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Master program for integrated storm water management in the Great Guadalajara, Mexico

Gestion intégrée des eaux pluviales du Grand Guadalajara, Mexique

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RÉSUMÉ

À Guadalajara, deuxième ville du Mexique, existe un problème majeur concernant les inondations et la gestion des eaux pluviales. Ce problème est associé à une importante dégradation de l'environnement des milieux récepteurs, premièrement due au manque d'infrastructures de traitement des eaux usées et, deuxièmement aux polluants entraînés par les écoulements pluviaux de surface. En considérant le contexte local, Infraestructura Hidráulica y Servicios (IHS) a mis en marche un nouveau plan de gestion nommé Programme de Gestion Intégrale des Eaux Pluviales du Grand Guadalajara (PROMIAP). Ce programme est fondé sur trois concepts de base : (i) détention des eaux de surface par la mise en œuvre de mesures structurelles, toute en considérant leur intégration au paysage urbain ; (ii) mise en œuvre de mesures structurelles au moyen d'un financement partagé entre les autorités locales et fédérales ; (iii) changement graduel des pratiques par la mise en œuvre de mesures non structurelles et de techniques alternatives de contrôle à la source à l'intérieur des nouvelles zones urbaines. Cet article présente donc les aspects essentiels qui ont permis le succès de la mise en marche du PROMIAP, à savoir : (i) la procédure de conceptualisation, (ii) la stratégie de communication des nouveaux paradigmes, (iii) la stratégie de mise en œuvre et (iv), les différentes mesures structurelles et non structurelles de lutte contre les inondations subies chaque année par la population du Grand Guadalajara.

ABSTRACT

In Guadalajara, second most important city in Mexico, there is a hard problem concerning the control of urban storm water and the consequent process of flooding. This problem is associated to a strong environmental degradation due to the both deficit of sanitation infrastructure and deposit of diffuse pollutants into the natural areas during the rainfall period. Considering the local context, Infraestructura Hidráulica y Servicios (IHS), have proposed and carried out, a new master plan named "Master Program for Integrated Storm Water Management for the Great Guadalajara" (PROMIAP) which is based on three fundamental aspects: (i) Detention of urban storm water through the implementation of structural measures, by considering their integration to the urban landscape; (ii) implementation of structural measures through the shared financial schemes between both the federal and the local authorities. (iii) Gradual change of the local practices through the implementation of non structural measures and the implementation of best management practices in suburban areas. The paper presents the fundamental topics that they have allowed the success of the PROMIAP, being these the following: (i) The conceptualization procedure as well as the different technical studies realized, (ii) the strategy carried out in the communication of "the new" paradigms, (iii) the strategy of implementation of the PROMIAP and (iv) the different measures to implement for both sustainable storm water management and the fight against the floods that the inhabitants of the Great Guadalajara suffer every year.

KEYWORDS

Master program, Guadalajara, Mexico, management, urban storm water

1 INTRODUCTION

In the Last 100 years, Mexican cities have experienced an important growth in their extension as in the quantity of their inhabitants. This process initiated with the migration from the field toward the cities caused by the economic growth of the Post Revolution to continue with the growth of the birth rates and to converge nowadays with the inter-urban migration (Sobrino, 1999). As a result of this, Mexico initiated the process of integration, institutionalization and legal foundation for the planning of the human settlements, adopting techniques of functionalist planning to establish strategies, to define phases, to select criteria, to formulate politics and to set the necessary instruments for its set in motion. However, in the used model persists a deductive vision for the solution of the territorial problems and of urban development (Garcia-Salas, 2008a). The application of the urban development model, though has contributed in having better macroeconomic indicators and population wellbeing, they have not permitted to resolve the fundamental problems of the Mexican cities, among the ones that emphasizes, inefficient service of drinking water, low sewage system coverage, low sanitation coverage, nonexistent urban storm water management, among others (Garcia-Salas, 2008b).

