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Inundation controlling practice in urban area: Case study in residential area of Malang, Indonesia

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Abstract

Flood inundation processes in urban areas are primarily affected by artificial factors such as drainage facilities, local alterations of topography and land uses. The objective of this study is to examine the capability of hydrological model SIMODAS to estimate runoff and investigating the utilization of storage well in controlling runoff in a residential area. The result of the estimated runoff from the hydrological model was compared with the existing capacity of the drainage channel to identify which channel experienced the problem of inundation. The location of inundation was used to determine the location and number of storage well. The results showed that SIMODAS model could be applied in runoff analyses with 8.09% of relative error compared with runoff depth from field measurement. The existing capacity of the channel could not accommodate runoff Q_{10yr} where the inundation discharge was approximately 0.24 $m^3 \cdot s^{-1}$ (at outlet point 1) and 0.12 $m^3 \cdot s^{-1}$ (at outlet point 2). The inundation problem was overcome by using a combination system between channel normalization (reduce 35% of total inundation discharge) and storage well system (reduce 65% of total inundation discharge). The storage well was designed at 20 locations (at outlet point 1) and 16 locations (at outlet point 2) which each well had a discharge of 0.0058 $m^3 \cdot s^{-1}$. The storage well combined with channel normalization could be used as an alternative way to solve inundation problems in a residential area considering the constraint of land space limitation in the urban area.

Key words: *channel normalization, inundation, runoff, SIMODAS model, storage well, urban area*

INTRODUCTION

Flood inundation processes in urban areas are primarily affected by the artificial factors such as drainage facilities, local alterations of topography and land uses. The impact of climate change combined with landuse change contribute even more severe flood inundation problem in urban area [BERTILSSON *et al.* 2019; JAMALI *et al.* 2018]. Water resources and the related land use issues are a key element for the sustainable development. Spatial planning, therefore, has an important role to play in addressing water issues such as flooding and aquatic pollution which are strongly influenced by the nature and urban development [CARTER 2007]. The landuse change phenomena in an urban area which was not integrated spatial land management known clearly will extremely impact hydrological processes [DINKA, CHAKA 2019]. Runoff depth spatially in urban area is mostly influenced by landuse change especially in regard with percentage of impervious area alongside rainfall intensity and soil type [HARISUSENO *et al.* 2012; LEANDRO *et al.* 2016]. Other factor such as drainage or sewer systems needs to be considered as important factor in order to minimize inundation problem in highly developed urban areas [DONG *et al.* 2017; JANG *et al.* 2018].

Previous studies concerning runoff volume controlling in urban area have been conducted by some researchers where most of the controlling activities associated with physical rehabilitation, including channel rehabilitation, pump design, gate operation, etc. However, recent studies have attempted to take into account environmental aspect by considering storage effect in controlling runoff volume in urban area [CUNHA *et al.* 2016]. RECANATESI *et al.*

[2017] carried out stormwater management in a peri-urban watershed by employing best management practices (BMPs) to reduce runoff volume. CONSTANTINE *et al.* [2017] and GAO *et al.* [2015] simulated effectivity of vegetated swales, green roofs, wet ponds, and bioretention basins on reducing runoff volume and non-point source pollutant. The use of tankers or cisterns and urban landscape as a water conservation tool and an alternative source for domestic water supply in urban area had been carried out as well [GLENN *et al.* 2015; HAYDEN *et al.* 2015; VOLO *et al.* 2015]. NGUYEN and HAN [2018] proposed a house based storage system to control runoff volume by collecting rainwater from building rooftops. The utilization of storage well connected with drainage channel normalization system to control runoff volume is still rarely implemented in urban area, particularly in a residential area. Thus, the study concerning utilization of storage well system along with channel normalization for runoff control is still needed to be carried out. The present study has an aim to investigate utilization of storage well along with drainage channel normalization in controlling runoff in residential area.

