IUWM Workshop in Indonesia

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Integrated Urban Flood Management

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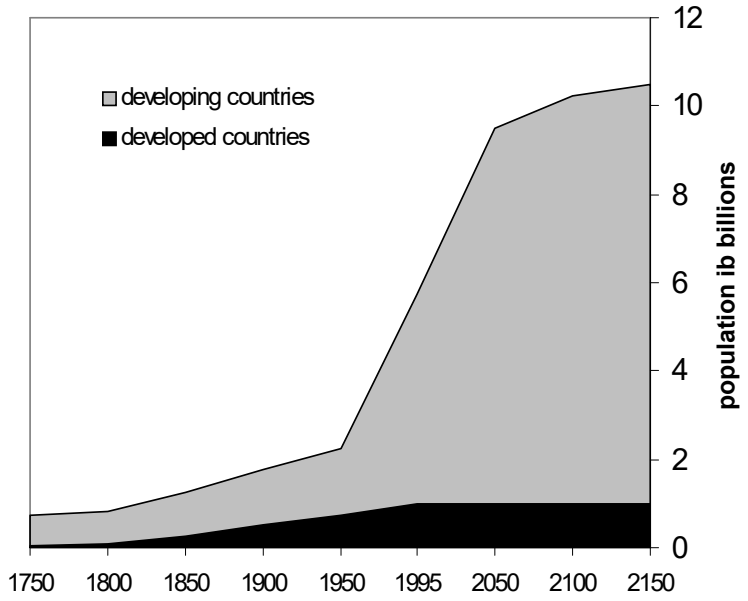
Outline

- Urbanization and its impacts
- Urban Floods
- Flood Plains
- Urban Drainage
- Urban Drainage Master Plan
- Case studies

Population and urbanization

- Population is growing fast in developing countries. Population stabilization is reach for 2.1 children's per couple;
- In 2050 urban population will be 70% and all new population is going to the cities in the following years;
- Urbanization tend to decrease the rate of population increase;
- Brazil move from 90 millions to 200 million from 1970 to 2000 (30 years)



Stages of urbanization

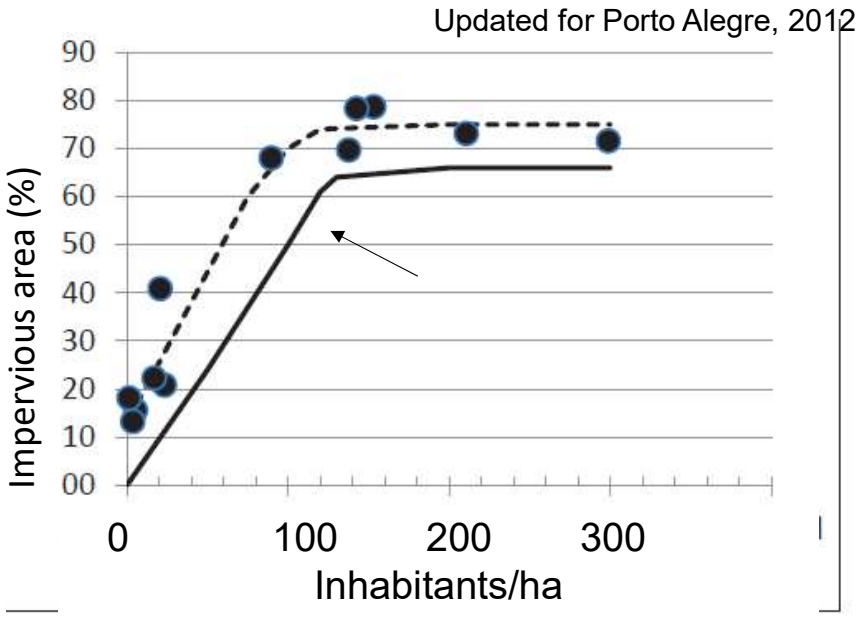
Urbanization Stages	Processes	impacts
Moving from rural to urban	Expansion of cities limits and large areas with slams	Contamination of water supply sources, lack of infra structure and floods
Urban transformations	Degradation of downtown and new central areas in the urban area	Lost of infrastructure in downtown; increasing ghettos of unregular population with pollution and floods
Reduction of density	Less population for the same area	Increase the cost of infrastructure and less people per impervious area and flood impacts

Rate of Growing inside of Brazilian cities

Cities	Population in 96 In millions	Increase downtown 91 – 96 %	Increase in the city boundaries 91-96 %
São Paulo	16,7	2	16.3
Rio de Janeiro	10.5	1.3	7.1
B. Horizonte	3.8	3.5	20.9
Porto Alegre	3.3	2	9,4
Recife	3.3	3.7	7.4
Salvador	2,8	6.6	18.1
Fortaleza	2.6	11.1	14.7
CuritibA	2.3	12.3	28.2
Belém	1.6	8.1	157.9

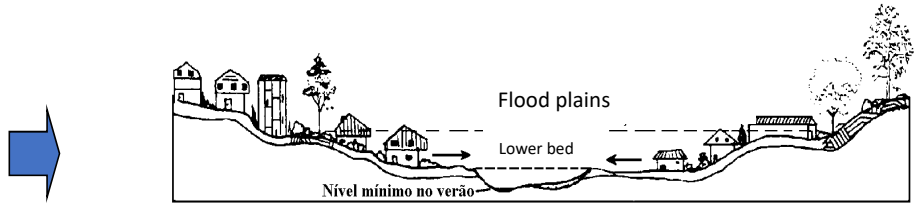
Urban Population ➡ impervious area ➡ Floods

- *Impervious area is the main parameter for urban drainage*
- Impervious area is related to urban density.
- The mean flood flow increases 6 to 7 times with impervious areas of 70%.
- 70% of impervious area represents a density greater than 100 inhabitants/hectare
- The increase the flood peak increase the floods and frequency in the urban areas

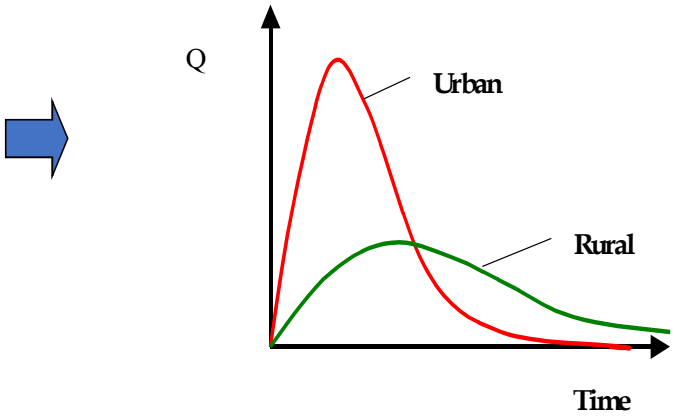


Floods

- ***Flood Plains*** : there are natural floods when the river flows through the flood plains, flooding its banks.

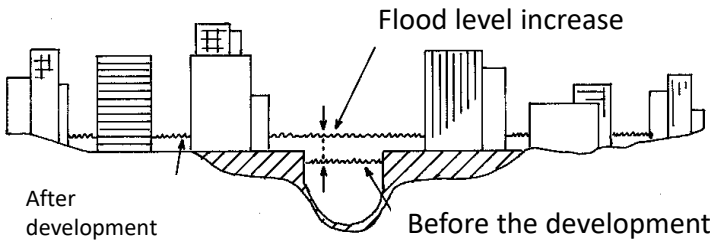


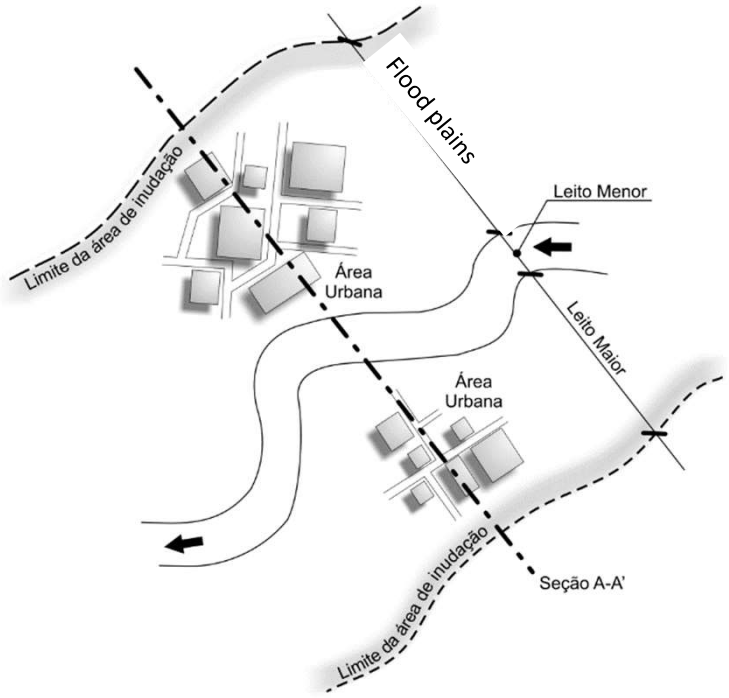
- ***Storm water***: flow through urban surfaces. The hydrologic cycle is changed, increasing its peak flow due to impervious areas and the increasing the pipes, channels and increase the flow velocity.



