RESEARCH PROPOSAL
INTERNATIONAL RESEARCH COLLABORATION
AND SCIENTIFIC PUBLICATION

STUDY ON RIVER MORPHOLOGY AND SAND MINING MANAGEMENT IN VOLCANIC RIVER

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Assalamu 'alaikum w.w.
Dengan hormat,
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Judul Program	: Study on river morphology and sand mining management in volcanic river
Kategori	: Kemitraan Penelitian Internasional
Fakultas	: Teknik
Institusi Mitra	: 1. Kyoto University Japan Graduate School of Engineering Department of Civil and Earth Resources Engineering
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بسم الله الرحمن الرحيم

Dengan ini saya menyatakan bahwa:

1. Seluruh informasi yang kami sampaikan dalam proposal berjudul **Study on river morphology and sand mining management in volcanic river** atau lampirannya adalah absah dan sahih.
2. Menjamin terselenggaranya program ini sesuai dengan ketentuan yang berlaku di Universitas Muhammadiyah Yogyakarta.

Demikian surat pernyataan ini dibuat dengan penuh kesadaran, semoga Alloh s.w.t. meridhoi. Amiin.

Hormat kami,

Jazaul Ikhsan, ST., MT., PhD

Dekan Fakultas .....

SUMMARY

Mt. Merapi is one of the most active volcanoes in Indonesia. Some of rivers that the origin is located at Mt. Merapi have a large amount of sediment resources after eruption. So, the rivers have a potential of debris flow when the eruption occurs. The lava production will deposited at the upstream area and it flows to the downstream during wet season. Then the river has sediment resources in a large number. The flow that contains a large of sediment transport causes damages on river constructions. This phenomenon should be considered by engineering during make a planning for construction in the volcanic river. The lava production which deposited at the downstream area also attracts the people to conduct sand mining activities. Progo River has this phenomenon. Recently, the sand mining activities in Progo River is increasing dramatically due to the 2010 eruption of Mt. Merapi. So, the bed morphology on the downstream area should be considered intensively. The river management in volcanic river is an importance issue.

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CHAPTER 1. INTRODUCTION

The river reach of Progo River system that located in Bantar is chosen in order to examine the interaction of channel geometry, concentration of bedload and bed deformation. The watershed area of Progo River is around 17,432 square kilometers. Several tributaries of Progo River are located in the Mt. Merapi. The irrigation water of Sleman and Kulon Progo Distric are taken from the river. Many structures, for example, bridges, railway bridges, are cross the river. So, the sustainability of the river should be monitor by Yogyakarta government. Due to the major eruption in October 2010, the sediment supply is more than the equilibrium condition. Figure 1 shows the Progo River system.

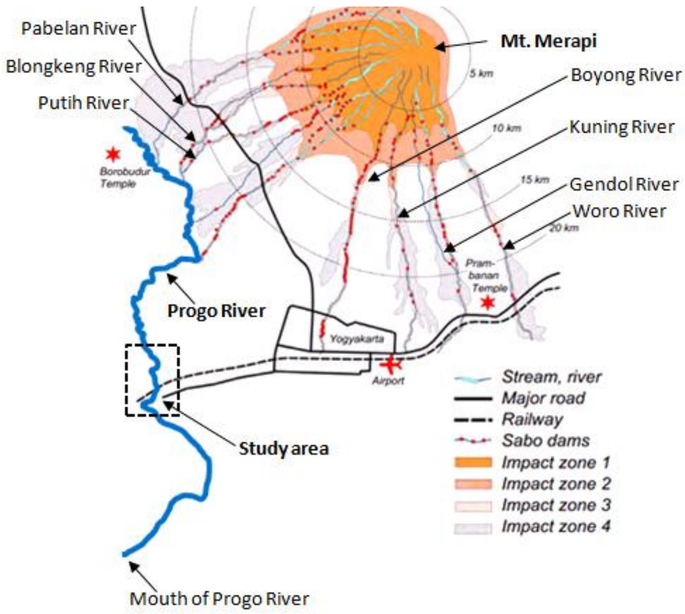

Figure 1 Location of study area

Mt. Merapi in Central Java, Indonesia had a major eruption on late October and early November 2010. The eruptions produced ash plumes, lahars, and pyroclastic flows. Therefore, a large number of sediment is deposited at the upstream of several volcanic rivers. It is approximately 130 million m^3. During rainy season, the deposited sediment flows to the downstream area and produced debris flow. The presence of debris flow increases the possibility riverbank erosion in some river reach, causing significant damage to various infrastructure and river structures. Hence the secondary disaster in term of rainfall induced debris flow may occur in long term period.

The sediment deposit produced by the eruptions of Mt. Merapi has market value, and its quality attracts sand miners. The sand mining activities have given some advantages for rural/local people, local government and reduced sediment run off. Sand and gravel material in Mt. Merapi offer many benefits such as employment opportunity, and an increase in economical benefit to farmers. Total number of mining workers in Mt. Merapi area amounts to about 21,000 man/day. The local government of Magelang Regency obtained benefit from the sand mining activities and the regency income increased from Rp. 236,000,000 (in fiscal 1997) into Rp. 2,218,000,000 (from fiscal 1998)4) . Klaten regency imposed a mining tax revenue of Rp 92,00,00 (in fiscal 1999) and Sleman regency imposed a mining tax revenue of Rp 500,000,000 (in fiscal 2000). It means that exploitation of sand and gravel material provides rural areas with considerable opportunities for economic development. However, uncontrolled sand mining has caused serious problems in the watershed such as unstableness of sediment control facility, bridge and irrigation intake by digging nearby, channel and riverbank instability due to riverbed degradation, and destruction of aquatic and riparian habitat due to natural and artificial armoring. As long as the sand mining is controlled, it can be one of measures for sediment control plan to give an extra empty in the sediment reservoirs and contribute to the rural economy.

The recent sand mining activities in Progo River tend to uncontrolled situation. The sand miners use the pump machine to take the sand from the river. The locations of sand mining are also near the river structures. For example, the sand mining at the Bantar Bridge is very active. From this point, sustainable sediment management assisted by sand mining is urgently necessary to mitigate the above issues.

