(capítulo do livro Urban Drainage in Humid Tropics que será publicado pela UNESCO)

7. Urban drainage management

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The main aspects of urban drainage and flood control management in developing countries of humid tropics are: climate, urban development and institutional aspects. Technical tools and principles of urban drainage control are well known in developed countries but their direct application in the developing countries has not been successful. They require some adaptation to the conditions of each country.

Urban drainage management is presented describing the climate conditions, urban drainage policies, institutional aspects and basic concept of the Urban Drainage Master Plan (UDMP), taking into account the difficulties related to the social, economic and environmental conditions of developing countries.

7.1 Urban drainage and flood control principles

The main types of flood which may impact urban areas can be classified in the following two types:

Due to urbanization: these are floods related to the increase of the impermeable areas and man-made drainage such as conduits and channels. Usually the land use surface in small urban basins are made of roofs, streets and others impervious surfaces. Runoff flows through these surfaces to the stormsewers. It changes the hydrologic cycle, increasing the overland flow and decreasing the groundwater flow. Under these circumstances the peak discharge increases together with the flood frequency. In addition, the washed urban surfaces during rainy days increases the pollution load in urban environment and to downstream rivers.

Since the 1970s in developed countries the source control of urban drainage has been developed by detention and retention ponds, permeable surfaces, infiltration trenches and others source control measures. In developing countries usually this type of control does not exist and the impacts are transferred to downstream in the major drainage. The cost to control of this impact are transferred from the individual to the public, since the county has to invest in hydraulics works structures to reduce the downstream floods impacts.

Due to flood plain occupation: these are natural floods which mainly occur in medium and large sizes rivers. When no reliable urban plan and regulation exists, the population occupies the flood plain after a sequence of low flood years, because these areas have a flat topography and are near to valuable city land and have a low cost. However, when a larger flood occurs, flood damage increase and the municipality is requested to invest in flood protection in this area.

The reliable experience in flood control of many countries has now led to some main principles in urban drainage management, which are:

- Flood control evaluation should be done in the whole basin and not only in specific flow sections;
- Urban drainage control scenarios should take into account future city developments;
- Flood control measures should not transfer the flood impact to downstream reaches, giving priority to source control measures;
- The impact caused by urban surface wash-off and others related to urban drainage water quality should be reduced;
- More emphasis should be given to non-structural measures for flood plain control such as flood zoning, insurance and real time flood forecasting.
- Management of the control starts with the implementation of Urban Drainage Master Plan in the municipality;
- Public participation in the urban drainage management should be increased;
- The development of the urban drainage should be based on the cost recovery investments.

These principles have been applied in developed countries and are not fully used even in some of these countries. The urban drainage practices in most of the developing countries do not fulfill these principles. The main causes are the following:

- Urban development in the developing countries cities occurs too fast and unpredictably. Usually the tendency of this development is from downstream to upstream which increase the damage impacts (Dunne, 1986);
- Urbanization in periurban areas is usually is developed without taking into account the city regulations. This urbanization is as follow:

  Unregulated developments: In periurban areas of big cities the real estate is low priced. Regulation of this area requires investments which are almost the price of the land. As consequence private land owners develop urbanization without the infra-structure, selling it to the low- income population;
  Invasion of public areas (such as public green areas) usually the invasion of public areas which were planned in Urban Master Plan for future parks, public construction and even streets. Due low income conditions (the homeless) and slow decision-maker by public administration these developments are consolidated receiving water and electricity. In 1973 Bogota had 59 % of illegal developments and most of them lacked sewers, water and electricity;

- Periurban and risk areas (flood plains and hill side slope areas) are occupied by low income population without any infra-structure. Spontaneous housing development in risk areas in Humid Tropics cities are on land prone to flooding: Bangkok, Bombay, Guayaquil, Lagos, Monrovia, Port Moresby and Recife; hill sides prone to landslides: Caracas, Guatemala City, La Paz, Rio de Janeiro and Salvador (WHO, 1988);
- Municipality and population usually do not have sufficient funds to supply the basics of water, sanitation and drainage needs;
- Lack of appropriate garbage collection and disposal decreases the water quality and the capacity of the urban drainage network due filling. Desbordes and Servat (1988) mentioned that in some African countries there is no urban drainage and when system drainage exists it is filled with garbage and sediments. Tokun (1983) also mentioned this type of problem in Nigeria where the drainage systems used as garbage collector;
- There is no prevention program for risk area occupation and when the flood occur non-returnable funds are given to the local administration to cope with the problem, without any requirement of future prevention programs.
- Population, States and Counties administration do not have enough knowledge on how to deal with floods using the above principles;

- Lack of institutional organization in urban drainage at a municipal level such as: regulation, capacity building and administration. In Asian cities there is a lack of (Ruiter, 1990): comprehensive project organization and clear allocation of responsibilities; adequate urban land-use planning and enforcement; capability to cover all phases and aspects of technical and non-structural planning;
- In cases where separate system is applied solid waste is dumped into stormsewers. This is a situation which occurs also in some developed countries;
- When there are unrealistic regulations for urban occupation related to social and economic conditions the owner uses different procedures in order not to comply (see box 7.1).

Box 7.1 Urban occupation pressure on regulated areas

The city of Curitiba (Brazil) regulations have restrict of land occupation in preservation of the basins used for urban water supply and flood prone areas. Urban development had, to a certain extend, approached these areas thus increased the real state value. The property owners used to do the following: (i) clandestine development; (b) helped their land to be invaded by the poor population in order to break down the regulations and 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 due to the lack of compensation for private owners in the regulations since he has to preserve the space unused and pay land taxes without getting economic benefits from it. No taxes and some appropriate land use which does not degraded the water quality would provide more incentive to land use conservation.

