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Sustainable Cities: Challenges and Constraints towards Urban Water Management

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Introduction

Among the largest cities in the world at the present time, Tokyo, Delhi, Shangai, Seoul, Mexico City, Sao Paulo, all exceed 20 million inhabitants. But many others like Mumbai, Beijing, Cairo, Karachi, Lagos are also part of the so called megacities, because all of them exceed a population over 10 million, above which they come to be considered under such category. Because of the proliferation of this phenomenon, the 20^{th} century has been called the century of urbanization (Harvey, 1996:403).

Many of these recent sprawling cities are located in developing countries, where their growing process is being related with a high migration of people seeking for jobs and better livelihood opportunities in the urban areas. But at the same time, such a process has favored the generation of increasing poverty, social exclusion and inequality in the new urban settlements, where there is not always enough and proper infrastructure to provide basic public services, like energy and water supply. This kind of cities have grown rapidly without any urban planning, facing ecological degradation as they sprawl over forested areas, polluting air and water sources. If we take into account United Nation forecasts, it is expected that by 2050 around 70% of world population will be living in cities, and a high percentage of the largest cities will be in developing countries (Roth, 2012). Therefore, it is important to drive new policies toward sustainable urban planning. This engages more efficient public policies and mechanisms to enhance the rational use of city´s available natural resources, without polluting and depleting its surrounding environment or hinterland.

There are already too many environmental challenges that will soon be affecting human life in this planet, and megacities might come to be the most vulnerable places for life if we do not face the problems of inequality and marginalization caused by present urbanization patterns. It is not only a matter of coping with the risks and hazards caused by the uses and misuses of natural resources, but also to find the best ways toward a rational and sustainable management of our environment, as well as searching alternative measures for risk reduction and wise adaptation.

A system´s view of the city must be applied in relation to urban planning and integrated management, as a means to find a balance between people and nature, even if it seems almost a utopia. The type of urbanization and its consumption patterns have to be guided through nature´s own processes (Inoguchi et al.,1999:1), which means to follow the same nature´s cycles, as close as possible. An ecosystemic view toward urban metabolism could be a possible way to manage a city, as Robert Forman (2008:315) has suggested, like a “box of inputs and outputs”. A city should achieve sustainable development by resembling ecosystem´s natural cycles on resources management; which involve recycling resources and materials, saving energy and avoiding waste generation.

Ernest Callenbach asserts that a sustainable city rests on the implementation of ecological basic rules which are essential for building what he calls an eco-society:
“An ecosystem or a society is only sustainable in a medium-to-long run (of 100 years or so) if it recycles almost all “nutrients”(and materials) and uses energy with high efficiencies similar to those of living systems.” (Callenbach, 1999:18)

However, the most difficult part of planning urban sustainability deals with its social context. Building a just city is an important component of sustainability, as much as it is expected to provide equitable and affordable basic services for the whole population. (Fainstain, 2010).

Water supply for megacities

Megacities and present growing cities are facing one of the worst problems for urban sustainability: water supply. Hydric resources are not always available in the right place and quantity according to the high increases of population in very short periods of time. As it has been said, many cities in developing countries grow without any urban planning. In such cases municipal governments ought to find solutions when the problem is already there; when the new built environment has covered aquifers recharge areas and river beds or crooks have been polluted with garbage, heavy metals and toxic substances.

At the same time, the available water resources are misused or even lost because of inefficient practices. Yet, water is usually seen as a renewable resource and is not really taken care of. There are current urban practices that do not recognize water cycles, so dry water beds of former crooks are covered with new constructions, giving way to floods when torrential avenues happen. These practices prevail in many cities of developing countries, making people more vulnerable to flooding damages and health diseases. Sometimes the same cities suffer from lack of water as well as floods, without attending any preventive policies to avoid these events, like protecting risks and aquifers recharge areas, implementing rain harvest practices and other innovative means for storage and water recycling.

Whenever the city growth exceeds the available water sources for its urban and industrial requirements, the most usual practice is to bring water from the neighboring resources to cover the insatiable demand. For many centuries, dams and aqueducts became the most common construction to transfer water from one place to another. The first 5,000 large dams[1] were built mainly in industrialized countries before 1950. As soon as water demand increased and innovations in hydraulic technologies made it possible, the “dam boom” took place over the next 60 years, giving way to more than 45,000 new large dams worldwide (WCD, 2000:8). The construction of dams and water transfers changed some of the city’s growth restrictions. Until then, the capacity of a city was constrained mainly to its available water resources (Inoguchi et al.,1999:5).

But nowadays, new problems arise with the competition for the same water sources, driving to social and political conflicts between cities and regions, as well to irreversible impacts on ecosystem’s equilibrium. Environmental changes caused by large dams are facing ecosystem modifications, like diversion of former river streams and its water quality, soil and biodiversity deterioration, increasing climate change.

Urban water supply happens to be the most difficult problem governments are facing nowadays. Some of the coming challenges will require more innovative ways to optimize water resource circulation cycle by means of integrated solutions. But most of all, urban supply ought to be provided under a context of sustainability. Innovations will have to deal within the areas of water treatment advances, water purification, sewage treatment systems, rainwater harvest, absorption wells and so on.

[1] A large dam is defined by the size of its curtain: above 15 meter high.

These are some of the challenges that urban water management must face trying to avoid environmentally aggressive and socially inequitable solutions for water supply. Some alternatives might be found through "soft path"[2] methods, "instead of endless sources of new supply" (Gleick, 2002: 1). Somehow it means local community participation and fine scale solutions, which should resemble natural water cycles to be sustainable. This concerns a cultural change toward a new paradigm in water management. We have long been used to depend on modern hydraulic "hard path" technologies; usually those that guarantee the largest amounts of water supply, without considering the social and environmental costs.

It is no worth any more to keep depending on external sources for water supply, like water transfers from one basin to another. This kind of strategy is just turning water scarcity issues to medium or long term problems in those areas where the population growth becomes more difficult to face. On the other side, the extracting areas run out of the water they usually depended on for their survival. This is why it becomes necessary to turn to "soft path" strategies to manage local water systems efficiently, but most of all to encourage changes in urban lifestyles and consumption patterns.

The study cases

The following papers are the end product of a working team that gathered at the Technische Universität Braunschweig (TUB), with the support of the Excellence Center for Development Cooperation (EXCEED) through the Sustainable Water Management Program. The guest chair team incorporated a master student in chemical engineering, a doctoral student on peace and conflict studies and myself, a PhD social anthropologist. We worked together for six months at the Social Sciences Institute, under the kind advice of Prof. Dr. Ulrich Menzel. The team held weekly meetings to discuss recent theories on sustainable urban planning as well as social theories connected with environmental justice and just cities. At the same time, we took over our research advances on the perspectives of urban sustainability, taking into account the experiences of our own cities: Jakarta, Ibadam and Guadalajara. The invitation of a doctoral student

[2] Peter Gleick suggests that "soft path" methods can improve productivity of water use investing in decentralized facilities with the support of efficient technologies and human capital (2002:1)

at TUB to our meetings added his experience of the city of Cairo to the comparative case analysis.

The next two papers deal with the cases of water problems in two growing cities located in developing countries. The cases of Jakarta, in Indonesia and Guadalajara, in México are emblematic of two different and opposite problems that are the main target for governmental strategic urban water management: floods and water scarcity.

Guadalajara is a fast growing city, the country’s second largest city after the conurbated area of México City. Today, Guadalajara is the home of almost 5 million people in the West of México. Water supply has been the most important problem during the last twenty years, but whatever policies have been adopted are far from the required long term solutions, considering its population growth. As soon as the city wells became insufficient in the 80’s, water transfers from the Chapala Lake and the Calderón dam were implemented. Since then, the city depends on external water resources. Most of the selected policies deal with hydraulic infrastructure projects; large dams and aqueducts to bring water from abroad. However, these policies are facing social upheaval, unseen environmental consequences and recently, also a strong political struggle over the competence for the same river with the neighboring city of León in Western México.

Jakarta is a megacity in Indonesia, with more than 11 million inhabitants, and growing at a rate of 1.06%. Its rapid built-up urban areas during the last decades have given way to changes in land use, deforestation, constraints in river flows, less penetration of rainfall into the ground, and ground subsidence because of aquifers overexploitation. The city faces periodical floods as a consequence of the mentioned changes and increasing precipitations resulting from climate change. Therefore, the city suffers floods risks as well as problems of water supply, which show that there is not enough environmental concern in urban governance.

Part of the methodological approach for this analysis was to get into a broad diagnosis through mapping city’s resources and the most vulnerable zones as a first mechanism to recognize nature´s dynamic reproduction chains. In doing so, the impacts generated by human action over the environment could be easily localized. The two study cases give way to compare the results of the implementation of different water management policies. The analysis also shows the limits on the capacity of a city, its carrying capacity, considering the fragile relation between the available water resources and the population growth as the main constraint.

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Cecilia Lezama[3]

Water Management Policies in the Growing Patterns of Guadalajara, Jalisco

Introduction

Water supply has become a critical problem for urban sustainability in several cities of México. Rapid population growth has exceeded self-supply alternatives on the basis of the city´s own existing water sources. When the available aquifers become overexploited and superficial water bodies get polluted due to domestic and industrial discharges, the most usual trend is to bring water from the city´s hinterland sources to satisfy the urban requirements. This water transfers might come from more than hundred kilometers away, increasing dependence on exogenous water sources for urban supply. Such has been the case of large cities like Mexico, Guadalajara, Monterrey, Hermosillo and León. However, this kind of policies have found restrictions in its implementation process, mostly because of the emerging conflicts over the competition for water sources and opposition of the affected communities.

The city of Guadalajara, located in the western part of México, has faced a water supply problem since long ago. Before 1950, most of the water supply came mainly from the aquifers of Agua Azul, the streams in the Colomos Park, Tesistán and Toluquilla, all of them allocated within 15 kms. from the city center. From then on, new sources of water had to be explored from farther away to cope with the population growth and the introduction of new economic activities. The last dam and aqueduct were built in 1991 to transfer water from the Calderón River, located 31 km. to the eastern side of the city. By the same time, another 42 km. long aqueduct was constructed from Lake Chapala to Guadalajara, whose operation started also by the same year.

But the persistent expansion of the city continued, and with it, increases on water demand. So, in the following decades, water management policies toward urban supply

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and sanitation took a priority place in Jalisco´s development programs. These policies were grounded on a water crisis discourse, which justified the need of huge infrastructure projects to deal with the problem toward the long run.