These problems have as origin, diverse social, political, technical, economic, and technical factors, whose meticulous analysis surpasses the objective of the present article, however the reader could consult Garza, (2003); Sobrino (1998); Unikel, (1978) to deepen in those topics. Among the main consequences, the degradation of the urban environment is found characterized, among others aspects by: (i) massive waterproofing of the urban ground, (ii) air, water bodies, and urban ground pollution, (iii) drinking water sources pollution, (iv) local drinking water sources collapse, (v) river beds and urban streams strangulation, (vi) frequency of the surface and level of floods increment, (vii) urban ground pollution, (viii) urban forest lost and, (ix) urban landscape degradation. To resolve them in a pragmatic way, it is necessary a model application based on the deceleration of the environment negative impacts (natural and artificial), which permits in a parallel way, to revert the tendency of the urban water bodies degradation and to decrease the urban storm water negative effects in the cities of developing countries, especially the Mexican cities. This deceleration strategy is based on the adaptation and water management integrated plans appropriation, whose results have been successfully tested in other latitudes (Garcia-Salas, 2008b). This implies of any way, to sow the driving seed of change through the technological adaptation, "forcing" the paradigms change. In different cities of the world, the driving seed of the change emerged in a spontaneous way and represented in its moment, the development motor element of new paradigms. To deepen on this theme, the reader could consult (Wong, 2006; Brown, 2007).

Under this theoretical framework, in the present article the main elements which have permitted the conceptualization and set in motion of an integrated urban storm water management model in the Great Guadalajara are shown, whose main objective is the fight against floods presented every single year, and it establishes the necessary bases to travel toward an integrated water management in this urban environment.

2 PROBLEM DESCRIPTION

As a purpose of illustrating the magnitude of the urban storm water management problems nowadays in the Great Guadalajara which justifies the conceptualization and set in motion of the Master Program for Integrated Storm Water Management (PROMIAP), subsequently a brief diachronic analysis of the drainage system of the city is presented.

2.1 Historical context

From ends of the 19th century, Guadalajara city experienced an important urban growth affecting particularly the natural hydrographical network. This network has been substantially modified as a part of the urbanization process in the catchment; streams were conceived as sanitary collectors, which generates at the beginning of the 20th century an important sanitary problem (see figure 1).

This environmental problem was solved through the rivers canalization, mainly San Juan de Dios River, Barranca Ancha River, and Chicalote River, that crossed downtown the city. After Mexican Revolution, and taking advantage of the economic boom of the following four decades, Guadalajara city experienced an important growth, increasing the sanitary affluent loads, and also urban storm

water volumes caused by the catchment waterproofing.

