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INTEGRATED FLOOD MANAGEMENT

CASE STUDY

BRAZIL: *FLOOD MANAGEMENT IN CURITIBA METOROPOLITAN AREA*

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BRAZIL: *FLOOD MANAGEMENT IN CURITIBA METOROPOLITAN AREA*

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Location: The Metropolitan Area of Curitiba (RMC) (State of Paraná, Brazil, fig1) has 2,5 million inhabitants. Most of this urban area was developed in the Upper Iguaçu River Basin which has a basin area of 1000 km^2 in J. Belem (fig 2). The main tributaries are presented in figure 2. Most of these tributaries have basin area of about 100 km^2. The highest urban concentration is in Belem Basin and other neighbors basins such as Atuba and Palmital.
There are flow gages on the main stream and in the tributaries but the series are short and non-stationary due to the urbanization effect. Curitiba has one of the longest rainfall series of Brazil. It started on 1889. In figure 3 is presented the non-dimensional maximum seven days rainfall in Curitiba.

Figure 1 Location of RMC in South America

Floods Impacts : In RMC there are two types of floods:

- *Flood due to urbanization* which occur mainly in the tributaries of Iguaçu River such as Belem and Atuba. These floods usually occur in downtown of Curitiba and in the highly urbanized sites of the cities in the Metropolitan area. In figure 4 is shown the mean annual flood from a basin in Belém (72 m^3/s, 42 km^2 and 40% of impermeable area) and its estimate of the pre-development mean annual flow (12 m^3/s) from a regional extrapolation of non-urban basins. The flood increase due to urbanization is six fold. In Curitiba downtown there were many channels works transferring floods from on point to another resulting in high cost for the cities;

- This river has a large *natural flood plain* due to the small river conveyance and bottom slope. The main causes of the floods in this area are: low river capacity, about 55 m^3.s^{-1} (return period of 2 years) in BR-277 (figure 2); flood plains occupation by the population; peak discharge increase due to urbanization, mainly in Belém, Palmital and Atuba rivers. flow obstruction due to urban works such as bridges, land fill, poor drainage projects.

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During the flood months the hydrograph is damped by the storage capacity of the valley and the regional administration ruled against occupation of the floodplain. However, since 1980 there were heavy pressures for occupation of the flood plain. It was done through invasion of public green areas and by unapproved developments and occupation. In July 1983 and January 1995 two major floods occurred with severe damages of US$ 50.3 millions and 40.2 millions, respectively, (Consorcio, 1997). The 1995 flood had a seven day rainfall with more than a 100 year return period (largest in the 110 years of data). The critical flood volume duration in the main river usually is seven days.

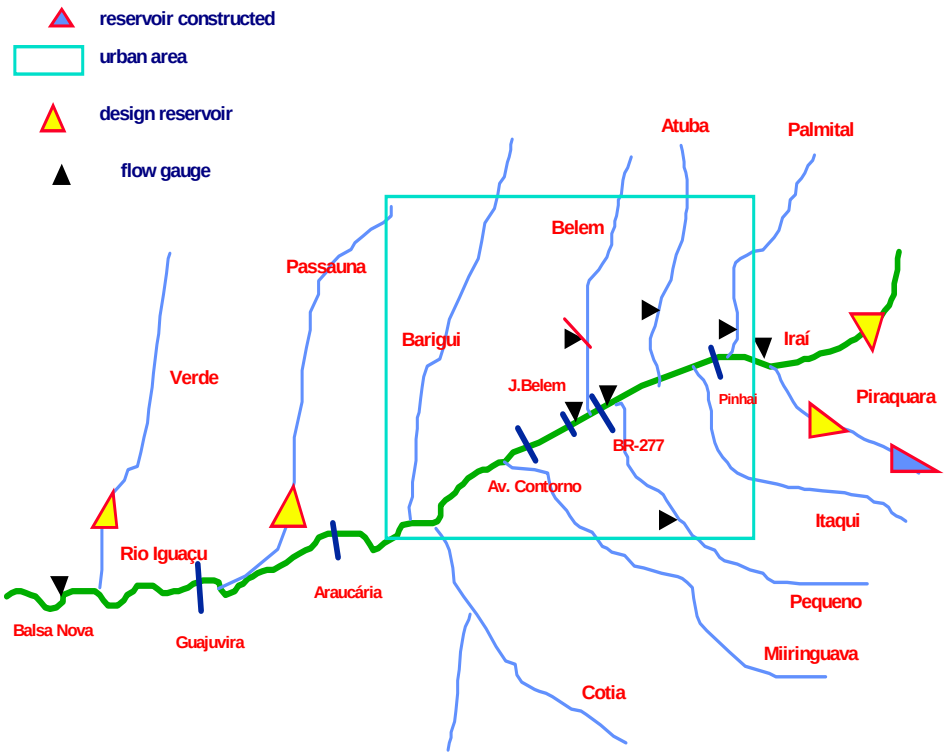


Figure 2 Iguaçu River at Metropolitan Region of Curitiba (Tucci, 1996)

