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Rainwater harvesting in public buildings : health issues, geographic areas of interest, regulation and local settings

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SYNTHESIS

Rainwater harvesting in public buildings: health issues, geographic areas of interest, regulation and local settings

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ABSTRACT

This synthesis is about rainwater harvesting systems in public facilities in four distinct parts of the world: France, Texas, South Australia and Uganda. The main aim is to provide a general understanding about when rainwater harvesting is implemented in these different geographic areas. For each state, the origin of rainwater harvesting is explained and put into the context of differing climatic, historic, and economic patterns. The regulatory frameworks and technical details concerning rainwater harvesting are compared. A spotlight is shone on the existing rules of connexion between the public water supply and rainwater supply systems, particularly appropriate cross connection safeguards and the distinguishing features of both networks. This paper highlights the outdoor, potable and no potable indoor purposes of rainwater around the different geographic areas. As far as possible the norms of quality for each usage are explained. According to the state the public facilities allowed for the use of rainwater vary. The synthesis will conclude by examining the factors in favour of the development of rainwater harvesting systems by highlighting the existing financial contributions or rebates offered and by providing examples of successful projects. The potential for the further development of rainwater harvesting is also described.

Keywords : Rainwater harvesting, rainwater, France, Texas, South Australia, Uganda, public facilities, local settings, regulatory frameworks, rainwater plumbing guides, guidelines, potable and no potable indoor purposes, sanitary requirements**,** norms of quality, financial contributions.

RESUME

Cette synthèse porte sur la Récupération et Utilisation de l'Eau de Pluie (RUEP) dans les bâtiments à usage public. Elle se focalise sur quatre zones géographiques : France, Texas, Australie Méridionale et Ouganda. L'objectif principal de cette étude est de parvenir à cerner les raisons d'installation de dispositifs de RUEP dans ces différentes régions du monde. Pour chaque Etat, l'origine de l'émergence de la RUEP est croisée avec son contexte climatique, historique et économique. Le cadre réglementaire et les règles de l'art de mise en place de dispositifs de RUEP sont étudiés. Un focus portant sur les règles de connexion du réseau d'eau de pluie au réseau de distribution public d'eau potable est réalisé : système de déconnexion par surverse et code de distinction des réseaux. Ce document met en valeur les différents usages extérieurs, intérieurs potable et non-potable de l'eau de pluie dans ces quatre Etats. Dans la mesure du possible, les normes de qualité pour chaque usage de l'eau de pluie sont communiquées. Suivant les Etats, les bâtiments à usage public autorisés à pratiquer la RUEP ne sont pas les mêmes. Cette étude mettra en exergue les facteurs contribuant activement au développement de la pratique de la RUEP en présentant des projets réussis et l'existence d'aides financières suivant les pays. Des enseignements à tirer pour un développement de la RUEP seront aussi fournis.

Mots clés : Récupération et utilisation de l'eau de pluie, eau de pluie, France, Texas, Australie Méridionale, Ouganda, bâtiments à usage public, contexte local, cadre réglementaire, guide de plomberie, recommandations, usage potable et non potable de l'eau de pluie, exigences sanitaires, normes de qualité, contributions financières

LIST OF ABBREVIATIONS

AWQC : Australian Water Quality Center ;

CSHPF : Conseil Supérieur d'Hygiène Publique de France ;

DGS : Direction Générale de la Santé ;

MWE : Ministry of Water and Environment ;

RWH: Rainwater Harvesting ;

SA Water : South Australian Water ;

SDWA : Safe Drinking Water Act ;

US EPA : the United States Environmental Protection Agency ;

TWDB : Texas Water Development Board ;

URWA : Uganda RainWater Association.

Table of contents

INTRODUCTION

Rainwater Harvesting (RWH) varies according to the country concerned. The reasons for rainwater harvesting are diverse: the use of an alternative resource to drinking water in an eco-citizen spirit, access to a water resource for primary needs, the search for better quality water than the public distribution system, the desire to save money on water bills, or managing stormwater on site.

RWH system also known as impluvium, is made up of 3 main components: a catchment area (roof or membrane), a delivery part (gutters, down pipes, first flushing pipe and filter unit) and a storage system (storage tank or cistern).

My study concerns the RWH exclusively in public buildings: residential buildings, hotels, schools, offices, hospitals, industrial or agricultural facilities etc. It will focus on four geographical areas: France, Texas, South Australia and Uganda. This selection took place firstly on the number and the quality of the documentary resources found. In order for the panel of states to be representative of the diversity of uses that can be made of rainwater, I had to choose geographical areas where the primary motivation of the rainwater harvesting was not the same. Moreover, it seemed appropriate to find regions of the world where this practice was or was not framed (quality criteria relative to use, technical details). Finally, I found it wise to select my sample of states on different continents: Africa, North America, Oceania and Europe.

The objective of my technical synthesis consists in a first phase to compare the above geographical areas according to different criteria: the existence or otherwise of regulations governing RWH, the abundance or the restriction of usages of rainwater, for each type of usage the existence or not of minimum water quality to be followed, the knowledge of the public buildings practicing the RWH, the government's motivation to educate the population to practice it. At the end of this comparison it will be easy to understand why one State is ahead of the others. But also, to determine what was the major element that favored the emergence of the practice.

What are according to the States the obstacles to the development of the RWH and, on the other hand, the strengths suggesting a progression of this practice in the future? To do this, a summary of RWH will be completed for each State, starting first with the study of the local context of the geographical area. This will consist in crossing the climatic situation of the States with data on the distribution of water resources. We will then examine the regulatory framework governing RWH. Finally, the socio-historical aspects of this practice will be studied. At the end of the study of the different states, we shall try to compare where they are in respect of this practice and explain the main reasons.

FRANCE

PRESENTATION OF THE STUDY AREA AND LOCAL SETTINGS

Water availability and resource allocation

In France, we are a long way from the stakes of water stress encountered by some countries located in arid climatic zone. The country has a water resource that is abundant. At the beginning of 2016, France had 64.5 million inhabitants (Nauze-Fichet et al., 2016). In 2012, 30 billion cubic meters of fresh water were collected in metropolitan France to meet the needs of the different sectors of activity. With 63% of the total volume of water withdrawn, the energy production sector leads the way. But it is actually very low water consumption (22%), since the majority of the water withdrawn is returned to rivers. Conversely, water withdrawals from the agricultural sector account for 3 billion (9%) of the total water withdrawn, but irrigation is the most water consuming sector (48%), compared with 24% for the production of drinking water (Le Centre d'information sur l'eau, 2015).

Climate and precipitation

France, an average sized territory of 640,000 km², is subject to a temperate climate. It falls on average 867 mm / year. Depending on the region, precipitation varies (Groupe de la Banque Mondiale, 2016).

LEGISLATION AND REGULATION OF RWH

European framework

The most important directive is **Directive n° 98/83/CE** on the quality of water intended for human consumption (cf. appendix 1).

French framework

Article **R.1321-1 of the Public Health Code (CSP)** transposes the above European Directive into national law (cf. appendix 1).

In France, the **decree of 21 August 2008** stipulates t**he authorized uses of untreated rainwater recovered downstream from inaccessible roofing** (cf. appendices 1 et 2). **Important rules must be observed in the event of a backup by the public drinking water supply network** and to facilitate the distinction between the two networks (cf. appendix 1).

