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Development an Integrated Sediment Disaster Simulator and Application to Sediment Disaster Mitigation and Reservoir Sedimentation Management in the Brantas River Basin, Indonesia

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Synopsis

This paper is a concise report of International Research Project (Project Reference Number: 29W-01) entitled of Development of an Integrated Sediment Disaster Simulator and Application to Sediment Disaster Mitigation and Reservoir Sedimentation Management in the Brantas River Basin, Indonesia. The main objectives of the project are to establish an appropriate and adequate mechanism to support the sediment disaster mitigation and the sustainable reservoir sediment management through utilization of most collaborative-based technology on the development of integrated sediment disaster simulator and an establishment of monitoring system for sediment disaster management. We assessed the sediment transport processes in the upstream of Brantas river basin, analyze its potential sediment disaster, and then formulate adaptation strategies to reduce the loss of reservoir capacity. The selected site of this research project is Wlingi reservoir that is located on the southern skirts of Mt. Kelut. This basin is suffering from watershed erosion and heavily loads of volcanic ash ejected from the eruption of Mt. Kelut, the most active volcanoes in Indonesia. The methodology and approaches adopted in this project are then discussed with collaborators via project events for prescribing better accuracies of the improving model. The application of the integrated sediment disaster model to this mountainous watershed has been successfully providing detailed information on sediment transport processes in Wlingi sub-basin. The results show Wlingi reservoir to receive higher volcanic material as bed load and suspended load during high-intensity rainfall from the northern slopes of catchment and sheet erosion material as suspended load from the southern part of remaining basin. Overall, the results are useful to contribute in establishment of variety options to counter sediment disaster in the Wlingi reservoir.

Keywords: reservoir, sediment, disaster, volcanic, mitigation, management

1. Introduction

Secondary disasters such as volcanic debris flows are often triggered by rainfall as massive sediment movement after a volcanic eruption. If volcanic debris flow being trapped by a dam, severe sedimentation problem will take place in its reservoir. A major impact of reservoir sedimentation is the loss of its capacity for flood control thus will increase flood risk disaster.

In general, massive sediment movements take place in steep areas when an external factor such as rainfall, volcanic activity, or seismic motion exceeds some critical level, and can cause sediment disasters of potentially high cost. Runoff processes from headwaters in upland flows to the reservoir consisting of three sub-processes: sediment production, sediment supply, and sediment transportation. Lump models (such as USLE or other statistical models) may predict and estimating the potential erosion in productive area but transport processes was not known in detail. It is important to know the processes of sediment transport both in land and stream for better reservoir sediment management. Therefore, the integrated sediment disaster simulator needs to be established for understanding these complex phenomena.

The targeted area of this research is the Brantas river basin, East Java, Indonesia. Reservoir sedimentation due to huge material eruption and watershed erosion are the important problems in this basin. Recently, the reservoirs in the Brantas river basin have lost their storage capacities more than half of their originals (see Figure 1).

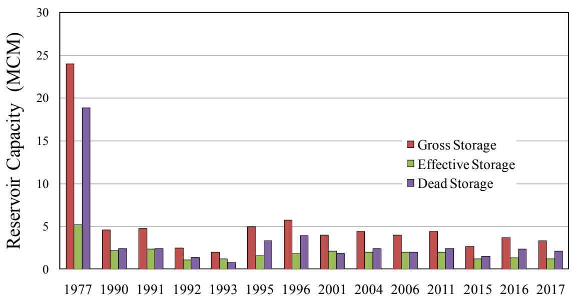

Fig. 1 Loss of capacity in Wlingi reservoir due to sedimentation.

There are some sites of sand mining in the mountainous rivers carrying eruption material down to reservoir. Sometime the debris flow occurred and buried the trucks remaining in the site (see Photo 2). Despite of reservoir sedimentation problem, the understanding of sediment transport processes in the upstream part of river basin therefore seems give benefit to minimize the damages.

Photo 1 The upstream rivers of Wlingi sub-basin.

Photo 2 The buried truck in sand mining sites due to flash flood/debris flow.

2. Research Report

2.1 Research Purpose

The main objectives of the project are to establish an appropriate and adequate mechanism to support the sediment disaster mitigation and the sustainable reservoir sediment management through utilization of most collaborative-based technology on the development of integrated sediment disaster simulator and an establishment of monitoring system for sediment disaster management.

2.2 Summary of Research Progress

The project started in July 2017 and finished in March 2019. As project started, we introduced the detailed methodological approaches of the developed model in small group discussion to share the idea and to determine the selected site of research project as well as for the field survey and collecting the secondary data (see Photo 3 and Photo 4). After the site have been determined (see Figure 2), then it was followed by field survey to clarify the model parameter and model variables whether they already represented the origin of sediment and also checking the assumptions being made. The area of study is Wlingi reservoir. This reservoir has catchment area of about 670 km^2 and part of the upper Brantas river basin. The topographical data, hydrological data and sedimentation volume necessary for the simulator were collected with the cooperation of Jasa Tirta-1.

