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Special edition

Hydraulic-hydrological calibration of a peri-urban watershed in the SWMM mode

Calibração hidráulico-hidrológica no modelo SWMM de uma bacia hidrográfica periurbana

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ABSTRACT

In urban watersheds mathematical modeling, a very important process is the impact of changes land use on the hydrological cycle of urban centers. Some modeling parameters are difficult to investigate in situ and it is necessary estimate through calibration methods. Considering the calibration importance and complexity, the objective of this study is to represent the physical characteristics of the Arroio Cancela Watershed in SWMM model and calibrate it from precipitation and flow data monitored. It was possible to observe that the calibration and validation were within the range recommended by the literature. Thus, it is considered that the model has the ability to satisfactorily reproduce the events that occur in this watershed.

Keywords: Watershed Modeling; SWMM; Calibration

RESUMO

Na modelagem matemática de bacias hidrográficas urbanas, um processo muito importante é avaliar o impacto de mudanças do uso do solo no ciclo hidrológico dos centros urbanos. Alguns parâmetros de modelagem são difíceis de determinar no campo e precisam ser estimados por métodos de calibração. Tendo em vista a importância e a complexidade de realizar uma boa calibração, o objetivo deste estudo foi representar as características físicas da bacia hidrográfica do Arroio Cancela no modelo SWMM e calibrá-lo a partir de dados de precipitação e vazão monitorados na área de estudo. Foi possível observar que a calibração e validação se mantiveram dentro da faixa recomendada pela literatura. Portanto, considera-se que o modelo é capaz de reproduzir satisfatoriamente os eventos hidrológicos ocorridos na bacia hidrográfica.

Palavras-chave: Modelagem de Bacias; SWMM; Calibração

1 INTRODUCTION

Understanding the dynamics of runoff in a watershed of peri-urbanized regions is essential to support the appropriate design of hydraulic structures, drainage networks, and even the proposal for the implementation of Low Impact Development structures. The comprehension of these dynamics is usually supported by the use of hydraulic-hydrological simulation tools (Eckart; Mcphee; Bolisetti, 2017; Fletcher *et al*., 2014).

Simulations that model hydraulic-hydrological processes have been used effectively to assess the impact of land use changes on the dynamics of rainfall runoff and the heterogeneity of surfaces and drainage systems (Zhou; Leng; Su; Ren, 2019; Mikovits *et al*., 2017; Karamouz; Hosseinpour; Nazif, 2011). Accurate understanding of these processes can help planning urban land use, minimizing the costs of stormwater runoff systems, and future damages caused by floods, as it is essential to establish strategies to create more resilient cities in terms of sustainable stormwater management (Menezes Filho; Tucci, 2012; Jha; Bloch; Lamond, 2012; Leibowicz, 2017; Blanco *et al*., 2011).

Understanding the interactions between urban areas and hydraulic and hydrological processes is especially challenging due to the high heterogeneity of urban surfaces, and the strong non-linearity of the hydrological processes (Beven, 2001). Several studies attempt to elucidate these processes (De Lavenne *et al*., 2016; Ghosh; Hellweger, 2012; Goldstein; Foti; Montalto, 2016); however, further investigations are still necessary.

According as models that simulate hydraulic-hydrological processes become more complete and specific, begin to require a greater number of input parameters to characterize the system. Some of the parameters are not measurable or are difficult to determine and need to be estimated through calibration methods, to promote adjustment to the expected responses of the model (Leibowicz, 2017).

Therefore, the present study aimed to calibrate and validate a model under the conditions of a peri-urban watershed characterized by the heterogeneity of its the surface and its hydraulic system. The model SWMM (Storm Water Management Model) was chosen primarily for its functionality, which enables the modeling of a variety of hydraulic and hydrological processes, such as the generation and propagation of surface runoff in open channels or forced conduits, backwater conditions, among others. The Arroio Cancela Watershed, situated in the southern Brazilian city of Santa Maria, was analyzed in the present study. This basin features a heterogeneous drainage system (natural and artificial channels) and different occupation elements such as green areas, parks, and permanent preservation areas, as well as consolidated and expanding urban areas. The region historically records several flood and waterlogging problems (Garcia, 2005).

