Rain Garden Model for Stormwater Management in Sentul City, Bogor, Indonesia

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Abstract. Developing area is a multidimensional process and often has minimum attention in water management aspect. Sentul City is an example of an area in Bogor Regency that is growing rapidly but has problems in water management. The limitation of raw water is caused by the lack of groundwater and frequent disruption in the water distribution system. This causes the raw water supply depends on the Local Water Company of Bogor Regency. In fact, Sentul City has the potential to conduct independent raw water from its high rainfall. Therefore, rainwater harvesting is needed through stormwater management, one of its application is by the rain garden. The objective of this paper is to present the research result of the rain garden model recommendation that is suitable to be applied in Sentul City. The used methods are mapping the existing site conditions, analysis of the rain garden suitability, calculate the rain garden dimensions, and modeling the rain garden. This study conducted in Lake Indah, Lake Teratai, Siliwangi Street, M.H Thamrin Street, and Plaza Niaga 1. The rain garden analysis and dimensions are affected by the soil, topography, catchment area, and runoff volume of the site. The required rain garden surface area is 171.50 m² at Lake Indah, 312.48 m² at Lake Teratai, 6,449.88 m² at Siliwangi Street, 6,573.01 m² at M.H Thamrin Street, and 896.51 m² at Plaza Niaga 1, while the required rain garden depths are 15-30 cm and 45-60 cm. The rain garden model is designed based on the form, inflow and outflow design, planting media, and plant aspects. Thus, the results of rain garden models are different according to the conditions of each site. Keywords: curve number method, land suitability analysis, rainwater harvesting, phytoremediation, urban landscape

1. Introduction

1.1 Background

The development area is a dynamic process of integration between sectors ([1] Nofitasari 2016). Bogor Regency is one example of a region with a population growth of 2.28% from 2016 and a population density of 2,145 people/km² ([2] Central Bureau of Statistics Bogor Regency 2017). However, the developing area that occurs has lack attention of environmental aspects, especially in water management.

An example area with water management problem is Sentul City. Sentul City is a residential and tourist area in Bogor Regency with the total area of 3,100 ha. The facilities in Sentul City increasing in accordance with the market and the population, thus the demand of water is also increasing. However, the problem is on water management for raw water availability. The problem occurs due to the low soil
permeability that causes minimum availability of groundwater and the disruption in the water distribution system during the dry season.

The raw water supply for the residents is still depends on the Local Water Company of Bogor Regency. In fact, Sentul City has the potential in providing raw air independently from the stormwater management because it has a high rainfall of 3,271.7 mm/year ([2] Central Bureau of Statistics Bogor Regency 2017). In fact, it is necessary to have an adaptive stormwater management. One of stormwater management applications is the rain garden.

The rain garden is a garden area that can absorbs, harvests, and filters stormwater from various sources. The rain garden controls the qualitative of stormwater in intense rainfall condition ([3] Autixier et al. 2014). The rain garden can minimize water dependency from groundwater and the Local Water Company for daily use, minimize the occurrence of excess runoff, and improve the water quality through phytoremediation process. Thus, it is necessary to have a suitable stormwater management in the form of rain garden model to be implemented at Sentul City.

1.2 Objectives
The objectives of this paper are: 1) Mapping the existing condition of Sentul City and site research; 2) Mapping the suitable rain garden location and position in Sentul City; 3) Calculating the dimensions of rain garden in the site research; 4) Designing the suitable rain garden models in the site research.

2. Methodology

2.1 Location and Time
The site research was located in Lake Indah (LI), Lake Teratai (LT), Siliwangi Street (SS), M.H Thamrin Street (TS), and Plaza Niaga 1 (PN) in Sentul City. The research was conducted from January to October 2018.

2.2 Tools and materials
The tools and materials used in this research are digital camera, base map, and interview guidelines. While the used softwares are Google Earth, ArcGIS 10.3, Auto CAD 2013, Adobe Photoshop CC 2017, SketchUp 2016, and V-ray 3.4.

2.3 Research methods
The methods consist of (1) Mapping the existing condition of Sentul City and site research; (2) Analysis of the rain garden suitability; (3) Calculate the rain garden dimensions; and (4) Modeling the rain garden.

