Sistemas & Gestão 12 (2017), pp 215-220

SYSTEMS & MANAGEMENT
Electronic magazine

MANAGEMENT OF WATER RESOURCES FROM THE PERSPECTIVE OF URBAN DRAINAGE PLANNING AND LAND USE: THE CASE OF THE BASIN OF TRAPICHE RIVER, IN ITAGUAÍ

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ABSTRACT

In half century, an unbridled process of urbanization converted a rural population into a concentrated mass mainly located in the cities of Brazil. The process is characterized by the lack of planning, allowing the occupation of fragile/inadequate areas, not taking into consideration the necessities for infrastructure, such as providing the new homes road access, nor connection to the public sewage system. Until today, many cities use rivers to transport their sewage, worsening the environmental quality and capacity for water flow. The difficulties to confront these and other many challenges are even harder due to the diversities of competencies involved in the solutions. The management of water resources is one example of the necessity to integrate many systems: a drainage plan can work as an integrating element while dealing with aspects of sanitation, waste, land use, and macro-drainage. Behind this aspect, this study presents the development of the planning for macro-drainage based on the case study of the Basin of Trapiche River, located in the Brazilian city of Itaguaí, using simple models, which are low cost and more accessible, for example, for small budget town halls. It was emphasized the use of non-structural, sustainable steps as means to support the management, increasing the capacity of infiltration and damping of the basin. The objective is to minimize the impacts of flood peaks, the frequent floods, and the risk of claims in Downtown basin, where the main administrative and commercial activities of the city are located.

Keywords: Water Resource Management; Drainage.

1. INTRODUCTION

With the growth of the demands of present urban communities, and starting from the premise that preventive actions are always more efficient and economically more viable than the remediation ones, it has been demonstrated the necessity to perform a more effective planning, which captures the desires of a diversifying society, such as the modern one. In many aspects, this planning must take into consideration the demand for integration of many policies, plans, and projects, besides the participation of various agencies from public administration, and their respective competencies.

Recently, the necessity for planning and the integration of the relevant urban issues, such as the adequacy of proper sanitation, the management of solid waste, and drainage plans took the federal government to demand the Brazilian municipalities to design their respective Municipal Sanitation Plans, giving an emphasis to institutional integration of Environmental Sanitation, including the provision of water, sewage system, pluvial water management, and solid waste.

Together with the demands of gradual expansion of the fields of municipal administration, there is an increase in the challenges the local agencies have in managing and operating all these systems. The cities are facing crescent difficulties in managing and planning, thus being required to get equipped and trained to perform the vast number of new attributions. This occurs at the same time they live with the notorious lack of resources and trained staff to properly respond both the new and the old responsibilities.

In regards to the management of water resources, it is a competence linked to the state agency (in Rio de Janeiro, the INEA), and to the Committees of Hydrographic Basin, besi-

PROPPI / LATEC
DOI: 10.20985/1980-5160.2017.v12n2.1097

Electronic Journal of Management & System
Volume 12, Number 2, 2017, pp. 215-220
DOI: 10.20985/1980-5160.2017.v12n2.1097

des these committees are not directly responsible for creating legislative pieces to respond to fundamental questions in order the management is fully functional, thus leading to a not so effective presence. The aspects, such as the management of land use, solid waste, and urban drainage belong to the municipal competence (INEA, 2014).

Except from the work of some committee of the most important basins, and even with a Basin Plan, the planning and performance of actions and measure is performed primarily by the state agency, except for the federal rivers. On the other side, few cities have specific agencies to manage water resources, in which drainage is part of the responsibilities of a pubic construction and/or public services department.

According to Canholi (1995), drainage is basically a matter of allocation of spaces and the prioritization of "sanitation" measurements by transporting the problems from the city downstream. For many times, the rivers transcend the geopolitical-administrative limits of the cities, and sometimes states, thus drainage must be considered as a regional approach system, being the hydrographic basin the basic unit for planning.

