DETERMINATION OF FLOOD INUNDATION FOR SUNGAI BERTAM BY HYDRAULIC PHYSICAL MODEL

NURFATIHAH IDAYU BINTI ROHALIM

SCHOOL OF CIVIL ENGINEERINGUNIVERSITI SAINS MALAYSIA

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By

NURFATIHAH IDAYU BINTI ROHALIM

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Name of Student: Nurfatihah Idayu Binti Rohalim

I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

Signature:

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Date:

Approved by:

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(Signature of Supervisor)

Name of Supervisor: Prof. Hj. Ismail Abustan

Date :

Approved by:

____

(Signature of Examiner)

Name of Examiner: Assoc. Prof Dr Rozi Abdullah

Date :

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ABSTRAK

Empangan dibina sebagai tempat simpanan air untuk mengimbangi kenaikan dan penurunan aliran di kawasan tadahan dan untuk menjana elektrik. Walau bagaimanapun, jumlah pelepasan yang tidak terkawal dikeluarkan dari pintu alur limpah empangan akan memberi kesan kepada kawasan hilir. Pada 23 Oktober 2013, banjir yang berlaku di hilir Sungai Bertam mungkin disebabkan oleh jumlah pelepasan yang tinggi yang dikeluarkan dari empangan Sultan Abu Bakar (SAB). Kesan daripada banjir itu, tiga orang telah disahkan maut dan hampir 100 rumah dimusnahkan atau tenggelam manakala lebih daripada 100 kenderaan rosak teruk. Oleh itu, kajian mengenai pelbagai pelepasan yang dikeluarkan di sepanjang sungai telah dijalankan. Objektif utama kajian ini adalah untuk menentukan pelepasan maksimum tanpa sebarang banjir di Kampung Baru Lembah Bertam untuk 175 m^3/s untuk 100 tahun ARI. Tahap air banjir dapat membantu menilai kesan di kawasan itu akibat pelepasan empangan SAB. Ujian model fizikal dilakukan untuk menganalisis pelbagai pelepasan yang dikeluarkan. Selepas ujian model fizikal, perisian Surfer digunakan untuk menggambarkan keadaan dan kawasan risiko banjir. Jumlah pelepasan pelepasan yang digunakan dalam eksperimen adalah 8, 16, 24, 32, 40, 48 dan 56 l/s. Pelepasan air adalah berdasarkan cadangan pembebasan empangan oleh Tenaga Nasional Berhad (TNB). Akibatnya, kedalaman maksimum, halaju maksimum, dan ilustrasi dihasilkan. Temuan ini dapat meramalkan kawasan bahaya banjir. Kajian ini juga akan membantu pihak berkuasa mengendalikan jumlah tahap pelepasan maksimum yang dibenarkan dari empangan untuk mengelakkan banjir berlaku di kawasan hilir Sungai Bertam.

ABSTRACT

Dams are constructed as water storage to compensate for fluctuations in catchment area and to generate electricity. However, uncontrollable amount of discharges released from the gated spillways of the dam would impact the downstream area. On October 23 2013, floods occurred in downstream of Sungai Bertam probably due to a huge volume of discharges were released from Sultan Abu Bakar (SAB) dam. Impacts of that flood, three people were confirmed dead and nearly 100 houses destroyed or under water while over 100 vehicles badly damaged. Thus, study on various discharges released along the river was conducted. The main objective in this study is to determine the maximum discharge without any flood inundation at Kampung Baru Lembah Bertam for 175 m^3/s for 100 year ARI. The flood water level can help evaluate effect of in that area due to SAB dam release. The physical model testing was done to analyse various discharges released. After the physical model testing, Surfer software was used to illustrate the condition and risk area of flooding. The amount of discharges release used in the experiment was 8, 16, 24, 32, 40, 48 and 56 l/s. The water discharges were based on recommendation dam release by Tenaga Nasional Berhad (TNB). As a result, maximum depth, maximum velocity, and inundation illustration were produced. This finding will be able to predict risk area of flooding. This study will also help authorities to control amount of maximum discharge level allowed from the dam as to prevent flood occur in downstream area of Sungai Bertam.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

SAB	**S**ultan **A**bu **B**akar
TNB	**T**enaga **N**asional **B**erhad

NOMENCLATURES

Q	Flow discharge
A	Cross-sectional averaged velocity
g	Acceleration of gravity
h	Cross-sectional averaged water depth
f	Darcy-Weisbach friction factor
C	Chezy coefficient
n	Manning coefficient

CHAPTER 1

INTRODUCTION

1.1 Background

Hydraulic physical modeling is used to evaluate important elements of a complex free surface fluid flow. Hydraulic modeling can refer to numeric modeling in which a simulation is performed on a computer or mathematical model, and physical modeling where the physical flow geometry is scaled in such a way that it can be modelled in the laboratory. Hydraulic physical model is always three-dimensional because it has vertical and horizontal scale. Physical hydraulic modeling must be used when unsteady vortex dynamics is a concern, such as in spillway, pump or turbine intakes. The hydraulic model testing is usually required in many major water-related projects such as river, dam, water supply and others. A testing on physical model is to ensure the suitability and the safety of the design. It is also to minimize the cost of operation and maintenance in the future.

