ASSESSMENT OF SEDIMENTATION PROCESS AT KENYIR DAM RIVER USING HYDRAULIC PHYSICAL MODEL

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ABSTRAK

Empangan merupakan peranti yang mempunyai kepelbagaian fungsi, tidak sahaja untuk mengatasi masalah banjir dan aktiviti air, malahan juga untuk menjana elektrik daripada operasi turbin. Walaubagaimanapun, aliran air keluar dari operasi turbin memberi impak kepada kawasan hilir. Penyelidikan ini menyatakan kajian terhadap ciri-ciri aliran operasi turbin di Empangan Kenyir dan untuk menentukan kebarangkalian pemendapan di hilir semasa turbin beroperasi. Model fizikal Empangan Kenyir dibina dengan skala 1:50 adalah replikasi dari tapak sebenar dengan kegunaan batu granit untuk menghasilkan keputusan tepat dengan keadaan sebenar. Hasil dari pemerhatian yang dijalankan, ciri-ciri aliran dan kebarangkalian untuk pemendapan di kawasan hilir semasa turbin beroperasi dapat ditentukan. Hubungan antara profil halaju, kontur tanah dan aliran air dapat menentukan lokasi pemendapan. Penyelidikan ini menjalankan dua kajian kes, iaitu operasi turbin dengan kadar aliran 5 l/s, 10 l/s dan 15 l/s dan gabungannya bersama operasi alur limpah dengan kadar aliran 100 l/s. Ciri-ciri aliran bergantung kepada jumlah pelepasan air. Oleh itu, pemendapan di kawasan hilir dapat dianggarkan. Dalam kajian ini, pemendapan berlaku apabila halaju air berkurang ke dalam lingkungan halaju pengenapan lalu angkutan zarah sedimen dianggap terenap di kawasan itu. Halaju untuk sedimen terenap ialah 0 hingga 4 cm/s setelah ditukar ke halaju model. Kajian ini menunujukkan pemendapan adalah berdasarkan corak kontur tanah dan aliran air dari empangan.

ABSTRACT

The dam is a multi-function device, not only provides flood mitigation and water activities but also generates electricity through turbine operation. However, the flowing water discharge from turbine operation can have an impact on the downstream area. This research presents the study of flow characteristics of turbine operation at Kenyir Dam and to determine the possibility of sedimentation at the downstream during the operation of the turbine. This physical model of Kenyir Dam built by the scale of 1:50 is the replication of the real site with the using of granite to produce the exact result to the real condition. Through intensive observation, the flow characteristics and the possibility of sedimentation at downstream area during turbine operation are determined. The relationship between velocity profile, the ground contour and the flow pattern has determined the location of sedimentation. This research conducts with two cases study of the operation of the turbine with 5 l/s, 10 l/s and 15 l/s and its combine operation of spillway with 100 l/s. The flow characteristic depends on the amount of water discharge. Therefore, the sedimentation in the downstream area can be expected. In this study, the sedimentation happens when the velocity of the water is slowing down into the range of settling velocity, thus the transportation of the sediment particle is considered to be deposit in that area. The velocity for the deposition of sediment is 0 to 4 cm/s after ratioed to the model velocity. This study shows the sedimentation is based on ground contour pattern and the water discharge from the dam.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Dam is a barrier that stops and controls the water flow to create a reservoir and lakes to benefits human beings. The reservoir created can supply water to the people for human activities such as agricultural, irrigation, industrial, commercial, and domestic. In another way, the water discharge from the dam's outlet can be a good opportunity to generate electricity from hydropower station. Besides, dam operation and reservoirs play an important role in reducing the flood inundation area and flood damage to buildings, assets, and agriculture (Shrestha & Kawasaki, 2020).

Kenyir Dam is the main device in utilizing the water flow from Kenyir lake. It was mainly built for hydroelectric power and flood control purposes (Suratman et al., 2017). Kenyir lake is one of the biggest man-made lakes in Southeast Asia. This lake is a boundary between three states, Terengganu, Kelantan and Pahang. It connects the main Terengganu River and its tributary of Kenyir River in the Hulu Terengganu District. The total water surface area of the lake is approximately 38,000 ha, with its surrounding is about 260,000 ha. The catchment area is by damming Terengganu River to build Sultan Mahmud Hydro-electric Power Plant in 1986 (Azmi & Geok, 2016).

The outflow of the dam consists of two main structures, which are spillway and turbine generator at the bottom outlet and mix at the downstream. The dam has a maximum height above the foundation of 150 m, crest length of 800 m, and earth core rock fill type dam. The volume of fill can reach 15.20 million cubic meters. The outlet structure for the upper part is a free-flow type of spillway to avoid overtopping of flow.

The bottom outlet comprises four turbines by the power house of 100MW each (Hossain et al., 2018). The 50 m wide spillway has a capacity of 7000 cubic meters per second while the power house controls the four penstocks to the turbine generators of 100MW each, four air-cooled generators of 120 MVA each, and four transformers of 120 MVA each.

Hydropower plants use water turbines to turn potential energy into mechanical energy, which is then used to produce electricity. The turbine generator is renewable energy that is purposely built to create hydroelectric power. It is a clean and cheap source of electricity (Iliadis & Gnansounou, 2016). The dam has a significant elevation stores lots of water behind the reservoir. The water intake will fall into the bottom penstock inside the dam caused by gravity. The moving water causes the shaft from the turbine to goes up into the generator. The generator produces the power and will be connected by a power line to carry electricity. Therefore, the continuity of flow of water is important to be created to be used for power generation.

The discharge of water through the bottom outlet of the dam through the turbine generator involves some parameters to determine flow characteristics such as velocity and flow pattern. From the flow characteristics, the possibility of sediment settling can be studied. Besides, the bed of the downstream may change due to the water discharge from the hydropower plant of the dam (Yao et al., 2018).