2.3.1 Mapping the existing condition of Sentul City and site research
This method was conducted by physical data for location and position analysis of rain garden, biophysical data for rain garden dimension calculations, and social data to determine stakeholder perceptions of water problems.

2.3.2 Analysis of the rain garden suitability
The analysis was conducted by (1) Identification of rain garden locations: The selection of potential sites for rain garden applies landscape classification that moves on the micro, meso, and macro scales ([4] Farina 2006); (2) Land suitability analysis for rain garden position: Determine the rain garden position was carried out by land suitability analysis on each site. The used land suitability classes are S1 (very suitable), S2 (fairly suitable), S3 (marginal suitable), and N (not suitable) ([5] Ritung et al. 2007).

| Table 1. Topographic aspects in land suitability analysis for rain garden (overlay data) |
|-----------------------------------------------|-------------------|
| Land Characteristics | Suitability Class |
|---------------------|-------------------|
Adapted from: Ritung et al. (2007), Ernskie and Unchaper (2012), modified (2018)

### Table 2. Soil aspects in land suitability analysis for rain garden (non-overlay data)

| Land Characteristics | Suitability Class |
|----------------------|-------------------|
| Soil Texture         | S1 (4) | S2 (3) | S3 (2) | N (1) |
| Sand-sandy loam      |         |         |         |       |
| Silt loam            |         |         |         |       |
| Clay loam            |         |         |         |       |
| Clay                 |         |         |         |       |
| Soil Permeability    | >2,5 cm/hour | 0,6-2,5 cm/hour | 0,25-0,5 cm/hour | ≤0,05-0,24 cm/hour |

Adapted from: Ritung et al. (2007), Ernskie and Unchaper (2012), modified (2018)

Each land suitability class has a score, i.e 4 for S1, 3 for S2, 2 for S3, and 1 for N. After the scoring has been done on all four indicators, then the results showed in the form of the land suitability maps for rain garden on each site. The interval score is 3, then the final score for S1 is 13-16, S2 is 10-12, S3 is 7-9, and N is 4-6.

**2.3.3 Calculate the rain garden dimensions**

The calculation of rain garden dimension were conducted by (1) Catchment area calculation: Calculating the catchment area can be known through the existing site area by multiplying the percentage of water directed to the rain garden. The ideal percentage of water directed to the rain garden reaches 100% that calculated in decimal format, which is 1.00. The catchment area formula described as follows ([6] Ernskie and Unchaper 2012):

\[
\text{Effective catchment area} = \text{total area} \times \text{percent of water directed to rain garden} \times \text{runoff coefficient}
\]

**Table 3. Runoff coefficients for surface materials**

| Surface                        | Typical Range | Recommended Value |
|--------------------------------|---------------|-------------------|
| Concrete                       | 0,80-0,95     | 0,90              |
| Brick                          | 0,70-0,85     | 0,80              |
| Roof                           | 0,75-0,90     | 0,85              |
| Paving stones                  | 0,10-0,70     | 0,40              |
| Grass pavers/turf blocks       | 0,15-0,60     | 0,35              |
| Lawns and grass on sandy soil  | 0,05-0,20     | 0,12              |
| (for a gentle (5%) slope, with values increasing as slope increases) |
| Lawns and grass on heavy soil  | 0,13-0,35     | 0,22              |
| (for a gentle (5%) slope, with values increasing as slope increases) |
| Landscaped beds                | 0,15-0,30     | 0,20              |
| Crushed aggregate             | 0,15-0,30     | 0,20              |

Adapted from: Ernskie and Unchaper (2012)

Next method was (2) Runoff volume calculation: The common method to estimating the runoff volume after a rain is the Natural Resources and Conservation Service (NRCS) Curve Number Method ([7] Jaber et al. 2013). Curve number (CN) is a land use and soil type factor that reflects the imperviousness of the ground surface (Table 4). The formula described as follows:

\[
\text{Runoff depth} = \frac{(P - 0.2S)^2}{(P + 0.8S)}
\]

P is precipitation (inches) and the value used was 1 inch. The value of S was obtained through the following formula.
\[ S = \frac{1000}{CN} - 10 \] (3)