The decree of 17 December 2008 and **the circular of 9 November 2009** define and specify the **conditions for the control of rainwater harvesting installations**.

SOCIO-HISTORICAL ASPECTS OF RWH, STRENGTHS AND LIMITS

History of RWH

In France, RWH is an ancient practice dating back to the Middle Ages, which had almost completely disappeared in the 19th century in urban areas with the development of major public drinking water networks (De Gouvello, 2015). **The renewed interest in the recovery of rainwater in France is linked to the water scarcity management plan of October 2005**. Indeed, some regions have faced successive drought episodes. This management plan is a set of measures to restore the balance between water supply and demand in the medium term. It defines a framework for action to support the emergence of new innovative techniques for water valuation: RWH, the reuse of treated wastewater, winter groundwater recharge etc. This plan for managing water scarcity requires legislative adaptations that are taken through the draft Loi sur l'Eau et les Milieux Aquatiques : LEMA (2006) (Boinel et Ministère de l'Ecologie et du Développement Durable, 2006).

In addition to the management plan, the emergence of environmental sensitivity and the development of eco-construction are other factors in the re-emergence of RWH.

The criterion of profitability (return on investment via savings on the drinking water bill) is very rarely used to encourage property developers to set up RWH systems. The motivation of promoters revolves around obtaining an environmental label, exemplarity and an educational role. In 2011 the First National Adaptation Plan to Climate Change was published and which aims to develop water savings.

Advantages of RWH and examples of successful projects

In general, RWH projects are justified by an environmental interest expressed in terms of alternative management of rainwater and preservation of water resources, but also by an eco-citizen approach (Herault et al., 2006).

Experience shows that the most suitable buildings for rainwater harvesting are secondary schools, residential buildings, office buildings, industrial buildings and cultural buildings (De Gouvello, 2015) (cf. appendix 3).

In 2011, an inventory of RWH was carried out in 55 French Departments. The analysis was carried out on a sample of 367 RWH operations excluding individual housing (cf. appendix 4). It emerges from this analysis that the Nord-Pas de Calais, Lorraine and Bretagne are the most motivated regions by this practice. The main motivations of the project owners are savings in drinking water and pedagogical motivation for teaching institutions. Of the 367 projects identified, 40% use rainwater for outdoor use, 18% for domestic use, 15% for outdoor and indoor uses, and the remaining 27% do not specify (Mucig et al., 2013). Although not relating to public buildings, but having promoted the development of RWH in France, a tax credit for the equipment of the main house was voted in 2006 through the LEMA and was the subject of a decree (decree of 3 October 2008). This decree was extended until 2015 (Boinel et Ministère de l'Ecologie et du Développement Durable, 2006). In 2017, RWH systems are not eligible for the Energy Transition Tax Credit (Crédit D'impôt Transition Énergétique ou CITE). The reasons are unknown. On the other hand, some municipalities subsidize the installation of devices. It is recommended to contact one's department to find out. (ECO infos Energies renouvelables, 2017).

Obstacles to development

In France, there is reluctance on the part of the public authorities (la Direction Générale de la Santé, DGS and le Conseil Supérieur d'Hygiène Publique de France, CSHPF) to use rainwater whatever the use (cf. appendix 5). The arguments put forward are that the drinking water network offers a better level of safety with regard to consumers and a better comfort of use (pressurised water) (Herault et al., 2006).

The French state has difficulties in promoting rainwater harvesting because it is unprofitable to make savings on its water bill: the need to take into account the price of water at local level, the necessary investment and the sewerage charges for indoor use (De Gouvello, 2005).

French health institutions perceive RWH as potential risks of health regression. **These are indeed the brakes in France to the developments of this practice**. Moreover, professionals see the RWH's progression in France as a long-term disruption of the logic of major projects and management of centralized and industrial water networks (De Gouvello, 2005).

TEXAS

PRESENTATION OF THE STUDY AREA AND LOCAL SETTINGS

Water availability and resource allocation

The population of Texas in 2016 was 27.9 million (United States Census Bureau, 2016). It is expected to double over the next 50 years. At the same time, declines in surface water and groundwater resources are predictable for reasons such as sedimentation in reservoir dams and declining aquifer yields. (Texas Rainwater Harvesting Evaluation Committee, 2006a).

Some regions are already facing water shortages, partly because demand exceeds available supplies. [1]

Texas is regularly affected by **periods of severe drought** (Géoclimat, 2011) (cf. appendix 7). In order to address this issue, the State has put in place successive plans dedicated to the management of water in the event of drought. The latest is the State Water plan 2012 (Bernollin, 2014). In this sense, RWH could provide Texas residents with the opportunity to maintain and expand their existing water resources.

In terms of resource allocation, the agricultural sector is the largest consumer of water, accounting for almost 60% of total water consumption, of which 86% comes from groundwater, 11.6% from surface water, and 2.4% of a combination of the two (Bernollin, 2014). Similarly, the energy industry is a very important sector and consequently uses a significant amount of water.

Climate and precipitation

The climate is of subtropical humid type in the southeast, dry continental inland, dry subtropical in the west and desert in the extreme west. Annual precipitation ranges from 1538.5 mm in Jasper County in the east and 239.5 mm in El Paso in the west (cf. appendix 8). Texas is drained by many coastal rivers - Nueces, Brazos, Neches - and limited to the southwest by the Rio Grande (Buchot, 2016). The vegetation passes from the dense forest (to the east) to the desert soil strewn with cactus (to the west).

LEGISLATION AND REGULATION OF RWH

Federal legislation on RWH.

At federal level, there is no legislation or regulation dealing specifically or in part with RWH (De Gouvello et al., 2012). Nevertheless, several elements of federal water policy are likely to contribute to its development.

At national level, the **Safe Drinking Water Act (SDWA)**, developed in 1974, is the law that protects the health of the population by regulating drinking water utilities (cf. appendix 1). The SDWA delegates to **the United States Environmental Protection Agency (US EPA)** the development of drinking water quality standards (the National Primary Drinking Water Regulations) and ensures that they are met by the public water supply (United States Environmental Protection Agency, 2004).

Texas State Regulations

At the present time, there is no national law on rainwater harvesting at US level. In Texas, however, several laws in favor of rainwater harvesting have been passed at various legislative meetings (Texas Legislature). The Legislature consists of the Senate and the House of Representatives.

In 2005, **the Texas Water Development Board (TWDB)** published a technical guide on RWH: **The Texas Manual on Rainwater Harvesting** (Texas Water Development Board et al., 2005). The objective of the TWDB is to promote rainwater harvesting by providing financial assistance for public rainwater supply projects at district and municipality level. In Texas, rainwater is used for all uses, including those requiring drinking water quality, subject to appropriate treatment (cf. appendix 1).

[1] Additional information on the local settings can be found in appendix 6.

In 2005, the Rainwater Harvesting Evaluation Committee, consisting of the TWDB and three other agencies, was established: Texas Commission on Environmental Quality, Department of State Health Services, and the Texas Section of the American Water Works Association. This Rainwater Harvesting Committee recommends minimum rainwater quality standards for indoor (potable and non-potable) use. It provides methods for the treatment of rainwater for indoor use, with which it is possible to use water from the public distribution network (The Legislature of the state of Texas, 2005).

