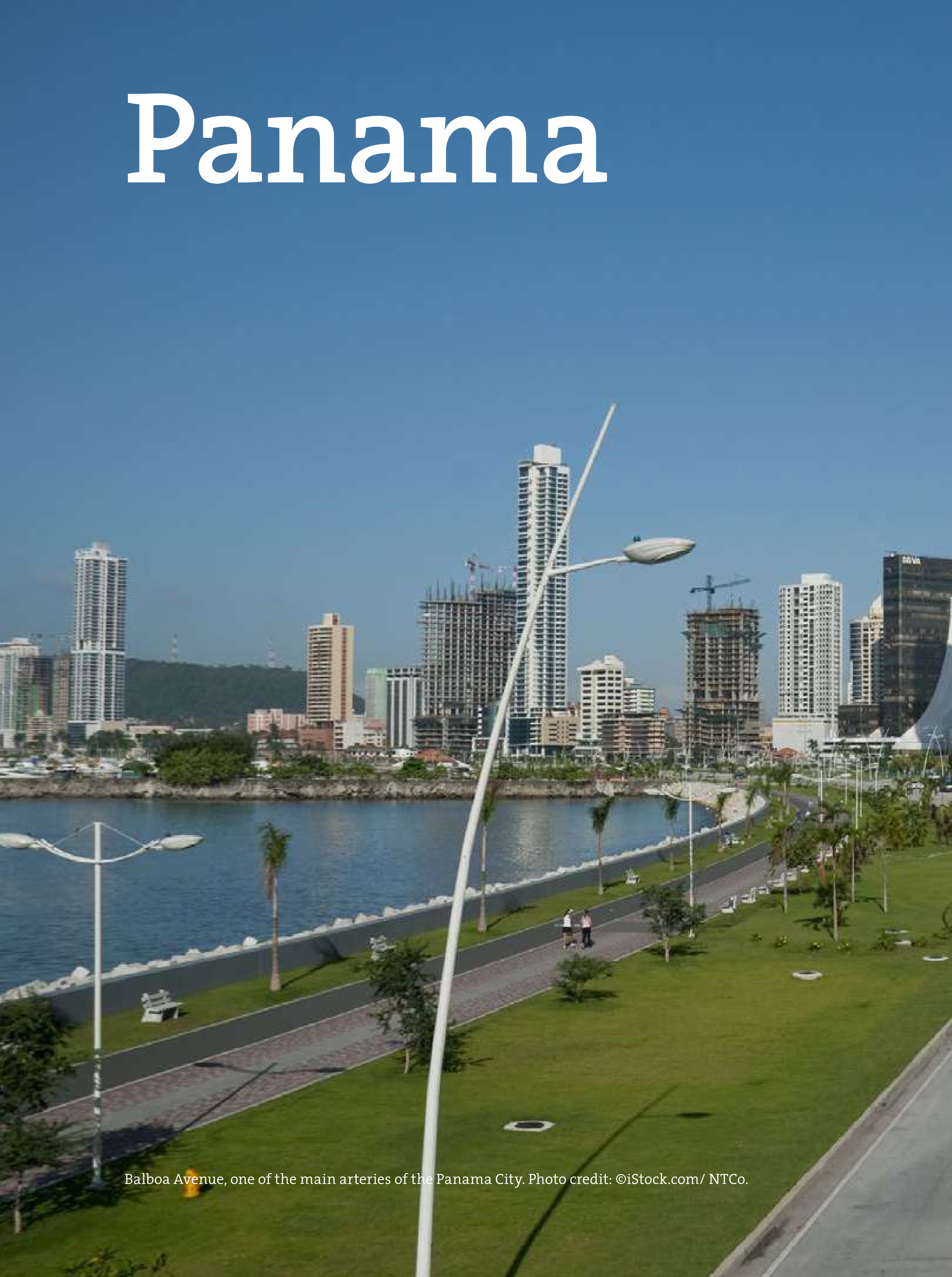
Panama



Balboa Avenue, one of the main arteries of the Panama City. Photo credit: ©iStock.com/ NTCo.

“Panama is a country with abundant water resources with over 90% of the population having access to potable water in general. However, drinking water sources for urban areas focused almost exclusively on surface water sources, the existence of regions (particularly indigenous areas) where less than half the population has access to potable water, appropriate resources to manage the increasingly larger water related infrastructures, and climate change are the main challenges to be addressed in the near future”

Urban Waters. Panama

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Abstract

Panama is a country with abundant water resources and an average annual rainfall of 3000 mm. However, 66% of the population live in populated areas with more than 1,500 inhabitants, considered urban zones, hence the importance of good urban water governance and management in Panama. Most of the urban population uses surface water (rivers and lakes) as a source of water to meet its needs, with groundwater sources being rarely used to supply urban communities.

In Panama, drinking water is administered by two entities: on the one hand, the Institute of Aqueducts and Sewerage (IDAAN), which serves populations with over 1,500 inhabitants, and on the other, the Ministry of Health (MINSA), which, through the Rural Water Management Boards (JAAR), serves towns with under 1500 inhabitants, especially in rural areas. There are isolated cases in peri-urban areas where water is managed by JAAR. In general, according to the last census (2010), over 90% of the population have access to potable water. However, this figure does not represent the reality of certain marginalized areas, as in the case of indigenous regions, where figures can be as low as 28%.

Regarding wastewater treatment, and according to World Bank indicators, in 2012, 80% of the population had access to improved sanitation facilities. In urban areas, under the administration of IDAAN, 57% of the population have sewerage which translates in total terms of the population into 45%. Regarding wastewater treatment, thanks to a series of rules approved in the late last century and at the beginning of this one, there are now approximately 100 wastewater treatment plants (WWTP) with secondary treatment. Likewise, the “Panama City and Bay

Sanitation Project" is currently underway. Launched in 2006, it is designed to restore the health and environmental conditions of the metropolitan area and to remove the pollution caused by untreated wastewater in urban rivers and the coastal areas of Panama Bay. Thanks to this project, the only WWTP in the country providing tertiary treatment for the waters it receives is already operating, with a capacity of up to 2.2 m^3/s. By 2035, this plant is expected to meet the demands of approximately 1.2 million people and achieve a volume of treated water of approximately 6.4m^3/second.

With respect to vector-borne diseases that develop in water, it is important to note that **dengue** in urban areas is one of the main public health problems in Panama. Isolated studies on raw water used by water treatment plants in certain urban centers have found *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts in the dry season. In the rainy season, results were negative, except for a study that found *Cryptosporidium* spp. in treated water. On the other hand, in the Chilibre treatment plant, which supplies water to most of the urban population in the capital city, the presence of these parasites was not detected. However, studies undertaken in the city of La Chorrera seem to indicate a relatively high prevalence of *Cryptosporidium* spp. and *Giardia* spp. in children.

Lastly, the link between urban water and climate change is becoming increasingly important, mainly due to the rapid growth experienced by the Panama City. Various studies and analyses point to an increase in the frequency of extreme events and the vulnerability of urban areas, reflected not only in the increase in the number of floods, but also in the number of people affected by these events. In order to address climate change in Panama, with regard to both adaptation and mitigation, institutional and legal developments include the adoption of the National Policy on Climate Change, within the National Environmental Authority (ANAM) and the creation of the National Committee on Climate Change, which has representatives from 27 public sector institutions including the academic sector. There are various alternatives designed to increase urban resilience to climate change. One of the most important alternatives being promoted worldwide are green buildings. In this regard, Panama ranks second in Central America and the Caribbean in terms of LEED certified buildings. In addition to structural solutions, urban resilience to climate change depends on sensitizing the public and awareness of the role each plays in both the problem and the solution.

1. Water Sources in Urban Areas and the Impacts Caused by Urbanization

Panama is a country with abundant water resources, with a maximum annual average rainfall of around 3000 mm, a minimum of 1000 mm and up to 7000 mm in some areas of the country. On its surface, the rains form a network of short rivers that rise in the continental divide and flow into one of the two coasts (150 rivers in the Atlantic and 350 rivers in the Pacific). Panama also has 67 lake systems, including reservoirs, ponds and wetlands. Panamanian groundwater has not been studied in detail, although it is known that there are three main types of aquifers: predominantly intergranular aquifers, predominantly fissured aquifers and areas with local intergranular or fissured aquifers with limited productivity.

With regard to the population, the latest census indicates that 66% of the population in the country (2,249,394 people) live in 224 urban locations (towns with over 1500 inhabitants), while 34% (1,155,884 people) live in 11,391 places with fewer than 15 hundreds inhabitants, defined as rural (Table 1).

Table 1. Population distribution in Panama

Type of Population	Population	%	Populated places	%
Urban Population	2,249,394	66	224	2
Rural Population	1,155,884	34	11,391	98
Total	3,405,813	100	11,615	100

Source: Compiled by the author based on the 2010 Census of the Comptroller General of Panama.

1.1 Regions in the Country with a Predominance of Use of Surface / Ground / Combined Waters

As seen in Table 2, and only using treatment plants administered by IDAAN, urban zones in Panama (99.9%) mainly use surface water for human consumption. Groundwater is used slightly more often in rural areas.