### Table 4. Curve numbers for various types of land and hydrologic groups

| Cover Type and Hydrologic Soil Group                                      | A   | B   | C   | D   |
|-------------------------------------------------------------------------|-----|-----|-----|-----|
| Open space (lawns, parks, golf courses, cemeteries, etc.)               | 49  | 69  | 79  | 84  |
| Paved parking lots, roofs, driveways, etc                               | 98  | 98  | 98  | 98  |
| Streets and roads:                                                      |     |     |     |     |
| Paved, curbs and storm drains                                           | 98  | 98  | 98  | 98  |
| Paved, open ditches                                                     | 83  | 89  | 92  | 93  |
| Gravel                                                                  | 76  | 85  | 89  | 91  |
| Dirt                                                                    | 72  | 82  | 87  | 89  |
| Urban areas:                                                            |     |     |     |     |
| Commercial and business (85% impervious)                                | 89  | 92  | 94  | 95  |
| Industrial (72% impervious)                                             | 81  | 88  | 91  | 93  |
| Developing urban areas: Newly graded areas (pervious areas only, no vegetation) | 77  | 86  | 91  | 94  |

Adapted from: Jaberet al. (2013)

After the calculation of runoff depth obtained, the total runoff volume can be calculated by multiplying the runoff depth with the catchment area. This calculation formula described as follows:

\[
\text{Runoff volume (US gallon)} = \text{Runoff depth (inches)} \times \text{catchment area (ft}^2) \times 0.623 \quad \ldots \quad (4)
\]

(3) Surface area and depth of rain garden calculation: After the runoff volume obtained, the rain garden surface area can be determined by dividing the water volume on the site by the volume per square foot. The formula described as follows ([7] Jaber et al. 2013):

\[
\text{Volume per square foot (gallon)} = \text{Water depth (inches)} \times 0.623 \quad \ldots \quad (5)
\]

\[
\text{Surface area of rain garden (ft}^2) = \frac{\text{volume runoff (US gallon)}}{\text{volume per square foot (US gallon per ft}^2)} \quad \ldots \quad (6)
\]

After the surface area of rain garden obtained, the depth of rain garden can be determined according to the recommendation value based on soil texture (Table 5). The recommended depth of rain garden is targeted 100% of stormwater directed to the rain garden.

### Table 5. Typical rain garden depth based on soil texture

| Soil Texture | Recommended Excavation Depth |
|--------------|------------------------------|
| Sandy loam   | 15-30 cm                     |
| Silty loam   | 30-45 cm                     |
| Clayey loam  | 45-60 cm                     |

Adapted from: Ernskie and Unchaper (2012)

2.3.4 Modeling the rain garden
The recommendation of rain garden models can be determined after the location and dimensions of rain garden in each site were already known. The rain garden model designed based on the aspects of shape, inflow and overflow design, planting media, and plants. The rain garden models were presented as site plan, illustration, and cross section in 2D accompanied by a description of size, planting media, and type of plant.

3. Results and discussion
3.1 Mapping the existing condition of Sentul City
Sentul City has a total area of 3,100 ha. In general, the land use of Sentul City consists of residential areas, commercial areas, open space areas, and settlement areas. The geographic location of Sentul City is at 06°33'55" -06°37'45" S and 106°50'20" -106°57" 10 "E. During its development, Sentul City included eight villages in two sub-districts namely BabakanMadang District and Sukaraja District in Bogor Regency.

Based on data from the Citeko Station of Bogor Meteorology and Geophysics Agency in 2017, it is known that the average temperature per month is 21.5°C. The highest rainfall occurred in February at 24.6 mm, while the lowest rainfall occurred in September at 1.1 mm. The average rainfall per month is 272.6 mm and the amount of rainfall in 2017 is 3271.7 mm.

Sentul City has latitude of 180-600 meters above sea level. The type of soil in Sentul City area consists of eight types of soil, but only two types of soil covering the five sites research. M.H Thamrin Street, Plaza Niaga 1, Lake Teratai, and part of Siliwangi Street are located in locations with yellowish brown podzolic soil types, while Lake Indah and part of other Siliwangi Street are located in locations with brown latosol soil types. The raw water source in the Sentul City area comes from the Local Water Company of Bogor Regency, springs, rivers and lakes.

