ENVIRONMENTAL RESTORATION OF THE WATER RECHARGE AREA AND DEVELOPMENT OF SPRING CHANNELIZED IN SOUTHERN PART OF MERAPI VOLCANO SLOPE FOR SUSTAINABLE WATER RESOURCE MANAGEMENT

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ABSTRACT

Environmental restoration of spring Catchment Area (CA) and groundwater Recharge Area (RA) was almost impossible to achieve without any integrated environmental management effort in a long term periode because it was related to various stakeholder's interests. Protecting water resources policy in Southern part of Merapi Volcano Slope using CA and RA concepts became the ultimate goal of this study. Methods were used comprehensive and holistic environmental conservation approaches, involving abiotic, biotic, and cultural aspects to recover the environmental function through restoration of CA and RA areas. Spring CA and groundwater RA perimeter delineation were implemented as unit of study for recovery and enhancement of CA and RA land cover precentage as well as for increasing the spring discharge and groundwater volume. Increasing the spring's discharge would lead to addition of paddy field areas that could be irrigated and enhancing the river discahrges to add up water availability of river region or watershed areas, while enhancement of CA and RA land cover precentage would result in increasing the infiltration capacity as well as groundwater storage including shallow and deep groundwater storages. Short-term result of site visit showed there was a river infrastructure development (SABO Dam) for lahar retention underconstruction. Land cover enhancement was dominated by natural plant of Soga (*Accasia Decurens*) and man-planted Sengon (*Albizia Falcataria*). In between, mixed crops were also planted by local people thus the landuse was identified as mixed garden. For the time being, the land cover enhancement has not yet recover the hydrological condition in the study area, which should be indicated by emerging springs and increasing river discharges, thus water scarcity still became the main issue for some rivers whose upstream poured out from southern part of Merapi volcano slope, such as, Opak river and Sriwil river from Kinahrejo-Pangukrejo Villages, Opak river from Kepuharjo Village and Gendol river from Kalitengah and Srunen Villages. The waterflow of Opak river were contributed from Nduwet (Sanga) and Cakran springs in Kalisongo Village and the waterflow of Sriwil river were from Umbul Celeng spring. Meanwhile, the waterflow from those springs (Nduwet/Sanga, Umbul Sodokan, Cakran, Pandan, Umbul Celeng) were utilized by local people for paddy irrigation, fish ponds, and daily domestic needs. The depth of shallow groundwater in lahar-covered area was more than 20 m (sea level), such as, in Plosokerep (Kepuharjo), Karanggeneng

(Umbulharjo), Jetisumur (Glagaharjo), sidorejo (Hargibinangun), wonorejo (Purwobinangun), Bening and Kratuan (Girikerto), and Gondoarum (Turi). Special areas were villages of Cangkringan and part of Pakem Districts which then fulfilled the fresh water needs using artesian well whose depth was up to 150 m (sea level). The excessive flow from springs and groundwater would be stored in Opak, Sriwil, Tepus, and Gendol rivers. Different with cangkringan and Pakem Districts in Hargobinangun, Purwobinangun, Girikerto, and Turi Districts the waterflows was dominated by spring and seepages which is emerging in river banks and vallies, such as, Sidorejo, Wonorejo, Kratuan, pelem, Jineman, Kuncen and Gondoarum villages. Starting From Boyong, Tangkil, Degong, and Sempor river dams the waterflows were channelized as gravitation flowdown into lowland to create wetland rice is called "*sawah*". Study on planning and designing the open channel flow from springs (Cangkringan and Pakem Districts) and rivers (Turi District) channelized to the channel network using site selection method to create a kind of Mataram Channel (from Progo to Opak rivers) would be the target of next study step.

Keyword: spring and seepages, groundwater, river and channel, landcover and landuse, water usage, environmental restoration

INTRODUCTION

The general environmental problem was suffered by Yogyakarta Special Region about decreasing of groundwater surface (water table) which is occured to reach more than 2 meter every year. In case would be assumed that, first, in short time, because of the development of urban spread that followed by it's activity, such as, infrastructure, housing, and pavement of yard, etc. In the long time, because of land use changes in both of groundwater recharge areas and spring catchment areas. Since the eruption of Merapi volcano on November 2010 a vary of areas were impacted by lahar deposits with distant moreless 15 kilometer started from upper slope up to middle slope of Merapi volcano. A lot of trees, house bulding, bridge, stream, valley, and others landscape wer covered by lahar deposits. In the same time the waterflows which initially from springs, and also streamflows to be lower and even there is no waterflow. Many problems which is emergence to become negative impact, such as, leakage of domestic water, irrigation water, swamp for fisheries, and other needs (Public Pers (*Kedaulatan Rakyat*), 2016a, 2016b, 2016c dan 2016d, Gunawan, 2012, 2014).

Hydrogeomorphological phenomenas in upper part of Merapi volcano were characterized by the stream pattern is radial centrifugal, very steep slope, high drainage density, high dissection, high capacity soil infiltration, and also high potential erosion, and overland flows. Hydrogeological phenomenas in upper part of Merapi volcano were characterized by pyroclastic and unconsolidated materials, stratigraphic and underlying layers, confortable and structural (crack, joint, feasure, fracture, and fault). Based on the characteristics of the hydrogeomorphological phenomenas of Merapi volcano related to the hydrological phenomenas they have long and permanen rivers which is supported by springs and seepages on the river banks and vallies, a lot of spring and seepages emergencies on the break of slope, and few man-made of traditional gravitation irrigation channels were taken from intake of river dams in upper stream and then distributed into lowland for irrigation of wet land paddy (sawah) (Babar, 2005).

Chacteristics of the hydrogeological phenomenas of the Merapi volcano related to hydrological phenomenas were determined of the occurrence of the aquifer layer related to the groundwater types. In upper part of Merapi volcano in the slope areas there is no aquifer layer because dominated by lava block, but they have specific character of joint and fracture structures, so they can conveying water infiltration and percolation capacity to form a kind of long fissure as a waterflows. The waterflow was concentrated from many of long fissure it can be called as baseflow and then emerging to land surface after find break of slope is called spring neither can be found on the river banks or vallies. In the foot slope areas there is just can be found the initially aquifer layer (as unconfined aquifer layer) and was occurred initially of groundwater (as shallow groundwater). The groundwater flow in unconfined aquifer layer just still have high fluctuation depend on the size of the recharge areas (RA) to become outflows after cutted by brake of slope hence then emerging of springs and/or seepages, such as, one of them is called depression spring (Domenico, et al., 1990).