7.2 Climate conditions

Most of the developed countries are in temperate or cold climates and some of the developing countries are in tropical climates where the temperature, rainfall intensity and frequency are higher. Tropical and mainly humid tropics climates create much more difficulties in environmental management of cities in which urban drainage is one of the main challenges.

The main climate aspects related to urban drainage in humid tropics are:

- Rainfall intensity is about 25% greater than in some temperate climates (see chapter 3 and table 7.1) which requires more investments for the same risk level of drainage control since the peak discharge are also higher, in a larger proportion than the related rainfall intensity;
- Design conditions are not based only on the local rainfall intensity but also on the rainfall duration during the rainy season. Low intensity long duration storms maintain a high water level in the major drains over long-periods thus creating downstream boundary conditions (backwaters) for the drainage system. In this situation the related volume can be too large and every year the streets are flooded. Some examples of this situation can be seen during monsoon seasons in India in Bangladesh cities. The options to cope with problems are: (a) learn to leave with flood, reducing their damage (box 7.2); (b) structural protection with dikes when economics conditions allow it; (c) use a lower return period in the humid tropics for urban drainage design;
- High temperature conditions throughout the year allow the development of many related and water born diseases such as malaria, yelllow fever, dengue (the host mosquito develops in warm climate in storage water without pollution) and schistosomiasis (the host develops in lakes, such was observed in the urban lake of Pampulha in Belo Horizonte).

Table 7.1 Rainfall Intensity (2 years of return period) in mm / h

Place	Continent	5 min	15 min	30 min
Cities in the tropics				
Niamey	Africa	160	110	79
Kinshasa	Congo / Africa		126	93
Kuala Lumpur	Asia	250	148	110
Babinda	Australia	129	107	84
Paranaibo	South America		124	88
Manaus	Brazil / South America	186	112	76
Belém	Brazil / South America	167	106	72
Outside the tropics				
Paris	France / Europe	82	41	27
Porto Alegre	Brazil	122	79	53
Montpellier	France / Europe	126	69	48

Box 7.2 Examples of Floods Impacts

Belém (Brazil): Belém is a city near equator line and close to the mouth of Amazon River in Atlantic Ocean. It is located in the humid tropics and every year in March there are some days (about a week) in which the downtown area streets are under approximately one meter of water due to rainfall intensity and high tide conditions. The worse situation usually is when high tide and peak flow drainage of the surroundings basins coincide.
The population lives with this condition transferring the goods and other valuable objects to the second floor.
The gutter size and some small car bridges in the houses entrances shows that during rainy seasons the amount or water is greater than other cities. In Belém there are about 280 days in a year with thunderstorms of short duration and high intensity.

Bangkok (Thailand): Low (1993) reports that in Bangkok there is heavy flooding every year during October and November with many economic losses. In 1975 floods impacts were of about US $ 50 millions. Theses floods are due to heavy monsoon rainfall and lack of drainage capacity.

7.3 Policies

Flood Control policies in developing countries

Flood control policies in most of the developing countries are not adequate to minimize the related impact. The main aspects of theses policies are presented below:

Urban Drainage in developing countries is designed based on the concept of draining water from urban surfaces as quickly as possible through pipe and channel networks; but this increases the peak flow and the cost of the drainage system. There is no control of peak increase at a minor drainage level and most of these impacts will appear in the major drainage.

To cope with this problem, city and state administrations had developed many works such as channels in the major drainage and pipes in the secondary drainage network. This type of solution has only transferred the flood problem from one section of the basin to another, with high costs. In addition, the water quality impact is great, since the overflow is of water with a larger amount of solids and load of metals and other toxic components.

This process is illustrated in the following sequence of figure 7.1. The hydrographs of figure 7.1b shows the flows changing along these described stages:

***stage 1*:** urbanization usually begins from downstream to upstream. Flood frequency and peak flow increase in section A due to upstream urbanization. The solution usually applied is to increase the channel capacity in the flooded reach without taking into account the downstream impact and the future development in the basin (figure 7.1 a).

stage 2: After the channel is constructed in the reach A, floods do not occur in A but they are transferred downstream into reach B, which begins to have suffer the impact as they had in reach A (figure 7.1b).

stage 3: With the upstream urbanization in the basin and the construction of channels in other reaches which had floods (C and D), floods begin to occur again in reach A (figure 7.1c).