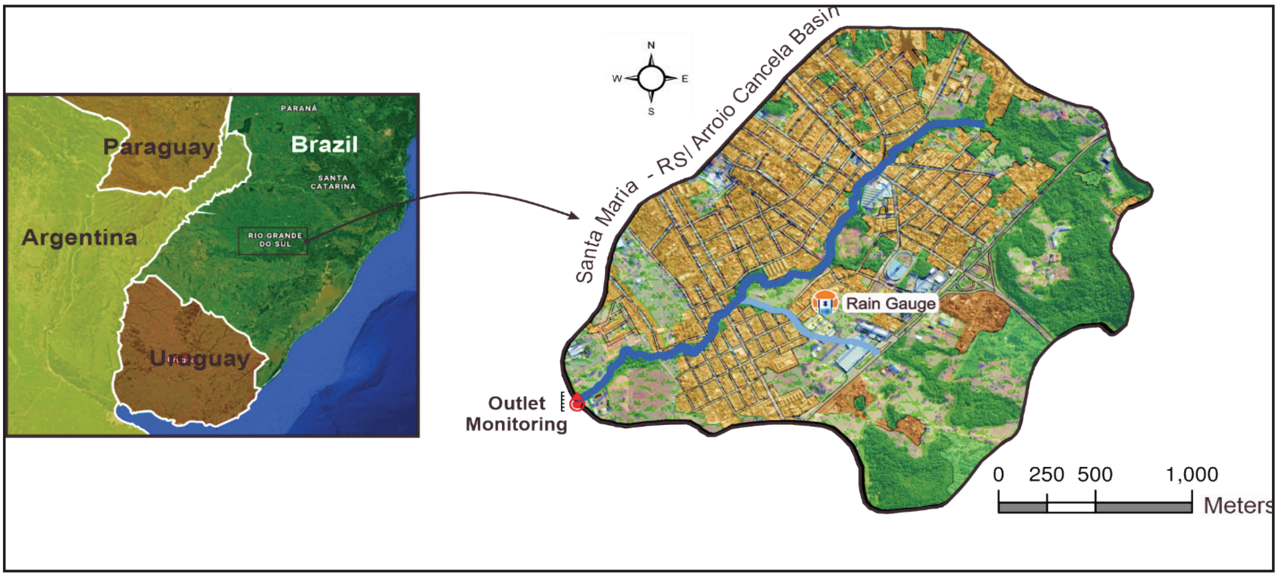
2 METHODOLOGY

2.1 Study area

The study was conducted on the Arroio Cancela Watershed (Figure 1), which spans a total area of 5.13 km² and it is situated in a peri-urban area of the city of Santa Maria, located in the state of Rio Grande do Sul, Brazil. According to the Köppen-Geiger Classification (Cfa), the study area has a predominance of a humid subtropical climate. The annual precipitation levels range from 1500 mm to 1700 mm, evenly distributed throughout the year, without a defined rainy season (Rossato, 2011; Wmo, 2018).

The Arroio Cancela is the main watercourse in the study area, with a length of approximately 3 km, and a tributary with a length of approximately 0.9 km. The relief of the basin ranges from 75 m to 239 m, with an average slope of approximately 8%. According to the classification of the Resources Conservation Service (NRCS) (NRSC, 2009), the area is mainly composed of soils from the GHC group (77.9%), GHB (16.7%), and GHD (5.4%) (Alves; Sausen; Lacruz, 2011). In terms of land use and cover, forests cover the largest areas (2.33 km²), accounting for 45.3% of the total area of the basin, followed by built-up areas (1.1 km²), representing 21.3%. Additionally, there are areas of low vegetation (0.98 km² - 19.1%), paved roads (0.45 km² - 8.6%), bare soil (0.29 km² - 5.5%), and flooded areas (0.01 km² - 0.2%).

Figure 1 – Study Area – Arroio Cancela Watershed



Source: Authors (2023)

2.2 Model setup

In the model setup, the study area was divided into 17 sub-basins, based on the topographic characteristics of the region. Due to the absence of registered information on the microdrainage network, the delineation process of the sub-basins considered the paths that surface runoff would supposedly take until reaching the macrodrainage network, mainly due to the roads. Furthermore, during the discretization process, an attempt was made to create homogeneous sub-basins while respecting the known inputs in the macrodrainage network. The contour of each sub-basin was manually adjusted, considering criteria such as the road network in urbanized regions and the stretches of the macrodrainage network (Froemming, 2019; Garcia, 2005).

The physical characteristics of each sub-basin were determined through a combination of survey data, satellite images, and GIS tools. The input data required by the SWMM model are the following parameters: total area of each sub-basin (A), percentage of impervious area (%Imp), average slope (So), width of the sub-basin (W), storage parameters for impervious (S-Imp) and pervious areas (S-Perv), Manning roughness coefficient for impervious (n-Imp) and pervious surfaces (n-Perv), percentage of impervious areas without storage (Pct-Zero), and percentage of impervious areas with directed flow towards pervious areas (Pct-Routed).

The percentage of impervious area (%Imp) was estimated based on a detailed land use survey, while the slope parameter (So), which represents the average slope of the sub-basin, was estimated from a Digital Elevation Model (DEM). The width (W) of the sub-basin was estimated using a methodology that defines an equivalent rectangle related to the compactness of the basin (Froemming, 2019; Garcia, 2005; Garcia; Paiva, 2006). The initial estimates for the hydraulic parameters were obtained from previous studies, and adjustments were made during the calibration/validation process. These hydraulic parameters include Manning roughness for pervious (n-Perv) and impervious surfaces (n-Imp), natural channel roughness (n-CNat) and artificial conduit roughness (n-Cond), storage parameters for pervious (Dp) and impervious areas (Di), Pct-Zero, and Pct-Routed.

