THESIS

STUDY TO ANALYZE THE VIABILITY OF RAINWATER CATCHMENT FROM ROOFS FOR ITS REUSE IN TEGUCIGALPA, HONDURAS

Submitted by

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ABSTRACT

STUDY TO ANALYZE THE VIABILITY OF RAINWATER CATCHMENT FROM ROOFS FOR ITS REUSE IN TEGUCIGALPA, HONDURAS

Water scarcity is a problem in many parts of the world. In some regions, there is physical water scarcity because there are not enough resources of water to supply the increasing demand, while other parts of the world have an economic scarcity, where resources are more abundant but poor governance and other problems render water unavailable for most of the population. Where the problem is economic water scarcity, there are many solutions that could ameliorate the problem, but most times the solutions require a change in government, more economic resources and a better willingness. Solving the problem requires long-term changes; however the need for water is immediate. This is why many methods have been developed for water storage and reuse, however because the problem is not a lack of water but poor management, implementing and maintaining systems is simply not a reality in many parts of the world, particularly in Africa and Latin America. Water supply systems in Honduras provide service to approximately 86% of the total population (WHO/ UNICEF 2010), however the service is not continuous, and the quality of the water supplied is not high enough to be considered potable.

Simple mechanisms that address urgent problems have had to be used to supply citizens with water. Rainwater catchment or rainwater harvesting is one option worth analyzing for the capital city of Honduras, Tegucigalpa. Rainwater catchment systems are a simple solution that can be adopted in many parts of the country; many houses are already equipped with storage tanks and catching rainwater would require only a basic catchment system and make the most

from the natural resources available. Stored rainwater can serve as a supplement to the city's supply system or as sole source of water for many growing areas that are not connected to the water supply network. Other alternatives include graywater reuse, well drilling and communal water storage tanks.

For this study, household scale rainwater catchment systems were analyzed, where water can be channeled through pipes installed on each roof. The pipes transport water either to an underground or elevated tank, which many houses in Tegucigalpa already have. Water samples were collected from rooftops of different materials in three different locations and tested according to the Honduran regulation to analyze the quality of water. Precipitation data for Tegucigalpa was used to determine the amount of water that can be collected in order to compare this with the costs of implementing household scale rainwater catchment systems and determine whether it is a feasible solution for water scarcity in Tegucigalpa. In the end, all aspects were analyzed to determine whether this could be a solution worth implementing in Tegucigalpa to alleviate water scarcity problems as well as the possible positive and negative impacts it would have on the economy, society and the environment.

Based on the analyses performed, it becomes clear that rainwater harvesting is not the one answer that will solve all water scarcity issues in Tegucigalpa. Storage tanks would need to be much larger, precipitation more abundant, roofs would have to have a bigger area and tanks be cheaper for it to be the sole source of water supply in the city. However, though maybe not ideal, it may be used as complementary to current public and private supply systems; it can reduce water bills and increase the supply in some areas of the city. It might be good investment for families that buy water from private companies and for homes where there already is a tank installed for water supply and storage.

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Additionally, I would like to thank everyone that helped me collect and understand the information processed for this study. This includes SANAA (National Autonomous Water and Sewerage Service), Office of Water Resources' National Weather Service, Fundación Vida, as well as other institutions back in Honduras that provided information and background data.

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INTRODUCTION

Objective and Importance of Study

The purpose of the study is to analyze the feasibility of using rainwater catchment on roofs in Tegucigalpa, Honduras and storing it for household uses. Different alternatives for rainwater harvesting systems were analyzed to determine whether the technology is suitable for the city by testing the water quality of rainwater from rooftops in Tegucigalpa, analyzing precipitation data from the city and evaluating the costs and benefits of its implementation.

The importance of this study lies in severe water scarcity in some areas of Honduras, particularly in the capital, where although rainwater is abundant during a long part of the year, economic and institutional decisions prevent citizens from having access to drinking water. Being the capital, the city is rapidly growing but in a disorganized way, and the current water supply system is not adequate to provide water for the growing population.

Tegucigalpa has a tropical climate, with rainy months from May to November, with approximately 118 days of rain in the year and an annual precipitation of 40 inches (National Weather Service, 2011). Considering the chronic water scarcity in the city, a considerable amount of homes have elevated or underground water storage tanks installed to provide water for their daily use. These two observations make rainwater catchment systems a great option to be considered because the approach takes advantage of the opportunities the city's climate as well as existing infrastructure.

In order to determine whether this is a solution worth implementing, 3 different alternatives for rainwater storage and supply were analyzed to see which one presented a better financial situation under varying scenarios. Water samples were collected from rooftops of different materials and various locations to determine the quality of harvested rainwater. Samples were collected from three different neighborhoods, Villaflor, Villanueva and San Angel, and a basic quality evaluation was performed in accordance with Honduran Standards. Precipitation records were analyzed with the purpose of defining appropriate tank volumes and consequently costs.

BACKGROUND

Geographical Information

This study is focused on analyzing rainwater catchment specifically in the city of Tegucigalpa, Honduras, at an individual household level.

Tegucigalpa is the capital city of Honduras, a country located in Central America, bordering with El Salvador, Guatemala and Nicaragua as seen on Figure 1.

Figure 1: Location of the area analyzed in the study. Tegucigalpa, Honduras (Transunion, 2011)

Honduras has an area of 112, 492 km^2, and is located between 13° N and 17° N and between 83° W and 89° W. One important thing to mention is that Honduras does not have the four seasons typical of mid-latitudes, but only two seasons occur, wet and dry. The rainy season begins in late May and ends in late November, September being the wettest month. Hydrologic information is detailed in the precipitation analysis.

Honduras is divided into three regions: the northern coastal plains or Caribbean lowlands (16% of the country) with hot and rainy tropical climate, with rainfall of up to 2000 mm and rainforest-like vegetation, the mountain region or interior highlands and valleys (82% of the country), with mountains of a height up to 2849 meters above sea level. This region has a subtropical climate, moderate rainfall, vegetation varied valleys with dry tropical vegetation type, and the other region is the Pacific coastal plain and lowlands (2% of the country) with savanna features of tropical rainy and dry periods. With regards to the hydrographic system, it is made up by a series of basins that start in the upper parts of the slopes of the Atlantic and Pacific oceans, the first comprising 82.72% of the country, and the second 17.28%.

The central area of the country is made up by the departments (provinces or states) of Francisco Morazán, Comayagua, La Paz and El Paraíso. According to the Köppen weather classification, this area is a tropical savanna, with wet and dry seasons, as mentioned before, with dry months from January to April, February being the driest month with an average precipitation of 8.0 mm. The wet season goes from May to November with a maximum of 211.0 mm of precipitation in the wettest month of September (this has been so historically, however from the data used in this study, for the last decade, the rainiest month has been June). The average annual precipitation is 1004.0mm with 118 days of rain and a mean relative humidity of 70%. The annual mean temperature is 24.9°C (77°F) with a maximum of 27.1°C (81°F) in April and a minimum of 22.7°C (73°F) during January in places of up to 500 meters above sea level. For regions where elevation is higher than 1,000 meters above sea level, mean temperature is 21.5°C (71°F), maximum is 23.5°C (74°F) during April and the minimum is 19.5°C (66°F) during January (National Weather Service, 2011).

The U.S. Geological Survey divides the country into watersheds and Figure 2 is the area of the Choluteca Watershed where Tegucigalpa is located. As can be seen from the image, there are rain gaging stations in Tegucigalpa. This will help in measuring the amount of precipitation that can be stored for reuse.

Figure 2: Rain gaging and River Stations in the Watershed where the area of study is located. Information from this station was used for the precipitation analysis (USGS, 2011)

<u>*Economic Situation*</u>

The Distrito Central (Central District) is made up of the twin capital cities of Tegucigalpa and Comayagüela, has a population of 1, 126,500 people (BCH, 2010). This is the largest urban area of the country and it is growing at a rate of 2.1% annually. The country´s Gross Domestic Product for 2010 was 291, 990 million Lempiras (Honduran currency; 1 US$= 18.97 Honduran Lempiras). Its low human development index (HDI=0.625), ranks it as one of the countries where many social inequities occur and poverty is closely related to access to water supply and sanitation. According to the United Nations Development Program, Human Development Report for 2011, the country´s gross national income per capita is $3.44, locating the country in between the low and medium development categories and 23.3% of the population lives below the international poverty line.

Human development and poverty are important and relevant in this case because they have effects on the environment, water quality and eventually on the health of the population. The same report mentioned above, establishes there are 178 deaths per million inhabitants caused by water pollution and approximately 30% of Hondurans are unsatisfied with the quality of water they receive.

Water quality problems are the effect of inefficient treatment plants providing water to the population or discharging polluted water into rivers, as well as lack of sufficient treatment plants for the entire population. Water scarcity is also root for these problems because in their need for obtaining water, citizens end up buying water of poor quality and getting their supply from any place they can find or afford and then do not follow up with adequate treatment.

Water Scarcity

Tegucigalpa is a rapidly growing city, with a population slightly over a million people, being the government center, an economic major city and the country's largest city. The city's growth, however, is happening in a disorganized way, illegal settlements known as invasions are emerging on the city limits. These informal homes are typically made out of recycled materials, cardboards, wood, plastic and many materials improvised by the new settlers. Due to the disorganized growth, poor housing construction and sometimes the illegality, many of these houses are not connected to any water supply or sanitation services and the ones that are connected, are increasing water demand significantly.

Honduras suffers from what is known as economic water scarcity. This occurs when scarcity is not physical, because resources are abundant or at least sufficient to supply the population's demands but because of economic issues, lack of infrastructure, investment, and poor governance water is not delivered to citizens. Figure 3 is a map presenting the different cases of scarcity and abundance in the world, it can be seen that Honduras' water scarcity is economic.