Using field survey, experimental and numerical model, this research is to study (1) the change of morphology in Progo River due to the large bedload transport from the upstream to the downstream area and its impact on riverbed and riverbank deformation, (2) the stability of river structure in Progo River due to the change of river morphology and predicting in future condition (3) the amount of sand mining material that can be dredged from the river and its impact on river structures stability. The result from this research will be submitted in international journal, i.e. Journal of Sediment Research and Journal of Hydro Environment Research.

The Ujigawa Open Laboratory in Kyoto University is the one of the biggest laboratory in the world that has some experimental equipment to study the sediment transport related disaster management. Prof. Masaharu FUJITA is the head of this laboratory and very active for conducting the research on sediment related disaster especially in Mt. Merapi. The research collaborations are conducted with several universities in Indonesia. The recent joint research is namely SATREP which JICA, Kyoto University and Gadjah Mada University are the main institutions in those activities. And also, Prof. Yasunori MUTO (Tokushima University) conducts an investigation the sand mining in Progo River, recently. Regarding to the activities of both scientist, it is important to conduct research collaboration with Kyoto University and Tokushima University.

CHAPTER 2. LITERATURE REVIEW

The bedload transport and its impact on morphology have been studied by many researchers. Erosion or re-suspension is one of the important processes in cohesive sediment's transport system (Mehta *et al.*, 1989a and Mehta *et al.*, 1989b). Erosion is one of the main processes in river morphology. Many researchers have studied to clarify the erosion behavior of cohesive sediment, involving theoretical approaches, numerical analysis and field observations. They observed the erosion rate characteristics of cohesive sediments considering the physicochemical parameters. Those parameters are the salinity (Gularte *et al*., 1980 and Parchure and Mehta, 1985), temperature (Gularte *et al*., 1980 and Nishimori and Sekine, 2009), water content (Gularte *et al*., 1980 and Sekine and Izuka, 2000) and bulk density (Aberlea *et al*., and Parchure and Mehta, 1985). The results of those research show that the strength of the cohesive sediments is controlled by many parameters and explained as follow:

- the erosion resistance increases with increasing in salinity.
- the erosion resistance increases with increasing in temperature.
- the erosion resistance decreases with increasing in water content.
- the erosion resistance decreases with increasing in bulk density.

And also, they studied the erosion characteristics of cohesive sediment bed only using clear water as eroding media. However, the flow in natural rivers that containing only clear water are limited by the fact that most flows in rivers have sediment transport such as bed load, suspended or wash load. In other words, sediment transport is a common phenomenon in natural rivers and the transport rate depends on the flow characteristics. The presence of sediment transport changes the characteristics of the flow. This phenomenon also had observed by many researchers. The research's results on feedback effect of sediment transport on the flow characteristics are described below.

Kamphuis (1990) observed the influence of coarse sediment transport on erosion of cohesive bed. The test used both clear water and water containing sand as eroding media. The experiments show the importance of the variations of hydraulic condition to study the effect of bed-load transport in the flow. The various flow conditions are applied to analyze the effect of bed-load transport in erosion of cohesive bed.

Song and Chin (1998) used various supplied sediment to investigate the effect of bed-load's movement to the flow friction factor. The experiments compared the frictions between the flow in clear water and the flow containing both water and sand. The results showed that the presence of bed-load increases the friction factor. In other words, the bed load decreases the mean flow velocity. He argued that, the bed load transport extracts momentum from the flow and causes a reduction of flow velocity. These results give knowledge that the presence of bed-load transport can decreases the flow velocity and also the bed shear stress.

The results between Kamphuis (1990) and Song and Chin (1998) show that the bed load transports not only can decrease but also can increase the flow velocity. This phenomenon was agreed by Carbonneau and Bergeron (2000). In a given hydraulic condition, the flow that consist only clear water will produce different bed shear stress compare to the flow which has sediment transport.

The volume of bed-load transport increases the erosion rate of cohesive sediment when the bed-load transport rate under the small rate conditions. However, after achieving a certain volume, the erosion rate will decrease. This tendency indicates that the relationship between the volume of bed-load transport and erosion rate of cohesive sediment bed is a non-linear function. In fact, the volume or concentrations of the bed-load transport effects on the magnitude of the dynamic shear stress on the bed (Harsanto, 2012).

The bed-load transport in the real channel (in the river), which has equilibrium and non equilibrium are not explained clearly yet. The large of sediment supply due to the lahar material in Progo River has a potential to make the sediment transport in the river is not in equilibrium condition. And also the season in Indonesia is dry season and wet season, so, it is need to be investigated the volume of sediment transport both in dry and wet season. The river structures also need to be investigated to find correlation between sediment transport phenomenon and stability of the structures.

The Mt. Merapi's lava production data from 1890 to 1922 have been compiled by Siswowidjoyo et al., (1995). The production volumes of individual eruption events are varied widely from less than 1 million m^3 to more than 20 million m^3. The annual average lava production rate is approximately estimated at 1.2 million m^3. The sand mining volume in the foothills (upper area) of Mt. Merapi in 2000 is estimated at 5-6 x 10 6 m^3/year. The sand mining persists not only in the foothills area but also in the lower reach of river channel, especially in Progo River. It concentrated in the lower reach area, for example, in Bantar and Sapon area. The sand mining is estimated at about 2.933 m^3/day, Ikhsan (2009). Recently, due to the 2010 eruption, sand mining activities are very active and the equipment is not only manual system but using the pump machine. Obviously, the pump machine produces the rate of sand mining more than manual system. The pump causes a local lose of bed material in river channel, dramatically. The dramatically changes of riverbed morphology will produce the non equilibrium sediment transport in the river. This phenomenon occurs at Bantar area which has some river structures on it. There are three bridges, i.e., highway bridge, water supply (PDAM) bridge and railway bridge. So, it is importance to conduct an investigation about the volume rate of sand mining and the quantities of sand that can be pumped or dredged every day, so, the sediment transport still in equilibrium condition and the river construction is in stable condition. And also, the predicting of sustainability of sand mining should be investigated, because the sediment supply from the upstream is not continuously.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research Planning

The relation among of sand mining activities, bed-load transport and river morphology will be investigated using field survey, numerical simulation and laboratory experiment. The research of river morphology due to the sand mining and bed-load transport in Progo River are shown bellow.