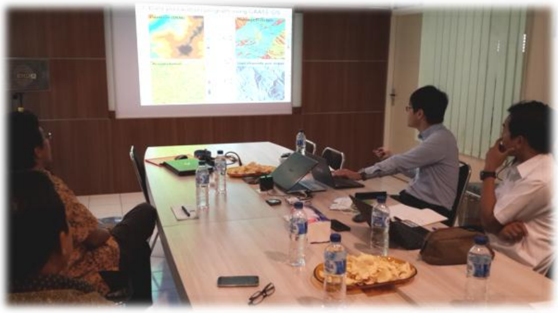

Photo 3 The group meeting for introducing the methodological approach for Integrated Sediment Disaster Simulator.

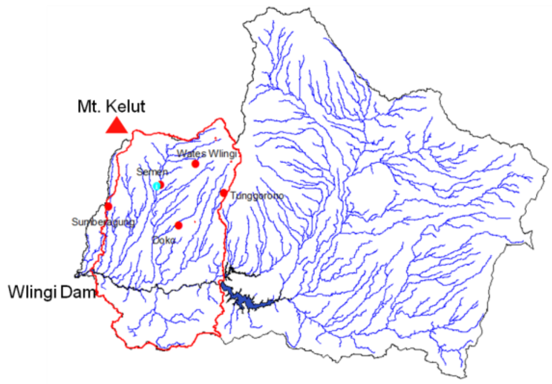

Fig.2 The cacthment area of Wlingi reservoir as part of Upper Brantas Basin.

Photo 4 Field survey for upstream rivers of Wlingi reservoir.

Interval camera was planned to be placed in Lekso river to monitor daily flow and to get model parameters (Photo 5). Since April to October 2018, there has been a continuous flow observation. The incidence of rain and increased river flow was captured by this monitoring camera and valuable for validating the model results (Photo 6).

Photo 5 An interval camera monitoring in Lekso river.

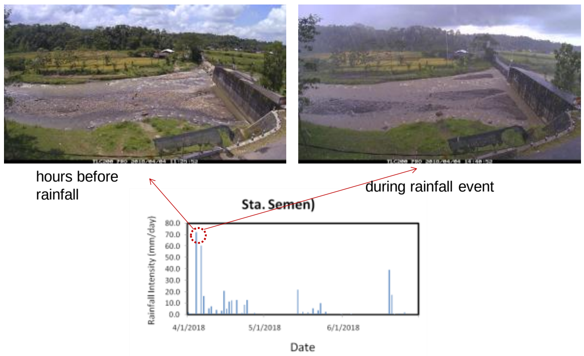

Photo 6 Observation discharge in Lekso river with interval camera.

During the project period, there were mini-laboratory workshops to exchange the ideas for sediment countermeasures and learning from their best practices conducted in Ujigawa and Hodaka Laboratories. Both of them covered discussion over the research of sediment disaster (see Photo 7).

Photo 7 Sediment measurement facilities in Hodaka Laboratory.

2.3 Summary of Research Findings

To improve the simulator model, FUJIYAMA has been developed by Yamanoi and Fujita (2015) and to apply it into Brantas river basin, the field survey and data collection has been conducted during the first year of the project. The SEDIMENT-K model is an improvement of FUJIYAMA model (Fujita *et al*, 2015), an integrated sediment runoff model has been developing by combining sediment production, sediment supply and sediment transport sub-process models into a single basin model that was composed of unit channels and unit slopes. In this improved model, the reservoir operation rule-curves supposed to be considered in determining trap-efficiency for downstream sediment routing.

In the second year, we apply the simulator to the reservoir sedimentation management and the sediment disaster information system after large scale sediment production such as volcanic eruption. As shown in the Figure 3, the increase of bed load from Lekso river transporting down to Wlingi reservoir was likely influenced by the duration of flooding rather than its magnitudes. The model was also able to capture the morphology changes as the dynamic of sediment transport is represented by alteration of bed level (see Figure 4).These results also show the effectiveness of the model to identify the local deposition area where the bed load materials generally take a long term processes to be deposited in the reservoir. Reversely, the amounts of suspended and wash load were linearly associated with the magnitude of flood. The suspended load material was likely composed of volcanic material (from Lekso river) and top-soil erosion from southern remaining basin. In term of wash load discharge, almost of rivers provide wash load material to the Wlingi reservoir.