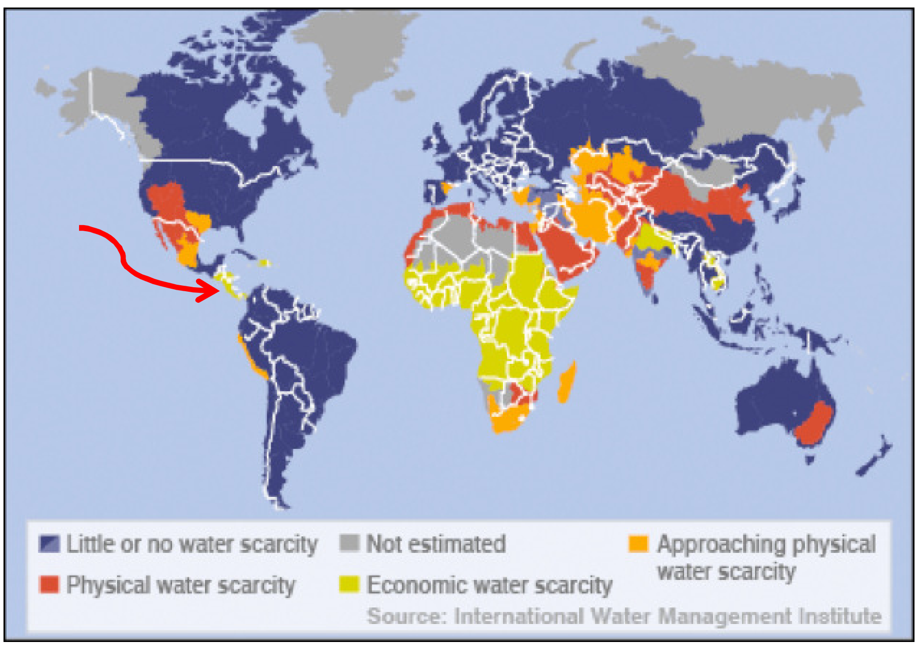


Figure 3: World Map with water scarcity issues (International Water Management Institute, 2006)

Projections for the year 2025, state that Tegucigalpa is one of the cities that will be suffering from severe water scarcity as identified by the National Hydrologic Balance. In Tegucigalpa, water shortages are programmed for 365 days annually already. Shortages are a serious problem in the city and it is foreseen that by 2029, water demand will be doubled. As an example of the critical situation in Tegucigalpa, in December 2009, the Government of Honduras declared a state of emergency in the city because of the severe water shortages due to droughts caused by the "El Niño" phenomenon (UNDP, 2010).

Each year, more frequent and more severe shortages are observed in Tegucigalpa. During the wet season most homes receive water every other day and only for a few hours and the government has announced more shortages because of the negative impact of climate change and is trying to develop solutions and alternatives for the situation. So far, there is no short term solution and there is a serious need to come up with an inclusive, holistic approach involving short and long term plans as well as the participation from the government, society and different agencies. This should include new infrastructure that can deliver water to a larger population and storage structures to supply citizens particularly during the dry season.

Water scarcity increases vulnerability in social and economic conditions for the on growing population in low income areas. Since these areas are not connected to the public water supply service, they have to buy from private suppliers that provide water through water tankers and they end up paying about 50 times more than neighborhoods connected to the water system. In some cases the cost of buying water from external providers can mean 25% of the total income if considering the minimum wage in the country. Related to the same issue is the prevalence of water borne diseases as dengue, malaria, skin conditions and diarrhea (UNDP, 2010).

The National Autonomous Water and Sewerage Service (SANAA) is the agency responsible for providing water and sewerage services to Tegucigalpa and nearby communities. Before 2007 SANAA was the national water entity, but a Water Law was approved to decentralize services and now, municipalities, water boards and private utilities under concession in other regions of the country and SANAA serves exclusively the capital city and surrounding areas and is still in the process of transferring management functions to municipalities. Water supplied to the city of Tegucigalpa comes 88% from superficial sources, 3% is groundwater and 9% comes from water tankers (SANAA, 2011). The three main superficial sources for the city are:

- La Concepción, a reservoir located at the southwest part of the capital, with a capacity for 35M m^3 (Figure 4). This reservoir receives water from the Río Grande Choluteca and represents approximately 45% of the water distributed by SANAA's supply system.
- Los Laureles, a dam located on the west side of Tegucigalpa, receiving water from the Río Guacerique with a storage capacity of 12M m^3 and representing approximately 30% of the water supplied to users coming from surface waters (Figure 5).
- El Picacho, located inside La Tigra National Forest, at the northeast part of the city, provides approximately 20% of the water to the city (SANAA, 2011).

Flow from El Picacho has decreased because of deforestation in La Tigra National Park. In Los Laureles, deforestation of the river basin for Río Guacerique has increased sedimentation in the reservoir decreasing its storage and supply capacity, in addition, urbanization along the river has increased population and thus pollution in the reservoir.

This situation has caused a water deficit in Tegucigalpa, according to SANAA, deficit amounts to 1.2 m^3/second as a result of:

Water demand in Tegucigalpa	=	3.2 m^3/second
Supply	=	2.4 m^3/second
Deficit	=	1.2 m^3/second

This means that specifically in Tegucigalpa, the water deficit is approximately 37.5%, only 62.5% of city residents are being supplied with the water they need. This situation has created the need for authorities to find new solutions for the problem. New methods and technologies have had to be used to provide water and shortages are programmed daily for the entire city. Inhabitants do not have enough water to supply their needs and rainwater harvesting becomes one possible solution

Figure 4: Los Laureles Reservoir (Hondudiario, 2011)

Figure 5: La Concepcion Reservoir (Panoramio, 2010)

Figure 6 is a compilation of the water distribution schedules for the three areas analyzed in this study (Villaflor, Villanueva and San Angel, locations of water quality sampling). It is also important to note that although only 3 areas are shown, a similar situation is experienced in all the city, shortages occur year round, and are even more severe during the driest months.

Table 1: Water Distribution Schedules for some areas in Tegucigalpa (SANAA, 2012)

Segment	Neighborhood or Area	Time	1	2	3	4	5	6	7
			Sun	Mon	Tues	Wed	Thu	Fri	Sat
3	Villanueva, Sectors 3, 4, 5, 6, 7	9 am- 2 am	x			x			x
	Villanueva Sector 6	4 pm- 7 am		x		x		x	
	Villanueva Sectors 1, 2 7, 8	5 am - 7 pm		x	x	x	x	x	x
	San Angel	4 pm- 7 am		x		x		x	
	Villaflor	7 am- 9 pm		x		x		x	

Rainwater Harvesting

Rainwater harvesting is most often referred to as an "emerging technology"; however, rainwater cisterns are not a new concept. In the Middle East in 2000 B.C., typical middle-class dwellings stored rainwater in cisterns for use as a domestic supply as well as private bathing facilities for the wealthy (Consulting- Specifying Engineer, 2011).

Rainwater harvesting can be defined as the capture of rainwater before it reached the ground and its storage on tanks for its use. It is the interception of rainwater that would otherwise end up in surface or groundwater. Rainwater catchment can be done at a domestic level for household uses, industrially for use in factories or at an agricultural level for irrigation purposes. For each of these types of uses, water can be stored differently; however, the way it is collected is always the same, sometimes rainwater is even used for groundwater recharge (Ferrera, 2010).

According to Ferrera (2010), the 6 main characteristics of successful rainwater catchment systems are:

- Only water from roofs can be collected.
- Requires adequate roofs with hard, impermeable surface and storage tank.
- Provides water directly to homes.
- Does not require large areas to work.
- It is an alternative that can be easily installed and maintained.
- Renders water of good quality and if properly maintained it represents no hazard to human health.

Even though this may be an efficient technology, it is considered as complement to other methods, it should be combined with other sources and technologies which are already being used, especially in dry, arid areas (Ferrera, 2010).

Rainwater catchment systems include four basic components, collection, storage, disinfection and delivery (Consulting- Specifying Engineer, 2011).

According to Ferrera (2010), the amount of water that can be harvested will depend on four aspects:

1. The amount of precipitation in the area.
2. The area of the rooftops.
3. Water losses due to evaporation and runoff.
4. Volume of the water storage tank.

The volume of water that can be harvested, thus tank size required, can be estimated by the product of roof area and precipitation:

Q=A*P

Where Q is the flow of water that can be captured from precipitation on rooftops, which will be available for reuse. A is the area of the rooftops and P is the depth of precipitation in the area being considered for the technology to be applied. Flow (Q) can be multiplied by 0.80, assuming an efficiency of 80% if we consider 20% of the water can be lost due to evaporation and runoff. (Efficiency will depend on roof material)

The main parts of a rainwater harvesting system are the roof, a storage tank or cistern and pipes and channels that conduct water from the roof to the storage tank. Roofs with large areas and impermeable surfaces are better and tanks must be covered, have some ventilation, ideally made from a durable material, easy to access and clean. Pipes and channels are used in the lower end of the roof and pass water to the tank, a filter must be included to prevent solids from entering the tank.

The next page includes two schemes of rainwater harvesting systems. Figure 7 presents the scheme for a rainwater collection system that transports water through pipes into a storage tank, from which it is then pumped and filtered before it is used inside the house. Figure 8 presents a different alternative, one that has been used in Honduras before, in rural communities, underground tanks are used for storing water during the dry months and. These tanks receive water from a first rain diverter, and are pumped to carry water to elevated supply tanks that provide water for different uses inside and outside of the house. This study analyzes a basic structure, aiming to reduce costs for users and avoiding complexity that might increase rejection from potential users. A basic structure consists of drains and pipes that catch and transport rainwater from rooftops, a filter, a storage tank and supply tanks.

