# A STUDY OF FLOW CHARACTERISTICS AT STILLING BASIN OF TAWAU DAM SPILLWAY, SABAH

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**SCHOOL OF CIVIL ENGINEERING**
**UNIVERSITI SAINS MALAYSIA**
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# A STUDY OF FLOW CHARACTERISTICS AT STILLING BASIN OF TAWAU DAM SPILLWAY, SABAH

**By**

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Title:

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

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Name of Examiner :Date :

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# ABSTRAK

Empangan mempunyai pelbagai fungsi, dan ia bukan sahaja dibina untuk penjanaan kuasa elektrik, malah ia jugak untuk mengatasi masalah banjir. Walau bagaimanapun, air yang mengalir hendaklah dikawal supaya ia boleh mengurangkan kesan di kawasan hilir. Objektif utama kajian ini adalah untuk mengkaji profil permukaan, halaju dan tekanan dan untuk menetukan keupayaan blok penampan yg dicadangkan in model Empangan Tawau, Sabah. Model fizikal empangan Tawau telah dibina di makmal dengan skala 1:30 dengan menggunakan perspek, supaya ciri-ciri aliran dapat dilihat. Peralatan yang digunakan semasa menjalankan kajian ini ialah ‘Nixon Streamflow Meter Velocity’ dan Ultrasonic Flow Meter’. ‘Nixon Streamflow Meter Velocity’ digunakan untuk mengukur kadar aliran air model. Untuk menentukan ketepatan peralatan, ujian penentukaran seharusnya dilakukan bagi mengelakkan mengelirukan data. Melalui pemerhatian yang intensif, ciri-ciri aliran di lembah limpahan dan lembangan pegun telah ditentukan. Beberapa graf dan halaju, tekanan dan kedalaman air di dalam limpahan dan juga dalam lembangan telah dilplot. Kajian mendapati dua kes iaitu 50 L/s bersamaan dengan 246.5 $m^3/s$ dan 100 L/s bersamaan dengan 493.0 $m^3/s$. Dari kajian ini, dapat disimpulkan ciri aliran bergantung pada jumlah pelepasan. Oleh itu, bagi reka bentuk blok penampan untuk lompatan hidraulik, aliran yang dijangkakan maksimum hendaklah ditentukan dan diperhatikannya ciri-ciri.

# ABSTRACT

The dam has a multi of functions, and it is not only built for power generation, but also a flood mitigation purposes. Flowing water should be controlled so that it can reduce the impact on the downstream area. The main objective of this study is to determine the velocity and to positioning of baffle blocks in stilling basin to reduce hydraulic jumps in Tawau Dam spillway model. The physical model of the Tawau Dam spillway was produced by scale 1:30 using perspex so that the characteristic of the flow could be visualized. The equipment used during this study are 'Nixon Streamflow Meter Velocity' and ‘Ultrasonic Flow Meter'. The 'Nixon Streamflow Meter Velocity' is used to measure the velocity of water at each point in the spillway and stilling basin while the 'Ultrasonic Flow Meter' is used to measure the flow rate of supply water to the model. To determine the accuracy of the equipment, the equipment had be ensure reliable set of calibration done data. Through an intensive observation, the flow characteristics in the spillway and stilling basin had been determined. Several graph had been plotted and velocity, pressure and water profile in the spillway as well as in the stilling basin. The study observed two cases of 50 L/s which is equalized to 246.5 $m^3/s$ and 100 L/s is 493.0 $m^3/s$. From this study, it can be concluded that the characteristic of flows are depend on the amount of discharges. Therefore, to design baffle blocks for hydraulics jumps, the maximum expected flow should be determined and observed it characteristics.

## TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# ABBREVIATION

| | |
|---|---|
| $P$ | Pressure |
| $V$ | Velocity |
| $G$ | Gravity |
| $z$ | Depth of water |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

A dam is a barrier that impounds water or underground streams. Reservoirs created by dam not only control floods but also provide water activities such as irrigation, human recreation, industrial use, aquaculture and navigability.

Tawau Dam Spillway is located at Jalan Gudang 4, Tawau, Sabah. Tawau residents will receive 209 million litres per day of raw water supply when Phase Three of the Tawau Water Supply Scheme comprising the construction of a multipurpose dam.

Tawau Dam Spillway it could be served on a flood-mitigating factor as well, to reduce flooding in the Tawau town-ship and nearby villages with the building of an additional structure that could hold 4.6 million litres of water per day. Tawau residents also facing a problem of water supply and clean water to residents. So that, the state government has heard the grouses of Tawau residents and the voice of their elected representatives on the need to build a dam that can consistently supply raw and clean water to the residents. The main proposed of Tawau Dam spillway are to get the clean water supply and flood mitigation.

## 1.2 Problem Statement

The problem faced by the residents Tawau is lack of water supply in the dry season. This problem can effected their daily life and their economy. In the Tawau, it should have the dam or reservoir where can store the water. When dam is design, the capacity of water supply should be refer to the population and it usage of the particular area. The discharge of the dam has to be controlled, so that it can prevent negative impact to downstream area. Such as flooding and local banks scouring. Then, Tawau area always faced with the heavy rain can cause the flood at that area. When the flood happen, it can clogged the drain.

## 1.3 Objectives

In this research, the objectives are:

1. To study the surface, velocity, and pressure profiling of Tawau spillway at maximum flow rate.
2. To determine the capability of proposed baffle blocks in Tawau spillway at maximum flow rate.

