Urban drainage network sizing solution to flooding problem in the city of Bebedouro/SP

Solução de dimensionamento de rede de drenagem urbana para problema de inundação na cidade de Bebedouro/SP

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ABSTRACT
Most developing countries, including Brazil, have experienced urban expansion in the last few decades with poor drainage infrastructure, resulting from flooding problems mainly from the rapid expansion of the urban population. A point that causes major inconvenience to the population and does not receive improvement works and thus floods during the period of heavy rains is located on the west side at the intersection of Avenida Raul Furquim with the Armando Sales de Oliveira SP 322 highway, the point has heavy traffic in peak hours is an important route to the city of Bebedouro. The general objective of the research was to analyze and dimension new galleries of rainwater in the section under study, in the municipality of Bebedouro and the impacts caused by the deficiency and absence of the management process of these waters.

Keywords: Dimensioning, drainage, flood, network, topography.

1 INTRODUCTION

According to the IBGE, Bebedouro-SP had in the 90s a rural exodus, with new and growing population flows in search of life improvement.

The human development index (HDI) of the city in 1990 was 0.55 in the year 2010 the situation became 0.78 in the region.

The municipality has a tropical climate with a dry season, has average monthly temperatures above 18 °C in all months of the year, and typically has a very pronounced dry season, with the driest month having less than 60 mm of precipitation and also less than 100 mm of precipitation of the month during the year, thus causing at that time the appearance of several areas of flooding due to rain.

The Municipality of Bebedouro/SP has a very wide hydrography in its urban perimeter, emphasizing the need for studies and projects for the implementation of efficient measures in the urban drainage sector, therefore, as a case study, a stretch of Avenida Raul Furquim was chosen.

A point that generates great inconvenience to the population and does not receive improvement works and thus presents flooding in the period of heavy rains is located in the west zone at the intersection of Avenida Raul Furquim with Rodovia Armando Sales de Oliveira SP 322, the point has intense traffic at peak times is an important route for the city of Bebedouro, passage for the population that is destined to the north and central zones, access to small cities around, among other destinations of locomotion, is extremely important for the social sphere.

The justification for the development of this work is linked to the importance of having an efficient drainage system, with the capacity to drain exceptional rains, adapting the existing system with measures to control sources that generate problems.

Floods can hide potholes and depressions, which increase the risk of accidents to the population, and the water flow can also lead to the risk of drowning.

After interviews and informal registration with residents of the city, many reported several points of flooding in the urban perimeter, where the most notable was the intersection of Av. Raul Furquim and Rod. Brigadeiro Faria Lima. Subsequently, in a visit to the site, it was found that after a moderate rain there was flooding in the region.

Both the absence and inefficiency of urban drainage systems lead to an excessive increase in the volume of surface runoff, which can be further aggravated by urban sprawl. This increase in the volume of surface runoff promotes floods that consequently bring with them enormous losses. The proposition of criteria to be assumed in the dimensioning of the galleries through a rainwater software, without any use of abacus, are integral parts of a calculation system that allows to fix diameter, slope, gallery coverage, as well as flow and flow velocity, in addition to ground elevations, gallery and manholes that will guide the construction of the network. Consequently, the work will focus on improving the social and cultural life of the entire population of Bebedourense.

The municipality has other areas that are similar to this, the problem is such that it is difficult to predict the system for planning and control. The current system should be studied for implementation of appropriate solutions. The present work aims to suggest possible structural measures to reduce urban drainage problems at the intersection.

The research had as general objective to analyze and size new stormwater galleries in the stretch under study, in the municipality of Bebedouro and the impacts caused by the deficiency and absence of the management process of these waters.

2 URBANIZATION AND SANITATION

In Brazil, for many years, as in other countries, urban drainage in large metropolises was approached in an ancillary manner, in the context of land parceling for urban uses. In most of these large metropolises, the growth of urbanized areas has been accelerated and only in some of them urban drainage has been considered a preponderant factor in the planning of their expansion.