Flood Plains

- It is a *natural process* of a flood seasons when the river floods its banks;
- The main causes of the impacts are related to the occupation of the flood plains during the dry season or low flood season;
- Usually *who* occupy the risk area suffer the direct impact ;
- Lower bed = water level most of the time. Its limits is about 2 year flood
- Floods limits = usually defined for 100 years flood





Flood control measures

- *Structural* measures are related to the change of the basin and/or the river such as dams, dikes, channel conveyance, basin forestation, among others.
- *Non-structural measures* are based in measures related to flood mitigation such as: insurance, flood zoning, and *flood forecasting*. Structural solutions have higher costs and it is feasible only when damages costs are greater than their development or due to intangible social aspects.

Main Structural Measures

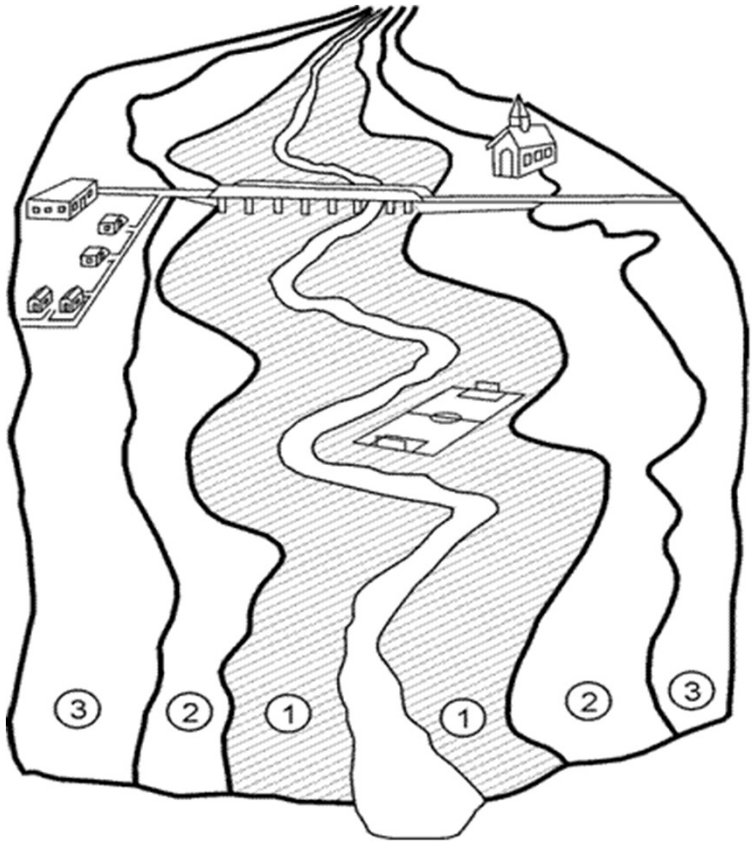
Measure	Descriptions	Application	Limitations
Reservoirs for flood control	A reservoir can be of single or multiple purposes. A reservoir constructed for flood control is more effective.	Small and medium size basins	• For small frequency floods the effect of reservoir decreases; • Use of land for reservoir volume.
Dike	Local or specific control of the flood. Requires the use of pumping the flow from the drainage of protected areas.	Large basins	• Limited to six meters high; • Risk of break which create more damage if it does not exists; • Requires flood forecasting.
River section change	Decrease level in the area of interested increasing the flow capacity. It can be done by increasing river section, decreasing roughness or increasing river slope (cutting meanders or change channel bed).	small and medium size rivers	• environment impacts in the reach and downstream; • high cost with a extended reach intervention.

Non-Structural measures

- *Flood zoning* is the planning of the soil occupation and regulation in order to decrease future flood impact. Since part of the population still will be living in risk areas;
- the *flood forecasting* is developed in order to alert this population and decrease their damages to flood;
- *Insurance* is preventive procedure used in order to recover the cost damage of properties in flood risk areas. It is feasible for owners and properties with important value. In addition, not all country the insurance is available for ordinary people;
- *Flood proofing* is an individual measure developed by the owner in order to protect its physical assets.

Flood zone maps and Zoning

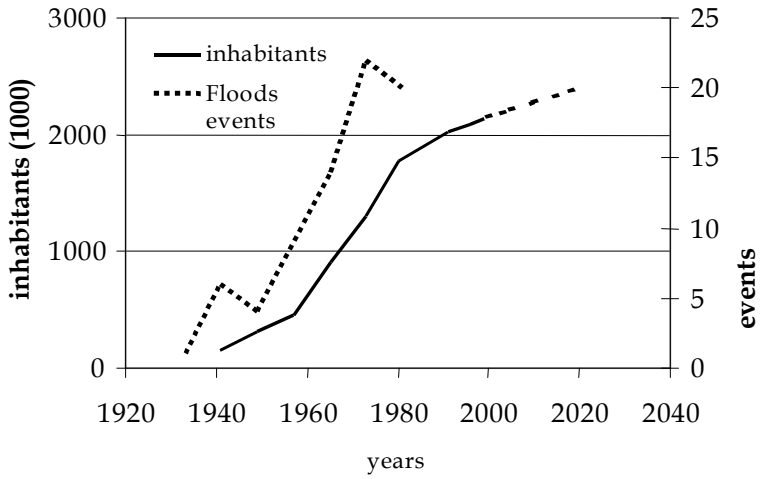
- **Floodway –** which the area which the river uses in order to develop the flow and the occupation of this area could increase the level upstream.
- **Area with restrictions**: it is allowed the occupation with some conditions;
- **Low risk areas:** where still there are some restrictions but it is more a warning to the real state owners.



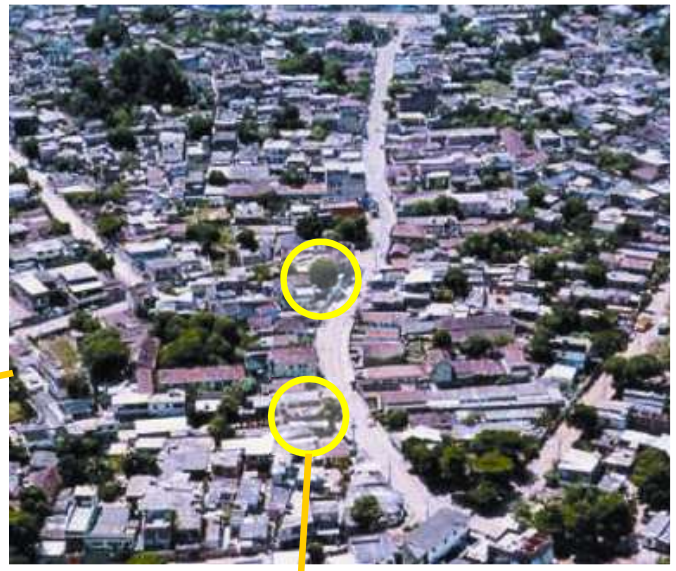
Stormwaters

- Increase in the peak flow and flood frequency due to impervious areas and pipes and channels;
- Increase of the solids in the rivers because of the unprotected surfaces and waste from the population ;
- Decrease of the water quality because of pollution of washing urban surfaces.
- Diseases related to water in the floods such as leptospirosis

Belo Horizonte - Brazil



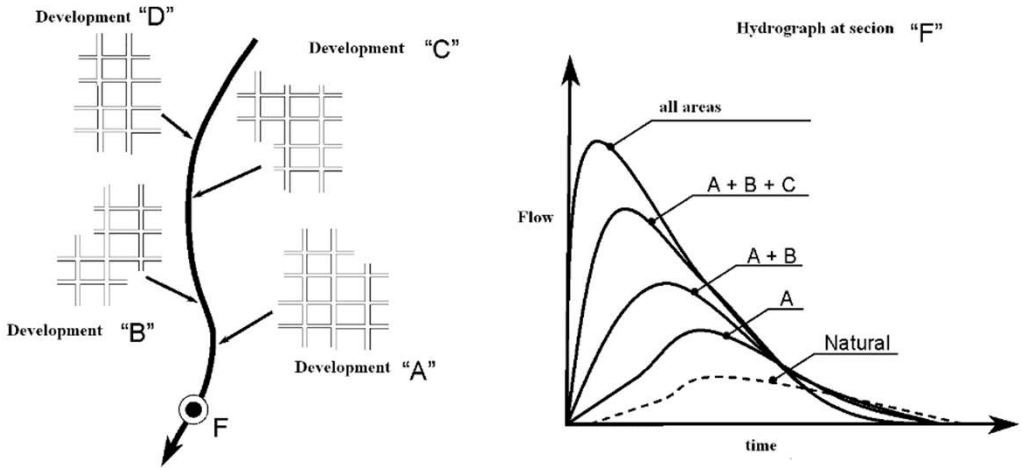
Usually who produce the impact does not suffer from it