1.2 Problem Statement

Kenyir lake has a reservoir and dam that can retain 15.20 million cubic meters volume of water. The lack of efficiency of dam operation should be high in every aspect as this dam was built to give supply people in terms of electricity, water supply, and avoid flood disaster. Therefore, the best decision is essential to overtake the problems in the present or any possibility in the future.

Kenyir Dam has experienced water spilling from the main dam several times. This is due to the elevation of water level is exceeded 145 m which is the highest operating level that can achieve. During the whole duration of water spilling occurrence, the amount of energy generated was no much different. The discharge of each turbine at the station at full load and operating level of 145 m and above was estimated to be 400 $m^{3/s}$ as the rate of discharge for 1 MW is equivalent to 1 $m^{3/s}$. The power station is already at the maximum power output.

Other than that, the sedimentation at the river of Kenyir Dam could occur due to inconsistency of water discharge flow value from the dam. The low rate of water discharge could decrease the water velocity and influence the settlement of particles. At the maximum power output, the highest water discharge rate could be one of the conditions that need to be observed in which the flow rate abruptly decreases over time. The temporary matting of transporting sediments settles and forms bed materials. Due to the possibility of sediment settling, the flow characteristic of the water profile is determined in this research.

1.3 Objectives

In this research, the objectives are:

1. To study the flow characteristics at different turbine operations at Kenyir Dam.
2. To study the possibility of sedimentation along Kenyir Dam River at different turbine operations.

1.4 Scope of Work

The data from the physical model of Kenyir Dam is collected from this research. The design scale for the model is 1:50 from the actual dimension. From the physical model, the downstream of the right-hand side of the model is the main position where the research is studied. The power house at the left side of the spillway is where the electricity is generated from four units of turbine generators of 100 MW each. The water discharge from each turbine generator then flows along the downstream.

The flow characteristics such as water velocity and flow pattern from each of four turbine generators are determined in the results observation process. The velocity of water and flow pattern is measured using miniature Nixon Streamflow Velocity and dye tracer, respectively. Then, the data is taken along the downstream from the bottom outlet to determine the flow characteristics at any particular position. Along the flow of water at the downstream, velocity profile of the flow is generated using Surfer Software. The sedimentation possibility of the downstream in the model is determined and marked based on the velocity profile and flow pattern.

1.5 Justification of Research

The hydraulic physical model testing in this study is important to study the impact of the water release from the turbine. The model simulates the water discharge from four turbine generators at the bottom outlet of Kenyir Dam River. It allows the visualization observation in order to ensure the model replicates the prototype. From this model, the flow characteristics of water from each of four turbine generators and the possibility of sedimentation near downstream at the site can be determined.

1.6 Outline Dissertation

This thesis consists of five chapters for a better understanding of the study. The outline of each chapter was described below:

Chapter 1: This chapter gives an overview of this study, the background of the study, and the problem statement to understand why need to study this research. As well as the objective, the scope of the work and justification of work to have a better view of the purpose of this study.

Chapter 2: Literature Review discusses the previous researches that were conducted by other researchers according to the related topic for fundamental understanding in the study of physical modelling of Kenyir Dam.

Chapter 3: Methodology explains in further detailed the flow of experimental work that needs to be done to accomplish the objective of this project and to answer the problems defined.

Chapter 4: Result and Discussion highlight the outcome for the results and analysis of the velocity profile, flow pattern and sedimentation possibility with supporting evidence and reports from the experimental work and study in physical modelling of Kenyir Dam.

Chapter 5: Conclusion and Recommendation is the final chapter that will comprise all data and knowledge obtained, as well as findings and recommendations for future research in this area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review chapter discusses the basic knowledge regarding the study of physical hydraulic modelling, hydropower plant, spillway, and the effect of the downstream of the dam. The importance and the basic understanding of physical hydraulic modelling such as similitude theory of scaled model and scale factor in this research will be mentioned in this chapter. For hydropower plant, the hydropower plant dam, hydropower plant operation, classification of the hydropower plant, the classification of the turbine in the operation of hydropower plant is represented. This chapter discusses the spillway located next to the hydropower plant, which contributes to the outflow of water at the downstream. Furthermore, the effect of the discharge of water from the reservoir into the downstream in an aspect of the sedimentation, and the hydrology and ecosystem are described in this chapter.

2.2 Physical Hydraulic Modelling

Hydraulic structures are important in the control of hydropower development, drainages, irrigation, etc. Many problems related to flow structure designs are unique and very complex due to their site-specific geometric design. Therefore, lots of studies of physical hydraulic modelling, which allow Froude model results for the prediction of prototype behavior by the engineer (Hassan et al., 2020). A scaled representation of a hydraulic flow situation is referred to as a physical model (Torres et al., 2018). Physical hydraulic models are widely used during the design stage to refine a structure and ensure it is safe for operation. From hydraulic modelling, the suitable design can be selected through visualization of the flow. Physical hydraulic modelling is usually smaller in size compared to the prototype in the civil engineering field (Javaid & Khalil, 2020).

Generally, the physical model studies practically can improve the geometry of the structures and increase hydraulic performance or the same performance with a less cost solution (Hassan et al., 2020). This hydraulic physical modelling can solve engineering problems with aid of data collection, accurate data, and data analyses. The model contains accurate principle can be trusted as a reliable, although sophisticated measurement-methods only to increase the accuracy of wrong interpretation. The study using physical modelling also able to do something repeatedly of many complicated flow situations and can deal with expensive and complex hydraulic works. This physical modelling is designed with scale and still reliable for evaluation of the designs of hydraulic structures as the scale model enables the modification and remedial tasks to be urgently investigated (Firdaus Zulkefly et al., 2019).