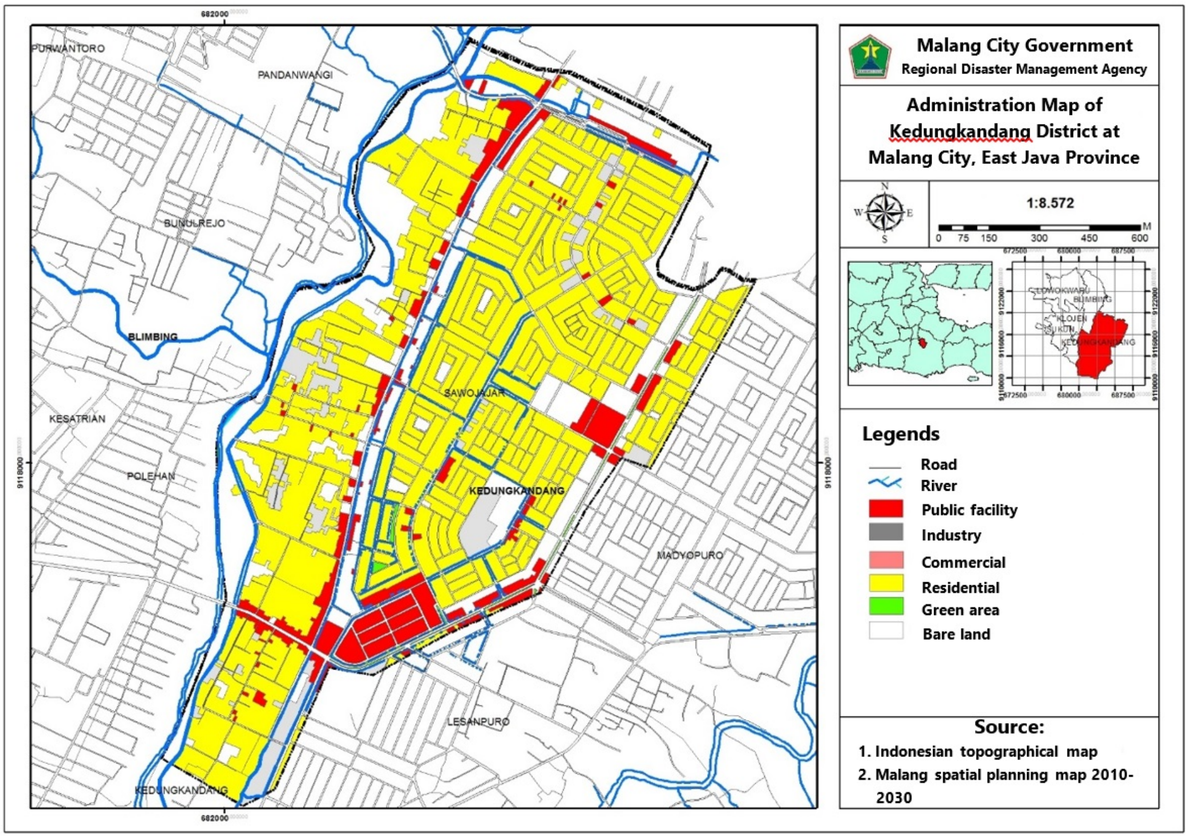
MATERIALS AND METHODS

STUDY AREA

The study area was located at Kedungkandang District, one of the districts with high density of population in Malang Municipality, East Java Province, Indonesia. Total area of the district is 39.89 km^2 where land use type was dominated by residential and commercial areas. Figure 1 displays the location of the study area along with land use type. The study area suffered flood inundation every year due to a high rainfall event during the rainy season with an average of inundation depth 25–50 cm. To obtain a better result in runoff analysis process, the small urban area was chosen which encompasses approximately 6.19 ha of total area. Figure 2 shows detail of the study area where network of drainage channels was grouped into two groups, namely Danau Laut Tawar drainage (outlet point 1) and Danau Ranau drainage (outlet point 2) based on flow direction of surface runoff identified from contour map. The outlet point 1 (Danau Laut Tawar) and outlet point 2 (Danau Ranau) encompassed approximately 3.64 ha and 2.55 ha, respectively.

STUDY METHODS

Rainfall data were collected from Kedungkandang rain gauge within 2009–2018. Soil surveys and laboratory analyses were performed to obtained soil physics characteristics (soil structure and texture). These data were used for parameter input in the hydrological model to estimate runoff depth in the study area. Land use interpretation at the research location was collected directly by conducting a field survey in 2018. The usage of land use map was used to represent curve number (*CN*) as parameter input for runoff analysis using the hydrological model. In order to support analysis of drainage network on reducing inunda-



Source:
1. Indonesian topographical map
2. Malang spatial planning map 2010-2030

Fig. 1. Location of study area; source: own elaboration based on Regional Disaster Management Agency map [BPBD 2015]

Fig. 2. Outlet point of drainage network at study area;
source: own elaboration based on field survey & Google Earth

tion depth in the research area, data of drainage network along with its dimension were collected as well. Surface runoff depth at the outlet point was estimated using a hydrologic model where the result of estimated surface runoff then compared with observation data resulted from field survey on several locations at research location. In addition, a field survey consisting of direct measurement of inundation depth in rainy period at ten measurement points was conducted to be used in hydrological model calibration by comparing measurement data with estimated runoff depth from the hydrological model. Model efficiency on estimating runoff depth was examined by using Nash–Sutcliffe efficiency (*NS*) and percent relative error (*RE*) as well [KNOBEN *et al.* 2019; LIN *et al.* 2017]. Further, the functionality of drainage network on reducing surface runoff at research location was examined, then location and number of storage well could be determined to reduce inundation problem. In addition, based on runoff inundation depth resulted previously, further analysis was performed to know effectiveness of drainage network in the study area on reducing inundation depth. The evaluation of existing drainage capacity was performed to know capacity of drainage channel on collecting design discharge caused by design rainfall with return period 10 year ($Q_{10\text{yr}}$) in the study area. Analysis was conducted by calculating existing capacity of drainage channel and then examining whether capability of drainage channel to accommodate design discharge which probably occurred in the study area. Inundation occurs if the existing capacity of drainage channel was lesser than the design discharge. The location of inundation become consideration to plan location and number of storage well system.