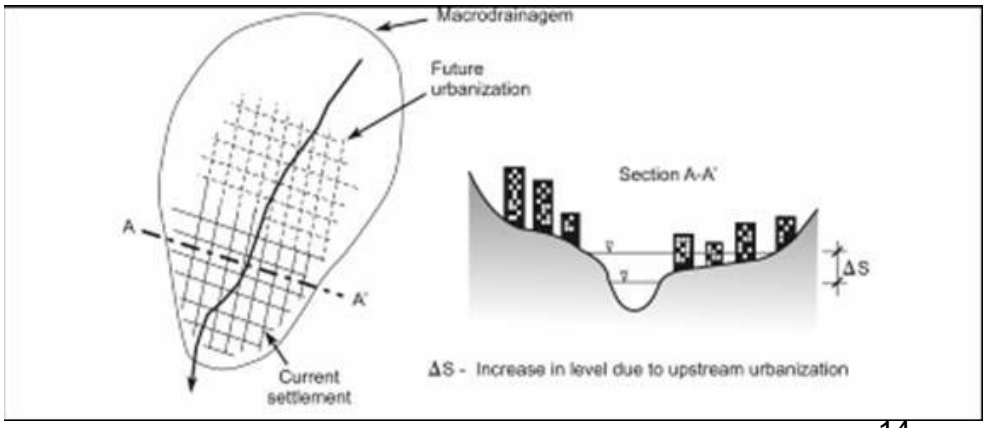
IMPERVIOUS AREAS

Main issues on urban drainage

- *Floods frequency and peak increase with urban development due impervious area and conduits.* In the figure floods increase at F with each new development upstream;

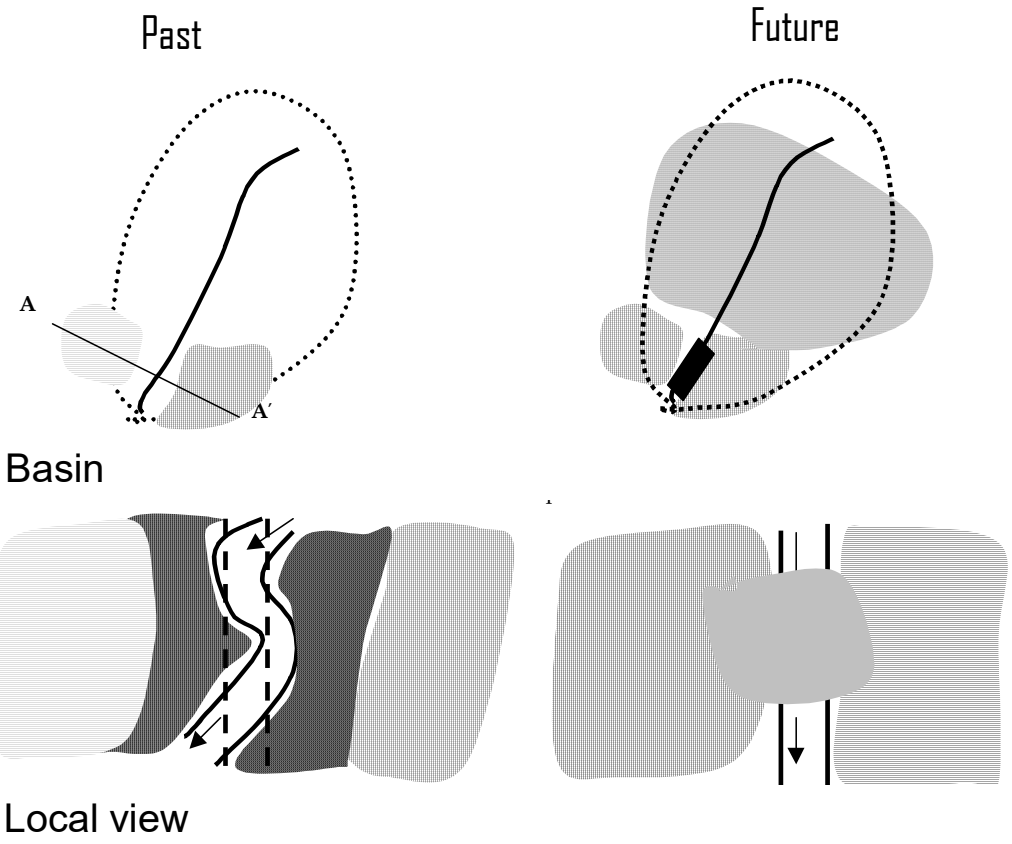


- When developments occurs from *downstream to upstream*, the existing population is impacted by new population. In the figure, after the increase of urban development upstream *flood frequency and peak increase downstream.*



Combined effect of flood plains and stormwater

- In the past the population was in safe area and near the river is risk of floods;
- With population increase is developed a channel and population occupy the area. Upstream the basin is occupied increasing the peak floods.
- The floods come back to the river and there is not more space for sustainable solutions



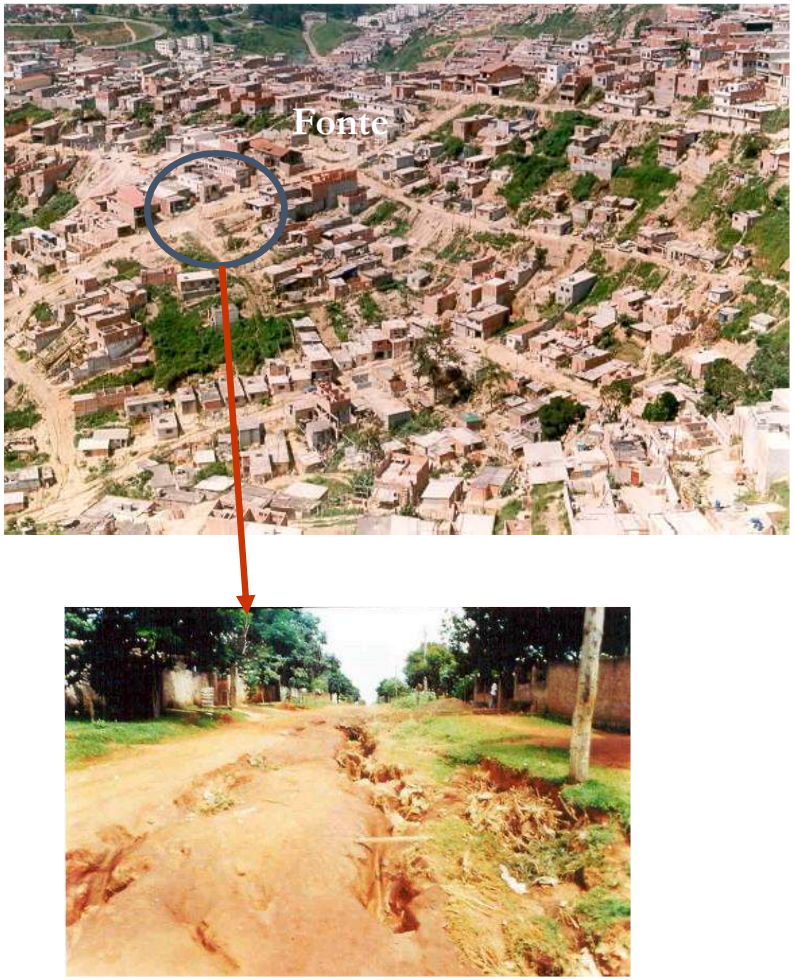
Solids

Total solids = *Sediments + solid waste*

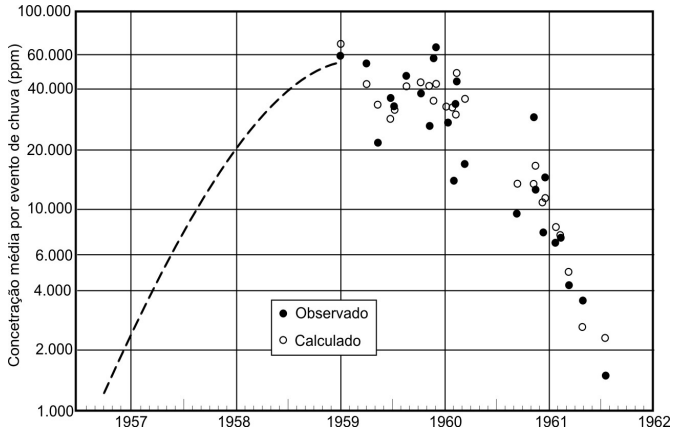
- Sediments = increases with unprotect surfaces and flow velocity;
- Solid Waste = increase with population, bad of services and education.

