CHAPTER 2

Multifunctional landscapes for urban flood control: the case of Rio de Janeiro

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Abstract

The urbanisation process changes the natural landscape, generally aggravating flood problems. In developing countries, urbanisation is not always accomplished by the implementation of the adequate infrastructure required. Lack of planning frequently worsens this situation. Focus on urban flood problems has been changing in the past few decades. The traditional approach that basically focused on improving conveyance, by canalising and rectifying watercourses, is being complemented or substituted by different conceptions. This new approach tries to equate an integrated solution for the basin, with distributed interventions aiming to recover pre-urbanisation flow patterns and combining water quality and quantity control aspects. These newer concepts deal with storage and infiltration techniques. In densely urbanised environments, however, it is not always easy to find suitable areas available for construction of detention/retention reservoirs or extensive infiltration measures. In such situation, an interesting option may be the use of multifunctional landscapes, in which urban solutions gain additional hydraulic functions, gathering urban planning and hydraulic engineering aspects in order to revitalise urban environment and control floods in a sustainable approach. The use of existing parks and squares, remodelled to aggregate permanent or temporary ponds, can be an interesting option. In most developing countries, as in the example of Rio de Janeiro City, Brazil, water quality problems due to untreated sewer disposal are generally more crucial than those associated with watershed wash-off. Worse than this is the fact that water quantity problems are still so severe that quality control is a secondary concern. In this context, this chapter presents and discusses a revision on urban flood problems and two case studies, where multifunctional landscapes are proposed. The first one is related to
the urban basin of Joana River, which is one of the major tributaries of the drainage net of centre-north zone of Rio de Janeiro City. Traditional town districts are part of this basin and there are several areas subjected to floods. The designed solution proposed included a set of distributed measures, including some multifunctional landscapes. A mathematical model was used to simulate this integrated flood control project and the results presented show the potential benefits that can be achieved through the use of multifunctional landscapes associated with public squares with storage capacity. This kind of solution points to an articulation of architecture, urbanism and engineering to help in solving flood control problems in urban environments, especially those regarding developing countries reality, where resources are scarce. The other case study is related to a polder area, at Baixada Fluminense, a very low land in the metropolitan area of Rio de Janeiro city. In this case, a set of soccer fields were proposed as multi-functional landscapes, in order to recover the polder capacity, which was lost over the years because of uncontrolled urban growth.

2.1 Introduction

Present urban shape of most of the cities has appeared in Europe, in the second half of 19th century, focusing the concept of a ‘functional city’ with large urbanised spaces (squares, avenues, gardens, wide streets). City planning intended to allow a better flux of people and goods, as well as aimed to produce a better integration between men and built and natural environments. However, even in this context, urbanisation is surely a man-made action that causes great environmental impacts. Some of them, especially those related to land use changes, generate direct consequences on the drainage system. This fact may be felt in flood aggravation problems, decrease of dry season discharges, water quality deterioration and, therefore, fluvial ecosystems degradation.

In this way, once urbanisation is a fact, flood control is one of the major issues with which urban planners must deal nowadays. According to Freeman [1], 60% of human life losses and 30% of economic losses caused by natural disasters are due to floods. In developing countries this problem is often more critical. While developed countries face challenges related to an integrated control of water quantity and quality, most of the developing countries are still solving quantity problems.

The concepts applied to the design of stormwater control interventions have changed a lot in the past few decades. In general, most of the solutions developed in the past were based on the enlargement of the drainage network in order to suite channels and pipes to convey stormwater flows that grow as the urbanisation process takes place. Modern concepts try to focus on the reduction of urbanisation hydrological impacts by using infiltration and storage measures [2]. In some highly populated urban regions, the lack of free spaces to settle flood control facilities and the high costs required to provide the removal and reallocation of the population living in high flood risk areas restrict the range of solutions available. In this context, one interesting possibility is the use of multifunctional landscapes designed with additional hydraulic and hydrologic functions. This chapter presents and
compares two different case studies developed in Brazil in which these techniques are being or could potentially be applied.

