

Guatemala



Guatemala City. People rest and shop on the "Parque Central", fountain and the National Palace's monumental facade. Photo credit: ©iStock.com/mtcurado.



“In Guatemala, an integral approach to urban waters is incipient and related information that would make it possible to diagnose the types of impact caused by urbanization has been concentrated in the capital city and in the neighboring municipalities (the metropolitan area or MA)”

Urban Water in Guatemala

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Summary

In Guatemala, an integral approach to urban waters is incipient and related information that would make it possible to diagnose the types of impact caused by urbanization has been concentrated in the capital city and in the neighboring municipalities (the metropolitan area or MA).

The water supply for the Metropolitan Area and other urban areas presents two challenges: overuse of the aquifers, with the consequent increase in pumping costs, and access to new water sources that are found outside their jurisdiction, which creates conflicts. In the first case, the solution to the problem depends fundamentally on organizing how the aquifers are used through the different management institutions. To do so, the parties need to come to a consensus and encourage the infiltration and reuse of rainwater from areas that have been impermeabilized. In the latter case, assignment and compensation mechanisms will need to be considered. Urbanization has caused contamination of water sources due to a lack of wastewater treatment and the increase in flooding represents a risk to human lives.

1. Introduction

In Guatemala, an integral approach to urban waters is incipient and related information that would make it possible to diagnose the types of impact caused by urbanization has been concentrated in the capital city and in the neighboring municipalities (the metropolitan area or MA). The country's population is

14,061,666 inhabitants in an area of 108,000 square kilometers. The amount of water available annually is 97,120 billion cubic meters, of which 33,699 billion cubic meters are renewable groundwater. Figure 1 shows a map of Guatemala, depicting the country's hydrographic division with more water being discharged into the Pacific Ocean, followed by discharge into the Gulf of Mexico, and lastly, discharge into the Caribbean Sea.

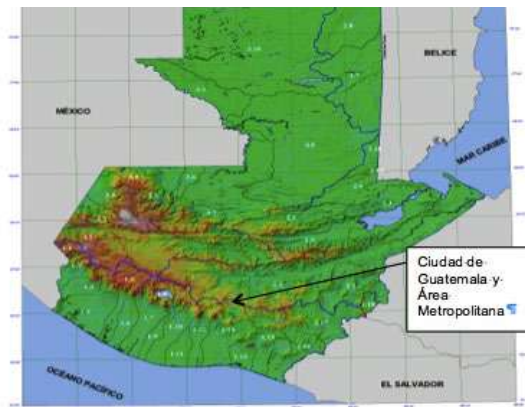
2. Water Sources in Urban Zones and the Types of Impact Caused by Urbanization

Since the country is located between two oceans and is crossed by the Sierra Madre and Cresta de Gallo mountain ranges, it has abrupt topography, with several cities being located in the *altiplano* (the high part of the watersheds) where the main source of water is underground. The rest of the municipal headwaters are located in the medium and low parts where there is more surface water available. Since it is contaminated by discharging untreated wastewater from the medium and high parts, however, groundwater is also a major source of water supply for the population.

Guatemala City and part of the rest of the Metropolitan Area are found on the water divide for the Pacific and Atlantic watersheds. Therefore, surface water is comparatively scarce and, as a consequence, the underground sources have had to be exploited. Urban growth in Guatemala City since it was created in 1776, but especially other municipalities in the MA in the last four decades, has caused a reduction in infiltration of water due to impermeabilization and overuse of the aquifer due to growing demand, as well as contamination of the surface and groundwater sources due to the discharge of untreated wastewater.

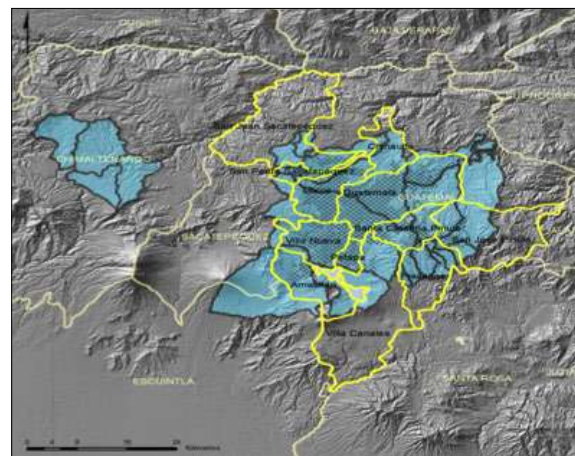
The MA is made up of 12 municipalities, running from San Lucas Sacatepéquez to Fraijanes and from Amatitlán to Palencia, encompassing 20 sub-watersheds and around 2 million inhabitants (INE, 2002), with an annual growth rate of 3.5%, occupying an area of 1,461.15 square kilometers. Figure 2 shows the municipalities and the watersheds in the MA.

Figure 1. Map of the Republic of Guatemala



Source: Instituto Geográfico Nacional, IGN.

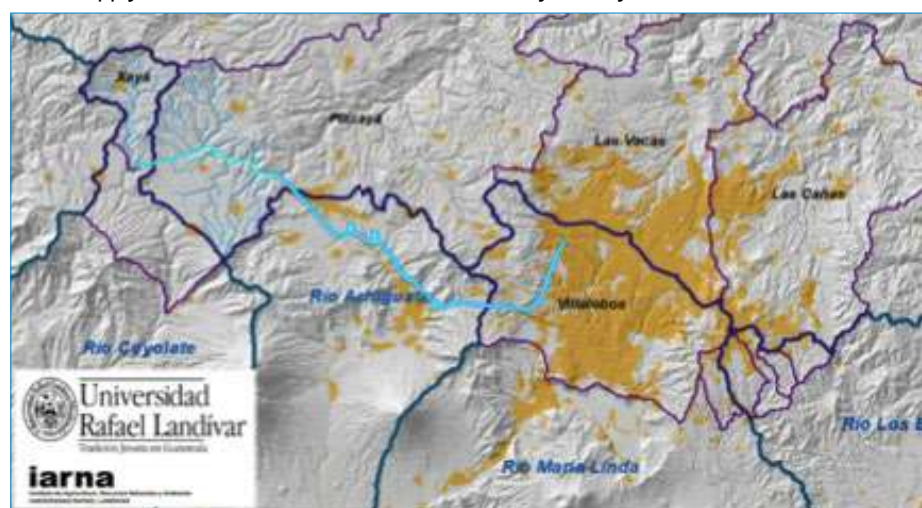
Figure 2. Watersheds and Municipalities of the Metropolitan Area (MA)



Source: IARNA-TNC 2012.