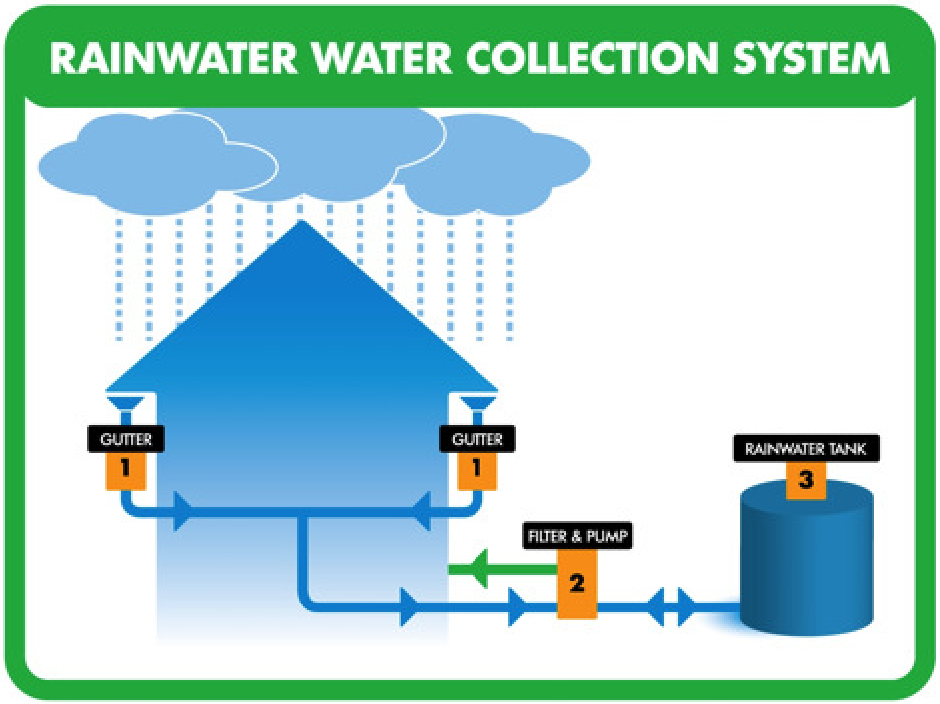


Figure 6: Rainwater Harvesting (Rainwater Distribution Systems, 2011)

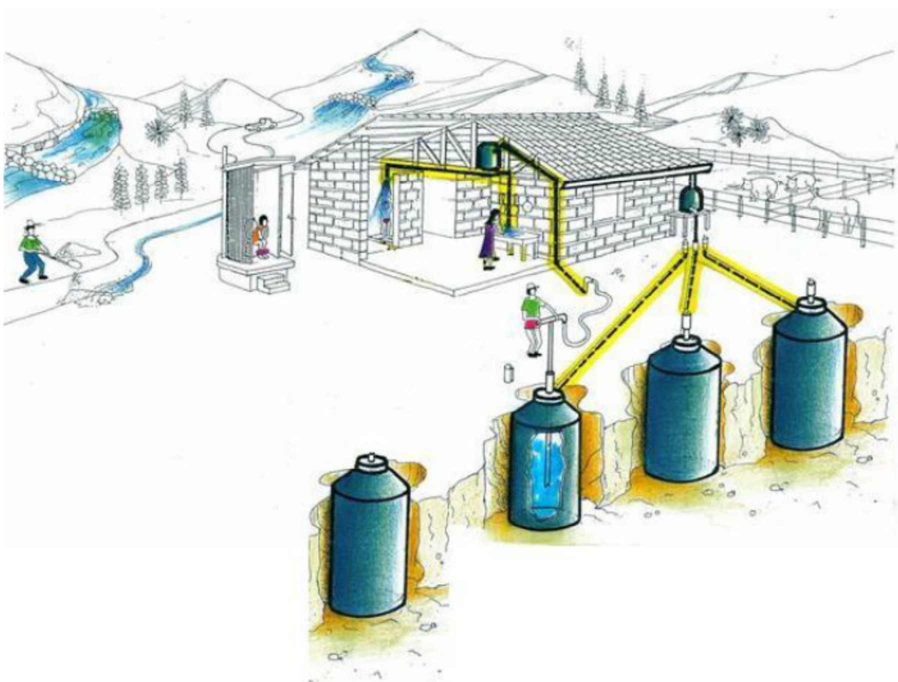


Figure 7: Rainwater harvesting scheme used for project in Honduras (Forcuencas, 2008)

Previous Rainwater Harvesting Applications in Honduras

Sometimes rainwater harvesting is considered as an emerging technique but in reality it has been used for many years as a mean of accessing water, for irrigation and for domestic use. Economics, growth in urban areas, poverty in rural areas and weather characteristics make many Latin American and African countries the ideal setting for developing this technology. Rainwater harvesting has been applied in different communities in Honduras, mostly in poor rural areas that have no access to water and precipitation is not limiting. This technology for domestic use can be found throughout the country but to a moderate extent, particularly in the departments of Valle and Choluteca (Pacific watershed), where for different reasons of a cultural and climatic nature, the population feels more pressure to supply itself with water, thereby resulting in a very high potential for water demand for human consumption. For agricultural use, this technology is used extensively, preferably in the cattle-raising valleys of the center and south of the country, primarily through the construction of earthen dams over seasonal channels containing rainwater, which serve to provide water to numerous cattle ranches. The establishment of both uses has increased substantially over the last 10 years primarily as a result of competition for water service in those areas where the land is used intensively (OAS, 1997).

Rainwater harvesting can be done individually, at a household level, and at community level. For the purpose of this study only individual application is being considered, primarily because it is simpler, many individual homeowners already have tanks installed; being in urban areas, community involvement is harder to get and lot sizes are much smaller and communal tanks require larger areas to be installed. This makes the social component of such projects very important because users have to be strongly involved in maintaining and monitoring the system by cleaning tanks and roofs periodically. It is important for users to understand the benefits that can be obtained from the application of the technology so that they will be more interested in maintaining the system in good quality, since its efficiency is highly dependent on homeowners.

In Honduras rainwater harvesting has been applied in many regions, in Alauca, El Paraíso in three communities: Las Limas, La Jagua and El Pedregalito. Usually projects in Honduras are sponsored by national or international NGOs, agencies and donations and in many cases developed through the Ministry of Natural Resources (SERNA), the National Autonomous Water and Sanitation Service (SANAA) and municipalities. Other initiatives have been developed in west part of Honduras, in Gualaco, Olancho in San Antonio de Oriente, Cruta in Gracias a Dios, and San Marcos de la Sierra, Intibucá.

Before 2010, FHIS (Social Investment Fund) was working with 24 projects throughout the country; World Vision was implementing the technology in 500 houses in the southern departments of Choluteca and Valle; Catholic Relief Services had a project in the region of Intibucá and Agua para el Pueblo had started a project using communal water storage tanks in the eastern part of the country in Gracias a Dios. Most of these projects are done at community level, for schools and through water boards involving entire communities. Figures 8-10 show previous rainwater harvesting projects in Honduras.

In 2007 a study was conducted by Fundación Vida and PRASCA (Central American Regional Water and Sanitation Network) to analyze the viability of using rainwater catchment systems for low income neighborhoods in Tegucigalpa. The study included 3 different scenarios to be considered, household level in urban areas, community level in urban areas and at household level in rural areas. The results from the study concluded good feasibility of all scenarios and so a model project was developed in San Antonio de Oriente, Francisco Morazán, concluding that such projects are viable, can be successful and are an alternative worth implementing in Tegucigalpa.

Figure 8: Rainwater Harvesting Project in Gualaco, Olancho (El Heraldo, 2010)

Figure 9: Rainwater Harvesting Project for a School in San Antonio de Oriente (Fundacion Vida, 2008)

Figure 10: Rainwater Harvesting in urban areas of Tegucigalpa (El Heraldo, 2010)

METHODOLOGY

In order to determine whether rainwater catchment is an option worth considering for the water scarcity issue in urban areas of Honduras, particularly Tegucigalpa, water quality, water availability, economic benefit and overall advantages had to be considered. According to the World Health Organization's regional office Pan American Health Organization (PAHO) on its publication on Design Guideline for Rainwater Catchment, 2001, when analyzing the feasibility of rainwater catchment projects, 3 factors must be considered: technical aspects which in this case include water availability, precipitation, demand and water quality; economics including a comparison of the costs of implementing this system with the costs of obtaining water through other means; finally, the social factor which include the community's response to the project, their involvement and interest. This study aims to analyze all three factors to determine the viability of implementing the project in Tegucigalpa, Honduras.

First, the technical aspects were analyzed. These include water sampling, testing and precipitation analyses. Water samples were collected from different locations and rooftop materials and analyzed to determine their quality. Water quality standards were measured according to the Honduran Technical Regulation for Potable Water, First Stage (E1) which is a basic analysis measuring organoleptic, physical, chemical and microbiological parameters of water.

Sampling and testing were the first steps in developing the study. Nine samples were collected at three different locations within the city limits of Tegucigalpa. The 3 neighborhoods chosen were selected considering their location, water scarcity issues and rapid growth. At each location, 3 samples were collected, from different rooftop materials, tile, tin roof and asbestos for a total of 9 samples. Two of the locations chosen, groups 2 and 3 are areas on the city's limits and were chosen specifically for this reason, because these areas are experiencing a very rapid growth from people who are migrating from rural areas into the urban outskirts, a lot of which improvise houses from any kind of material they can find, are usually not the rightful property owners and thus some are not connected to a water supply system. These are areas where water scarcity is a very serious problem which only worsens the population's living conditions. Samples from group1 are from a neighborhood that is more centrally located, middle class population and the population is not growing as fast because of its location, less land availability and costs are higher in that part. Water shortages are common in all Tegucigalpa and even though 3 areas were selected to be analyzed, it is a general problem that affects all neighborhoods and social classes.

Water availability can be determined by analyzing the amount of precipitation that falls annually in the area being studied and rooftop areas to get a volume that can be stored in tanks and reused domestically. Precipitation records for at least 10 years, for Tegucigalpa were used in conjunction with typical rooftop areas to determine water volumes and storage needs. Rainwater harvesting also includes the installation of water storage tanks as well as pipes and channels that transport rainwater that falls on top of roofs into storage tanks that can be either elevated, at ground or underground level, filters to sieve big particles that may be carried by the water and finally some basic treatment to make the water usable.

Second, economic factors were analyzed, the economic benefit of implementing this technology was calculated by computing the volume of water that can be stored in tanks and then using local water consumption rates and comparing this value with the investment needed to install, operate and maintain a rainwater catchment system at a household level. Taking into consideration that the city has serious water scarcity problems, rainwater catchment can still be considered an option even when prices can be higher if compared to buying water to private utilities.