The proposal to plan an urban basin, taking into account the issue of flooding, is linked to the perception that are both issues to be solved and opportunities to be explored (Prefeitura de São Paulo, 2012). Drainage is part of the urban infrastructure and its planning must be multidisciplinary and compatible with other plans and projects of the segments involved in public (and private) service, especially those aimed and/or that have an interface with urban waters management. This alignment must always occur in issues that involve the need of an integrated action of the spheres of governance, aiming to prevent and/or minimize the floods, as well as in the delimitation of the protective marginal band of river bodies. It is important to have a consonance with the zoning plans, municipal directory plans, and other correlated documents.

As preponderant factors in the planning of urban drainage there are environmental sanitation, besides the social, political, economical, institutional, and administrative issues. The definition of drainage in more sustainable basis consists in giving privilege, in the structuring of the planning, the emphasis that large constructions and interventions are not necessarily a priority, giving more emphasis to non-structural measures (Canholi, 1995), in special considering short- and medium-term horizons.

These non-structural steps include various types of action, such as those that implement the conservation and the recuperation of the natural environment. The aspects of systemic order are prioritized, such as the increase of permeable areas in the basin to promote more infiltration, more retention in the source, besides trying to reduce the erosive and silting processes. Its main purpose is to hold and/or reduce the run off, to increase the natural capacity of basin damping, thus reducing the consequence of flow peaks, avoiding the simple transference of impacts and issues of the floods to the upstream, which usually happen when prioritizing constructions that increase the speed of flow and reduce the time of concentration in the basin.

The zoning of potentially flooded areas and the delimitation of protected marginal bands are other mechanisms that can be used. According to Tucci (2010), through the delimitation of areas due to the risk of flooding, it is possible to establish a zone and a respective regulation for construction, or ultimately, a complete prohibition. This type of approach also considers other aspects not less important that the presented ones, such as the improvement in management and maintenance of the system, besides a higher participation of the community covered.

On the other side, the use of this model does not necessarily imply in a total suppression of structural measurements that may be required. Structural measurements are defined as those corresponding to constructions and physical interventions that can be implemented aimed to the correction and/or the prevention of issues originated from floods, and also include other actions, such as increase of section and retilinization of rivers, implementation of damping structures, diversion tunnels, among others. (Canholi, 2005).

In a general sense, the costs of protection of a flooded area through structural measurements are higher than the non-structural ones. According to Walesh (1989), the estimated cost of structural measurements related to the protection against flood of an area corresponding to a third of a basin was, in average, the cost of protection by non-structural measurements of the rest of the area of the same basin. Canholi (2005) supports that, on one side, a certain structural procedure can create a false sensation of security, leading eventually to a higher permissiveness in permitting a higher occupation rate in the flooded areas, which in the future can result in significant loss and damage.

Still according to Canholi (2005), non-structural actions look to discipline land occupation, the behavior of consumption of people, and the economic activities. They include the mechanisms present in legislation, rules, and management to fulfill the objectives, principles, and strategies, as for example, the regulation of the use and occupation of the land, the implementation of alert systems and flood forecast, and the consciousness of the population to keep the drainage devices in a good state.

The present study presents a case of municipal management and planning, with a focus on the water resources,

Electronic Journal of Management & System
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DOI: 10.20985/1980-5160.2017.v12n2.1097

giving privilege to the aspects of local competencies, such as pluvial drainage and land use and occupation, as well as steps based in a broader sense of sustainability.

When dealing with projects aimed to urban drainage, it is seen there is no availability and/or sufficiency of river data. Therefore, it is necessary to perform the mathematical analysis to define the parameters of the project in a non-empirical format, using simulations and models for this purpose. These models are fed in the beginning by physiographic, rainfall, and hydrological data, thus generating flow and deflution data required to subsequent hydraulic simulations. These models permit to prevent and study scenarios that can come to reality due to a number of factors, variation of parameters, such as time of reoccurrence, or even the result of a certain intervention in the basin.

In the present study, the specific objective was to observe the viability of the use of hydrologic and hydraulic model as a planning tool, using it to evaluate the impact of non-structural interventions in a real drainage basin of Viana Channel, part of the Trapiche River Basin, located in the town of Itaguaí.

