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Proposing compensatory drainage measures as a participatory governance tool: the case of the Tiburtino Watershed, São Paulo/ SP[1]

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SUMMARY

This paper addresses the problem of flooding in the Tiburtino Stream Watershed, focusing on a desirable adaptation towards urban resilience oriented towards environmentally fragile areas of the basin. It is assumed that the construction of small parallel reservoirs located upstream of the critical points of event occurrences would considerably mitigate their severity and intensity, thus indicating a feasible possibility of adaptation that must be taken into consideration by the competent authorities when planning. of future urban drainage actions in the region. The method used was the convolution of the SCS Unitary Hydrogram from upstream to downstream of the watershed, and Lapa Market was defined as the measurement point – a critical location in terms of occurrences – for a quantitative verification of the damping of the peak flow in two scenarios: a single reservoir, of larger proportion; distributed smaller reservoirs. The results validated the initial hypothesis, demonstrating that small reservoirs located below the road system are as efficient or more efficient than a single reservoir of more robust proportions with a high potential for environmental impact.

KEYWORDS: Drainage. Resilience. SDG 11.

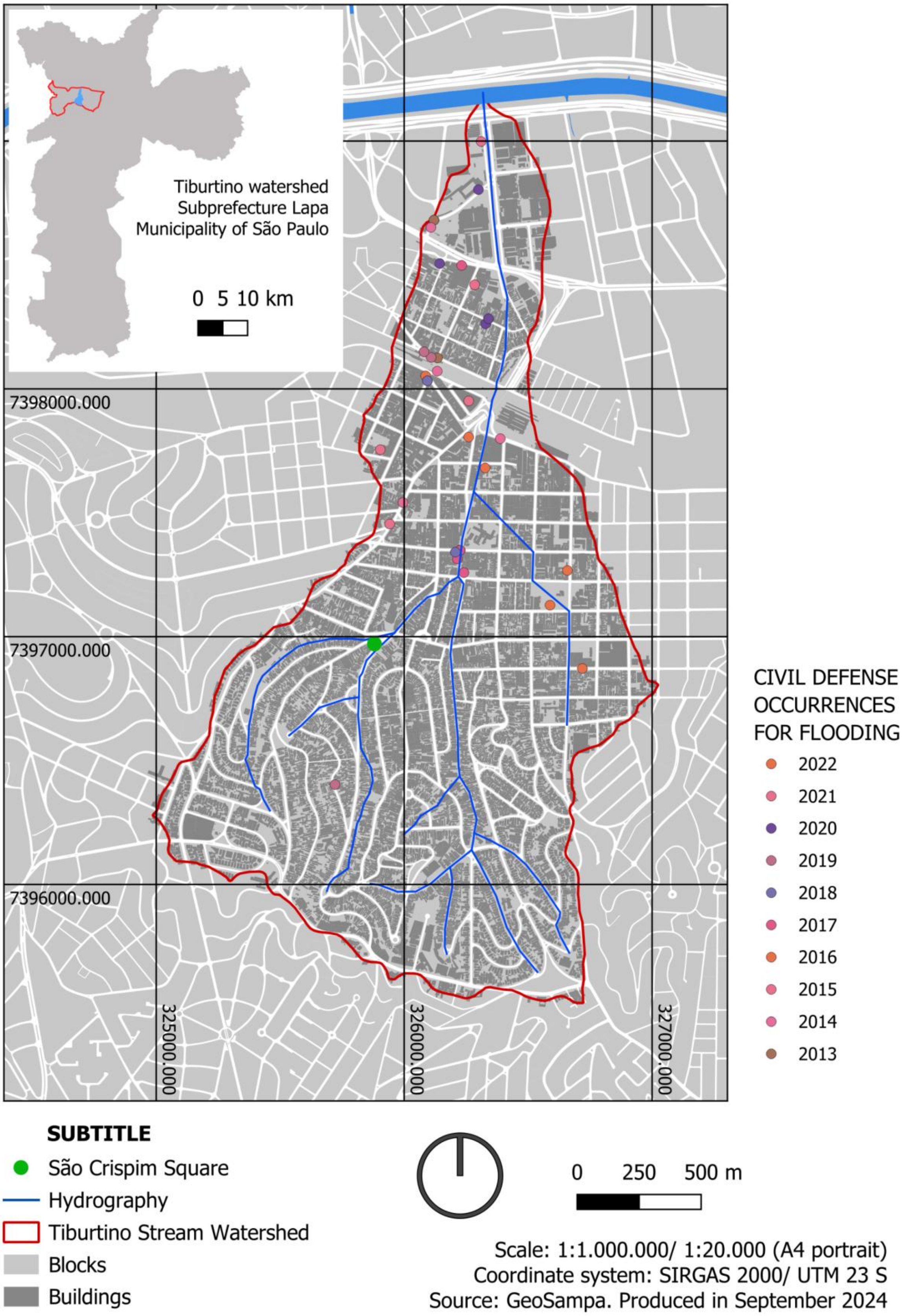
1. INTRODUCTION

This paper presents a hydrological model that was developed as an alternative proposal for compensatory drainage to mitigate the occurrence of flooding and inundation in the Lapa region, municipality of São Paulo (Figure 1). According to the mapping of recorded occurrences of flooding, landslides and inundations by the Civil Defense of the State of São Paulo, between 2013 and 2022, a greater concentration is noted around the Lapa Market (Figures 2 and 3), which can be considered a critical point in this watershed.

The problem in question was recently addressed by the Infrastructure and Public Works Secretariat of the City of São Paulo (SIURB) together with the Hydraulics Technological Center Foundation (FCTH), with the proposal to build a rainwater containment reservoir at the site of São Crispim Square (Figures 4 and 5), in the heart of the Tiburtino Stream watershed. Because it is a public green area that provides important ecosystem services, such as maintaining biodiversity and thermal comfort, the proposal encountered strong resistance from the local population, which culminated in the creation of a working group, located at the Regional Council for the Environment, Sustainable Development and Culture of Peace of the Lapa Subprefecture. This process of forming a community governance network was described in detail in a previous stage of this research (LIMA and SILVA, 2023).

Therefore, the hydrological model that will be presented here is part of this context of participatory governance, demonstrating how an appropriation of technical knowledge can become a political tool in the decision-making process when constructing public works.

