Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 19, número 2, 2023

Biovalley analysis as a LID control to delay surface runoff in the city of Recife/PE

Kássia Carneiro da Silva Santana1
Mestranda, UPE, Brazil.
kcss@poli.br

Willames de Albuquerque Soares
Professor Doutor, UPE, Brazil
was@poli.br

SUMMARY

Urban growth brought with it the formation of large impermeable areas in cities, causing a reduction in the infiltration of rainwater into the soil and an increase in the volume of surface runoff, causing setbacks on days of extreme precipitation events. In this context, the present research aimed to analyze the use of a biotaver as a Low Impact Development (LID) for delaying surface runoff in areas prone to flooding in the city of Recife/PE. As a methodology, the QGIS model was used to extract data from raster images, and the Storm Water Management Model (SWMM) for scenario simulation. Three scenarios were simulated with rainfall of 20.00mm, 39.00mm and 60.00mm. The results showed that the implementation of the bioditches provided a reduction in the total flow of the study area by 0.50% and in the maximum flow of the SB1 sub-basin for scenarios 2 and 3 by 77.96% and 41.23% respectively. In addition, there was a reduction in surface runoff of 11.15% on average and an increase in green area of 4.00%. The bioretention system showed infiltration ranging from 29.83mm to 89.35mm between the three scenarios. Thus, through the SWMM model, it was possible to analyze that the implantation of bioditches as a control for delaying surface runoff and increasing infiltration into the soil is valid, and the literature recommended that various types of sustainable devices be implemented and integrated into the existing drainage network and urban space so that more expressive results are possible.

KEYWORDS: Surface runoff. Biovalleys. SWMM.

1 INTRODUCTION

Urban sprawl has been dynamic and complex in large centers due to lack of planning. Resulting from the increase of constructions and infrastructures and promoting the expansion of impermeable areas regarding the use of soil, urban expansion has altered the built environment and the existing green spaces. This has reflected on the quality of life of city users and caused environmental, socio-cultural, and economic impacts. The higher the population growth of a city, the larger the impervious area of its soil and the lower its environmental quality (LI, *et al*., 2019; LIU, W.; ENGEL, B. A.; FENG, Q., 2021; SAHANA, 2018).

The United Nations Department of Economic and Social Affairs (DESA) has stated that by the year 2050 more than 2.5 billion of the world's population will have chosen an urban center for housing. This statement came in 2019, when the United Nations (UN), in commemoration of World Cities Day, reported that the urbanization of cities is a global and irreversible phenomenon, and recommends that city planners seek sustainable solutions and use of clean technologies to ameliorate existing urban and climate problems in urban centers (UN, 2019).

Thus, with the advance of urbanization, the factors that cause flooding from rainfall are enhanced and where there are impermeable areas in the soil, they are predominant. In turn, the growth of impervious soil areas and the deficiency of the traditional urban drainage system have collaborated to the formation of larger regions of flooded areas (ABASS, 2020)

Currently, European, Asian, and American countries have sought techniques or methods capable of mitigating flooding or slowing surface runoff from strategies that address stormwater management in the local urban drainage system, such as source control, and that are sustainable, focusing on the infiltration of these waters and their effective application. These strategies seek to resemble the elements of the environment, promoting the use of soil characteristics and the conservation of the environment (ADASA, 2018; SOUZA; GIELEN *et al*., 2018; CRUZ; TUCCI, 2012).

Note: 1. text from the first author's dissertation.

An example of this is Low Impact Development (LID), which through sustainable devices, connected or not to the existing drainage network, acts as a strategy to improve the existing urban drainage system and rescue the natural water cycle and flow (ADASA, 2018; GIELEN *et al*., 2018).

In addition, LID techniques such as infiltration wells, biovalets, green roofs, rain gardens, infiltration trenches, vegetated ditches, detention basins, and permeable sidewalks have promoted adaptations in cities capable of mitigating the impacts from climate change, which contribute to the generation of rainfall peaks and cause urban flooding. These techniques provide (BAE; LEE, 2020).

In order to mitigate the impacts caused by rainfall peaks, several researchers such as Alves (2020), Ballard *et al*., (2015) and Castro-Fresno *et al*., (2013) have been analyzing, evaluating and simulating strategies to mitigate flooding in cities.

In order to understand the behavior of flooded areas in watersheds, many scholars make use of hydraulic-hydrological models that portray the reality, in a simplified way, of an urban watershed, aiming to understand the processes that involve them and are able to simulate hypotheses, making predictions of the future and assisting in decision-making regarding urban stormwater management (ALMEIDA; SERRA, 2017; CLARKE, 1973; SANTOS, 2009).

Thus, the SWMM model is capable of simulating the hydraulic-hydrological performance, allowing it to be visualized in various formats. The spatial variability is achieved by subdividing the study area into smaller and uniform areas that are the sub-basins, with their parameters. Thus, the runoff is carried between the sub-basins and the urban drainage system, through networks of channels, pipes and devices (ROSSMAN, 2016).

