THE EFFECTS OF SEDIMENTS CARRIED BY OVERLAND FLOW ON THE AFFECTIVITY OF INFILTRATION WELLS IN THE SUB URBAN AREA

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ABSTRACT

Infiltration wells have been widely applied in urban areas to control runoff so that flooding can be reduced or even prevented. Rain water falling in the roof or impervious object forms overland flow infiltrate into the infiltration wells. Overland flow contains some sediments and chemicals that may enter into the infiltration wells and deposited in the wells. Therefore, it can reduce the effectiveness of the infiltration wells. This study aims to analyze the characteristics of sediment carried by overland flow and its influence on the effectiveness of infiltration wells in sub-urban area. This research was conducted in Sub-Urban dense with housing. A total of 19 infiltration wells have been observed and sediment in those wells were collected and analyzed to study the sediment characteristics. Grains size of the sediment was analyzed in the laboratory. This study shows that the sediments deposited in the infiltration wells mostly classified as loam to sand. Of the 19 wells which were studied, most of them have been filled with sediment over a third of its depth that occurred during the period of 2010-2016. Based on the grain size characteristics, it could be concluded that sediment originated from the surrounding yard area and some of them as a results of Mt. Merapi eruption in 2010 and Mt. Kelud in 2014. Infiltration wells that collect overland flow from the roof tend to have the finer sediment than those collect overland flow from road and yards. They also have a thicker sediment layer. Therefore, infiltration wells that collect water from the roof is more effective than infiltration wells that collect water from roads.

Keywords: sub-urban area, overland flow, infiltration wells, sediments, grain size

INTRODUCTION

Changing the non residential area into a residential area, causing a change in the nature of the land to absorb water. Areas that previously can infiltrate water easily is turned into an area that is watertight (Sudarmadji 1997[b]). The area change into a residential area as well as other facilities that are watertight. Facilities such as village roads have been built by local people. The roads were made into a cement road or air paving blocks and even asphalt. Changes in hydrological characteristics will affect the hydrological processes that cause changes in output assigned by higher flow compared to its previous state (Lazaro, 1990, Chapman 1992). Therefore, flooding often occurs due to the impact of land use change on hydrology (Suprayogi, 2013). In addition to changes in the quantity, output in the form of water quality also changed. Changes in water quality can continue to water pollution (Broz et al., 2002). The flow coming from dense residential areas also have high enough levels of sediment (Sudarmadji, 1997[a]). These sediments can be originated from the yard area as results of splash and sheet erosion.

To mitigate the impact caused by land cover changes some effort have been made to reduce the flow by constructing infiltration wells (Adelila, 1998, Suprayogi 2015). In addition of reducing the runoff, infiltration wells may be also used as groundwater recharge, so the lack of groundwater can be reduced as well, especially during the dry season. Infiltration wells can be constructed on the side of the house in which rainwater falling on the roof via gutters enter into the well. Infiltration wells can also be constructed on the side of the road or in the middle of the road to accommodate overland flow flowing on the road. Infiltration wells simply assume that the water that goes into the well water is relatively clean, because it comes from rain water. In fact, infiltration wells were not only gets input from the rainwater directly. Rain falling on the roofs or on yards and roads form overland flow may also enter into infiltration wells. Water in the overland flow also contains some nutrients derived from residential areas and yards as well as sediment that carried into the infiltration wells. If the sediment enter into the infiltration wells through overland flow over long periods of time, it can be presumed that the effectiveness of infiltration wells in accommodating and infiltrating water will decrease.

Natural disasters such as the eruption of Merapi Volcano in 2006 and 2010, eruption of Kelud Volcano in 2014 brought volcanic ash which was deposited in many places. These volcanic ash and sand were also transported by overland flow into the infiltration wells. It will reduce the effectiveness of the infiltration wells. Infiltration wells have been applied in the densely residential housing requires to maintenance. However, since the infiltration wells were constructed the maintenance never carried out. This study aims: 1) revealing the condition of infiltration wells in terms of its effectiveness based on the sediments deposited in the wells, 2) analyzing the characteristics and sources of sediments in the infiltration wells.

