

# THE IMPORTANCE OF PHYSICAL INDICATORS IN AREAS OF URBAN FLOOD

## THE CASE OF THE METROPOLITAN REGION OF BELÉM

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The city of Belém, Pará (PA) suffers the problem of unplanned settlement around its rivers. Therefore, the access to the rivers has become difficult. There is a lack of governmental plans to promote the anticipation of feasible investigation and solutions to urban flooding. The purpose of this study is to identify the physical characteristics of the hydrological resources of this urban area in order to establish physical and spatial indicators. To describe the study site, flooding areas were located and the application of statistical analysis was necessary. After the descriptive analysis was done, a profile was verified, where the most critical points are pointed by the survey data. In Pearson's chi-squared test the variables which showed the greatest correlations were settlement density and canal characteristics. In short, in areas with higher population density a greater quantity of household and building waste are found in the canal. These areas are also characterized by low-income from the population and an unorganized settlement. By identifying the sites where floods occur in the urban area together with the proposed solutions, the respective authorities or institutions could carry out actions that would improve life quality of the local population.

**Key words** - Urban Area, Urban Pollution, South American, Rivers, Sea Level.

### I. INTRODUCTION

The rapid urbanization and the lack of planning has been responsible for various problems within the Brazilian urban centers, especially those related to the sewage system and urban drainage basins. According to the Brazilian Institute of geography and statistics [6], over 99% of the population of the city of Belém/PA live in urban areas concentrated around its rivers, which slows down the access to them (Figure 1).

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(a)



(b)

(c)

**Fig. 1**– (a) Belém City Plan; (b) and (c) aerial view of the city of Belém. Source: Macapuna (2009).

One of the impacts of increased unplanned settlement in the urban part of Belém can be observed in the artificialization of basin-total freshwater drainage, contrary to the stipulations within the forest law. In this respect, the forest law specifies that the area of spring, which is understood as the place where water upwelling occurs on the surface of the lithosphere at the head of the river micro-basin, must have a security radius of 50 m without occupation. It is important that around the water course a riparian forest can develop, since this has important hydrological and ecological functions, such as soil protection, water management, conservation of biodiversity, wildlife shelter, maintenance of water quality and the regularization of water courses.

The problem of disorderly occupation around the water courses in the city of Belém, notoriously has not received proper attention by the public authority, essentially regarding to research and investments in projects of anticipation to urban flooding. Although the conditions and the socio-economic and environmental knowledge have a duty to act in an integrated

manner; it can be seen that the role played by the institutions not always takes into account this integration in developing public projects for the population, particularly with regard to sanitation and urban drainage.

It is in this context that this study focuses on: understanding the management of watercourses in the metropolitan region of Belém; subsidizing the integrated management of natural resources in urban watersheds; contributing to the planning and management of regional water resources; raising socio-environmental awareness of the population and government.

## II. GOALS

The research aims to characterize in a general form, physically and spatially the water resources in urban area of Belém-PA, considering the problems related to urban drainage systems infrastructure and the difficulties of operation and maintenance of these systems.

The specific objectives of analysis are restricted to:

- Analyze using Geotechnology for mapping flooding vulnerability of the city of Belém-PA;
- Ascertain the socio-economic impacts on which the population of Belém is subject.

The result of this work can be a further contribution in raising awareness of the development of flood risk management plan for the city of Belém in planning its territory and land-use and on minimizing human and material losses.

## III. METHODOLOGY

The methodological procedures were divided into 5 main steps: bibliographical analysis, constructions of data collection worksheets, on-the-spot visits, GPS, data collection on and analysis of collected data.

The analysis of bibliography and an on-the-spot visit enabled to make the description of the study area and locate the critical areas of flooding in the city of Belém. Then the correlation of variables used in the process of data collection for the study area was calculated, which permit to achieve a profile with the most critical points of flooding the urban area. These indicators, chosen on the basis of the natural characteristics of the area under study, showed a significant value in the statistical analysis to the hydrological or social risk assessment.

SPSS software was used and Excel 2007, version 17.0 for descriptive analysis and correlation test, and Pearson test.

