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Article

Challenges of Water Sensitive Cities in México: The case of the Metropolitan Zone of Guadalajara.

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Abstract: Mexico is currently facing important water management challenges. Cities in the country are facing water scarcity and at the same time they struggle with floods during the raining season. The water sensitive urban design (WSUD) approach has proved to be helpful in tackling urban water challenges such as floods and water scarcity and it is being implemented in cities around the world. The WSUD approach highlights the role of both the water cycle and the water utilities systems, when transitioning towards a water sensitive stage. Therefore, the objective of this research is to analyse the current situation of the water cycle and the water utility (SIAPA). To do so, we have selected the Metropolitan Area of Guadalajara (MAG) and proposes a case study approach. Within our case of study, we answer two questions: 1) What are the causes of water scarcity and flooding in the MAG? and 2) What are the proposals to solve these problems under a WSUD approach? By answering these questions, we identified that the water management in the MAG corresponds to a single purpose infrastructure. This type of management does not contribute to solve the problems of water scarcity and floods. The water supply policy is based only on the construction of large dams disregarding the storage and use of rainwater, and reuse of greywater, and water-conservation devices. In order to transition towards a water sensitive stage, a WSUD approach that includes multi-purpose infrastructure should be considered. Such as green roofs, swales, rainwater gardens, infiltration trenches, etc.

Keywords: Water Sensitive City; Water Sensitive Urban Design; Water Cycle; Water Utilities

1. Introduction

The Metropolitan Area of Guadalajara (MAG) is located in the western part of Mexico. It belongs to the capital of the state of Jalisco. Guadalajara is the second largest city in the country and together with the municipalities of Zapopan, San Pedro Tlaquepaque, Tonalá, Tlajomulco de Zúniga, El Salto, Ixtlahuacán de los Membrillos and Juanacatlán create the MAG. The MAG has a population of approximately 5 million inhabitants [1]. Its water management exemplifies the water challenges that most Mexican cities face.

This research analyses the current water problems of scarcity and floods in the MAG by focusing on the water cycle and the services provided by the water utility named Sistema Intermunicipal de los Servicios de Agua Potable y Alcantarillado (SIAPA). By analysing the current situation, this article also demonstrates the importance of a water sensitive urban design approach (WSUD) [2]. The relevance of the study relies on the fact that water scarcity and floods are becoming more

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common and their solution is becoming more and more complex. Additionally, if the current situation continues, it will be complicated to reach the Sustainable Development Goals (SDGs) in 2030 [3].

The analysis of urban areas is important because while cities cover just 1% of the earth's surface, they produce 80% of the GDP and host 54% of the population, which is expected to reach 66% by 2050 [4]. Cities are complex systems where various actors and processes interact through geographic, institutional and governance scales [5]. This complexity creates challenges when implementing strategies for climate change adaptation. It requires strategic investments to deliver sustainable solutions in the long-term [6]. The type of adaptation depends on the cultural, technological, economic and governance contexts [7].

Understanding that the water sector is where climate change adaptation faces one of its main challenges, a framework for water adaptation issues at the city was developed by the Cooperative Research Centre for Water Sensitive Cities in Australia (CRCWSC). They created the concept of "water sensitive cities" (WSC) with the idea that nowadays the largest part of the population lives in urban areas and it is necessary to transition to a sustainable water management at the city level [6]. They propose a transition framework that allows benchmarking at the macro-scale by establishing a typology of six city stages. Figure 1 below shows the evolution process proposed by the Urban Water Management Transitions Framework (UWMTF) [6]. The final goal in this water transition framework is for a city to reach a WSC stage.

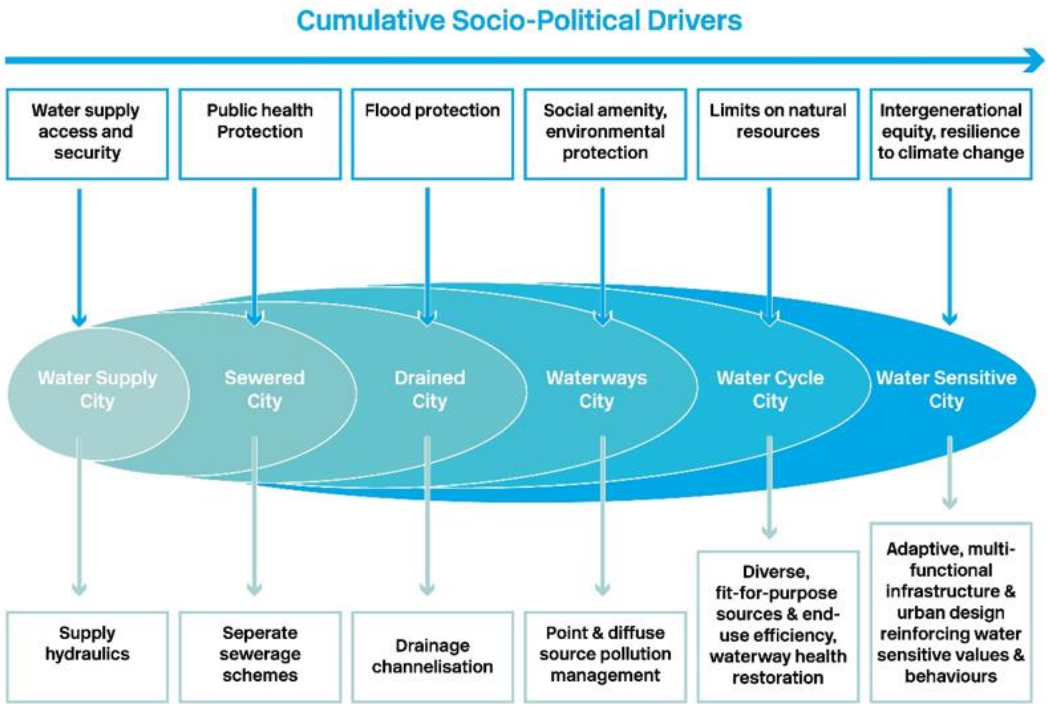

Figure 1. Urban Water Management Transitions Framework [6]