Methods

Location

This research was conducted in a sub-urban area that physically now gradually developed into an urban area. The research area is a dense residential areas and densely populated, in the hamlet of Banteng, Jalan Kaliurang, north area of Yogyakarta (Figure 1). This is done with the consideration that this area is still developing. The area mostly covers by buildings, but some houses still have yards, cultivated with various crops. In the yards the splash erosion and sheet erosion can take place. It could be a source of sediments. In addition, the area is also covered with village roads hardened by cement or con block, that makes this area becomes impermeable. By changing this area into an impermeable area, it has great potential to generate large overland flow.

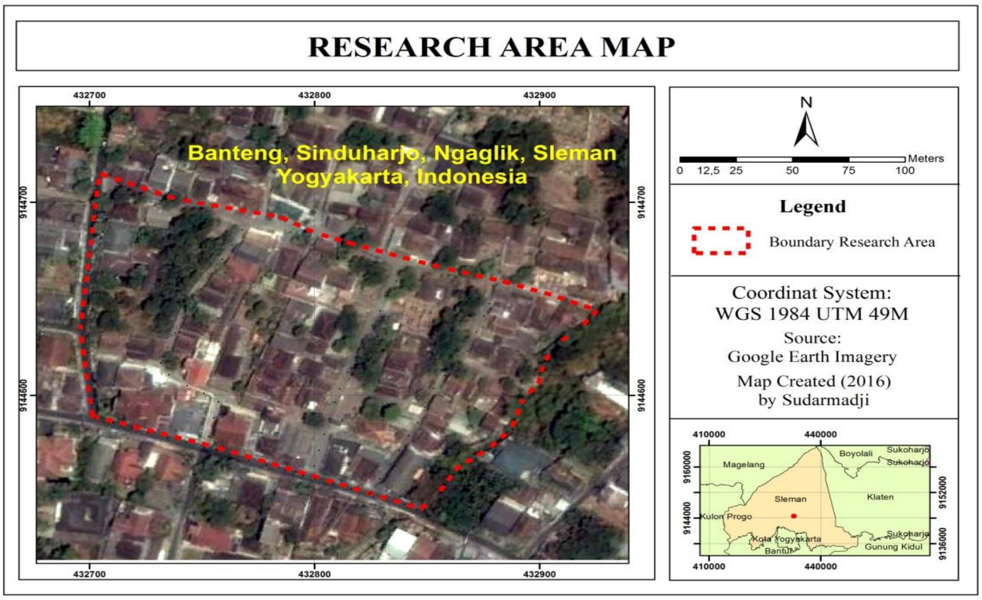

Fig. 1. Research Area

Data Collecting and Analysis

This research required primary and secondary data. Primary data was collected based and observation and measurement directly in the field and laboratory analysis as follow: a) data of physical condition research areas such as land use conditions yard, housing, roads and facilities supporting observed directly in the field, b) data on condition of the soil in the form of soil physical properties observed in the field, c) data on rainfall obtained previous research, d) The characteristics of the sediment collected from infiltration wells while physical characteristics mainly the grain distribution analysis were obtained by laboratory analysis.

The data collected in the field is processed by means of descriptive quantitative with the help of the cross table. Data analysis results tabulated by the appropriate table so easily analyzed. The analysis used is quantitative descriptive analysis using cross table. Sediment characteristics presented in the form of sediment frequency diagram based on grain size and compared between samples. Sediments deposited in the infiltration wells derived from many sources (yards and roads) were compared using charts and tables to analyze the differences in characteristics.

RESULT AND DISCUSION

Sediment in Overland flow

Sediment transport by overland flow starts with splash erosion occurring on lands in the settlement area. Splash erosion can occur in an open land as well as on land covered by vegetation. In open land, the splash erosion can take place directly from raindrops falling from the sky. Splash erosion can also occur on the lands having vegetal cover, caused by water droplets from crown drip, and stem flow (Sudarmadji, 2015). Further erosion may occur after the overland flow is formed. In this study we mainly focused on bed load carried by overland flow. Since it is not possible take bed load samples on overland flow, then the bed load was collected from sediment left by overland flow in the infiltration wells. Sediment deposited in infiltration wells is concidered to accumulate in a considerable period of time. A total of 20 sediment samples were collected to analyze the characteristics of the grain (Figure 2). One sediment sample is material of Kelud Volcano eruption in 2014, which is used as a comparison.