The flow condition in the physical modelling can represent the real prototype if the model shows similarity in form of geometric similarity, kinematic similarity, and dynamic similarity (Erpicum et al., 2016). Geometric similarity itself cannot ensure the flow patterns in the model and prototype. Geometric similarity has similar shape and dimensions of length, area, and volume in the model are λ times smaller than the real-world prototype (Tabarestani, 2016). For kinematic similarity, in order to achieve the same kinematic of flow, the ratios of the velocities on all corresponding should be the same on both prototype and model. While dynamic similarity necessitates the same ratio of the quantum and direction of all forces acting on the corresponding points on both model and prototype. The similarity of the combination of forces by following Froude

Law, Reynold Law, March law, and others on the modelling also can ensure the same dynamic of flow (Javaid & Khalil, 2020).

Hydraulic performance data derived from hydraulic physical modelling in previous researches have been a foundation for most prototype spillway and weir designs model-prototype (Erpicum et al., 2016). In another study, hydraulic physical modelling is used to evaluate various river-engineering structures and the experiments carried out in the laboratory instead of the costly site programs. The main objectives of the river physical modelling are to replicate the real phenomenon of the river at the real site, to determine the performance of various hydraulic structures, and to investigate bed deformation under various hydraulic and sediment conditions. The Sediment-Transport similitude are described in term of sediment suspension, which is settling velocity similitude and the sediment transport similitude. The photos of physical modelling of Rio Grande river located at the border of Mexico and United State is shown in Figure 2.1 (Julien, 2012). Figure 2.2 shows the hydraulic physical model of Poonch River at Nandipur Research Institute to study the behavior of sediment. From this model, data for various scenarios of sediment flushing can be obtained in the cascade reservoir system. The River geometry, hydraulic structures, cross-sections, riverbanks, and other physical attributes of the river were prepared from a topographic survey (Javaid & Khalil, 2020).

From the study by the Researchers at the Bureau of Reclamation's Hydraulic Investigations and Laboratory Services Group, the movable bed physical scale models based on a relationship between dimensionless bed shear (Shields parameter) and dimensionless unit sediment transport (Taylor's function) has been designed. The method used is including the selection of the model of particles sizes are based on fall velocity. The parameter for model-prototype similitude has been identified based on the aspects of sediment transport including incipient motion and approximate transport energy (Gill & Pugh, 2009). There is also a study about Missouri river bend, which replicated into the model in another study as shown in Figure 2.3. The study of the sedimentation using physical hydraulic modelling can be applied in the determination of the interest location for deposition and a reasonable amount of scouring. The sediment modelling in this study referred to the modelling of bed load transport which is based on providing similarity between prototype and model for several parameters such as fall velocity, dimensionless shear, and channel roughness (Mefford Brent and Gill Tom, 2011).

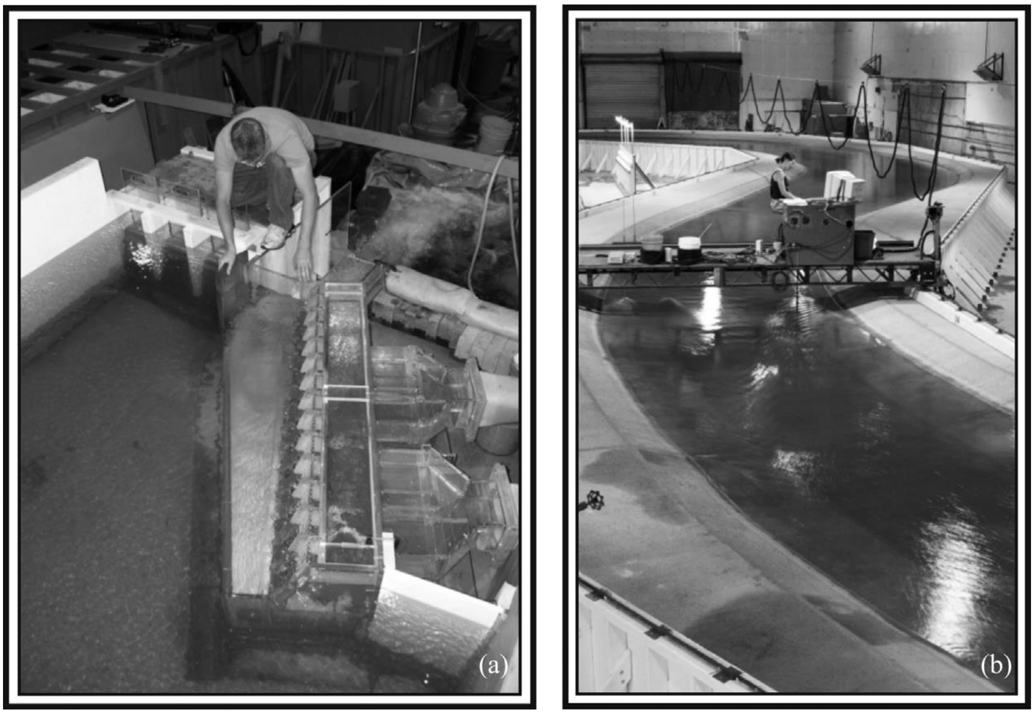


Figure 2.1: River physical model of Rio Grande: (a) Hydropower intake and (b) River bends

(Julien, 2012)

Figure 2.2: Physical model of Poonch River sedimentation project.