The first three stages describe the evolution of the water system to provide essential services: access to potable water (Water Supply City), public health protection (Sewered City) and flood protection (Drained City). These three stages are followed by the Waterways City, Water Cycle City and ultimately a Water Sensitive City. The last three stages describe the evolution towards a higher order of services. These are: social amenity and environmental protection, provide reliable water services under a constrained resources context, and ensure intergenerational equity and resilience to

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climate change [8]. Developing cities tend to be located in the first three stages where cities have single purpose infrastructure. While developed cities tend to be located in the last three stages where there is multi-functional infrastructure and therefore a more advanced water management [9]. Figure 2 below exemplifies this transition.

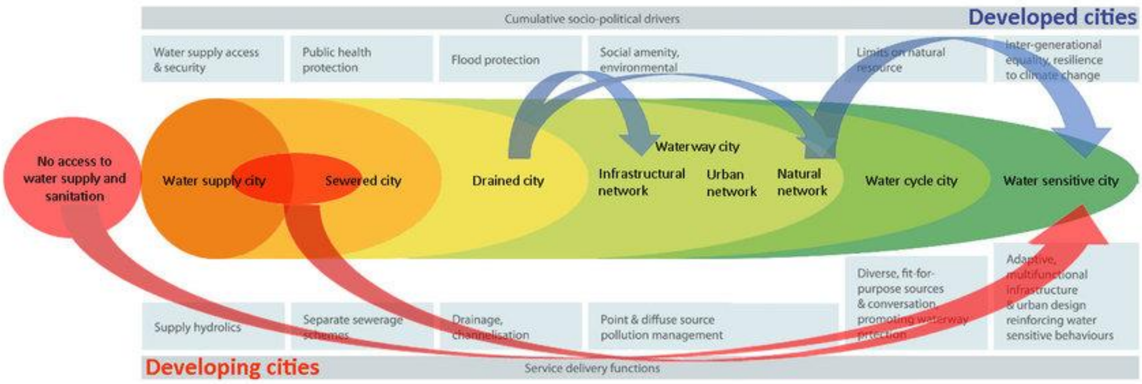

Figure 2. Adaptation of the Urban Water Management Transitions Framework for leapfrogging of developing and developed cities [8]

In the case of the MAG, the problematic presents a paradox. On one hand more than 55% of rainwater is drained into the sewage system, and on the other hand, the aquifers are drying due to their overexploitation [10]. Faced with this situation, the local government has proposed the construction of large dams where small communities are located and they will be flooded to create El Zapotillo Dam [11]. This policy is not considering reverting the damage to the water cycle caused by disorderly urbanization sprawl, and the poor services provided by the water utility in the MAG. Against this background, this research is focused on the relevance of both the water cycle and water utility services with WSUD strategies to help the MAG to transition towards a Water Sensitive City (WSC) stage in the future.

The water management approach in Guadalajara in the last 40 years, has been focused on overexploiting the water sources and draining the rainwater. The WSUD strategies are necessary to support a transition towards a WSC stage. These strategies can be divided into two aspects: 1) the restoration of the water cycle and 2) the improvement of the services provided by the water utility, SIAPA. The first includes catching the rainwater from rooftops; infiltration of water into the ground using trenches, wells, swales or impermeable concrete to increase evapotranspiration via trees and green areas. The second focuses on the implementation of monitoring systems in the different water utility systems, this includes water distribution infrastructure; wastewater treatment systems and campaigns to favour the sustainable use of water at the household level.

2. Materials and Methods

This study includes both positivist and interpretivist approaches [12]. The positivist approach consists in contrasting existing hypothesis with the purpose to test an existing theory, using the deductive method. The interpretivist approach consists in the construction or generation of one theory from the series of propositions drawn from a theoretical perspective that works as a starting point for the researcher, using the inductive method [13].

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From the interpretivist approach and inductive method, emerges the Case Study method. Case Study is a research design that traditionally involves in-depth study using a range of techniques over a lengthy time period to produce detail information [14]. Case studies are analysis of persons, groups, events, decisions, periods, policies, institutions or other systems that are studied holistically by one or more methods [15]. Yin [16] considers that the Case Study method is appropriate to investigate new cases and it has the following features:

- Examines or inquires over contemporary phenomenon in its real context
- The borders between the phenomenon and its context, are no evident clearly
- Various sources of information are utilized
- It can include one or more cases

Yin proposes a way of thinking of design of the research including five important components:

- Research questions
- Theoretical propositions
- Unit or units of analysis
- Logic relationship from data to the propositions
- Criteria for interpretation of data

Considering the case study features aforementioned, this research uses a qualitative or interpretivist approach. The focus of this study relies on the analysis of the water management challenges in the MAG. The challenges of the MAG are not unique, on the contrary, they are similar to those that can be found in other metropolitan areas in Mexico such as Puebla [17,18]. Our approach can help to set the main causes of the problematic and define the solutions based on WSUD approach and Water Sensitive City theory [19]. The analysis for this research is outlined in Figure 3.