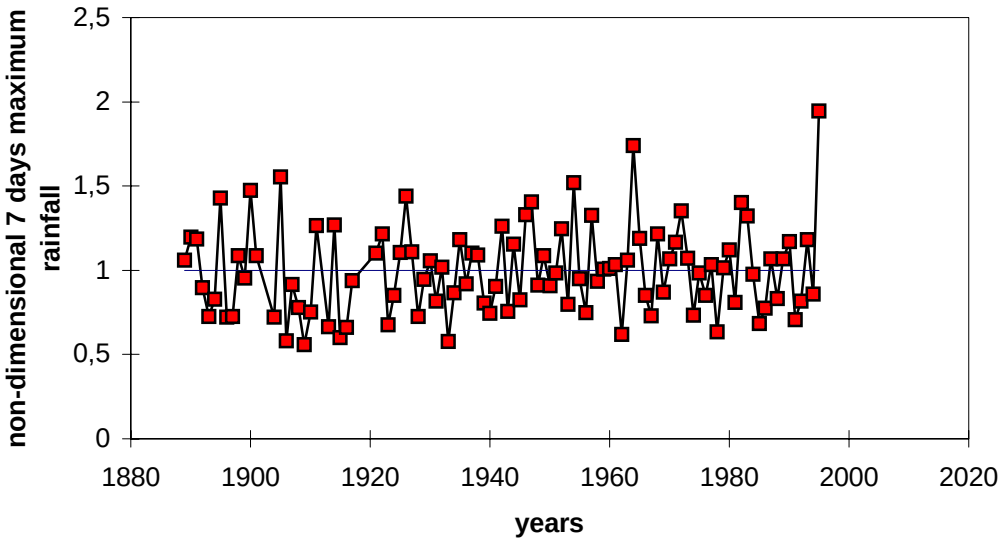


Figure 3 Non-dimensional 7-day annual maximum rainfall in Curitiba

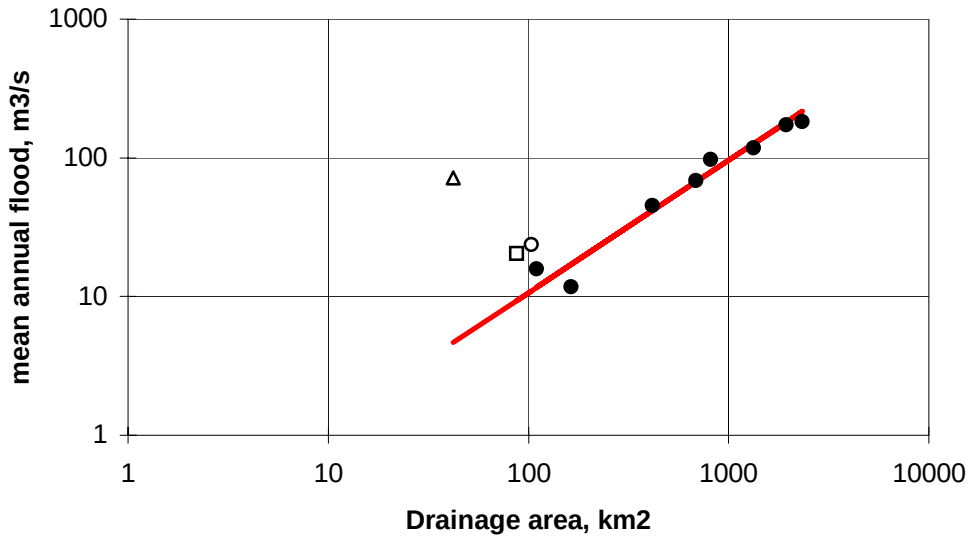


Figure 4 Mean annual discharge function of basin area for the Metropolitan Area of Curitiba: (i) triangle: Belém Basin (40% of impermeable area); (ii) circle: Atuba Basin (15% of impermeable area); (iii) square: Palmital Basin (7% of impermeable area); (iv) others basins: below 4% (Tucci, 1996).