(Javaid & Khalil, 2020)

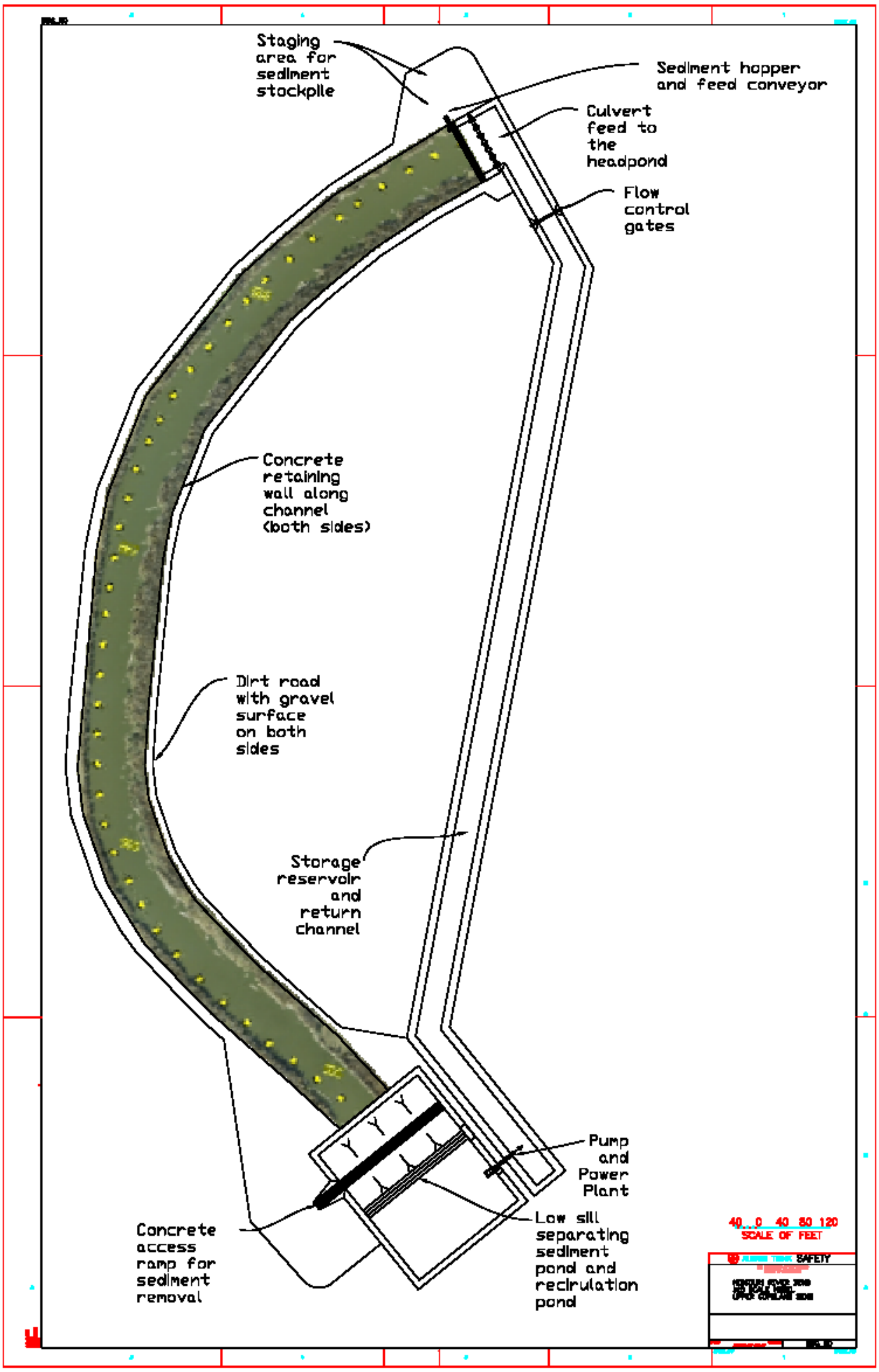


Figure 2.3: Plan view of 1:15 scale recirculation model of Missouri River.

(Mefford Brent and Gill Tom, 2011)

2.2.1 Similitude Theory of Scaled Model

If the similarity is to be obtained between model and prototype for flow conditions where inertial and gravitational forces are dominant, the Froude Number of the model and prototype must be the same. For viscous forces, it can be shown by dimensional analysis that the Reynolds Number in the model and prototype should be the same. The Froude and Reynolds Numbers are non-dimensional and are defined as follows (Hassan et al., 2020):-

Froude Number; $F = \frac{V}{(gL)^{0.5}}$ (Eq. 1)

Reynolds Number; $R = \frac{VL}{K}$ (Eq. 2)

where: V = velocity

g = gravitational constant

L = characteristic length

K = kinematics viscosity

Both the Reynolds Number and Froude Number for the model and prototype cannot be made equal. Fixing the same Froude Number for model and prototype results in the velocity being reduced in the model depth and a fixed gravity constant. Fixing the Reynolds Number will result in the increase of velocity in the model given geometric scale reduction of dimensions and constant kinematics viscosity. Hence, Froude and Reynolds Number equality could only be achieved simultaneously by using a fluid with suitable kinematics viscosity in the model to adjust the Reynolds Number to match the prototype Reynolds Number (Aydin et al., 2019).

In free surface work, the gravitational forces are the most important so the Froude Number must be made equal to that in the prototype in preference to the Reynolds Number (Firdaus Zulkefly et al., 2019). This ensures surface profiles; rotational flow and waves are correctly represented. For turbulent flow, the Reynolds Number is not particularly important as long as both model and prototype have values in the same flow regime. If the reduced Reynolds Number of a model approaches the transitional point of turbulent to laminar flow, then laminar flow could occur in the model but the turbulent or transitional flow would occur in the prototype. Clearly, this is not acceptable, and consequently, a minimum operable Reynolds Number has to be chosen. Based on the adoption of the Froude Number similarity and a model scale of (S), the following model to prototype relationships may be derived as clearly shown in Table 4.1 (Chanson, 2004).

