Exploratory Assessment of SUDS Feasibility in Nhieu Loc-Thi Nghe Basin, Ho Chi Minh City, Vietnam

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Authors’ contributions

This work was carried out in collaboration between all authors. Author HHL designed the study, performed the PCSWMM modeling and stakeholder interviews, and wrote the first draft of the manuscript. Authors MSB and KNI provided technical advice on the modeling and survey analysis and edited versions of the manuscript. Authors PMD and SW managed the literature search. All authors read and approved the final manuscript.

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ABSTRACT

Aims: In recent decades, Ho Chi Minh City, Vietnam, frequently has been affected by local floods and inundation from heavy rainfall. Conventional flood mitigation measures such as building flood gates and upgrading sewerage systems have been implemented but problems persist. The objective of this research is to assess another approach for flood control measures, namely Sustainable Urban Drainage Systems (SUDS), with application to the Nhieu Loc - Thi Nghe Basin, located in the central part of Ho Chi Minh City.

Methodology: A combination of the Stormwater Management Model (PCSWMM) and interviews with 140 households was used to assess the efficacy and acceptability of four of the most popular SUDS: Rainwater harvesting, green roofs, urban green space and pervious pavement. Thirteen SUDS and urban build-out scenarios were simulated under 6 design storm conditions.

Results: PCSWMM results showed that inundation from intense rainfall could be reduced with proper land-use control, specifically by maintaining imperviousness at 65% or less of the surface area.

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area. With respect to SUDS performance, green roofs were best at reducing peak runoff (22% reduction), followed by pervious pavement, urban green space, and rainwater harvesting systems. Regarding environmental improvements, as represented by reduction in total suspended solids load, urban green space was best with 20% of the solids load removed compared to the base case scenario, followed by green roofs, pervious pavement, and rainwater harvesting. The household interviews revealed the majority of people preferred pervious pavement to the other SUDS options and the least preferred option was green roof technology.

**Conclusion:** Considering the combination of water quantity and water quality controls, it seems that green roof technology was the best performer for this area of Ho Chi Minh City, followed by urban green space, pervious pavement and rainwater harvesting. However, green roof technology also was the least favored option for the public and stakeholder acceptance will impact SUDS implementation.

**Keywords:** Urban flooding; Sustainable Urban Drainage Systems (SUDS); Storm Water Management Model (PCSWMM); rainwater harvesting; green roofs; urban green space; pervious pavement.

**1. INTRODUCTION**

Frequent and localized flooding in Ho Chi Minh City (HCMC) not only causes serious economic losses but also degrades the quality of life and this is particularly true for those living in the Nhieu Loc-Thi Nghe (NL-TN) Basin of the central part of the city. Rainfall events of greater than 90 mm depth, which alone could cause local inundation in some places, have occurred more frequently. This phenomenon, together with other adverse effects such as increased downstream water level due to sea level rise, has resulted in a regularly overloaded drainage system, despite hard engineering improvements that have been implemented over the past decade [1,2].

Sustainable Urban Drainage Systems (SUDS) technologies consider environmental, social and economic pillars in the design process. SUDS should integrate stakeholders in the decision making and ultimately, could achieve multiple benefits along with flood and inundation mitigation. There are several SUDS technologies available. Within the scope of this study, four of the most popular SUDS technologies were considered:

(i) Rainwater harvesting – which can be a supplement for water supply sources; reduce extra direct discharge to the drainage system and prevent urban flooding [3-5];

(ii) Green roofs – have numerous benefits [6], including: Reduction of runoff peaks and volumes, resulting in lower urban flood risks [7-10]; the insulation of heat transfer, resulting in lower cost for air conditioning, and reduction of the heat island effect [11,5,12]; reduction in air pollution [13]; provision of wildlife habitat for birds and general enhancement of environment for the area [14-16,5];

(iii) Urban green space provides improved resiliency in runoff management and multiple other ecosystem services [17-20];

(iv) Pervious pavement - a technology that both enhances infiltration and improves surface runoff quality [21-23]. There is some concern about clogging of pervious pavement, with observed clogging rates being highly variable, but Drake and Bradford [24] have reported on new generation maintenance methods to regenerate permeability.

