Efficacy Analysis of Urban Planning Scenarios for Flood Mitigation with Low Impact Development Technologies Using SWMM: A Case Study in Saitama City, Japan

S Uchiyama1,*, Y Bhattacharya2 and H Nakamura2
1Graduate School of Systems Engineering and Science, Shibaura Institute of Technology
2Department of Planning, Architecture and Environment Systems, Shibaura Institute of Technology, Japan
*
	mf21009@sic.shibaura-it.ac.jp

Abstract. LID (Low impact Development) has been widely promoted as a measure against urban flooding which has recently been increasing due to urbanization and climate change. However, studies that consider the combined effects of distributing multiple LIDs simultaneously in an urban area of specific size as urban planning scenarios are few. In this study, two cases of past rainfall data (short duration and long duration heavy rainfall), are used to simulate the effects of 3 different urban planning scenarios of distributed LID (i.e. combined LIDs implementable at the 1) building-level, 2) in open spaces, and 3) combined implementation of both 1&2), in addition to simulating for separate implementation of each LID type using the Storm Water Management Model (SWMM). The results show that in the case of short duration heavy rainfall, all 3 LID scenarios provide a greater decrease in the rate of flood volume compared to the case of long duration heavy rainfall. This points to the fact that LIDs have a high potential to mitigate flood volumes resulting from short duration heavy rainfall - the type of rainfall which has become more frequent recently. Furthermore, the paper also organizes the LID types according to their implementability under different urban planning scenarios, and shows that such combined use of LIDs results in higher flood mitigation efficacy.

1. Introduction

As our cities become more and more complex we are expected to face multiple challenges in terms of environmental, social and economic aspects relating to climate change [1]. According to The IPCC’s Fifth Assessment Report (AR5), due to global warming, average surface temperature will increase considerably in the coming years all over the world [2]. All prediction scenarios for global warming indicate temperature increase, whilst the worst case scenario predicts on increase of up to 4.8 degrees. This directly relates to increase in the risk of storms and extreme precipitation, resulting in urban area flooding [2], which is further exacerbated by the increasing impervious surface areas in cities due to urbanization which prevents rainwater from penetrating the ground.

In Japan, the situation is no different. According to the Automated Meteorological Data Acquisition System [3], the number of short duration heavy rainfall events exceeding 50mm/hour has increased approximately 1.4 times compared to 30 years ago, and approximately one-third of the areas in Japan have observed the largest rainfall in history since 2012. Serious flood disasters have been occurring...
almost every year in Japan; namely Kanto-Tohoku Heavy Rainfall in 2015, Typhoon for Hokkaido and Tohoku in 2017, Typhoon in East Japan in 2019 [4].

Urban development contributes to the increase in flood risk because of the reduction in ground infiltration capacity due to transformation of the natural soil into impervious surface. We can however use alternative methods that improve permeability, as well as better spatial planning techniques to mitigate future flood risks in flood prone areas [5]. One approach to mitigate flood risk is through the use of “Low Impact Development (LID)” [6]. LID defines types of compact development approaches that are distributed throughout the site to decrease impervious area and stormwater runoff, pollutant loading and aid in stormwater management. Common practices such as permeable pavement and bioretention are well known. The goal of LID implementation is to maintain or replicate the pre-development hydrologic regime of an area to create a functionally equivalent hydrologic landscape [6] [7]. LID began to be used as a new measure to achieve better environmental design that also reduce economic losses from disasters, and has since become a popular approach for stormwater management with many major cities around the world incorporating such type of green infrastructure [8] [9].

Simultaneously, in recent years, the use of computational model for planning and design of stormwater management has become frequent [10]. One such model is the EPA’s (U.S. Environmental Protection Agency) Storm Water Management Model (SWMM) which is a dynamic rainfall runoff simulation model used for single event or long-term simulation of runoff. SWMM has been used in thousands of sewer and stormwater studies, and continues to be widely used for planning, analysis and design related to storm water runoff and drainage system in urban area as well as non-urban area. The latest version SWMM5.1 can simulate the effect of eight different types of LID controls [11].