(1) Basic research: The sand mining activities in Progo River (2009)

(2) Basic research: Bank erosion characteristics on cohesive and non-cohesive channel (2010)

(3) Basic research: Study on bank erosion processes with cohesive and non-cohesive material (2012)

(4) Basic research: Effect of bed-load transport on erosion rate bank erosion (2012)

(5) Application research: River Morphology Modeling at the Downstream of Progo River Post Eruption 2010 of Mount Merapi (2014)

(6) Application research: The behavior of riverbed degradation and aggradation along Progo River (2015)

(7) Application research: River morphology modeling at the upstream of Progo River Post Eruption 2010 of Mount Merapi (2016)

(8) Application research: River structures stability (2016)

(9) Application research: Sand mining management in Progo River (2016)

(10) Application research: River structures maintenance and management in Progo River (2017).

(11) Application research: Automatic sediment transport recorder (2017)

(12) Application research: River management policy in volcanic river (2018).

The flowchart of this research is shown in Figure 2.

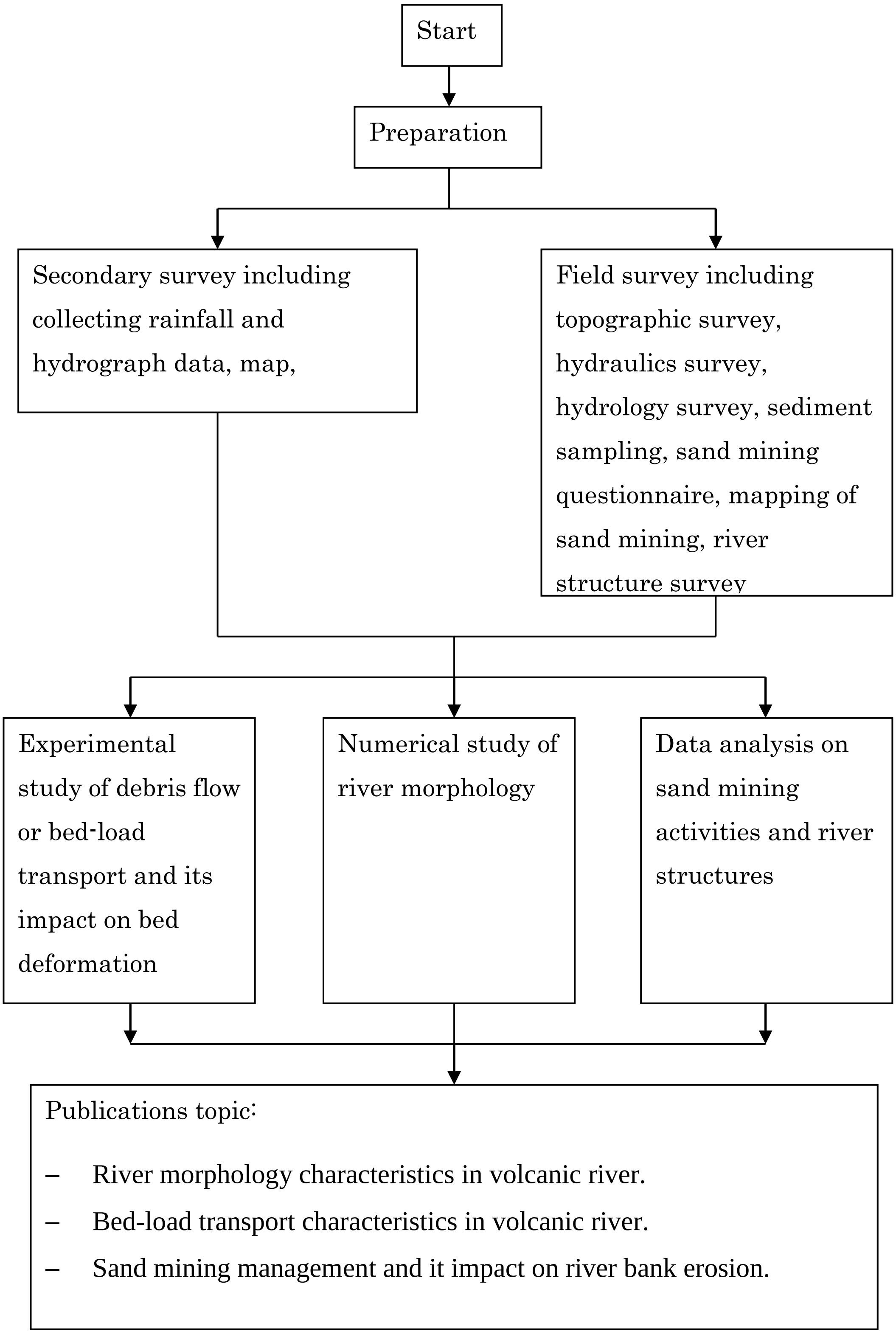

Figure 2 Research flow-chart in general

3.2. Field Study

Field data collecting are conducted in this step and will be done during dry and wet season. The activities are shown below.

(1) Geodetic survey is conducted to get the topographic condition of the river. The survey is located in the river reach that the changes of river morphology will be analyzed.

(2) Hydraulics survey is conducted to get the data of flow velocity.

(3) Riverbed and riverbank material sampling.

(4) Sediment transport survey. This activity is conducted to get the volume of bed-load transport and suspended load.

(5) The questionnaire survey consists of four parts, namely general information, rate of sand mining, socio-economic, perception on volcano hazard and sediment disaster prevention structures, and perception on impact of sediment disaster prevention structures on ecology.