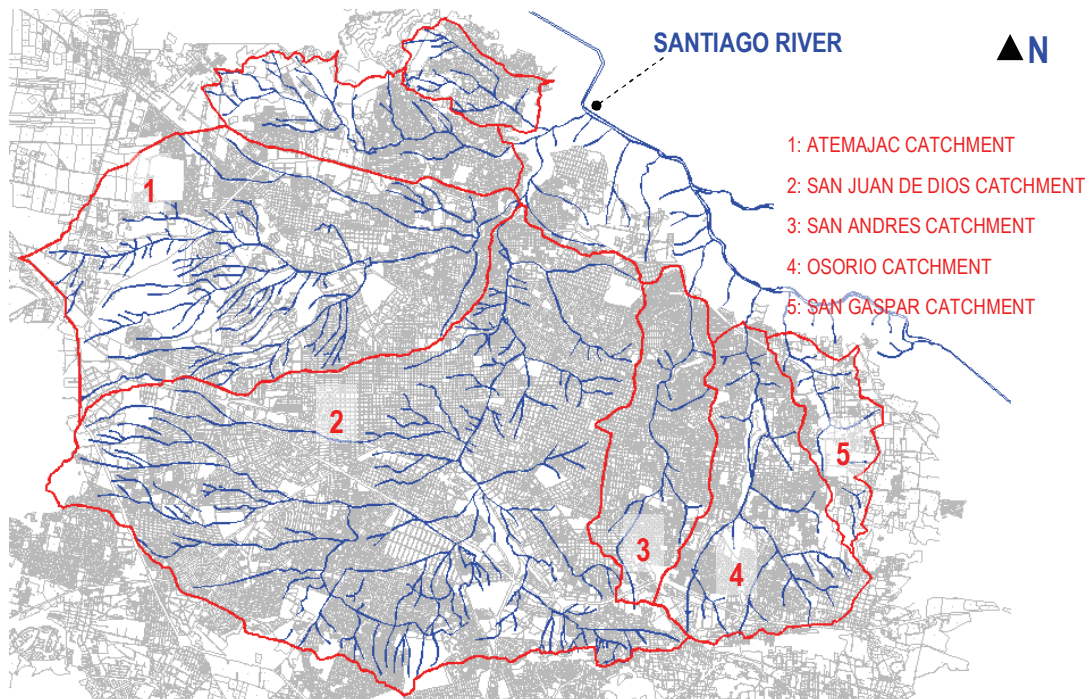


Figure 1. Original hydrographical network of the valley of Atemajac (at the moment disappeared) and actual urban stain of the Great Guadalajara.

This economic boom also caused the speculation of urban ground and it continuous until today, forcing firstly to occupy protection streams areas and secondly, to eliminate the hydrographical network for substituting it for highways and consequently, by main sewers which moves the sanitary affluent out of the new settlements created around historical downtown. In this way, the primary hydrographical network of the Atemajac valley was substituted by seven main sewers, designed in its time with return periods up to 10 years.

Besides, the engineering criteria used in the middle of the 20th century, did not consider the horizons of urban planning about land use and, they systematically used smaller rain intensities. According to Rueda (2008), the runoff coefficient used in those times were close to 0.45 (now the same coefficient is about to 0.79) Also the average design rains, were close to 50 mm/hr for a 60 minutes rain and a return period of 10 years. Now it is estimated that the same rain has a magnitude close to the 65 mm/hr.

From the historical city context it stands out the creation of the Master Plan of Main Sewers created between 1965 and 1970 and the Metropolitan Plan of Main Sewers created between 2003 and 2004 as both a response to the non functional drainage system of the Great Guadalajara and to the urbanization process.

The first plan essentially established the following: (i) the construction of parallel conduits to the existing main sewers to take out the combined affluent caused by the new city sectors; (ii) the replacement of natural river beds by main closed sewers to “definitively” solve the problem and to leave the urbanization free; (iii) the construction of an only sanitary and industrial sewer, (iv) the urbanization of sanitized lands and to take the protection river bed areas to become street gardens or green areas. Additionally and in a paradoxical way, this plan gave emphasis to the preservation of high parts of the valley, uninhabited at the time, with the purpose of controlling the storm water through infiltration deposits that allowed reloading the aquifers. This approach was soon surpassed and the solution prevailed alone a few years.

The second plan established an analysis and conceptualization similar to the first one: (i) reinforcement of the existing drainage system through the construction of 119 Km of new separated main sewers and (ii) rehabilitation of the existing detention ponds. This plan was presented in 2004 and received the refusal from the different stakeholders of the urban drainage system of the Great Guadalajara. However, this plan represented a great effort of diagnosis. It fits to emphasize that this plan permitted the supply of most of the information required in the PROMIAP. Face to the strong

sanitary component of the praxis, it was evident a need of changing the management and urban storm water control paradigms of the Great Guadalajara.

2.2 Description of the study area

The study area is called Great Guadalajara (zone 1 and zone 2; see below), it is located 480 Km from Mexico City northwest, in the Ocean Pacific side. At present, it concentrates around 85% of the urban district of Guadalajara population and is conformed by the Municipalities of Guadalajara, Zapopan, Tlaquepaque and Tonalá.

For general planning effects, the Urban District of Guadalajara was divided into four zones, being the following: (i) zone 1: Catchments of Atemajac, San Juan de Dios and San Andrés, (ii) zone 2. Catchments of Osorio and San Gaspar, (iii) zone 3: Catchment of Ahogado, (iv) zone 4: Catchment of Arroyo Hondo y el Caballito, (see Figure 1).

The hydrologic process is characterized by a rainy season that covers the months from June to October. On average, 90 rain days are presented; around 77 days concentrate the 91% of the mean total rain, which reaches a value of 935.2 ± 25 mm. On the other hand, the hydrologic process is characterized by concentrate on an hour, 62% of the raining day, by presenting registered maximum intensities up to 123.4 mm/hr (Rueda, 2008).