The IARNA-URL and TNC (2012a)¹ summarize the water situation in the MA as follows: “The water supply for the metropolitan area is based on five surface water systems linked to five hydrographic watersheds (Coyolate, Pixcayá, Las Vacas, Plátanos, and María Linda), as well as an undetermined number of mechanical wells that exploit the local aquifers. Water distribution is handled by the Municipal Water Company (EMPAGUA in Spanish) in Guatemala City and by the local governments and the other municipalities in the Metropolitan

1. Water availability in the Guatemala Metropolitan Area: Fundamental Bases for Water Management with a Long-Term Vision.

Figure 3. Water supply for the subwatersheds in the MA and Xayá Pixcayá

Source: IARNA-TNC 2012.

Table 1. Total Water Supply in the Metropolitan Area (millions of cubic meters)

Scenario	Metropolitan Area	Xayá Pixcayá
Base	1,611	298
To 2020	1,481 (-8.1%)	275 (-7.7%)

Source: IARNA-URL TNC (2012a).

Area. Some of them have hired companies such as Agua de Mariscal. Most of the urban developments and private companies (industry, hotels, shopping centers, etc.) are supplied by groundwater through their own mechanical wells. Currently, there are no regulations related to extracting water at the national level, much less at the metropolitan area level. The complexity and lack of regulation that characterize the water extraction system contribute to the unsustainability of the water system in the Metropolitan Area overall (supply and demand)."

Table 1 shows the results of the total water supply in the MA sub-watersheds and the area of Xayá-Pixcayá, as well as the trend out to 2020. Figure 3 shows the Metropolitan Area and the Xayá-Pixcayá sub-watersheds.

The IARNA-URL and TNC (2012b)² analyzed the groundwater situation in the MA and estimated

the extraction of groundwater and characterized the aquifers in the zone. The report indicates that "initially, the upper or free aquifer is used and then, due to the increase in demand, the multiple aquifers found in the stratified volcanic landfills are used. The increase in usage of groundwater and the extension of the urban borders have had an influence on the drop in recharging these aquifers. This is made evident by the decrease in the levels of groundwater in the zone and has required deeper wells to be able to penetrate the aquifer being used farther and/or to search for deeper aquifers. Therefore, the regional aquifers that are found at a greater depth are used, which are recharged in the areas of the volcanic landfills in the zone and the geologic formations that cross the hydrographic watersheds. In general, these aquifers are in fractured volcanic rocks and in fractured sedimentary rocks and/or rocks with a degree of karstification. Currently, groundwater supplies part of the urban, rural, industrial, and irrigation zones and has been estimated to cover on the order of 60% to 70% of the demand in the zone of interest."

The IARNA-URL and TNC (2012b) indicate that, in the Metropolitan Area, "the wells in the Metropolitan Area are in the range from 80 feet to more than 2,000 feet deep depending on the aquifer or aquifers being captured."

The conclusions drawn by the IARNA-URL and TNC (2012b) are: "i) The Metropolitan Area, to supply

2. Analysis elements to characterize the status and estimate the consumption of groundwater in the Guatemala Metropolitan Area.

water for its different services (supplying water to the population, irrigation activities, and industry) is making use of the groundwater resource. In the preliminary estimates that were made, there are areas with intense use of groundwater from different aquifers. Over time, their reserves have decreased, which is reflected in the variance in the time for the groundwater level and requires the implementation of reforestation projects, artificial recharging that boosts infiltration, proper use of the resource, etc., and that involve using the resources sustainably. ii) Water extraction in most of the micro watersheds is much higher than the local estimated recharge, especially for the more urban watersheds. iii) Although the local aquifers may benefit from additional recharge coming from outside the micro-watersheds that were studied, the conclusion may be drawn that using groundwater is an unsustainable trend in the Metropolitan Area, since the amount that is extracted is more than what is recharged."

The types of impact in the country are similar to the types of impact in other cities in the world. They include: impermeabilization of the soil due to unplanned urban growth, recharge zones are not preserved, water infiltration has dropped and aquifer feeding has been reduced. Runoff and the discharge, are also generated by intense rains, causing damages to the infrastructure and representing a risk to human life as well as the fact that the minimum yearly water flows are lower. In addition, unlike other countries where wastewater is treated, in Guatemala the percentage that is treated is minimal, causing a deterioration in the quality of surface and groundwater (absorption wells) and limiting its use downstream.

The sources of contamination in the country are similar to the sources of contamination in other cities in the world. The predominant sources of contamination include the discharge of domestic wastewater; however, in the Metropolitan Area there are also relevant industrial and agro-industrial sources of contamination. In the Metropolitan Area, it has only been recently that wastewater treatment has been mandatory based on the issuance of Government Agreement 236-2006. Even so, water that is discharged from the municipal drains that have been collecting wastewater from housing and industry since before the promulgation of the government agreement is still not treated.

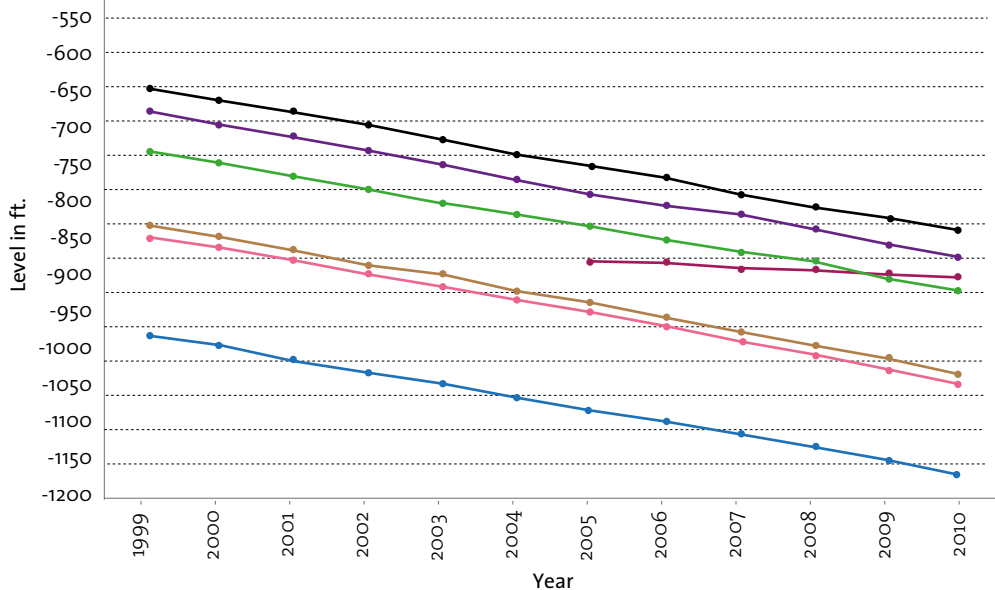
For a long time, the country has faced problems with the water quality in the urban areas but still has not been able to solve them. An example is the deterioration the quality of the water in Lake Amatitlán (1,080 meters above sea level). Since Amatitlán is located downstream from the southern part of Guatemala City and from some municipalities in the MA (1,500 meters above sea level), it receives untreated wastewater that have taken it to a state of hypereutrophication. In addition, due to the inadequate soil and water management in Amatitlán's watershed, the lake is also experiencing silting. For the last bathymetry taken in 2012, silting caused its useful life to be 110 years (AMSA, 2012). In the 60s, the lake was conceived to be able to be a water reservoir to supply the MA; at this point in time this would require a multimillion dollar investment.