The assignment of large amounts of financial and human resources for some of the dam projects have been strongly questioned lately by civil society because of the high risks for the population involved and toward ecosystems sustainability. This kind of projects were never questioned before, in part because people still believed on the promised benefits attached to most development projects. But over the years, people became aware of the ecological externalities emerging upstream and downstream the dams that left behind environmental deterioration to soil and biodiversity, as well as breaking natural river cycles and ecosystems equilibrium.

Furthermore, instead of the promised development in the rural areas, the construction of dams brought unemployment, poverty, upheaval and social conflicts. People were uprooted from their homeland, losing their cultural patrimony, identity and social networks. After their resettlement, they even found barriers toward their integration to the new society. Contrary to expectations, government institutions in charge of development programs failed to comply with their promises and compromises. Finally, most of the affected communities were not fully compensated for their lost patrimony.

The above mentioned outcomes have opened the eyes of new generations after several decades of dam building. After several decades, there are communities where the grandchildren of the originally displaced people are still claiming their compensations. These claims and the opposition of civil society to the most recent dam projects have brought confrontations between the affected communities and authoritarian officials, whose responses have generated psychological pressure, fear and different levels of violence when authorities fail to convince people to accept their projects. Under these circumstances, one can perceive that the present water management policies for urban supply are favoring urban and industrial growth at the expense of rural life and ecosystem´s preservation.

Main objectives and methodology

The questions that will be addressed in this essay are associated with an overview of the development policies being held by the Mexican government to promote and sustain urban and industrial expansion in the western region of the country. The focus on water resources availability is the mainstream of this essay, as it is considered the most critical factor to handle urban sustainability. In these terms, the target is centered within the context of water supply management policies to provide the growing cities located on the Santiago river basin. The struggle for water supply nowadays in the Santiago river basin has given way to competition and conflicts between the neighboring cities of Guadalajara and León.

So, it is important to examine which has been the predominant criteria that determines urban water management policies in the state of Jalisco, as well as some of the externalities generated by large dams and water transfers. This will let us understand the rationale of expert knowledge that justifies the implementation of such hydraulic policies, especially toward water sustainability.

The general aim is to analyze the impacts of the urbanization process over the available natural water resources and those of the surrounding municipalities that have been affected by urban growth in the Santiago river basin.

The main purpose of the research project involves a review of the following issues:

- urban growing patterns of the city of Guadalajara and the impacts of the urbanization process over available natural water sources
- water management policies and the implementation of hydraulic infrastructure for urban supply
- emerging conflicts arising from the competition for water supply between the growing cities of Guadalajara and León
- environmental and social costs generated by hydraulic management policies

The starting point of this research lies on a previous diagnosis on the water sources of the city of Guadalajara, in the State of Jalisco, and a brief background of the past urban water supply policies. It will help to contextualize the most recent hydraulic policies being held by today´s governments. This examination will be accomplished with a review and follow up of selected water supply projects implemented in the Santiago river basin. This includes a review of institutional documents and proceedings for those projects and also a water management official´s discourse related to their committed development goals. The study has been conducted through field work in the Santiago river basin, with the aid of cartographic, statistical and historical archives. Qualitative information was also collected by means of interviews to public officials and other key informants from local communities. The present essay gathers partial results of an ongoing research.

In order to organize some of the outcomes of this inquiry, I shall summarize the results in four sections. The first will address the urban growing patterns of Guadalajara, focusing on spatial and demographic issues of the urbanization process. The second section shows the impacts and pressures of this process over the most important water sources located in the inner urban area. Next, some of the policies of urban water supply management will be exposed as means of understanding the present paradigm that guides what is called the hydraulic perspective, formerly carried out by the federal government since the last century. The fourth section covers a brief overview of El Zapotillo dam and aqueduct, as an emblematic case of the hydraulic paradigm, which shows the mechanisms of the neoliberal policies that contribute to environmental deterioration of local water resources, triggering an impoverishment process of the people to whom development programs are supposed to benefit.

The urban growing patterns of Guadalajara

The urbanization process of Guadalajara is closely related to some of the growth problems affecting the evolution of many cities in developing countries; such as an accelerated and unplanned process of urbanization, a trend to urban macrocephaly and a rather weak local administration system (Cabrales, 2000:68), which trigger a fast economic growth at the expense of its environment.

Over the last two decades, the city of Guadalajara followed a development model that lead to a rapid economic growth, without being aware of its high social and environmental costs. Most of the following urbanization policies have been guided towards the attention to emergent needs of the central city at the expense of the natural resources of the surrounding municipalities and its people´s well-being. The present results of this uncontrolled urban expansion have brought also a wide social polarization and the emergence of unexpected problems.

Since the 90s, the city of Guadalajara has been sprawling beyond the borders of the four municipalities that shape the so-called first ring of the metropolitan area: Guadalajara, Zapopan, Tlaquepaque and Tonalá. In recent years, the expansion has spread over the neighboring municipalities to the south of the city. The now called conurbated zone of Guadalajara joins four more extra neighboring municipalities: Tlajomulco, El Salto, Juanacatlán and Ixtlahuacán (see map 1). These last four municipalities thus become a second ring of expansion which marks the conurbation and functional articulation of the city of Guadalajara (Cabrales, 2000:65). Although there has been a significant growth of the city to the northwest of the territory of Zapopan, the trend has been more intense towards the south. The imposing fracture that runs along the Santiago River and the protected area of the Bosque de la Primavera are the natural barriers that impede the urban sprawl to the northeast and west of the city, respectively.

The area encompassing the city of Guadalajara has been increasing at an average rate of 1,243 hectares per year approximately. In 1982, the size of the city was calculated over 20 000 hectares, whilst for 1995 its size expanded to over 40,000 hectares. By the year 2010, the suburbs would significantly raise to about 58,700 hectares (Cabrales, 2000: 66-72). These figures give the dimensions that the urban sprawl has reached along a span of 28 years. In demographic terms, statistics show that the city of Guadalajara doubled the population registered in 1980, increasing from 2,335,690 individuals to a total of 4,695,833 by 2010, thus concentrating around 60% of the State population. The capital of Jalisco currently ranks as the second largest metropolis in the country, according to its population.

The demographic data of the conurbated municipalities of Tlajomulco and El Salto are the most relevant, accounting to the high rate of population growth in the last two decades. Tlajomulco´s population grew at an astonishing rate of 12.9%, passing from 68,428 inhabitants in 1990 to 416,552 in 2010, according to the 2010 census (table 1). The growth in absolute numbers of the municipality of El Salto nearly tripled, on the basis of the 1990 population from 38,281 inhabitants to 138,585 in 2010. Such figures confirm that Tlajomulco, along with El Salto have become the most important front of the city's urban expansion.

The urban sprawl over this area is attributed to public development policies from the 70´s toward the promotion of industrialization. Such policy was thought as an aid to create a socio-economic development pole, new infrastructure and employment generation. The industrial pole in the State of Jalisco was originally planned to be allocated away from the city of Guadalajara, in order to avoid possible risks and hazards of the incoming factories for the inhabitants. The allocation of this industrial pole 30 km. south from the city included the assignment of 450 hectares for exclusive industrial use, considering its potential expansion over the following years. Nevertheless, at the end of the last century this process reverted in an anarchic growth. Since then, the urban sprawl was strongly oriented to the south of the city, mainly over El Salto, without complying to previous land use regulations. Housing and commercial zones were settled next to factories, taking over industrial land use.

The rapid expansion of the city, towards El Salto and Tlajomulco, exceeded the expectations in terms of urban planning, which always seemed to stay behind in relation to the available infrastructure to provide enough housing and adequate public services, like potable water, sewage systems, sanitation, energy, public transport, and other public services to ensure the well-being of its population. At the same time, pollution and environmental degradation spread without control, spoiling available water sources and causing serious health diseases to the population. According to this, the city is far from attending a sustainable urban planning model; it rather tends to generate problems of unsustainability.

Map 1. - Urban sprawl of Guadalajara (1990-2010)