General considerations about the area of the project

Located at the margins of Sepetiba bay, and having the largest port of the state of Rio de Janeiro, Itaguaí is a municipality in full development. It presently counts with large public and private investments, especially due to its strategic location, once it is placed between the two largest metropolis of Brazil. The demographic growth rate is one of the highest of the state and the country (IBGE,2010). However, in important requisites the municipality of Itaguaí does not have a proper urban structure, being the sanitation system yet too precarious. The city has a HDI score of 0.715, in the 1,475th position of the rank, against all cities of Brazil (PNUD, 2010).

As there is no sanitary sewage system from the absolute separator system, the effluents flow to the local rivers (CEDAE, 2014). The demand for water is repressed, being considerably higher than the offer, according to data from local town hall. In the case of a higher offer of water, the tendency is the considerable increase of the flow of effluents. Without the implementation of a sewage system, this effect will certainly lead to a worst deterioration of the environmental quality of water bodies, which are already noticeably compromised.

In regards to the solid waste, there is regular garbage collection, being the final destination presently done in the landfill located in the neighboring city of Seropédica (Prefeitura de Itaguaí, 2014). Itaguaí belongs to the hydrographic region of Guandu River.

Its main drainage basins are the Itaguaí River, the Mazomba-Cação River, and the Trapiche River, all flowing directly or indirectly to Sepetiba Bay. Besides they do not have a famework, the water bodies mentioned are not monitored, and there is a considerable lack of information regarding them, except for the Mazomba-Cação River (INEA, 2014).

With almost 100% of its basin of 9 km^2 waterproofed, the Trapiche river has in its main course, around 5 km, inserted in the central region of the municipality, exactly where is located the administrative and commercial center of the city. Its margins and tributaries are almost completely occupied with informal buildings.

The landscape and the physiographical conditions, which add steep mountains upstream and sea-level plains, with low alveolar slope, allied with an elevated rainfall intensity, generate flood peaks in relatively short periods of concentration.

The elevated degree of waterproofing and the occupation of river banks and nearest areas due to the process of uncontrolled and unplanned urbanization contribute to create a scenario that is likely to flood, as observed in the history observed, there is a tendency to believe they will become more intense and more frequent. The situation is worse when these events are associated to an elevate sea level of the main water body receiver, the Sepetiba bay.

2. METHODOLOGY

This research was supported in the development of an initial step, related to the calibration of a model to be used in the design of a drainage plan for the whole basin, which is made by the three rivers previously mentioned.

Having a general base chart in hands, the sub-basins were defined, considering the topographic divisions. Then, it was analyzed the typology of the characteristic areas of each sub-basin, from certain parameters.

It was considered aspects such as the predominance of land use (if rural or urban), degree/level of occupation of the margins and longitudinal angle of the main thalweg. For this purpose, preliminary available topographic and bathymetric data was used, as well as tools such as Google Earth's Street View, besides a considerable amount of photographical documentation from the location.

Due to its higher complexity, it was decided to take as initial reference for the present study the observation of the basin of Trapiche river. To better understand and analyze, it was divided in three smaller basins, according to the main tributaries. These sub-basins were named according to the

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rivers/channels that compose them: basin of the channel of the Engenho district, Viana channel, and Trapiche river itself, with total areas of 3 km², 2,5 km², and 3 km², respectively.

Later, they were again subdivided, according to the definition of notable points ("knots"), in which specific points were chosen arbitrarily, such as bridges/section bottleneck, confluences, and affluence of the bay/external contribution. In the basin of the Trapiche river were found a total of 18 different sections.

Considering the Viana channel one of its main tributaries, as well as its larger amount of data for an initial model of the scenarios, it was adopted as pilot and base for modeling suggested by the present research.

To continue building the necessary models, and to analyze the sections of the river and the area of study, it was defined as hydrological model the rain-flow transformation, acquiring the data from the resulting hydrograph of the effective rain, calculated by the SCS Runoff Curve Number method. The rain-flow transformation was performed by the SCS single hydrograph method. For the periods of reoccurrence of rain during the project, it was defined a return period varying from five to 50 years (five, 10, 25, and 50 years), common in urban drainage studies.