Japan recently designated green infrastructure as one of its policies with national importance for the first time in 2015 [12]. Since which, the concept of green infrastructure and LID have begun to be widely adopted. Although there have been some case studies for simulating the flood mitigation efficacy of LID in an urban area, as far as we know there are only few studies which consider the combined effects of spatially distributing multiple LIDs simultaneously in an urban area of a specific scale in terms of urban planning scenarios [13][14].

The purpose of this study is to consider the flood mitigation efficacy of different implementable LID-based urban planning scenarios in an urban area where past floods have been recorded. Two cases of past rainfall data (short duration and long duration heavy rainfall), are used to simulate the effects of 3 different urban planning scenarios of distributed LID (i.e. combined LIDs implementable at the: (1) building-level, (2) in open spaces, and (3) combined implementation of both (1)&(2), in addition to simulating separate implementation of each LID type using the Storm Water Management Model (SWMM) with 1-chome Daitakubu Midori-ward in Saitama-city as the study area.

2. Methodology

2.1 SWMM
In this study, SWMM is applied to simulate: (1) total runoff and flood volume, (2) conduit capacity and flood volume from manhole, during single urban precipitation event.

Sub-catchment division, drainage system and other main parameters are necessary for the simulation of SWMM. Firstly, the target area is divided into several sub-catchments according to the sub-catchment division map of Saitama City. Each sub-catchment can be divided into three areas, including a pervious area and two impervious areas, one with and one without depression storage. The drainage system including junctions and conduits as well as the points where the rainfall is collected by drainage system and flows into the outlet (set as the nearby Touemon River) are modelled according to the sewerage map of Saitama City (see Figure 1). In addition, Kinematic wave routing model is selected as flow routing model, and Soil Conservation Service (SCS) curve number method is selected as infiltration method. Parameters of sub-catchment are presented in Table A-1 (see appendix A) based on SWMM User’s Manual Version 5.1 [11].
2.2 Precipitation scenarios

The characteristics of the two precipitation scenarios used in this study are shown in Figure 2. The first case is Typhoon No.19 (Typhoon Hagibis) a long duration heavy rainfall scenario which recorded the largest wide area precipitation covering eastern Japan on 12/10/2019; while the second case is a short duration heavy rainfall that recently flooded in the study area on 8/12/2020. Both cases record a heavier rainfall resulting in flood around peak time (14:00 and 21:00 on 10/12/2019, 14:00 on 8/12/2020) respectively.

![Figure 1. Sub-catchment division and drainage system, outlet location.](image1)

![Figure 2. Precipitation scenarios (12/10/2019 and 8/12/2020).](image2)

3. Study Area

The area of this study is located in Midori-ward, Saitama-city, Japan, and the total area is approximately 25ha, as shown in Figure 3. Flood control facilities of Saitama-city are designed for rainfall of 55.5 mm per hour. However, a number of rainfall events recording more than 100 mm per hour have occurred recently [15]. Typhoon No.19 in 2019, flooded over 1000 houses in Saitama-city, and many physical damages were reported [16]. The study area is within this flooded region and selected based on the following 4 criteria below.

1. Much of the area is impervious. (see Figure 3(a-b))
2. The area has been flooded in the past. (see Figure 3(c))
3. The area has lower elevation is compared to its surroundings making it prone to flooding. (see Figure 3(d))
4. The soil type of the area is permeable. (see Figure B-2 in Appendix B)

![Aerial photograph](image3)

![Study Area](image4)
4. Usability of SWMM

Although there is no official water flow data for the study area, since there is an official water level data of outlet points from the Saitama water level information system [17] during the flood event, the simulated outlet water levels could be compared against the official data to verify the accuracy of the SWMM simulation. This verification is presented in Figure 4 (a) and (b), which show similarity in peak time values for both cases. This demonstrates that a fairly accurate simulation of flood situation maximized on peak time is possible through SWMM. Furthermore, even at non-peak times, where there is variance between the SWMM and official empirical data, the general trends of increasing and decrease in values are still similar and do not contradict. Consequently, we can assume that the SWMM methodology employed in this study can produce fairly accurate results of the simulation that mitigates inland flooding using LID within the sub-catchment.