Flood Management : PROSAM was a Sanitary Program developed to cope with environmental impacts on the Metropolitan area of Curitiba and financed by World Bank. The flood management component of PROSAM, which commenced in 1996, had the objective of developing the flood, measures taking into account urban constraints and minimizing its economic and social impacts.

The planned project steps were the following:

- *Emergency measures*: preliminary studies and actions which could minimize flood impacts. It was developed in the begin of the program and decreased some local floods;
- *Medium term* flood control measures: which were the studies and actions in the Iguaçu river:
- *Long term measures*: plan projects and actions in the tributaries together with the Urban Drainage Master Plan for the Metropolitan Area. The two first step were developed and the third step is almost concluded.

This text presents the lessons learned from the Flood Management in Iguaçu River. The usual approach would be to increase the Iguaçu river capacity to cope with the 50 or 100 year flood. Under these conditions the population would occupy the floodplain because of the flood frequency decrease just after the works. After a few years the development of the upstream basin will change the hydrograph and increase the flood frequency and peak of the floods. In this future scenario there will not be more space for the increase of the section width, since the flood plain would be occupied. In this scenario the flood control could be done only by dikes (with pump station and internal drainage) or deepening the river by a reach of at least 50 km, which represents high cost. This is the scenario occurred in the Metropolitan Region of São Paulo and the cost of deepening the channel was evaluated in more than a billion dollars in 1986!

There are two main requirements for addressing this problem:

- create a space for flow and storage;
- develop a process to control the population invasion of flood plains (at present there exist difficulties due to the lack of law enforcement – see box 1).

Box 1 Urban occupation pressure on regulated areas

The regulations in the city of Curitiba (Brazil) have restricted land occupation for the preservation of the basins used for urban water supply and flood prone areas. Urban development had, to a certain extent, approached these areas and increased their real estate value. The property owners adopted the following: strategy (a) clandestine development; (b) helped their land to be "invaded" by the poor population in order to break down the regulations and then sell it to the municipality as a social solution. This usually occurs during election years where the political pressure is higher.

This situation is mainly caused by the low compensation for private land owners in the regulations as they have to preserve the space unused and at the same time pay land taxes without getting economic benefits from it. Lower taxes and designating appropriate land use which does not degrade the water quality would have provided more incentive for land use conservation.

The conceptual approaches used were:

- *In the main river* (Iguaçu): The flood plain of Iguaçu was preserved as storage area along the Metropolitan Area. A park 300m to 1km wide and an area of about 20 km^2 was planned and its implementation is in development. The boundaries of this area are a channel in one side and the Iguaçu in the other side (figure 5). The channel was planned in order to create a limit to urban settlement pressure and increases the river flow capacity for the Iguaçu basin in this area. The main recommendation was that the park has to be designed and implemented together with the channel construction. In figure 6 is presented the schematic plan of the system and a aerial of the park and the urban development pressure. In figure 7 is presented zoom of part of the implemented park and a picture of it. In figure 8 is presented a picture of a reach of the channel. Channel works were finished and the park implementation is under way. In a small part of the park there were a small popilation and they has been transferred to other areas. There were not major floods since 1995, but for the last years conditions it solved the problem of invasion. Most of the area was bought by the State and its implementation has been developed by minimal cost facilities. Some areas has been reserved for constructed wetlands in order to improve the water quality of some tributaries which is a project phase. A flood warning system has been developed by the State (SUDHERSA is the name of the State Institution in charge of the flood management). There is a telemetric system of rainfall and runoff stations which sent information to a center which make flood forecast and warning for the main river system. The model operation is the MIKE11 of DHI Danish Hydraulic Institute in which the delay time for the Iguaçu is sufficient. The urban areas require very small lead times. The main difficulty for SUFHERSA has been to keep the qualified personnel under economics restrictions of the State.