Social economic and cultural aspects of Merapi volcano society have specific characteristics especially to face hazard and risk, both eruption of hot cloud (*wedus gembel*) and/or lahar deposits (*lahar dingin*). Bio-geophysical (chemical) aspects (such as, hidrogeomorfology and hydrogeology) have close related to socio-economic and cultural aspects, there are three relationships minimally, such as, interaction, interrelationships, and interdependency. Environmental problems usually is very complex can be reviewed from bio-geophysical (chemical) aspects and socio-economic and cultural aspects which is called environmental totally. The solution of the environmental problems should be involved from variety of disciplines and can be solved through multidiscipline, interdicipline, and trans-dicipline approaches. Environmental restoration of recharge areas and catchment areas in the southern part of Merapi volcano slope should be involved Bio-geophysical (chemical) aspects and socio-economic cultural aspects (Brown, et al., 1983).

The importance environmental restoration of recharge areas of the southern part of Merapi volcano slope as the aims of study, the first one, identification of dominant factors which is the influence and to become main issue land degradation in recharge areas and catchment areas were supported groundwater storages and spring discharges. The second one, observation and measurement capability of spring and streamflow discharges to support of the irrigation of wet land paddy (sawah) and other inhabitant needs and to utilize the excessive of these waterflows after used for other needs. The third one, to develop the drainage system to collection of water excess from irrigation of wet land paddy to utilize that waterflows as the main program (next step study) in the framework for integrated water resource management project (IWRMP). In the general program land rehabilitation and reclamation for environmental restoration especially in water resources management regulation in the framework for sustainable development goals (SDGs) in regional and national development countries (Act of Republic of Indonesian No. 5/1990 conservation of Biotic natural resource and ecosystem , No. 32/2009 Environmental Management and preservation, No. 37/014 Soil and Water conservation).

Data And Method

Location

The southern part of Merapi volcano slope was interested location and problem of the environmental degradation since eruption in year 2010 a lot of inhabitant loosing their job as a farmer and also to destroy all of infrastructure made all of human activity stopped. The most negative impact was scarcity of availability the water resources to human and ecological needs for few month and even annual because of it's recharge and catchment areas covered by lahar deposits. The requirement of environmental restoration for environment total especially which is very urgent and important to improvement of the groundwater recharge and spring catchment areas. Research location map can be seen on Figure 1 and satellite (Landsat 8) image recorded 2015 can be seen on Appendix 1.

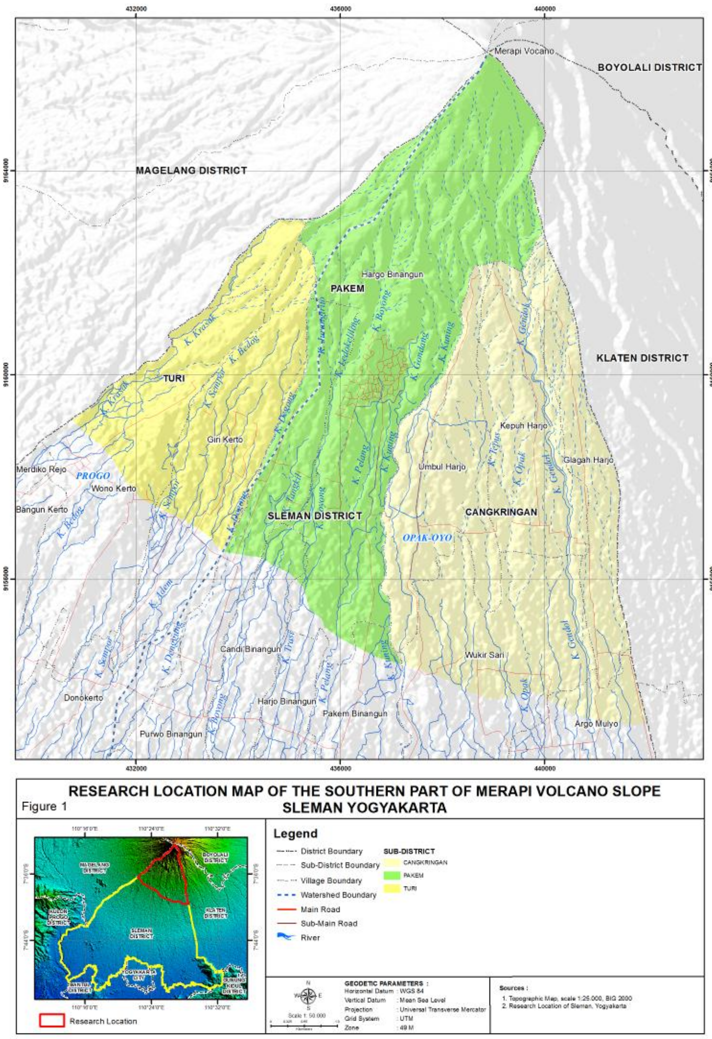

Figure 1. Research location map of southern part of Merapi volcano slope

Data and Variable

Data and variable requirements which are needed in this research consists of bio-geophysical (chemical) aspects, biotic (chemical) aspects, and socio economic cultural aspects. The primary data of bio-geophysical (chemical) aspects can be obtained from field observation and measurements, such as, percentages of land cover and land use especially rice field coverage, spring and river discharges, physical and chemical water qualities, depth of water table, initial and type of aquifer, potential of groundwater (discharge and/or volume), size and boundary of spring catchment areas and groundwater recharge areas. The secondary data of bio-geophysical (chemical) aspects were collected from Statistical Beureu and others institution. The primary data of socio-economic and cultural aspects can be obtained from interview to respondents or key person and/or informans using guiding list and also focus group discussion (FGD).

Data Collection and Analyses

Data collection of biological (chemical) primary data of planting and agricultural crops were taken proportional sampling divided by without and impacted areas in percentages of coverage. Geophysical (chemical) primary data of spring, streamflow, aquifer layer, and groundwater were taken areas sampling divided by without and impacted areas stressing on it's dicharges. Respondents or key person and/or informans were taken percentages were classified by types of water resource needs. Documentation of field condition of natural and cultural resources and landscape were taken representation of existing condition. Data analyses of land cover and/or land use map were overlaid by spring catchment areas and groundwater recharge areas to describe the effect of percentages of coverage to spring discharges and groundwater volume. Data analyses of hydrogeomorphological and geohydrological maps especially to describe the occurrence of initial aquifer layer, depth of water table above sea level, groundwater discharge and/or volume to describe the groundwater potential. Data analyses of hydrological map especially the spring and streamflow discharges to describe surface runoff potensial. Data analyses of population density maps were overlaid by socio-economic and cultural aspects to describe it's important role of rehabilitation and/or reclamation of land and forest to conserve groundwater recharge s and spring catchment areas.