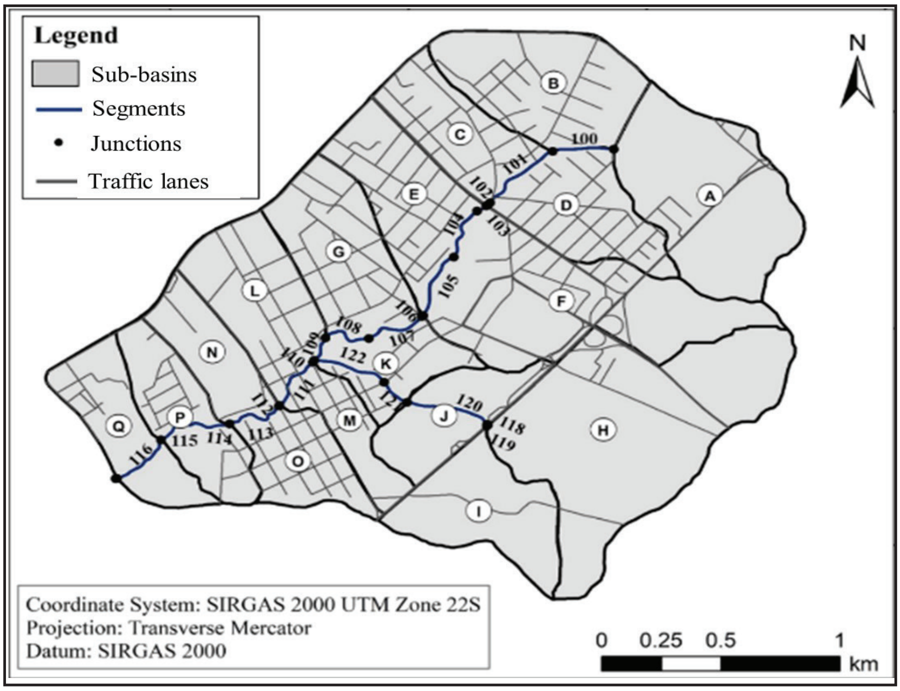
The effective rainfall method adopted was the Curve Number (NRCS, 2009), where the CN parameter inherent to each sub-basin was established based on the soil hydrological group composition and land use characteristics.

The summary of the main physical characteristics of the sub-basin, as well as the sub-basins discretization, are shown in Table 1 and Figure 2.

The channel exhibits typical characteristics of peri-urban environments, with natural sections being the primary components interspersed with artificial conduits (open channels with lining, closed channels with different geometries, and pipelines).

The macro-drainage was represented by 23 segments, of which 5 are in the tributary. Each segment corresponds to the space between two entry points (nodes) where runoff from sub-basins occurs. The segments were characterized by their cross-section, including whether it was natural or artificial, as well as upstream and downstream bottom elevations, length, cross-sectional attributes such as geometry, and Manning’s roughness coefficient. Additional information regarding the cross-sections can be found in Figure 3.

Figure 2 – Watershed discretization in SWMM model



Source: Authors (2023)

Table 1 – Physical parameters of each sub-basin

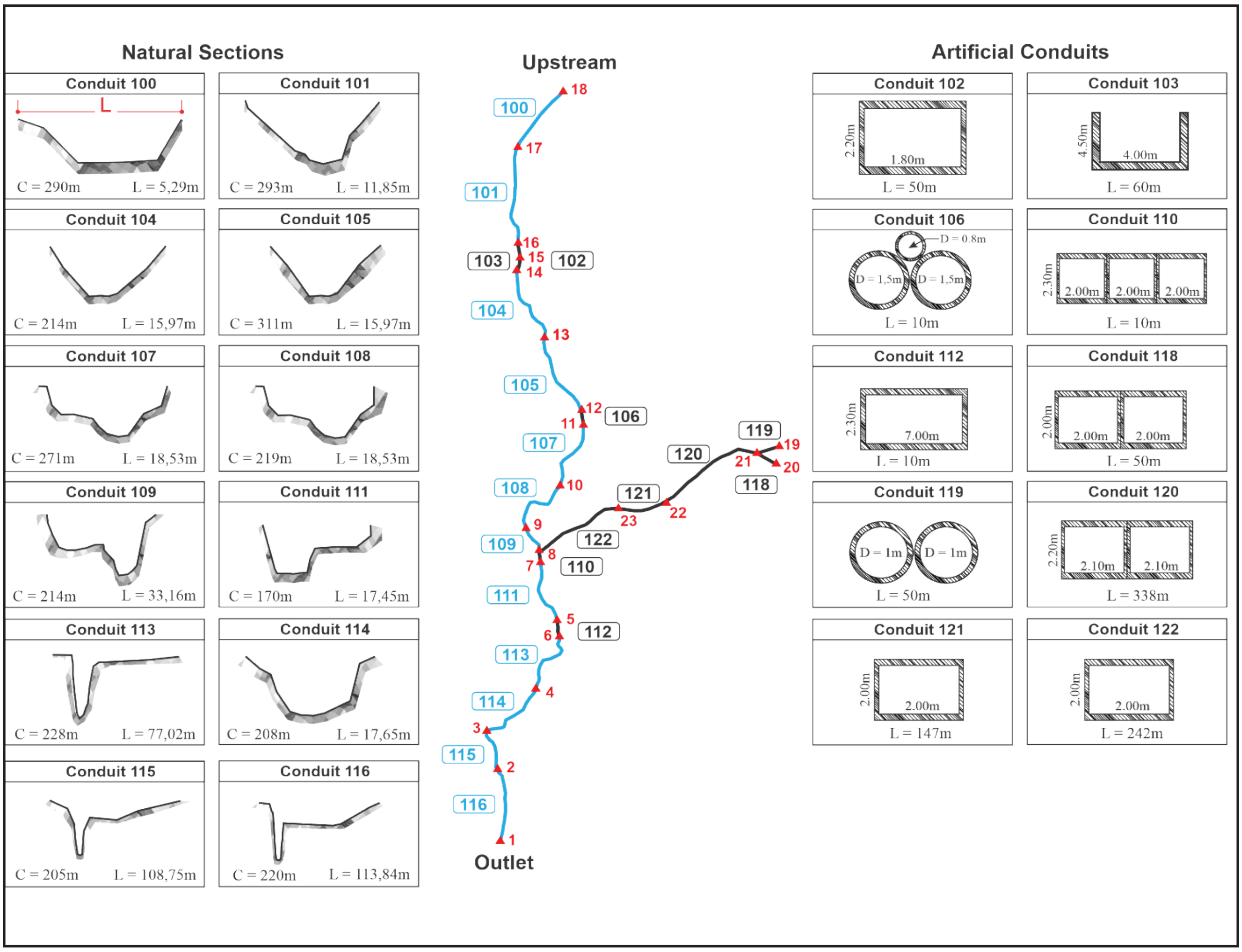
Sub-basin	Area (ha)	Width W (m)	Impervious area (%)	Slope (%)	CN (Curve Number)
A	48.90	565.16	11.95	15.6	75.17
B	36.12	545.52	33.30	12.7	76.18
C	22.44	280.31	37.63	13.2	74.28
D	26.28	325.36	40.80	08.9	80.65
E	27.70	277.93	44.55	14.8	72.39
F	57.02	350.64	31.77	13.0	79.08
G	31.14	385.25	33.74	10.8	69.67
H	79.10	458.45	11.93	12.7	74.89
I	27.49	282.46	20.11	16.9	72.08
J	19.94	256.64	41.47	05.3	81.97
K	16.54	213.01	34.65	09.3	81.15
L	28.60	368.73	32.99	10.5	75.15
M	12.67	151.87	41.22	04.9	81.02
N	17.01	229.53	21.99	07.4	77.55
O	17.88	235.91	50.37	04.3	82.40
P	22.79	259.14	36.39	09.5	79.95
Q	21.64	225.54	34.55	05.2	79.74