SWMM (Storm Water Management Model) is a comprehensive computer model for analysis of quality and quantity problems associated with urban runoff [25]. Both single event and continuous simulations can be performed on catchments having storm sewers, combined sewers, or natural drainage, for prediction of flows, stages and pollutant concentrations. The model offers several choices for simple rainfall-runoff estimates and includes kinematic and dynamic wave routing options to generate flow hydrographs. Another welcome feature of SWMM version 5 is the explicit representation of Low Impact Development (LID) technologies (an alternative name for SUDS in North America). One objective of this study was to use a personal computer version of SWMM (i.e. PCSWMM) in assessing SUDS technologies to enhance flood mitigation measures already implemented in the
NL-TN Basin. A second objective of this study was to solicit stakeholder opinion about the relative desirability of the different SUDS options. This represents one of the first efforts in Vietnam to model the relative benefits of SUDS in urban areas, and more importantly it's the first instance we are aware of that integrates engineering practice with social science considerations to improve drainage and the local environment.

2. METHODOLOGY

2.1 Nhieu Loc-Thi Nghe Canal and Basin

The NL-TN Basin (Fig. 1) is located in the central part of HCMC and occupies an area of approximately 33 km², stretching across 7 city districts (1, 3, 10, Phu Nhuan, Tan Binh, Go Vap and Binh Thanh). The population of the Basin is about 1.2 million people (20% of the total HCMC population), representing a population density of 290 people per hectare. Land use is mixed, with 49.3% being residential and the remaining representing commercial, public and industrial uses. Elevation within the Basin is variable, with the north and northwest sections being up to 8 m above sea level, while the southern part of the Basin averages only 1.3 m above sea level.

Le [4] described the historical development of the NL-TN Canal and Basin, as it progressed from a rural, northern boundary area of HCMC in the 1700’s to an area of extensive informal housing in the 1960’s. By the 1960’s HCMC had grown further north, so the NL-TN area was now part of the central city and the river, which formerly had provided fishing and water for domestic use, was now called “Kinh Nuoc Den”, or “Black Water Canal” due to extensive degradation from wastewater discharge. Le [4] also provided a firsthand account of frequent flooding in the basin. Wust et al. [26] reported that since 1995, the city had conducted a program of cleaning up the NL-TN Canal, relocating informal settlements, and improving drainage. Ho [27] noted that since 1998 more than $1 billion USD had been spent on urban flood control projects for all of HCMC while Duc and Truong [28] discussed the comprehensive project to build a new drainage system for the NL-TN Canal which had a budget of $200 million USD over the 2001-2007 period and included funding of $166 million USD from the World Bank. Despite improved drainage conditions, Lempert et al. [29] recently concluded the new infrastructure in the NL-TN Basin would reduce risk compared to current levels if three-hour rainfall event intensities increase by no more than approximately 6% and if the Saigon River rises less than 45 cm. However, it seems possible that both of these thresholds may be exceeded by mid-century, in which case flooding risk increases above current levels even with this infrastructure in place. For example, based on projections of linear trends over the past 20 years, Ho [27] concluded sea level increase averaged 1.5 cm per year for the Ho Chi Minh City region. Ho [27] also reported an increase in the annual maximum 180 minute rainfall for the city of about 0.8 mm/year between 1952 and 2002.

2.2 Model Development

The drainage system of the NL-TN Basin was simulated using PCSWMM which was adapted from an earlier SWMM model developed by Camp, Dresser and MacKee [30], but updated to more accurately represent surface slope using DEMs in Arc GIS; represent current land use characteristics and percent imperviousness; and consider new bathymetric data for the NL-TN Canal. In total, 228 sub-catchments, 333 conduits and 228 junctions were included in the model (Fig. 2).