RESULT RESEARCH AND DISCUSSION

Land Cover and Land Use Existing

Eruption of Merapi volcano in year 2010 have been destroyed landform and land use because of its coveraged by lahar deposits, such as, golf sport field in Kepuharjo District, left and right Gendol river with distant over natural levee in between 500 meter to 1,5 kilometer width and along moreless 12 kilometer downstream award. Land and forest rehabilitation and reclamation in the lower part on the impacted areas of lahar deposits using variety of crops consists of many kinds of tree and fruits, unfortunately, not suitable for land characteristics and land qualities. Different with impacted areas in the upper part not necessary were performed land and forest rehabilitation and reclamation because over there, such as, Srunen and Kalitengah villages Glagaharjo sub-District (Cangkringan District) after 2 (two) year (2012) from eruption activity (2010) naturally grow as an endemic plant is called Soga (*acasia decurent*). These condition were also suffered by impacted areas in upper part east of Kuning river, such as, Pangukrejo, Kinahrejo, and Bebeng villages (Umbulharjo sub-District). In the west of Kuning river generally from Harjobinangun and Purwobinangun sub-Districts (Pakem District), Girikerto and Wonokerto sub Districts (Turi District) were not impacted areas by lahar deposits, so there are not occurred land use changes drastically, although, year to year was occurred land use changes from wet land paddy to became wet land (salak). This land use changes spread out especially was distributed in west part of Merapi volcano slope since from Gondoarum, Ngelodadi, and Sorowangsan villages (Wonokerto sub District), Bening, Kuncen, and Pelem (Girikerto sub-District), Kratuan-Poncoh, and Kemiri-Tawangrejo villages (Purwobinangun sub-District), and Wonorejo, and Sidorejo villages (Hargobinangun sub-District) could be showed in land use map (see Appendix 2).

Land Cover and Land Use Changes Related to Hydrological Phenomenas

What is the importance role between land cover and land use changes related to the hydrological phenomenas in the southern part of Merapi volcano slope can be divided into 2 (two) part, first one, areas impacted lahar deposits were occurred totally land cover and land use changes from vegetation cover to become bare land were covered by lahar fields. For that reasons it was caused land degradation to become decrease the capability of groundwater recharge areas and spring catchment areas. It can be verified using ground truth result in the field, for instant, in east part of Kuning river (Cangkringan District) the area were impacted by lahar deposits, such as, pangukharjo and Kinarejo willages (Umbulharjo sub-District), Trukan, and Kaliadem villages (Kepuharjo sub-District), Srunen and Kalitengah willages (Glagaharjo sub-District) there were covered of mixed garden (1,558.47 hectars) and dry land (1,251.89 hectars) as dominant land cover/land use, meanwhile, grass or king grass (487.85 hectars) locally just still can be found in Petung (Kepuharjo sub-District) and Singlar (Glagaharjo sub-District). The distribution of land use types in every villages and sub-district (size and percentage) recapitulation totally could be seen in Table 1, meanwhile, detail land use could be seen in Appendix 3.

Condition of the east part of the Kuning river quite different with the west part of the Kuning river, such as, Hargobinangun and Purwobinangun sub-Districts (Pakem Disatrict) and Girikerto and Wonokerto sub-Districts (Turi District). These areas not impacted by lahar deposits were dominant covered by Land cover and land use changes from wet land paddy to wet land fruit tree (salak). In fact actually that land cover and land use changes become wet land fruit tree (salak) can increases depth of water table 7 meter (from land land surface) in Bening Villages (Wonokerto sub-District) and depth of water table 4.10 meter (from land surface) in Kratuan villages (Girikerto Sub-District). Actually depth of water table not increases, such as, just still as usual 23.8 meter (from land surface) in Sidorejo villages (Hargobinangun sub-District) could be seen depth of water table (see next Appendix 3).

Hydrological Phenomenas

Rivers and Irrigation Channels Existing and Analyses

In this study area was located in up-land southern part of Merapi volcano slope have steep a slope, hilly, high dissection, and a lot of first order streams were occurred emerging of spring and seepages which is emerging in river banks and beds, such as, in Kuning river (Cangkringan District), Boyong-Code rivers (Pakem District), and Bedog river (Turi District). Field measurement each of rivers on August 2016 their discharge in upper part of Kuning river (Banteng bridge) as much as 50 liter per second, Boyong river (Kalegan bridge) as much as 25 liter per second, and Bedog river (Tunggularum bridge) as much as 15 liter per second. The waterflows in each of rivers has been showed that in dry season there are sources of water from spring or seepages emerging from river banks and base of vallies. In lower part of these rivers were made river dams to catch the waterflows then to drain gravitationally flowdown as traditional irrigation wet land paddy and wet land fruit trees (salak). For example, in Bedog river the first river dam and the first channel irrigation in Gondoarum village (Wonokerto sub-District) with channel irrigation discharge as much as 50 liter per second for the areal irrigation wet land paddy minimal 50 hectares were predicted up to Sempu, Balerante, Bedoklempong, and Imorejo villages. River or channel irrigation discharges measurement in southern part of Merapi volcano slope can be seen in Appendix 4.

In Sempor river the first river dam for the first channel irrigation in Manggungsari village (Girikerto sub-District) with intake discharge as much as 20 liter per second for 20 hectares wet land paddy were predicted up to Sorowangsan and Soprayan villages. Discharge irrigation channel in Kuncen village 60 liter per second and Pelem village 95 liter per second for areal irrigation were predicted up to Kuncen, Babadan, Mencor and Soprayan villages. Degong and Tangkil rivers (Purwobinangun sub-District) for irrigation channel with discharge each of 20 liter per second and 37 liter per second for areal irrigation were predicted for 57 hectares wet land paddy up to Sukorejo, Ngelo, and Poncoh villages. Wonorejo irrigation channel and Pelang river (Hargobinangun sub-District) for irrigation channel with discharge each of 35 liter per second and 15 liter per second for areal irrigation were predicted for 60 hectares wet land paddy up to Sumberan, Ngetehan, and Purworejo villages. In Kuning river the first dam and the first intake for irrigation channel to the west part the waterflow with discharge as much as 37 liter per second for areal irrigation were predicted for 37 hectares to supply Sidorejo and Purworejo villages (Hargobinangun sub-District). Meanwhile to the east part in Bendosari village (Umbulharjo sub-District) the first dam and the first irrigation channel the waterflow with discharge as much as 18 liter per second were predicted for 18 hectares wet land paddy up to Kedungsriti, Grogol, and Bendo villages.

