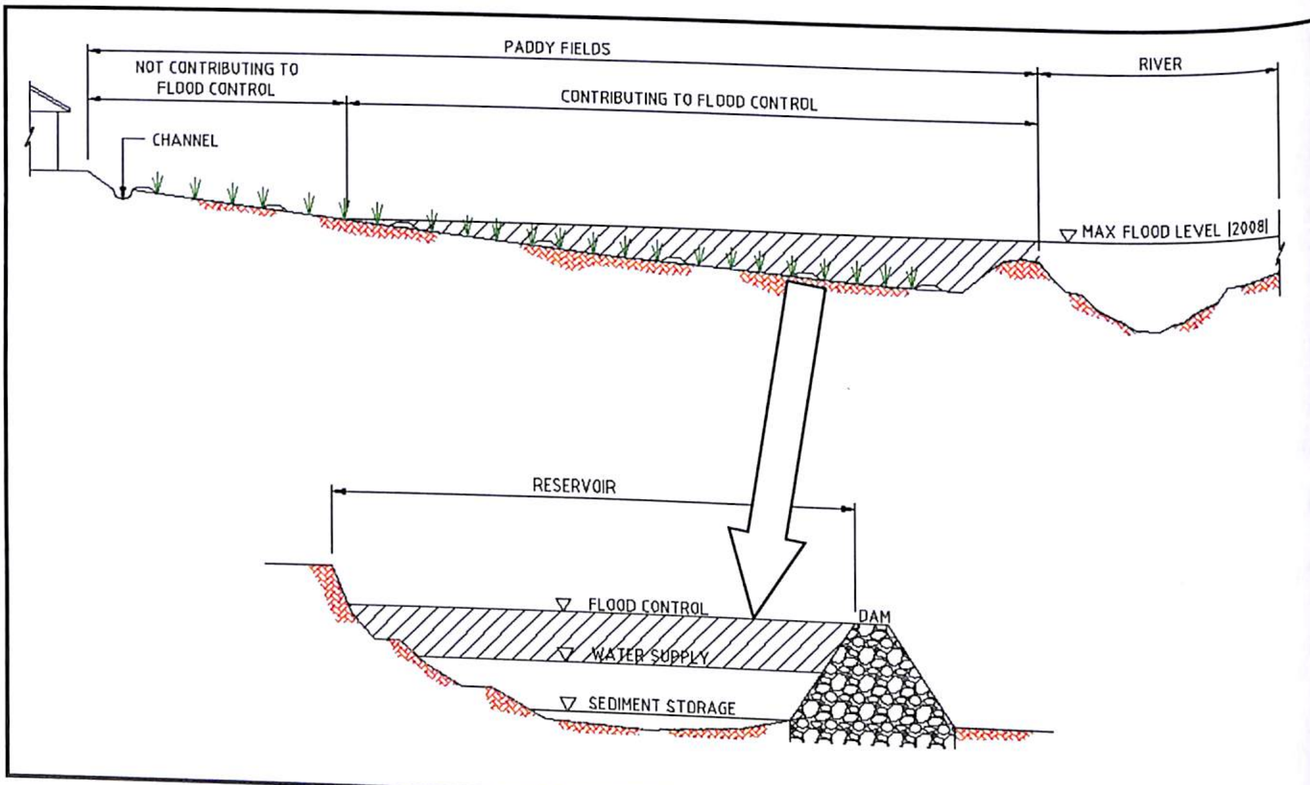


Figure 3.18: Conceptual illustration of cost replacement method for paddy field flood control monetary assessment

CHAPTER 4
RESULT AND DISCUSSION

4.1 River Floodplain Modeling

The flood inundation in the floodplain was performed using the Hydrologic Engineering Centers-River Analysis System (HEC-RAS) model.

The Hydrologic Engineering Centers-River Analysis System (HEC-RAS) is a one-dimensional river-hydraulics computer program developed by the Hydrologic Engineering Center of the Corps of Engineers designed to aid hydraulic engineers in channel flow analysis and floodplain determination. The recently released Version 4.1 of HEC-RAS (2010) incorporates various aspects of hydraulic modelling, including steady flow water surface profile computations and bridge hydraulics, unsteady flow simulation, movable boundary sediment transport computations and water quality analysis.

HEC-RAS simulations were performed to generate flood profiles and sedimentation using November 2009 flood event and ArcView GIS software was used to facilitate the physical data input and visualisation of modelling results.

4.1.1 Model Setup

HEC-RAS requires a set of data to perform the computations. The data requirements for simulation are the geometric data, values of Manning's (n) and hydraulic / hydrologic data.

4.1.2 Geometric Data

The geometric data consists of study limit determination, schematic river system, cross- section geometry, ineffective flow areas, and reach lengths. HEC-GeoRAS extension in the ArcView GIS software was used to produce the import file for the HEC-RAS model.

Data available to produce the geometric data was the river survey plan (in hardcopy format) provided by MADA office. This information was transferred to ground levels and distances in spreadsheet. Figure 4.1 shows the cross-section of CH 34,500 extracted from river survey plan.

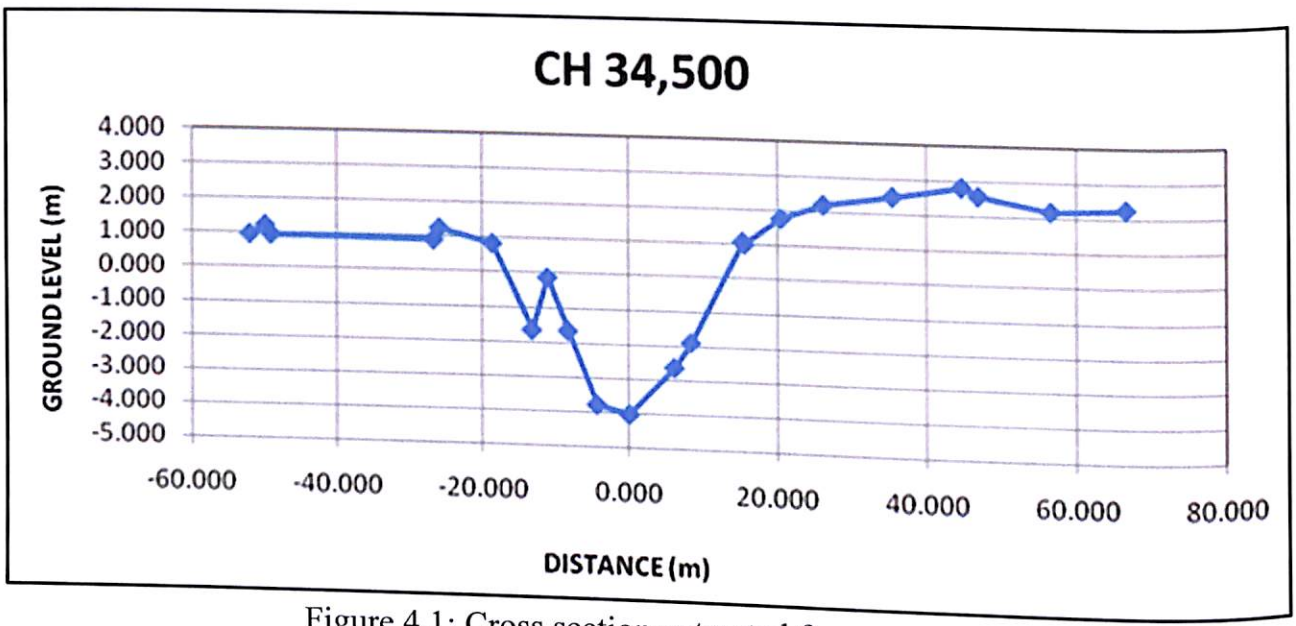
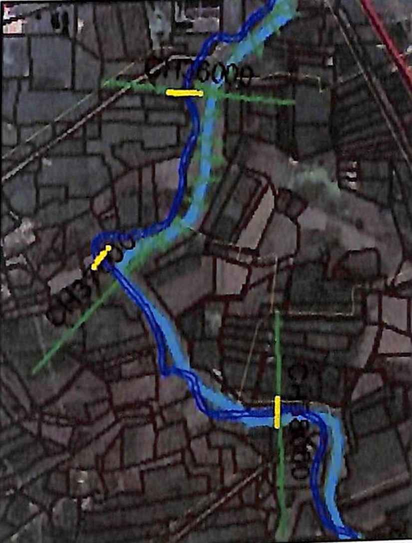
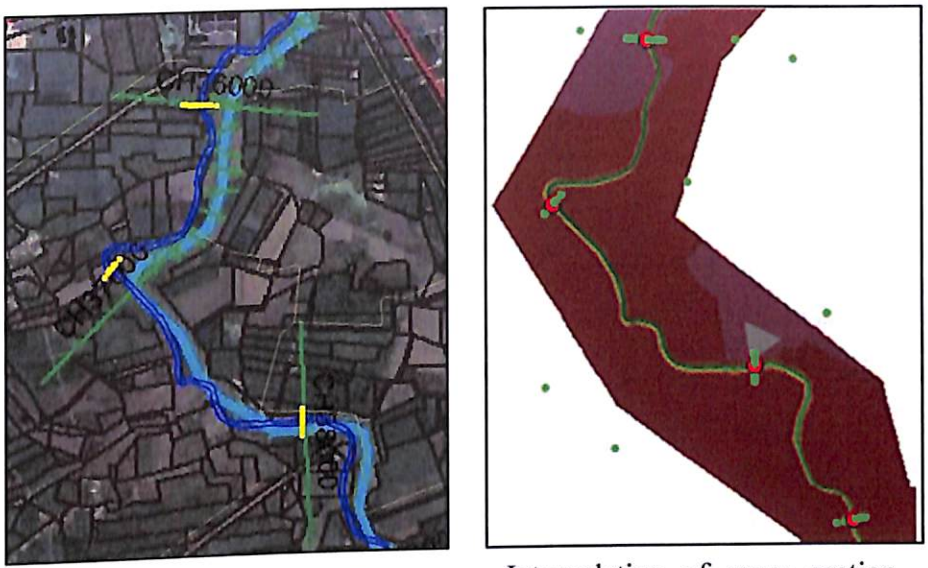


Figure 4.1: Cross section extracted from survey plan

Using ArcView GIS software, the cross-sections were converted into GIS format. Cross-sections were georeferenced based on river alignment extracted from Google^{TM} Earth and interpolated to create estimated river profile in Triangulated Irregular Network (TIN) as shown in Figure 4.2.



PT 6000



Georeferencing cross sections

Interpolation of cross section river profile estimation in TIN format

Figure 4.2: Preparation of georeferenced river profile

The maximum width for the surveyed cross section is only 150 m and insufficient to represent the floodplain. Spot height survey for the floodplain was conducted by the survey team. The floodplain was constructed based on these spot heights. Topography was generated using assumed levels. Elevation for roads and irrigation canals were set at 5.00 m. Figure 4.3 shows the Digital Terrain Model (DTM) in TIN format.

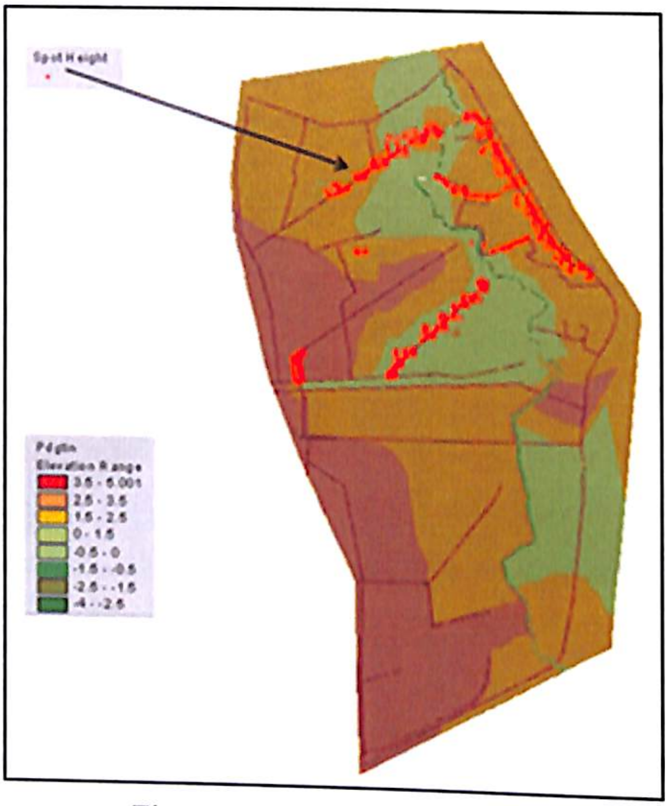
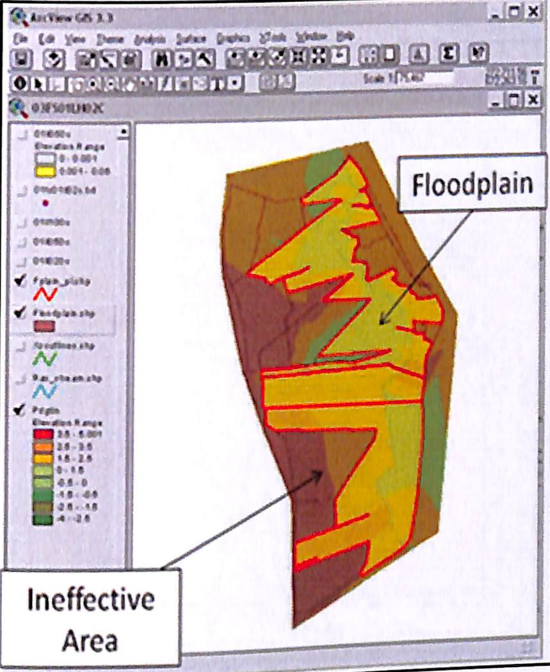
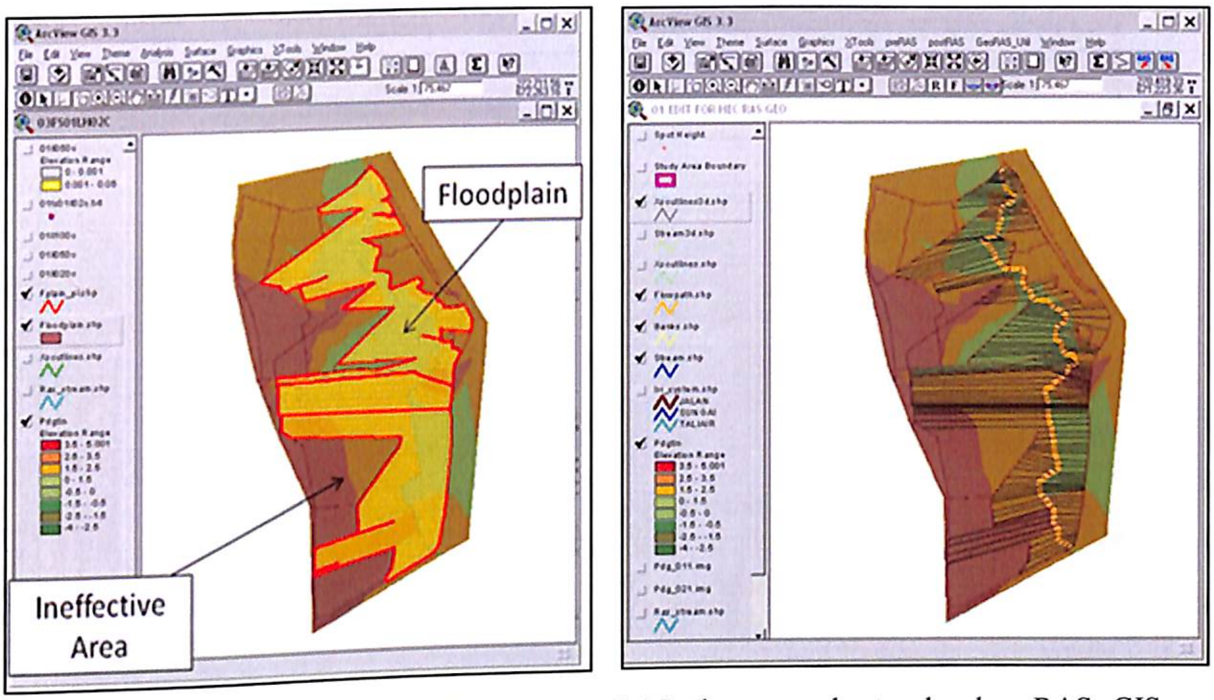


Figure 4.3: DEM of floodplain

Once the DTM of the study area was completed, RAS GIS import file for simulations in HEC-RAS was generated. This was done using HEC-geoRAS extension in conjunction with 3-D analyst of ArcView GIS software. Since HEC-RAS is one dimensional hydraulic model, only effective flow areas (areas that are actively conveying water) were delineated before developing the RAS GIS import file (Figure 4.4). For this modelling, the ineffective flow areas are the areas to the left and right of irrigation canals or roads.


Floodplain
Ineffective
Area



Floodplain delineated for the modelling

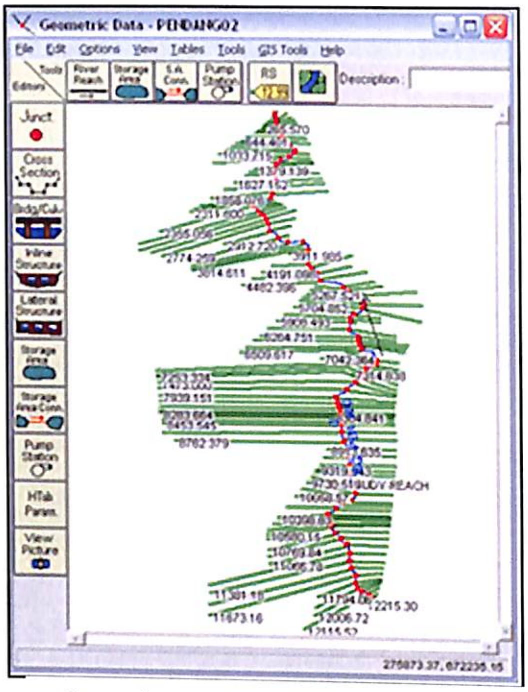
RAS theme ready to develop RAS GIS import file

Figure 4.4: Developing RAS GIS import file in ArcView

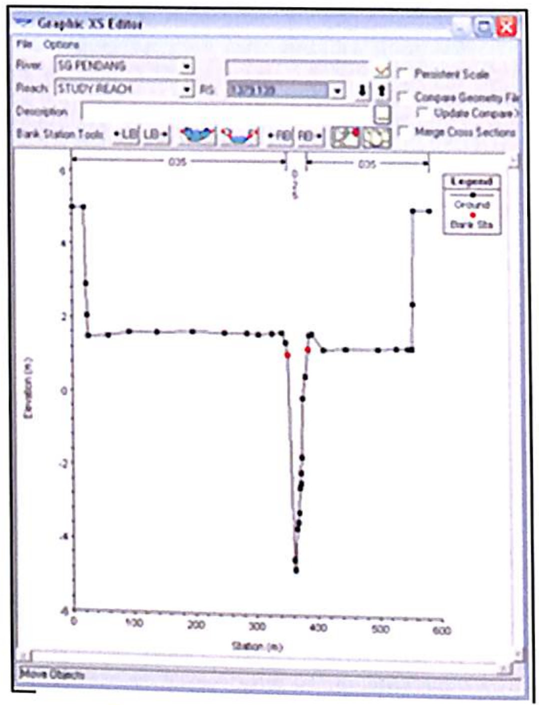
The RAS GIS import file was imported in HEC-RAS model and the geometric data was generated as shown in Figure 4.5. The geometric data were further edited and refined. For a more complete process, refer to HEC-RAS User's Manual.

4.1.3 Manning's Roughness Coefficient (*n*)

HEC-RAS uses Manning's equation to estimate the energy and hydraulic grade lines at each cross-section. Hence, selection of suitable values for Manning's *n* is very significant to the accuracy of the computed surface profiles. Manning roughness used for the simulation is 0.025 for river and the floodplain (equivalent to excavated or dredge river, earth winding and sluggish and with some vegetation) (Figure 4.6(a)). Manning roughness of 0.025 for river and 0.1 for floodplain is being tested (as shown in Figure 4.6(b)).

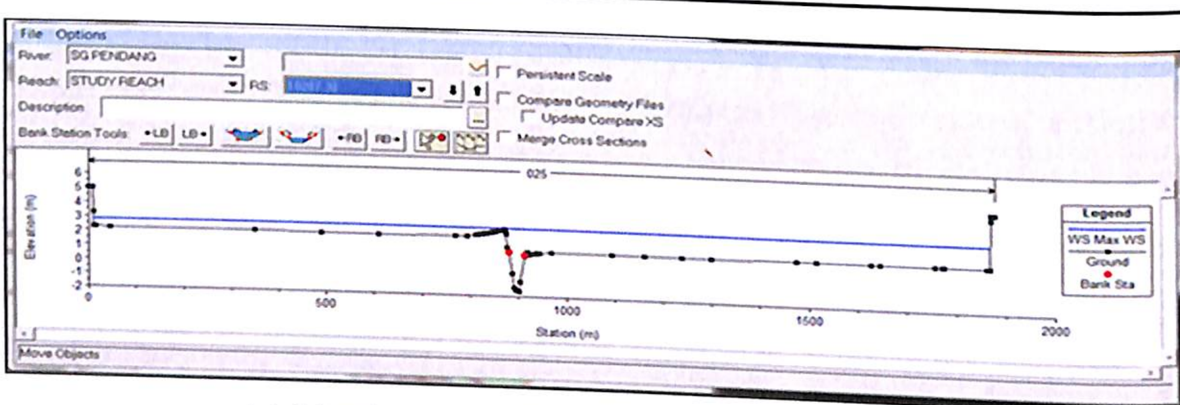


Sungai Pendang HEC-RAS Model

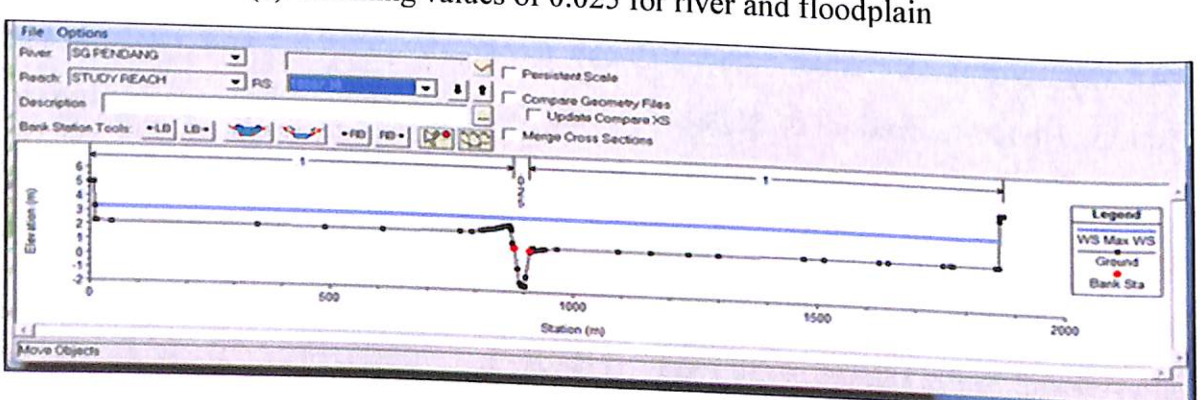


Example of cross section

Figure 4.5: Geometric data in HEC-RAS



(a) Manning values of 0.025 for river and floodplain



(b) Manning values of 0.025 for river and 0.1 for floodplain

Figure 4.6: Manning values for the simulated reach

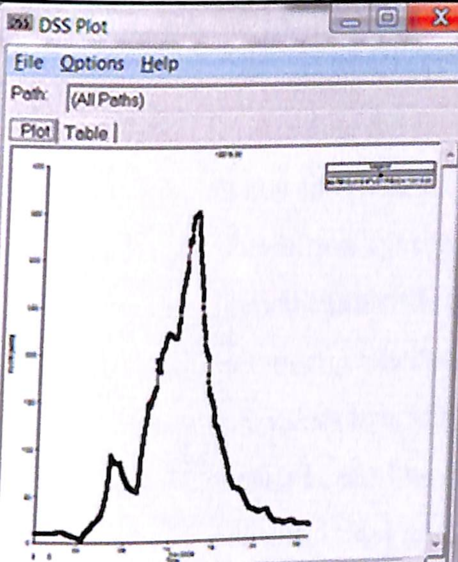
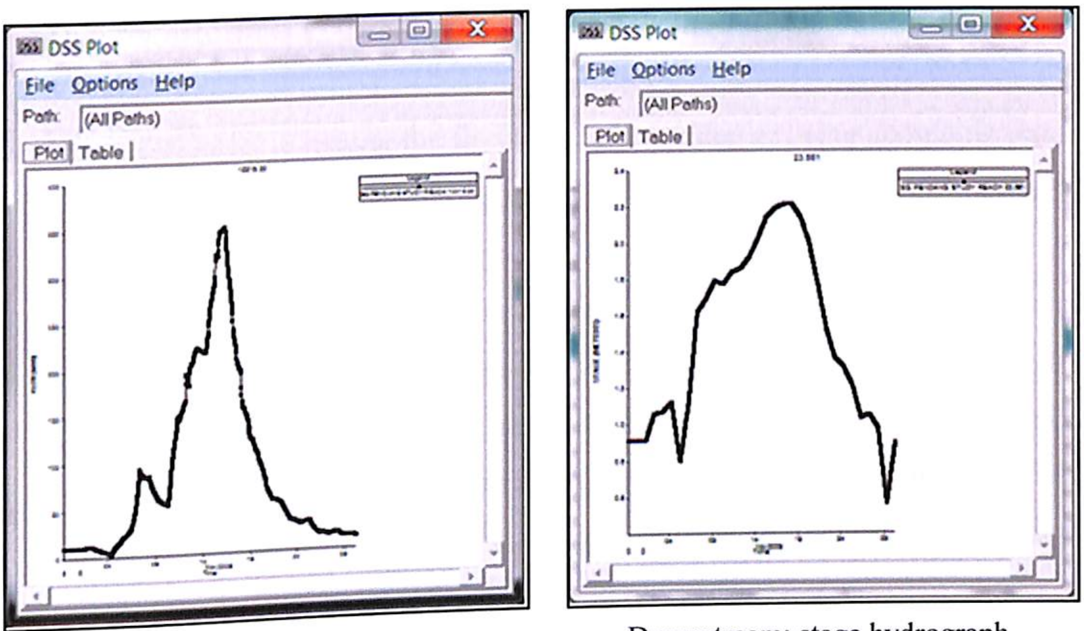

DSS Plot
File Options Help
Path: (All Paths)
Plot Table

Figure 4.7 shows hydrograph at Sungai Pendang from 01 November 2009 to 30 November 2009 was used as input for upstream and downstream condition.