3.3. Experimental Study

Location of experiments is in Ujigawa Open Laboratory (UOL) of Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan. The experiments were conducted in a tilting flume channel with 8 m long. The channel has a rectangular cross section with 0.15 m wide and 0.25 m height. Both of walls have rails on the top. A moveable point gauge is installed on the rails. The point gauge can move in the longitudinal and the transverse directions. Figure 1 illustrates the experimental setup from right side. Photo 1 shows the top view of the channel.

This research is addressed for investigation of the effect of bed load transport in erosion characteristics of cohesive material. Thus, all experiments use the same hydraulic condition to allow comparative analysis. Several preliminary experiments are conducted to determine the appropriate slope, discharge and size of bed load material. The appropriate condition means that the coarse sediment particles can move as bed load transport over the cohesive sediment bed. Also the flow condition should be set to avoid the local erosion on the bed.

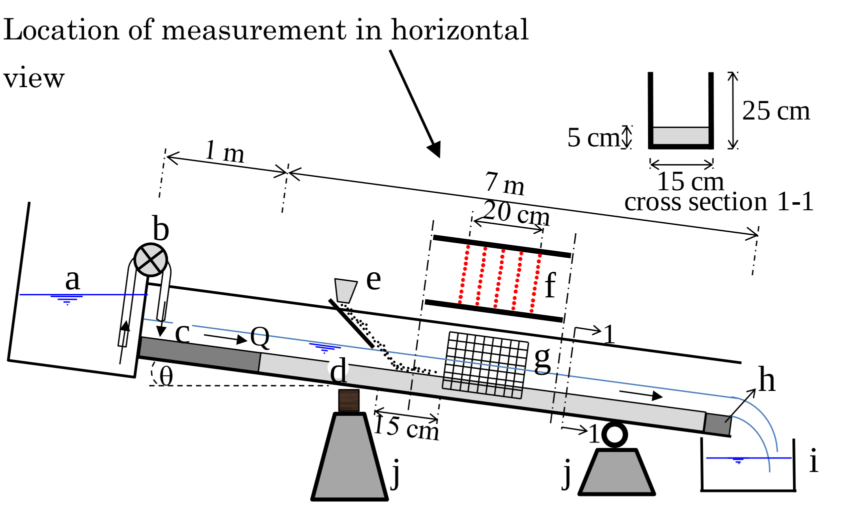

Figure 2 The experiment setup, where a) water tank, b) pump, c) rigid bed, d) cohesive sediment, e) sediment feeding location, f) horizontal view of cross sections, g) screen grid, h) downstream weir, i) downstream tank, and j) tilting machine)

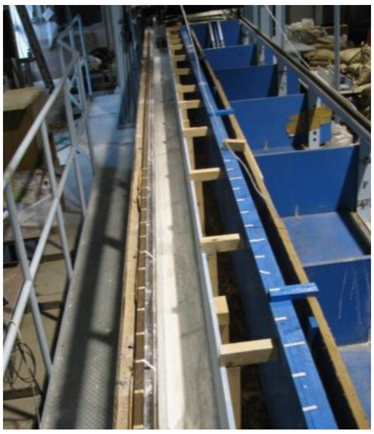

Photo 1 The flume test channel and the flow direction is to bottom side

3.4 Numerical Study

Numerical simulations are performed using the horizontal two-dimensional flow model which the equations are written in general coordinate system. The model uses the finite difference method to solve the different equations. Relationship between Cartesian coordinate system and General coordinate system is as follows.

.

$$J = \frac{1}{\left(\frac{\partial x}{\partial \xi}\frac{\partial y}{\partial \eta} - \frac{\partial x}{\partial \eta}\frac{\partial y}{\partial \xi}\right)} \quad (1a)$$

$$\frac{\partial \xi}{\partial x} = J\frac{\partial y}{\partial \eta} \quad (1b)$$

$$\frac{\partial \eta}{\partial x} = -J\frac{\partial y}{\partial \xi} \quad (1c)$$

$$\frac{\partial \xi}{\partial y} = -J\frac{\partial x}{\partial \eta} \quad (1d)$$

$$\frac{\partial \eta}{\partial y} = J\frac{\partial x}{\partial \xi} \quad (1e)$$

Where, ξ and η are the coordinates along the longitudinal and the transverse directions in generalized coordinate system, respectively, x and y are the coordinates in Cartesian coordinate system. Computation of surface flow is carried out using the governing equation of the horizontal two-dimensional flow averaged with depth. The conservation of mass, i.e., inflow and outflow of mass by seepage flow, is taken into consideration as shown in the following equation [1].

$$\Lambda\frac{\partial}{\partial t}\left(\frac{z}{J}\right) + \frac{\partial}{\partial \xi}\left(\left(\frac{\partial \xi}{\partial t} + U\right)\frac{h}{J}\right) + \frac{\partial}{\partial \eta}\left(\left(\frac{\partial \eta}{\partial t} + V\right)\frac{h}{J}\right) + \frac{\partial}{\partial \xi}\left(\left(\frac{\partial \xi}{\partial t} + U_g\right)\frac{h_g}{J}\right) + \frac{\partial}{\partial \eta}\left(\left(\frac{\partial \eta}{\partial t} + V_g\right)\frac{h_g}{J}\right) = 0 \quad (2)$$

Where, t is the time, z is the water surface level. Surface flow depth is represented as h, seepage flow depth is h_g. U and V represent the contravariant depth averaged flow velocity on bed along ξ and η coordinates, respectively.