RUNOFF ANALYSIS

A hydrological model SIMODAS (Ind. Sistem Informasi dan Model Daerah Aliran Sungai) developed by TUNGGUL *et al.* [2012] from Department of Agricultural Technology, University of Brawijaya was employed to analyze the runoff discharge in the study area. The SIMODAS is an event-oriented, conceptual based model describing the processes of interception, infiltration, surface runoff, and erosion from small agricultural and urban watersheds (≤100 km^2). The modeling concept was built by using Soil Conservation Service (SCS) runoff curve number (*CN*) method developed by U.S. Department of Agriculture (USDA) incorporated with Geographical Information System (GIS) and supported with several processes that consist of delineation process of catchment and synthetic river network of research area from Digital Elevation Model (DEM), digital land-use map, digital soil map, and rainfall data analysis [TUNGGUL *et al.* 2012; WIROSOEDARMO, TUNGGUL 2012].

SIMODAS uses one-dimensional kinematic equations where watershed is represented by a cascade of rectangular planes and channels and the partial differential equations describing overland flow and channel flow are solved by finite-difference techniques. The equation of finite-difference of the linear kinematic wave was explained by CHOW *et al.* [1988]:

$$Q_{i+1}^{j+1}=\frac{\frac{\Delta t}{\Delta x}Q_i^{j+1}+\alpha\beta Q_{i+1}^{j}\left(\frac{Q_{i+1}^{j}+Q_i^{j+1}}{2}\right)^{\beta-1}+\Delta t\left(\frac{q_{i+1}^{j+1}+q_{i+1}^{j}}{2}\right)}{\frac{\Delta t}{\Delta x}+\alpha\beta\left(\frac{Q_{i+1}^{j}+Q_i^{j+1}}{2}\right)^{\beta-1}} \qquad (1)$$

Where: $\alpha=\left[nP^{2/3}/\sqrt{S_0}\right]^{0.6}$, β = 0.6, Q = surface runoff discharge (m^3·s^{-1}), q = lateral flow (m^2·s^{-1}), if no lateral flow $q \approx 0$, t = routing time (h), P = wetted perimeter (m) ≈ 1 for a flow through very wide surface area, x = length of surface area (m), n = Manning coefficient, S_0 = land slope.

The estimated runoff discharge obtained from SIMODAS is then converted into runoff depth by considering inundation area and length of inundation time.

The curve number (*CN*) was used as calibrated parameter in the SIMODAS model where calibration process were performed by adjusted several number of curve number (*CN*) parameter in the model and analyzed the estimated runoff depth yielded from the model for each curve number (*CN*). The selected *CN* parameter was established based on the results of model comparison analysis between estimated runoff depth from the model and the one from field measurement [AJMAL *et al.* 2016; SAVVIDOU *et al.* 2018].

Quantitative analyses consist of Nash–Sutcliffe efficiency (*NS*) and percent relative error (*RE*) were employed to examine the accuracy of the hydrological model on estimating runoff depth where high of *NS* value indicates model good performance, while low of *RE* value shows good similarity from model results with field measurement [KNOBEN *et al.* 2019; LIN *et al.* 2017].

The resulted runoff depth was used to identify the potential inundation area that can be used as consideration aspect in the spatial planning and management. The output of the model was runoff depth over the research area accompanied by attribute data such as inundation location, area of inundation, and depth of inundation.

EVALUATION OF DRAINAGE CHANNEL CAPACITY

The reliability of the drainage channel in conveying runoff discharge robustly is identified by comparing the discharge of existing drainage channel capacity (Q_{capacity}) with runoff discharge with return period 10 yr ($Q_{10\text{yr}}$) yielded from SIMODAS. The result of discharge comparison is used for deciding whether the existing drainage channel still has ability to convey runoff discharge or not. The drainage channel indicates good performance if $Q_{\text{capacity}} > Q_{10\text{yr}}$, conversely if $Q_{\text{capacity}} < Q_{10\text{yr}}$ results in possibility of inundation problem [RISMASARI *et al.* 2018]. The procedure for designing drainage channel refers to continuity and Manning equation as shown in Equations (2) and (3) respectively, including procedure for channel rationalization as well.

$$Q = A\,v \tag{2}$$

$$v = \frac{1}{n} R^{2/3} s^{0.5} \tag{3}$$

Where: Q = discharge ($\text{m}^3\cdot\text{s}^{-1}$), A = area of channel cross section (m^2), v = flow velocity derived from Manning equation ($\text{m}\cdot\text{s}^{-1}$), R = hydraulic radius where $R = A : P$ (m), P = channel wetted perimeter (m), n = Manning's roughness cofficient, s = channel slope.