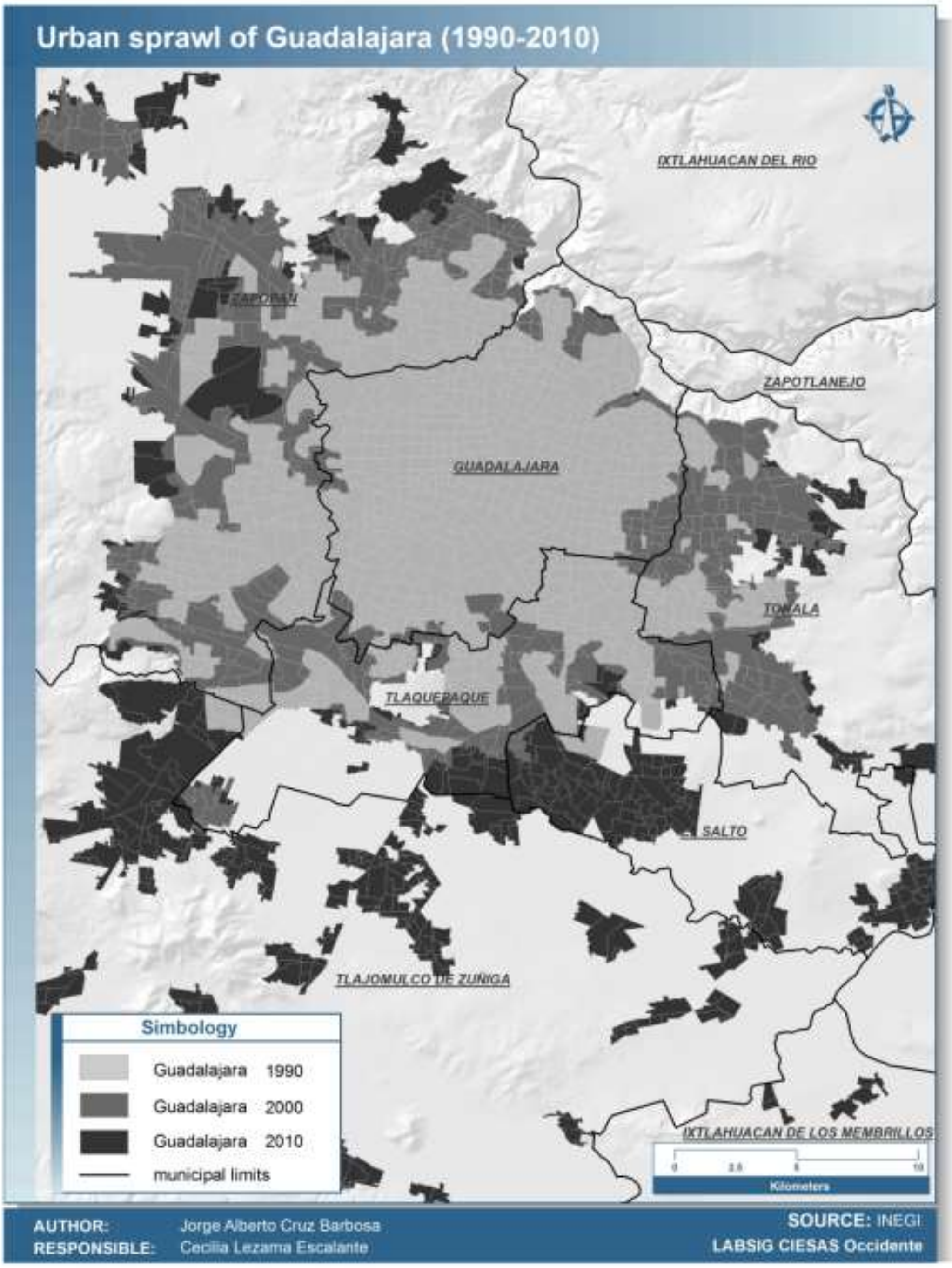


Table 1- **Demographic evolution 1970-2010 – Metropolitan Zone of Guadalajara**

	1970	1980	1990	2000	2005	2010	Growth rate 2000-2010
Guadalajara	1 199, 391	1 626, 152	1 650, 205	1 646, 319	1 600, 940	1 494, 134	-0. 97
Central city Subtotal	1 199, 391	1 626, 152	1 650, 205	1 646, 319	1 600, 940	1 494, 134	-0.97
Zapopan	155, 488	389, 081	712, 008	1 011, 021	1 155, 790	1 243, 538	2.09
Tlaquepaque	100, 945	177, 324	339, 649	474, 178	563, 006	608, 187	2.52
Tonalá	24, 648	52, 158	168, 555	337, 149	408, 729	478, 981	3.57
1° Ring (radio 15km) Subtotal	281, 081	618, 563	1 220, 212	1 812, 348	2 127, 525	2 330, 706	2.54
El Salto	12, 367	19, 887	38, 281	83, 453	111, 436	138, 585	5.20
Juanacatlán	5, 501	8, 081	10, 068	11, 792	11, 902	13, 218	1.15
Tlajomulco	35, 145	50, 697	68, 428	123, 619	220, 630	416, 552	12. 92
Ixtlahuacán	10, 652	12, 310	16, 674	21, 605	23, 420	41, 057	6.63
2° Ring (radio 35km) Subtotal	63, 665	90, 975	133, 451	240, 469	367, 388	609, 412	9.74
TOTAL	1 544, 137	2 335, 690	3 003, 868	3 699, 136	4 095, 853	4 434, 252	1.82

Source: Censos de Población del Instituto Nacional de Estadística, Geografía e Informática (1970- 2010)

The proliferation of illegal settlements on marginal areas is usually associated to precarious housing on high risk grounds. Some of these settlements have been located over the floodplains of the Santiago River and the wetlands of the lower area of El Ahogado basin, where the grounds are swampy and prone to floods in times of heavy rains. However, the area is being crowded with low interest housing developments (high density housing, type H4), which do not always cover the requirements related to changes of land use nor the construction permits. Settlements that have spread in this areas lack the most basic services (water, sewage, street lighting, paving, safety); which places the population in conditions of increased vulnerability. Implementation of new infrastructure has also become more complex for municipal governments, since planning and economic resources for public services always fall short with respect to high increases in demand. There is no doubt that the need of enough water supply, sewage and housing are perhaps the most critical problems faced by current municipal governments.

The change in land use and permits for housing developments over floodplains areas have been given by municipal authorities of El Salto and Tlajomulco. Some other state government officials have also tried to promote housing developments over the wetlands of the Ahogado dam, located at the southeastern part of the city. That was the case of the Tierra Mojada housing project in 2004, which considered setting up around eight thousand low-income houses right in the border of the wetlands. By doing so, the urbanization policies seemed to ignore the regulations toward the protection of water bodies and its ecosystem services as regulator of the wetlands of El Ahogado dam. The almost approved project had to be suspended because of some irregularities found in the land ownership and sale conditions.

However, the promotion of housing policies unleashed real-estate speculation associated with indiscriminate approval of land use changes by municipal authorities, surpassing current regulations. Changes in land use regulations were enforced by speculation even violating protected areas with the consequent loss of forests, aquifer recharge zones, river banks, among others. Authorities did not contemplate their own capacity to provide basic services for the future inhabitants, neither the risks induced by inappropriate distribution of their already authorized licenses. The case of La Azucena, a low-income residential complex built over the floodplains of the river, is a sad example of it. Houses were flooded in the rainy season of 2008. The water level reached one meter high in some parts of the neighborhood, causing havoc in the homes of a large number of the new settlers. Many houses have been abandoned by its owners because of severe damages and flood risks. Nevertheless, the municipal council continued authorizing the construction of new housing developments in the area close to La Azucena, relying on recent protection built to prevent possible flooding. These kinds of policies enforce the allocation of popular housing in areas of risk, which means that the externalities of environmental degradation are transferred to the most vulnerable population (Harvey, 1992).

The impacts of urbanization and its pressure over water sources

Urban sprawl has taken its way over many of the natural resources around the city, mostly because there has not been a close supervision of regulations toward land uses and preservation of forests, parks, wetlands, aquifer recharging zones, urban streams and creeks. The new settlements, in a regular or irregular way, have started building housing and commercial facilities over forest reserves and even over the aquifers which provide urban water supply, without any municipal control.

This process can be seen in the southern side of the Bosque de la Primavera, where the new urbanization plans include medium and high income residences, schools and also the city´s largest football stadium. Contiguous to the northern part of this same national park is the town of Tesistán in the Zapopan municipality, which is known for its abundant aquifers and used to have the most productive agricultural lands of the region. In the past two decades, numerous low-income housing projects have crowded the area, hardly considering any green spaces and their now paved areas reduce the possibilities of aquifer´s recharge.

The Bosque de la Primavera has also been selected for the installation of a geothermic plant right in the middle of the forest; a project that will be harmful for the forest ecosystem. Another example that shows government`s urban development policies took place not long ago when a housing complex was built over the area of El Bajío, a privileged aquifer recharge zone, right below the hills of the Bosque de la Primavera. The project was located there after an authoritarian imposition from federal officials. The housing facilities were initially designed to provide accommodation for the athletes attending the 2012 Panamerican Games. After the games were over, the same complex was planned to provide housing facilities for the increasing population. The project was executed quite fast, considering that there was the participation of real estate companies, financing opportunities, precise timing requirements and government´s approval. The opposition of civil society finally came to stop the project after the competition was over. There is still a trial going forward over claims on ecosystem´s damages caused by the allocation and no compliance of building regulations.

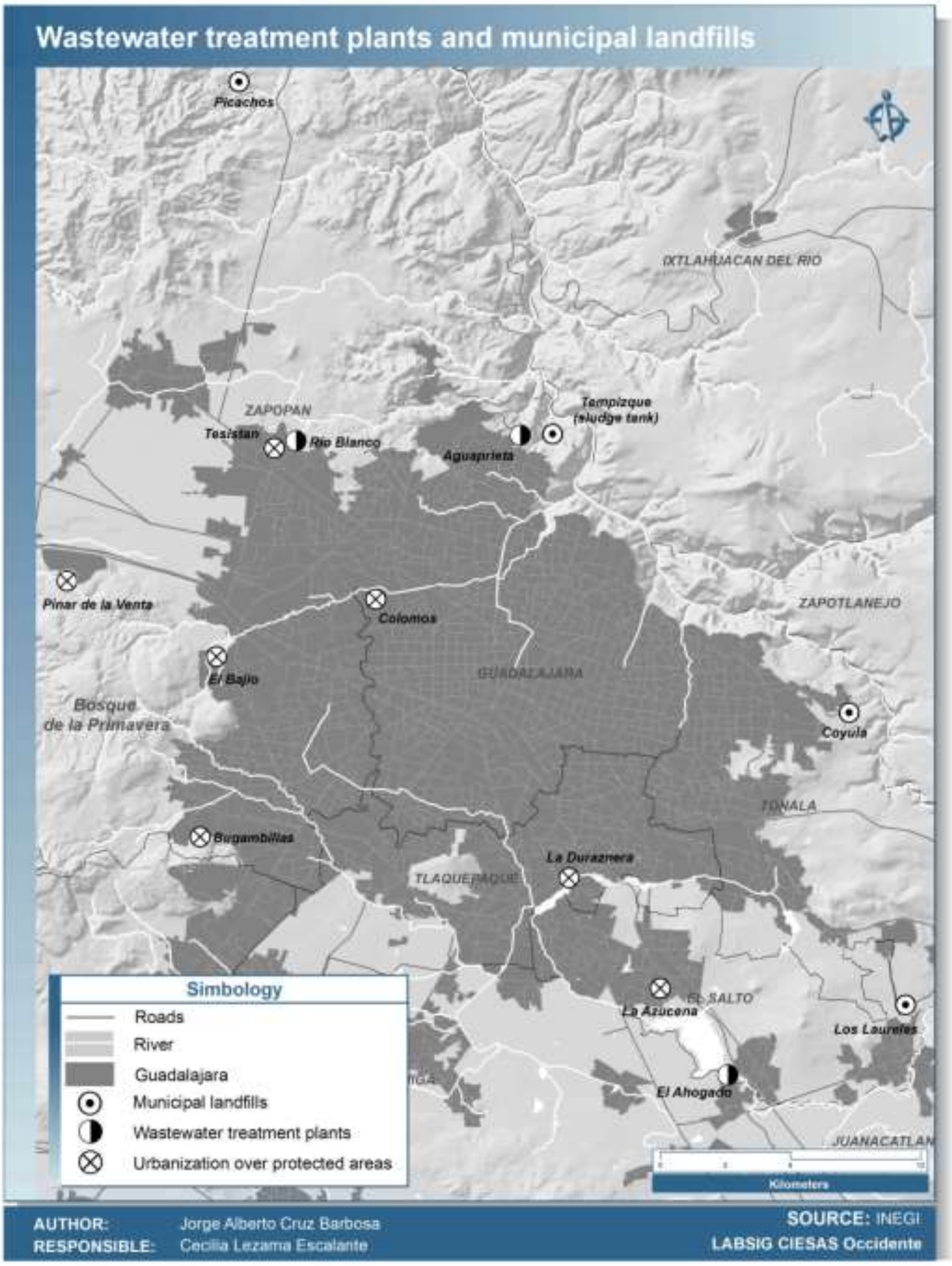
Moreover, the same process can be seen in the area of the Colomos park[4], whose magnificent wellspring once provided water for the city through infiltration galleries built in the 18th century. The park located at the west side of the city lost more than double of its actual size due to the urbanization process, mainly bounded to new high

[4] This urban park should be protected as a conservation area because its ecosystem is the source of wellsprings, aquifers recharge and forest. The conservation area was 248 has., but nowadays there are only 98 has. left for the park.

income residences and commercial areas. Additionally, the area was also planned to harbor several state administration buildings for the judicial city, which finally were not authorized. Nonetheless, an increase in land value of this area, known as the golden zone, has given place to a rapid development of a complex of high buildings for business, commercial and residential uses. Nothing has stopped this urbanization process of paving aquifer recharge zones and the beds of several seasonal creeks, also tributaries of the Atemajac river. This small seasonal river crosses the northern part of the city in a west-east direction, pouring jointly part of the Colomos stream clean waters, seasonal rainfall and heavy polluted domestic waters into the Santiago river.

