Contingency planning of Mount Bromo’s cold lava flood in Probolinggo peri-urban areas

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Abstract. Probolinggo municipal is nearly located to Mount Bromo which may affected by cold lava flood as the impact of volcanic eruption. In the last eruption on 2015, twelve precints are under risk of and affected by cold lava overflow. Contingency plan is required to increase the community awareness in affected area. This paper aims to formulate a comprehensive account of community-based cold lava flood contingency plan in Probolinggo peri-urban areas. The method used in this research based on common disaster-risk management process. The first step is identifying the damages and losses caused by cold lava flood. Then analyzing the evacuation routes, sectoral planning, and facility needs to formulate the contingency plan. The results then combined with the stakeholder’s perception among governments, organizations, and communities through Focus Group Discussions. The finding shows that the impact level of cold lava flood is up to 1.25 meter high within 2 days and mainly affect Dringu River areas. Then, based on the Closest Distance Analysis, the selected evacuation route is 14 routes to an assembly point in the Karang Lor Gas Station, Wonoasih Military Headquarter Field, Kedunggalen Field and Mastrip Sports Hall. Contingency plan consists of scenario, sectoral planning, facility needs, policies and strategies according to lava flood prevention sectors. Seven sectors are classified; consist of management and coordination, information and communication, evacuation and protection, health, refuge, infrastructure, and logistics distribution sector.

Keywords: Bromo, could lava flood, contingency

1. Introduction
Probolinggo municipal is located in Java’s coastal area and has a relatively flat and lowland. It caused potentially high and various disasters risk. In addition, this city is located 33.2 km to Mount Bromo which may affected by volcanic eruption. Mount Bromo is an active volcano of a strombolian eruption type with an altitude of 2,329 m above sea level [1]. Its eruption activity contains eruptive products particularly volcanic ash and lava flows which formed when hot spatter melts together and flows downslope [2]. Cold lava flood, which categorized as secondary hazard of volcanic eruption activity, occurs when the precipitate of volcanic erupted material on top and slope and transported by rain or surface water [3]. This flood carried mudflow that possibly transport materials, change the river areas topography it passed, and damage the infrastructure surrounded.
Bromo erupted for every 5 years eruption period with low explosivity level but long last enough. In the last eruption on 2015, twelve precintes are under risk of being affected by cold lava overflow. There are Triwung Kidul, Triwung Lor, Ketapang, Wonoasih, Pakistaji, Kedopok, Kareng Lor, Sumber Wetan, Pohsangit Leres, Kedunggalen, Ketangasem, and Sumber Taman. Lava flood has been increasing on several rivers, specifically Pessir, Legundi and Drigun River, which exactly flow in Probolinggo peri-urban areas. Based on the previous lava flood events and potentially geological phenomenon of Mount Bromo that is unstable in the last ten years, it is necessary to anticipate the potential possibility of cold lava floods as the impact of Mount Bromo eruption.

Disaster risk reduction in Probolinggo municipal, included cold lava floods, has not refer to systematic and planned procedures, so the decision making is often overlap and even important efforts are not well managed. National Act No. 24 of 2007 on Disaster Management and Government Regulation No. 21 of 2008 on Disaster Management Organization clearly describe the roles and responsibilities for organising disaster management. Furthermore, disaster management has been stated as priority issue summarized in Probolinggo Medium Term of Development Program 2015-2019.

In order to build coordinated, planned and integrated form in cold lava flood management in Probolinggo, a research is needed as stakeholder’s reference for decision making which is appropriately allocate resources. For that reason, contingency planning may useful in preparedness phase of cold lava flood so that it is very important for faster, precise, effective, and efficient response.

Childs & Dietrich [4] mentioned contingency as “The additional effort should be prepared for unexpected or quickly changing circumstances”. Contingency planning provides guidance for managing catastrophic events by defining who possess the capabilities, resources and ability to coordinate response to foreseen, unforeseen and extreme disasters [5]. These two definitions indicate the relevance of contingency plan for increasing the community awareness in affected area. Through contingency planning, the consequences of unexpected circumstances can be minimized by developing scenarios and projecting needs assumptions for emergency response. This paper aims to formulate a comprehensive account of community-based cold lava flood contingency plan in Probolinggo peri-urban areas.

