GROUNDWATER CONSERVATION MODEL ON RECHARGE AREA OF VOLCANIC SLOPE

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Abstract

Landuse change becomes common environmental issue in each country. In developing countries, landuse change from forest to agriculture and residential area, decrease the environment quality. The impacts of landuse change to aquifer are decreasing potential groundwater, trigger for land subsidence and changing soil ecosystem. The purpose of this study is developing model to conserve the degradation aquifer caused by landuse change. Recharge area has a big role to keep groundwater infiltrated to aquifer zone. Research location of this research is in Merapi Volcano, an active volcano in the world. Some methods applied to conserve the aquifer, such as: build infiltration wells, terraces, artificial lakes and replantation. The results of this research is a model conservation of groundwater that can improve water infiltration capacity and manage water storage in aquifer zone.

Keywords : Landuse Change, Aquifer, Infiltration, Water Storage

A. Introduction

In fulfilling their needs, human cannot be separated from the presence of water which is one of the life-supporting material life. Various ways are taken to get clean water, including by taking water from the earth or below ground level. Getting the water from below the ground surface is considered as familiar and commonly done by people, based on some reasons namely: ground water is easy to obtain, ground water is relatively clean because it passes filtering process through the structure of soil and rocks, and ground water is economically cheaper.

The availability of ground water stored in the earth in two zones, which is in non-saturated zone and saturated zone. Non-saturated zone (aeration zone) is the distribution of land which the cavity among the soil particles is predominantly filled with air and partly filled with water. Aeration zone is ranged from plant roots to capillarity of saturated water. In this zone, there are soil moisture, vadose water and capillary water [1], [2]. This zone is the most responsible zone for agriculture. The availability of groundwater in these zones is mentioned as water holding capacity. Furthermore, Saturate Zone is a zone with water distribution which fills the cavities between the soil particles. In this zone the availability of groundwater is abundant, and utilized for clean water stock by people. Saturated zone starting from the water table up to the impermeable rock layer. The potential for groundwater supply capacity is the sum of water in aeration zone and saturated zone. Groundwater availability depends on the level of infiltration and percolation in the recharge area.

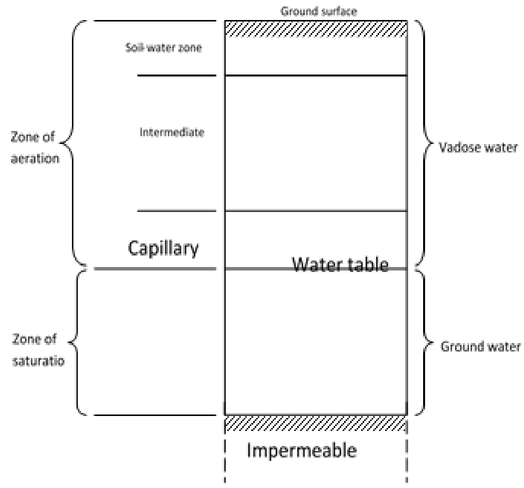

Figure 1. Cross Section of Open Aquifer

Recharge areas in Yogyakarta is affected by the physical condition of the upstream land, in this case is the slope of Mount Merapi. It is the backbone of the geohydrology system of Yogyakarta and surrounding areas. Water which flows from its mountain body is not only for the people who live on the slope, but also Yogyakarta and surrounding areas' people. Yogyakarta area with varied topography from the slopes of Mount Merapi in the north, then to the south there is a lowland, and ends with southern coastal areas. On the southeast side of the city, there is limestone mountain with great ground water potential, but hidden in the halls of underground river. Each region has different groundwater potential. That is, water is stored in different soil layer. As its function as a water recharge area, the southern slopes of Merapi is a subordinate protected area. Changes in land use has resulted in reduced levels of infiltration into the soil. As a result, these conditions result in adverse effects as region fungi hydrogeological, which is the fluctuations of surface position of groundwater in Jogja plains during the dry season decreased 5-10 meters. This condition not only because of the increasing uptake, but also reducing water input. This article focus on the analysis of landuse change and groundwater supply on recharge area of Merapi slope.

B. Materials and Methods

1. Study Area

This study is limited to the southern slopes of Mount Merapi which acts as groundwater recharge area, including: Slope region of Upper, Middle, Lower, Slope foot, Cones Tillers and Volcan Merapi.

