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# Sustainability of hydropower as source of renewable and clean energy

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**Abstract.** Hydroelectric energy has been in recent times placed as an important future source of renewable and clean energy. The advantage of hydropower as a renewable energy is that it produces negligible amounts of greenhouse gases, it stores large amounts of electricity at low cost and it can be adjusted to meet consumer demand. This noble vision however is becoming more challenging due to rapid urbanization development and increasing human activities surrounding the catchment area. Numerous studies have shown that there are several contributing factors that lead towards the loss of live storage in reservoir, namely geology, ground slopes, climate, drainage density and human activities. Sediment deposition in the reservoir particularly for hydroelectric purposes has several major concerns due to the reduced water storage volume which includes increase in the risk of flooding downstream which directly effects the safety of human population and properties, contributes to economic losses not only in revenue for power generation but also large capital and maintenance cost for reservoir restorations works. In the event of functional loss of capabilities of a hydropower reservoir as a result of sedimentation or siltation could lead to both economical and environmental impact. The objective of this paper is aimed present the importance of hydropower as a source of renewable and clean energy in the national energy mix and the increasing challenges of sustainability.

## 1. Introduction

All dams are designed to store flood-waters, primarily for the benefit of human beings. The damming of streams and rivers has been an integral part of human civilization from its early history. Reservoirs and dams are constructed by human to deal with the need of water and power. Dams and reservoirs are constructed primarily to function as multipurpose functions including as flood control, drinking water, agricultural water supply, hydro power generation, recreation and others [1, 2, 3].

ICOLD [4] defines large dams as those more than 15 m in height, while including smaller dams up to 10 m height as well, if they are otherwise significant with respect to storage volume, density of population, etc. Large dams generate 19% of the world's total electricity supply. One-third of the countries in the world rely on hydropower for more than half their electricity supply. Half the world's



large dams were built exclusively or primarily for irrigation. Some 30-40% of the 271 million hectares irrigated worldwide rely on dams. For hydropower reservoir, the life span design allows for slow deposition of sediments within designated levels above the reservoir bed. However in most cases, during the annual sediment inflow estimates used during the design stage are exceeded half way through the life span or even sooner. This therefore creates serious risk and operational difficulties in term of the functionality of the reservoir to operate as designed.

## **2. Sustainability of Hydropower**

In recent times, the most biggest and important challenge that is faced with the sustainability of the hydro plants are to cope with reservoir sedimentation and loss of storage mainly contributed by uncontrolled deforestation, poor agricultural land management, residential development and infrastructure developments within the vicinity of the once protected forest catchment area. The eroded sediments from the catchment are expected to increase the reservoir sedimentation rates. It is estimated that about 1% of the total storage capacity in the world's reservoirs is lost annually due to sedimentation [6, 7, 8]. Perhaps one of the most sediment affected catchment would be the Cameron Highlands and Batang Padang catchment which contributes to combined total hydropower generation capacity of 262MW.

## **3. Cameron Highlands and Batang Padang Hydroelectric Scheme**

In Malaysia, the Cameron Highlands and Batang Padang Hydroelectric Scheme is located in the central highlands of West Malaysia, at some 160km north of Kuala Lumpur. Ringlet Reservoir is a part of its upper scheme. The upper catchment that contributes to the Ringlet reservoir has an area of 183km<sup>2</sup>. It utilizes headwater from two major rivers i.e. Sungai Telom and Sungai Bertam for the generation of electricity. Ringlet reservoir originally the reservoir had a total storage capacity of 6.7 million m<sup>3</sup> of water, meanwhile Jor Reservoir had a total storage of 3.8 million m<sup>3</sup> while Mahang reservoir was designed at 0.4 million m<sup>3</sup>.

### *3.1. Sedimentation Rate*

The Cameron Highlands and Batang Padang Scheme appears to have experienced sedimentation problems soon after commissioning. The Batang Padang catchment experiences much less sediment problems and sediment sampling on that catchment started only in the late 1980's. The data suggest that as a result of the large sediment loads carried by the different rivers feeding Ringlet reservoir, the reservoir silted up very quickly. In 1963, at commissioning, the reservoir gross storage was about 6.5 million m<sup>3</sup>, of which 4.7 hm<sup>3</sup> were for live storage. The live storage was reduced to 4.2 million m<sup>3</sup> in 1983, 3.2 million m<sup>3</sup> in 1991, and 2.2 million m<sup>3</sup> in 1996, 1.7 million m<sup>3</sup> in 1998 and to 1.4 million m<sup>3</sup> in 1999. The rate of filling increased from 30,000 m<sup>3</sup>/yr in the 1960's to 50,000 m<sup>3</sup>/yr in the late 1970's and early 1980's [11].