In 2011, Texas Legislature introduced n**ew measures to be followed for the installation of rainwater harvesting systems** (cf. appendix 9).

SOCIO-HISTORICAL ASPECTS OF RWH, STRENGTHS AND LIMITS

History of RWH

Rainwater harvesting has occurred historically and has developed in isolated areas not served by a public water utility. This is true around farms. RWH then spread to cities following droughts (De Gouvello et al., 2012)

Advantages of RWH and examples of successful projects

RWH in Texas is very encouraged by the TWDB's actions, which organize annual elections of the most attractive RWH projects (Texas Water Development Board, 2007) (cf. appendix 10). But also through the laws of the government such as **House Bill 3391**, voted in 2011 (cf. appendix 1).

The TWDB believes that the practice of rainwater harvesting, particularly in urban and suburban areas, has a little exploited potential, whereas the latter could generate a very interesting additional water supply. It argues that if an urban area the size of Dallas used just 10% of the roofs of the city to harvest rainwater, 2 billion gallons, or 7.6 million gallons m^3 of drinking water would be saved (Texas Rainwater Harvesting Evaluation Committee, 2006c).

Obstacles to development

In Texas RWH systems are not regulated by the building code and the lack of guidelines can discourage homeowners and property developers from installing these systems. (Texas Water Development Board, 1999)

SOUTH AUSTRALIA

PRESENTATION OF THE STUDY AREA AND LOCAL SETTINGS

Water availability and resource allocation

The Commonwealth of Australia has about 24.1 million Australians (Australian Bureau of Statistics, 2016). The majority of the population is located in the south - east of the country. The state of South Australia had 1.7 million inhabitants in 2016. The majority of the population is concentrated in Adelaide, along the South-East Coast and on the banks of the Murray River.

In rural areas, rainwater is of better quality than water from public drinking water networks. There is no concentration of pesticides in rainwater. However, particles derived from bush fires can give a taste to the water, or alter the color, but no impact has so far been noted on the quality of the water.

In most industrial regions of Australia, industrial emissions and gases from road traffic are not significant enough to affect the quality of rainwater. The quality of rainwater depends more on the catchment area. Except for a smelter in South Australia in Port Pirie, whose emissions lead to a lead concentration (61µg / L) in the rainwater collected in the storage tanks. The health authority (enHealth Council) advised residents not to consume rainwater and not to use it for personal hygiene (Environmental Health Committee (enHealth) of the Australian Health, 2011).

Climate and precipitation

There are two different climates in this state. On the coast, it is a Mediterranean climate. In the interior, there remains a semi-arid, even arid climate with many dried-up lakes. Most of the territory consists of vast desert or semi-desert expanses with several mountain ranges including Mount Lofty. Most precipitation occurs during the period from June to August. The average annual precipitation is 553 mm.

LEGISLATION AND REGULATION OF RWH

National legislation and regulations relating to RWH

In Australia drinking water is considered a foodstuff and may be subject to either general food legislation or specific drinking water legislation (Environmental Health Committee (enHealth) of the Australian Health, 2011).

The Australian Department of Health examined health issues related to rainwater harvesting and wrote a paper entitled **Guidance on use of rainwater tanks**, the latest version of which dates back to 2011. This guide provides information on the potential risks to the quality of rainwater, the preventive actions to be taken to stop these risks, the monitoring to be carried out, the maintenance activities and, where appropriate, the corrective actions to be taken (Environmental Health Committee (enHealth) of the Australian Health, 2011).

In Australia, many public buildings are used for rainwater harvesting and the uses are very varied (cf. appendix 1). Contrary to the situation in France the clothes washing is acquired. What is debated are uses for personal hygiene. The health authorities of the different States advise against rainwater for the preparation of meals or drinks, except for South Australia where these uses are the choice of the user (De Gouvello et al., 2012). For all uses requiring drinking water, care must be taken to ensure that the threshold values of the physico-chemical and microbiological parameters of the current **Australian Drinking Water Guidelines** are met. This is the drinking water quality standard in Australia, published by the Department of Health (Department of Health) (cf. appendix 1).

The use of rainwater in public buildings requires good maintenance of the RWH systems and continuous monitoring of the water quality distributed. The tests, their frequencies have to be planned in a risk management plan for the water supply of the building. This management plan includes various documents: the RWH plan (catchment area, storage tank, location of filling taps ...), the preventive measures plan, the monitoring process and the corrective actions to be taken if necessary (Environmental Health Committee (enHealth) of the Australian Health, 2011). Rainwater quality testing should be conducted by the **Australian Water Quality Center** (**AWQC**) (cf. appendix 11). In any case, a continuous treatment device must be installed. If the building is in an area at risk of pollution, chemical tests must be carried out as well.

The Australian and New Zealand Plumbing and Drainage Standard also noted **AS/NZS 3500** standard brings the regulations to follow to connect a RUEP device to indoor plumbing equipment: flush, water heater, washing machine etc. (cf. appendix 1).

Regulation established by the State

The AS/NZS Standard is supplemented by that of the State of South Australia **(South Australian Variations)**. Based on these two regulations, **Rainwater Plumbing Guide** produced by South Australian Water (SA Water) is a manual for plumbers, builders and owners to install standard RWH systems (South Australian Water, 2006).

In South Australia, the supply of rainwater through the drinking water supply system cannot be made without prior consultation with the local water authority (**Local Council**) in the city or district (cf. appendix 12).

The state of South Australia has its own regulations relating to construction: **"Building Rules"**. This regulation integrates RWH. (cf. appendix 13).

SOCIO-HISTORICAL ASPECTS OF RWH, STRENGTHS AND LIMITS

History of RWH

The practice of rainwater harvesting in South Australia dates back to the development of drinking water systems in the Commonwealth of Australia. It continues today to be a very common practice, due to its low population density and its often remote rural areas, making it impossible to cover public water supply networks (De Gouvello et al., 2012). In isolated areas of South Australia, the emphasis is on the use of alternative resources for all uses.

Advantages of RWH and examples of successful projects

There is no recommendation in South Australia regarding the use of rainwater for drinking. It's up to the owner to decide. This is because the state is sparsely populated and served by the public drinking water network (De Gouvello et al., 2012). Also as seen previously the uses of rainwater are very abundant and this in any type of buildings.

The State of South Australia, in comparison with the other states of Australia, is the one with the largest proportion of the population which owns rainwater tanks in its territory. Indeed, the network coverage of drinking water is very low. To this is added a low rainfall but also a population unsatisfied by the quality of the drinking water served (De Gouvello et al., 2012).

Since 2009, the existence of federal aid financed by the Australian government (Water Plan for the Future) has also encouraged this practice.

Obstacles to development

There is no real obstacle to the progression of RWH in South Australia. It is currently possible to use rainwater for toilets and to drink. In the other States of Australia, what is still debated is the use about personal hygiene. Drinking rainwater is not recommended by the health authorities.