Like the Atemajac River, most of the urban rivers have been used for decades as the sewage of domestic and industrial wastewaters. That is the case of San Andrés, Osorio and San Juan de Dios rivers, also tributaries of the Santiago river. Some of municipal solutions to control polluted rivers have given way to cover partial tracts of its channels, as soon as they become too nauseous or too dangerous regarding health conditions for the population. According to this rationality, the San Juan de Dios River was the first to be covered in 1903 for sanitary reasons. This kind of solutions were taken again in 2007, when a short tract of the Santiago River was covered, following the death of a child, who was intoxicated with industrial polluted waters after falling accidentally to the river, close to El Salto. Covering the river was also the sort of solution given to avoid the risks of floods upon the populated area of La Azucena, built over the banks of the river.

Map no. 2. Wastewater treatment plants and municipal landfills



The population growth around this area of the city has exceeded urban plans forecasts and its chaotic outcomes are far from authority's control. Nowadays, the results of perverted housing developments over the lowlands of the Ahogado basin have given place to an increase of flooding events and sanitary risks. With seasonal rains, many neighborhoods have to face flooding damages of long time announced risks and dangers. Every time it happens, state government has to deliver special funds as compensation for the damages caused by floods.

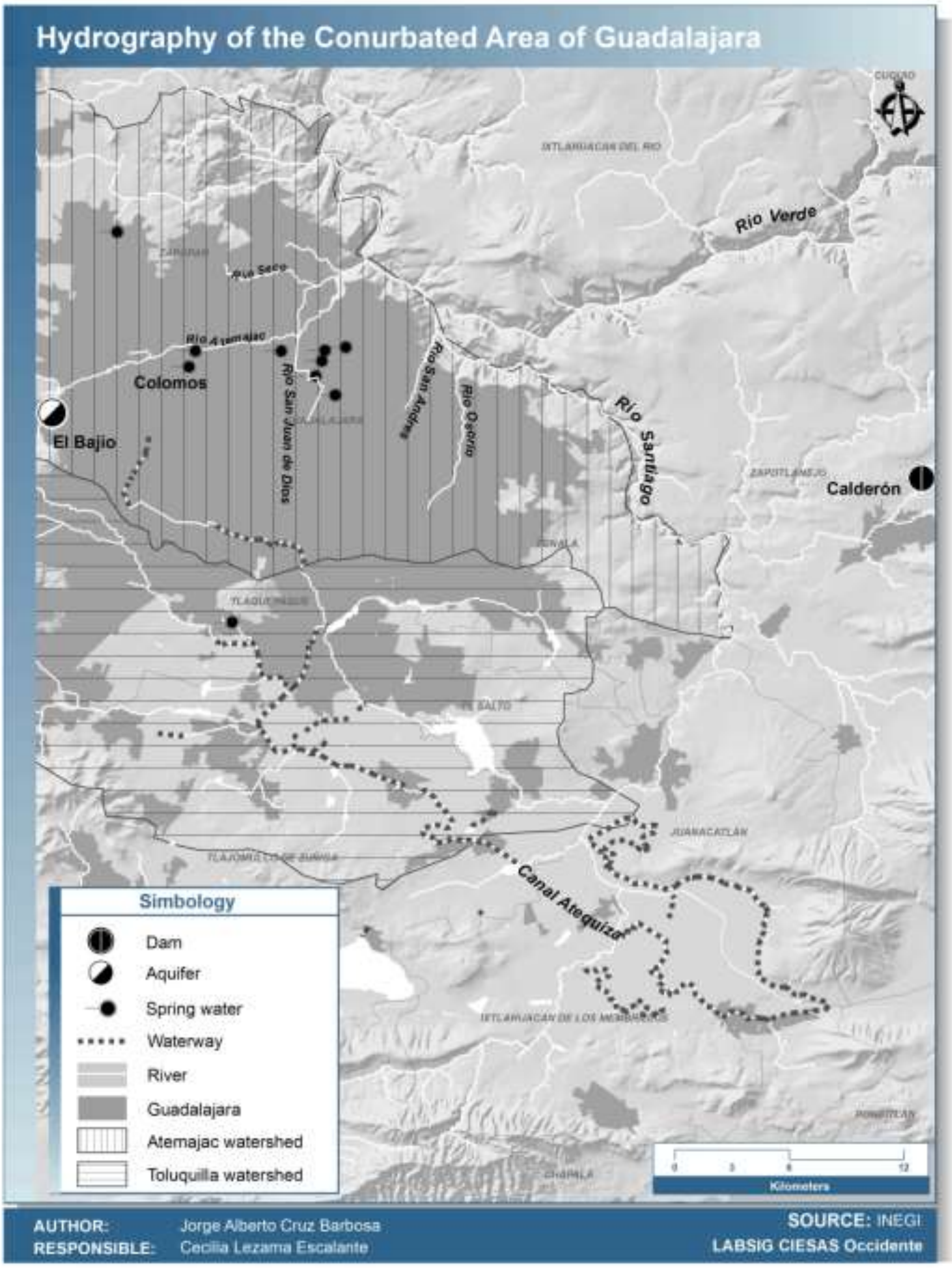
Damages upon the Santiago River are also due to municipal policies over garbage facilities. It is surprising to contemplate the allocation of urban dumps of solid wastes in places that entail high vulnerability for ecosystems. Such is the case of several city dumps that have been located on river slopes or next to creeks. The drain of leachates, or leakages proceeding from the garbage deposits, brings runoffs to the river, besides polluting aquifers underneath. This is the case of the dumps of Los Laureles and Coyula, whose leachates drain to the Santiago river, contributing to the above mentioned industrial and domestic pollution. This kind of municipal policies are exacerbated by state water sanitation facilities. The most important water treatment plant for Guadalajara´s discharges is being built in Aguaprieta, but its resulting sludge was planned to be deposited in the area of El Tempizque, right on top of a slope that also drains over the Santiago river. The local community claimed a turnover for this decision, considering that it will affect their crops, health, wellness and the whole ecosystem.

All the previous facts let us perceive that there is an absence of the adequate public policies toward the protection and maintenance of surface and underground water. On the contrary, actual facts seem to confirm negligence to cope with the sustainability of water resources. At the end, this shows the absence of an integrated water management planning for the city´s growing requirements.

Urban water supply management

As we have seen, the city´s water resources have long been under strong pressure because of the urbanization process, in such a way that the quality and quantity of available water is deteriorating and diminishing. The aforementioned outcomes we are facing today have led to a water scarcity official discourse, which justifies the need to promote water transfers. Hence, it is important to examine what has led to the assumption of a water crisis. In doing so, we must take into account several practices on water management policies.

Map no. 3. Hydrography of the Conurbated Area of Guadalajara



To begin with, one of these practices is related to a non-compliance of environmental laws and its regulations. The backgrounds of environmental national regulations come from the late 70´s, although its enforcement as state regulations came years after. An example of it is the State of Jalisco 1982 decree on the *Management Plan of the Metropolitan Zone of Guadalajara and the declaration of reserves, uses and destinations of their areas and plots* (Decree No. 10959, March 30, 1982) established to preserve, regenerate and take advantage of the natural and cultural environment, as well as to enforce the rules to preserve the physiognomic characteristics of areas whose natural and cultural values should be retained as collective heritage. Nevertheless, not much has_been done to prevent the loss of these values. There is a lack of attention to the areas of protection of water flows, floodplains and aquifers recharge zones. There is neither much enforcement to preserve forests and its ecosystems.

Water pollution also accounts for this kind of mismanagement practices. It was long before the antipollution measures for rivers were taken into account. Even though the Water Act towards pollution was issued since 1989, its regulations were not fully carried out by industry or municipalities after several years. State regulations were first established on the Mexican Official Norm (NOM-001-ECOL-1996) for industrial and municipal discharges, which pointed a deadline to be enforced at the latest on January 2000, but fines and penalties were always postponed. At the end of 2007 the enforcement date was deferred until the end of 2011, because there was still no achievement of targets on water pollution levels. State and municipal authorities not even gave priority to build water treatment plants for municipal and domestic discharges. These facilities were not built until the project was finally approved in 2009.

In the meantime, river pollution kept increasing, as well as ecosystems continued its deteriorating process; less than 30% of the city´s wastewaters are treated. The heavy pollution of the Santiago river prevents from using water for urban supply or many other uses. Projects for urban water treatment plants have been delayed for so long that pollution and its damages to the environment are almost irreversible. For that reason, the river shows an advanced eutrophication process and sediments of heavy metals accumulated on the bottom prevent any possible aquatic life. Furthermore, the polluted waters have the most important incidence on the transmission of diseases for local people, who suffer dermatological, gastrointestinal and respiratory diseases, as well as cancer, kidney deficiencies and congenital deformities.

It was until 2012, after a quite complicated process, that the water treatment plant of El Ahogado started cleaning 2.8 l/sec. of municipal discharges. The second water treatment plant built at Aguaprieta, is expected to clean 8.5 l/sec. as soon as it is fully finished by the end of 2015. Many reasons can be considered for this delay, like the lack of adequate technologies to deal with industrial pollutants and financial support or even industry's reluctance to clean their own discharges and to recognize their responsibility on the polluters pay principle. The fact is that industrial discharges have not been supervised more strictly, and many small and micro factories still keep on pouring them directly to the river without any kind of previous treatment. Such practices denote a weak institutional capacity of state authorities to enforce regulations and agreements to protect ecosystems and society as well.

The other side of water management policies shows the ambivalence between the values supported by development programs and the actual water management projects and practices. There is always an official discourse that handles development goals and assistance to provide water to the poorest sectors of society, but at the end most of the benefits are favoring only some sectors of the urban growth. Most municipal candidates promise water supply to marginal communities during its political campaigns in order to get their vote of support. However, when they are in charge these promises are neglected or at best used to get financial support from multilateral institutions. The World Bank granted a loan for a water supply program called “Water for everybody” (Agua para todos, 2006-12), that failed to install the pipelines and required infrastructure to conduct water to the participant communities because the money was diverted for other purposes.