Figure 1 – Flooding and inundation occurrences in the Tiburtino watershed



Source: prepared by the authors, 2023.

Figure 2 – Flooding around the Lapa Market on October 20, 2016

Source: Jornal da Gente, photo by Gerson Azevedo.

Figure 3 – Flooding around Lapa Market on March 20, 2018

Source: Play FM, photo by Vinicius.

Figure 4 – Aerial view of São Crispim Square, 2023

Source: Google Earth.

Figure 5 – View of São Crispim Square

Source: extracted from Lima e Silva, 2023.

2. OBJECTIVES

In general terms, the main objective of this research is to provide the civil population with technical knowledge about hydrology and urban drainage, so that they can participate in the planning of interventions by the government in the region where they live. In more detail, the research has three specific objectives:

1) Verify the performance of the reservoir proposed by FCTH and SIURB;
2) Propose the implementation of smaller reservoirs in other parts of the watershed;
3) Verify the performance of the smaller reservoirs and compare the two scenarios.

3. THEORETICAL FRAMEWORK

From the perspective of urban studies, river basins are a complex and multifaceted topic, due to the multiple scales at which they can be observed in the territory (AMÉRICO-PINHEIRO and BENINI, 2019). Basically, the river basin constitutes a natural limit of the relief in relation to the hydrological cycle, delimiting the effective area of surface runoff of perennial waters – springs, streams and rivers – and transitory waters – rainwater. Hence its strategic importance, since it is this conditioning and delimitation that will organize all water resource management. In addition, there is also a multidimensional process in which, in addition to the natural limits of the basins, others are superimposed, of a political-administrative nature, but also physical-environmental, with emphasis on the implications of climate change, as exposed by the Intergovernmental Panel on Climate Change – IPCC.

In this context, we must consider the rapid urbanization process of São Paulo, which has resulted in high rates of impermeability of watersheds, causing an increase in the quantity and speed of surface runoff (CANHOLI, 2005; TUCCI, 2006), thus intensifying extreme events, more specifically floods that indiscriminately affect several regions of the São Paulo Macrometropolis (CANIL et al., 2020). As a result of this situation, compensatory drainage measures are necessary, and there is already a range of references and good practices (MOTA, 2013).

It is understood, therefore, that the technical decisions that determine the form and quality of urban infrastructures, in this case drainage systems – and, even more so, their insufficiency – as observed today, are the result of a political arrangement that has already been traditionally pre-established between these different actors. Thus, for a transformation to occur in the way in which this infrastructure provision takes place – assuming that it is not sufficiently adequate – it is necessary that one or more modifications, albeit subtle, also occur in the structure that constitutes this arrangement (SILVA, KOURY, 2023a).