5. Simulation scenarios

This study uses 6 types of LID (namely, bio-retention, permeable pavement, infiltration trench, green roof, rain barrel, rooftop disconnection). It considers the efficacy of implementing each LID separately as well as combined implementation scenarios of LID based on spatial planning. Three different LID scenarios are used in terms of their applicability for: 1) the building level; 2) the open spaces; and 3) both combination of building and open space implementation representing the maximum possible LID use within the sub-catchment. However, in SWMM it is impossible to reflect accurate distribution of LIDs as shown in Figure 5. Therefore, this study compares distribution of LIDs (see Figure 5) with sub-catchment division map (see Figure 1). Figure 1, following which, each LID component presented in...
Table C-1 (in Appendix C) is created, then added to SWMM according to the size and number of each LID within each sub-catchment.

5.1 Singular LID scenarios
The description of each LID type considered and its placement in the study area are presented in Table 1, and Partial Parameter of each LID type is presented in Table C-1 (in Appendix C)

**Table 1. Parameters of singular LID scenarios**

| LID                | Description                                                                                           | Placement                                                                 | Total used area   | Others / Notes                                                                 |
|--------------------|--------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------|-------------------------------------------------------------------------------|
| Bio-retention      | Allows the infiltration of rainfall on the surface into the ground through the grass and soil.        | In the parking lots. (Each area is set as one-tenth of each parking lot area.) | 14,339m²          | Inflow all rainfall within each parking lots in addition to rainfall that fell directly onto it. |
| Permeable Pavement | Allows the infiltration of rainfall from the surface into the ground through high permeability pavement. | On the wide walkways with more than 3m width.                             | 35,044m²          | Only inflow the rainfall that fell directly onto it (i.e. not including the rainfall from other places.). |
| Infiltration Trench| Leads the surface rainwater to infiltration pipe in the ground, allowing infiltration rate the ground from side and bottom of the pipe. | In detached house site. (Each area is set 2m² (width 0.4m* length 5m.).)   | 15,490m²          | Only inflow the rainfall that fell directly onto it (i.e. not including the rainfall from other places.). |
| Green Roof         | Allows infiltrating of rainfall falling on roof through using grass and soil set on the roof.         | Apartment buildings with a flat roof.                                     | 172,994m²         | The rainfall that does not infiltrate is set to flow directly into drainage system through drainage mat. |
| Rain Barrel        | Retains the rainwater falling on roof through a downspout.                                            | In detached house site. (The bottom area 0.266m², Capacity 200L.)         | Capacity 1,549,000L (2,060m³) | The roof area of each detached house collected by one rain barrel is set as 35.75m². |
| Rooftop Disconnection | Allows the rainfall from the roof to flow into the current pervious area via the downspout within the site of the detached house. | In detached house site.                                                   | 276,884m² (Total roof area used for rooftop disconnection) | The roof area of each detached house collected by one downspout is 35.75m². |

5.2 Combined scenarios

- **Scenario 1 – LIDs adoptable at the building level**
  This scenario envisions the use of infiltration trench and a combination of rain barrel and rooftop disconnection for detached house; and a combination of green roof and rooftop disconnection for apartment buildings with a flat roof. Overflow from the rain barrel and green roof LIDs can flow into the pervious area due to the combination with rooftop disconnection. Since these LIDs need to be adopted at the building level, their implementation can be incentivized through subsidies aimed at the house owners. For our study we assume the scenario as shown in Figure 5(a) with the combined LID usage area being 190,544 m².

- **Scenario 2 – LIDs implementable in open spaces**
  This scenario envisions the use of permeable pavement for all wide walkways with width over 3m and bio-retention for all parking lots within the sub-catchment. The implementation of these LIDs is based on public spaces and therefore under the jurisdiction of the municipal urban development authority. This scenario can be adopted easily and widely in comparison to scenario 1 if the neighborhood is in a development or re-development stage. However, it may be difficult to be adopted in an already
developed area. For our study we assume the scenario as shown in Figure 5(b) with the combined LID usage area being 179,382 m².

- **Scenario 3 – Maximum use of LIDs**

  This scenario combines scenarios 1 and 2 to examine how much rainfall flood mitigation is possible if both the building-level strategies and open-space oriented strategies are adopted. This would give the maximum flood mitigation efficacy possible in the study area through the use of LIDs. For our study we assume the scenario as shown in Figure 5(c) with the combined LID usage area being 648,809 m².