Karangmelok, Plupuh and Umbultritis with Umbulceleng springs into Sriwil river for the first irrigation channel in Umbulharjo sub-District areas with discharge each of 4 liter, 17 liter, and 22 liter per seconds were predicted for 43 hectares wet land paddy up to Bedoyo, Selorejo, and Watuadeg villages. Sumber Opak, Kalisanga, and Cakran with Srondokan springs into Tepus and Opak rivers for the fist irrigation channel in Kepuharjo sub-District areas with discharge each of 22 liter, 50 liter, and 9 liter per seconds were predicted for 81 hectares wet land paddy up to Bulaksalak, Kergan, Krajan, Cakran, Geblok, and Bakalan villages. Bronggang, Ngandong, and Mudal springs into Gendol river for the first irrigation channel in Glagaharjo sub-District areas with discharge each of 21 liter, 6 liter, and 4 liter per second were predicted for 31 hectares wet land paddy up to Guling, Tegalgadingan, and Gayam villages. Detail measurement of spring and seepages in Kepuharjo and Glagaharjo sub-

Districts can be seen in Appendix 5. Hydrological phenomenas map of the southern part of Merapi volcano slope can be seen in Appendix 6.

Hydrogeomorphology and Hydrogeology Analyses

Generally geomorphology in southern part of Merapi volcano slope can be divided into three categories, (1) upper part of Merapi volcano slope (2) middle part of Merapi volcano slope, and (3) lower part of Merapi volcano (coastal alluvial plain), in this research mainly in upper part of Merapi volcano slope. In this studi area was conducted in upper part of Merapi volcano slope which have specific characteristics of geomorphoecology. Turgo and Plawangan hills, it become buffer of the material eruption of Merapi volcano to downward. The eruption of Merapi volcano year 2010 was concentrated to southeast ward following Gendol river and around of Cangkringan District especially in Glagaharjo sub-District. Lahar deposits have been changed landscape and land cover to become dry open space consists of boulders, pebble, and others coarce material. For the time being, in short time just two years (2012) it has been grown forest plants, such as, Soga (*accasia decuren*) and others quickly grow, for example, in Kalitengah (north and south) and Srunen villages (Glagaharjo sub-District), in Bebeng, Kinarejo, and Palemsari villages (Umbulharjo sub-District), and also Kaliadem, Trukan, and Petung villages (Kepuharjo sub-District). Different with these upper part, that in the middle part were growing regreening tree was Sengon (*albizia falcataria*) mainly in left and right of Gendol river moreless 500 meters width and others trees which were supported by a lot of institution to cultivate combination as mixed garden.

Interrelationships between Geomorphology and hydrology processes was called hydrogeomophological processes, for example, they have specific features of drainage pattern was centrifugal spread out from peak of mount to the lower part, depth of water table to follow the surface topography, soil formed to follow toposequent, fine to very fine soil texture to lower part of topography, etc. The upper part of topography usually very steep slope there was noting waterflow in the stream because high infiltration capacity. Hydrogeomorphology close related to hydrogeology as a basic hydrological phenomenas, because hydrogeomorphology to represent surface topography, meanwhile, hydrogeology to represent sub-surface (geology) topography. For example, water table very related to hydrogeomorphology but groundwater types very related to hydrogeology. More specific underground features, such as, permeable and impermeable layer of lithology dominant relation to hydrogeology, meanwhile, depth of water table follow surface topography.

Hydrogeomorphologically analyses in southern part of Merapi volcano slope as general consists of coarse material, dominant sand texture, length and steep slope have high infiltration capacity. Hydrogeologically analyses the condition of high infiltration capacity were supported high percolation capacity, in upper part the condition of lava block have secondary permeability, such as, there were joints, fractures, and fissures. The waterflow from high percolation capacity have been concentrated passing into these secondary permeability as a baseflow. Finally the baseflow in a journey flows out after cutting break of slope or river bank and valley as spring or seepages and into the streamflow. On the other hand, the baseflow did not cutted by surface topography continue flow down into deep groundwater (artesian groundwater). For example, in Gondang and Plosorejo villages (Umbulharjo sub-District) as impacted areas the requirement of domestic water (included drinking water) have been supplied by artesian groundwater.

Groundwater Hydrology (Geohydrology) Phenomenas Analyses

One of the hydrological phenomenas was groundwater hydrology, it can be divided into two part in general, (1) shallow groundwater in the unconfined aquifer layer, and (2) deep groundwater in confined layer. In southern part of Merapi volcano slope mostly dominant of lava block there were not occurred unconfined aquifer layer and shallow groundwater up to Singlar village (Glagaharjo sub district), Kopeng village (Kepuharjo sub-District), Gondang village (Umbulharjo sub-District), Banteng village (Hargobinangun sub-District), Ngepring village (Purwobinangun sub-District), Ngangkring village (Girikerto sub-District), and Tunggularum village (Wonokerto sub-District). Unconfined aquifer layer and shallow groundwater at initially can be found in Jetissumur village (Glagaharjo sub-District), Gondang village (Kepuharjo sub-District), Plosorejo village (Umbulharjo sub-District), and Sidorejo village (Hargobinangun sub-District) with depth of water table > 20 meter (from topographic surface). Detail measurement of depth water table in southern part of Merapi volcano slope can be seen in Appendix 7.

Different with areas of west part of Boyong river unconfined aquifer layer and shallow groundwater at initially can be found in Kratuan village (Purwobinangun sub-District), Bening village (Girikerto sub-District) and Gondoarum village (Wonokerto sub-District) with depth of water table 6 to 7 meter (from topographic surface). The depth of water table have been occurred increasing moreless 5 meter (from 11 meter to 6 meter from topographic surface) for 10 years more because of land use changes from wet land paddy to wet land fruit trees (salak). Meanwhile, areas eastern part of Boyong or Kuning river the depth of water table have been occurred decreasing moreless 5 meter (from 15 meter to 20 meter topographic surface) for 6 years more because of impacted areas lahar deposits of Merapi volcano eruption year 2010 ago (see Appendix 7)

Spring and Seepages Emerging Analyses

In quite contrast between eastern and western parts of southern part of Merapi volcano slope with zone of transition was along Boyong and Kuning rivers about of spring and seepages emerging. General principles in eastern part has been dominated by spring and seepages zones (belts), but in western part have been occurred combination with irrigation channels more confused with tend to dominant irrigation channels with intake have been taken from the main river. The most of rivers in western part the waterflow have been came from spring and seepages emerging in river bank and basic vallies. Sometime the waterflow into the river again in the lower part because of the waterflow flesh back from excess water wet land paddy (sawah) and then return back to river again.