2 OBJECTIVES

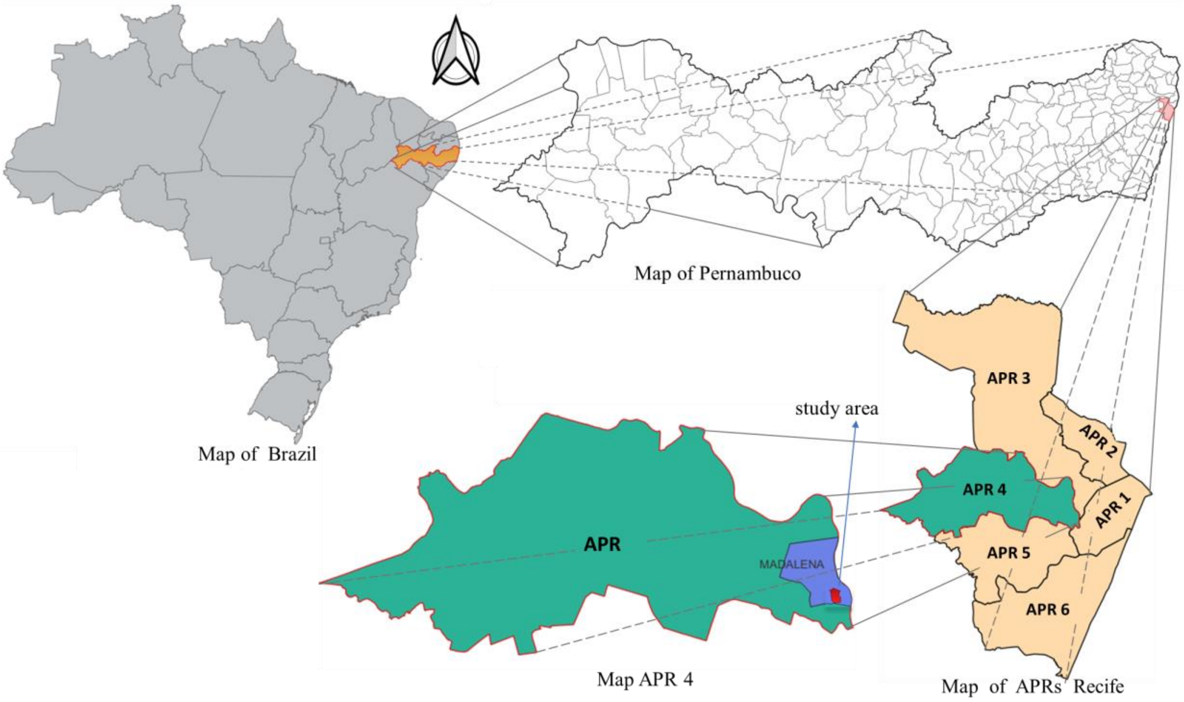
In this context, this paper sought to analyze the implementation of biovalets as a LID strategy to slow down surface runoff in flooded areas in the city of Recife/PE, making use of the SWMM hydraulic-hydrological model for scenario simulation.

3 METHODOLOGY / ANALYSIS METHOD

3.1 Location and study area

The study area is located in the city of Recife, in the Political Administrative Region (APR) 4, which has ninety-four neighborhoods in its totality, according to Figure 1, including the neighborhood of Madalena, in the western part of the city. The area was selected because it is still one of the critical points of flooding in the urban center.

Figure 1: Location of the study area



Source: AUTORA, 2022

The study area has an extension of 65,733.83m², being composed of about 14.25% green areas or natural soil and 85.75% of impermeable areas, which corroborates the many floods that occurred. The area is bathed by the Capibaribe River and has a mixed-use construction typology.

3.2 Hydraulic-hydrological model

For the simulation of the scenarios, SWMM was used, which is known as a deterministic, conceptual and hydrodynamic hydraulic-hydrological model widely used for the stormwater management, as it has a rainfall-runoff simulation that allows the analysis of the quantity and quality of surface runoff, through continuous or single events, taking into account spatial variability. The model was developed by the U.S. Environmental Protection Agency (EPA), the U.S. Environmental Protection Agency, which is responsible for the preservation of water and natural resources and takes actions to safeguard water availability and environmental protection, based on research programs conducted in the United States (ROSSMAN, 2012).