2. Methods
In responding the situation above, a research on contingency planning can decrease the impact of cold lava flood, primarily in Probolinggo peri-urban areas. Contingency plan should be simultaneously planned by multisector stakeholders involved. Lack of coordination in assigning responsibilities, action, and procedures in planning will have significant impact on events [6]. The method used in this research is based on common disaster risk management process. The first step is identifying the damages and losses caused by cold lava flood. Variables used in the assessment include the flood duration, depth, and types of damage and losses experienced include 5 aspects, that are social/community aspect, facilities/infrastructure aspect, economical aspect, governmental aspect, and environmental aspect.

The next stage is analysing the evacuation routes using Closest Distance Analysis that consist several alternative routes for emergency response. This analysis determines the best evacuation route selection based on evacuation location, closest distance, and community indicator [7] [8] [9] [10].

Then, determining sectoral planning and facility needs to formulate the contingency plan. The contingency planning will focus on how the communities can immediately response to the future cold lava flood event. The results are then combined and verified with the stakeholder’s perception among governments, organizations, and communities through Focus Group Discussions (FGD). There are useful ways to formulate contingency plan by integrate knowledge of local community and the experience of the technical personnel competent in handling the disaster [11]. Thus, the application of contingency plan can potentially lead to effective response.
3. Results

3.1. Identification of Damages and Losses Caused by Cold Lava Flood

Based on transect mapping and interview on Nopember 2016, cold lava flood has been increasing on several rivers, that are Pesisir River, Legundi River, and Dringu River. Those three rivers are located in Probolinggo peri-urban areas and have characteristics as follows:

- **Pesisir River** on the eastern part of the area passes through Ketapang, Triwung Lor and Triwung Kidul precinct. The water debit is approximately 189 liters/second during the rainy season and 142 liters/second during dry season. It has 2,210 meters in length with 15-20 meters surface width, 12-17 meters base width, and 5-6 meters height. Potentially affected objects around this river are such as settlements, public facilities, agricultural areas and livestock.

- Legundi River on the southern part of the area passes through Pohsangit Leres, Sumber Wetan, Kareng Lor, Wonoasih, Kedopok and Pakistaji precinct. The water debit is approximately 434 liters/second during the rainy season and decreasing into 318 liters/second during dry season. It has 7,416 meters in length with 10-13 meters surface width, 9-12 meters base width, and 3-4 meters height. Potentially affected objects around this river are such as settlements, public facilities, floodgate, also rice and corn farmland.

- Dringu River on the south-eastern part of the area, passes through Kedunggaleng, Kedungasem, and Sumber Taman precinct. The water debit is approximately 1,279 liters/second during the rainy season and decreasing into 201 liters/second during dry season. It has 5,750 meters in length with 30-35 meters surface width, 25-30 meters base width, and 5-6 meters height. Potentially affected objects around this river are such as public facilities and agricultural area.

Identification of damages and losses caused by cold lava flood are based on 5 aspects of affected objects, that are social/community aspect, facilities/infrastructure aspect, economical aspect, governmental aspect, and environmental aspect.

- Impacts on social/community aspect such as death, injuries, refuge, disappearance, etc.
- Impacts on facilities/infrastructure aspect such as road, bridge, settlements, water supply installation, communication network, power grid, and others public facilities damaged.
- Impacts on economical aspect such as corp failure, inhibited access, trade disruption, etc.
- Impacts on governmental aspect such as lost documents/archives, also building and equipment damaged.
- Impacts on environmental aspect such as landscape destruction, pollution, farmland damage, etc.

Damages and losses on those three river borders are mostly in facilities/infrastructure aspect, where those are damage on settlements, education facilities, main roads, and others facilities. At some points, the river as a drainage of ash and lava from Mount Bromo eruption were overcapacity so that it overflows and causes damage around. In Kedungasem precinct, the floodgate and dam have been broken. In environmental aspect, the lava flood impacts to agricultural destruction and livestock drifting. Although the previous eruption occurred in 2015, the rest of volcanic materials remain and potentially bring cold lava floods during the rainy season.