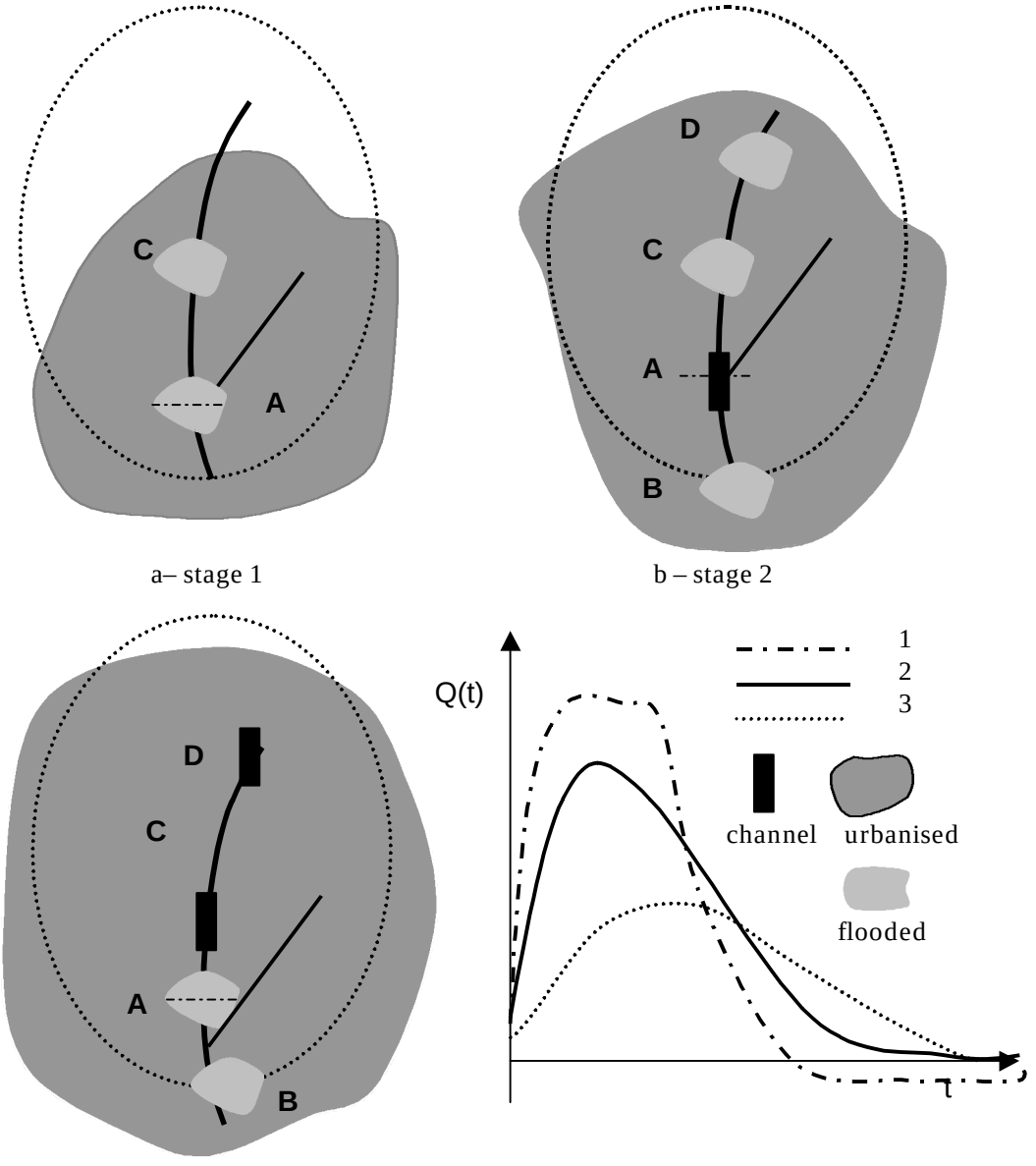


Figure 7.1 Stages of channel development and impact in flood control

The cities in developing countries usually are short of money for investments and when they invest in urban drainage, this sequence showed that it is done in the wrong way, creating more problems than they had before, with loss of public money.

Flood Plain : A common scenario in an uncontrolled urbanization is that flood plain occupation by the population takes place, in a sequence of years with small flood levels. When higher flood levels return, damage increases and the public administrations have to invest in population relief. Structural solutions have higher costs and it is feasible only when damages costs are greater than their development or due to intangible social aspects. Non-structural measures have lower costs, but there are some difficulties in their political implementation.

In the United States one of the main measure has been flood insurance, but it is feasible only in countries of large areas with great climate variation, since its risk can be distributed and the insurance cost can be redistributed among the population.

Flood zoning and forecasting are a combination of sound flood control measures. The main difficulties in the implementation of these measures are:

- Real state owners will fight against regulation of their areas and usually have influence on the municipal politics;
- When flood occur the county receives a non-refundable loan from State and Federal governments. Under this circumstances there is no incentive for a prevention program.
- Structural measures are not economically feasible but have much more political visibility. Non-structural measure require much effort from both the population and politicians. This is a difficult political task and politicians usually do not practice it.

Figure 7.2 presents a common scenario of cities which have both types of floods (flood plain and due to urbanization). In the first stage the flood frequency does not allow the population to occupy the flood plain. With the increased value of the real estate in the neighborhood of the flood areas, the pressure for its occupation also increases, which occur during a sequence of low flood level years.

During wet years this population suffers from the floods and due to pressure of public and construction companies, the solution for flood protection is to increase the river flow capacity or a levee system taking into account the urbanization scenario of that stage. In this condition the population feels safe from floods and occupy all the spaces in this area. In the following years the upstream basin is also urbanized and the floods levels downstream increase again, as consequence the channel does not have the capacity to cope with these peak flows, which brings back flood damages to the same city area. (second scenario of figure 7.2).

During this last stage, flood control costs are sky high as compared to prevention measures since structural controls such as river deepening (there is no more lateral space), building upstream reservoirs and other high cost measures are the only options left. The city of São Paulo is the well known example of this sequence and, in 1986, in the last stage the deepening of Tiete River in São Paulo (which will have only limited effects) had a forecasted cost of about US 1 billion (see chapter 7).