Source: Authors (2023)

2.3 Data availability

The data used for the calibration and validation process (Table 2) were obtained from a hydrological monitoring carried out in the basin. These monitoring events occurred between 2003 and 2005 and consisted of 15 rainfall events with their respective discharge series.

Figure 3 – Longitudinal and transversal characteristics of the macro drainage (not to scale) – C = Extension of the section; L = Width



Source: Authors (2023)

Table 2 – Rainfall and runoff data set

Event	Data	Rainfall			Discharge			
		Volume (mm)	Duration (h)	Return Period (years)	Volume (m³)	Duration (horas)	Mean Flow (m³/s)	Peak Flow (m³/s)
E01	24/11/2003	19.36	07.25	0.0002	23541.30	10.42	0.63	02.96
E02	22/04/2004	21.5	02.67	0.0028	17104.85	06.92	0.69	02.39
E03	07/05/2004	49.23	15.83	0.0185	73725.66	24.92	0.82	07.22
E04	10/06/2004	51.17	09.50	0.9915	108147.27	23.50	1.28	17.83
E05	23/06/2004	21.09	06.08	0.0005	19071.90	09.58	0.55	02.02
E06	29/07/2004	38.63	23.33	0.0022	45357.89	31.25	0.40	01.09
E07	06/08/2004	32.14	15.25	0.0014	55064.89	23.33	0.66	02.82
E08	16/10/2004	51.57	12.92	0.0349	106788.63	22.42	1.32	08.05
E09	03/11/2004	41.49	06.17	0.4979	63679.61	17.33	1.02	09.27
E10	09/11/2004	73.21	19.50	0.1470	163665.07	28.66	1.59	08.16
E11	06/12/2004	35.27	05.67	0.2791	33801.13	08.17	1.15	09.28
E12	19/12/2004	28.78	03.33	0.0266	25408.23	07.58	0.93	05.11
E13	03/01/2005	62.78	03.17	1.8448	79635.39	08.17	2.71	14.34
E14	15/01/2005	38.34	08.67	0.2024	41799.52	12.33	0.94	09.13
E15	12/03/2005	32.71	09.83	0.0034	21879.62	11.41	0.53	02.09

Source: Authors (2023)

2.4 Calibration and Validation

The calibration process was performed manually, starting from initial estimations for each hydraulic and hydrological parameter corresponding to both macrodrainage segments and sub-basins. During calibration, all parameters were kept constant except for one, which was varied seeking to find the best fit between the observed and calibrated flow while staying within the ranges recommended by the literature and aligning with the basin's physical reality. Table 3 presents the parameters required for calibration, differentiating between those relating to the hydrographic basin and the drainage channel.

The quality of each calibration attempt was assessed in terms of the Nash-Sutcliffe Efficiency (NSE) and Percent Bias (PBIAS) coefficients. The NSE coefficient evaluated the fit between the observed and simulated hydrographs point-by-point, while the PBIAS coefficient compared the total volume of the hydrographs. Calibration of each of the 15 events was considered successful when the NSE coefficient was above 0.5 and the PBIAS coefficient was between -15% and +15% (Moriasi; Gitau; Pai; Daggupati, 2015).

Table 3 – Calibrated parameters of sub-basins and macrodrainage

Parameters related to sub-basins	Parameters related to macro-drainage
Curve Number (CN)	Conduits roughness (*n*-CNat)
Percentage of impervious area (%Imp)	Roughness of left and right banks
Roughness of permeable surfaces (*n*-Perv)	Roughness of conduits (*n*-Cond)
Roughness of impervious surfaces (*n*-Imp)	
Storage of permeable areas (S-Perv)	
Storage of impervious areas (S-Imp)	
Percentage of impervious areas without depression storage (Pct-Zero)	
Percentage of impervious areas with flow directed towards permeable areas (Pct-Routed)	

Source: Authors (2023)

Once the model was calibrated for all events, six events were selected for validation using the median values obtained for each parameter. The events used for validation were: E03, E05, E06, E10, E11, and E14 (Table 2). Validation was considered complete when the NSE coefficient was above 0.5 and the PBIAS coefficients were between -15% and +15% (Moriasi; Gitau; Pai; Daggupati, 2015), as median values were used for the parameters at this stage.