2.2.1 Boundary conditions and model calibration conditions

Fig. 1 shows the locations of the Tan Son Hoa meteorological station and Phu An hydrological station from which the model boundary conditions were collected. Boundary conditions for this study were defined by considering the typical tidal curve obtained from the Phu An Station, located at the downstream end of the Basin. Fig. 3 shows a typical tidal curve (1.48 m peak) from the Phu An Station.

Because sewer flow is not routinely monitored in Vietnam, an alternative approach was used to calibrate the model. A 90 mm design storm was used as input (Fig. 4) and model results for the water level along the NL-TN Canal under a similar rainfall event were compared to observed levels.
Goodness of fit between the model simulation and the observed data were assessed based on:

Efficiency Index (EI)

$$ EI = \frac{\sum_{i=1}^{n} (X_i - \bar{X})^2 - \sum_{i=1}^{n} (X_i - Y_i)^2}{\sum_{i=1}^{n} (X_i - \bar{X})^2} $$

Root mean square error (RMSE)

$$ RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_i - Y_i)^2}{n}} $$

Mean Absolute Percentage Error (MAPE)
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{X_i - Y_i}{X_i} \right| \times 100 \tag{3}

Correlation Coefficient (R)

R = \frac{\text{cov}(X, Y)}{s_x s_y} \tag{4}

Where:

X_i = \text{Observed (measured) data at time } i
Y_i = \text{Computed (predicted) data at time } i
n = \text{Number of data points}

\overline{X} = \text{Mean value of observed data}
\overline{Y} = \text{Mean value of computed data}

Fig. 2. PCSWMM representation of sub-catchments and sewer network

Fig. 3. Typical tidal curve at Phu An Station
The model was validated by comparing the flood hazard map generated by the model and the flooded streets reported by the Urban Drainage Company (UDC) and Flood Control Center (FCC) for a 100 mm storm event. UDC and FCC are two agencies assigned by the People’s Committee of HCMC to be in charge of flood and inundation management for the city.

2.3 SUDS Efficiency Evaluation

The efficacy of SUDS was evaluated based on two main criteria, flood attenuation capacity and pollutant removal rates. The flood attenuation capacity is calculated as follows:

\[ F = (1 - \frac{Q_o}{Q_o}) \times 100 \% \]  

(5)

Where:

- \( F \) is the flood attenuation capacity
- \( Q_o \) is the peak flow after SUDS application (m³/s)
- \( Q_o \) is the peak flow before SUDS application (m³/s)

The pollutant removal rate is calculated as follows:

\[ TE = (1 - \frac{M_s}{M_o}) \times 100 \% \]  

(6)

Where:

- \( TE \) is the trap efficiency
- \( M_s \) is the total pollutant mass after SUDS application (kg)
- \( M_o \) is the total pollutant mass before SUDS application (kg)

The total pollutant mass is the TSS introduced through a storm event with a given concentration. This concentration is assumed to be constant through the time of simulation. This concentration used is a mean value from rainwater quality survey. This approach was used to provide a planning level estimate of the removal capacity of SUDS with respect to pollutants. A more comprehensive study is needed to better estimate this benefit of SUDS.

2.4 Citizen Surveys

An innovative aspect of this research was that, to our knowledge, citizen stakeholders in HCMC were asked for the first time about their views on localized flooding. A total of 140 households were interviewed in the watershed and these were categorized according to low, medium, and high income based on size and construction material of the house and the number of motorbikes and cars owned. The locations for the interviews were chosen based on the annual inundation reports from the FCC. During the interviews, the households were introduced to the different SUDS options and asked about their preferences with respect to rainwater harvesting, green roofs, urban green space, and pervious pavement.

3. RESULTS AND DISCUSSION

3.1 PCSWMM Calibration

PCSWMM was calibrated by comparing the water level simulation along the NL-TN Canal at a 1.48 m peak tide and under the 90 mm, 2 year design rainfall. Results are shown in Figs. 5a and 5b.
Additionally, the Efficiency Index, RMSE and MAPE were calculated and are displayed in Table 1. These calibration results suggest that the model is capable of reproducing local hydrology and that the model can be used with some confidence.