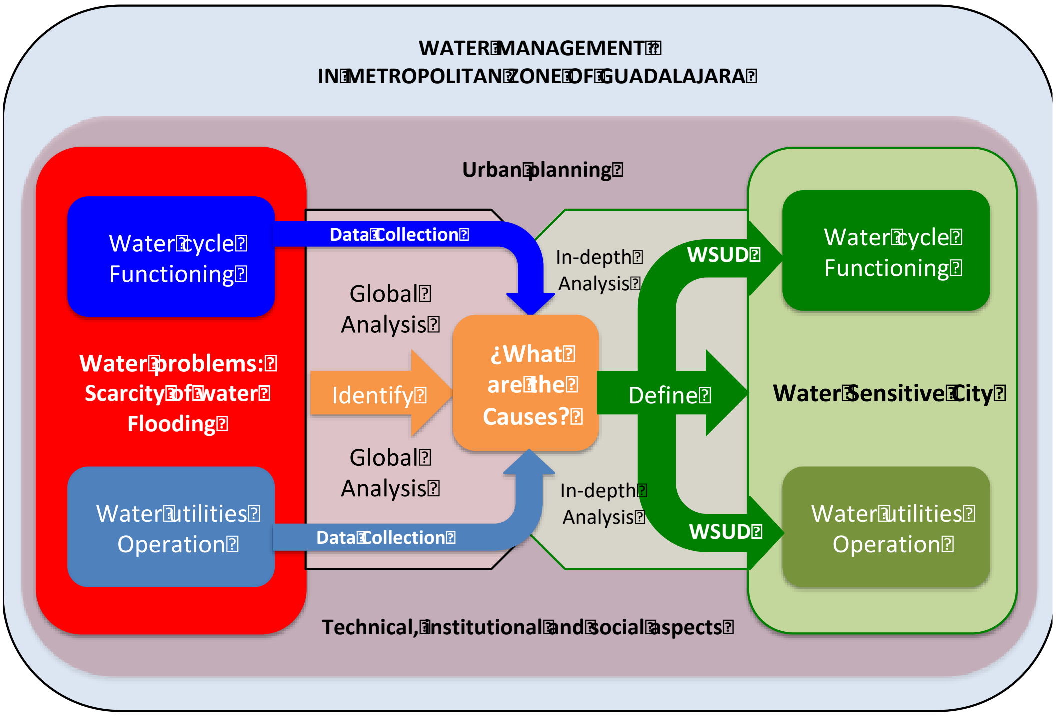

Figure 3. Analysis of the case study

2.1. Description of the Case of Study

The MAG is the second largest urban area in Mexico and it is located in the western part of the country. Figure 4 shows the three watersheds that are included in the MAG: Río Blanco river, Atemajac Valley and El Ahogado. Guadalajara, the largest city in the metropolitan area, was founded in 1542 near the River San Juan Dios located in Atemajac Valley watershed. The urban growth has covered almost 70% of the surface through the construction of houses, streets and roads. This has impacted the natural water cycle. The SIAPA is in charge of the water policy and its management in the MAG. It is an intermunicipal body that was created in 2013. It provides the services of drinking water, sewage infrastructure and wastewater treatment. It can coordinate actions with the state and federal governmental levels, and it is in charge of the strategies for water conservation and use [20].

The infrastructure developed by the SIAPA has lacked a proper planning. Today, it is impeded to cover the total domestic water demand, there is insufficient stormwater drainage and wastewater treatment infrastructure. The consequences of these deficiencies are among the reasons for increasing water scarcity in the city, the constant floods during the rainy season, and the persistent contamination of water bodies, especially in the Santiago River [21].