Control policies

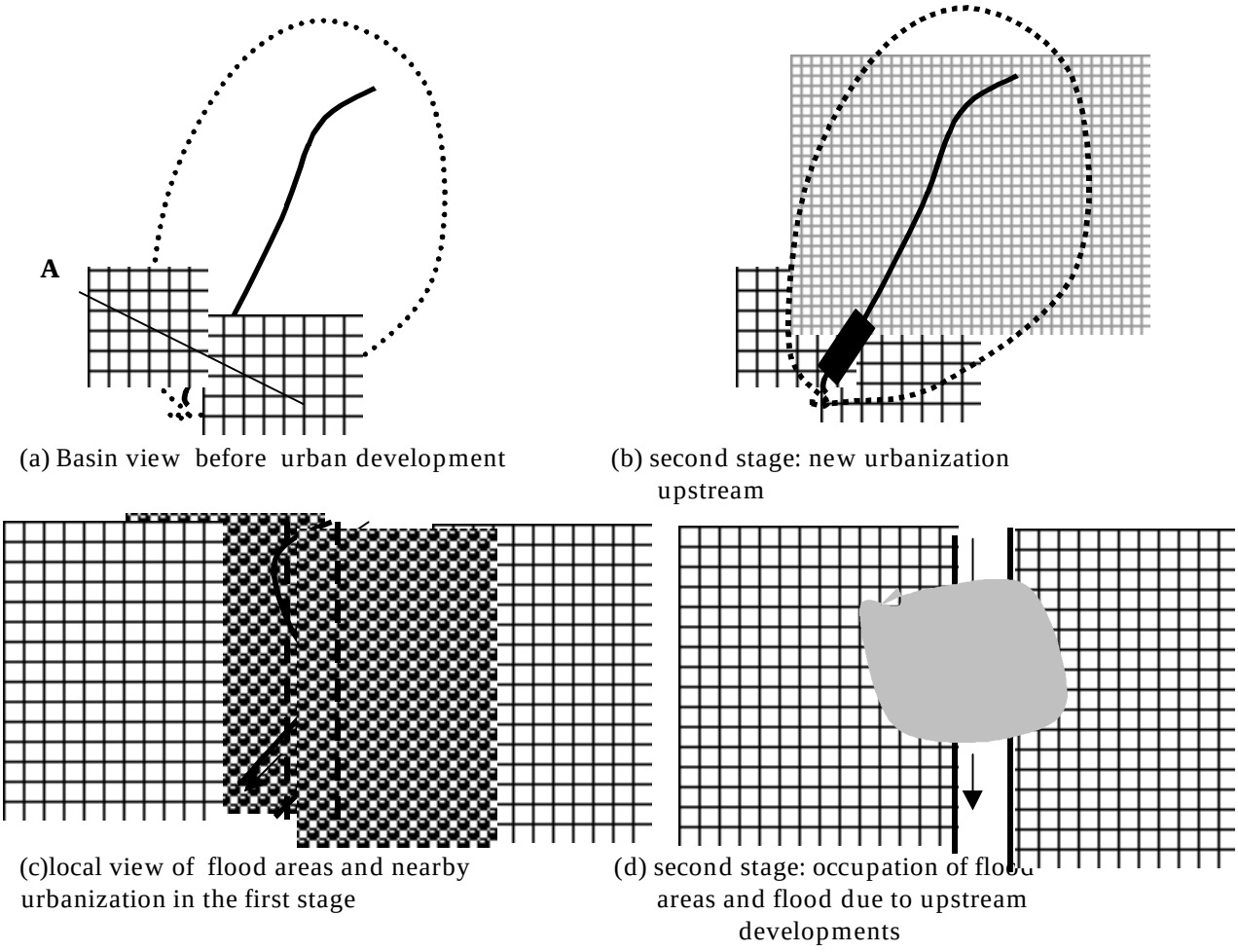
Wrigth (1997) claims that the sanitation control in developing countries has been done through a "supply-driven" procedure which has had unsuccessful results. Supply-driven is the evaluation of population needs and planning its requirements based on the standard of developed countries, where economic and social conditions are far different from developing ones. The author mentioned that "demand-driven" planning is more appropriate since it is developed based on public participation, realistic cost recovery such as the willingness of repay of the community which will receive the investment.

There is a strong public perception of water issues, however the impacts and causes are not clearly understood by the population (box 7.3). Whittington et al (1997) presented a public opinion research among Indonesian city residents (table 7.2) where 1/3 of population flood control and urban drainage puts as first priority among other water issues. In Belo Horizonte, Brazil, the representative of the public in the county budget, selected the Urban Drainage Master Plan as the fifth investment among 34 in city budget for 2000.

In box 7.4 are presented some of the current controls and experiences of flood zoning in Brazilian cities.

Desbordes and Servat (1988) recommended that good solutions for urban drainage in developing countries should have the following conditions:

- they must not induce strong constraints for the population;
- easy and quick solutions to be fast adapted to changing conditions;
- do not create new problems;
- use local equipment and material, increasing the local economy;
- solutions adapted to the real climate and socio-economic conditions of each place.



(a) Basin view before urban development

(b) second stage: new urbanization upstream

(c)local view of flood areas and nearby urbanization in the first stage

(d) second stage: occupation of flood areas and flood due to upstream developments

Figure 7.2 Stages of basin occupation and impacts

Hufschmidt (1993) presented a summary of major flooding and storm drainage problems and management strategies (table 7.3).

In urban drainage the main impact is transferred downstream due to the current policies, therefore it is difficult to implement the local demand-driven approach since the source of impact is upstream and the population which creates it is not the one which suffer the impacts.

This process has to involve the whole community in the commitment of urban drainage control and practices.

Tabel 7.2 Respondents'social and environment priorities in cities of Indonesia (Whittington et al, 1997)

Selection	% of respondents ranking as top priority*
Drainage of flood waters	33
Safe, adequate water supply	27
Improved sanitation services	11
Solid waste collection	10
Improved hospitals and clinics	8
Quality of education and schools	6
Improved road conditions	5

* mean of Bugangan, Dadapsari and Sekaya.

Box 7.3 Conflicts and lack of understanding of flood control requirements among the population.