## IV. RESULTS

Based on field work in Belém and analysis of demographic variables, we defined the process of the selection of the sample to investigate, having been chosen 41 points. To construct the physical indicator we used the following variables:

- condition of the road,
- channel type,
- density of occupation,
- housing type,
- characteristic of the channel.

Each variable was categorized and valued as follows:

- Condition of the road: not paved (1), paved (2), mixed (3), other (0);
- Type of channel – Natural (0), sinuous (1), rectilinear (2), ground (3), underground(4);
- Stocking density – less (0), dense (1), much (2);
- Type of housing - wood (1) Masonry (2), mixed (3);
- Analyzed characteristics of the channel - riparian vegetation (0), siltation (1) water catchment (2), trash and debris (3), artificialization margin (4).

For the physical gauge construction the following variables were used: track condition, channel type, density, housing type, characteristic of the channel. The results obtained for each of the variables can be observed in Figure 5 to 1 Graphics 2.

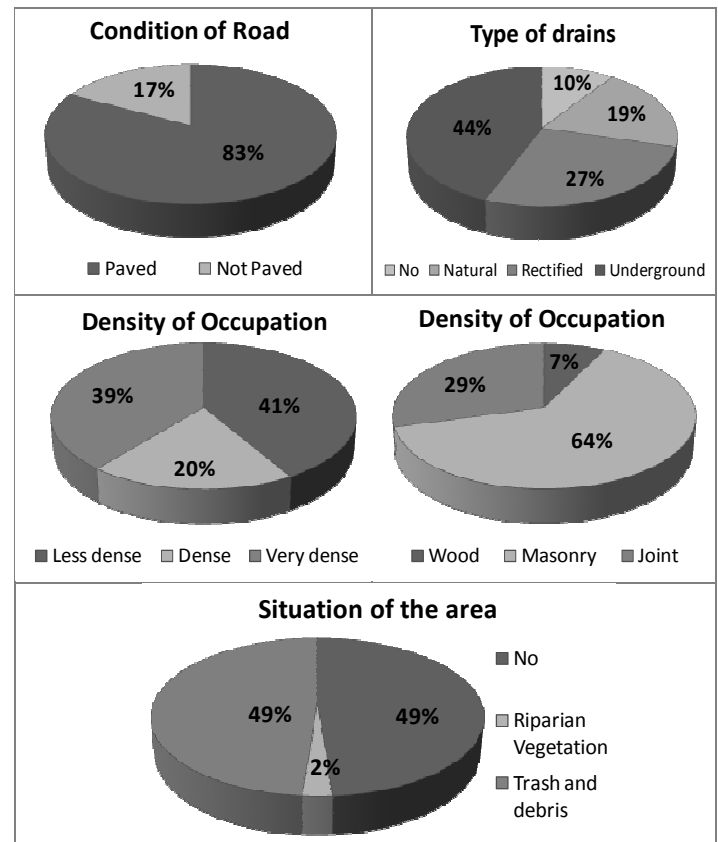


Fig. 2 – Pie charts illustrating the variables used for the construction of physical indicator.

The graphs in Figure 2 revealed the following findings:

- 83% of surveyed area is paved;
- the most frequent type of drainage is underground drainage and/or shallow with 44%;
- the "density" prevailed less dense with 41% considering the sign of the house above 4 meters followed by very dense 39% considering the sign of the house with less than 3 metres;
- the villas of masonry are prevalent with 63%;
- almost 50% of the channel is blocked by garbage and rubble.

The analysis of graphs characterizes the channels and show that most of them are paved pathways, with underground drainage or superficial, contained less dense population occupying the very dense, being primarily in masonry houses.

An obvious problem in most visited channels is the occurrence of residues of various origins. Only in the year 2011, more than 32 thousand tons of waste has already been withdrawn from canals, ditches and storm drains, such as mud, rubble, garbage, refrigerator, sofas, telephones, bicycle tires, dead animals and scrap cars [14].