These velocities are defined as

$$U = \frac{\partial \xi}{\partial x} u + \frac{\partial \xi}{\partial y} v \tag{3a}$$

$$V = \frac{\partial \eta}{\partial x} u + \frac{\partial \eta}{\partial y} v \tag{3b}$$

where, u and v represent depth averaged flow velocity on bed along x and y coordinates, respectively. U_g and V_g represent the contravariant depth averaged seepage flow velocity along ξ and η coordinates, respectively. These velocities are defined as

$$U_g = \frac{\partial \xi}{\partial x} u_g + \frac{\partial \xi}{\partial y} v_g \tag{4a}$$

$$V_g = \frac{\partial \eta}{\partial x} u_g + \frac{\partial \eta}{\partial y} v_g \tag{4b}$$

where, depth averaged seepage flow velocities along x and y coordinates in Cartesian coordinate *system* are shown as u_g, v_g, respectively. Λ is a parameter related to the porosity in the soil, wherein $\Lambda = 1$ as $z \gamma z_b$, and $\Lambda = \lambda$ as $z < z_b$, where z_b is the bed level and λ is the porosity in the soil. Seepage flow is assumed as horizontal two-dimensional saturation flow. Momentum equations of surface water are as follows.

$$\begin{aligned}
&\frac{\partial}{\partial t}\left(\frac{hU}{J}\right) + \frac{\partial}{\partial \xi}\left(\left(\frac{\partial \xi}{\partial t} + U\right)\frac{hU}{J}\right) + \frac{\partial}{\partial \eta}\left(\left(\frac{\partial \eta}{\partial t} + V\right)\frac{hU}{J}\right) \\
&\quad - \frac{hu}{J}\left(\frac{\partial}{\partial t}\left(\frac{\partial \xi}{\partial x}\right) + \left(\frac{\partial \xi}{\partial t} + U\right)\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial x}\right) + \left(\frac{\partial \eta}{\partial t} + V\right)\frac{\partial}{\partial \eta}\left(\frac{\partial \xi}{\partial x}\right)\right) \\
&\quad - \frac{hv}{J}\left(\frac{\partial}{\partial t}\left(\frac{\partial \xi}{\partial y}\right) + \left(\frac{\partial \xi}{\partial t} + U\right)\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial y}\right) + \left(\frac{\partial \eta}{\partial t} + V\right)\frac{\partial}{\partial \eta}\left(\frac{\partial \xi}{\partial y}\right)\right) \\
&\quad = -gh\left(\frac{1}{J}\left(\left(\frac{\partial \xi}{\partial x}\right)^2 + \left(\frac{\partial \xi}{\partial y}\right)^2\right)\frac{\partial z_s}{\partial \xi} + \frac{1}{J}\left(\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x} + \frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial z_s}{\partial \eta}\right) - \frac{\tau_{b\xi}}{\rho J} \\
&\qquad + \frac{1}{J}\left(\frac{\partial \xi}{\partial x}\right)^2 \frac{\partial}{\partial \xi}(h\sigma_{xx}) + \frac{1}{J}\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}\frac{\partial}{\partial \eta}(h\sigma_{xx}) + \frac{1}{J}\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial x}\frac{\partial}{\partial \eta}(h\tau_{yx}) + \frac{1}{J}\frac{\partial \xi}{\partial y}\frac{\partial \xi}{\partial x}\frac{\partial}{\partial \xi}(h\tau_{yx}) \\
&\qquad + \frac{1}{J}\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial y}\frac{\partial}{\partial \eta}(h\tau_{xy}) + \frac{1}{J}\frac{\partial \xi}{\partial x}\frac{\partial \xi}{\partial y}\frac{\partial}{\partial \xi}(h\tau_{xy}) + \frac{1}{J}\left(\frac{\partial \xi}{\partial y}\right)^2 \frac{\partial}{\partial \xi}(h\sigma_{yy}) + \frac{1}{J}\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\frac{\partial}{\partial \eta}(h\sigma_{yy})
\end{aligned} \tag{5a}$$

$$\begin{aligned}
&\frac{\partial}{\partial t}\left(\frac{hV}{J}\right)+\frac{\partial}{\partial \xi}\left(\left(\frac{\partial \xi}{\partial t}+U\right)\frac{hV}{J}\right)+\frac{\partial}{\partial \eta}\left(\left(\frac{\partial \eta}{\partial t}+V\right)\frac{hV}{J}\right)\\
&\quad-\frac{hu}{J}\left(\frac{\partial}{\partial t}\left(\frac{\partial \eta}{\partial x}\right)+\left(\frac{\partial \xi}{\partial t}+U\right)\frac{\partial}{\partial \xi}\left(\frac{\partial \eta}{\partial x}\right)+\left(\frac{\partial \eta}{\partial t}+V\right)\frac{\partial}{\partial \eta}\left(\frac{\partial \eta}{\partial x}\right)\right)\\
&\quad-\frac{hv}{J}\left(\frac{\partial}{\partial t}\left(\frac{\partial \eta}{\partial y}\right)+\left(\frac{\partial \xi}{\partial t}+U\right)\frac{\partial}{\partial \xi}\left(\frac{\partial \eta}{\partial y}\right)+\left(\frac{\partial \eta}{\partial t}+V\right)\frac{\partial}{\partial \eta}\left(\frac{\partial \eta}{\partial y}\right)\right)\\
&\quad=-gh\left(\frac{1}{J}\left(\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}+\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial z_s}{\partial \xi}+\frac{1}{J}\left(\left(\frac{\partial \eta}{\partial x}\right)^2+\left(\frac{\partial \eta}{\partial y}\right)^2\right)\frac{\partial z_s}{\partial \eta}\right)-\frac{\tau_{b\eta}}{\rho J}\\
&\qquad+\frac{1}{J}\frac{\partial \eta}{\partial x}\frac{\partial \xi}{\partial x}\frac{\partial}{\partial \xi}(h\sigma_{xx})+\frac{1}{J}\left(\frac{\partial \eta}{\partial x}\right)^2\frac{\partial}{\partial \eta}(h\sigma_{xx})+\frac{1}{J}\frac{\partial \eta}{\partial y}\frac{\partial \xi}{\partial x}\frac{\partial}{\partial \xi}(h\tau_{yx})+\frac{1}{J}\frac{\partial \eta}{\partial y}\frac{\partial \eta}{\partial x}\frac{\partial}{\partial \eta}(h\tau_{yx})\\
&\qquad+\frac{1}{J}\frac{\partial \eta}{\partial x}\frac{\partial \xi}{\partial y}\frac{\partial}{\partial \xi}(h\tau_{xy})+\frac{1}{J}\frac{\partial \eta}{\partial x}\frac{\partial \eta}{\partial y}\frac{\partial}{\partial \eta}(h\tau_{xy})+\frac{1}{J}\frac{\partial \eta}{\partial y}\frac{\partial \xi}{\partial y}\frac{\partial}{\partial \xi}(h\sigma_{yy})+\frac{1}{J}\left(\frac{\partial \eta}{\partial y}\right)^2\frac{\partial}{\partial \eta}(h\sigma_{yy})
\end{aligned} \tag{5b}$$