3.2 Mapping the existing condition of site research
Lake Indah is located in Northridge Cluster, Telaga Indah Street, Sentul City. The area of the lake is 3.86 Ha and has a depth of 5 meters. The site boundary of the lake area is 8.58 Ha which includes a lake border with buffer area of 50 meters. The landscape of the lake is quite natural because it is still conserved by vegetation even though it is located in an artificial landscape in the form of residential area. The main function of the lake is enhancing the location aesthetic quality and as a rainwater reservoir that serves raw water supplies.

Lake Teratai is located in Sentul Nirwana Marketing Office, M.H Thamrin Street, Sentul City. The area of the lake is 0.88 Ha and has a depth of 3-5 meters. The site research boundary of the lake area is 1.85 ha with buffer area of 28-32 meters from the edge of the lake. The landscape is artificial and surrounded by office areas, restaurant areas, parking lots, and the streetscape. There is a jogging track on the lake border within two meters. The function of the lake is enhances the location aesthetic quality, as the borrowed landscape for culinary area, recreation area, photo area, and sports area.

Siliwangi Street and M.H Thamrin Street are Sentul City’s primary collector roads. The length of Siliwangi Street is about 2,6 km and the length of M.H Thamrin Street is around 3,6 km. Both of these roads are in the form of a green line with two vehicle circulation lines and a road median. The second width of the vehicle lane is nine meters with good pavement conditions. The median road has a width of 10 meters and there is a V-drain in the middle with 65 cm width. V-drain is found along the buffer area of road with distance about 5 meters from the edge road. The V-drain structure at the median road uses concrete, while the vegetated V-drain structure found in the buffer area of road. There is a surface water channel along the buffer area with a distance of 5 meters. This water channel functions to drain water if the runoff volume exceeds the capacity that can be supplied by V-drain.

Plaza Niaga 1 is one of Sentul City’s main Central Business District (CBD) areas located in M.H Thamrin Street. Plaza Niaga 1 is a commercial location with an area of 2.6 ha. The intensity of visitors at Plaza Niaga 1 is quite high because it includes office, culinary, property, and services.

3.3 Mapping the location and position of rain garden
Identification of rain garden locations: Based on landscape ecology, the prospects for developing landscape management depend on a scale development approach. Thus, landscape management shall be done at multi scale level. There are five locations on the micro and meso scale which are used as site research, there are Lake Indah, Lake Teratai, Siliwangi Street, MH Thamrin Street, and Plaza Niaga 1. The backgrounds of rain garden in Lake Teratai and Lake Indah are to improve water quality based on phytoremediation. Whereas the background of the rain garden on the two main streets of Sentul City is to revitalize the V-drain and surface water channel towards the artificial river along side the road. At
Plaza Niaga 1, the rain garden aims to show its potential that can be applied in various locations, including CBD by harvesting stormwater from pavement and buildings.

Land suitability analysis for rain garden position: In Lake Indah, the topographic aspect shows diverse slopes and reliefs. Whereas in the aspect of soil, the site has brown latosol soil type with clay texture ([8] Hakim et al. 1986). This soil texture belongs to the marginal suitability class with a score of 2. While the permeability value of this soil is 0.25 cm/hour ([9] Sumner 2000). This value is classified as the marginal suitable class with a score of 2. The total score result a land suitability map that produces three land suitability classes, there are fairly suitable with the total score of 10 and 12, marginal suitable with the total score of 8, and not suitable with the total score of 6.

In Lake Teratai, most of the slope equally at the value of <5% which is classified as the very suitable with score 4. This causes in the relief aspect also dominated by gentle that classified as the very suitable with the score 4 as well. The soil type in the Lake Teratai is yellowish brown podzolic with a texture of sandy clay ([8] Hakim et al. 1986). Thus, this texture is classified as very suitable with score 4. This type of soil permeability is 6.12 cm/hour ([9] Sumner 2000). This value is also classified as very suitable with score 4. The four scores are summed and produce two classes of land suitability, there are very suitable with the total score of 14 and 16 and fairly suitable with the score of 12.

Based on the results of the topographic analysis of Siliwangi Street, the slopes with a value of 5-15% and moderate relief dominate the site that classified as fairly suitable with the score of 3. The soil type in the site is yellowish podzolic and brown latosol. Both of these soil types have a texture of sandy clay with a score of 4 and clay texture with a score of 2 ([8] Hakim et al. 1986). Soil permeability value in sandy clay texture is 6.12 cm/hour, while soil permeability value in clay texture is 0.25 cm/hour ([9] Sumner 2000). The four score indicators are summed and produce four classes of land suitability, namely very suitable with the total score of 14 and 16, fairly suitable with the total score of 10 and 12, marginal suitable with the total score of 8, and not suitable including the paved road area.