Table 1. PCSWMM calibration results

| Indicator                          | Values |
|-----------------------------------|--------|
| Efficiency index (EI)             | 0.93   |
| Root mean square error (RMSE)     | 0.02   |
| Mean absolute percentage error (MAPE) | 1.5 %  |
| Correlation coefficient r         | 0.962  |

3.2 PCSWMM Validation

The validation was done using two approaches. The first approach compared the locations of flooded manholes using the 1D PCSWMM simulation option with flooded streets from observation made by the UDC and FCC (Fig. 6a). From Fig. 6a, it appears that the 1D model can be used to identify the flood locations, although some areas, such as the south central part of the Basin, were less accurately represented. The evaluation of flood extent regarding depth and affected area also was handled with the application of the 2D routing option in PCSWMM. The results are shown in Fig. 6b.

Fig. 6a and 6b show reasonable consistency between inundated streets observed by the flood control agencies of HCMC and flood hazard maps generated by the model. Additionally, Table 2 summarizes the comparison of flood depth between simulation results and observed data.
Recognizing the uncertainty associated with the limited observed data for this study, it can be concluded that the model was adequately calibrated and validated and can be used for inundation analysis of the NL-TN Basin.

3.3 Simulations

3.3.1 Design storms and urbanization scenarios

A set of simulation scenarios with different impervious percent values and surface roughness coefficients, covering the entire study area, were developed to explore impacts of urban development. This is to evaluate the effects of integrated measures. Each scenario either varied percent imperviousness or a combination of imperviousness and Manning’s n. The increased roughness might result, for example, by promoting green space within the urban area. Details of each hypothesized scenario are listed in Table 3.

3.3.2 Summary of simulation results

Scenario 1 was used as the basis of comparison scenario against which all other scenarios were assessed. Results for the different development scenarios, using different storm depths and return periods are summarized in Fig. 7.

Table 2. Flood Depth Validation Results

| Locations (Street names)       | Maximum flood depth (m) | Simulation | Observation |
|-------------------------------|--------------------------|------------|-------------|
| Truong Cong Dinh             | 0.28                     | 0.35       |
| Pham Van Hai                 | 0.28                     | 0.35       |
| Dong Den                     | 0.36                     | 0.3        |
| Nguyen Thai Son              | 0.25                     | 0.25       |
| Truong Chinh                 | 0.32                     | 0.3        |
| Dinh Tien Hoang              | 0.3                      | 0.3        |
| Phan Dinh Giot               | 0.23                     | 0.2        |
| Tran Khanh Du                | 0.35                     | 0.3        |
| Hoang Van Thu                | 0.28                     | 0.3        |
| Dinh Tien Hoang              | 0.27                     | 0.3        |
| Tran Khanh Du                | 0.23                     | 0.25       |
| Phan Dinh Phung              | 0.37                     | 0.4        |
| Xo Viet Nghe Tinh            | 0.3                      | 0.25       |
| Van Kiep                     | 0.27                     | 0.3        |
| D2                           | 0.28                     | 0.2        |

Fig. 7 shows that Scenarios 2A and 3B1 generally exhibited increased surface flooding compared to current conditions. Both scenarios represented an imperviousness of 85%. The scenarios with 65% imperviousness, however, exhibited a decrease in flooded area compared to current conditions, for the whole range of design storms. This result shows that future development should try to maintain per cent imperviousness at 65% or less, assuming no other interventions (e.g. SUDS) are considered.