2.3 Current situation

As it is mentioned in this paper, the chaotic growth of the Great Guadalajara have caused a chronic non functional sewer system, that year by year evidence itself in the following way. This problem is related to their hydrographical characteristics, to the sanitary praxis in the urban storm water and also to the hydrological process. It is characterized by:

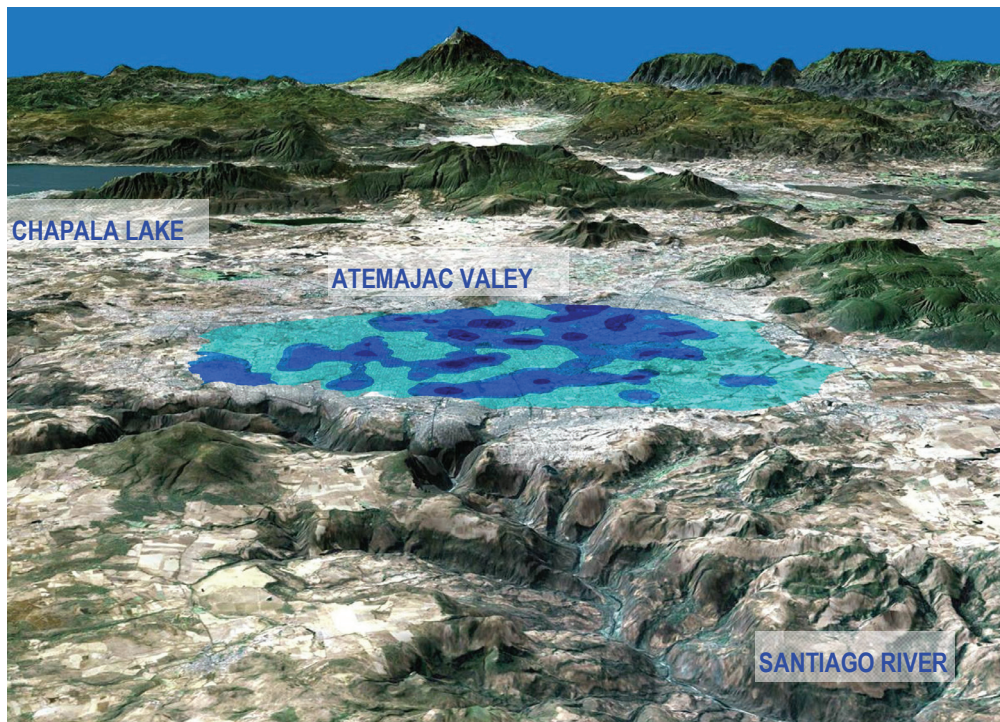


Figure 2. Digital Terrain Model of Urban District of Guadalajara and flood map from 0.20 m to 1.5 m. Modified from the Metropolitan Plan of Main Sewers.

- 73 flood points with deeps from 0.20 m to 1.50 m caused by both the storm water runoff and underflow of the sewer network.
- 5 dead people every year directly related to both the storm water runoff and floods.
- Negative impacts on 2800 houses and 650 commercial establishments per year.

- Total lost of 35 cars per year
- Lost of 440,000 working men hours per year.

As a result, the contingent evaluation study permitted to establish the economical annual costs associated to the Great Guadalajara floods which are approximately around the 600 million Mexican pesos (30 million Euros).

3 PROMIAP

As a result of the conceptual solutions failure established in the Metropolitan Plan of Main Sewers, the Inter-municipal Utility for Drink Water and Sewage Services (SIAPA), requested the elaboration of a master program to resolve the city flooding problems, considering the following points of reference: (i) to use the existing infrastructure, (ii) the optimization of impacts due to the city works related to the urban storm water infrastructure, (iii) the rehabilitation of infiltration ponds built in the 1960-1970 period, (iv) the economic nature of the solutions.

In the face of the information above, Infraestructura Hidráulica y Servicios Company (IHS) started to redefine a storm water management plan, considering a new management and control of urban storm water paradigm. Subsequently the main steps that have permitted the set in motion of the Master program for integrated storm water management in the Great Guadalajara, (PROMIAP) are presented.