For the hydrological model, the present study used the hydrological simulation software HEC-HMS, from HEC (Hydrologic Engineering Center) systems, developed by the US Army Corps of Engineers, vastly widespread and used in projects of this nature. It is a free software, which makes it considerably easy to be used. From the entry data, such as the projected rain, physical and hydrologic parameters of the basin, and hydrological information of the model selected, the chosen software calculated the excessive precipitation and simulated the rain-flow process.

For the hydraulic simulations, it was used the HEC-RAS software, also developed by the US Army. Based on the available topography, it was analyzed the flow capacity according to the gutter, bottleneck points, and other characteristics that directly influence the hydraulic performance of each studied section, including the evaluation of backwater, and natural damping of the water body.

From the models and the cartographic base, a digital terrain model (DTM) was built. The DTM was generated using the ArcGIS 10.2 software, from the equidistant curves set in 1 meter, and points provided from a topographic base acquired from the software Global Mapper, using IBGE cartographic bases.

From the definition of the development model of the hydrologic and hydraulic study, as well as the maximization of its usage, a preliminary evaluation was performed, using a pilot area from the basin of Viana channel.

Then, the comparison of the present baseline and future scenarios took place, which can be reached from the planning and adoption of certain procedures aimed to improve the conditions for basin's drainage, minimizing the resulting flood spots and risks for flooding. It was considered that these improvements can be reached from the increase of infiltration rates and damping of the basin as a whole, through the adoption of non-structural interventions.

To subsidize this simulation, starting from the premise that the use of instruments such as zoning of risk/flood areas, creation of linear city parks, and the incentive to measures that protect and/or reinstate the riparian forest and other forest cover can lead to an increase of the infiltration area in 50% of the total area of the basin. Such infiltration also had a side effect by reducing significantly the CN measured in areas of the basin of Viana channel, which in the present scenario has a CN rate of 95% in the waterproofed basin. With the change in CN, it was possible to observe and to evaluate the results in the hydraulic model. As a safety factor, it was not considered a reduction in the permeability of the external contributing basin to the Viana channel.

Simulations took place for this basin using the referring rain results on the extreme TR, which means, from five to 50 years. Thus, it was possible to evaluate its behavior for the minimal and maximum flow estimated in the channel under investigation.

3. SYNTHESIS AND COMPARISON WITH THE RESULTS FOUND

The data acquired from the model and comparison of the two basic scenarios observed (Chart 1) indicate that with the increase of infiltration predicted for the basin, there was a clear reduction of the drainage flow in all sections studied, except for the section referred as external basin (VI-01), as it was kept under the same present waterproofing conditions. Considering the total drained flow, and the run off from downstream, only the increase of permeability/infiltration was responsible for the reduction of around 20% of the flow related to the rain, corresponding to the rain with reoccurrence period of five to 50 years, respectively.

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DOI: 10.20985/1980-5160.2017.v12n2.1097

Chart 1 - Flow rates observed by section of the Viana channel for TR from five and 50 years

Characteristics of the Basin of Viana Channel			Scenario 1 (present)		Scenario 2 (50% waterproof)	
Knot	Description	Drainage area (km2)	Q5 (m3/s)	Q50 (m3/s)	Q5 (m3/s)	Q50 (m3/s)
1	VI-01	0.90	12	18.5	12.0	18.5
2	VI-02	0.29	5.1	8.6	3.1	5.8
3	VI-03	0.62	12.8	2.4	7.7	15.7
4	VI-04	0.80	16.4	28.9	9.9	20.2
5	VI-05	0.12	2.4	4.3	1.4	3.0
6	VI-06	0.02	0.4	0.6	0.2	0.4
7	VI-07	0.06	1.3	2.2	0.8	1.5
8	VI-08	0.22	4.5	7.9	2.7	5.6
9	VI-09	1.03	37.7	65.2	31.1	55.8

However, this decrease does not show itself enough to mitigate the generated flood spot, once the water lines corresponding to the extreme rain scenarios adopted in the model (for five to 50 years) extrapolate in every dimension the capacity of flow of the water body under investigation (Images 1 and 2).