Sungai Bertam is one of the main rivers in Cameron Highlands, Pahang as shown in Figure 1.1. The downstream river has changed because of it brought huge volumes of water to the Ringlet reservoir, together with solid wastes, debris and siltation for the Sultan Abu Bakar (SAB) dam cause the river to be shallow from what was described as massive land clearing and farming activities. This study deals with the impacts of uncontrolled water released from SAB dam to downstream hydraulic capacity of Sungai Bertam especially during monsoon season. In order to study the detail downstream impact due to dam release, a hydraulic physical model of Sungai Bertam for 0.5km length (up to Kampung Baru Lembah Bertam) had been constructed and detail study had been investigated. The Ringlet Reservoir was designed for a gross storage of 6.3 million m^3, of which 4.7 million m^3 is the active or live storage and 1.6 million m^3 is the inactive or dead storage. The dead storage was designed for a useful lifespan of approximately 80 years which translates to 20,000 m^3/year of sediment inflow.

Figure 1.1: Ringlet reservoir (Source: The Sun daily, 2013)

The SAB dam lower catchment covers the Sungai Bertam down to Ringlet reservoir which was formed by the construction of the Sultan Abu Bakar dam. Overflow from the reservoir is controlled by one tilting with 5.1m (20ft) wide and three radial gates with each 13.2m (40ft) wide, which together will pass a maximum total of about 963 m^3/s at level 1058.98 m (3474 ft). According to Waagner-Graz, the tilting gate is bottom hinged at 1068.02 m (3504.0 ft) above datum and is arranged to commence opening when the Ringlet reservoir level is at 1070.76 m (3513 ft). It is fully open when the reservoir has risen to 1071.07 m (3514 ft) at which level it will pass approximately 65.13 m^3/s. The radial gates will commence opening at a water level of 1071.09 m (3514.08 ft) and are fully open when the reservoir has risen to

1071.37 m (3515 ft) at which level each will pass about 300.16 m^3/s. All four gates are float operated. When the radial gates are in shut position, the highest parts of the radial gates are at a level of 1071.62 m (3515.8 ft). All three radial gates and a tilting gate are capable of being manually opened by the operation of valves, provided that the reservoir level is at or above the level of the gate control intake (Waagner-Graz, 1962).

The SAB dam is also equipped with 1.8 m (70.9 in) internal diameter concrete lined bottom outlet pipe with its upstream centre line at level 1037.59 m (3404.5 ft) and controlled by means of a hollow jet regulator valve at its downstream end and the butterfly type guard valve near its upstream. The discharge capacity of the bottom outlet with the regulator valve fully open is approximately 31.15 m^3/s or 1100 ft^3/s when the reservoir is at 1061.92 (3484 ft) (Waagner-Graz, 1962).

However, due to there is not available stage-discharge rating curve for SAB dam that had been served since 1960's, the water release operation is a main problem to TNB Bhd. The amount of water released can cause a flash flooding in the downstream of the Ringlet reservoir as what were happen in the 2014 flood disaster in Cameron Highland.

1.2 Problem Statement

Dams are built across rivers and streams as massive barriers to confine and utilize the flow of water. One of reasons why SAB dams were build is to generate hydroelectricity to serve TNB main electricity grid. Further, SAB dams also controls flooding, in which it was constructed to either stop or slow the amount of water in Sungai Bertam. In addition even though it is insignificant, SAB dam also helps in irrigation of local farms.

However, the uncontrolled amount of discharge released from a dam can give the negative impacts to the downstream areas. For example, the uncontrolled amount of discharge released from SAB Dam caused Sungai Bertam suddenly rise and breach its banks and lead to the incident of mud flood in Bertam valley in 2014, the worst and others small events for almost one or twice annually. This 2014 tragedy caused three dead and one missing as muddy flood washed away nearly 100 cars and destroyed some 80 homes sometime after midnight as shown in Figure 1.2.

Thus, this study is to investigate the impact on various discharges released from SAB Bakar dam to the downstream river by constructing physical model of Sungai Bertam. A Hydraulic physical model is used to simulate a prototype condition by constructing a smaller scale replica of the Sungai Bertam with scale ratio of 1:25 (model:prototype). The hydraulic model can be operated over the full range of expected flow rates, in which enables to observe flow conditions, flow patterns, velocities and inundation areas. The water level inundation results will then be calibrated with a scaled model.

