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Flood Containment System for Vilarinho Avenue Region: Detention Basin

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Abstract-Belo Horizonte, such as other large urban centers, has constantly expanded, however this has resulted in some consequences, because with this expansion there is the waterproofing of soil that has caused floods and often the drainage system doesn't satisfy the necessary demand. Through searches, it was concluded that the Vilarinho Avenue has faced floods in raining periods and the detention basin, which is a flood containment structural, would be ideal for be deployed in the region. Furthermore, an important problem that has contributed for the flood is the trash deposition on the streets, which makes necessary, the awareness of the population.

Keywords- *Detetion Basin, Floods, Vilarinho Avenue*

I. INTRODUCTION

Urban infrastructure is understood as a set of constructions that are used as basis for the economic development. Such as highways, telecommunications, basic sanitation, railways, among others. The demand for urban infrastructure works has grown considerably due to rapid growth of cities. However, this development is not always beneficial because the irregular and disorderly occupation of geographical space in the great urban centers can cause serious problems to the population. One of the most common disorders is the waterproofing of soil owing to the large number of buildings. The results of this situation are frequent floods, in specific areas of the city, which has exposed thousands of people to the dangers that these floods can cause, such as materials damage, diseases and deaths. The problem is aggravated due to failures in the drainage system of cities, in addition to excessive deposition of garbage in public road.

The lack of macro drainage planning system is responsible for the critical state of Brazilian flood control. However, there are measures to avoid flood damage. Among them are the structural measures, which are works located in the same place where the problem exists, such as watercourse's channelization, detention and retention basins, flow deviation, among other. On the other hand, there are the non-structural measures that include regulations for the soil occupation, warning systems and especially the awareness of the population about the maintenance of drainage systems [3]. The city of Belo Horizonte is in this context of urban growth, which was not always followed by a proper planning.

The climate changes in recently years have caused heavy rains and the flood problems have become more common. The Vilarinho Avenue has undergone for some flood situations that have resulted a lot of damages there: cars and buses loaded by water, houses flooded by water and trade destroyed.

Given the current problems faced in the rainy season, the viability of this flood control system and the retention of excess water volume for the Vilarinho Avenue were questioned. To solve this problem, a proposal to contain floods in this area was created, in order to solve this problem, through the use of reservoir for flood control, known for detention basin.

Therefore, local hydrological data were collected and the existing flood containment projects were investigated, with focus on detention basin and its structure was chosen due to hydrology and free space for construction in the region.

With the creation of this containment proposal, a reduction of floods in place during periods of heavy rain is expected, as well as benefits for the local population.

II. METHODOLOGY

The methodological processes began with the hydrological data collection of the Vilarinho Avenue region in order to study the place and to check the need for the system for containing floods.

After rate the place, researches have been done in order to know about the existing projects flood, emphasizing the detention basin so that researchers could plan a flood containment system. Therefore, the researchers compiled all the data collected with the information from the detention basin projects and developed a system to solve the problem above. Calculations were developed to determine the precipitation and the maximum flow rate to be adopted in the region, in order to build a possible detention basin of floods.

III. THEORETICAL REFERENCE

A. *Flood control methods*

River flood is natural phenomenon, but with the occupation of river area has appeared a big problem that affects the cities, which are the flood of city. Flood in big cities is one of the biggest infrastructure problems in cities so it is necessary to found measures to avoid and treat the problem. These actions are classified according to their nature in structural and non-structural measures.

Non-structural measure are those that aim to reduce the problem without the implantation of works, for example warning systems, maintenance of existing drainage systems and especially awareness of the population.

On the other hand, the structural measures are works that treat or minimize floods. Among this works, it is possible to highlight: expansion and restoration of main river channels, channelization, flow deviation, through expansion and restoration of main river channels. Besides this, it is important to emphasize the replacement of the vegetation cover and erosion control along the drainage basin.

B. *Urban drainage in Belo Horizonte*

The natural drainage system of Belo Horizonte is composed mainly by the Ribeirão Onça and Ribeirão Arrudas and has another part which is connected to Ribeirão das Velhas.

According to the Municipal Sanitation Plan of Belo Horizonte [12], the channelization of watercourses and the discharge of untreated waste in the canals entail in overflows and consequently flooding. Besides this, the system failure as a whole occurs due to the miscalculation in your projects, due to the rapid growth of urban areas, the incorrect disposal of solid waste, and irregular occupation on river banks.

However, the county has programs to solve the problem of floods, such as the Programa Drenurbs and the Plano Diretor of the city, which has several mechanisms of study to find the best solution.

C. *Waterproofing of soil*

The introduction of impermeable materials such as cement and asphalt in the soil entails the loss of the water absorption capacity of the soil, which makes it waterproof.

The process of urbanization in urban centers has a direct influence on the process of soil waterproofing [4]. This process causes the amount of water infiltrated to be smaller and the superficial flow of water to be bigger [11].