Finally, the social component was analyzed. The social aspects of this study include an analysis of the public acceptance to similar projects previously implemented in the country and the level of involvement required for the project to be successful.

Location

The quality of water supplied by the national service provider is not of drinking quality, so users still need to buy drinking water from private companies. This being the case, if rainwater is considered as another option for water supply, it be set to the national standards of quality because though this water is not intended for drinking purposes, user will be in direct contact with it. A total of 9 samples were collected at 3 different locations and different roof materials in the city of Tegucigalpa.

Samples from Group 1 were collected at a neighborhood called San Ángel, which is located at the east central part of the city. Group 1, which includes the 3 first samples collected, is located in the southern part of the city, and the neighborhood is known as Villaflor, and Group 3 which included samples taken at Villanueva, located on the eastern city limits. All samples were analyzed for a simple, stage 1 analysis according to the Honduran Regulation. Tables 2 and 3 present the sampling dates and locations, Figures 11-17 are aerial photographs and maps showing the location of the sampling groups.

Table 2: Sampling groups, roof type and date of sampling

Sample #		Location	Roof Material	Date of Sampling
1	Group 1	San Angel	Asbestos	Nov-16-2011
2		San Angel	Tin (zinc)	Nov-16-2011
3		San Angel	Tile	Nov-16-2011
4	Group 2	Villaflor	Asbestos	Dec-12-2011
5		Villaflor	Tin (zinc)	Dec-12-2011
6		Villaflor	Tile	Dec-12-2011
7	Group 3	Villanueva	Asbestos	Dec-12-2011
8		Villanueva	Tin (zinc)	Dec-12-2011
9		Villanueva	Tile	Dec-12-2011

Table 3: Location and Elevation of sampling points

Sample #		Location	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Elevation (ft)
1	Group 1	San Angel	14.073197˚	-87.179901 ˚	997.00	3271.00
2		San Angel	14.072291˚	-87.179756˚	997.00	3271.00
3		San Angel	14.072429˚	-87.179526˚	996.70	3270.00
4	Group 2	Villaflor	14.033797˚	-87.208966˚	1002.50	3289.00
5		Villaflor	14.034026˚	-87.209185˚	1003.10	3291.00
6		Villaflor	14.033904˚	-87.208697˚	998.22	3275.00
7	Group 3	Villanueva	14.058917˚	-87.160021˚	1178.66	3867.00
8		Villanueva	14.059972˚	-87.159605˚	1178.66	3867.00
9		Villanueva	14.060398˚	-87.159838˚	1171.96	3845.00

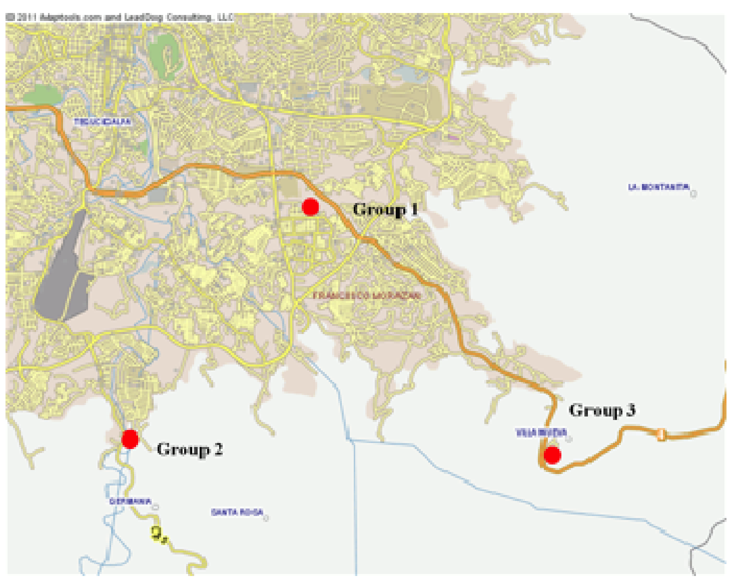


Figure 11: Location of the 3 groups where water samples were collected (GIS Imaptools, 2011)

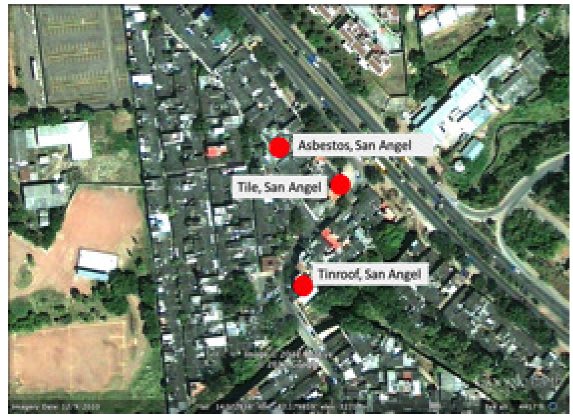


Figure 12: Location of Group 1 (GIS Imaptools, 2011)

Figure 13: Aerial View of the 3 rooftops where samples were collected from Group 1 (Google Earth, 2011)

Figure 14 : Location of Group 2 (GIS Imaptools, 2011)

Figure 15 : Aerial View of the 3 rooftops where samples were collected from Group 2 (Google Earth, 2011)

Figure 16: Location of Group 3 (GIS Imaptools, 2011)

Figure 17: Aerial View of the 3 rooftops where samples were collected from Group 2 (Google Earth, 2011)

Methods

Water Quality

The collection of water samples was performed following the Honduran Technical Operating Manual for Environmental Health Technicians. According to this manual samples can be collected and stored in sterile plastic bags or sterile glass bottles with a secure cap for bacteriologic analysis and glass or plastic clean bottles for physical-chemical analyses. The 9 samples used for this study were collected from rainwater falling directly from rooftops using sterile plastic bags and clean plastic bottles with secure caps. Bags and bottles had to be previously marked and identified to avoid any confusion. Two liters were collected in clean plastics bottles (soda bottles can be used as long as they are washed with soap and clean water previously and then washed 3 times with the water being sampled) as that is the minimum needed for physical-chemical analyses to be performed. Figure18 and Figure 19 show how samples were identified and collected.

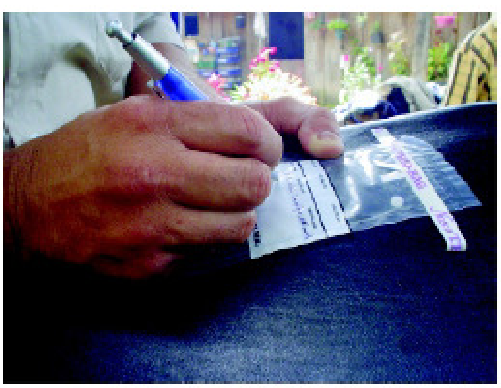


Figure 18: Sample Identification

Figure 19: Sample Identification and Collection

Samples from group 1 were collected in mid-November, which is considered within the rainy season in Tegucigalpa, samples from groups 2 and 3 were collected in mid-December, when the rainy season is over, and only scattered showers occur, meaning samples from these groups can be considered as first rain because several days had gone by with no rain before this December rain occurred. Samples were collected on different dates to analyze water quality from rainwater from rooftops in the middle of the rainy season in between precipitation events and after a dry period when dirt and particles have accumulated on roofs and washed down with precipitation.

Since 1995, Honduras has had a Technical Regulation for Potable Water that dictates the level of analyses required to be carried out in water samples when these are for potable supply. It indicates the parameters that need to be controlled, recommended values and the maximum values that can be found so as to still consider using the water being sampled.

After collected, and transported for analysis, samples were tested according to the Honduran Technical Regulation at the Laboratory for Water Quality and Control, part of the Health Ministry. The analysis performed was conducted following what is defined as Stage 1, basic analysis (E1) by Honduran Standards as: Basic Analysis easily performed at any authorized water quality control laboratory. Control parameters at this stage are: fecal or total coliforms, odor, taste, cloudiness, color, temperature, concentration of hydrogen ions, conductivity and residual chlorine (Honduran Technical Regulation for Potable Water, 1995) Regulation also establishes the methods that are to be used for measuring parameters. The methods suggested are those stipulated by the American Water Works Association in its 17th Edition of the Manual for Water and Wastewater Analysis (Table 4).

Table 4: Parameters and methods for an E1 basic analysis (Honduran Technical Regulation for Potable Water, 1995)

Parameter	**Method**
Coliforms (total and fecal)	Multiple fermentation tubes; Membrane filtration
Color	Visual Comparison; Spectrophotometry
Odor	Odor threshold
Taste	Taste Threshold; Taste range evaluation; Taste profile evaluation
Temperature	Laboratory or field measurement
pH	Electrometric
Conductivity	Wheaston bridge
Turbidity	Nephelometry

These are the parameters corresponding to the basic level of analysis, color was measured visually, odor was analyzed roughly, evaluating there was no repellent smell, taste was not measured, and thus there is no quantitative result for those parameters.

Precipitation

After the first steps were carried out, precipitation data of Tegucigalpa was collected from the Ministry of Natural Resources, specifically the Office of Water Resources' National Weather Service. Records were available from 1944 to 2008 (although collected yearly, information for the last 3 years is excluded because data was not available). A 10 year period of monthly precipitation data was used from 2000 to 2009, which was the most recent information available. This data was processed as an average annual precipitation depth, summing up all precipitation in the city. The purpose of this is to calculate a volume of water that can be collected when multiplied by roof area. Figure 20 is the national precipitation map for Honduras provided by Ministry of Agriculture. From the map, (Figure 20) we can see that Tegucigalpa (circled in red) receives on average 700-1000 mm (27.6- 39.5 in) of rain annually.