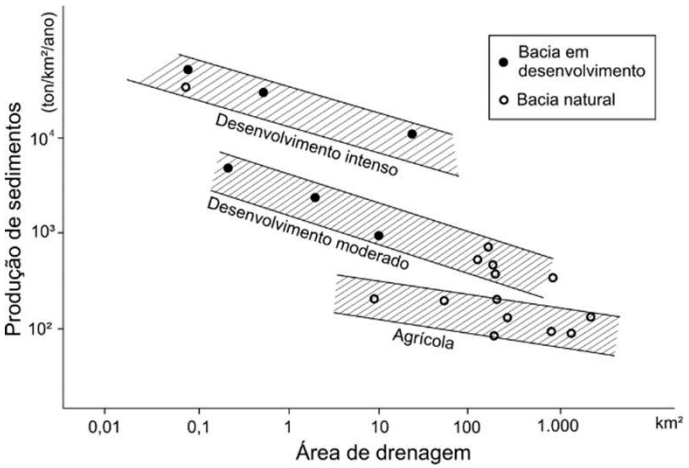
Phase I – City under development - high increase in sediments and low amount of solid waste when the

Phase II – City developed - decrease sediments yield and increases the solid waste



Sediments yield





Solid Waste

Solid waste = SW

SW = Tc + Tli + Td

Tc = colected

Tli = from cleanning

Td = stormwater

- When the first two terms are not developed or are not efficient the last term increases, leaving for the environment;
- Loss of conveyance capacity

Stormwater quality

- 90% of air substances which drops in impermeable areas are transported to rivers (Oberts, 1985);
- In the urban areas the surfaces are contaminated by the population by chemistry compounds, organics, etc. It can be aggravated by the water acidity;
- Organics such as BOD, N, P, etc
- metals: Plumb, Copper, etc;
- High load in the beginning of the flood when the former days were dry
- 90% of the load is in the first part of the rain

Stages of Urban Waters

Stages	Period	Characteristics
Pre-hygienist	Until early 20 century	Urban systems without sewer and stormwater networks and treatment; sometimes septic tanks and stormwater in the streets with high proliferation of water born diseases.
Hygienist	Until 70's	Safe water supply, sewer network without treatment plants and river contamination; channels and conduits in the stormwaters or street flows, transferring the impact of impervious surface to downstream.
Correction	After 70's	Sewage treatment, detention and retention ponds in the stormwater systems, regulation for increase flow from urbanization.
Sustainable	After 90's	Regulation and measures for stormwater pollution; natural practices of infiltration and recovery and maintenance of natural functions of the basin. Planning the urban space taking into account its natural flow conditions.

Main principles for sustainable flood management

- Flood control for the *whole urban basin*;
- Take *into account future city developments*;
- *Do not transfer the flood impact* to downstream reaches;
- Priorities of solutions *which keep the natural functions of land and aquatic systems*;
- *More emphasis should be given to non-structural measures* such the regulation, capacity building and other prevention programs;
- Management instrument is the *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.*

Sustainability

- ***At property level*** *(private enterprise)* : Green Building, Low Impact Development are private programs which certification to buildings give sustainability in terms of eficiency and environment.
- ***Ar state level***: urban recovery and inegrated management of urban areas developed to transform the cities. In this scenario a flood is not a problem. It is a opportunity to change the city

Source measures – inside of the private property

Public Urban drainage – minor and macro drainage

Opportunities at source level

- *Harvesting water* – using roofs to collect was and reuse inside of the house and buildings. Its effects is much more on supply side of the equation. Supply part of water used in this buildings;
- *Green roof* – the main effect is on reduction of temperature and energy and some smaller effect on floods
  https://www.youtube.com/watch?v=FlJoBhLnqko?
- *Infiltration* – supports the vegetation, increase groundwater recharge (the impervious area reduce it) and reduce overland flow

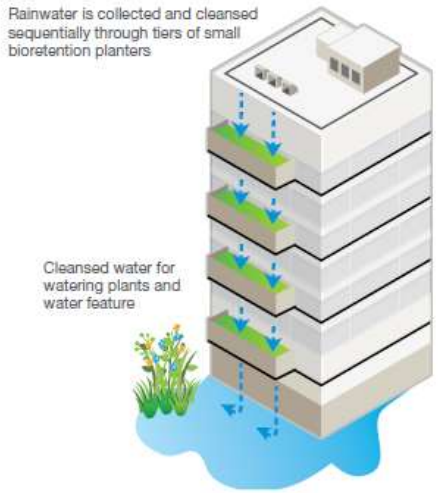
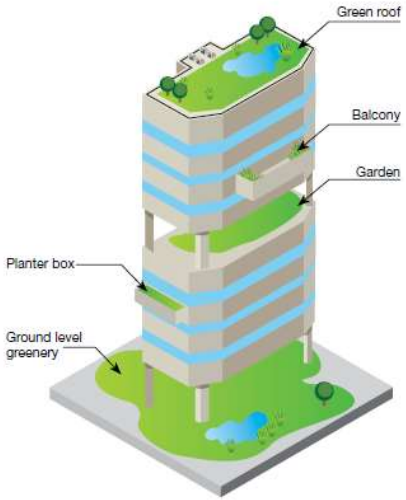



Fig. 4.11 Balconies and planters are greatly utilized in public as well as private developments in Singapore (Khoo Teck Puat Hospital).

Fig. 4.4 and Fig. 4.5 Cleansing Biotopes installed at Potsdamer Plarz, Berlin, Germany (left), and the Centre of Excellence, Sindelfingen, Germany (right). *(images by Atelier Dreiseitl)*

Infiltration and small ponds can reduce local flow to natural conditions

Regulation for storm water requires the new construction keep the flow from natural conditions.
These source measures allow that in each construction the flow to outside drainage is the same as previous in a natural land.

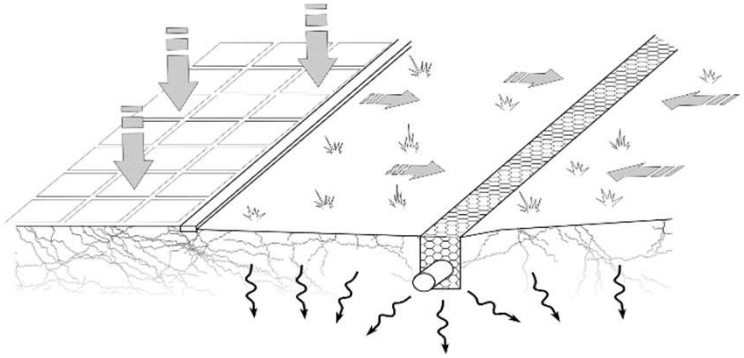


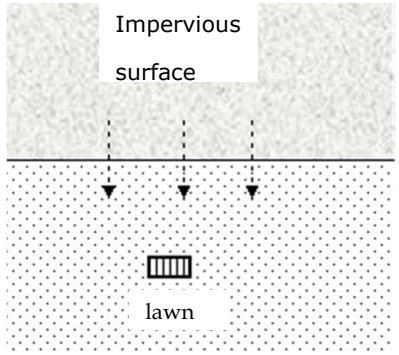
Green surfaces

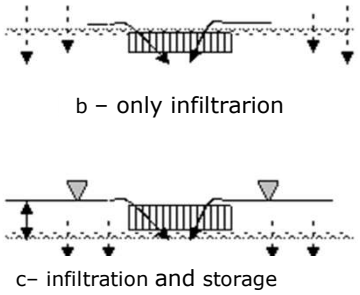
Infiltration

Infiltration surfaces*:* In general, the infiltration area is an area of grass that receives precipitation from an impervious.

- It reduces the overland flow and *recharge the groundwater*, recovering the natural hydrologic cycle



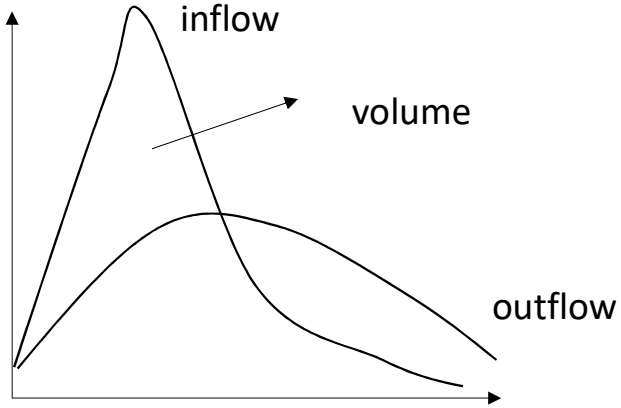


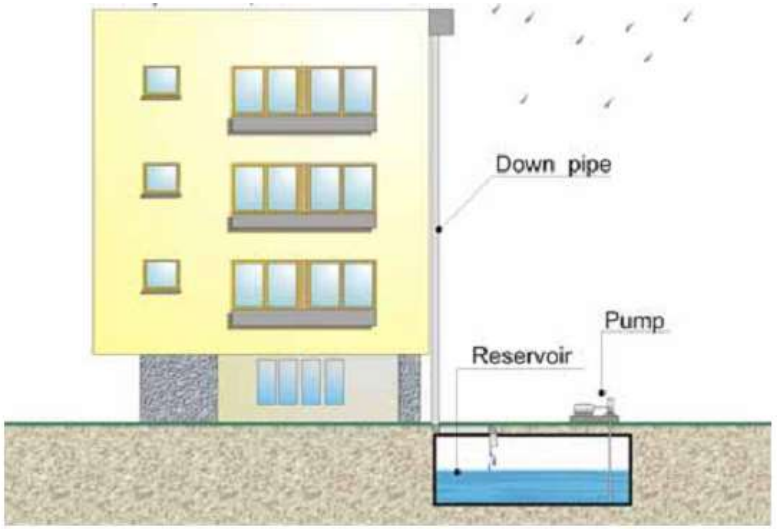


Streets without curbs

Storage

- Storage can take place on roofs, in small residential reservoirs, car parks, sports fields, etc;
- There are various possible configurations for reservoir lay out into urban housing development and projects