The contrast about the availability of sources of water in the eastern western parts of southern part of Merapi volcano slope also affecting the land cover and land use pattern, one of the spring and seepages belts in Kalisanga and Cakran sources (Kepuharjo sub-District) have been occurred on transition zone of dry land use (*tegalan*) and wet land paddy (*sawah*) have been depicted so clearly on satellite image. Diffeterent condition with Kratuan (purwobinangun sub-District) and Bening (Girikerto sub-District) have also been occurred land cover and land use changes from dry land use to wet land use, but actually there were not found any spring and seepages and also that land use changes appear like spots features depicted on satellite image documents (see Appendix 1).

Based on the emergence and the occurrence of the spring and seepages which were occured in Kalisanga and Cakran and others (Kepuharjo sub-District) we have to think that the spring and seepages discharges should be increased with improvement of land and forest rehabilitation and reclamation. In the first step we have to know the boundary of the drainage divide of the spring and seepages which called the catchment areas (CA). What is the relationship between spring and seepages emergences and the occurrence of groundwater can be verificated from field experiences that areas around the spring and seepages emergence can be found shallow groundwater in the forms of dug well. For example, in Kalisanga spring near Sanga (Duwet) village (Kepuharjo sub-District) can be found dug well with depth of water table moreless 6 meter (from topographic surface), and also in Umbulgading spring near Mudal village (Glagaharjo sub-District) can be found dug well with depth of water table moreless 11.6 meter (from topographic surface).

Environmental Restoration of Recharge and Catchment Areas

This international paper was the part of the main research about environmental restoration of recharge areas to develop drainage system of spring southern part of Merapi volcano slope. This paper strongly to discover the boundary of recharge and catchment areas have been used for increasing the spring discharge and groundwater volume. Based on result of mapping of land cover and land use can be obtained total 7,765.62 hectares consists of mixed garden 1,558,47 hectares (20.07%) especially in Kepuharjo 328. 36 hectares (4.23%), dry land 1,251. 89 hectares (16.22%) especially in Kepuharjo 175.24 hectares (2.26%) and schrub 1,214.92 hectares (15.64%) especially in Kepuharjo 199.61 hectares (2,57).

Land cover and land use improvements have not yet changes the depth of water table, for example, the dug well in Gondang village (Kepuharjo sub-District) on July 25 meter and decreasing up to 20 meter on August 2016 and even in along time of dry season the dug well was dry. In fact it can be explained that the recharge areas in Kepuharjo and it environment have been impacted areas by lahar deposits although a lot of effort during 6 year more to land rehabilitation and reclamation, but have not yet been affected recharge areas to supply regional groundwater resources. In fact based on the reality that there were relation between the availability of groundwater recharge areas and spring and seepages emergence, such as, in Kalisanga spring emergence have been occurred interrelationships with depth of water table in Sanga (Duwet) village.

For that reason, from these result research can be created two hypothesis, the first, in Kalisanga spring have permanen discharge as much as 19.4 liter per second (see Table 3) can be predicted that recharge areas have not only originated from local catchment area, and the second, in Cakran spring have non permanen discharge as much as 5.2 liter per second (see Table 3) can be predicted that recharge area have only originated from local catchment area. Different with in western part of study area especially in Girikerto and Purwobinangun sub-District, such as, Sempor river and it irrigation channels (15 and 20 liter per second) and Degong river and it irrigation channels (65 liter per second) have permanen discharges (see Appendix 4) actually originated from regional recharge areas.

CONCLUSSION

The first, from result research about land cover and land use were extracted from satellite (Landsat 8) and IKONOS images and field checking and survey in southern part of Merapi volcano slope can be divided into two parts, (1) in eastern part of Hargobinangun except Purwobinangun (Pakem District) and Umbulharjo, Kepuharjo, and Glagaharjo (Cangkringan District) were dominated by mixed garden, and (2) in western part of Wonokerto and Girikerto (Turi District) added Purwobinangun (Pakem District) were dominated by wet land fruit trees (especially salak).

The second, from result research about hydrological phenomenas were extracted from satellite (Landsat 8) and IKONOS images and field measurement in southern part of Merapi volcano slope can be divided into two parts, (1) in eastern part of Kuning river areas up to Gendol river areas have certain specific of hydrogeomorphology and hydrogeology, therefore, hydrological phenomenas areas were dominated by spring and seepages emergence, and (2) in western part of Kuning river areas up to Bedog river areas have permanen river, therefore, hydrological phenomenas were dominated by irrigation channels.

The third, environmental restoration recharge areas in southern part of Merapi volcano slope can be divided into two parts, (1) environmental restoration in eastern part especially impacted areas by lahar deposits at Cangkringan District areas during more 6 years (2010-2016) have not yet showed a good result, (2) environmental restoration recharge areas in western part have not impacted by lahar deposits especially in Wonokerto, Girikerto, Purwobinangun, and Hargobinangun Districts areas up to know have a good recharge areas.