2.2 Brief review of historical growth of the cities

Industrial revolution marks a deep society change. The decreasing of death rates, combined with an increasing production, pictured a general growth trend. From this moment on there was a rupture in a secular equilibrium, in which each generation tended to occupy the place of the preceding one. In this way, cities started to grow quickly, encompassing natural population increasing and migration fluxes. At the same time, liberal economists sustained that public intervention should be limited in all branches of social life, including urbanising controls. The consequences were critical to city development. In the first half of 19th century, the industrial city problems appeared to be too numerous to be completely solved. Original city centres did not support adequately the ever-growing housing and traffic needs. City centre started to become vacant and poorer. Peripheral areas started to be occupied by districts of different characteristics in a compact urban pattern [3].

The post-liberal city appeared as an alternative to the industrial city. This time, freedom given to the private enterprise was limited by the intervention of the public manager, establishing limits in regulations and acting in public works for people welfare. In this context, public administration managed to put the city to work in a minimal adequate way. At that time, commerce and circulation of goods were privileged in detriment of the remaining productive activities. As a consequence, modern urbanism searched for an alternative city model, in which ‘artists’ and ‘technicians’ started to work jointly in order to try to reach a better equilibrium for the built environment. Modern architects criticised the contrast between public interest and private property and indicated as an alternative the re-conquering of public control over all the city spaces [3].

In developing countries, however, with their late industrialisation, the process of urban population growth happened to be faster and concentrated in the second half of 20th century. Little investments, lack of infrastructure, uncontrolled growth, minor opportunities and poverty were negative consequences of this process. In this context, the situation of a built landscape adequately designed, in a city guided by urban plans, referred only to one part of the population. The other part is not in condition to be assisted by regular services from the formal city and organises by itself in non-proper conditions, near to urban chaos. The formation of an irregular city, standing aside the regular one, forces the need to re-consider recent architecture development trends.

Architecture and Engineering are placed at the crossroad created and they need to find solutions to recover the irregular city, providing the needed infrastructure and developing urban plans that correspond to the real needs of local communities and stakeholders. Figure 2.1 shows two examples of the growing of an irregular city in Rio de Janeiro, Brazil, where it can be seen sub-habitations on hill slopes and in riverine areas.
2.3 Urbanisation process and urban flood problems

Natural floods are phenomena caused by high runoff rates generated from intense rainfalls. The urbanisation of a watershed generally tends to aggravate the natural floods as it promotes original vegetation removal, increases imperviousness, canalises river reaches and promotes the occupation of flood plains (Fig. 2.2).

Therefore, greater water volumes flow more quickly over the basin and finally accumulate in lower areas, which are often densely occupied. When urbanisation is not adequately planned, the consequences of this process may become critical and cause several economic and social losses, besides great annoyance for the affected population (directly and indirectly).

In some cases, the urbanisation process may progress until a level in which very high imperviousness and demographic density rates are achieved, with a generalised occupation of the basin, including areas usually subjected to natural floods. In such cases, it is difficult to equate the problem and the set of structural measures available for flood control becomes more limited, as the lack of free areas and the high cost of properties and public infrastructure act restraining the possibilities of intervention.

Since a long time, flood control design concepts have been evolving, accompanying historical demands of urbanisation and its consequences. The traditional approach for the problem focused on the drainage net itself, arranging channels and pipes in an artificial flow net system, with the objective to convey the exceeding waters away from the interest sites, as stated in the introduction of this chapter. At a first moment, canalisation solutions were able to deal with floods in certain areas, transferring waters downstream with no major consequences. However, more and more areas of the watershed turn impervious when urbanisation grows and the city develops. Upstream occupation stresses the system as a whole and the drainage net tends to fail. By this time, it becomes difficult to depend exclusively on improving channels conveyance capacity to try to adjust the system behaviour.
Urbanisation itself limits river canalisation enlargement. Streets, buildings and urban facilities tend to occupy banks and the original flood plain – once flat areas are always desirable. Upstream reaches of the main river cannot be canalised without aggravating downstream problems, where the former city area lays. Focus now is forced to move to a systemic approach, where the whole basin must be considered. Distributed actions spread around the basin comply with the drainage net in order to control flow generation. Spatial and temporal aspects must be considered together in a way that the proposed set of solution measures may reorganise flow patterns and minimise floods. Therefore, distributed flow control can be an important alternative, once it acts at the source of the problem. This kind of structural measures are often cheaper than traditional enlargement of drainage channels [5].

