

Fischer River catchment urban flooding - mitigation and participatory management

Teresa Lindoso

Rio de Janeiro State University, Postgraduate Program in Environmental Science, Rio de Janeiro, Brazil
teresalindoso@gmail.com

Luciene Pimentel da Silva

Rio de Janeiro State University, Faculty of Engineering, Department of Environmental and Sanitary Engineering, Postgraduate Program in Environmental Science, Rio de Janeiro, Brazil
luciene.pimenteldasilva@gmail.com; lpds@uerj.br

ABSTRACT: The numerous interventions in watercourses are one of the main factors that increase the occurrence of flooding in urban areas. Using a system of gutters, pipes and channels, these works were originally intended to facilitate and speed up runoff flows. For a long time, municipal governments have overlooked the occupation of wetlands, riparian areas and the excessive canalization of urban streams. As a result, floods are more frequent and their impacts worsen with urban expansion and population increase. Recently, more effective LID drainage measures, still seen as a novelty in Brazil, have been proposed to address the causes of the problem, seeking to retard and lower flow peaks, and to reduce drained volumes, thereby working towards more resilient and environmentally sustainable cities. However, non-acceptance and non-commitment by public agencies and the communities involved is still an obstacle to the application of these measures. The overall objective of this work is to present a case study involving the implementation of LID techniques in a catchment area of approximately 7.78 km² in southeastern Brazil. The techniques involved exposing conflicts that arose in the relationship between the Office of the State Public Prosecutor and the property owners and using participatory management to obtain proposals for mitigating recurrent flooding. The results include the local arrangements involving landowner participation in the works and/or actions proposed.

Keywords *flood, community engagement, urban areas*

1. INTRODUCTION

Populations and, consequently, urban areas, grew significantly during the twentieth century, especially in developing countries like Brazil (IBGE, 2003). However, cultural and socio-economic problems contributed to prevent the urban infrastructure from adequately accompanying that growth. At the same time, the strategy for urban occupation and human development, and increasing greenhouse gas emissions, were catalysts that contributed towards the forming of heat islands and global warming. It has been noted that in Brazil and many other parts of the world, the increased frequency of heavy rainfall, especially in urban centers, along with stormwater drainage systems that were not designed to handle events of such magnitude, have exposed the urban infrastructure, buildings and the population to greater risk. Several studies have shown that the poorest are the most vulnerable and the ones who are least able to recover from natural disasters (Marengo, 2008).

Adequate drainage systems can contribute to sustainable development and improve the quality of urban life, by helping to balance the different issues that influence the growth of municipalities. Interference in the natural hydrological processes should be reversed, minimized or compensated. It is important to promote these changes in public policies on land use and occupation, as well as the conservation of natural environments and their dynamics. It is necessary, and has already occurred in other countries, to revise the notion that rainwater is undesirable and must be removed downstream as quickly as possible, and to seek solutions that appreciate rainwater as a natural resource that is to be preserved (Van Roon & Van Roon, 2005; Fletcher *et al.*, 2015).

This new vision implies that the management of rainwater considers the factors related to rainfall quantity and excess (flooding), water quality (pollution control) and society's needs, which can be discussed on a collective basis, in order to consolidate drainage systems and stormwater management, aimed at municipal sustainability. Only by improving these indicators will it be possible to ensure a better quality of life for all the people, as well as the conservation of rainwater. Often, in the search for solutions to the recurrent problem of flooding, tangible results have been obtained by developing awareness of the issues among those who live and work within the areas where they occur, since they have local knowledge and are directly affected by the consequences.

In this paper, it was casted a spotlight on the community that has been located for more than 40 years on the banks of the River Fischer, a 3rd order tributary off the right bank of the River Paquequer, in the urban area of the 1st district of the municipality of Teresópolis, in the state of Rio de Janeiro. Within that area, flooding has been frequent during the rainy season and in recent years it has been noted that the frequency and intensity of these events has been increasing.

The solution for the reduction of flooding in this area is time consuming and costly, because it also involves complex social issues. Seeking the help of the Public Authorities, the local residents presented a formal request to the Office of the State Prosecutor for the implementation of measures to minimize flooding in the neighborhood. Faced with this situation, a meeting took place between the Municipal Secretary of Environment and the Office of the Attorney for Public Stewardship to seek solutions to the recurrent flooding. At this meeting, the need was identified to conduct a preliminary study of the land use and cover and a study of the environmental conditions in the whole catchment area.