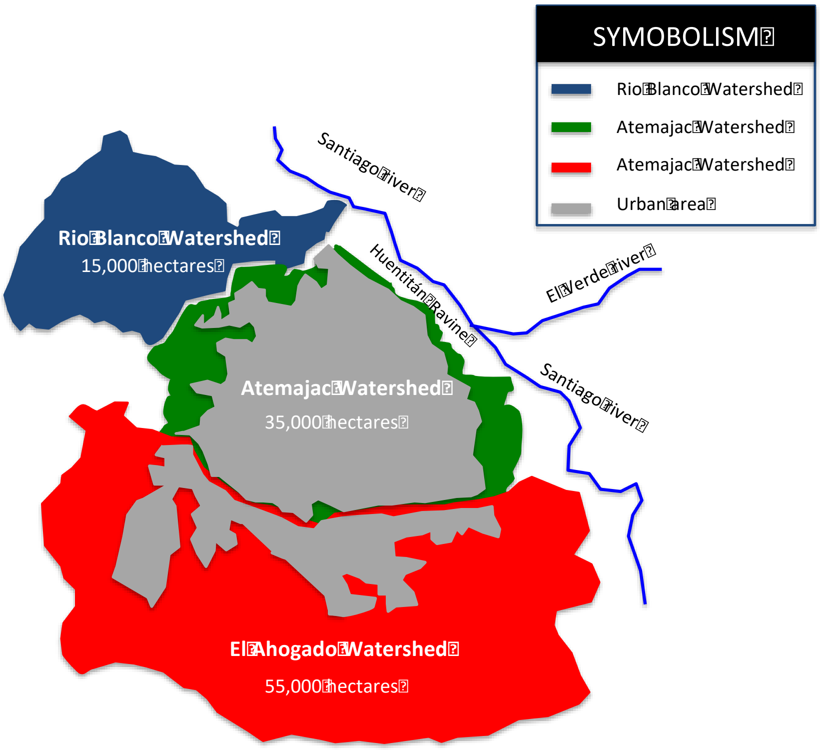

Figure 4. Metropolitan Zone of Guadalajara and its watersheds

Following the Case Study methodology, the focus of this research are the water cycle and the water utility infrastructure. The WSUD approach provides the perspective of analysis and defines the proposals [2]. The research questions for this case study are: 1) What are the causes of water scarcity and flooding in the MAG? 2) What are the proposals to solve these problems under a WSUD approach? These questions have the purpose of obtaining the necessary evidence to reach the objective of this research which is to demonstrate the relevance for cities of a water sensitive urban design approach.

2.2. Procedures

The key information obtained for this research is collected data by the first author during the last 20 years of research in the MAG. This includes government information, several field visits to both the watershed regions and the water utility infrastructure, analysis of academic studies, interviews with water public servants, and debates with political actors. The methodological procedure of this research is shown in figure 5.

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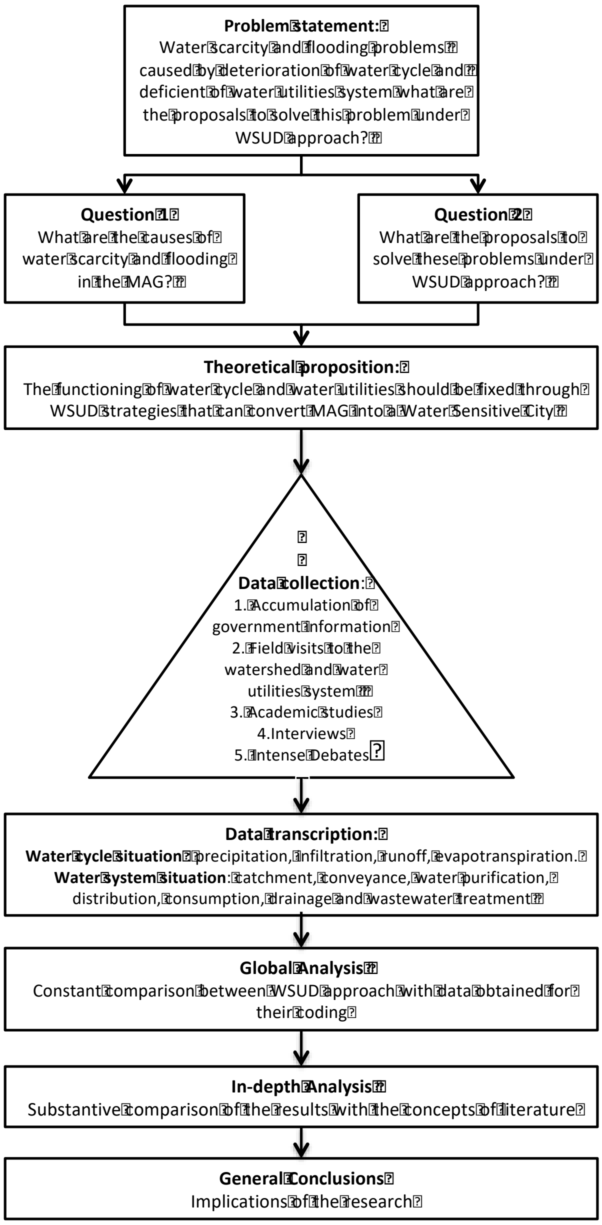

