Investigation of Sarawak River Kiri Sedimentation Before and After Bengoh Dam Construction

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Abstract: ***This research was conducted to study river sediment at Sarawak Kiri River before and after Bengoh Dam construction. The relationships of Bengoh Dam, Batu Kitang Submersible weir and Sarawak Kiri River sediment are thoroughly analysed and discussed. Future rainfall will increase 3% in 2050s, 5% in 2080s relative to 2000s. InfoWorks RS was employed to model Sarawak Kiri River using hydrological data from July 2015 to October 2015 for model calibration, while November and December 2015 for model validation. The study demonstrated that before Bengoh Dam construction, most of the eroded materials at upper catchment will settle at Bengoh and Git with annual total bed of 0.023m since the river flow is very slow. Annual total bed deposition will increase to 0.026m and 0.028m as the rainfall increase to 3% and 5% respectively. After Bengoh Dam is constructed, most of sediment materials will be deposited inside the reservoir behind Bengoh Dam with annual total bed of 0.032m. Less sediment were found at Git and Batu Kitang. With the rainfall increment of 3% and 5%, annual total bed will yield to 0.033m and 0.034m respectively at Bengoh, and 0.015m and 0.016m respectively at Git. Generally, it can be concluded that the river morphology at Sarawak Kiri River had changed significantly with the construction of Bengoh Dam.***

Keywords: Sediment, Annual Total Bed Changes, Hydraulics Structures, Infoworks RS

1. Introduction

The sediment cycle normally starts with the process of erosion, where the particles are wearing away from rocks, geologic and soil materials by hydraulics forces. Natural erosion takes place at a relatively slower rate. However, erosion caused by human activities may take place at a much faster rate. The segregated particles or sediments will then be transported within the natural streams. As there is not enough energy to transport the sediment, the sediment comes to rest, sink and deposit at the river bed.

Surface erosion, sediment transport, scour, and deposition have been the subjects of study by engineers and geologists for centuries, due to their importance to economic and cultural development. All rivers carry sediments, due to surface erosion from watersheds and bank erosion along the river. The understanding of dynamic equilibrium between sediment supply from upstream and a river's sediment transport capability is important to the success of river engineering design, operation, and maintenance.

According to Natural Resource Conservation Service (2004), sediment is responsible for more stream and river degradation than any other pollutant. Deposits of sediments in ditches, streams, reservoirs and rivers reduce their capacity to store water resulting in more frequent and severe flooding and increased in property damages. Accumulation of sediments may result in severe damage to storm drain systems, reservoirs, and water treatment plants.

Besides, sediments also severely affect the aquatic animal habitats and degrading water quality. Areas needed for reproduction and food sources are destroyed when fine silts cover the sand and gravel streambed [1]. Besides, decreased clarity of the water prevents sunlight from reaching plants resulting in loss of aquatic plant communities, and also reducing the number and variety of fishes and other aquatic lives. Meanwhile, toxic chemicals may attach or adsorb by sediment particles and then transport and deposit to other areas [2]. The presence of sediments in water can also wear out the pumps and turbines when water is taken from streams and lakes for domestic, industrial, and agricultural uses. It was observed that a dam trapped with sediments will decrease the size of the reservoir and thus reduce the life expectancy of reservoirs created for power generation [2].

According to Petts and Gurnell [3], dam construction is usually utilized as one of the flood mitigation methods as it is able to reduce the peak flow intensity and river flow capacity to erode the channel. Hence, less sediment will be entrained at downstream [1] after dam or weir construction. A decrease in the amount of sediments from upstream along with the decrease in erosive capability downstream may lead to bed armoring, channel narrowing, an increase of fine sediments along banks and gravel bars (floodplain formation), vegetation establishment on banks and deltaic erosion [4]. In contrast, sediments will be trapped behind the dam, starving the channel just downstream [5]. Therefore, it is initiated in this study to investigate the impact of Bengoh dam to geomorphological changes at upstream flow regime of Sarawak Kiri River before reaching Batu Kitang submersible weir..