Based on the damages and losses experienced in the three river borders, this study categorized the impact level according to the flood depth and duration in each region. This study found three classification of the impact levels as follows (Table 1. and Figure 1.).

| Impact Levels | Lava Flood’s Criteria | Affected Areas | Area (Ha) |
|---------------|-----------------------|----------------|----------|
| Low impact level | Up to 0.1 m | Less than 24 hours | Sumbertaman, Wonoasih, Kedopok, and Kareng Lor precinct | 4.80 |
| Impact Levels      | Lava Flood’s Criteria  | Affected Areas                                                | Area (Ha) |
|--------------------|------------------------|----------------------------------------------------------------|-----------|
| Medium impact level| Depth (m): Up to 0.75   | Ketapang, Triwung Lor, Pohsangit Leres, Sumber Wetan, Pakistaji| 320.07    |
|                    | meter                  | and Kedungasem precinct                                      |           |
| High impact level  | Depth (m): Up to 1.25   | Kedunggaleng and Kedungasem precinct                        | 161.92    |
|                    | meter                  |                                                                 |           |

The expected damages and losses of Mount Bromo’s cold lava flood give impact to several things, among others:

- Inhibition of transportation access that affect to evacuation process and distribution process of logistics;
- Disruption of public economy such as agricultural damages and livestock losses;
- Lack of clean water supplies due to the pollution by cold lava flood;
- Disruption of public health services; and
- Disconnection of communication network and power grid.

3.2. Participatory Evacuation Routes Assessment

Evacuation route is the best alternative routes for transfer, displacement, and rescue the victim in emergency events. There are two main components of evacuation: evacuation route and assembly point. The evacuation route analysis have been verified by participatory mapping among community and stakeholder’s perception so the evacuation routes could be more easily understand.
The influential variables used in the evacuation routes selection of Mount Bromo’s cold lava flood are:

- Accessibility and minimum travel time;
- Road topography;
- The evacuation transport facilities supplied; and
- The number of refugees and livestock.

In term of determining assembly point of Mount Bromo’s cold lava flood, it considered by several criterias such as:

- Public facilities or open spaces provided at least 60 x 60 cm² spaces area with minimum height of 2 meters for each person;
- It should be the accessible areas; and
- Calculated the minimum travel time to evacuate.

This study propose evacuation routes after considering impact level maps and the possible location for assembly point. This study decide four appropriate assembly points, there are Kareng Lor Gas Station area, Wonoasih military area, Kedunggalen field, and Mastrip Sport Centre. Table 2 and Figure 2 illustrate 14 alternatives evacuation routes.

**Table 2. The Alternatives Evacuation Routes**

| No. | Routes | Assembly Point                  | Area               |
|-----|--------|---------------------------------|--------------------|
| 1.  | a-b-c-d-e | Kareng Lor Gas Station           | Sumber Wetan       |
| 2.  | b-c-d-e  | Kareng Lor Gas Station           | Sumber Wetan       |
| 3.  | c-d-e    | Kareng Lor Gas Station           | Sumber Wetan       |
| 4.  | d-e      | Kareng Lor Gas Station           | Sumber Wetan       |
| 5.  | e        | Kareng Lor Gas Station           | Sumber Wetan       |
| 6.  | f        | Kareng Lor Gas Station           | Sumber Wetan       |
| 7.  | g        | Kareng Lor Gas Station           | Sumber Wetan       |
| 8.  | h        | Wonoasih military area           | Wonoasih           |
| 9.  | i, i     | Wonoasih military area, Kedunggalen field | Wonoasih, Kedungasem |
| 10. | j-i, j   | Wonoasih military area, Kedunggalen field | Wonoasih, Kedungasem |
| 11. | k, k     | Wonoasih military area, Mastrip Sport Centre | Wonoasih, Jebeng Wetan |
| 12. | l, l     | Kedunggalen field, Mastrip Sport Centre | Kedungasem, Jebeng Wetan |
| 13. | m, m     | Kedunggalen field, Mastrip Sport Centre | Kedungasem, Jebeng Wetan |
| 14. | n-m, n   | Mastrip Sport Centre             | Jebeng Wetan       |
In certain circumstances that require evacuation, the routes above can be a reference for refugees to evacuate in cold lava flood emergency event.

3.3. Focus Group Discussion to Formulate Contingency Plan

Contingency plan is a preparation plan for immediate response. It consists of scenarios, sectoral planning, facility needs, policies and strategies according to cold lava flood prevention sectors. Focus Group Discussion (FGD) is used to discuss and formulate those key outputs. FGD can also build a commitment among stakeholders particularly in implementing the contingency plan [12].

The participants involved in contingency plan formulation are head of villages, representatives of Probolinggo municipal's government agencies which are Board for Disaster, Board for Regional Development Planning, Social Affairs Agency, Health Agency, Public Works Agency, Transportation Agency, Military Office 0802, Police Officer, and related official organizations such as PMI (Palang Merah Indonesia-Indonesian Red Crosss Society) and radio community.