A preliminary technical study was presented to the State Prosecutor, setting out the action that could possibly be having a negative impact on the natural drainage system of the River Fischer. It was concluded that the hydrological response in that area was the result of the human occupation upstream, calling attention to the process of urbanization

without proper planning and highlighting the need to consider the entire catchment area in the planning of land occupation and use. Based on that report, the Attorney decided that suitable measures to minimize the flooding would be taken up with all the social bodies and interested parties involved in finding a solution to the problem.

In this context, it is seen that, in developed countries, the identification of negative impacts on ecosystems and society caused by the inappropriate management of rainwater leads to the development of a new management proposal based on the reduction of impermeable areas, increased rainwater infiltration (Roy *et al.*, 2008) and the effective participation of the community (CIRIA, 2015). This approach, known in the USA as LID (Low Impact Development), has been adopted in several cities around the world and endorsed by various government agencies (Roy *et al.*, 2008).

The aim of this paper is to report the partial results of the LID application in the River Fischer catchment area (7.78 km²), especially regarding the action by all the social bodies involved, aimed at clarification, study and reflection, during the participatory development of flood control proposals.

2. METHODOLOGY

This study began in July 2010, upon the presentation of the preliminary technical study to the State Prosecutor, reporting the possible action that could be having a negative impact on the River Fischer natural drainage system. Based on that report, the Attorney decided that the application of suitable measures to minimize flooding would be handled by sub-basin, since the study area is downstream from 4 sub-basins and the hydrological response in that area is the result of the land occupation upstream.

In this paper, emphasis is given to the situation of the main basin and the two neighborhoods (Fonte Santa and Quinta Lebrão) situated on the banks of the River Fischer, and a joint solution is proposed that involves the participation of all the stakeholders: municipal government, local residents and traders, and mediated by the State Prosecutor.

Among the strategies adopted in the LID is keeping the hydrological cycle as the focus for reducing the surface runoff resulting from the urbanization process. Among the most commonly used techniques are establishing retention basins, increasing the permeable areas, re-naturalization of rivers or areas of natural flooding and the reutilization of rainwater. Simultaneously, it is necessary to look to the needs of the population, a process in which their participation is essential, not only to develop environmental awareness, but to ensure that their knowledge and concerns are taken into account in designing the project that is to be implemented in their neighborhood.

On these lines, the methodology of action research proposed by Michel Thiollent (Thiollent, 2002) was adopted. That methodology recommends working together with the stakeholders on clarification, study and reflection for guiding the efforts to minimize the problems and, as appropriate, any social and environmental conflicts. It is a form of research based on the knowledge acquired by experiencing the reality of a situation, in contact with the social agents involved, which determines the order of priority of the problems to be investigated, as well as the solutions to be presented in the form of concrete action. Whether it is to assist in resolving a collective problem or at least clarifying the observed problems presented by the situation, thereby providing the researchers and their subjects the means to respond with the maximum efficiency to such problems. Application of the methodology involved two phases: exploratory phase and structured meetings..

2.1 Exploratory phase

The main aim of the exploratory phase of the project was the development of the study. This was carried out in collaboration with students on the Environmental Engineering course of FESO (Serra dos Órgãos Educational Foundation). The participative investigation combined field research (interviews) and bibliographic reviewing. Events were held to promote interaction with the local community, which included: meetings with local representatives, interviews with local residents and business people, walking around the neighborhood (sometimes in the company of residents) and participation in community gatherings. Simultaneously, photographic records were made and geo-referencing of the conditions of the River Fischer as it passes through the communities of Quinta Lebrão and Fonte Santa was carried out. Through the exploratory phase, a study of the River Fischer catchment area was produced.

The analysis of the River Fischer catchment area used ArcGIS software to obtain the primary data and material information for the study of the land use and occupation, based on the WorldView-2 satellite image with a 50 cm resolution.

The survey of the conditions of the River Fischer in the Quinta Lebrão district was conducted with the help of local residents, using a Garmin Oregon 500 GPS and a ruler. The residents pointed out several places that can be considered critical, due to interference carried out on different occasions. The hydraulic capacity of those sections was calculated empirically using Manning's Equation for channel flows.