Considering this brief discussion, it is possible to say that the design of urban drainage measures is a process that must consider local aspects, related to the particular basin and city, making each solution unique. Therefore, the pure replication of successful experiences can most often lead to non-effective solutions and unnecessary expenditure of money.

The reality of developing countries, in general, is much different from the one observed in developed regions. In this way, understanding urban trends in terms of growth and changes of patterns of land use in developing countries is very important in order to support the definition of urban plans and flood control strategies [6], which should also consider social, cultural and environmental aspects [7, 8]. Some
urbanisation aspects and urban floods issues common to developing countries are emphasised below:

- extremely high population growth over a small period of time;
- unplanned urban growth and patterns;
- deficiency in spatial coverage of drainage, water supply, sewerage and wastewater treatment infrastructure;
- lack of appropriate removal and disposal of solid wastes;
- lack of investment capability;
- great needs in terms of definition of plans and guidelines for urban drainage management and qualification of local authorities staff;
- conflicts in terms of definition of responsibilities of governmental authorities;
- habitation policies that are usually unable to prevent irregular settlements;
- legal and illegal occupation of flood risky areas;
- communities with large number of occurrences of water-related diseases;
- large number of poor slums, where most of the problems are located;
- lack of education and awareness of population, which sometimes cause damages to flood control structures and dispose garbage over river banks;
- difficulty to diagnose problems and to settle solutions due to public security problems (e.g. poor areas under influence of organised crime).

2.4 Flood control measures and urban solutions

Recent trends in urban flood control involve the use of the so-called Best Management Practices (BMP) and the concept of low impact development (LID). BMP is defined as the set of planned actions implemented in a watershed, with the goal of promoting the attenuation of the urbanisation impacts, considering not only water quantity concerns but also water quality aspects [9]. Coffman et al. [2] recommend the use of low hydrologic impact projects, which consider the use of measures aiming to re-establish storage and infiltration conditions previous to the catchment urbanisation. Distributed control of surface flow generation should be considered regarding not only on-site areas but also public spaces, such as streets, sidewalks and squares. In some cases, the flow re-distribution may be achieved through detention or retention structures varying from large reservoirs, locally damping discharges from large watershed portions, to smaller reservoirs distributed over the urban landscape. Therefore, the urban flood problem is presently being considered under a new point of view in the scientific and technical discussions. It is assumed to be more important to treat the problem at its source, in a systemic way, with distributed actions over the urban landscape, aiming to decrease and delay flood peaks, also allowing groundwater recharge and looking to recover the approximate conditions of natural flow. In this way, seeping pavements, on-site detention reservoirs, detention ponds, infiltration measures, reforestation, green areas preservation, sidewalk gardens and greenways, among others, can be good solutions to achieve the proposed goals, and can also integrate the urban environment harmonically as some of them can be
designed as recreation areas at dry seasons, thus assuming multifunctional landscape characteristics.

Many cities have been working to minimise concrete surfaces impacts. The city of Saarbrücken, in Germany, for instance, has developed a program of subsidies for projects that allow water conservation and surface flow decreasing. Some detached actions are related to projects for harvesting and use of rainfall water, projects of substituting impervious pavements by vegetation or seeping pavements and projects for green roofs construction [10].