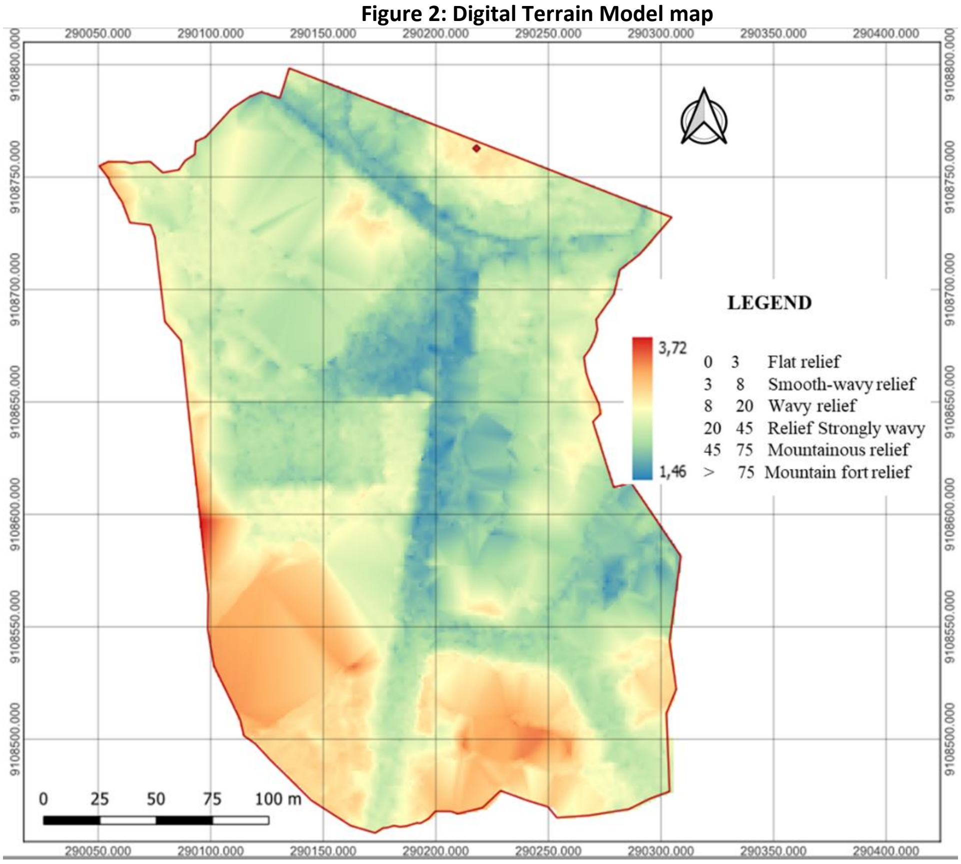
The Geographic Information System (GIS) model QGIS that belongs to the Open Source Geospatial Foundation (OSGeo), free multi-platform software, was also used for modeling and extraction of some physical parameters of the study area and for the demilitations of the sub-basins, necessary to feed the SWMM.

Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 19, número 2, 2023

3.2.1 Physical Parameters

The physical parameters data were obtained through modeling, in Qgis, from a raster image provided by the Pernambuco 3D portal. Then, the Digital Terrain Model (DTM) was made, as shown in Figure 2.

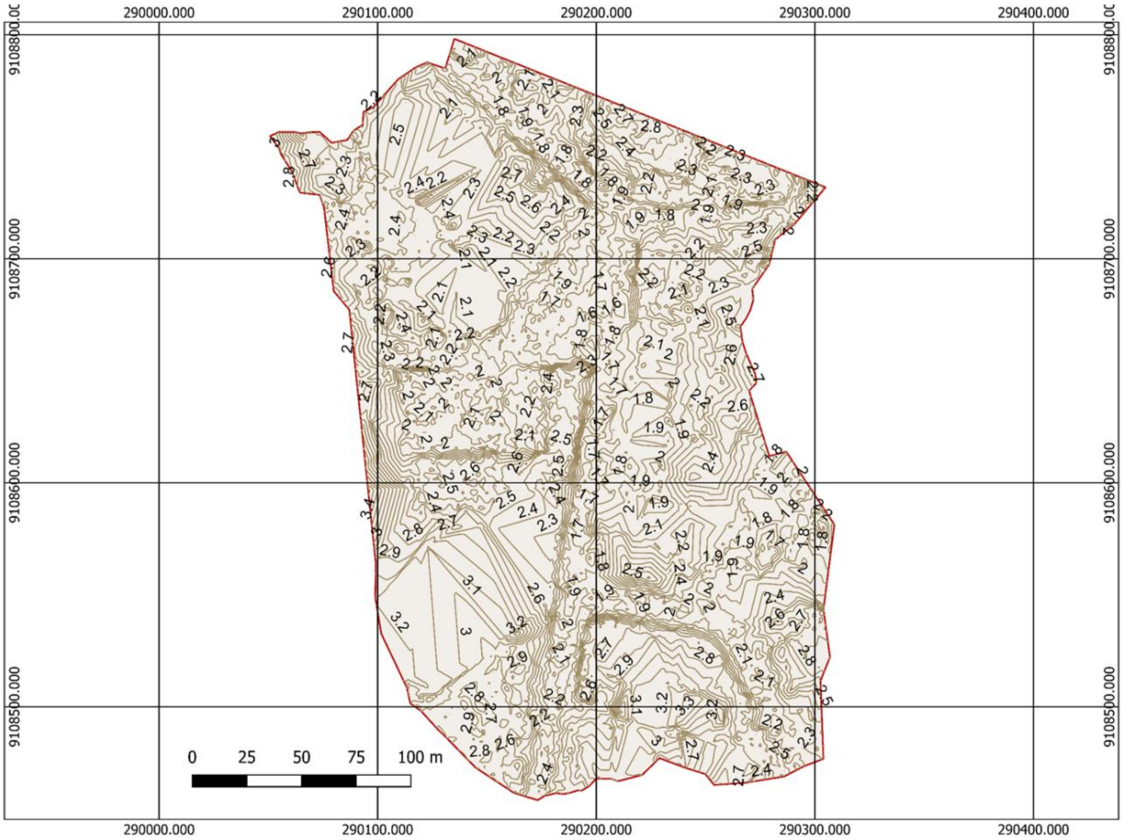
Figure 2: Digital Terrain Model map



Source: PREPARED FROM THE RASTER IMAGE

Then the contour map was prepared, considering the contours cast every 0.10m, seeking to more accurately represent the topography of the study area, as shown in Figure 3. From this map and together with the drainage network it was possible to delimit the nine sub-basins.