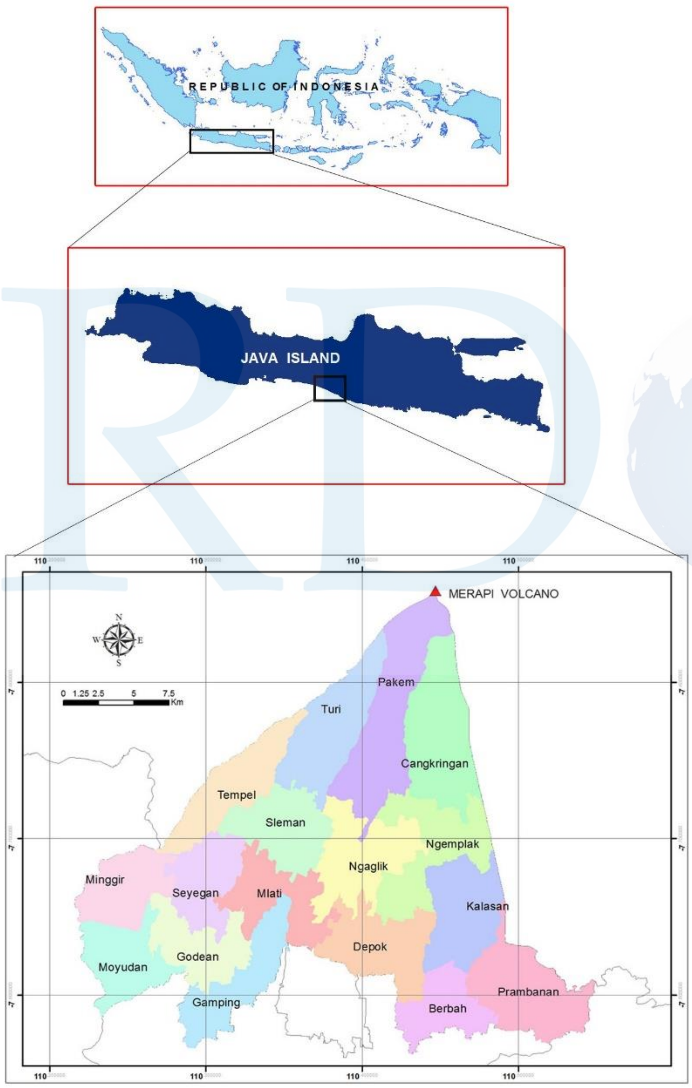

Figure 2. Research Location

2. The Typology of Aquifer System of Mount Merapi

The knowledge of geometry concerning groundwater availability below the surface can explain about characteristics and nature of groundwater. Conditions and distribution of aquifer systems in geological systems are controlled by lithology, stratigraphy and structure factors of geology deposits. Lithology is the constituent which physically include mineral composition, grain size and container from sediments or rocks that make up the geological systems. Stratigraphy describes the condition of the geometry and the relationship between the layers or lithologies in geological systems. While geological structure is a geometry form/nature of geological systems caused by deformation that occurs after the rocks formed. On a nonconsolidated/compact sediment, the active control is lithology and stratigraphy. Knowledge concerning the three above factors will guide to the understanding of the characteristics and distribution of aquifer system [[3]]. The similarity of climate and geological conditions in a specific region will cause equality in groundwater system. This condition will affect the character of physics and chemistry as well as the quality of groundwater in the system.

The typology of aquifer system is Typology of Aquifer System the Mount Merapi Volcano Deposition. Morphologically, the volcanic mountain is divided into five parts: Upper, Middle, Lower and Foot, as well as the Deposition plain. In each of these sections, the formation and spread of groundwater has specific properties and characteristics.

The existence of groundwater in this area is generally located on very porous rock and not compact, alternating with layers of lava flows which generally waterproof. This leads to the accumulation of quite large amount of groundwater and emerged as water springs with varied discharge.

In addition to pore system media, ground water potential in this area is also found in the aquifers with fracture media system that commonly found on lava. The fractures are formed by burl that occur as a result of cooling process, or as a result of tectonic or volcanic activity. Some areas of springs with this fracture system shows very large discharge.