In Pearson's test, which achieved the largest variables were occupying density correlations and channel characteristics, that is, the more dense the study area, the greater the amount of garbage and rubble in the channel, with a view that this population is low-income and its occupation is chaotic. The disorderly urban occupation is a factor that exacerbates the impacts that the urban floods can cause, since in many cities or coastal communities, the waters can reach the villas, the public roads (streets, roads, and sidewalks), leisure areas, trade and industry.

#### *Urbanization versus floods*

Cities become increasingly urbanized areas and grow constantly, assuming role in the scenario of the global environment. It becomes crucial to recognize the global nature of urban problems and engage the best efforts to make the cities places more worthy to live – and more environmentally friendly [21]. Urbanized areas are more susceptible to flooding, a result of large flow rates and widespread flooding, due mainly to the removal of vegetation, soil sealing and the channeling of the watercourse, in addition to the delivery of sediments, sewage and garbage to the watercourses [5].

The city of Belém is located in the Amazon River delta, more precisely at the mouth of the River Guamá next to Guajará Bay, in the State of Pará. [10]. Geologically, Belém is situated on an alluvial plain sediments which are predominantly riverine in nature with some marine deposits and sea wind. The lithology is predominantly ARENE-clay or sometimes with pudding -stone levels or with silt levels [13]. This whole area has suffered multiple episodes "to the present day sea level variation of superposed high frequency to a main trend of transgression to the open sea» [14].

Based on climatological normals for the period between 1931 and 2010, there is a high rate of precipitation in the city of Belém / PA, especially in the period between January and March, with various peaks ranging from 280 to 460 mm of rain [7]. This period is known locally as the rainy season and according to the port authorities, the gauges record the highest tide level, which can also enhance hydrological problems in the city. This combination of high rainfall and higher tides, combined with low topographic dimensions, often results in the increase of wetlands in the city.

For [15], the convective-type rainfall in short periods of time with values above 35 mm and without the influence of high tide levels are sufficient to generate disturbances in the city with flooding, which clearly shows that the storm

drainage system is insufficient for receiving the precipitation prevailing in the region.

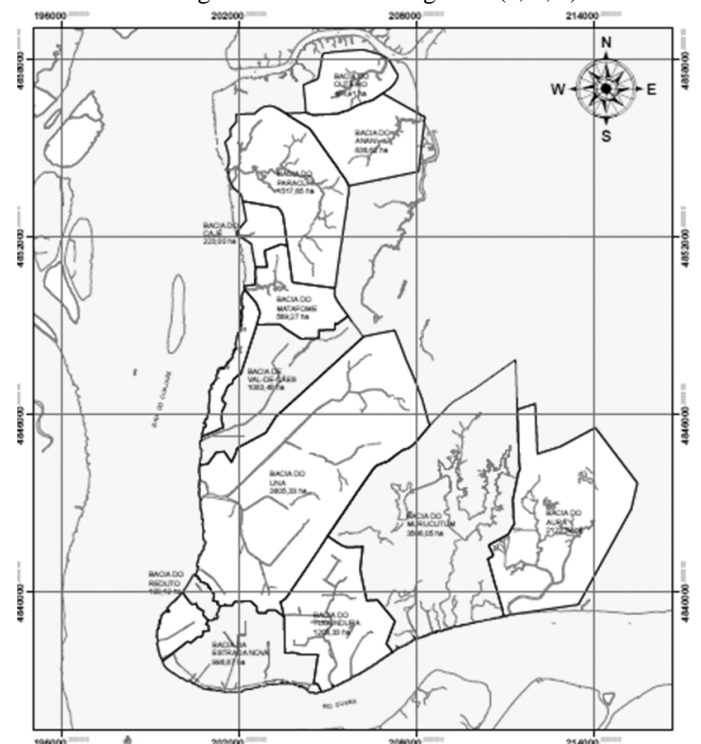
For the region of Belém / PA, which has a high density rainfall, rainfall is a triggering element of the flood-related accidents, but the inadequate occupation of areas subject to flooding is a major component of the vulnerability of the population to these events, which result of political, economic and cultural.

Thus, there is at Belém / PA, the increase of the areas of flooding, resulting in an increase in the number of people affected too extreme in recent years, not even during storm events, which is related to increasing the degree of exposure of the local population to flooding.