Table 2.1: Relationship between model and prototype based on Froude Number similarity

Relationship	Model	vs	Prototype (actual)
Length	F_m	=	F_p
	$V_m^2/(g.L_m)$		$V_p^2/(g.L_p)$
	L_m		$L_p/(V_m^2/V_p^2)$
	L_m		$L_p/((V_p^2/S)/V_p^2)$
	L_m		L_p/S
Velocity	F_m	=	F_p
	$Vm^2/(g.Lm)$		$V_p^2/(g.L_p)$
	V_m		$(V_p.V_p.L_m/L_p)^{1/2}$
	V_m		$V_p/(S^{1/2})$
Flow	F_m	=	F_p
	Q_m		$L_m.L_m.Q_p/(L_p.L_p.S^{1/2})$
	Q_m		$Q_p.L_p^2/(S^2.L_p.L_p.S^{1/2})$
	Q_m		$Q_p/(S^2S^{1/2})$
	Q_m		$Q_p/(S^{2.5})$

2.2.2 Scale Factor

The modelling of the spillway, chute, and stilling basin, are based on the following theoretical aspects:

1. The inertia and gravitational forces will be represented well by Froude Number, Fr.
2. The viscous force, represented by Reynolds Number, is negligible for free-flow condition unless the Reynolds number falls in the range of laminar flow.

As the scale factor for Kenyir Dam is $L_r = 50$, the scale factors of other parameters could be derived and these are presented in Table 2.2 (Aydin et al., 2019; Hassan et al., 2020)

Table 2.2: The used Scale Factor

Parameter	Scale factor
Velocity	$Vr = V_p/V_m = \sqrt{\frac{lp}{lm}} = \sqrt{lr} = \sqrt{50} = 7.071$
Time	$Tr = T_p/T_m = \frac{lp * Vm}{Vp * lm} = \frac{lr}{\sqrt{lr}} = \sqrt{lr} == \sqrt{20} = 4.47$
Pressure	$Pr = P_p/P_m = \rho_p/\rho_m * V_p^2 / V_m^2 = 1 * lr = 50$
Force	$Fr = Pr * lr^2 = lr * lr^2 = lr^3 = 50^3 = 125000$
Discharge	$Qr = Vr * lr^2 = \sqrt{lr} * lr^2 = 50^{2.5} = 17678$
Reynolds Number	$Rr = R_p/R_m = \rho_p/\rho_m * V_p / V_m * l_p / l_m = 1 * \sqrt{lr} * lr$ then, $Rr = lr^{1.5} = 50^{1.5} = 353.6$

2.3 Hydropower Plant

Hydropower plant converts the gravitational potential energy of water into electrical power. Therefore after energy generation, the water release is available for irrigation and other usages (Kadier et al., 2018). Hydropower energy is produced when water moving from higher to lower locations (Elbatran et al., 2015). Hydropower plant has shown its impact on social and environmental as compared to other forms of renewable energy. The power generated from a hydropower plant can be improved as well as the consistency in achieving the environmental flow for downstream ecosystems efficient and hassle-free technology of power generation. Moreover, this renewable energy resource is always available, clean, efficient, and hassle-free technology of power generation (Singh & Singal, 2017).

The advantages of the hydropower plant are having a sustainable source of electricity, minimal operating cost as well as the environmental effect (Elbatran et al., 2015; Kadier et al., 2018). In Malaysia, hydropower plant has been ranked top three in the contribution of electricity generation after natural gas and coal (Hossain et al., 2018). Sarawak Energy Berhad (SEB) and Tenaga Nasional Berhad (TNB) are the important agencies for the transmission, generation, and distribution of electricity in Peninsular Malaysia and Sarawak, respectively. Moreover, the installed capacity of hydropower plant on 31 December 2016 was 5819 MW, where Peninsular Malaysia contributed 2367 MW, while Sabah and Sarawak are 66MW and 3452MW, respectively (Hossain et al., 2018).

2.3.1 Hydropower Plant Dam

Dams have transformed as much as 92% of river outflow while other 8% of the surface of large river systems is free of any development of hydro-technical (Gierszewski et al., 2020). It transforms the river by fragmenting river networks, creating artificial lakes, and considerably distorting natural patterns of sediment transport and seasonal variation in stream flow and water temperature. There were about 58,000 large dams which are more than 15m high control the river in the world that supply water for municipalities and irrigation, allow downstream navigation, and enable hydropower production (Neugebauer et al., 2016).

The purposes of dam related to hydropower are to store water and raise the water level. (Neachell, 2014). The inflow of water into the reservoir shows a large different compared to the outflow of water. This is due to its functioning during floods and water discharge to improve navigation (Gierszewski et al., 2020). Due to its purposes of the hydropower dam, the construction of dams has considered the size, purpose, and socio-economic importance. Moreover, the dams have been most commonly classified according to the size, purpose, construction design and material, potential safety hazard, and technology (Neachell, 2014). Therefore the dam failure risk assessment should be considered in the design inflow, existing reservoir storage, debris blockage, the failures of gate, and emergency operating rules (Hecht et al., 2019). For the downstream of the dam part, both chemical/physical water characteristics and biological conditions typical of natural watercourses can be guaranteed if the downstream flowrate is equal to minimum flow (Cioffi & Gallerano, 2012)

2.3.2 Hydropower Plant Operation

The hydro power operation is extracted from the potential energy of water in upstream, flowing down to generate kinetic energy through the penstock, to drive the turbine for the generation of power electricity by power house as shown in Figure 2.4 (Elbatran et al., 2015). The motion of water from any source like rivers, ocean, and waterfall can move vane-like blades in a turbine then turns a shaft connected to a generator. The generator is a powerful electromagnet that is turned inside a coil of copper bars, then electricity flow or electric current is created (Oyebode & Olaoye, 2019). The overall efficiency from water to operation is almost 90%. The general equation for the power output of any hydro system is:

$$\text{Power output energy;} \quad P = \eta \rho g Q H \qquad \text{(Eq. 3)}$$

Where P is the mechanical power produced at the turbine shaft (watts), η is the hydraulic efficiency of the turbine, ρ is the density of water volume (kg/m^3), g is the acceleration due to gravity (m/s^2), Q is the flow rate passing through the turbine (m^3/s) and H is the effective pressure head of water across the turbine (m).