Where, g is the gravity, ρ is the water density. $\tau_{b\xi}$ and $\tau_{b\eta}$ represent the contravariant shear stress along ξ and η coordinates, respectively. These shear stresses are defined as

$$\tau_{b\xi}=\frac{\partial \xi}{\partial x}\tau_{bx}+\frac{\partial \xi}{\partial y}\tau_{by} \tag{6a}$$

$$\tau_{b\eta}=\frac{\partial \eta}{\partial x}\tau_{bx}+\frac{\partial \eta}{\partial y}\tau_{by} \tag{6b}$$

where, τ_x and τ_y are the shear stress along x and y coordinates, respectively as follows.

$$\tau_x=\tau_b\frac{u_b}{\sqrt{u_b^2+v_b^2}} \tag{7a}$$

$$\tau_y=\tau_b\frac{v_b}{\sqrt{u_b^2+v_b^2}} \tag{7b}$$

$$\frac{\tau_b}{\rho}=u_*^2 \tag{8}$$

$$u_*^2=\frac{n_m^2 g}{R^{1/3}}\left(u^2+v^2\right) \tag{9}$$

Where, u_* is the friction velocity, n_m is the Manning's roughness coefficient, R is the hydraulic radius, k_s is the roughness height. u_b and v_b represent velocity near the bed surface along x and y coordinates, respectively. Velocities near the bed are evaluated using curvature radius of streamlines as follows.

$$u_b = u_{bs}\cos\alpha_s - v_{bs}\sin\alpha_s \tag{10a}$$

$$v_b = u_{bs}\sin\alpha_s + v_{bs}\cos\alpha_s \tag{10b}$$

$$u_{bs} = 8.5u_* \tag{11}$$

$$v_{bs} = -N_*\frac{h}{r}u_{bs} \tag{12}$$

Where, $\alpha_s = \arctan(v/u)$, N_* is 7.0 [2]. r is the curvature radius of stream lines obtained by depth integrated velocity field as follows [3].

$$\frac{1}{r} = \frac{1}{\left(u^2+v^2\right)^{3/2}}\left\{u\left(u\frac{\partial v}{\partial x} - v\frac{\partial u}{\partial x}\right) + v\left(u\frac{\partial v}{\partial y} - v\frac{\partial u}{\partial y}\right)\right\} \tag{13}$$

σ_{xx}, σ_{yy}, τ_{xy} and τ_{yx} are turbulence stresses as follows.

$$\sigma_{xx} = 2\nu\frac{\partial u}{\partial x} \tag{14a}$$

$$\sigma_{yy} = 2\nu\frac{\partial v}{\partial y} \tag{14b}$$

$$\tau_{xy} = \tau_{yx} = \nu\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right) \tag{15}$$

$$\nu = \frac{\kappa}{6}u_* h \tag{16}$$

Where, ν is the coefficient of kinematics eddy viscosity, κ is the Karman constant, k_t is the depth-averaged turbulence kinetic energy [1].

$$u_g = -k_{gx}\left(\frac{\partial\xi}{\partial x}\frac{\partial z_b}{\partial\xi} + \frac{\partial\eta}{\partial x}\frac{\partial z_b}{\partial\eta}\right) \tag{17a}$$

$$v_g = -k_{gy}\left(\frac{\partial\xi}{\partial y}\frac{\partial z_b}{\partial\xi} + \frac{\partial\eta}{\partial y}\frac{\partial z_b}{\partial\eta}\right) \tag{17b}$$

Where, k_{gx} and k_{gy} is the coefficient of permeability along the longitudinal and the transverse directions, respectively. When the water depth of surface flow becomes less than the mean diameter of the bed material, the surface flow is computed only in consideration of the pressure term and bed shear stress term in the momentum equation of surface flow [4].

Grain size distribution is evaluated using the sediment transport multilayer model as follows [5]:

$$\frac{\partial}{\partial t}\left(\frac{c_b E_b f_{bk}}{J}\right)+(1-\lambda)F_{bk}\frac{\partial}{\partial t}\left(\frac{z_b}{J}\right)+\left(\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial t}\frac{c_b E_b f_{bk} r_b}{J}+\frac{q_{b\xi k}}{J}\right)+\frac{\partial}{\partial \eta}\left(\frac{\partial \eta}{\partial t}\frac{c_b E_b f_{bk} r_b}{J}+\frac{q_{b\eta k}}{J}\right)\right)=0 \quad (18a)$$

$$\begin{cases} F_{bk} = f_{d1k}, & \partial z_b/\partial t \le 0 \\ F_{bk} = f_{bk}, & \partial z_b/\partial t \ge 0 \end{cases} \quad (18b)$$

$$\frac{\partial}{\partial t}\left(\frac{E_{d1} f_{d1k}}{J}\right)-F_{dk}\frac{\partial}{\partial t}\left(\frac{E_{d1}}{J}\right)=0 \qquad \begin{cases} F_{dk} = f_{d1k}, & \partial z_b/\partial t \le 0 \\ F_{dk} = f_{bk}, & \partial z_b/\partial t \ge 0 \end{cases} \quad (18c)$$