STORAGE WELL

Storage well was designed to reduce inundation discharge which occurred in the research area. The design of storage well was calculated using equation as follows [SETYANDITO *et al.* 2015; SUNJOTO 1994]:

$$Q_{\text{storage well}} = \frac{HFK}{1-e^{-\frac{FKT}{\pi r^2}}} \tag{4}$$

Where: $Q_{\text{storage well}}$ = discharge of storage well ($\text{m}^3\cdot\text{s}^{-1}$), r = radius of storage well (m), H = depth of storage well (m), K = soil hydraulic conductivity ($\text{m}\cdot\text{s}^{-1}$), t = land inundation time (s), F = geometric factor (5.5 for rectangular shape).

The number of storage wells required for reducing inundation discharge calculated by using the following equation:

$$Q_{\text{inundation}} = n_w\, Q_{\text{storage well}} \tag{5}$$

Where: $Q_{\text{inundation}}$ = discharge which should be reduced by storage well ($\text{m}^3\cdot\text{s}^{-1}$), n_w = number of storage well, $Q_{\text{storage well}}$ = discharge of storage well ($\text{m}^3\cdot\text{s}^{-1}$) obtained from Equation (4).

The effectiveness of storage well in managing inundation discharge is assessed by evaluating how effective it reduces inundation discharge and its effect on lengthen of time of concentration (*Tc*) in the each outlet point.

RESULTS AND DISCUSSION

The runoff analysis using SIMODAS model was performed using 10 year return period of design rainfall ($R_{10\text{yr}}$) as the model input along with landuse map on 2018 and soil structure and texture. The model calibration process was conducted by comparing runoff depth of 2018 resulted from hydrological model SIMODAS with those derived from field survey at ten measurement points that conducted on December 12th, 2018 considering that there was a high rainfall event in that time which caused inundation in the study area. Hence, rainfall data recorded on December 12th, 2018 was used as input variable to SIMODAS model and subsequently, accuracy of the model on estimating runoff depth was investigated.

In the model calibration, several curve number (*CN* = 83, 84, 85, and 90) parameters were employed on SIMODAS model where the estimated runoff depth yielded from the model from each *CN* parameter was compared with the one from field measurement [AJMAL *et al.* 2016; SAVVIDOU *et al.* 2018]. The range number of *CN* parameter for model calibrating process was determined by considering the landuse characteristic (dominated by residential and commercial area) and soil type (dominated clay) in the study area, thus it was reasonable to take range value of curve number (*CN*) within 83–90 [THOMPSON 1999]. Table 1 summarizes results of model accuracy analysis for whole measurement point. As shown in Table 1, the model calibration results showed that the best parameter of *CN* for the model was approximately 83 where comparison between runoff depth resulted from the hydrological model and field measurement showed had no significant different which was explained by 8.09% of *RE* and 0.975 of *NS* value, respectively. Figure 3 presents estimated runoff depth from the model for various *CN*. It may be seen that the *CN* 83 yielded estimated runoff depth that has relatively no difference with field measurement.

Accordingly, the curve number (*CN*) 83 was used for analyzing runoff depth with design rainfall 10 year return period ($R_{10\text{yr}}$) as model input using hydrological model SIMODAS. The runoff hydrograph for discharge 10 year

Table 1. Summary of results of comparison between model results and field measurement

Point	Coordinate	Runoff depth from field measurement (m)	Runoff depth from model (m) at different curve numbers (*CN*)			
			CN = 83	*CN* = 84	*CN* = 85	*CN* = 90
1	7°57’12.74”N, 112°36’44.47”E	0.187	0.195	0.205	0.243	0.256
2	7°57’16.4”N, 112°36’43.23”E	0.075	0.068	0.088	0.101	0.115
3	7°57’9.23”N, 112°36’44.93”E	0.052	0.061	0.060	0.078	0.065
4	7°57’8.01”N, 112°36’46,48”E	0.061	0.058	0.050	0.070	0.088
5	7°57’7.85”N, 112°36’49.10”E	0.121	0.119	0.116	0.121	0.157
6	7°57’5.31”N, 112°36’51.11”E	0.077	0.082	0.080	0.091	0.080
7	7°57’6.79”N, 112°36’43.93”E	0.031	0.032	0.042	0.052	0.043
8	7°57’4.99”N, 112°36’54.51”E	0.056	0.052	0.067	0.070	0.078
9	7°55’3.99”N, 112°36’50.51”E	0.089	0.084	0.078	0.091	0.077
10	7°53’7.01”N, 112°38’46,48”E	0.044	0.048	0.039	0.041	0.042
Relative error *RE* (%)			8.09	14.49	23.24	27.52
Nash–Sutcliffe efficiency *NS*			0.975	0.966	0.879	0.754

Source: own study.