Schilling [11] has studied the use of water tanks in Germany in a residential area of 2.69 ha where 29% represented roofs. Using 140 water tanks with 0.5 m³ area, he obtained reductions of 10% to 20% in the peak discharges for different return periods (RP). For frequent floods (recurrence less than 1 year) the reduction reached 80%. O’Loughlin et al. [12] have analysed the use of on-site detention varying according to the type of the construction. This study involved the city of Sidney, in Australia, where the Municipal Council has indicated the use of on-site detention, incorporated to the constructions and to government land use guidelines.

Hall and Porterfield [13], searching to find solutions to recover the harmonic design of communities, arranging their growth in a sustainable way, while preserving the landscape characteristics, stress the importance of runoff control. These authors state that detention or retention basins, used for flood control, can also be used as amenities, when projected with imagination, helping to create healthy and functional environments, favouring the conservation of a diversity of vegetable and animal species, as well as adding aesthetical aspects that help to increase land value. The possibility of integrating drainage solutions with urban revitalisation programs may be an interesting option for flood control projects, due to the opportunity to combine different objectives in multifunctional interventions, allowing the optimisation of public resources investments. Figure 2.3 shows some different examples of simple flood control measures integrated to urban solutions.

2.5 Mathematical modelling as an aid to evaluate integrated design projects

Urban watersheds tend to produce large inundated areas. When leaving drainage system, water flow paths may be diverse from that of the drainage net, following patterns dictated by the urbanisation. Sidewalks along channels may become weirs for the rivers, spilled waters may flow through the streets that start to work as channels, and the storage of waters on streets, buildings, squares or parks make these areas work as reservoirs (although in an undesirable way). This extreme situation gets worse when micro-drainage does not work as expected, what is often usual, especially in developing countries, due to obsolescence, lack of maintenance, or obstructions generated by the presence of litter and flood debris carried by the flow. In fact, when microdrainage does not work as expected, flooding in urban areas can begin even without the occurrence of macrodrainage spilling.
In this context, assessment of urban flood problems is very difficult if there is not an appropriate tool to aid in the simulation of the basin as an integrated system. Moreover, the design of urban flood control projects may not be effective if considering local solutions. It becomes necessary that the use of a mathematical model be able to represent systemic hydrologic and hydraulic characteristics of the basin. The construction of such a model, an urban flood model [14–16], based on the concept of flow cells [17] provided a valuable option as a tool for urban floods diagnosis and flood control design. This model focuses on the representation of the urban surface through cells, acting as homogeneous compartments. In each cell a rainfall runoff transformation is performed. The chosen set of cells for a certain basin is able to integrate all the basin areas, linking superficial flows with drainage net system and making them interact through cell links, considering various different hydraulic laws. Different types of cells and links give versatility to the model. Figure 2.4 shows a catchment profile, where it is possible to see a schematic cell division and the interaction between cells, while Fig. 2.5 illustrates the hydrological process in a cell.

2.6 Comparison of different multifunctional landscape approaches – case studies

Different authors have presented several definitions of multifunctional landscapes. The basic idea is that a given area can fulfil different functions and
Figure 2.4: Schematic representation of a region divided into cells, showing different interactions.

Objectives regarding ecological, economical, cultural, historical and aesthetical concerns [18].

The application of this technique to developing countries is feasible but must consider particular aspects related to local communities and other stakeholders in order to be successful. The following case studies present two multifunctional
landscape approaches, with stormwater control functions, developed for Rio de Janeiro State (RJ), in Brazil.

2.6.1 Adding stormwater control features to urban revitalisation programs in Rio de Janeiro municipality

The municipality of Rio de Janeiro presents a highly urbanised environment, with many irregular occupations in slope and natural flood areas. Floods caused by intense rainfall during the summer are one of the major concerns of the population. In this town, the City Hall has been developing, since 1993, a revitalising program of the urban space, acting on public squares, re-defining streets alignment, creating new parking areas and bikeways, recovering sidewalks and acting on the major drainage net. This program is known as ‘Rio-Cidade’. The main focus of the drainage actions already held by this program was on pipes and channel enlargements. These measures, most of the time, transfer the flooding problem.
to areas located downstream. Following an analysis of the implemented projects, some alternative actions were proposed, in the context of multifunctional landscapes, avoiding actions on the existing drainage net and using distributed control of runoff flows. The use of distributed storage and on-site control techniques is usually cheaper than traditional approaches of enlargement of the drainage net. In this way, developing countries, where significant investment capability restriction is a reality, should make an effort to use these kinds of solutions more frequently.