In the formulae above, f_{bk} is the concentration of bed-load of size class k in the bed-load layer, f_{dlk} is the sediment concentration of size class k in the m^{th} bed layer, c_b is the depth-averaged concentration of bed-load. E_{be} is the equilibrium bed-load layer thickness; it is estimated by the following equation [6]:

$$\frac{E_{be}}{d_m}=\frac{1}{c_b\cos\theta(\tan\phi-\tan\theta)}\tau_{*m} \quad (19)$$

where d_m is the mean diameter of bed-load, ϕ is the angle of repose, and τ_{*m} is the non-dimensional shear stress of mean diameter. E_{sd} is the sediment layer thickness on cohesive sediment bed. E_b is the bed-load layer thickness, $q_{b\xi k}$ and $q_{b\eta k}$ are the bed-load of size class k in ξ and η directions, respectively, q_{bxk} and q_{byk} are the bed-load of size class k in x and y directions, respectively as follows [7] [8].

$$q_{bxk}=q_{bk}\cos\beta_k \quad (20a)$$

$$q_{byk}=q_{bk}\sin\beta_k \quad (20b)$$

$$q_{bk}=17\frac{\rho u_{*e}^3}{(\rho_s-\rho)g}\left(1-\sqrt{K_c}\frac{u_{*ck}}{u_*}\right)\left(1-K_c\frac{u_{*ck}^2}{u_*^2}\right)f_{bk} \quad (20c)$$

Therein, ρ_s is the sediment density, u_{*e} is the effective shear velocity, the non-dimensional critical friction velocity of size class *k* is evaluated as follows [7].

$$u_{*ck}^2 = u_{*cm}^2 \left[\frac{\log_{10} 19}{\log_{10}\left(19 d_k / d_m\right)} \right]^2 \frac{d_k}{d_m} \quad (21a)$$

$$d_k / d_m \geq 0.4 \quad (21b)$$

$$u_{*ck}^2 = 0.85 u_{*cm}^2 \quad (22a)$$

$$d_k / d_m \leq 0.4 \quad (22b)$$

Iwagaki's formula which is formulated for uniform bed material is used for evaluating u_{*cm}. K_c is the correction factor due to the influence of bed inclination on sediment motion [9].

$$K_c = 1 + \frac{1}{\mu_s}\left[\left(\frac{\rho}{\rho_s - \rho} + 1\right)\cos\alpha\tan\theta_x + \sin\alpha\tan\theta_y\right] \quad (23)$$

where α is the angle of deviation of near-bed flow from the x direction as follows.

$$\alpha = \arctan\left(\frac{v_b}{u_b}\right) \quad (24)$$

μ_s is the coefficient of static friction. θ_x and θ_y are bed inclinations in x and y directions, respectively. These inclinations are evaluated as follows,

$$\theta_x = \arctan\left(\frac{\partial\xi}{\partial x}\frac{\partial z_b}{\partial\xi} + \frac{\partial\eta}{\partial x}\frac{\partial z_b}{\partial\eta}\right) \quad (25a)$$

$$\theta_y = \arctan\left(\frac{\partial\xi}{\partial y}\frac{\partial z_b}{\partial\xi} + \frac{\partial\eta}{\partial y}\frac{\partial z_b}{\partial\eta}\right) \quad (25b)$$

Hence, the local bed slope along direction of bed-load of sediment mean diameter (θ) is obtained as follows.

$$\sin\theta = \cos\beta_m \sin\theta_x + \sin\beta_m \sin\theta_y \tag{26}$$

where β_m is the deviation angle of bed-load of mean diameter to the x direction. The deviation angle of bed-load of size class k to the x direction (β_k), which depends on the flow near bed and inclination of the bed, is calculated by the following relation

$$\tan\beta_k = \frac{\sin\alpha - \Pi\Theta_y \left(\frac{u_{*ck}^2}{u_*^2}\right)\tan\theta_y}{\cos\alpha - \Pi\Theta_x \left(\frac{u_{*ck}^2}{u_*^2}\right)\tan\theta_x} \tag{27a}$$

$$\Pi = K_{ld} + 1/\mu_s \tag{27b}$$

$$\Theta_y = \frac{1}{1 + \tan^2\theta_x + \tan^2\theta_y} \tag{27c}$$

$$\Theta_x = \Theta_y + \frac{\rho}{\rho_s - \rho}\cos^2\theta_x \tag{27d}$$

Evolution of bed elevation is estimated by means of the following formulae.

$$\frac{\partial}{\partial t}\left(\frac{c_b E_b}{J}\right) + (1-\lambda)\frac{\partial}{\partial t}\left(\frac{z_b}{J}\right) + \left(\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial t}\frac{c_b E_b}{J} + \sum_{k=1}^{n}\frac{q_{b\xi k}}{J}\right) + \frac{\partial}{\partial \eta}\left(\frac{\partial \eta}{\partial t}\frac{c_b E_b}{J} + \sum_{k=1}^{n}\frac{q_{b\eta k}}{J}\right)\right) = 0 \tag{28}$$

In them, n represents the number of the size class of sediment.

CHAPTER 4. BUDGET AND RESEARCH PLAN

4.1 Budget

The budget of this research is shown in Table 1.

Table 1 Research budget 2016

No.	Activity	Budget	Percent of total budget (%)
1	Topography (Geodetical) survey and analysis	Rp 70,000,000.00	23
2	Sediment transport measurement	Rp 25,000,000.00	8
3	River structures survey	Rp 35,000,000.00	12
4	Sand mining survey	Rp 35,000,000.00	12
5	Experimental study	Rp 20,000,000.00	7
6	Numerical simulation	Rp 10,000,000.00	3
7	Data analysis	Rp 25,000,000.00	8
8	Publication	Rp 15,000,000.00	5
9	Fee (researcher, assitent and surveyor)	Rp 55,000,000.00	18
10	Transportation	Rp 10,000,000.00	3
	Total budget	Rp 300,000,000.00	100

4.2 Research Plan

The general research plan is show in Table 2.