By theoretical analysis and discussion, this study formulated strategies and policies in handling Bromo’s cold lava flood as follows:

- Implementing risk reduction activities by preparing pre-disaster activities based on participatory community empowerment;
- Organizing and encouraging the supporting agencies both of local and government authorities;
- Minimizing the number of victims and ensuring to help the victims;
- Increasing the effective evacuation activity, protection and provision of basic needs and rehabilitation;
- Preventing the further damages and losses by well-planned reconstruction.

In order to implement the strategies and policies, it required sectoral planning or clustering based on the distribution rules and facility needs during event. Seven sectors are classified; consist of
management and coordination, information and communication, evacuation and protection, health, refuge, infrastructure, and logistic distribution sector. Table 3 describes roles, actors and facility needs among those seven sectors commanded by Probolinggo Municipal Board for Disaster.

Table 3. Sectors, Distribution Roles, Main Actors, and Facility Needs

| No. | Sectors          | Distribution Roles                                                                 | Main Actors                                                                 | Facility Needs                                                                 |
|-----|------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 1.  | Management and Coordination | Performing daily monitoring and evaluation of the operational plan and ensure each cluster worked properly. | Board for Disaster | 1. Communication devices such as Radio HT, TV, cellular phone, digital camera, affected areas map, information board, etc.  
2. Monitoring transportation such as patrol car and operational motorcycle |
| 2.  | Information and Communication | Receiving, reviewing, and exposing information about the ongoing situation and number of victims, losses and logistical needs. | Board for Disaster, Police Office, radio community | 1. Communication devices such as Radio HT, radio VT, TV, cellular phone, digital camera, laptop etc.  
2. Internet connection support |
| 3.  | Evacuation and Protection | • Evacuating the victims into safe place/assembly points for medical care;  
• Coordinating all of disaster rescue agencies. | Board for Disaster, Police Office, Military Office | 1. Volunteer rescue team  
2. Rescue transportation such as safety boat, trucks, and rescue car  
3. Safety tools and equipments such as life jacket, radio HT, and other supporting tools |
| 4.  | Health          | • Performing first aid;  
• Preparing adequate health resources and fast access to health services. | Health Agency, PMI | 1. Medical tents  
2. Ambulance  
3. First aid kit and medical equipment. |
| 5.  | Refuge          | Identifying the victims and preventing the psychological disturbance. | Social Affairs Agency, Head of Village | 1. Tents such as platoon tent, post tent, health service tent, logistic tent and also specific tents for worship and kitchen  
2. Supporting equipment such as generator set, toilet containers, and lighting |
| 6.  | Infrastructure   | • Providing the basic facility needs for victims and refugees;  
• Providing facilities and infrastructures in order to recovery and reconstruction | Public Work Agency, Board for Regional Development Planning, Transportation Agency | 1. Basic facilities such as temporary shelters, clean water supplies, and sanitation  
2. Transportion such as truck and heavy equipment (excavator) if needed  
3. Supporting equipments |
| No. | Sectors                  | Distribution Roles                                                                 | Main Actors            | Facility Needs                                           |
|-----|--------------------------|-------------------------------------------------------------------------------------|------------------------|----------------------------------------------------------|
|     |                          | process.                                                                            |                        | such as generator set, water pump, lighting, cable, and electric socket. |
| 7.  | Logistic Distribution    | Accepting and distributing logistical support for victims, refugees, and team.     | Social Affairs Office, PMI | 1. Food (rice, instant food, drinking water)             |
|     |                          |                                                                                     |                        | 2. Clothing                                               |
|     |                          |                                                                                     |                        | 3. Special equipments for babies and woman (diapers)      |
|     |                          |                                                                                     |                        | 4. Cooking utensils                                       |
|     |                          |                                                                                     |                        | 5. Logistic truck                                        |

4. Conclusion
Contingency plan is formulated to respond Mount Bromo’s cold lava flood, particularly in Probolinggo peri-urban areas. Planning by community is useful to upgrade community and government awareness to disaster. In making contingency plan, damages and losses should be firstly identified to estimate potentially future hazards. Then FGD also involve the community in designing contingency plan, consists of evacuation routes, sectoral planning, and facility needs. The output can be a reference for Probolinggo Municipal Board for Disaster in cold lava flood management included before, during, and after disaster event. This contingency plan is expected to build effective, efficient, transparent, responsible, and sustainable implemented in planning, implementation, monitoring and evaluation.

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