UGANDA

PRESENTATION OF THE STUDY AREA AND LOCAL SETTINGS

Water availability and resource allocation

Uganda is a landlocked country in Eastern Africa in the White Nile Basin. Its population in 2016 was 40.3 million inhabitants (Worldometers, 2017). About 80% of the population still lives in rural areas. The rate of access to drinking water throughout the country is now 65%. However, there are large disparities, particularly in rural areas, where sometimes the coverage rate can fall to 25% (Agence Française de Développement, 2010).

In rural areas, wells and boreholes, which are the only sources of water, are often far from schools. As a result, children spend less time in the classroom because they have to get water (Haileybury Youth Trust Uganda, 2014). Implementing RWH systems on schools would make time to study.

The country's first economic activity is agriculture. It is a rain-fed agriculture, practiced in a traditional way in average size farms. Unfortunately, agricultural activity is threatened by the succession of episodes of violent rains and prolonged drought. This, indeed, is at the origin of periods of congestion of the soil and of withdrawals.

Climate and precipitation

The territory is 241 040 km2 with a tropical climate. The territory is marked by the presence of large bodies of water: Lake Victoria, Lakes Albert and Edward (Projet d'action environnementale transfrontalière du Nil et al., 2006). Supply to cities, including the capital Kampala, on the shores of Lake Victoria depends exclusively on this resource. 54% of the population lives less than 100 km from the shores of Lake Victoria (Agence Française de Développement, 2010). Kampala alone accounts for 45% of the urban population of Uganda.

Uganda is a very interesting country for rainwater harvesting because it receives an average annual rainfall of between **1000 and 1500 mm per year** (Climats et Voyages, 2010). But the distribution of rainfall is different depending on the regions. **The south is the rainiest region.** It is marked by **two rainy seasons** separated by two relatively dry periods (January to February and June to August). The long rains season is from **March to May**, while the rainy season is from **late September to December**. The rains fall mainly in the form of very brutal showers and thunderstorms often leading to flash floods. Rainwater harvesting systems will have to be able to resist these brutal showers. **The northern center of the country has only one rainy season** from April to October, and a dry season from December to February. **The southwest and northeast are the two driest regions**. On average 800 mm fall per year.

LEGISLATION AND REGULATION OF RWH

Uganda framework

There are currently no regulations or standards governing the RUEP in Uganda. However, guidelines are being drafted by **the Ministry of Water and Environment (MWE)** (cf. appendix 1). However, that the MWE encourages districts to include RWH projects in schools, health centers and shops (Government of Uganda, Ministry of Water and Environment, 2013). Uganda has still not met the Millennium Development Goal targets. The RUEP appears to be a solution allowing a permanent access to improved water. For this reason, **Uganda RainWater Association (URWA)** defends its promotion. Many non-governmental organizations (NGOs) support URWA in these activities.

SOCIO-HISTORICAL ASPECTS OF RWH, STRENGTHS AND LIMITS

History of RWH

RWH was probably practiced informally by certain populations. But few documents exist on the subject. We can say that the practice of RWH as understood in the sense of improved device dates from the late 20th century. The idea of having URWA only came in 1998.

Moreover, RWH is a practice still little developed at the territorial scale (De Gouvello et al., 2013). This is explained by the fact that the government favored the construction of shallow wells, deep wells, public water distribution systems instead of installation of RWH systems a decade ago. Now RWH is recognized as a key solution to provide drinking water especially in rural areas (Government of Uganda, Ministry of Water and Environment, 2013).

Advantages of RWH and examples of successful projects

Water supply through the practice of RWH in the Kapchorwa district is an example of successful projects among many others. It was supported by a close collaboration between Rain and URWA. In this district there was a pressing need to improve access to water in order to reduce the prevalence of water-borne diseases and malnutrition. This project consisted of constructing about 20 rainwater harvesting tanks of 5 m3 each built of ferrocement. The total success of the mission lies in the fact that the two associations have succeeded in involving the local population in the construction of these tanks. In parallel training sessions, including district decision-makers, were organized. The sessions were aimed at encouraging them to invest in RWH equipment and to develop the creation of specialized companies. It was also an opportunity to promote sanitation and hygiene, as well as to transmit the automatisms of proper maintenance of RWH systems. URWA also encouraged district decision-makers, newly sensitized to the RWH, to communicate and to dialogue with the population on the health benefits of using this practice and to remind the risks incurred to consume stagnant water (Lenderink, 2016). This example shows how national non-governmental and governmental organizations are stimulating the adoption of the RWH through micro-financing and cost-sharing schemes (Rain, 2010).

In addition to the aid provided by NGOs contributing to the development of the RWH practice, it should be noted that currently 45% of the population of the country does not have access to an improved source of drinking water. The number of people connected to the public water network is still very low. Moreover, the water tariff for public utilities is too high for a large majority of the population (Rain, 2010).

Obstacles to development

A first obstacle to the development of this practice comes from precipitation. Indeed if the abundance of rains during the year suggests that Uganda is an excellent candidate for RWH, it is not counting on the intensity of the showers. Indeed, the latter are often particularly violent. This requires RWH systems to be able to withstand these events. It would appear that tanks of 6 m3 capacity can store water to meet the needs of a family for 4 days during the long rainy season (Agence Régionale de l'Environnement et des Nouvelles Energies (ARENE), 2009).

If the NGOs who are planning RWH projects are particularly present in the territory, it is clear that a large majority of them consider their mission to be fulfilled once the systems have been built. In order for people to know how to use and maintain them, they must be trained. The general observation is that people are unfortunately poorly trained by their government and NGOs on the use and maintenance of RWH systems. Many people are still affected by waterborne illnesses by the lack of a guide to maintaining RWH systems provided by the government.

OVERVIEW ASSESSMENT AND LESSONS LEARNED FOR RAINWATER HARVESTING PROJECTS WORLDWIDE

USE AND RAINWATER QUALITY

In France, the use of rainwater for food or personal hygiene purposes has been slowed down by the Direction Général de la Santé (DGS) and the Conseil Supérieur de Hygiène Publique de France (CSHPF). The latter prefer to compare the physicochemical and microbiological rainwater qualities with the regulatory quality limits defined for drinking water. These limits are too strict to allow new rainwater uses. For a diversification of uses, an article should be created in the decree of 21 August 2008 on regulatory limits for rainwater by type of use. The ASTEE working group "Récupération et utilisation de l'eau de pluie » could try to influence the French state by proposing guiding values by type of use as is already the case in South Australia and Texas.

In Uganda, rainwater is considered safe when the RWH system is well designed and well maintained. It is used as an improved source of drinking water to meet primary needs (drinking, meal preparation and personal hygiene). Moreover, in rural areas, the use of RWH systems makes it possible to limit the prevalence of water-borne diseases.

At the end of my study, South Australia appears (compared to France and Texas) as the most advanced state in terms of diversity of rainwater uses. The use of rainwater is currently acquired for: "washing machine, toilet flushing, domestic hot water production, watering and other outdoor use as well as water from ponds and artificial ponds, firefighting and, more recently, the cooling of industrial towers " (De Gouvello et al., 2013). On the other hand, health authorities and network operators advise against the use of rainwater for drinking or personal hygiene purposes, but do not forbid it. Regarding the quality of uses, guide values were defined (Rotavirus, Cryptosporidium and Campylobacter) (cf. appendix 1). In Texas, there are also guide values to be observed by type of use supplemented by suggestions for the treatment of rainwater (Texas Rainwater Harvesting Evaluation Committee, 2006b).