Porto Alegre, Brazil (about 2,5 millions inhabitants) has a flood control protection system based on polders and concrete dikes in the downtown area. It was constructed in 1970 to protect the city against the floods generated in the basin of about 80,000 km^2. Since the last important flood was in 1967, part of the population has questioned the usefulness of this concrete wall downtown which separates the river from the population. Several organized institutions created a public campaign to demolish this structure despite the engineers warnings about floods risk. The city council approved a special law allowing the City Administration to get rid of the downtown dike based on some misleading reports. However, the City Administration was against this decision based on a sound engineering technical evaluation. Since the flood risk did not change, it was only updated by more hydrologic data (about 100 years flood levels). The County would be responsible for the reduction of citizens security against flooding in the downtown area.

In two interactive TV show, the public response changed from even (yes or no choice about maintaining the dike) to 70% in favor to keep it, when during the second show, there was a technical explanation about decisions consequences of the decision.

Table 7.3 Urban Flooding and Storm Drainage Management (Hufschmidt, 1993)

Problems	**Management Implications**
Rapid urbanization, including human occupancy of flood plains has magnified flood risks and consequent damages	Effective land use planning, including flood plain zoning, flood proofing, evacuation programs and redevelopment of flood-prone areas.
Costly structural flood control measures are beyond of financial capacity of cities	Emphasize non-structural measures and low-cost physical measures, e.g., using street for temporary flood storage
Planning effective urban storm drainage systems requires rainfall and runoff data with very fine time and space resolutions: these are generally not available for humid tropics cities.	Establishing and maintaining hydrologic data systems suited for urban areas in humid tropics
Effective flood control program, combining structural and non-structural and non-structural measures requires a high level of management, not available in most cities	Building management capacity and appropriate institutions for integrated flood management

Box 7.4 Some flood control measures in Brazilians cities

Urban Drainage: Belo Horizonte, (4 millions inhabitants) has in its Urban Master Plan restricted to impervious areas but their limits are low for urban drainage (about 20-30% of site area). The regulation requirements give the option of On-Site Detention (OSD) in the proportion of 30 liters per m^2. Since 1996 when the regulation was approved did not work because there is an article which allows the owner to avoid the regulation based on an engineering evaluation, which is often given. Curitiba and Porto Alegre (about the same population of 2,5 millions of inhabitants) have some regulation using OSD. These cities São Paulo, and Rio de Janeiro are developing their Urban Drainage Master Plan.

Flood plain zoning: Studies of flood zoning were developed in five cities along the Uruguay River (IPH, 1984) and eight cities on the Itajaí River (Tucci, 1986). In both situations the studies were contracted from State and Federal organizations without local participation. The results of the studies were not implemented since the cities did not participate and the municipal administration did not have any interest in that type of solution.

In Estrela (Rezende and Tucci, 1979) the 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 taxes incentives. The tax incentives were the exchange of building construction area permits downtown with flood risk areas. Flood damages losses and population involved have decreased over the years since 1979.

União Vitória and Porto União (Tucci and Villanueva, 1997) are on the border of the State of Parana and Santa Catarina and are the community (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 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 the study was developed for this organization whose goals were: 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 way the city's capability of dealing with the floods (see chapter 8 for more details).

Urban drainage management requires the following actions:

Prevention planning of the urban space taking into account urban drainage flood plain areas in city development. 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.

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. (figure 7.3)

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; increase the public awareness of the urbanization impact on urban drainage;

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.

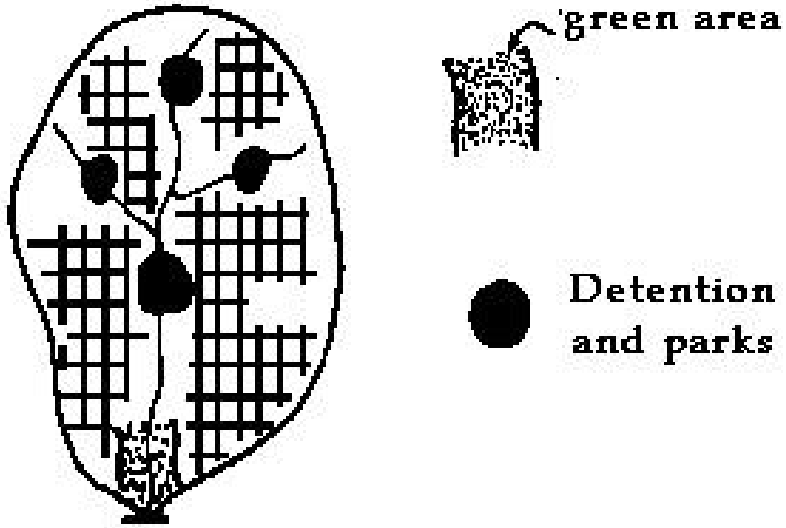


Figure 7.3 Detention for urban drainage control in the planning stage

7.4 Institutional aspects

The main differences between developed and developing countries are the institutional aspects, since in the former the institutions are already established and the Urban Master Plan is much more a technical document on hydrology, hydraulics and environmental analysis of alternatives

based in economics evaluation. In developing countries the main restrictions are related to institutional aspects. The main difficulties on these aspects are *the lack of*:

- Laws and regulation at municipal level related to quantitative and qualitative aspects of urban drainage. When they exist, usually are outdated. There is no about the effective control or enforcement;
- Institutions for management control;
- Qualified professionals and when such professional exist they do not stay long on the job due to they low income;
- Understanding flood control measures. Often the population ask for works such as channels or conduits which are expensive.

The lack of flood control management related to urban development is a common situation in cities of developing countries. The delay in planning and developing non-structural measures such as regulation of space occupation will increase the cost of future actions. Usually there is no source control which would prevent the peak flow increase from urbanization in new urban developments. A real state condominium developer will not construct any source control measure for drainage if there is no regulation and law enforcement.