The way of the operation of a hydropower plant can affect the transformation of the flow regime in terms of frequency and rate of change in flow. This is associated with the periodic stoppage of the outflow of water from the dam during security works and renovation. Therefore, hydropeaking occurs as reducing in the degree of transformation of the most feature of the flow. The water flow variability increased (Gierszewski et al., 2020). In other words, the discontinuous releases of water from hydropower plant can cause hydropeaking (Carolli et al., 2017). The hydropeaking regime from the operation of the dam can cause destabilization of banks and impairment to the infrastructure. However, the operating conditions of the hydroelectric power plant and weirs are not affecting the flood control of the dam (Gierszewski et al., 2020). For the solution, the temporal increases of flow release can avoid hydropeaking when the hydropower generation is interrupted (Nguyen et al., 2018)

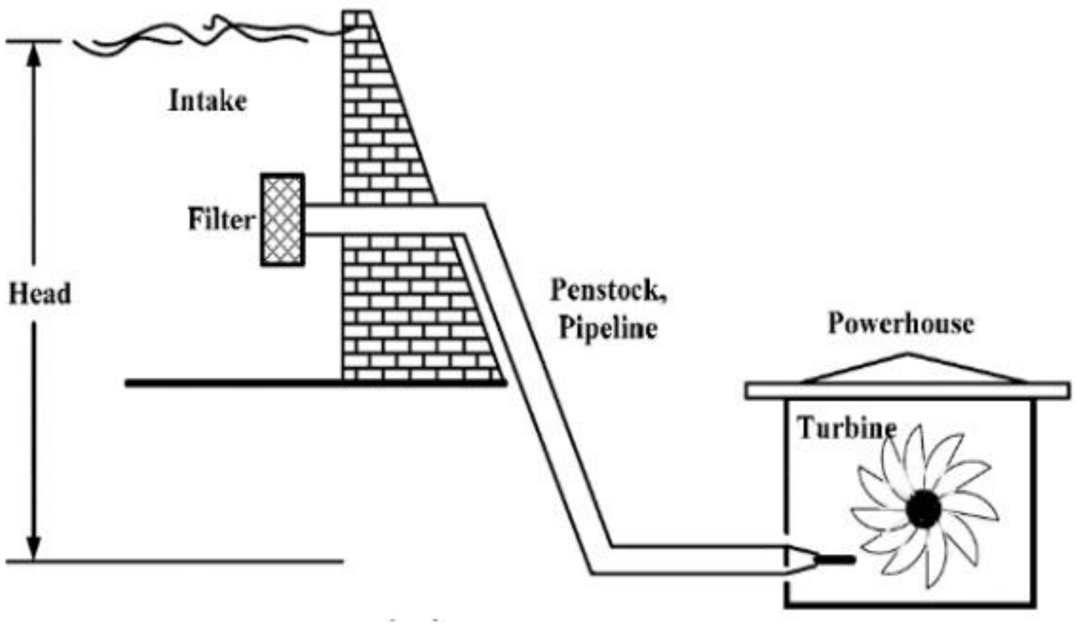


Figure 2.4: Hydropower electric generation

(Elbatran et al., 2015)

2.3.3 Classification of Hydropower Plant

The installation facility and power storage are two standards required for the hydropower plant classification (Elbatran et al., 2015). The first one classified according to power scale is large, Small, Mini, Micro, and Pico hydropower (Elbatran et al., 2015; Kadier et al., 2018). The other one is consists of three installations which are storage, run-of-river, and pump storage (Neachell, 2014)

2.3.3(a) Power Scale

The capacity measured in MW is the standard to classify the categories such as micro, 'small hydro' and 'large hydro' although various countries define various scales of hydro power plants (Elbatran et al., 2015). Pico hydropower plant is the smallest hydropower plant that can be used to generate electricity output to 5 kW. This Pico hydropower plant is the best alternative for rural areas and can easily adapt to the environment without any concern about the large water resources and the population. The operating cost is the lowest of any other hydropower plant (Kadier et al., 2018). Micro hydro power plant generates electricity output 5 kW to 100 kW and between is described as a Mini hydro power plant (Elbatran et al., 2015). Between 1 MW and 10 MW is generally those defined as small hydro power plant but the upper limit can vary from country to country and in certain cases may up high to 30 MW. A Plant with more than 10 MW or up to 30 MW is classified as a large hydropower plant (Breeze, 2018b). From Yao et al. (2018) has mentioned that large hydro power plant has often been considered as ecologically friendly. Table 2.3 shows the classification of the size of the plant according to the power scale. The hydro power plant for Kenyir Dam is 00 MW each of 4 turbines, therefore, classified as large hydro power plant as its power scale.