1.2 Water Sources Relative to Urban Population Distribution

Most of Panama´s economic activity (that includes 75% of the population) is concentrated in 5.3% of the territory in a few cities on the Pacific slope. In contrast and according to the Environmental Atlas of Panama (National Environmental Authority -ANAM-, 2010), a quarter of the population, occupying slightly less than 95% of the country, lives in scattered villages, poverty and without access to the most basic services.

The three largest municipalities with the greatest economic activity in the country (Panama, San Miguelito and Colón), accounting for over 62% of the urban population (2010 census), are mainly supplied by water from the Panama Canal Watershed administered by the Panama Canal Authority, with high control and management standards. The basin, covering an area of 2,982 Km², constitutes a huge water potential (Panama Canal Authority -ACP-, 2006).

1.3 Overexploitation of Surface and Groundwater Sources

The Panama National Plan for Water Resources (PNGIRH) (ANAM, 2011) reports the results of the water balance achieved in ten priority watersheds located on the Pacific coast in 2008. These basins were prioritized on the basis of population density, water demand, conflict scenarios, vulnerability to climate change and so on. It was reported that only the Antón River has a water shortage, while the other basins experience a situation ranging from equilibrium to abundance. Seasonal analysis showed that the Tonosí and La Villa basins have water availability problems during the dry season.

The same report mentions that although groundwater concessions seem insignificant, the uses and extractions observed in the basins, especially in the area called Arco Seco (which includes the provinces of Herrera, Los Santos, Coclé and part of Veraguas), tend to be intensive.

1.4 Impacts of Urbanization on Water Quantity and Quality in the Various Sources. Specific and Diffuse Sources of Pollution Inside and Outside the City

The National Environmental Authority (ANAM), the organization responsible for the environment in Panama, estimates that over 80% of wastewater discharges come from the domestic and commercial sector, with the remaining 20% correspond to the industrial sector (ACP, 2006). It should be pointed out that for the industrial sector, although the discharge volume is lower, the pollutant load is much higher than the domestic contribution, which is critical, since ANAM reports that few companies submit requests for permission to discharge water into either surface water bodies or sewerage (ANAM 2011).

ANAM (2011) has found a link between the water quality degradation of the country's rivers and population concentration: out of a total of 17 rivers monitored in the province of Panama, ten range from "polluted to highly polluted." These include

Table 2. Water source of treatment plants administered by IDAAN

Type of supply plant	Number	Nominal Capacity (Mm³/day)	Actual production (Mm³/day)	Population benefiting(a)
Reservoir	5	1.022	0.885	1,294,566
River or stream	47	0.541	0.408	943,713
Well and river	1	0.003	0.001	2,652
Total plants operating	53	1.57	1.29	2,240,931

(a) Up to 2014. Source: http://www.idaan.gob.pa/detalle.php?cid=2&sid=31&id=38

Mataznillo, Curundú and Río Abajo, located in the capital (Figure 1). PNGIRH attributes water pollution to several factors: i) Wastewater discharge with no or insufficient treatment (domestic and industrial) of solid waste discharges, ii) use of chemical products: agrochemicals and detergents, iii) Oil and other polluting material spills, and iv) Deforestation and extreme rainfall that contribute sediments.

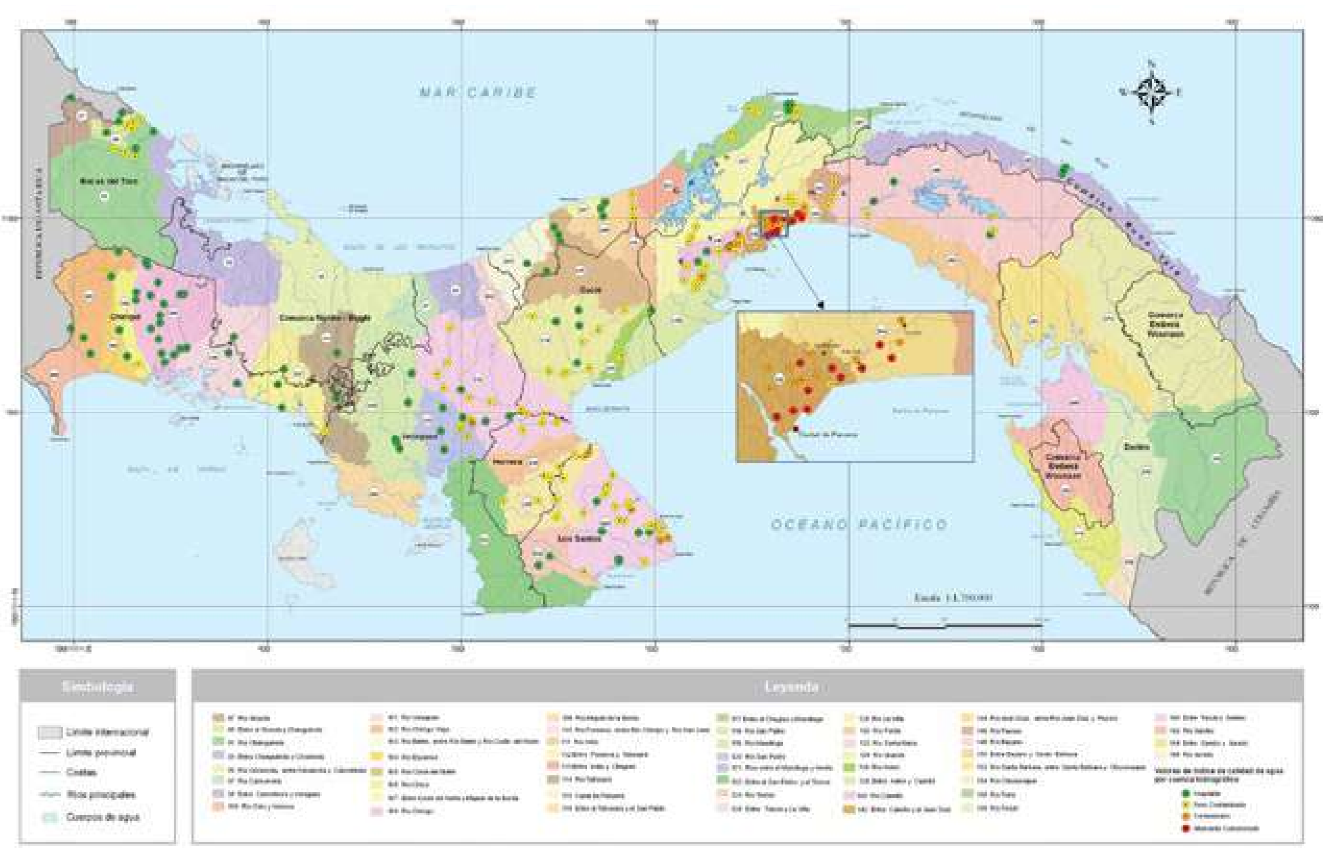
At least two important cases of water source pollution have been reported in the country. One was caused by heavy rains in December 2010[1] that led to a high concentration of sediments in water, causing the collapse of purification plants that supply Panama City and a water crisis. A second case is currently taking place due to the discharge of the herbicide Atrazine above the water purification plant intakes, which also supply several rural aqueducts and other uses, affecting tens of thousands of people in the provinces of Los Santos and Herrera.

1.5 How Water Quality Problems Have Been Addressed in Urban Areas

It was known (ANAM, 2011) that the Curundú, Matasnillo, Río Abajo, Matías Hernández, Juan Díaz, Tapia, Tocumen and Cabra rivers (within Panama City or in its surroundings) received domestic wastewater and liquid discharge from 674 compa-

1. The hydrological yearbook of the Panama Canal Authority reported that according to records in the hydrometric stations, the flow for December 2010 in all the major rivers in the basin exceeded the historical average for that month by 200% to 400%.
Study available at: https://micanaldepanama.com/wp-content/uploads/2012/06/Anuario/2010.pdf

Figure 1. Water Quality Index by Watershed



Atlas ambiental de la República de Panamá (ANAM, 2010) nies (including slaughterhouses, poultry, dairy and sausage processing plants, metallurgical companies, paint and car battery factories, construction material, non-metallic mineral extraction, petroleum derivative processing companies, sawmills, tanneries, workshops and sheet metal plants). These rivers flowed into Panama Bay, opposite the city, causing unpleasant odors and making it unsuitable for recreational purposes.

In order to restore the health and environmental conditions of the metropolitan area and eliminate the pollution due to untreated wastewater in urban rivers and the coastal areas of Panama Bay, the Ministry of Health has implemented the Panama City and Bay Sanitation Project. In addition to this, in recent years, residential projects have been obliged to include private wastewater treatment systems, although they often fail to comply with regulations (ANAM, 2011).

Since 2002, the National Environmental Authority (ANAM) has monitored 95 rivers nationwide through 519 points and uses a water quality index (ICA) to classify water quality (Figure 1). Likewise, ANAM has developed a series of programs and projects for watershed management, designed to halt and reverse the environmental degradation to which they are subjected. However, this institution also has greater responsibility for enforcing water discharge standards, although it has admitted having achieved limited success (ANAM, 2011).

1.6 Specific Problems Related to Water Sources for Peri-Urban Areas and Informal Settlements

The It also notes the deterioration of health conditions and public services. Shows the growth rate of Panama City in the past 30 years, where peri-urban areas have grown considerably. The towns of Chilibre and Arraiján are peri-urban sites studied with respect to their links with water resources located within the Panama Canal Watershed.