One of the proposed actions consists in the possibility of re-urbanisation of public squares to work as temporary detention reservoirs. In urban regions, the lack of free spaces to be used as stormwater control facilities is often critical. On site detention measures could surely help to solve the problem, but it depends basically on the acceptance of stakeholders (who usually must assume the cost of construction, operation and maintenance of the facilities) and, in developing countries, government authorities can hardly certify that these measures are operating properly or even if they were set [19]. In this way, the use of public spaces to work as stormwater control measures can lead to a minor risk of failure of the system.

The use of public squares as flood control measures faces two major challenges.

(a) Convince local community and stakeholders of the importance of this measure and develop public acceptance – this action is extremely important and a problem that occasionally happens is that sometimes the community living close to the square that is going to be adapted does not suffer with flooding (this is more typically found in upstream reaches), reducing local acceptance of this kind of measure;

(b) Develop strategies to prevent frequent flooding of the storage chambers during more frequent rainfall events and to clean the place right after the end of an intense storm event. The reason for this is to allow the regular use of the square most of the time, using this space for flood control only once in a while and preventing the spread of water-related diseases, as stormwater quality is critical, with the presence of sewer and consequently pathogen organisms.

The first case study presented in this chapter refers to Joana River Basin, an urbanised watershed with approximately 11 km², comprising the districts of Grajaú, Andaraí, Vila Isabel and Maracanã, at the northern region of Rio de Janeiro city, in southeast of Brazil. Grajaú, Vila Isabel and Andaraí were neighbourhoods that took part of the ‘Rio-Cidade’ Urban Program. Joana and Maracanã Rivers are the main rivers of the Mangue Channel basin, an important city reference, located at the city port zone. In this major basin, there are some of the most critical flooding points of the city, including the Bandeira Square and the surroundings of Maracanã Stadium and Rio de Janeiro State University. Some characteristics of Joana River basin encompass: high urbanisation; there is few space for construction of major works related to temporary storage ponds; the existing macro-drainage net presents reaches of stormwater galleries flowing under buildings, which are places difficult to access, with sharp angle curves, sudden cross section reductions and
other types of interferences; a significant portion of the slope areas (about 50%) is occupied by slums; water quality parameters values are similar to those found in sewer wastewaters although the area is provided with a separate sewer system, and floods are generally produced by heavy summer storms. In this context, the use of squares as multifunctional landscapes can be an interesting option to increase storage capacity inside the basin, while revitalising urban spaces.

As an illustration of the developed discussion, Fig. 2.6 shows a profile view of the project for Edmundo Rego square, in the Grajaú district, proposed by COP-PETEC [20] with an alternative layout, lowered at different levels, for acting as a temporary detention storage pond (total volume of 4,500 m$^3$). Figure 2.7 shows a plain chart of the square with its different storage compartments. Figure 2.8 shows inflow and outflow hydrographs (20-year RP) for this square simulated with the cell model. Some aspects of this project that deserve to be highlighted are:

(a) a stormwater gallery was diverted to pass below the square;
(b) a hydraulic structure was designed to prevent flooding of the storage chambers for floods up to 1-year RP;
(c) the discharge of the pond occurs only by gravity;
(d) this stormwater control facility does not need operation although it is required to clean the square after flooding.

Mascarenhas et al. [21] presented results showing that a combination of storage facilities in 12 squares, plus three reservoirs in upstream reaches of the formers of the main river of the basin and a set of on-site detention measures could eliminate the 10-year RP floods at the most critical reach of Joana River catchment – near Maracanã Soccer Stadium.