## 1.4 Scope of Work

The scope of works for the hydraulic model includes the data collection from the physical model of Tawau Spillway. The design scaled for this hydraulic physical model of Tawau Dam Spillway according to the actual dimension is 1:30 (model: prototype). The total discharge that should be tested is two where is 50.0 L/s (246.5 $m^3/s$) and 100.0 L/s (493 $m^3/s$).

In the results observation process, velocities at each discharge points were measured using a miniature Nixon Streamflo Velocity Meter. Furthermore, the height of hydraulic jump was also measured. Finally, the type of proposed baffle blocks is determined based on United States Bureau of Reclamation (USBR).

## 1.5 Justification of research

The hydraulic physical model testing in this study is essential to ensure the safe operational of the Tawau Dam Spillway discharge release especially during heavy downpour in the upstream of the catchment. Hydraulic physical model allows visualization observation in order to ensure the model replicates the prototype.

## 1.6 Limitation of the study

There are several limitation of this study. Firstly, the scale effect is the main limitation of this study. Scale effect not possible to stimulate to all relevant variables in correct relationship between the model and the prototype (Heller, 2011). A smaller prototype-to-model scale ratio $L_r$ should be considered to minimize the scale effects. Secondly human error could be happened because the model can create artificial situation that do not always represents in real-life situations. Human error also plays a key role in the validity of the project during data collections. Furthermore, the total of pump used is six. So that the value of discharge to be tested need to be control among six pump. To get the velocity, it is depends on the value of discharge in pump sump. In order to increase the value of velocity, the value of discharge need to be increased. The pumps were used to control the discharge of the model. Lastly, from the value of velocity that observed, velocity profile can be developed and the height of hydraulic jump can be measured. Based on these observation, the type of baffle block based on the type I, II, III and IV USBR (USBR, 1984).

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter discusses the study of hydraulic physical modelling, spillway and baffle block. For the hydraulic physical modelling, the main concept, scale effect, model similarities such as geometric similarity, kinetic similarity and dynamic similarity are represented on this chapter. Furthermore, the energy dissipator such as hydraulic jump and baffle block are also presented. The equipment used in the experiment such as ultrasonic flow meter and a Nixon Velocity meter are also being describe in this chapter.

## 2.2 Physical Hydraulic Model Spillway

A hydraulic physical model is built by reducing or enlarging the size of the prototype system in correct proportion to the actual size. Physical hydraulic models are commonly used during design stages to optimize a structure and to ensure a safe operation of the structure(Chanson, 2007). The physical model is being widely used in hydraulic structure especially in spillway design.

Physical hydraulic models are often used to predict prototype performance in designing and rehabilitating hydraulic structures (Mohamed. Yossef, 2015). The physical modelling studies ultimately increase the safety of the hydraulic structure by identifying and eliminating potential problems, thus reducing construction and maintenance costs (DP Loucks, 2017). They are particularly useful where hydraulics structure and system are of unusual design or configuration and hydraulic parameters cannot be adequately evaluated state-of-the-art analytical or computational method (Tung, 1996). Furthermore, physical model will incorporate the appropriate governing equations without the simplifying assumptions that are often necessary in analytical or numerical models (Kumar, 2015). Physical hydraulic models may also be used to establish conservative and reasonable design or operating bases for sites, structure or system involving thermal and erosions problems (Burke, 2008). The advantages and disadvantages of physical model are presented in Table 1.

Table 1: Advantages and disadvantages of physical model (Briggs, 2014).

| Advantages | Disadvantages |
|---|---|
| • The physical model integrates the appropriate equations governing the process without simplifying assumptions that has to be made for analytical or numerical models.<br>• Physical model are used to determine empirical coefficient for analytical and numerical model<br>• Physical model assist in evaluating the effect of simplifying assumptions on numerical model predictions.<br>• Prototype construction may be very risky or uneconomical without a model to verify assumptions and performance.<br>• Physical model can be used in conjunction with numerical models as a hybrid model to take advantage of their individual benefits. | • Scale effects occur in models that are smaller than prototype if it is not possible to stimulate all relevant variables in correct relationship to each other.<br>• Laboratory effects can influence the process of being simulated to the extent that suitable approximation of the prototype is not possible.<br>• Forcing functions or boundaries in the prototype may not be stimulated in the model due to cost and practicality.<br>• Except in rare instances, physical models are undeniably more expensive to operate that numerical model. |

## 2.3 Basic principle of hydraulic physical model

In physical model, the flow condition are said to be similar to those in the prototype if the model displays similarity of form or geometric similarity, similarity of motion or kinematic similarity and similarity of forces or dynamic similarity (Chanson, 1999). Geometric similarity require similar in shape, i.e. all length dimensions in the model are λ times shorter than of its real-world prototype (Tabarestani, 2016). Kinematics similarity implies geometric similarity and in addition indicates a similarity of motion between model and prototype particles. It requires constant ratios of time, velocity, acceleration and discharge in the model and its prototype at all times (Heller, 2011). While dynamic similarity requires in addition to geometric and kinematic similarities that all force ratios in the two systems are identical(Heller, 2011).

## 2.4 Scale effect of a spillway model

Scale effect might defined as the distortions introduced by effects (e.g. viscosity, surface tension) other than the dominant parameter (e.g. gravity in free-surface flows) (Wang, 2013). They take place when one or more dimensionless parameters differ between model and prototype (White, 2001). Scale effect are often small but they are not always negligible altogether. Considering an overflow above a weir, the fluid were subjected to some viscous resistance along the invert section (Jobson and Froehlich, 1988). Then, the flow above the crest not significantly affected by resistance, the viscous effects are small and the discharge upstream head relationship and it can be deduced as an ideal fluid flow (Afshar et al, 2014). In free- surface flows, the gravity effect is dominant. If the same fluid (e.g. water) is used in both model and prototype, it is impossible to keep both the Froude and Reynolds number in model and full scale(Chanson, 1999).