The first stage in the planning process is to have a sound regulation, but it is not a guarantee of law enforcement. In some communities there is appropriate legislation but for many reasons there are a great number of situations where the regulation is not obeyed by the population. Some of them are: (i) lack of regulation enforcement due to weak county institutions or small number of personnel; (ii) low price of real estate and high cost to implement the regulation requirements; (iii) low income.

The best regulation are those which can be implemented in real life for a long period. Since the source of the impacts are upstream the main requirements for flood control and urban drainage are realistic and stable regulation together with institutions which have the capability of enforcing this regulation. However, due to the great differences in the social and economical conditions there is a strong need for public participation in order to get support from the population.

Since flood control and urban drainage as a service usually are not charged the cities does not have funds do deal with the problem. Most of funds come from emergency reserves and the flood management is often done through Federal or State organization which have much broader goals than improvement of the specific conditions of each city.

There are many small counties where their technical, economical and financial capacities are small to deal with this type of control and they need some support from State or Federal Agencies.

The main actions which can be developed at management level by public organizations to deal with flood control and urban drainage are recommended below:

Federal level: at this level some of the main measures and preventive programs are the following:

- Support the communities with non-refundable funds (grants) only when they have preventive flood control programs and Urban Drainage Master Plan. For those which do not have preventive program the support funds should be provided as a loan;
- Avoid the construction of public buildings, hospitals, schools and other with bank loan funds in flood risk areas or when there are no other option they should be built with all flood security standard;
- Whenever it is possible create a flood insurance system;
- Establish a flood control program for interstate and international basins;
- Support preventive programs and non-structural flood control such as: flood zoning, insurance, flood forecasting and regulation of urban drainage;
- Environment regulation for the city urban drainage water quality in the river systems

- Support to methodological development and implementation of data acquisition techniques.

State Level: the State may give support to the counties on preventive measures and help solve conflicts among more than one county. Some of the State provides support is the following:

- Create and support a technical team in the State to provide professional support to the counties on flood control and urban drainage in order to advise on preventive programs of planning, regulation, civil defense and environmentally-related issues;
- Establish standard and State measures for minimization of flood impact;
- Develop a system of monitoring and acquisition of hydrologic data, flood forecasting and water quality of the rivers near cities and in the major urban drainage areas;
- Develop economic incentives and taxation mechanisms to improve a flood protection and water quality control (see box 7.5);
- Evaluate flood losses and the results of the preventive programs;
- Develop Urban Drainage Plans for Metropolitan Regions which cover many counties. It has to be done in order to manage the conflicts of urban drainage impacts in the same urban basin..

Box 7.5 Tax program for water quality

In Brazil the main State tax is on goods consumed. This revenue is collected by the State and redistributed to the counties. In the State of Paraná, the county which improves down-stream water quality receives an increase in tax return. This process is controlled through gages monitoring along the rivers where the water quality was degraded in the last few years. This process increased environment awareness in many counties which increased the investment in waste load reduction from sanitation.

Municipal level: the management of urban drainage and flood occupation is usually done at a municipal level. At this level the Urban Drainage Master Plan is developed where laws and regulation are implemented. In this regulation should be included the basic non-structural measures and source control. Some of the main aspects which should be included in the Plan are the following:

- Hydrologic, hydraulic and environmental standards for planning and design described in a standard manual;
- development of efficient processes for law enforcement, management and maintenance of public services ;
- capacity building for technical staff;
- public participation;

These basic elements should be adapted to the prevailing conditions of each city. In the following some of the concepts of the Urban Drainage Master Plan are presented.

7.5 Urban Drainage Master Plan

The problems of urban development in developing countries are different from those in developed countries because of density of occupation, lack of regulations and law enforcement mainly due to weak institutions, large difference in population income which results in illegal occupation of public or private areas.

Each problem has its own solution and each situation may require a different approach to minimize the impact on the standard of living in the communities. Urban drainage and flood control plans require a good understanding of the urbanization pressures and the water behavior of the basin.

In figure 7.4 are presented the main components of the Urban Drainage Master Plan (UDMP) development. Some of these components are discussed below.

Concepts

Usually an Urban Plan is based on the goals and objectives related to the well being of the population and environmental conservation. In urban drainage the main goals are:

- Urban drainage planning is mainly a distribution of volume allocation in time and space in the urban basin based on urban space, hydraulic network and environmental conditions in order to reduce flood risks (Wright-MacLaughlin Engineers, 1969);
- Control the occupation of flood plain areas through regulation and other non-structural measures;
- Prevention and relief measures for low frequency floods;
- Improve the urban drainage water quality.

Urban development condition factors are not discussed here since they belong to Urban Master Plan (UMP) but there should be a strong interaction between this urban development document, drainage and others city plans. As described in this book, land use is strongly related to urban drainage and the UMP also has to take into account the restrictions of the UDMP in which this one is a component of the former.

Furthermore, there are other Plans related to it: water supply and sanitary control; garbage: street cleaning, garbage collection and its final disposal.

Plan Development

Urban flow control is developed by sub-basins and regulated by modules which are defined by a political city division but have the technical restrictions related to basin flow. The main flood control policies may be summarized based on the drainage system as follow:

In the major drainage: hold urban space for detention or in same way create linear parks within the river boundaries for storage flood volumes, sediment and trash detention and water quality improvement. Since part of the upstream urbanization is not controlled due to lack of law enforcement, as described before, this policy is used to avoid urban drainage impact to be transferred to downstream reaches. Instead of having the garbage and sediments distributed in conduits or along the rivers and channels, it is retained in specific places for cleaning and reduce the maintenance costs. In some situations this is not the best solution, it has to be evaluated based on local conditions.

When, in the major drainage, the selected solution for flood control are stormsewers or increase channel capacity, the plan or design has to control their downstream impacts.