Based on the results of topographic analysis of M.H Thamrin Street, the slope with the value of 5-15% and moderate relief were found dominate that classified as the fairly suitable with the score 3. Its soil type is yellowish podzolic with the texture of sandy clay ([8] Hakim et al. 1986) that classified as very suitable with the score of 4. Thus, this soil texture has a soil permeability value of 6.12 cm/hour ([9] Sumner 2000) which belongs to the very suitable class with the score of 4. The four scores are summed and produce three land suitability classes, there are very suitable with the total score of 14 and 16, fairly suitable with the total score of 10 and 12, and not suitable including the paved road area.

Based on the results of topographic analysis in Plaza Niaga 1, the slopes with value of 5-15% and moderate slope dominate the site that classified as fairly suitable with the score of 3. The soil type in Plaza Niaga 1 is yellowish brown podsolic with sandy clay soil ([8] Hakim et al. 1986) The soil texture is classified into the very suitable class with the score of 4. Thus, its soil permeability value is 6.12 cm/hour ([9] Sumner 2000) which belongs to the very suitable class with score of 4. The four scores are summed and produce three classes of land suitability. The classes are very suitable with the total score of 14 and 16, fairly suitable with the total score of 12, and not suitable including the pavement area and the building.
3.4 Calculation of the rain garden dimensions

Table 6. Rain garden dimension results on each site

| No. | Location            | Area (Ha) | Catchment Area (m²) | Run off Volume (L) | Surface Area of Rain Garden (m²) | Excavation Depth of Rain Garden (cm) |
|-----|---------------------|-----------|---------------------|--------------------|----------------------------------|--------------------------------------|
| 1   | Lake Indah          | 8.58      | 17,160              | 65,340.06          | 171.50                           | 45-60                                |
| 2   | Lake Teratai        | 1.85      | 36,075              | 119,047.86         | 312.48                           | 15-30                                |
| 3   | Siliwangi Street    | 11        | 121,000             | 2,457,234.57       | 6,449.88                         | 15-30 and 45-60                      |
| 4   | M.H Thamrin Street  | 11.21     | 123,310             | 2,504,145.36       | 6,573.01                         | 15-30                                |
| 5   | Plaza Niaga 1       | 2.3       | 44,850              | 341,550.55         | 896.51                           | 15-30                                |

Catchment area calculation: Calculation of catchment area includes site area, runoff coefficient, and percentage of water directed to the rain garden. Based on the area and the different runoff coefficients for each site, the catchment area results at each site are 17,160 m² in Lake Indah, 36,075 m² in Lake Teratai, 121,000 m² in Siliwangi Street, 123,310 m² in Thamrin Street, and 44,850 m² in Plaza Niaga 1.

Runoff volume calculation: Runoff volume is the amount of runoff flows on the site that is affected by the runoff depth and water catchment area. Based on these values on each site, it produces a runoff volume of 65,430.06 L in Lake Indah, 119,047.86 L in Lake Teratai, 2,457,234.57 L in Siliwangi Street, 2,504,145.36 L in Thamrin Street, and 341,550.55 L in Plaza Niaga 1.
Surface area and depth of rain garden calculation: Rain garden surface area is affected by runoff volume and volume per square foot, while rain garden depth is affected by soil texture. Volume per square foot is a calculation of runoff volume at maximum depth capacity that can be accommodated by a rain garden, which is 38.1 cm ([7] Jaber et al. 2013). Based on the calculation, the overall volume per square foot rain garden in each site is 35.39 L. The rain garden dimensions results in each site are attached in Table 6.

3.5 Modeling the rain garden
Shape: Generally, rain gardens are designed to capture and manage the flow of stormwater and runoff of 80-90% average annual rainfall that occurs ([10] Godwin et al. 2011). Thus, the applied rain garden model can be in any shape as long as it can captures runoff and merge with the existing landscape ([11] A Northern Virginia Homeowner’s Guide 2017).

Inflow design: Inflow is a water directed to rain garden from certain sources through the inlet. Some options for protecting the soil around the inlet are placing rocks or planting dense groundcovers ([6] Ernskie and Unchaper 2012).