REGULATIONS AND RULES OF ART

What makes RWH seem difficult to develop in France is largely due to its strict regulatory framework, which, unlike Texas and South Australia, blocks the gradual return of the competent actors' experiences who can enrich the production of texts in a relevant way. (De Gouvello et al., 2013).

In Texas or Australia, the technical aspects of RWH are largely not regulated, but rather by other types of formalized references from professional circles (plumbing or specific sectors of RWH). These reference documents can be translated into standards (De Gouvello et al., 2013). For example, in Texas, the TWDB developed the Manual on RWH, which served as development to the standard on the installation of RWH systems named Texas Health and Safety Code §341-042 of 2011. As for Uganda, there is a total absence of a regulatory framework for the RUEP.

In France, projects for the realization of RWH systems in public buildings must be approved by the Direction Départementale d'Action Sanitaire et Sociale (DDASS) and these buildings must not be part of the list of those proscribed by the decree of 21 August 2008. In South Australia, as in Texas, it is rare to find a reference to buildings where rainwater is prohibited due to the nature of the activities.

FACTORS CONTRIBUTING TO THE EFFECTIVE DEVELOPMENT OF THIS PRACTICE

The development of RWH is carried out on a scale of Australia and the USA by associations. For example, in the USA, the American Rainwater Catchment Systems Association (ARCSA) has contributed and continues to contribute to the development of the RWH by promoting it. RWH is promoted through organising webinars, conferences, workshops and also training sessions with accreditation for rainwater harvesting. These associations bring together a panel of experts: companies, regulators, water suppliers, architects, project managers, plumbers, etc.

Similarly, in Australia, the Australian Rainwater Industry Development Group (ARID) was created in 2004 to help industrialists and plumbers promote the benefits of RWH.

We find the equivalent of these two associations in France through the professional association Industriels Français de l'Eau de Pluie (IFEP), which is a grouping of actors and manufacturers who act in favor of the RWH.

In Uganda, the promotion of the RUEP is carried out by the Uganda RainWater Harvesting Association (URWA). This national association works hand in hand with numerous NGOs to enable people to access water.

What makes the promotion of the RUEP work well in Texas is that the government is encouraging municipalities and districts to offer reductions on rainwater storage tanks to public works builders. In addition, a municipality cannot cancel a building permit only because the client wishes to set up a RWH in the building. The government goes so far as to organize a competition to elect the most beautiful RWH projects in public buildings (The Texas Rain Catcher Award).

In Australia, regulation is used to encourage or even impose the introduction of RWH systems in some new constructions. Thus, according to the July 2006 regulations (Building rules), any new house with more than 50 m² must have an alternative water supply to the public distribution system.

A key factor for the use of RWH and promotion through local activities is the density of populations. In South Australia, as in Texas, low population densities are observed. The infrastructure for a drinking water network in some areas would be too expensive. In France, a densely-populated country, investment costs for a collective drinking water network are lower, resulting in a more limited enthusiasm for the practice of the RWH.

MAJOR ELEMENTS PROMOTING THE PRACTICE OF RWH IN PUBLIC BUILDINGS

France	Texas	South Australia	Uganda
Water scarcity management plan (2005), HQE-standard and eco-citizen approach	Pressure on water resources, droughts and dispersed populated habitat	Incomplete coverage of the public drinking water distribution system and droughts	Fulfilment of the Millennium Development Goals

CONCLUSION

Through this technical overview, a case study on RWH in public buildings was conducted in France, Texas, South Australia and Uganda. It emerges that each State has its own context which has contributed to the development of this practice. The authorized rainwater uses and buildings are very different depending on the study area.

Given the undeniable advance of the States of Texas and South Australia, it would seem that we need to review the workings of France’s overly binding regulations. In seeking to protect themselves against potential health risks, public authorities are blocking opportunities to extend rainwater uses to new uses. The regulatory framework, however, is not the factor that has contributed to the success of this practice in Texas and South Australia, but rather the different references provided by the RWH experts who have led to the development of standards.

It would be interesting to look at the case of India where the government is using regulation to impose the implementation of RWH systems, such as the State of Tamil Nadu, which the government has made compulsory since 2014 RWH systems construction for all public and private buildings.

France does not seem to be making any progress in terms of new rainwater uses. How could one explain the fact that its neighbor Germany has already classified the problem of the washing machine which seems challenging for the DGS? It may be relevant to look at the DIN (German standards) for RWH and to study the regulatory framework.

APPENDICIES

State	France	Texas	South Australia	Uganda
Regulatory framework and formalized references	**Directive 98/83/EC on the water quality intended for human consumption** lays down the standards applicable to drinking water for the states of the European Union.	<u>**At the federal level (United States):**</u> **There are no regulations dealing specifically with RWH.**	<u>**At the level of Australia:**</u> **The government is involved in health issues in relation to RWH.**	**No regulatory framework or standards governing RWH in Uganda.** Guidelines are being drafted by the **MWE**.
	Article R.1321-1 of the Public Health Code transposes European Directive 98/83/EC into national law. It is required the use of drinking water quality for all domestic uses: food, personal hygiene etc.	**The National Primary Drinking Water Regulations** developed by the United States Environmental Protection Agency (US EPA) are the **drinking water quality references.**	**Guidance on use of rainwater tanks**, drafted by the Australian Department of Health in 2011, provides information on potential risks to rainwater quality, preventive actions to be implemented, monitoring and maintenance activities.	**The major objective** for Uganda is to meet the Millennium Development Goal targets.
	The decree of 21 August 2008 declines the authorized uses of untreated rainwater harvested downstream of inaccessible roofs.	<u>**At the Texas level:**</u> **House Bill 2430**, enacted in 2005, is a law defining the Texas Rainwater Harvesting Evaluation Committee,	**The Australian Drinking Water Guidelines** developed by the Australian Department of Health are the drinking water quality references.	Presence of a national association that promotes RWH : **the Uganda RainWater Association** (URWA). It also works with many NGOs.
			The Australian and New Zealand Plumbing and Drainage Standart or AS /	

	The decree of 17 December 2008 and **the circular of 9 November 2009** define and specify the conditions for the control of rainwater harvesting systems.	**House Bill 3391**, voted in 2011, requires new buildings with a roof area of at least 4,645 m2 and located in areas with an average annual rainfall of 508 mm to be equipped with a RWH systems. Municipalities are also encouraged to promote RWH through incentive actions (rebates on rainwater storage equipment).	**NZS 3500** is the regulation for connecting a RWH system to indoor plumbing equipment such as flushing, water heaters, washing machines, etc.	
	ASTEE Technical Guide : Rainwater Harvesting from 2015, complements the French regulatory framework. This guide discusses aspects both for and against RWH. It deals with the parameters to be taken into account in order to implement a RWH systems. Finally, it provides technical recommendations for implementation.	**House Bill 1073 and Senate Bill 1073**, voted in 2011 requires that anyone wishing to connect their RWH system to the public drinking water network must first obtain written authorization from their municipality.	**<u>At the level of South Australia:</u>** **Rain Water Plumbing Guide** written by South Australian Water is the reference manual for the realization of RWH systems according to the AS/NZS standard adapted to the state of South Australia.	
			Building Rules is a regulation of July 2006 requiring that any new housing, extension and development of more than 50 m2 has an alternative water supply to the public distribution network.	