Upstream: flow hydrograph

Downstream: stage hydrograph

Figure 4.7: Hydrograph for November 2009 at Sungai Pendang

4.1.4 Hydraulic / Hydrologic Data

Hydrologic / hydraulic data were obtained from Hydrology Division of MADA for the stations listed in Table 4.1. Data provided comprise of daily rainfall, water level and manual evaporation reading for Stations 36, 40, 56 and 127.

Table 4.1: List of Hydrology Station within the Study Reach (Source: MADA)

Station ID	Station Location
36	Titi Haji Idris / Sungai Pendang Alor Binjal
40	Pendang
56	Tanah Merah
127	Pekan Pendang (Data started in 2009)

Out of these four stations, only two stations, i.e., Station 36 (Titi Haji Idris / Sungai Pendang Alor Binjal) which is located at the downstream of the study reach and the upstream most station, Station127 (Pekan Pendang-data started in 2009) have complete water level reading for the month of November 2009. A complete set of upstream and downstream water level reading for Ampang Jajar for the months of September and November 2009 were also provided by MADA office.

Stage hydrographs of Ampang Jajar (US), Titi Haji Idris (S36) and Pekan Pendang (S127) were plotted as shown in Figure 4.8. Water levels of Ampang Jajar (the downstream most station) are lower than water levels at Titi Haji Idris and Pekan Pendang. The reasons for this to happen are numerous and are not discussed in this report. Nonetheless, from the shape of the Ampang Jajar and Titi Haji Idris stage hydrographs, it can be concluded that the Ampang Jajar has no or very little influence to the water level at Titi Haji Idris and Pekan Pendang. Based on this conclusion, the modelling was conducted independent of Ampang Jajar influence.

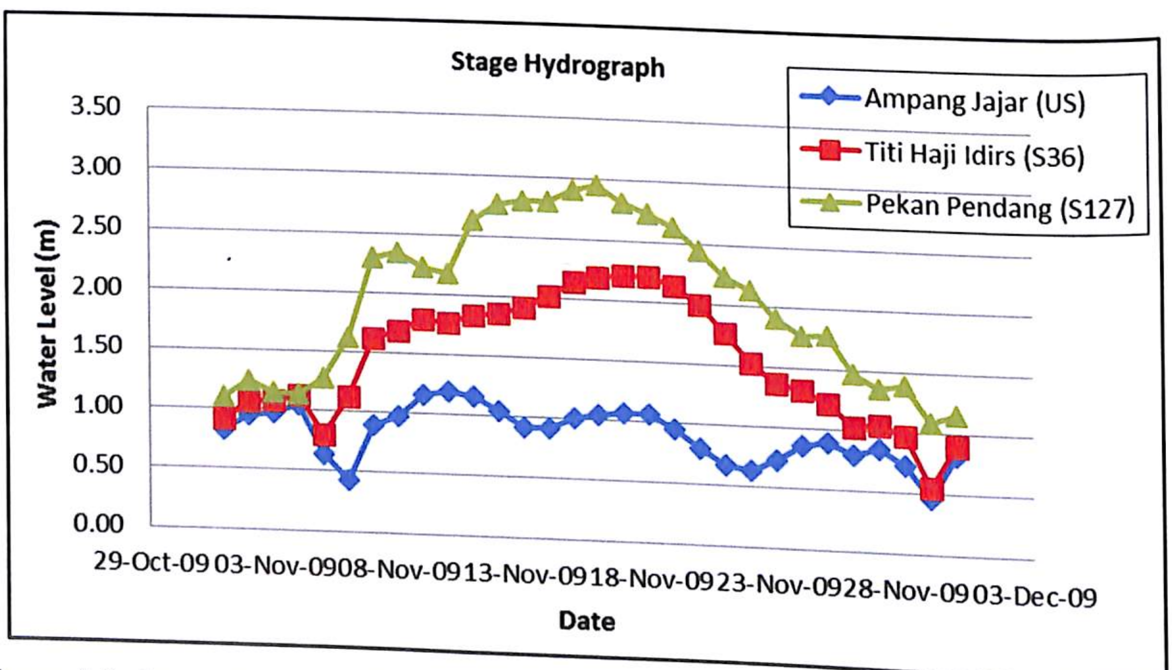


Figure 4.8: Stage Hydrographs of Ampang Jajar, Titi Haji Idris and Pekan Pendang for November 2009 (MADA, 2008)

4.1.5 Modelling Series

Three modelling series were conducted as summarised in Table 4.2.

Table 4.2: Modelling series

PROJECT NAME	HDYRAULIC MODELLING
PNDG02A	Running the flood modelling using existing geometric data.
PNDG02B	Running the flood modelling using modified geometric data. The floodplain levels of South Segment were increased to 4.0 m and maintaining the existing levels for South Segment.
PNDG02C	Running the flood modelling using modified geometric data. The floodplain levels of North Segment were increased to 3.0 m and maintaining the existing levels for North Segment.

4.1.6 Simulation Results

Flood modelling was conducted for three cases as listed in Table 4.2. The representative cross sections are as shown in Figure 4.9.

4.1.5 Modelling Series

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4.1.6 Simulation Results

Flood modelling was conducted for three cases as listed in Table 4.2. The representative cross sections are as shown in Figure 4.9.

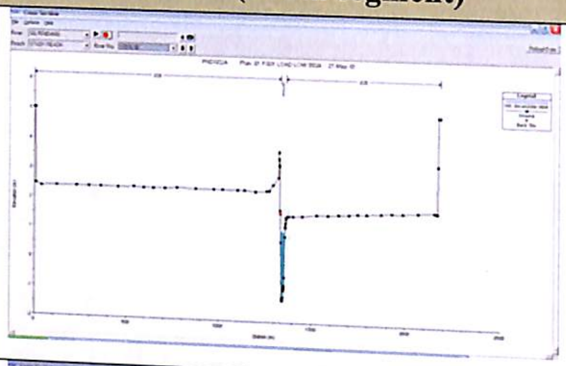
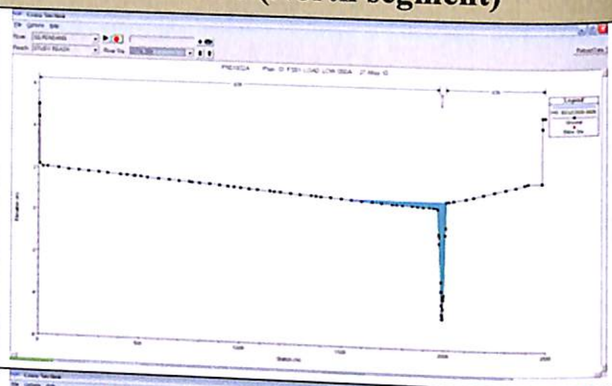
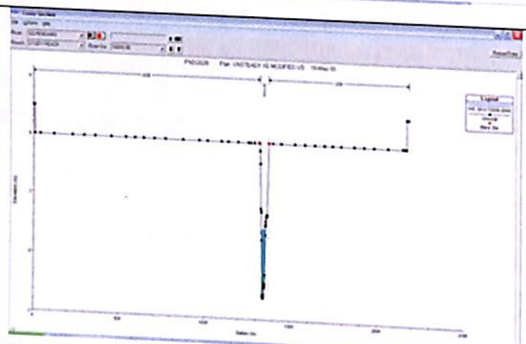
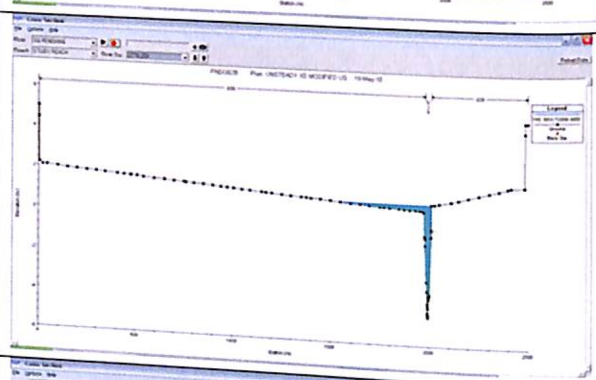
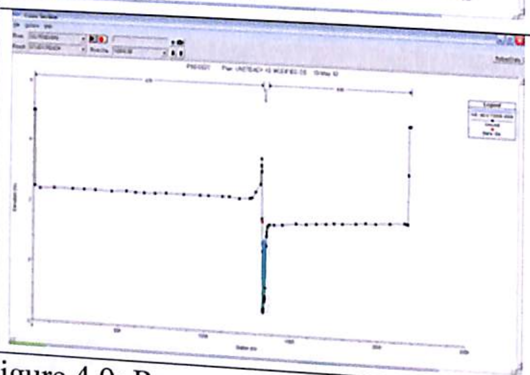
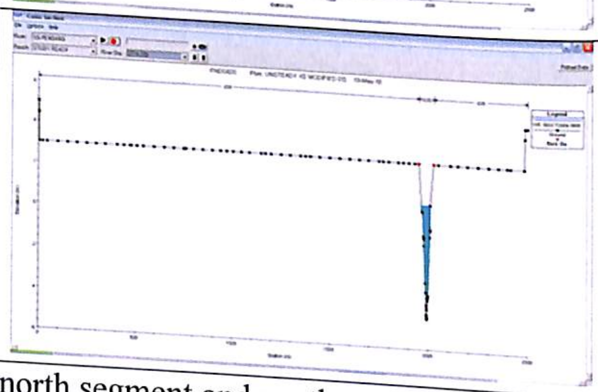
	River Section	
	10916.90 (South segment)	**10916.90 (North segment)**
PNDG02A		
PNDG02B		
PNDG02C		

Figure 4.9: Representative cross sections for north segment and south segment

Results of the hydraulic modelling were analysed using the water surface profile as shown in Figure 4.10. Result shows that modification of either upstream or downstream reach will affect the flood water levels. Impact is highest if the South Segment (upstream reach) is modified with the water level increases from 2.95 m (PNDG02A) to 4.50 m (PNDG02B).

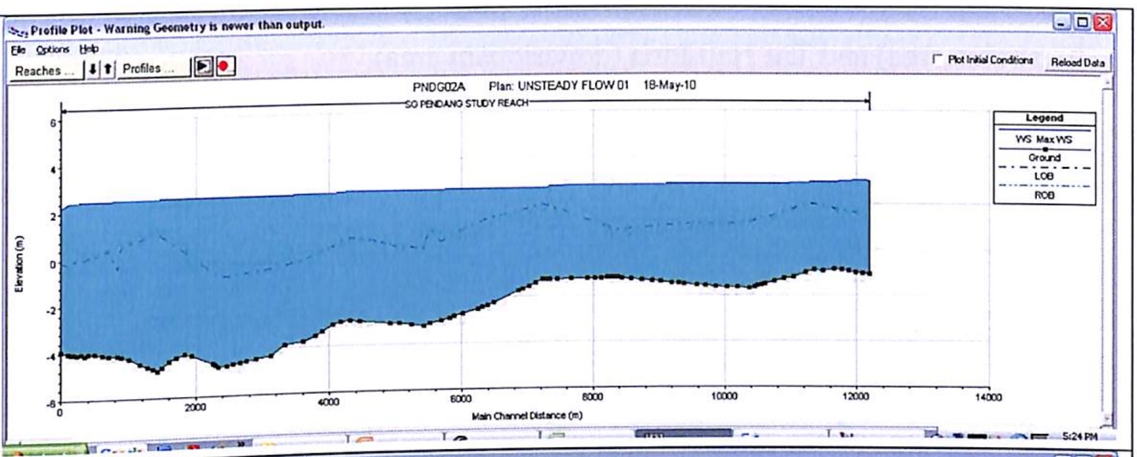
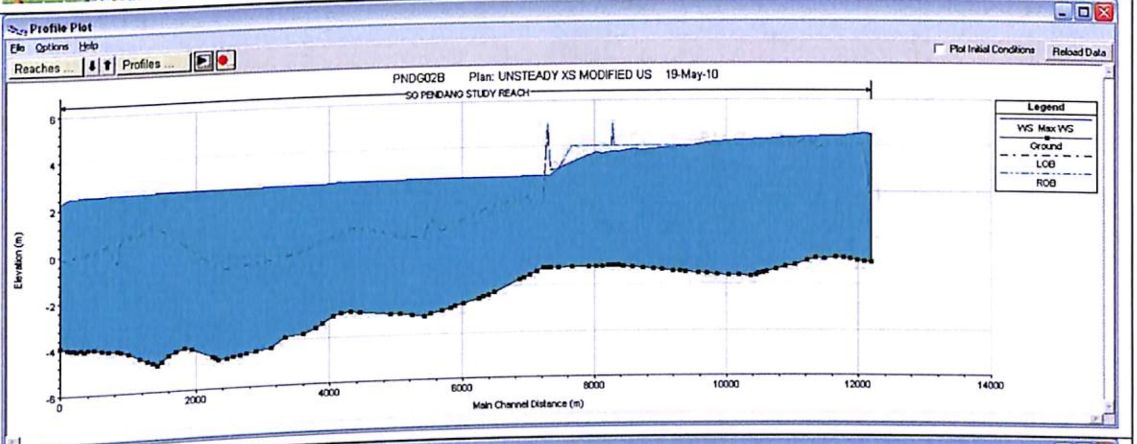
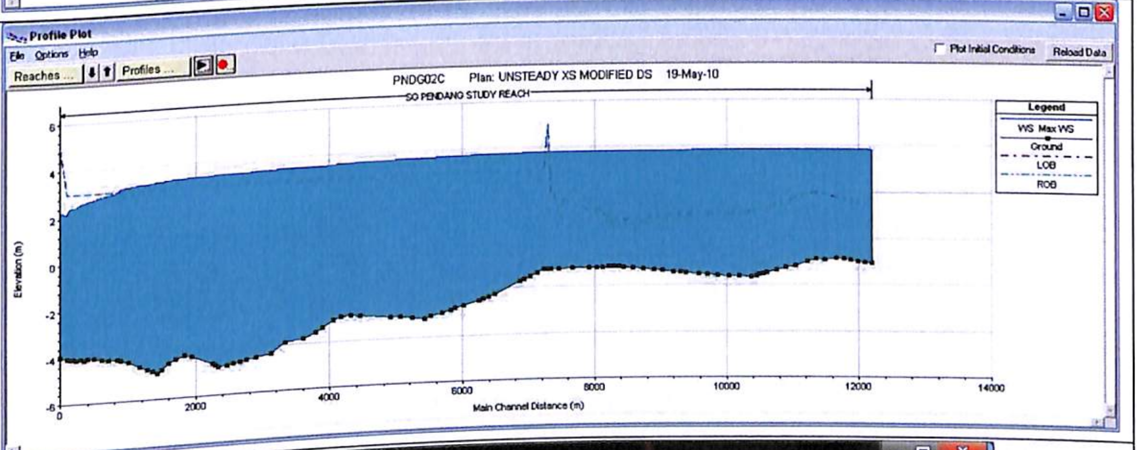
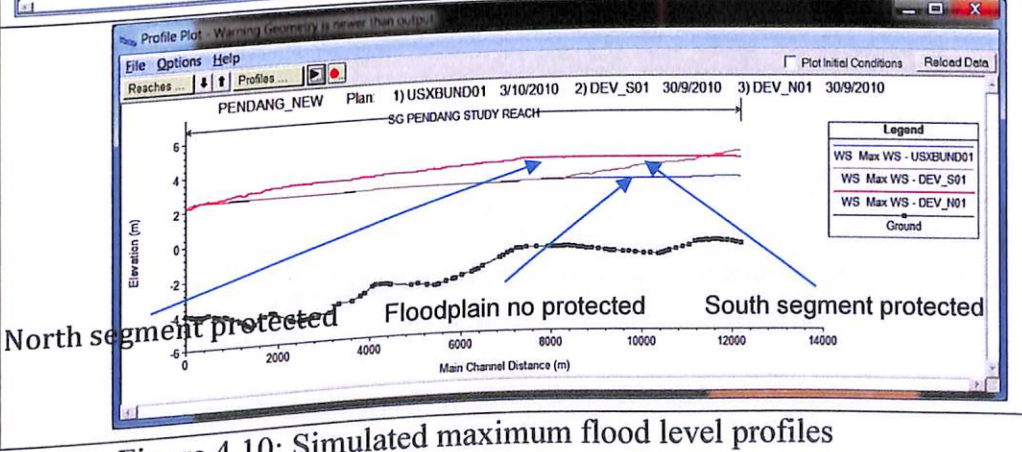
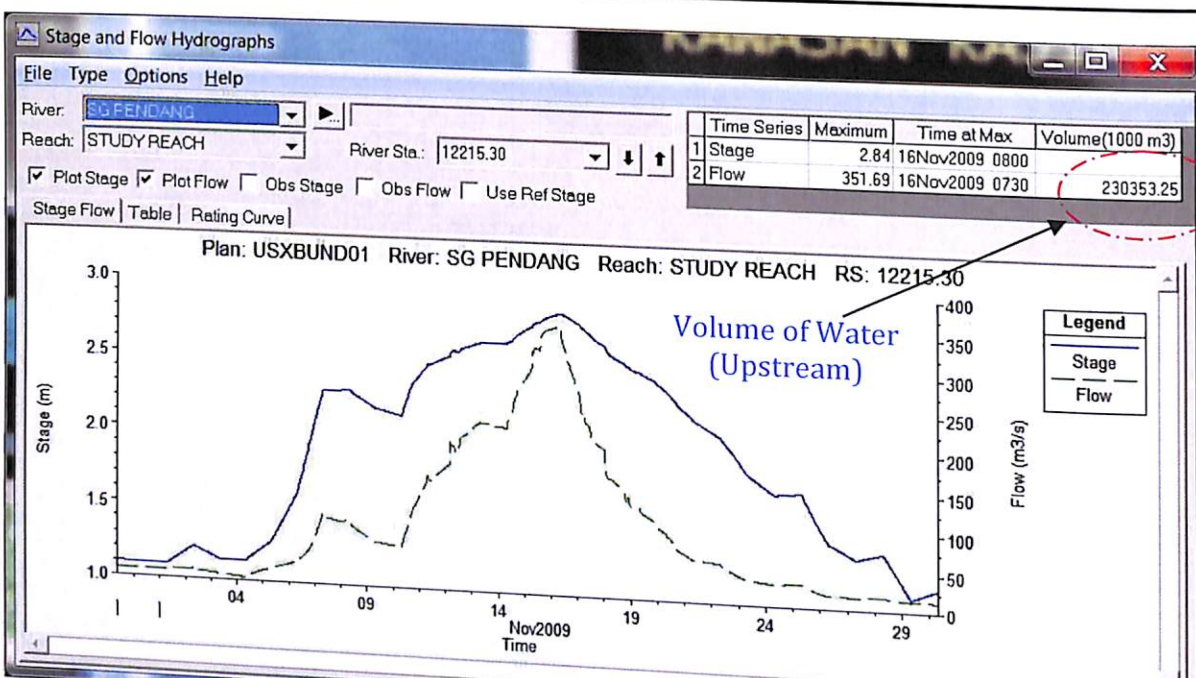
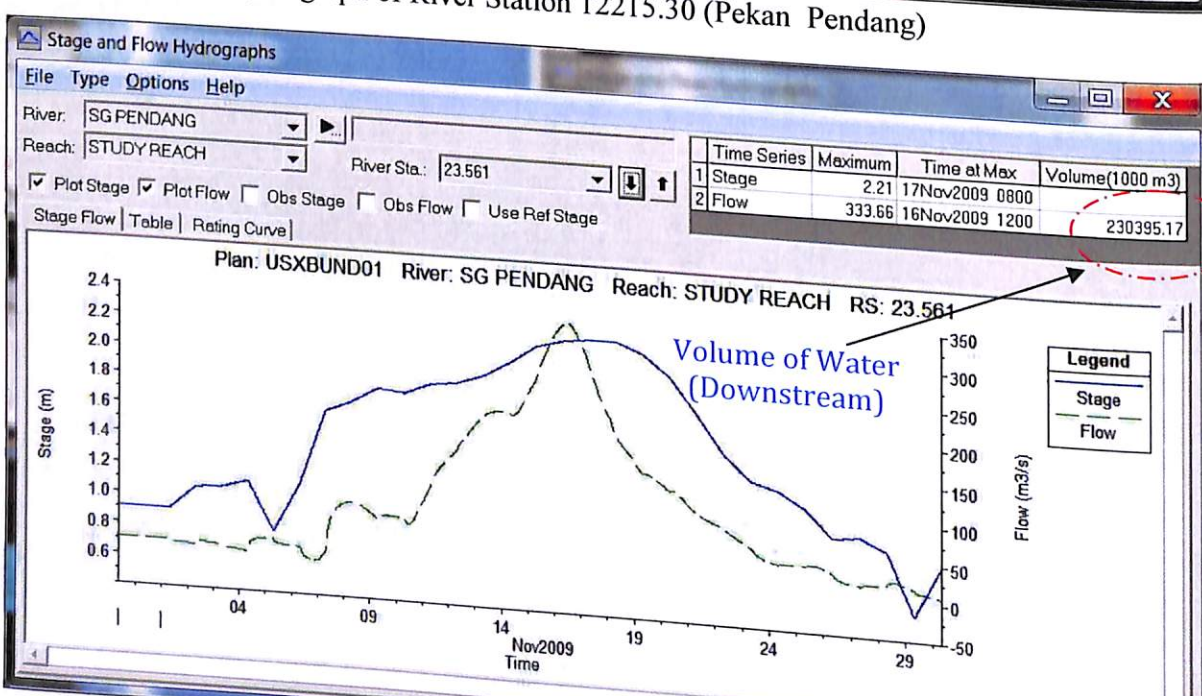
PNDG02A	
PNDG02B	
PNDG02C	
	

Figure 4.10: Simulated maximum flood level profiles

Figure 4.11 presents the total volume of water was stored in study area i.e. Pekan Pendang (upstream area) and Titi Haji Idris (downstream area).



(a) Hydrograph of River Station 12215.30 (Pekan Pendang)



(b) Hydrograph of River Station 23.561 (Titi Haji Idris)

Figure 4.11: Hydrograph at Sungai Pendang

Figure 4.12 below illustrated the maximum flood area along Sungai Pendang.

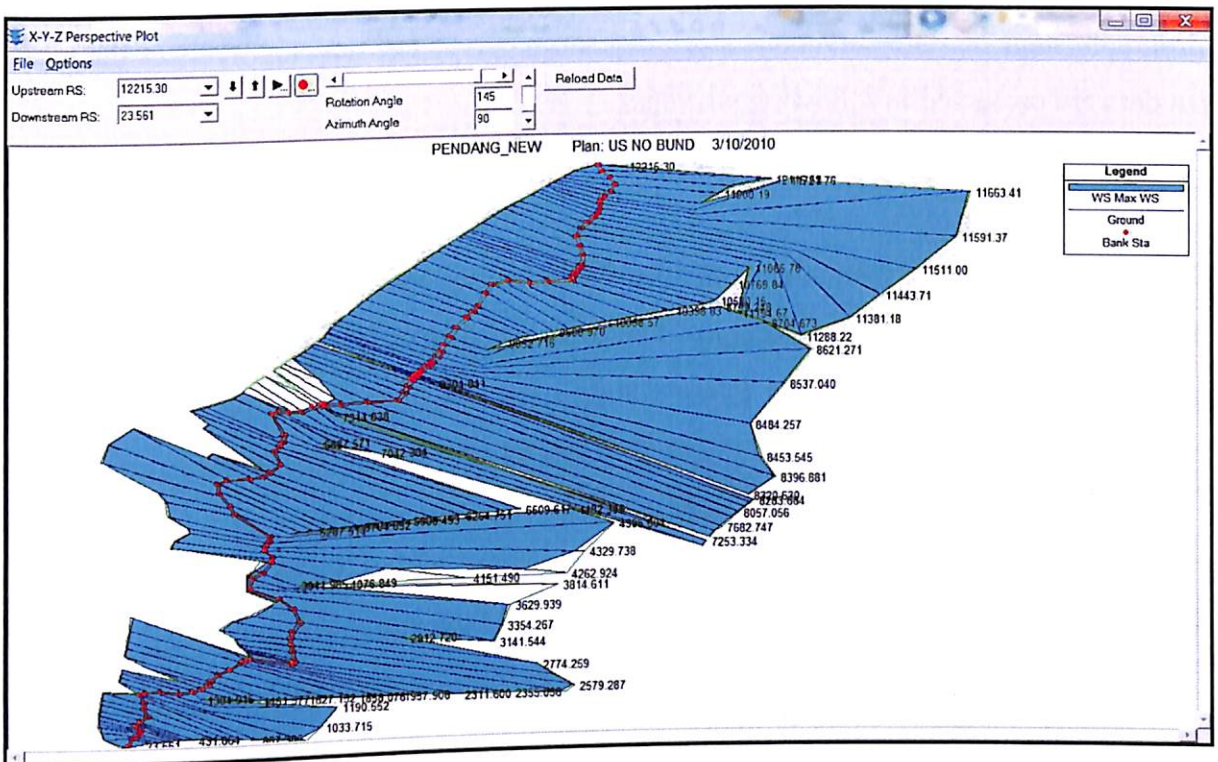


Figure 4.12: Maximum flood area

4.2 Micro-Scale Flood Control Analysis

Apart from playing an important role by acting as floodplain to control river flooding and sediments carried by the floodwater, paddy plot also has a part to play in local hydrology. The terrain and plot structure have made paddy plots into natural detention/retention basin, where they are able to prevent excessive runoff generation. This structure is unique to paddy planting as plot bunds are required to contain water for wet paddy plants and provide accessibility to farmers.

However, such process is heavily linked to farmers' activity and practices on site. This section of the study will investigate three study plot in Region III area on their capacity to provide flood and control at micro scale.

4.2.1 Model Setup

Three (3) types of input is required to produce a level pool routing analysis, i.e. inflow hydrograph, stage-storage curve, and stage-discharge curve. The developments of the mentioned input data are presented in following writings.

- ***Inflow Hydrographs***

Inflow hydrographs represents the timeline of incoming water into the paddy plot. In this analysis, only rainfall is considered as the input to the paddy plot and hence the inflow hydrograph actually represents the rate of rainfall volume onto the paddy plot. There are two types of rainfall examined, i.e. historical rainfall and stormwater design rainfall.