www.projectbrays.org/highlights.html

Stormwater detention pond in Seattle, Washington. Courtesy of: City of Seattle

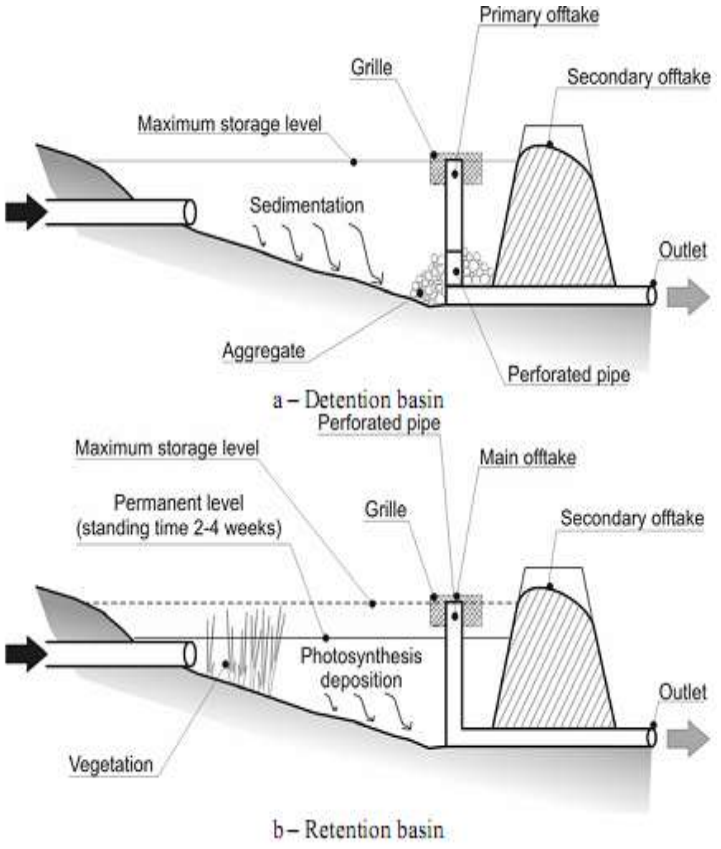
Main benefits of source measures

This measures developed distributed in the urban space has the following benefits

- Decrease the flood peak to previous natural conditions;
- Reduce the overland flow and the pollution on water quality;
- Decrease temperature ;
- Increase value for the properties and revenues on taxes;
- Brings strong political support for the decision makers since it has a strong visual accomplishment

Storage characteristics at macro drainage

- **Peak flow control:** is used to attenuate the upstream peak. Detention pond dry volume;
- **Water quality control:** used to improve the water quality, retention pond, part of volume is with water
- **Solids control:** when a significant quantity of sediment is produced, a detention basin can retain part of the sediment so that it can be removed from the drainage system.

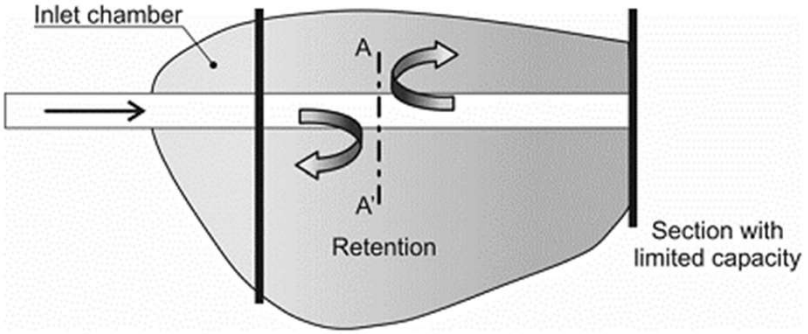


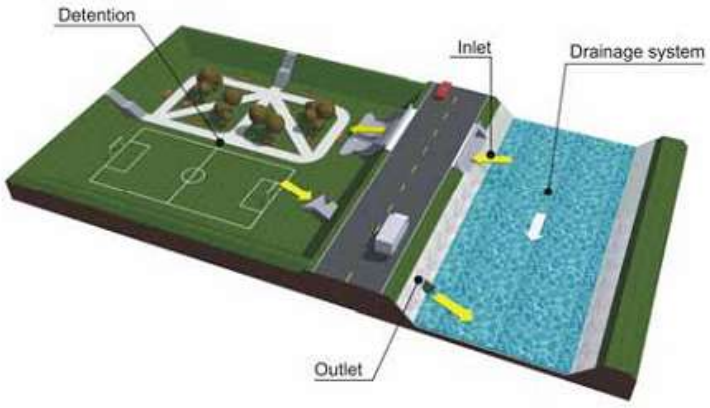
Detention

retention

Detention - Storage and the drainage

- **In-line** when the drainage flow through the storage. It needs a garbage control screen in the entrance
- **Off-line** when outside of the main drainage (used when the system is polluted). The area can be used for other uses and integrated to the urban environment





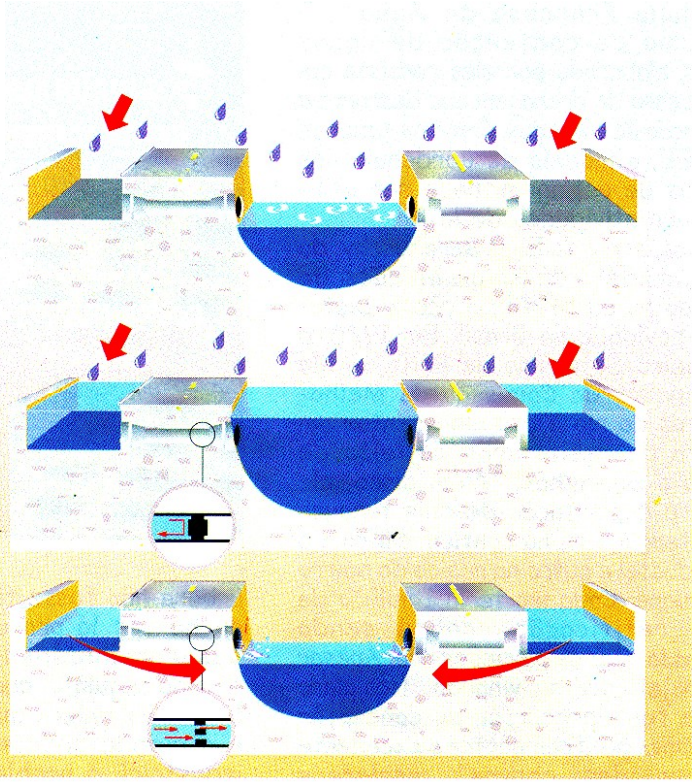
Off – Line Detention

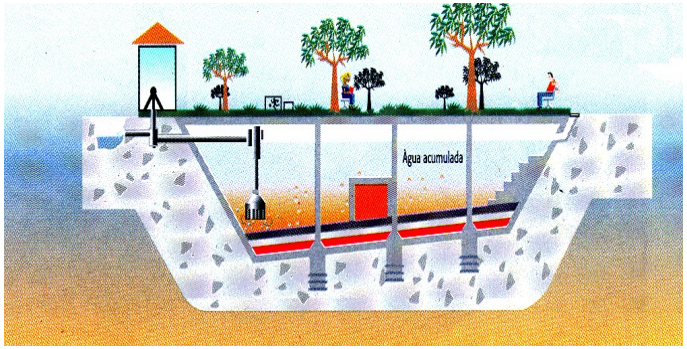
The detention is mainly used when there are combined sewers. During days without rain the contamined flow goes downstream. In flood days the less polluted flows is storage.

Until the flow is inside the channel flow all to downstream

When the capacity is less it floods the detention

When stops the rains it flow back to the channel.