3. Aquifer Conditions

Sleman has the multilayered aquifer system which is hydrogeologically forms Merapi Aquifer System (MAS) and has relatively similar hydraulics properties and interconnected. The northern part of Merapi Aquifer System is constituted by Upper Pleistocene volcanic rocks of Merapi Old, in the eastern part is constituted by Tertiary rocks of Semilir and Nglanggran Formation, and Tertiary rocks of Sentolo Formation in the west and south.

In general, groundwater flows from north to south, with spreading flow pattern which form radial centrifuges pattern. The distribution pattern is typical of volcanic morphology. Aquifer zoning laterally divided into two parts:

a. Recharge area, located on the upper, middle and lower slopes of Merapi Mountain. Groundwater comes from infiltration of rain water, river flow and irrigation flow. Recharge area is an area that needs to be maintained its authenticity, because it determines the availability of water pads of expenditure zone.
b. Discharge area, distributed to lower zone on Merapi Mountain slope, with narrowed gradient towards south. Along topographic gradient decline, followed by the fall of gradient groundwater level, so to the south, the groundwater velocity decreased.

Aquifer is generally thick (> 50 meters) and becomes thicker toward the south, including Ngaglik area area with 80-meters thickness, Karanggayam Bedog area with 140-meters thickness and Yogyakarta city reaches 150-meters thickness [4]. Merapi Aquifer System vertically divided into three main parts: the upper aquifer, the bottom aquifer, and the base aquifer [5]. The characteristics of each aquifer is described as follows.

a. Upper aquifer is formed by the formation of Yogyakarta, located in the northern area. This aquifer is composed of andesite lava and sediment of Old Merapi volcanic breccias. In some locations, lava and silty sand can be found. The middle section of Merapi Aquifer System is composed of moderate to coarse sand, gravel chunks clan with the diameter of about 0.5 m, and the lenses of andesitic breccias clan. In the southern part is composed by fine and moderate sand, sandy silt, sandy clay, fine gravel clan. In this part, lava lenses and breccias are hardly found as it can be seen in the center of the northern clan. The maximum depth of the aquifer reaches 25 meters.
b. Bottom aquifer is dominated by sediment derived from formation of Sleman. Northern part of the aquifer is composed of coarse sand material, rough gravel chunks clan, volcanic breccia deposition and andesite lava lens. In this part, we can find coarse tuff infiltration, silty sand, clay clan in local distribution. The southern part of this aquifer system is dominated by fine to moderate sand, fine gravel, sand silty clay sandy clan. Feature aquifers have a high level of productivity clan moderate to high permeability of the aquifer.
c. Base aquifers in the northern part is composed by breccia volcanic rocks of andesite lava clan which is very compact and derived from the sediment of Old Merapi. The central part of the southern clan is in the form of basin which is formed by Formation

of Sentolo; intrusive rocks in the western part are Tertiary rocks clan Formation of Nglanggran, Semilir formation.

4. Data Source and Analysis

Data obtained from secondary data about the physical nature condition of Southern slopes of Mount Merapi. It includes:

a. Indonesia Topographic Maps (RBI) Year 2000 (Sheet: 1408: 244; 241; 242; 223; 224; 232; 214);
b. Thematic Digital Map (Landuse, Landcover, Landform, Administrative);
c. Database of Sleman Regency Resource (Land Resources, Water Resources).

Data analysis techniques is a secondary data processing which is obtained, measured and calculated using data analysis techniques as follows:

a. GIS analysis to determine the spatial distribution pattern of groundwater potential by using software Arc View 3.3.
b. Water Balance to determine the potential of soil water availability by using the Rational Method and Thornthwhite Method.

The use of water capacity estimation methods and techniques of the estimated in the aquifer of southern slopes of Mount Merapi based on some assumptions, including:

a. Southern Mount Merapi aquifer is relatively homogeneous,
b. The gradient thickness of southern Mount Merapi aquifer is regular and dynamic,
c. Data Validity 1998 (Landuse, RBI).