It is elementary to show that a Froude similitude implies $(Re)_r = {L_r}^{3/2}$, and the Reynolds number becomes much smaller in the model than in the prototype (if $L_r$ <1). Different fluids may be used to have the same Reynolds and Froude numbers in model and prototype but this expedient is often neither practical nor economical(Chanson, 1999).

The main causes of scale effects are model roughness and model approach conditions associated with turbulent boundary layer development. Besides that, surface tension effects and associated aeration and vortex-formation problems and cavitation phenomena. Some of these scale effects can be overcome, or at least minimized, by using model scale giving sufficiently high model Reynold numbers which is reduced on the model for the same in prototype and Weber numbers(Novak at el., 2007).

## 2.5 Spillway

In general, a dams is equipped with spillway in order to avoid overtopping (Suprapto, 2013). The purpose of the spillway is to pass flood of water, and in particular the design flood, safely downstream when the reservoir is overflowing (Ren *et al.*, 2017). It has two principal components where are the controlling spillweir and the spillway channel. The purpose of the spillway is being to conduct flood flows safely downstream of the dam (Kharagpur, 2008). It may incorporate with a stilling basin or other energy-dissipating devices in order to reduce flow momentum downstream (Novak at el., 2007).

The spillway is among the most important structures of a dam project. It provides the dam with the ability to release excess or flood water in a controlled or uncontrolled manner to ensure the safety of the project. It is of paramount importance for the spillway facilities to be designed with sufficient capacity to avoid overtopping of the dam, especially when an earthfill or rockfill type of dam is selected for the project(USBR, 2014). In cases where safety of the inhabitants downstream is a key consideration during development of the project, the spillway should designed to accommodate the probable maximum flood (Sidek *et al.*, 2013). Many types of spillways can considered with respect to cost, topographic conditions, dam height, foundation geology and hydrology (Coleman at el, 2004).

Hydraulic aspects of spillway design extend to the design of the three spillway components which is control structure, discharge structure and terminal structure (U S Army Corps Of Engineers and Engineers, 1992). The control structure regulates outflows from the reservoir. Design problems relate to determining the shape of the section and computing discharge through the section. The flow released through the control structure is conveyed to the streambed below the dam is a discharge channel  (Tullis, Amanian et al, 1995). An estimate of the loss energy through the channel section is important in designing the terminal structure. Terminal structure are energy-dissipating devices that are provided of return the flow to the river without serious scour or erosion at the toe of the dam. these comprise a hydraulic jump basin, a roller bucket, a sill block apron, or a basin with impact baffles and walls (Joolaeian and Nohani, 2015).

### 2.5.1 Spillway classification

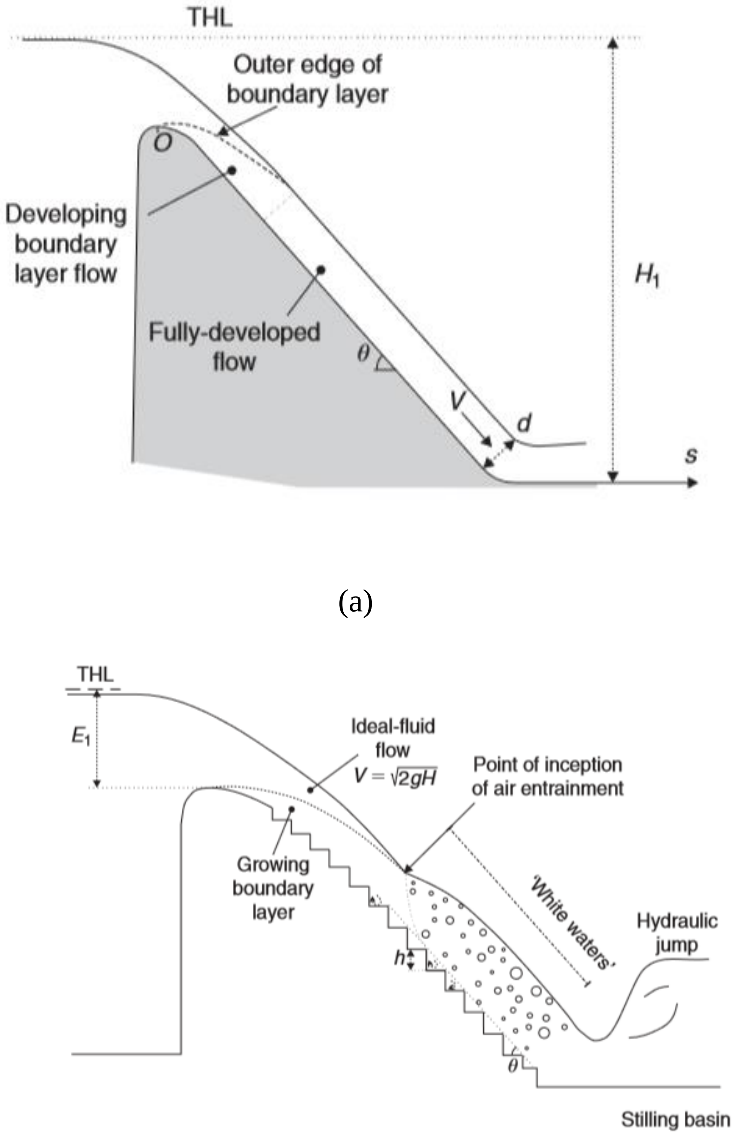
Spillway has been widely categorized into two types; service spillway and emergency spillway (Tullis, Amanian et al, 1995). The service spillway used during flood event when the reservoir level exceeds the crest level of the spillway. While emergency spillway is rarely used. The emergency spillway were operated during an extraordinary flood event, where the actual flood discharge exceeds the design capacity of the service spillway (U.S. Bureau of Reclamation, 2014). There are several type of spillway include free overfall, stepped, labyrinth, siphon and chute spillways.