2.2 Structured meetings

This step was conducted in close cooperation with the local community. The process of developing the studies began with the presentation of the project concept to a neighborhood resident who stood out as a community leader. This resident organized meetings with a group of locals and there was a general feeling among the residents that representatives of the Municipal Council and Executive Branch should not be included, out of fear that it be used for electoral purposes.

Over a two-month period, 4 meetings were held, two weeks apart and always on a Sunday, with the residents of the Quinta Lebrão and Fonte Santa districts. The chosen venue for the meetings was the neighborhood CIEP School (Integrated Public Education Center). The fourth meeting was attended by around 40 people.

A questionnaire was developed, with the main purpose of recording the frequency of flooding in Fonte Santa and Quinta Lebrão districts and how that flooding affected the lives of the local residents, as well as identifying their perceptions regarding the solution of the problems caused by the flooding. The questions were simple, as follows:

- How long have you lived in the district?
- How frequent is flooding in the district?
- How has the flooding affected your life? What is the solution to the problem of flooding?
- Would you move, if you could?

The idea was that the questionnaire should be very objective, reducing the response time to a maximum of 5 minutes. That way, it would keep the attention of the subject. At the same time, sufficient room was allowed for the subject, if interested, to recount anything he or she considered to be important.

All the participants completed the questionnaire on their perceptions of the flooding in the district and took forms to be filled by their neighbors or the local tradespeople. A total of

98 questionnaires were returned. Each completed questionnaire represented a home located within a maximum of 50 meters from the River Fischer.

3. PRESENTATION AND ANALYSIS OF THE RESULTS

3.1 Assessment of the Fischer River catchment area

The River Fischer catchment area is situated in the municipality of Teresópolis, in a range of high hills region of the state of Rio de Janeiro (altitude of 871 m). The municipality has a total area of 770.6 km², representing 14.1% of the mountain region and 1.76% of the total area of the state.

According to data from the Brazilian Institute for Geography and Statistics (IBGE, 2016), the estimated population of Teresópolis in 2015 was 173,015 inhabitants, and the municipal Human Development Index in 2010 was 0.73. The population is predominantly urban and is mostly concentrated within the 1st district, the town center. Approximately 81% of the urban population lives within the narrow valleys of the catchment area of the River Paquequer, of which the River Fischer is a tributary, so the predominant landscape offers low potential for urban expansion, given its physiographical characteristics. The drainage system under study is part of the hydrographical area of the River Paraíba do Sul, which occupies part of the territories of the states of São Paulo, Rio de Janeiro and Minas Gerais, in southeastern Brazil.

According to climate classification of Köppen, the climate is classified as Cwb. According to the climate normals (1961-1990) obtained from the station in the National Park, the average temperatures are typical of a mild climate, ranging from 20.8°C in summer to 14.8°C in the coldest month (June). The rainfall distribution over the course of the year is quite irregular, with summers registering a high volume, while the winter are dry, resulting in an annual average of 2,774 mm.

Vieira & Cunha (2011) assert that the rugged terrain and concentrated wet season favor the rapid surface runoff that, associated with increased urbanization, make the municipality of Teresópolis a potentially vulnerable area that is liable to develop areas of risk as a result of unstable hillsides and recurrent flooding.

The catchment area of the River Fischer, a 3rd order tributary off the right bank of the River Paquequer, is located in the northeast sector of the 1st district of the municipality of Teresópolis and covers an area of 11.6 km². From a morphological point of view, the main stream runs in a south-north direction and its sources are in the southeastern part of the area, at an altitude of about 1,067 meters above sea level, while the mouth enters the final third of the River Paquequer at about 744 meters above sea level, giving it a total length of about 7.11 km, with a slope of 4.4%.

Using the digital model of the terrain, information was obtained about the morphology of the catchment area and, despite the mountainous landscape, only a tiny part has a slope equal to or greater than 45° and that is over exposed rock. The greater part of the area has undulating relief, with a slope varying between 26% and 55%. The flat or gently undulating sections have a slope of up to 7% and are restricted to the floor of the valleys. The entire catchment area comprises small valleys and has different forms of occupation, with intensive urbanization occurring along the first 4 km of the main stream. That stretch lies on the town's urban periphery and IBGE data (2010) show a population of 9,000 people in 3,280 homes. It should be mentioned that the study by Soares and Lima (1981) states that the Quinta Lebrão and Fonte Santa districts contained 150 and 200 houses, respectively, which reveals the rapid occupation of the area in the last 35 years.