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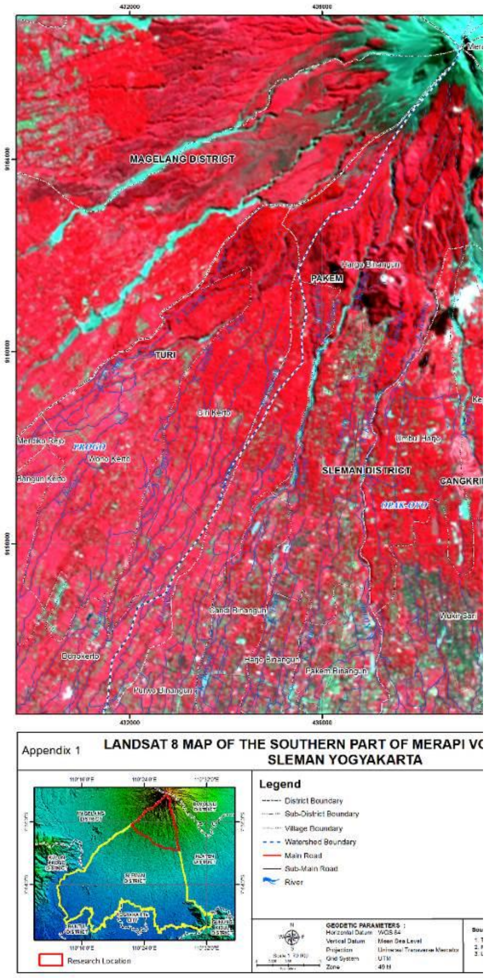
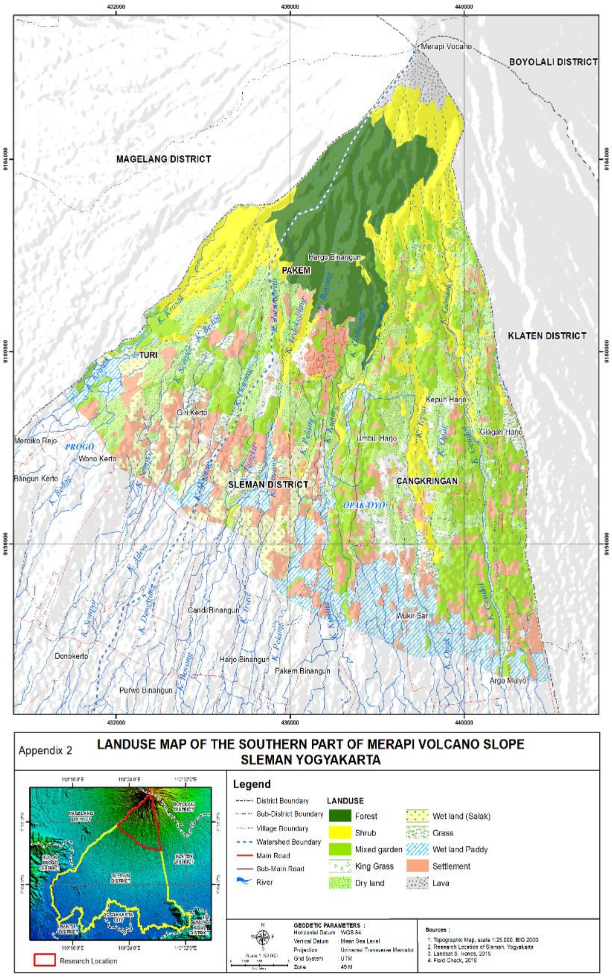




Appendix 3. Landuse Type of Southern Part of Merapi Volcano Slope in Cangkringan to Turi Districts

No	Type of Landuse	Village	Sub-District	Size(ha)	Percentage(%)
1	Forest	Hargo Binangun	Pakem	919.68	11.84
		Purwo Binangun	Pakem	0.18	0.00
2	Shrub	Argo Mulyo	Cangkringan	0.53	0.01
		Glagah Harjo	Cangkringan	44.86	0.58
		Kepuh Harjo	Cangkringan	199.61	2.57
		Umbul Harjo	Cangkringan	94.92	1.22
		Wukir Sari	Cangkringan	16.26	0.21
		Candi Binangun	Pakem	2.86	0.04
		Hargo Binangun	Pakem	560.42	7.22
		Pakem Binangun	Pakem	0.22	0.00
		Purwo Binangun	Pakem	16.19	0.21
		Giri Kerto	Turi	208.46	2.68
		Wono Kerto	Turi	70.58	0.91
3	Mixed garden	Argo Mulyo	Cangkringan	16.32	0.21
		Glagah Harjo	Cangkringan	281.47	3.62
		Kepuh Harjo	Cangkringan	328.36	4.23
		Umbul Harjo	Cangkringan	277.91	3.58
		Wukir Sari	Cangkringan	210.17	2.71
		Candi Binangun	Pakem	3.18	0.04
		Hargo Binangun	Pakem	186.11	2.40

No	Type of Landuse	Village	Sub-District	Size(ha)	Percentage(%)
		Pakem Binangun	Pakem	0.10	0.00
		Purwo Binangun	Pakem	50.08	0.64
		Giri Kerto	Turi	127.20	1.64
		Wono Kerto	Turi	77.55	1.00
4	King Grass	Argo Mulyo	Cangkringan	2.95	0.04
		Glagah Harjo	Cangkringan	1.81	0.02
		Kepuh Harjo	Cangkringan	26.27	0.34
		Umbul Harjo	Cangkringan	72.36	0.93
		Wukir Sari	Cangkringan	43.99	0.57
		Hargo Binangun	Pakem	41.88	0.54
		Purwo Binangun	Pakem	44.06	0.57
		Giri Kerto	Turi	29.31	0.38
5	Dry land	Argo Mulyo	Cangkringan	2.04	0.03
		Glagah Harjo	Cangkringan	128.79	1.66
		Kepuh Harjo	Cangkringan	175.24	2.26
		Umbul Harjo	Cangkringan	239.26	3.08
		Wukir Sari	Cangkringan	72.10	0.93
		Candi Binangun	Pakem	6.20	0.08
		Hargo Binangun	Pakem	140.75	1.81
		Purwo Binangun	Pakem	134.54	1.73
		Giri Kerto	Turi	170.25	2.19
		Wono Kerto	Turi	182.77	2.35
6	Wet land (Salak)	Candi Binangun	Pakem	30.55	0.39
		Hargo Binangun	Pakem	142.84	1.84
		Purwo Binangun	Pakem	54.98	0.71
		Giri Kerto	Turi	118.95	1.53
		Wono Kerto	Turi	86.43	1.11
7	Grass	Argo Mulyo	Cangkringan	10.51	0.14
		Glagah Harjo	Cangkringan	40.19	0.52
		Kepuh Harjo	Cangkringan	26.78	0.34
		Umbul Harjo	Cangkringan	17.92	0.23
		Wukir Sari	Cangkringan	30.36	0.39
		Candi Binangun	Pakem	0.28	0.00
		Hargo Binangun	Pakem	9.86	0.13
		Purwo Binangun	Pakem	16.52	0.21
		Giri Kerto	Turi	69.93	0.90
		Wono Kerto	Turi	2.87	0.04
8	Wet land Paddy	Argo Mulyo	Cangkringan	60.76	0.78
		Umbul Harjo	Cangkringan	44.02	0.57
		Wukir Sari	Cangkringan	314.27	4.05
		Candi Binangun	Pakem	10.69	0.14
		Hargo Binangun	Pakem	126.51	1.63
		Pakem Binangun	Pakem	28.56	0.37
		Purwo Binangun	Pakem	15.61	0.20
		Giri Kerto	Turi	27.50	0.35
		Wono Kerto	Turi	75.58	0.97
9	Settlement	Argo Mulyo	Cangkringan	39.83	0.51
		Glagah Harjo	Cangkringan	96.34	1.24
		Kepuh Harjo	Cangkringan	44.30	0.57