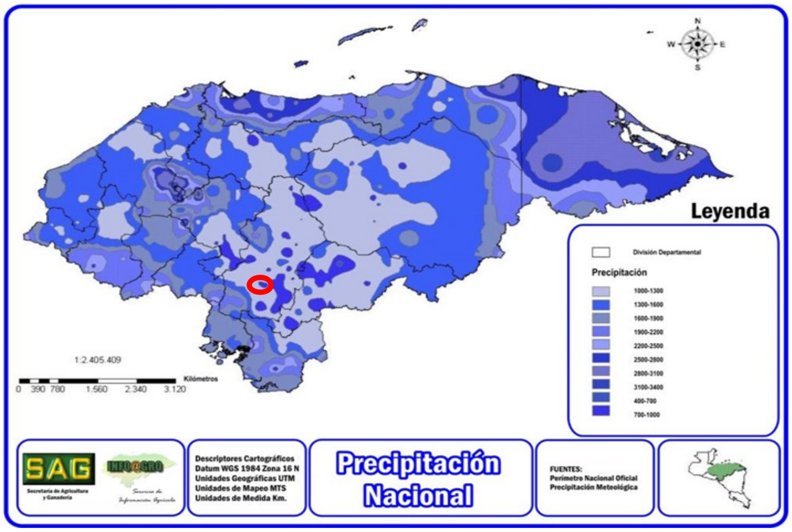


Figure 20: National Precipitation Map, Honduras (Ministry of Agriculture)

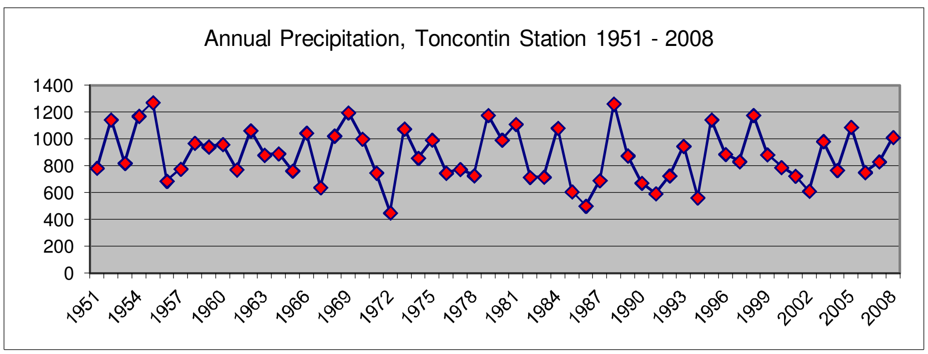


Figure 21: Annual Precipitation, Toncontin International Airport in Tegucigalpa, 1951-2008 (Weather Service,2011)

To calculate the total volume of water that can be harvested, roof areas must be known. The size for plots of land for housing used for this study is 70m^2, which is considered as a basic unit, or what is referred to as social housing. Houses can be smaller than that with overcrowding conditions and much larger than that, but the basic unit will be considered for the purpose of this study. With this calculation, the size of storage tanks was determined so costs could be analyzed. Starting from the basic unit and going up considering different scenarios to determine if and at what point the investment is returned and viable. This information is what we can define as the offer, the amount of water available for reusing, and it must be compared to the demand. The demand was calculated by using the water use per capita for Tegucigalpa assigned by SANAA (National Autonomous Water and Sewerage Service) which is 100 liters per person per day. According to the last census and survey developed by INE (National Institute of Statistics) the average number of people per house in urban areas is 4.4 individuals. This was used for estimating the amount of water required by an average home on a daily basis. This was compared to the offer to know how much of the demand can be covered by rainwater storage.

Precipitation analysis is important because it was used to determine tank volumes for storing rainwater capture from rooftops. A spreadsheet was prepared using daily precipitation records from the Toncontin station in Tegucigalpa, from January 1st, 2000 to December 31st, 2009, considering roof areas of 70 m^2, 100 m^2, 150 m^2, 200 m^2, 250 m^2, and 500 m^2.Annual precipitation for this period is represented in Figure 21.

The formula Q=A*P (where A= roof area (m^2), P=precipitation (mm) and Q=flow of rainwater available for storage (m^3)) was applied to determine rainwater volume. An 80% efficiency was used, trying to follow a conservative approach. This was used to compute the supply, storage, maximum storage, outflow, days with no rainwater supply and the percentage of annual demand that could be satisfied.

The following variables were considered and calculated to determine the best tank sizes:

D: (m^3) Daily water demand for an urban home.

T: (m^3) Tank volume.

S_t: (m^3) Daily storage, calculated by adding the initial stored water and the rain volume and then subtracting the daily supply. $S_t = S_{t-1} + R_v - Q$

S_{t-1}: (m^3) Initial stored water, from previous day, the first valued was assumed as 0. For the next days, S_{t-1} is equal to the previous daily storage (S_t).

S_p: (m^3) Supply. For each day, the value of supply will be the smallest value from comparing the demand and the available rainwater volume that can be stored. (Smaller of D and $S_{t-1)}$

$S_{max:}$ (m^3) Maximum Storage volume; this will be the largest number between the tank size being analyzed and the daily storage.

O: (m^3) Overflow. This was calculated by comparing the sum of the initial stored water and the daily rain volume with the tank size minus daily supply. If this is greater than the tank volume, there will be overflow, if not, there is no overflow that day.

For each year analyzed, the days with overflow were added to determine overflows per year as well as the times per year rainwater supply would not be available. The number of days when all rainwater could be captured was calculated by comparing S_{max} and Q, if the storage is bigger than the available rain volume; it is enough and will capture all precipitation. Finally, for each year, all daily supply was added and compared with the annual water demand to determine the percentage of that demand which can be supplied by the tank size analyzed. These calculations were performed on a spreadsheet for each one of the tank sizes considered: 0.25 m^3, 0.5 m^3, 1 m^3, 2 m^3, 3 m^3, 5 m^3, 7.5 m^3, 10 m^3, 12.5 m^3 and 20 m^3 and for each scenario, different roof areas were analyzed.

Cost Analysis

The third step performed for the study was the cost analysis. A rainwater harvesting system includes the materials for installing a rain catchment structure as well as qualified labor.

Once the system is installed, maintenance and operating costs, although minor, include periodic cleansing and any kind of basic disinfection that may be required for improving the quality of the harvested water. Cost analysis included calculating the cost of building a storage tank, collection systems and distribution tanks. Different alternatives were considered, and in all cases the scenario of an existing storage tank was included. It is important to mention that due to the water scarcity crisis that has been a problem in Tegucigalpa for years, many homes already have a water storage tank.

This cost, of installing a rainwater collection and storage system, was compared with the price assigned to the volume of water that can be stored from precipitation on roofs, with the purpose of determining whether rainwater can be a viable option in this city. The price used for water was that set by SANAA as rate for domestic water supply. SANAA has divided the city's residential areas into 4 different segments based on property size, taxes and home value. Rates include connection costs, a base minimum price for water supply services and a very low price for water meter maintenance. Each of the 4 segments has a different base price and rate per cubic meter; this rate increases as consumption increases. The total amount owed, will include these costs plus 25% of that amount corresponding to sewerage and sanitation costs.

Comparison of costs was performed using different scenarios, analyzing water costs for each of the different segments in Tegucigalpa and for different water consumptions. Since not all neighborhoods are connected to SANAA's supply system, some homeowners are forced to buy water from private companies who provide water to low income residences through water tankers; for these cases, the analysis also included an alternative for pricing water based on water tanker charges by private service providers. The investment required was calculated as annuity, considering a lifetime of 20 years, as recommended to the World Health's Organization (WHO) and Gould, 1999 and Huffon 2004. The interest rate used was 5.67% as established as an average by the Central Bank on its 2010 publication Honduras en Cifras.

$$\frac{A}{P} = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Equation 1: Annuity formula used to determine annual costs of the project.

Cost analysis was prepared for different roof sizes, in order to determine at which size this technology becomes profitable and at which roof size the investment is not reasonable for the amount of precipitation in the area. Finally, an overall analysis of the results was performed, including the economic, environmental and social aspects as well as a list of benefits, advantages, opportunities and alternatives that can be applied. This was performed including a cost benefit analysis, an environmental analysis as well as a social component, comparing strengths, weaknesses, opportunities and threats for each element.

Results

Water Quality Results

Samples from three locations where water was collected from different rooftop materials were analyzed at the Water Quality and Control Laboratory at the Metropolitan Region (Table 5). A total of 9 samples were tested based on the Honduran Technical Regulation for Water Quality and the results were compared to the Honduran water quality standards.

The parameters analyzed are those stipulated as basic E1 analysis for potable and drinking water, and include total and fecal coliforms, temperature, pH, turbidity and conductivity. Appendix 1 includes water quality results provided by the laboratory.

Table 5: Water Quality Results

Sample #		Total Coliforms (CFU/100 ml)	Fecal Coliforms (CFU/100 ml)	Temperature (°C)	pH	Turbidity (NTU	Conductivity (□S/cm)
		Honduran Standard					
		0 CFU/100ml	0 CFU/100ml	18°C -30°C	6.5-8.5	1 NTU	400 □S/cm
1	Group 1	6	0	20. 5	7	1.3	44.8
2		5	0	20.5	6	1.03	18.88
3		4	0	20.5	7	1.2	26.0
4	Group 2	17	12	20.5	7	1.3	61.5
5		17	10	20.5	7	1.5	65.0
6		23	15	20.5	7	1.4	70.5
7	Group 3	15	10	20.5	7	1.02	65.2
8		24	13	20.5	7	1.2	63.6
9		21	16	20.5	7	1.05	63.5

Coliform counts were higher in samples from groups 2 and 3, while undetectable or lower in group 1. Samples from Group 1 were collected on November 16th, 2011, while the rest of samples were collected on December 12th, 2011. The rainy season begins on late May and ends by the end of November, with sporadic showers the rest of the year. Samples from mid-November presented higher quality because roof were probably cleaner due to previous and constant rain, while samples from mid-December could be considered as “first-rain” or first flush because by that time rainy season has ended. The last samples collected in December were from a rain event occurring after approximately 2 weeks of dry weather, giving a chance for roofs to collect dirt, animal feces and debris and that was reflected in the results.

Water quality monitoring is recommended to ensure high quality water continuously; samples should be collected at the beginning of the rainy season, and then after the first rain showers. Water deposited in storage tanks should also be monitored to prevent users of the system from using low quality water that can be harmful to the family's health. First flow diverters can be installed to ensure water quality and make the system more reliable and not as dependent on the users maintenance.