In the big cities, the waterproofed soil rate reaches 70% and happens in different ways from region to region of the city, thus some places are more susceptible to flood. Furthermore, as there is not infiltration of water into the soil, all rainwater is destined for the main water bodies. However, due to silting problems and deposits of solid residues in the water bodies, in this case, they lose part of their free flow and the scenario becomes susceptible to floods [4].

D. *Detention basin*

The reservoirs for flood controls, which are known by detention basin, are structures that detain or retain flow of water from the rain, reorganizing the flow through the damping of the flood peaks. These structures can be installed to reinforce the flow capacity of a drainage system or to avoid flood in a specific place. Usually, the reservoir fills with the rain and then the water is drained [5].

They can be opened or closed. The open ones, Fig.1, have smaller capacity when compared to the closed ones, but they have simple implantation and are easy to keep. They can integrate with the urban landscape and due to this, they have a rigid maintenance plan, because the population can get in touch with them. The close ones are difficult to maintain, may have large volumes, they are more complex to deployed, so they are more expensive. They do not integrate with the urban landscape, thus the maintenance time is bigger because they do not get in touch with the population. It is important to emphasize that the detention basin can be dangerous if it is not properly projected, implanted and held.

Figure 1. Detention basin of Vila Paulicea, São Paulo.

1) *Current works*

In the metropolitan area of Belo Horizonte, there are some flood detention basin that were implanted to reduce the risk of flood in periods of heavy rains, such as Detention basin of Córrego Ferrugem, in Contagem, Basin of Córrego Bonsucesso, in Barreiro, among others.

The searches, in order to deepen the research, visited the detention basin of Córrego Engenho Nogueira, in the region of Pampulha, Fig.2, Fig,3, Fig.4, where they were assisted by Sudecap engineer responsible for the place. It supports a volume of 110,000m³ and was developed to minimize the effects of flooding at the Federal University of Minas Gerais and Pampulha Airport.

Figure 2. Detention basin of Córrego Engenho Nogueira.

Figure 3. Detention basin of Córrego Engenho Nogueira.

Figure 4. Detention basin of Córrego Engenho Nogueira.

E. *Problematization of the chosen location*

1) *Floods in the place*

The Vilarinho Avenue has a history of floods that has extended since 1979, Fig.5, when Belo Horizonte was passing for a big population growth, accompanied by bad urban occupation and consequently by the lack of city planning [18].

Figure 5. Detention basin of Córrego Engenho Nogueira.

2) *Causes of the incident*

Reference [2], cites as main causes of the problem:

- High rainfall indexes;
- Lack of adequate urban planning;
- Insufficient drainage system;
- Sealed soils;
- Excessive waste disposal, especially in sewers.

3) *Consequences*

Many losses have reached the region: dragged cars, flooded houses, paralyzed trades and loss of commodities, death, tree falls, streets full of garbage, mud and vegetation that have been washed away by rainwater and diseases that are caused by direct contact with the floods.

F. *Hydrological and topographic data*

Belo Horizonte is located in the Rio das Velhas Basin, which is contained in the São Francisco River Basin [7]. Its total annual precipitation is 1491.3 mm and the months of November to January are the rainiest [8].

In October of 2015 there was a great flood in one of the sub basins of the city: the Vilarinho sub basin, Fig.6, whose flood dragged cars and destroyed many trades. Reference [2], the City Hall of Belo Horizonte explained that the Hydrological Monitoring System of the County registered 57mm of rain in and most of them occurred in a period of 30 minutes, which increase the chances of flood.

Figure 6. Vilarinho sub basin.

The Table 1 shows daily rainfall data for this month of October 2015.

TABLE I. PRECIPITATION DATA FOR OCTOBER 2015.

Precipitação em Belo Horizonte		
Data	Hora	Precipitação
01/10/2015	1200	0
02/10/2015	1200	0
03/10/2015	1200	4.2
04/10/2015	1200	0.6
05/10/2015	1200	0
06/10/2015	1200	0
07/10/2015	1200	0
08/10/2015	1200	0
09/10/2015	1200	0
10/10/2015	1200	0
11/10/2015	1200	0
12/10/2015	1200	0
13/10/2015	1200	0
14/10/2015	1200	0
15/10/2015	1200	0
16/10/2015	1200	0
17/10/2015	1200	0
18/10/2015	1200	0
19/10/2015	1200	0
20/10/2015	1200	0
21/10/2015	1200	0
22/10/2015	1200	0
23/10/2015	1200	21.6
24/10/2015	1200	0
25/10/2015	1200	0
26/10/2015	1200	0
27/10/2015	1200	0
28/10/2015	1200	40.1
29/10/2015	1200	1
30/10/2015	1200	0
31/10/2015	1200	0

Fig. 7 presents a part of the topographic map of Belo Horizonte with focus on the region of Vilarinho. It has the contour lines and streams that pass through the region, among them the Vilarinho stream, which was channeled.