In the flood plain: use non-structural measures: flood areas zoning of low and high risk areas; constructions standards and overall regulation related of this control. Some of the common recommendations are the following: (i) public flood area which has its value increased due to urban development pressure has to be occupied with urban infrastructure such as parks, sports fields, playgrounds, etc. If these area are not developed they could be invaded. In Brazilian cities there is a market on *green areas*, which are partially invaded public areas where the real estate is sold by the squatters who had taken possession (but as not have a right). Since the Brazilian legislation allow the property right after some years of possession there is a market for poor income population; (ii) the same has to be done when a private area is bought for relocation. Just after the relocation, it has to have a public infra-structure since other families may move to the same place. (iii) education of neighborhood families about the flood impacts usually can preserve an empty space; (iv) improve tax benefits or alternatives uses for private area.

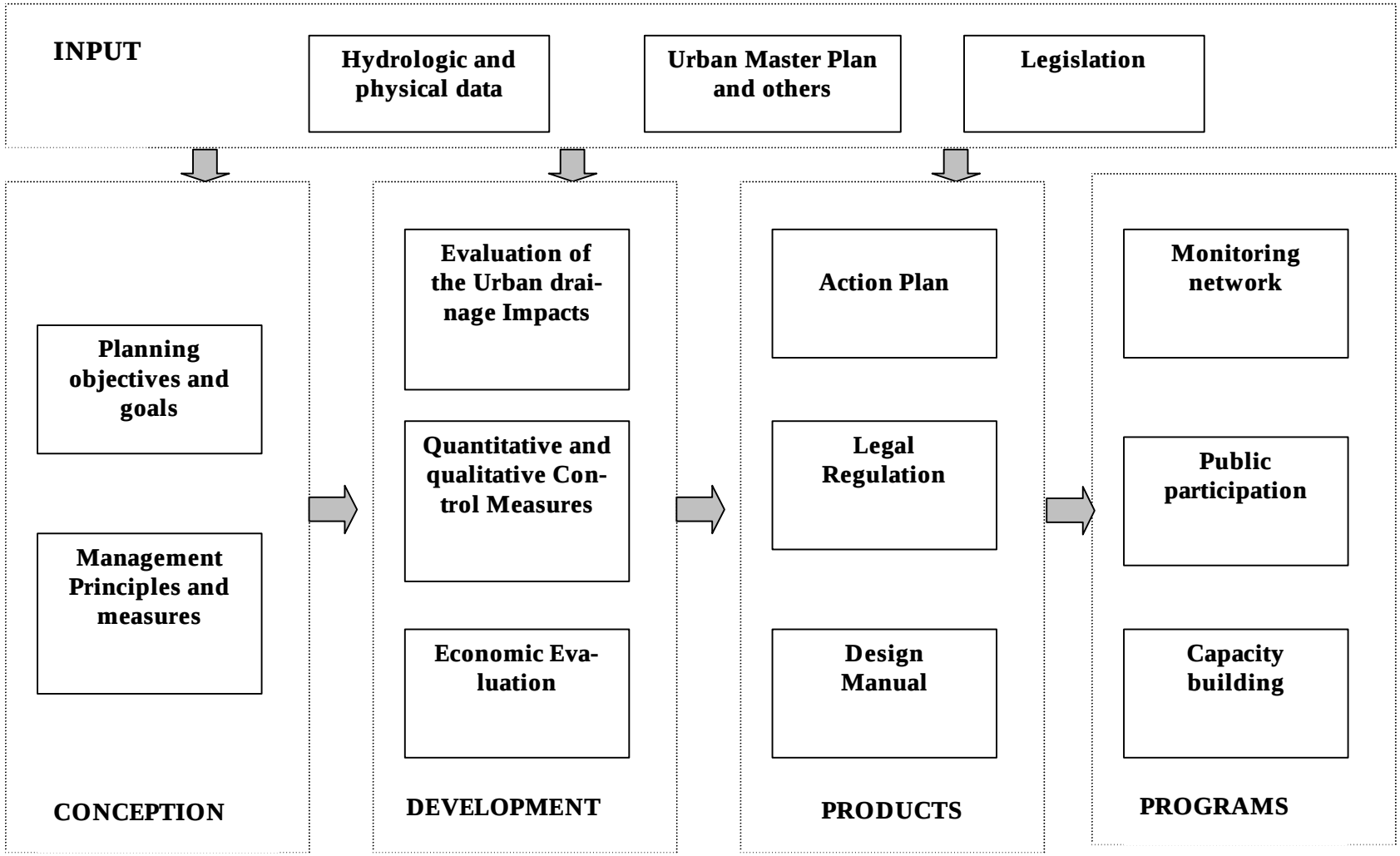


Figure 7.4 Urban Drainage Master Plan steps

The main studies in the plan are the following:

- Development of Basin Urban Drainage Plan study on flow control in the major drainage of the city;
- Develop regulation for future real state developments and for new areas inside the city boundaries;
- Develop other institutional aspects such are: county organization and personnel; capacity building; public participation and others.

Some of the main elements of the UDMP are:

Boundaries: regulation should cover the areas described in the Urban Master Plan. The Basin Plan studies should also cover all county basins and manage an agreement with others counties which share the same basin. This agreement is very important because it will be impossible to enforce the regulation if only one side of the basin is regulated.

Regulation module: regulation modules should be based on the county administration but taking into account basin conditions. In that situation, each basin may have more than one regulation module related to administrative boundaries which could have the same control goals inside the basin.

Risk and scenarios: Flood return period has been selected based on the characteristics of the urban area where the economic damages due to floods can vary. The recommended values were developed based on damages and constructions data of developed countries. For humid tropics it may not be realistic since the flood frequency is higher and the costs of construction, for the same flood risk, are greater than in developed countries and an economy with lower incomes. Appropriate economic studies should be done for this environment.