3.1 Conceptualization

PROMIAP emerges as a concept at the ends of 2005 to give a better institutional answer in the Great Guadalajara urban storm water control. The conceptualization shown in a schematic way in the figure 3, has its starting point in the problems establishment. Though the plans that preceded the PROMIAP established it, this was created to give a solution from a sanitary point of view. In other words, the city problem was seen as an evacuation of urban storm water problem as a result of the shortage of the existing main sewers.

So a first step consisted, in carrying out a bibliographical investigation to study the adopted master plans in other cities. The theoretical base, carried out from the works of Adams, (2000); Chocat, (1997); Delleur, (2003); Maksimovic, (2001); Marsalek, Rivard, (1998), permitted to establish the minimums technical requests necessary to adopt an integral paradigm, previously established in Garcia-Salas, (2006). It is determined just then, the incorporation of the synergic concepts around which should be the PROMIAP: (i) the hydraulic regulation through the urban storm water detention to optimize the hydraulic operation of the main sewers network and, (ii) the restoration of urban streams. In a succinct way emerges then the streams sanitation concept that still are found in the Great Guadalajara by controlling overflows and the consequent mass contaminants knock down. This conceptualization permitted to establish qualitative criteria in a control program of urban storm water that up to now had not been explored in any Mexico city, but in different countries had already shown their success, to see for example (MEDAD, 2000; Pilgrim, 1987; Rivard, 2005).

The institutional attributions of the local authorities were simultaneously studied as well as the legal base of the PROMIAP. The different Municipal, State, and Federal legislations were analyzed, this analysis permitted to identify two fundamental elements: (i) the absence of a local and general regulation about urban storm water control and (ii) the absence of the main stakeholder for the urban service. Topics already indicated by Newman, (2008).

After that, an information analysis of the drainage infrastructure as well as climatologic data was carried out. It was observed that the city had a referring dependable digital registration to the sewers network as a result of the previous studies. Nevertheless the climatologic data was limited and the daily rain registrations had an average between 50 and 100 years, with a little dense rain gauges network according to the features of the World Meteorological Organization. Additionally the existence of an automated climatologic station was identified with continuous rain registrations of 6 years.

An important part of the process was the communication and consensus with SIAPA authorities because it permitted the broadcast of concepts and the periodic communication of the handled advances during the process of PROMIAP's conceptualization. program

It permitted to initiate the changing process of paradigms in the urban drainage system praxis

necessary for the full acceptance of the notebook of charges that PROMIAP should have.

This task implied a great effort of communication and conviction, due to the SIAPA authorities bet on the used model in Mexico City: A large dimensions deep tunnel to conduct the urban storm water to the Santiago River with the purpose of "building the final solution". The conceptualization was supported with innumerable field investigations carried out: survey, verifications, photographic reports, interviews and routes over the affected zones during the raining season etc., providing a clearer vision of the situation. The process finishes with the elaboration of the PROMIAP's notebook of charges which was carried out by consensus with the SIAPA authorities.

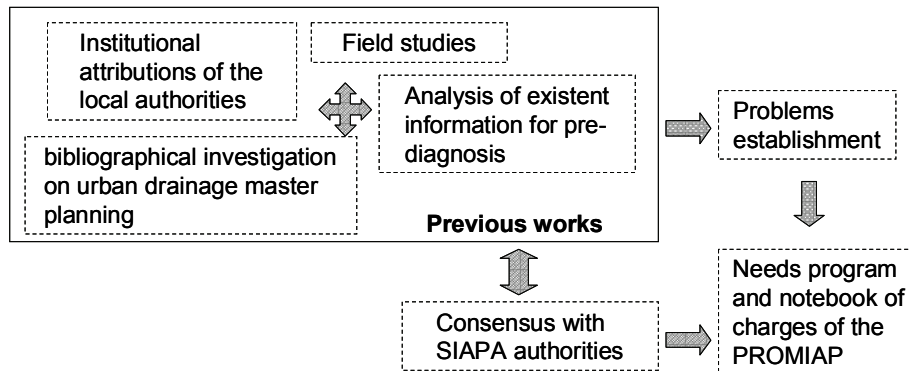


Figure 3. Conceptualization of Master Program for Integrated Storm Water Management in the Great Guadalajara.