2. Study Area

The selected study area is Sarawak Kiri River basin with a total catchment area of 633km2. Bengoh dam is located at the upper catchment of Sarawak Kiri River, one of the tributaries of Sarawak river (refer to Fig. 1). The main function of Bengoh dam is to store and supply the raw water supply to Batu KItang Water Treatment Plant, which is located at the lower catchment of Sarawak Kiri River. Batu Kitang water treatment plant is supplying 95% of treated water to Kuching and its surrounding areas including Kota Samarahan and Serian Divisions. The main hydrological gauging stations available within the studied catchment are Bengoh, Git, Seniawan and Batu Kitang, with average rainfall and water level records of 30 years that are published in Sarawak Hydrological Year Book [6].

Sarawak river was influenced by tidals previously, in which the salty sea water may backflow reaching Batu Kitang water treatment plant. In order to mitigate flood and saline intrusion problems, three hydraulic structures have been constructed along the Sarawak River [7]. These three hydraulic structures are Kuching Barrage and Shiplock, Batu Kitang Submersible Weir and Bengoh Dam (refer to Fig. 1).

Fig. 1: Location of hydraulic structures, hydrologic gauging stations available within Sarawak River Basin [6]

Kuching Barrage and Shiplock was completed in year 2000. This project interoperates three in one infrastructures include barrage, shiplock and bridge that serve to protect Kuching water supply and maintain water quality by controlling the saline intrusion into the upstream, to regulate the river water level upstream of Barrage and to mitigate fluvial and tidal flooding in Kuching by operating the Barrage gates. Batu Kitang Submersible Weir which was completed in year 2005, is a 1.5m height storage weir constructed across the Sarawak Kiri river with a screw down gates and a double locked gate. The function of this weir is to increase the safe yield of the Sarawak Kiri River to ensure reliable supply of raw water sources to Batu Kitang water treatment plant and also acted as a salinity barrier to prevent the saline intrusion reaching the water intake [7]. Recently, improvement works were carried out on the weir to increase the safe yield of Sarawak Kiri River. Meanwhile, Bengoh Dam with total water storage of 144Mm3 was constructed at Semadang River, a tributary upstream of the Sarawak Kiri River [8]. The function of Bengoh Dam is to ensure adequate raw water supply to Batu Kitang Water Treatment Plant during the low river flows and low rainfall.

3. Methodology

The data used for setting up the model are:

a) Ranfall data-rainfall data was collected at the dam sites and also at the upper catchment of the river basins. These rainfall data were collected from Department of Irrigation and Drainage (DID) Sarawak.
b) Discharge and sedimentation data- The monitoring of sediment transport was conducted within 3 months starting from 30 June 2015 to 31 Dec 2015. Four location had been identified namely Sungai Semedang, Bengoh, Kampung Git and Batu Kitang and the gauging was conducted on daily basis. The suspended sediment samplers used are Portable Suspended Sediment Load Sample model DH48 and Bedload Sampler model 404-010/Rickly/H-USA. The data collected from site will be tested on site using handheld TSS Meter (Portable) model Partech 3150/Insite/US.
c) Water level data – continuous water level data along Sarawak Kiri River was provided by DID Sarawak.
d) River cross-sections and longitudinal profiles - were provided by DID Sarawak.
e) LiDAR data - the topography for Sarawak River Basin was provided by DID Sarawak.
f) Height & Width of Bengoh Dam – information was provided by Public Works Department Sarawak.
g) Height & Width of Batu Kitang Submersible Weir – information was provided by Kuching Water Board (KWB).

The relationships of Bengoh Dam, Batu Kitang Submersible weir and Sarawak river stage are thoroughly analysed for calibration and validation of hydrologic model. The calibration was conducted using Infoworks River Simulation (RS) with hydrological data from 1st Jan 2015 to 31st Dec 2015. The purpose of model calibration is to ensure simulated river flow is as close as possible with observed runoff [9]. Model performances are evaluated using mean absolute peak error (MAPE) and Coefficient of Correlation (R).

Thereafter, the contructed hydrological model is further extended for developing sedimentation model. Total Suspended Solid (TSS) data gauged at three selected locations namely Semedang, Bengoh Kampung Git and Batu Kitang submersible weir, were input into the sedimentation model for calibration, validation and simulation. Daily TSS data were collected continuously for 6 months starting from 30 June 2015 to 31 Dec 2015. Data for the month of July 2015 to October 2015 were used for model calibration, while November and December 2015 data is used for model validation. Fig. 2 presents the flowchart of the model development and Fig. 3 presents the detail steps involved in creating sedimentation model.