Figure 1.2: Aftermath of the floods at Bertam valley (Source: The Star Online, 2013)

1.3 Objectives

The objectives of this study are as follows:

i. To design and construct a physical model of Sungai Bertam for 0.5 km downstream of SAB dam.
ii. To determine flow characteristic in the hydraulic physical model such as water depth and velocities due to specific water releases
iii. To determine the maximum discharge without any flood inundation at Kampung Baru Lembah Bertam for 175 m^3/s for 100 years ARI.

1.4 Scope of Work

The scope of work performed in this study is firstly, the design of cross section of Sungai Bertam, Cameron Highlands is produced using AutoCAD. The design is a scaled hydraulic physical model of Sungai Bertam according to the actual dimension for the scaled of 1:25 (model:prototype). Further, in order to minimize existing flow interferences, the use of Global Mapper software is to remove all the surrounding buildings and plantation to enable to get the image of Sungai Bertam only.

The calibration tests of Nixon Streamflo Velocity Meter and Ultrasonic Flow Meter equipment are conducted in Hydraulic Laboratory, School of Civil Engineering, and Universiti Sains Malaysia before using them in the actual hydraulic physical model simulations.

The hydraulic physical model was constructed with the help of a local contractor, PPKA technical staffs and students (PhD, MSc and UG) of Professor Ismail

Lab. The initial testings water released were determined by an automatic discharge of Ultrasonic Flow Meter and the ranges of discharges were 8, 16, 24, 32, 40, 48 and 56 l/s by utilizing a pumping circulation system with multiple globe valves as flow controllers. These value of water released are equal to prototype flows of 25, 50, 75, 100, 125, 150, and 175 m^3/s respectively. In the result observation processes, flows and their depth at each location along the Sungai Bertam was measured using a miniature Nixon Streamflo Velocity Meter and the maximum flood inundation was observed manually.

Finally, the utilisation of Surfer software to illustrate Sungai Bertam characteristics based on SAB dam released and the flood inundation for Sungai Bertam was determined.

1.5 Justification of Research

A hydraulic physical model is used to visualize information about the context that the model represents. It is very common for physical models of large objects to be scaled down and smaller objects scaled up for ease of visualization. Hydraulic model study allows us to simulate prototype condition by designing and constructing a smaller scale model of hydraulic structures. The model can be operated over the full range of expected flow rates, in which enables us to observe flow conditions, flow patterns, velocities and inundation affected areas. Besides that, by using hydraulic physical model, future potential impacts can be highlighted or simulated beforehand.

1.6 Limitation of the Study

Fluid motion is controlled by three basic principles: conservation of mass, energy and momentum. Derivatives of these principles are commonly known as the continuity, energy and momentum equations.

The limitation of this study is scale effects arise due to force ratios which are not identical between a model and its real-world prototype and result in deviations between the up-scaled model and prototype observations. To minimize scale effects, the model should be constructed as large as possible that fits within time, costs and available facility space constraints.

Besides that, the limitation of this study is the time spent and the cost of building alternatives, the particle similarity, the partial control of boundaries and the difficulty in measuring parameters in some model areas.

1.7 Dissertation Outline

This thesis consists of five chapters

Chapter 1: Introduction to the background of physical modeling and overall scope of study, the problem statement, and objectives of the study, scope of work, justification of the study and limitation of the study are all stated in this chapter.

Chapter 2: This chapter includes the review of the previous studies that have been done on the physical model. The positive and negative impacts of using physical model is also been includes in this chapter by using the previous studies.

Chapter 3: The overall methodology has been applied in this study is discussed and stated clearly in this chapter. The brief description of testing that has been carried in order to determine the optimum discharge result in no inundation for Sungai Bertam has been stated. The procedure of testing is also being discussed in this chapter.

Chapter 4: The accuracy of testing equipments is ensured by presenting the calibration result of Nixon Streamflo Velocity Meter and Ultrasonic Flow Meter. The results of discharge of Sungai Bertam for various discharges from Sultan Abu Bakar dam are also presented.

Chapter 5: Conclusion is drawn based on the results obtained from the experimental work and the recommendations related to the work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes on the literature review of the hydraulic physical modeling, spillway and discharge characteristics. For a hydraulic physical modeling, concept, scale effect, similarities such as geometric similarity, kinematic similarity and dynamic similarity are emphasised in this chapter.

2.2 Physical Hydraulic Modeling

Hydraulic physical modelling is a hands-on and practical approach to develop effective engineering design and conducting applied hydraulic research. As discussed in the Chapter 1, a hydraulic physical modeling allows us to simulate a prototype condition by constructing a smaller scale replica of a hydraulic structure. This model can be operated over the full range of expected flow rates, in which enables us to observe flow conditions, flow pattern, velocities, and inundation areas. Figure 2.1 shows the examples of hydraulic physical model a selected river.