3.2 Working out

PROMIAP's notebook of charges was divided into two large phases. The first one consisted of compiling, generating and purifying the necessary data to permit its elaboration. These required data in any management process and urban storm water control were divided in four types because its origin: (i) institutional data, (ii) structural data, (iii) hydrological data, (iv) social and economical data. To deepen on this theme, the reader could consult Fletcher, (2008).

The structural data were piled up in a Geographical Information System the same way as the physiographical characteristic of the study area, its ground use legislation to the planning horizon of each municipalities, etc. The hydrological data permitted to establish the rain process and to define, based on a complex monitoring system, the sewers network water quality, installed since 1993 as a result of the suffered sewers explosions downtown the city on April 22, 1992, which killed 209 people.

The socioeconomic data permitted to identify the assembly of stakeholders related to the drainage system; stands out: Industrialists located in the south west zone whose installations are affected every year by floods, civil environmentalists associations and ecologists, neighbourhood associations on the affected zones, engineers and architects associations, and universities related to the water topic. Besides a contingent evaluation study was carried out to determine the number of houses and commerce establishments affected during the floods and the related cost to the material losses, permitting thus to estimate the economic associated lost.

The second phase is characterized by four sub consecutive phases: Bases, Development, Products and Programs.

In the sub phase "Bases" were established the PROMIAP's objectives as a logical conclusion of the planning zones definition (definition of the necessary scale factors in the integrated water management, Gonzalez-Villarreal, 2006) and the elaborate diagnosis on each one of them.

The diagnosis was established with the aid of the contingent evaluation study results, with the official statistical information and with the aid of the drainage system model of the two planning zones attended by PROMIAP. This model was elaborated within the SWMM and it has 423 catchments and more than 2500 nodes. Once the diagnosis was carried out, PROMIAP's principal axes were defined summarized in their objective and reaches, which are presented subsequently.

PROMIAP's objective consists in "attending with urgent character the flooding problems by planning corrective and preventive actions to the urban storm water control in the Great Guadalajara and to avoid the damages generated to its population because of it". The non restrictive reaches are the

following: (i) to define the actions for the solution and mitigation of associated problems to the urban storm water in consolidated areas, (ii) to define the required infrastructure for the urban storm water control its conservation and use (iii) to provide management models, planning and development alternatives of associated projects to the urban development and civil protection, (iv) to generate legal, environmental, and technical features for the urban storm water management and its contaminants, with emphasis on the urban development of growing zones, (v) to generate drafts and to define structural actions investment costs, (vi) to define conservation and management politics of natural river beds that still prevail in the Great Guadalajara, (vii) to promote the low impact development and the use of sustainable urban drainage technologies adapted to the local context.

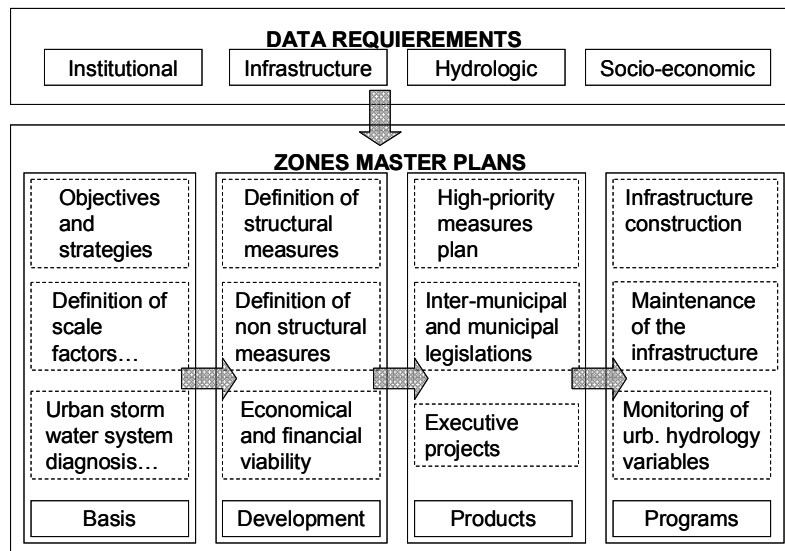


Figure 4. Working out schema of Master Program for Integrated Storm Water Management in the Great Guadalajara