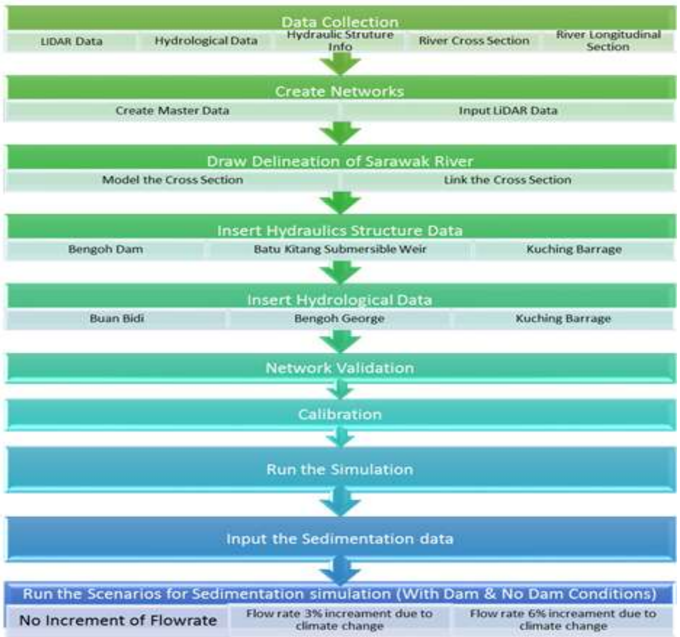

Fig.2: Flowchart for sedimentation simulation using Infoworks RS

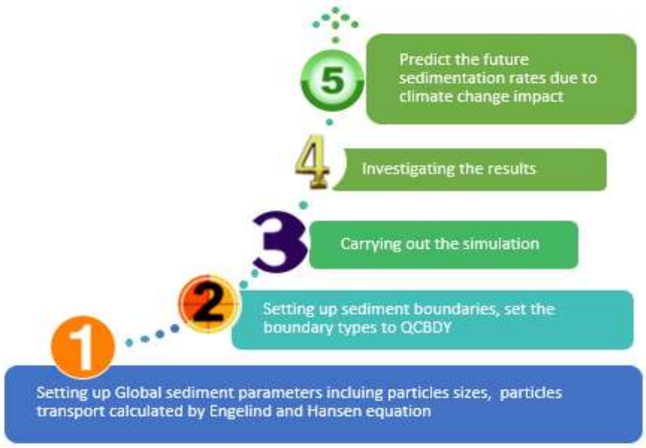

Fig.3: Flowchart to creating sediment model using Infoworks RS

4. Results and Discussion

Through model calibration, the optimal manning roughness coefficient (n) for left and right banks was found to be 0.12; while optimal n=0.065 was obtained for the river channel. The mean absolute peak error and R obtained using both optimal n values are 0.1866 and 0.85 respectively.

The developed hydrologic model will be further extended to investigate the sedimentation along Sarawak River Kiri under two different scenarios of with and without the construction of Bengoh Dam. It was found that that rainfall in 2050s and 2080s for Sarawak region will increased 3% and 5% respectively [10]. Therefore, yearly total bed changes will be simulated by increasing the rainfall intensity to 3% for 2050s and 5% for 2080s due to the impact of climate change for both scenarios. Total bed changes is simulated at three different locations namely Bengoh, Git and Batu KItang is presented in Fig. 4.

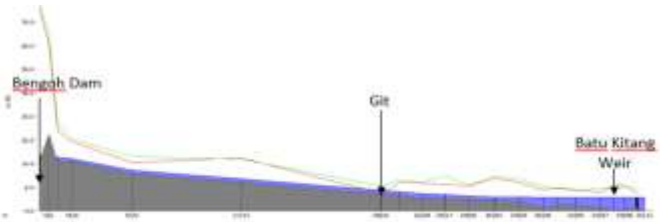

Fig. 4: Location of Bengoh, Git and Batu Kitang along Sarawak Kiri River.