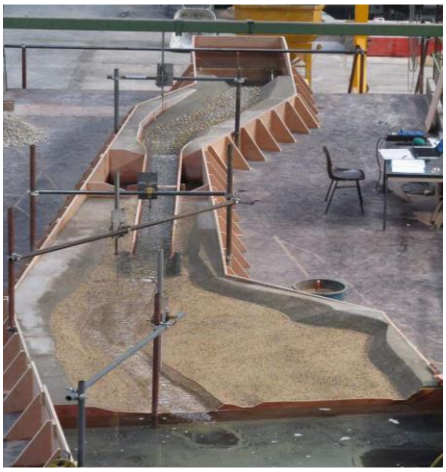

Figure 2.1: Example of physical model of river (Source: Artelia Group)

Hydraulic physical model is often utilized to predict prototype performance in designing and rehabilitating hydraulic structures especially for a very complex hydraulic flow characteristics. The physical modeling studies ultimately could increase the safety of hydraulic structure such as dam, barrage, channel and others by identifying and by eliminating potential problem, thus reducing construction and maintenance costs. They are particularly useful where hydraulic structure and systems are of unusual design or configuration and hydraulic parameters cannot be adequately evaluated by state-of-the-art analytically or computational methods. (Burke, 2008)

Furthermore, physical model will incorporate the appropriate governing equations without the simplifying assumptions that are often necessary in analytical or numerical models. Physical hydraulic models may also be used to establish conservative and reasonable design or operating bases of sites, structure or system involving thermal and erosion problems (Burke, 2008).

2.3 Concept of Physical Hydraulic Modeling

In a physical model, the flow conditions are said to be similar to those in the prototype if the model displays similarity of form (geometric similarity), similarity of motion (kinematic similarity) and similarity of force (dynamic similarity) (Heller, 2011). In general, the ratio of quantities in the model needs to be similar in many aspects of the prototype. A model is representation of a physical system that may be used to predict the behaviour of the system in some desired respect. It is also known as scale model or simply model. A prototype is a physical system for which the prediction was to be made. A hydraulic model scale is determined through a composite review of reproducibility, ability of flow supply to test laboratory, test model manufacturing space and measuring convenience (Kang et al., 2014). There are two types of model scale which is undistorted model have same geometric scale, but distorted model has different scale for horizontal and vertical dimension.

Table 2.1: Difference between undistorted and distorted model (Resources: Wang and Jiang, 2013)

Undistorted Scale/Normal model	Distorted Model
Same geometric scale in both horizontal and vertical reactions	Different scale for horizontal and vertical dimensions

There are some advantages of undistorted scale (normal scale) rather than distorted scale. Table 2.2 and Table 2.3 show the advantages of those two cases. The main advantage of undistorted model is the behaviour and working details of hydraulic structure can be easily predicted from it model.

Generally, undistorted model has geometrically similarity to the prototype in length, breadth, height and height of water. The prediction of an undistorted model is comparatively easy and some of the result obtained from the models can be easily transferred to the prototype.

When a model using undistorted model (normal model) scale is applied, it not involved distortion in flow analysis around a structure (Wang and Jiang, 2013). As a result, accurate flow analysis is easily able to determine. It is necessary to secure maximum water depth considering precision of water level measurement for the model in the usage of undistorted model.

Table 2.2: Advantages and disadvantages of undistorted model (Source: Yalin, 1971)

Undistorted scale/Normal model	
Advantages	Disadvantages
• The behaviour and working details of hydraulic structure can be easily predicted from it model • Failure mode of prototype can be easily detected from laboratory of the model testing. • Most economical, accurate and safe design may be selected from result of model testing. • Performance of complex of hydraulic structure can be easily predicted by model testing which results in total design cost, safe and reliable design.	• There is an inherent danger in the use of models because any undetected error in the model or test procedure of the model will lead to inaccurate prediction of performance of the prototype.

From the Table 2.3, the main disadvantage of distorted model is the velocity and pressure distribution in the model is not the same as that in prototype. In distorted models, there are deviations not only in the geometric similitude but also the kinematic and the dynamic similitude (Yalin,1971). When distorted model scale is applied, it involved distortion in flow analysis around a structure. As a result, accurate flow analysis is disable (Wang and Jiang,2013). But, for successfully flow reproduction, undistorted model is used than distorted model.