All of these practices give way to the persistent assumption that the city is facing water scarcity. Usually authorities argue that population growth and the increased economic activity reduce the availability of water supply, failing to recognize the incidence of many of the water management practices that affect its availability. Reality shows in this particular case, that scarcity is part of a social construction, responding to certain material conditions as well as to certain power relations that interfere in water control and access to it (Harris et al.,2013:4). The concept of scarcity is grounded nowadays in the dominant water governance discourses and practices. It is the kind of discourse that comes to focus water management policies mainly on increasing water supply through building more hydraulic infrastructure, without taking control of water demand, resources preservation and recycling.

It is true that available water volumes are already deficient, given the over exploitation of existing aquifers. So, the exhaustion of endogenous sources for water supply is leading to an increased dependence of urban population on water transfers from other neighboring regions. In order to satisfy water demand, hydraulic policies give way to an endless dependence on exogenous water sources. According to it, hydraulic policies become an essential strategy to guarantee urban water supply. In such terms, the challenge is closer to technical solutions, pointing to the best technological methods to import water from any surrounding sources.

The predominance of this hydraulic perspective in water management policies leads most of the water supply projects. This means the promotion of dams and water transfers for urban water supply. Larger dams are nearly favored to cope with the increasing volumes of supposed water needs. One indicator that sets the required volume of water for the city should be in accordance with the average number of liters per day per person. The average volume estimated for Guadalajara is as high as 250 l/day/pp. These estimates justify the account for higher volumes of water to satisfy urban demand. Upon this figure, the daily volume demand of water can extend to more than 180 mm^3 (millions of cubic meters), which cannot be covered through any existing sources. Under these parameters, it is more reliable to bring water from exogenous sources as the best alternative, even assuming the high accounting costs. Hence, there is no interest to improve endogenous water sources, such as reuse of treated water, water harvesting, pipeline systems maintenance, double pipeline systems supply, or neither to control water demand, to say the least.

The implementation of hydraulic infrastructure involves a huge debt, concerning the high investments required for large dams. This has also been the opportunity to facilitate public-private participation to afford the construction of dams, which has opened the way for privatization of water supply services. The real problem behind it, to put it bluntly, is the marketization of water management that works mainly through technical and financial feasibility criteria, leaving aside the environmental and social criteria that are essential to any regional development program.

Hydraulic policies for water supply

Construction of dams has been the most important strategy for water management in México since the 1940's. Large dams have been built for different uses: energy generation, irrigation, flood control and water storage. The promotion of the agrarian reform in 1936 and the beginning of industrial development were possible thanks to the governments' hydraulic policies, which provided water and energy. The following decades gave place to important development programs, many of them attached to dam building projects. The promotion of this kind of infrastructure was conceived in terms of achieving several national economic targets, including employment generation as a strategy to facilitate the incorporation of marginal communities to the country´s development process. In such cases, the allocation of the proposed dams required huge spaces along the rivers for the reservoirs and so, land had to be expropriated from many indigenous communities. At the end, these people had to be displaced from their homeland, and got to be the most affected and disadvantaged by the implementation of development policies.

The backgrounds of the dam building history in México were closely tied to energy generation, being the key factor for industrial and urban growth, as well as for social and economic development. Therefore, hydropower plants were taken as the best way to generate electricity, considering the available rivers around the country. Heading toward these policies, the Mexican government nationalized the electric industry in 1960, and took charge of all the energy supply projects, which until then had been mostly in hands of foreign private companies. In this way, since the early sixties the Santiago became one of the most relevant rivers to built large dams and hydropower plants. Santa Rosa was the first large dam built over this river for energy and irrigation uses. The latest and larger hydropower plants built over the Santiago River were Aguamilpa (1991), El Cajón (2006) and La Yesca (2012).

Most of the projects for water supply in the State of Jalisco during the second half of the 20th century favored investments in dam building and water transfers through aqueducts located over the tributaries of the Santiago River. Projects like the Chapala-Guadalajara aqueduct, the Zurda-Calderón System, the Purgatorio dam, the Arcediano dam, St. Nicholas dam and El Zapotillo dam are some examples of the planned infrastructure to deal with urban water supply. The competition of different stakeholders for water withdrawals in the basin has given place to conflicts between rural and urban uses, irrigation and industrial uses, and lately between the two more important cities of the western region of México: Guadalajara and León.

However, not all of the preceding projects were finally implemented, and in some cases results were rather poor, considering their cost-benefit relation. Among these were the cases of suspended projects that left behind high financial costs, essentially because there was not an integrated water management planning. During the last decade, several dam projects for urban water supply have faced problems as a consequence of the persistent resistance of civil society. This was the case of the St. Nicholas (2005) and the Arcediano (2009) dams, two of the most important government projects in the Santiago river basin, which had to be suspended. Such cancellation led to the approval of an alternative project: El Zapotillo project over the Verde river, which resulted the most feasible technical alternative for urban water supply for both cities, despite the strong opposition from the affected population. The reservoir will flood three communities: Temacapulín, Acasico and Palmarejo, affecting the homeland of at least thousand residents and other three thousand more that work abroad, but return intermittently and invest most of their savings in their home communities.

The competition for water is taking place over the flows of the Verde River, whose water flows were assigned by a presidential decree in 1985 to supply the cities of Guadalajara and León. While the water supply for Guadalajara has depended mainly on Lake Chapala and the aquifers of Toluquilla, Tesistán and Atemajac valleys, their overexploitation has led to the search new sources to ensure water for medium and long terms. On the other side, water supply for the city of León depends on the Lerma and Turbio rivers, being most of it used for industry and growing exportation crops in the region of El Bajío, in the State of Guanajuato. Given the serious limitations imposed by water supply for its industrial development, the city of León is turning to look for transfers from one basin to another. This mechanism involves transportation of water by artificial means (dams, aqueducts and pumping) from the Verde River, located 140 kms. away from León.

Water requirements for the cities of Guadalajara and León are currently around 504 576 000 m3/year, and it is estimated that in the short term the deficit could be around 3.8 m3/sec. for Guadalajara and 1.8 m3 /sec. for León. These estimates have led to a search for new sources, beyond the traditional sources in their own environments. El Zapotillo dam project is expected to have a favorable impact on reducing pressure of the overexploited aquifers of both cities. Here it lies the problem that has led to a fierce competition for water in the Lerma-Chapala-Santiago basin.

The construction of El Zapotillo dam must be finished by the end of 2016. It is estimated that the dam will regulate 500 million cubic meters, which should ensure water supply for a population of 2,361,000 inhabitants of both cities and other locations in the highlands of Jalisco for the next thirty years. The National Water Commission (CNA) discourses point out that the dam will generate development and better living standards in the region, helping to create direct and indirect employment during construction and operation of the dam, as well as fostering new jobs in fishing related activities, services and ecotourism around the reservoir area.

This is the usual discourse behind hydraulic policies attached to many of the dam projects. Socio-economic development is always the ultimate goal that justifies the construction of large dams. Dams are perceived as the best technological and economic solution to engender urban and industrial development and to solve water needs of the population growth. So, its costs always seem to be less compared to the expected benefits that come along with a dam.

Feasibility studies for dam projects are grounded on technical and economic criteria, concentrating efforts in depth analysis of geological, engineering and technological conditions, as well as financial, cost-benefit estimates and cost recoveries. Projects are usually justified in terms of optimistic and convincing statistics about the multiple benefits that could be brought to large populations and for the country´s economic development as a whole, sub-estimating social costs at a micro-level, which at the end will affect the most vulnerable local communities.

Feasibility studies barely consider environmental and socio-economic impacts. These usually become second order criteria or the side effects of a project. Following this rationality, the real environmental and social costs of dam projects are overlooked, or even taken as the necessary and unintended costs of development (Lezama, 2014). The WCD report (2000:47) found that many of those studies only consider direct project costs and benefits, which do not account on the social and environmental impacts associated to a dam.

The case of El Zapotillo dam and aqueduct can give a close view to the environmental and social impacts generated by hydraulic infrastructure, even though it is still in the construction process. Environmental impact assessment shows many of the expected outcomes, but the real costs will appear in the long run. The loss of biodiversity is the most significant impact, because it entails irreversible loses of natural capital. Almost all of the natural resources will disappear as soon as the reservoir floods the area. This involves the loss of native flora and fauna, local hot springs and mining resources, along with extensive agricultural and farming areas that are part of the community´s livelihood. This submerged flora soon will lead to the generation of greenhouse gases (carbon dioxide and methane) that affect the regional ecosystem and contribute so badly to climate change. More of the irreversible environmental damages will occur upstream and downstream the dam several years after its operation. These harms account for changes in landscapes and geomorphology because of erosion and sediment deposition, salinization of downstream soil, changes in the river flow regimes, water quality, biotic degradation, lost of biodiversity specially in fresh water fisheries and so on. If we consider that a dam’s life cycle has an average of 30 years, and that most of the damaged natural capital is irreplaceable, the environmental costs cannot be ignored.

Some of the economic impacts of the hydraulic policies have not been anticipated in the feasibility studies done for El Zapotillo aqueduct. Water transfers contribute to scarcity and microclimate changes on the area where the liquid is taken from. The affected farmers of the highlands of Jalisco argue that this is a semiarid area that depends mainly on the Verde River flows. As soon as water is diverted through the aqueduct to León, the occurrence of drought periods will be more frequent. These transfers will affect badly to a prosperous farming activity that stands for its national productivity records on egg and poultry, milk and pork products.

On the other hand, the social costs of a dam bring along upheaval and uncertainty to the concerned communities before and after their displacement. They are not informed about the dam project until it has been approved, and their claims are usually ignored. People's opinions and participation are not taken into consideration in the decision making process over resettlement plans. In such cases, as it happened in El Zapotillo project, communities are enforced to leave their hometown under the promises of compensations that include resettlement places with better houses, urban services and also land for agricultural and farming activities. Intimidation mechanisms have been used to make people sell their properties even against their will. People are managed as units that can just be moved from one territory to another, where they are expected to reorganize their lives. Development for these people means losing their jobs, their homeland and livelihood, including their community life, social networks, costumes, cultural patrimony and heritage. From then on, an impoverishment process starts for them, without a real support from the State.

Conclusions

Present worldwide urban growth tendencies are leading to demographic concentrations in large cities. In the coming decades it is expected that as much as 75% of the world population will live in cities. Urban development policies will have to face new challenges to cope with a rational use of fresh water resources and its decreasing availability in the city´s surrounding areas.