Design rainfalls were derived from the nearest rain gauge station, i.e. Alor Setar. The procedure is described in detail in Chapter 13, the Stormwater Management Manual for Malaysia (DID, 2000). Generally, a set of 4 coefficients was first determined based on the desired return period or Average Return Intervals (ARI) for Alor Setar and was given in Table 4.3. The coefficients were then fitted into a best fit equation (Equation 4.1), which was derived from the Intensity-Duration-Frequency (IDF) Curve with the desired rainfall duration.

$$\ln({}^{R}I_{t}) = a + b\ln(t) + c(\ln(t))^2 + d(\ln(t))^3$$

(Equation 4.1)

Where,

${}^{R}I_{t}$	=	Average storm intensity of R ARI with t duration (min) in mm/hr
a, b, c, d	=	Fitting constant

Table 4.4: Temporal pattern for various design storm

Time Segment	Duration (minute)				
	30	60	120	180	360
1	0.16	0.039	0.03	0.06	0.32
2	0.25	0.07	0.119	0.22	0.41
3	0.33	0.168	0.31	0.34	0.11
4	0.09	0.12	0.208	0.22	0.08
5	0.11	0.232	0.09	0.12	0.05
6	0.06	0.101	0.119	0.04	0.03
7		0.089	0.094		
8		0.057	0.03		
9		0.048			
10		0.031			
11		0.028			
12		0.017			
Time interval (minutes)	5	5	15	30	60

Table 4.3: Rainfall IDF Coefficients for Alor Setar Station

Design ARI	Constant Values			
	a	b	c	d
2	5.679	-0.0276	-0.0993	0.0033
5	4.9709	0.546	-0.2176	0.0113
10	5.6422	0.1575	-0.1329	0.0056
20	5.8203	0.1093	-0.1248	0.0053
50	5.742	0.2273	-0.1481	0.0068
100	6.3202	-0.0778	-0.0849	0.0026

This produced the average rainfall intensity of the design storm. The rainfall volume could be easily computed from by multiplying the average intensity with the duration of storm. Temporal pattern of the storm given in MSMA (Table 4.4) was then used to determine the fraction of rainfall volume during each time interval within a storm duration.

Table 4.4: Temporal pattern for various design storm durations for West Coast

Time Segment	Duration (minute)						
	30	60	120	180	360	720	1440
1	0.16	0.039	0.03	0.06	0.32	0.32	0.32
2	0.25	0.07	0.119	0.22	0.41	0.41	0.41
3	0.33	0.168	0.31	0.34	0.11	0.11	0.11
4	0.09	0.12	0.208	0.22	0.08	0.08	0.08
5	0.11	0.232	0.09	0.12	0.05	0.05	0.05
6	0.06	0.101	0.119	0.04	0.03	0.03	0.03
7		0.089	0.094				
8		0.057	0.03				
9		0.048					
10		0.031					
11		0.028					
12		0.017					
Time interval (minutes)	5	5	15	30	60	120	240

Design rainfall produced for 2, 5, 10, 20, 50 and 100-year ARI events with duration of 30, 60, 120, 180, 360, 720, and 1440 minutes were produced and used in this analysis. For duration of 720 and 1440 minutes, the temporal ratio was assumed to be based on that of 360 minutes due to limitation of data. Figure 4.13 shows an example of the derived storm hyetograph for 60-minute 10-year ARI storm event.

In order to convert the rainfall to pond inflow, the computed rainfall depth for each time interval was multiplied by the catchment area. The volume was divided by the duration of the time interval will produce inflow rate. As an example, Figure 4.14 shows the inflow hydrograph derived for Plot 1, Plot 2 and Plot 3 using rainfall hyetograph of Figure 4.13. Table 4.5 shows the derived design rainfall Inflow for Plot 1, 2, and 3.

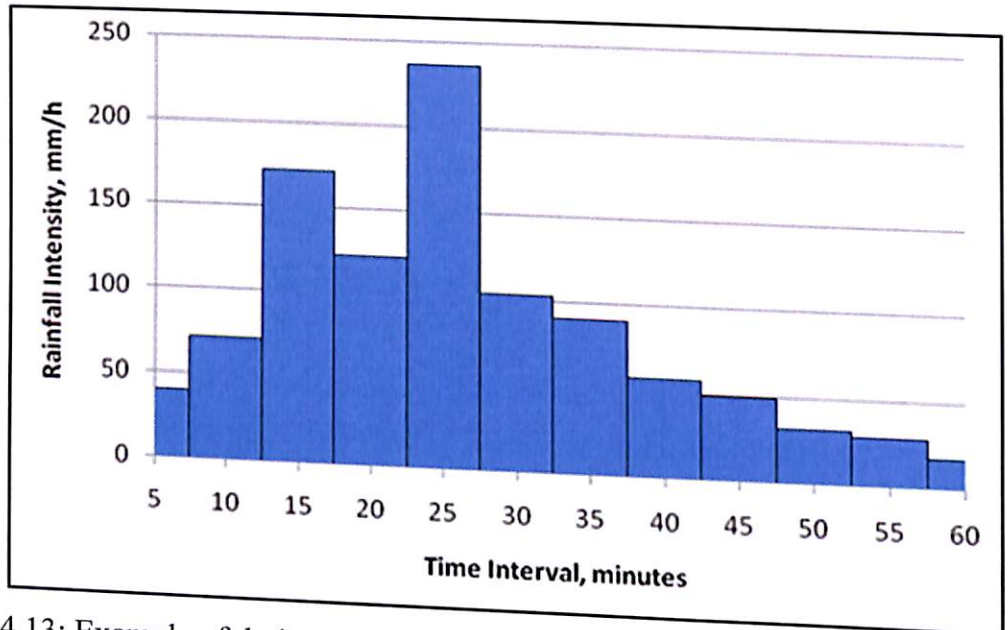


Figure 4.13: Example of derived rainfall Hyetograph for a 60-minute 10-year ARI event.

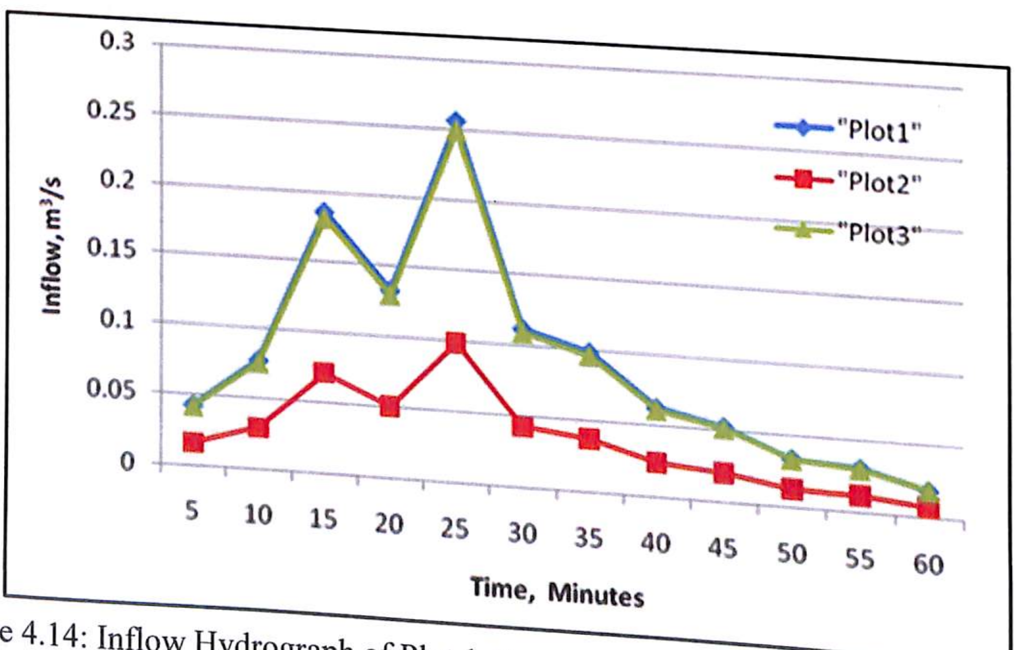


Figure 4.14: Inflow Hydrograph of Plot 1, 2 and 3 for a 60-minute 10-year ARI event

Table 4.5: Derived design rainfall inflow for Plot 1, 2, and 3

	2 ARI			5 ARI			10 ARI			20 ARI			50 ARI			100 ARI		
30 mins	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
	0.1000	0.0385	0.0975	0.1209	0.0465	0.1178	0.1343	0.0517	0.1309	0.1478	0.0569	0.1440	0.1654	0.0636	0.1612	0.1840	0.0708	0.1793
	0.1563	0.0601	0.1523	0.1888	0.0726	0.1840	0.2098	0.0807	0.2045	0.2310	0.0888	0.2251	0.2585	0.0994	0.2519	0.2875	0.1106	0.2801
	0.2063	0.0794	0.2010	0.2493	0.0959	0.2429	0.2770	0.1065	0.2699	0.3049	0.1173	0.2971	0.3412	0.1312	0.3325	0.3795	0.1460	0.3698
	0.0563	0.0216	0.0548	0.0680	0.0261	0.0662	0.0755	0.0291	0.0736	0.0832	0.0320	0.0810	0.0931	0.0358	0.0907	0.1035	0.0398	0.1008
	0.0688	0.0265	0.0670	0.0831	0.0320	0.0810	0.0923	0.0355	0.0900	0.1016	0.0391	0.0990	0.1137	0.0437	0.1108	0.1265	0.0487	0.1233
	0.0375	0.0144	0.0365	0.0453	0.0174	0.0442	0.0504	0.0194	0.0491	0.0554	0.0213	0.0540	0.0620	0.0239	0.0604	0.0690	0.0265	0.0672
60 mins	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
	0.0315	0.0121	0.0307	0.0387	0.0149	0.0377	0.0431	0.0166	0.0420	0.0475	0.0183	0.0463	0.0534	0.0205	0.0520	0.0590	0.0227	0.0575
	0.0565	0.0217	0.0550	0.0694	0.0267	0.0676	0.0774	0.0298	0.0754	0.0852	0.0328	0.0830	0.0958	0.0368	0.0934	0.1059	0.0407	0.1032
	0.1355	0.0521	0.1320	0.1666	0.0641	0.1623	0.1858	0.0715	0.1810	0.2045	0.0787	0.1993	0.2299	0.0884	0.2240	0.2542	0.0978	0.2477
	0.0968	0.0372	0.0943	0.1190	0.0458	0.1159	0.1327	0.0510	0.1293	0.1461	0.0562	0.1423	0.1642	0.0632	0.1600	0.1816	0.0698	0.1769
	0.1871	0.0720	0.1823	0.2300	0.0885	0.2241	0.2566	0.0987	0.2500	0.2824	0.1086	0.2752	0.3175	0.1221	0.3094	0.3510	0.1350	0.3420
	0.0815	0.0313	0.0794	0.1001	0.0385	0.0976	0.1117	0.0430	0.1088	0.1230	0.0473	0.1198	0.1382	0.0532	0.1347	0.1528	0.0588	0.1489
	0.0718	0.0276	0.0699	0.0882	0.0339	0.0860	0.0984	0.0379	0.0959	0.1083	0.0417	0.1056	0.1218	0.0469	0.1187	0.1347	0.0518	0.1312
	0.0460	0.0177	0.0448	0.0565	0.0217	0.0551	0.0630	0.0242	0.0614	0.0694	0.0267	0.0676	0.0780	0.0300	0.0760	0.0862	0.0332	0.0840
	0.0387	0.0149	0.0377	0.0476	0.0183	0.0464	0.0531	0.0204	0.0517	0.0584	0.0225	0.0569	0.0657	0.0253	0.0640	0.0726	0.0279	0.0708
	0.0250	0.0096	0.0244	0.0307	0.0118	0.0299	0.0343	0.0132	0.0334	0.0377	0.0145	0.0368	0.0424	0.0163	0.0413	0.0469	0.0180	0.0457
	0.0226	0.0087	0.0220	0.0278	0.0107	0.0270	0.0310	0.0119	0.0302	0.0341	0.0131	0.0332	0.0383	0.0147	0.0373	0.0424	0.0163	0.0413
	0.0137	0.0053	0.0134	0.0169	0.0065	0.0164	0.0188	0.0072	0.0183	0.0207	0.0080	0.0202	0.0233	0.0089	0.0227	0.0257	0.0099	0.0251
120 mins	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3
	0.0098	0.0038	0.0096	0.0121	0.0046	0.0118	0.0137	0.0053	0.0134	0.0151	0.0058	0.0148	0.0170	0.0065	0.0166	0.0189	0.0073	0.0184
	0.0390	0.0150	0.0380	0.0479	0.0184	0.0466	0.0544	0.0209	0.0530	0.0601	0.0231	0.0585	0.0675	0.0260	0.0658	0.0750	0.0289	0.0731
	0.1016	0.0391	0.0990	0.1247	0.0480	0.1215	0.1416	0.0545	0.1380	0.1565	0.0602	0.1525	0.1759	0.0677	0.1714	0.1955	0.0752	0.1905
	0.0682	0.0262	0.0664	0.0837	0.0322	0.0815	0.0950	0.0365	0.0926	0.1050	0.0404	0.1023	0.1181	0.0454	0.1150	0.1312	0.0504	0.1278
	0.0295	0.0113	0.0287	0.0362	0.0139	0.0353	0.0411	0.0158	0.0401	0.0454	0.0175	0.0443	0.0511	0.0196	0.0498	0.0567	0.0218	0.0553
	0.0390	0.0150	0.0380	0.0479	0.0184	0.0466	0.0544	0.0209	0.0530	0.0601	0.0231	0.0585	0.0675	0.0260	0.0658	0.0750	0.0289	0.0731
	0.0308	0.0119	0.0300	0.0378	0.0145	0.0368	0.0429	0.0165	0.0418	0.0475	0.0183	0.0462	0.0534	0.0205	0.0520	0.0593	0.0228	0.0578
	0.0098	0.0038	0.0096	0.0121	0.0046	0.0118	0.0137	0.0053	0.0134	0.0151	0.0058	0.0148	0.0170	0.0065	0.0166	0.0189	0.0073	0.0184

Table 4.5: Derived design rainfall inflow for Plot 1, 2, and 3 (continued)

	2 ARI			5 ARI			10 ARI			20 ARI			50 ARI			100 ARI		
180 mins	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**
	0.0342	0.0131	0.0333	0.0418	0.0161	0.0407	0.0480	0.0185	0.0468	0.0533	0.0205	0.0519	0.0599	0.0230	0.0583	0.0668	0.0257	0.0651
	0.0414	0.0159	0.0403	0.0505	0.0194	0.0492	0.0581	0.0224	0.0566	0.0645	0.0248	0.0629	0.0725	0.0279	0.0706	0.0809	0.0311	0.0788
	0.0342	0.0131	0.0333	0.0418	0.0161	0.0407	0.0480	0.0185	0.0468	0.0533	0.0205	0.0519	0.0599	0.0230	0.0583	0.0668	0.0257	0.0651
	0.0288	0.0111	0.0280	0.0352	0.0135	0.0343	0.0404	0.0156	0.0394	0.0449	0.0173	0.0437	0.0504	0.0194	0.0491	0.0563	0.0216	0.0548
	0.0248	0.0095	0.0242	0.0303	0.0117	0.0295	0.0349	0.0134	0.0340	0.0387	0.0149	0.0377	0.0435	0.0167	0.0424	0.0485	0.0187	0.0473
	0.0180	0.0069	0.0175	0.0220	0.0085	0.0214	0.0253	0.0097	0.0246	0.0280	0.0108	0.0273	0.0315	0.0121	0.0307	0.0352	0.0135	0.0343
360 mins	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**
	0.0295	0.0113	0.0287	0.0360	0.0139	0.0351	0.0421	0.0162	0.0410	0.0472	0.0182	0.0460	0.0530	0.0204	0.0516	0.0594	0.0229	0.0579
	0.0203	0.0078	0.0198	0.0248	0.0096	0.0242	0.0291	0.0112	0.0283	0.0326	0.0125	0.0317	0.0365	0.0140	0.0356	0.0410	0.0158	0.0399
	0.0163	0.0063	0.0158	0.0199	0.0076	0.0194	0.0232	0.0089	0.0226	0.0260	0.0100	0.0254	0.0292	0.0112	0.0285	0.0328	0.0126	0.0320
	0.0122	0.0047	0.0119	0.0149	0.0057	0.0145	0.0174	0.0067	0.0170	0.0195	0.0075	0.0190	0.0219	0.0084	0.0214	0.0246	0.0095	0.0240
	0.0142	0.0055	0.0139	0.0174	0.0067	0.0169	0.0203	0.0078	0.0198	0.0228	0.0088	0.0222	0.0256	0.0098	0.0249	0.0287	0.0110	0.0280
	0.0091	0.0035	0.0089	0.0112	0.0043	0.0109	0.0131	0.0050	0.0127	0.0147	0.0056	0.0143	0.0164	0.0063	0.0160	0.0184	0.0071	0.0180
720 mins	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**
	0.0160	0.0062	0.0156	0.0200	0.0077	0.0195	0.0234	0.0090	0.0228	0.0266	0.0102	0.0259	0.0299	0.0115	0.0291	0.0334	0.0128	0.0325
	0.0110	0.0042	0.0108	0.0138	0.0053	0.0134	0.0162	0.0062	0.0158	0.0183	0.0071	0.0179	0.0206	0.0079	0.0201	0.0230	0.0089	0.0224
	0.0088	0.0034	0.0086	0.0110	0.0042	0.0108	0.0129	0.0050	0.0126	0.0147	0.0056	0.0143	0.0165	0.0063	0.0161	0.0184	0.0071	0.0179
	0.0066	0.0025	0.0065	0.0083	0.0032	0.0081	0.0097	0.0037	0.0095	0.0110	0.0042	0.0107	0.0124	0.0048	0.0120	0.0138	0.0053	0.0135
	0.0077	0.0030	0.0075	0.0097	0.0037	0.0094	0.0113	0.0044	0.0110	0.0128	0.0049	0.0125	0.0144	0.0055	0.0141	0.0161	0.0062	0.0157
	0.0050	0.0019	0.0048	0.0062	0.0024	0.0061	0.0073	0.0028	0.0071	0.0083	0.0032	0.0080	0.0093	0.0036	0.0090	0.0104	0.0040	0.0101
1440 mins	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 1**	**Plot 2**	**Plot 3**
	0.0084	0.0032	0.0082	0.0112	0.0043	0.0109	0.0128	0.0049	0.0124	0.0147	0.0057	0.0143	0.0166	0.0064	0.0162	0.0181	0.0070	0.0177
	0.0058	0.0022	0.0057	0.0077	0.0030	0.0075	0.0088	0.0034	0.0086	0.0101	0.0039	0.0099	0.0115	0.0044	0.0112	0.0125	0.0048	0.0122
	0.0046	0.0018	0.0045	0.0062	0.0024	0.0060	0.0070	0.0027	0.0069	0.0081	0.0031	0.0079	0.0092	0.0035	0.0089	0.0100	0.0038	0.0098
	0.0035	0.0013	0.0034	0.0046	0.0018	0.0045	0.0053	0.0020	0.0051	0.0061	0.0023	0.0059	0.0069	0.0026	0.0067	0.0075	0.0029	0.0073
	0.0041	0.0016	0.0040	0.0054	0.0021	0.0053	0.0062	0.0024	0.0060	0.0071	0.0027	0.0069	0.0080	0.0031	0.0078	0.0088	0.0034	0.0085
	0.0026	0.0010	0.0025	0.0035	0.0013	0.0034	0.0040	0.0015	0.0039	0.0046	0.0018	0.0044	0.0052	0.0020	0.0050	0.0056	0.0022	0.0055

- ***Stage-Storage Curve***

Stage Storage Curve is a relation to relate the volume below a horizontal elevation. The volume below surface indicates the storing capacity of container (in this case the paddy plot) to store water. The relation is derived by first rebuilding the terrain and structure of the paddy plot in GIS software (ArcGIS 9.3). Spot height obtained from site using spot survey and GPS were used to create Triangular Irregular Network (TIN) that resembles the terrain of paddy plot. Figure 4.15 to 4.17 shows the TIN developed for Plot 1, 2 and 3 respectively. GIS software was then used to compute volume below horizontal plan automatically from the developed TIN. The volume was recorded for each 0.05m elevation difference. Figure 4.18 to 4.20 presents the obtained stage-storage curve for Plot 1, 2 and 3.

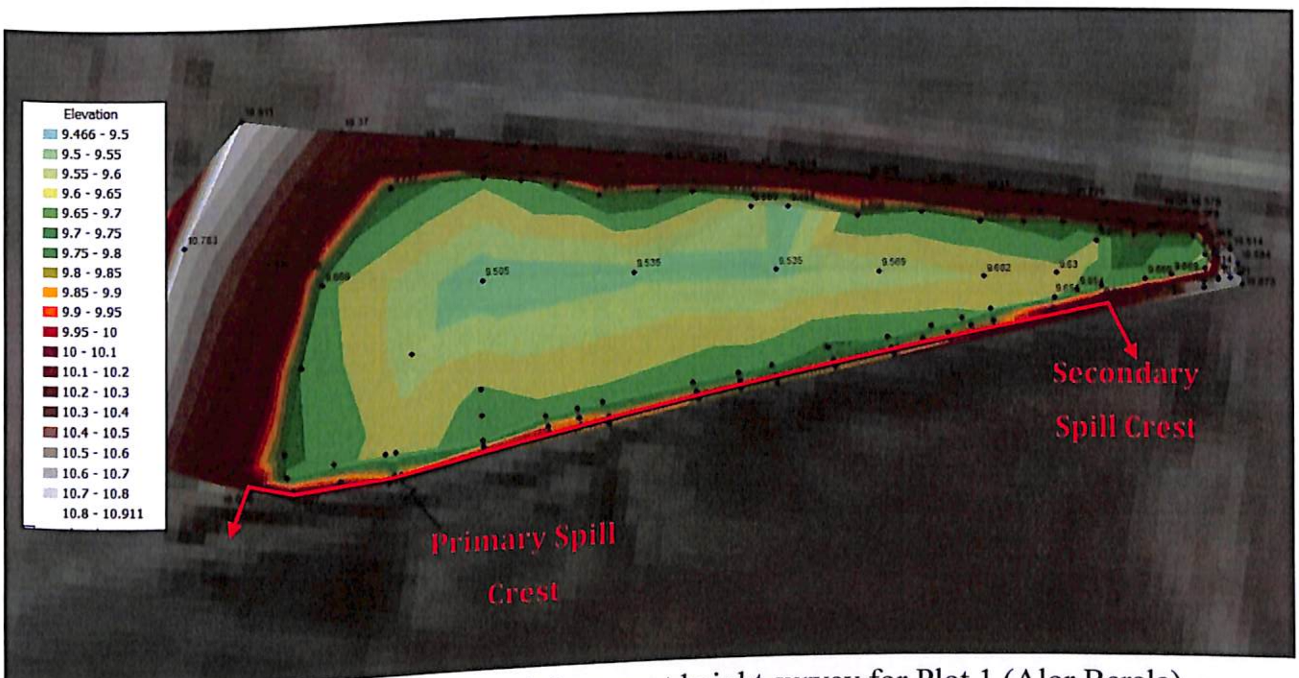


Figure 4.15: TIN developed from spot height survey for Plot 1 (Alor Berala)

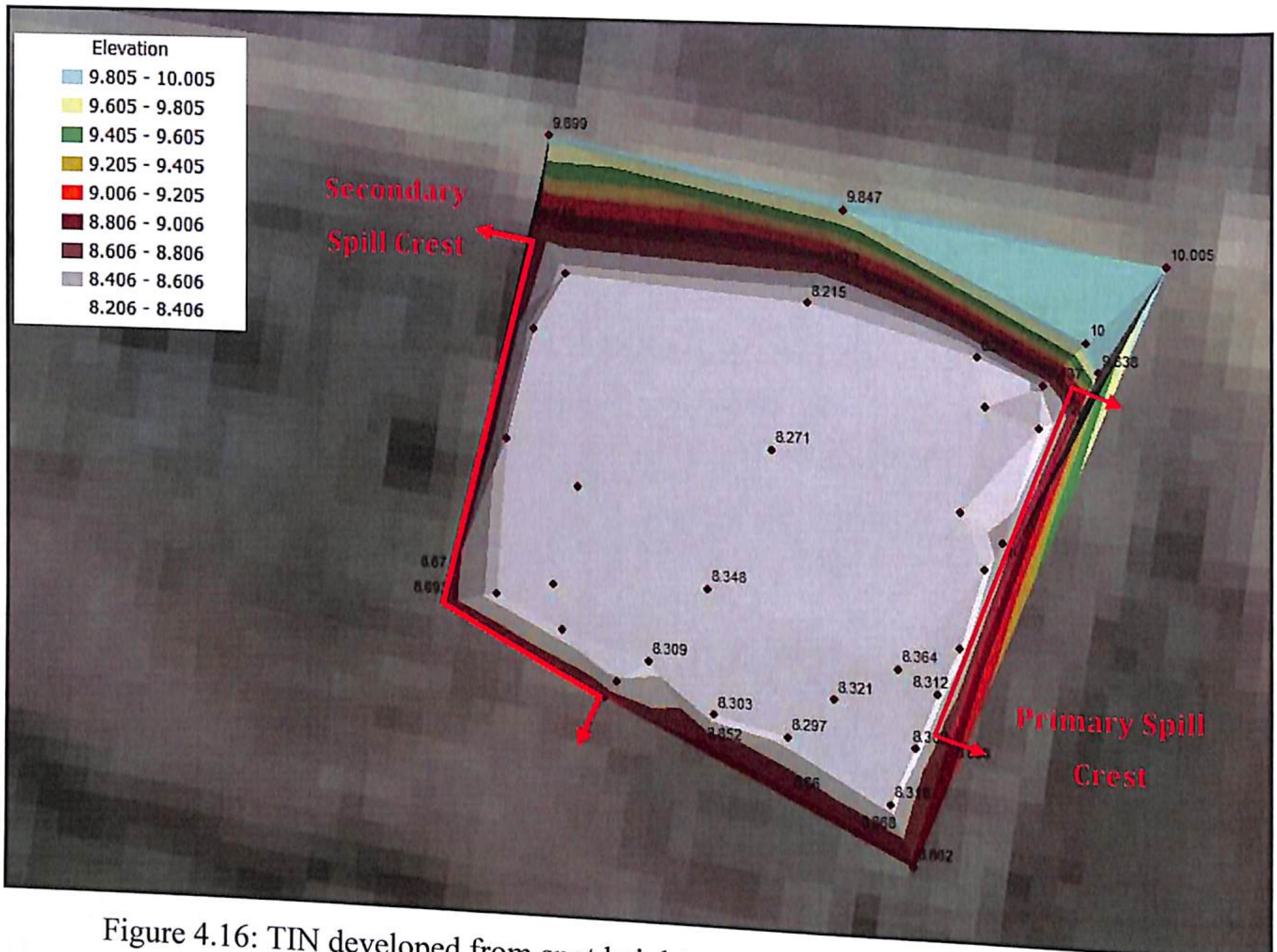


Figure 4.16: TIN developed from spot height survey for Plot 2 (Banggol Tok Ali)

