Comparison of monitored water levels and those calculated using design methods in two On-site Stormwater Detention (OSD)

Comparaison des niveaux d'eau mesurés et calculés à l'aide de méthodes de dimensionnement de deux ouvrages de stockage à la source des eaux pluviales

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RÉSUMÉ

Les réservoirs de contrôle d'eaux pluviales à la source sont construits dans de nombreuses villes du monde, pour réduire l'impact de l'urbanisation sur le système de drainage. Cependant, il y a seulement quelques études sur son efficacité à l'échelle réelle et comparaison de son comportement par rapport à celui attendu lors de sa conception. Cet article a pour but de comparer les données de suivi des deux réservoirs construits à Belo Horizonte/Brésil et les résultats obtenus par des méthodes théoriques, couramment utilisés dans la conception de ces ouvrages. Des limnimètres ont été installés à l'intérieur des réservoirs pour suivre le niveau d'eau lors des évènements de pluie. Les données ont été enregistrées d'avril 2015 à mars 2018, toutes les 30 secondes. Au total, 167 évènements de pluie ont été analysés. Concernant la hauteur maximale du niveau d'eau, il a été constaté que les valeurs observées étaient plus élevées que les valeurs théoriques. Les résultats de la méthode rationnelle sont plus proches des données que les résultats de la méthode du SCS.

ABSTRACT

On-site Stormwater Detention – OSD has been constructed in many cities around the world, to reduce the impact of urbanization on the drainage system. However, there are only a few studies about its efficiency in a real scale and its behaviour compared to the expected in its design. This paper aims to compare the monitoring data of two OSD built in Belo Horizonte/Brazil and the results determined by theoretical methods, commonly used in the design of urban drainage structures. A limnimetric sensors was installed inside of the OSDs to monitor the water level during rain events. The data was recorded on a data logger every 30 seconds from the period of April 2015 to March 2018. In total, there were analysed 167 rain events. Regarding the maximum heights of water level, it was found that the monitored values were higher than theoretical values. The results using Rational Method were closer to monitoring data than the results with SCS-UH Method.

KEYWORDS

On-site Stormwater Detention (OSD); Source control; Best Management Practices (BMP); Urban drainage.

1 INTRODUCTION

Considering the recurrent problems of flooding, many cities around the world have created regulations requiring the construction of OSDs in new developments (Tsuchiya, 1978, Urbonas & Glidden, 1983, Kelly & Brinck, 1987, O'Loughlin et al., 1995, Faulkner, 1999, Silveri & Rigby, 2006, Drumond et al., 2011, Petrucci et al., 2013).

As described by O'Loughlin et al. (1998), many papers on the topic were published at that time. However, source control techniques related to stormwater quality have come to the forefront and OSD has been relegated to the background. This fact can be confirmed in the review of modeling/monitoring studies on the hydrologic effects of stormwater control measures made by Li et al. (2017).

Nevertheless, OSD continues to be widely implemented and its real efficiency continues to be unknown due to the lack research, especially in the case of data monitoring.

Despite being the first city in Brazil, regarding to require the OSD construction, Belo Horizonte's regulation demands one of the lowest volumes of stormwater detention in the country, as demonstrated by Drumond et al. (2011).

Currently, Belo Horizonte's Municipality has required to designers of OSD to use the Rational method to calculate the peak flow and the Puls method for determination of peak flow attenuation. Other cities in Brazil and around the world adopted predetermined values for Permissible Site Discharge (PSD) and Site Storage Requirements (SSR) to design the OSD (Drumond et al., 2011, O'Loughlin et al.,1995, Silveri & Rigby, 2006, Van der Sterren et al., 2009, Petrucci et al., 2013).

Considering that OSDs have been built for decades in Brazilian cities and there are only a few studies that have evaluated their real performance, this paper seeks to compare the results obtained with the design methods and the monitoring data.

The Rational and Puls method, recommended by Sudecap – Belo Horizonte's authority responsible for urban drainage management (Belo Horizonte, 2009), and the SCS-HU (Natural Resource Conservation Service Unit Hydrograph Method - NRCS, 1986) method, usually used in urban drainage projects, were evaluated.