Table 2 Research plan on river morphology of volcanic river

No.	Research Plan	Year									
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Basic research: The sand mining activities in Progo River (2009)	■									
2	Basic research: Bank erosion characteristics on cohesive and non-cohesive channel (2010)	■	■								
3	Basic research: Study on bank erosion processes with cohesive and non-cohesive material (2012)		■	■							
4	Basic research: Effect of bed-load transport on erosion rate bank erosion (2012)			■	■						
5	Application research: River Morphology Modeling at the Downstream of Progo River Post Eruption 2010 of Mount Merapi (2014)					■					
6	Application research: The behavior of riverbed degradation and aggradation along Progo River (2015)						■	■			
7	Application research: River morphology modeling at the upstream of Progo River Post Eruption 2010 of Mount Merapi (2016)							■	■		
8	Application research: River structures stability (2016)								■	■	
9	Application research: Sand mining management in Progo River (2016)								■	■	
10	Application research: River structures maintenance and management in Progo River (2017).									■	
11	Application research: Automatic sediment transport recorder (2017)									■	
12	Application research: River management policy in volcanic river (2018).										■

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SUMMARY OF RESEARCH COLLABORATION WITH RESEARCH PARTNER.

Jazaul Ikhsan, ST., MT., PhD, Puji Harsanto, ST., MT., PhD and Prof. Masaharu FUJITA

1. Harsanto, P., Takebayashi, H., and Fujita, M.: Study on bank erosion processes with cohesive and non-cohesive material, Proceeding Annual Meeting of Japan Society of Erosion Control Engineering, JSECE Publication, No.66, pp. 288-289, 2012.
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3. Harsanto, P., Takebayashi, H., and Fujita, M.: Numerical analysis on countermeasures of bank erosion, Proceeding Int. Symposium on Sediment Disasters under the Influence of Climate Change and Tectonic Activity (2nd), JSECE Publication, No.63, pp. 44-45, 2011.
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5. Ikhsan, J., Fujita, M., and Takebayashi, H.: Study on sediment disaster and resources management in Mount Merapi area, Proceeding of Annual Meeting of Japan Society of Civil Engineers, JSCE, pp. 497-498, September, 2010.
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7. Ikhsan, J., Fujita, M., and Takebayashi, H.: Impacts of sediment management on socio-economic and environment in Mt. Merapi area, Proceeding of Annual Meeting of Japan Society of Erosion Control Engineering, JSECE Publication No.57, pp. 472-473, May, 2010.

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9. Ikhsan, J., Fujita, M., and Takebayashi, H.: Study on sediment management in volcanic area by considering disasters mitigation and resources management, *Proceeding of International Workshop on Multimodal Sediment Disasters Triggered by Heavy Rainfall and Earthquake and the Countermeasures*, pp. 67-76, March, 2010..
10. On going, Joint research SATREP 2015 to 2017.

Latter of Agreement

Prof. Masaharu FUJITA

Kyoto University Japan

Letter of Agreement for Research Collaboration

Dear Dr. Jazaul Ikhsan and Dr. Puji Harsanto,

As our previously negotiated, I would like to support your research entitled "Study on River Morphology and Sand Mining Management in Volcanic River". I am very interested in the topic. For supporting this research, you can do an experiment/numerical simulation in Ujigawa Open Laboratory, Kyoto University, Japan.

Kyoto, July 9th, 2015

藤田正治

Prof. Masaharu Fujita (Dr. Eng)
Disaster Prevention Research Institute,
Kyoto University, Japan
E-mail : fujita.masaharu.5x@kyoto-u.ac.jp
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Supporting in research:

The activity in Kyoto is an experimental investigation that study the impact of debris flow on channel bed deformation. Flume Test in Ujigawa Open Laboratory (UOL) is under Disaster Prevention Research Institute (DPRI), Kyoto University Kyoto Japan. The channel flume test is a tilting flume channel with 8 m long. The channel has a rectangular cross section with 0.15 m wide and 0.25 m height. Both of walls have rails on the top. A moveable laser point gauge is installed on the rails. This experimental test supports the research in 25%.

Letter of Agreement

Dear Dr. Jazaul Ikhsan and Dr. Puji Harsanto,

As our previously discussion, I would like to support your research entitled "Study on River Morphology and Sand Mining Management in Volcanic River". I am very interested in the topics. For supporting this research, you can do a part of the research in Department of Civil Engineering and Environmental Engineering, Tokushima University, Japan.

Tokushima, July 9th, 2015

Prof. Yasunori Muto (Ph.D)

Department of Civil and Environmental Engineering,

Tokushima University, Japan

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Workshop Civil Engineering Laboratory

List of equipments that will use in this research are shown below.

1. Digital Teodollite, topography survey to get channel geometry.
2. Camera, documentation survey.
3. PC, numerical simulation.
4. Sediment trapping, sampling the sediment transport in river.
5. Current meter, measure flow velocity in river.
6. Sieve equipment, riverbed material gradation (coarse material).
7. Geomatical equipment, riverbed material gradation (fine material).
8. Laser meter, topographic survey.

Curriculum Vitae

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Academics

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Curriculum Vitae

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Publications

- Harsanto, P., River Morphology Modeling at the Downstream of Progo River Post Eruption 2010 of Mount Merapi, Proceeding Annual Conference, 5th International Conference on Sustainable Future for Human Security, SustaiN 2014
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Affiliated programs (koza)	Org1： 工学研究科 Org2： 工学研究科 Org3： 社会基盤工学専攻

Activity Database on Education and Research, Kyoto University

				review	
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Academic Qualifications:

1997	Ph.D	Hydraulic Engineering, University of Bradford (UK)
1992	M.Eng.	Transportation Engineering, Kyoto University
1989	B.Eng.	Transportation Engineering, Kyoto University

Membership and Committees:

1995 Japan Society for Natural Disaster Science
1994 International Association for Hydro-Environmental Engineering and Research
1989 Japan Society of Civil Engineering

Present and recent interests of research:

- Flow and Fluvial Processes on Disaster Mitigation and Environment Restoration

Research Publications:

Refereed Journal Articles:

Takeyama, Y., Ohsawa, T., Yamashita, T., Kozai, K., Muto, Y., Baba, Y. and Kawaguchi, K.: Estimation of offshore wind resources in coastal waters off Shirahama using ENVISAT Advanced SAR images, Remote Sensing, 2013.

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