The River Fischer catchment area was unoccupied until it was cut longitudinally for the construction of the BR-116/RJ highway, in 1959. Currently, the land occupied by the Quinta Lebrão district and part of Fonte Santa belong to the INSS (National Social Security Institute), although it is almost entirely occupied by illicit construction. The IBGE Census data for the year 2000 revealed that all of the Quinta Lebrão district comprised an informal settlement, while in the Fonte Santa district, 68.6% of the housing is in the same situation. And since the municipal authorities have never proposed a ownership legalization program, it is to be expected that the current situation is the same or worse. Nowadays, the area is densely populated, with unregulated occupation in areas of risk, such as on hillsides and riverbanks, the predominance of low construction standards and little basic service infrastructure.

The local residents pointed out 9 places that are considered to be critical, due to practices and (bad) river interventions carried out on different occasions. According to the assessment of the hydraulic capacity of these sections of the River Fischer in the Quinta Lebrão district, it was noted that there is retention caused by obstruction of the channel, such as by buildings that cover or traverse the river. Such retention along the course of the River Fischer exacerbates the frequent flooding of the neighborhood, almost every year, according to information obtained from the local residents, causing them considerable inconvenience. On the other hand, this storage reduces the water level in neighborhoods located at lower altitudes downstream. So simply unblocking these stretches could lead to flooding further downstream. This situation confirms the need for a systemic approach to river basin management.

3.2 Community involvement

The first meeting was held on October 13, 2012 at the CIEP in the Quinta Lebrão district. Around 25 local residents were present and the majority made the commitment to contribute important information about the history of the area, such as old photographs, the memories of the older residents, etc. At the same meeting, they agreed to invite other residents to participate in the study, which resulted in twice as many participants at the next meeting, held in the same location two weeks after the first one. Subsequently, in the context of the River Fischer sub-basin, a group of "Neighborhood Collaborators" was formed, comprising 40 residents approved to work on the project, who conducted research about the community by asking neighbors and local tradespeople, in order to learn information, perceptions and opinions regarding the floods in the neighborhood. A total of 98 completed questionnaires were collected, 63 from the Fonte Santa district and 35 from Quinta Lebrão. Although there are social and economic differences between the two neighborhoods that were studied, there were very similar perceptions among their residents about flood-related issues and particularly their increasing frequency (Fig. 1).

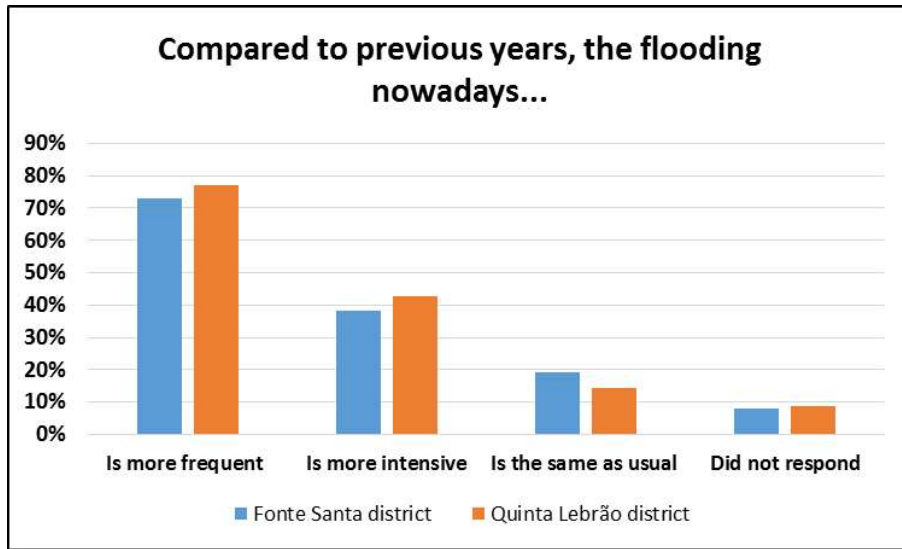


Figure 1: Responses to Surveys carried out in the districts of Quinta Lebrão and Fonte Santa