C. Results and Discussions

1. Land Capability of Southern Slopes of Mount Merapi

Land capability classification is the assessment of land component which according to Arsyad (1989) is the assessment of land components in systematic and grouping techniques into categories based on the properties of land use potential and obstacles [6]. Based on the Form of Land, the area of Southern Slopes of Mount Merapi have land capability classes and direction of land use as follows:

Tabel 1. Landuse Classification and Landuse Direction

No	Landform unit	Land Capability Class	Landuse direction	Landuse recently	Unsuitable
1	Volcanic Upper slope	VI	Production Forest Plantation, livestock	agriculture , residential, plantation, livestock, mines	residential, livestock, Limited mines
2	Volcanic middle slope	IV	Limited agriculture	agriculture, residential, mines	Limited mines
3	Volcanic lower slope	III	Limited agriculture	agriculture, residential, mines	Limited mines
4	Volcanic foot slope	I	Intensive agriculture	agriculture, residential	Localized residential
5	Sub cone	VIII	Protected forest	forest	suitable
6	Volcanic cone	VIII	Protected forest Protected forest	Forest, grassland	suitable

Source : Suratman Woro: 2005[7]

2. Analysis of Water Storage Capacity of Southern Slopes of Mount Merapi

The potential capacity groundwater availability (St) is the sum of amount of water in non-saturated and saturated zone. The calculation of the water storage capacity in each form of land is conducted with basic assumptions:

a. Initial Water Storage Capacity (St_0) in the form of land use original forest in the southern slopes of Mount Merapi; for Non-Saturated Zone water holding capacity (WHC) calculation is used and calculation of water storage for Saturated Zone is based on the porosity of the soil and rocks.
b. Current Water Storage Capacity Now (St_{sk}) in the form of current land use; yard, rice paddies, fields, forests and others; for Non-Saturated Zone water holding capacity (WHC) calculation is used and calculation of water storage for Saturated Zone is based on the porosity of the soil and rocks.

The storage capacity of water in the soil cannot be separated from the existing soil porosity in the specific region. Porosity shows the ratio of volume of air pores between soil particles per volume of the total land [8]. So it can be formulated as follows:

$$\alpha = \frac{v1}{V} \quad (1)$$

$$\alpha = \mathrm{Sy} + \mathrm{Sr} \quad (2)$$

$$Sy = \frac{Wy}{v3} x100\% \quad (3)$$

$$Sr = \frac{Wr}{V} x100\% \quad (4)$$

Where α is porosity, *Sr* is specific retention, v1 is air volume, Wy = available-to-take water, v2 is soil volume, Wr is stocked in the soil water, and Sy is specific yield

The measurement of water storage capacity in each region is formulated as:

a. Water Storage Capacity in Non-saturated Zone (St_1)

$$St1 = SmR \times If \times A \times h \quad (5)$$

b. Water Storage Capacity in Saturated Zone (St_2)

$$St2 = Sy \times A \times h \quad (6)$$

So the Water Storage Capacity in aquifer is:

$$St = St_1 + St_2 \quad (7)$$

The measurement on Non-Saturated and Saturated Zone conducted in Initial Landuse (forest) and Current Land Use (yard, fields, fields, forests and others), so the difference in water storage between the initial state (t_0) to the present (t_{sk}) is formulated as follows:

$$\Delta St = \sum St_0 - \sum St_{sk} \quad (8)$$

$$\Delta St = (St_1 + St_2)_{initial} - (St_1 + St_2)_{current} \quad (9)$$

Δ St shows the water deficit based on the land use change between the initial and the current state.

Groundwater conservation needs restoration effort of the slopes of Mount Merapi as a recharge area for the region beneath. The concept of water conservation in the recharge area is to increase the area of interception, infiltration and percolation; and also minimize the occurrence of overland flow with regards to several aspects, including:

a. The slope tilt, the thickness of the aquifer and the depth of the water table;
b. Surface Erosion Level of the land;
c. The land power to hold the cover vegetation masses.

The amount of initial and current water deficit in the Recharge area of Southern Slope:

$$\Delta St_{0\text{-}Sk} = St_0 - St_{Sk}$$

$= (1248,9 - 940,9) \text{ x million } m^3$

$= 308 \text{ million } m^3$

So the initial and current deficit in the Recharge area of Southern Slope of Merapi is 308 million m^3.

3. Water Conservation Alternative Effort in Southern Slopes of Mount Merapi

In order to cope with water deficit in Recharge area in the Southern slopes of Mount Merapi some alternatives of water conservation can be implemented, such as:

a. Physical-Mechanics Method, such as: build infiltration wells, terraces and artificial lakes;
b. Vegetative Method.

Furthermore, calculating water conservation in the recharge area of southern slopes of Mount Merapi can be explained as follows:

a. Physical Mechanics Method.