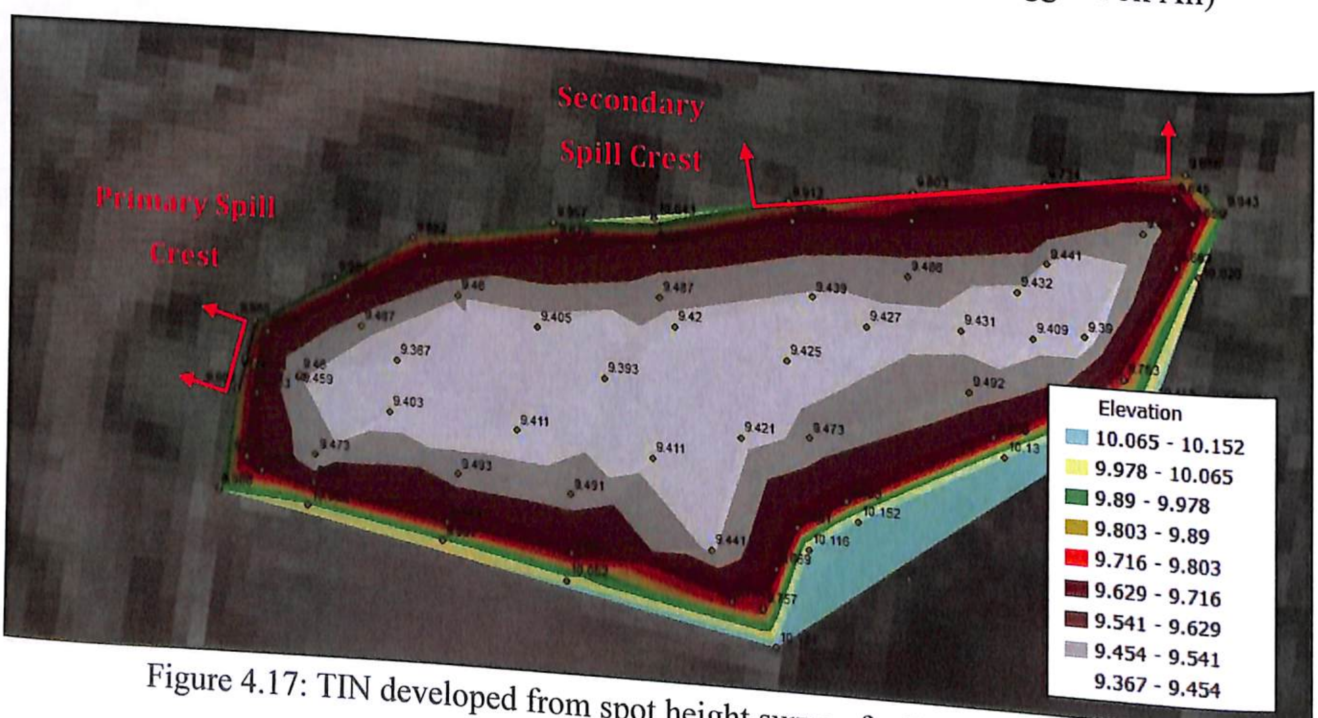


Figure 4.17: TIN developed from spot height survey for Plot 3 (Alor Punti)

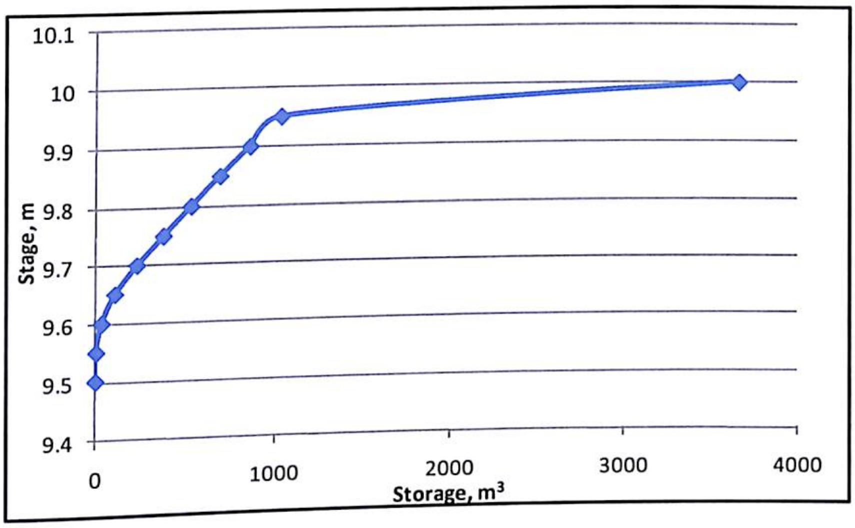


Figure 4.18: Developed Stage-Storage Curves for Plot 1

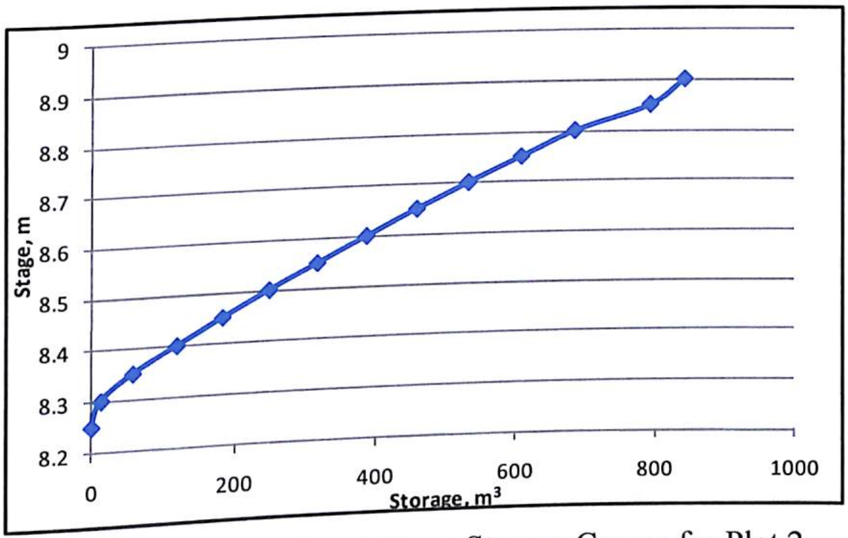


Figure 4.19: Developed Stage-Storage Curves for Plot 2

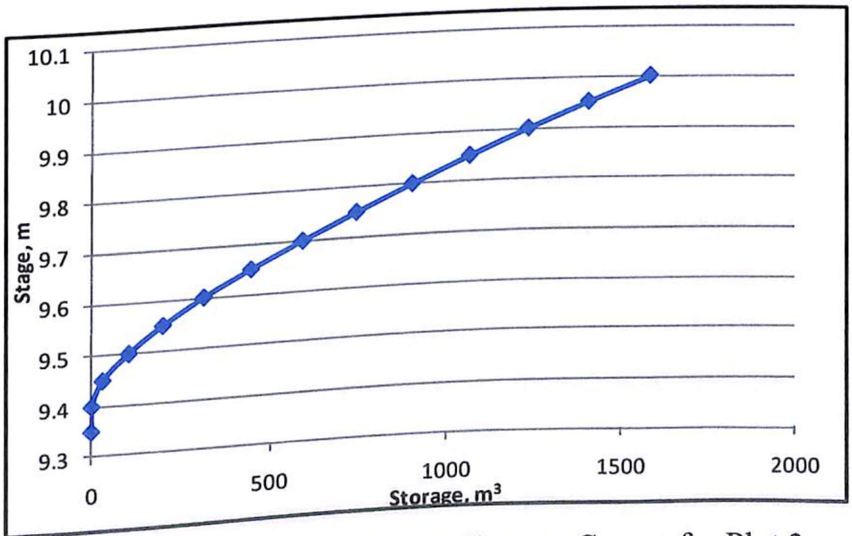


Figure 4.20: Developed Stage-Storage Curves for Plot 3

- ***Stage-Discharge Curve***

Stage-discharge curve relates the rate of outflow from the paddy plot to the water surface elevation. In general, many paddy plots have designated outlets in form of earth channel or pipe drains. During major rainfall, when water level continues to rise in the plot, part of the embankment will eventually be overtopped. Therefore, this analysis considers two main outlets for every paddy plots, i.e. the designated irrigation outlet, and the lower embankments of which water is susceptible to over-spilling.

All the study plots selected has earth channel irrigation outlet, which has a small earth embankment at the incoming end of the outlet to regulate water flow and control water level within the pond. The outlet structure resembles hydraulic function of a weir, and hence discharge capacities of the outlets were calculated using broad crested weir discharge equation. The same condition applies for overtopped embankment.

First the outlet is divided into multiple segments to capture different embankment levels and their corresponding discharge. Ideally, more segments produce more accurate results. Figure 4.21 illustrates the method used to compute discharge based on a water level. For each segment, the average crest height, E was applied. As the top of embankment is relatively very flat and segment width, B would be small enough so that the average crest height could correctly represent the actual crest level. For a given water level, the water depth or head difference (assuming no downstream effect) could be obtained by deducting crest height to water level. The computed B and H were then used to determine the discharge coefficient C based on design table presented in MSMA. The equation used to calculate discharge for each segment is given as Equation 4.2. The calculation was repeated to for other segments across the entire length of the delineated outlet reach. The sum of discharges for all segments would represent the effective discharge of the paddy plot at that particular water level. The computation is repeated to record discharges of different water level at 0.05 m intervals.

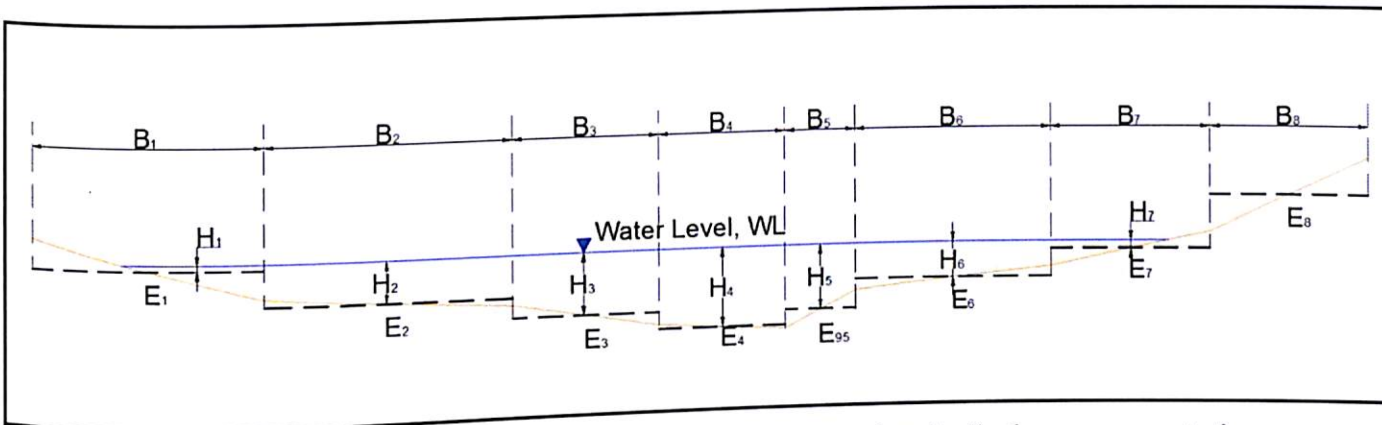


Figure 4.21: The conceptual illustration of a compound weir discharge computation

$$Q_i = C_{bcw} B_i \sqrt{2gH_i} \qquad \text{(Equation 4.2)}$$

Where,

i	=	the i^{th} segment, from one end to the other of spill crest;
C_{bcw}	=	Broad crested weir discharge coefficient, fixed to 1.70;
B_i	=	Width of i^{th} segment in metre;
H_i	=	Effective head of i^{th} segment in metre= $E_i – WL$; and
E_i	=	Average Elevation of i^{th} segment in metre.
WL	=	Water Level

The results of the computation are plotted in a stage-discharge curve as given in Figure 4.22 to 4.24 respectively. It can be observed that the discharge for Plot 3 was relatively smaller than Plot 1 and 2. This is because Plot 3 has a designated primary outlet and the bund levels were relatively flat, which means water starts to overflow from many places when the embankments were overtopped. Thus, the embankments are omitted in Plot 3. Table 4.6 summarised the stage discharge for all 3 plots. During lower stage, the discharge are almost similar. Furthermore, the routing results shows water did not rise more than a few centimetre, hence the limitation to discharge curve for Plot 3 would not have affected the results.

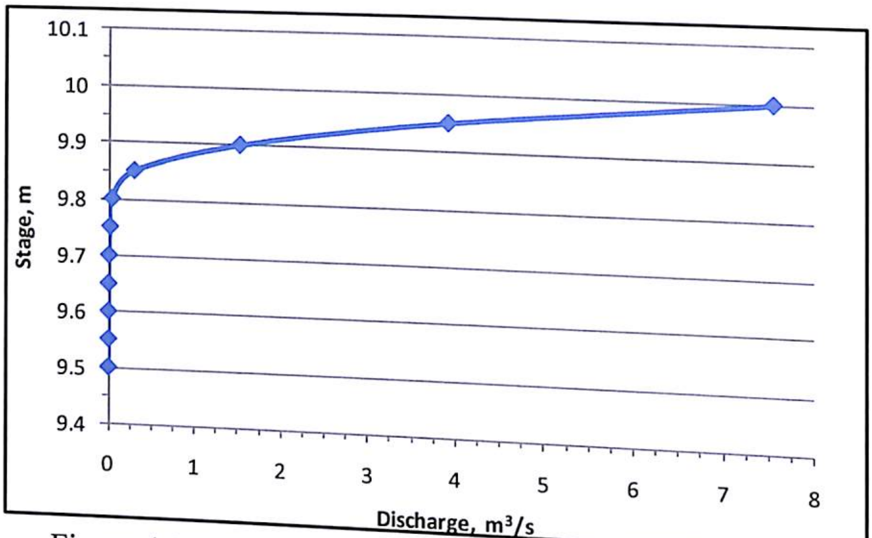


Figure 4.22: Computed Stage-Discharge Curve for Plot 1

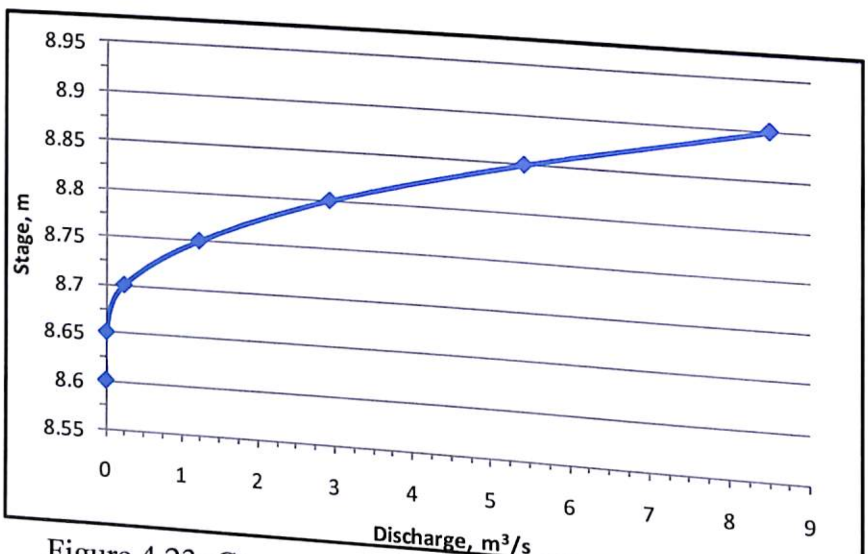


Figure 4.23: Computed Stage-Discharge Curve for Plot 2

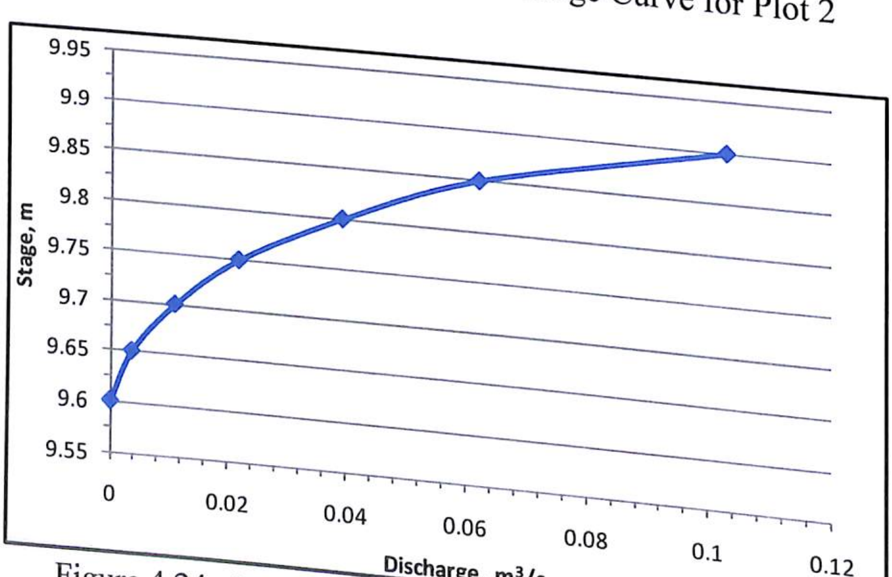


Figure 4.24: Computed Stage-Discharge Curve for Plot 3

Plot 1		Plot 2		P
Stage (m)	Discharge (m^3/s)	Stage (m)	Discharge (m^3/s)	Stage (m)
9.65	0.0000	8.60	0.0000	9.60
9.70	0.0011	8.65	0.0042	9.65
9.75	0.0127	8.70	0.2360	9.70
9.80	0.0356	8.75	1.2203	9.75
9.85	0.2956	8.80	2.9205	9.80
9.90	1.5211	8.85	5.4194	9.85
9.95	3.9110	8.90	8.5017	9.90
10.00	7.5457			

Table 4.6: Summary of stage- discharge relationship for the study plots

Plot 1		Plot 2		Plot 3	
Stage (m)	Discharge (m^3/s)	Stage (m)	Discharge (m^3/s)	Stage (m)	Discharge (m^3/s)
9.65	0.0000	8.60	0.0000	9.60	0.0000
9.70	0.0011	8.65	0.0042	9.65	0.0036
9.75	0.0127	8.70	0.2360	9.70	0.0110
9.80	0.0356	8.75	1.2203	9.75	0.0219
9.85	0.2956	8.80	2.9205	9.80	0.0394
9.90	1.5211	8.85	5.4194	9.85	0.0623
9.95	3.9110	8.90	8.5017	9.90	0.1030
10.00	7.5457				

4.2.2 Simulation Results

The inputs data are inserted into the prepared spreadsheet to compute two important parameters, i.e. outflow and water level. Both parameters were recorded in time series. In a typical detention facility design, 3 parameters are normally recorded to provide an overview of the efficiency in water detention. The maximum inflow and outflow were recorded to be compared for the flow reduction the detention facility provided. Then, there was the maximum water level, which was used as an indicator of how much the detention facility was filled up in response to the event (the maximum storage level have to be known).

Two cases were examined in this analysis. First, the plots were assumed to be empty, i.e. no initial water ponding. This reflects the condition and capacity of the pond during period which water is not detent in the plots, e.g. land preparation, harvesting, or the transition period between planting seasons. The level pool routing results for this condition were summarised in Table 4.7 for Plot 1, Table 4.8 for Plot 2 and Table 4.9 for Plot 3.

Another condition examined was the wet condition where water was assumed to pond initially in the plots, reflecting the condition during seeding, and growing. The results were summarised in Table 4.10 to 4.12 for Plot 1, 2 and 3 respectively.

Table 4.7: Level pool routing result summary for Plot 1 in dry condition

ARI	Duration (min) 30			60			120			180			360			720			1440		
	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)
2	0.206	0.001	9.73	0.187	0.002	9.75	0.102	0.005	9.77	0.041	0.007	9.77	0.029	0.029	9.77	0.019	0.006	9.77	0.008	0.004	9.76
5	0.249	0.001	9.75	0.230	0.006	9.77	0.125	0.009	9.79	0.051	0.010	9.79	0.039	0.036	9.79	0.020	0.008	9.79	0.011	0.005	9.77
10	0.210	0.003	9.76	0.257	0.008	9.78	0.142	0.012	9.8	0.058	0.014	9.80	0.042	0.042	9.8	0.023	0.010	9.80	0.013	0.006	9.77
20	0.231	0.005	9.76	0.282	0.010	9.79	0.156	0.017	9.81	0.065	0.019	9.81	0.047	0.047	9.81	0.027	0.011	9.81	0.015	0.008	9.78
50	0.341	0.007	9.77	0.230	0.014	9.80	0.176	0.023	9.82	0.072	0.024	9.82	0.053	0.053	9.81	0.030	0.013	9.81	0.017	0.009	9.78
100	0.380	0.009	9.79	0.351	0.019	9.81	0.195	0.028	9.83	0.081	0.029	9.84	0.059	0.059	9.82	0.033	0.015	9.82	0.018	0.010	9.79

Table 4.8: Level pool routing result summary for Plot 2 in dry condition

ARI	Duration (min)																				
	30			60			120			180			360			720			1440		
	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)
2	0.079	0.000	8.41	0.072	0.000	8.43	0.039	0.000	8.45	0.016	0.000	8.45	0.013	0.000	8.47	0.006	0.000	8.48	0.003	0.000	8.48
5	0.096	0.000	8.42	0.072	0.000	8.43	0.048	0.000	8.47	0.016	0.000	8.48	0.014	0.000	8.49	0.008	0.000	8.51	0.004	0.000	8.52
10	0.107	0.000	8.43	0.099	0.000	8.46	0.054	0.000	8.48	0.022	0.000	8.49	0.016	0.000	8.51	0.009	0.000	8.53	0.005	0.000	8.55
20	0.117	0.000	8.44	0.109	0.000	8.47	0.040	0.000	8.49	0.020	0.000	8.51	0.018	0.000	8.53	0.010	0.000	8.55	0.004	0.000	8.57
50	0.099	0.000	8.45	0.122	0.000	8.48	0.068	0.000	8.51	0.028	0.000	8.53	0.020	0.000	8.55	0.011	0.000	8.58	0.006	0.000	8.6
100	0.146	0.000	8.46	0.135	0.000	8.49	0.075	0.000	8.53	0.031	0.000	8.55	0.023	0.000	8.58	0.013	0.000	8.6	0.007	0.000	8.62

Table 4.9: Level pool routing result summary for Plot 3 in dry condition

ARI	Duration (min)																				
	30			60			120			180			360			720			1440		
	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)
2	0.201	0.000	9.59	0.132	0.000	9.62	0.099	0.000	9.64	0.040	0.000	9.65	0.029	0.000	9.66	0.016	0.000	9.67	0.008	0.000	9.67
5	0.243	0.000	9.61	0.224	0.000	9.64	0.121	0.000	9.66	0.049	0.000	9.68	0.035	0.000	9.69	0.019	0.003	9.69	0.011	0.000	9.69
10	0.270	0.000	9.62	0.250	0.000	9.65	0.053	0.000	9.68	0.057	0.000	9.69	0.041	0.000	9.71	0.023	0.005	9.71	0.012	0.420	9.70
20	0.297	0.000	9.63	0.275	0.001	9.67	0.152	0.003	9.7	0.063	0.005	9.71	0.046	0.006	9.72	0.026	0.007	9.72	0.014	0.005	9.71
50	0.332	0.000	9.64	0.309	0.002	9.68	0.171	0.005	9.71	0.071	0.008	9.73	0.052	0.009	9.74	0.029	0.009	9.74	0.016	0.006	9.72
100	0.370	0.001	9.66	0.342	0.003	9.70	0.128	0.008	9.73	0.079	0.010	9.74	0.058	0.012	9.75	0.033	0.011	9.75	0.077	0.007	9.72

Table 4.10: Level pool routing result summary for Plot 1 in wet condition

ARI	Duration (min)																				
	30			60			120			180			360			720			1440		
	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)
2	0.206	0.001	9.74	0.187	0.002	9.75	0.102	0.005	9.77	0.041	0.006	9.77	0.029	0.007	9.77	0.016	0.006	9.77	0.008	0.003	9.76
5	0.189	0.001	9.75	0.230	0.006	9.77	0.125	0.009	9.78	0.051	0.010	9.79	0.036	0.010	9.79	0.020	0.008	9.78	0.011	0.001	9.77
10	0.277	0.003	9.76	0.053	0.008	9.78	0.142	0.012	9.80	0.058	0.014	9.8	0.042	0.013	9.80	0.023	0.009	9.79	0.013	0.006	9.77
20	0.231	0.004	9.76	0.282	0.010	9.79	0.156	0.017	9.81	0.065	0.019	9.81	0.047	0.016	9.81	0.027	0.011	9.79	0.101	0.007	9.78
50	0.341	0.001	9.77	0.230	0.014	9.80	0.176	0.022	9.82	0.072	0.024	9.82	0.053	0.020	9.81	0.030	0.013	9.80	0.011	0.009	9.78
100	0.380	0.009	9.79	0.351	0.019	9.81	0.195	0.028	9.84	0.081	0.029	9.84	0.059	0.023	9.82	0.003	0.015	9.80	0.002	0.010	9.79

Table 4.11: Level pool routing result summary for Plot 2 in wet condition

ARI	Duration (min)																				
	30			60			120			180			360			720			1440		
	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)
2	0.079	0.000	8.47	0.072	0.000	8.48	0.039	0.000	8.48	0.016	0.000	8.48	0.013	0.000	8.70	0.006	0.000	8.49	0.003	0.000	8.49
5	0.096	0.000	8.47	0.088	0.000	8.48	0.048	0.000	8.49	0.019	0.000	8.49	0.014	0.000	8.50	0.008	0.000	8.51	0.004	0.000	8.52
10	0.107	0.000	8.48	0.099	0.000	8.48	0.054	0.000	8.49	0.022	0.000	8.50	0.016	0.000	8.51	0.009	0.000	8.53	0.005	0.000	8.55
20	0.117	0.000	8.48	0.109	0.000	8.49	0.060	0.000	8.50	0.025	0.000	8.51	0.018	0.000	8.53	0.010	0.000	8.55	0.006	0.000	8.57
50	0.131	0.000	8.48	0.122	0.000	8.49	0.068	0.000	8.51	0.028	0.000	8.53	0.020	0.000	8.55	0.011	0.000	8.58	0.006	0.000	8.60
100	0.146	0.000	8.49	0.135	0.000	8.50	0.075	0.000	8.53	0.031	0.000	8.55	0.023	0.000	8.58	0.013	0.000	8.60	0.007	0.000	8.62

Table 4.12: Level pool routing result summary for Plot 3 in wet condition

ARI	Duration (min)																				
	30			60			120			180			360			720			1440		
	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)	Inflow (m^3/s)	Outflow (m^3/s)	Water Lvl (m)
2	0.201	0.000	9.60	0.132	0.000	9.62	0.099	0.000	9.64	0.040	0.000	9.65	0.029	0.001	9.66	0.016	0.000	9.60	0.008	0.002	9.67
5	0.243	0.000	9.61	0.162	0.000	9.64	0.121	0.001	9.66	0.049	0.002	9.67	0.035	0.003	9.68	0.019	0.000	9.62	0.011	0.003	9.69
10	0.270	0.000	9.62	0.250	0.000	9.65	0.138	0.002	9.68	0.057	0.002	9.70	0.041	0.005	9.71	0.023	0.005	9.71	0.012	0.004	9.70
20	0.297	0.000	9.63	0.275	0.001	9.67	0.152	0.003	9.70	0.063	0.005	9.71	0.046	0.007	9.72	0.026	0.007	9.72	0.014	0.005	9.71
50	0.332	0.000	9.64	0.309	0.002	9.68	0.171	0.005	9.71	0.071	0.008	9.73	0.052	0.009	9.74	0.029	0.009	9.74	0.016	0.006	9.72
100	0.370	0.001	9.66	0.342	0.003	9.70	0.190	0.008	9.73	0.079	0.010	9.74	0.058	0.012	9.75	0.033	0.011	9.75	0.011	0.007	9.72

4.3 Finding Discussion

The level pool routing analysis was carried out to investigate the flood retention capacity of paddy field. The results presented earlier showed that despite heavy inflow from rainfall, the 3 studied plots generates very minimal outflow (sometimes no outflow at all). This has demonstrated the huge retention potential of paddy field in storing rainwater.