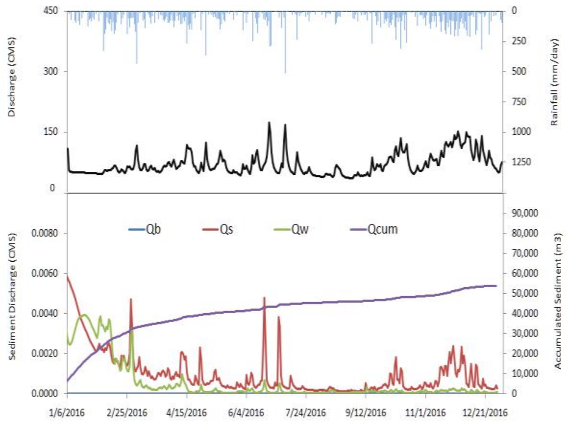

Fig. 3 The rainfall-runoff-sediment processes in Lekso river.

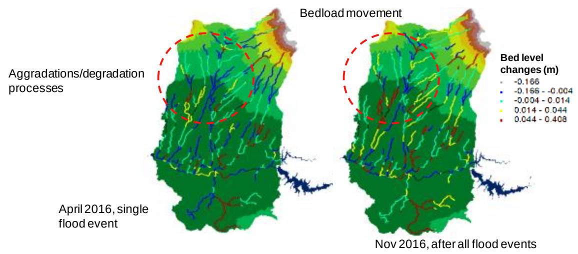

Fig.4 The bed load transport processes in Lekso river.

Then, an appropriate reservoir sediment management in Wlingi reservoir after huge eruption of Mt. Kelut was proposed by referring model results as follow;

a. The effectiveness of sabo dams in upstream Lekso river should be monitored and keeping their functions to trap the bed load material from Mt. Kelut eruption.
b. It is also important to mitigate the sediment disaster by educating people and sand miners that flash flood/debris flow may occur in long duration-light rainfalls.
c. To reduce the reservoir sedimentation from sheet erosion, the watershed conservation must be prioritized for the area of remaining

basin (southern part, where no eruption material deposited).

2.4 Publication of Research Findings

So far, publication of research findings have been made through poster exhibition in DPRI annual meeting, February 2018 and poster exhibition in the international symposium of SABO engineering (INTERPRAEVENT) in Toyama-Japan, October 2018 (Photo 8).

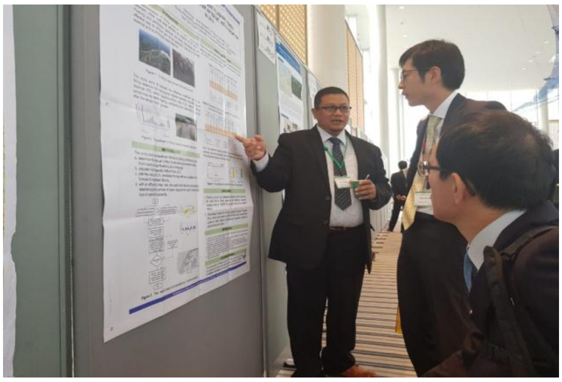

Photo 8 The poster exhibition at Toyama October 2018 (INTERPRAEVENT).

To get best practices in sediment disaster mitigation and reservoir sediment management, the project also co-organized the 8th International workshop on Multimodal Sediment Disaster (IWMSD-2019) and field excursion held in Solo, Indonesia where in all the project partners and collaborators got involved in rigorous discussions (Photo 9).

Photo 9 The 8th International Workshop on Multimodal Disaster Management, Solo-Indonesia.

This workshop enabled capacity building of project collaborators and knowledge transfer. Second publication was in the Proceedings of 8th International Workshop on Multimodal Sediment Disaster, Solo-Indonesia, January 22-23, 2019. We are planning to submit a manuscript to Journals or upcoming events in 2020 after all observation data are processed.

3. Conclusions

Here, the application of the integrated sediment-runoff model to a mountainous watershed has been successfully providing detailed information on sediment transport processes in Wlingi river basin. The results implied that the bed load material has been gradually transported to reservoir within long term period and mostly depends on the duration of flood events. Reversely, the suspended and wash loads could be directly transported within a single flood event. Their amount of transported materials was depending on the flood magnitudes.

The deposited material in Wlingi reservoir was likely dominated of suspended material from volcanic ash followed by top soil erosion from southern basin area. To increase calculation accuracy, more field observation (presence of sabo works and anthropogenic factors, sand mining) should be considered in results of bed load analysis as well as more grain size distribution need to be carried out.

The project has been helping in capacity building of the collaborators and partners in methodological knowledge transfer of sediment disaster management, best practices of disaster countermeasures. One potential area for further work is to carry out detailed capacity building including hands-on training on the methods utilized in this project. Extending the model application and improving the numerical evaluation of the model could be the second potential area for further work.

Acknowledgements

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