It is also necessary to advance in the understanding of the effective role of local actors in maintaining or transforming this scenario (LIMA, SILVA, 2023). Thus, the research seeks to provide new instruments for urban resilience (MERROW; NEWELL; STULTS, 2016), in line with the United Nations Sustainable Development Goals, especially with regard to the sustainable management of water and sanitation, the search for a safe, resilient and sustainable habitat, and in favor of taking consistent action in the face of climate change.

For the hydrological calculation, the SCS – Soil Conservation Service Unit Hydrograph method (PINTO et al, 1976) was chosen, with concentration time calculated by the kinematic wave formula (Figure 6), where N corresponds to Manning's Roughness Coefficient (0,015 used), L to the length of the thalweg, I to the precipitation intensity (mm/h) and S to the slope (m/km). This conceptual equation was chosen over other empirical ones, since it is an urbanized basin without relevant measurement data for intermediate points. The methodology that will be presented below is an adaptation that has already demonstrated validity in a previous study (SILVA, KOURY, 2023b, 2023c).

Figure 6 – Empirical Formula for Concentration Time by Kinematic Wave

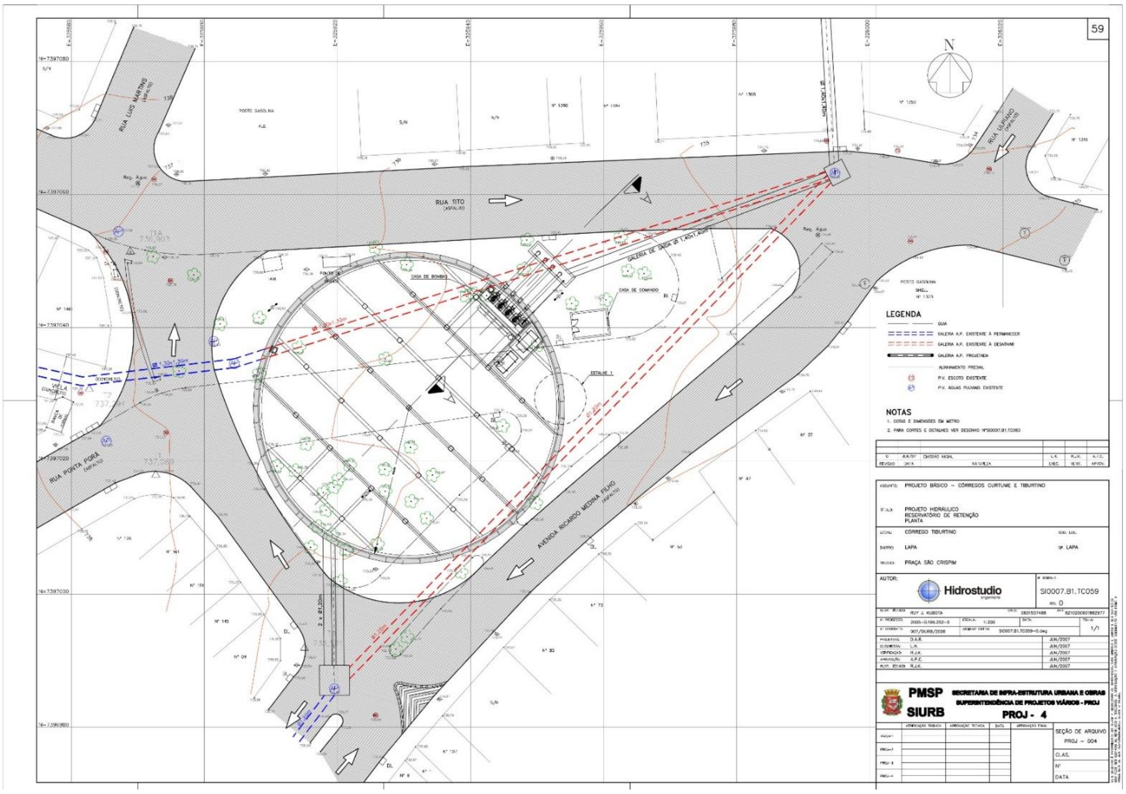
$$t_c = 55 \cdot \left(\frac{n^{0,6} \cdot L^{0,6}}{I^{0,4} \cdot S^{0,3}} \right)$$

Source: São Paulo University, 2023.