As it has been said in previous pages, the complexity to provide water in large cities cannot be managed through dependence on exogenous hydric sources. It is important to implement sustainable policies for permanent water supply as a means to guarantee part of the urban needs. This requires more efficient strategies and governmental efforts to provide public services on the basis of limited resources. In order to do so, many factors should be taken into account to let the city perform its basic functions in a more rational and autonomous way.

Environmental factors are important to ensure clean fresh water, a healthy atmosphere, efficient energy, wastewater treatment, waste disposal, recycling, etc. To be able to perform its basic social metabolic functions, a city should not exceed its proper size

(Forman, 2008). The proper size might be thought in relation to its carrying capacity; that is, the total equivalent area and resources used to support its people in a city. Population should not exceed this limit to maintain a certain minimal balance with nature as to keep a healthy living cycle for its inhabitants.

This drives to a systems view analysis of the city as a part of a larger system in order to find the best fine scale solutions to face urban sustainability. Nature's metabolic model is the best example of the systems operation. The basic components of a city system can be seen as the inputs (sources) related to production, food, water, storage, building materials, in one side; and outputs (sink) like sewage, wastes and pollutants in the other side (Forman, 2008:318). In such a way, urban metabolism should point to a system where the source and sink areas of a city operate without ending in an environmental crisis for the whole system.

The persistence of actual urban growing patterns in Guadalajara have shown that there are no coherent policies toward water sources preservation, while pollution and abandonment turn rivers and aquifers into increasing sink areas, without any possibility of restoration. At the same time, natural water cycles are being affected in different parts of its process, as we can observe with deforestation of urban forests, building over aquifer recharge zones and creeks, polluting rivers, garbage mismanagement, and so on.

Following this system view analysis, most hydraulic policies show a tendency to trigger many of the externalities that come out in the long run. Large dams and water transfers solve problems of water scarcity in urban areas in the short term, while scarcity appears time after in the neighboring rural regions, and with it, many of the related damages for the ecosystems. The question is: will it be possible to continue building more dams without having to confront these externalities? As far as we can see, there cannot be a sustainable water management within these hydraulic policies. It is in this sense that the urban metabolism model can give alternatives to think about creative solutions toward city growth and local "soft path" technologies to deal more efficiently with existing water sources in a sustainable view.

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Kustomo[5]

Water Absorption Wells for Mitigating Jakarta´s Future Flood Risks: Toward a Sustainable Urban Water Management

Abstract

Floods are the most devastating natural disaster in Jakarta, the capital city of Indonesia, in both damage and loss of economy. Increased flooding in Jakarta can be ascribed to a combination of two main factors i.e. change in land use and increased precipitation. This research will try to analyze the causes of increasing flood events in Jakarta and to provide an overview of disaster management in Jakarta, to understand why official strategies failed to reduce damages of flood events in Jakarta. Then, we will introduce possible management alternatives to mitigate flood hazards in urban environment and to promote sustainable water management based on the long-term protection of available water resources. The methodological approach of this research is based on secondary data about flood hazards in Jakarta´s megacity context, compiled through literature study and information obtained from relevant authorities. A review of the Economy and Environment Program for Southeast Asia (EEPSEA) on the climate change vulnerability index in Southeast Asia shows that from the 530 cities in 7 countries; (Indonesia, Thailand, Cambodia, Laos, Vietnam, Malaysia, and Philippines), Indonesia is the most vulnerable country to the impacts of climate change. Hence, flooding remains a threat to the citizens of Jakarta and needs a comprehensive approach to solve it. Water absorption wells could be an alternative solution of this problem because those are smaller than dams and absorb floods (rainwater harvesting) in floodplain areas. Then, water from reservoir could be used for urban supply after it is cleaned properly through water treatment processes (purification).

Keyword: Floods, Jakarta, water management, water absorption wells

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1. Introduction

1.1. Background

Floods are natural disasters that have been affecting human lives since immemorial times. Some flooding is part of the natural hydrologic cycle and the sustenance it brings to life on Earth. It becomes a disaster because of the way we have built upon areas susceptible to flooding. On the other hand, many are caused far worse by deforestation, draining of wetlands, and attempts to constrain river flow. Rain falling on deforested slopes washes away the soil that would previously have soaked it up. This increases the amount of water running into rivers, and the amount of sediment. Jakarta, the capital city of Indonesia, is one of the megacities and the heart of Southeast Asia's largest economy which has been undergoing serious problems associated with floods. Flooding is the most devastating natural disaster in Jakarta of the twentieth century, in both damage and loss of economy. Natural benefits of flooding become threats of flooding when not considered in community planning and building design because water is a renewable but limited resource.

Extreme weather events, flooding, drought, and environmental stresses impose new demands on design of buildings and communities, as well as our natural land and water resources. These stresses are impelled by climate change but also by the way we have built on flood risk areas and our coastal areas. Water absorption wells represent the sustainable urban water management which can contribute to mitigate the effect of floods by introducing a single system of coordinated objectives to be met through integrated water reservoir from floods (or rainwater harvesting) and water treatment processes (purification) to supply water demands for urban population. This proposed research is expected to solve problems associated with climate change, changes in population and demographics, a volatile global economy, increasing energy prices, heightened environmental awareness and more complex regulatory and social circumstances today.

Objectives

Based on the problems aforementioned, we will try to analyze the causes of increasing flood events and to provide an overview of the policies of disaster management in Jakarta, to understand why official strategies failed to limit damages of flood events in Jakarta. Then, we shall introduce possible management alternatives to:

1. Contribute to mitigate flood hazards in urban environment;
2. Promote sustainable water management based on the long-term protection of available water resources.

Methodological Approach

First, the research is particularly based on secondary data about flood hazards in the megacity context of Jakarta (Indonesia). Data were compiled through the literature study and information obtained from the relevant authorities, such as settlement agency officials, provincial-level officials, disaster management agency of Jakarta, and also newspapers. However, Jakarta is representative of many urban areas in developing countries, where extreme hazards have been experienced by the generations presently living in the area. It also represents a similar problematic situation as in other developing countries, particularly in the region of Southeast Asia which has high rainfall and is vulnerable to suffer floods.

Secondly, we will analyze to assess the inhabitants' perception of official strategies of disaster management, and of their own responsibility in increasing floods. Then, we will propose an alternative solution to deal with flooding in Jakarta by introducing an integrated system of sustainable water management in megacities, namely "water absorption wells".

2. Results and Discussion

2.1. Flooding in Jakarta

Jakarta, the capital city of Indonesia, is located on the northern coast of Java island with a total area of 653.66 square km (figure 1). As a capital city of a country with 247.57 million population, Jakarta is not only the seat of the national government and the provincial government; this city is also Indonesia's political center. Moreover, Jakarta is also the center of Indonesia's national finance and trade.

Figure 1. the Jakarta city, Indonesia (source: google maps, 2014)

Jakarta is a huge, sprawling metropolis, home to 10,187 million inhabitants, with a population growth rate of 1.06 percent. During the day the number of people increases with another 2 million as commuters from adjacent cities such as Bogor, Depok, Tangerang, and Bekasi which make their way to work in the city, and flock out again in the evenings (Eko T. Paripurno, et al., 2013). The impact of an increasing number of population in Jakarta is a decrease of water catchment area, at least when it is compared with the population of Jakarta in 1970, when it reached 4 million people, and in 1960 were only 2.9 million people. The population density in Jakarta is also increasing. Data of Government Statistics show that the average population density of Jakarta in 2009 was 13,000 persons/km^2, while the density in the area of central city (Central Jakarta) is higher than others, it reaches up to 19,600 people/km^2 (Population and Civil Records Agency of Jakarta, 2011).

Jakarta has a tropical monsoonal climate with a dry season and a heavy monsoon the rest of year, no cold season. Jakarta undergoes the peak of rainy season between January and February with an average rainfall of 350 millimeters (mm) and an average temperature of 27^{o}C. The monsoonal climate brings heavy intensive rainfall every rainy season.

Jakarta is located in the downstream area of the Ciliwung river basin, and is affected by the characteristics and conditions of the upstream area. In addition, around 24,000 ha (about 240 square km) of the main part of Jakarta is estimated to be below sea level. That makes the city vulnerable to severe flooding either when rain fall or when water runs off sea to land in the event of tide waves. Flooding is a perennial problem in sprawling Jakarta during the wet season. Severe floods have been reported to have hit Jakarta in the past, such as in 1996, 2002, 2007 (Pauline Texier, 2008), 2013, and 2014 (Darmouth Floods Observatory, University of Colorado, 2014).

2.2. The cause of flooding in Jakarta

There are several factors why Jakarta is always facing with annual problems like floods. Firstly, the cause of flooding is an urbanization rate which is increasing today. One of the negative impacts of urbanization is a process of artificial land use alteration occurring through time (Davies A. Semadeni, 2008). Moreover, the average soil in Jakarta is decreasing up to 10 cm. per year. Even in some areas in the northern part of Jakarta, the rate of decline in soil reaches 26 cm. per year. This land subsidence is being caused by the massive ground water absorption urban and industrial uses (Mirah Sakethi, 2010). Secondly**,** Jakarta has thirteen river flows from the highlands (Peak-Bogor) in the south, running north across the city toward the Java's sea and two flood canals along Jakarta (figure 2). All these rivers, combined with the wet season rains and insufficient drainage due to clogging with garbage, which many people dump into rivers and drains. At some locations along rivers and drains, water flows are hampered by provisional wooden houses and other small structures, built by many of Jakarta's poor who have settled on river banks and estuaries (Mark Caljouw, et al. 2005).