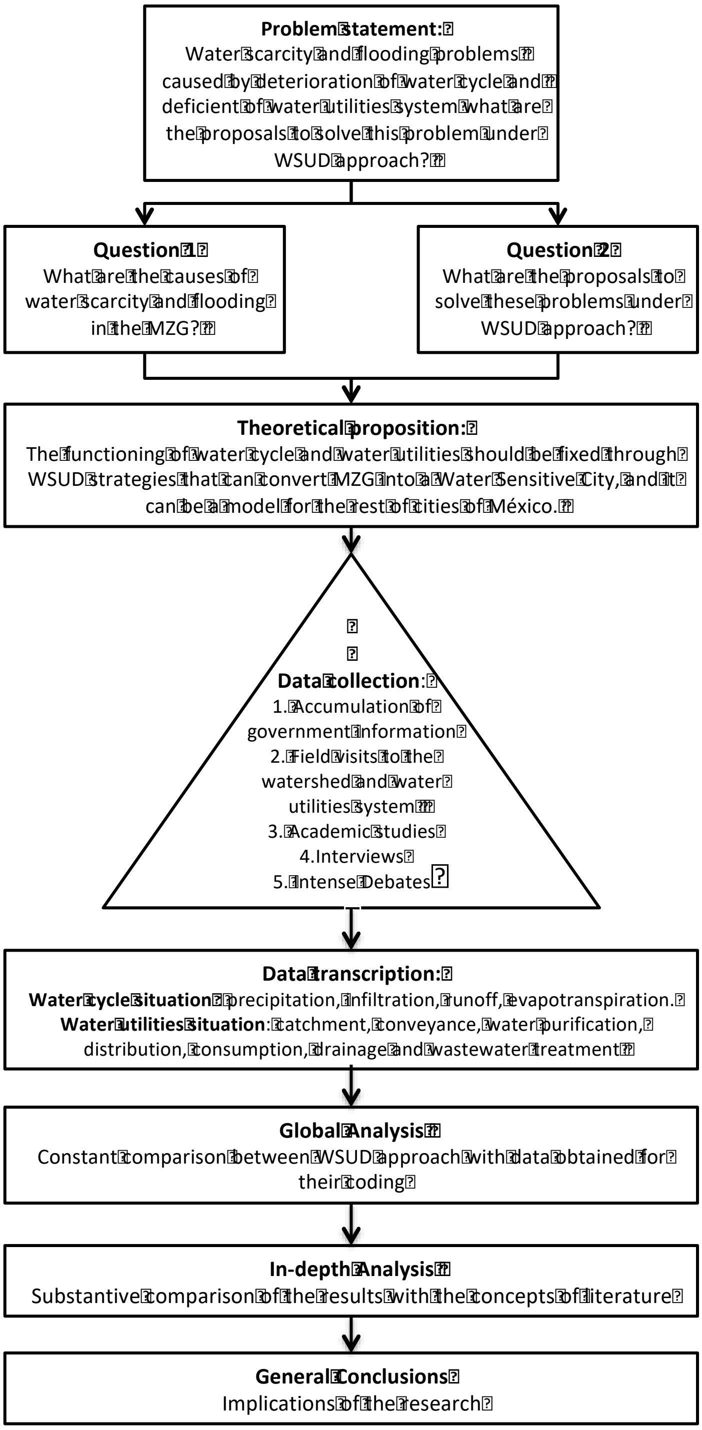

Figure 5. Methodological procedure of the study

2.2.1. Data Collection

The data was collected from the water cycle monitoring system. We revised the available information for the national and local weather systems. This included rainfall magnitude and intensity, evaporation and evapotranspiration. The revision for surface monitoring and groundwater flows were also reviewed. The data collection included visits to understand the conditions of the water cycle in urbanised areas and to verify if there was a water cycle monitoring system.

Secondly, the government data bases of the water utility system were revised to know the conditions under which it is functioning. The revision also helped to obtain data such as supply and drainage flow, the capacities of the wastewater treatment plants, water distribution and drainage system network conditions, waterflow meter devices capacities, and the organizational structure of the water utility.

Thirdly, the local and regional academic literature about the water problematic was reviewed. Surveys carried out by local universities, shows the hard work that academics have done during the last 20 years [22–24]. The literature of WSUD and WSC has been analysed by the authors to provide a theoretical body for this study [2,25–27]. Also, as part of academic work, the first author has participated in debates with water local authorities. The debates have helped to know better the point of view and the reasoning of the water authorities [28].

2.4.2. Data Transcription

The data was organised in two categories. The parameters of the water cycle and the water utility. In the case of the water cycle, the parameters were arranged according its functioning structure as it is shown in Table 1 [29].

Table 1. Data of Parameters of water cycle in MZG.

Parameter	Data
Rainfall	897 mm per year
Surface Runoff	Unknown
Groundwater flow	Unknown
Evapotranspiration	Unknown

The water utility system has seven phases: water supply sources, conveyance system, purification, water distribution, consumption, and drainage and waste treatment system. The data from the water utility was organised considering each phase of the system. The main data is shown in the table 2 [30].

Table 2. Data of each phase of water utilities system.

Parameter	Data
1. Water supply sources	1.1 Chapala 58%, (5.889 m^3/seg) 1.2 Groundwater 28% (2.796 m^3/seg) 1.3 Calderon 13% (1.287 m^3/seg) 1.4 Springs 1% (0.120 m^3/seg
2. Conveyance system	50 km of length of tubes.
3. Purification	Miravalle Plant (6 m^3/seg) San Gaspar Plant (1 m^3/seg)
4. Water distribution system	8,500 km of tubes

5. Consumption Household level	850 connections to houses
6. Drainage System	500 km of water collectors
7. Wastewater treatment capacity	7.1 El Ahogado Plant (1.45 m^3/seg) 7.2 Agua Prieta Plant (3.92 m^3/seg) 7.3 Rio Blanco (0.122 m^3/seg) 7.4 Virreyes Plant (0.023 m^3/seg) 7.5 North Tonalá Plant (0.011 m^3/seg) 7.6 El Vado Sur Plan (0.058 m^3/seg)

2.4.3. Global Analysis

Based on our qualitative research approach, the main objective was to understand the problem through an inductive analysis, guided by the framework of this research. In this case the WSUD framework. The intergovernmental agreement on a National Water Initiative defines WSUD as "the integration of urban planning with the management, protection and conservation of the urban water cycle, that ensures that urban water management is sensitive to natural hydrological and ecological processes" [2].

The term WSUD compromises two parts 'Water Sensitive' and 'Urban Design'. Urban Design is a well-stablished field associated with the planning and architectural design of urban environments, covering issues that have traditionally appeared outside of the water topic, but which actually have environmental effects on land and water. WSUD brings 'sensitivity to water' into urban design, i.e., it aims to ensure that water is given priority within the urban design processes. The words 'Water Sensitive' define a new paradigm in integrated urban water cycle management that integrates the various disciplines of engineering and environmental sciences associated with the provision of water services, including the protection of aquatic environments in urban areas. Community values and aspirations of urban places necessarily govern urban design decisions and therefore water management practices. Collectively WSUD integrates the social and physical sciences" [31].