In addition, in case a structure installed within a river is the key target of interest, an undistorted model (normal model) must be used in order to reproduce three-dimensional (X,Y and Z directions) flow behaviour, such as the impact of turbulence around the structure (Kang et al.,2014)

Table 2.3: Advantages and disadvantages of distorted model (Source: Yalin, 1971)

Distorted model	
Advantages	Disadvantages
• Due to substantial height obtained by distortion, measurement in the vertical direction is fairly accurate • Hydraulic similitude is achieved due to distortion • Turbulent flow in the model becomes possible • Cost of model can be reduced • Viscous effects absent in the prototype are eliminated in the model • Movement of sand and silt in the model can be simulated to that of the prototype • Reduce the size of the model, which save the space and facilitates that easy operation of the model	• Due to different scales in the different directions the velocity and pressure distribution in the model is not the same as that in prototype • Slopes, curve bends and cutting in earth are not truly represented in the models. • Waves are not simulated in the distorted model

2.4 Scale effect toward hydraulic model

Scale effect may be defined as the distortions introduced by effects viscosity and surface tension other than the dominant one such as gravity in free-surface flows. They take place when one or more dimensionless parameters like Reynolds Number, Froude Number and other differ between model and prototype. Scale effect is often small but they are not always negligible altogether. Considering an overflow above a weir, the fluid is subjected to some viscous resistance, the viscous effects are small and the discharge-head relationship can be deduced as for ideal-fluid flow.

In free-surface flows, the gravity effect in the experiment, a smaller prototype to model scale is needed to apply. So that it can minimize these effects and can overcome the problem happen at model and find a solution to overcome that problem. (Heller, 2011).

Froude similarity is normally considered in open-channel hydraulics, where friction effects are negligible (deep-water wave propagation) or highly turbulent phenomena, since the energy dissipation depends mainly on the turbulent shear stress terms which are statistically correctly scaled even though the turbulent fine structures and the average velocity distribution differ between the model and prototype flows. The gravitational acceleration is not scaled as well as the other numbers. To avoid scale effects the influence of the gravity force on fluid flow should be negligible in a Reynolds model.

Reynolds similarity is normally considered in air models, laminar boundary layer problems, intake structures, seepage flows, creeping around immersed bodies or head losses elements (for lower values of Re). The other force ratios (numbers) are not properly modelled. A serious disadvantage is the scale velocity which will lead, for the same fluid, to higher velocities rather than in prototype. For that the use of air models is more appropriate. Hydraulic Froude models should be run under the same hydraulic rough regime as in nature in order to have the same losses' level and not a faster decay as append sometimes with waves in a model. (Ercan, 2017)

It is not normal to build a model according to Weber similarity, so this can lead to some scale effects. Surface tension is negligible in most of hydraulic prototypes, but is important in scale models for air entrainment (wave breaking), small water depths, small wave heights and periods (capillary waves) or large fluid paths. Since many dimensions are smaller in the model this can lead to a dominant surface tension – larger relative air bubbles' sizes, faster air detrainment and smaller volume fractions of air. Phenomenon that includes air flow (that depends also on the atmospheric pressure) needs a relative large scale.

Cauchy number is related with Young's modulus, E, which in the case of water is not scaled, so its behaviour in impact phenomena, like wave-structure interaction, should be analysed with precaution. In fact a distensible structure (with Est) must be scaled without changing the Poisson number. In a Froude model, Est scales linearly with $1/\lambda$, so if same material as the prototype is used the model structure will be λ too stiff which lead to erroneous resistance obtained in the model. This is also the case of air-water mixtures, for instance during the interaction of waves with a vertical quay. To model fenders is another example, where sometimes its Est is modelled with a spring system that includes the non-linear behaviour.

The Euler number considers pressure forces as relevant especially for high pressures (pipes, cavitations of turbines, pumps or hydraulic structures). If the cavitations number is not correctly modelled in a Froude model, the cavitations phenomena will be not observed.

2.5 Similarity in Hydraulic Physical Model

A primary goal of any experiment is to provide the result as part of prototype and final build of any application result. To achieve that end, the concept of similitude is often used so that measurements made one system in the laboratory environment can be used to describe the behavior of other similar system in real world and outside of the laboratory. The laboratory built systems are often thought as model while the first build of the similar systems based on behaviour its model, beyond laboratory frame called prototype. Construction of a scale model, however, must be accompanied by an analysis to determine what conditions it is tested under. While the geometry may be simply scaled, other parameters, such as pressure, temperature or the velocity and type of fluid may need to be altered. Similitude is achieved when testing conditions are created such that the test results are applicable to the real design (Zohuri, 2015).

Two systems, described by the same physics, operating under different sets of conditions are said to be physically similar in respect of certain specified physical quantities, when the ratio of corresponding magnitudes of these quantities between the two systems is the same everywhere (Zohuri, 2015). In the field of mechanics and hydraulic models as in sand box model, there are three concepts of types of similarities, which constitute the complete similarity between problems of same kind. We recognize these three concepts as geometric similarity, kinematics similarity and third one is known as dynamic similarity. There are other types of similarity as well, all which must be satisfied in order to have a complete similarity totally to exist between the flow phenomena in the two systems of fluids for example.