- Making Infiltration Wells

The calculation of the amount of water in the soil infiltrated with wells is:

$$V = A \text{ x } C \text{ x } (rP - rEP) \quad (10)$$

Where V is volume of water in the infiltrated soil, C is index of water recharge, A is size of recharge area, rP is mean of annual precipitation, rEP is mean of annual evapotranspiration. rEP is calculated based on the monthly evapotranspiration

$$PEx = 16\left(\frac{10t}{j}\right)^a$$

(PEx), with monthly temperature (tn). So it can be measured with some of the following equations:

(11)

where:

$$j = 0{,}09 tn^{\frac{3}{2}} \quad (12)$$

$$J = \sum_{1}^{12} j \quad (13)$$

$$a = 0{,}016 J + 0{,}5 \quad (14)$$

The calculation of the amount of water in the soil infiltrated with infiltration wells in the yard region of the recharge area of the southern slopes of Mount Merapi is: (Σ A = 7713 Ha; rP = 2554.2 mm/yr; rEP = 964.8)

V = A x C x (rP - rEP)

= 77.13 million x 0.95 x (2.554 to 90% x 0.965)

V = 123.5 million m^3/year

So the volume of water which can be infiltrated through the infiltration wells in an area of 7713 hectares yard is 123.5 million m^3/yr.

- Build terraces

Terrace on Wet Agricultural Land II - IV Classes with the tilt of <15% can be found in Pakem and Ngaglik (Σ A = 3718 Ha), with amount of water which can be infiltrated in the wet agriculture land is:

V = A x C x (rP – rEP)

= 3.718 million x 0,75 x (2,554 – 0,965)

V = 44.3 million m^3/year

So the volume of water which can be infiltrated in an area of 3718 hectares of wet agriculture land is 44.3 million m^3/year.

- Build artificial lakes

Built artificial lake in dry agriculture land (∑ A = 3232 ha)

V = A x C x (rP – rEP)

= 3.232 million x 0,95 x (2,554 – 0,965)

V = 48,8 million m^3/year

So the volume of water which can be infiltrated using Situ (pond) in an area of 3232 hectares of wet agriculture land is 44.8 million m^3/year.

b. Vegetative Method

Increasing the quantity and quality of Land Cover vegetation:

» Utilizing 50% Miscellaneous land for Greenbelt (ΣA = 1568 Ha), then the amount of water that can be infiltrated is:

V = A x C x (rP – rEP)

= 1.568 million x 0,9 x (2,554 – 0,965)

V = 22.4 million m^3/year

So the volume of water which can be infiltrated using green belt (forest) in an area of 1.568 hectares of miscellaneous land is 22.4 million m^3/year.

The efficiency which can be done to cope with the deficit of soil water in recharge area of the southern slopes of Mount Merapi are:

Efficiency (ŋ) = Volume of Conservated Water - Water deficit (ΔSt_{0-Sk})

= {(123,5 + 44,3 + 44,8 + 22,4) - 308} . million m^3/year

= - 69 million m^3/year

So land conservation efforts which have been implemented has not been able to restore the amount of water infiltration into the soil as the initial state (forest) accounted for 69 million m^3/year; nevertheless. it reaches the efficiency of water infiltration for 239 69 million m^3/year.

D. Conclusion and Recommendation

1. Depreciation of Water Storage Capacity in the plains of Merapi Sediment is caused by:
   a. changes in land use and Land cover in Recharge Area region,
   b. deforestation by humans,
   c. population growth effects in increasing the amount of groundwater needs and enlarge the volume of groundwater retrieval,
   d. land Processing is not in accordance with class of land capability,
   e. reducing volume of the aquifer due to not environmental-friendly mining business.
2. Water conservation recommendation
   a. Physical Mechanic Method
      » The construction of infiltration well in yard = 123.5 m^3/year
      » The construction of terrace on Wet Agricultural Land II - IV Classes in Pakem and Ngaglik = 44.3 m^3/year
      » The construction of Situ (Pond) on field = 48.8 m^3/year
   b. Vegetative method
      » Using the 50% miscellaneous lands for greenbelt = 22.4 m^3/year