In the development phase and considering the work of Andjelkovic, (2001), the structural measures, the non structural measures, the organization of both by hierarchy and their financial economic viability were defined. Among the structural measures, stands out the following:

- Construction and rehabilitation of 25 detention ponds with an estimated regulation volume around 3 million cubic meters.
- Restoration and rehabilitation of 9 Km lineal detention deposits
- Construction of 19 km of main sewers.
- Restoration and rehabilitation of 21 km of urban streams.

Among the non structural measures, stands out the following:

- Source control measures with adapted technologies to the local context.
- Local legislation adaptation.
- The creation of the Urban Drainage and Storm Water Pollution Control District in the Great Guadalajara.
- Drawing up the Urban Drainage System Regulation and Urban Water Pollution Control in the Great Guadalajara.
- Drawing up the Technical Manuals for Urban Drainage System and Urban Water Pollution Control in the Great Guadalajara.
- Self-sustainable financing measures
- Implementation of a permanent monitoring system in urban hydrology.

After these two first phases, the PROMIAP was published in 2008 and proceeded to its implementation within the context of a continuous institutionalization strategy which is explained in the following section.

3.3 Institutionalization strategy and set in motion

The institutionalization strategy that is carrying out was initiated in parallel way during the conceptualization period, from the identification of the drainage system main stakeholders in the Great Guadalajara. For this reason, the PROMIAP was promoted to these actors through an assembly of business meetings, courses and public events among the ones that emphasize the conferences "Infiltration and urban storm water management", "International forum of analysis and experiences discussion about urban storm water management", "Seminar of practice methodologies in urban hydrology", "International Course of Urban Hydrology". These events were realized between 2006 and 2007. Once the fact that the different stakeholders adhered to the program was verified, the PROMIAP is presented to the Board Directors of the Inter-municipal Utility for Drink Water and Sewage Services (SIAPA), whom adopted in 2008 as the principal axis for fight against urban floods in the Great Guadalajara.

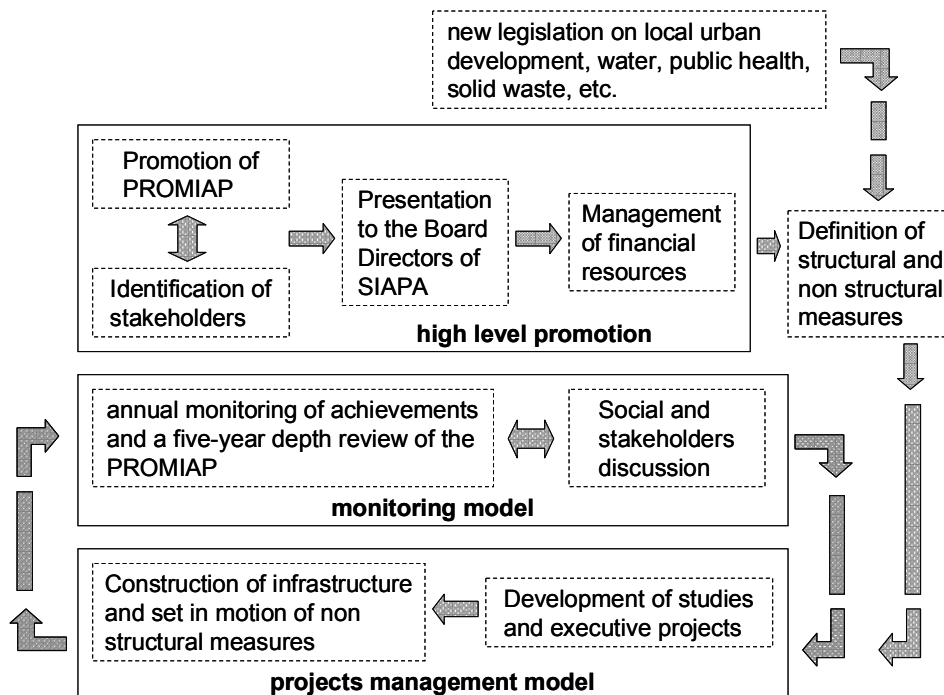


Figure 5. Institutionalization strategy and set in motion schema of Master Program for Integrated Storm Water Management in the Great Guadalajara