It is interesting to mention that, in the 60s, Guatemala City, built collectors in the high part of the Lake Amatitlán watershed on counterslopes to keep the wastewater from being discharged into Lake Amatitlán. The plans were for industries to be located in one specific sector (Petapa) so wastewater from the different industries could be treated together in the future. However, due to the lack of planning and compliance with the functions by the municipalities in the MA, most of the wastewater is not treated, which causes surface and ground water to deteriorate.

In the MA, the ground has been covered (impermeabilized) due to the advance of urbanization without any compensation to boost natural or artificial recharge.

Until the 60s, there were several lagoons in Guatemala City and the neighboring areas such as the one located in the Industry Park and in El Naranjo. There were also springs such as the swimming pools at Lo de Bran and Ciudad Vieja. They dried up when the water table dropped and water was no longer supplied. Furthermore: the prehispanic population at Kaminal Juyú settled there (west of Guatemala City) due to the availability of surface water, since there were some lagoons in existence.

The output from the mechanical wells has decreased from 1,246 liters per second to 701 liters per second and the water table levels have dropped from 450 feet to 1,700 feet deep. This situation has caused the fact that water has to be extracted from deeper in the wells with lower output, increasing

Figure 4. Drop in groundwater levels at seven monitored wells, the Northern Limestone Aquifers (1999-2010)

Source: IARNA-URL and TNC, 2012b.

the cost. For example, in 2010, the average cost to produce a cubic meter at the Lo de Coy plant (gravity fed) was 0.50 Quetzals, but for a surface source that is pumped, such as at Las Ilusiones, the cost varies between 3.00 and 5.00 Quetzals.³

As an indication of the variance in the groundwater level over time, IARNA-URL and TNC (2012b) performed a 10-year analysis for six 12-inch wells at 1,300 feet deep and another analysis of a well for five years at 1,700 feet located in the northern limestone. Figure 4 shows the variance in the water levels measured in the wells. The trend is for the water level to drop over time. This indicates that more water is being extracted than is being recharged into the aquifer; six wells show a drop of 16 feet per year, while the remaining wells show a drop of four feet. The latter is because the extraction is deeper.

Due to the lower relative availability of surface water in the high part of the MA and due to urban growth, the government planned and built the Xayá Pixcayá pipeline in the 70s. The pipeline captured 1 m³/second when water levels were low, 60 kilometers from Guatemala City. From its inauguration to today

(35 years), transporting this water has contributed to around 400,000 people having water in the city (216 liters/inhabitant/day). Even more so, from its inception, planners designed the pipeline to be able to conduct water up to 3 m³/second. The planners had a vision and foresaw that additional water could be added from other surface and underground sources. There is another version that indicates that the pipeline was over-dimensioned. Currently, despite more volume could be possibly transported with the current infrastructure, it has not been feasible to add this flow due in part to the lack of the financial retribution instrument (payment) and social conflicts. In part due to that situation, EMPAGUA (2012) has seen the need to purchase approximately 20% of the water that it distributes to private companies; that figure will probably continue to grow.

In the 12 municipalities that make up the Guatemala Metropolitan Area, a total of 553.4 million cubic meters of water is consumed per year, which is the equivalent of an average of 189 m³ per capita per year. Some 91% of the water that is consumed comes from the aquifer mantles where the Las Vacas and Villalobos micro-watersheds provide 67% of the total (which denotes at the same time the intensity of extraction from those watersheds) and 9% from

3. One American dollar is the equivalent of 7.70 Quetzals, the currency in Guatemala.

the Xayá and Pixcayá watersheds (51.1 million m³) (URL-IARNA and TNC, 2012b).

The job opportunities that the MA offers has induced people to migrate. This has caused some municipalities to have a growth rate of up to 10% annually and has also caused municipalities such as Guatemala, Mixco, and San Miguel Petapa to be totally urbanized. Depending on the income of the people in the MA, they settle in peripheral urban zones and informal settlements, always in the MA.

The lack of planning and exercise of functions by the municipalities has caused a proliferation of informal settlements, mainly in the marginal zones, where the natural threats and their vulnerability represent a high risk to people's lives. These settlements get their water from tank trucks, whose quality is questionable and whose price is higher than the municipal system's price.

In peripheral urban zones made up of residential developments, water is supplied by mechanical wells. The municipality does not have any control over these wells in relation to overexploitation of the aquifer and means of recharge. Likewise, there is no evaluation of the efficiency of wastewater treatment in the neighborhoods and its effect on the surface and underground sources of water.

Recently, an initiative promoted by The Nature Conservancy (TNC) was initiated. It is known as the "Fund for Water Conservation in the Guatemala Metropolitan Region" (FONCAGUA). An alliance also exists in Latin America that is made up of 25 initiatives by eight countries in the Americas, including Guatemala. In June 2013, the Second Meeting for these initiatives was held in Panama. Its purpose is to be a financial mechanism for investing in green infrastructure (protecting the soils, forest, and water; best production system practices; water collection and hydric recharge infrastructure; strengthening governance and institutionalization; education on saving water) (Juan Carlos Godoy con. per.).