### *3.2. Recent Study and Findings*

A study by TNB Research in 2004 concluded that the two (2) major water inflows carrying average sediment inflow of 194,000t/yr or 102,000m<sup>3</sup>/yr into Ringlet Reservoir. The breakdown of sediment inflows are from Ringlet End (Sg. Ringlet) which contributes approximately 67,000 ton/yr (35,000m<sup>3</sup>/yr) and Habu End (Sg. Habu, Sg. Bertam and Habu Power Station) with sediments contributes approximately 127,000ton/yr (65,000m<sup>3</sup>/yr). At present the long term annual capacity loss or sedimentation rate of Ringlet Reservoir in 2008 is estimated at an average of almost 6 fold since commissioning to 139,712m<sup>3</sup>/yr in 2008 [12].



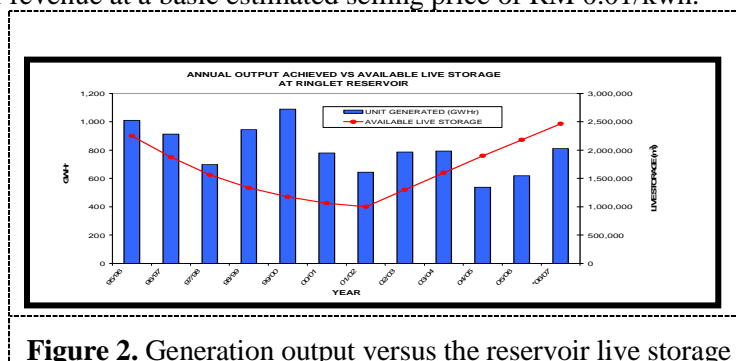
**Figure 1.** Longitudinal bed profile of the reservoir for different years of depositions as compared to the original bed.

#### 4. Impacts of Sedimentation

A number of studies were conducted in the past to examine the effects of development of the catchment on the hydro scheme. The studies [13] have shown that, the operation and maintenance as well as energy generation of the hydro station of the Cameron Highlands scheme are affected by land development. Among the major impacts directly affected by sedimentation maybe concluded as below:

- Loss of Live Storage which affects the revenue from power generation output;
- Loss of energy production and revenue due to frequent shutdown of intakes and operations of outlet valves which diverts water from reservoir;
- Increase the risk of flooding downstream through controlled spilling especially during monsoon seasons;
- Increased cost of maintenance by carrying out frequent dredging, excavation and disposal of sediments and also replacement of plants mechanical components;
- Reservoir considerably filled with sediments pose a threat for great environmental disaster in case of a dam failure.

The impacts in term of power generation capabilities are also quite significant. Generally as the reservoir storage reduces due to sedimentation so does the power generation as shown in Figure 2. The graph below shows the annual power generation output at Cameron Highlands versus the available live storage since the FY 95/07. It can be observed that in the FY 95/98, the live storage loss due to reservoir sedimentation has gradually reduce the capability of the plants to generate annual output as per the design requirements of 843 GWh. In the FY 97/98, the annual generation output drops to 699GWh below the normal operating limits with a difference of 144 GWh which translates to RM 1.44 million loss of revenue at a basic estimated selling price of RM 0.01/kwh.



**Figure 2.** Generation output versus the reservoir live storage

#### 5. Mitigation Measures for Improving Reservoir Sustainability

The most desirable method for controlling reservoir sedimentation is probably by reducing soil loss and erosion from the reservoir watershed. This can be achieved by reducing sediment inflow through soil conservation, watershed management, gross pollutant traps (GPT), vegetative screens and etc.

Some of the most commonly used methods for reducing sediment deposition in reservoirs are as follows:

1. Reducing sediment inflow to the reservoir:
  - a. Watershed management and soil conservation
  - b. Constructing a check or debris dams upstream to retain relatively coarse sediments
2. Reducing sediment deposition in the reservoir:
  - a. Flood flushing through bottom outlets or undersluices
  - b. Drawdown flushing to evacuate new and old settled deposits
  - c. Reservoir operation policies oriented towards sediment releases.
3. Rehabilitating reservoir storage capacity:
  - a. Siphon dredging - easily implemented and very effective for small to medium reservoirs
  - b. Reservoir dredging and disposal

The first category, the objective is to reduce sediment deposition in the reservoir by increasing sediment outflow from the reservoir through use of density currents, releasing flows with heavy sediment concentrations during floods events, and/or drawing down and flushing the reservoir during high flows. The second category however is the opposite of the first whereby the reservoir storage capacity is recovered by either dredging it, and/or siphoning the deposited sediments.

## 6. Conclusions

Hydropower remains an important component of clean energy requirement in the near future. During the 19th Conference of the Electric Power Supply held in Bali recently, most countries in the Asian region as well as globally pledged to increase investment and enhancing clean technology for future sustainable power needs. However the challenges faced with the development and operations of existing plants as shown in the case of Ringlet Reservoir, Cameron Highlands is very real. Ever increasing inflows of sediments annually threatens the sustainability use of hydropower as a source of clean energy. Therefore importance should be made towards including effective sediment mitigation strategies during the development stages. As for the existing hydro power plant, strict law enforcement along with legislation protection towards watershed management should be derived to protect the assets such as dams and reservoir for future power generation.

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