Figure 3: level curve maps



Source: MADE FROM DTM

The data of the existing drainage network were extracted from the ESIG system, made available by the City of Recife. The dimensions of the manholes were obtained from Silva's research (2018). The Manning roughness coefficients adopted were the same used by Silva Júnior (2015) and Silva (2018).

The average width of the sub-basins was calculated by Equations (1) and (2), which were used by Collodel (2009) and Silva (2018), where the realistic basin is considered not to have a rectangular shape and thus relates its perimeter to the area.

$$L = \frac{Kc\sqrt{A}}{1{,}12}\ x\ [1 - \sqrt{1-(1{,}128/Kc)^2}] \tag{1}$$

$$Kc = 0{,}282\ \frac{P}{\sqrt{A}} \tag{2}$$

Where:

L = average width (m)
A = sub-basin area (km²)
Kc = compactness coefficient
P = perimeter of the sub-basin (km)

Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 19, número 2, 2023

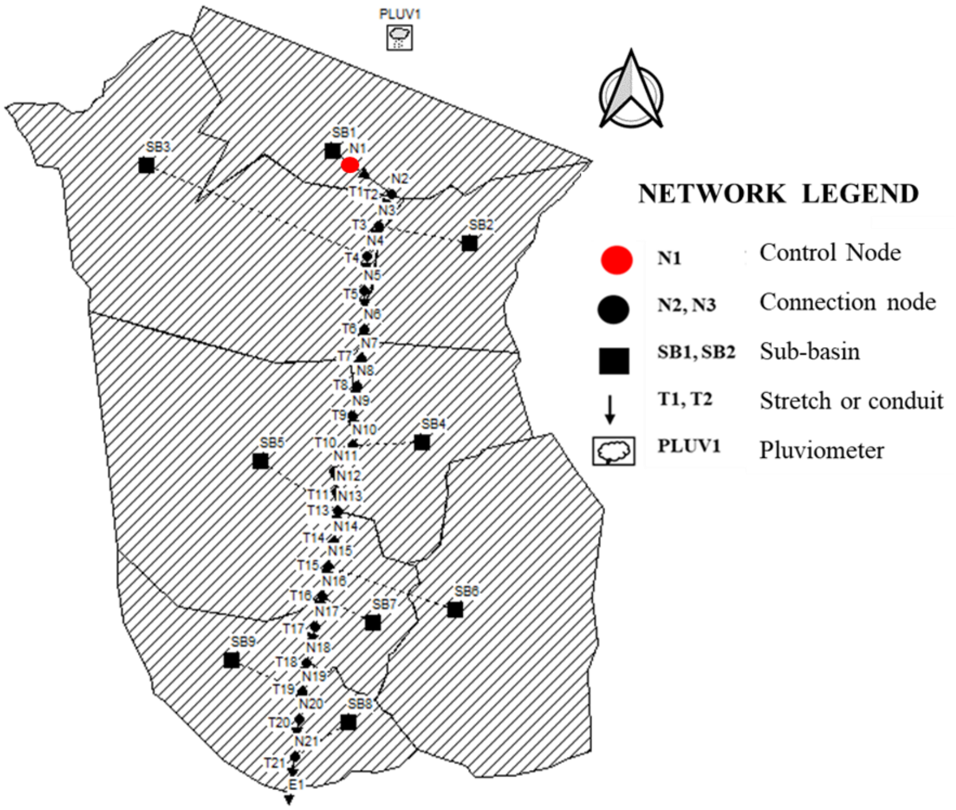
These data were obtained using QGIS. The infiltration rate used was that presented in the study by Silva (2018) which resulted in minimum infiltration rates of 211.96 mm/h and maximum of 295.08 mm/h, with a decay coefficient of 0.163, which will be cast as the infiltration parameter in the model. The precipitation and tide table data are the variables in the model.

3.2.2 Drainage system

With the ESIG data and the data obtained from Silva's (2018) research, the drainage network map and sub-basins were made in SWMM as shown in Figure 4.

In the simulations it was considered that the existing drainage network was operating at 83.33% of its total capacity, assuming possible accumulations of solid waste, in addition to sediment carriage. The highlighted N1 node was defined as the control point.