THE EFFICIENCY OF WATER STORAGE CAPACITY = 239 m^3/year

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TABEL 1. WATER STORAGE CAPACITY ANALYSIS IN RECHARGE AREA AQUIFER (BEGINNING) SOUTHERN MERAPI VOLCANO

No.	District	Landform	(Ha)	Soil Texture	Specific Yield (Sy)	Landuse Forest SmR (mm)	C	If	Luas (Ha)	Aquifer thick (m)	Aquifer mean (m)	Mean of Non Saturated Zone thick (hA) (m)	Mean of Saturated Zone (hB) (m)	i Water table fluctuation (m)	Mean of Non Saturated Zone thick' (hA`) (m)	Mean of Saturated Zone thick' (hB`) (m)	WHC (million m3)	Storage Saturated zone (million m3)**	Maximum Storage Aquifer (million m3)
1	Tempel	Foot Slope	2057.7	Sand (m)	0.240	250	0.1	0.90	2058	52.5 - 91	71.8	7	64.8	2.5	4.5	74.3	20.8	122.2	**143.0**
		Fluvial Plain	1191.3						1191	91 - 140	115.5		108.5			118.0			
2	Sleman	Foot Slope	2125.3	Sand (m)	0.240	250	0.1	0.90	2125	52.5 - 91	71.8	11	60.8	3.1	7.9	74.9	37.8	127.3	**165.0**
		Fluvial Plain	1006.7						1007	91 - 140	115.5		104.5			118.6			
3	Ngemplak	Foot Slope	2123.2	Sand (m)	0.240	150	0.1	0.90	2123	52.5 - 91	71.8	9.7	62.1	3.4	6.3	75.2	18.1	127.6	**145.7**
		Fluvial Plain	1447.8						1448	91 - 140	115.5		105.8			118.9			
4	Ngaglik	Foot Slope	2361	Sand (m)	0.240	250	0.1	0.90	2361	52.5 - 91	71.8	9.7	62.1	3.1	6.6	74.9	35.1	141.4	**176.4**
		Fluvial Plain	1491						1491	91 - 140	115.5		105.8			118.6			
5	Cangkringan	Foot Slope	1450.8	18 % Sand (m); 72 % Sand (c)	0.232	250	0.1	0.90	1451	52.5 - 91	71.8	11.8	60.0	2.8	9.0	74.6	29.4	83.6	**223.3**
		Lower Slope	1674.2						1674	41.5 - 52.5	47.0		35.2			49.8		64.4	
		Middle Slope	1227.6						1228	30.5 - 41.5	36.0		24.2			38.8		36.4	
		Upper Slope	446.4						446	19.5 -30.5	25.0		13.2			27.8		9.5	
6	Turi	Foot Slope	1846.7	88 % Sand (m); 12 % Sand (c)	0.239	250	0.1	0.90	1847	52.5 - 91	71.8	10	61.8	2.9	7.1	74.7	29.5	109.7	**222.7**
		Lower Slope	1231.2						1231	41.5 - 52.5	47.0		37.0			49.9		48.9	
		Middle Slope	861.8						862	30.5 - 41.5	36.0		26.0			38.9		26.4	
		Upper Slope	369.3						369	19.5 -30.5	25.0		15.0			27.9		8.1	
7	Pakem	Foot Slope	1289.4	40 % Sand (m); 60 % Sand (c)	0.236	250	0.1	0.90	1289	52.5 - 91	71.8	10	61.8	2.7	7.3	74.5	21.2	75.5	**172.8**
		Lower Slope	653.3						653	41.5 - 52.5	47.0		37.0			49.7		25.5	
		Middle Slope	722.1						722	30.5 - 41.5	36.0		26.0			38.7		21.8	
		Upper Slope	945.6						946	19.5 -30.5	25.0		15.0			27.7		20.4	
		Cones	343.8						344	25-32.5	28.8		18.8			31.5		8.4	
		Volcan cone	429.8																
																		TOTAL WATER STORAGE CAPACITY (BEGINNING)	**1248.9**