Water funds are efficient mechanisms that are self-sustainable and able to generate resources to pay for conserving the water production areas. As was indicated previously, for every 1m³/second of water drawn off for the last 35 years, the Xayá and Pixcayá River watersheds have not been paid back anything for conserving the natural resources of their watersheds. The model predicts that large water users are willing to put up financial

resources to strengthen the fund to ensure the water quantity and quality in the future at a lower cost. The funds are institutional mechanisms with multiple stakeholders. Their objective is to provide financing resources to protect key territories in terms of the production of ecosystem services and in particular, water. Success for these funds lies in an accurate quantification of those services as well as in adopting sustainable financial mechanisms with transparent management. Some of the documents used to prepare this chapter that were in turn prepared by IARNA-URL and TNC are technical studies that are necessary to design the fund (Juan Carlos Godoy, con. per.).

To design and start operations for FONCAGUA, a promotion group has been created with the participation of private enterprise, public authorities, local governments, academic institutions, and NGOs. Actions have already been taken such as reforestation of 150,000 hectares in the Xayá Pixcayá watersheds with the participation of the Agrobosques company and TNC (Juan Carlos Godoy, con. per.).

The Fund's objectives are: i) Ensure, in the mid-term, the water quality and quantity for the inhabitants and institutional and business users in the MA; ii) Improve environmental management of the watersheds and water recharge zones (private reserves, community forest, and municipal forests in the MA greenbelt; iii) Increase the citizen awareness in the MA in relation to sustainable use and consumption of water and its implications for environmental costs; and, iv) Contribute to being able to govern the water and strengthen institutions for water management (Juan Carlos Godoy, con. per.).

IARNA-URL and TNC (2013)⁴ did a study of the demand and consumption of water in the Metropolitan Area and established the economic value that forests possess due to their contribution to the hydrologic cycle in the zone. In the study, an environmental assessment is used to estimate the value of the forest for water production and conservation in the Metropolitan Area of Guatemala City, i.e., it estimates the value of the ecosystem service that forests provide to supply the vital liquid to the population in the central Guatemala

4. Analysis of the demand for water and evaluation of the environmental value in the water recharge zones in the Guatemala City Metropolitan Area.

metropolis. That involves elements for creating a fund that promotes conserving the forest to ensure provision of water to the population.

URL-IARNA and TNC (2012a) estimated the water balance sheet for the MA by “calculating the total incoming flow is the equivalent of 2,211 million cubic meters of water, of which precipitation comes to 86%, storage in the soil represents 12% and infiltration coming from irrigation is 2%.”

URL-IARNA and TNC (2012b) show that “water extraction from the aquifer mantle is the main source of supply for consuming the liquid in the Metropolitan Area, which has been estimated to be 91% of the total consumption in the zone. In that regard, a claim may be made that a major component in water management lies in correctly balancing infiltration and extraction of water from the aquifer mantles.”

URL-IARNA and TNC (2012b) show that “61% of groundwater extraction is for domestic purposes, 31% for municipalities, 7% for industry and commerce, and 2% for irrigation. These figures suggest, therefore, that homes are the main consumers in the Guatemala Metropolitan Area.”

3. Potable Water Service in the Urban Zones

At a national level, there is a coverage deficit in Guatemala. Besides, the services for the network are intermittent and the quality of the water is deficient. According to ENCOVI (2011), coverage for homes with water service for human consumption was 75.3%. Figure 5 shows the water supply service coverage trend.

What may be observed in Figure 5 is that, according to information from ENCOVI (2006), water coverage for human consumption was 78.7%, which represents a step backwards with respect to 2006 of 2.4% as of 2011. The cause for this decrease is not known. It may be assumed to be due to damages caused by extreme hydro-meteorological events that occurred in the country in the last few years (Tropical Storm Agatha in 2010) and the increase in access to services, so it has been lagging behind in relation to the population growth. For 2002, urban coverage was 89.4%, representing 50.2% of the total homes at the national level.

In reference to intermittent services in the grid, a study prepared by the IDB⁵ in 2008 estimated that 80% of the systems in the country worked intermittently, providing between 6 and 12 hours of service per day. In relation to water quality, it is estimated that just 15% of the water supplied by the systems is purified and that just 25% of the municipalities at the urban level have purification systems. Data from the National Water Quality Oversight Program, PROVIAGUA of the MSPAS, show that, of the 10,277 water systems that are registered,⁶ just 17% have water purification.

In relation to sanitation services, according to ENCOVI (2011), national sewage system coverage is 38%. The rest of the population meets its needs for domestic sanitation by using a latrine, a blind well (41% of homes), a flushable toilet (7% of homes) and a toilet connected to a septic tank (6% of homes). Figure 6 shows the coverage trend.

The water supply in Guatemala City is the responsibility of the Municipal Water Company (EMPAGUA) and private companies that have their own mechanical wells. The other municipalities in the MA supply just a small percentage of urban users. Hotels, industry, and other users that demand comparatively large volumes of water install their own wells to ensure quantity and continuity. However, a high percentage of the urban population that lives in marginal areas obtains its water by purchasing from private tank trucks at elevated prices compared to what is paid for the EMPAGUA service, for example, and the quality is questionable.

In addition, the water supply service rates do not meet the operating and maintenance expenses except in certain sectors of Guatemala City (EMPAGUA, the Agua Mariscal company and companies that supply private residences). The result of this has been a deterioration in the existing infrastructure, subsidies for urban areas, and expansion of services by means of alternate systems (tank trucks). As indicated previously, they are of dubious quality and the cost is higher. The

5. Samper, Olga (2008). Informe Final: Plan Estratégico del Sector Agua de Agua Potable y Saneamiento (Final Report: Strategic Plan for the Potable Water and Sanitation Water Sector). Guatemala: The International Development Bank. Washington, D.C.

6. Information coming from the system inventory for water transferred to PROVIAGUA during the workshop with Sanitation Directors and Supervisors of Health Areas, June 2012.