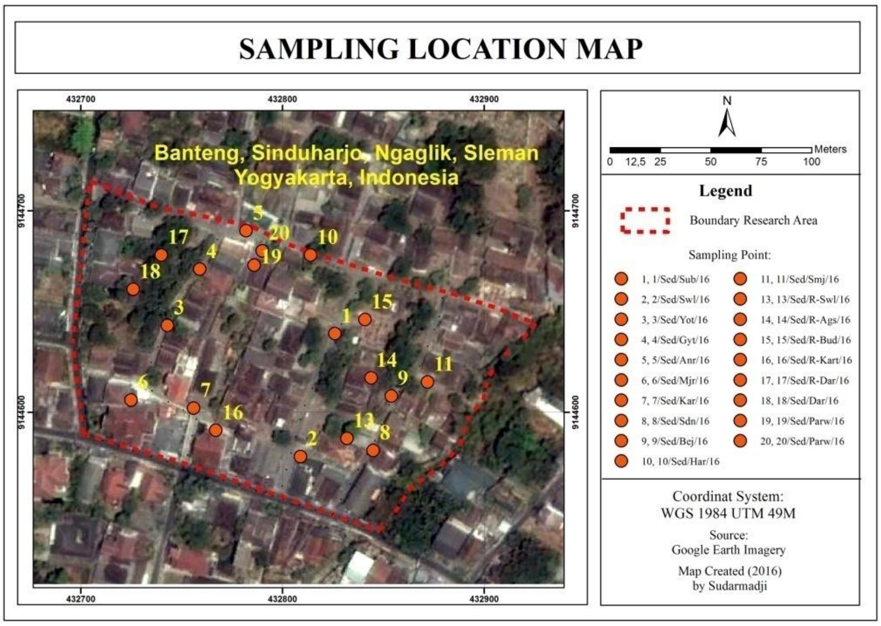

Figure 2. Sampling Location

Data collected from the bed load that has been deposited in the infiltration wells. These sediments have been accumulated since 2010, the time when infiltration wells rehabilitated due to eruption of Mt. Merapi. The sediment can enter into infiltration wells carried by overland flow. Figure 3 shows the process of collecting sediment samples from infiltration wells. In collecting sediment samples some wells need to be drained, because they are unable to absorb water. The may have been filled-up with water and sediment. During collecting the sediment samples the thickness of sediment deposited in the infiltration wells were also recorded.

Figure 3. Collecting Sediment Samples

Sediment Thickness

Data on sediments in infiltration wells are shown in Table 1 and Table 2). The table shows the depth of infiltration wells and thickness of sediment layer in those wells. From the table it is clearly seen that most of the infiltration wells have been filled with sediment over a third, even more than half. From these data it can be seen that the sediments that enter the infiltration wells would reduce the function of infiltration well to accommodate and absorb runoff.

Table 1. Depth of Infiltration Wells and Sediment Thikness in the Wells

No.	X	Y	Sed Code	Depth on Inf. Well (cm)	Thickness of Sediment (cm)	Explanation
1	432826	9144639	1/Sed/Sub/16	500	225	Road
2	432809	9144578	2/Sed/Swl/16	500	200	Road
3	432743	9144643	3/Sed/Yot/16	500	150	Road
4	432759	9144671	4/Sed/Gyt/16	500	175	Road
5	432782	9144690	5/Sed/Anr/16	600	150	Road
6	432725	9144606	6/Sed/Mjr/16	500	200	Road
7	432756	9144602	7/Sed/Kar/16	500	200	Road
8	432845	9144581	8/Sed/Sdn/16	500	250	Road
9	432854	9144608	9/Sed/Bej/16	500	100	Road
10	432814	9144678	10/Sed/Har/16	500	150	Road
11	432872	9144615	11/Sed/Smj/16	500	100	Road
12	-	-	12/Abu-KLD/16	-	-	Volc.Material
13	432832	9144587	13/Sed/R-Swl/16	300	175	Yard
14	432844	9144617	14/Sed/R-Ags/16	300	100	Yard
15	432841	9144646	15/Sed/R-Bud/16	300	75	Yard
16	432767	9144591	16/Sed/R-Kart/16	300	150	Yard
17	432740	9144678	17/Sed/R-Dar/16	500	75	Yard
18	432726	9144661	18/Sed/Dar/16	300	50	Yard
19	432786	9144673	19/Sed/Parw/16	300	50	Yard
20	432790	9144680	20/Sed/Parw/16	300	75	Yard