The study on "Socio-demographic and economic characterization of the basin" (TETRATECH, 2010) links peri-urban settlements to environmental changes and their effects on water quantity and quality, such as plant cover loss, the reduction of water infiltration into the soil, pollution from solid, liquid and gaseous, sometimes toxic waste, and the modification of waterways and the landscape in general. It also notes the deterioration of health conditions and public services.

2. Drinking Water Service in Urban Zones

2.1 Drinking Water Management in Panama

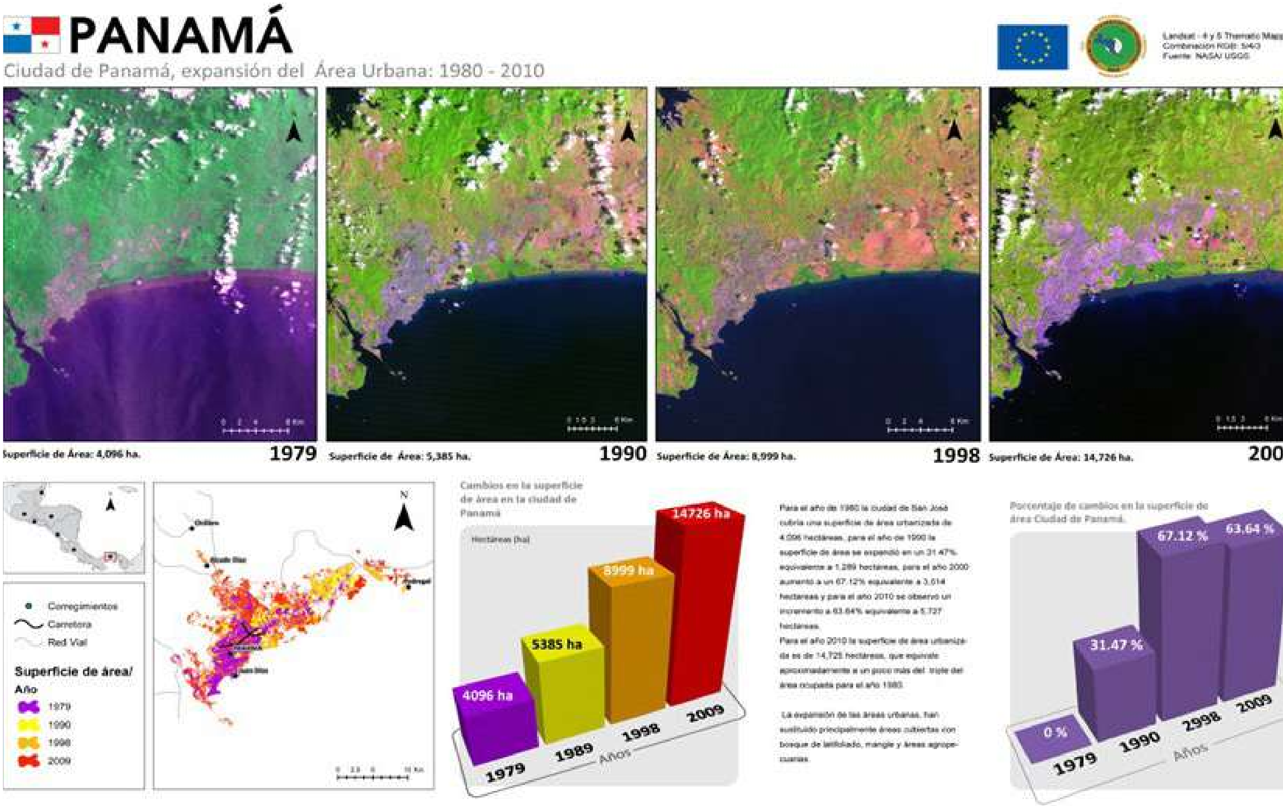
In Panama, drinking water is administered by two entities: on the one hand, the Institute of Aqueducts and Sewers (IDAAN), which serves populations with over 1,500 inhabitants, and on the other, the Ministry of Health (MOH), which serves towns with under 1,500 inhabitants, especially in rural areas, through Rural Water Management Boards (JAAR). However, despite this distinction, there are urban areas where administration is undertaken by a JAAR, as in the case of the community of Génesis, in Las Mañanitas de Tocumen, east of Panama City.

Given this separation of powers by population, IDAAN currently manages 124 water systems nationally (Cano, 2013), and serves a population of 2,644,464 inhabitants, with 93% coverage (Figure 3). In terms of population, this coverage represents an increase of approximately 70% compared with 1987, when IDAAN managed 135 water systems throughout the country to meet the demands of 1.5 million inhabitants, through 25 water treatment plants, 2 slow filters, 317 wells, six infiltration galleries and five waterwheels (Fábrega, 1992).

The IDAAN set rates for metered consumption, which differ from one urban area to another. In other cases, the IDAAN has contracted water supply through tanker trucks, especially for populations located on the outskirts of the capital of Panama such as Las Garzas de Pacora, Altos de la Torre, La Paz, Jalisco, Alto Lindo and Guarumalito. In this respect, although tanker tanks distribute nearly 190,000 gallons a day, there are almost daily protests due to the lack of supply.

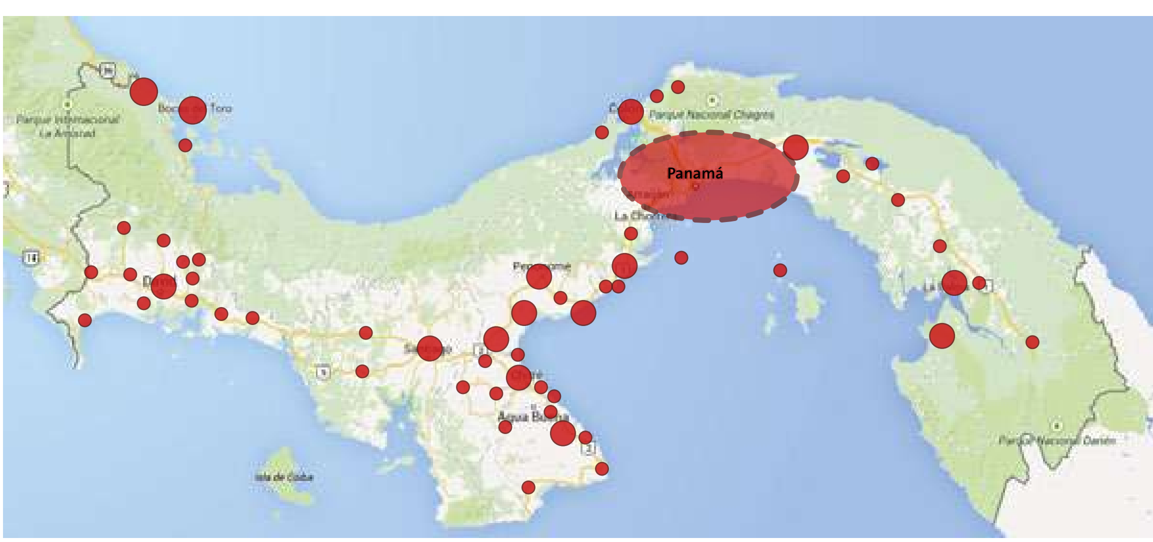
This is compounded by the fact that, according to the IDAAN's Statistical Bulletin No. 24 (2008-2010), water bills are sent to users on the basis of: meter reading (34.1%), averaged calculations (20.6%) or without using a meter (44%). Similarly, 41.4% of water is unaccountedfor, which is an indicator of serious physical and commercial losses accentuating the institution's financial crisis.

Figure 2. Change of urban area in Panama City



Source: CATHALAC (2011) as part of the PREVDA project

Figure 3. Location of the country's 124 aqueduct systems administered by IDAAN



Source: Cano, Ivan. Oral presentation: "Descripción de los Sistemas de Acueducto Panamá Metro y Panamá Oeste, Instituto de Acueductos y Alcantarillados Nacionales (IDAAN). Dirección de Operaciones. 2011

At the same time, MINSA has registered 2,673 JAARs throughout the entire country, with legal status. In JAARs, regularity means charging a fixed fee, which varies regardless of per capita consumption. Rarely have micrometers been installed for the purpose of having a rate for metered consumption (MINSA, 2014).

Table 3. Percentage distribution of drinking water sources among the population: 2010 Census

Sources	Porcentaje
IDAAN Public Aqueduct	70.8
Community Public Aqueduct	19.8
Scoophole	2.1
River, stream or lake	2.0
Health Pit	1.6
Private Aqueduct	1.1
Unprotected covered well	1.0
Tanker Truck	0.7
Rainwater	0.5
Bottled water	0.3
Other	0.1
TOTAL	100.0

Source: National Institute of Statistics and Census. Comptroller General's Office

2.2 Drinking Water Coverage in Urban Zones

Although the Panamanian Constitution does not recognize the human right to water, it does have a policy and plan for drinking water supply in urban areas, which has been partially implemented (MINSA, 2013). This plan is expected to achieve 97% coverage in urban areas by 2014.