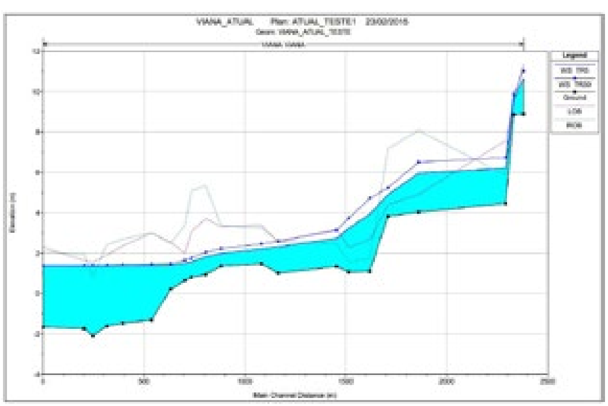

Image 1 - Water lines for 95% waterproof of the basin of Viana channel (present scenario)

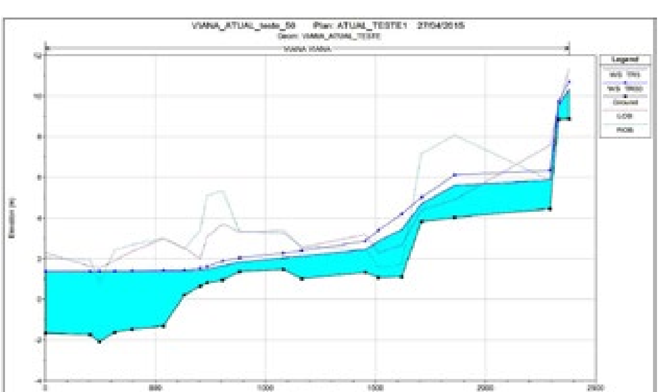

Image 2 - Water lines for 50% waterproof of the basin of Viana channel (future scenario)

The most critical section identified was located between the Emiliano Neri Street and Professor Luis de Souza Street, where the water lines predicted indicate significant overflow for both periods of reoccurrence investigated. Therefore, in parallel it was necessary the use of structural procedures in these locations. Such adequacies aim to increase the capacity of flow in critical areas, from interventions as the increase of river gutter, suppression of existing bottlenecks, among others.

Even with the necessity to provide outflow for higher peaks, the sessions located downstream do not presented more issues, seen by the good capacity for drainage of the gutter in these places, where the local government performs periodical dredging.

4. CONCLUSIONS AND RECCOMENDATIONS

Despite the results are considered preliminary, and are focused on a specific segment of the whole basin, it can be observed that the methodology and the model used answer the basic demands of a more generic study with the characteristics of a Plan, and they can work as the base for the whole project. The data acquired by the present diagnose – based on the methodological script presented – has demonstrated to be pertinent and consonant to the information gathered from technicians who work for the city hall and the residents interviewed by the field research teams. The methodology has found to be agile and easy to manipulate.

Notwithstanding it is important to highlight that the model presents some restrictions, as for example, the necessity of a larger number of control sections and a higher precision of this information. Therefore, in the model, it is necessary to include other elements, such as the influence of the various levels of the tide of the receiving water body, and the interventions that change the characteristics of the run off, such as preventive dredging performed by the local government.

The many scenarios passible to be generated can create the limits to improve planning, and to define the priorities and the decision making process. Through the pilot model of the main area of the project was possible to identify the existence and location of critical places of Viana basin, compatible with the observations made in field visits performed until the present time.

It was also observed that the main drainage issue of this basin – the overflow in certain locations – was seen in the upstream section, exactly where it is most densely occupied. This area is characterized by its riversides almost completely occupied by edifications, besides a large concentration/presence of sewage effluents in the drainage system.