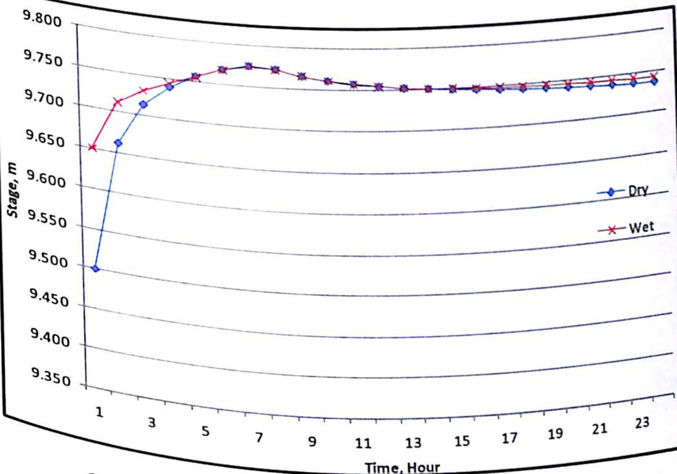
4.3.1 Effectiveness of Paddy Field as Water Retention Facilities

During dry period, the studied plots showed very good retention capacity. All the studied plots had shown little or no outflow for smaller return period (ARI). Plot 2 in particular is unresponsive to all design storms, due to its large capacity to store water before the very first over spill. Plot 1 and 3 released minimal amount of water in response to the design storms. Table 4.13 provide the efficiency level of the plots in response to the design events. The effectiveness is calculated by dividing the difference between maximum inflow and maximum outflow over the maximum inflow. The result was then converted into percentage.

As the ARI increased, the level of efficiency reduced. Rare events brought higher rainfall volume as well as intensity. Therefore, in some plots (Plot 1 and 3), the efficiencies were reduced as plots discharged water. However, Plot 2 remained capable of absorbing 100% of the rainfall due to its huge storage depth.

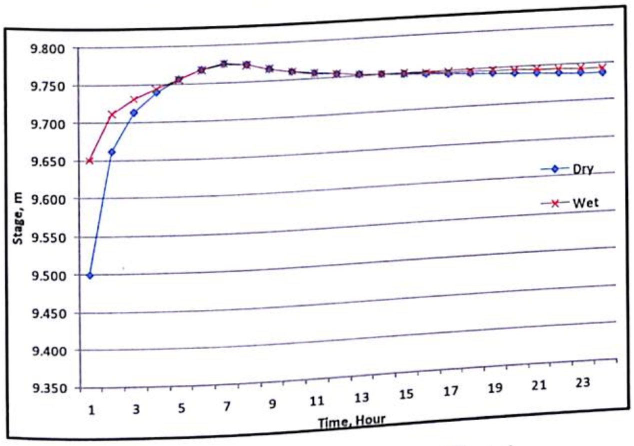
Table 4.13: Summary of plot efficiencies (%)

	Plot 1		Plot 2		Plot 3	
ARI	Dry	Wet	Dry	Wet	Dry	Wet
2	84.28	85.49	100.00	100.00	100.00	99.75
5	79.62	79.82	100.00	100.00	100.00	96.14
10	75.91	76.08	100.00	100.00	94.70	94.17
20	71.32	71.32	100.00	100.00	91.89	91.89
50	67.29	67.43	100.00	100.00	89.23	89.23
100	64.27	64.27	100.00	100.00	87.94	87.06

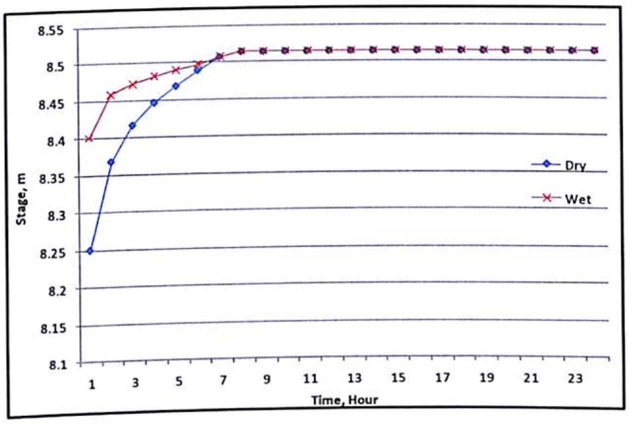


9.800
9.750
9.700
9.650
9.600
9.550
9.500
9.450
9.400
9.350
Stage, m
Dry
Wet
1
3
5
7
9
11
13
15
17
19
21
23
Time, Hour

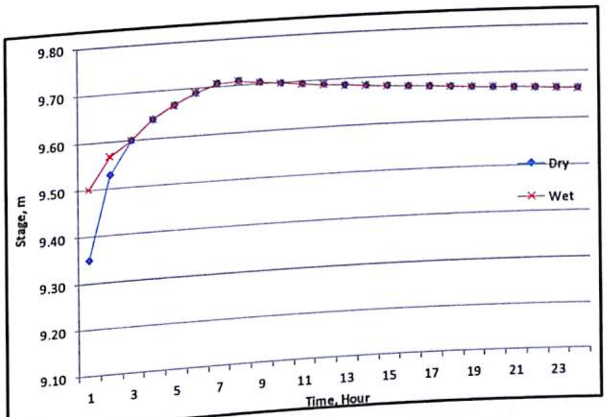
There was no significant difference between wet and dry condition of the paddy fields in terms of stormwater performance. During dry period, water built up slower due to the additional storage. In wet condition, water level built up faster. However as water level increased, the discharge increased as well. Hence, there would be a point which water levels of both condition settled at a same level for the same event. Figure 4.24 shows the records of the described observation in all three plots.



b) Water level plot for Plot 1



a) Water level plot for Plot 2



c) Water level plot for Plot 3

Figure 4.24: Difference in water levels for studied plots in response to 10 Year ARI 120 minutes storm.

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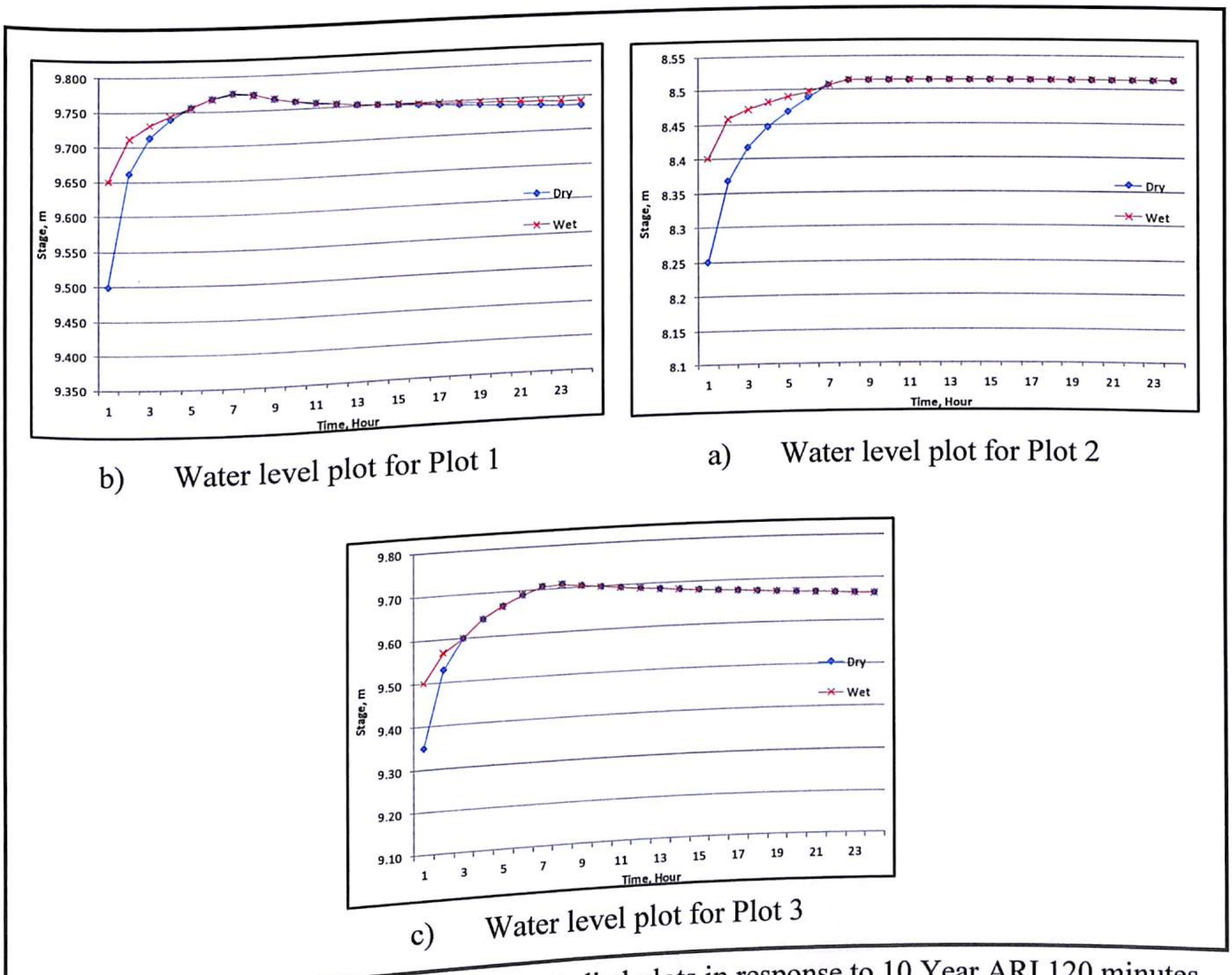


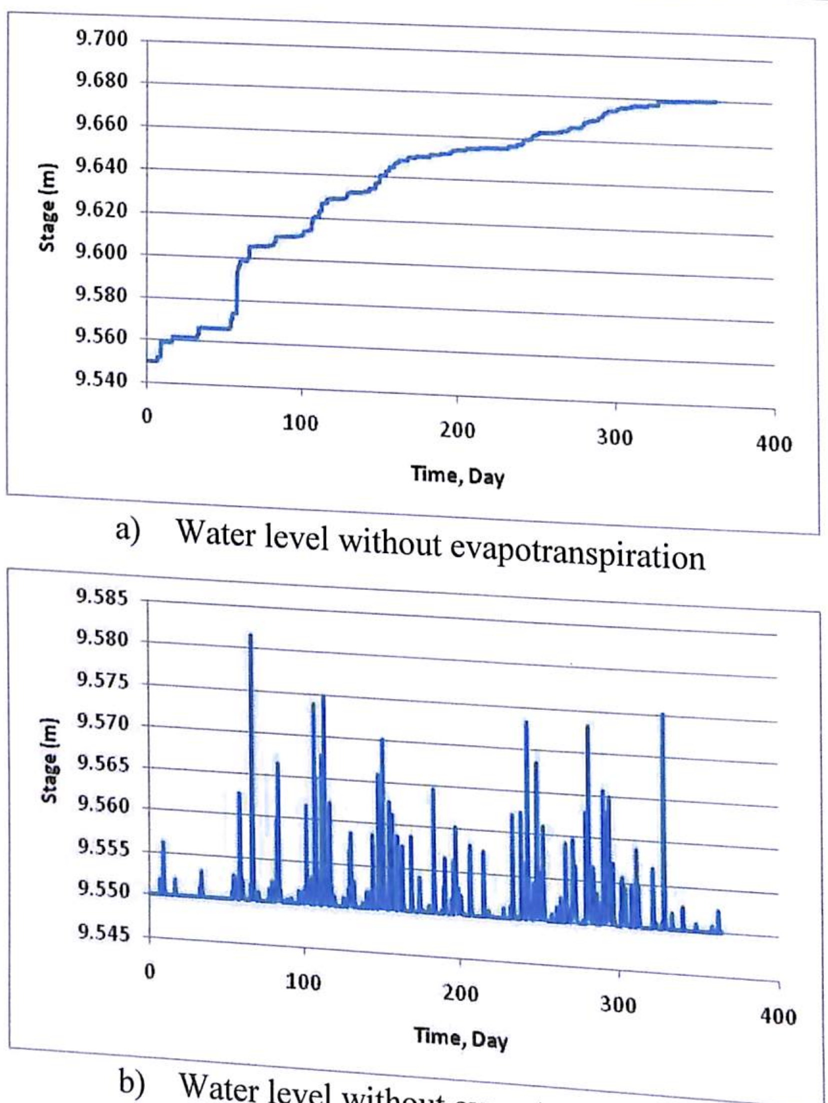
b) Water level plot for Plot 1

a) Water level plot for Plot 2

c) Water level plot for Plot 3

Figure 4.24: Difference in water levels for studied plots in response to 10 Year ARI 120 minutes storm.

The analysis had used design rainfall to investigate the effectiveness of the plots in flow retention. A further investigation was conducted to examine the response of the plots in longer simulation. Therefore, a recent 2008 rainfall was used as input for long duration simulation to study the response of paddy field over a period of a year. The least effective Plot 1 was selected for this further analysis. For more realistic simulation, evapotranspiration was included in the model. A fixed 3 mm/day evapotranspiration was included, which works out to a constant 0.000135 m^3/s of water loses over the year.



a) Water level without evapotranspiration

b) Water level without evapotranspiration

Figure 4.25: Difference water level response with and without evapotranspiration

Figure 4.25 showcased how the water level fluctuates in response to 2008 rainfall with and without the evapotranspiration. Figure 4.26 shows the results for flows at the inlet and outlet. There was no flow detected flowing out of the plot all year round due to the relatively large storage as compared to the rainfall depth. Should the pond remain in wet condition all year round there will be slight discharge during heavy rainfall as shown in Figure 2.27.

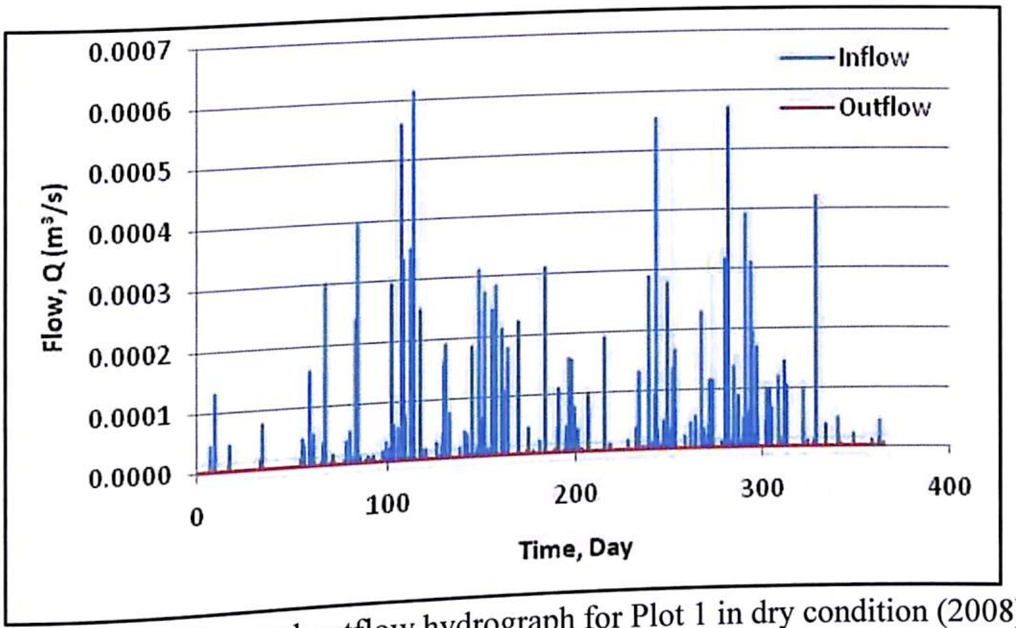


Figure 4.26: Inflow and outflow hydrograph for Plot 1 in dry condition (2008)

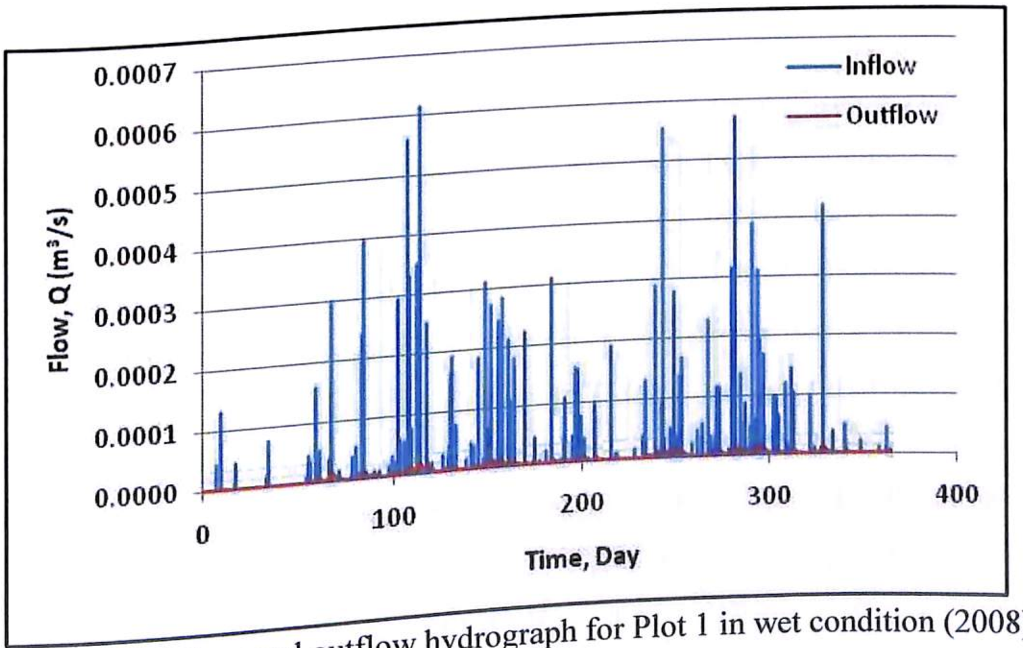


Figure 4.27: Inflow and outflow hydrograph for Plot 1 in wet condition (2008)

4.3.2 Factors Affecting Water Retention Capacity

Obviously from the analysis, the height of embankments surrounding the plots played a significant role in determining retention efficiency. Table 4.14 summarised the physical properties of the studied plots. It was observed that Plot 2 has the largest depth between plot base level to the lowest discharge level. Relating this to the efficiency of the plots, it was not hard to conclude that higher embankment produced higher flood retention capacity. It should however be noted that there shall be a limit for retention depth due to the paddy plants within the plots. Higher retention depth put plants under higher risk of crop damage.

Table 4.14: Summary of physical properties of studied plots

Properties	Condition	Plot 1	Plot 2	Plot 3
Active Storage at lowest discharge (m^3)	Dry	232	386	448
	Wet	123	267	344
Initial Water Level (m)	Dry	9.5	8.25	9.35
	Wet	9.65	8.4	9.5
Maximum Water Level (m)	Dry	9.75	8.62	9.75
	Wet	9.75	8.62	9.75
Level of lowest discharge (m)		9.7	8.65	9.65
Minimum Effective Depth (m)		0.05	0.25	0.15

Another physical factor which contributed to better flood retention is the storage capacity. Unfortunately, this study did not manage to capture the effect of storage changes. This was because the inflow used for performance testing was based on direct rainfall rate, which is related proportionally to the size of the plots. However, based on the conceptual model of level pool routing, for a fixed inflow, if the size of storage is larger, there will be less increment to water level. This delays the water reaching discharge levels.

Finally, the size and level of the outlet determines the effectiveness of the plots. The size of the outlet determines the discharge capacity of the outlet. By using the same stage-discharge relationship, an outlet with larger opening discharges faster than a smaller one for fixed water level. The sitting of the outlet is also important as it determines the stage-discharge relationship. Outlet placed at lower elevation allows faster water discharge as water builds up from below, and therefore drains the plot faster.

4.4 Monetary Assessment for Flood Control

The flood control monetary evaluation required two important parameters, i.e. the volume of flood water (function volume), and the unit cost to store the flood water (unit cost). The volume of flood water was determined from two sources, i.e. retention capacity of paddy plots and temporary storage of paddy fields, while the unit cost was estimated using CRM, assuming the unit value of flood control of paddy fields equated to that of a flood prevention dam.

4.4.1 Determining Function Volume, FV_{FC}

According to floodplain modelling and paddy plot water balance analysis, it was proven that paddy fields provide flood control through two different mechanisms. First, the paddy plot structures resembling retention ponds actually reduce the amount of runoff generation from precipitation, thus reducing the risk of flooding. This is referred to as the retention capacity of paddy fields. Secondly, during river overspill, paddy fields located within the floodplain contribute towards flow retardation by providing storage column and additional boundary roughness through paddy plants. This is termed the temporary storage function of paddy fields in this study. As both flood control mechanism could occur independently, the total flood control function volume was determined to be a sum of both mechanisms.

For retention capacity, the quantity of water a paddy plot is capable of storing is the active storage available within the boundary of the plot ridges. This can be simply determined by multiplying the average height of the ridges (H_L) to the area of paddy plot (A_{EF}). For this study area, the total paddy plot area is 24,901,999.0 m^2 while the average levee height was 0.3m. This yielded a function volume for retention capacity (FV_{RC}) of 7,470,599.7m^3 for this study area.

The temporary storage function volume (FV_{TS}) was directly extracted from the river and floodplain model. In order to determine the monetary value for flood control function of paddy field in annual basis, the volume function used must reflect floods that occur within a year. In MADA paddy irrigation scheme, floods normally occurs once a year, and therefore the event examined in the previous 1-D hydraulic model (August to September 2008) can be used to represent an annual flood.

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Occasionally, small or isolated river overspill does occur at paddy plots adjacent to the river but without detailed information and in the view that the impact was perhaps insignificant (compared to the vast unaffected paddy field), those small events were not considered in computing the flood function volume.

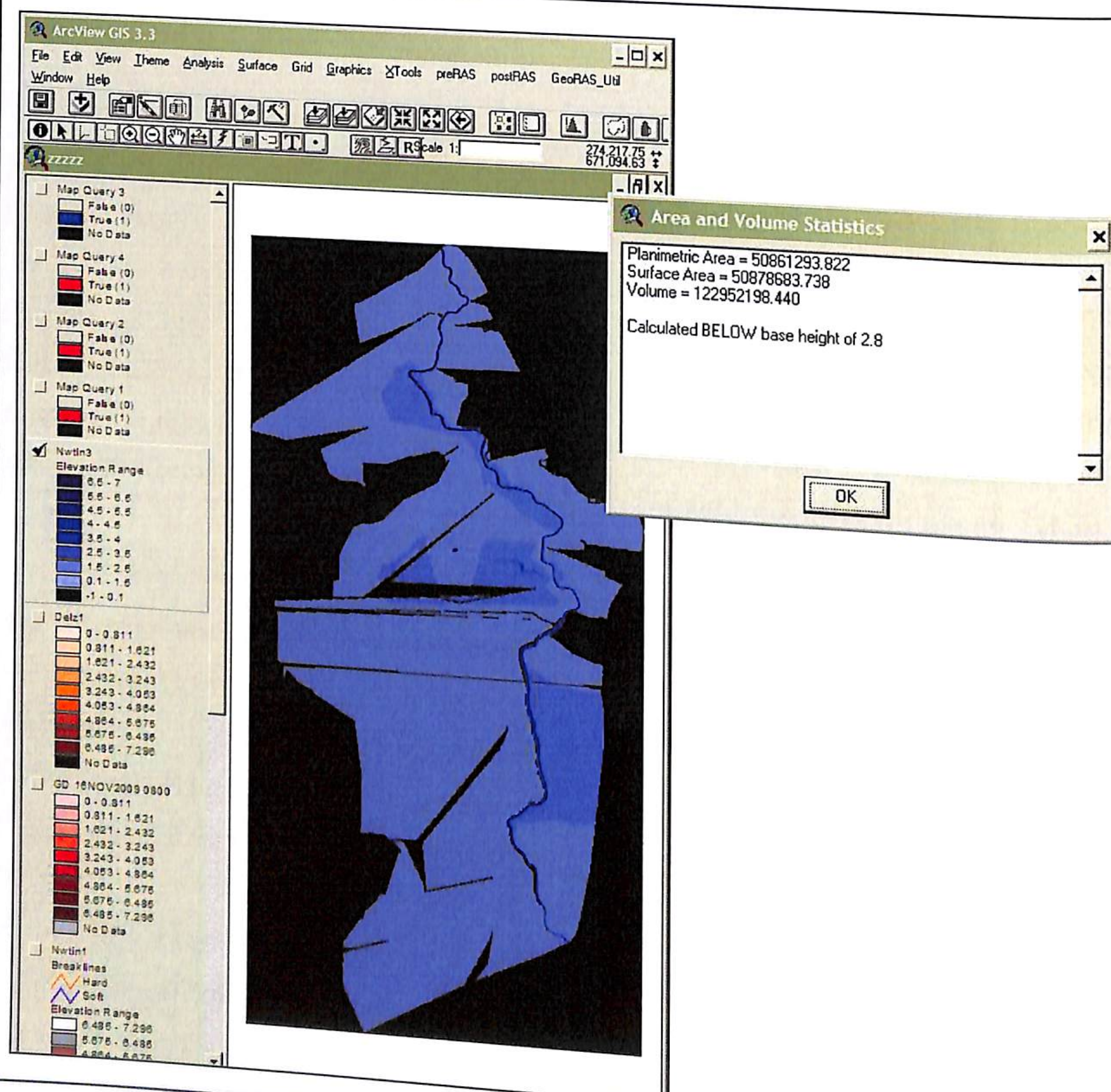

Figure 4.28: Computation of flood volume in GIS environment

The flood volume for the studied event is obtained by post processing the simulation results. From the hydraulic model, the information on flood extent and flood depth can be obtained as part of the results. This information was then re-process in GIS software (ESRI's ArcView 3.x) to compute the volume of maximum flood water contained within the paddy field during the flood. Figure 4.28 provides a snapshot of the flood extent and flood depth results from hydraulic model being imported and reprocessed in GIS environment to produce flood volume for the studied event. The maximum flood volume stored in paddy fields during a flood is 3,688,934.9 m^3. It should be noted that the result was obtained based on volumetric computation between the digital ground model and a horizontal plane (maximum water level). Theoretically, the flood profile would show slight gradient, but due to the almost flat terrain and also effect of the backwater, the gradient is so small and negligible. Hence a horizontal plane can adequately represent the flood profile and provide reasonable estimation of the flood volume contained in the paddy fields. Therefore the total sum of flood control function volume (FV_{FC}) is 11,159,534.60m^3.