- *In the tributaries:* Development of the Urban Drainage Master Plan for the Metropolitan Region using the following principles: (i) developments of urban parks in the tributaries to damp the potential increase in the peak flow of the uncontrolled upstream area; (ii) implement the counties regulation for the counties in the tributaries. This regulation should enforce the source control on new developments. These strategic parks were planned to reserve storage areas in order to damp the floods that could not be controlled by regulation and law enforcement. Tucci (2000) showed the requirement space for flood damping varies from 1 to 2% of the total basin area. The Urban Drainage Master Plan of The Metropolitan Region (UDMP) was developed and some cities started to implement it and numerous meetings were held with the counties. The main lesson from it is that is required a program to bring all counties inside of the Region UDMP which has to have some economical incentives and law enforcement. The planned program had two components: (a) law

enforcement of the water legislation: In the legislation requires that all flow changes conditions from urban areas requires a water permits; (b) Investment Fund in which the county could receive money to develop the UDMP in its limits. The institutional arrangements necessary for the whole process present the main obstacle. Several recommendations were made to the State Government on this issue. Furthermore, these programs were not implemented yet partly due to economical difficulties in the State and some counties started the implementation of the UDMP using their own resources.

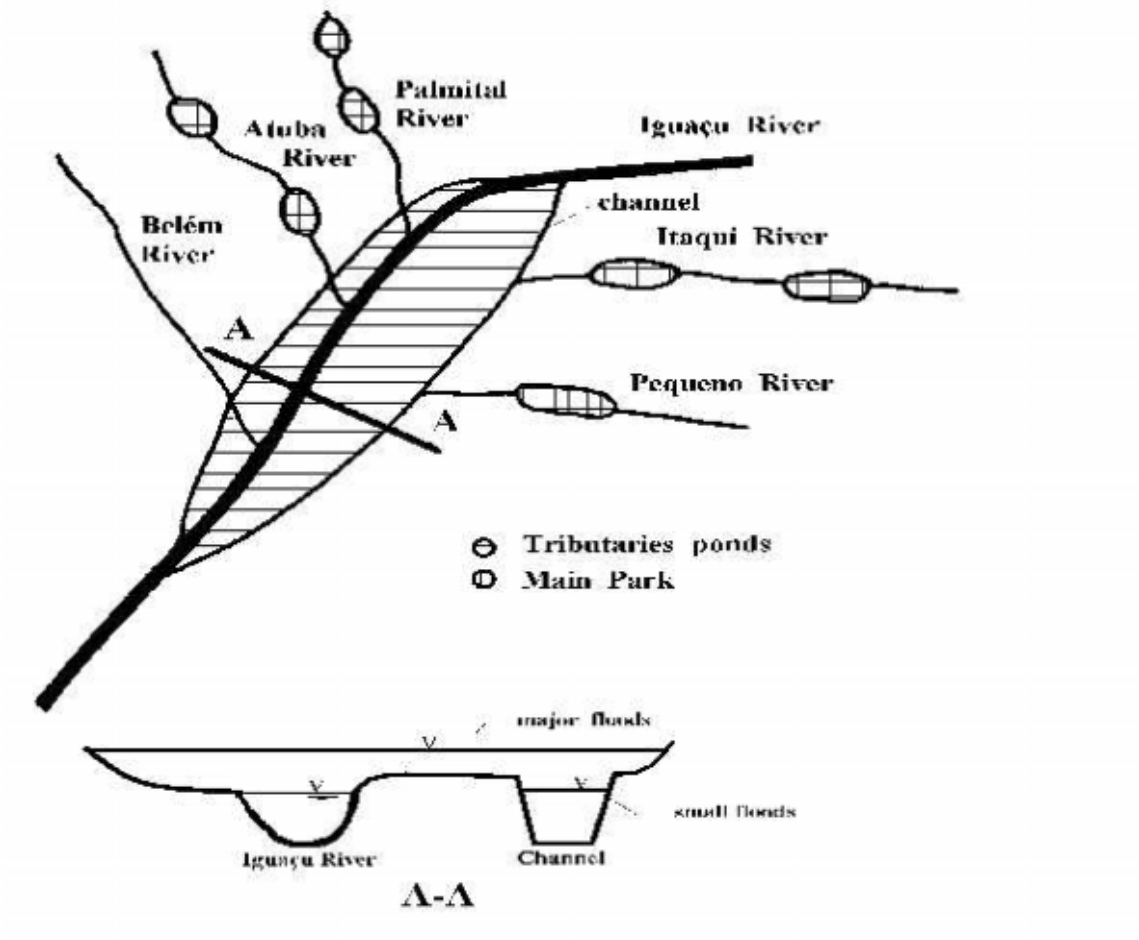
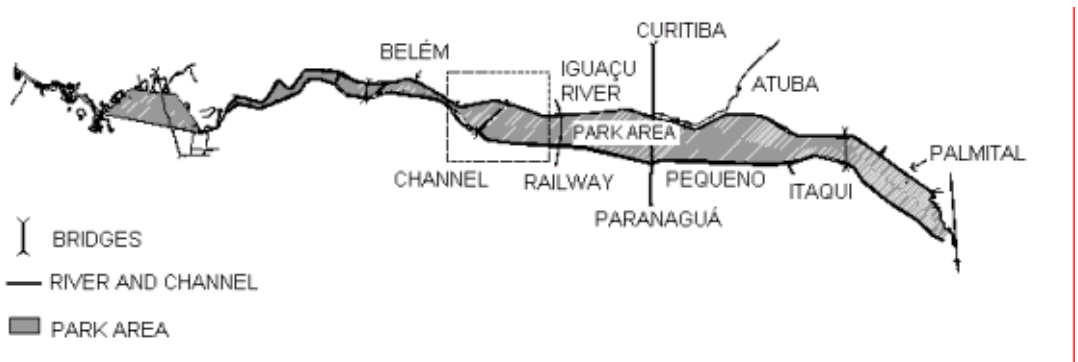