Sanitation in almost the entire country is a challenging issue as a public policy for managers, especially municipal managers, who are directly responsible for promoting development and reducing social inequalities and improving the health of the community. For Guimarães, Carvalho and Silva (2007) sanitation is equivalent to health, because sanitizing means making healthy, healthy, that is, sanitation promotes preventive public health, reducing the need to seek hospitals, because it eliminates the chance of contagion by diseases.

Urban areas are the most human-modified environments where urbanization affects all parts of the hydrological cycle (Semadeni-davies et al. 2008). It promotes the removal of vegetation cover and sealing, increasing the volume and velocity of stormwater runoff and, consequently, the risk of flooding.

Several cities in the country present constant problems related to urban stormwater drainage. The increase in urbanization together with the lack of planning increases the risks of these problems. The need for urban planning related mainly to urban drainage, added to the changes that the environment suffers as a result of inadequate land use, are favorable ingredients for the generation of urban problems that are often difficult to solve and, in most cases, require costly structural measures (works).

Most Brazilian cities do not have inspection standards for urban drainage. For according to Tucci (2002), the Urban Master Plan exists for each municipality to introduce land use and environmental legislation, but hardly addresses urban drainage.

Planning or managing urban drainage systems involves managing a space allocation problem. Chaotic urbanization and inappropriate land use reduce the natural storage capacity of runoff, which in turn will require other places to occupy. Historically, the engineers responsible for urban drainage have tried to solve the problem of loss of natural storage, causing the increase in the speed of flows with channeling works (CANHOLI, 2014).

2.1 DATA FOR THE AREA STUDY

For this study, a search was conducted on the website of the municipality of Bebedouro/SP to obtain data regarding the flood region, master plan and pertinent information of the region. On the site was acquired only the complete map of the city of Bebedouro / SP, with the existing dimensions. Other data for the study of the site were made in loco by the company Geo-Top Precision Technology.

The study of the chosen area is characterized by the on-site survey of the water accumulation point. The sizing was carried out using a C3DRESNG calculation software, taking into account the contribution basin for the area of flooding. During this period the problem point was photographed and analyzed with different levels of precipitation.

The study area of the present work refers to an intersection between Av. Raul Furquim and Rod. Armando Sales de Oliveira, located in the city of Bebedouro/SP. The municipality of Bebedouro is located in the northern region of the state of São Paulo. According to the Brazilian Institute of Geography and Statistics - IBGE (2018), the municipality has a total area of 682.511 km² and an estimated 77,436 inhabitants.

The municipality of Bebedouro has a small stormwater gallery in the area in question (West), the study is being done based on visually collected information and theoretical and technical studies.

To determine the flows in the study area, studies developed by the Department of Water and Electric Energy of the State of São Paulo were used for the city of Barretos-SP, approximately 58km away from the site under study. The rainfall intensity equation was used, which relates intensity - duration - return period (frequency).

3 TOPOGRAPHICAL DATA AND INFORMATION

In the planialtimetric topographic survey, it was carried out with RPA imaging.

The work was developed at an altitude of 110 meters by drone, consequently processed by RPA.

The basic elements available for the preparation of this study are the following. Planialtimetric topographic surveys in the project area; Intense rainfall equation for the city of Barretos;

Climatological and Ecological Atlas of the State of São Paulo;

Attempt to evaluate surface runoff according to soil and vegetation cover in São Paulo State conditions;

Topographic maps of the city and IBGE at scales 1:2,000 and 1:50,000 respectively;

Visual Inspection - The project team went to the field and inspected the section under study in order to identify existing problems and assess local characteristics.

3.1 TECHNOLOGICAL APPLICATION OF RPA

Robotic Process Automation (or just RPA) is gaining increasing attention around the world. Using RPA tools, a company can configure software, or a "robot", to capture and interpret applications to process a transaction, manipulate data, trigger responses and communicate with other digital systems. RPA scenarios range from something as simple as generating an automatic response to an email to deploying thousands of bots, each programmed to automate tasks in an ERP system. The drone is controlled by the RPA system, drones are small unmanned aircraft also known by the acronym UAV (unmanned aerial vehicle). It is an aircraft controlled remotely by remote controls. Drones, applied to aerophotogrammetry, have built-in cameras in order to obtain aerial images that, together with other variables, are capable of generating topographic data with more details and speed compared to surveys carried out in a conventional way, such as Total Station or GNSS RTK, in addition to the usefulness of the generated image itself. In a few minutes the drone accomplishes a job that would take days with conventional topographic equipment.