The following criteria are required to achieve similitude and represents types of physical similarity according to Zohuri, 2015:

Geometric similarity - The model is the same shape as the application, usually scaled. In other words, if the specified physical quantities are geometrical dimensions, the similarity is called Geometric Similarity.

Kinematic similarity - Fluid flow of both the model and real application must undergo similar time rates of change motions (i.e. fluid streamlines are similar). In other words, if the quantities are related to motions, the similarity is called Kinematic Similarity.

Dynamic similarity - Ratios of all forces acting on corresponding fluid particles and boundary surfaces in the two systems are constant. In other words, if the quantities refer to forces, then the similarity is termed as Dynamic Similarity.

2.6 Physical Modelling and Numerical Modelling

Numerical models represent the real problem but with some simplifications. Thus, the modeller is forced to make a compromise between the details of the model and the prototype. Several advantages and disadvantages of physical model testing are usually reported.

An incorrectly designed model always provides wrong predictions, independently of the sophistication of the instrumentation and measuring methods. The cost of physical modelling is often more than that of numerical modelling, and less than that of major field experiments, but this depends on the exact nature of the problem being studied (ref). Physical modelling has gathered new perspectives due to the development of new sophisticated equipment, allowing the measurement of variables in complex flows, which was previously impossible. New experimental techniques, automated data acquisition and analysis systems, rapid processing and increased data storage capabilities also provide useful information for the validation of numerical models (Frostick et al.,2011).

Other advantages of physical models are the study of new phenomena, the lower level of simplification, to confirm through measurements theoretical results, to obtain measurements from complex phenomena inaccessible from theory, to test extreme conditions, to test a wide variety of environmental conditions and the immediate visual feedback. Despite all these advantages there are still some problems of physical modelling to solve such as the scale effects, the incomplete modelling, the laboratory effects and the costs of installation and maintenance.

To obtain theoretical solutions, simplifications of the physical environment (especially the boundaries) are needed as well as of the equations that govern the phenomena. As a result of that mathematical solutions may have lower quantitative value, and therefore could be more useful for qualitative or comparative analyses. The geometry can be reproduced with the desired detail but it is not enough to ensure a correct reproduction of the reality in the model as this can generate a behaviour sometimes different from the prototype. So calibration is needed. Physical modelling reproduces both linear and nonlinear aspects of the phenomena, avoiding the simplifications of the numerical modelling that simplifies not only the geometry but also fundamental equations.

Other advantages of physical modelling are intermediate and controllable cost, they represent reality at a certain scale, the involved variables and boundaries can be controlled, measurements are in general easy to perform and the comprehension of the processes is facilitated.

On the other hand, the disadvantages of physical modelling are the time spent and the cost of building alternatives, the particle similarity, the partial control of boundaries and the difficulty in measuring parameters in some model areas. The actual level of research needs common efforts between the various available tools, namely physical and numerical modelling in order to decrease the lack of knowledge in some areas. The problems to solve or which are not solved yet are so complex that only this integrated approach is feasible in order to obtain better accurate results not only for researchers but also for designers and practitioners.

There is still a need to design and construct new and more advanced laboratory facilities, develop new reliable measuring instruments and techniques, minimize laboratory effects, and understand the scale effects that arise from incomplete modelling.

Physical and numerical model input conditions can be controlled and systematically varied, whereas field studies have no such control. However, many problems in engineering are not amenable to mathematical analysis because of the nonlinear character of the governing equations of motion, lack of information on wave breaking, turbulence or bottom friction, or numerous connected water channels. In these cases it is often necessary to use physical models for predicting prototype behaviour or observing results not readily examined in nature. The growing use of numerical models in coastal engineering has not stopped the use of physical models and in some cases they made progress in conjunction with each other. Recent trends have included the concept of hybrid modelling where results from a physical model of complex region are used as input or boundary conditions for a comprehensive numerical model covering a wider region of interest. Alternatively, numerical model results may be used to provide input conditions at the boundaries of the physical model.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes on the methodology in physical modeling of Sungai Bertam. In addition, the physical model testing of the variable discharges are conducted in order to determine the optimum discharge required before the occurrence of flood inundation locally. The correct procedure and method while conducting test is essential to ensure the accuracy and precisent of the observed test result. The process of calibration of equipment used must follow the practical standard in the correct manner to ensure the quality of collected data. The calibration of Nixon Streamflo Velocity Meter and Ultrasonic Flow Meter is conducted in the Hydraulic Laboratory, PPKA before they are being utilized in the modeling test.

3.2 Hydraulic Physical Model Study at Universiti Sains Malaysia (USM)

The physical modeling test is conducted in Ruang Penyelidikan Bersepadu (RPS) in Universiti Sains Malaysia (USM), Pulau Pinang, Malaysia. The physical model was constructed in RPS according to an undistorted model that inhibits the same physical features of Sungai Bertam, Cameron Highland. All the construction hydraulic physical model works were done by a contractor with the helping hands technicians School of Civil Engineering and several students from Prof. Ismail Lab in order to ensure the hydraulic physical model functioning well and in good condition for the process of testing.