** Assumtion: the Proportion of Gravel, Rock and Sand are the same (33,3%)

TABEL 2. WATER STORAGE CAPACITY ANALYSIS IN RECHARGE AREA AQUIFER (RECENT) SOUTHERN MERAPI VOLCANO

No.	District	Landform	(Ha)	Soil Texture	Specific Yield (Sy)	Landuse: Yard				Rice field				Agriculture Land				Forest				Others				Aquifer thick (m)	Mean of Aquifer thick (m)	Mean of Non Saturated Zone (m)	Mean of Saturated Zone (m)	WHC (juta m3)	Storage Saturated zone (million m3)**	Maximum Aquifer Storage (million m3)
						SmR (mm)	C	If	Luas (Ha)	SmR (mm)	C	If	Luas (Ha)	SmR (mm)	C	If	Luas (Ha)	SmR (mm)	C	If	Luas (Ha)	SmR (mm)	C	If	Luas (Ha)							
1	Tempel	Foot Slope	2057.7	Pasir Sedang	0.240	30	0.95	0.05	1018	50	0.25	0.75	1854	150	0.2	0.80	7	250	0.1	0.90	0	76	0.35	0.65	305	52.5 - 91	71.8	7	64.8	6.1	106.6	**112.7**
		Fluvial Plain	1191.3																							91 - 140	115.5		108.5			
2	Sleman	Foot Slope	2125.3	Pasir Sedang	0.240	30	0.95	0.05	973	50	0.25	0.75	1647	150	0.2	0.80	8	250	0.1	0.90	0	76	0.35	0.65	504	52.5 - 91	71.8	11	60.8	9.8	103.2	**113.0**
		Fluvial Plain	1006.7																							91 - 140	115.5		104.5			
3	Ngemplak	Foot Slope	2123.2	Pasir Sedang	0.240	30	0.95	0.05	840	30	0.25	0.75	2039	150	0.2	0.80	282	150	0.1	0.90	0	76	0.35	0.65	410	52.5 - 91	71.8	9.7	62.1	9.8	105.3	**115.1**
		Fluvial Plain	1447.8																							91 - 140	115.5		105.8			
4	Ngaglik	Foot Slope	2361	Pasir Sedang	0.240	30	0.95	0.05	1320	50	0.25	0.75	1922	150	0.2	0.80	200	250	0.1	0.90	0	76	0.35	0.65	409	52.5 - 91	71.8	9.7	62.1	11.5	117.1	**128.6**
		Fluvial Plain	1491																							91 - 140	115.5		105.8			
5	Cangkringan	Foot Slope	1450.8	18 % Pasir Sedang; 72 % Pasir Kasar	0.232	30	0.95	0.05	1470	50	0.25	0.75	1135	150	0.2	0.80	1192	250	0.1	0.90	150	76	0.35	0.65	852	52.5 - 91	71.8	11.8	60.0	31.1	67.1	**170.6**
		Lower Slope	1674.2																							41.5 - 52.5	47.0		35.2		45.1	
		Middle Slope	1227.6																							30.5 - 41.5	36.0		24.2		22.7	
		Upper Slope	446.4																							19.5 -30.5	25.0		13.2		4.5	
6	Turi	Foot Slope	1846.7	88 % Pasir Sedang; 12 % Pasir Pasir Kasar	0.239	30	0.95	0.05	1046	50	0.25	0.75	1373	150	0.2	0.80	1187	250	0.1	0.90	236	76	0.35	0.65	466	52.5 - 91	71.8	10	61.8	27.2	90.7	**175.8**
		Lower Slope	1231.2																							41.5 - 52.5	47.0		37.0		35.9	
		Middle Slope	861.8																							30.5 - 41.5	36.0		26.0		17.7	
		Upper Slope	369.3																							19.5 -30.5	25.0		15.0		4.4	
7	Pakem	Foot Slope	1289.4	40 % Pasir sedang; 60 % Pasir Kasar	0.236	30	0.95	0.05	1045	50	0.25	0.75	1796	150	0.2	0.80	356	250	0.1	0.90	48	76	0.35	0.65	190	52.5 - 91	71.8	10	61.8	13.2	62.6	**125.3**
		Lower Slope	653.3																							41.5 - 52.5	47.0		37.0		18.8	
		Middle Slope	722.1																							30.5 - 41.5	36.0		26.0		14.6	
		Upper Slope	945.6																							19.5 -30.5	25.0		15.0		11.0	
		Cones	343.8																							25-32.5	28.8		18.8		5.0	
		Volcan cone	429.8																													
TOTAL WATER STORAGE CAPACITY (RECENT)																																**940.9**

** ** Assumtion: the Proportion of Gravel, Rock and Sand are the same (33,3%)