Figure 4: Drainage sistem in the model



Fonte: AUTORA, 2022

4 RESULTS

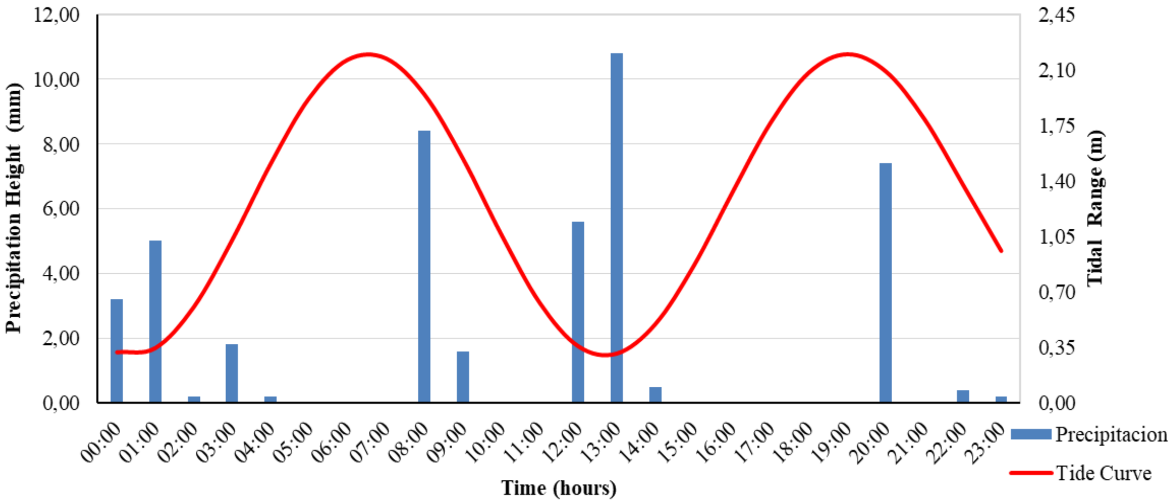
4.1 Calibration and Validation

Manual calibration was performed in the model, which consisted of the trial and error method of adjusting the parameters, also used by Silva & Cabral (2014) and Silva Junior et al., (2017). In this research it was chosen to perform the adjustment in the Manning roughness coefficient of the sections, because it proved to be more sensitive.

The calibration was performed adopting the event of March 22, 2022, which presented a tide table with amplitude of 1.90m, as can be seen in Figure 5. The tide curve was elaborated with the interpolation of the tide variations, in a time interval for one hour, taking into account the rainfall events.

During the heaviest rainfall the tide was still at low tide with about 0.30m.

Figure 5: Precipitation x tidal curve - calibration



Source: PREPARED BY THE AUTHOR FROM CEMADEN AND DHN DATA, 2022

The March 22, 2022 event had a total precipitation of 101.60mm. The blade height observed at the control node was 0.23m (Figure 6) and the calculated flood volume was 241.00m³. It was estimated for this event a flooded area of 1,050.00m² for node N1, control point.

Figure 6: Calibration Event, image

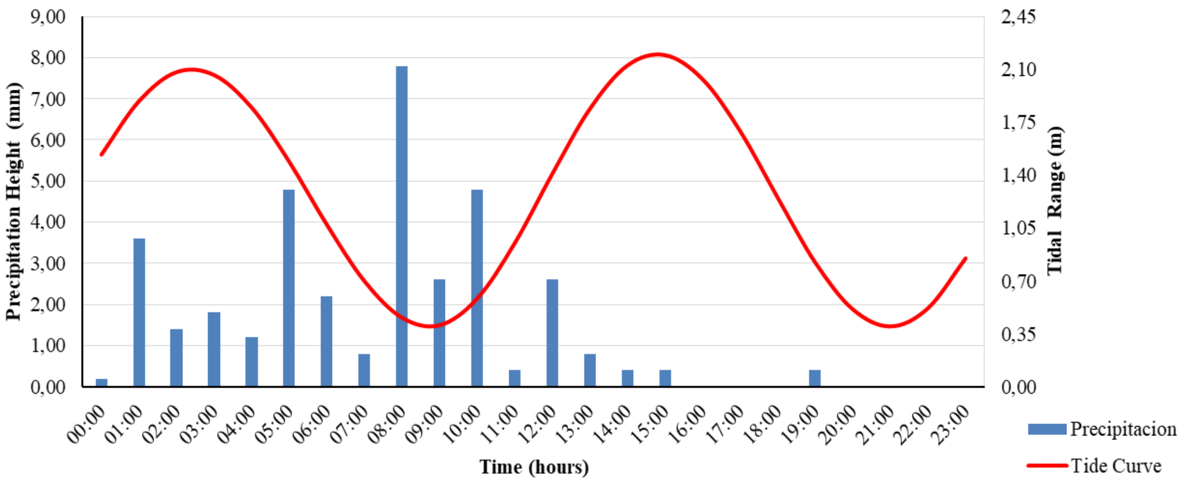
Surce: AUTORA, 2022

The validation was performed with the event that occurred on May 28, 2022, where there was a total precipitation of 192.60mm, which corresponded to 26.54% of the total precipitation processed for the month, which was 725.50mm according to the National Center for Monitoring and Alerts of Natural Disasters (CEMADEN).

The heaviest rain of this event occurred at 08:00am with 7.80mm of precipitation, causing major disruption to the city.

The tide for that day that had an amplitude of 1.80m, being still at low tide during the highest precipitation with about 0.60m Figure 7.