4.4.2 Determining Unit Cost, UC_{FC}

As mentioned, the unit cost for flood control function in paddy field was calculated based on cost replacement method. The equivalent substituted chosen was the cost per unit volume of stored flood water in a dam project. The unit cost of a dam construction consists of depreciation cost and maintenance cost. Depreciation cost consists of all the cost required to put the dam in place and this should include construction costs and compensation costs (mainly to land owners). Maintenance cost consists of the costs required to run, operate and maintain the dam. This cost is normally estimated to last over a period of time. Therefore the unit cost for dam construction can be written as Equation 4.3.

(Equation 4.3)

$$UC_{FC} = UC_D + UC_M$$

Unit Depreciation Cost (UC_D) is calculated by dividing the total cost required to put the dam in place (including construction fee, design fee, land acquisition etc) by the designed volume allocated for flood control. The amount should be evenly spread over the design life span of the structure to reflect a fairer annual cost. The unit depreciation cost can be written as Equation 4.4 below.

$$UC_D = \frac{C_C}{(V_F \times Y_D)} \quad \text{(Equation 4.4)}$$

where,

UC_D = Unit dam depreciation cost, RM/m^3/yr
C_C = Total sum of depreciation cost, RM
V_F = The designed volume for flood control, m^3
Y_D = The design life span for the dam, yr

Unit Maintenance Cost is calculated by dividing total cost of maintenance over total design volume allocated for flood control. The amount should be then divided by the period of which the maintenance cost is planned to cover. The unit maintenance cost can be written as Equation 4.5 below.

$$UC_M = \frac{C_M}{(V_F \times Y_M)} \quad \text{(Equation 4.5)}$$

where,

UC_M = Unit dam maintenance cost, RM/m^3/yr
C_M = Total sum of maintenance cost, RM
V_F = The designed volume for flood control, m^3
Y_D = The design life span for the dam, yr

For this study, the calculation of unit cost for flood control in paddy field was carried out using a dam construction project for flood control. The dam construction being referred to was a multipurpose dam proposal for Sungai Lebir Catchment, Kelantan. The design details for the dam were given in Table 4.15. Cost breakdown was presented in Table 4.16.

Table 4.15: Design details for the proposed Lebir Dam

Design Criteria	Values
Purpose of Dam	Flood control and water supply
Total Catchment	2480 km^2
Reservoir (Inundated Area)	23,463 ha
Flood Control Capacity	256 million m^3
Water Supply Capacity	101 million m^3
Dam Design Life Span	100 years

Table 4.16: Cost breakdown for proposed Lebir Dam

Cost Component	Cost (Millions RM)
Construction Cost: 1. Dam Structure 2. Spillway & Embankment	332.00 134.00
Compensation Cost: 1. Land Acquisition 2. Crop Compensation	590.00 89.00
Total Depreciation Cost, C_C	1,145.00
Maintenance Cost (first 10 years), C_M	55.00
TOTAL PROJECT COST	1,200.00

Using Equation 4.4, the unit depreciation cost was computed, as shown below.

$$UC_D = \frac{C_C}{(V_F \times Y_D)} = \frac{1{,}145{,}000{,}000}{(256{,}000{,}000 \times 100)} = 0.045\ RM/m^3/yr$$

Using Equation 4.5, the unit maintenance cost was computed, as shown below.

$$UC_M = \frac{C_M}{(V_F \times Y_M)} = \frac{55{,}000{,}000}{(256{,}000{,}000 \times 10)} = 0.021\ RM/m^3/yr$$

The total unit replacement cost for flood control function of paddy field could therefore be determined using Equation 4.3, as shown below.

$$\boldsymbol{UC_{FC}} = UC_D + UC_M = 0.045 + 0.021 = \mathbf{0.07\ RM/m^3\ /yr}$$

4.4.3 Monetary Value of Flood Control, MV_{FC}

Monetary value of flood control function at study site can be calculated by multiplying the volume function with the unit cost, which can be represented in a mathematical form shown in Equation 4.6.

$$MV_{FC} = FV_{FC} \times UC_{FC} \qquad \text{(Equation 4.6)}$$

where,

$MV_{flood\ controFCl}$	=	Monetary value for flood control, RM/yr
V_{flood}	=	Flood volume stored in the study area, m^3
$UC_{flood\ control}$	=	Unit replacement cost for flood control function, $RM/m^3/yr$

Using Equation 4.6, the monetary value for flood control function of paddy field in study site was computed as shown below.

$$MV_{FC} = FV_{FC} \times UC_{FC} = 11{,}159{,}534.60 \times 0.07 = \mathbf{781{,}167.42\ RM/yr}$$

4.4.4 Consideration of Crop Damage as Economic Loss, MV_{CD}

Even though paddy is accustomed to wet condition, submergence in flood water above tolerable levels would result in compromised rice yield. Worse still, if submergence extended beyond the tolerable period, paddy plants would just die off, causing complete loss of investment to the farmers. Therefore the use of paddy fields for flood controls does come with a trade-off, which should be considered in practical terms when working out the monetary values of the flood control function.

Monetary value of crop damage could be calculated by directly measuring the crop damage during or after a flood. However, due to lack of such information, an alternative estimation could be made. A reasonable estimation of crop damage would be the special aid given out by the government for damage crop during a flood. The Government of Malaysia provides aid to paddy farmer after a flood to facilitate replanting based on the area of farmland and the stage of growth of the damage paddy plant, as given in Table 4.17 Subsequently, the monetary trade-off for flood control function in a paddy field can be given as Equation 4.7.

$$\boldsymbol{MV_{CD} = A_F \times GA} \qquad \text{(Equation 4.7)}$$

where,

MV_{CD}	=	Monetary value for crop damage, RM /yr
A_F	=	Area of paddy field being submerged by flood, ha
GA	=	Rate of government aid for crop damage, RM/ha

Table 4:17 Government aid based on paddy growth stage

Growth Stage	Government Aid (RM/ha)
Growing Stage	RM876
Ripening Stage	RM1800

In this study, the flooded paddy field area was determined as 5,087,868.4m^2. Using Equation 4.7, the monetary value of crop damage was determined as below.

$$\boldsymbol{MV_{CD}} = A_F \times GA = \frac{5{,}087{,}868.4}{10{,}000} \times 876 = \mathbf{445{,}697.27\ RM/yr}$$

The same equation was used to compute the crop damage during ripening stage, which was determined as RM 915,816.31 per year. Therefore, if crop damage is taken into account in determining the worth of flood control function of paddy fields, the net value would varies between -134,648.89 and 335,470.15. Should flood event occurs during ripening stage, the loss of crop damage is more significant than the value of flood control function. However, during growing stage, environmental service provided by flood control function out weights the crop damage. Based on this understanding, there is a possibility to maximise flood control function of paddy fields, by proper timing of planting such that the flood event does not coincide with ripening of paddy plants.

CHAPTER 5
CONCLUSION

The flood inundation modelling in the floodplain was performed using HEC-RAS model. HEC-RAS is 1-D river-hydraulic computer program designed to aid hydraulic engineers in channel flow analysis and floodplain determination.

The modelling was conducted in several cases. The situations consists of running the flood modelling using existing geometry data, running the flood modelling using modified geometry data. The first case for modified geometry data is the floodplain levels of southern segment were increased to 4.0 m and maintaining the existing for South Segment. For the second case, the floodplain levels of north segment were increased to 3.0 m and maintaining the existing levels for North Segment.

After running the modelling, the result shows that modification of either upstream or downstream reach will affect the flood water levels. According to maximum water levels, the water level will increases from 2.95m to 4.5m.

The volume of water at upstream area (Pekan Pendang) and downstream area (Titi Haji Idris) are 230353.25x10^3 m^3 and 230395.17x10^3 m^3, respectively. However, downstream area can store water more than upstream area. the reason for this happen are water from upstream flowing to downstream, then store before out through Ampang Jajar.

The monetary value of the paddy field on flood control at national level can be estimated based on findings of current study. A linear extrapolation was used to predict the monetary value of flood control function for paddy field at national level. This is done by equating the monetary value of the flood control functions found for the site to the national total paddy planting area. Finally a preliminary national projection was carried out to estimate monetary values of paddy fields flood control functions using the new assessment approaches.

In order to simplify the computation of function volumes, several modifications were introduced;

- Flood volume was converted into flood inundation area (with an average depth determined through the HEC-RAS model). A ratio of effective flood inundation area (areas which are submerged and upstream of development) to total paddy planting area of a site was factored in to rationalize a more practical estimation of flood controlling paddy fields area in the country.
- For flood volume contributed by individual plots retention capacity, the volume is computed by multiplying area which is upstream of development and the average height of levee.

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UNIVERSITI SAINS MALAYSIA

APEX

The Role of Paddy Field in Flood Control: Case Study of Muda Irrigation Scheme (Region 3)

GUIDELINES FOR MONETARY ASSESSMENT OF FLOOD CONTROL IN PADDY FIELDS

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GUIDELINES FOR MONETARY ASSESSMENT OF FLOOD CONTROL IN PADDY FIELDS

1. Multi-functionality & Environmental Services of Paddy Fields

A paddy field is a flooded parcel of arable land used for growing rice and other semi-aquatic crops. Apart from rice production, there are multiple outputs from agriculture, most of which have non-market values. The term 'multi-functionality' refers to an agricultural activity that could have multiple outputs besides providing food and fibres and, therefore, may contribute to several objectives at once. The multiple roles of agriculture include food security, maintaining and ensuring viability of rural communities and environmental protection, such as land conservation, sustainable management of renewable natural resources, preservation of biodiversity, landscape, etc.

Being an agricultural activity that generates economy for countries, multi-functionality has been extensively studied in paddy field management and operation. Several researches have been carried out to determine the non-commodity output of paddy field operations. Matsumoto et al. (2006) had systematically categorized the multiple roles of paddy fields into 4 categories, as given in Figure 1.

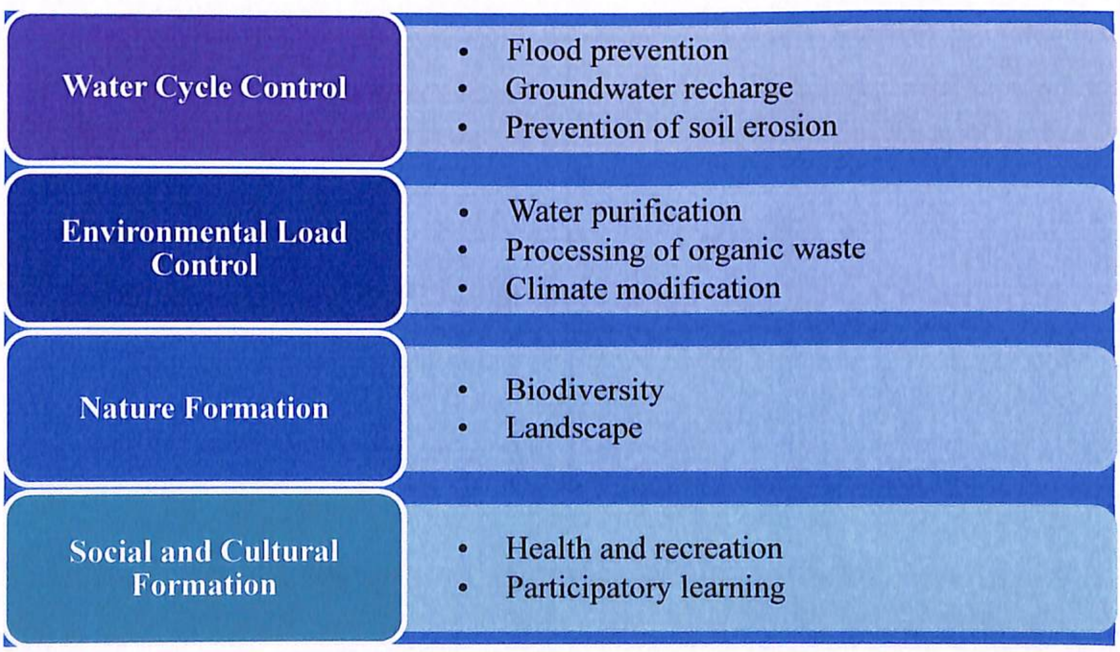

Figure 1: Multiple functions of paddy fields (adapted from Matsumoto et al, 2006)

2. Monetary Assessment or Ecosystem Valuation of Paddy Fields

Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem. Some examples of ecosystem functions are provision of wildlife habitat, carbon cycling, or the trapping of nutrients. Thus, ecosystems, such as wetlands, forests, or estuaries, can be characterized by the processes, or functions, that occur within them. Ironically, paddy fields are complete and independent ecosystem themselves, despite being shaped and worked on by humans. Their unique landscape, water bodies, and plants help to create and sustain a healthy ecosystem that provides in turn, provide multiple ecosystem functions similar to wetland ecosystem.

Ecosystem services are the beneficial outcomes, for the natural environment or people that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, and the provision of clean water or scenic views. In order for an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, humans is required. Thus, functions of ecosystems are value-neutral, while their services have value to society. Ecosystem values are measures of how important ecosystem services are to people – what they are worth.

3. Flood Control Monetary Assessment

The function of paddy field for flood control/ prevention has been well documented. Many studies have acknowledged this function of paddy fields (Masumoto, 2003; Matsuno et al., 2006; Huang et al., 2006; Kim et al., 2006). This chapter discussed the determination of function volume and unit cost of paddy fields in flood control before providing a monetary evaluation on the paddy field. Flood control function of paddy field can consist of two contributors, i.e. paddy plot retention capacity and the temporary storage it provides during floods. The procedure of assessing flood control monetary values is given in Figure 2.

3.1 Concept of Flood Control in Paddy Fields

Paddy fields contribute to flood control in two ways. First, paddy fields have huge retention capacity and potential due to the structure and land cover provided by paddy cultivation. This means that less runoff is generated from a paddy plot compared to a developed area of the same size. This helps to prevent unexpected flash flood at downstream area due to sudden surge of large-volume runoffs from upstream area. Secondly, as most paddy plots are located within delta or floodplain, they play a significant role in providing storage and attenuation for flood. Without paddy fields, excessive water would have flooded urban areas, causing more flood damage. It is therefore important to consider both the roles in flood control when putting monetary value on this benefit carried by the paddy fields.

3.1.1 Local Hydrology Approach

The rainfall will eventually form surface runoff that flows into streams and in occasion of major rain, can cause overflow or flooding. As rain falls, a small fraction is intercepted and absorbed by plants while other is absorbed by the soil. The structures of paddy fields with raised embankment to divide plots as well as to store water needed for paddy cultivation forms pockets of storage compartments, capable of providing huge amount of depression storage.

Factors affecting the potential flood retention capacity of paddy plots include:

- Soil moisture & initial water level in the plot;
- Inflow from canal;
- Outflow to drainage; and
- Average perimeter height bund.

These data was collected on selected paddy plot and covered different planting season as well as plant growth stages. The variations have different implications on the retention capacity of paddy fields. For example, during growing season, water is retained in paddy field to aid growth, therefore reduces the depression storage depth available for detention of excess rainfall but during harvesting, the ground maybe drier, allowing more excess rainfall to be retained.

The retention capacity of paddy field is determined by the amount of rainwater capable of being stored within the plot without the need to be released (as runoff). The function volume of paddy fields in flood prevention can therefore be directly related to the retention capacity of paddy field. However, while all paddy fields possess retention capacity (and hence flood prevention), not all flood prevention are of significant monetary values for human or the community. Furthermore, retention capacity fluctuates all year round based on site condition and climate. Figure 3 shows an illustration of water retention capacity of paddy fields during storm events.

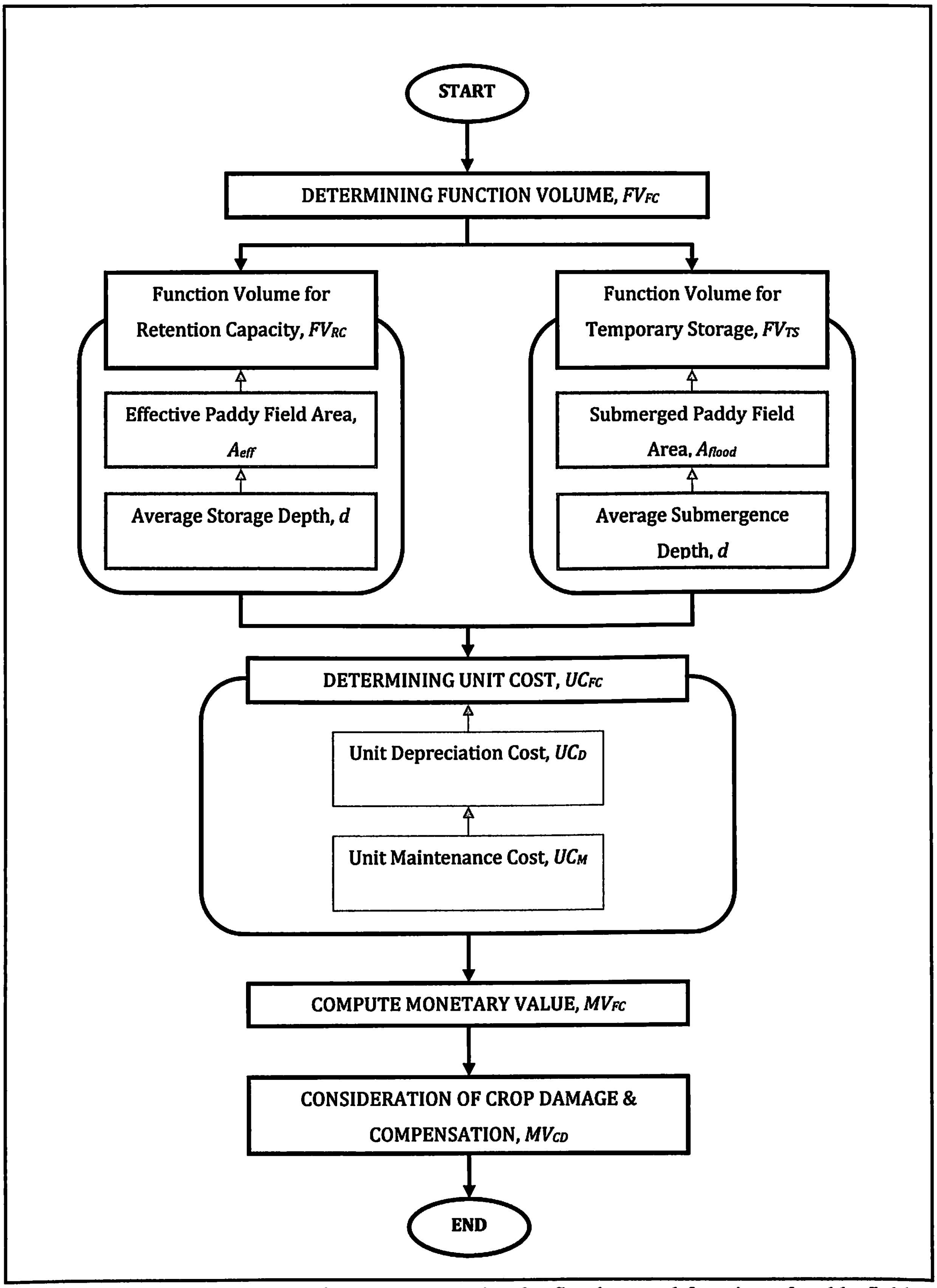

Figure 2: Flow chart for computing monetary value for flood control function of paddy fields

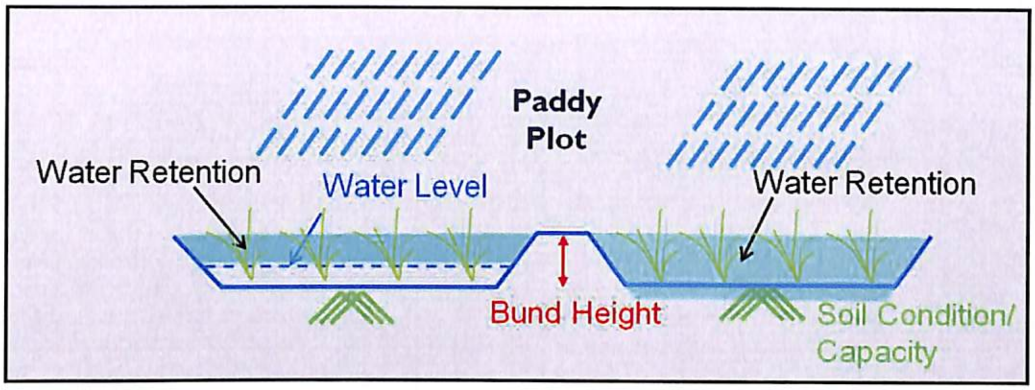

Figure 3: Illustration of water retention capacity of paddy fields during storm events

3.2.2 External Flood Control Approach

When flood has occur, paddy fields also function as flood control, by providing temporary storage for flood water, hence slowing down flood propagation and damage potential to any downstream development. Although it may be argued that the floodplain would be functioning just as well without the paddy fields, but under current urban land demand, many land would require back-filling to raise platform level for development or cultivation of other commercial crops (rubber and oil palm). In other words, the preservation of floodplain would be very hard if the land use is substituted with anything other than paddy fields. Therefore, paddy cultivation can therefore be viewed as one of the win-win solution for floodplain preservation and economic generation in many paddy planting developing countries. Figure 4 shows paddy fields as flood plain for flow attenuation and flood prevention

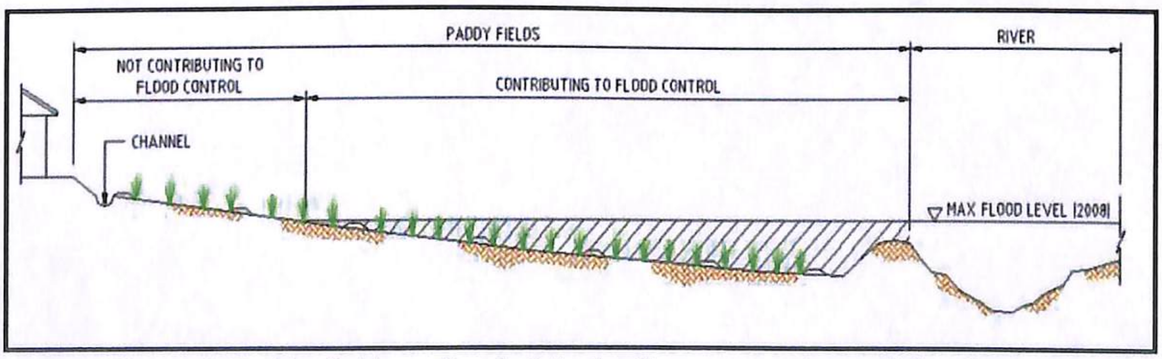

Figure 4: Paddy fields as flood plain for flow attenuation and flood prevention

The existence of paddy fields ensures floodplain stays at a lower elevation, hence preserving its flood control function. The ability of the floodplain (which the paddy fields are situated) to store/ contain water can therefore be translated into the function volume of the paddy field in flood control. Since not all paddy field are located within floodplain, it is extremely to determine the function volume based on effective flood control paddy plot only. The function volume shall only consider the area of paddy field situated within the floodplain.

3.3 Determination of Function Volume, FV

Function volume is the measured quantity of service delivered by paddy fields in flood control. As mentioned earlier, there are two ways to look into flood control function of paddy field, and hence different ways to evaluate function volume.

3.2.1 Flood Control through Retention Capacity

In order to determine function volume for flood control through retention capacity (FV_{RC}), the geometrical structure of the paddy plots must be identified. Using Equation 1, FV_{RC} can be estimated by the multiplying of the effective paddy field area (A_{eff}), the average storage depth of the plot (d).

The effective paddy field area is the actual area that contributes to the flood control function. While all paddy plots retain flood, not all are translated into economic values. This is because if flood occur within a nature setting, there should be no economic flood damage involved. Only in areas where floods occur in develop areas will it inflict flood damage. Therefore, paddy fields are only considered to contribute to flood control if there is a significant development (either township, or agricultural land) situated downstream. Figure 1 illustrates the definition of effective paddy field area.

The average storage depth of a paddy plot is measured from the water surface to the top of the levee/ embankment that forms the paddy plot. Throughout the course of a year/ planting season, water level fluctuates in response to hydrology processes and cultivation practices. However, an average depth can be computed. It is also acknowledged that different areas might have different storage depth due to local practices.

Evaluator could choose to calculate FV_{RC} using an overall average depth or calculate function volume for each group of storage depth and sum it up.

$$FV_{RC} = A_{eff} \times d \qquad \text{(Equation 1)}$$

where,

FV_{RC}	=	Function volume for retention capacity, m^3;
A_{eff}	=	Effective area of paddy field that contributes to flood control, m^2;
d	=	Average storage depth available throughout a year, m.

3.2.2 Flood Control through Temporary Storage

The most important information to obtain for computation of function volume through temporary storage (FV_{TS}) for paddy fields is the flood extent and flood depth. FVTS can be calculated using Equation 2. The flood extent and depth are used to compute the temporary storage volume. The information can be obtained through the following method:

Hydrodynamic Flood Modelling. Hydrodynamic models provide proper flood simulation. The user would require to provide good quality of topography data (DEMs and cross sections) to set up the model and test it against design or historical (preferable) annual flood flow. Once calibrated and validated, the model simulation would directly provide flood extent and flood depth. The information can then be imported into Geographical Information System (GIS) to compute the effective flood area by intersecting flood extent with land use map. An average flood depth for the entire submerged paddy plot can also be determined using GIS.

Field survey can be conducted to obtain secondary source of information from farmers and flood victims. Flood extent map if available can be use as primary data to identify flooded paddy fields. Without flood map, researchers would require to carry out site survey to determine the flood extent by interviewing the locals and inspecting flood marks. Global Positioning System (GPS) can be used to help correctly map the locations. Information of flood depth can also be obtained using the same method.

It should be noted that variation in magnitude of flood and its frequency produces different flood extent and depths. The researcher should seek to obtain information on annual floods (flood that occurs once a year) only. If higher return period of flood is use to derive flood extent and depth, the evaluation would generate higher function volume, but this would not happen annually, and hence are not suitable to represent the monetary assessment which is a annual based assessment.

$$FV_{TS} = A_{flood} \times d \qquad \text{(Equation 2)}$$

where,

FV_{TS} = Function volume for retention capacity, m^3;

A_{flood} = Effective area of paddy field submerged during annual flood, m^2;

d = Average annual flood depth, m.