An overfall spillway can be gated or ungated and provide for floe over an arch or arch-buttress dam, where the flow free-falls some distance before entering a plunge-pool energy dissipator in the tailrace(Coleman, at el. 2004). Stepped spillway have been used for a very long time. The design increase the rate of energy dissipation on the chute and decrease the size of the downstream energy dissipation system(Chanson, 1999).

Next, the labyrinth spillway is particularly well-suited for rehabilitation of existing spillways and for providing a large-capacity spillway in a site with restricted width. This is due to the significant increase in crest length for a given width. The free-overflow labyrinth spillway can be designed to allow reservoir storage capacity equal to that provided when using a gated spillway, but without increasing the maximum reservoir elevation (Houston, 1983). The labyrinth spillway hydraulic characteristic are extremely sensitive to approach flow conditions(U S Army Corps Of Engineers and Engineers, 1992).

Standard siphon spillway is used when a large discharge capacity is required in an extremely narrow head range without the use of operating gates (Kharagpur, 2008). It is ideal for emergency overflows in remote locations. To minimize losses, the upper leg transition should well proportioned to provide gradually contracting area, and the inlet area should be two or three times area of the throat(Coleman at el. 2004).

Chute spillway is usually used in conjunction with an earth-or rock-filled dam. However, concrete gravity dams also employ chute spillways (Novak at el., 2007). The chute spillway is generally located through the abutment adjacent to the dam and it could be located in a saddle away from the dam structure. Then, chute spillway are normally designed to minimize excavation (Padulano *et al.*, 2017). The primary concerns for the design of the chute spillway are to provide an invert slope that will ensure supercritical flow throughout the chute for all discharges, and provide a design of piers, abutments and sidewall transitions and bends that to minimize wave disturbances(U S Army Corps Of Engineers and Engineers, 1992). Once the water flows past the crest, the fluid is accelerated by gravity along the chute. At the upstream end of the chute, a turbulent boundary layer is generated by bottom friction and develops in the flow direction. When the outer edge of the boundary layer reaches the free surface, the flow becomes fully developed(Chanson, 1999).



(a)

(b)

Figure 2.1: Sketch of a steep chute (a) smooth chute and (b) stepped chute (Chanson and Carvalho, 2015)

## 2.6 Stilling basin

Stilling basin is a concrete structure that contains and promotes turbulent kinetic energy dissipation to decrease the high velocity flow erosive power (May, 1987). Thus, it protects the stream-bed by dissipating energy and preventing damage/scouring around the structure (Chanson and Carvalho, 2015). The stilling basin employs the hydraulic jump for energy dissipation and is the most effective method of dissipating energy in flow over spillway (Peterka, 1984). The two basic parameters to be determined for design of stilling basin are the apron elevation and length. Effective energy dissipation can be attained with a stilling basin having either a horizontal or sloping apron(U S Army Corps Of Engineers and Engineers, 1992).

### 2.6.1 Type of stilling basin

Each stilling basin has different appurtenant and dimension. The common energy dissipators are USBR Type II, USBR Type III and USBR Type IV stilling basin in order to complete the spillway structure (Peterka, 1984).

For USBR Type II stilling basin is design include chute blocks and dentate end sill, thus reducing by 30% the required length compared to a classical hydraulic jump (Peterka, 1984) as shown in Figure 2.3. The flow is lifted up by chute blocks and dissipate energy through eddy wave that perform well at Froude number of 4 to 14 . However, the height, width and spacing between each of the chute blocks should be equal to the depth of the incoming flow (Kharagpur, 2008). The height of dentate sill should be equal to 0.2 times the depth of the incoming flow depth. Length of the basin is dependent on Froude number and incoming flow depth (Padulano *et al.*, 2017). This type of stilling basin is often considered too traditional due to high cost of structure maintenance relative to low discharges at steady velocities.

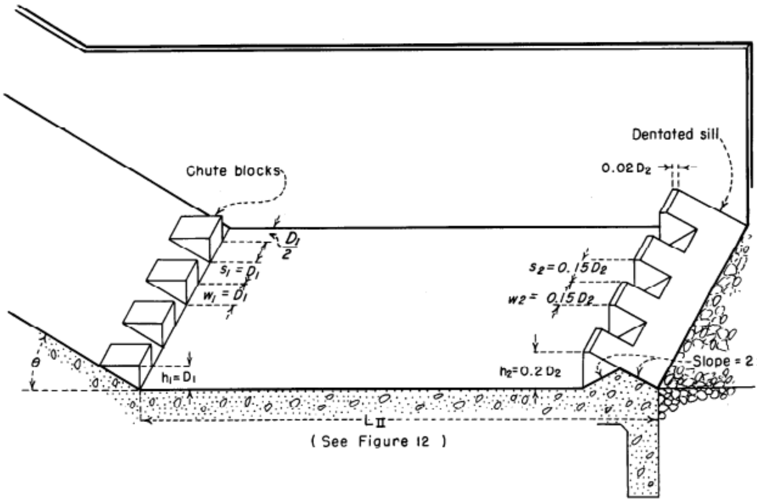


Figure 2.1: Stilling basin Type II (Peterka, 1984).