Figure 7: Precipitation x tidal curve - validation



Source: PREPARED BY THE AUTHOR FROM CEMADEN AND DHN DATA, 2022

A floodplain of 0.33m was estimated at the control point for this event according to Figure 8.

Figure 8: Validation Event Image

Source: AUTORA, 2022

And in order to delay surface runoff and mitigate flooding in the area, it was proposed to implement LID control in bio-valet modules, on the sidewalks of the Euclides da Cunha Square, the Intenacional Club and the Polytechnic School of the University of Pernambuco.

Rainfall intensity was classified according to Souza; Azevedo; Araújo (2008) and presented in Table 1.

Table 1: Classification of rainfall intensity

Classification of rainfall intensity	
Type of Rain	**Values**
Very Light Rain (Cmf)	2.20≤ P < 4.20 mm
Light Rain (Cf)	4.20≤ P < 8.40 mm
Moderate Rain (CM)	8.40≤ P < 18.60 mm
Heavy Rain (CF)	18.60≤ P < 55.30 mm
Very Heavy Rain (CMF)	55.30 ≤ P < 100.00 mm
Extreme Rain (CE)	100.00 ≤ P < 150.00 mm
Very Extreme Rain (CME)	≥ 150.00mm

SOURCE: SOUZA; AZEVEDO; ARAÚJO, 2008 – ADAPTED

4.2 Scenarios

Simulations were performed in three different scenarios, considering them without LID control and with LID control.

The LID control was given considering the implementation of a bio-retention system by means of modulated bio-valves with dimensions of 4.80 m long, 1.20 m wide and 1.45 m deep. Thus, the implementation of 52 units in total was considered, being the maximum possible for the area available in the sub-basin of intervention, SB1, as seen in Figure 9, in order to verify the reduction of surface runoff and the infiltration capacity of the biovalets, which possibly will follow to supply the water table.

Figure 9: Schematic view of the implementation of the biovalley

Source: AUTORA, 2022

For each of the scenarios, the rainfall and tide table variables were entered indepedently, as shown in Table 2. The rainfall data were obtained by CEMADEN, while the tide table data were obtained by the Directorate of Hydrography and Navigation (DHN).

Table 2: Rainfall Data and Rainfall Classification

Name	Rainfall	Rain Intensity Classification
Scenario 1	20.20mm	Heavy Rain (CF)
Scenario 2	39.00mm	Heavy Rain (CF)
Scenario 3	60.00mm	Very Heavy Rain (CMF)

Source: AUTORA, 2022 – ADAPTED

In the calibration event the water balance showed a total surface runoff of 85.03mm, with 83.69 % of the total rainfall in the study area.

The simulation represented the flood blade height of 100% relative to the observed value and the flow rate at node N1 at 99.79%, respectively for the control node, as shown in Table 3.

Table 3: Calibration Results

Aspects - Calibration		
Synthesis	**Observed**	**Simulated**
Flooding Blade (m)	0.230	0.230
Maximum flood volume (m³)	241.500	242.000
Continuity Errors Surface Flow		0.000
Errors Continuity Flow propagation		0.402

Source: AUTORA, 2022

In the validation event, the water balance showed a surface runoff of 163.88mm, corresponding to 85.17% of the total precipitation, with a blade height of 0.38m, 13.15% higher than the observed one, and a flood volume of 371.00m³, as shown in Table 4.

Table 4: Validation Results

Aspects - Validation		
Synthesis	**Observed**	**Simulated**
Flooding Blade (m)	0.330	0.380
Maximum flood volume (m³)	346.500	371.000
Continuity Errors Surface Flow	0.000	
Errors Continuity Flow propagation	0.079	

Fonte: SOURCE, 2022

Scenario 1

The rainfall intensity classification for this scenario, although considered as Heavy Rain, had no significant influence with respect to the tidal curve heights.

Scenario 2

The total precipitation for scenario 2 was 39.00mm that occurred on May 26, 2022, and had a peak rainfall of 7.40mm. The event also has a rainfall intensity classification as Heavy Rain.

Scenario 3

In scenario 3 the total rainfall was 60.00mm, occurred on June 07, 2022, much higher than the previous scenarios, with the highest rainfall of 3.60mm. This event had approximately 15 hours of duration, being the first hours of rain between low tide and high tide, and has a rain intensity classification as Very Heavy Rain.

Scenario Analysis

At first the simulation of the three Scenarios without LID control was considered. The monitoring took place at node N1 and sub-basin SB1, of its location. Scenario 1 did not presented a flooded blade. Scenarios 2 and 3 presented the same flooding blade heights. As for surface runoff, 9.41mm, 18.8mm, and 28.68mm of the total precipitation were drained respectively, infiltrating 10.42mm, 20.11mm, and 30.94mm in each of the Scenarios. Maximum flows in the exultory were as shown in Table 5.