WSUD is centred on integration at a number of levels:

- The integrated management of the three urban water streams of potable water, wastewater and stormwater.
- The integration of the scale of urban water management from individual allotments and buildings, to precincts and regions.
- The integration of sustainable urban water management into the built form, incorporating building architecture, landscape architecture and public art.
- The integration of structural and non-structural sustainable urban water management initiatives.

Once the government documents were analysed, some visits to watershed and water utilities took place in order to obtain the data of the water cycle and the water utilities systems. Based on this information a comparison was made between the obtained data and the WSUD framework. The results showed important differences. The current condition of the water cycle is not taken into account in the urban planning and the provision of water services together with the constant flooding are proof of this [32]

There is no sensitivity to water urban design, the deterioration of the watershed shows that the urban area covers almost 90% of the MAG surface. This can be observed in the absence of green areas. The disciplines of engineering and environmental sciences are not associated with the provision of water services. These types of challenges have been identified in other Mexican cities

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such as San Pedro Cholula [18]. The general approach only relies on the satisfaction of water demand. The construction of the Zapotillo Dam is the principal planned project to meet the scarcity of water in the MAG. The budget of this project does not include any integration and protection to the water cycle [33].

The budget is focused on the planning of large dams and deep drainages, not in protection of aquatic environments [34]. The water cycle and water utilities are not integrated into a comprehensive system, each one functioning separately. A disconnection of the three-urban water streams, potable water, wastewater and stormwater is present in the current water management. A linear system prevails in the functioning of different services provided by the SIAPA, which is disconnected to the water cycle and urban planning. Figure 4 shows the comparison between the WSUD approach and the current water management in the MAG. The lack of an integral water management is demonstrated in the pollution levels of the Santiago river, which is the most polluted water body in Mexico [35].

In the urban planning, the water is just considered another element among other environmental issues [36]. This contradicts the WSUD approach that establishes the water management should bring 'sensitivity to water' into urban design. In other words, the water does not have prominence within the urban design processes. This absence of prominence can be observed in the document of Metropolitan Land-Use Management of the MAG (POTMET, abbreviations in Spanish) made by the Metropolitan Planning Institute (IMEPLAN, abbreviations in Spanish) [37].

A focus in water supply and drainage prevails throughout the document. Table 3 shows the differences between elements of conventional and sensitive water management in the MAG and based on Newman proposal [38].

Table 3. Differences between elements of conventional and sustainable water management.

Category	Conventional	Sensitive
Water Supply	Large Dams Large Pumps and long Conveyance Groundwater bores	Supplemented by community groundwater schemes as a secondary supply for all outdoor use in households and for POS
Water Conservation	Neither interior nor exterior water conservation devices	Application of low water use applications and technologies
Public Open Spaces (POS)	Design dominated by high water use plants and they are polluted	Design based on WSUD techniques
Sewerage	Standard reticulation systems without planning	Full recovery of water used in POS rather than direct linkage to main
Stormwater	Large sums and piped systems only to drain the rainwater without treatment	Application of WSUD and Best Management Projects concepts

These differences show that the current water management is still within the first stages of the UWMTF, therefore, it is very different from the WSUD approach. This type of water management in the MAG corresponds to a single purpose infrastructure and contributes to the problems of water scarcity and floods. Changes are required in order to guarantee the water availability for present and future generations.

3. Results

This section presents the results obtained from the in-depth analysis, obtained through the comparison of the results with the WSUD concepts.

3.1. Findings about water cycle functioning

The lack of a planned urbanisation has deteriorated the water cycle. The consequences can be observed in the floods and depletion of the aquifers. The economic losses are in order of the 50 million US dollars because of floods yearly [39]. The availability of groundwater is descending critically, the authority stated there is a deficit in both aquifers (Atemajac and Toluquilla) in the MAG. Table 4 shows the deficits from both aquifers, Atemajac [40] and Toluquilla [41].

Table 4. Situation of Aquifers of MZG.

Aquifer	Recharge Mm^3/year	Extraction Mm^3/year	Déficit Mm^3/year
Atemajac	147.3	158.39	-11.09
Toluquilla	49.1	121.41	-72.31

[1] Mm^3: Millions of Cubic Meter

The analysis of the urban planning documents, helped to identify that the water cycle does not have prominence in urban planning as the WSUD states [37]. Thus, a protection strategy for the water cycle is absent. The urbanization of recharge zones are proof of this absence of protection [42]. The policy is oriented only to meet the water demand and mitigate the floods by large tubes; disregarding the restoration of water cycle even partially. These characteristics place the policy in the MAG within the first three stages of the UWMTF. Additionally, under these circumstances, it seems the policy will not change, and the water problems will continue increasing in the MAG.

3.2 Findings about water utilities system, SIAPA

The intensive and accelerated housing building has been one of the main drivers of urban development. The construction of urban developments has affected the hydrology configuration of the territory, such as the construction of housing in the riverbed, which has caused floods in the last two years [43]. Another example is observed when high tower buildings are constructed, and their foundations hinder the groundwater flows; this provokes floods in their basements. Then, the water has to be pumped to the municipal drainage system [44].