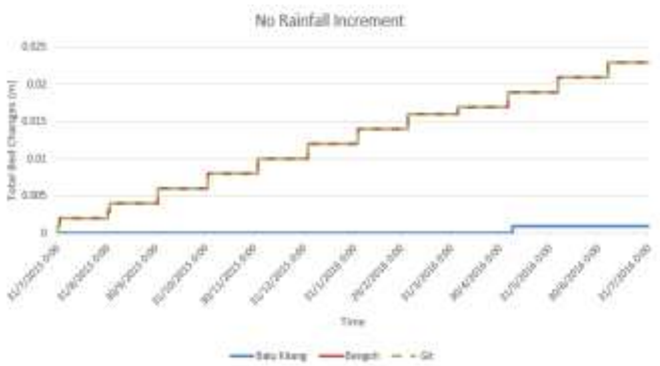

Fig. 5: Total Bed Changes Under "No Rainfall Increment" and "No Dam" Scenario.

Under the scenario of no rainfall increament and without the construction of Bengoh Dam, it was found the all the eroded materials at upper catachment will settle at Bengoh and Git (refer to Fig. 5). The total bed changes for both Bengoh and Git after one year settlement is expected to be 0.023m. Only little sediment settled at Batu Kitang which is estimated to be 0.001m after one year deposition. This is because most of the sediments have been deposited in slow flowing river at Bengoh and Git before reaching Batu Kitang.

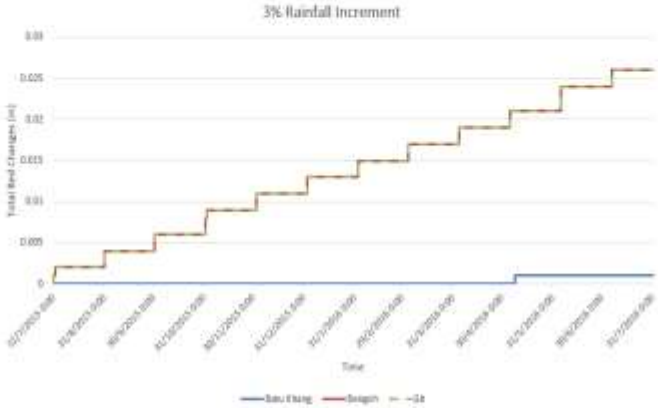

Fig. 6: Total Bed Changes Under "3% Rainfall Increment" and "No Dam" Scenario.

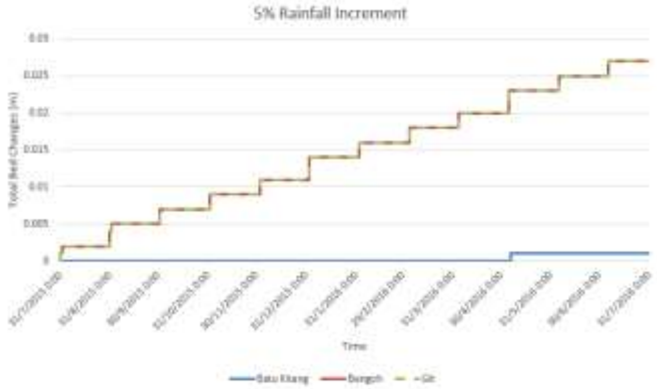

Fig. 7: Total Bed Changes Under "5% Rainfall Increment" and "No Dam" Scenario.

Fig. 6 and Fig. 7 present the total bed changes along Sarawak Kiri River under 3% and 5% rainfall increment respectively with "no dam" scenario. Once again, it was observed the total bed changes at Bengoh and Git are equally the same. The total bed deposition for both Bengoh and Git is expecting increased to 0.026m for 3% rainfall increment, whilst 0.028m deposition for 5% rainfall increment after one year sedimentation process. This is because as the rainfall increased, the eroded materials will increase as well. This will lead to the increment of deposited materials. Meanwhile, total bed sediment at Batu Kitang is still maintained at 0.001m.

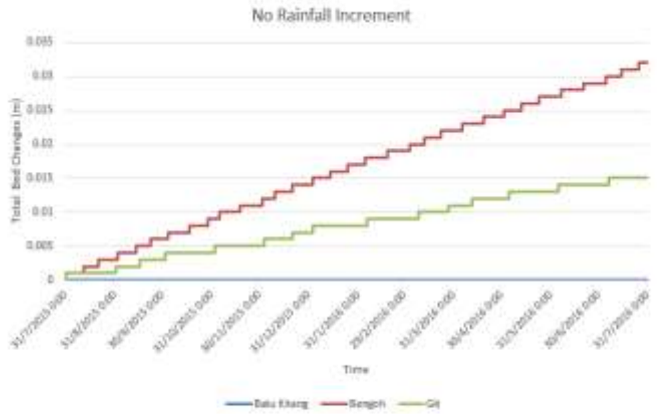

Fig. 8: Total Bed Changes Under "No Rainfall Increment" and "With Dam" Scenario.