Table 5: Simulation without LID control

No LID control					
Scenario Name	**Total surface runoff SB1 (mm)**	**Total infiltration (mm)**	**Maximum flow N1 node (l/s)**	**Blade Flooding (m)**	**Maximum flow at the Outlet (l/s)**
Scenario 1	9.41	10.42	0.00	0.00	72.95
Scenario 2	18.48	20.11	96.63	0.14	98.23
Scenario 3	28.68	30.94	164.03	0.14	106.24

Source: AUTORA, 2022

With the LID control, the surface runoff showed a reduction for the three Scenarios and an increase in precipitation infiltration. The maximum outflows in the node were reduced in Scenarios 2 and 3. The infiltration rate in the SB1 sub-basin was increased in the three Scenarios that now also present the infiltration referring to the LID control, according to Table 6.

Quadro 6: Simulation whit LID control

With LID control						
Scenario Name	**Total surface runoff SB1 (mm)**	**Total infiltration (mm)**	**Maximum flow N1 node (l/s)**	**Blade Flooding (m)**	**Maximum flow at the Outlet (l/s)**	**LID result - Infiltration (mm))**
Scenario 1	8.36	11.50	0.00	0.000	72.56	29.83
Scenario 2	16.42	22.22	21.29	0.14	98.20	57.91
Scenario 3	25.48	34.18	96.40	0.14	106.13	89.35

Source: AUTORA, 2022

As for the nodes or connections, the three Scenarios presented a reduction in relation to surface runoff in sub-basin SB1 of 11.15%. With the addition of green area, provided by the implementation of the biovalleys, infiltration into the soil was also increased by 10.44% on average.

The maximum flow rate at node N1 was reduced 77.96% and 41.23% respectively in Scenarios 2 and 3, as shown in Table 7.

Infiltrations in the LID control varied between 29.83mm, 57.91mm and 89.35mm in that order. The bio-valet modules resulted in a green area addition of 249.60m² for sub-basin SB1, representing about 4.00%.

Table 7: Comparison with LID control and without LID control

Comparison - With LID and Without LID						
Scenario Name	**Total surface runoff SB1 (mm)**	**Total infiltration (mm)**	**Maximum flow N1 node (l/s)**	**Blade Flooding (m)**	**Maximum flow at the Outlet (l/s)**	**LID result - Infiltration (mm))**
Scenario 1	11.15%	10.36%	0.00%	0.00%	0.53%	29.83
Scenario 2	11.14%	10.49%	77.96%	0.14	0.00%	57.91
Scenario 3	11.15%	10.47%	41.23%	0.14	0.11%	89.35

Source: AUTORA, 2022

5 CONCLUSION

The implementation of the biovalleys provided a reduction in the total flow of the study area by 0.50%. In sub-basin SB1, where the control node is located, one can see that the maximum flow was reduced by 77.96% and 41.23% for Scenarios 2 and 3, respectively, because in Scenario 1 there was no flooding blade.

In addition, there was an increase of green area of 4.00%, which changed from impermeable to permeable area, favoring the infiltration of surface runoff in sub-basin SB1. The biovalley system presented an infiltration that ranged from 29.83mm to 89.35mm among the three Scenarios in the simulations with LID controls. During the simulation process, the SWMM performs a moisture balance by controlling the amount of water moving into and entering the LID layer storage.

Although simulations do not accurately describe reality, hydraulic-hydrological models are reliable and exploited by the scientific community because they allow short-term answers.

Thus, by means of the SWMM model it was possible to analyze that the implementation of bio-valets as a method to delay runoff and infiltration is valid and the results demonstrate that a LID control method alone does not bring great achievements, but has its relevance in terms of sustainable stormwater management.

Thus it is emphasized that source control methods must be used in conjunction with other sustainable devices in order to achieve more meaningful results.

ACKNOWLEDGMENT

The first author thanks CAPES for the master's scholarship.

BIBLIOGRAPHICAL REFERENCES

ABASS, K.; BUOR, D.; AFRIYIE, K.; DUMEDAH, G.; SEGBEFI, A. Y.; GUODAAR, L.; GARSONU, E. K.; ADU-GYAMFI, S.; FORKUOR, D.; OFOSU, A.; MOHAMMED, A.; GYASI, R. M. Urban sprawl and green space depletion: Implications for flood incidence in Kumasi, Ghana. **International Journal of Disaster Risk Reduction**, v. 51, n. October, p. 101915, 2020.

ADASA. Agência Reguladora de Águas, Energia e Saneamento Básico do Distrito Federal. **Manual de Drenagem e Manejo de Águas Pluviais Urbanas do Distrito Federal**. Brasília: SDU, 2018.

ALMEIDA, L.; SERRA, J. C. V. Modelos hidrológicos, tipos e aplicações mais utilizadas. **Revista da FAE**, v. 20, n. 1, p. 129–137, 2017.

ALVES, P. B. R., RUFINO, I. A. A., FEITOSA, P. H. C., DJORDJEVI´C, S., JAVADI, A. Land-use and legislation-based methodology for the implementation of sustainable drainage systems in the semi-arid region of Brazil. **Sustainability (Switzerland)**, v. 12, n. 2, 2020.

BAE, C.; LEE, D. K. Effects of low-impact development practices for flood events at the catchment scale in a highly developed urban area. **International Journal of Disaster Risk Reduction**, v. 44, n. May 2019, p. 101412. 2020.