With this approval, the execution of works for financial economic viability proceeded to justify the different financing sources of the PROMIAP. This study, permitted to define among others aspects, the infrastructure and non structural actions investment costs, which are up to approximately 3,500 million Mexican pesos (175 million Euros) distributed in a uniform way along 7 years except for the first one where the investment is smaller, the indicating benefit/cost, the economic feasibility and the necessary investment flows in the Mexican legislation are necessary to get resources in the different government Levels.

Thanks to this, the local authorities obtain international financing originated from the Inter-American Development Bank (AIDB), initiating thus the implementation works of structural measures by the end of 2008, which are framed inside the institutionalization process in the phase of management of projects.

In 2009 the executive projects for the rehabilitation of 15 Km of urban streams, 12 Km of main sewers and 14 detention deposits were finished as well as the rehabilitation and reinforcement of the first detention pond (linear pond along 1,9 Km) with a regulation volume of 129.000 m³. The 2009 total investment was up to 316.2 million MXP (15.8 million Euros). These actions were carried out by 19 local consultancy companies and they were supervised and directed by the PROMIAP's projects management team, conformed by Infraestructura Hidraulica y Servicios Company personnel and by the Inter-municipal Utility for Drink Water and Sewage Services using the projects management model established in the PMI, (2008).

The institutionalization contemplates also the implementation of a new legislation that will involve the

stakeholders of the local Urban Development and the Federal and State main stakeholders of water management. This new legislation will permit to create the Urban Drainage and Storm water Pollution Control District in the Great Guadalajara. This utility should be formed by highly qualified specialists; it will be part of the public interest and intends to be opened to the private investor's participation with plans that guarantee their public nature. Moreover, it will be the one in charge of the urban storm water management and control, as well as the new infrastructure projection and construction, the existing infrastructure maintenance, etc. Its attributions will cover also the pollutants control; lead by the urban storm water and they will be framed inside the PROMIAP's objectives.

Finally, it has been established in the PROMIAP an annual monitoring of its achievements and a five-year depth review to maintain brought up to date the program solutions that it will offer to the Great of Guadalajara inside of the context of its dynamics of growth.

4 ACHIEVEMENTS

Since 2006, there have had significant achievements. These achievements are shown in the subsequent list

- Emergency of new paradigms in the urban storm water control and management in Guadalajara.
- Grouping of the different actors of the urban drainage system around a priority topic.
- Politicians acceptance.
- Significance in three different local administrations (in Mexico municipalities change every three years without re-election possibility).
- Civil society acceptance.
- Methodology significance to national level.
- Urban development and construction industrialists are interested in applying new materials and best management practices.

5 CONCLUSIONS AND FUTURE PERSPECTIVES

The Master Program for Integrated Storm water Management in the Great Guadalajara, Mexico is the continuous effort result of a great number of people lead from Infraestructura Hidraulica y Servicios Company and by the Inter-municipal Utility for Drink Water and Sewage Services and it represents the way that will permit to the city, to live together with the storm water through a negative impacts deceleration transitive model that the same city has generated, establishing from the local context, the bases for the integrated water management to different scales in the Great Guadalajara. The significance of this program is situated in the initial focus, rejecting traditional solutions and innovating in a context where the sanitary praxis already represents, at least in the Mexican cities, a development brake.

The program also represents a continuous challenge to stop the number of deceases that in this city are presented year by year and which are from any point of view unacceptable. Besides it is established a "new" urban drainage praxis paradigm that could be adapted to any other Mexican City. The perennial perspectives are encouraging: in a short time there have been compromised economic resources to continue with the executive projects elaboration and the construction of a part of the infrastructure already projected. In the medium and long time, the local specialized technicians formation, will guarantee the qualified personnel for the correct implementation, monitoring and updating of the PROMIAP.

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