Drones can be useful in several other segments, from applications with higher levels of specialization to everyday applications. These can be exploited in the areas of public and private security, mining, energy, real estate for surveys, mapping of various purposes, inspections for insurance purposes, construction monitoring and several other applications that are yet to emerge. Drones also offer many job opportunities for operators and professionals specialized in data processing and analysis. In addition to jobs, it is also estimated that many operating costs will be reduced and this can reflect directly in the pocket of the final consumer.

3.2 HYDROLOGICAL INFORMATION FOR THE SIZING OF THE STORM DRAINAGE NETWORK

Area of Contribution - (AD): 170 Ha Payback Time (T): 10 years

Calculation method used - Rational method

Name of the watercourse involved: Córrego do Mandembo UTM coordinates - SIRGAS 2000:

N= 7683220.81m E= 760086.76m

Geographical coordinates: Latitude: 20°55'59.40"S Longitude: 48°29'57.00"O

Hydrological Region (Parameter C): Y - (C7, M = 0.80)

Similar Hydrological Region: N Average Annual Precipitation: 1350mm

Figure 3.2.1: Contributing watershed

Source: Google Earth Pro

Figure 3.2.2: Site section

Source: Google Earth Pro

Figure 3.2.3: Flooding point at the intersection of Avenida Santos Drumond and Avenida Prefeito Joaquim A. Guimarães.

Source: Google Earth Pro

4 PARAMETERS FOR DETERMINING THE DESIGN FLOW RATE

The flooding point was considered to receive all rainwater from the catchment, which is not infiltrated into the ground.

To estimate infiltration, the RUNOFF coefficient of 0.70 (C=0.70 - Source DAEE - Department of Water and Electric Energy of the State of São Paulo) was adopted.

For the purpose of calculation, the slope was considered to be the greatest straight-line distance from the highest point to the lowest point in the catchment area.

4.1 RETURN PERIODS

A return period of 10 years was used, since only surface drainage devices were designed.

4.2 RECURRENCE PERIOD

The Period of Recurrence adopted for the areas under study, once the time of recurrence and the time of concentration of the sub-basin have been fixed, the calculation of the average intensity of precipitation will be carried out, considering the values referring to the various times of duration of the rain, which relate times of recurrence with the corresponding maximum heights of precipitation obtained through statistical studies of the hydrological data for the hydro meteorological station adopted.

4.3 RECURRENCE PERIOD

The runoff coefficient used for streets and paved or covered areas is equal to 1.0; for grassed and cleared areas equal to 0.60; and for areas covered with forest equal to 0.30. The coefficient used in the project was c= 0.70.O

4.4 CONCENTRATION TIME

This is the time taken for all parts of the catchment to contribute to the measured drainage section from the start of the rainfall.

In other words, it is the time it takes a particle to flow from the furthest point of a basin to the section considered.

By the very design of the Rational Method, the time of concentration will be equated to the duration of precipitation. The error in estimating the time of concentration will be more serious the shorter the duration to be considered, the greater the variation of intensity with time. For large durations of time of concentration, the variations of intensity with equal increments of time are much less important.

The following are the parameters of the drainage basins to be considered:

- Basin area;
- Length and slope of the main channel (the longest);
- Shape of the basin;
- Average slope of the terrain;
- Roughness of the channel;
- Type of plant cover.

For urban drainage projects, the time of concentration will be calculated as being composed of two portions, which are:

a) Time of surface runoff:

It is the time taken by the water precipitated at the furthest points of the basin to reach the first manhole.

This is the time it takes for water to travel over roofs, gutters, sidewalks, etc.

This time will be between 3 and 20 seconds. According to recommendations made in the "Report of the Study for Erosion Control in the Northwest of the State of Paraná - OAS/DNOS".