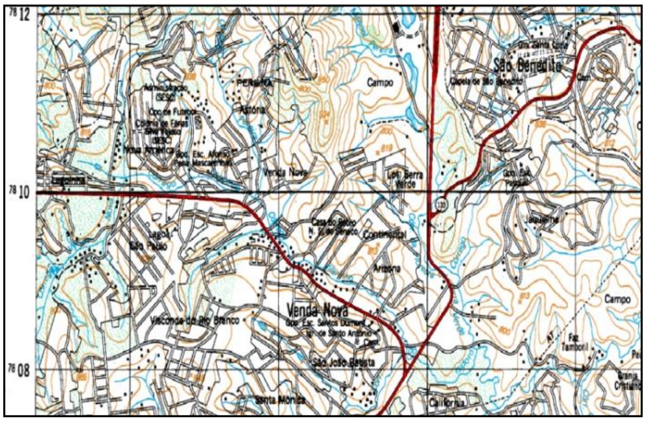

Figure 7. Topographic map of Belo Horizonte.

When the region is analyzed more specifically, it is possible to see that the area which suffers more with the floods is located in lower altitudes, Fig. 8.

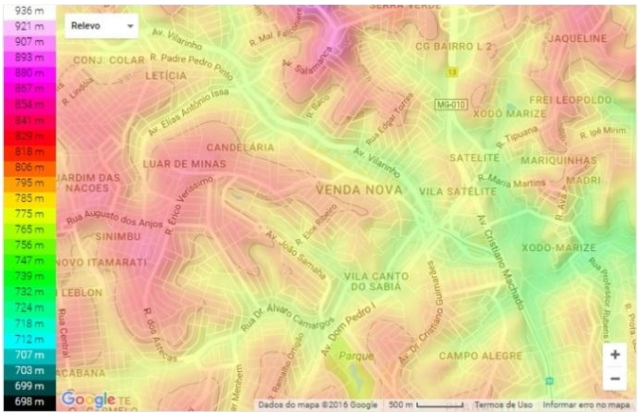

Figure 8. Topographic map of Belo Horizonte.

The flow that falls in the basin required the calculation of the maximum flow rate for the detention basin as a function of the return period. It is necessary to adopt a period of 100 years of return to the project detention basin in urban areas [16].

IV. RESULTS AND DISCUSSIONS

To start the calculations, it is necessary to have the data of the maximum precipitations of each year, in a minimum period of 20 years (Table 2).

TABLE II. MAXIMUM ANNUAL PRECIPITATIONS.

	Precipitação máxima (mm)			
Período de Dados	198_	199_	200_	201_
0		56,6	158,8	75,5
1		97	63,7	91,4
2		130,6	75,9	80,6
3		85,8	83,4	111,4
4		64,9	81,4	71,3
5		138,7	84,4	68,6
6		88	156,3	
7		147,4	53	
8	68	88,7	94,2	
9	109,6	84,2	48	

The maximum rainfall of the project was calculated using the Gumbel Distribution Method, through the formula presented in (1):

$$X=\overline{X}+\frac{\sigma_x}{\sigma_n}(y-y_n) \tag{1}$$

Where:

X = Maximum rainfall of the project;

$\overline{X}$ = Arithmetic Mean of the data;

σ_x= Standard Deviation of data;

σ_n= Reduced Standard Deviation (in function of the number of data);

y_n= Reduced Mean (in function of the number of data);

y = Calculated in (2):

$$Y=-\ln\left[-\ln\left(1-\frac{1}{T}\right)\right] \tag{2}$$

Where:

T = Return Period, in years.

After these calculations, the values below were found:

X= 91.34 mm;

σ_x= 29.95;

σ_n= 1.1047;

y_n= 0.5343;

y = 4.60.

When the data are applied in (1), the value of X can be found:

$$X=91.34+\frac{29.95}{1.1047}(4.60-0.5343)$$

Finally, the maximum rainfall of the project got for a period of 100 years of return was 201.56 millimeters.

With satellites images obtained in the software of Google Earth, it was possible to demarcate the coverage area of the detention basin, Fig.9.

Figure 9. Delimited area.