3.4 SUDS Efficiency Evaluation

3.4.1 Representative sub-catchment characteristics

Simulation of the SUDS technologies was done using the LID editor in PCSWMM that explicitly represents the structure and hydrology of these technologies [31,25]. For each of the Rain Harvesting, Green Roof, Rain Garden, and PerVIOUS Pavement, information required for input to the model included surface storage depth, roughness and slope, vegetation coverage, thickness and hydraulic conductivity of the underlying substrates and underdrain characteristics. Details about these elements are discussed in US-EPA [25,32]. The efficacy of SUDS was evaluated based on two main criteria; flood attenuation capacity and pollutant removal rates. The NL-TN Basin has in total more than 200 sub-catchments, as discussed above. Within the scope of this study, three representative sub-catchments were chosen to simulate the effect of SUDS. The selected sub-catchments are typical in land use patterns, area and were not located close to the watercourse (to avoid the confounding factor of flooding due to tides). Specific information regarding area, land use, SUDS configurations and impervious percent of these representative sub-catchments are shown in Table 4.
3.4.2 SUDS evaluation

The SUDS technologies were applied to the selected sub-catchments as noted in Table 4 and the results for the simulations are displayed in Table 5. The rainfall chosen for SUDS evaluation was the 5 year return storm with 103 mm of depth.

3.4.3 Stakeholder survey results

Combining results for all socio-economic groups, the SUDS technology preferences were (based
on the mean of a 1-5 Likert-type scale): Pervious pavement (score of 3.4); green space (score of 3.3); rainwater harvesting (score of 3); and green roofs (score of 2.4). Interestingly, however, the lowest socio-economic group favored rainwater harvesting (with a mean score of 3.4) above all other technologies.

### 3.5 Discussion

Although green roof technology had a strong hydrologic and water quality performance, it was least favored, in general, by the citizens surveyed. This type of technology appears to be too strange to be accepted by the majority of people. When asked, people showed substantial doubt about the applicability of vegetation coverage on their roofs. In contrast, green roofs are a common practice in Singapore Irvine et al. [33] and it would be interesting to explore whether the Singaporean experience could be transferred to HCMC through exchange and training programs. Rain barrels will be filled quickly with large storms, hence could only offer limited improvement. Although a commonly promoted technology in North America, Chaosakul et al. [34] also concluded rain barrels would have a relatively small impact on runoff for a peri-urban area of Bangkok, Thailand. The lowest socio-economic group for a couple of reasons may prefer rain barrels. First, they may preferentially see rainwater harvesting as an inexpensive water source; and second many in this category may have recently migrated from the countryside where rainwater harvesting traditionally is practiced. The other two methods, urban green space and pervious pavement require specific available space for application, thereby resulting in a variable performance. More specifically, Sub catchment 1 has available areas with suitable conditions to apply urban green space and pervious pavement. These two technologies also were most favored by the surveyed citizens when results were pooled for socio-economic class. Satiennam [35] investigated the limitations of SUDS implementation arising from local attitudes in the flood prone area of Bangkok’s Latkrabang District, such as inadequate plot size, inadequate budget for implementation, no homeowner’s time for maintenance and lack of SUDS gardening skills. It was concluded that SUDS could not be achieved if its concepts were not compatible with local conditions, and could also be constrained by the poor enforcement of flood legislation. It should be emphasized that SUDS technologies are not a one size fits all solution. In fact, by design, SUDS implementation will be spatially distributed and must consider the existing urban landscape, as well as the public acceptance of particular technologies.

#### Table 4. SUDS application in representative sub-catchments

| Parameters                          | Sub-catchment | 1 | 2 | 3 |
|-------------------------------------|---------------|---|---|---|
| **Characteristics**                 |               |   |   |   |
| Area (ha)                           | 102           | 13| 32|
| Residential area (%)                | 46            | 54| 65|
| Roads (%)                           | 14            | 30| 27|
| Parks, paddies, (%)                 | 40            | 16| 8 |
| Population (capita)                 | 13630         | 2030| 5510|
| Households                          | 2726          | 406| 1102|
| Impervious %                        | 65            | 65| 65|
| **Rainwater harvesting system**     |               |   |   |   |
| Number of replicate units           | 2726          | 406| 1102|
| Area of each unit (m²)              | 60            | 60| 60|
| **Urban green space**               |               |   |   |   |
| Number of replicate units           | 4000          | 200| 300|
| Area of each Unit (m²)              | 100           | 100| 100|
| **Pervious pavement**              |               |   |   |   |
| Number of replicate units           | 1400          | 400| 900|
| Area of each unit (m²)              | 100           | 100| 100|