A stilling basin Type III is for a short stilling basin on canal structures, small outlet works and small spillway. includes chute blocks and end sill as shown in Figure 2.4 (U.S. Bureau of Reclamation, 2014). Additional of baffle piers where place at the downstream. This configuration creates a step hydraulic jump with minimal wave action on the downstream area. Baffle block as a impact wall device which improve the dissipation of flow energy at the stilling basin. This type of stilling basin work well with Froude number of 4.5 to 17 (Peterka, 1984). With the inclusion of baffles, the inflow velocities are restricted to avoid cavitation damage to the concrete surface and reduce the impact force to the blocks (May, 1987). The downstream water level should be at least 0.832 × $d_2$ to guarantee the formation of a hydraulic jump inside the basin. The basin sidewalls must be vertical, rather than trapezoidal because to ensure the proper performance of the hydraulic jump dissipator (Chanson and Carvalho, 2015). A minimum size of basin was designed for a smaller structure with the velocity at the entrance of the basin is mild or low

(15m/s – 18m/s) and the discharge per foot of width is less than 5.6 cubic meter per sec (Peterka, 1984).

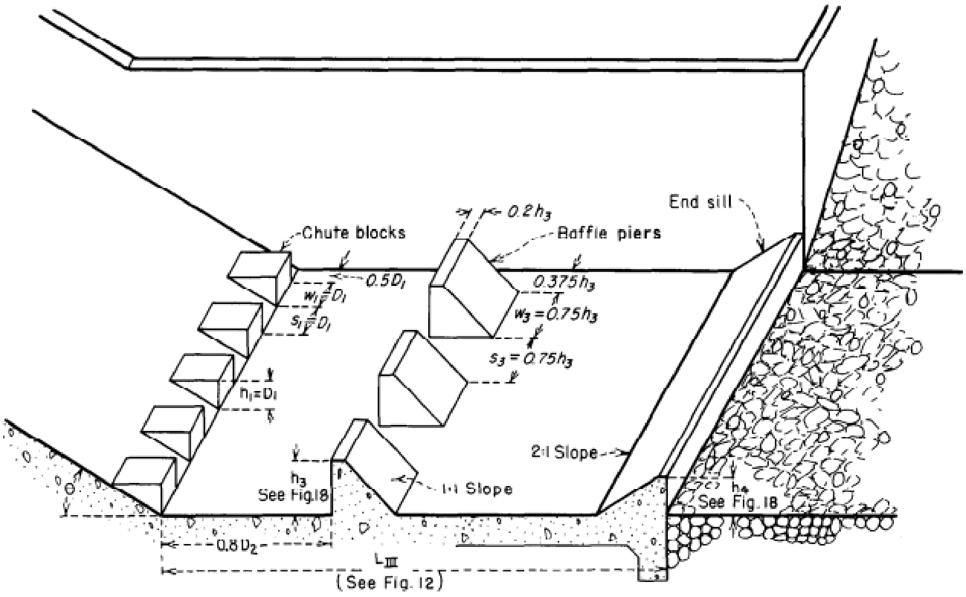


Figure 2.2: Stilling basin Type III(Peterka, 1984).

For stilling basin Type IV as shown in Figure 2.5, it is utilizes chute blocks and optional end sill to dissipate energy that some goes to the stilling basin Type II (U S Army Corps Of Engineers and Engineers, 1992). It is use for the cases with low Froude number. This type of stilling basin function well with the Froude number of 2.5 to 4. Since the flow of the hydraulic jump may not fully develop which could result in downstream waves (Heller, 2011).

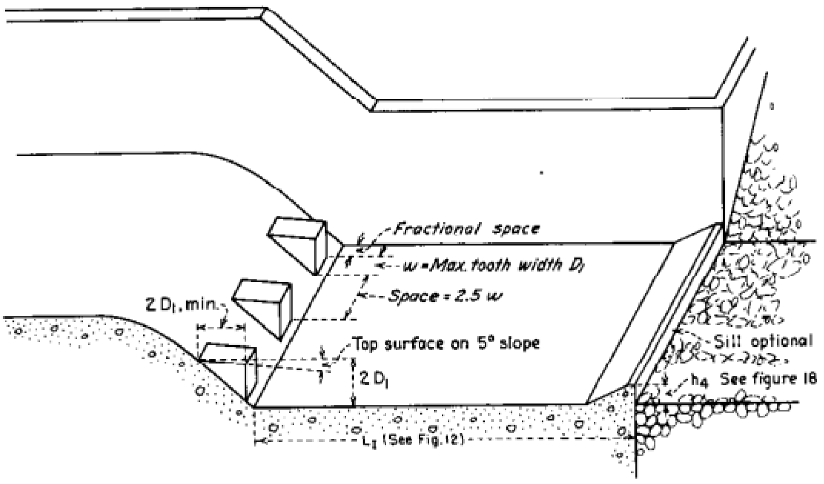


Figure 2.3: Stilling basin Type IV(Peterka, 1984).

There is most effective way to shorten stilling basin is to modify the jump by the addition of appurtenances in the basin. One restriction imposed on these appurtenances, however, is that they must self-cleaning or non-clogging. This restriction thus limits the appurtenances to baffle piers or sills which can be incorporated on the stilling basin apron (Peterka, 1984).