Table 2.3: The classification of hydro power plant based on power scale

(Breeze, 2018; Elbatran et al., 2015; Kadier et al., 2018)

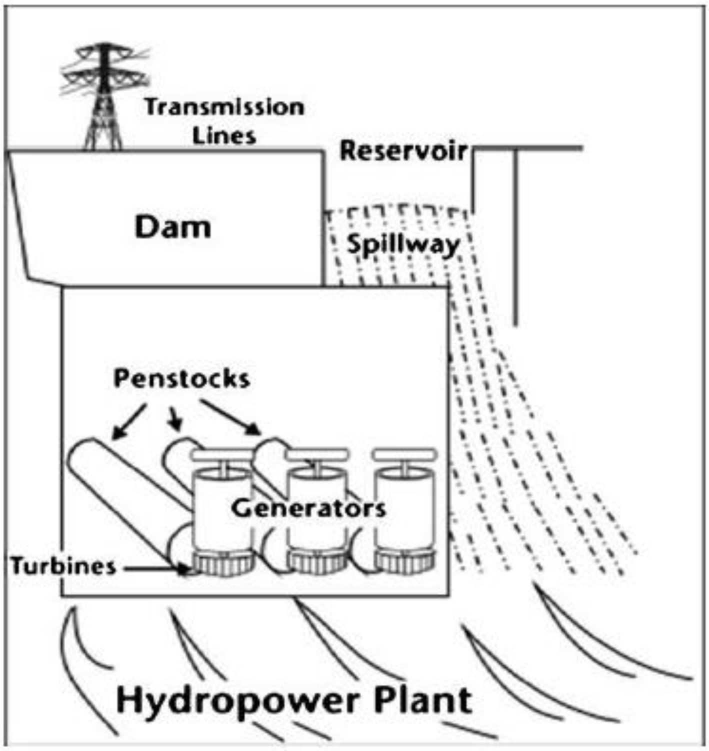
Large	Above 10-30 MW
Small	1 to 10-30 MW
Mini	100 kW to 1 MW
Micro	5 to 100 kW
Pico	Above 5 kW

2.3.3(b) Type of Operation

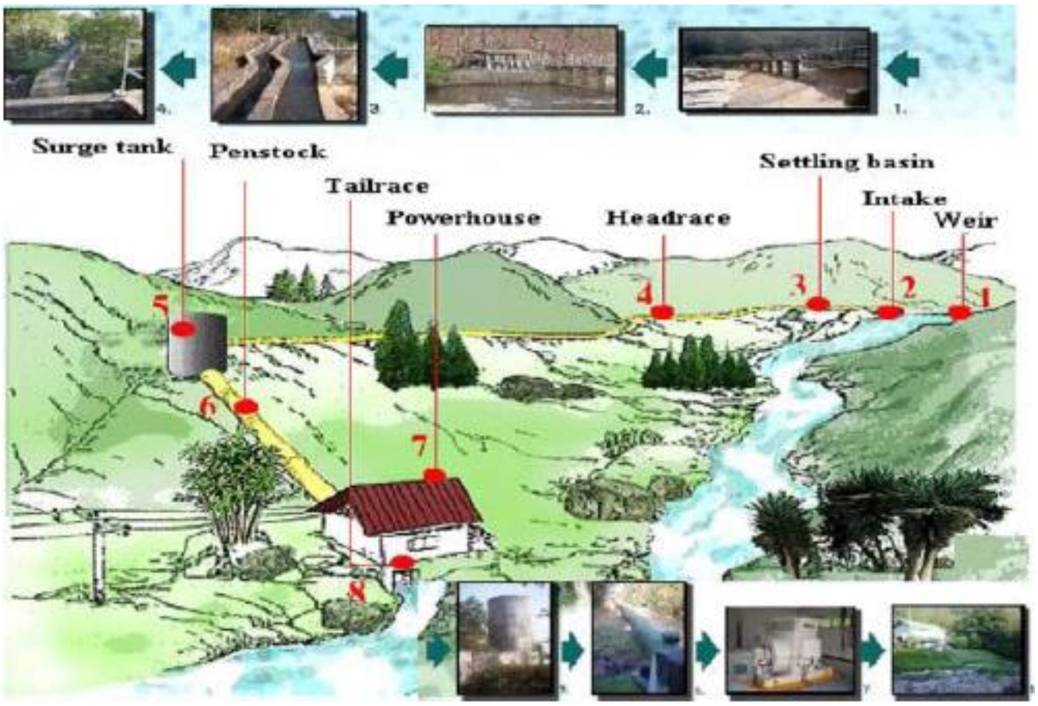
Storage installation facility is the operation of generation stations at the dam reservoir to or further downs which linked to the reservoir through pipelines or tunnels. Through this facility, the fluctuation of the water can be reduced (Elbatran et al., 2015). Kadier et al. (2018) and Neachell (2014) have defined the storage hydropower plant as the device that can store an excessive amount of water from the river and the power generated can be controlled based on the seasonal load demand. Run-of-river has less control over the release of water downstream as the storage dam has a larger volume of resorvoir and longer residence times (Neachell, 2014).

Run-of-river is a small hydropower station that has no utilization from reservoir. This is because the electricity produces is based on the variations of hydrological on the site. The small hydropower construction benefits the time and the investments for the construction. This is due to the small area exploits, therefore use local labor and material. Run-of-river type of hydro power generation utilizes the flow of the water of the natural range of the river (Elbatran et al., 2015). In the flow of a river aspect, this kind of hydropower generation is dependent on the natural incoming flows and does not control the water flow, as the inflow water to the hydropower plant and the water discharge is approximately equivalent (Neachell, 2014). Subsequently, during the dry season, it suffers a shortage of water and the water rises to a high volume of water during rainy seasons (Kadier et al., 2018). Other than that, it also can significantly alter the morphodynamics of the river and interrupt the sediment continuity (Sindelar et al., 2017). The advantage of this type of scheme is the operation will not lead to the people's rehabilitation as it has negligible environmental impact due to the instantaneous flow of water to drive the turbine (Singh & Singal, 2017). Other than that, the fluctuation of reservoir surface elevation is minimal (Neachell, 2014).