"This value should not exceed 10 minutes (initial time). In the project in question, this limit value was adopted for the sizing of the collectors".

b) Travel time:

This is the flow time inside the conductors, from the first manhole to the section under consideration. This time can be calculated taking into account the average velocity of the flow in the collector and the length of the route based on the MANNING formula.

4.5 RAINWATER NETWORK PARAMETERS

a) Minimum flow velocity in concrete pipe: v = 0.75 m/s

b) Maximum flow velocity in the concrete pipe: v = 5.00 m/s

c) Coefficient of roughness considered for concrete: n = 0.015 s/m

d) Diameter and Slope adopted for the pipe connecting the manholes to the manholes or junction box is: 0.60 m and 0.80 m for branches and 1.50 m and 2.00 for the main network, maximum slope of 9.50 % respectively.

e) Maximum distance between manholes: 150 meters

f) Minimum pipe coverage: 0.80 meters

4.6 PRELIMINARY SERVICES

The work will be carried out according to specifications that comply with the construction standards and, in compliance with the drawings and details of the project prepared by the company with the approval of the inspector.

The structural design, architectural design and descriptive memorial are complementary to each other, and the contractor must, when submitting his proposal, declare that he has not found any divergence between them, nor doubts in the interpretation of the details.

Any services not approved or which are defective in execution will be demolished and rebuilt at the contractor's expense.

Materials that do not meet the specifications or are deemed unsuitable will be removed from the construction site within 48 hours of the determination of the supervisory engineer.

4.7 STRUCTURE

An energy dissipator was planned at the launch site, with a wing, hydraulic ladder and dissipation in marble stone with cement mortar. In the frontal stretch to the launching flow in the two banks of the LD/LE watercourse, the execution of 30m of gabion was foreseen so that the launching of the adequate water flow is carried out without causing environmental damage of loading of solid, organic material and water erosion in the watercourse in the stretch, emphasizing that the angle of arrival of the GAP in relation to the watercourse in the downstream launching stretch, was designed in such a way that the arrival of the GAP network in the watercourse is at an angle less than 45 ° degrees.

Figure 4.7.1: Energy sink.

Source: Developed by the authors

Figure 4.7.2: Sink with brownstone.

Source: Developed by the authors

5 RESULTS

Contribution time

For contributing areas Kirpich's formula, published in California "Culverts Practice" (1956), was used, expressed as:

Tc = 57 (L2 / I) 0,385

Where: L = Length of the route in (km); I = Slope of the watercourse in meter (km);

Tc = Time of concentration of the basin in minutes; Substituting the values in the above expression, we will have:

$$Tc = 57\left(\frac{L^2}{I}\right)^{0,358} = 25\ min$$

The minimum concentration times to be adopted are as follows: Griddle culverts: 5 minutes.

From the starting point of the drainage system, the flow travel time calculated using the kinematic method must be added, as shown below:

$$tp = te + \left(\frac{L}{60V}\right)$$

Where: inlet minimum concentration time (laminar phase) (min); tp: travel time (min);

L: length to be covered by the runoff (m); v: runoff velocity (m/s);

Substituting the values in the above expression, we will have:

$$tp = 5 + \left(\frac{300}{60.5}\right) = 15\ min$$

5.1 CRITICAL RAINFALL

For the calculation of the critical rainfall, the value of "Tc" calculated in item 4.1.1.2, return period of 10 years will be used.

The calculation of the critical rainfall intensity (i), for the location closest to the dam construction, will use the critical rainfall intensity equation of Barretos - SP, given by the following expression:

I= 17.78. (Tc+20) ^-0.834 + 4.98. [(Tc+20) ^-0.834. ln (T-0.50)]

I= 2.215 mm/min or 132.90 mm/h

Where: I = critical rainfall intensity (mm/min); Tc = Time of Concentration (min)

T= Payback period (10 years)

5.2 FLOOD FLOW CALCULATIONS

The design flows were calculated using the indirect method of the Rational Formula, due to the small partial areas of contribution.