Grain Size Characteristics

Sediment carried by overland flow deposits and accumulates in the infiltration wells. Infiltration wells that collect water overland flow directly from the roof of the houses, from the yards and from the roads. Water coming from the roofs of the houses, from the yards or and the roads have different characteristics. Table 2 shows the results of analysis of the characteristics of sediment from infiltration wells that collect overland flow from different sources. Results of the analysis shows the characteristics of the sediment by grain size. It shows the percentage of clay, loam sand and gravel by weight.

The grain size characteristics are presented in tabular form based on the percentage of cumulative grain size. Examples of characteristics of sediment grain size as presented in Figure 4 to Figure 6. Figure 4 shows the grain size of sediments from infiltration wells collecting overlandflow from roads, Figure 5 shows the characteristics of volcanic ash. While Figure 6 shows the sediment charateristics from infiltration wells collecting overlandflow from yards.

Table 2. Sediment Characteristics Based on Texture

No.	Code	Clay	Loam	Sand	Gravel
1	1/Sed/Sub/16	0,41	63,45	33,30	2,84
2	2/Sed/Swl/16	0,44	70,91	24,12	4,53
3	3/Sed/Yot/16	1,45	68,93	27,83	1,77
4	4/Sed/Gyt/16	0,86	55,08	38,50	5,57
5	5/Sed/Anr/16	0,86	44,97	46,15	8,02
6	6/Sed/Mjr/16	2,98	69,62	24,85	2,54
7	7/Sed/Kar/16	1,49	53,57	40,37	4,55
8	8/Sed/Sdn/16	1,79	49,17	43,98	5,07
9	9/Sed/Bej/16	1,15	75,30	20,12	3,43
10	10/Sed/Har/16	3,35	80,94	13,44	2,27
11	11/Sed/Smj/16	1,08	76,81	16,80	5,28
12	12/Abu-KLD/16	3,78	96,10	0,12	0,00
13	13/Sed/R-Swl/16	9,06	90,87	0,08	0,00
14	14/Sed/R-Ags/16	3,40	87,28	9,11	0,20
15	15/Sed/R-Bud/16	4,22	90,14	5,52	0,11
16	16/Sed/R-Kart/16	6,01	91,03	2,87	0,09
17	17/Sed/R-Dar/16	4,74	82,58	12,28	0,4
18	18/Sed/Parw/16	1,60	42,43	44,83	11,13
19	19/Sed/Parw/16	0,45	90,84	8,48	0,23
20	20/Sed/Dar/16	2,55	95,98	1,38	0,09

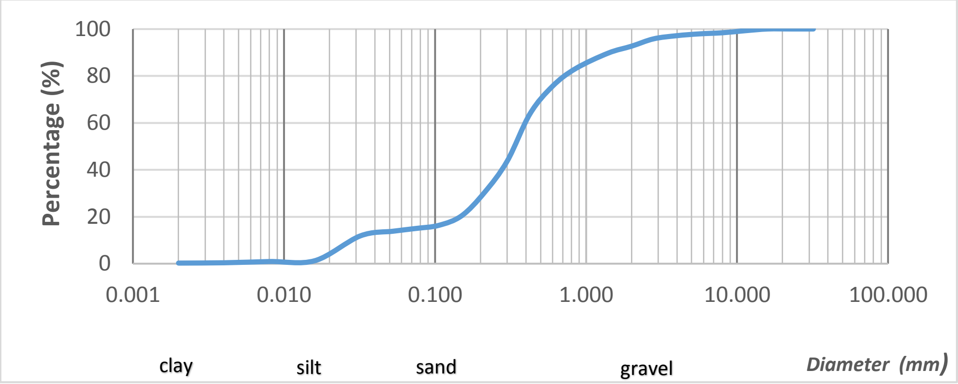

Figure. 4. Grain Size Distribution of Sediment Collected from Infiltration Wells on Roads