Figure 5. Homes with improved access to sources of a potable water supply: homes with water supply connected to pipes inside or outside the home and public water supply

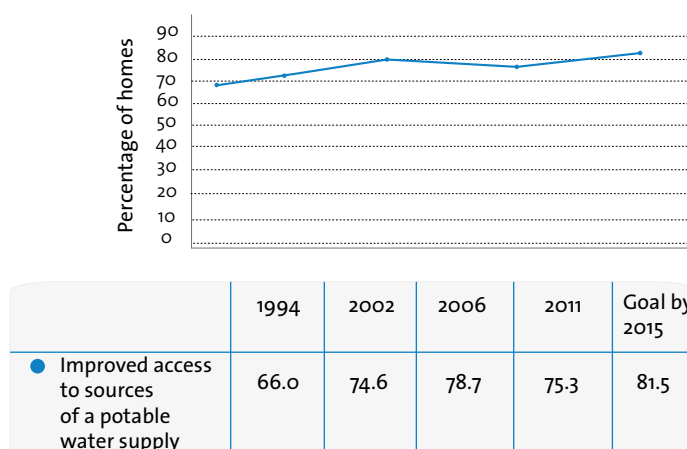
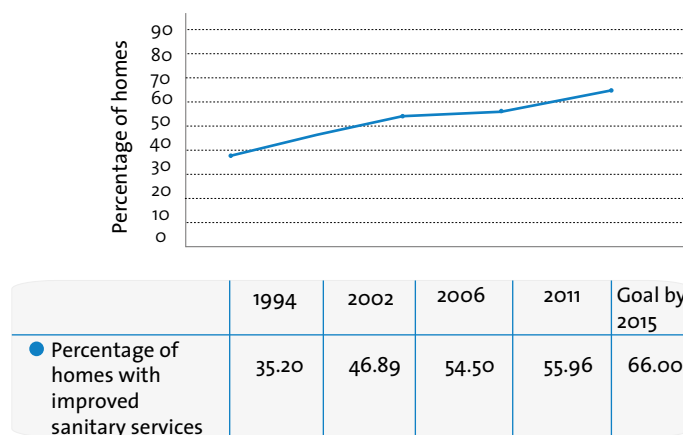


Figure 6. Homes with improved sanitation services: homes with a toilet connected to the drainage network, a toilet connected to a septic tank, and a flushable toilet



Source: Presentation: "The 7C Goal in the ODM", SEGEPLAN, 2012.

municipality of Villa Nueva (a municipality in the MA) provides a monthly subsidy to users in the amount of 1.0 million Quetzals (around US \$125,000). The average price per cubic meter charged by EMPAGUA is 1.80 Quetzals, when the production cost is 3.50 Quetzals. The EMPAGUA rate is 2.90 Quetzals per cubic meter for usage between 1 to 20 cubic meters. Q. 3.71 per cubic meter for usage between 21 and 40 cubic meters; Q. 4.45 per cubic meter for

usage between 41 and 60 cubic meters; and, Q. 8.90 per cubic meter for usage between 61 and 120 cubic meters.⁷

Another relevant indicator is the percentage of losses in the water service systems. In urban areas, the losses reach 50% while in the rural area they are 10%.

7. Free Press.

The water supply for the Metropolitan Area and other urban areas presents two challenges: overuse of the aquifers, with the consequent increase in pumping costs, and access to new water sources that are found outside their jurisdiction, which creates conflicts. In the first case, the solution to the problem depends fundamentally on organizing how the aquifers are used through the different management institutions. To do so, the parties need to come to a consensus and encourage the infiltration and reuse of rainwater from areas that have been impermeabilized. In the latter case, assignment and compensation mechanisms will need to be considered.

4. Water Treatment in Cities

In the municipalities located in the Lake Amatitlán watershed, which encompasses part of the MA, there are 79 wastewater treatment plants. Table 2 shows that 58 of the plants are municipal and the rest are private in the charge of residential committees.

Table 3 shows that the treated volume for the 79 wastewater treatment plants in the municipalities in the Lake Amatitlán watershed is 126,201 m³. The projected population in 2014 for the Lake Amatitlán watershed is 1,147,540 inhabitants. They will produce

around 137,705 m³ of wastewater per day so 91.6% of the wastewater could be treated.

However, as shown in Table 4, few of the plants are functioning properly. In addition, when 47 of the 79 wastewater treatment plants were evaluated, seven were reported to no longer be functioning, 14 were totally abandoned, eight function at minimum capacity, eight function at medium capacity, nine are functioning at their maximum capacity, and one is in the construction phase. No treatment plant has an operator; they just have guardians.

EMPAGUA invests US\$392,000 per month to treat raw water and make it potable, which is the equivalent of US\$4.7 million per year (P. Alvarado, con. per.). A percentage of this investment is due to the fact that the raw water is contaminated by wastewater.

5. Water and Health in the Cities

In general, the information to analyze and make decisions comes from national censuses and surveys, but this information is not generated in a systematized, continuous form.

As of 2010, the general mortality rate was three deaths for every 1,000 inhabitants and the infant mortality rate was 30 for every 1,000 births. In

Table 2. Number of Wastewater Treatment Plants

Municipality	Municipal	Private	Total
Amatitlán	4		4
Fraijanes	2		2
Guatemala	4	4	8
Magdalena Milpas Altas	2		2
Mixco	13	1	14
San Bartolomé Milpas Altas	1		1
San Lucas Sacatepéquez	2		2
San Miguel Petapa	5	5	10
San Pedro Sacatepéquez	3		3
Santa Catarina Pinula	3		3
Santa Lucía Milpas Altas	1		1
Villa Canales	1	2	3
Villa Nueva	17	9	26
General Total	58	21	79

Source: AMSA, 2013.

Table 3. Volume of Wastewater in Treatment Plants

Municipality	Volume (m ³ / día)
Amatitlán	2,246.40
Fraijanes	604.80
Guatemala	18,489.60
Magdalena Milpas Altas	259.20
Mixco	24,114.24
San Bartolomé Milpas Altas	1,728.00
San Lucas Sacatepéquez	345.60
San Miguel Petapa	40,617.50
San Pedro Sacatepéquez	518.40
Santa Catarina Pinula	518.40
Santa Lucía Milpas Altas	86.40
Villa Canales	3,231.36
Villa Nueva	33,441.12
General Total	126,201.02

Source: AMSA, 2013.

Table 4. Status of Wastewater Treatment Plants

Municipalities	01 - Land	02 - Under construction	03 - Rehabilitation	04 - Normal Operations	Capacity			08 - Structures S-Destroyed	09 - Structures Destroyed	10 - No Plant	11 - Unknown	General Total
					05 - Maximum	06 - Mean	07 - Minimum					
Amatitlán					1	1		1	1			4
Fraijanes	1				1							2
Guatemala						5		1	2			8
Magdalena Milpas Altas				2								2
Mixco		1	1	3		1	2	2		4		14
San Bartolomé Milpas Altas								1				1
San Lucas Sacatepéquez		1			1							2
San Miguel Petapa					1	2	4	3				10
San Pedro Sacatepéquez								3				3
Santa Catarina Pinula		1			2							3
Santa Lucía Milpas Altas				1								1
Villa Canales					1	1	1					3
Villa Nueva			3	6	3	1		6	3		4	26
General Total	1	3	4	12	10	11	7	17	6	4	4	79

Source: AMSA, 2013.

children five years old, the main causes of mortality included infectious diseases and parasites (66 for every 100,000) and conditions originating in the perinatal period (37 for every 100,000).⁸

Data from the Health Information Management System (SIGSA in Spanish) indicate that, during 2011, the events that occupied the greatest number of first consultations for morbidity (4,490,279 consultations) related to health services, in all age groups, were acute respiratory infections with 48%, followed by intestinal parasites with 10%, gastritis with 9%, infections of the urinary tracts with 7%, and other acute diarrhea related diseases with 6%, which represents 80% of all consultations.⁹ The top 10 causes of general morbidity at the national level are shown in Table 5.