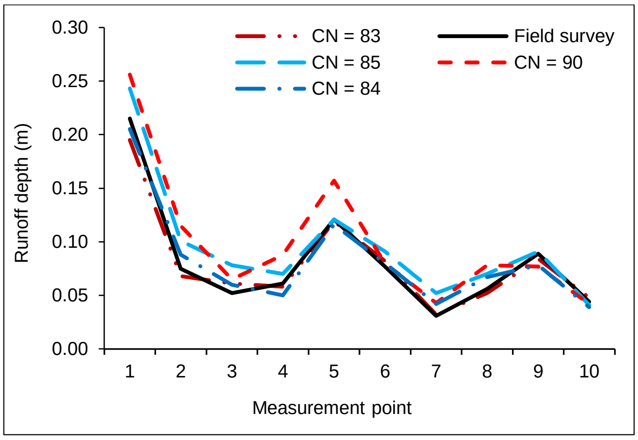


Fig. 3. Estimated runoff depth from model for various curve number (*CN*); source: own study

return period ($Q_{10\text{yr}}$) along with the drainage channel capacity at outlet point 1 and point 2 is exhibited in Figure 4. The beginning time of land inundation at outlet points 1 and 2 demonstrates relatively similar where land inundation was commenced at 10th minute and 12th minute at outlet point 1 and 2, respectively. It is reasonable that the beginning time of land inundation is relatively similar for both outlet points since the catchment area of outlet point 1 and 2 is predominantly mild to rather steep land slope and relatively same land-use characteristic. Further, the outlet point 1 experiences longer ending time of land inundation than that one from the outlet point 2 where the ending time gives 40th minute and 34th minute for outlet point 1 and 2, respectively. The same situation is in regard to the length of land inundation time as well, where it takes 30 min for inundation at outlet point 1 to terminate and that was 10 min longer than the one at outlet point 2 (22 min). We presumed that the length of land inundation time at the outlet point most likely associate with soil infiltration characteristic at each catchment area of the outlet point [HARISUSENO *et al.* 2019]. In addition, we noticed that the length of land inundation time probably has a similar concept with recession time in a hydrograph concept in a catchment area. KRAKAUER and TEMIMI [2011] found that the length of recession time of hydrograph is greatly influenced by soil characteristics in catchment area particularly soil infiltration capability. The infiltration processes are known as a driving factor that controls storage time prolongation in the surface of catchment area [CHOW *et al.* 1988; THOMPSON 1995]. Figure 5 displays the soil texture of both outlet points obtained from soil sieve analysis and soil texture triangle. Soil infiltration rate measurement was carried out along with soil sampling at each outlet point as well. As shown in Figure 5, the soil texture in the outlet point 1 included silt loam which is mostly characterized by low infiltration rate (averagely 0.17 mm·min^{-1}) whereas medium infiltration rate (averagely 0.60 mm·min^{-1}) was shown by sandy loam at the outlet point 2. Thereby, it is well understood that the length of land inundation time at the outlet point 1 shows longer than the one in the outlet point 2. The low infiltration rate at the outlet point 1 intensely causes runoff inundation need a long time to recede, hence it increases length of land inundation time. Figure 6 exhibits hydrograph discharge with return period 10yr ($Q_{10\text{yr}}$) and *S*-curve hydrograph. As presented in Figure 6, the time to peak of hydrograph (*Tp*) was different between the outlet points where it took 30 minutes for runoff at the outlet point 1 and 20 minutes at the outlet point 2 to reach peak of hydrograph, respectively. The catchment area of the outlet point 1 which is wider than the outlet point 2 is presumed become main causal factor in this situation since it associates with the time travel of runoff to the outlet point 1 [ROODSARI, CHANDLER 2017].