4. METHODOLOGY

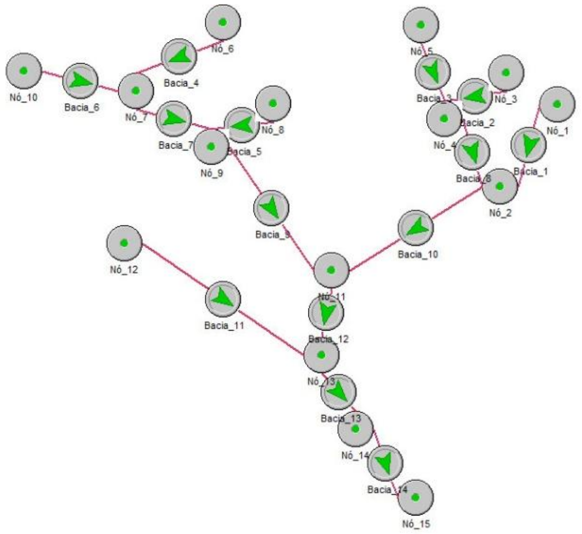
First, an analysis was carried out of the project proposed by the partnership between SIURB and FCTH, a cylindrical reservoir with proportions of 1592,45 square meters of area and 18 meters high (Figure 7). Then, the methodological procedure of computational representation was carried out, with the calculation of the convolution of the hydrograph from upstream to downstream of the basin. For this, the topology of the system was then constructed (Figure 8), using the ABC6 program – Complex Basin Analysis, developed by the Laboratory of Decision Support Systems of the Polytechnic School of the University of São Paulo - Department of Hydraulic and Environmental Engineering.

Figure 7 – Design sheet of the reservoir proposed by FCTH and SIURB



Source: Authors' collection, 2023.

Figure 8 – Sytem topology of the Tiburtino watershed in the ABC6 software



Source: prepared by the authors, 2023.

The following parameters were also defined for the calculation: rainfall duration of 360 minutes; the Intensity, Duration and Frequency curve used is that of the São Paulo Hydraulics Technological Center; the return time is 25 years; the damping coefficient is 0.25 (dimensionless). The temporal discretization interval used was 30 minutes, and for basins that exceed this interval, the kinematic wave equation was used to calculate the concentration time.

The input data for the Tiburtino river basin to be inserted into the hydrological modeling itself (Table 1) were extracted by geoprocessing analysis and are as follows: basin area, in square kilometers; area and height of reservoirs; length of the canal – thalweg – in meters; difference in altitude of the thalweg, in meters; curve-number (CN), or runoff coefficient (dimensionless).

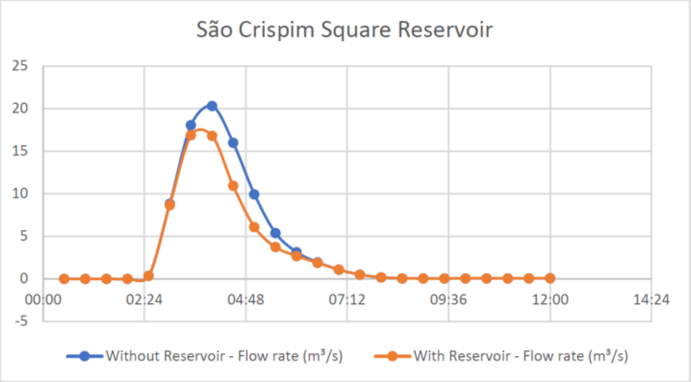
Table 1: Tiburtino watershed input data for ABC6 software

SUB-BASIN	AREA	LENGTH	ALT I	ALT F	HEIGHT	CN
1	0,4	1165,22	792	735	57	75
2	0,12	330,84	765	739	26	80
3	0,23	847,79	765	735	30	80
4	0,41	563,28	779	742	37	80
5	0,08	329,3	756	738	18	80
6	0,15	662,52	787	740	47	80
7	0,08	313,97	742	737	5	80
8	0,06	314,28	739	735	4	85
9	0,35	819,28	737	730	7	85
10	0,13	350,28	735	730	5	85
11	0,49	1108,18	771	729	42	85
12	0,15	348,84	730	728	2	85
13	0,31	376,63	728	727	1	85
14	0,49	1256,69	727	720	7	85

Source: prepared by the authors, 2023.