Overflow design: Overflow is a water that flows out of the rain garden when it exceeds the storage capacity. Overflow design is divided into two, there are surface drains and underdrains and dry wells ([6] Ernskie and Unchaper 2012).

Soil: There are three options for providing rain garden soil. The first option is to replace the entire existing soil. This option requires if the existing soil has poor quality of soil permeability. The second option is to change the existing soil on the side of rain garden so it can be reused. This option is applied if the existing soil is moderate to good quality with minimum clay content. The third option is to change the existing soil on-site of the rain garden directly. This option can be applied if the existing soil has good quality with minimum clay content ([12] Hinman 2013).

Mulch: The mulch layer can be applied to the surface of rain garden. The depth of mulch layer shall not more than 7.62 cm ([12] A Northern Virginia Homeowner’s Guide 2017).

Plant: The most suitable plant for rain garden is local species that is tolerant of wet and dry conditions. In general, rain garden plants has three planting zones, (1) Zone 1: this area is the wettest area, so the plants must be able to tolerate excess water. (2) Zone 2: inundation that occurs in this area is generally only for a moment so that the selected plants must be able to survive in moist soil. Furthermore, this zone requires plants to help stabilize the slopes. (3) Zone 3: this area is the driest area so that the plants must be able to tolerate drought.

Table 7. Rain garden plants

| No. | Scientific Name | Local Name | Function |
|-----|----------------|------------|----------|
| Zone 1: Plants absorb water pollutants |
| 1. | *Canna indica* | Kana/Bunga tasbih merah | Absorbs lead (Pb) |
| 2. | *Cyperus alternifolius* | Bintang air | Absorbs nitrogen (N) dan phosphorus (P) |
| 3. | *Cyperus papyrus* | Papirus | Absorbs cadmium (Cd) |
| 4. | *Echinodorus paleofolius* | Melati air | Absorbs nitrate (NO₃⁻) dan phosphate (PO₄³⁻) |
| 5. | *Equisetum hyemale* | Bambu air | Absorbs lead (Pb) and chromium (Cr) |
| 6. | *Ipomea aquatic* | Kangkung air | Absorbs mercury (Hg) |
| 7. | *Typha latifolia* | Ekor kucing | Absorbs phosphate (PO₄³⁻), lead (Pb), as an environmental bioindicator |
| Zone 2: Plants stabilize the slopes |
| 8. | *Axonopus compressus* | Rumput paetan | Controls erosion |
| 9. | *Panicum maximum* | Rumput benggala | Controls erosion |
10. *Pennisetum purpureum*  
Rumput gajah  
Controls erosion, absorbs zinc (Zn)

11. *Vetiver aizianoides*  
Akar wangi  
Controls erosion, absorbs oil and lead (Pb)

### Table 7. Rain garden plants

| No. | Scientific Name                  | Local Name         | Function                      |
|-----|----------------------------------|--------------------|-------------------------------|
| Zone 2: Plants stabilize the slopes |
| 12. | *Calliandra calothyrsus*         | Kaliandra merah    | Controls erosion              |
| Zone 3: Aesthetic plants |
| 13. | *Lantana camara*                 | Lantana            | Groundcover, hanging plants, pot scaping |
| 14. | *Amaryllis sp.*                  | Amarilis           | Bush                          |
| 15. | *Turneras ubulata*               | Kembang pukul sembilan | Border                      |
| 16. | *Aglaia odorata* Lour.*           | Kemuning kulang    | Fragrant border, topiary     |
| 17. | *Cordyline terminalis*           | Hanjuang           | Direction, display, screen   |
| 18. | *Lagerstromia indica*            | Bungur             | Centre point                  |
| 19. | *Cryptostachis renda*            | Palem merah        | Direction, point of interest |

Rain garden model in general: In general, the rain garden modeling at Sentul City adapts to the type of soil on each site. M.H Thamrin Street, Plaza Niaga 1, Lake Teratai, and part of Siliwangi Street is located in a location with yellowish brown podzolic soil type. This soil texture is dominated by sandy clays, so the recommended rain garden model is an inflow and outflow design using rock layers, soil media mixed with compost with 15 cm depth, mulch layer with 5 cm depth, ponding area with 15 cm depth, and local plants that suit with the existing site conditions. Whereas in Lake Indah and some other Siliwangi Street are located with brown latosol soil types. Latosol soil is dominated by clay texture. The recommended rain garden model is an inflow design using rock layers, the outflow design in the form of underdrains that applies rock layers, sand layers, gravel layers, and drain pipes, the new mixed soil media with 30 cm depth, mulch layer with 5 cm depth, ponding area with 15 cm depth, and the local plants that suit with the existing site conditions.