At present, according to data collected in the Population and Housing Census 2010 (Table 3), 91.7% of the population have access to safe drinking water through household connections such as IDAAN public aqueducts, or community or private aqueducts. At the same time, 6.7% have access without household connections and 1.6% rely on other types of supply such as rain or tanker trucks. Likewise, drinking water access coverage varies according to the type of source (Table 4). These values assume that approximately 3.1 million people in the country have a reliable supply of healthy water. However, figures show that by geographic area, the indigenous regions of Embera and Ngobe Bugle have the worst conditions for water use and consumption (Tables 4 and 5). Factors such as scattered villages, limited road access and cultural influences contribute to these results.

Table 5. Population with or without access to drinking water, by province and indigenous region: 1990, 2000 and 2010 Censuses (as a percentage)

Provinces and indigenous regions	Population with or without access to drinking water by Census					
	1990*		2000		2010	
	Yes	No	Yes	No	Yes	No
TOTAL	81.2	18.8	90.2	9.8	92.9	7.1
Bocas del Toro	60.2	39.8	74.1	25.9	74.6	25.4
Coclé	75.9	24.1	91.5	8.5	95.1	4.9
Colón	83.3	16.7	92.0	8.0	93.5	6.5
Chiriquí	65.3	34.7	82.3	17.7	87.9	12.1
Darién	31.9	68.1	58.4	41.6	72.4	27.6
Herrera	78.4	21.6	93.6	6.4	96.6	3.4
Los Santos	85.7	14.3	96.1	3.9	98.6	1.4
Panama	93.7	6.3	97.1	2.9	98.6	1.4
Veraguas	57.4	42.6	83.3	16.7	88.8	11.2
Kuna Yala			67.7	32.3	77.8	22.2
Emberá			10.7	89.3	27.6	72.4
Ngobe Buglé			29.9	70.1	38.6	61.4

*Since indigenous territories had not been created, indigenous areas were included in the provinces surrounding these regions.

Table 4. Dwellings by source of water supply, province and indigenous region: 2000 and 2010 Censuses

Provinces and indigenous regions	Total	IDAAN Public Aqueduct	Community's Public Aqueduct	Private Aqueduct	Health Pit	Unprotected covered well	Rain water	Scoopho le	River, stream or lake	Tanker Truck	Bottled water	Other
2000												
TOTAL	681,928	459,803	143,390	9,132	9,067	9,698	1,929	23,001	19,307	2,748	3,853	-
Bocas del Toro	16,999	2,394	9,756	454	781	112	732	968	1,562	-	240	-
Coclé	44,496	18,189	21,171	1,333	496	269	6	1,810	978	-	244	-
Colón	49,716	36,966	8,188	608	612	97	111	1,112	1,697	-	325	-
Chiriquí	87,509	48,161	21,619	2,238	3,017	7,730	80	2,739	1,038	-	887	-
Darién	9,088	1,577	3,660	70	276	178	421	529	2,311	-	66	-
Herrera	27,202	16,034	9,052	382	178	71	3	972	322	-	188	-
Los Santos	25,052	14,778	8,693	602	242	116	1	241	193	-	186	-
Panamá	350,472	304,555	30,212	2,750	2,266	713	286	3,272	2,165	2748	1,505	-
Veraguas	49,103	17,149	23,195	545	867	267	8	4,887	2,003	-	182	-
Kuna Yala	4,281	-	2,894	4	65	5	5	73	1,229	-	6	-
Emberá	1,498	-	157	3	83	1	135	4	1,113	-	2	-
Ngobe Buglé	16,512	-	4,793	143	184	139	141	6,394	4,696	-	22	-
2010												
TOTAL	896,068	634,780	177,840	9,850	14,005	8,816	4,711	18,497	17,650	6,588	2,207	1,124
Bocas del Toro	24,628	11,500	5,769	463	891	577	2,708	474	1,606	41	563	46
Coclé	57,193	24,608	27,946	1,514	567	430	13	1,123	693	113	46	140
Colón	63,502	48,747	9,745	403	694	894	155	647	1,733	160	154	170
Chiriquí	113,012	63,704	32,935	2,040	7,559	3,623	153	1,449	915	166	334	134
Darién	11,906	2,312	5,688	237	234	172	635	262	1,983	219	132	32
Herrera	32,591	20,414	10,505	456	113	111	17	516	357	44	43	15
Los Santos	29,363	18,021	9,884	934	166	68	0	99	75	9	27	80
Panamá	470,466	420,837	33,602	2,373	2,492	791	219	1,260	1,814	5,822	856	400
Veraguas	60,209	24,637	27,668	1,055	484	687	38	3,503	2,055	4	10	68
Kuna Yala	4,999	-	3,840	28	2	86	4	70	948	-	12	9
Emberá	1,940	-	519	1	27	1	328	-	1,048	1	12	3
Ngobe Buglé	26,259	-	9,749	346	776	1,376	441	9,094	4,423	9	18	27

Source: National Institute of Statistics and Census.

In the Panamá Metro region, the main problem is demographic pressure, which creates a constant demand for services from IDAAN, whose system and equipment continuously break down, affecting storage levels, water pressure or distribution to the high sectors located far away from the metropolitan aqueduct network (Fabrega, 1992). The improvised, uncontrolled settlement of certain communities in districts located on the peripheries of urban areas has triggered a series of socio-economic problems, including the lack of drinking water. This is compounded by the lack of indicators for measuring equitable service coverage according to the location of the populations and the various economic groups (MINSA, 2013).

On average, dwellings with household connections have water supplies 6.4 days per week and 19.5 hours a day during the dry season (6.6 and 20.5 in the rainy season, respectively) (Ministry of Economy and Finance, 2012). As for drinking water treatment, Panama's main treatment plant (Figure 4), located in Chilibre within the Panama Canal Watershed, has its outlet at Lake Alhajuela, one of the lakes that enables the Panama Canal to function. This plant has an installed capacity of 0.95 million m^3/day, used to supply much of Panama City.

3. Water Treatment in Cities

Management and final disposal of wastewater, whether domestic or industrial, and the regulation of sewerage service provision pose a major challenge to be achieved in the XXI century in the world in general and Panama in particular. According to World Bank indicators (http://data.worldbank.org/indicator/SH.STA.ACSN.UR) for 2012, the urban population in Panama had 80% access to improved sanitation facilities.[2]

2. In addition to health services (sewerage systems, septic tanks or pit latrines), these include solutions such as improved ventilated pit latrine, pit latrine with slab and composting toilet.

Figure 4. Chilibre water treatment plant with a capacity of 250 MGD, the largest in Panama

Source: Cano, Ivan. Oral presentation: "Descripción de los Sistemas de Acueducto Panamá Metro y Panamá Oeste, Instituto de Acueductos y Alcantarillados Nacionales (IDAAN). Dirección de Operaciones. 2011

3.1 Legal Framework of Domestic and Industrial Wastewater

In 2000, Panama passed various guidelines and technical regulations on various aspects of wastewater such as: i) reuse of treated wastewater (DGNTI-COPANIT, 24-99),[3] ii) discharge of liquid effluents directly into surface and groundwater (DGNTI-COPANIT, 35- 2000), iii) discharge of liquid effluents directly into wastewater collection systems (DGNTI- COPANIT, 39-2000), and iv) use and final disposal of sludge (DGNTI-COPANIT, 47-2000), in order to ensure their implementation and achieved the goal of restoring natural water bodies that had been heavily polluted, not only physically, chemically and microbiologically, but also as a result of the disposal of wastewater into surface and underground streams without proper treatment.

3.2 Drainage and Sewerage Systems

Panama is currently experiencing one of the greatest periods of economic growth in its history. For example, according to data from the CIA Worldfactbook (https://www.cia.gov/library/poublications/the-world-factbook/geos/pm.html), averaging the growth of Panama's GDP from 2011 to 2013 shows that it has grown by 9.7% annually. However, this growth is not fully reflected in its sanitation figures. For example, the IDAAN Statistical Bulletin No. 26 (2010-2012) shows that the percentage of the population with sewerage service, which is the responsibility of IDAAN (populations of over 1,500) is 57%. In terms of Panama's total population, this percentage translates into approximately 45%. This same document indicates that this coverage is achieved through 21 sewerage systems representing 312,696 residential connections, in addition to housing units in communities with over 1,500 inhabitants.

According to the Central American and Dominican Republic Forum on Drinking Water and Sewerage (FOCARD-APS) 2013, the most commonly used technologies for the management of excreta are sewer systems (collection with and without treatment including oxidation ponds, septic tanks, Imhoff tanks and treatment plants). This document also states that the type of technology is associated with batch size, as regulated by the Ministry of Housing and Land Management (MIVIOT). However, this rule is not fully observed in areas where there are informal settlements, especially in peripheral areas of cities, where the system used is latrines (FOCARD-APS, 2013).

The first sewerage systems in Panama, dating from the early 20th century, were combined systems. It is not until the middle of last century that sewerage networks emerged in the cities of Panama and Colón. However, these systems ended in direct discharges into water bodies. Nowadays, as a result of the Panama City and Bay Sanitation Project, described elsewhere in this chapter, recent years have seen the construction of approximately 138.7 kilometers of sewerage networks representing 13,978 household connections at a cost of $29.6 million USD (FOCARD-APS, 2013).