During 2011, 378,602 cases of diseases transmitted by food and water were reported. The reported cases included diarrhea, hepatitis, food poisoning, and other costs. The whole country

had 2.6% of the total population affected, which, compared to 2010, represented a decrease of 29% in registered cases.¹⁰

Table 5. Top 10 Causes of General National Morbidity for 2011 - January to November

Diagnostic Description	Female	Male	Total
Acute Respiratory Infections	1,234,579	903,224	2,137,803
Intestinal Parasites	304,699	147,003	451,702
Gastritis	254,182	145,667	399,849
Urinary Tract Infection	242,913	61,754	304,667
Other Acute Diarrhea Related Diseases	144,398	126,247	270,645
Anemia	119,751	41,521	161,272
Cefalea	126,755	32,942	159,697
Conjunctivitis	54,029	38,491	92,520
Dermatitis	53,092	38,125	91,217
Unspecified Allergy	51,214	32,338	83,552
Total	2,745,294	1,744,985	4,490,279

Source: The Ministry of Public Health and Social Assistance National Health Diagnosis. March 2012.

8. The Ministry of Public Health and Social Assistance National Health Diagnosis. March 2012.

9. Ibidem

10. Ibid.

In relation to rotavirus, 724 cases in children younger than five years old were reported in 2011, compared to 2010 (5,932 cases), which represented a decrease of 88%. In a time series, the effect that the introduction of the vaccine had on this event may be observed. The vaccination that is applied currently contains the viruses that have circulated in the last three years. The departments that reported the most cases were Escuintla (160 cases), Quiché (134 cases), and Huehuetenango (113 cases). There was no significant difference by gender.¹¹

During 2011, 3,281 cases of dengue were reported, of which 78% were clinical, with 687 confirmed, and 29 cases of hemorrhagic dengue. There were 11 deaths attributed to dengue. Compared to 2010, 2011 was not an epidemic year for this event.¹²

In 2011, during the 52 epidemiological weeks, there were reports to the SIGSA of 2,664 confirmed cases of malaria at a rate of 22 x 100,000 inhabitants, with *Plasmodium vivax* being the most frequent at the national level, with 98% of the total recorded cases. Note that, in comparison to 2010, only one-half of the cases were recorded, which is a trend that has been observed over the last several years.¹³

When a correlation is done with the indicators developed by the World Health Organization (WHO) in relation to the impact of investments in potable water and sanitation on health, for every dollar invested, at least a 10% reduction in diarrhea related diseases is able to be achieved. In other words, for every dollar that is invested, a reduction of five dollars could be achieved in the Ministry of Health's budget.

6. Variability and Climate Change, Its Impact on Water Resources in Cities

Guatemala is highly susceptible to extreme hydro-meteorological phenomena, especially great magnitude floods. In the last decade, Hurricane Stan in 2005 and Tropical Storm Agatha in 2010

caused losses to the country of more than US \$1.9 billion, of which US \$745,000 directly affected the infrastructure.¹⁴ In the Department of San Marcos alone, 331 water supply systems were damaged. In the case of Agatha, it was the effect of the storm combined with the eruption of the Pacaya volcano. Hurricane Mitch in 1998 affected a broader area and also presented damages of more than US \$115 million in infrastructure;¹⁵ the number of water systems damaged was 237.

With the effects of climate change and variability, this type of event is predicted to be increasingly more frequent. As a developing country, the costs of investment in damaged infrastructure implies sidetracking resources into reconstruction, which limits the construction of new work. This is a financial cost that affects the country's whole economy and not just the place that was specifically affected.

Although Guatemala is highly vulnerable due to the threat of hydro-meteorological phenomena and their high indices of at-risk populations and infrastructure, there is very little that can be done to actually reduce the effects of greenhouse gases. The reason is that the large industrialized countries emit more than 80% of the gases worldwide, so the media for adaptation to reduce vulnerability needs to be concentrated.

The main effect of climate change in the urban zones consists primarily of flooding, in addition to the droughts that mostly affect the availability of water for the supply systems. Flooding is due to the increase in intensity or magnitude of storms, as well as the rising trend in their frequency. In other words, storms occur with a greater intensity and they occur increasingly closer to each other. This is confirmed by the fact that, in the last 15 years, three events of a great magnitude have occurred, represented by hurricanes Mitch and Stan, as well as Tropical Storm Agatha. Figure 7 shows the 24-hour precipitation during Stan and Agatha in different parts of the country.

Fuentes (2013) quantified the effect associated with urbanization during the water cycle, principally on the components of precipitation and surface