#### Table 5. SUDS evaluation

| Parameters                          | Sub-catchment | 1 | 2 | 3 | Mean |
|-------------------------------------|---------------|---|---|---|------|
| **Current situation**               |               |   |   |   |      |
| Peak Runoff (m³/s)                  | 29.11         | 4.17| 10.45| 14.58|
| TSS (kg)                            | 573           | 71 | 177| 273.67|
| **Rainwater harvesting system**     |               |   |   |   |      |
| Peak Runoff (m³/s)                  | 27.26         | 3.91| 9.8 | 13.66|
| F (%)                               | 6.36          | 6.21| 6.23| 6.27|
| TSS (kg)                            | 557           | 68 | 171| 265.33|
| TE (%)                              | 3.06          | 2.81| 3.38| 3.06|
| **Green roofs**                     |               |   |   |   |      |
| Peak Runoff (m³/s)                  | 24.29         | 3.18| 7.74| 11.74|
| F (%)                               | 16.54         | 23.7| 25.94| 22.06|
| TSS (kg)                            | 478           | 57 | 141| 225 |
| TE (%)                              | 16.58         | 19.72| 20.9| 19.07|
| **Urban green space**               |               |   |   |   |      |
| Peak Runoff (m³/s)                  | 14.8          | 3.26| 9.09| 11.59|
| F (%)                               | 21.32         | 3.7 | 9.76| 14.86|
| TSS (kg)                            | 355           | 60 | 167| 192.33|
| TE (%)                              | 38.91         | 15.49| 5.65| 20.02|
| **Pervious pavement**              |               |   |   |   |      |
| Peak Runoff (m³/s)                  | 26.81         | 2.62| 9.79| 13.07|
| F (%)                               | 7.89          | 37.15| 6.57| 17.13|
| TSS (kg)                            | 552           | 38.3| 167| 244 |
| TE (%)                              | 3.66          | 46.06| 5.65| 16.20|

F = flood attenuation capacity as defined by eq. (5); TE - trap efficiency as defined by eq. (6).
4. CONCLUSION

Reducing the impervious percentage could contribute to alleviating the flood situation of the NL–TN Basin. Future development should try to maintain per cent imperviousness at 65% or less, assuming no other interventions (e.g. SUDS) are considered. The surface roughness improvements would work better for urban areas with moderate to low impervious surface. These improvements could be achieved by applying appropriate surface materials or promoting green space in the cities. If surface roughness (Manning’s n) increased from 0.1 to 0.4, the number of flooded locations would decrease by 10% and 15% with 65% impervious and 45% impervious, respectively. Increasing surface roughness, however, might not be easy to achieve in practice and therefore SUDS should be considered instead.

With respect to SUDS evaluation, green roof technology was the best performer followed by urban green space, pervious pavement and rainwater harvesting when flood attenuation capacity was considered as the assessment criteria. The ranking for pollutant removal capacity was quite similar, although urban green space rated higher in trap efficiency than green roofs in this assessment category.

Despite an increasing body of research related to SUDS technologies, Marsalek and Schreier [36] noted that implementation at the municipal level has been limited. Most of the research that has been done for SUDS technologies focuses on temperate climates [31,37], although Silveira [38] and Goldenfum et al. [39] review the challenges to implementing sustainable urban drainage, particularly in developing countries having a tropical climate. There is some concern that SUDS technology will be less effective for larger storm events (or greater rainfall as experienced in tropical climates), however, the experience in Singapore [33] seems to counter this concern and similarly, an unpublished report by Drexel University for a test area in Cambria Heights, New York City, showed that SUDS performed exceedingly well in controlling runoff from Super Storm Sandy and Hurricane Irene.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES

1. JICA (Japan International Cooperation Agency). The Study on Urban Drainage System for Ho Chi Minh City in the Socialist Republic of Viet Nam. Final Report; 1999.