2 METHODS

In the requirements of OSD design, Belo Horizonte's Municipality recommends the use of Rational method for rainfall-runoff transformation, followed by the Puls method and the discharge equation of orifices, considering that the discharge structure works as an orifice.

In order to verify the performance of an OSD built in Belo Horizonte, designed according to the methodology recommended by Belo Horizonte's Municipality, it was decided to monitor the water level inside two structures through the use of a limnimetric sensor, from April 2015 to March 2018.

2.1 Details of the OSDs monitored

There were chosen two OSDs to monitor, one was built in a hospital (OSD-H), located in the South-Central region of Belo Horizonte and the other was constructed in carmaker company (OSD-C), located in the Nothern region of the city.

The structures were constructed underground in a rectangular shape, made by concrete. The OSDs contribution areas and the storage volumes are:

- **OSD-H**: 4,149 m² of contribution area (3,517 m² of impervious area and 632 m² of green roof) and 45.5 m³ of storage volume;
- **OSD-C**: 20,592 m² of contribution area (14,163 m² of impervious area and 6,429 m² of permeable area) and 206.4 m³ of storage volume.

2.2 OSDs Monitoring

After companies' authorizations, the water levels sensors were installed (model SNS-400 of the brand Global Waters, with measurement range of 0 to 4 meters of water level and accuracy ± 0.1% FS). The monitored data was recorded every 30 seconds and stored in the Global Waters model GL 500 data logger. The equipment was powered by a 12 volt and 7 amperes battery. The data were downloaded to a laptop every 14 days.

2.3 Theoretical calculations

The water levels monitored inside the OSD were compared with the theoretical results calculated using the Modified Rational and SCS-UH methods. In the theoretical calculations, it was used the same rainfall event recorded on site (10 minutes of rainfall discretization). The concentration time adopted was 5 minutes. The weighted averages of the runoff coefficient were 0.91 (OSD-H) and 0.87 (OSD-C) and of the Curve Number were 95.87 (OSD-H) and 88.95 (OSD-C).

The theoretical calculations of the OSD performance were made using the Puls method, calculating the water levels inside the structures. The value of discharge coefficient used was 0.61.

To determine the quota-flow curve, the occurrence of free flow was considered up to the height of the discharge tube diameter. From that point until the height of the spillway, the flow was considered under pressure and above the spillway height, it was defined the occurrence of overflow in the OSD.

After determining the quota-volume and quota-flow curves, there was determined the volume in the OSD at each interval time and consequently the height of the water level.

3 RESULTS AND DISCUSSION

The results of the maximum water levels obtained in monitoring of the OSD and in the simulations carried out with the Rational/Puls and SCS-UH/Puls methods are presented in Figure 1 and 2.