BALLARD, W., B, WILSON, B., UDALE-CLARKE, H., ILLMAN, S., SCOTT, T., ASHLEY, R., KELLAGHER, R., **The SuDS Manual**. Londres, Inglaterra, 2015.

CEMADEN - Centro Nacional de Monitoramento e Alerta de Desastres Naturais. Disponível em: http://www.cemaden.gov.br/mapainterativo/#. Acesso em: 15 nov. 2022.

DHN - Diretoria de Hidrografia e Navegação. Ministério da Marinha**. Previsão de Marés**. Disponível em: https://www.marinha.mil.br/chm/tabuas-de-mare. Acesso em: 15 nov. 2022.

CLARKE, R.T. Mathematical Models in Hydrology. **FAO Irrigation and Drainage Paper**, n. 19, p. 1973.

COLLODEL, M. G. **Aplicação do modelo hidrológico SWMM na avaliação de diferentes níveis de detalhamento da bacia hidrográfica submetida ao processo de transformação chuva-vazão**.2009. 225p. Dissertação (Mestrado). Universidade Federal de São Carlos. São Carlos, 2009.

LIU, W.; ENGEL, B. A.; FENG, Q. Modelling the hydrological responses of green roofs under different substrate designs and rainfall characteristics using a simple water balance model. **Journal of Hydrology**, v. 602. 2021.

SAHANA, M.; HONG, H.; SAJJAD, H. Analyzing urban spatial patterns and trend of urban growth using urban sprawl matrix: A study on Kolkata urban agglomeration, India. **Science of the Total Environment**, v. 628–629, p. 1557–1566, 2018.

GIELEN, E., RIUTORT-MAYOL, G., PALENCIA-JIMÉNEZ, J. S., CANTARINO, I.; An urban sprawl index based on multivariate and Bayesian factor analysis with application at the municipality level in Valencia. **Environment and Planning B: Urban Analytics and City Science**, v. 45, n. 5, p. 888–914, 2018.

LI, X.; FONG, P. S. W; DAI, S.; LI, Y. Towards sustainable smart cities: An empirical comparative assessment and development pattern optimization in China. **Journal of Cleaner Production**, v. 215, p. 730-743, 2019.

ONU – Organização das Nações Unidas. **O Dia Mundial das Cidades.** Disponível em: https://news.un.org/pt/interview/2019/10/1692941. Acesso em: 20 abril 2022.

PREFEITURA DA CIDADE DO RECIFE. Prefeitura Municipal. **Informações Geográficas do Recife** - **(ESIG)**. Disponível em: http://www.recife.pe.gov.br/ESIG/. Acesso em: 18 jul. 2022.

ROSSMAN, L. **SWMM 5.0 – Manual do usuário.** Laboratório de Eficiência Energética e Hidráulica em Saneamento da Universidade Federal da Paraíba, UFPB. 2012.

ROSSMAN, L. A.; HUBER, W. C. Storm Water Management Model Reference Manual Volume I – Hydrology (Revised). **Cincinnati: National Risk Management Laboratory Office Of Research And Development U.s. Environmental Protection Agency,** p. 233, 2016.

SANTOS, L. L. Modelos Hidrológicos: Conceitos e Aplicações. **Revista Brasileira de Geografia Física**, v. 1, n. 1, p. 1, 2009.

SILVA, A. C**. Modelagem hidrológica- hidráulica para atenuação de alagamentos no entorno da Escola Politécnica de Pernambuco.** 2018. 103 p. Dissertação (Mestrado em Construção Civil). Escola Politécnica da Universidade de Pernambuco. Programa de Pós-Graduação em Engenharia Civil. Recife, 2018.

SILVA JÚNIOR, M. A. B. **Alternativas compensatórias para controle de alagamentos em localidade do Recife-PE. Recife: UPE**, 2015. 153 p. Dissertação (Mestrado). Escola Politécnica da Universidade de Pernambuco. Programa de Pós-graduação em Engenharia Civil. Recife, 2015.

SILVA JUNIOR, M.A.B.; OLIVEIRA, R.L.M.; CABRAL, J.J.S.P.; SILVA, P.O.; SILVA, S.R. Reservatório de detenção em logradouros como alter- nativa para os alagamentos urbanos: uma análise para a cidade do Recife-PE. In: XXII Simpósio Brasileiro de Recursos Hídricos, 2017b, Florianópolis. **Anais**... Florianópolis: ABRH, 2017, p. 1-8.

SILVA, P.O. & CABRAL, J.J.S.P. Atenuação de picos de vazão em área problema: estudo comparativo de reservatórios de detenção em lote, em logradouros e em grande área da bacia. **Revista Brasileira de Recursos Hídricos**, v. 19, n. 2, p. 7-18, 2014.

SOUZA, W. M.; AZEVEDO, P. V; ARAÚJO, L. E. Revista Brasileira de Geografia Física Classificação da Precipitação Diária e Impactos Decorrentes dos Desastres Associados às Chuvas na Cidade do Recife-PE**. Revista Brasileira de Geografia Física**, v. 02, p. 250–268, 2008.