![Figure 5](image)

**Figure 5.** Location used of each combined scenario:
(a) Placement of Scenario 1; (b) Placement of Scenario 2; (c) Placement of Scenario 3

6. **Simulation Results and Analysis**

Simulation results regarding runoff, flood volume, and the resulting flood situation in the study area are shown in section 6.1 and 6.2 as explained. In this study, “runoff volume” is defined as the volume of rainfall not infiltrating to the ground and instead directly flowing to the drainage system from the whole sub-catchment area. Similarly, “flood volume” is defined as the volume of runoff overflow due to exceedance of drainage capacity of the sub-catchment area.

6.1 **Runoff and flood volume**

6.1.1 **Short duration heavy rainfall (8/12/2020).** Table 2 shows the simulated total runoff and flood volumes for each LID type, and their corresponding rate of decrease when compared with the current situation (no LID present – as shown on the left column of the table), as well as the detailed peak time transition of these volumes (from 14:10 – 14:40). All LID types show the potential to decrease the flood
volume. Especially, LIDs such as bio-retention, green roof, rooftop disconnection, rain barrel, which can be used in large areas show higher potential.

When compared in terms of the scenarios explained in the previous section (employing different combinations of LIDs), Scenario 1 shows greater potential compared with Scenario 2 at 68% flood volume decrease, while Scenario 3 which combines the two scenarios shows approximately 86% decrease in flood volume.

Table 2. Simulated total runoff and flood volumes for transition on peak time.

| Scenario | Runoff V (m³/s) | Flood V (m³) |
|----------|-----------------|--------------|
| Current Condition | Runoff V (m³/s) | Flood V (m³) |
| Permeable Pavement | 51.72 × 10^3 | 12.24 × 10^3 |
| Bio-retention | 50.66 × 10^3 | 11.35 × 10^3 |
| Green Roof | 48.62 × 10^3 | 9.98 × 10^3 |
| Infiltration Trench | 47.51 × 10^3 | 8.15 × 10^3 |
| Rooftop Disconnection | 51.22 × 10^3 | 11.58 × 10^3 |
| Rain Barrel | 50.09 × 10^3 | 6.10 × 10^3 |

6.1.2 Long duration heavy rainfall (10/12/2019). Table 3 shows the simulated total runoff and flood volumes for each LID type and, their corresponding rate of decrease when compared with the current situation (no LID present – as shown on the left column of the table), as well as the detailed peak time transition of these volumes (from 20:40 – 21:50). Both runoff and flood volume of LIDs such as green roof, rooftop disconnection and rain barrel which showed high effectiveness previously show low effectiveness. Bio-retention also shows comparatively lower effectiveness in the case of long duration heavy rainfall. The following reasons can be assumed for this outcome: 1) in the case of green roof, most of the rain directly flows into the drainage system due to declining infiltration and storage capacity of the thin soil layer on the roof from continued precipitation; 2) in the case of rooftop disconnection, the rain flows to the pervious areas, causing its infiltration capacity to decline from continued precipitation; 3) in the case of rain barrel, it has limited storage capacity which is exceeded by the inflowing rainfall; 4) in the case of bio-retention, surface runoff due to declining infiltration and storage capacity of the soil and gravel layer from continued precipitation can occur.

The rate of decrease of permeable pavement and infiltration trench are almost similar with short duration rainfall, indicating that all infiltration can be infiltrated without causing decline in the infiltration and storage capacity throughout the whole rainfall event used for the study. However, it is necessary to note that the simulation inputs are set to only collect the rainfall falling directly on a location rather than considering the accumulated flow of rainfall from other locations.

All combined scenarios show low effectiveness in line with rate of decrease of singular LID scenarios. Especially, both runoff and flood volume of Scenario 1 and 3 show considerably lower effectiveness; Their rate of decrease of flood volume is approximately 60% lower when compared with short duration rainfall.
6.2 Conduit capacity and flood volume from manhole

In addition to the runoff and flood volume, SWMM can also visualize the capacity of conduit and flood volume from manhole in time series in the drainage model. This allows for further comparison of the flood situation for cases with and without LIDs.