Principal rules of art for the possible connection of rainwater network to the public water supply network, network distinction codes, signaling of dispensing tap	Prohibition on connecting the rainwater network to the public water supply network. In the event of a drinking water supply to the rainwater network through the public distribution network. In the event of a drinking water supply to the rainwater network through the public distribution network, a system of disconnection by total overflow must be installed. A visible air guard must be installed. In the case of indoor use of rainwater, the valves and pipes connected to the rainwater system must be marked with a plate stating that the water is not potable. Prohibition in residential buildings of having water taps that distribute water of different quality (rainwater and drinking water).	Prohibition on connecting the rainwater network to the public water supply network. In the case of joint use of the public water supply system it is compulsory to create an air gap at the storage tank to prevent contamination by the discharge of rainwater into the network and to install at the level of the drinking water meter, a valve equipped with a disconnector with a reduced pressure zone (30 Texas Administrative Code § 290.44). The rainwater network must be visible and orange in color. Taps should mention that the water is not drinkable. Indoor uses of rainwater are restricted to non-potable uses in the event of joint use of the public water supply system.	Prohibition on connecting the rainwater network to the public water supply network. In the case of joint use of the public water supply system, a backflow prevention device with two valves must be installed. The use of drinking water coming from the public distribution network must be done without interruption and automatically through a switch. When using rainwater for non-food use, it should be clearly stated on the taps. Rainwater taps must be painted green. The rainwater system must be marked with inscriptions stating that it is rainwater.	Lack of information on this subject. In rural areas, there is often no public water supply network. In urban centers, the connection of the rainwater system to the drinking water distribution network is not subject to any regulations.

Authorized outdoor use	Outdoor floor cleaning, watering, washing the car **no minimum water quality recommended**	Outdoor floor cleaning, watering, washing the car **no minimum water quality recommended**	Outdoor floor cleaning, watering, washing the car **Guidances values defined in the appendices (cf. appendix 14)**	Rainwater is used for all domestic purposes and mainly for hygiene (shower) and for food use (preparation of meals, drinks). Rainwater can also be used as a productive use: watering of animals and irrigation. **no minimum water quality recommended**
Authorized non potable indoor use	Toilet flushing, floor cleaning, washing machine (on an experimental basis), professional and industrial usages **no minimum water quality recommended**	Toilet flushing, floor cleaning, washing machine, professional and industrial usages **Recommended minimum quality threshold :** Total Coliforms < 500 cfu / 100 mL ; Fecal Coliforms < 100 cfu / 100 mL ; It is recommended to check the rainwater annually.	Toilet flushing, floor cleaning, washing machine, professional and industrial usages, reserve for firefighting Guidance values have been defined for different types of uses, **involving three pathogenic microorganisms** (Rotavirus, Cryptosporidium and Campylobacter jejuni) (cf. appendix 14)	
Authorized potable indoor use	**no use currently authorized**	Hot water (shower, bath), food use (preparation of meals, drinks, dishwasher) **Recommended minimum quality threshold :** Total Coliforms – 0 Fecal Coliforms – 0 Protozoal cysts (Giardia Lamblia and Cryptosporidium) – 0 Virus – 0	Hot water (shower, bath), food use (preparation of meals, drinks, dishwasher) **Recommended minimum quality threshold :** The Escherichia coli bacterium should not be detected in a 100 mL sample of rainwater.	

		Turbidity < 0,3 NTU Monthly checks must be carried out.	**The Australian Drinking Water Guidelines** impose the quality thresholds**.**	
Public buildings	Prohibition of using rainwater in buildings housing a sensitive public such as healthcare facilities and social and medical-social facilities, nursing home, doctors' surgeries, dentists ' surgeries, medical laboratories nursery and primary schools. The most suitable buildings for the establishment of RWH systems are: schools (schools and colleges), residential buildings, office buildings and cultural buildings.	Use of state-promoted rainwater for all commercial, residential and industrial buildings. RWH is authorized in primary school, medical facilities and hotels.	RWH systems are implemented in all types of buildings including : nursing home, hospitals, schools (including primary school), food services.	During the second half of the 20th century, the first RWH systems were installed in schools, hospitals and police stations. This was a failure because the populations were not trained in operation and maintenance. For this reason, RWH for public buildings was abandoned in favour of RWH for domestic use. Today NGOs are looking to install RWH systems in schools or hospitals.

Annexe 1 : Table summarizing the key points of the technical overview. Source : author

Understanding of the key points of the Order of 21 August 2008:

Rainwater can be used for outdoor and indoor use (cf. appendix 1).

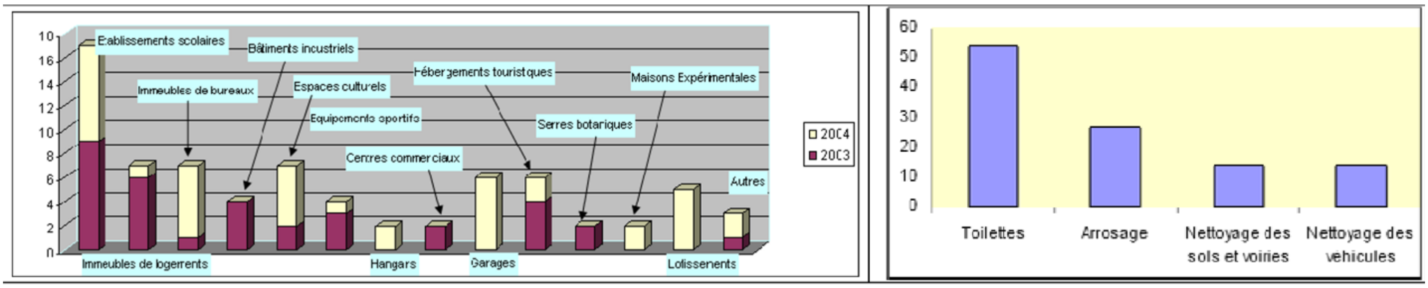
Main obligations:

For indoor use of rainwater, a filtration system with a threshold of 1 mm or less must be installed upstream of the storage tank. The storage tank must be watertight and have an overflow pipe. It is the responsibility of the owner to maintain his RWH system and to write his maintenance book. In the case of indoor use of rainwater, the latter must declare its installation to the local authority and pay the sanitation tax corresponding to the volume of rainwater discharged into the public sewerage network.

Main Prohibitions:

For indoor use of rainwater, lead or asbestos roofing should be avoided. The use of rainwater is prohibited in buildings housing a sensitive public (cf. appendix 1). It is strictly forbidden to make a stitching directly on the public distribution network.