Several experiments were conducted using various type and arrangement of baffle piers and sills of their performance in order to get the best solutions for every different situation (Maatooq and Taleb, 2018). USBR (2014) has carried out experiments and some arrangement tested are shown in Figure 2.6. The blocks were positioned in both single and double rows, the second row staggered with respect to the first. Arrangement “a” in Figure 2.6 consisted of a solid curved sill which was tried in several positions on the apron. This sill required an excessive tail water depth to be effective. The solid sill was then replaced with baffle piers.

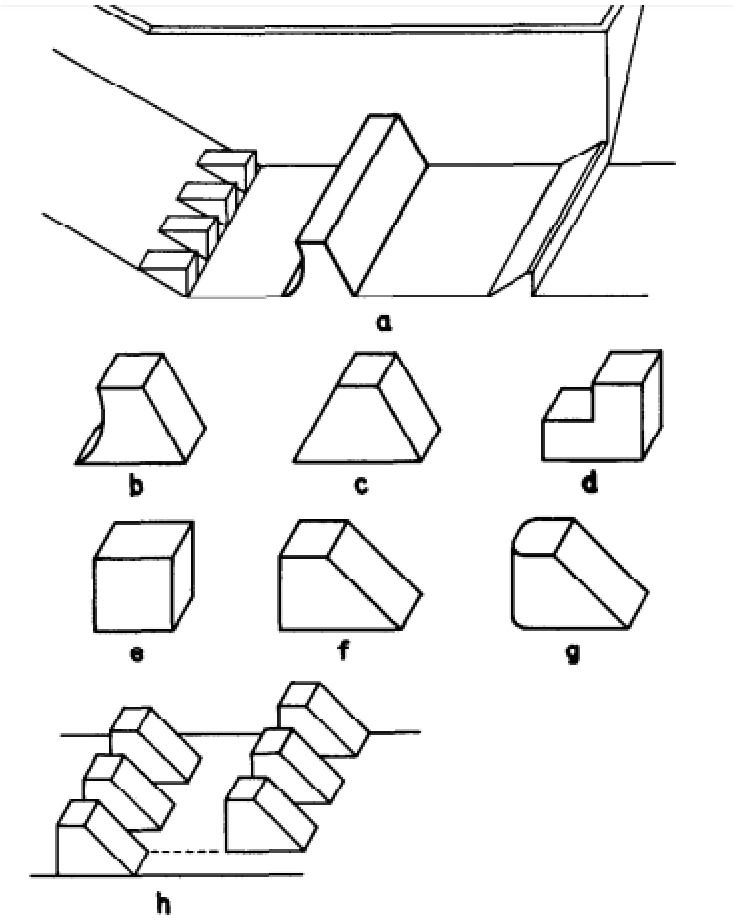


Figure 2.4: All shapes of the buffer blocks(Peterka, 1984).

For certain height, widths, and spacing, block ‘b’ performed well, resulting in a water surface similar to ‘a’. Block ‘c’ was ineffective for any height. The high-velocity jet passed over the block at about a 45° angle with little interference and the water surface downstream was very turbulent with waves (Peterka, 1984) .

Stepped block ‘d’ both for single and double rows was much the same as ‘c’. the cube ‘e’ was effective when the best height, width, spacing and position on the apron were found. The front of the jump was almost vertical and the water surface downstream was quite flat and smooth. Block ‘f’ performed identically with the cubical block ‘e’. the important feature as to shape appeared to be the vertical upstream face. The foregoing block and others not mentioned here were tested in single and double rows. Block ‘g’ was the same block ‘f’ with corner (Peterka, 1984).

It was found that rounding the corner greatly reduced the effectiveness of the blocks. In fact, a double row of blocks which had rounded corner did not perform as well as a single row of blocks ‘b’, ‘c’ or ‘f’. even slight rounding of the corner tended to streamline the block and reduce its effectiveness as an impact device. Block ‘f’ usually preferable from a construction standpoint, it was used throughout the remaining tests to determine a general design with respect to height, width, spacing and position on the apron (Peterka, 1984).

In addition to experimenting with the baffle piers, variations in the size and shape pf the chute blocks and the end sills were also tested. It was found that the chute blocks should be kept small, no longer than $D_1$ if possible, to prevent the chute block from directing the flow over the baffle piers. The end sill had little or no effect on the jump proper when the baffle piers are places as recommended. There is no need for a dentated end sill and almost any type of solid end sill will suffice (Peterka, 1984).

The main purpose of the end sill in Basin III is to direct the remaining bottom currents upward and away from the river bed. The chute blocks aid in stabilizing the jump and the solid type end sill is for scour control (Peterka, 1984). In addition stilling basin Type III has a large factor of safety against jump sweep out and operates equally well for all value of the Froude number above 40 (Peterka, 1984).

Then, basin Type III should not be used where baffle piers will exposed to velocities above the 15m/s to 18m/s range without the full realization that cavitation and resulting damage may occur. For velocities above 15m/s, basin Type II is suggested be used or hydraulic model studies should be made.

The recommended position, height and spacing of the baffle piers on the apron should be adhered to carefully, as these dimensions are important. For example, if the block are set appreciably upstream from the position shown they will produce a cascade with resulting wave action. If the baffles are set farther downstream than shown, a longer basin is required. If the baffle are too high they can produce a cascade. If it is too low, jump sweep out or a rough water surface can occur (Peterka, 1984).