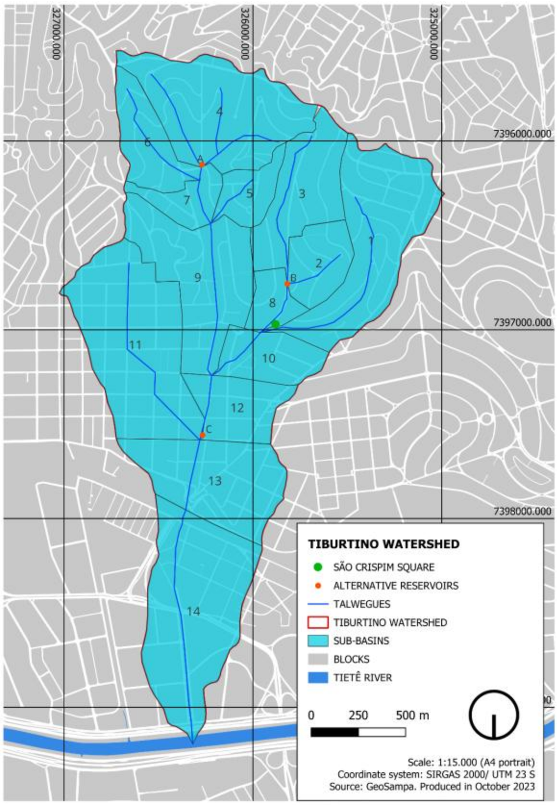
The result of this first calculation showed that the reservoir proposed by FCTH and SIURB presents a damping of around 17.24% of the peak flow (Figure 9), for the parameters that were stipulated. Once the proportions and performance of this system were known, three alternative reservoirs were proposed (Figure 10), both with a height of five meters: A) further upstream of the basin, at the roundabout where Paumari, Mota Pais, Jaricunas and Votupoca streets meet, with an area of 540 square meters; B) intermediate, at the height of the Ricardo Gonçalves Municipal Full-Time Education School, 720 square meters; C) downstream, in the parking lot next to Praça Nicola Festa, with an area of 1.400 square meters.

Figure 9 – Performance hydrograph of the reservoir proposed by FCTH and SIURB



Source: prepared by the authors, 2023.

Figure 10 – Alternative reservoir proposal

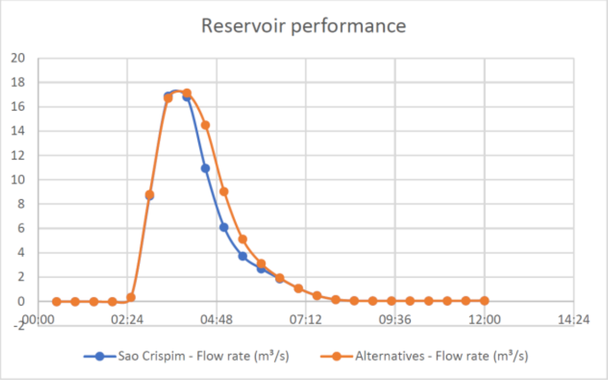


Source: prepared by the authors, 2023.

5. ANALYSIS OF RESULTS AND DISCUSSIONS

The construction of the system topology allowed the collection of output data and the comparative design of the hydrographs for the two scenarios (Figure 9), quantitatively demonstrating equivalence between the proposals. This proves the hypothesis that was put forward, that small reservoirs located below the road system are as efficient or more efficient than a single reservoir of larger proportions with a high potential for environmental impact, especially if carried out in an area with native vegetation and that functions as a leisure and recreation space.

Figure 9 – Comparative analysis of reservoir performance



Source: prepared by the authors, 2023.

This result raises a major question about which areas are effectively available in the urban fabric for these compensatory drainage measures, and whether or not there is a "real need" to propose an aggregated system instead of a distributed one. In any case, the methodology presented proves that it is not only possible, but also desirable, for civil society to improve its technical knowledge of hydrology and urban drainage, in order to demand that the solutions proposed by the government be debated with the minimum of foundation and depth.

6. CONCLUSIONS

This study demonstrated the importance of using technical knowledge of hydrology as a tool for participatory governance, since it allowed not only the analysis of the proposal made by the government, but also the development of an alternative proposal. It thus attests to the relevance of the methodology developed by the authors, constituting a scientific product of social inclusion that satisfactorily responds to the challenges posed by climate change and the sustainable development agenda.

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