Thirdly, the losses of green space and water catchment areas due to be converted into luxury apartment, flats, hotels, and large shopping centers also contribute to worsen floods that occurred in Jakarta (figure 3). Rainwater can no longer be directly absorbed by soil, because water catchment areas and green spaces have turned into concrete jungles (Mark Caljouw, et al, 2005). Lastly, climate change cannot be denied, it also contributes significantly to flooding events in Jakarta. Climate change impacts in changing weather patterns and rising sea levels. A review of Economy and Environment Program for Southeast Asia (EEPSEA) has found that population density is one of the important factors in determining risks of climate change and how a region can anticipate and adapt to climate changes. Of the 530 cities in 7 countries; Indonesia, Thailand, Cambodia,

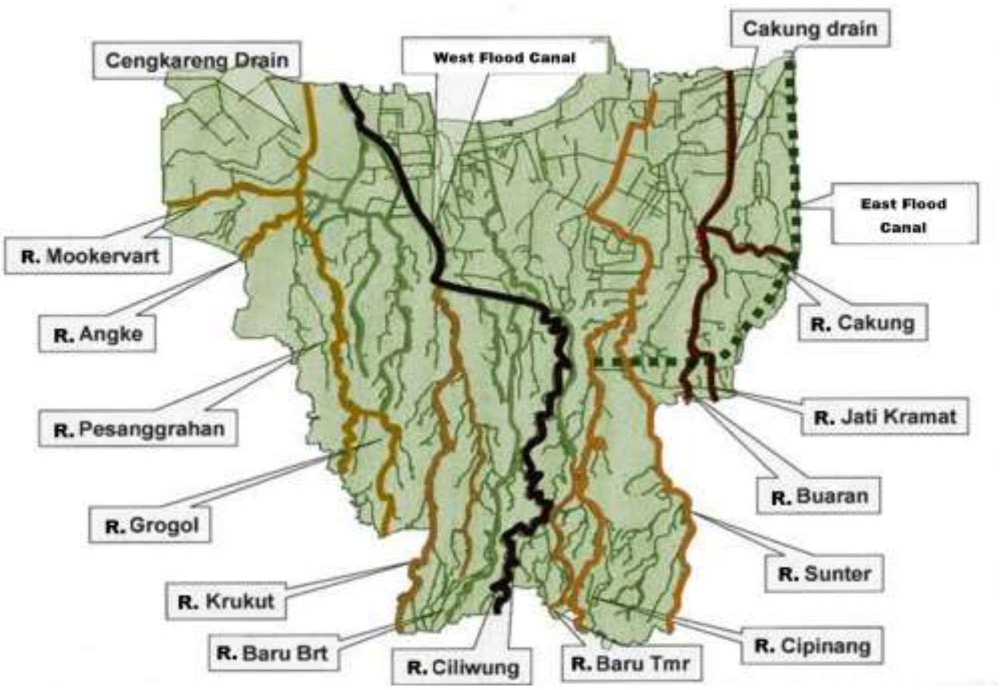

Figure 2. Watershed systems in Jakarta, Indonesia (source: own figure)

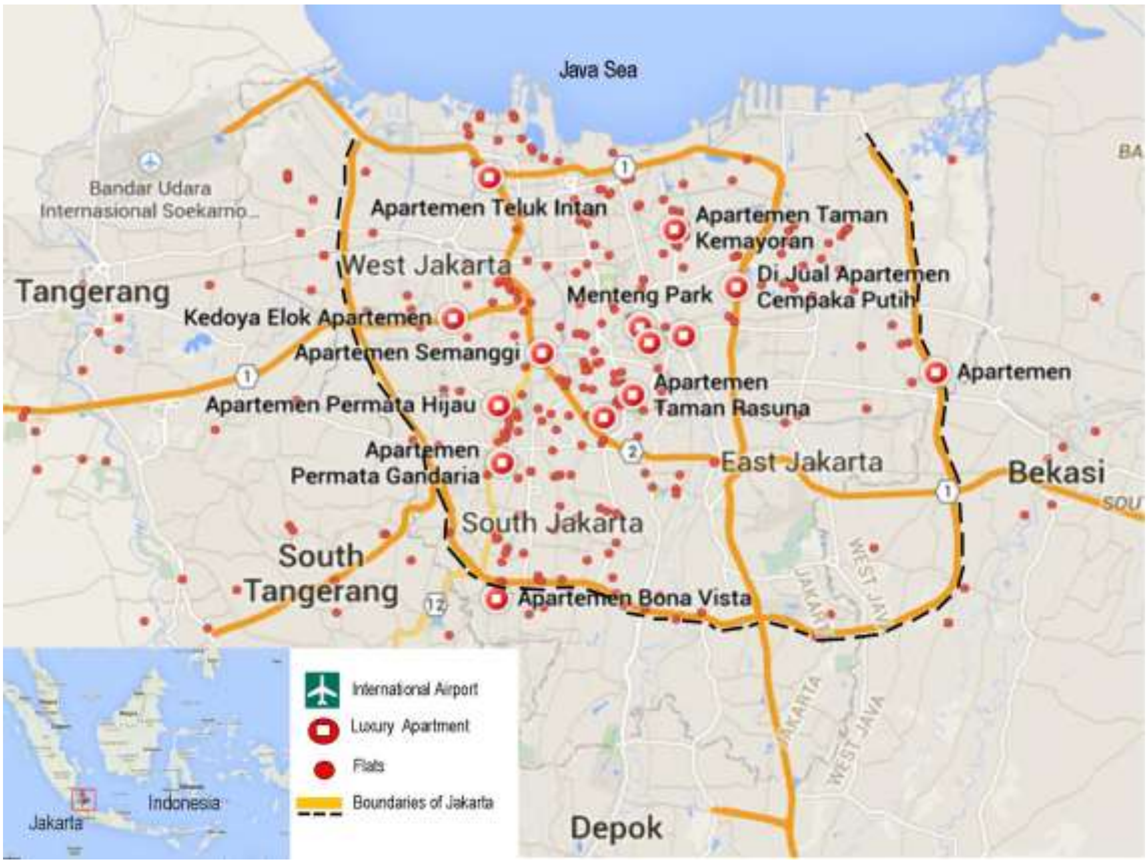

Figure 3. Several luxury apartment and flats in Jakarta (source: own figure)

Laos, Vietnam, Malaysia and Philippines, Indonesia is the most vulnerable country to the impacts of climate change (Arif and Herminia, 2009).

2.3. Disaster Management

2.3.1. Vulnerability and Risk

The damage of the upper stream due to changes in the forest area of Bogor, into tea plantations and vacation homes have increased surface flow (run-off). It makes flooding in Jakarta will be severe in the future if heavy rain happens to coincide with high tides. Figure 4 is related to the structural land of Jakarta, showing upstream and downstream areas from Bogor to the Java sea with in combination when rainy season comes.

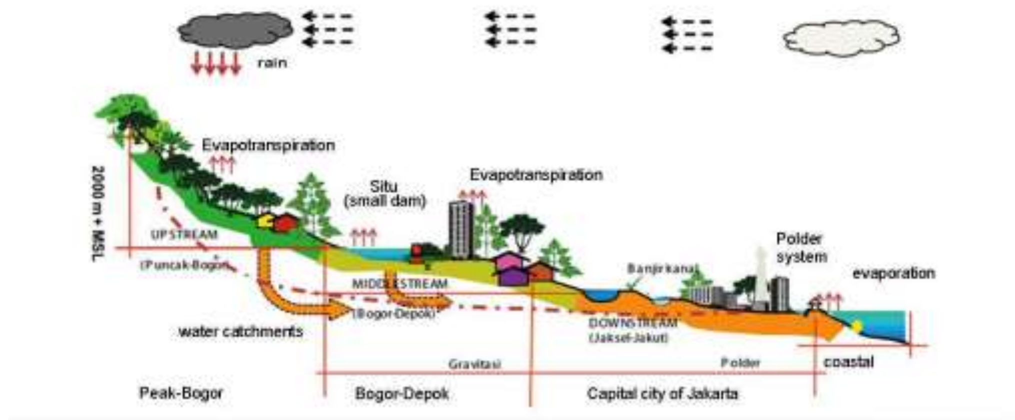

Figure 4. The structural land of Jakarta (source: Mirah Sakethi, 2010)

The Economy and Environment Program for Southeast Asia (EEPSEA) has derived the overall climate change vulnerability index, showing the combination of climate-related hazards (tropical cyclones, floods, landslides, droughts, and sea level rise) and the hotspots in Southeast Asia by overlaying a series of maps (figure 5). The latter includes the north-western and Mekong region of Vietnam, the coastal regions of Vietnam facing the South China Sea, Bangkok and its surrounding areas in Thailand, practically all the regions of the Philippines, and the western and eastern parts of Java Island, Indonesia. For the legend, the scale used is 0-1 indicating the lowest vulnerability level (0) to the highest vulnerability level (1).

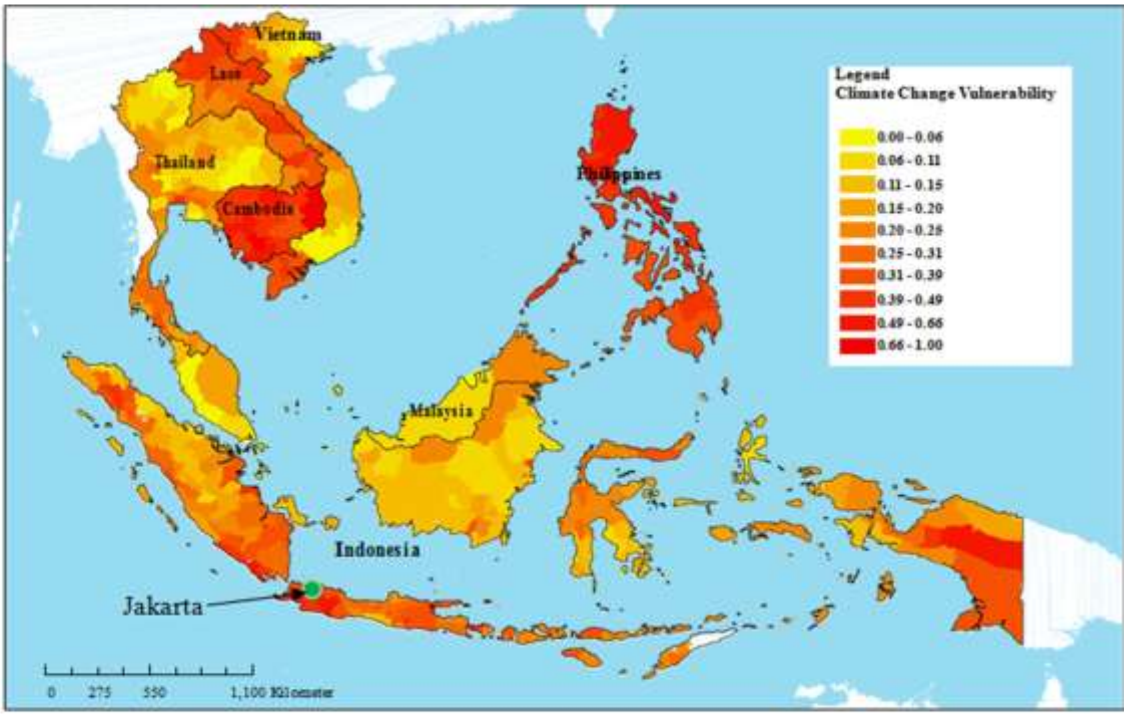

Figure 5. Climate change vulnerability map of Southeast Asia (source: EEPSEA, 2009, enhanced by own explanation)

The following table (table 1), lists the climate hazard hotspots and their dominant hazards in each country in Southeast Asia.