It was also found that every year the residents of the Quinta Lebrão and Fonte Santa districts suffer from some kind of trouble caused by heavy rains, ranging from difficulty in returning home, due to flooding in the streets, to the loss of property from up to 2 meters of water inside the home (Fig. 2), as noted in the event of April 6, 2012 (this work did not study the damage caused by the major regional natural disaster in January 2011). In the opinion of the local residents and tradespeople surveyed, the solution to the problems caused by the flooding lies mainly in carrying out works to widen and channel the river, as shown in Figure 3. On the other hand, they assign all the responsibility for solutions to minimize the flooding to the Public Authorities, without taking into account their own action as a causal factor in the occurrence of flooding, such as throwing rubbish directly into the water course or provoking changes in sections of the channel (Figs. 3, 4).

On the negative side, difficulties were confirmed in seeking dialogue with the Public Authorities, which, despite frequently promoting social participation, do not commit to implementing the programs required by the local community. This may help to explain the second negative - social participation was marked by a proportionately low number of local residents. And, at least in the beginning, the distrust between the participants and those who were trying to promote it.

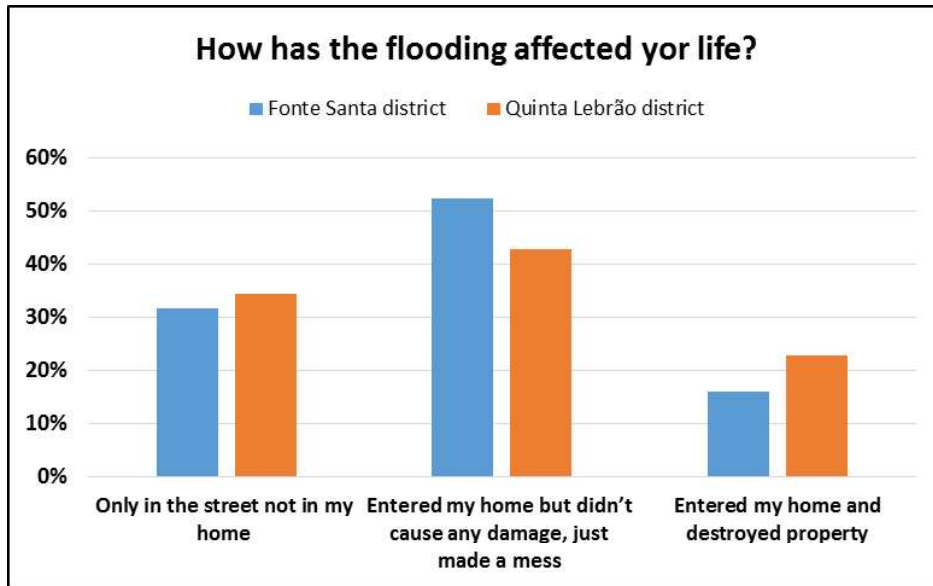


Figure 2: Responses to Surveys carried out in the districts of Quinta Lebrão and Fonte Santa

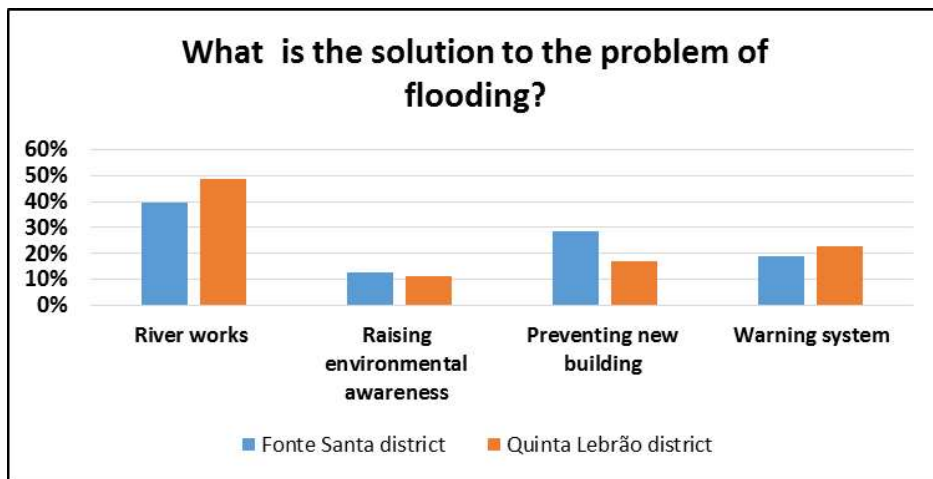


Figure 3: Responses to Surveys carried out in the districts of Quinta Lebrão and Fonte Santa