Água acumulada

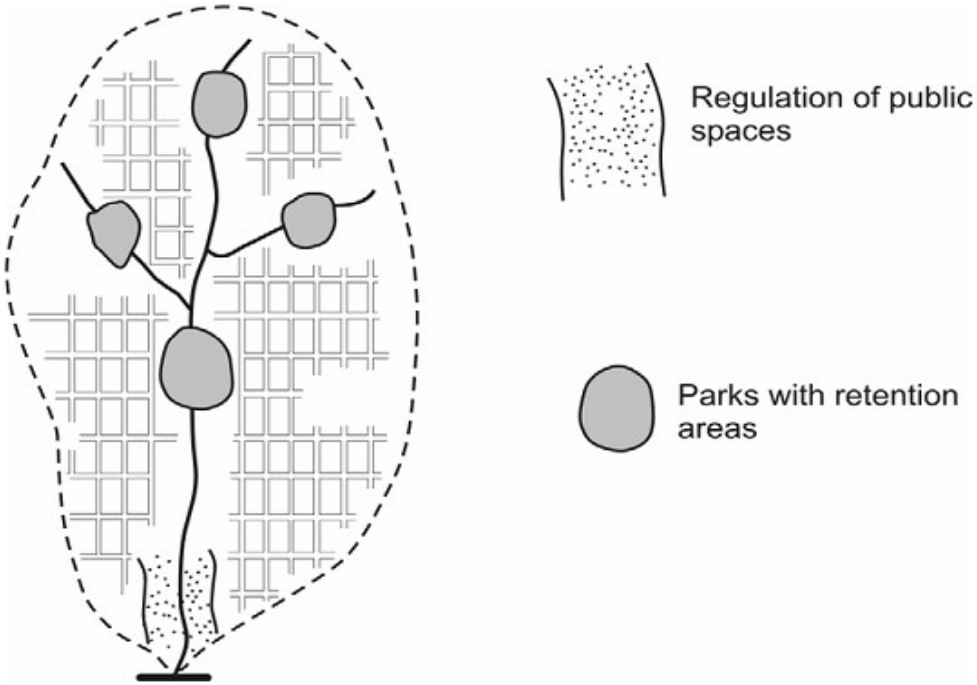
Macro drainage alternatives

- Flood control in an urban basin is a combination of: (a) increase flow capacity of conduits or channel; and (b) storage (detention or retention pond).
- The cost of flood management in a basin varies from of about US$ 0.5 millions/km^2 to up 10 millions/km^2.
- The lowest cost is for use only of detention pond without land cost (public areas) near the drainages. The high cost is for use of conduits underground with high urbanization and no storage
- the retention or detention has to be integrated to the urban landscape in order to be accept as an asset by the community;
- he maintenance is important to keep the storage as an asset. Population could be against this type of solution after bad services;

Urban scenario	Type of solution	Cost US$ million/km2
Developed dense urban area	Channel and conduits	6 - 10
Developed and dense urban area	Mainly Detention (storage)	1 - 2
Under development area with many spaces	Source measures and detentions	<0.5

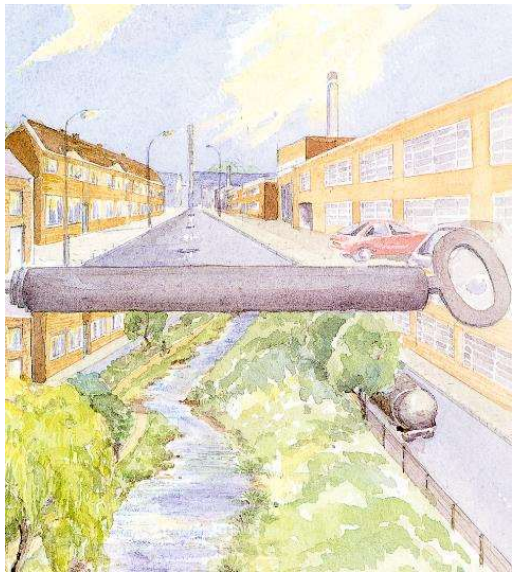
Drainage Planning for expansion urban areas

- Reserves the spaces near to the natural drainage ;
- Use these areas for parks and other amenities;
- the reservation of space for detention is based on 1 to 2% of the basin area.
- The park area can be added to this amount
- When de area is urbanized the park-detention can be implemented with low cost
- All the flood increase upstream of the area can be dumped in the area.
- This process integrated urban development and drainage.



Urban Recovery – Integrated Solutions

- Reurbanization and ressetlement
- Transport
- Recovery of natural functions of urban water systems
- Sanitation solutions
- Solids services
- Urban drainage water quality
- River water quality recovery

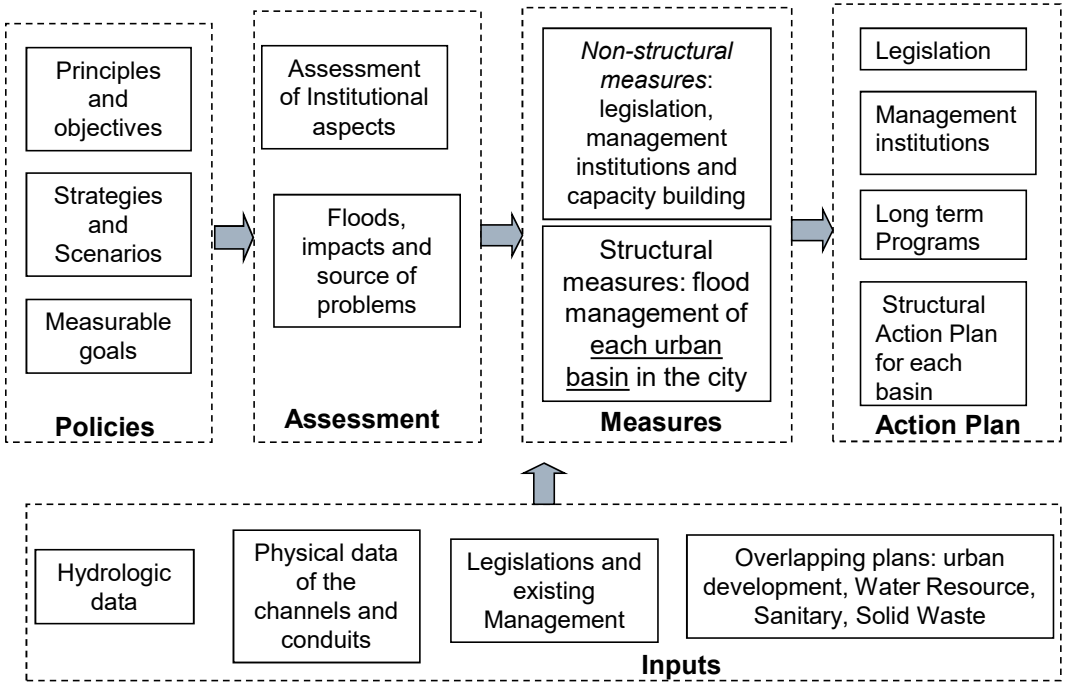


Before

After

INTEGRATED URBAN FLOOD MANAGEMENT PLAN

- *Policies* which are: objectives, principles, goals and scenarios definitions for the studies in the plan;
- *Assessment* of existing conditions related to flood. It evaluates which are the floods along the cities for the scenarios and presents the follow up recommendations;
- Development of the *Measures* (non-structural and structural) to reduce the impacts and reach the goals; and deliver the outputs and outcomes for the city.
- *Outputs* - Plan of the urban basins; no-structural measures and Action Plan



TERESINA, Brazil

- It is Northeast State capital from Piaui, State of Brazil. Below the mean GDB per capita in Brazil;
- Teresina has a population of about 800.000;
- North Lagoon is the area of investment with 13 km2 and population of about 100.000;
- The more visible issue for the population was the frequent flood, but the environment condition was very bad.