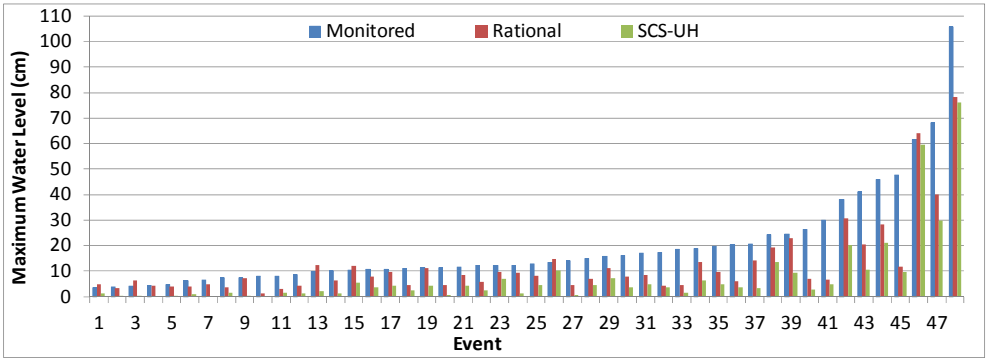
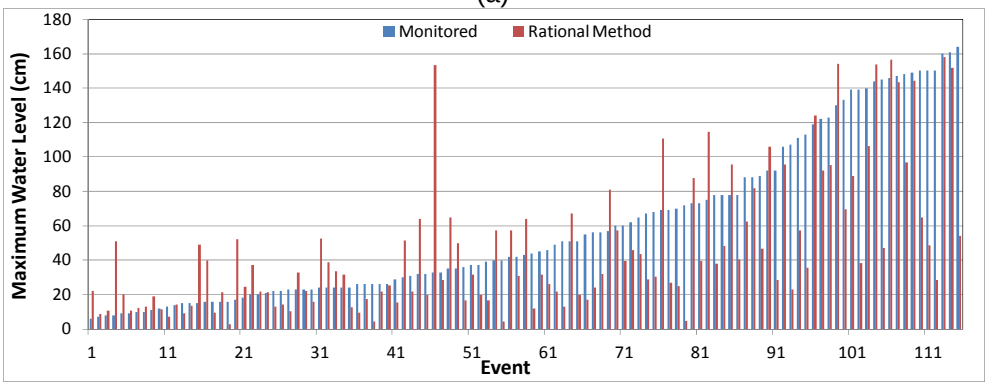


Figure 1: Comparison between maximum water levels monitored and calculated with theoretical methods (OSD-H)

(a)



(b)

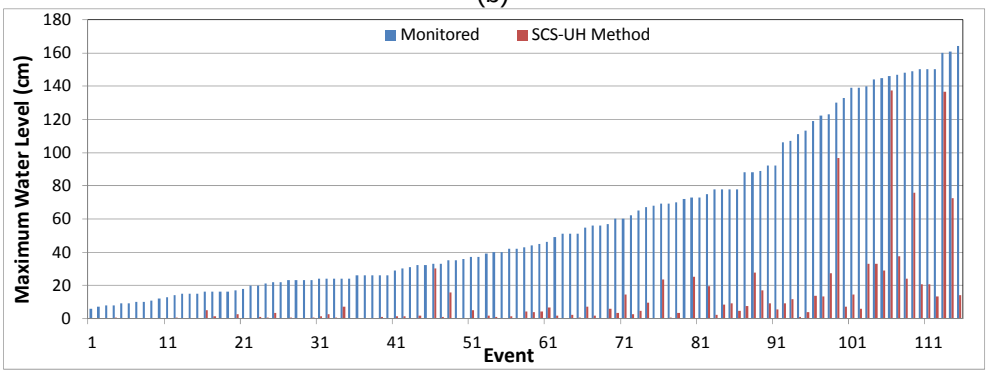


Figure 2: Comparison between maximum water levels monitored and calculated with (a) Rational Method (b) SCS-UH Method (OSD-C)

In general, the results showed that the maximum water levels recorded in the OSDs were higher than those simulated. In the comparison between the theoretical results, it was observed that the maximum water heights calculated with the Rational method were closer to the data monitored than the water levels determined with the SCS-UH method. The results indicated that the SCS-UH method did not have a good representation of the events, especially in events with low precipitation.

The differences observed between the monitored data and the theoretical results, which underestimated the water levels, may have occurred mainly due to: i) the discretization time defined in the Rational method, that uses the average of rainfall intensity. There were intervals during the events which intensities exceed the average; ii) the values of absorbed rainfall and initial abstraction used in the SCS-UH method. These values were significant, especially in the low rainfall events; (iii) divergence between the precipitation used and that occurred on site; (iv) differences between the real values of the runoff coefficients and Curve Number and those used in theoretical simulations.

4 CONCLUSION

The comparison of the maximum water levels inside the OSDs showed that the theoretical simulations presented lower values than those monitored. The results with Rational Method were closer to the data monitored than the results obtained with the SCS-UH method.

Therefore, it is recommended, the use of the Rational method in the design of OSD. However, new researches must be carried out to improve the imperfections of the method, especially regarding the temporal discretization of rainfall.

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