Moreover, as displayed in S-curve hydrograph, it was known that magnitude of runoff discharge showed trend to decrease in the outlet point 2 while opposite trend was given at the outlet point 1. This is due to the soil texture at the outlet point 1 namely silt loam that own low infiltration rate as has been discussed previously. The runoff depth analyses from hydrological model SIMODAS produced runoff discharge at the drainage channel 0.56 m^3·s^{-1} (at outlet point 1) and 0.32 m^3·s^{-1} (at outlet point 2), respectively. In addition, analysis of existing capacity of drainage channel exhibited that the drainage channel could not accommodate runoff discharge with return period 10 yr ($Q_{10\text{yr}}$). The results of field survey of drainage channel geometry showed that the existing capacity of drainage channel were 0.32 m^3·s^{-1} (outlet point 1) and 0.20 m^3·s^{-1} (outlet point 2), respectively. Thus, the discharge which could not

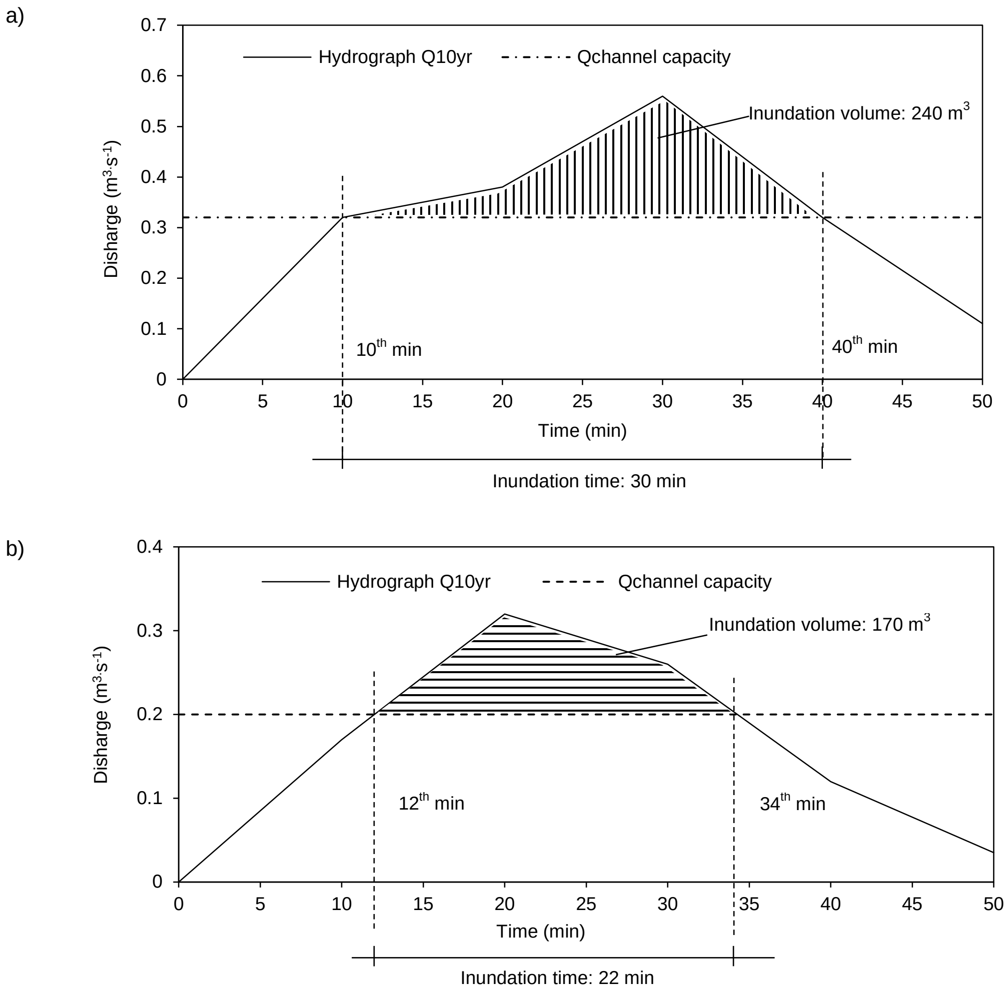


Fig. 4. Runoff hydrograph for discharge 10 year return period (Q_{10yr}) along with the drainage channel capacity at: a) outlet point 1, b) outlet point 2; source: own study