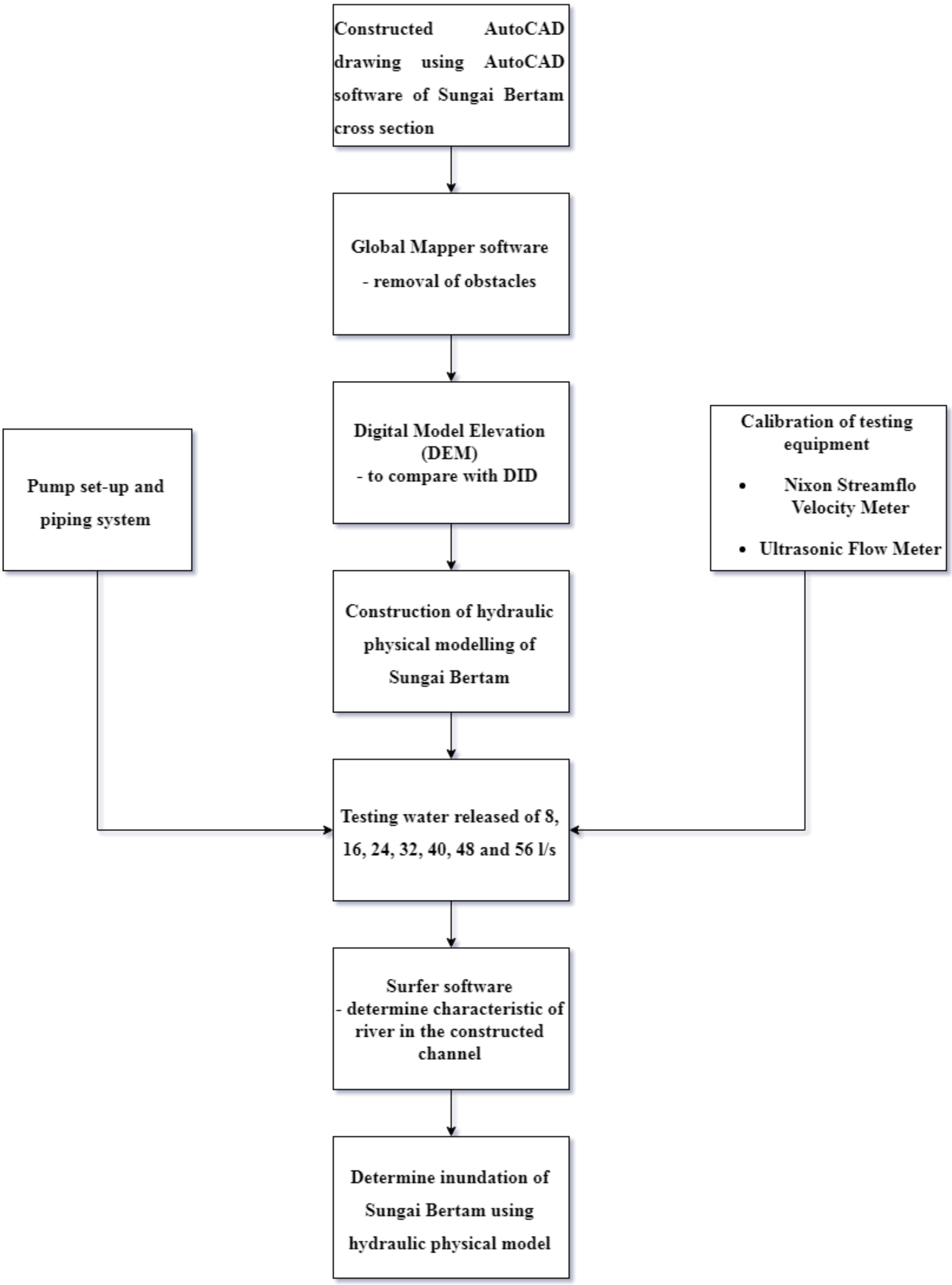

Figure 3.1: Flowchart of Methodology

3.3 Physical model of Sungai Bertam

A 1:25 ratio scale model to prototype is proposed for Sungai Bertam model to eliminate viscosity fluid effect and the end result will produce a good and reliable model. The availability of space in the laboratory and the pump capacities for the amount of discharge are also needed to be check before the construction of scale model can be proceed and the relationship between model and prototype was shown in Table 3.1. The dimension of the proposed model is 5.35m in wide and 20.5m in length and all the Sungai Bertam physical features such as contour is based the observation by drone on site. Finally, the main components of physical model include several pumps with the maximum capacity of 60 l/s at the inlet and outlet, rectangular box weir at the inlet and outlet, and channel for the flow of water along the model as shown in Figure 3.2.