2.5 SWMM Settings

SWMM's basin model was specifically designed to replicate the propagation and rainfall-runoff processes that occur within the macrodrainage network during events.

To ensure numerical stability, a time step of 0.5 seconds was employed during simulations. The Dynamic Wave methodology was used for flow propagation within the macrodrainage network as it accurately solves the full Saint-Venant equations, resulting in more precise results. The complete values of the inertial terms were maintained, and the slope and Froude number were chosen as the normal flow criterion. The Hazen-Williams equation was utilized to calculate friction losses during pressurized flow, and the internally calculated variable time step was deactivated to maintain the selected interval throughout the calculations. The SLOT algorithm was chosen as the pressurization resolution method due to its stability and precision, according to Pachaly, Vasconcelos and Allasia (2021).

3 RESULTS AND DISCUSSIONS

3.1 Model Calibration

The calibration results and their respective Nash-Sutcliffe Efficiency (NSE) and Percent Bias (PBIAS) coefficients for each of the 15 events can be observed in Table 4.

Overall, it is possible to observe that all calibration efficiency coefficients were found to be satisfactory. The lowest NSE was obtained for event E01, with a value of 0.90, while the highest NSE values were found for events E02 and E09, both with an NSE of 0.98. Regarding the coefficient that presents the volume error (PBIAS) between the observed flow hydrograph and the simulated hydrograph in SWMM through calibration, the best coefficients were 0.19% and -0.43% for events E11 and E13, respectively. The PBIAS adjustment had lower quality for event E06, with a value of 8.53% volume error. According to Moriasi *et al*. (2015), NSE values greater than 0.50 and PBIAS values less than or equal to ±15% indicate satisfactory calibration.

Table 4 – Calibrated parameters and efficiency coefficients

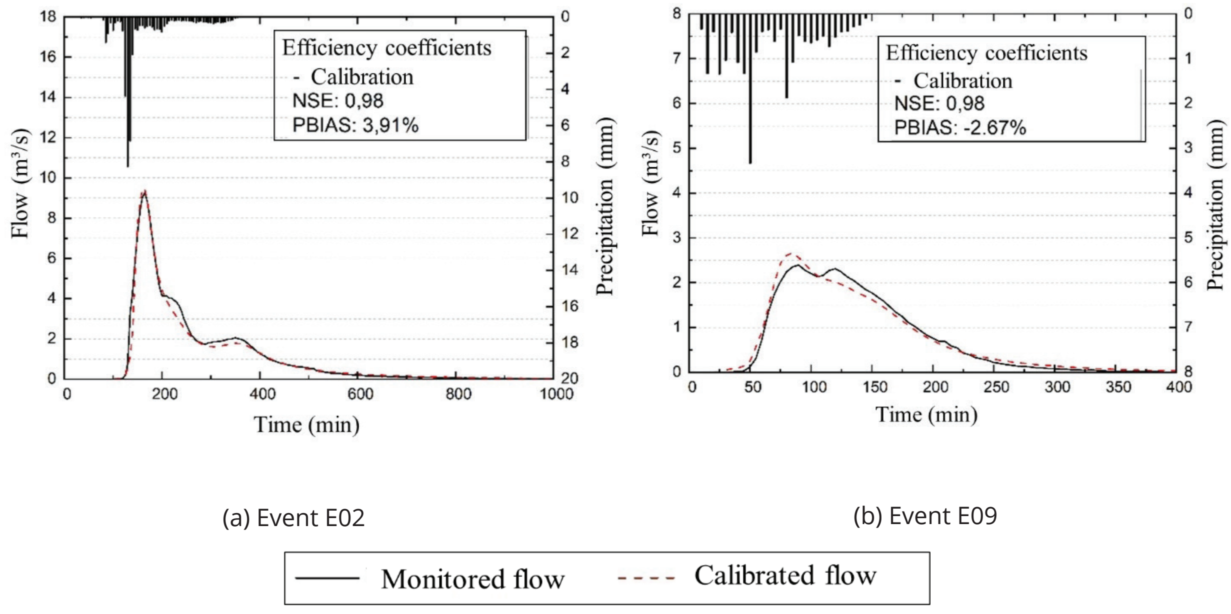
Event	Sub-Basins Characteristics					Conduits Characteristics			Efficiency Coefficients	
	n-Imp	*n*-Per	S-Imp	S-Perv	Pct-Zero	*n*-CNat	*n*-Cond	*n*-Banks	NSE	PBIAS (%)
E01	0.02	0.30	00.50	10.00	10.00	0.05	0.012	0.10	0.90	3.23
E02	0.02	0.40	01.20	30.00	10.00	0.03	0.012	0.10	0.98	-2.67
E03	0.05	0.20	01.25	18.00	10.00	0.03	0.012	0.10	0.94	4.11
E04	0.05	0.20	01.25	08.00	10.00	0.05	0.012	0.10	0.96	-4.11
E05	0.02	0.35	04.00	10.00	10.00	0.02	0.012	0.10	0.92	4.85
E06	0.03	0.08	03.00	18.00	10.00	0.04	0.012	0.10	0.92	8.53
E07	0.05	0.10	04.00	05.00	10.00	0.05	0.012	0.10	0.94	-2.03
E08	0.05	0.10	02.30	12.00	10.00	0.04	0.012	0.10	0.93	4.82
E09	0.08	0.20	03.00	12.00	10.00	0.05	0.012	0.10	0.98	3.91
E10	0.02	0.15	05.00	15.00	10.00	0.04	0.012	0.10	0.91	-4.62
E11	0.05	0.30	11.00	30.00	10.00	0.04	0.012	0.10	0.94	0.19
E12	0.08	0.55	02.54	30.00	10.00	0.02	0.012	0.10	0.97	0.97
E13	0.03	0.20	12.00	25.00	10.00	0.02	0.012	0.10	0.92	-0.43
E14	0.05	0.35	02.54	20.00	10.00	0.04	0.012	0.10	0.97	5.79
E15	0.05	0.50	05.00	20.00	10.00	0.04	0.012	0.10	0.97	-7.32