6.2.1 Short duration heavy rainfall (8/12/2020). Figure 6 (a-d) visualizes the peak situation at 14:20 which recorded the highest flood volume in the study area (see Table 2). Based on the previous analysis presented in Table 2, the manhole and conduit details of the LIDs which showed high mitigation potential (i.e. bio-retention, rooftop disconnection, and scenario 3-maximum use of LID) are compared against the current condition of no LID use (see Figure 6 (a-d)).

Without the case of any LIDs, flood results from most manholes in the study area as they exceed the drainage capacity (Figure 6 (a)), however this is considerably mitigated especially with the use of bio-retention and rooftop disconnection. Moreover, full flood prevention is possible (no flood occurrence) in the case of Scenario 3 which uses multiple LIDs. This emphasizes our previous finding that LID has high potential to decrease flood in the study area for short duration heavy rainfall.

1 Reason for a positive rate of decrease.

In these cases, the total runoff volume slightly decreases while the total flood volume slightly increases compared with the current situation. This could be due to exceedance of the infiltration capacity and storage capacity of the LID at an earlier time, which would lead to an increase in the total runoff volume compared to the current situation.

Table 3. Simulated total runoff and flood volumes for transition on peak time.

| Scenario | Runoff V (m³) | Flood V (m³) | Runoff V (m³) | Flood V (m³) | Runoff V (m³) | Flood V (m³) | Runoff V (m³) | Flood V (m³) | Runoff V (m³) | Flood V (m³) |
|----------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|--------------|
| **Current Condition** | 667.41 × 10³ | 78.28 × 10³ | 667.37 × 10³ | 78.74 × 10³ | 667.41 × 10³ | 78.95 × 10³ | 667.39 × 10³ | 78.80 × 10³ | 667.41 × 10³ | 78.95 × 10³ |
| **Scenario 1** | 652.67 × 10³ | 73.78 × 10³ | 652.67 × 10³ | 73.78 × 10³ | 652.67 × 10³ | 73.78 × 10³ | 652.67 × 10³ | 73.78 × 10³ | 652.67 × 10³ | 73.78 × 10³ |
| **Scenario 2** | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ |
| **Scenario 3** | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ | 662.95 × 10³ | 74.89 × 10³ |
| **SUM** | 667.41 × 10³ | 78.28 × 10³ | 667.37 × 10³ | 78.74 × 10³ | 667.41 × 10³ | 78.95 × 10³ | 667.39 × 10³ | 78.80 × 10³ | 667.41 × 10³ | 78.95 × 10³ |

| Rate of decrease | | | | | | | | | | |
Figure 6. Conduit capacity and flood volume from manhole at 14:20 for: (a) Current condition (without LID); (b) Bio-retention; (c) Rooftop Disconnection; (d) Scenario 3 - maximum use LID

6.2.2 Long duration heavy rainfall (10/12/2019). Figure 7 (a-d) visualizes the peak situation at 21:10 which recorded the highest flood volume in the study area (see Table 3). Based on the previous analysis presented in Table 3, the manhole and conduit details of the LIDs which showed high mitigation potential (i.e. bio-retention, rooftop disconnection, and Scenario 3-maximum use of LID) are compared against the current condition of no LID use (see Figure 7 (a-d)).

Without the use of any LIDs, flood results from most manholes in the study area as they exceed the drainage capacity (Figure 7 (a)). However, compared with the case of short duration heavy rainfall, LID use in long duration heavy rainfall does not seem to have much flood mitigative effect (Figure 7 (b-d)).