Rain garden model at Lake Indah: The rain garden at Lake Indah has a purpose in stormwater management to improve the water quality based on phytoremediation in vegetated lake landscapes. Thus the location of rain garden is prioritized on the inlet channel. The site plan sample of rain garden has 175.50 m² of surface area with the total proposed rain garden area areaseare 1,930.50 m².

Rain garden model at Lake Teratai: The main focus of rain garden in the site is stormwater management to improve the water quality based on phytoremediation in artificial lake landscapes. The site plan sample of rain garden is located in the inlet channel with 125.73 m² of surface area. The total proposed rain garden area areaseare 425.61 m².

![Figure 2. Cross section of rain garden on podsolicsoil (left) and latosol soil (right)](image-url)
Rain garden model at Siliwangi Street: The main focus of rain garden at Siliwangi Street is stormwater management through revitalizing surface water channel and V-drain in the median and buffer area of the road. The site plan sample of rain garden on the edge of road in third segment has 296.81 m² of surface area.

Rain garden model at M.H Thamrin Street: The main focus of rain garden in the site is stormwater management through revitalizing surface water channel and V-drain in the median and buffer area of the road. The site plan sample of rain garden in the median of road in third segment has 341.25 m² of surface area.

Rain garden model at Plaza Niaga 1: The rain garden aims to show its potential that can be applied in various locations, including CBD by harvesting stormwater from pavement and buildings. The site plan sample of rain garden located in the green open space area of parking lot has 170.33 m² of surface area with the total proposed rain garden areas are 1,467.05 m².

Figure 3. Rain garden at Lake Indah

Figure 4. Rain garden at Lake Teratai

Figure 5. Rain garden at Siliwangi Street
**Figure 6.** Rain garden at M.H Thamrin Street

**Figure 7.** Cross section of the main road before and after revitalize with rain garden

**Figure 8.** Rain garden at Plaza Niaga 1

4. **Conclusions and suggestions**
4.1 Conclusion

Based on the results of research that has been done, there are conclusions as follows:

1. In general, Sentul City is located in Bogor Regency which has an area of 3,100 Ha with an altitude of 180-600 masl and includes residential, commercial, green open space and village areas. While the general conditions of the five sites are blue open space, primary collector roads, and commercial areas that have an important role in Sentul City's environmental, social, cultural and economic aspects.

2. The mapping results show that the location has the potential to build a rain garden includes micro and mesoscale areas, there are Lake Indah, Lake Teratai, Siliwangi Street, M.H Thamrin Street, and Plaza Niaga 1. The results of the analysis based on topographic and soil aspects is that the rain garden on each site is spread over the entire site of the water catchment area.

3. The dimensions of rain garden that needed depend on each site. The rain garden surface area results are 171,50 m² in Lake Northridge, 312,48 m² in Lake Teratai, 6,449,88 m² in Siliwangi Street, 6,573,01 m² in M.H Thamrin Street, and 896,51 m² in Plaza Niaga 1. While the depth of rain garden needed is 15-30 cm and 45-60 cm. The results of the rain garden dimensions are affected by factors of the water catchment area, runoff volume, and soil type.

4. The rain garden model refers to the shape, inflow and outflow design, planting media, and plant. The purpose of the rain garden model that is designed is not only capable of stormwater management, but also in absorbing water pollutants, water and soil conservation, and improving the aesthetic quality of the landscape.

4.2 Suggestion

The implementation of the rain garden should be conducted in Sentul City area referring to the recommendations of this study in supporting the availability of independent raw water. The implementation of rain garden should be conducted in five site research because it utilizes existing technology, so that the potential of the site can be developed. Although in general the planning of Sentul City has already ideal, but with the application of the rain garden, the ecological functions of the landscape can be further improved. The rain garden should also use local plants and designs that have been designed to suit the potential of the existing site.

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