In the case of wastewater discharges on the banks of the Panama Canal and the adjacent sea (downstream of the Miraflores Locks on the Pacific and of the Gatún Locks on the Atlantic), Rojas-Márquez (2006) counted over 80 discharge points, which are characterized by directly contaminating the area into which they are discharged, and producing an unpleasant odor, leading to environmental deterioration. Given this scenario, urgent action is required to improve the quality of wastewater discharged into this important area in the country and ensure that the plants' collection and pipeline systems are in good working order. This would prevent the aquatic, mainland and marine area surrounding the Panama Canal from continuing to be polluted and destroyed (Rojas- Márquez, 2006). In response to this situation, the Panama Canal Authority (ACP) is seeking to implement solutions to treat the wastewater flowing into the Canal, which would solve the problem of large towns in the area such as: Albrook, Clayton, Cárdenas, Balboa, Amador, among other towns.

3.3 Wastewater Treatment Systems

The technologies traditionally used for waste-water treatment in Panama, registered by IDAAN, are septic tanks, Imhoff tanks and oxidation ponds with final discharge into rivers and oceans. However, in

3. Directorate General of Standards and Industrial Technology of the Ministry of Commerce and Industry of Panama (ICIM). COPANIT: Panamanian MICI Commission for Industrial and Technical Standards.

recent years, largely as a result of the adoption of the standards mentioned in section 3.1, nearly 100 secondary treatment plants have been introduced (WWTP) mainly in districts with a high urban concentration in the provinces of Panama and West Panama (La Chorrera, Arraiján and Panama), representing about 100,000 beneficiaries. However, according to information from IDAAN, only 40 of those 100 treatment plants comply with the requirements to be transferred by their builders to IDAAN (FOCARD-APS, 2013).

3.4 Panama City and Bay Sanitation Project

The Panama City and Bay Sanitation Project is the country's largest investment in environmental health. This public infrastructure work was begun in 2006, at a cost of $655 million USD. The project seeks to restore the health and environmental conditions of the metropolitan area and eliminate pollution due to untreated wastewater in urban rivers and the coastal areas of Panama Bay. This project, implemented by the Ministry of Health, will be carried out in three stages and comprises four components: i) Construction of Sewerage Networks, ii) Construction of Collecting Lines, iii) Construction of the Interceptor system, and iv) Construction and Operation of a Wastewater Treatment Plant. At present, the first phase of the project is well advanced. The year 2013 saw the launch of the first phase of the Wastewater Treatment Plant, which currently receives 1.8 m^3/s, (Figure 5), previously discharged into the Matías Hernández and Matasnillo rivers (http://www.saneamientodepanama.com/planta-de-tratamiento-de-aguas-residuales). This plant is the only WWTP in the country to perform tertiary treatment on the water it receives. With the first phase completed, this plant is expected to handle up to 2.2 m^3/s. By 2035, it is expected to meet the demand of about 1.2 million people. Once the three phases have been completed, the volume of treated water will total approximately 6.4m^3/sec of water. (FOCARD-APS, 2013).

This project is expected to greatly contribute to compliance with current discharge regulations. Moreover, it will feature a cogeneration process, which will allow the project to be registered as a clean development mechanism and enter the carbon sales market .

4. Water and Health in Cities

According to the "State of Health of Panama" report (MINSA, 2013), expansion of potable water and sanitation in Panama has meant that most of

Figure 5. Wastewater Treatment Plant in Panama Bay Sanitation Project

http://www.saneamientodepanama.com/planta-de-tratamiento-de-aguas-residuales the urban population now has access to improved drinking water sources. However, there are frequent protests over deficiencies in the distribution and quality of the water received as well as complaints relating to the collapse of urban sewerage exposing wastewater. Official figures state that access to drinking water increased by approximately 11.5% from 1992 to 2010, achieving 92.9% coverage. This same report states that in urban zones, sanitation coverage is 98.9%, while acknowledging that weak points as regards sanitation include coverage, quality of service and urban wastewater treatment, the latter being regarded as the main cause of serious pollution problems in many parts of the country.

The infant mortality rate in children under five, an important indicator of the interaction of multiple factors, including the increase in basic service coverage, especially as regards drinking water and sanitation, decreased from 24.5 deaths per thousand live births in 1990 to 16.6 in 2011. However, urban areas have not seen an improvement in this indicator, which may be related to the migration of people to the city in search of work and the consequent formation of pockets of poverty around urban areas, where safe drinking water and sanitation is almost nil.

4.1 Water-Related Diseases

With respect to diseases transmitted by vectors that develop in water, it is important to note that **dengue** in urban areas is a major public health problem in Panama, because of the complexity of factors that simultaneously interact, such as poverty, population growth, uncontrolled or unplanned urbanization, migration, environmental degradation, tire selling without sustained recycling, lack of access to safe drinking water, inadequate disposal of solid waste that collects water, an increase in the amount of scrap and plastic (non- biodegradable), climate change, poor environmental sanitation education, lack of an ecosystem approach (Ecohealth) for addressing the control of vector-borne diseases, a tropical climate with over nine months of rain and the lack of coverage and useful breeder control policies that would be useful for institutions, Panama has reported *Aedes aegypti* and *Aedes albopictus*, both vectors capable of transmitting the **dengue** and **chikungunya** viruses in urban and rural areas. Currently, 80% of the breeders reported are useful, usually containers for storing drinking water, while only 20% are useless containers such as waste or scrap. These data indicate that the main risk factor associated with the development of the epidemic in Panama is related to water supply problems (http://www.minsa.gob.pa/informacion-salud/boletines-semanales-2012).

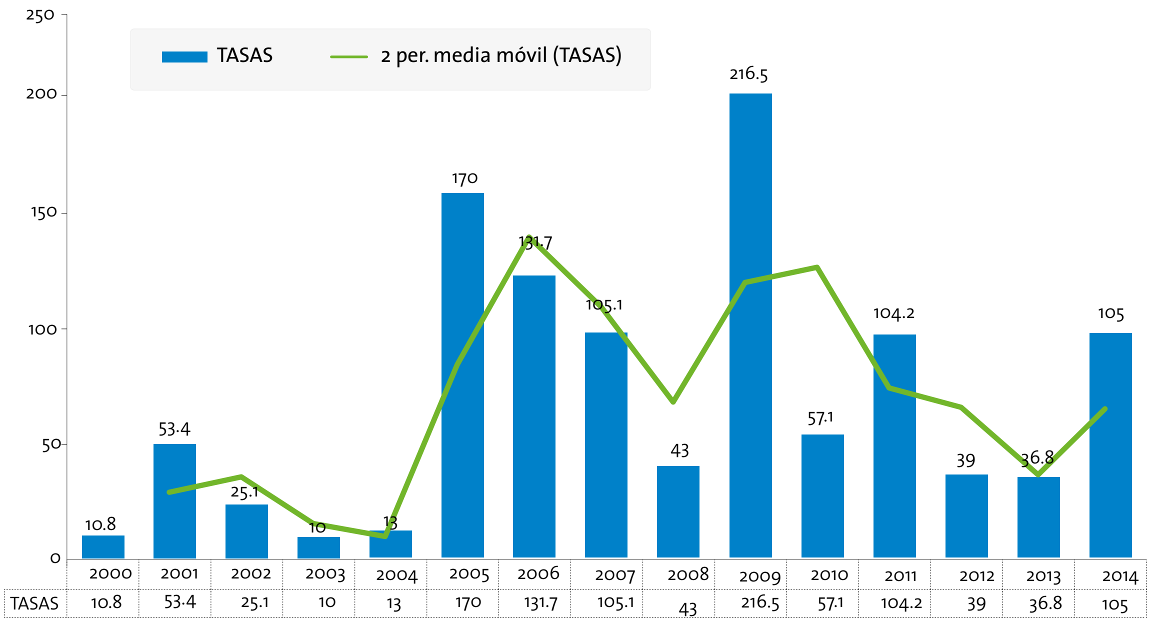
The annual incidence of **dengue** fluctuated between 2005 and 2013 (Figure 6), with the lowest rate per 100,000 inhabitants being reported in 2013 (36.8) with six severe cases of **dengue** and no deaths. During this period, the highest rate was reported in 2009 (216.5), with 46 severe cases of **dengue** and seven deaths. It is striking that in 2011, with 51% of the number of cases reported in 2009 and a rate of 104.2 cases per 100,000 inhabitants, there were 38 severe cases of **dengue** and 17 deaths, making it the year with the highest number of deaths since 1993, when the first case of indigenous **dengue** was reported. That year (2014), the number of cases exceeded the figure reached in 2011, indicating the lack of sustainability in **dengue** control in Panama. By June 2014, the surveillance system had detected three imported cases of **chikungunya**, from Dominican Republic and Haiti (http://articulos.sld.cu/dengue/tag/panama/).

With regard to **malaria**, from 2005 to 2013, morbidity rates experienced a sustained decline from 113.6 cases per 100,000 inhabitants in 2005 to 9.5 in 2011 with a slight increase in 2012 (23.4). In recent years, the mortality rate has remained low with a stable trend. It is important to note that **malaria** cases do not occur in urban areas, except for certain sporadic imported cases. Endemic areas include Darién, the Guna Yala region, Bocas del Toro and the Ngäbe Bugle region. Lastly, the last cholera outbreak in Panama was reported from 1991 to 1993, since when no further cases have been reported.