Table 1. Climate hazard hotspots and dominant hazards

Climatic hazard hotspots	Dominant Hazards
Northwestern Vietnam	Droughts
Eastern coastal areas of Vietnam	Cyclones, drought
Mekong region of Vietnam	Sea level rise, floods
Bangkok and its surrounding area in Thailand	Sea level rise, floods
Southern regions of Thailand	Droughts, floods
The Philippines	Cyclones, landslides, floods, droughts
Sabah state in Malaysia	Drought
Western area of Java Island, Indonesia (**Jakarta**, Banten, West Java, Central Java)	**Floods**, landslides, sea level rise
Eastern area of Java Island, Indonesia (East Java, West and East Nusa Tenggara)	Droughts

(source: EEPSEA, 2009, enhanced by own explanation)

2.3.2. Floods prevention efforts by Government of Jakarta

Design for flooding builds on the emerging concept of resilience and considers flooding as a natural process and human activities. Addressing flooding as a given natural process of weather and human activities inside the cities leads to imaginative and comprehensive approaches to resilient design, applicable at regional, community, and building scale (Donald Watson and Michele Adams, 2011). The basic principles of floods prevention in Jakarta is flowing water from upstream areas in the southern part into the Java sea directly via the suburbs of Jakarta by the West Flood Canal and Cengkareng Drain in the Western part and the East Flood Canal and Cakung Drain in the Eastern part. The Southern Part of Jakarta, upstream areas, had made drainage for channeling water naturally by utilizing the force of gravity. In some lower areas, it will be using polder system to pump water out and to dry that places.

Flood prevention efforts in Jakarta are not only done through infrastructure development such as channels, reservoirs and canals, but also through social behavioural approaches of people living in Jakarta. Therefore, the Provincial Government of Jakarta used both of the two approaches in flood control, structural and non-structural approaches. The structural approach is focused on six aspects, namely are the construction of a flood canals, normalizing the rivers (figure 6), the maintenance of the rivers, anticipating the high tide by building the dike, structuring drains, as well as the construction of pumps, water gates and filtering of garbages. Whereas the non-structural approach is focused in making local government policies to the communities who live in Jakarta to cope with floods together, such as by the establishment of the legal basic of flood prevention which are implicit in Act (*Undang Undang*) No. 24 year 2007 and Government Regulation (*Peraturan Pemerintah*) No. 22 Year 2008 on Disaster Management, as well as they made the guidance book of disaster management plans of Jakarta (Eko Teguh Paripurno, et al, 2013).

Ciliwung river before normalization Ciliwung river after normalization

Figure 6. Normalizing the rivers in Jakarta (source: Eko Teguh Paripurno, et al, 2013)

2.4. Alternative solutions to mitigate floods in Jakarta

2.4.1. Water Absorption Wells

The implementation of flood management for urban areas is not the same for rural areas, because the characteristics of urban and rural areas are significantly different (Ivan Andjelkovic, 2001). Flooding in Jakarta is still occur until today. Although the prevention of flooding in Jakarta has been done after severe floods in 2007 by several efforts, in fact, floods still occured in 2013 and in 2014. Therefore, It is necessary to find another solution to mitigate floods in Jakarta. It is important to recognize also that vulnerability (or consequence) in turn has two components (Roger Few, 2007): physical vulnerability (whether a person will be exposed to a given flood) and social vulnerability (the ability of the individual or community to adapt to the flood). Design for flooding turns floods threat into an opportunity to improve water resources and community resilience at regional, community, and building scale.

Water absorption wells can be an alternative solution for this problem because these constructions are smaller than a dam (figure 7). It can absorb floods and rainwater harvesting which often take place in megacities. Rainwater harvesting refers to the practise of collecting and storing water or absorbing water from floods before it can reach a river (Theib Y. Oweis, et al., 2012). Afterward, water can be stored into a water reservoir and it can be used as water conservation in such city for sustainable water management. Water conservation can effectively double water availability but has not yet been adopted to the scale of its potential (Donald Watson and Michele Adams, 2011). The construction of "water absorption wells" will be put on the flood prone areas in Jakarta to mitigate future flood hazard (figure 8).

Figure 7. Design of the water absorption wells program in megacities (source: own figure)

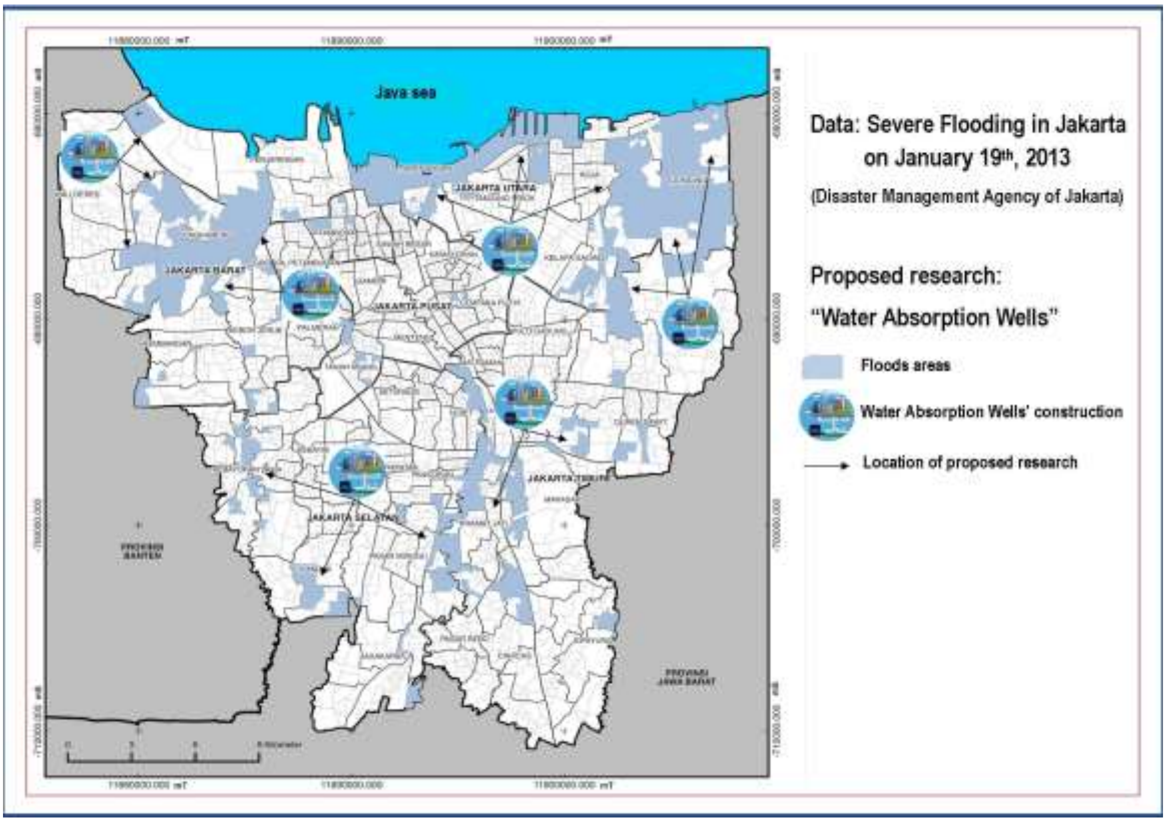

Figure 8. Location of proposed research (water absorption wells)
(Source: own figure)

2.4.2. Water reservoir and water purification

Water is fundamental to health, and the installation of a plentiful, reliable supply of water in a urban area is one of the most effective ways of improving the health and well-being of a large group of people (Shimon C. Anisfeld, 2010). This section addresses the major treatment process applied to water supplies. Several aspects of water treatment are becoming more important, especially as pressures increase for water reclamation and recycle. Another consideration of growing importance in water treatment is the development of new technologies. It is important to consider the sustainability of developing techniques including costs and by product generation. One of the examples of a municipal water treatment plant is shown in figure 9 (Stanley E. Manahan, 2013).

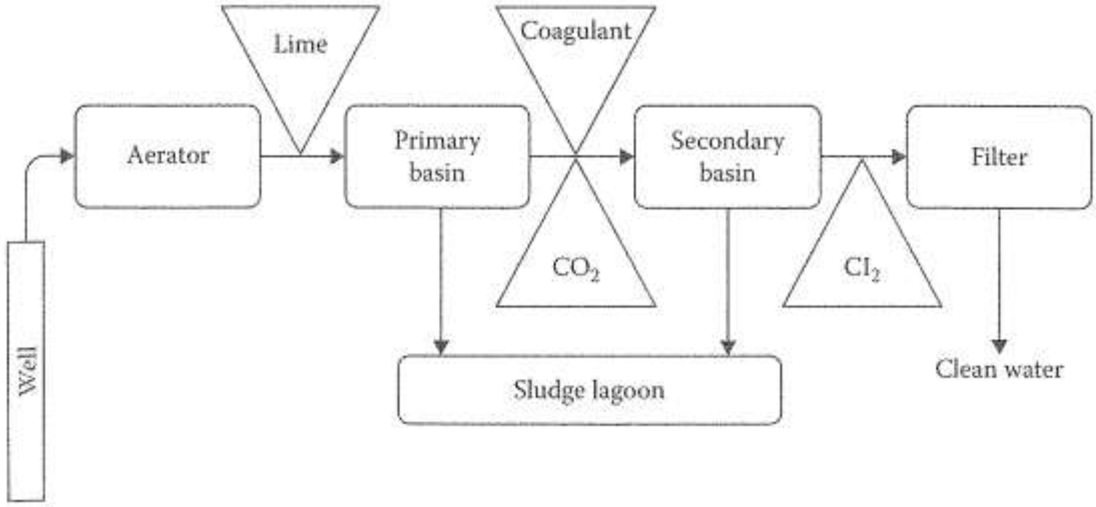

Figure 9. A schematic diagram of a municipal water treatment plant

In some cases, these systems have served as the main source of drinking water when operated properly. Although it is generally not advised as a source of drinking water for humans, harvested rainwater can be used for irrigation, for domestic applications other than drinking or cooking, for live stock, in car wash facilities, and in other applications where potable water is not required.

3. Conclusion

The flood problem in Jakarta is complex, and needs a comprehensive approach to solve it. The implementation of flood management for urban areas is not the same for rural areas, because the characteristics of urban and rural areas are significantly different. The probable effects of a changing climate provide a challenge for sustainable water resource management. Water absorption wells are an alternative solution to mitigate future flood risk and to supply water when there is scarcity of water. This solution is suitable applied to countries which have high rainfall such as in the Southeast Asia regions.

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