Once Bengoh Dam is constructed, certain amount of sediment materials will be deposited inside the reservoir behind Bengoh Dam. Annual total bed changes had yielded to 0.032m (refer Fig. 8) at Bengoh. Thereafter, less amount of sediment, which is only 0.015m sediment deposited at Git. There is almost no sediment deposited at Batu Kitang.

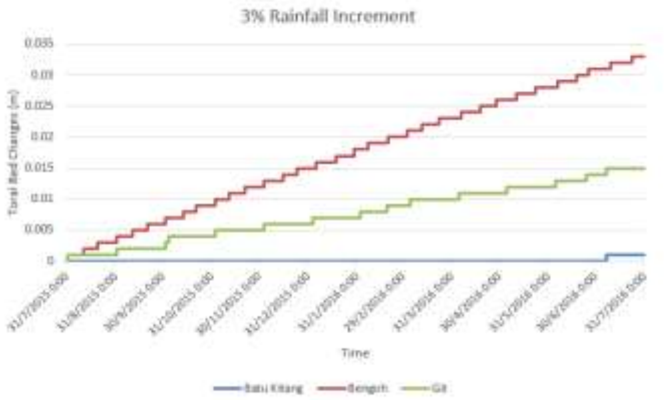

Fig. 9: Total Bed Changes Under "3% Rainfall Increment" and "With Dam" Scenario.

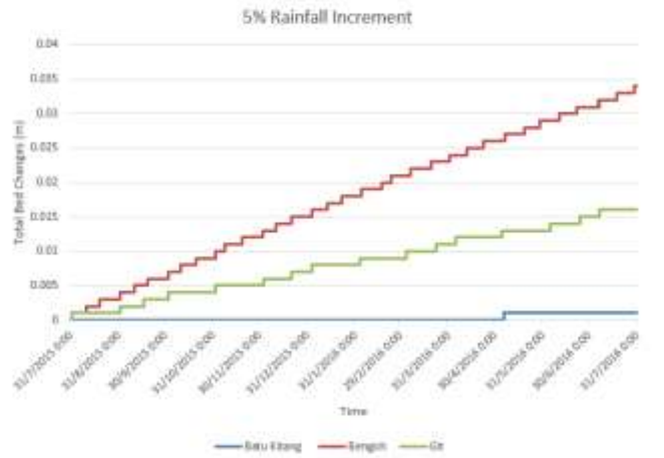

Fig. 10: Total Bed Changes Under "5% Rainfall Increment" and "With Dam" Scenario.

After construction of Bengoh Dam, total bed changes along Sarawak Kiri River with 3% and 5% rainfall increment will yield to 0.033m and 0.034m respectively at Bengoh (refer Fig. 9 and Fig. 10). Whilst at Git, total bed also increased gradually to 0.015m and 0.016m for 3% and 5% rainfall increment, respectively. The increment of deposition is due to the increment of rainfall will lead to increment of eroded materials, thus increase the deposited materials. Meanwhile, there is not much change of total bed at Batu Kitang.

5. Conclusion

Hydrology analysis of Sarawak Kiri river found that the optimal manning roughness coefficient (n) for river channel is 0.065 and 0.12 for both left and right banks. For sedimantation analysis, it was found the all the eroded materials at upper catachment will settle at Bengoh and Git without the construction of Bengoh Dam. As the rainfall increase to 3% and 5%, the total bed deposition will increase as well. This is because as the rainfall increased, the eroded materials will increase too. This will lead to the increment of deposited materials. Once Bengoh Dam is constructed, huge portion of sediment materials will be deposited inside the reservoir behind Bengoh Dam that yielded the annual total bed deposited to 0.032m and less sediment were found at Git and Batu Kitang. It can be concluded that the river morphology at Sarawak River had been affected by the construction of Bengoh Dam.

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