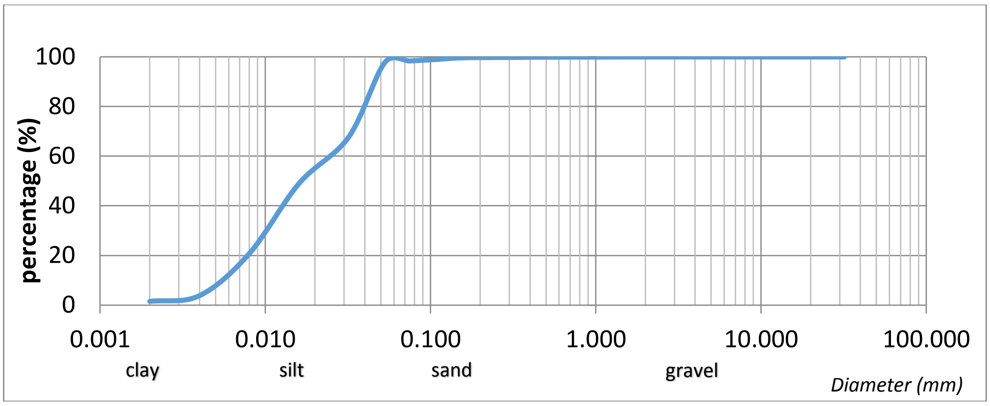

Figure 5. Grain Size of Materials Erupted by Mt. Kelud

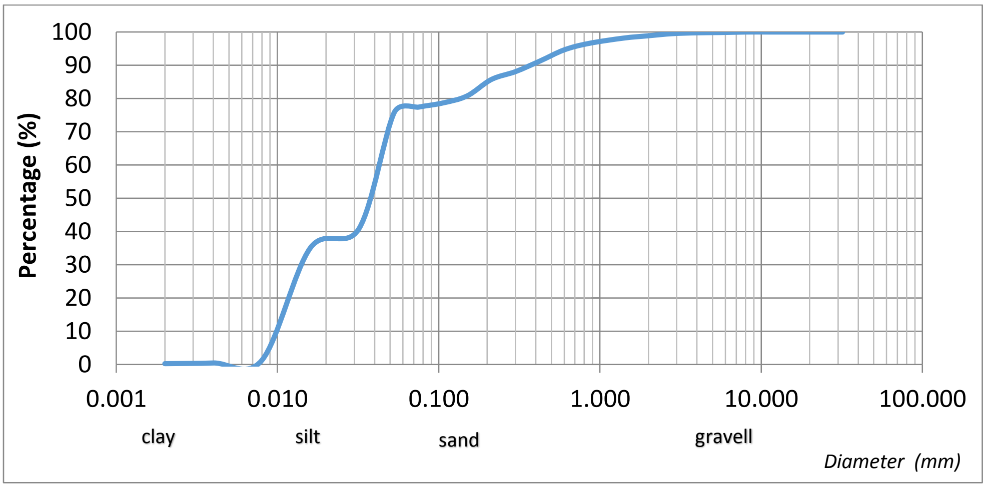

Figure 6. Grain Size Distribution of Sediments Collected from Infiltration Wells in Yards

In the analysis of the characteristics of sediment it was also compared sediment from infiltration wells that collect water from the yard and from the road, using parameters of D_{10}, D_{50} and D_{90}. D_{10} is the particle size at which 10% of the sample by weight is smaller than the size; D_{50} is the grain size of which 50% of the sample by weight is smaller than the size and D_{90} is the grain size of which 90% of the sample by weight is smaller than the size (Table 3).

It could be seen that generally sediments in the infiltration wells collecting overland flow from the roads is coarser compared to sediment in the infiltration wells collecting overland flow from the yards.