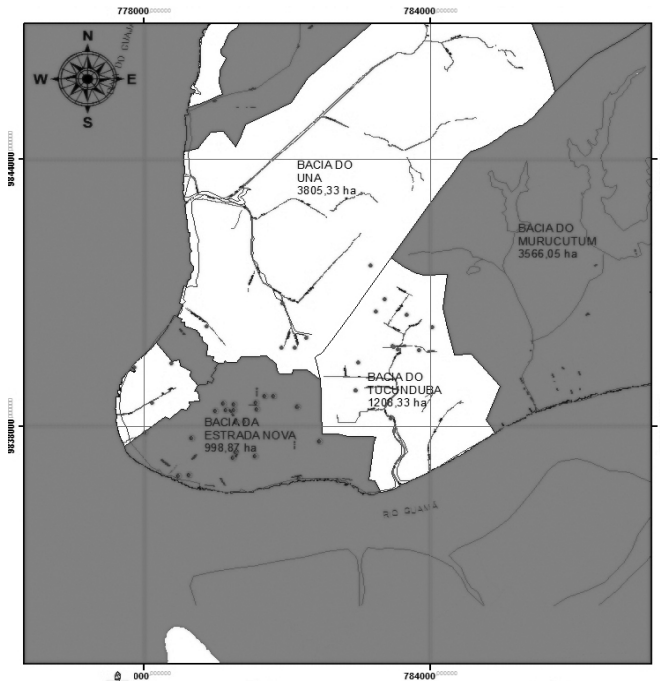
For [20] states that the municipality of Belém / PA has doubled its population within 30 years, reaching in 2010 a population of 1,393,399 inhabitants according to the [6]. However, this rapid growth did not come accompanied by the necessary infrastructure to serve the entire population, resulting in problems of access to public services for the poorest. Among these problems, there is the system of water supply, sewage and stormwater collection and disposal of solid waste.

This growth and population density are aspects that should also be considered in this analysis, since the occupation of areas vulnerable to flooding occurs quickly and unplanned.

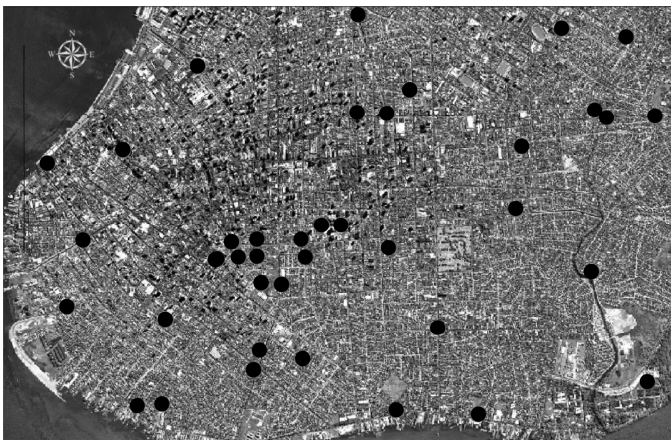
Belém since 12 January of the year of 1616 has been growing without a plan for minimizing human and property losses in case of floods. Currently, in many districts of the municipality of Belém the pavement was done without first provide the proper drainage system to the area. This led to increased flooding area as shown in Figure 3 (a, b, c).



**Fig. 3.a** – Map of drainage basins and the city of Belém. Source: Map 1/50000 scale, Federal University of Pará on watersheds and drains on the region of Belém.



**Fig. 3.b** – Critical points of flooding in the region of Belém. Source: Map 1/50000 scale, Federal University of Pará on watersheds and drains on the region of Belém.



**Fig. 3.c** – Points of flooding in Belém. Source: Source: Map 1/50000 scale, Federal University of Pará on watersheds and drains on the region of Belém Google Earth, 2011.

The 10 neighborhoods subject to flooding are located mainly in the areas corresponding to the first sheet of league city, but also in the areas of land near the sea [11].