N-Imper = Manning roughness coefficient for impervious surfaces; N-Per = Manning roughness coefficient for pervious surfaces; Dstore-Imper = initial volume stored in impervious areas (mm); DStore-Per = initial volume stored in pervious areas (mm); %Z-Imper = impervious area without storage depression (%); N-Cond = Manning roughness coefficient for concrete conduits; N-Nat = Manning roughness coefficient for natural conduits; N-Banks = Manning roughness coefficient for the channel banks.

Source: Authors (2023)

Figure 4 illustrates the events E02 and E09 with their observed and calibrated precipitation and streamflow. The calibrated hydrograph for event E02 shows good agreement with the monitored hydrograph for both the rising and recession limbs, but the first peak was overestimated, and the second peak was underestimated, resulting in a PBIAS of -2.67%. Event E09 demonstrates a good fit in the rising and peak of the hydrograph, but differences are observed in the recession of the monitored and calibrated hydrographs, with a volume error of 3.91%. An NSE of 0.98 was obtained for both events.

Figure 4 – Sample of calibrated events (a) E02 e (b) E09



(a) Event E02 (b) Event E09

Source: Authors (2023)

3.2 Analysis of the calibrated parameters

3.2.1 Manning roughness coefficient for the sub-basins

In terms of calibrated parameters, the Manning roughness coefficient is highly variable, mainly in urban areas where land cover heterogeneity makes it difficult to assign a specific value (Garcia, 2005). However, the roughness parameter plays a critical role in model calibration, as it has a significant influence on peak flow estimates (Silveira; Cavalcanti; Menezes Filho; Severino, 2022).

Figure 5 (a) presents the values of the Manning roughness coefficient found during the calibration of the SWMM model, which varied from 0.02 to 0.08 for impermeable surfaces (n-Imper) and from 0.08 to 0.55 for permeable surfaces (n-Perv), falling within the ranges of values reported in the literature (Formiga; Carvalho; Silva; Soares, 2016; Froemming, 2019; Garcia, 2005; Shinma; Reis, 2011).

The median Manning roughness values for the sub-basins used in the model validation were 0.05 for impervious surfaces and 0.20 for pervious surfaces, indicating that pervious areas had four times more roughness than impermeable areas. It is worth noting that for the Manning roughness of the impervious areas, the median coincided with the third quartile, and the mean was very close to the median. For the Manning roughness of the pervious areas, the median was lower than the mean, indicating that some events increased the mean and justifying the use of the median for validation.

3.2.2 Initial storage

The initial storage in depressions reflects the retention of water on the surface and it is used to adjust the runoff volume (Garcia, 2005).

During the calibration, the values of initially stored volumes for impervious surfaces (S-Imp) ranged from 0.5 mm to 12 mm, while for pervious surfaces (S-Perv), the range was 5 mm to 30 mm, as shown in Figure 5 (b). In the validation phase, the median values of 3 mm and 18 mm were found for impervious and pervious areas, respectively, with the storage in pervious areas being six times greater than in impervious areas.

For initial storage in pervious areas, the mean and median values were very close, but for initial storage in impervious areas, two calibrated events were considered outliers, causing an inflation in the mean value. Therefore, the median value was used for model validation.

The percentage of impervious areas without storage depressions (Pct-Zero) remained fixed at 10% for all events during calibration, as no changes were made in the total impermeable areas and CN between events. As a consequence, the same value was used for model validation. This parameter was adjusted during calibration as it strongly affects maximum flows and the displacement of the hydrograph (Santos; Neves, 2020).

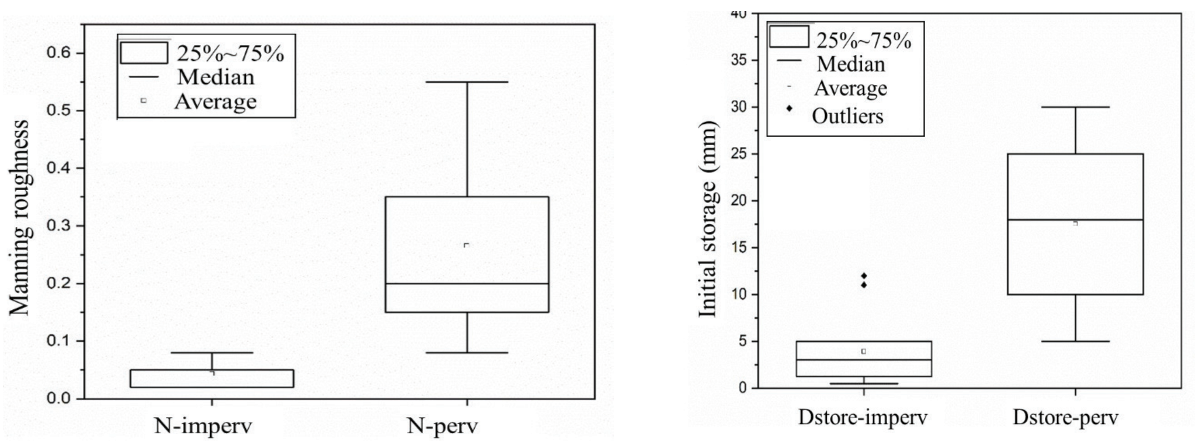
3.2.3 Manning's roughness coefficient for macrodrainage