1995 Flood in the area


Flood 2008


Irregular occupation


Lack of
infrastructure

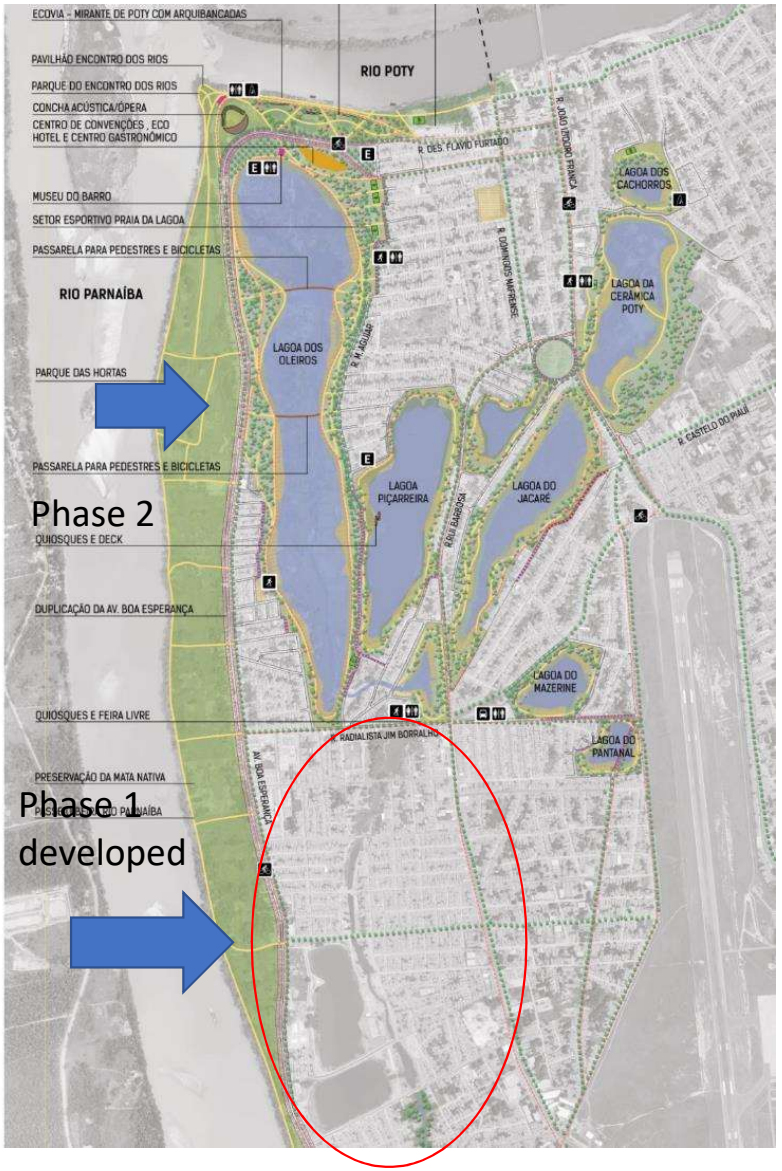

Solids and pollution

Integrated solutions

- Flood control and drainage: conservation of the lakes storage, increase capacity of pumping to the rivers;
- Sanitation: collect and treat all sewage of the urban settlement;
- Based on the flood study and level of security, resettlement of population on risk area;
- Housing for resettled population
- Implementation of parks, streets and transport of the areas
- Use part of public space for school, and cultural activities such as museum;
- Alternative job opportunity for existing very low income population

Project Phases

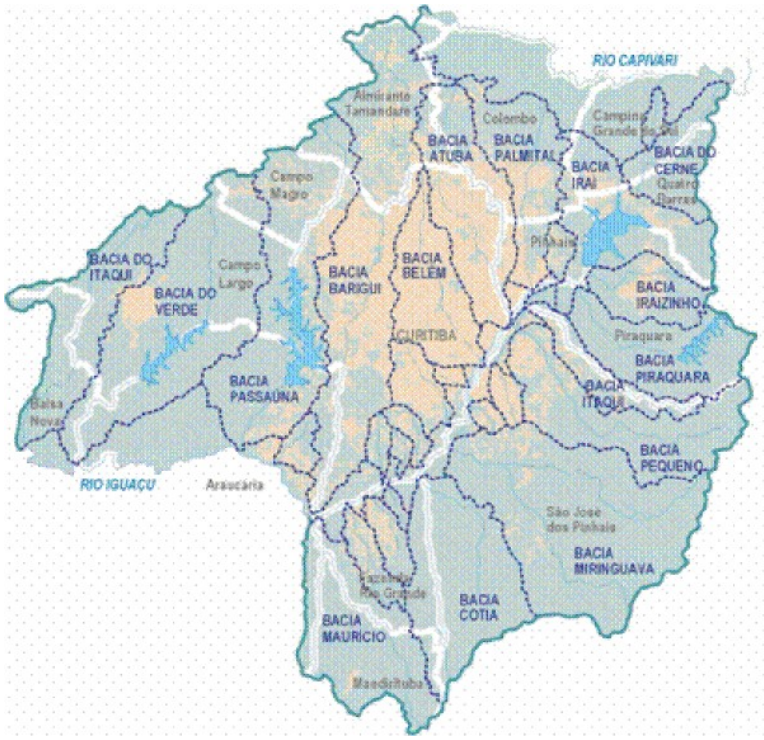
- First phase: flood control measures, sanitation: collecting and treatment project and implementation with water quality improvement; urban basic infrastructure, parks, cultural space: school and museum;
- Second Phase: complement the first phase, cover all area, institutional arrangement and incentives to private investments



after

Metropolitan Area of Curitiba (MAC)

- The Metropolitan Region of Curitiba (RMC, State of Paraná, Brazil) has a population of 2.7 million, It comprises 15 municipalities in an area of some 3,000 km^2, in Iguaçu River;
- Flooding of the city of Curitiba and the surrounding area occurs due to a combination of river flooding (Iguazu River) and urban drainage of urbanized watersheds;
- Iguazu River has about 1,000 km2 when it cross MAC.
- In 1994 there was a flood of about 300 years return period in Iguaçu River



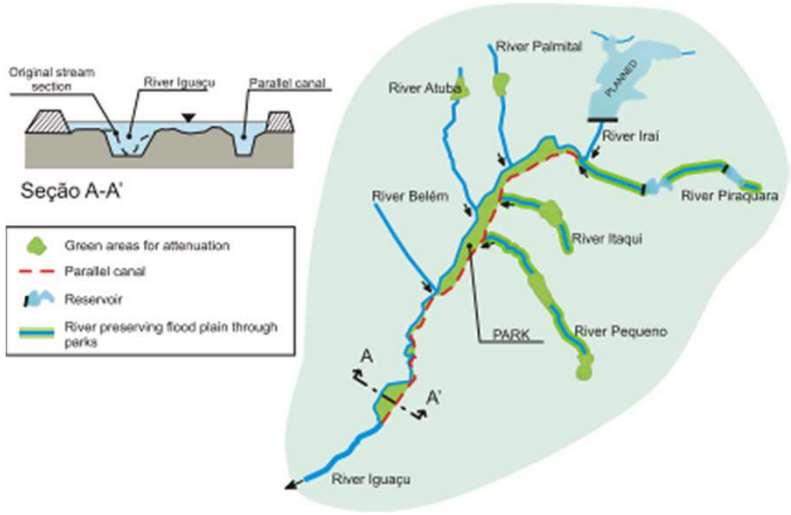
Flood management

I. Flood Management was developed in three stages:

- *emergency measures* tackling visible problems and immediate management;
- *Flood Plain impacts in Iguazu River*: managing the flood plain risk area with parks;
- *Urban drainage master plan* for the metropolitan area developed area which covers about 250 km2 of dense population;

II. Alternatives for the Flood Plain areas

- *Zoning of areas of high risk*
- *Reservoirs*
- *Confining runoff with dykes*
- *Increasing the runoff capacity*



III. Solution

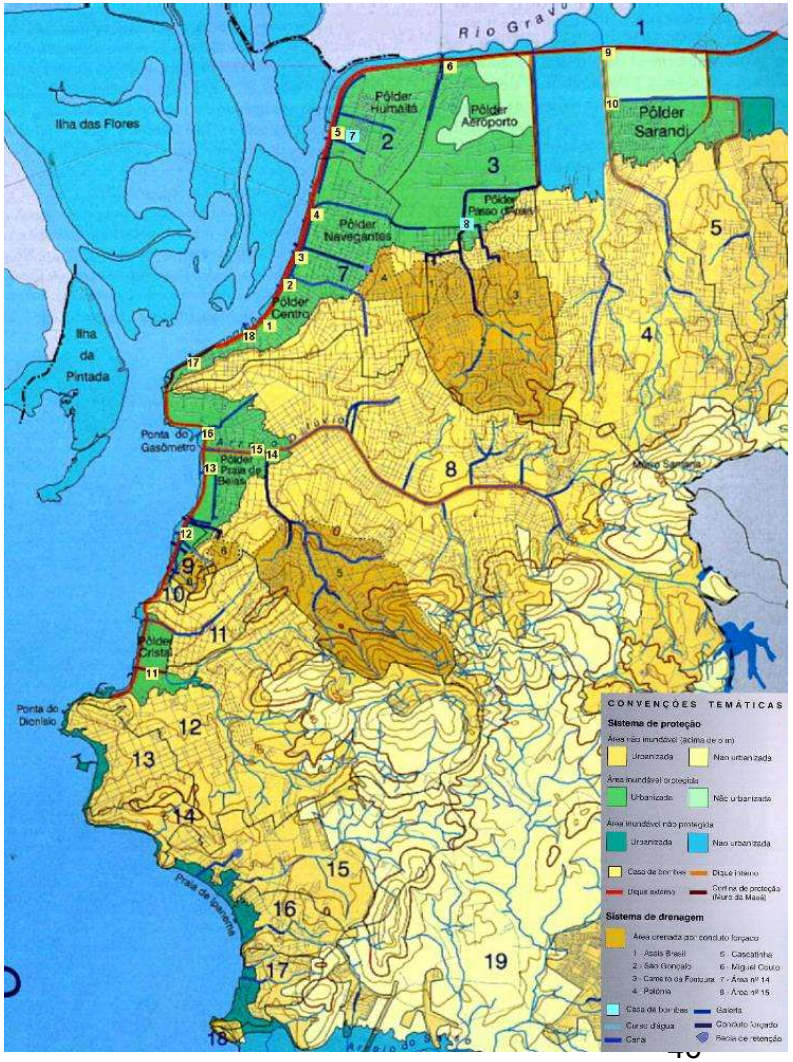
Combination of parks and channels and upstream storage