3.3 Determination of Unit Value

This cost replacement method evaluate substitute the cost of flood control function with the cost require to store the same amount of water within a reservoir. The unit cost (per m^3 of stored water) for flood control function of paddy field is therefore the unit cost of a reservoir or dam construction. Since This replacement cost can be therefore applied to both FV_{RC} and FV_{TS} to produce monetary values the both flood control function approaches. The unit cost for flood control (UC_{FC}) is the sum of unit depreciation cost (construction cost over the design life span) (UC_D) and the unit maintenance cost (UC_M), as shown in Equation 3 below.

$$UC_{FC} = UC_D + UC_M \qquad \text{(Equation 3)}$$

where,

UC_{FC} = Unit flood control cost, USD /m^3/yr

UC_D = Unit dam depreciation cost, USD /m^3/yr

UC_M = Unit dam maintenance cost, USD /m^3/yr

Unit depreciation cost (UC_D) is calculated by dividing the total cost required to put the dam in place (including construction fee, design fee, land acquisition etc) by the designed volume allocated for flood control. The amount should be evenly spread over the design life span of the structure to reflect a fairer annual cost. The unit depreciation cost can be written as Equation 4 below.

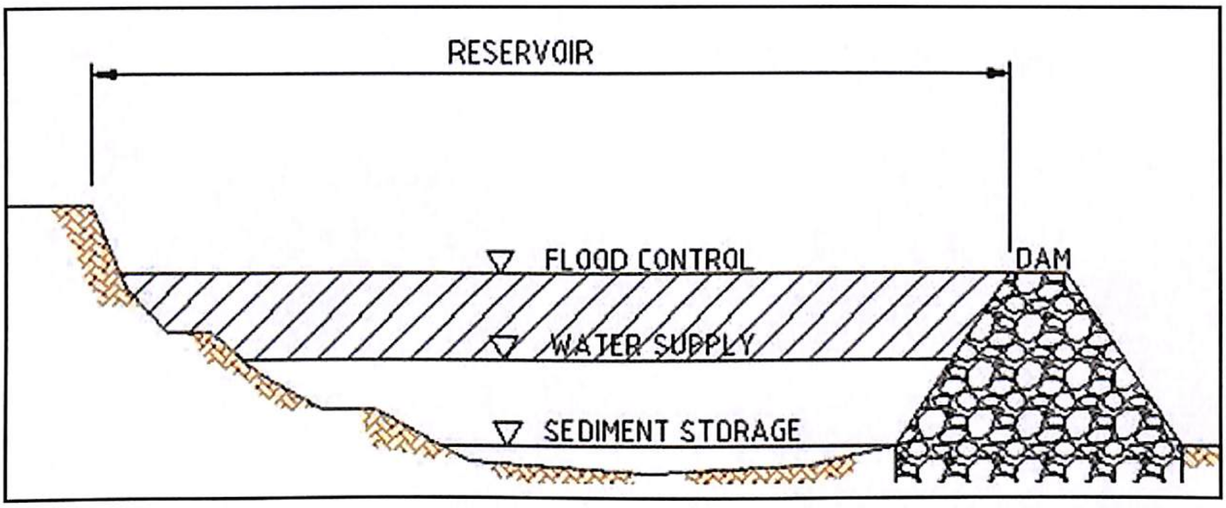

Figure 6: Equating flood volume stored in paddy fields to dam capacity for flood control

$$UC_D = \frac{C_D}{V_F \times Y} \qquad \text{(Equation 4)}$$

where,

UC_D	=	Unit dam depreciation cost, USD/m^3/yr
C_D	=	Total sum of depreciation cost, USD
V_F	=	The designed volume for flood control, m^3
Y	=	The design life span for the dam, yr

Unit Maintenance Cost (UC_M) is calculated by dividing total cost of maintenance over total design volume allocated for flood control. The amount should be then divided by the period of which the maintenance cost is planned to cover. The unit maintenance cost can be written as Equation 5 below.

$$UC_M = \frac{C_M}{V_F \times Y} \qquad \text{(Equation 5)}$$

where,

UC_M = Unit dam maintenance cost, RM/m^3/yr

C_M = Total sum of maintenance cost, RM

V_F = The designed volume for flood control, m^3

Y = The number of year the schedule is planned for, yr

3.4 Consideration of Crop Damages and Compensation

Even though paddy is accustomed to wet condition, submergence in flood water above tolerable levels would result in compromised rice yield. Worse still, if submergence extended beyond the tolerable period, paddy plants would just die off, causing complete loss of investment to the farmers. Therefore the use of paddy fields for flood controls does come with a trade-off, which should be considered in practical terms when working out the monetary values of the flood control function.

Research in Thailand relates rice yield of a paddy field to period of submergence. It was found that only during tender age could paddy survive prolong submergence. Table 1 summarises the reduction in yield due to submergence. It can be safely concluded that submergence more than 10 days would meant total damage to the crops regardless of the growth stage. The study also found that beyond tillering stage, rice yields are totally destroyed even for submergence of 5 days. To include crop damage loss in monetary assessment for flood control, Equation 6 can be used to compute the worth of crop damage trade-off for flood control function.

$$MV_{CD} = A_{flood} \times Y_{ave} \times UC_{RP} \times P \qquad \text{(Equation 6)}$$

where,

MV_{CD} = Monetary value for crop damage, USD /yr

A_{flood} = Area of paddy field being submerged by flood, ha

Y_{ave} = Average rice yield per unit area, ton/ha

UC_{RP} = Market unit rice price, USD/ton

P = Percentage of yield loss in flood submergence (Table 2)

Table 1: Percentage of crop damage based on growth stage and submergence duration

Growth Stage	Percentage of Yield Loss (%)			
	5 Days	10 Days	15 Days	20 Days
Initial Stage (7 days after transplanting)	5	90	95	100
Tillering Stage (14 days after transplanting)	50	100	100	100
Booting Stage (40 days after transplanting)	100	100	100	100
Flowering Stage (70 days after transplanting)	100	100	100	100
Ripening Stage (90 days after transplanting)	100	100	100	100

Alternatively monetary value of crop damage could be represented by the compensation given out by the government on damaged crops. Information on the compensation rate could be retrieved from respective country. For example, a compensation rate based on paddy growth stage for Malaysia is given in Table 2. Subsequently, Equation 6 can be modified into Equation 7 as shown below:

$$MV_{CD} = A_{flood} \times CR \qquad \text{(Equation 7)}$$

where,

MV_{CD} = Monetary value for crop damage, USD /yr

A_{flood} = Area of paddy field being submerged by flood, ha

CR = Compensation rate for crop damage, USD/ha

Table 2: Government aid based on growth stage for Malaysia

Growth Stage	Government Aid (USD/ha)
Growing Stage	100 (RM876)
Ripening Stage	600 (RM1800)

3.5 Estimation of Monetary Value for Flood Control

Equation 8 shows the mathematical computation for monetary value for flood control of paddy field.

$$MV_{FC} = [(FV_{RC} + FV_{TS}) \times UC_{FC}] - MV_{CD} \qquad \text{(Equation 8)}$$

where,

MV_{FC}	=	Monetary value for flood control function of paddy field, USD /yr
FV_{RC}	=	Function volume for retention capacity, m^3
FV_{TS}	=	Function volume for temporary storage, m^3
UC_{FC}	=	Unit flood control cost, USD/m^3/yr
MV_{CD}	=	Monetary value for crop damage or compensation, USD /yr

CALCULATION SHEET FOR ESTIMATION OF FLOOD CONTROL MONETARY VALUE

PARAMETER		VALUE	UNIT	CALCULATION
1. Total Paddy Field Area	=		ha	(1)
2. Percentage of Effective	=		%	(2)
STEP 1: DETERMINATION OF FUNCTION VOLUME, FV_{FC}				
A. Function Volume for Retention Capacity				
A1. Effective Paddy Field Area, A_{eff}	=		ha	= (1) x (2) = (3)
A2. Average Storage Depth, *d*	=		m	(4)
A3. Function Volume for Retention Capacity, FV_{RC}	=		m^3	= (3) x (4) x 10,000 = (5)
B. Function Volume for Temporary Storage, FV_{TS}				
B1. Submerged Paddy Field Area, A_{flood}	=		%	(6)
	=		ha	= (3) x (6) = (7)
B2. Average Submergence Depth, *d*	=		m	(8)
B3. Function Volume for Temporary Storage, FV_{TS}	=		m^3	= (7) x (8) x 10,000 = (9)
C. Total Function Volume, FV_{FC}				
C1. Total Function Volume for Flood Control, FV_{FC}	=		**m^3**	**= (5) + (9) = (10)**
STEP 2: DETERMINATION OF UNIT COST, UC_{FC}				
A. Determination of Depreciation Cost, UC_D				
A1. Total Dam Construction Cost	=		USD	(11)
A2. Design Flood Control Volume	=		m^3	(12)
A3. Design Service Life Span	=		years	(13)
A4. Unit Depreciation Cost	=		USD/m^3/y	= (11) / ((12) x (13)) = (14)
B. Determination of Unit Maintenance Cost				
B1. Total Maintenance Cost	=		USD	(15)
B2. Design Flood Control Volume	=		m^3	(12)
B3. Total Maintenance Period	=		years	(16)
B4. Unit Maintenance Cost	=		USD/m^3/y	= (15) / ((12) x (16)) = (17)
C. Total Unit Cost, UC_{FC}				
C1. Total Unit Cost for Flood Control, UC_{FC}	=		**USD/m^3/y**	**= (14) + (17) = (18)**

CALCULATION SHEET FOR ESTIMATION OF FLOOD CONTROL MONETARY VALUE (CONTINUED)

PARAMETER		VALUE	UNIT	CALCULATION
STEP 3: CONSIDERATION FOR CROP DAMAGE				
OPTION A: Yield Reduction				
A1. Flood Affected Area	=		ha	(19)
A2. Average Rice Yield	=		ton/ha	(20)
A3. Unit Rice Price	=		USD/ton	(21)
A4. Percentage of Yield Reduction	=		%	(22)
A5. Total Crop Damage Compensation	=		**USD**	**= (19)x(20)x(21)x(22) = (23)**
OPTION B: Compensation Rate				
B1. Compensation Rate	=		USD/ha	(24)
B2. Flood Affected Area	=		ha	(19)
B3. Total Flood Compensation	=		**USD**	**= (24) x (19) = (23)**
STEP 4: COMPUTE MONETARY VALUE, MV_{FC}	=		**USD/y**	**= [(10) x (18)] - (23) = (25)**
	=		**USD/ha/y**	**= (25) / (1)**

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APPENDIX

APPENDIX A: DATA FROM MADA

LEMBAGA KEMAJUAN PERTANIAN MUDA
PENYATA HUJAN BULANAN
STESEN NO.56 (TANAH MERAH)
TAHUN 2007-2009

LEBAT HUJAN (mm)

	Jan	Feb	Mac	Apr	Mei	Jun	Jul	Ogos	Sep	Okt	Nov	Dis
2007	58	111	131	232	173	198	273	62	404	342	125	128
2008	61.0	155.0	122.0	183.0	72.0	80.0	94.0	174.0	183.0	406.0	321.0	67.0
2009	4.0	51.0	146.0	270.0	310.0	67.0	177.0	448.0	158.0	126.0	308.0	

LEMBAGA KEMAJUAN PERTANIAN MUDA
PENYATA HUJAN BULANAN
STESEN NO.40 (PENDANG)
TAHUN 2007-2009

LEBAT HUJAN (mm)

	Jan	Feb	Mac	Apr	Mei	Jun	Jul	Ogos	Sep	Okt	Nov	Dis
2007	60	89	194	172	177	216	328	82	494	327	151	103
2008	7.0	219.0	102.0	210.0	103.0	104.0	95.0	178.0	253.0	513.0	168.0	81.0
2009	9.0	72.0	200.0	325.0	417.0	30.0	228.0	568.0	138.0	221.0	222.0	

LEMBAGA KEMAJUAN PERTANIAN MUDA
PENYATA HUJAN BULANAN
STESEN NO.36 (SUNGAI PENDANG, ALOR BINJAL)
TAHUN 2007-2009

LEBAT HUJAN (mm)

	Jan	Feb	Mac	Apr	Mei	Jun	Jul	Ogos	Sep	Okt	Nov	Dis
2007	79	156	169	163	184	264	202	168	385	255	124	111
2008	12.0	117.0	122.0	218.0	99.0	127.0	124.0	130.0	267.0	437.0	162.0	42.0
2009	0.0	69.0	178.0	178.0	205.0	27.0	211.0	639.0	180.0	182.0	386.0	

JADUAL PENANAMAN PADI 2009/2010

LOKALITI		FASA	MUSIM	TARIKH MULA BEKALAN AIR	TARIKH HENTI BEKALAN AIR
D-III	Titi Haji Idris	II	M1/2009	08-Apr-09	04-Aug-09
		III	M2/2009	22-Sep-09	25-Jan-10
E-III	Pendang	II	M1/2009	08-Apr-09	04-Aug-09
		II	M2/2009	08-Sep-09	11-Jan-10

JADUAL AKTIVITI DI SAWAH PADI 2010

No	Tarikh	Lokasi	Aktiviti
1	04 April 2010	Alor Berala	Penyediaan tanah (membajak)
		Banggol Tok Ali	Penyediaan tanah (membajak)
		Alor Punti	Penyediaan tanah (membajak)
2	13 Mei 2010	Alor Berala	Penanaman padi (tabur terus, tanam)
		Banggol Tok Ali	Penanaman padi (tabur terus)
		Alor Punti	Penanaman padi (tabur terus)
3	26 Mei 2010	Alor Berala	Penanaman padi (tabur terus, tanam)
		Banggol Tok Ali	Penanaman padi (tabur terus, tanam)
		Alor Punti	Penanaman padi (tabur terus, tanam)
4	14 Jun 2010	Alor Berala	Penanaman padi (tabur terus, tanam)
		Banggol Tok Ali	Penanaman padi (tabur terus, tanam)
		Alor Punti	Penanaman padi (tabur terus, tanam)
4	01 Julai 2010	Alor Berala	Penanaman padi (tabur terus, tanam)
		Banggol Tok Ali	Penanaman padi (tabur terus, tanam)
		Alor Punti	Penanaman padi (tabur terus, tanam)
4	15 Julai 2010	Alor Berala	Penanaman padi (tabur terus, tanam)
		Banggol Tok Ali	Penanaman padi (tabur terus, tanam)
		Alor Punti	Penanaman padi (tabur terus, tanam)

SENARAI ID

ID Stesen	Lokasi Stesen
36	Titi Haji Idris / Sungai Pendang Alor Binjal
40	Pendang
56	Tanah Merah
127	Pekan Pendang (Data bermula pada tahun 2009)

JADUAL MENANAM PADI 2009

LOKALITI		FASA	MUSIM	TARIKH MULA BEKALAN AIR	TARIKH HENTI BEKALAN AIR
D-III	Titi Haji Idris	II	M1/2009	08-Apr-09	04-Aug-09
		III	M2/2009	22-Sep-09	25-Jan-10
E-III	Pendang	II	M1/2009	08-Apr-09	04-Aug-09
		II	M2/2009	08-Sep-09	11-Jan-10

ARAS AIR DI AMPANG JAJAR, TITI HAJI IDRIS & PEKAN PENDANG BAGI TAHUN 2009

Tarikh	Ampang Jajar (US) (in metre)	Titi Haji Idris (S36) (in metre)	Pekan Pendang (S127) (in metre)
01-Nov-09	0.823	0.91	1.10
02-Nov-09	0.945	1.06	1.23
03-Nov-09	0.976	1.07	1.14
04-Nov-09	1.037	1.12	1.13
05-Nov-09	0.640	0.80	1.27
06-Nov-09	0.427	1.12	1.61
07-Nov-09	0.884	1.62	2.29
08-Nov-09	0.976	1.69	2.34
09-Nov-09	1.159	1.79	2.23
10-Nov-09	1.189	1.77	2.18
11-Nov-09	1.159	1.84	2.63
12-Nov-09	1.037	1.86	2.77
13-Nov-09	0.915	1.92	2.80
14-Nov-09	0.915	2.02	2.80
15-Nov-09	1.006	2.14	2.91
16-Nov-09	1.037	2.19	2.95
17-Nov-09	1.067	2.21	2.81
18-Nov-09	1.067	2.21	2.73
19-Nov-09	0.945	2.14	2.63
20-Nov-09	0.793	2.00	2.45
21-Nov-09	0.671	1.77	2.24
22-Nov-09	0.640	1.52	2.13
23-Nov-09	0.732	1.36	1.90
24-Nov-09	0.854	1.31	1.77
25-Nov-09	0.884	1.21	1.78
26-Nov-09	0.793	1.03	1.46
27-Nov-09	0.854	1.05	1.35
28-Nov-09	0.732	0.97	1.39
29-Nov-09	0.457	0.56	1.09
30-Nov-09	0.823	0.90	1.16

APPENDIX B: MONETARY ASSESSMENT BY INWEPF (2008)

INWEPF

Monetary assessment on multi-functional roles of paddy fields in the Asian monsoon region

July 2008
INWEPF Japanese Committee
(Chair of Working Group 3)

< Introduction and Background >

The purpose of Working Group 3 (WG3) is "Monetary Assessment and Value Adding in the Multifunctional Roles of Paddy Fields." The INWEPF Japanese Committee, the chair of WG3, did a trial calculation of monetary assessment in the multifunctional roles of paddy fields in INWEPF countries.

In this draft, we picked up three major multifunctional roles including flood prevention function, groundwater recharge function, and soil erosion inhibiting function. These may be calculated relatively easily.

To calculate the monetary values of these three, we collected some data such as area of paddy fields of each country and so on. However we could not find appropriate data of some factors. Therefore, we would like to ask you to let us know these missing data of your countries. If you also cannot find the data, we plan to use other countries' data. (Another attached file is the result of these calculations.)

< Schedule >

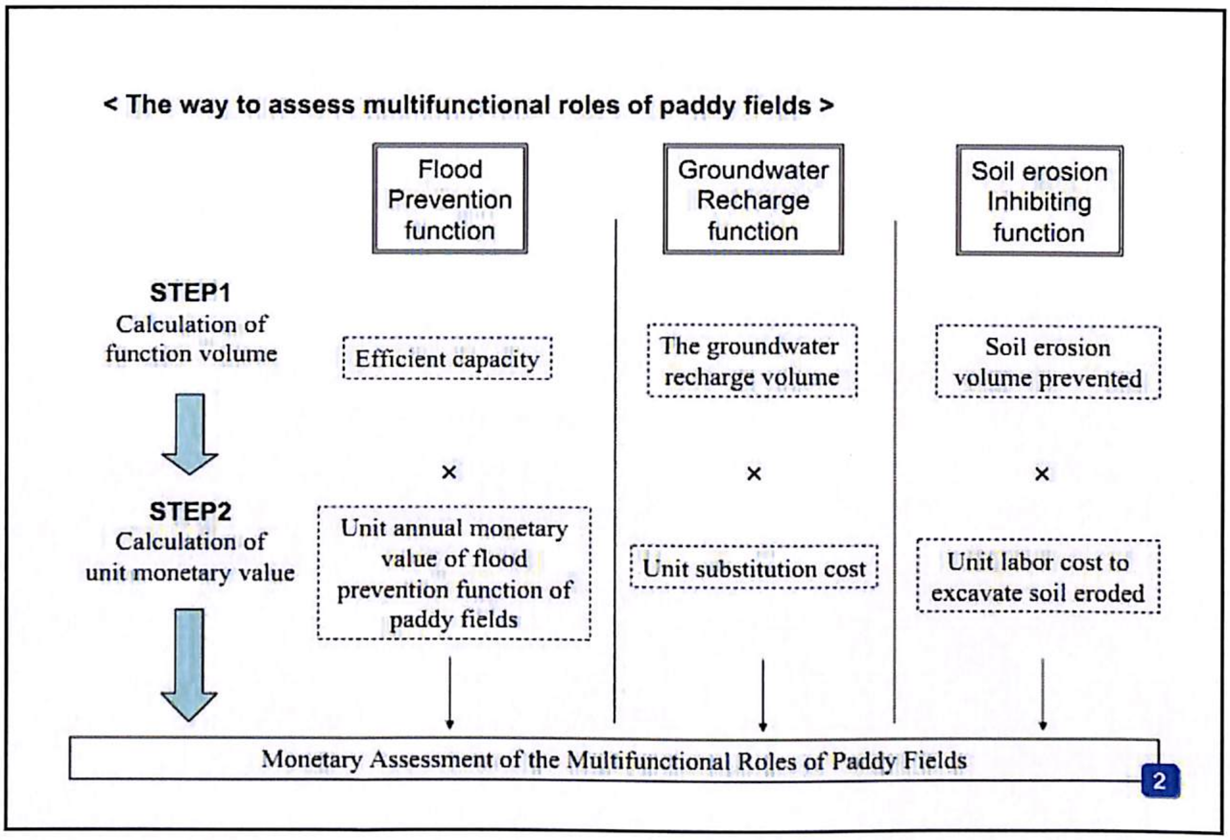
We would like to improve this draft by late August by using your country's data. We plan to use this draft at the 5th INWEPF Steering Meeting.

< Requests >

1. Please check the attached Excel file.
2. Please fill in the blank at the bottom of each sheet of the Excel file.
3. Please send data of your country as much as possible. If your country does not have the data, please let us know so.
    - 3-1. Please replace the data in red.
    - 3-2. Please replace the data in blue if possible.

** For more detail, please see from the next page.*

1



1.Monetary assessment on flood prevention function

【Requests】

(We need the following data to evaluate flood prevention function.)

1. Ratio of paddy fields which has no benefit to prevent flood damages
2. Height of levee in average (cm)
3. Depth of pool water in average (cm)
4. Average construction cost of dams (million US$)
5. Average efficient capacities of dams (m^3)

3

<STEP1> Requests to calculate efficient capacity of paddy fields [2/2]

2. Height of levee in average

- In this draft, Japanese committee substituted average height in Japan of 15cm before land improvement for your country's data.
- If this 15 cm is inadequate for your country, please choose the nearest one from the following numbers.

10cm	20cm	25cm	30cm	35cm	40cm

[Reference] Average height of levee in Japan
- Before land improvement : 17cm
- After land improvement : 30cm

3.Depth of pool water in average

- In this draft, Japanese committee substituted average depth of pool in Japan of 3cm for your country's data.
- If this 3 cm does not match with your country, please report your data of the half of depth of pool water at the time of managing the deepest ponding depth

[Reference] Depth of pool water in average in Japan
- Depth of pool water when planting is 5 cm, so average depth can be calculated by 5/2 = 2.5 ≒3cm

6

<STEP1> Requests to calculate efficient capacity of paddy fields [1/2]

1. Ratio of paddy fields which has benefit to prevent flood damages

- This ratio is needed to calculate the efficient areas of paddy fields excluding the paddy field in the areas which has no benefit to avoid flood damages.
- In this draft, Japanese committee used 100% as your country's data because Japanese committee could not obtain your country's ratio.
- If you have the information of this ratio, we expect you to report its value and how to calculate the ratio. (For example, utilization of your country's GIS data, rough measuring your country's map)
- If you cannot obtain the ratio, it is fine just to say so. Japanese committee will use 100% as your country's data.

[Reference] The following equations show how to calculate the ratio in Japan.

Ratio (%) ={(Total area of paddy fields) - (Area of paddy fields which has no benefit to prevent flood damages in low-lying areas)} / (Area of paddy fields in low-lying areas)

5

<STEP2> Requests to assess the monetary value of flood prevention function

4. Average construction cost of dams
5. Average efficient capacity of dams

- In this draft, Japanese committee substituted annual amount of depreciation cost per unit efficient capacity in Japan of $0.75\text{US\$}/m^3$ for Korea's data and that in Indonesia of $0.15\text{US\$}/m^3$ for other countries'.
- Please report your country's average construction cost and average efficient capacity of dams, whose construction project finished after 2000.
- If you do not have these data, please report so. Japanese committee will use the data as explained above.
- If you have a more suitable method for your country than the substitute method explained here, we will be glad to know your idea and concept to assess the flood prevention function.

<About annual amount of maintenance cost per unit efficient capacity of dams >

We plan to assume that annual amount of maintenance cost per unit efficient capacity of dams is 1% of annual amount of depreciation cost per unit efficient capacity of dams, because maintenance cost is very small compared with depreciation cost and, in case of Japan, annual amount of depreciation cost per unit efficient capacity of dams are 263 (yen/m^3/yr) and annual amount of maintenance cost per unit efficient capacity of dams are 2.3 (yen/m^3 /yr). This is about 0.88% of depreciation cost.

8

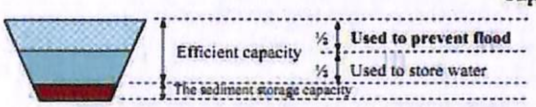
<STEP2> How to assess flood prevention function

○ We used a substitute method to assess the flood prevention function of paddy fields. That is, we assessed this function by using annual depreciation cost and annual maintenance cost of dams which have equal capacity efficient capacity of paddy fields.

Unit annual monetary value of flood prevention function of paddy fields ($\text{US\$}/m^3/yr$)
= Annual amount of depreciation cost per unit efficient capacity of dams for flood prevention ($\text{US\$}/m^3/yr$) + Annual amount of maintenance cost per unit efficient capacity of dams for flood prevention ($\text{US\$}/m^3/yr$)

Definition

Efficient capacity of dam for flood prevention= (Total capacity of dams – The sediment storage capacity of dams during 100 years)/2



We assume that the half of efficient capacity can be used to prevent flood because the remaining capacity is usually used to store water

Annual amount of depreciation cost per unit efficient capacity of dam for flood prevention ($\text{US\$}/m^3/yr$)
= Construction cost of dams ($\text{US\$}$) $\times i \times (1+i)^n/((1+i)^n-1)$ / efficient capacity of dam for flood prevention(m^3) (i: social discount rate (0.04) n: period of depreciation (80 years))

Annual amount of maintenance cost per unit efficient capacity of dam for flood prevention ($\text{US\$}/m^3/yr$)
= Annual maintenance cost of dams ($\text{US\$}/yr$) /efficient capacity of dam for flood prevention (m^3)

7

◆ Summary of monetary assessment on flood prevention function

	Source	Remarks	Request
Height of levee in average (cm)	Japanese data	The height of levee before land improvement in Japan	We need your country's data.
Depth of pool water in average (cm)	Japanese data	The half of depth of pool water at the time of managing water deeply	We need your country's data.
Paddy fields area (m^2)	FAOSTAT	[Rice, Paddy 2005]	–
Ratio of paddy fields which has benefit to prevent flood damages (%)	–	N/A	Please send your country's data if you have.
Average construction cost of dams (US$)	Japanese or Indonesian data	Average total construction cost of dams (Korea and Japan : Japanese data; Other countries : Indonesian data)	We need your country's data.
Efficient capacity of dams (m^3)	Japanese or Indonesian data	Average efficient capacity of dams which are used to calculate average construction cost of dams above. (Korea and Japan : Japanese data; Other countries : Indonesian data)	
Annual amount of maintenance cost per unit efficient capacity of dams (US$/$m^3$/yr)	Japanese data	The 3% of annual amount of depreciation cost per unit efficient capacity of dams	Please send your country's data if you have.