Table 3. Sediment Characteristics Based on D_{10}, D_{50} dan D_{90}

Nomor sampel	Tebal (cm)	**X**	**Y**	**D_{10} mm**	**D_{50} mm**	**D_{90} mm**
1/Sed/Sub/16	225	432826	9144639	0,028	0,030	1,778
2/Sed/Swl/16	200	432809	9144578	0,123	0,282	1,549
3/Sed/Yot/16	150	432743	9144643	0,020	0,177	1,999
4/Sed/Gyt/16	175	432759	9144671	0,034	0,257	1,778

Nomor sampel	Tebal (cm)	**X**	**Y**	**D_{10} mm**	**D_{50} mm**	**D_{90} mm**
5/Sed/Anr/16	150	432782	9144690	0,355	0,490	2,818
6/Sed/Mjr/16	200	432725	9144606	0,019	0,162	1,259
7/Sed/Kar/16	200	432756	9144602	0,251	0,380	2,041
8/Sed/Sdn/16	250	432845	9144581	0,033	0,417	2,089
9/Sed/Bej/16	100	432854	9144608	0,251	0,194	1,000
10/Sed/Har/16	150	432814	9144678	0,010	0.042	0,617
11/Sed/Smj/16	100	432872	9144615	0,031	0,129	1,259
12/Abu-KLD/16				0,006	0,016	0,048
13/Sed/R-Swl/16	175	432832	9144587	0,004	0,015	0,043
14/Sed/R-Ags/16	100	432844	9144617	0,008	0,033	0,398
15/Sed/R-Bud/16	75	432841	9144646	0,104	0,339	0,209
16/Sed/R-Kart/16	150	432767	9144591	0,006	0,0234	0,049
17/Sed/R-Dar/16	75	432740	9144678	0,008	0,030	0,513
18/Sed/Dar/16	50	432726	9144661	0,028	0,490	4,898
19/Sed/Parw/16	50	432786	9144673	0,010	0,038	0,380
20/Sed/Parw/16	75	432790	9144680	0,006	0,032	0,508

From Table 2 and Table 3 one can see clearly that the sediment in the infiltration wells that collect overland flow from yards, have a finer grain size compared to the infiltration wells that collect overland flow from the road. Some reasons of the phenomena can be explained as follows.

1. Water in the overland flow on the yards also come from roof.
2. While sediments come from yards are finer than that which comes from the road. In the roof usually the dust is only found, while on the road is a mixture of sediment that came from nowhere, such as a place in the surrounding road.
3. In a residential area the construction of houses is still in progress. In the construction of houses and other facilities, some materials are used (including sand) stacked on the roadside. The overland flow may transport some of the materials entering the infiltration wells.
4. Some of yard is still not planted, the soil is left open and this is a source of sediment washed by overland flow.

It is most possible of the remaining material in the development process is not discarded, stacked on road side and carried away by overland flow into the infiltration wells (Figure 7). It means that the human activities may also have significant effect on the sediment characteristics deposited in the infiltration wells.

Figure 7. Construction of Houses Leaving Materials Stacked on Road Side

In addition to causing infiltration wells fill up rapidly, the materials also caused the wells can no longer absorb runoff. Volcanic ash of Kelud volcano eruption in 2014 is very fine. The volcanic ash will clog pores in rocks or soil. Therefore the capacity of rock and soil to infiltrate water is significantly decrease. This also causes the capacity of infiltration wells to collect and infiltrate water decline, in other word it will reduce the effectivity of infiltration wells.

CONCLUSION

Based on this research, the conclusion could be drawn as follows.

1. Sediment carried by overland flow into the infiltration wells mostly consists of loam followed by sand, gravel and clay.
2. The sediments carried by overland flow in roads and deposited in the infiltration wells is coarser than the sediment carried by overlandflow from the yards.
3. Effectiveness of infiltration wells to absorb rain water decreases due to the deposition of sediment in the wells.
4. Volcanic materials (especially volcanic ash) erupted by Merapi and Kelud Volcanoes constributed significantly to reduce infiltration capacity and effectivity of infiltration wells.

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