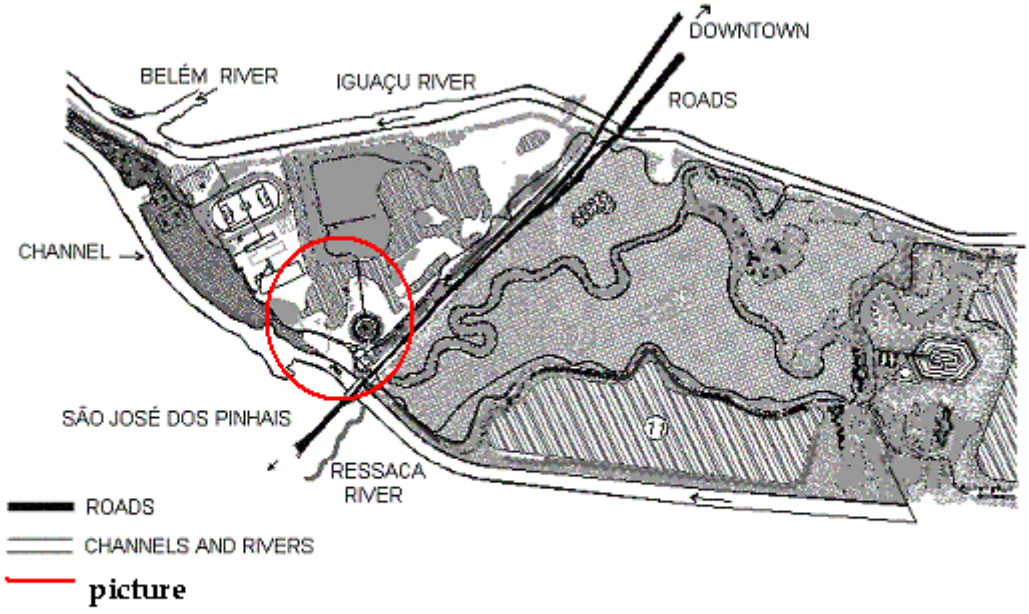
Figure 5 Flood Management in Iguaçu River at Metropolitan Area of Curitiba (Tucci, 1996)



(a) schematic view of the park system

(b) aerial picture of the park

Figure 6 Iguaçu River Parallel channel and Park area



(a) plan view of part of the park implemented

(b) picture of part park (see location in a red circle)

Figure 7 Zoom view of the Park and channels

Figure 8 Channel under construction (parallel to Iguaçu River)

Integrated urban drainage management

Urban Flooding is one of the major threats to cities. Most of the existing public policies in developing countries are not technically, socially or economically sustainable. Integrated Urban Drainage and Flood Plain Master Plans are the main instruments needed to develop a sustainable policy to manage flood impacts in urban areas.

Integrated urban drainage management is based on goals and objectives related to the well being of the population and environmental conservation. Urban drainage and flood control master plans are are developed based on urban space, hydrologic conditions, hydraulic network and environmental conditions in order to reduce flood risks. Usually the main goals of such plans are the:

- Regulation of the use of flood plain areas through legislation and other non-structural measures;
- Prevention and relief measures for low frequency floods;
- Improvement in the urban drainage water quality.