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter provides information on method and procedures required in order to achieves the objective of this study. This chapter describes the methodology of the testing on the hydraulic physical modelling of Tawau Dam, Sabah. From this study, the observed data from the different of velocities with using the different discharge were observed. To ensure the accuracy of the data, the calibration of the equipment has been conducted first. All procedure of equipment has followed the specific instruction from the manual to ensure the quality of data collection.

## 3.2 Study location of Tawau Dam physical model

The testing of physical model was conducted in the Integrated Research Space of Universiti Sains Malaysia (USM), Engineering Campus, Pulau Pinang, Malaysia. The model was fabricated based on the drawing by China CITIC Wijaya Construction Sdn. Bhd, Kota Kinabalu. The School of Civil Engineering has been required to constructed and tested the hydraulic physical scaled model of Tawau Dam. Several improvements of the model were done by technicians from School of Civil Engineering to ensure the physical model functioning well and in a good condition for testing hydraulic proposes.

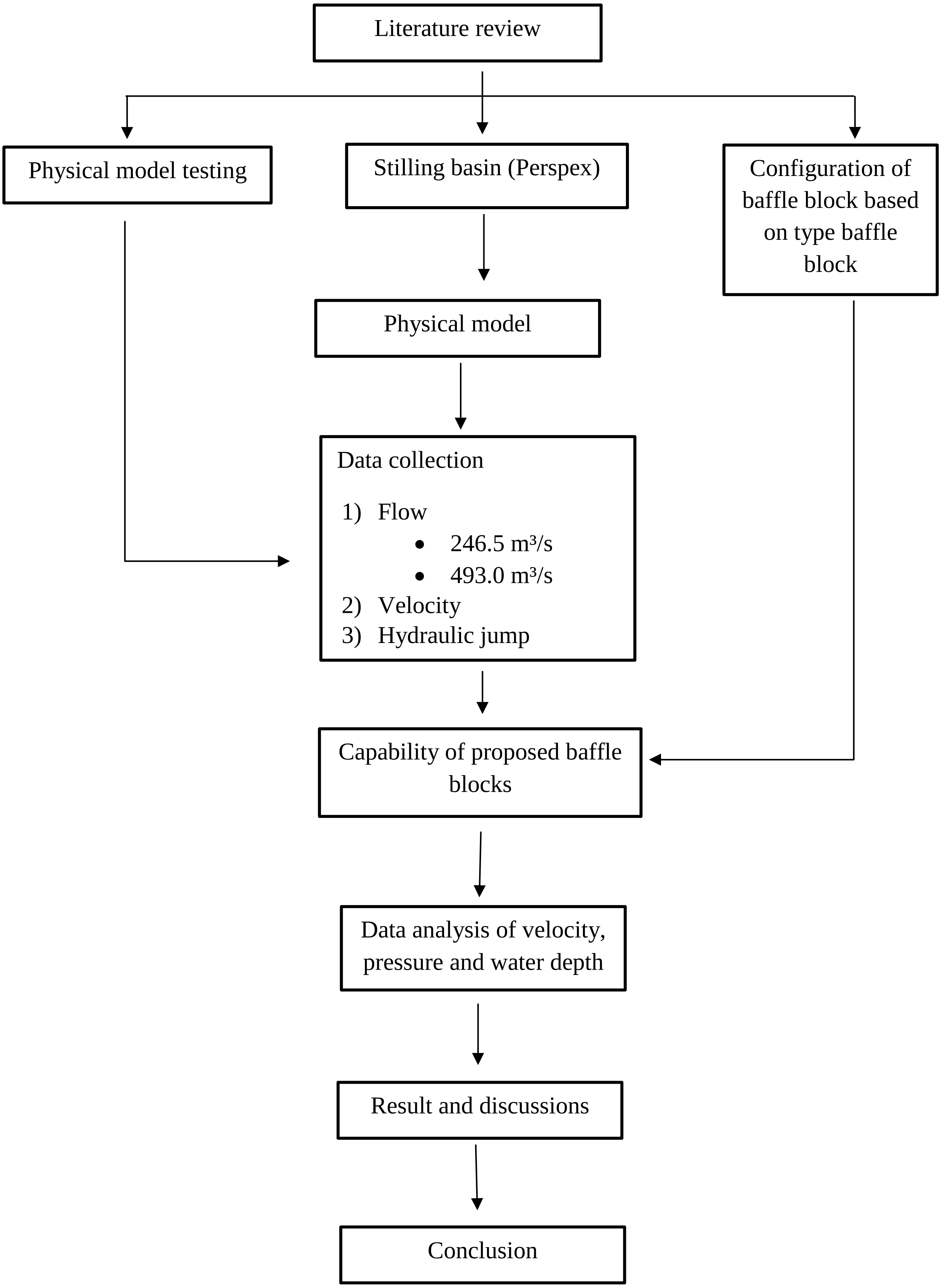


Figure 3.1: Flow chart of the overall study

## 3.3 Physical model of Tawau Dam

The Tawau Dam was constructed and tested in a scale 1:30 of a hydraulic physical model in a open area of Ruang Penyelidikan Bersepadu (RPS) Laboratory. Figure 2 presents the final version of the constructed physical model with its reservoir, spillway, weir and others.

Figure 3.2: Physical model of Tawau Dam

The overall proposed physical hydraulic was 10.45m long, 3.508m wide and 2.88m height. Table 2 shows the detailed dimension of model/prototype relationship of the physical model.