11. Ibidem

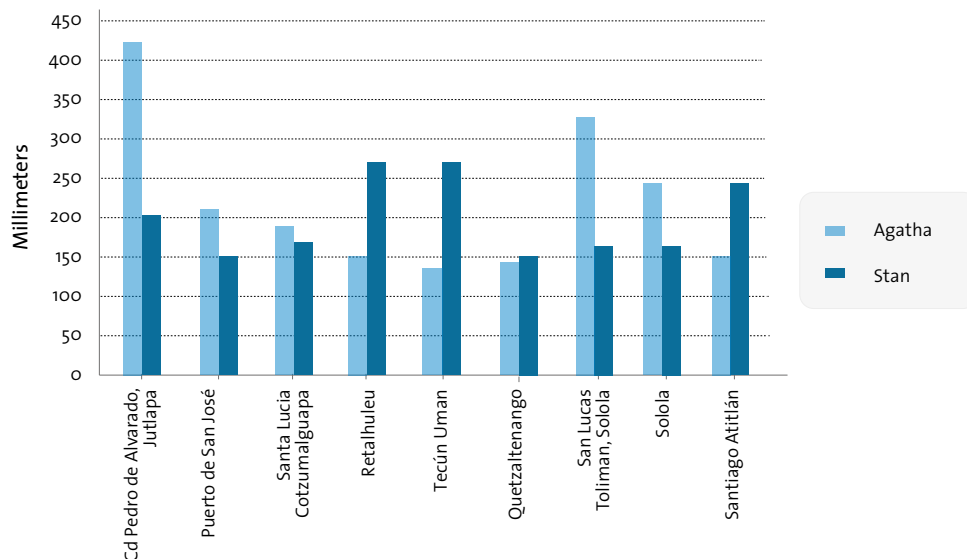
12. Ibidem

13. Ibidem

14. Reports by the CEPAL about Stan (2005) and the SEGEPLAN report (2010) on Agatha.

15. CEPAL report on the evaluation of damages caused by Hurricane Mitch (2004).

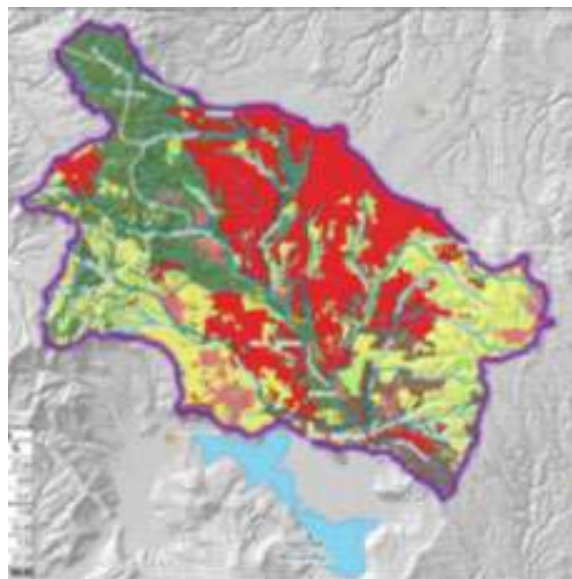
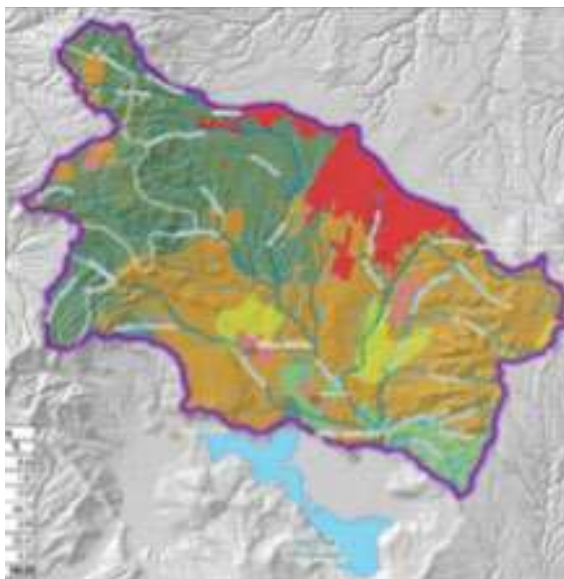
Figure 7. Comparison of 24-hour rain data for Tropical Storm Agatha (25-30 of May, 2010) versus Hurricane Stan (1-10 of October, 2005)



runoff in the Villalobos River sub-watershed, where a part of the MA has been settled. The analysis indicated that two groups of seasons were clearly established: those located in areas exposed to the urbanization process and those where the process is lesser. In addition, the annual and maximum

series (of daily rainfall and maximum annual daily rise) show a significant positive uptick. To estimate the impact on surface runoff, the hydrogram was modeled for the most extreme event that occurred (Tropical Storm Agatha) for urbanization conditions in 1972 and 2012 (Figures 8 and 9).

Figure 8 and 9. Land use in the Villalobos River Sub-Watershed in 1972 (above) and 2012 (below)
The area in red is the urban part



Source: J. C. Fuentes, 2013.

The increase of urban areas in the last 40 years (approximately 22% of the total area of the Villalobos River-Late Amatitlán sub-watershed) has caused significant increases in the hydrogram components, peak water flow, and surface runoff primarily, only decreasing the concentration over time since the sub-watershed is in a continuous urbanization process. The results show that there is actually a considerable impact on the hydrological cycle (Figure 10).

AMSA (2013) issued a contract for a bathymetry study for Lake Amatitlán and sediment carried by the Villalobos River. The study results indicated that between the last bathymetry in 2001 and the bathymetry in 2012, $14.5 \times 10^6 \text{ m}^3$ of sediments were deposited. During that period, around 9% of the lake's total volume was lost (Figure 11). In addition, the sedimentation rate is doubled during extreme climate events, such as Agatha in 2010.

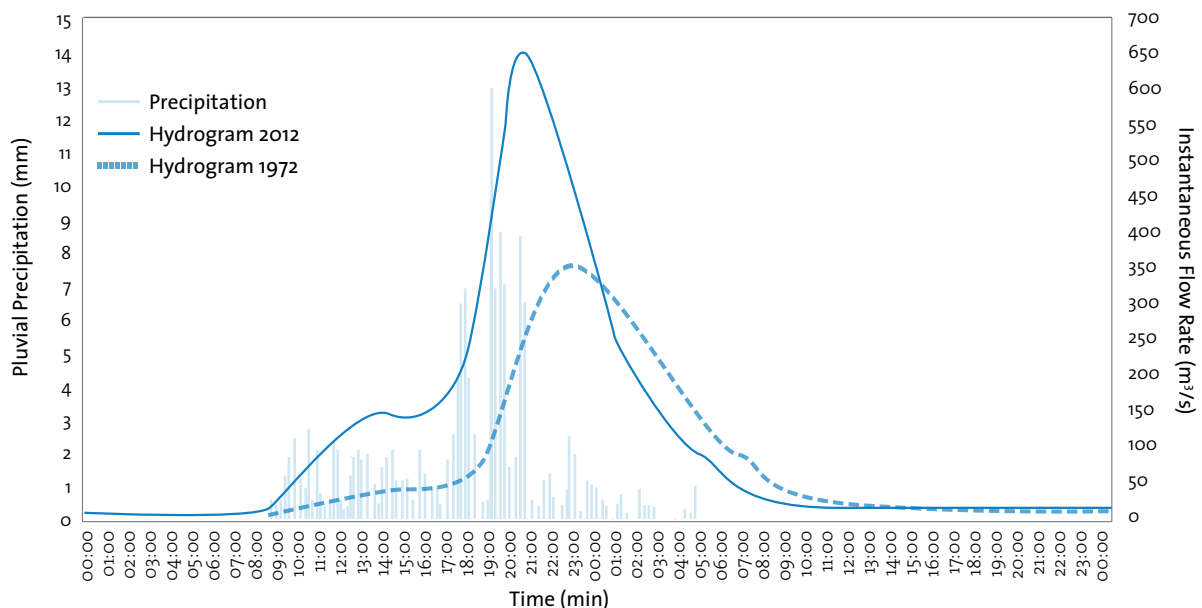
The URL-IARNA and TNC (2012a) reported that “forests provide the best conditions for water infiltration in the aquifer mantles and identify the areas that should be conserved and those that should be reforested to improve the water supply in the metropolitan area. The current forest coverage in the Metropolitan Area in Guatemala is 21,244 hectares and contributes to the infiltration of 214.5 million cubic meters of water per year into the

subsoil. In addition, reforestation of 39,831 hectares was considered, which would infiltrate some 206.7 million additional cubic meters annually.”