The calibration of Manning's roughness coefficient for the main channel was performed differently for concrete channels (n-Cond), natural channels (n-CNat), and natural channel banks (N-Banks). For concrete sections, a fixed value of 0.012 for the Manning's coefficient was considered, as recommended by ASCE (1982). The banks of natural channels were kept with a fixes value of 0.10, as indicated by Rossman (2015), since they did not show variations in calibration results. For natural channel sections, the Manning's roughness coefficient varied from 0.02 to 0.05, falling within the range of values indicated by Rossman (2015) of 0.02 to 0.1, as shown in Figure 5 (c).

During model validation, the Manning's roughness coefficient for concrete channels was set to 0.012, 0.035 for natural channels, and 0.10 for the banks of natural channels. It was observed that the mean and median values of Manning's roughness for natural channels were very close. Thus, it was decided to use the median for model validation, as was done for the other parameters described earlier.

Figure 5 – Range of the parameters found in the calibration

(to be continued)

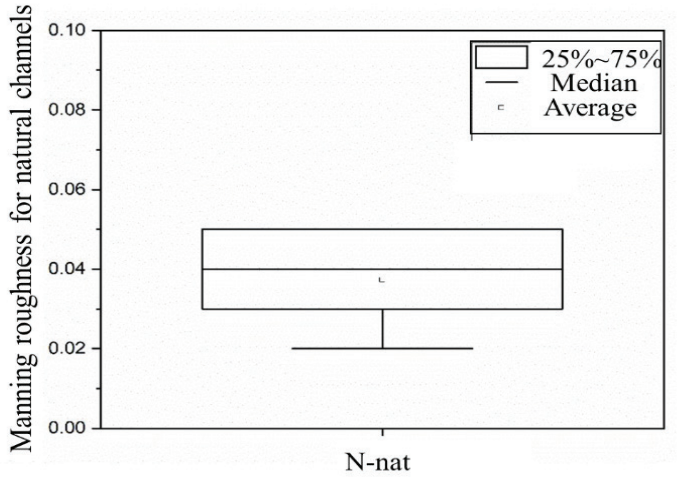


a) Manning roughness for the sub-basins

b) Initial volume stored

Figure 5 – Range of the parameters found in the calibration

(conclusion)



c) Manning roughness for natural channels

Source: Authors (2023)

3.3 Model validation

After the calibration of the 15 events, a median value was estimated for each parameter (Table 5), which was used in the validation stage. Six events (Table 2) with distinct characteristics were selected to make the validation representative of the monitored events: E03, E05, E06, E10, E11, and E14. Among these, events E03, E10, E11, and E14, with a return period of up to 0.2 years, presented peak flows ranging from 7.22 m³/s to 9.28 m³/s. Events E05 and E06 had milder characteristics, with peak flows of 2.02 m³/s and 1.09 m³/s, respectively.

Table 5 – Median parameters used for the model validation

1.	Sub-basin characteristics					Conduits characteristics		
	***n* -Imp**	***n* -Perv**	**S-Imp**	**S-Perv**	**Pct-Zero**	***n* -CNat**	***n* -Cond**	***n* -Banks**
Median values used for model validation	0.050	0.200	3.000	18.0	10.0	0.035	0.012	0.10