Planned area and implemented

Urban Drainage Plan of Porto Alegre

- The Metropolitan Region of Porto Alegre (State of Rio Grande do Sul, Brazil; 3 million) is sited on the delta of the Jacuí River and Guaíba lake, with a watershed of some 80,000 km^2 and a confluence of four rivers at the delta that subsequently run into the lake;
- Flood dike was constructed in 1970 and urban development increases in last 40 years with internal floods;
- Flood impacts on urban drainage

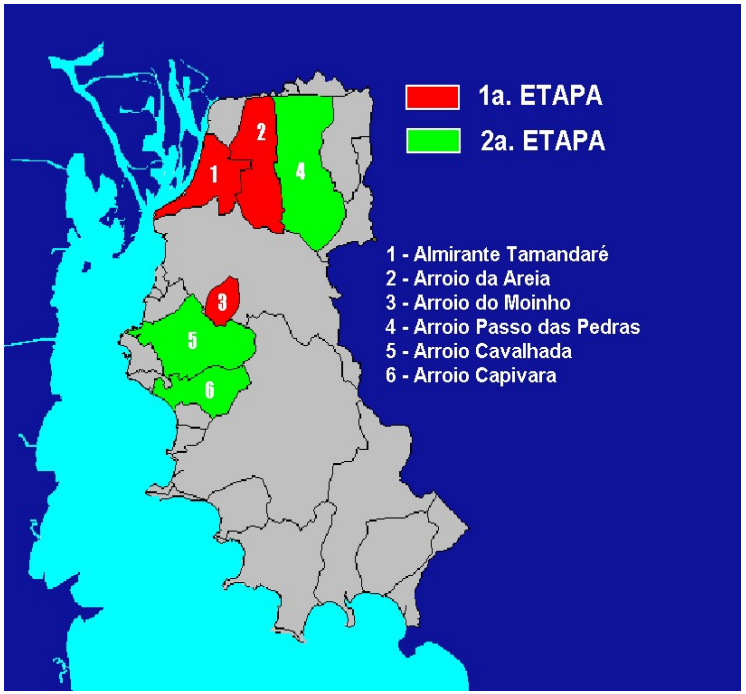
Dike constructed in 1970 Red line



Urban Drainage Master Plan

The Plan was designer to be developed by steps:

- *Step 1 - Non-structural measures*: urban drainage regulation; Urban Drainage Manual; Review of Flood Plains dike. The Utility exist since 1973 2000-2001;
- Step 2 – Plan for three watersheds(2000-2001);
- Step 3 - a further three watersheds were recently developed (2001-2002);
- Step 4 – Other basins along the following years and implementation of the works



Non-structural

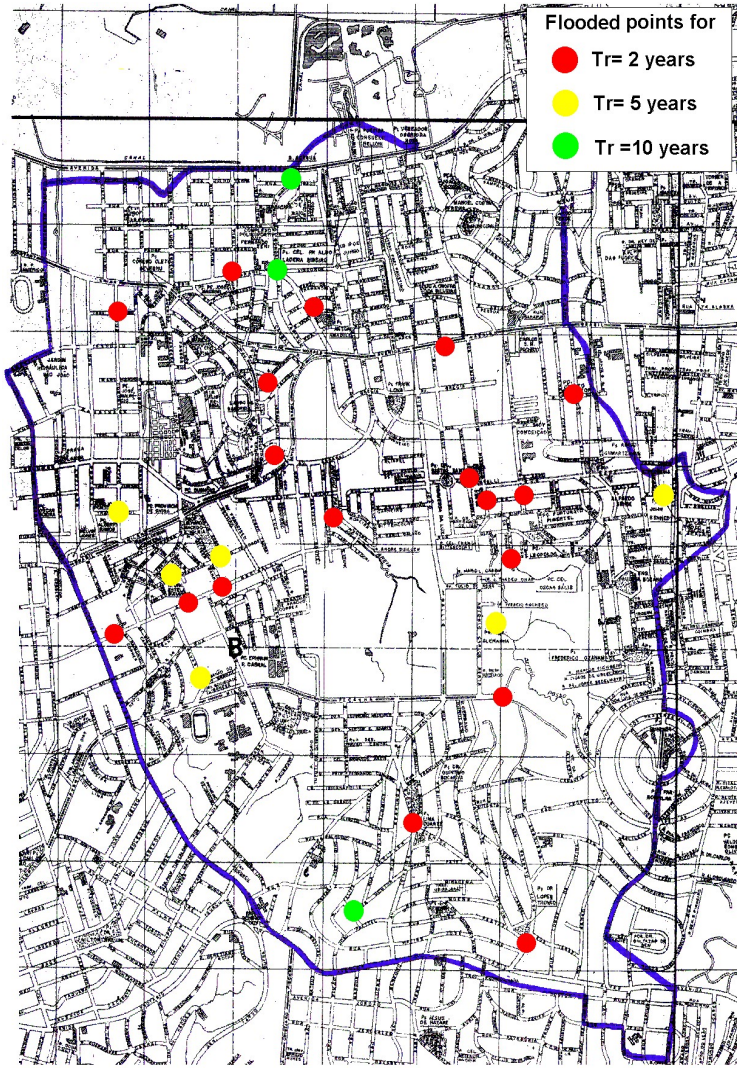
- Urban Drainage Manual was developed to support professional in the design drainage in the city;
- Regulation in order to control the urbanization effect of the drainage. It was implemented by the utility.
- After 7 years these procedures are very well received and the estimated cost reduced was about US$ 3 millions/year for the county;
- Assessment of dike system and the risk for flood protection.

Urban Master Plan for each sub basin

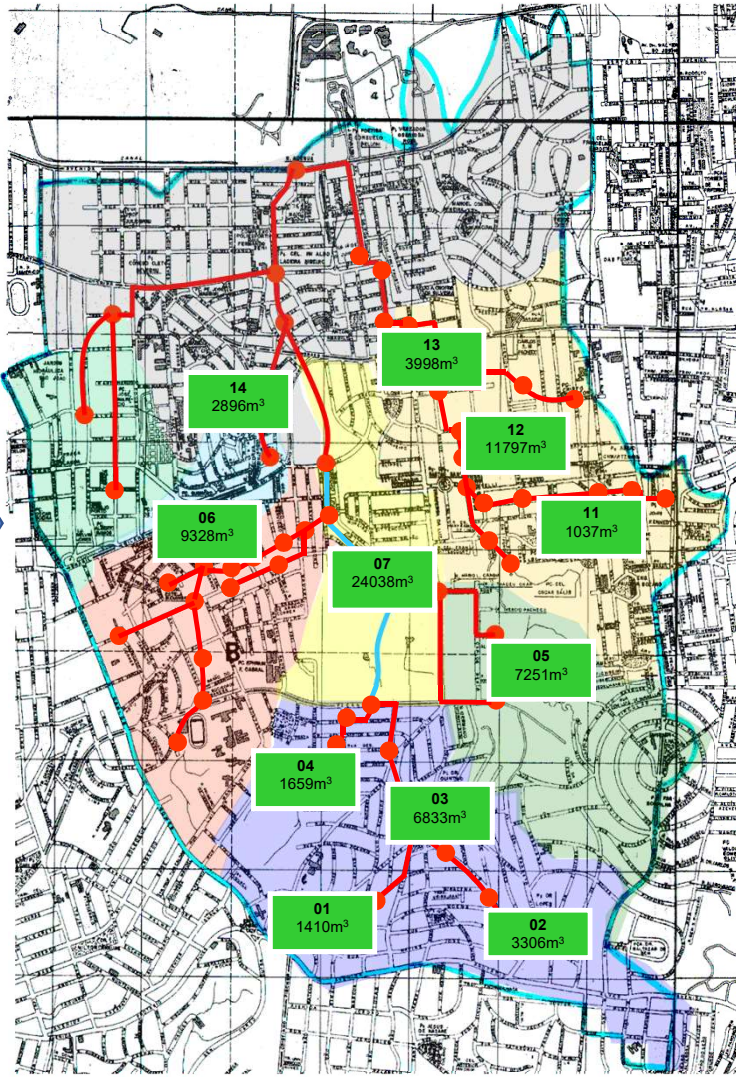
- Evaluation of the runoff capacity of the drainage system;
- Identification of areas liable to flooding;
- Combination of detention and increase in runoff capacity, endeavouring to keep the outflow equal to the current capacity for the future scenario;
- Check of scenarios exceeding the design values. sub-watersheds.
- **Areia Basin** - The watershed is in two parts, the upper section (12 km^2) that drains in conduits under pressure above the 9 metre level directly into the river Gravatai, and a second part of a similar area that is drained by pumping (in the area of the airport).
- High density of population and high income.

•Detention ponds solutions represents lower as compared to increase flow capacity of the conduits and channels.

Existing Floods Places



Detention ponds solution



Conclusions

- Managing floods requires an integrated view in the city, taking into account urban developments and all aspects of urban waters;
- The institutional aspects are necessary in order to have a sustainable management;
- Usually the low cost solutions are the best but usually are more politically difficult to implement
- The public participation is the fundamental
- This is a process in many steps.