Appendix 2 : Overview of the Order of 21 August 2008. Source : author



Appendix 3 : Type of RWH operations and main intended uses (De Gouvello et al., 2004)

Tableau 1: Echantillon de projets issus des analyses documentaires, enquêtes en ligne et entretiens, classés par types et catégories d'opérations

Type de projets	Catégorie	Sous-total par type de projet[3]	Sous-total par catégorie
Habitats collectifs	Habitat	9	45
Hébergements collectifs		8	
Lotissements ou groupements de parcelles pour l'habitation dans une opération d'aménagement		28	
Ecoles	Etablissement Recevant du Public[4] (hors habitats)	24	207
Collèges et lycées		57	
Bureaux		43	
Bâtiments commerciaux		18	
Equipements publics et collectifs (salles des fêtes, maisons de l'enfance,…)		65	
Arrosage public (parcs, serres communales,…)	Opérations d'arrosage et/ou de nettoyage	59	91
Opération de nettoyage (flotte de véhicules, voiries,…)		32	
Installations industrielles	Autres	9	49
Installations agricoles		3	
Autres (jardins familiaux, réserves incendie,…)		37	

Appendix 4 : Nature of rainwater harvesting projects in France in 2011 (Mucig et al., 2013)

Analyse de la position sanitaire du CSHPF sur l'utilisation de l'eau de pluie

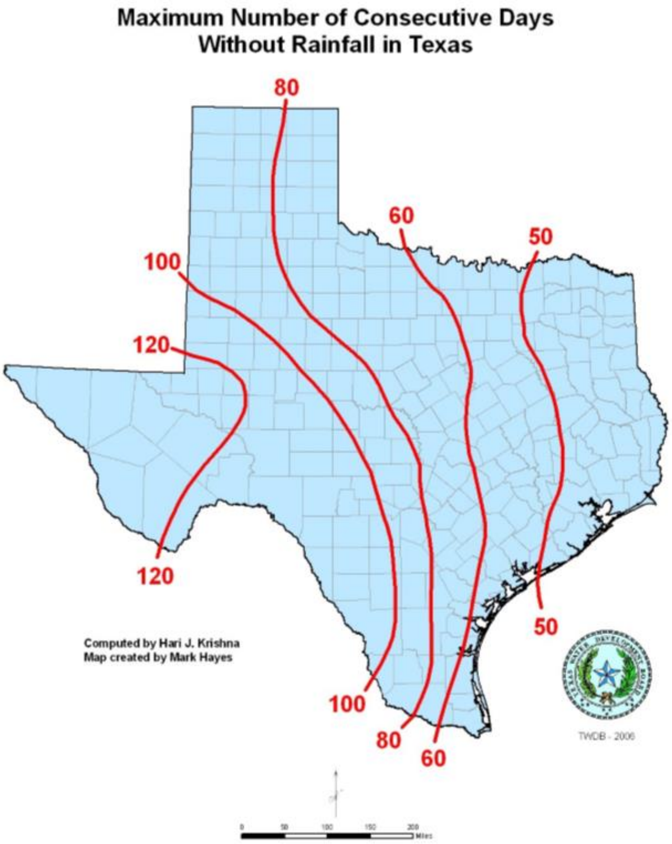
The Conseil Supérieur d'Hygiène Publique de France warns users that the use of rainwater **without prior treatment of potabilisation** exposes them to significant health risks (Herault et al., 2006). The first category of risk is that related to the exposure of the users. Thus three modes of direct exposure can lead to a situation of health risk: ingestion, inhalation and dermal exposure (contact). There is also a mode of indirect exposure: eating vegetables washed with rainwater for example. Direct ingestion of rainwater may cause gastroenteric or diarrhea. Inhalation exposure is likely to occur during a shower or when watering the garden with rainwater. In fact, there is formation of aerosols. The main health risks are: risks of contamination of the mucous membranes by Pseudomonas and Legionellas (Centre d'information sur l'eau, 2010). The health risks due to dermal exposure are the absorption of heavy metals such as lead. It should be noted that in New Zealand rainwater used for showering is suspected of having led to an outbreak of legionnaires' disease. The other two categories of health risk identified by the CSHPF are due to the quality of the rainwater and the risks of picking up and interconnecting with the drinking water system which can lead to a backflow of rainwater into the network.

Annexe 5 : Clarification of health risks due to lack of drinking water treatment. Source : author

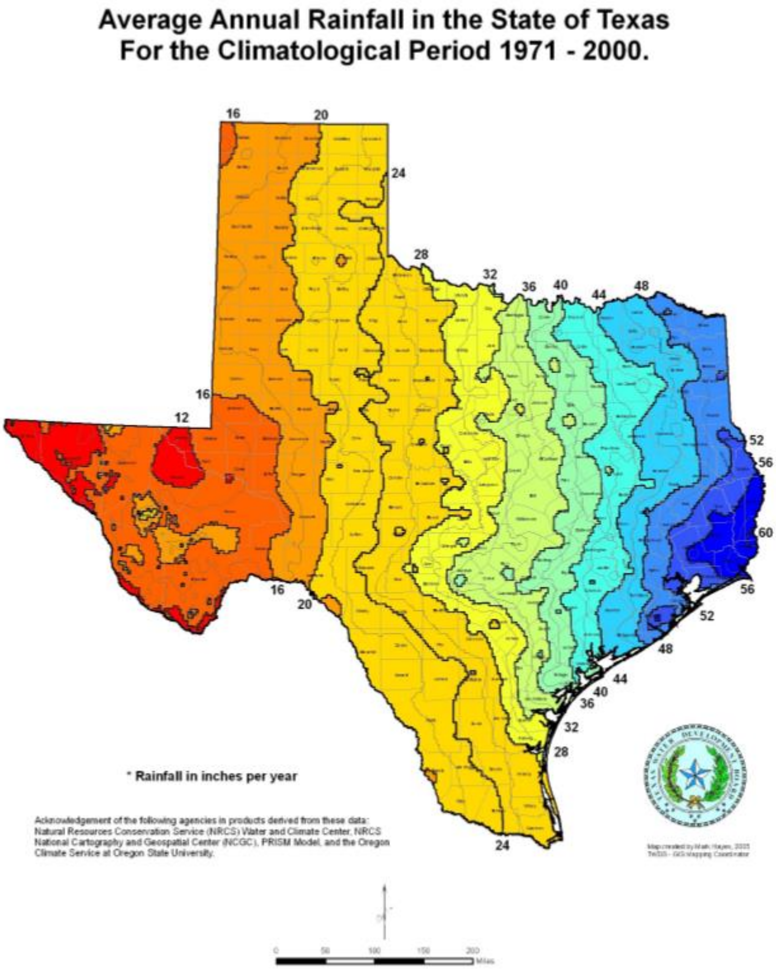
Choice of water source depending on the geographical situation and observation of the increase in the water bill

Western Texas mainly uses **groundwater** while the east has **greater surface water consumption** (Bernollin, 2014). Texas is facing today a widespread increase in water prices. For example, in the capital Austin, the monthly water bill - divided into 3 tranches: drinking water consumption, wastewater collection and treatment, charge for urban runoff control - for a large consumer family (150 gallons/day/person) increased by 40% between 2014 and 2015 (Walton, 2015).