After the demarcation, the data below were extracted:

A = area = 0,52km² = 52ha

T = return period = 100years

L= talweg length = 0,98km

H= difference in quotas = 6m

I= declivity = 11%

According to Manning's equation (3) for paved area, the velocity V obtained is equal to:

$$V=0.6078\times I^{0.4976} \tag{3}$$

V=2m/s

This value was used to obtain the time of concentration, according to the kinematic method (4):

$$t_c=\frac{1000}{60}\sum_{i=1}^{n}\frac{Li}{Vi} \tag{4}$$

$$t_c=\frac{1000x0.98}{60\times 2.0}$$

t_c = 8.17 minutes

Therefore, the maximum mean precipitation intensity, (i), can be calculated in (5):

$$i=\frac{kT^a}{(t+b)^c} \tag{5}$$

Where,

i = maximum mean precipitation intensity;

k,a,b, c= parameters to be determined in this region, that were found in the software Pluvio 2.1 according to the geographical coordinates of the place (Latidude:19°48'4"S e Longitude: 43°59'19"W), so:

k=1058.128

a=0.178

b=11.091

c=0.752

and:

$$i = \frac{1058{,}128 \mathrm{x} 100^{0.178}}{(8{,}17+11{,}091)^{0.752}}$$

Maximum mean precipitation intensity = 259.69mm/h.

To calculate the maximum flow rate, through the rainfall data of the region, the rational method was used, which is indicated for areas between 500 000m² and 5 000 000m², (6).

$$Q_{max} = \frac{C i_m A}{360} \tag{6}$$

Where:

Q_{max} = Maximum Flow Rate;

C = runoff coefficient; which, according to [13], can be obtained through the Tab. 3, with values of the volumetric coefficient (C2), as a function of urban zoning [1], identified by the mapping shown in Fig.10.

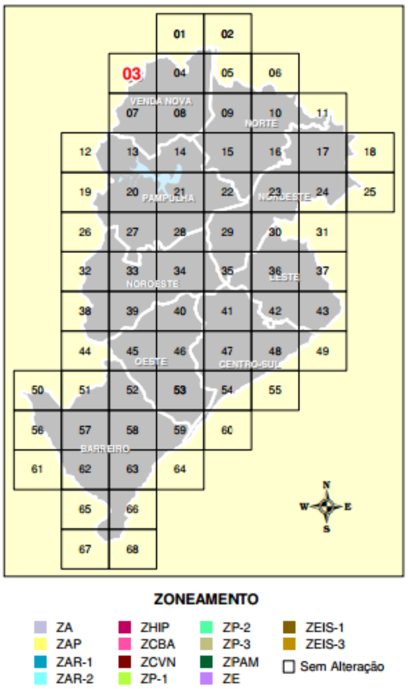

Figure 10. Urban zoning.

With the value found, it is possible to calculation C, (7):

$$C = 0.67 \mathrm{x}\ C2 \tag{7}$$

$$C = 0.67\ \mathrm{X}\ 1 = 0.67$$

Therefore, the value found for Q_{max} was:

$$Q_{max} = \frac{0.67 \times 259.67 \times 52}{360}$$

$$Q_{max} = 25.13\ \mathrm{m^3/s}$$

After the local hydrological data were obtained, the group located in the demarcated area, an empty lot on Vilarinho Avenue, which may be the location of the detention basin, 11.

TABLE III. VOLUMETRIC COEFFICIENT

N.	Zoneamento	Codigo da Zona	C_2
1	Zona de Preservacao Ambiental	ZPAM	0.20-0.90
2	Zona de protecao-1	ZP-1	0.30-0.50
3	Zona de protecao-2	ZP-2	0.50
4	Zona de protecao-3	ZP-3	0.60
5	Zona de Adensamento Restrito-1	ZAR-1	0.70
6	Zona de Adensamento Restrito-2	ZAR-2	0.75
7	Zona Adensada	ZA	1.00
8	Zona de Adensamento Preferencial	ZAP	0.80
9	Zona Hipercentro	ZHIP	1.00
10	Zona Central do Barreiro	ZCBA	1.00
11	Zona Central de Belo Horizonte	ZCBH	1.00
12	Zona Central de Venda Nova	ZCVN	1.00
13	Zona de Especial Interesse Social	ZEIS	0.70
14	Zona de Grandes Equipamentos	ZE	0.30-0.90

Figure 11. Empty lot for possible contruction.

The project would be a detention basin, with leisure area: field, square or an open air gym, as in Fig.12, Fig.13.

Figure 12. Detention basin in São Bernardo do Campo.

Figure 13. Praça Niterói on a detention basin with capacity for 58 million litters of water.

The basin of detention would have a lowering in relation to the level of the street, to the best use of the flow rate found. In addition, information signs for the population, with guidelines for evasion of the area in case of heavy rains and with the risks of permanence in the area in this situation.

V. CONCLUSIONS

With the data collected and the information obtained, the viability of the project in question as a solution for rainwater retention and flood prevention in this area was verified.

Furthermore, there is negligence of the population in relation to waste disposal, which directly influences the aggravation of the above situation. To solve the problem, it is necessary the population's awareness concerning to the correct disposal of waste.

Finally, it was possible to verify the need of a more detailed study about the availability of construction in the indicated lot and its subsequent sizing of the detention basin.

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