No	Type of Landuse	Village	Sub-District	Size(ha)	Percentage(%)
		Umbul Harjo	Cangkringan	121.31	1.56
		Wukir Sari	Cangkringan	146.56	1.89
		Candi Binangun	Pakem	10.77	0.14
		Hargo Binangun	Pakem	263.83	3.40
		Pakem Binangun	Pakem	18.26	0.24
		Purwo Binangun	Pakem	112.16	1.44
		Giri Kerto	Turi	166.30	2.14
		Wono Kerto	Turi	88.02	1.13
10	Lava	Hargo Binangun	Pakem	87.77	1.13
Total				**7,765.71**	**100.00**

Appendix 4. River or Irrigation Channel of Southern part of Merapi Volcano Slope in Cangkringan to Turi Districts

No	Names of River or Irrigation Channel	Village	Sub-District	Quantity	Quality	
				Discharge (dm^3/sec)	EC meter (μS/cm)	pH
1	Mudal River	Argo Mulyo	Cangkringan	4	265	7.6
2	Banaran River	Argo Mulyo	Cangkringan	6	309	8.1
3	Gendol River	Argo Mulyo	Cangkringan	21	615	8.2
4	Bakalan River	Argo Mulyo	Cangkringan	80	241	7.7
5	Ngemplak Irrigation Channel	Argo Mulyo	Cangkringan	11	247	7.9
6	Geblok Irrigation Channel	Wukir Sari	Cangkringan	8	245	7.5
7	Opak River	Wukir Sari	Cangkringan	22	233	7.7
8	Ngaglik Irrigation Channel	Wukir Sari	Cangkringan	13	234	7.7
9	Tepus River	Wukir Sari	Cangkringan	9	261	7.9
10	Plupuh Irrigation Channel	Wukir Sari	Cangkringan	17	253	7.7
11	Watuadeg Irrigation Channel	Wukir Sari	Cangkringan	22	236	8
12	Bedoyo Irrigation Channel	Wukir Sari	Cangkringan	4	247	7.8
13	Bendo Irrigation Channel	Wukir Sari	Cangkringan	18	243	8.5
14	Kali Kuning Irrigation Channel	Hargo Binangun	Pakem	37	248	6.6
15	Pantiasih Irrigation Channel	Hargo Binangun	Pakem	7	191	6.3
16	Code Irrigation	Hargo	Pakem	35	242	6.4

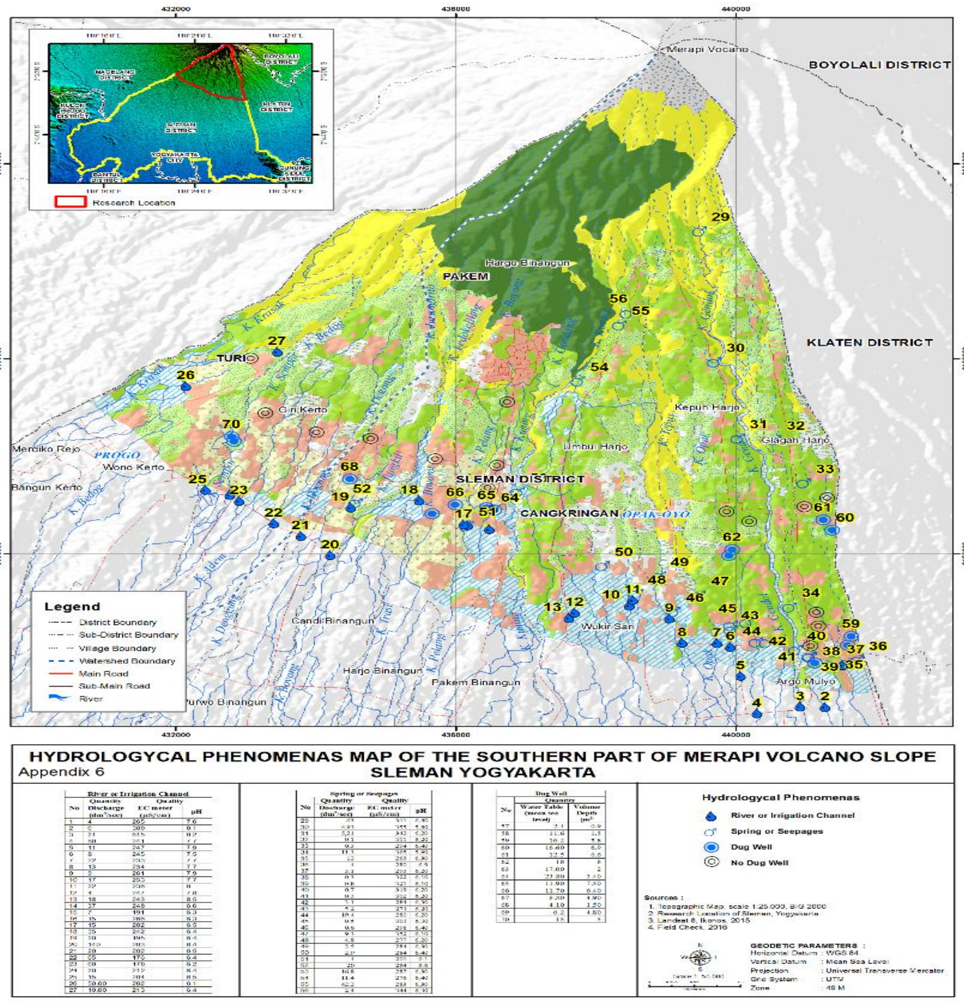
	Channel	Binangun				
17	Pelang River	Hargo Binangun	Pakem	15	266	6.3
18	Pelang Irrigation Channel	Hargo Binangun	Pakem	15	202	6.5
19	Tangkil River	Purwo Binangun	Pakem	20	195	6.4
20	Tawangrejo Irrigation Channel	Purwo Binangun	Pakem	140	203	6.4
21	Pancoh Kulon River	Purwo Binangun	Pakem	20	202	6.5
22	Degong River	Giri Kerto	Turi	65	176	6.4
23	Kuncen River	Giri Kerto	Turi	60	178	6.2
24	Sempor Irrigation Channel	Giri Kerto	Turi	20	212	6.4
25	Sempor River	Giri Kerto	Turi	15	204	6.5
26	Gondoarum Irrigation Channel	Wono Kerto	Turi	50	262	6.1
27	Bedog Irrigation Channel	Wono Kerto	Turi	10	213	6.4
Total				719	6144	

Appendix 5. Spring or Seepages of Southern part of Merapi Volcano Slope in Cangkringan to Turi Districts