The project proposed for Edmundo Rego Square has not yet been executed. However, a similar proposal has been constructed by the water department of Rio de Janeiro municipality (Rio-Águas) in a public park (Parque Urbano Pinto Teles).

Figure 2.6: Profile view of the new arranges proposed for Edmundo Rego Square.
Figure 2.7: Plain chart of the architectural project proposed as an alternative conception for Edmundo Rego Square.

Figure 2.8: Flood dumping result for Edmundo Rego Square.
Flood Prevention and Remediation

The region used to suffer with frequent floods and the area where the park is located had no previous occupation. After the construction of this park with stormwater control features, the frequency of flood in the region has decreased significantly although the absence of hydrological monitoring makes it impossible to determine precisely this reduction. Nowadays, several activities integrated with local community, such as public fairs and shows, are taking place at this park.

Some other flood control measures that could be adopted by ‘Rio-Cidade’ Program, such as the use of seeping pavement on sidewalks, bioretention strips close to parking areas, rain gardens, reforesting of hills, were proposed and evaluated by Mascarenhas et al. [21] and Miguez et al. [22].

Another important urban program in Rio de Janeiro is the ‘Favela-Bairro’. This program deals with rehabilitation and development of basic urban infrastructure for slum areas. Most of these slums are present in extremely impervious areas located at steep slopes, where there used to be forests (Atlantic forest vegetation). The hydrological impact caused by this change in the occupation of hill areas in Rio is significant [23]. A concern that arises when a close look is set on the actions carried out by the ‘Favela-Bairro’ Program is that the imperviousness rate of these communities is increasing considerably. Miguez et al. [22] proposed some measures that could be adapted to this program in order to reduce the hydrological impacts of these areas through storage and infiltration techniques.

2.6.2 Use of soccer fields as complementary areas of a temporary storage pond in a poor community

This second case study refers to a region known as Baixada Fluminense, located in the metropolitan area of Rio de Janeiro City and occupied mostly by low-income families. This region is also characterised by low level lands naturally subject to floods caused by Iguacu and Sarapuí rivers. Dikes have been built to prevent the flooding of this region, and as a consequence, polder areas were created. The typical arrangement of these polders consists of a stormwater temporary storage pond which receives the major drainage channels and is connected to Iguacu or Sarapuí rivers through flap gates (Fig. 2.9). The use of flap gates to allow discharge of these polders has the advantage that this kind of structure is passive, robust and requires no operation. The disadvantage is that the discharge can only take place during low tides and these periods can sometimes be delayed due to the routing of floods in the Iguacu and Sarapuí rivers and adverse climatic conditions. Pump stations could overcome these limitations, but the use of this kind of solution in such case can be considered inappropriate due to the lack of security of the facilities (electric cables and pumps could be robbed – a frequent situation in poor areas) and high operation and maintenance costs. As a result, in order to prevent the water from rising up to a certain level that could cause uncontrolled flood of the surrounding area and consequent failure of other elements of the drainage system, a greater temporary storage volume is required.

Polder Alberto de Oliveira, which receives drainage of part of São João do Meriti and Duque de Caxias municipalities (RJ), can be taken as an example of what is occurring in other polder areas in the Baixada Fluminense region. Regular and
irregular buildings have occupied almost 80% of its original area designed to work as stormwater temporary storage pond, as it can be seen in Fig. 2.10 [24]. Visiting this community, it can be observed that one of the measures developed by local population, in order to prevent flood losses, was building their homes over 1.0 to 1.5 m tall pillars. Urbanisation of the catchment also aggravates the problem, as the runoff production got higher than that estimated at the time the original pond was designed. These two factors caused the flood risk of the region to rise considerably. Recent storms and the extension of flooding areas caused a lot of public pressure over the municipalities and state governments. The response of the authorities was the creation of a program to reduce the flood risk in this area. So far, studies have been carried out in order to determine which interventions are needed to maintain the water inside the pond, considering a maximum water level that could cause no flood hazard to the surrounding community. A hydrodynamic and hydrological cell model [15] was used to simulate the flood in the polder area and at the Sarapuí River. A 20-year RP storm was set for the polder area and a 10-year RP storm was used for the Sarapuí river basin. The modelled region comprised a complex hydraulic system. In the upstream reach of the basin, there is a reservoir, conformed by Gericinó dam, regulating discharges of the upper Sarapuí River reaches. Downstream, Sarapuí River is submitted to tidal influence, because of its proximity to Guanabara Bay. Numerous rivers and brooks cross the region and several flooding areas appear. Great part of the basin is urbanised, with micro and macro-drainage interacting. Therefore, all this diversity needed to be captured by model representation, in order to adequately assess the situation.