4.2 Algae, Cyanobacteria and Toxins in Water Treatment Plants

In the urban area of Panama City, there are two water treatment plants: in Chilibre and Miraflores; the former run by the Institute of Aqueducts and Sewers (IDAAN) and the second by the Panama Canal Authority (ACP).

Figure 6. Dengue incidence rates in Panama, 2000-2014



Data from the Panamanian Ministry of Health, 2014

According to Guerra and Marciaga (2012), since 2012, the IDAAN Water Quality Laboratory has performed tests to detect the presence of algae, cyanobacteria and toxins in supply sources and treated wastewater in the Chilibre, Rufina Alfaro Los Santos, Roberto Reina Chitre and Santiago de Veraguas plants. Guerra and Marciaga (2012) they also note that the Chilibre plant has algae that produce a distinctive taste and odor, such as *Staurastrum* and cyanobacteria such as *Gomphosphaeria, Anabaena, Oscillatoria, Cylindrospermum*, the latter being one of the most toxic cyanobacteria.

The ACP has various water quality monitoring programs, in both the basin and the water treatment plants in Miraflores, Monte Esperanza and Mendoza. The water quality index (WQI) in the Gatún and Alajuela reservoirs ranges from good to excellent. In the raw water intake in Paraíso and Gamboa, there are green algae and diatoms that are sometimes displaced by cyanobacteria, as happened in 2011, when the nontoxic cyanobacteria Cyanogranis ferruginea was identified in the Gamboa water intake. The ACP maintains a surveillance system for detecting cyanobacteria outcrop with a sensor attached to the HIDROLAB DS5 probe, with a neighborhood watch system, and monitors microcystins in water intakes and certain points of the purification process, in addition to using techniques for the detection of potentially toxic cyanobacteria genes.

4.3 Biological Water Quality in Water Treatment Plants

4.3.1 Detection of *Giardia* spp. and *Cryptosporidium* spp. in Water Treatment Plants

Annual ACP reports since 2005 state that monitoring of the presence of *Giardia* spp. and *Cryptosporidium* spp. in the Miraflores (Panama) and Monte Esperanza (Colón) treatment plants continues as part of water quality monitoring. At the same time, the functions of the Public Services Authority (ASEP) and prior to that, the Public Services Regulator in 2003 as an external entity, include monitoring water quality from the biological point of view and ensuring that treatment plants in Panama City monitor the presence of cyanobacteria, toxins and protozoa.

Studies on treatment plants in communities around the capital by Rivera et al. (1991) reported *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts in raw water treatment plants in La Chorrera, Chitre and Chepo during the dry season although results for the rainy season in the three treatment plants were negative. Similarly, the study by de la Cruz et al. (1997) indicates the presence of *Giardia* spp. and *Cryptosporidium* spp. oocysts in raw and treated water from the treatment plant in La Chorrera in the dry season, and only *Cryptosporidium* spp. in treated water in the rainy season. The Colón purification plant reported the presence of *Cryptosporidium* spp. in raw water during the rainy season. However, in the Chilibre treatment plant, which supplies water to most of the urban population in the capital city, the presence of these parasites was not detected.

4.3.2 Studies on the Microbiological Quality of Water in Treatment Plants

Herrera et al. (2005) studied the microbiological quality of drinking water from the distribution networks of the metropolitan area and La Chorrera and failed to detect the presence of fecal coliform. It was also found that the concentration of heterotrophic bacteria was within the quality parameters. In a similar study on the purification plants of Monte Esperanza, Sabanitas and Rio Gatún, Abre et al. (2008) reported that water quality in these water treatment plants met COPANIT-DGNTI 1999 standards. In a study undertaken at the Mendoza water treatment plant in La Chorrera and its distribution networks, Barranco and Gonzalez (2010) proved the presence of total coliforms, fecal coliforms and heterotrophic of above acceptable values during the first three months of operation, with variability according to the month and point of sampling.

4.4 Studies on the Water Quality of Natural and Recreational Urban Sources

Pimentel et al. (2007) conducted a study on the microbiological water quality of Lago de las Cumbres with regard to the presence of fecal and total coliforms, finding a fluctuation in the density of these entities with a greater presence in September, when the highest rainfall was recorded. In a similar study on the Juan Díaz river, Acevedo and Sánchez (2009) determined that the highest level of pollution in the river is at the bottom near the mouth, the greatest incidence being in October. Chifundo and Hughes (2011) reported that in Gatún Lake, the presence of total and fecal coliforms is higher in places associated with increased anthropogenic activity during the rainy season. Lastly, no studies have been conducted in Panama to determine the presence of free-living amoebae in recreational waters nor have cases of primary amoebic meningoencephalitis, or granulomatous amoebic encephalitis been documented.

4.5 *Cryptosporidium* and *Giardia* in children under five

Álvarez et al. (2010) found that *Cryptosporidium* spp. has a prevalence of 6.4% in children under five in a study covering various parts of the country, adding that Chorrera had the highest prevalence (16%), followed by Panamá Metro (11%). It is striking that although the studies by De la Cruz et al. 1997 and Rivera et al. (1991) were undertaken several years ago, they coincide as regards the high incidence of cryptosporidiosis in children under five in La Chorrera. Álvarez et al. (2010) found a relatively high prevalence of *Giardia* spp. (10%) in the same population, although this was not the highest rate recorded.

5. Variability and Climate Change, their Impact on Water Resources in Cities

5.1 Climate Change in Panama: Observations with an Emphasis on Cities

According to the IPCC (2013), climate change is unequivocal and its impact tends to increase over time. The Fifth IPCC Report has placed particular emphasis on the assessment of climate change in urban areas, acknowledging that many climate change risks worldwide are concentrated there: heat waves, extreme precipitation events, floods, landslides, air pollution, drought and water shortage (IPCC, 2014). The IPCC also indicates (2014) that Latin America is one of the geographical regions with the highest percentage of urban population (82%). This percentage far exceeds the world average of urban population, which, according to the Millennium Ecosystem Assessment, was approximately 50% in 2005. The high percentage of urban population, along with other factors that increase the vulnerability of such populations, has underlined the importance of focusing on adaptation to climate change in urban areas.

Patterns of human settlements around the world, the dynamics of urbanization and unequal economic conditions have contributed to the current trends in vulnerability to extreme events and impacts related to climate change (IPCC, 2012). As indicated by the IPCC (2014), rapid growth of urban areas has led to the emergence of areas that are highly vulnerable to extreme weather events, especially in developing countries. The metropolitan area of Panama City is experiencing rapid growth. Panama's urban population has increased exponentially, from 36% in 1950 to over 62% in 2000 (ANAM, 2012). This population growth, coupled with poor urban planning and an unprecedented rise in the frequency of extreme events increases vulnerability and the magnitude of impacts. These facts point to the need to implement strategies to address climate change, both as regards adaptation and mitigation, but especially adaptation, since the impacts of climate change are affecting the quality of life and ecosystems in Panama.

5.2 Climate Variability and Climate Change

Olmedo and López (2014), in the "GEO Report 2014: Behavior of some aspects of the climate in Panama," analyzed the variables of precipitation and temperature for five weather stations nationwide. Analyses of precipitation (for the periods from 1970 to 2012 or 1974 to 2012) and wind temperature for the period from 1971 to 2012 were undertaken.

In general, an upward trend in both precipitation and wind speeds was observed over time. An example of these trends can be seen in Figures 7-9, corresponding to the Tocumen Station in Panama City. This station was chosen because it was the only one in the study in the metropolitan area. As one can see from these figures, both maximum and minimum temperatures experienced an increase of approximately one degree in approximately 40 years. Likewise, total annual rainfall during this period rose by about 55 mm (Figures 7-9).

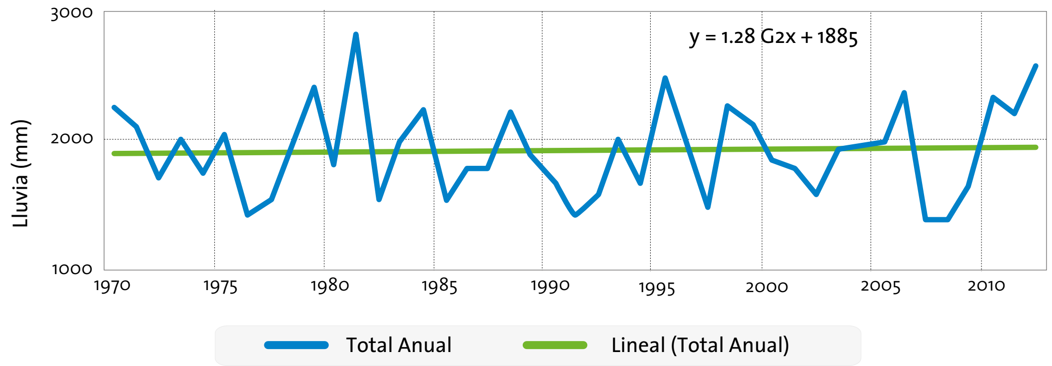
5.3 Extreme Hydrometeorological Events and their Impacts

According to the IPCC, there is a "statistically significant trend of extreme precipitation events in some regions" (IPCC, 2012, p.6). Climate change involves changes in the frequency, intensity, duration and spatial and temporal distribution of extreme events, which may cause disturbances in the functioning of natural and human ecosystems (Marengo, 2013). Over the past 30 years, Central America has seen a significant upward trend in temperature and an increase in extreme events including storms, floods and droughts (IPCC, 2014). In this respect, Garlatti (2013) indicates that during the period from 1987 to 1998, the annual number of disasters related to climate change in developing countries was 195, whereas in the period from 2000-to 2006, this figure rose to 365. These statistics indicate an increase of 87%. Garlatti also maintains that 75% of the disasters in the 1990s were related to climate events, with the largest number of events being in the category of floods and droughts, while more than 95% of the deaths caused by natural disasters occurred in developing countries.