Figure 7. Conduit capacity and flood volume from manhole at 21:10 for: (a) Current condition (without LID); (b) Bio-retention; (c) Rooftop Disconnection; (d) Scenario3 - maximum use LID

7. Conclusion
The purpose of this study is to consider combined effects of implementing urban planning scenarios of multiple LIDs simultaneously distributed in an urban area as a measure against urban flooding. Our result shows that LIDs have a high potential to mitigate flood volumes resulting from short duration heavy rainfall - the type of rainfall which has become more frequent in recent times. Similarly, it also highlights that long duration heavy rainfall due to continuing precipitation causing capacity shortage caused by continued precipitation. Furthermore, this study also organizes the LID types according to their implementability under different urban planning scenarios, showing that LIDs have a high
mitigation potential for flood volume during short duration heavy rainfall even if it occurs frequently as long as it is possible to sufficiently distribute various LIDs over the urban area through proper spatial planning. In this regard, three scenarios have been presented which can be strategically implemented through incentivization at the home-owner level (Scenario 1), or through development initiative of the municipal authority (Scenario 2). Both cases as well as their combined output (Scenario 3) show higher flood mitigation efficacy compared to the current situation with no LIDs.

The study also demonstrates the usability of SWMM for urban planning. It can visualize not only flood volume and drainage capacity, but also exceeding volume of the infiltration and storage capacity for every LID, enabling the evaluation of different spatial plans with varied forms of LID distributions. A point to note however, is that this study shows simulation results on a daily basis only. Simulation for monthly and yearly basis could yield higher accuracy with consideration of long-term precipitation trends.

Acknowledgement
The authors would like to thank Takanori Tanabe (graduated student) for his contribution to the project, and Saitama City for providing with the sub-catchment division and sewerage maps for their cooperation.

Appendix A

Table A-1. Parameters in SWMM

| Parameter      | Parameter Meaning                        | Value |
|----------------|------------------------------------------|-------|
| N-Imperv       | Manning coefficients in impervious areas | 0.01  |
| N-Perv         | Manning coefficients in pervious areas   | 0.1   |
| Dstore-Imperv  | Depression storage in impervious areas (mm) | 2     |
| Dstore-Perv    | Depression storage in pervious areas (mm) | 6     |
| %Zero-Imperv   | Percent of impervious area with no depression storage (%) | 25    |
| Infiltration   | Curve Number                             | 77    |
| Data           | Drying Time                              | 7     |
| Roughness (conduit) | Manning’s roughness coefficient | 0.013 |

Appendix B

Figure B-1. Permeability Capacity Map [18]
Appendix C

Table C-1. Partial Parameters of LIDs.

| Layer         | Parameter                  | Unit | Bio-retention | Permeable Pavement | Infiltration Trench | Green Roof | Rain Barrel | Rooftop Disconnection |
|---------------|----------------------------|------|---------------|--------------------|--------------------|------------|-------------|-----------------------|
| Surface       | Berm Height                | mm   | 152           | 1.5                | 0                  | 152        | 700 (Height) |
|               | Vegetation Volume Fraction |       | 0.2           | 0                  | 0                  | 0          |             |
|               | Surface Roughness          |       | 0.15          | 0.015              | 0.04               | 0.15       |             |
|               | Surface Slope              | Percent | 1.0          | 1.0                | 1.0                | 1.0        |             |
| Pavement      | Thickness                  | mm   | 50            |                    |                    |            |             |
|               | Void Ratio (Volids / Solids) |       | 0.165          |                    |                    |            |             |
|               | Impervious Surface Fraction |       | 0             |                    |                    |            |             |
|               | Permeability               | mm/h | 3960          |                    |                    |            |             |
|               | Clogging Factor            |       | 0             |                    |                    |            |             |
| Soil          | Thickness (mm)             | mm   | 700           | 114                |                    |            |             |
|               | Porosity (Volume fraction) |       | 0.4           | 0.4                |                    |            |             |
|               | Field Capacity (Volume fraction) |   | 0.15          | 0.15               |                    |            |             |
|               | Wiling Point (Volume fraction) |       | 0.03          | 0.03               |                    |            |             |
|               | Conductivity               | mm/h | 150           | 200                |                    |            |             |
|               | Conductivity Slope         | Percent | 45           | 45                 |                    |            |             |
|               | Suction Head               | mm   | 50            | 50                 |                    |            |             |
| Storage       | Thickness                  | mm   | 550           | 200                | 700                | 0          |             |
|               | Void Ratio (Volids / Solids) |       | 0.165          | 0.165              | 0.165              |            |             |
|               | Seepage Rate               | mm/h | 108           | 108                | 108                |            |             |
|               | Clogging Factor            |       | 0             | 0                  | 108                |            |             |
|               | Surface Roughness          |       | 0.01          |                    |                    |            |             |
|               | Surface Slope              | Percent | 2.0          |                    |                    |            |             |
| Drainage Mat  | Thickness                  | mm   | 25.4          |                    |                    |            |             |
|               | Void Fraction              |       | 0.5           |                    |                    |            |             |
|               | Roughness                  |       | 0.01          |                    |                    |            |             |