9

1.Monetary assessment on flood prevention function

(1)Please fill in data of your country as much as possible.(Red & blue figure)

Country	Area of paddy	Classification of height of levee Type1 : Before land improvement Type2 : After land improvement		Classification of Area	Level of height of levee in average	Depth of pool water at the time of managing water deeply	Depth of pool water in average	Capacity stored by paddy	Ratio of paddy fields which has benefit to prevent flood damages	Efficient capacity	Average construction costs of dams	Average efficient capacities of dams	Annual amount of depreciation costs per unit efficient capacity of dams	Annual amount of maintenance costs per unit efficient capacity of dams	Unit annual monetary value	Monetary assessment	Producer price of rice • production quantity	Ratio of monetary assessment to (producer price of rice • production quantity)
	ha			ha	cm	cm	cm	10^6m^3		10^6m^3	10^3US$	10^3m^3	US$/$m^3$/yr	US$/$m^3$/yr	US$/$m^3$/yr	10^6US$	10^6US$	%
	(1)	(2)		(3)=(1)*(2)	(4)	(5)	(6)=(5)/2	(7)=((4)-(6))/100*(3)	(8)	(9)=(7)*(8)	(10)	(11)	(12)=(10)/(11)	(13)=(12)*0.03	(14)=(12)+(13)	(15)=(9)*(14)	(16)	(15)/(16)
Japan	2,602,319	Type1	41%	1,066,951	15	5	3	1,280	0.953	1,220			5.2	0.1	5.3	6,408	22,856	119%
		Type2	59%	1,535,368	30	5	3	4,145	0.953	3,951			5.2	0.1	5.3	20,749		
Bangladesh	10,524,067	Type1	100%	10,524,067	15	5	3	12,629	1.000	12,629			0.4	0.0	0.4	5,102	5,725	89%
		Type2																
Cambodia	2,414,500	Type1	100%	2,414,500	15	5	3	2,897	1.000	2,897			0.4	0.0	0.4	1,171	879	133%
		Type2																
China	29,116,000	Type1	100%	29,116,000	15	5	3	34,939	1.000	34,939			0.4	0.0	0.4	14,115	27,467	51%
		Type2																
Egypt	613,300	Type1	100%	613,300	15	5	3	736	1.000	736			0.4	0.0	0.4	297	1,353	22%
		Type2																
India	43,660,000	Type1	100%	43,660,000	15	5	3	52,392	1.000	52,392			0.4	0.0	0.4	21,166	20,620	103%
		Type2																
Indonesia	11,800,901	Type1	100%	11,800,901	15	5	3	14,161	1.000	14,161			0.4	0.0	0.4	5,721	11,352	50%
		Type2																
Korea	979,717	Type1	100%	979,717	15	5	3	1,176	1.000	1,176			5.2	0.1	5.3	6,175	3,654	169%
		Type2																
Laos	736,020	Type1	100%	736,020	15	5	3	883	1.000	883			0.4	0.0	0.4	357	313	114%
		Type2																
Malaysia	**676,200**	**Type1**	**100%**	**676,200**	**15**	**5**	**3**	**811**	**1.000**	**811**			**0.4**	**0.0**	**0.4**	**328**	**474**	**69%**
		Type2																
Myanmar	7,008,000	Type1	100%	7,008,000	15	5	3	8,410	1.000	8,410			0.4	0.0	0.4	3,397	3,244	105%
		Type2																
Nepal	1,541,729	Type1	100%	1,541,729	15	5	3	1,850	1.000	1,850			0.4	0.0	0.4	747	614	122%
		Type2																
Pakistan	2,621,400	Type1	100%	2,621,400	15	5	3	3,146	1.000	3,146			0.4	0.0	0.4	1,271	1,776	72%
		Type2																
Philippine	4,070,421	Type1	100%	4,070,421	15	5	3	4,885	1.000	4,885			0.4	0.0	0.4	1,973	2,766	71%
		Type2																
Sri Lanka	915,260	Type1	100%	915,260	15	5	3	1,098	1.000	1,098			0.4	0.0	0.4	444	517	86%
		Type2																
Thailand	10,224,966	Type1	100%	10,224,966	15	5	3	12,270	1.000	12,270			0.4	0.0	0.4	4,957	4,980	100%
		Type2																
Viet Num	7,329,200	Type1	100%	7,329,200	15	5	3	8,795	1.000	8,795			0.4	0.0	0.4	3,553	4,356	82%
		Type2																
Total	136,834,000							166,504		**166,249**			21.6	0.2	21.8	**97,932**	**112,946**	**87%**

(2)Please write your comments on this function.

(3)If you have a more suitable method for your country, please write down.

APPENDIX C: LIST OF PUBLICATION (ICSEWR, 2015)

Assessment the Role of Flood Control of Paddy Fields in Muda irrigation Scheme, Malaysia (Region 3)

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Keywords: 1-D Hydraulic Modeling, HEC-RAS, Floodplain, Paddy Plot, Hydraulic Behaviour

Abstract. 1-D hydraulic modeling is used to study the function of paddy fields as part of the river system. Generally, many paddy plots are situated within the floodplain of rivers. Floodplains are normally low and frequently flooded to cater to storing excessive flood waters. Floodplains temporarily store floodwater and therefore attenuate flood wave. This is very crucial as it helps to reduce flood level, hence reducing flood extent and damage particularly in the downstream area. HEC-RAS is developed to study the hydraulics behaviour of river system, including floodplains (USACE, 2006). The recently released Version 4.1 of HEC-RAS (2010) incorporates various aspects of hydraulic modeling, including steady flow water surface profile computations and bridge hydraulics, unsteady flow simulation, movable boundary sediment transport computations and water quality analysis.

1. Introduction

Rice is the staple food in Malaysia, where rice farming always plays an important role in agricultural activities. The paddy fields and irrigation activities hold diversified functions or multi-functionalities such as production, eco-environmental and living-associated functions. Traditional paddy field of Peninsular Malaysia yield crops once a year for centuries. Through the establishment of MADA, paddy plant was successfully cultivated twice a year. First season starting in March until August of the current year. Main season or second season started in September of the current year to January next year. State of Kedah receives high rainfall throughout the year. This can cause problems to farmers and their paddy field due to heavy rain could potentially cause flood and losses to the farmers. In addition, this can also affects the paddy production target set by MADA and contributes to the shortage of rice because the state of Kedah is one of the largest rice producers in Malaysia.

Muda Agricultural Development Authority or MADA is divided into four regional offices for the smooth administration, namely Region I, II, III, and IV. Region III that cover almost the entire Pendang District in Kedah is selected as the study area upon recommendation by MADA office. It should be noted that the actual study area involved in this study only consists of a portion from the Region III, which was found to be suitable in achieving the scope of study. Topographically, most of the area in the Region III is flat. The landscape is dominated by paddy fields and sparse farm houses. Several towns are situated within the region, most notably is the Pendang Town. The region is furnished with series of irrigation supply and drainage networks serving the paddy cultivation industry, which is the major economic contributor for the area. Sungai Pendang is the only main river flowing through the study area. Figure 1 shows the study area in Region III. Due to the flat terrain, the river frequently overspill its bank, flooding vast paddy fields located on both sides of the banks. It is especially so during monsoon that brings heavy rains. Flooding causes a lot of damage, especially for the paddy fields and paddy crops. Sungai Pendang flows northwards, from Pekan Pendang heading to Titi Haji Idris and eventually discharge into Sungai Anak Bukit in the Kota Setar District. The stretch involves a length of roughly 17.5 km of Sungai Pendang, with a general river width of about 30 m and depth of 5 m.

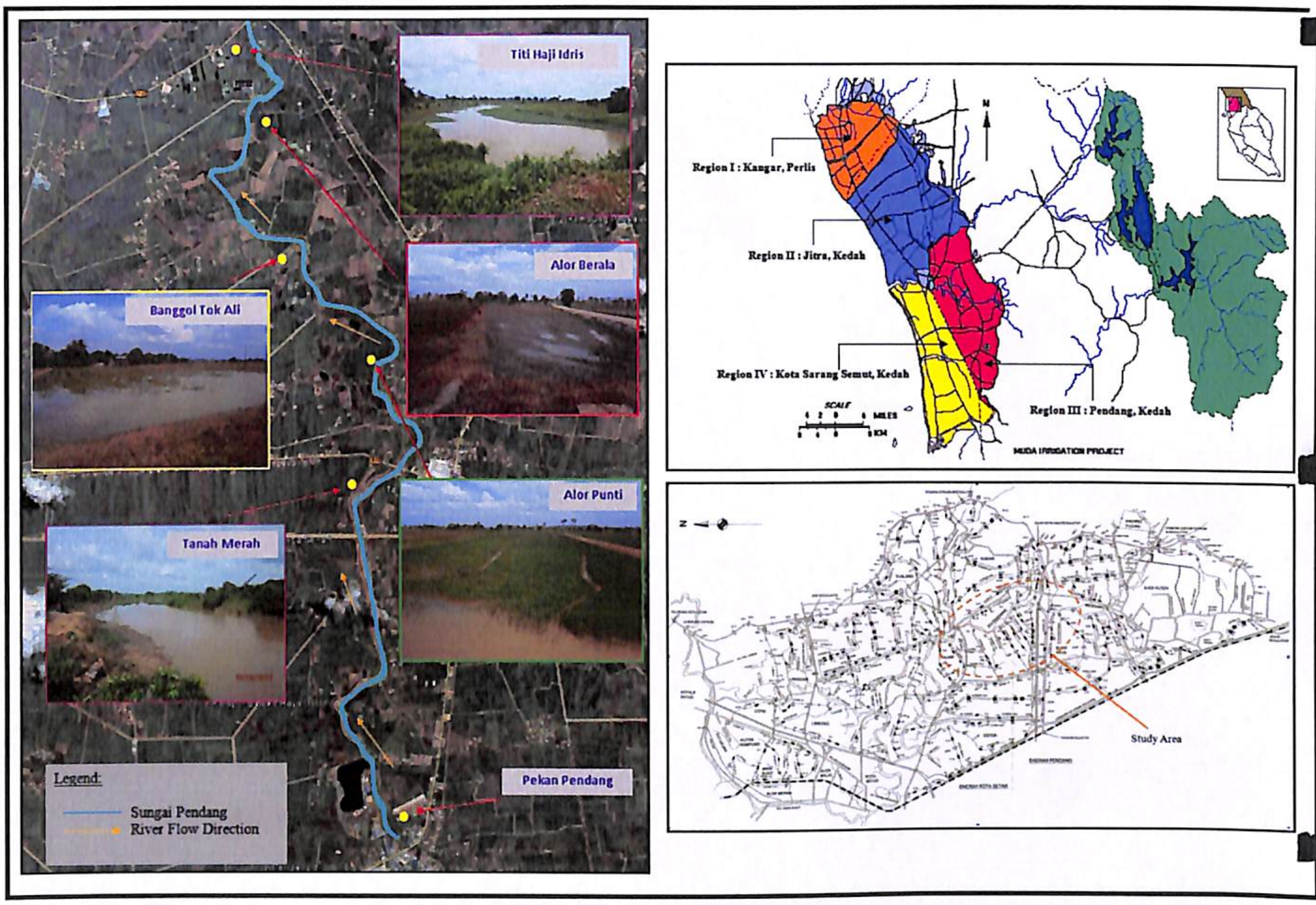

Figure 1: Study Area

2. Literature Review

Flood control is one of the functions of paddy field that is widely recognized. The land parcels of paddy field are surrounded by ridges. Ridges serve as earth embankments to hold water for culturing rice crops, to provide access routes, and to divide crops for management purpose. When additional water flows into paddy fields, they are stored within, bounded by the ridges, thus creating impoundment effect. The large amount of water stored in the paddy fields might functions as many small reservoirs or dam. They hold rainfall in the fields, thus reducing peak flow and preventing flood (Huang et al., 2006).

Masumoto et al. (2006) developed an index for evaluating flood prevention function of paddies in a macro (regional or river basin) scale perspective. The index relates storage capacity of the storage depth in paddy field and the maximum drainage capacity of area downstream. This relation was said to be able to help river basin manager and agricultural planner to correctly utilize the flood control capacity of paddy field in catchment wide flood management. The expression is given in Equation 1.1 below.

$$\frac{S}{S_o} = \left[\frac{(D_o - D)}{D_o} \right]^u \qquad (1.1)$$

Where S_o and D_o are the maximum storage and drainage capacities respectively, and u is the curve parameter, determined by regression method. If the downstream drainage capacity exceeds the maximum drainage capacity of the basin, no additional storage will be required for flood alleviation; If the drainage capacity is limited, then storage will be required to be allocated to cater the flood volume.

Flood control capacity of paddy field was estimated by studying the major hydrological processes of paddy field and other land use type by Wu et al. (2001). Evapotranspiration, deep percolation (assumed to be groundwater recharge capability) and runoff were examined by comparing the estimations of these processes on paddy field, fallow and dry land in response to same rainfall event. It was found that paddy field has superior evapotranspiration, lower runoff, and higher percolation rate. It was thus concluded that paddy fields were better in runoff control and ground water recharge compared to dry land and fallow on the same plot of land.

3. Materials and Method

The study will be conducted to examine the flood control capacities of paddy fields. In this part, the functions will be examined in two scales, namely micro (local) and macro (regional) scales. Finally, the flood control capacity will be determined.

Data Collection

Data collection will be carried out to gather all relevant information available. This information will be cleaned, processed, and formatted to produce useful data for modeling purposes. In general, two types of data are required. Desk study provides published data and information for the study area. The data includes rainfall and river water level records provided by relevant authorities. On top of that, field works will be carried out to obtain necessary data.

Flood Analyses

Paddy fields play important role to mitigate flood. The capacity of paddy field in resuming this function however can be affected by several factors. In a micro-environment, i.e. within the field itself, paddy cultivation helps to reduce runoff generation. Depending on type and seasonal difference, paddy is able to reduce runoff generation through interception and infiltration. The structure of paddy plot is also expected to significantly increase the capacity of paddy field to reduce flood risk.

In a regional aspect, paddy field also serves as floodplain for adjacent rivers. The flat and wide terrain of paddy fields acts collectively as a huge detention storage area. The storage area temporarily stores flood water, therefore reducing flood risk on other more important lands such as towns or villages.

Flood Retention Capacity

The structure of paddy fields with raised embankment to divide plots as well as to store water needed for paddy cultivation forms pockets of storage compartments, capable of providing huge amount of depression storage. In order to study the relationship as well as factors affecting the potential flood retention capacity of paddy plots, site data will be collected, which include water level in paddy plot, inflow from canal, outflow to drainage and infiltration rate.

Flood Modeling

1-D hydraulic modeling is used to study the function of paddy fields as part of the river system. Generally, many paddy plots are situated within the floodplain of rivers. Floodplains are normally low and frequently flooded to cater to storing excessive flood waters. Floodplains temporarily store floodwater and therefore attenuate flood wave. This is very crucial as it helps to reduce flood level, hence reducing flood extent and damage particularly in the downstream area.

The main objective of HEC-RAS is to produce hydraulic properties (particularly water level) at cross section of interest. The profile computation begins at a cross section with known or assumed starting conditions, and proceeds upstream for subcritical flow or downstream for supercritical flow. HEC-RAS is capable of simulating both steady and unsteady flow conditions. Data requirement for basic hydraulic simulation include flow regime, starting condition, flow rate, loss coefficient, roughness, cross-sectional geometry and reach length.

Flood Control Capacity

After all analyses are carried out, we will able to determine the flood control facility based on the case study carried out. The capacity of flood control will be determined by (1) The attenuation effect on hydrograph, (2) The volume of detention the paddy field is able to provide, and (3) The overall performance of paddy field compared to other land use in flood control.

4. Results and Discussion

The current model is set up using data available at the time of report. Some of the parameters such as hydrological input and floodplain elevation are still not available, hypothetical values and assumptions are made. This practice is to validate that the model being set up so far is able to produce reasonable result. The model will be gradually updated, depending on the availability of the data. In order to verify the data entry and model set up to-date, a hypothetical hydrograph resembling a flood wave is used as upstream boundary input (Figure 2). During simulation run, the wave is routed the Sungai Pendang model and the response of the river can then be evaluated. The current downstream boundary is set to 'normal' depth, where the water level is calculated by the model using manning's equation (Figure 3).

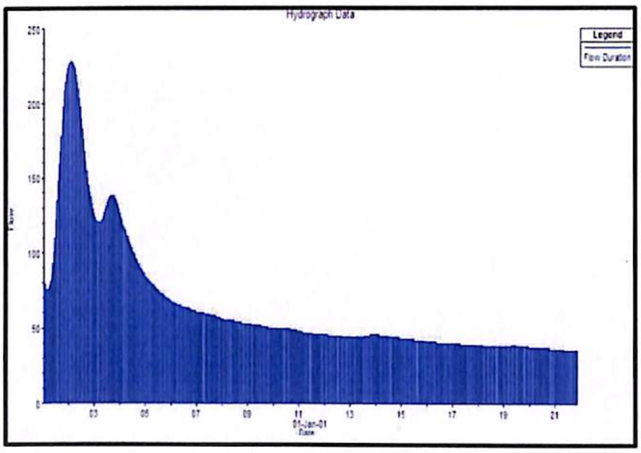

Figure 2: Hypothetical Flow Hydrograph as Upstream Input

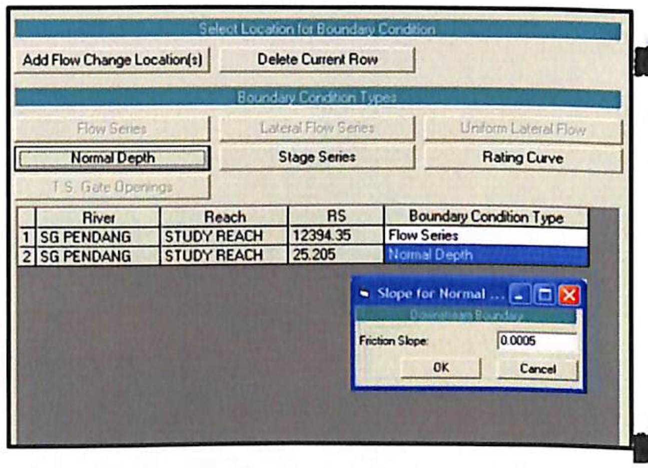

Figure 3: Settings of Upstream and Downstream Boundary Conditions

Figure 4 shows that for a simulation of about 225m3/s (peak of hypothetical hydrograph), many part of the channel has overtopped the model bank levels. This indicated that water moves into the floodplains, which are the paddy fields. Figure 5 shows an example cross section view of how floodwater is contained within the floodplain (paddy field) as it overspill the river banks. A layout presentation of modelling result showed in Figure 6 demonstrates water level rising above the banks of simulated river. The exercise showed that the model is able to produce result, albeit the accuracy of result is still unknown. By further improving data entry and calibration, the model will be able to give prediction and result in similar ways as demonstrated in this exercise.

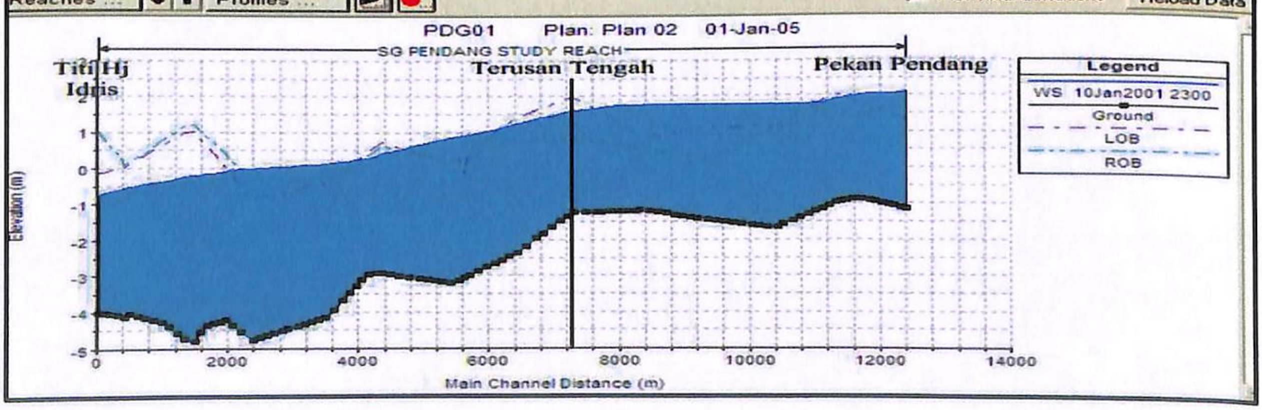

Figure 4: Longitudinal Section View of Simulated Result

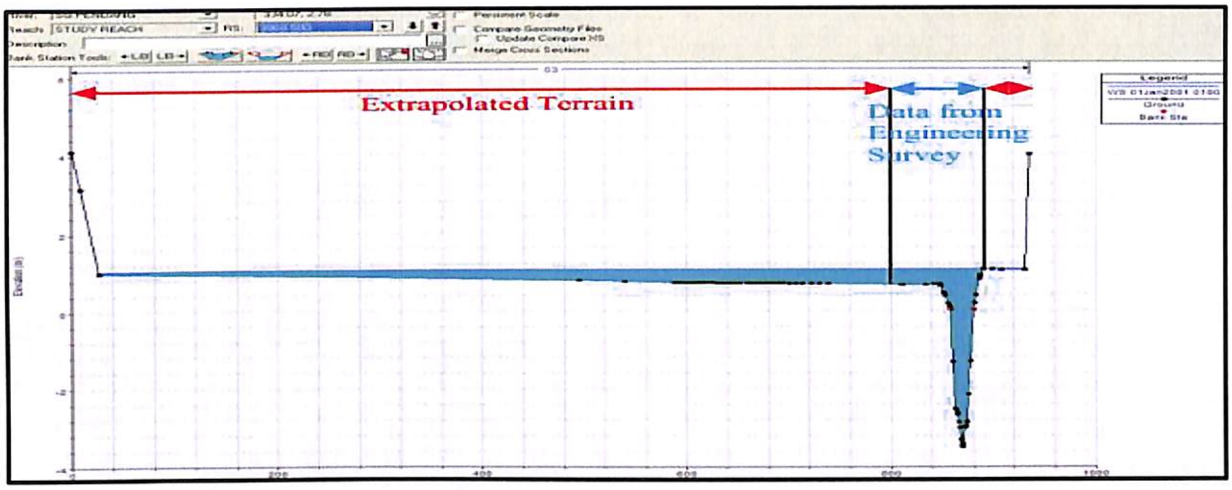

Figure 5: Cross Sectional View of Flood Inundation in Floodplain

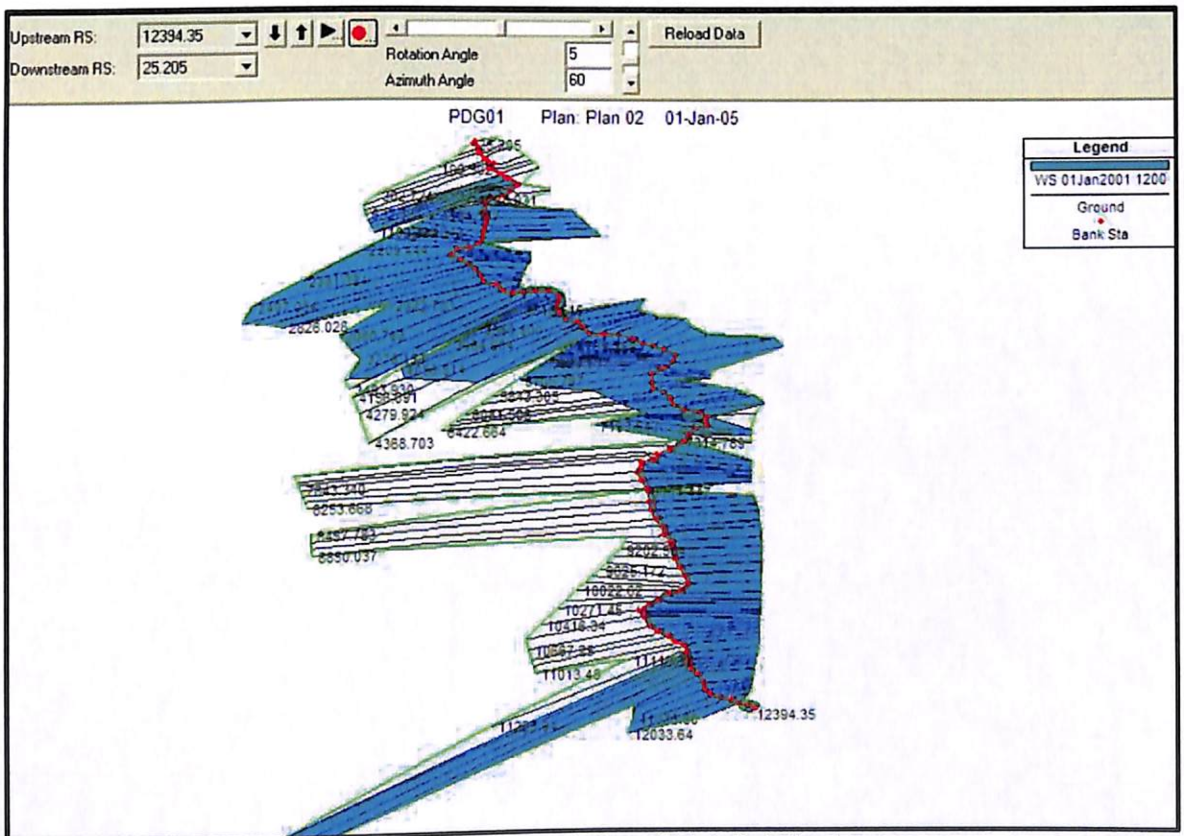

Figure 6: 2-D Representation of Modelled Flood Extent

Paddy fields contribute to flood control in two ways. First, paddy fields have huge retention capacity and potential due to the structure and land cover provided by paddy cultivation. This means that less runoff is generated from a paddy plot compared to a developed area of the same size. This helps to prevent unexpected flash flood at downstream area due to sudden surge of large-volume runoffs from upstream area. Secondly, as most paddy plots are located within delta or floodplain, they play a significant role in providing storage and attenuation for flood. Without paddy fields, excessive water would have flooded urban areas, causing more flood damage. It is therefore important to consider both the roles in flood control when putting monetary value on this benefit carried by the paddy fields.

When flood has occur, paddy fields also function as flood control, by providing temporary storage for flood water, hence slowing down flood propagation and damage potential to any downstream development. Although it may be argued that the floodplain would be functioning just as well without the paddy fields, but under current urban land demand, many land would require back-filling to raise platform level for development or cultivation of other commercial crops (rubber and oil palm). In other words, the preservation of floodplain would be very hard if the land use is substituted with anything other than paddy fields. Therefore, paddy cultivation can therefore be viewed as one of the win-win solution for floodplain preservation and economic generation in many paddy planting developing countries.

The existence of paddy fields ensures floodplain stays at a lower elevation, hence preserving its flood control function. The ability of the floodplain (which the paddy fields are situated) to store/ contain water can therefore be translated into the function volume of the paddy field in flood control. Since not all paddy field are located within floodplain, it is extremely to determine the function volume based on effective flood control paddy plot only. The function volume shall only consider the area of paddy field situated within the floodplain.

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