Observations of climate variability and change, like the associated impacts, indicate that the most important consequences for Central America are related to extreme weather events, including floods, landslides and droughts (Garlatti, 2013). The Central American Integration System (SICA) has acknowledged that there is high variability of annual precipitation in the region, where intra-annual patterns have disrupted the temporal and spatial distribution of precipitation. In this respect, Aguilar et al. (2005) argue that although there are no significant differences in the total amount of annual rainfall in the region, there has been an increase in the periods of wet and very wet days, indicating a rise in the number of extreme precipitation events.

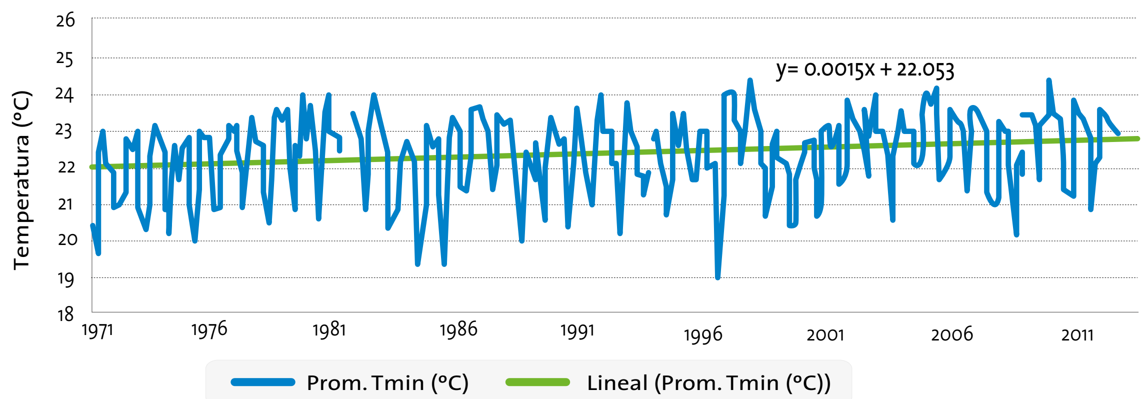
In the case of Panama, Fábrega et al. (2013) reported an increase in the frequency of extreme precipitation events. The main impacts of climate change in Panama are related to the occurrence of extreme precipitation events and the consequent flooding and landslides due to the saturation of slopes and the increased incidence of vector-borne diseases such as **dengue**. ANAM indicates, for example, that

Figure 7. Dengue incidence rates in Panama, 2000-2014



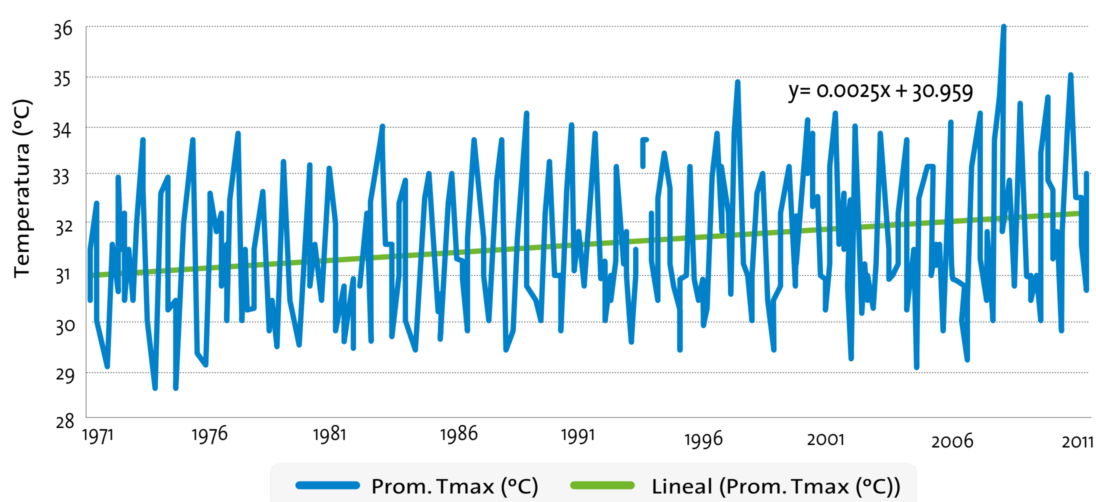
Olmedo and López, 2014

Figure 8. Average Minimum Temperature at Tocumen Station. Period from 1971-2012



Olmedo and López, 2014

Figure 9. Average Maximum Temperature at Tocumen Station. Period: 1971-2012



Olmedo and López, 2014

since 2004 there has been an unusual increase in the magnitude and frequency of extreme events, especially hydro- meteorological events (2011). This is confirmed by data obtained from international disaster databases.

The most important extreme precipitation event for the metropolitan area occurred in December 2010. This storm is known as "La Purísima," a name that refers to recent rainfall in the rainy season occurring about five days before or after December 8, the feast of the Immaculate Conception of the Virgin Mary (Espinosa, 2010). According to ACP records (Espinosa, 2010), La Purísima was the largest, three-day storm in the history of the Panama Canal watershed, producing a record 760 mm of rain in 24 hours. The rainfall recorded from December 7 to 9 2010 was between two and five times greater than normal precipitation in December, corresponding to a return period of 400 years (ACP, 2011a). Moreover, in all the major rivers in the Panama Canal watershed in December 2010, there were higher than average flows for the month, exceeding the latter by between 200% and 400% (ACP, 2011a). As a result of this precipitation event, the flooding of major rivers that flow into Lake Alajuela and over 500 landslides produced excess sediment in the water bodies (ACP, 2011b).

One of the main impacts of climate change in the urban areas of Panama are floods. These are likely to become more common over the next 100 years in regions with high precipitation levels. In addition to the human and economic losses associated with flooding, these events pose a risk to human health through the spread of infectious, water- borne and vector-borne diseases.

Figure 10. Location of Panama's five major cities

DesInventar, 2014

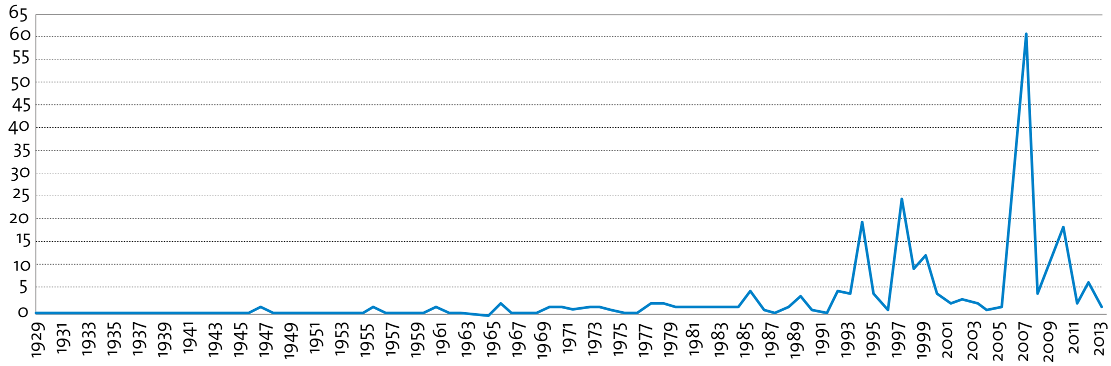
The "DesInventar" database was used to analyze the occurrence of floods in major cities in Panama: Panama City and San Miguelito, Colón, Santiago de Veraguas and David, shown in Figure 10. The "DesInventar" database was developed in 1994 by the Network for Social Studies on Disaster Prevention in Latin America (The Network), to provide decision makers with data on disaster events and the number of people affected. This database contains information on medium- and large-scale disasters in Latin America over the past 40 years. In Panama, the organization responsible for updating the database is the National System of Civil Protection (SINAPROC).

The historical records in "DesInventar" indicate an increase in recent decades in flood events and the number of people affected by these events, as can be seen in Figures 11 and 12. A comparison of the number of people affected in each city shows that Panama City has the highest proportion of people affected by floods in urban areas of Panama (Figure 13).

Another important impact of extreme precipitation events and landslides experienced in the urban areas of Panama is the disruption of the functioning of water systems. The clearest example is the La Purísima event in 2010. Landslides caused by the storm had resulted in the excessive sediment in suspension in Lago Alajuela, which increased turbidity to values of over 700 Nephelometric Turbidity Units (Espinosa, 2010). Lake Alajuela captures water from the main water treatment plant for human consumption supplying Panama city. This plant collapsed, since it was unable to handle the high levels of turbidity, leaving much of Panama City without drinking water for approximately 50 days (Espinosa, 2010). Another important impact of this extreme event was the interruption of the passage of ships through the Panama Canal for 17 hours (www.laprensapanama.com).