The urban planners and local authorities have simply ignored the inventory of the water supply and sewerage infrastructure. Thus, the new urban developments do not offer good water services – water supply and sewerage–[45]. Also, the implementation of water conservation systems in the planning of water utilities is not included. A water supply policy based only on the construction of large dams prevails disregarding the storage and use of rainwater, and reuse of greywater, and water-conservation devices. This is observed in the definition of public policies and budgets. The reduction of demand of water is not encouraged; the approach is to increase the water supply.

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3.3 Findings about the current water management of the MAG

One outstanding finding is the lack of a robust monitoring system for the water cycle. The precipitation information is incomplete, not all the weather stations work correctly, so the meteorological systems are weak. Hence, they do not provide accurate real-time and historical information. During the field visits it was not possible to identify aquifers' monitoring systems that could show the quantity and quality of underground water, the locations of underground water flows or piezometric level. A National Water Information system was founded but its data is incomplete as shown in its website of the National Water System [46].

The same situation was identified with surface water, there is no monitoring system that can measure in real-time the quantities of surface flow and the location of waterways [47]. There is no data regarding extractions from current sources in terms of quality and quantity. Neither about the rate of water losses in the water distribution system because of leakage. The percentage of acceptable losses by international institutions is 10% minimum of the total of the water distributed [48]. The measurement of household consumption is unknown; the people hardly pay their real consumption. The current water management is carried out with absence of basic technical information that can support the planning and the construction of new alternatives.

4. Discussion

A strong relationship between the water cycle and the water utilities system has been reported in this article. While this study has presented an analysis of the current situation of the water cycle and the SIAPA, it is necessary to study further the relationship between the water cycle and the water utility system, considering the sustainable view that WSUD provides.

The deterioration of the water cycle is an issue ignored in the water public agenda. The deterioration is growing and there is no governmental action to change this situation. If the water cycle continues being ignored in urban planning, how can be assured the availability of water in the short and the long-term? How the water resources will be planned if their quantity and quality are unknown? How the water will be distributed in an appropriate and efficient manner? It is even surprising that the budgets are formulated without water balance information.

Due to the absence of considering the water cycle in urban planning, most of the urban developments are authorized without knowing the water availability that guarantees the water supply for the present and future inhabitants. The lack of this information fosters the urban disorder that affects the water bodies in terms of quantity and quality. Some urban developments are built on recharging aquifer zones where the leakages of wastewater infiltrates into the aquifer. Most of the consumers do not receive constant water supply services, nor an efficient sewage water collection, and there is not a wastewater treatment. Also, hydrology as well as hydrogeology behaviours are ignored, the floods cause enormous human and economic losses as it has been seen in the case of urban development around the river [43]. The lack of technical information limits a design of water policies sensitives to the water cycle. The lack of technical information prevails in the water utility systems and increases the water problems. The number of extractions from current water sources is unknown, and it prevents an appropriate distribution among the consumers. Some of the inhabitants receive too much water and others too little or even nothing. Even when the water utility makes some calculations, the data is inaccurate.

The knowledge regarding the quality of drinking water in real-time is one of the most important challenges. Today, the population needs to buy bottled water for drinking, because they do not trust the water utility. There is no digital system that informs the quality of water in the distribution system to assure the water supply for the inhabitants. As the time goes and the water sources are contaminated, the risk of diseases is growing.

Another issue is the lack of precise knowledge on the water losses in the distribution system. In this respect, there are some official assumptions, but SIAPA does not have accurate information. The government assumes 40% of losses throughout the 8500 kilometres of the water network. The annual cost of water production is about $15 million USD, but then 40% of this money is lost.

The domestic use of water is not measured, so the payment is not based on the consumption. The water utility does not have an efficient payment system, which makes difficult the collection of the money to finance its tasks. In addition, local authorities do not encourage the consumers to implement water conservation devices, which together with the lack of measurements provokes a high level of water consumption. Instead of reducing the water demand, the policy is driven to increase the water supply.

Regarding the drainage system, it is a sensitive issue related with the health and security of the population. As it has been presented, the frequent flooding demonstrates the incapacity of the sewage system to conduct the water in an appropriate manner. During floods, the sewage water enters into the houses affecting the health of the inhabitants and destroying their belongings. The local government has conducted different actions but they have not solved the problems. They have been designed without taking into consideration technical information such as rainfall intensity, runoffs, infiltration rates, etc. The poorly designed infrastructure complicates the creation of appropriate solutions. This situation gets more complicated when the limits for sustainable use are not monitored so the risk is high, and an overuse is present at any time. Actually, the drainage system needs a deep rehabilitation.

One of the most important challenges is the insufficient wastewater treatment. Despite the creation of wastewater treatment plants, there is still a deficit of treatment. This is a common situation in Mexico [49]. The local government has proposed the construction of more plants, but the number of discharges are ignored in spite of the existence of monitoring systems. It has been observed that there is strong bias towards the construction of large treatment plants but the number and location of the discharges to water bodies is ignored. Lack of monitoring of the quantity and quality of wastewater flows make difficult to define the type of treatment. The wastewater treatment in general, is insufficient and inefficient [17].