The results of the mathematical simulation showed three possibilities to reduce water level in the storage pond area to the desirable level [24]:

(a) double the number of flap gates;
(b) set an 8 m³/s pump station close to the remaining storage area;
(c) reallocate the part of the population that occupies the original temporary pond area.

Figure 2.9: Illustrative profile view of a generic polder area.
Due to the already mentioned problems concerning pump facilities, this alternative has been abandoned. One demand of state authorities was the reduction of the number of families in need of reallocation. The final scenery proposed considered an increase of the number of flap gates (60% more flow capacity) and the lowering of the ground level of two areas close to the remaining storage pond. Few families occupy one of these areas and several soccer fields occupy the other. Figure 2.11 shows the cell division of the region and these areas. As an illustration of the modelling process, Fig. 2.12 shows the details of the topological model at the polder region, where it is possible to see the connectivities established between cells, integrating the modelled area.

An interesting aspect about the behaviour of local communities in Brazil is that it is very hard to prevent the occupation of free spaces close to poor communities, but soccer field areas are almost always respected, as there is a public perception that these areas serve as leisure and sport facilities for the community. A part of the strategy was setting a multifunctional landscape at the soccer fields area, so that it could assume a new function, the flood control. The proposal was lowering this area to a ground level higher than the other new storage area which is being added to the remaining pond, so that this complementary storage volume gets used only in the case of more intense storms, allowing its sportive function at most of the time. The set of measures presented in the final scenery are currently under construction.

2.6.3 Other possibilities of using multifunctional landscapes

There are many other possibilities of using multifunctional landscape in urban environments. One of them is the use of greenways, which can often assume a large number of functions, including ecological or hydrological features [25, 26]. This kind of measure could be applied to riparian areas occupied by irregular settlements whenever the removal of this population is needed. The establishment
of greenways can even cause the price of properties in the surrounding community to rise due to the proximity of natural or aesthetical landscape among other expected benefits [27]. Another possibility of using multifunctional landscape is the use of rooftop gardens. This kind of structure also allows the development of several activities and functions. Thinking on rooftops with a stormwater control concern, it can be noted that these areas are very impervious surfaces in which source control techniques could possibly be applied. In this way, the construction of rooftop gardens may reduce this problem. In Singapore, this kind of measure has shown good results [28] and the use and the perception of relevance of these spaces by the population is growing with time.

2.7 Concluding remarks

Several regions located in developing countries suffer with serious flooding problems. Traditional engineering solutions frequently show the trend to transfer problems to downstream reaches (e.g. channel enlargement measures). A multidisciplinary approach can be applied in order to develop new control measures acting over the urban landscape. In this way, typical urban structures may incorporate hydrologic and hydraulic functions, as complementary features, in order to allow a systemic action over the basin, rescuing when possible flow patterns close to the natural ones. These alternative proposals, as illustrated in the presented case studies of this chapter, have potential to generate very positive results.
In developing countries, this approach can also meet other important goals, such as the revitalisation of irregularly occupied areas. This approach can be an important ally in the search for a harmonic and sustainable environment in a long term. On the other hand, it is also important to say that a systemic mathematical model is an important tool to aid engineers and planners in deciding and designing efficient, economic and integrated solutions for flood control in urban basins.

Figure 2.12: Topology associated with the cell model for Alberto de Oliveira Polder.
References