Rainwater harvesting systems include a filter to sieve the water from any large particles that can be carried through roofs, pipes and channels, however not all undesired contaminants are removed by this filter and so some kind of treatment is recommended before coming in direct contact with the collected water.

Considering this kind of project aims to reduce costs and enhance quality of life for citizens, extra expenses are avoided, and the recommended disinfection methods that can be used without increasing costs are solar disinfection (SODIS), chlorination and boiling water before its use.

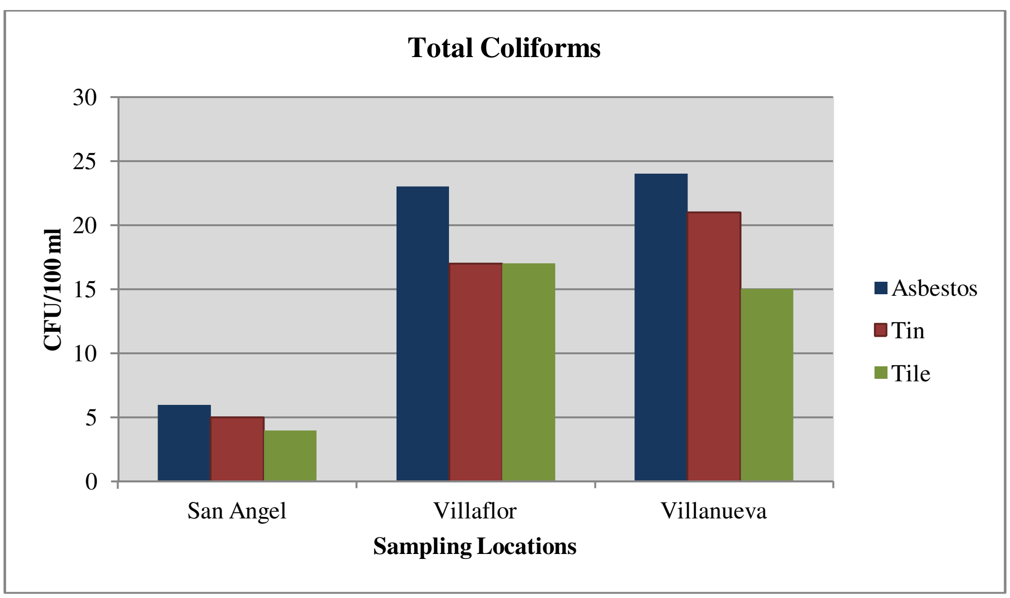


Figure 22: Total Coliforms in rainwater samples for all 3 locations

Samples collected at Location 1, San Angel, had less total coliforms than samples from Locations 2 and 3, Figure 22 illustrates this parameter. Samples from the first group were collected in mid-November, when precipitation was still falling on a daily basis, so many particles from animal feces or other sources have been washed down by earlier storms. Samples from groups 2 and 3 were collected in mid-December, when the dry period had already started and rainfall was not very frequent, so roofs were not clean and bacteria were present.

Although many types of coliform bacteria are harmless, some can cause health problems which include diarrhea, cramps, nausea and vomiting. Together these symptoms comprise a general category known as gastroenteritis. Gastroenteritis is not usually serious for a healthy person, but it can lead to more serious problems for people with weakened immune systems, such as the very young, elderly, or immuno-compromised. (EPA, 1989)

Fecal coliform and *E. coli* are bacteria whose presence indicates that water may be contaminated by human or animal wastes. Microbes in these wastes can cause short term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems. (EPA, 1989)

Fecal Coliform results (Figure 23) are similar to total coliforms, higher for samples taken in mid-December, no fecal coliforms in samples from location 1. According to the Environmental Protection Agency's (EPA) Total Coliform Rule: Disinfection with chlorine, ultra-violet light or ozone, all of which act to kill or inactivate *E. coli.* Systems using surface water sources are required to disinfect to ensure that bacteria are inactivated, are all treatment methods proven to be effective for removal or inactivation.

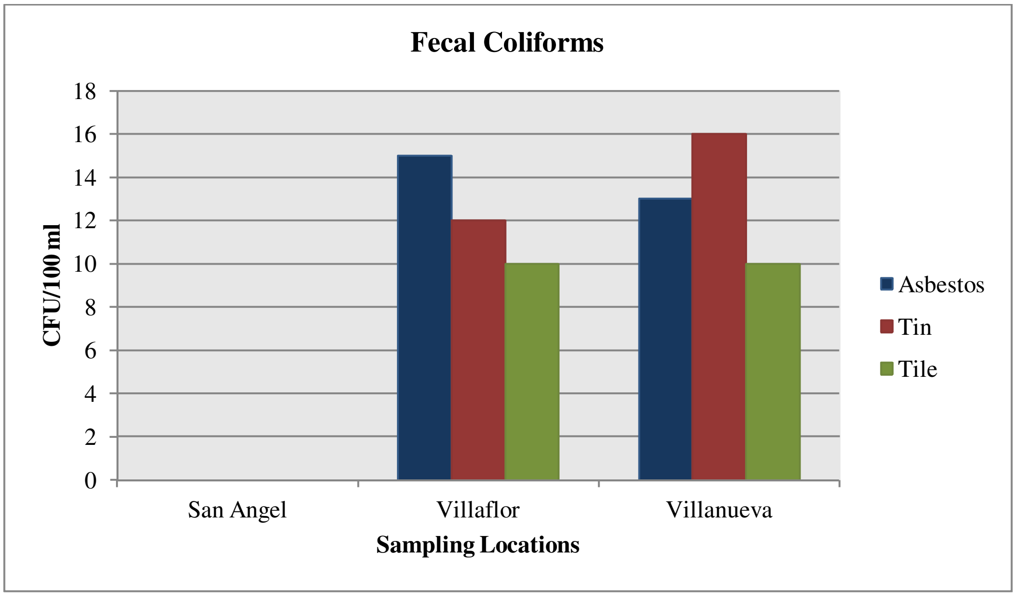


Figure 23: Fecal Coliforms in rainwater samples from all 3 locations

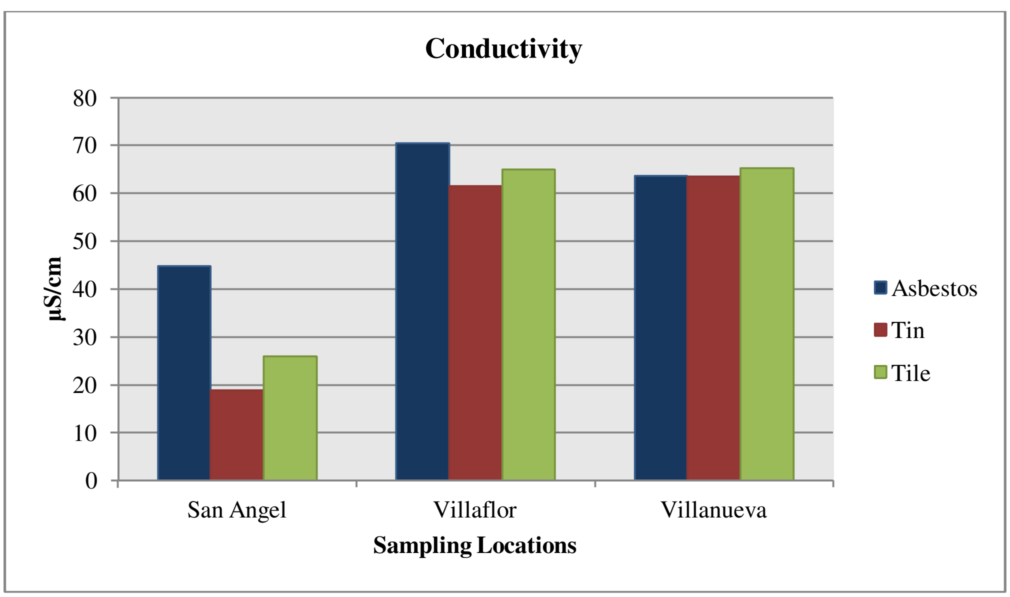


Figure 24: Conductivity in rainwater samples from all 3 locations

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. (EPA)

Conductivity was lower in samples from Group 1 (San Angel) when compared to results from the other two groups as can be seen on Figure 24. This makes sense considering the sampling dates, in between precipitation events, so there were probably less dissolved solids, which lowers conductivity. Measured conductivity levels for groups 2 and 3, though higher than group 1, are still very much under the established maximum.

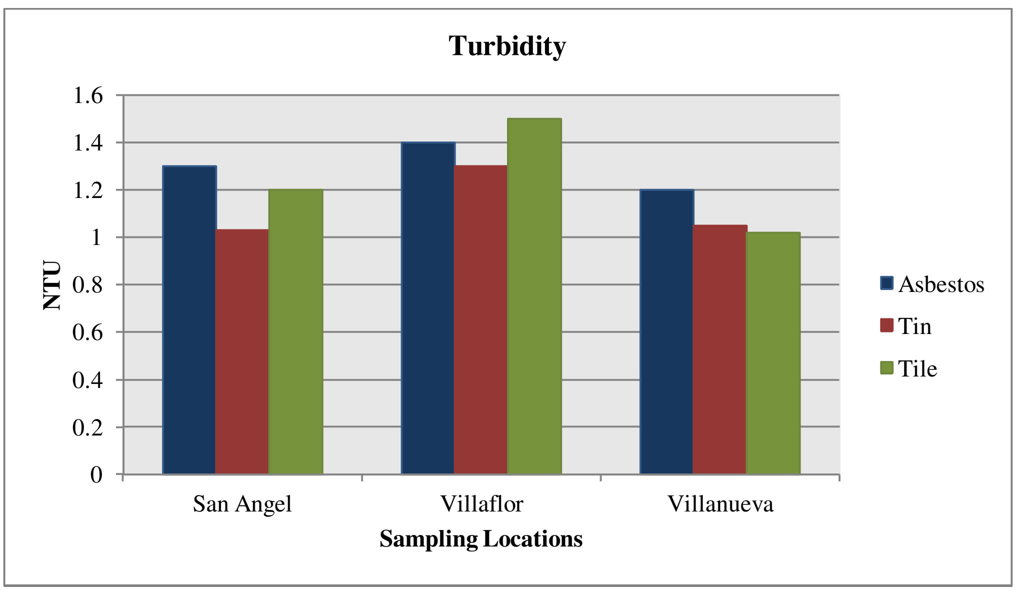


Figure 25: Turbidity in rainwater samples from all 3 locations

Turbidity is a measure of water clarity and how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water (EPA, 2012). Figure 25 illustrates the results for turbidity in all three locations, for the three different roof materials sampled. All samples presented higher turbidity levels than what the national regulation states.

Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO.

Treatment methods that have been proven effective for removal or inactivation include: Filtration, including conventional, direct, slow sand, and diatomaceous earth filtration and alternative filtration technologies such as cartridges, bags, or membranes. (EPA, 2012).

It is important to mention that rainwater quality is very dependent on the maintenance given to the system, periodic cleaning and roof preservation. Roof materials play an important role in this technology as some are more prone to retaining particles that can be harmful to users. Asbestos roofs present a growing concern to users due to recent discoveries as how exposure to this material can cause serious health problems. The problem with asbestos comes from constant and longtime exposure to inhaling its fibers, which is most common from occupational contact. The Honduran Health Ministry banned the use of asbestos, or any material containing it since 2004, to prevent health problems. There is no regulation for homes built before that year, which already have asbestos rooftops.

However, there is no proven link between asbestos in water and health problems. In the U.S. the Safe Drinking Water Act established a Maximum Contaminant Level Goal for Asbestos of 7 million fibers per liter of water (M.L.). EPA believes this level of protection would not cause any potential health problems and is a non-enforceable level, based solely on possible health risks and exposure. (EPA, 2011)

According to the World Health Organization's (WHO) Guidelines for Drinking Water Quality (2003): Although asbestos is a known human carcinogen by the inhalation route, available epidemiological studies do not support the hypothesis that an increased cancer risk is associated with the ingestion of asbestos in drinking-water. Moreover, in extensive feeding studies in animals, asbestos has not consistently increased the incidence of tumors of the gastrointestinal tract. There is therefore no consistent, convincing evidence that ingested asbestos is hazardous to health, and it is concluded that there is no need to establish a guideline for asbestos in drinking-water

According to EPA's guidelines, Individuals who wish to take extra measures to avoid waterborne pathogens can bring their drinking water to a full boil for one minute (longer at higher altitudes). Boiling water is the most effective way to inactivate (kill) pathogens. As an alternative, a point-of-use (personal use, end-of-tap, under-sink) filter that removes particles one micrometer or less in diameter provide the greatest assurance of Cryptosporidium removal.

Based on the basic analysis performed, which also included constant temperate and pH values, it can be said that though not all parameters met Honduran standards for drinking water, quality was overall fair and simple treatments could easily be added to improve it. Rainwater quality sometimes is better than water being bought by users from private supplier who are not regulated and can sell any kind of water they want, because the need is so big, users will buy it.

Precipitation Results

The success of a rainwater harvesting system will depend on many factors. Water demand in the area, cost feasibility, and precipitation are some of the most important issues to consider when analyzing the viability of implementing such systems.

Precipitation data is needed to determine the volume of water that can be captured, with rain depth and roof area, and then use that information to compare with the daily demand in an average urban household.

Precipitation records from a period of 10 years (2000-2009) provided by the Office of Water Resources' National Weather Service were used for determining the tank volumes that show the most benefits when compared to its costs, for different roof sizes, percentages of demand met, and overflow. Monthly averages are presented in Table 6.

Daily precipitation records were used and based on that information, monthly average precipitation was obtained as shown in the next table and graph.

Table 6: Monthly and Annual Precipitation Average (National Weather Service, 2010)

Month	Average Monthly Precipitation (mm)	Average Monthly Precipitation (in)
Jan	5.79	0.23
Feb	6.68	0.26
Mar	7.78	0.31
Apr	41.16	1.62
May	146.75	5.78
Jun	164.26	6.47
Jul	76.10	3.00
Aug	93.64	3.69
Sep	142.12	5.60
Oct	115.22	4.54
Nov	30.27	1.19
Dec	12.44	0.49
Annual	842.21	33.16

Based on the Köppen weather classification, by which Tegucigalpa, the city where this study is located, is classified as a tropical savanna. This type of climate is characterized by dry and wet periods, corresponding to the data collected.From the 10 year period of precipitation analyzed, it is very noticeable that the dry season starts by the end of November through April and the wet season begins in May and goes through October. During this period the maximum monthly average was 164.26 mm (6.47 in) for the month of June and the minimum was 5.79 mm (0.23 in) for January.

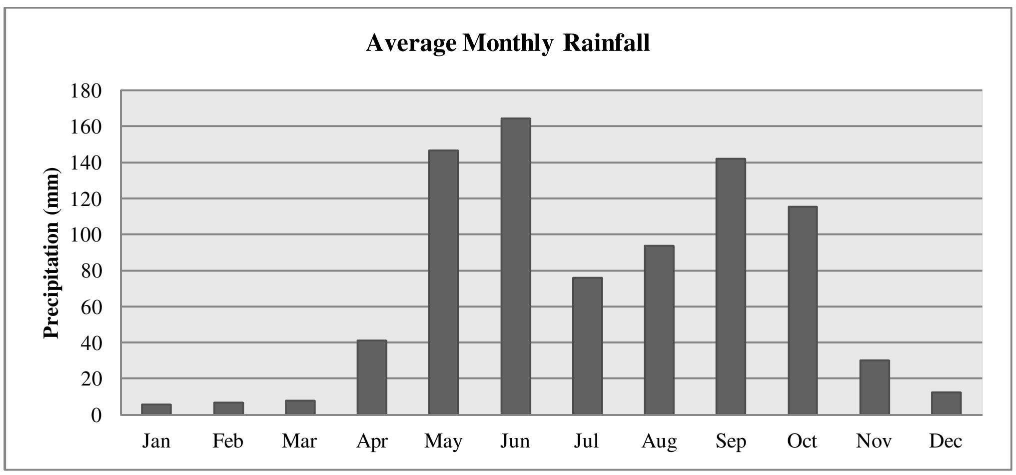


Figure 26: Average Monthly Rainfall (2000-2009)

Figure 26 illustrates that for the decade analyzed, June, July and September, in that order, were the months with the most precipitation. January, February and March are the driest months of the year. Annually, Tegucigalpa receives in average 842.21 mm of precipitation. This corresponds to the city's climate; rainy season and national precipitation map that states the area will receive from 700-1000 mm of rain per year.

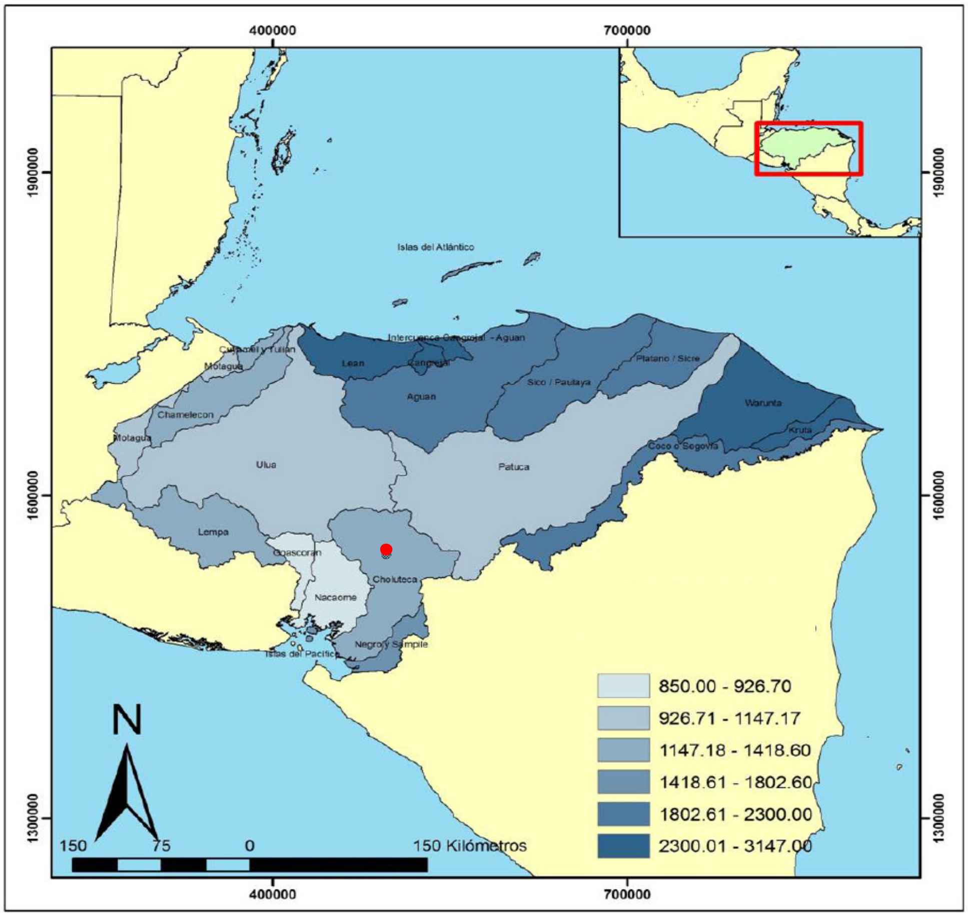


Figure 27: National Precipitation Plot, Honduran Basins. The red dot represents the basin where Tegucigalpa is Located (Rodriguez, 2010)

The previous map, a national precipitation plot dividing the country into its 19 basins, indicates the annual precipitation for each watershed. Tegucigalpa is located in the Choluteca River Basin, which historically and considering all rain gage stations receives on average 1147.18mm (45.16 in) to 1418.60 mm (55.85 in) of rain annually. This study only includes the city of Tegucigalpa and records for a decade of precipitation.