The results of this research show that the SIAPA needs to implement changes in the operation of its systems if they want the city to transition towards a more sensitive stage. The WSUD approach offers a wide range of techniques to accomplish it. Through the implementation of WSUD techniques the water cycle could be restored, and the water utilities system could be rehabilitated. These techniques can help to restore the functioning of the water cycle by the implementation of rainwater catchment systems because they may help to save water and reduce the floods. Currently important projects are starting to take place in this direction [50]. If the rainwater is storage in the buildings or houses, the water can be used for domestic consumption reducing the water demand [24]. This rainwater also can be infiltrated to recharge aquifers. This allows reducing the extractions from current water sources. Raingardens can help to retain and infiltrate rainwater reducing the runoffs as well as the swales and trenches [51]. These techniques reduce the inlets of runoff into the current drainage so it can work more efficiently. All of these alternatives can support the restoration of the water cycle and the rehabilitation of water utilities system. The sponge city is an example of the implementation of WSUD approach [52].

Finally, the results show that the main approach of water management is focused on the construction of large works –dams and collectors– and the increasing of water supply. However, both the water cycle restoration and water utility infrastructure condition are ignored. The main focus of water management lies in resolving the consequences instead of addressing the causes. To favour a urban water management transition, it is necessary to stop the deterioration of the water cycle and start actions of restoration. It is also required to improve the operation of the water utilities system to guarantee better services for the inhabitants. Increasing the capacity of dams and large deep drainage are end of the pipe solutions that strength a water management that belongs to the first three stages of the UWMTF, a common characteristic of developing cities.

5. Conclusions

The results of this study indicate that it is important to take into account in urban planning both the water cycle and water utilities system due to their key role in the city urban system and because they are strongly related. Therefore, we propose a restoration of the water cycle considering WSUD strategies. This restoration can start with the implementation of an automatic monitoring water cycle system with the purpose to measure the water inlets (rainfall) and outlets (evaporation, evapotranspiration, runoff, and infiltration rate) to calculate a more accurate water balance. In this way, this information can help to propose a water balance strategy considering the water cycle. Accurate knowledge about the situation of water cycle can help to plan the water usage more efficiently. If the quantity and quality of water are known, the water availability and its distribution can be done in a more effective way. If the runoffs are measured, the design of collectors can be more precise. Nowadays the design is based on the application of empirical formulas that are useful but are not based on the current reality. This is one of the reasons why the rainwater collectors lack the capacity to deal with the rainwater runoffs appropriately. Accurate information can help to create strategies for urban growth, assuring the sufficient water supply and efficient drainage in the short and long term.

Some example of this could be the Automatic Hydrologic Information System of the Ebro river basin situated in Spain [53] or the USGS National Water Information System located in USA [54]. Such type of systems should be included as part of the urban planning tools. The appropriate implementation of WSUD techniques requires information regarding evaporation and evapotranspiration rates or infiltration capacity. For example, by knowing the infiltration rate, the design of a raingarden can be more efficient. Some of the potential techniques are: the green roofs, rainwater harvesting, swales, rainwater gardens, infiltration trenches, and others [51,55].

The public budgets should include the implementation of automatic monitoring systems for the water cycle in order to know the quantity and quality for making rationale distribution for usages. This can contribute to guarantee the water availability for the next years. The water utility systems also need to be monitored. The lack of knowledge of its current operation prevents to improve it. As it was aforementioned, the monitoring system for the water utilities systems should be included as part of the water management policy. If there was an Automatic Hidro-Sanitary Information System, the construction of hydraulic works could be more precise and they could really help to improve the water supply and drainage problems. If the water utility had information about the conditions of the network, they could also detect the leakages and repair them. If the domestic consumption is monitored in real-time, the charges of the service could be fair and more efficient. If the behaviour of the drainage system was monitored, the explosive limits could also be understood in order to avoid any possible accident.

Finally, if the wastewater discharges were monitored, the control of them could help to decrease the pollution of water bodies. All these actions should be reflected in the public budget that can support the implementation of a digitization system in all the parts of the system. This type of system can provide technical information to reach an urban planning sensitive to water.

Hence, we consider that the WSUD approach should be considered to be implemented in the MAG. A WSUD public policy could support a transition towards a WSC stage. The restoration of the water cycle could be possible through WSUD techniques. The University of Guadalajara have made some pilot projects like some rainwater catchment systems, stormwater models, educational water programs among citizens; but it is necessary to implement more pilot projects in order to strengthen this innovative approach [55]. The literature on urban water transition has emphasised the important role that pilot projects have [18,56]. It is also necessary the rehabilitation of water utilities system, starting with the implementation of monitoring systems. Through these actions the transition towards a WSC stage can be supported. This requires that the water cycle be included in the urban planning; otherwise, problems might be likely to increase. The deterioration can be reduced if the restoration of the water cycle and rehabilitation of water utilities are accomplished.

The current water management is still in the early stages of the UWMTF, focused on a single purpose infrastructure, typical of a developing city. Since there are still issues regarding wastewater treatment and there is no flood control, it seems that the MAG mainly belongs to the Sewered city stage. This management at this stage does not guarantee the water availability to present and future generations, nor solve the flood problems. The model of water management needs to shift to a sustainable water management, which can be reflected in multi-purpose infrastructure. This transition is urgent to be implemented in the MAG to ensure water sustainability and to accomplish the SDG. Finally, this study is an effort to contribute to the development of the WSC concept in the Mexican context and to contribute to the transition of cities towards a Water Sensitive City stage. While this article has focused on technical aspects of the water utility, we suggest that future research focuses on the institutional and governance challenges that the implementation of this technology could face.

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