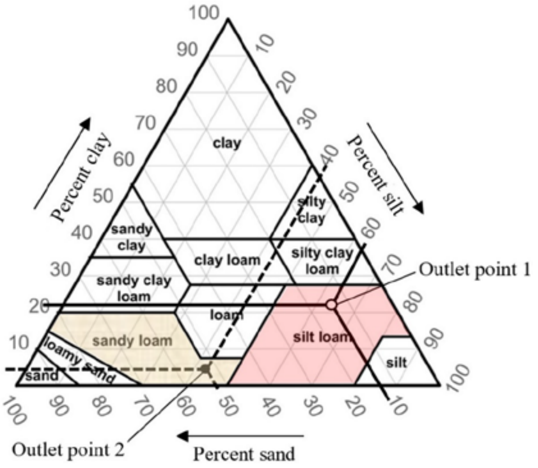


Fig. 5. Soil texture at outlet point 1 and outlet point 2; source: own study

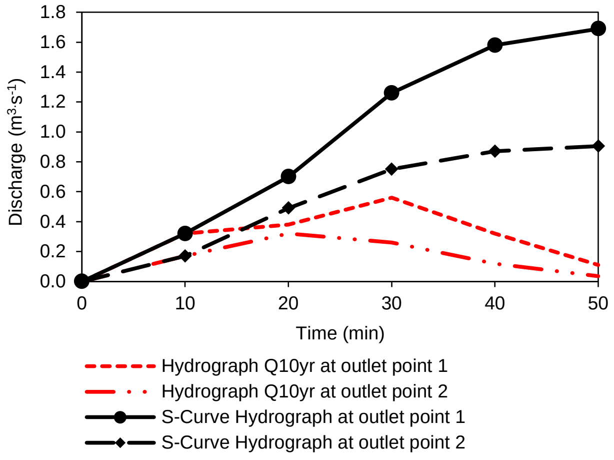


Fig. 6. Hydrograph discharge with return period 10 years (Q_{10yr}) and *S*-curve hydrograph; source: own study

Table 2. Comparison between maximum discharge values from SIMODAS model and existing capacity of drainage channel

Outlet control point	Area (ha)	Q_{runoff} (from SIMODAS model)	$Q_{existing\ capacity}$ of drainage channel	$Q_{inundation}$
		$m^3 \cdot s^{-1}$		
Outlet point 1	3.64	0.56	0.32	0.24
Outlet point 2	2.55	0.32	0.20	0.12

Source: own study.

be accommodated by existing drainage channel and inundation to the surface land were approximately 0.24 $m^3 \cdot s^{-1}$ (at outlet point 1) and 0.12 $m^3 \cdot s^{-1}$ (at outlet point 2) as shown in Table 2. These maximum inundation discharges were used to design channel normalization and storage well system in the residential area served by drainage channel system [SENNAOUI *et al.* 2019]. Based on the land availability and feasibility analysis in the study area, it was revealed that only approximately 35% of inundation discharge could be managed by existing drainage channel normalization. Hence, 0.08 $m^3 \cdot s^{-1}$ and 0.04 $m^3 \cdot s^{-1}$ of inundation discharge were controlled by drainage channel normalization, while the remaining inundation discharge (65%) was managed by the storage well system. Table 3 summarizes comparison of channel geometry between existing condition and normalization.

Table 3. Summarizes comparison of channel geometry between existing condition and normalization

Channel geometry parameter	Outlet point 1		Outlet point 2	
	existing	normalized	existing	normalized
Height *H* (m)	0.8	0.8	0.5	0.5
Width *B* (m)	0.8	1.0	0.8	1.0
Discharge capacity ($m^3 \cdot s^{-1}$)	0.3	0.4	0.2	0.3

Source: own study.

The rest of inundation discharge (65%) was controlled by storage well system (0.16 $m^3 \cdot s^{-1}$ at the outlet point 1 and 0.08 $m^3 \cdot s^{-1}$ at the outlet point 2, respectively). Table 4 shows the parameters design of storage well. Considering the depth of shallow groundwater water table at the study area (14 m below land surface), consequently the depth of storage well (*H*) was designed at 6 m. The discharge of each storage well was calculated using Equation (4) as follows:

Table 4. Design components of storage well

Design component	Dimension
Diameter of storage well (*d*)	1.5 m
Depth of storage well (*H*)	6 m
Soil hydraulic conductivity (*K*)	0.00009 $m \cdot s^{-1}$
Inundation time (*t*), for outlet point 1	30 min
Inundation time (*t*), for outlet point 2	22 min
Volume of storage well	10.59 m^3

Source: own study.

$$Q = \frac{HFK}{1-e^{-\frac{FKT}{\pi r^2}}} = \frac{6 \cdot 5.5 \cdot 3.14 \cdot 0.75 \cdot 0.00009}{1-e^{-\frac{5.5 \cdot 0.00009 \cdot 1800}{3.14 \cdot 0.75^2}}} = 0.0058\ \mathrm{m}^3 \cdot \mathrm{s}^{-1}$$

The number of storage wells on each outlet point was obtained by dividing total amount of inundation discharge on each outlet point with design discharge of one storage well (0.0058 $m^3 \cdot s^{-1}$) as previously explained in Equation (5). Thus, the storage well was designed at 20 locations (inundation discharge 0.16 $m^3 \cdot s^{-1}$ at outlet point 1) and 16 locations (inundation discharge 0.08 $m^3 \cdot s^{-1}$ at outlet point 2) where each storage well had discharge of 0.0058 $m^3 \cdot s^{-1}$.