In the near future, due to climate change, “less rain is expected in the metropolitan area. If the current coverage (21,244 hectares) is conserved, in 2020, 195.6 million cubic meters will be infiltrated, which would represent 10% less than what is infiltrated today. If, in addition to conserving the forest, a total of 39,831 hectares is reforested, 206.7 million cubic meters would be infiltrated, which would represent a decrease of just 5%.”

Thus, the urban areas are conditioned, first of all, on progress in the urban zone or densification. These changes are extremely rapid due to migration and development that are caused by how attractive urban centers are as sources of employment, study, and culture. In addition to this progress, the effects of climate variability with more intense, more frequent rainfall have to be taken into account. These all represent worrisome challenges for the municipal structure for managing urban water. Faced with progress in the urban area and climate variability, municipalities generally outdo themselves in providing services, especially when it comes to rainwater drainage, sanitary sewers, and providing potable water.

Figure 10. Hydrogram in the Villalobos River Sub-Watershed in 1972 and 2012



Source: J.C. Fuentes, 2013.

In that regard, there is a need to seek mechanisms that make operating public systems viable. One alternative is to internalize the impact of water on new developments in relation to municipal public services. Once the types of impact are defined, mitigation measures should be suggested that will decrease them. The municipalities can achieve this by regulating new developments to reduce their impact. If they are not willing to do so, they should pay for the infrastructure that is required to properly manage water.

Thus, the impact of water that any new development produces are the following:

- Impact due to lack of infiltration;
- Impact due to increase in demand;
- Impact on the sanitary system;
- Impact due to contaminated discharge;
- Impact due to run-off produced; and
- Impact due to intervention in riverbeds.

Figure 11. Volume of Sediment Deposited in Lake Amatitlán between 2001 and 2012



Source: AMSA, 2012.

The municipality of Guatemala has undertaken some measures such as harvesting rain water in reservoirs for schools and housing in the peri-urban areas as well as holding tanks, etc., with the participation of the beneficiaries.

7. Conclusions

Guatemala City and part of the rest of the Metropolitan Area (MA) are situated on the water divide for the Pacific and Atlantic watersheds. Therefore, the surface water is relatively scarce and, as a consequence, underground sources have had to be exploited. The MA is made up of 12 municipalities, 20 sub-watersheds and around 2 million inhabitants with an annual growth rate of 3.5% in an area of 1,461.15 km².

Urban growth in Guatemala City since it was created in 1776, but especially other municipalities in the MA in the last four decades, has caused a reduction in infiltration of water due to impermeabilization and overuse of the aquifer due to the growing demand, as well as contamination of the surface and groundwater sources due to the discharge of untreated wastewater.

The increase in urban areas in the last 40 years (approximately 22% of the total area of the Villalobos River sub-watershed) has caused significant increases in the hydrogram components,

peak water flow, and surface runoff primarily, only decreasing the concentration over time and evidencing that there actually are considerable types of impact on the water cycle.

Recent study results indicate that between the previous bathymetry in 2001 and the bathymetry in 2012, 14.5 million cubic meters of sediments were deposited. During that period, around 9% of the lake's total volume was lost. In addition, the annual sedimentation rate is doubled during extreme climate events, such as Tropical Storm Agatha, which occurred in May 2010.

In the near future, due to climate change, less rain is expected in the metropolitan area. If the current coverage (21,244 hectares) is conserved, in 2020, 195.6 million cubic meters will be infiltrated, which would represent 10% less than what is infiltrated today. If, in addition to conserving the forest, a total of 39,831 hectares is reforested, 206.7 million cubic meters would be infiltrated, which would represent a decrease of just 5%.

8. Recommendations

The water supply in the MA requires a coordinated effort by the municipalities due to the fact that using groundwater so far is unsustainable if infiltration is not boosted naturally and artificially and the demand is improved (lower consumption), along with the supply (fewer leaks and illegal connections). The Municipality of Guatemala recently began projects to harvest rainwater and set up holding tanks.

The Metropolitan Area's Water Fund initiative is an attempt to have financial mechanisms to conserve forests and to provide an incentive for changing how the recharge areas are used. The purpose is to attain a sustainable balance between supply and demand now and in the future for the water supply in the Metropolitan Area. The initiative should be supported by both the public and private sectors.

Another line of coordinated action between the municipalities in the Metropolitan Area is to treat all wastewater. The multimillion dollar investment required should be shared by the generators. The contamination in Lake Amatitlán due to the discharge of untreated wastewater coming from the Villalobos River watershed is evidence of how serious the matter is.

Investigation into the causes and effects of urbanization in the Metropolitan Area and the measures to be taken should be promoted by research centers and universities since recent studies carried out by IARNA-URL, TNC, and AMSA, and the master's thesis in hydrology by Engineer Fuentes have been the first ones to evidence the effects of urbanization on the water resources in the Metropolitan Area.

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10. Acronyms

MA

Metropolitan Area

AMSA

The Authority for Sustainable Management of the Lake Amatitlán Watershed

EMPAGUA

Municipal Water Company of Guatemala

ENCOVI

National Housing Survey

FONCAGUA

Fund for Water Conservation in the Guatemala Metropolitan Region

IARNA Institute of Agriculture, Natural Resources, and the Environment

IGN

National Geographic Institute

INE

National Statistics Institute

MSPS

The Ministry of Public Health and Social Assistance

MDG

Millennium Development Goals

WHO

World Health Organization

PROVIAGUA

Program for Water Quality Oversight

SEGEPLAN

General Planning Secretariat

SIGSA

Health Information Management System

TNC

The Nature Conservancy

URL

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