References

[1] Judy Busha, Andreanne Doyonb, 2019 Cities Building urban resilience with nature-based solutions: How can urban planning contribute? 95 102483

[2] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp 10-13

[3] Japan Meteorological Agency Automated Meteorological Data Acquisition System https://www.jma.go.jp/bosai/amedas/#area_type=japan&area_code=010000

[4] Social Capital Development Council 2020 Water-related disaster preparedness in the conte with climate change ~A shift to sustainable watershed flood control by the stakeholders ~(in Japanese) pp 9-11

[5] Ahmed Mustafa, Martin Bruwier, Pierre Archambeau, Sebastian Epicum, Michel Pirotton Benjamin Dewals and Jacques Teller 2018 Journal of Environment Management Effect of spatial planning on future flood risks in urban environments 225 193-204

[6] Christopher Pykea, Meredith P. Warrena, Thomas Johnsona, James LaGro Jr. b, Jeremy Scharfenbeerge, Philip Grothld, Randall Freede, William Schroere and Eric Mainf 2011 Landscape and Urban Planning Assessment of low impact development for managing stormwater with changing precipitation due to climate change 103 166-73

[7] United States Environmental Protection Agency 2000 Low impact development (LID) a literature review EPA-841-B-00-005

[8] Larry S. Coffman, Associate Director Department of Environmental Resources Prince George’s County, Maryland 2000 Low-Impact Development Design: A New Paradigm for Stormwater
Management Mimicking and Restoring the Natural Hydrologic Regime An Alternative Stormwater Management Technology p 158

[9] Fanhua Kong, Yulong Ban, Haiwei Yin, Philip James and Iryna Dronova 2017 Environmental Modeling & Software Modeling stormwater management at the city district level in response to changes in land use and low impact development 95 132-42

[10] Alexander H. Elliott Sam A, Trowsdale and Sanjay Wadhwa 2009 Journal of Hydrologic Engineering. Effect of Aggregation of On-Site Storm-Water Control Devices in an Urban Catchment Model 14 9

[11] Lewis A. Rossman Environmental Scientist, Emeritus U.S. Environmental Protection Agency 2015 Storm Water Management Model User’s Manual Version 5.1

[12] Landscape and Ecology Division, National Institute of Land and Infrastructure Management Ministry of Land, Infrastructure, Transport and Tourism, Japan 2018 TECHNICAL NOTE of National Institute for Land, Technical Note on Green Infrastructure Planning for Urban Resilience -Handbook of Landscape Planning for Disaster Risk Reduction in Urban Areas- p6

[13] Mehran Niazi, Chris Nieetch, Mahdi Maghrebi, A.M.ASCE, Nicole Jackson, Britatny R Bennett, Michael Tryby, and Arash Massoudieh, M.ASCE J. 2017 Sustainable Water Built Environment Storm Water Management Model: Performance Review and Gap Analysis 3(2) 04017002

[14] Kyle Eckart, Zach McPhee, Tirupati Bolisetti 2017 Science of the Total Environment Performance and implementation of low impact development – A review 607-8 413-3

[15] Saitama City 2017 Saitama City Guidelines for Integrated Rainwater Control Measures (Summary) (in Japanese) https://www.city.saitama.jp/001/010/008/p011862_d/fil/gaiyou.pdf

[16] Saitama City 2019 Situation in the city due to Typhoon No.19 (Typhoon Hagibis) (in Japanese) https://www.city.saitama.jp/001/011/015/010/p075963.html

[17] Saitama Prefecture Saitama water level information system https://www.flood-info.city.saitama.jp/JP/index.html

[18] Saitama Prefecture Saitama Prefecture Permeability Capacity Map https://www.pref.saitama.lg.jp/a1007/usuijyourei/usuiryuusyutu.html