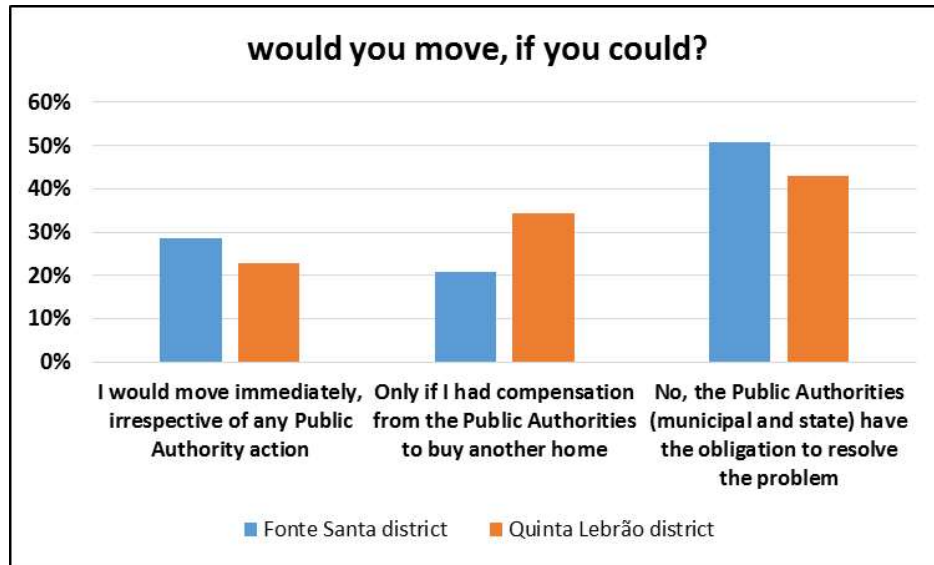


Figure 4: Responses to Surveys carried out in the districts of Quinta Lebrão and Fonte Santa

4. CONCLUSIONS

The unregulated occupation of urban areas causes negative impacts and its effects can be seen in places that are far apart, especially those relating to changes in the hydrological cycle, thus requiring an urban planning approach that takes in the entire catchment area. Implementing the LID application strategy with regard to the engagement of the whole community has proven to be effective for clarification, study and reflection on the part of all the social protagonists involved in the participatory development of proposals for flood control.

Along these lines, the study methodology developed by Thiollent in the action research method is inspirational and involves elements that fit the objectives and assumptions of environmental education that are critical to the development of participatory environmental management, in an active manner that satisfies collective and citizenship needs. As such, the social protagonists participate collaboratively in identifying the causes, consequences and possible solutions of the social and environmental problems they face. Thus, one seeks to stimulate and ratify local community involvement in order to reinforce the action of the public environmental management and to preserve the local ecosystems.

The community living on the banks of the River Fischer is yearning for solutions to minimize the damage caused by repeated flooding, including indirect damage, which is usually overlooked in the assessment of damages. Participation in the Sunday morning meetings confirmed the feeling of being ignored by the Public Authorities, because on the one hand, they are assigned full responsibility for carrying out the public works and inspection, while on the other there is no prospect of such action occurring. Moreover, the local community wants to participate in the decisions concerning the future of the neighborhood and make its opinion known, in a democratic process of exercising citizenship. Furthermore, the community does not want to leave its homes and move to other technically safer places. That is because they believe in "engineering solutions" and the obligation of the Public Authorities to carry them out. This position strengthens the need for educational programs, in the form of debates, campaigns and lectures that can help to raise the level of awareness, as well as encourage involvement in environmental issues and, especially, sharpen the perception of risk.

The impact of participation in the development of initiatives was much greater, in terms of

increasing self-esteem and recognition of a citizen participating in the system, with the right to be heard in relation to the variables that directly interfere in their lives, than in terms of tangible improvements in their living conditions. That is mainly due to the fact that the improvements depend on action by the Public Authorities.

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