Table 2: Relationship between model and prototype (Phase Three of the Tawau Water Supply Scheme)

| | |
|---|---|
| Length | 1:30 |
| Velocity | 1:5.48 |
| Flow | 1:4930 |

Figure 3 shows the 3D dimension of hydraulic physical model for Tawau Dam. Figure 4 show the dimension of chute block, baffle piers and end sill at stilling basin.

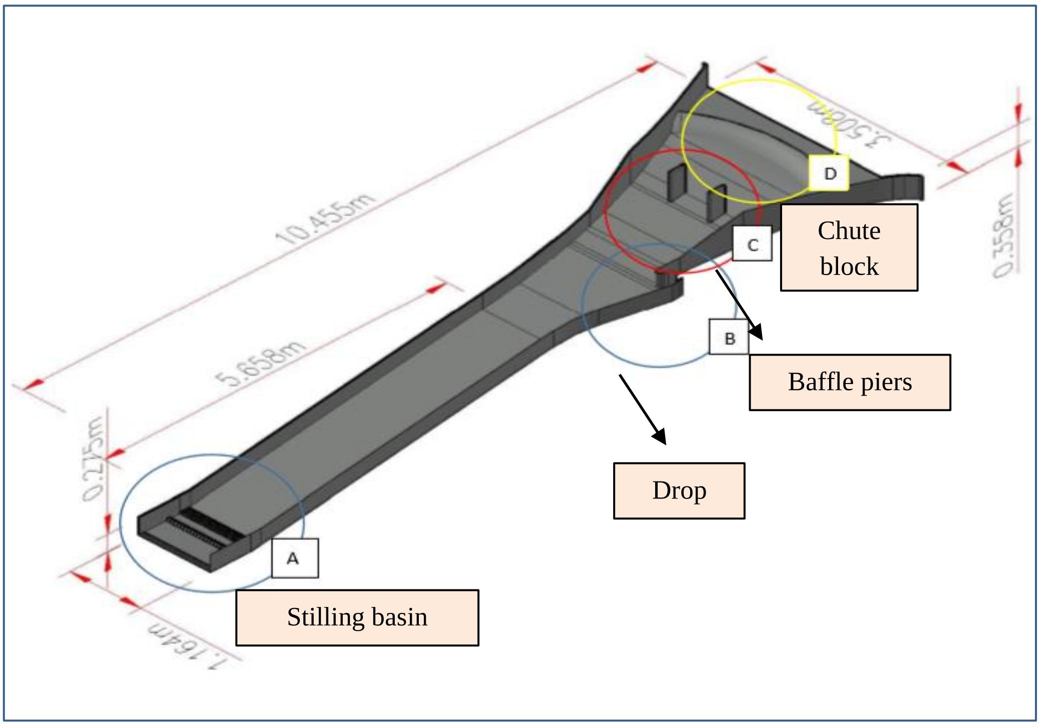


Figure 3.3: Overall dimension physical model of Tawau Dam.

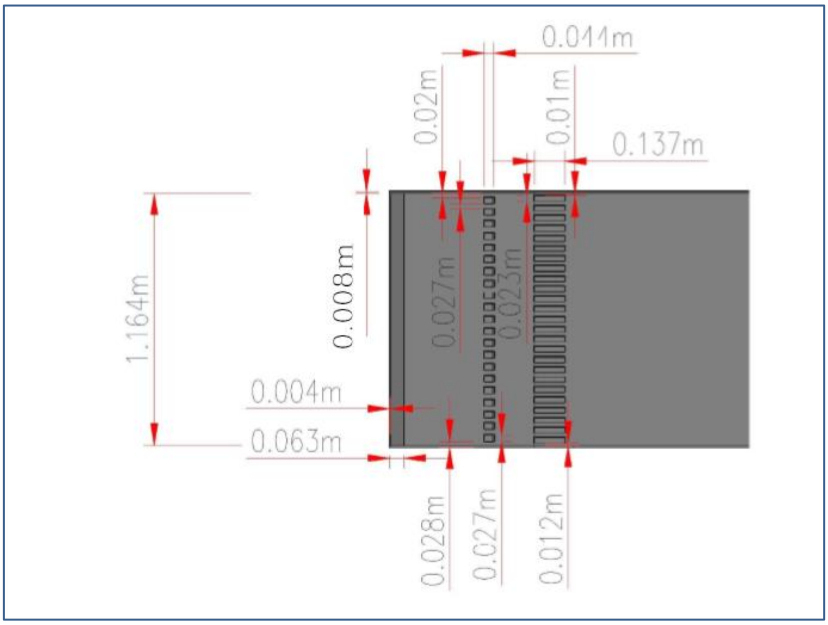


Figure 3.4: The detail dimension of baffle blocks in stilling basin.

## 3.4 Equipment Calibration

### 3.4.1 Nixon Streamflo Velocity Meter

The Streamflo instrument is to measure the flow velocity of water and other conductive fluids. This Nixon Streamflo Velocity Meter has been designed for measuring low velocities of conducting fluids, usually water in open channels. The system is highly sensitive responding to velocities as low 5.0 cm/s up to 150 cm/s. The probe is comprised of an acoustic sensor with a high precision instrument that can be relied upon to give accurate reading ± 2% of true velocity. The probes are an assembly of measuring head which consists of five bladed rotor mounted on a hard stainless steel spindle. It is connected to an electronic measuring unit via a co-axial cable. It is also equipped with a calibration chart which refers frequency to linear velocity. Figure 6 is shown a calibration chart.

Figure 3.5: Nixon Streamflo Velocity Meter