Figure 3.2: A constructed of Hydraulic Physical Model of Sungai Bertam in RPS

Table 3.1: Relationship between model and prototype

Scale	1:25
Length (m)	1:25
Flow (m^3/s)	1:3125

Figure 3.3 shows the cross section of Sungai Bertam. This drawing was produced by using AutoCad 2015 Software (Version 20.0).

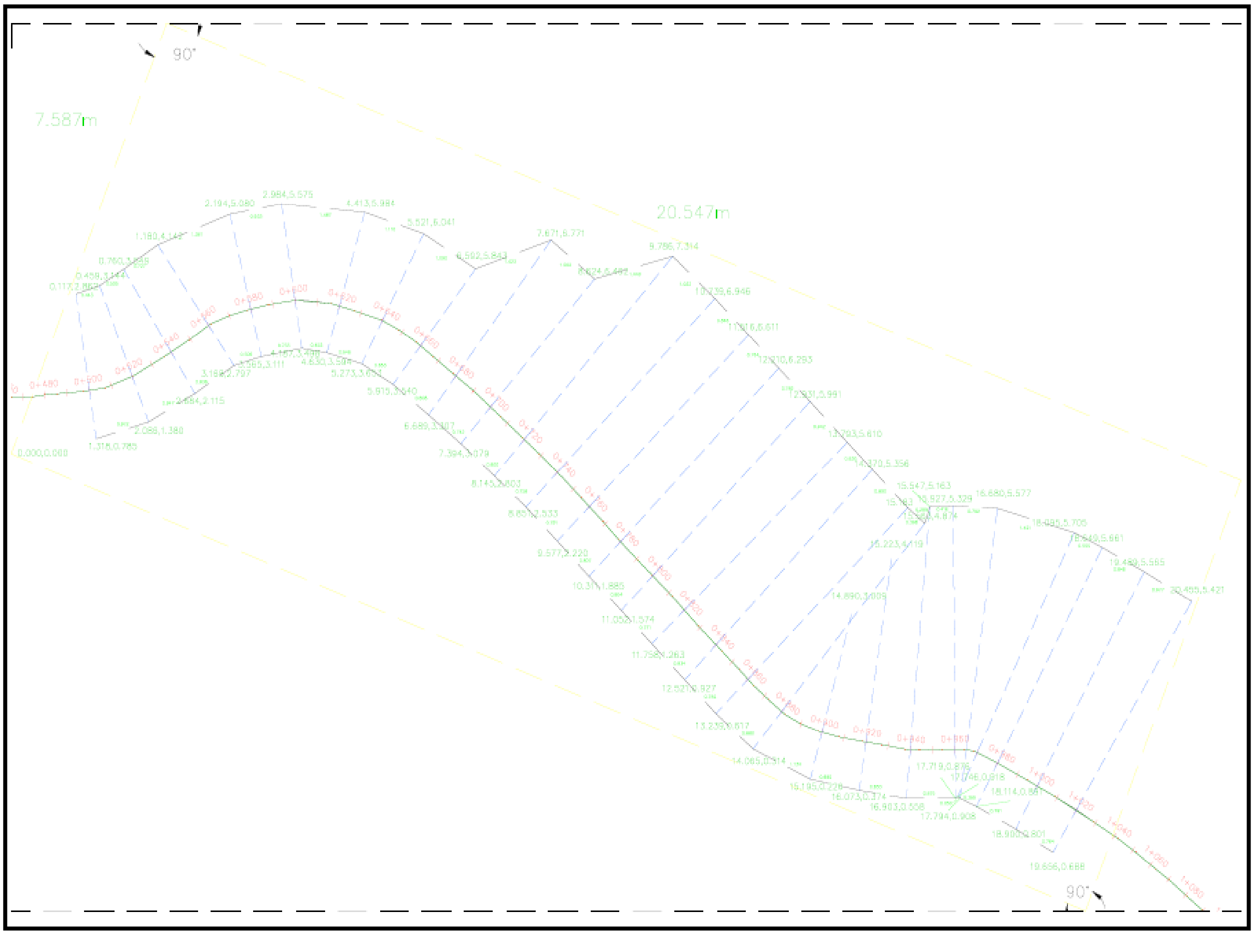

Figure 3.3: Diagram of the proposed physical model of Sungai Bertam (0.5km)

3.4 Water recirculation system

Water recirculation system was used for this physical model testing. Water reticulation system is the process of using the same water in a system. The water from the water pump sump which is located at the lowest part of the model and the water are transferred to the physical model by using the pumps and then return back from the rectangular box weir at the outlet to the sump also by using the pumps. Six pumps were provided to transfer water from the sump to the physical model while four pumps used