2. Wust S, Bolay JC, Du TTN. Metropolitanization and the ecological crisis: Precarious settlements in Ho Chi Minh City, Vietnam. Environment and Urbanization. 2002;14(2):211-224.

3. Eroksuz E, Rahman A. Rainwater tanks in multi-unit buildings: A case study for three Australian cities. Resources Conservation Recycling. 2010;54:1449–1452.

4. Kim RH, Lee S, Kim YM, Lee JH, Kim SK, Kim JG. Pollutants in rainwater runoff in Korea: Their impacts on rainwater utilization. Environment Technology. 2005;26:411–420.

5. Riversides. Rainwater harvesting, energy conservation and greenhouse gas emission reductions in the City of Toronto; 2009. Available: http://www.toronto.ca/taf/pdf/river_sides-080709.pdf

6. Berndtsson JC. Green roof performance towards management of runoff water quantity and quality: A review. Ecological Engineering. 2010;36:351–360.

7. Ghani Ab, Zakaria NA, Abdulla R, Yusof MF, Moh Sidek L, Kassim AH, Ainan A. Bio-ecological drainage systems (BIOECODS): Concept, design and construction. Proceedings of the 6th International Conference on Hydro-science and Engineering (IHCE-204). Brisbane, Australia; 2004.

8. Bengtsson L, Grahn L, Olsson J. Hydrological function of a thin extensive green roof in southern Sweden. Nordic Hydro. 2005;36(3):259–268.

9. Mentens J, Raes D, Hermy M. Greenroofs as a tool for solving the runoff management problem in the urbanized 21st century. Landscape Urban Plan. 2006;77:217–226.

10. Wong NH, Chen Y, Ong CL, Sia A. Investigation of thermal benefits of rooftop garden in the topical environment. Building Environment. 2003;38:261–270.

11. Fang CF. Evaluating the thermal reduction effect of plant layers on rooftops. Energy Build. 2008;40:1048–1052.

12. Simmons MT, Gardiner B, Windhager S, Tinsley J. Green roofs are not created equal: The hydrologic and thermal performance of six different extensive green roofs and reflective and non-reflective roofs in a sub-tropical climate. Urban Ecosyst. 2008;11:339–348.

13. Wong NH, Tan PY, Chen Y. Study of thermal performance of extensive rooftop greenery systems in the tropical climate. Building Environment. 2007;42:25–54.

14. Brenneisen S. The benefits of biodiversity from green roofs key design consequences. Conference Proceedings. Greening Rooftops for Sustainable Communities, Chicago, USA; 2003.

15. Brenneisen S. Space for urban wildlife: Designing green roofs as habitats in Switzerland. Urban Habitats. 2006;4(1):27–36.

16. Gedge D, Kadas G. Green roofs and biodiversity. Biologist. 2005;52(3):161-169.

17. Bolund P, Hunhammar S. Analysis of Ecosystems in urban areas. Ecological Economics. 1999;29:293-301.

18. Marsalek J, Schreier H. Innovation in stormwater management in Canada: The way forward. Water Quality Research Journal of Canada. 2009;44(1):5-10.

19. Philip R, Anton B, Van der Steen P. SWITCH Training Kit: Integrated Urban Water Management In the City of the Future. SWITCH project; 2011. Available: http://www.switchurbanwater.eu

20. Silveira ALL. Problems of urban drainage in developing countries. In: International Conference on Innovative Technologies in Urban Storm Drainage, Novatech 2001, Lyon; 2001.

21. Brattebo BO, Booth DB. Long-term stormwater quantity and quality performance of permeable pavement systems. Water Research. 2003;37:4396–4376.

22. James W, Verspagen B. Thermal enrichment of stormwater by urban pavement. In W. James, ed. Advances in Modeling the Management of Stormwater Impacts, CHI, Guelph. 1997;5:Ch. 8.