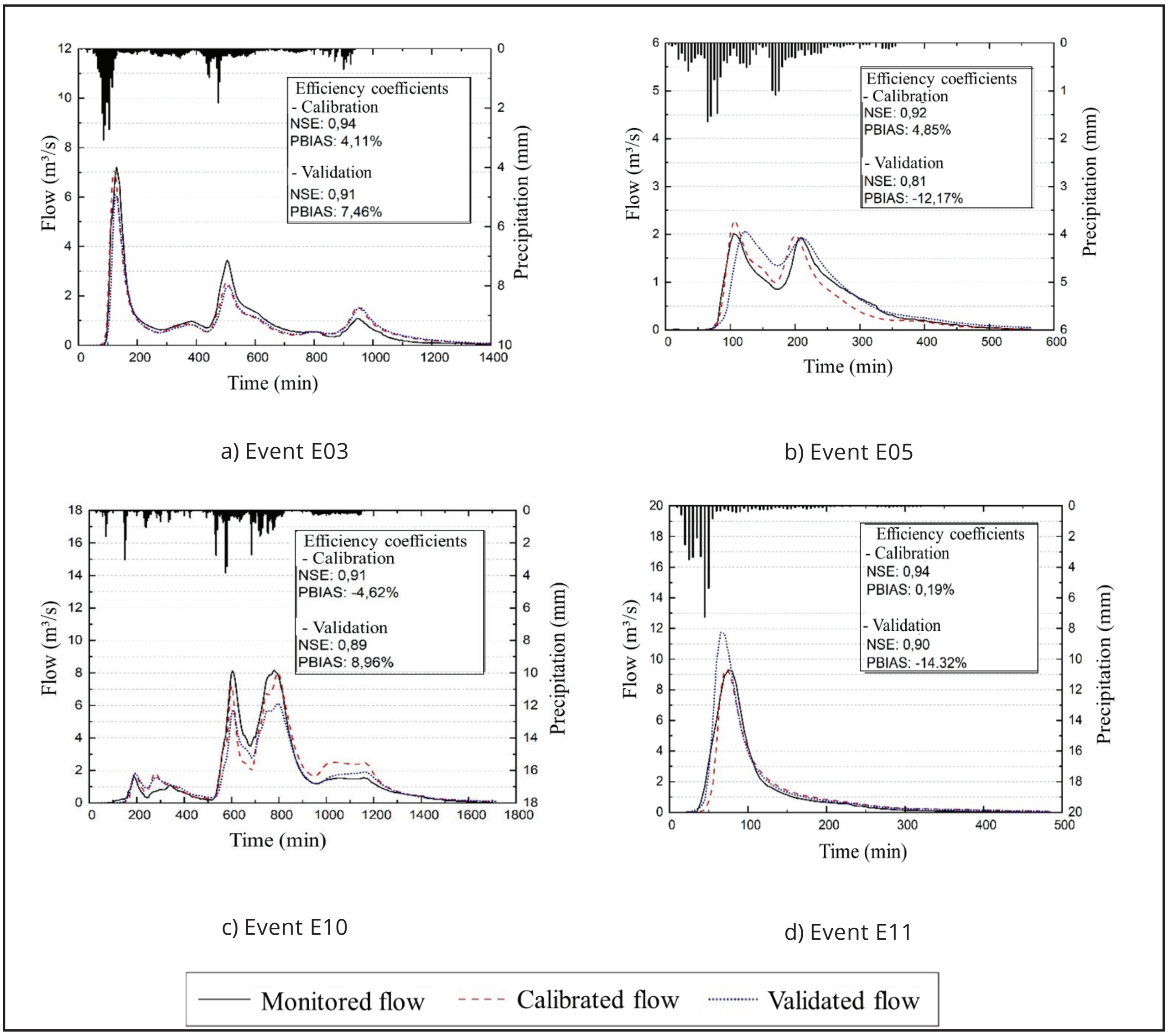
Source: Authors (2023)

Figure 6 displays the validation results for some of the selected events. It can be observed that events E03 and E10 underestimated the volume of the validated hydrograph, with PBIAS values of 7.46% and 8.96%, respectively. Regarding NSE, both events showed adequate values of 0.91 and 0.89, respectively, demonstrating good fit between the validated and observed hydrographs. For events E05 and E11, it was observed that the volumes of the validated hydrographs were overestimated, with PBIAS values of -12.17% and -14.32%, respectively. Event E05 showed a lower NSE value (0.81), with a deviation in the rise of the validated hydrograph and a volume discrepancy between the two peaks.

As in the calibration phase, the validation was considered satisfactory when the coefficients had a performance of NSE > 0.50 and PBIAS ≤ ±15% (Moriasi; Gitau; Pai; Daggupati, 2015).

The validation efficiency coefficients for each of the 6 validated events are presented in Table 6. All validated events remained within the range of values proposed by Moriasi, Gitau, Pai and Daggupati (2015), with event E14 showing the best fit for both NSE coefficient (0.97) and PBIAS (-2.77%). The worst fit in terms of NSE was for event E06, with a value of 0.72, and the worst fit for PBIAS was -14.32% for event E11.

Figure 6 – Sample of the validated events (a) E03; (b) E05; (c) E10 e (d) E11



a) Event E03

b) Event E05

c) Event E10

d) Event E11

Source: Authors (2023)

Table 6 – Validation efficiency coefficients

Event	Efficiency coefficient - Validation	
	NSE	PBIAS (%)
E03	0.91	07.48
E05	0.81	-12.17
E06	0.72	03.47
E10	0.89	08.96
E11	0.90	-14.32
E14	0.97	-02.77

Source: Authors (2023)

In general, it is evident that the validation efficiency coefficients indicated lower results when compared to the calibration coefficients. This was an anticipated outcome, given that in the calibration phase, the parameters were optimized for each event, whereas in the validation phase, median parameters were used for all events.

4 CONCLUSIONS

This article aimed to calibrate the SWMM model for a peri-urbanized basin, characterized by the heterogeneity of land use and land cover and the macrodrainage system. The results of both calibration and validation demonstrated that SWMM was suitable for simulating the watershed, with satisfactory outcomes. During calibration, the Nash-Sutcliffe Efficiency (NSE) coefficient ranged from 0.90 to 0.98, and Percent Bias (PBIAS) varied from +8.53 to +0.19. During validation, NSE ranged from 0.97 to 0.72, and PBIAS varied from -2.77 to -14.32. All calibrated parameters remained consistent with the literature and the reality of the watershed. Thus, it is considered that the model has the ability to satisfactorily reproduce the events that occur in the watershed.

With the results, was possible to observe that the study basin was adequately characterized, about the cross-sectional attributes, average slope, sub-basins definition, area, land use and cover, among others. Thoutgh the simplifications of the model, as runoff from sub-basins occurs at a single point and non-simulation of microdrainage networks, simulations showed that the model represented the real watershed

In general, itis concluded that calibration and validation are not trivial processes, and their efficiencies are subject to input data and assumed conditions and hypotheses. Is up to the researcher to modeling assumptions understand considered, and consequences consider on the model’s results.

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