Most of this neighborhood, located in areas below the level of 4 meters and known locally as the "downloaded from Belém" suffer the influence of high tides and reveal the difficulty in rainwater runoff.

For [11] refers to this aspect associated with the physical and natural features of the city of Belém as the genesis factor for the occurrence of floods. Its hydrographic network is another important aspect, since it presents a rich network of drainage systems, such as the Una River Basin and Basin Tucunduba, which cut a significant amount of city neighborhoods. In addition to these natural factors, there is also the high rainfall, which is around 360 mm per month,

ignited by a drainage system inefficient and scrapped unable to drain all the water precipitated.

To natural factors identified which result in efficient water flow reduced or even prevented, must be added other, namely:

- Urban sprawl,
- The successive engineering works that alter the drainage network and the transverse and longitudinal sections of the watercourse.

All these actions will lead to changes in environmental and hydrological process.

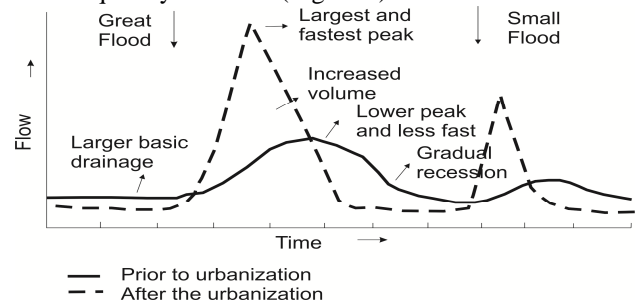
According to [16], learn to co-exist with the floods through the mitigation of its adverse impacts is a measure that should be adopted by civil society and government agencies through an integrated environmental and urban planning. The current public actions, in many Brazilian cities, are unduly focused on the structural measures with specific vision. Channeling has been widely used to transfer the flood from one point to another in the bowl, without being assessed downstream effects or the real benefits of the works [18].

It was found in the field that the urban impacts are caused mainly by inadequate occupation of urban space. This situation occurs mainly in areas where the resident population is low-income and the land belongs to the government. Medium risk zones flooding, when this occurs, suffer high losses also. One of the factors that explain this situation in most Brazilian cities relates to the lack of restrictions and conditions imposed by the urban master plans in respect of the lots in flood risk areas.

For [4], the watershed presents itself as a great laboratory for the study of environmental problems and as a unit inclusive of natural and social sectors and should be administered with this function, so that environmental impacts are minimized.

#### *The physical landscape in urban space of Belém*

One reason for the scenarios of the drainage of Belém/PA is excessive paving, preventing the rainwater to percolate into the soil, reducing infiltration capacity and causing increased runoff and drainage density. To [19] this is characterized as flood areas of marsh due to urbanization or urban drainage, linked to increased impermeable areas and to the canalizing of water lines culminating in the saturation of drainage systems and consequently in floods (Figure 4).



**Fig. 4** - Changes in land use due to urbanization and its effect on the flood levels and hydrograph. Source: TUCCI, 1997.

Another visual scenario in Belém results in construction over the canals, thus obstructing the free flow of water and increasing vulnerability, with obvious damage to housing residents (Figure 5).



**Fig. 5** - Homes on the canal, making the passage of water, source: PEGADO, 2011.

In addition to the above-mentioned scenarios, there is another, also very serious, that is the municipal solid waste dump in watercourses. The SESAN (Secretary) tries to minimize these problems with cleaning and unclogging of canals. The maintenance of the canals is through dredging, performed with the use of equipments that remove mud, deepening the channel bed. This activity is called "winter operation" takes place once a year, always occurring in the rainy season from December to May in the city of Belém/PA. Withdrawal is also made of rubble and the bank cleaning in these areas, procedure adopted by the municipality of Belém for the maintenance of the canals, so as to mitigate the flooding in the city. (Figure 6).



**Fig. 6** – Cleaning and unclogging of Belém-PA channels. (a) dredging, (b) manual cleanup. Source (SESAN, 2011)

Urban drainage management in Belém focuses primary on actions in specific works of implementation and application of piping without considering the interventions of the basin as a whole, and therefore, the impacts that such measures may result in downstream areas.