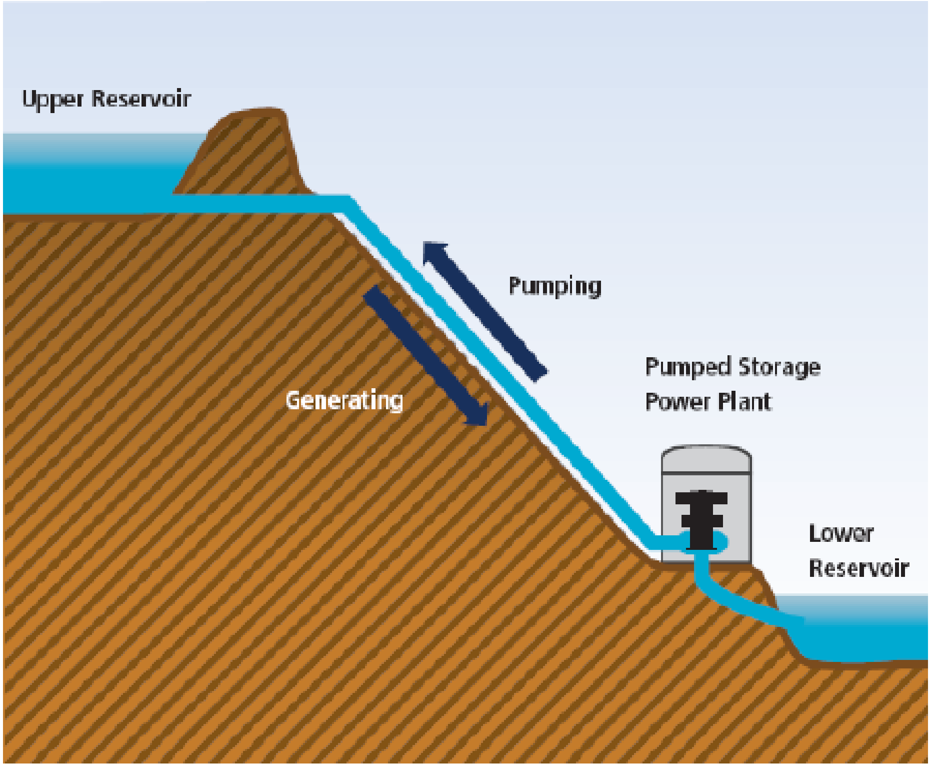
Besides the run-of-river type of hydropower plant installation, the pump storage also can reduce the impact of damming construction (Nguyen et al., 2018). In the electricity market, pump storage hydropower plant installation is the only proven as having large-scale energy storage technology with between 300 and 500 large-scale pumped storage power plants (>100MW) that operating worldwide (Bermúdez et al., 2017). The operation flow of pumped storage type is the water resources from a water reservoir located at the lower level will be pumped up using power to the water reservoir at the top transforming water into potential energy (Bermúdez et al., 2017; Kadier et al., 2018). The base load power plants supply electricity to the upper reservoir during off-peak hours. Then, during the daily peak load period or temporary peak in demand, the reserve flows to release the water to downstream to generate electricity (Bermúdez et al., 2017; Elbatran et al., 2015). This is the most efficient technology for energy storage as its concept to pump water back to the upper reservoir during an off-peak hour is a net energy consumer (Elbatran et al., 2015). When the water is pumped to the higher elevation storage reservoir, the lower-cost energy generation is used (Neachell, 2014). The huge water level fluctuation can be seen greatly exceeding their natural fluctuation (Kutyła, 2015). The component of a typical hydropower plant is shown in Figure 2.5.


Transmission Lines
Reservoir
Dam
Spillway
Penstocks
Generators
Turbines
Hydropower Plant

(a)


Surge tank
Penstock
Tailrace
Powerhouse
Headrace
Settling basin
Intake
Weir
1
2
3
4
5
6
7
8

(b)



(c)

Figure 2.5: (a) Typical hydropower plant with reservoir, (b) component of run-of-river hydropower plant and (c) typical pump storage hydropower plant

(Elbatran et al., 2015)

2.3.4 Classification of Turbine

Turbine reforms the gravitational potential energy of water flowing from a high level to lower into rotational mechanical work by a rotary engine. A common turbine supports the nozzle or stator, shaft, and runner. The water flow has driven the turbine blades and rotate the turbine, which is connected to the generator by a shaft. The water head plays its role to force to turn the impeller of the water turbine, subsequently generating electricity. The penstock is a pipeline that connects the water from the reservoir to the turbine. It is a crucial device as it controls the flow of water and very powerful to force the rotation of the mechanical shaft of the turbine. The decision of the length and diameter of penstock is very important since it is an expensive component of the system. The water turbines are broadly classified into four main types which are Impulse, Reaction, Archimedes Screw, and Waterwheel (Kadier et al., 2018).

The impulse turbine utilizes the water velocity to rotate the runner and the water flows discharge out the bottom of the turbine housing at atmospheric pressure. The water jet strikes the turbine in an open environment to create kinetic energy for the generation of power (Elbatran et al., 2015). Impulse turbine has three different types such as Pelton, Turgo, and Cross-flow turbines. The design of the impulse turbines is simple and low-priced (Kadier et al., 2018). Reaction turbines operate from the combination of pressure and moving water. They do not have nozzles as the radial arrangement of the blades from the outer of the runner is formed and mounted so that the spaces between the blades create the shape of the nozzle (Elbatran et al., 2015). From the movement of the water flow, it produces an upward hydrodynamic force which rotates the blades (Kadier et al., 2018). This type of turbine has greater performance in high flows sites and low heads (Elbatran et al., 2015). Archimedeans screw turbine is commonly being used for lower-head sites because the minimum head can be set is 1 m. Furthermore, it is very suitable for sites with large water flow. Water wheels have been used for many years to produce small capacities of hydroelectricity. Although water wheels have less efficiency rather than water turbine, it is still considered an economical and practical choice as it suitable in certain places and cases. Therefore, the water wheel is easy to be controlled and maintained (Kadier et al., 2018).