This method is applied to calculate flows for areas up to 200 ha. Its fundamental concept is that the maximum flow occurs when the entire basin is fully contributing and the rainfall intensity is constant and uniformly distributed throughout the basin area.

(Drainage area AD ≤ 1.70 km2).

$$Qp = 0{,}1667\,.\,C.I.AD$$

Where: Qp = Flood Flow (m3/s)

C = Runoff coefficient (c=0.70)

I = Critical rainfall intensity (mm/min) - 2.215mm/min A = Catchment area (Ha) - 170 Ha

D= Coefficient of spatial distribution of rainfall (K=0.99) Substituting the values in the above expression, we will have:

$$Qp = 0{,}1667\,.\,0{,}70\,.\,2{,}15\,.\,170\,.\,0{,}99 = 42{,}22\ m^3/s$$

Urban infiltration rate: 14%, therefore:

$$Qp = 36{,}31\ m^3/s$$

The above expression assumes the fundamental concept that the maximum flow, caused by a rainfall of uniform intensity, occurs when all parts of the basin start contributing at the collector section or point.

This reasoning ignores the complexity of the processing of runoff, not considering in particular the storage of water in the basin caused by the type of terrain, as well as the average slope of the basin and the variations in intensity and coefficient of runoff during the course of the rainfall period.

5.3 HYDRAULIC DIMENSIONING

The dimensioning of drainage devices, especially the grating culverts, becomes feasible after the detailing of the executive geometric design.

The elements for the hydraulic design of drainage devices are:

The Manning's Formula associated with the Continuity Equation was used to determine the water level and flow velocity in the culverts, as well as for the design of gutters, ditches and channels, as follows:

$$V = \frac{Rh^{2/3} . i^{1/3}}{n}$$

Where: V= flow velocity, in m/s; i= longitudinal slope, in m/m; Rh= hydraulic radius, in m;

n= roughness coefficient;

Substituting the values in the above expression, we will have:

$$V = \frac{0{,}196^{\frac{2}{3}} . \ i^{\frac{1}{3}}}{0{,}015} = 3{,}18 \ m/s$$

The project presented here is justified by the recent occurrences of flooding in the region. The contribution basins in the region have Raul Furquim Street as their normal course of rainwater. At the lowest point of the street, at the intersection with Rodovia Armado Sales de Oliveira, there is the highest concentration of water, where the greatest number of accidents occur.

The urban area has gutters, culverts, manholes and galleries in the streets, being the main hydraulic structures responsible for collecting and disposing of surface water from rainfall. The total of these units are not sufficient for the entire urbanized area of the region, and are therefore non-existent in some points. Thus, there is, as in other Brazilian cities, little use of this type of hydraulic structure, mainly galleries and manholes, with the function of receiving, collecting and disposing of rainwater generated in the urban environment.

Where microdrainage structures are insufficient, rainwater tends to flow exclusively over existing gutters or the roadbed, contributing to its deterioration and compromising the quality of life of the local population.

Some of the floods are observed in the field are presented in the following Figures.

Figure 5.3: Flooding at the intersection of Raul Furquim and Rodovia Armando Sales de Oliveira.

Source: Developed by the authors - Photos taken in the city of Bebedouro-SP.

6 CONCLUSION

The present work demonstrated that the problems related to urban drainage at the intersection of Raul Furquim Avenue and Rod. Armando Sales, possibly refer to the sizing of the rain galleries, aggravated due to the lack of drainage system.

The manholes are insufficient for the flooding problems, they are not able to withstand the average rainy days.

The stormwater galleries were incompatible with the current urban development, the grading depths would be too high for the existing pipe, as well as the velocity is excessive due to the slope of the terrain.

These problems have their collapses observed at the lowest point of the drainage system, which is at the studied intersection, and as the galleries cannot drain the water during heavy precipitations the stretch is flooded.

The galleries need adjustment and a new dimensioning, the present work suggests a new storm drainage dimensioning project. Other solutions to reduce the problem would be the construction of rainwater retention areas, use of permeable asphalt, other structural and non-structural measures.

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