Appendix 6 : Additional information about Texas. Source : author



Appendix 7 : A map of Texas with isolines showing the maximum number of consecutive days without rainfall (Krishna, 2003 ; TWDB, 2005). Source : (Texas Rainwater Harvesting Evaluation Committee, 2006c)



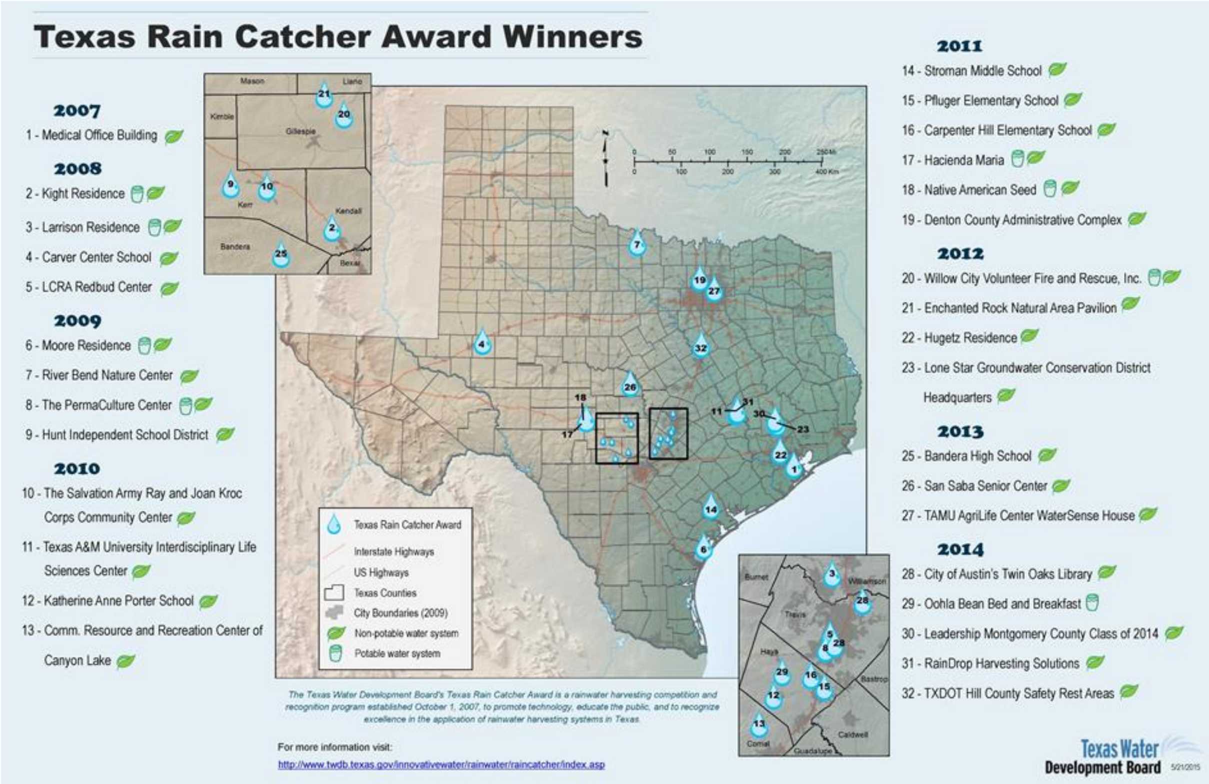
Appendix 8 : Average annual rainfall in Texas (in inches) (Texas Rainwater Harvesting Evaluation Committee, 2006c)

Understanding the key points of Texas Health and Safety Code §341-042. Standards for Harvested Rainwater

Important rules must be observed in the event of the public drinking water distribution network is used as a back-up source of water (cf. appendix 1). It is also the duty of every Texan citizen

who wishes to use public water as a back-up system for the RWH system, to seek the consent of the municipality or the public network operator before any work is done. In addition any person who installs and maintains this RWH system with a public drinking water distribution network used as a back-up source of water must be graduated by the Texas State Plumbing Plumber Examiners Master Plumber or Plumber Companion and be accredited by the Board as a specialist in water supply protection.

Appendix 9 : Overview of Texas Health and Safety Code §341-042 Standards for Harvested Rainwater. Source : author



Appendix 10 : Texas Rain Catcher Award Winners (Texas Water Development Board, 2007)

Rainwater harvesting system maintenance indicator

The faecal indicator E.Coli makes it possible to check whether a good maintenance of the RWH system is carried out. The frequency of tests depends on the population of the public buildings, the risk management procedure plan put in place, the type of building (hospital, school, library, etc.). By using UV disinfection, the number of tests can be reduced.

Appendix 11 : Further information on water quality tests. Source : author

Approach to installing a drinking water system on its RWH system

The addresses can be found on the Local Government Association of South Australia website. In general, Local Councils take important precautions to avoid the phenomena of rainwater backflow in the drinking water supply network. The South Australia Health Council may also be consulted to ensure the proper maintenance of the RWH systems. This advice incorporates the health requirements of the Australian Department of Health.

Appendix 12 : The use of local Councils. Source : author

Understanding of the requirements of “Building Rules” in relation to the RWH

This regulation of July 2006 requires that any new housing, extension and development of **more than 50 m²** has an alternative water supply to the public drinking water distribution system. It can be a rainwater tank connected to the general water supply, a water reuse facility, or even a connection to the community rainwater storage tank. It is not clear whether this new requirement also applies to public buildings. Nevertheless, regardless of the type of building, only a certified plumber can connect the rainwater tank to the various sanitary facilities and water points of the building (toilets, water heaters, cold water circuit). At the end of the installation, he can deliver a certificate of conformity. This regulation obliges the RWH tank to be equipped with an overflow system and a mosquito grid.

Appendix 13 : Overview of South Australian Building Rules (Department of Environment, Water and Natural Ressources, 2016).

Table A3.3 Tolerable pathogen levels and required reductions for stormwater reuse

Use	Reference pathogen	Tolerable concentrat-ion (infectious units per L)	Required reduction	
Municipal, including open-space irrigation and nonpotable construction activities (eg dust suppression, earthworks compaction) (exposure = 50 mL/person/year)	Rotavirus	0.050	95.0%	1.3 log
	Cryptosporidium	0.32	82.2%	0.8 log
	Campylobacter jejuni	0.76	95.9%	1.3 log
Dual reticulation for indoor and outdoor use (eg toilet flushing, laundry use, irrigating garden food crops, ornamental garden watering) (exposure = 670 mL/person/year)	Rotavirus	0.0037	99.6%	2.4 log
	Cryptosporidium	0.024	98.7%	1.9 log
	Campylobacter jejuni	0.057	99.6%	2.4 log
Firefighting (exposure = 1000 mL/person/year)	Rotavirus	0.0025	99.8%	2.6 log
	Cryptosporidium	0.016	99.1%	2.1 log
	Campylobacter jejuni	0.038	99.8%	2.6 log
Commercial food crops (exposure = 490 mL/person/year)	Rotavirus	0.0051	99.5%	2.3 log
	Cryptosporidium	0.033	98.2%	1.7 log
	Campylobacter jejuni	0.078	99.5%	2.3 log
Non-food crops (eg trees, turf, woodlots, flowers) (exposure = 50 mL/person/year)	Rotavirus	0.050	95.0%	1.3 log
	Cryptosporidium	0.32	82.2%	0.8 log
	Campylobacter jejuni	0.76	95.9%	1.3 log

Appendix 14 : Tolerable pathogen levels and required reductions for stormwater reuse (Natural Resource Management Ministerial Council et al., 2009)

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