In the present study, typical of storage well geometry was adopted from study conducted by BISRI and NORMAN [2009] as shown in Figure 7. The storage well system was connected with drainage channel in order to assure the per-

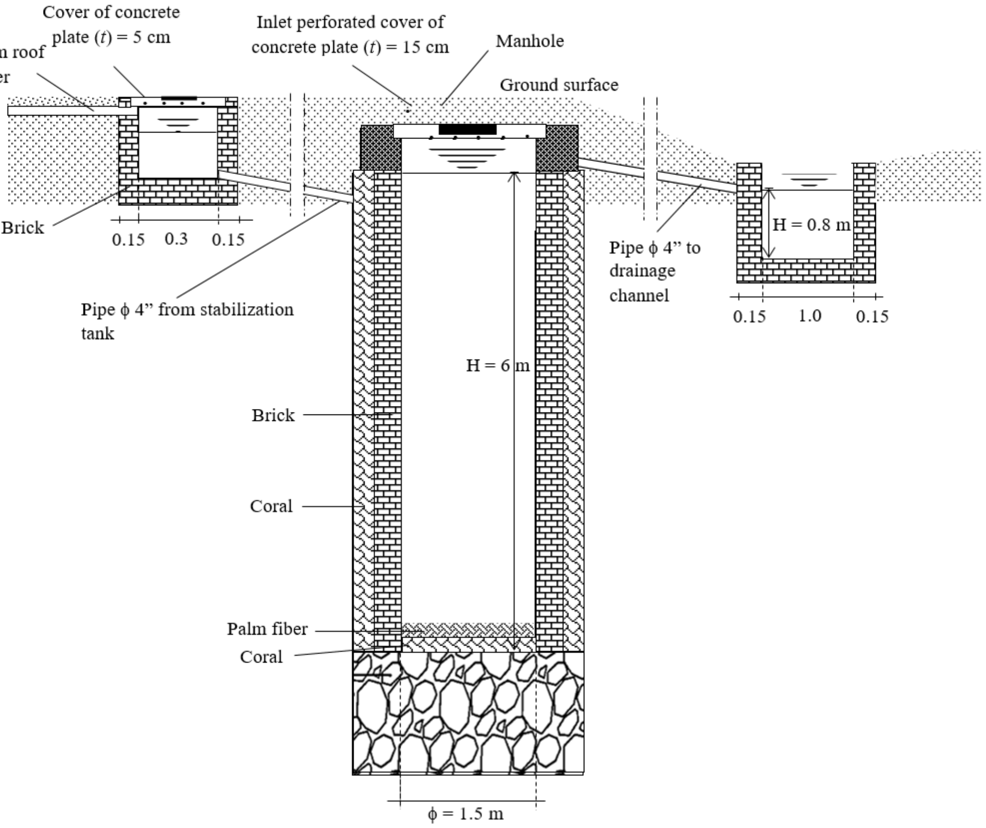


Fig. 7. Plan and section of storage well; source: own elaboration based on BISRI and NORMAN [2009]

formance of drainage system in reducing runoff effectively (Fig. 7). If rainfall with a magnitude similar or higher than design rainfall $R_{10\mathrm{yr}}$ with duration approximately 30 min (at the outlet point 1) and 22 min (at the outlet point 2) takes place, then theoretically it is most likely the inundation problem occurs in the study area. Most of volume of inundation is managed by storage well system, however if the volume of runoff entering exceeds the capacity of storage well to store volume of inundation, then the excess runoff discharge will move along outlet pipe to drainage channel. Refer to Figure 7, the storage well was equipped with filter layers in its wall and base floor which consist of palm fiber, coral, brick layer structure, and gravel.

By means of these filter layers, the water quality of runoff discharge that enter storage well remain preserved. The placement of storage wells was determined by considering the land availability, particularly green space area and layout design of residential buildings as well. Considering the limitation of land availability, thus the location of storage well was placed in an area where the storage well is afforded to serve runoff management for three houses integrately.

CONCLUSIONS

The present study introduced the utilization of storage well along with drainage channel normalization to control runoff volume in residential area where. The hydrologic model SIMODAS was employed to estimate runoff discharge with 10 year return period ($Q_{10\mathrm{yr}}$) and the result confirmed that the hydrologic model SIMODAS could be well applied in runoff analyses in residential area. Further result revealed that the existing capacity of drainage channel could not accommodate runoff discharge ($Q_{10\mathrm{yr}}$) since increasing of runoff due to landuse change in last decade in the study area. The study found that the length of inundation time greatly depend on the soil texture that controls infiltration rate. Additionally, the length of time to peak found to strongly relate to area of catchment area whereas the length of recession time was closely influenced by soil characteristics particularly soil infiltration capability. The present study confirmed that the storage well combined with channel normalization could be used as an alternative way to solve inundation problems in residential area considering considering constraint of land space limitation in urban area. Design of storage well was highly dependent on the amount of inundation discharge and soil parameters particularly soil hydraulic conductivity and shallow groundwater table. Future research should be conducted in order to know the effect of storage well system on reducing runoff time of concentration and increasing groundwater recharge in the urban area.

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