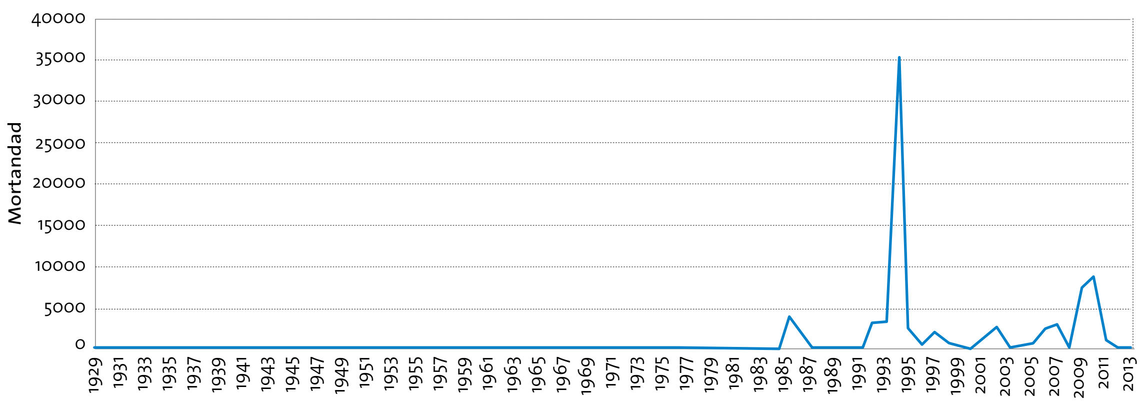
The alteration of water resources due to climate change also has implications for hydropower generation. Panama's energy matrix consists of approximately 60% of hydropower. Panama City has suffered the impacts of drought in watersheds that feed the main hydropower generating plants. One example was the suspension of classes for three days at schools and universities in Panama in May 2013. In 2014, it was also necessary to implement energy saving measures to cope with the low levels

Figure 11. Floods in five cities in Panama, from 1929 to 2013



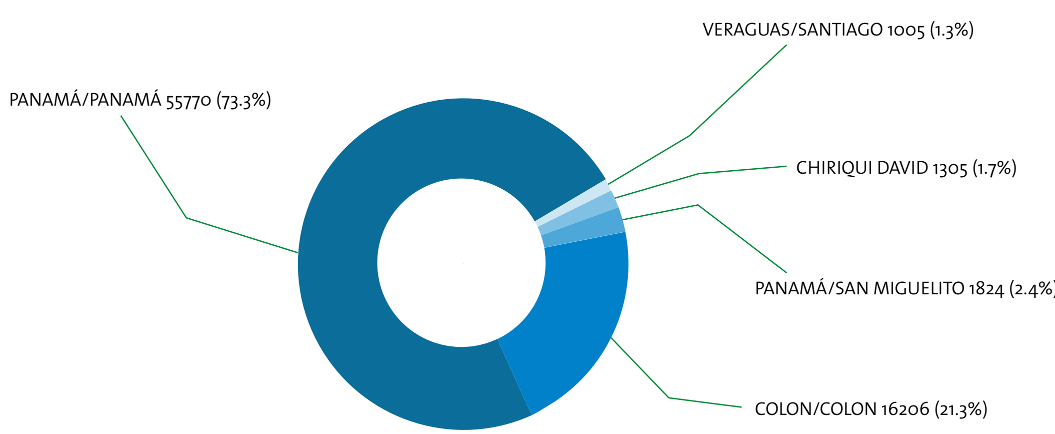
DesInventar, 2014

Figure 12. Number of people affected by floods in five cities in Panama, from 1929 to 2013



DesInventar, 2014

Figure 13. People affected by floods in five cities in Panama



DesInventar, 2014

of hydroelectric generation due to lack of water in the reservoirs, because the dry season extended beyond the normal limit.

5.4 Increased Incidence of Vector-Borne Diseases

Global warming and climate change and variability are producing significant impacts on human health in Central America (IPCC, 2014). Specific impacts reported by the Fifth IPCC Report include: respiratory and cardiovascular diseases, waterborne diseases and those transmitted by vectors such as **malaria**, **dengue**, yellow fever and hantavirus. Climate change will exacerbate existing risks and vulnerability due to population growth, health services and sanitation, including waste management and environmental pollution (IPCC, 2014).

One disease that has affected Central America in recent decades is **dengue**. Epstein (2000) argues that **dengue**, a disease that had been virtually eradicated in the Western Hemisphere, re-emerged with more than 200,000 cases in 1995. Statistics show that these numbers have tended to increase over the years. The proliferation of *Aedes aegypti* and **dengue** incidence has been such in recent decades that the World Health Organization has listed it as one of the major public health problems, because in the past 25 years, it has reached epidemic proportion in some countries in the Americas (San Martin and Brathwaite, 2007). These authors reported **dengue** cases in at least 30 countries in the Americas, with approximately 3 million cases between 2000 and 2005, of which 65,235 were severe cases, causing approximately 800 deaths.

5.5 Addressing Climate Change Issues Through an Appropriate Legal and Institutional Framework

Around the world, all levels of government are accumulating experience concerning climate change adaptation and there are a number of cities that are taking the route of resilience seriously (Newman et al., 2009). However, the experiences reported for Central America focus very little on urban resilience and are related more to the management of natural areas, crops and integrated water resource management (IPCC, 2014). Increasing urbanization of the region, coupled with the need for improved infrastructure systems such as aqueducts, sewerage and other basic systems means that there is an urgent need to increase adaptation measures in urban areas. Among the strategies for addressing climate change, the legal and institutional framework plays a very important role, as do capacity building, research and structural and non-structural solutions.

To address climate change in Panama, with regard to both adaptation and mitigation, institutional and legal developments include the adoption of the National Policy on Climate Change within ANAM and the creation of the National Committee on Climate Change, with representatives from 27 public sector institutions including the academic sector.

To meet international commitments on the issue of climate change, Panama has submitted two National Communications to the United Nations Framework Convention on Climate Change. The Second National Communication, submitted in 2011, states that according to the greenhouse gas inventory using 2000 as the baseline, Panama is a carbon fixing country. The Panama National Plan for Integrated Water Resource Management 2010-2030, designed to guide decision-making "to maximize the economic, environmental and social role of water" (ANAM, 2011), was recently passed. This plan includes climate change analysis, risk management and vulnerability and considers climate scenarios for Panama, extreme events and their impact on water resources and mitigation and adaptation options, among other aspects.

5.6 Factors of Urban Resilience to the Impacts of Climate Change

Various alternatives have been designed to increase urban resilience to climate change. One of the most important alternatives being promoted worldwide are green buildings. In Panama, buildings with LEED (Leadership in Energy and Environmental Design) certification are promoted through the Panama Green Building Council, affiliated to the World Green Building Council. The Panama Green Building Council was formed in 2009 to promote sustainability in Panama through the design, construction and operation of buildings with LEED certification (www.panamagbc.org).

According to information provided by the Panama Green Building Council, there are currently 10 LEED certified buildings in Panama City and 60 registered projects. Panama ranks second in Central America and the Caribbean in terms of LEED certified buildings. It is important to note, however, that in Panama there are currently no incentives for sustainable construction. Another structural solution that helps increase resilience to flooding are permeable pavements, whose use in Panama requires further study.

In addition to structural solutions, urban resilience to climate change depends on sensitizing the public and awareness of the role each plays in both the problem and the solution. A change in lifestyle that includes a reduction of consumption patterns and the promotion of healthy lifestyles is needed since a population with adequate health conditions are more likely to cope successfully with the disruption of systems caused by extreme weather-related events.

6. Final Considerations

We can infer from this chapter that Panama is a country with abundant water resources. However, their use as a source of drinking water for urban areas has focused almost exclusively on surface water sources. Likewise, although over 90% of the population has access to potable water in general, there are still regions (particularly indigenous areas) where less than half the population has access to potable water.

In the case of wastewater management, the past few years have seen enormous progress in both the legal framework and operational aspects. In recent years, nearly 100 wastewater treatment plants (WWTP) with secondary treatment have been built, particularly in new urban developments. At the same time, there has been heavy investment by the state since 2006 through various governments with the “Sanitation of Panama City and Bay,” project which includes a WWTP, which, once the three phases of the project have been completed, will collect approximately 70% of the sewage from Panama City, with tertiary treatment to be provided in Panama. It is a matter of concern, however, that this investment is not accompanied by providing IDAAN, the institution ultimately responsible for financing these WWTP, with the management capacity (human and financial resources) required to accomplish this task.

With regard to health, dengue can currently be said to be one of the major public health problems in Panama. Studies show that the presence of Giardia spp. and Cryptosporidium spp. has been detected in sources of raw water for treatment plants in urban centers, particularly in the dry season. This situation requires increased surveillance of the presence of these parasites to prevent a possible outbreak of related diseases.

Finally, the relationship of urban waters with climate change is more important every day. Two aspects should be noted here: first, the increase in extreme events and the vulnerability of urban areas to these phenomena, and second, the need not only for structural responses that require the investment of resources, but also greater awareness on the part of citizens about the role we all play in the problem.

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