Floods are natural processes linked to the river being, however, enhanced by anthropogenic changes in the

environment, through the soil sealing, straightening and canalization of rivers [17].

With the increasing problems of environmental degradation and imbalances caused by human interventions that affect the elements of the natural landscape, the water becomes an important feature that along with the catchment basin must be preserved [12].

#### *The management and socialization of flood risk – Some aspects to consider*

The floods have always struck vast areas of Belém. However, in recent years seems to be a trend towards the increased frequency and severity of their occurrence, giving rise to growing concerns about exposure and vulnerability of the urban population to this phenomenon. The various characteristics of the city of Belém, the unbridled urban growth, the waterworks environmentally inadequate and episodes flood constants, entitle you to the attributes that are necessary to understand the role and responsibility of the municipal government and the citizen, with regard to human, social and economic consequences, and environmental hydrological extremes episode.

The floods have sparked intense debate in recent decades about the mechanisms for mitigation and prevention of the phenomenon in question. In the context of flood prevention in Belém, is creating measures of the legislative framework governing land use and corrective actions in drainage basins.

The route and the changes that are being introduced in the basins and water lines (land use, housing works, intense – soil sealing), reinforce a growing need to have the perception of the risk of flooding (for areas where the risk is significant) and implement measures (risk management) to reduce the likelihood of flooding and the potential consequences.

Stressed, therefore; the importance of social risk management of floods and floods in order to reduce its likelihood and/or impacts in urban areas. The socialization of risk and its management must pass by the bet on the prevention of damage caused by floods, avoiding the construction of dwellings and industries in areas of risk, at present and in the future, and promoting land use practices appropriate agricultural and forestry. Prevention therefore involves the control of conditions of flow generation and soil sealing and ensuring flow capacities generated and the safeguard of full beds, which requires an appropriate scaling of natural drainage network and built. It is therefore essential to promote with protection measures, both structural and non-structural, to reduce the likelihood of floods and/or their impact in certain locations. Another important aspect of managing hydrological risk has to do with the forecast and alert. These require monitoring of the meteorology and the hydrometry and their alert and warning systems, as well as the preparation of the population through the dissemination of information about the risks and how to act in case of occurrence. This step requires a priori identification and characterization of risk areas by the competent authorities, as well as the default procedures together of local populations. Another important aspect related to the socialization of risk is

associated with the recovery and experience gained during crises and consequent return to normal conditions and mitigation of the social and economic impact on the affected population.

In this sense, it is considered as an urgent priority the need to draw up a plan for the town of Belém with clear objectives in reducing and managing flood risk, risk analysis and assessment, to define the level of protection and in the identification and implementation of sustainable prevention measures. This is a very important instrument of communication and planning, which also aims to increase public awareness and thereby justify procedures for decision.

#### V. FINAL CONSIDERATIONS

The diagnosis of the area, geoprocessing techniques used in this work, the processing of input data and the elaborate cartography through the tools SIG allowed:

- generating information about plans of the variables used in the evaluation;
- running the intersection among the plans;
- highlighting the identification of places of occurrence of floods in urban areas;
- determining the spatial and physical indicators for intervention and mitigation or resolution of problems;
- illustrating the data made available to the competent public bodies for decision making with actions

The example of floods in Belém shows a diversity of hydrological situations that urge to be deepened. Negligible importance according to flood analysis in broader issues of planning and management in riparian areas hinders the demarcation and definition of flood areas, which contributed to the emergence of situations of breach and/or of questionable sustainability. Any study that takes account of the drainage basins in the town of Belém should always encompass extreme hydrological situations in order to rationalize the management of actions of prevention and mitigation of their consequences, as well as seek to influence new ways of managing natural resources in sensitive areas [8].

Floods in Belém are phenomena which have always marked and will continue to mark the city's urban experience. Living with floods undoubtedly implies a new approach with this type of phenomenon and therefore assumes and understands the risk-a new philosophy of risk, knowing how to manage uncertainty, promote the integrated management and ensure sustainability. This is certainly a new vision where the responsibility of the municipality, the state government and citizen are shared [3].

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