No	**Names of Spring or Seepages**	**Village**	**Sub-District**	**Quantity**	**Quality**	
				Discharge (dm^3/sec)	**EC meter (µS/cm)**	**pH**
1	Sidorejo	Umbul Harjo	Cangkringan	16.8	287	6.3
2	Plunyon	Umbul Harjo	Cangkringan	11.4	276	6.4
3	Kalikuning	Umbul Harjo	Cangkringan	42.2	283	6.3
4	Pelemsari	Umbul Harjo	Cangkringan	2.4	344	6.3
5	Petung	Kepuh Harjo	Cangkringan	4.93	355	5.8
6	Batur	Kepuh Harjo	Cangkringan	5.21	342	6.2
7	Kalimacan	Glagah Harjo	Cangkringan	0.1	311	6.2
8	Umbul gading	Glagah Harjo	Cangkringan	0.3	294	6.4
9	Banjarsari	Wukir Sari	Cangkringan	11.3	365	5.9
10	Kalisililing	Argo Mulyo	Cangkringan	12	265	6.3
11	Pucungpitu	Argo Mulyo	Cangkringan	4	280	6.9
12	Mudal	Argo Mulyo	Cangkringan	3.1	293	6.2
13	Ngandong timur	Argo Mulyo	Cangkringan	0.3	322	6.1
14	Ngandong	Argo	Cangkringan	0.8	321	6.1

	barat	Mulyo				
15	Nguling	Argo Mulyo	Cangkringan	0.7	319	6.2
16	Umbul Srondokan	Wukir Sari	Cangkringan	0.3	302	6.2
17	Pandan	Wukir Sari	Cangkringan	3.1	284	6.3
18	Cakran	Wukir Sari	Cangkringan	5.2	273	6.2
19	Kalisongo	Wukir Sari	Cangkringan	19.4	280	6.2
20	Nduwet	Wukir Sari	Cangkringan	0.5	303	6.3
21	Umbul Celeng	Wukir Sari	Cangkringan	0.6	298	6.4
22	Sumber Opak	Wukir Sari	Cangkringan	9.3	352	6.1
23	Plupuh	Wukir Sari	Cangkringan	4.8	277	6.2
24	Umbul Tritis	Umbul Harjo	Cangkringan	2.5	284	6.3
25	Karangmelok	Wukir Sari	Cangkringan	2.9	284	6.4
26	Bebeng	Hargo Binangun	Pakem	63	311	6.4
27	Tanen	Hargo Binangun	Pakem	4	201	6.1
28	Tangkil	Purwo Binangun	Pakem	20	264	6.6
Total				251.14	8370	

Sources : Field Work. August 2016



Appendix 6. Hydrological Phenomenas Map of southern part of Merapi volcano slope

Appendix 7. Dug Well of Southern part of Merapi Volcano Slope in Cangkringan to Turi Districts

No	Names of location dug well or nothing	Village	Sub-District	Quantity		Quality		
				Water Table (mean sea level)	Volume Depth (m^3)	EC meter (µS/cm)	pH	Colour Smiley
1	Jetissumur dug well Glagahharjo	Glagah Harjo	Cangkringan	12.5	6.6	-	-	nothing
2	Glagahmalang no dug well Glagahharjo	Glagah Harjo	Cangkringan	-	-	-	-	-
3	Ngemplak dug well Glagahharjo	Glagah Harjo	Cangkringan	16.6	6.9	-	-	nothing
4	Tegaljetis no dug well Glagahharjo	Glagah Harjo	Cangkringan	-	-	-	-	-
5	Cepitsari dug well Argomulyo	Argomulyo	Cangkringan	16.2	5.8	-	-	nothing
6	Banjarsari no dug well Glagahharjo	Glagah Harjo	Cangkringan	-	-	-	-	-
7	Mudal dug well Argomulyo	Argomulyo	Cangkringan	11.6	1.5	-	-	nothing
8	Maras no dugwell Glagahharjo	Glagah Harjo	Cangkringan	-	-	-	-	-
9	Guling dug well Wukirsari	Wukirsari	Cangkringan	2.4	0.9	-	-	nothing
10	Tegalsaren no dug well Glagahharjo	Glagah Harjo	Cangkringan	-	-	-	-	-
11	Gondang dug well Wukirsari	Wukirsari	Cangkringan	18	8	-	-	nothing
12	Pagerjurang no dug well Kepuhharjo	Kepuh Harjo	Cangkringan	-	-	-	-	-
13	Gandu dug well Wukirsari	Wukirsari	Cangkringan	17	2	-	-	nothing
14	Manggung no dug well Kepuhharjo	Kepuh Harjo	Cangkringan	-	-	-	-	-
15	Wonorejo dug well Hargobinangun	Hargo Binangun	Pakem	8.3	4.9	-	-	nothing
16	Boyong no dug well Hargobinangun	Hargo Binangun	Pakem	-	-	-	-	-
17	Tanen dug	Hargo	Pakem	11.70	6.4	-	-	nothin

No	Names of location dug well or nothing	Village	Sub-District	Quantity		Quality		
				Water Table (mean sea level)	Volume Depth ($m^{3)}$)	EC meter (μS/cm)	pH	Colour Smiley
	well Hargobinangun	Binangun						g
18	Ngipiksari no dug well Hargobinangun	Hargo Binangun	Pakem	-	-	-	-	-
19	Sidorejo dug well Hargobinangun	Hargo Binangun	Pakem	11.90	7.5	-	-	nothing
20	Sidorejo no dug well Hargobinangun	Hargo Binangun	Pakem	-	-	-	-	-
21	Sidorejo dug well Hargobinangun	Hargo Binangun	Pakem	23.8	3.4	-	-	nothing
22	Banteng no dug well Hargobinangun	Hargo Binangun	Pakem	-	-	-	-	-
23	Ngepring no dug well Purwobinangun	Purwo Binangun	Pakem	-	-	-	-	-
24	Pelem no dug well Girikerto	Girikerto	Turi	-	-	-	-	-
25	Kratuan dug well Girikerto	Girikerto	Turi	4.10	1.5	-	-	nothing
26	Bening dug well Girikerto	Girikerto	Turi	7.00	6	213	6.4	nothing
27	Ngangkring no dug well Girikerto	Girikerto	Turi	-	-	-	-	-
28	Gondoarum dug well Girikerto	Girikerto	Turi	6.20	5	265	6.6	nothing
29	Tunggularum no dug well Girikerto	Girikerto	Turi	-	-	-	-	-
Total				167.3	66.4	478		

Sources : Field Work. August 2016

Appendix 8. Figure Land Use of Merapi Volcano Slope
in Cangkringan to Turi Districts

Appendix 9. Figure Hydrologycal Phenomenas of Merapi Volcano Slope
in Cangkringan to Turi Districts