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If the present model of disorganized occupation, without any control of the land use in the basin, specially nearby the riverbank, the processes of higher densification and waterproofing, with crescent number of bottlenecks, besides the undesired collateral effects, such as the increase of silting. These factors implicate in the increase of the probability of events of more intense flooding, and the risk of more damage and losses on the population.

If well applied, the zoning and the management of floodable riverbank areas are important instruments of relatively low cost that can contribute significantly in both the improvement of the general conditions of the basin and in better conditions to face the problems caused by the floods. There will be a reduction of the social and economic costs, of the problems and risks to public health, and the occurrence of illnesses transmitted through the water.

However, for the present case – Basin of the Viana – the non-structural measures do not seem enough to stop flooding, accompanied by structural interventions and constructions, such as the increase of the gutter or the implementation of structures to damp floods.

It is recommended, first, that the sequence of work is followed, going deeper in the study of the rest of the Trapiche's basin, and then, the rest of Itaguaí's basins, which will provide more consolidated information to elaborate a flood control plan. Through a DTM, and through the interface of ArcGis software, it is possible to perform a better evaluation of the results/scenarios, determining in a plan the reach of these floods, and evaluating the population to be hit by these events from the dimensions of the flood spots correspondent to a flood caused by a reoccurring rain.

Among other issues to be modeled/evaluated in sequence, are: adoption of the estimated future population by the method of urban saturation, respecting the different existing demographic densities; to evaluate the different scenarios considering other periods of reoccurrence (10, 15, 25, and 50 years), as well as scenarios that demonstrate the impact of different combinations of non-structural and/or structural measures.

Starting from the principle, seen in the field, that one of the major issues of the basin studied is the improper disposition of solid waste and sewage in the rivers, creeks, and channels banks, the drainage planning incurs in the necessity to have more compatibility with other aspects of the management of water resources and urban planning, among those in special the ones related to sanitation systems.

REFERENCES

Canholi, A. P. (1995), Soluções estruturais não convencionais em drenagem urbana, tese de doutorado, Escola Politécnica, Universidade de São Paulo, São Paulo.

Canholi, A. P. (2005), Drenagem Urbana e Controle de Enchentes, São Paulo: Oficina de Textos.

CEDAE. Companhia Estadual de Águas e Esgotos (2014), available from: http://www.cedae.com.br/ (Access 2015 AUG 14).

IBGE. Instituto Brasileiro de Geografia e Estatística (2010). Cidades. Rio de Janeiro: Itaguaí, available from: http://www.cidades.ibge.gov.br/xtras/perfil.php?lang=&codmun=330200&search=rio-de-janeiro|itaguai (Access 2014 SEP 18)

INEA. Instituto Estadual do Ambiente (2014), available from: http://www.inea.rj.gov.br (Access 2014 AUG 14).

PNUD - Programa das Nações Unidas para o Desenvolvimento. Atlas do Desenvolvimento Humano no Brasil. Itaguaí, RJ, available from: http://www.atlasbrasil.org.br/2013/pt/perfil_m/itaguai_rj (Access 2014 JUL 20)

Prefeitura de São Paulo (2012), Manual de drenagem e manejo de águas pluviais: gerenciamento do sistema de drenagem urbana, São Paulo, available from: http://www.prefeitura.sp.gov.br/cidade/secretarias/urbanismo/biblioteca_digital/manual_de_drenagem/index.php?p=49018 (Access 2015 MAY 26).

Prefeitura Municipal de Itaguaí (2014), available from http://itaguai.rj.gov.br/ (Access 2014 SEP 15).

Tucci, C. E. (2010). Urbanização e Recursos Hídricos, em: Bicudo, C., Tudizi, J., Scheuenstuhl, M. (Org.). Águas do Brasil: Análises Estratégicas, São Paulo, Instituto de Botânica, pp. 113-128.

US Army Corps of Engineers (2012), HEC-GeoRAS: GIS Tools for Support of HEC-RAS using ArcGIS User's Manual.

Walesh, S. G. (1989), Urban surface water management, New York.