23. Pataki DE, Carreiro MM, Cherrier J, Grulke NE, Jennings V, Pinckel S, Pouyat RV, Whitlow TH, Zipperer WC. Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. Frontiers in Ecology and the Environment. 2011;9:27-36.

24. Drake JAP, Bradford A. Assessing the potential for rehabilitation of surface permeability using regenerative air and
vacuum sweeping. In James W, Irvine K, Joksimovic D, Li JY, McBean EA, Pitt RE, Vasconcelos JG, Wright SJ, Wu JS, eds. Pragmatic Modeling of Urban Water Systems, Monograph 21. CHI, Guelph. 2013;Ch 16.

25. VanWoert ND, Rowe DB, Andresen JA, Rugh CL, Fernandes RT, Xiao L. Green roofs stormwater retention: Effects of roof surface, slope and media depth. Journal of Environmental Quality. 2005;34:1036–1044.

26. Yang J, Yu Q, Gong P. Quantifying air pollution removal by Greenroofs in Chicago, Atmos. Environment. 2008;42: 7266–7273.

27. Ho LP. Impacts of climate changes and urbanisation on urban inundation in Ho Chi Minh City. 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK; 2008.

28. Duc HN, Truong TP. Water resources and environment in and around Ho Chi Minh City, Vietnam. Electronic Green Journal. 2003;1(19). Available: http://escholarship.org/uc/item/2tk6z0xg.

29. Le TN. Rethinking urban streams: Opportunities for the Nhieu Loc – Thi Nghe River. Unpub. Master in City Planning Thesis, MIT; 2008.

30. Camp Dresser and MacKee International (CDM). Feasibility Study and Preliminary Design Project for Nhieu Loc Thi Nghe Basin. Project Final Report; 1999.

31. Rossman LA. Modeling low impact development alternatives with SWMM. In Dynamic Modeling of Urban Water Systems, Monograph 18, In James W, Irvine KN, Li JY, McBean EA, Pitt RE, Wright SJ, eds. CHI, Ontario. 2010;11.

32. US – EPA. Storm Water Management Model User’s Manual. USEPA 600/R-05/040. Cincinnati, OH, USA; 2010.

33. Irvine KN, Chua LHC, Eikass HC. The Four National Taps of Singapore: A holistic approach to water resources management from drainage to drinking water. Journal of Water Management Modeling; 2014. DOI:10.14796/JWMM.C375.

34. Chaosakul T, Koottatet T, Irvine KN. Low impact development modelling to assess localized flood reduction in Thailand. Pragmatic Modeling of Urban Water Systems, Monograph 21, James W, Irvine KN, Joksimovic D, Li JY, Mc Bean EA, Pitt RE, Vasconcelos JG, Wright SJ, Wu JS, eds. Computational Hydraulics International, Guelph, Ontario. 2013;Ch 18.

35. Pratt CJ, Newman AP, Bond PC. Mineral oil degradation within a permeable pavement: Long term observations. Water Science and Technology. 1999;39:109–130.

36. Lempert R, Kalra N, Peyraud S, Mao Z, Tan SB, Cira D, Lutsch A. Ensuring Robust Flood Risk Management in Ho Chi Minh City. World Bank Policy Research Working Paper. 2013;6465.

37. Sidek LM, Takara K, Zakaria NA, Ghani AA, Abdullah R. An assessment of stormwater management practices using MSMA Manual in Malaysia. 1st International Conference on Managing Rivers in the 21st Century. 2004;479-495.

38. Satiennam T. Adoption of low impact development (LID) at site level for mitigating conflict in flood prone area: A study of the Latkrabang District in Bangkok, Thailand. AIT master thesis; 2006.

39. Goldenfum JA, Tassi R, Meller A, Allasia DG, Silveira AL. Challenges for the sustainable urban stormwater management in developing countries: From basic education to technical and institutional issues. In: 6th International Conference on Sustainable Techniques and Strategies in Urban Water Management, Novatech 2007, Lyon; 2007.

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