Urban development scenarios present a lot of uncertainties due to uncontrolled urbanization. In this situation the scenarios usually are: (i) current situation; (ii) future urban plan conditions; (iii) uncontrolled urban plan conditions.

Evaluations: The basin Urban Drainage Plan usually has the following parts:

1. *Structural Measures*: develop solutions for the current scenario of development based on public investment, since the floods are already a problem;

2. *Regulation*: develop regulations related to urban drainage to hold the downstream impact on peak discharge and limits for water quality degradation, taking into account the social and economical conditions.
   The best regulation is that which increases public participation. Some of the basic aspects of this type of regulation are: the new development has to keep the peak discharge equal to or below the pre-development scenario and limits for impervious surfaces in each development.
   In developing countries part of the city expansion is developed based on illegal developments while most of the city densification (approval of construction in existing urban infrastructure) follows the county administration regulation, since the real estate has more market value. This is not the best stage to regulate drainage control, but for the city areas where downstream drainage is a problem, source control at this stage of development can be an important management option. In this situation, the regulation can be done through permeable areas or OSD (On site detention) (see box 7. 4).

3. *Plan the future development:* select public green areas or parks which could be used as detention. These public area can be used to damp the flood rise from uncontrolled develop-

ments (lack of law enforcement). It is a prevention process in holding the impact inside of some urban basins. They are recreational sites which also improves the environment. If these areas are selected in the natural drainage they could be used to control the drainage urbanization impacts with low cost.

Some of urban development problems which create important impacts on drainage are presented in table 7.4. In the table are also discussed the potential source of the problems and proposed solutions.

Plan products

Action plan : This should include the implementation of the main measures planned for the critical areas. Usually there is: an emergency plan for the most important critical problems which require a quick solution; medium and long term actions which have to be developed over the time in order to implement all the public actions in urban drainage.

Regulation: regulation is part of the non-structural measures for spatial control. It is established in the county legislation or included in the City building code.

The non-structural public measures in the Plan should be concentrated in: urban drainage regulation on urban densification and new developments; selection and development of green public areas as volume storage; develop public education and participation on the subject; update of engineers and architects.

Urban drainage manual: the urban drainage manual is used to advise the engineer on city restrictions and procedures accepted by the city in urban drainage design. The main recommended contents of this manual are:

Principles and conceptions of the Urban Drainage Master Plan: This chapter should present the main conceptual elements of the Urban Drainage Master Plan such as: source control; hold the peak discharge increase without transferring its impact downstream; improve water quality; take into account future urban development scenarios;

Regulation: Identify clearly the regulation related to drainage such as: flow limits for selected return period; detention and impermeable area limits; urban densification; tax incentives for flood control; type of building construction for risk areas, among others;

Design: The manual should advice about the technical potential alternatives available for flow and water quality control, main advances and limitations. However, the manual does not need to specify how to prepare the calculations in each situation, but the main available methods, criteria, parameters recommendations, return period, maintenance procedures among others have to be covered.

Programs

The programs are long term actions which provide support to the Plan goals. The main programs usually are: hydrologic and water quality monitoring; public participation (box 7.6) and capacity building at all levels.

A hydrologic and water quality monitoring network is needed to allow the estimation of model parameters used in planning, design and evaluation of control measures in urban drainage. This information reduces the cost of these actions since they are done based on local basin behavior and not on literature information.

Public participation can be obtained by: (i) statistics on public opinion; (ii) discussion of main issue in each neighborhood public session and priorities decision (see box 7.3); (iii) explaining the impacts and benefits of the plan and projects during their development and receiving inputs from

the local population. When new administration comes in (after elections) many projects are discontinued or closed down, thus increasing public participation gives long- term planning a project has a greater chance to survive political changes.

Capacity building should be developed at all levels: update technical support for county and private engineers of about new concepts of flood control and urban drainage; more information about source control and non-structural control measures for architects and engineers in order to design improved constructions, taking into account this kind of measures; overall population to help their participation in public decisions.

Box 7.6 Public participation in county investiments

Some Brazilians cities decide on their budget investments thorough a sequence of public hearing for each neighborhood and for the main city projects. In Porto Alegre this budget decision process has been developed now for twelve years and in Belo Horizonte for six years. In the most recent one the Urban Drainage Plan has been chosen as a fifth priority among 34 main city projects.

Table 7.4 Some urbanization issues and main proposal for control

Urbanization issues	**Potential causes**	**Water impact**	**Control Alternatives**
Illicit connections of waste water sewage to stormwater pipe networks	Lack of investments in sewage system Lack of enforcement	• Raw Sewage flows in the stormdrainage with bad odor during dry weather periods; • Increased the chance of disease dissemination during street floods • the cost of urban drainage control increases	• Source control in order to reduce the downstream flow • Detention for selected areas; • Improve sewage network and separation enforcement • Penalty system
Occupation of risky areas	low income population and other social and economic problems	• Risk to lives • Economic losses	• Plan for control of risk areas: population transfer to safe areas and public infrastructure investments • Structural control
Occupation of public area by poor population	Low income and other social and economic issues	• Lack of infrastructure such as water supply, sanitation, garbage collection and drainage, with impact inside and outside the area; • Bad environment with disease proliferation	• Garbage recycle incentive; • Community participation with partial public subside; • Leave space for detention in macro-drainage
Unofficial developments	• low price of the land in peri-urban areas and high cost of regulation requirements; • Lack of enforcement	• Downstream impact on the drainage; • sewage system overflows	• increase of law enforcement • investments in urban facilities for new neighborhoods; • Plan detention areas; • Control at densification level

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