There should be a strong interaction between urban master plans, urban drainage and flood control master plans and other city plans related to water supply and sanitation and solid waste management. Land use is closesly related to urban drainage. Therefore, urban drainage master plans should be essential components of urban master plans.

Lessons Learned

Based on the above-mentioned practices/situations, the following actions will be needed for integrated urban drainage management.

Prevention planning: City development plans should take into account urban drainage flood plain areas. Source control and non-structural measures are the main choices at this planning stage. Some of these measures are related to:

- the increased public use of the designed green areas which prevents invasion, thus making undesirable settlement much more difficult. In some cities, invasion of public spaces has been discouraged by the existence of barriers such as river channels, roads or railway lines;
- reserve areas for detention storage in parks;
- tax incentives for conservation of flood risk areas (see box 2).

Box 2 : Tax incentives

In Estrela, (Rezende and Tucci, 1979), a study was prepared for the city together with the Urban Master Plan and implemented in the municipal regulation. After the legislation was implemented the risk areas were preserved and gradually the remaining population was removed to safe areas using tax incentives. The tax incentives were the exchange of building construction area permits downtown with flood risk areas. Flood damage losses and population affected have decreased over the years since 1979.

Source control measures: the planning should control the impacts at their source creating public responsibility towards the problem. This control has a distributed characteristic but has to be seen in an overall picture

Park Detention ponds as a drainage control reserve: Sub-catchments lying within the city boundaries or close to them should allow for future development by evaluating their capacity for

settlement and the limits to which they can be reasonably developed. Limits can be defined for increases in the peak flow resulting from increases in impervious areas, and by planning public facilities such as parks with urban detention ponds to which flood-waters can be diverted. Such areas can be used to lessen the impact of high flows within cities, but must be designed as such before they are invaded or developed by private interests.

Permanent Institution elements: regulation of minor drainage taking into account the peak flow increase; regulation of land use in flood plains; tax incentives for conservation areas and for already constructed for drainage control areas; public procedures to control and legislation enforcement based on local conditions; Increase law enforcement at a site level when it is already partially developed.

Capacity building: improve the technical capacity of county personal; create better working conditions which can allow a good professional to remain in the job; city urban drainage manual; technical education program for architects and engineers; general population education.

Public participation: use public poll about urban drainage facilities and requirements; create a public consultation through NGO representative for Plans and Projects related to urban drainage at all stages of this development; and increase the public awareness of the urbanization impact on urban drainage. (See box 3).

Box 3: Public Participation

União Vitória and Porto União (Tucci and Villanueva, 1997) are on the border of the State of Parana and Santa Catarina and have a population of about 150,000 inhabitants. This urban area is subjected to frequent floods but in 1980 a large hydropower reservoir was constructed downstream. In 1983 there was a major flood, which had an important economical impact (sixty days of flooding). The population began to blame the Electric Company (COPEL), which claimed that it was a natural flood and that the dam did not create any additional impact. But in 1992 another major flood took place, smaller than the 1983 flood but also with a high damage impact. It created a major conflict between the city and the Company. A NGO (Non-governmental organization) was created by the population and a study was developed for this organization to carry out: diagnosis of the flood conditions, negotiations with the Company for operation rules and flood zoning planning for the city. The study brought some results and the negotiations improved the city's capability of dealing with floods.

Increase hydrologic data : lack of hydrologic data and also physical one are a chronic problem in urban areas of developing countries. It causes inadequate design projects with higher cost or under-designed. A program of data acquisition and development of methodologies for use of data in production of information for urban drainage in humid tropics are important requirements for sound urban drainage planning.

REFERENCES

CONSÓRCIO, 1997. Parque e Controle de Cheias do Alto Uruguai: Obras Componentes do Sistema de Controle de Cheias. Consórcio ENERCONSULT/ELC/TEI

FRENDRICH, R.; E FREITAS, C.O A (1989). Estduo de Chuvas Intensas do estado do Paraná, ISAM PUC.

TUCCI, C.E.M., 1996. Estudos Hidrológicos – Hidrodinâmicos do rio Iguaçu na RMC. PROSAM SUCEAM Curitiba 2 volumes;

TUCCI, C.E.M. 2000. *Coeficiente de escoamento e vazão máxima.* Revista Brasileira de Recursos Hídricos V5 n.2 .