Daily water demand for Tegucigalpa was estimated based on what the National Autonomous Water and Sewerage Service (SANAA) defines for daily water demand per capita. SANAA authorities calculate that the average citizen of Tegucigalpa requires 120 liters of water per day for toilette flushing, showering, clothes' washing and to meet other household uses (31.7 gal). The National Institute of Statistics (INE) in Honduras established that the average urban home accommodates 4.4 people in urban areas and 5.1 in rural regions. The same institution calculates that the basic house, often referred to as social housing projects, has an area of 70 m^2 (753.5 ft^2). This is the size used in the study as basis for calculation, although different areas were also considered in order to determine cost feasibility. Based on these numbers, the average daily water demand in an urban house is 528 liters/day (139 gal/day) as shown in Table 7.

Table 7: Daily Water Demand

Water Demand		
Daily Water demand	120	lppd (liters per person per day)
Basic roof size	70	m^2
Average # people/house	4.4	urban areas
	5.1	rural areas
Daily Water Demand in Average House	528	liters /day
	139	gal/day

Monthly precipitation analysis can be used as general indicator of the percentage of demand satisfied monthly for an average household in Tegucigalpa.

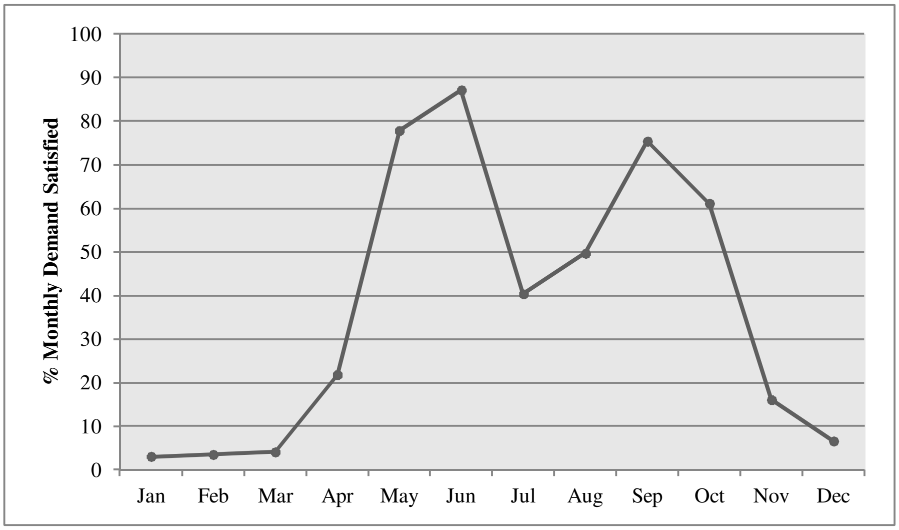
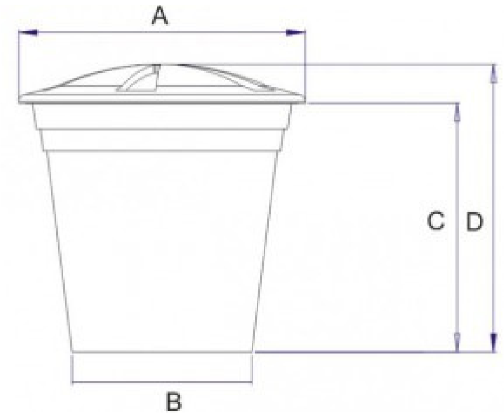


Figure 28: Percentage of Monthly Demand that can be satisfied by rainwater

Figure 28 serves as a general estimation of the efficiency of a rainwater harvesting system based on monthly precipitation and monthly demands in the city. The graph is a comparison of the monthly demand and the percentage of it that could be satisfied by rainwater collected from rooftops. A day-to-day precipitation analysis was performed to better determine the days in the year when precipitation is enough to supply daily demand, the percentage of the demand that can be covered with the stored water and the amount of days when there can be an overflow. This was analyzed by using daily precipitation records from January 1st 2000 to December 31st 2009 of station 78720 located at Toncontín International Airport in Tegucigalpa, Honduras. Daily precipitation depths were multiplied by rooftop area to calculate the volume of water available to supply the daily demand of an average home.

Figure 29 is a basic sketch of a typical commercial storage tank commonly used in Tegucigalpa. Table 7 is a description of tank dimensions and volumes.

Table 8: Commercial Polyethylene Tank Sizes, A,B,C and D are defined in schematic on the right (Rotoplast, 2012)



Tank Volume (Liters)	A	B	C	D
250	946	626	670	810
500	1075	680	966	1080
1000	1417	890	1236	1446
2000	1585	1165	1570	1790
3000	1880	1460	1725	1550
5000	2050	1700	2035	2300
7500	2305	1975.5	2267.5	2639.5
10000	2560	2251	2500	2979

Figure 29: Sketch of a basic polyethylene water storage tank (Rotoplast, 2012)

The tank sizes used for calculating daily supply were based on commercial sizes typically used in Honduran homes from plastic tank providers.

The analysis of precipitation records was useful in determining which tank volume presented the most benefits when compared to its costs, for the amount or rain falling daily in Tegucigalpa. Based on the analysis, the average number of days each year, when all the precipitation can be stored in different tank volumes.

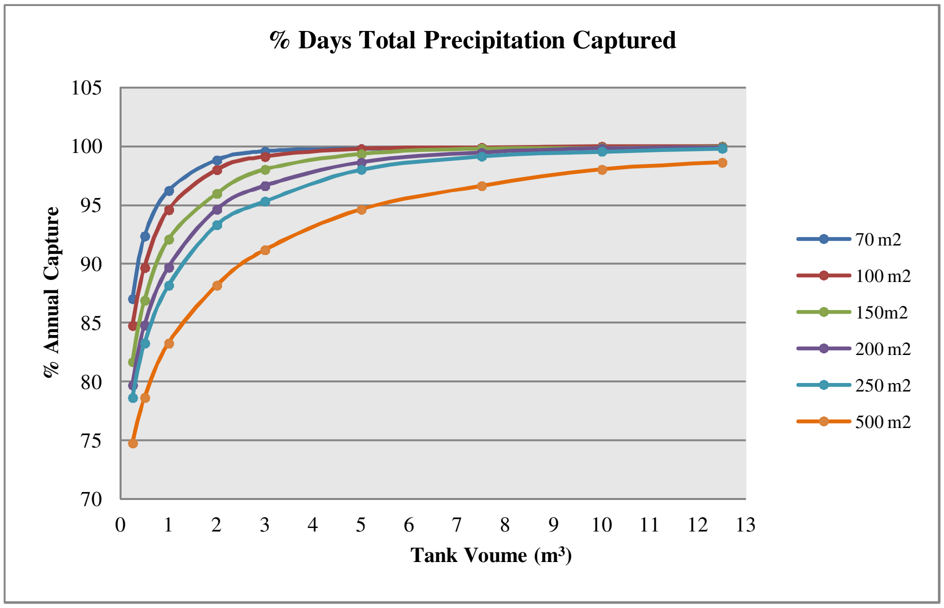


Figure 30: Percentage of Days/year when the total precipitation can be captured

From the Figure 30 it is evident that as roof areas increase, the volume of precipitation that could potentially be stored increases, and so the tank size required to capture the total amount of precipitation is larger. The graph's behavior illustrates how as rooftop areas are larger, the percentage of days when all daily precipitation can be captured by the proposed tank volumes, decreases. It is also evident that there is a point at which, tank sizes can get larger, but there will be a small or no benefit from that increase.

This information provides a clear view for determining appropriate tank volumes that can be installed for rainwater harvesting system. Precipitation analysis was also used to determine how much supply could be provided to users, whether this technology could be implemented as a sole solution or if its application should be considered as a complementary supply to other systems.

Figure 31 presents the number of days when there will be no water supply for Tegucigalpa residents, only considering rainwater as source. The graph demonstrates that as tank volume increases, the number of days with no supply decreases, considering there is more space available for water storage.

An area of 500 m^2 was considered for rainwater harvesting to see how much more water could be stored in a considerably larger household. In this particular case a 20 m^3 tank was also analyzed taking into account the considerably larger volume of water that can be harvested from a large roof. Analyzing roof sizes and tank capacities can be never-ending, home sizes vary widely; however, this study focuses on the areas of the city where access is remote, and these tend to be smaller households. From an institutional perspective, installing rainwater harvesting systems could be a project worth investing in by the water supply utility.

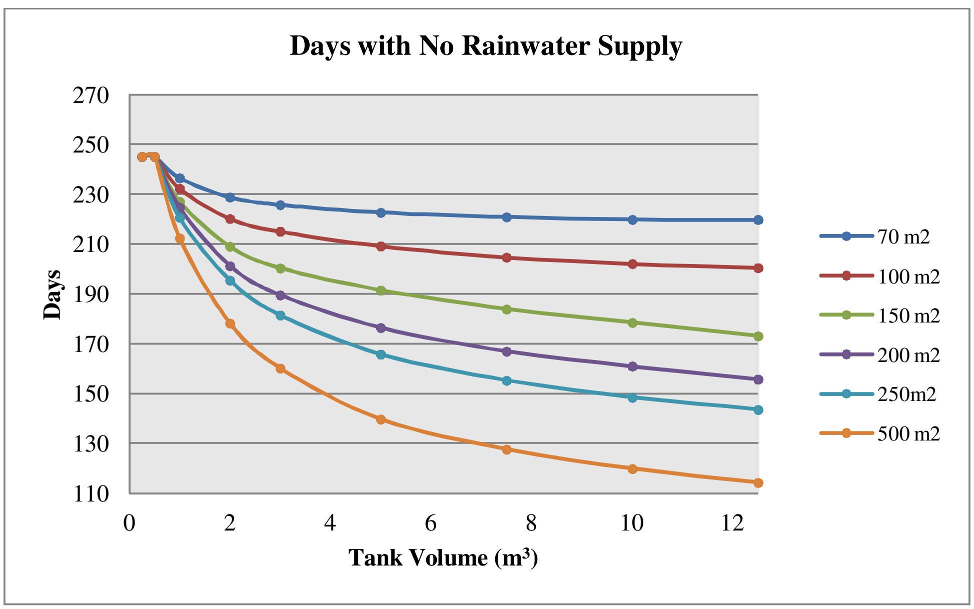


Figure 31: Days with no rainwater supply

Figure 32 shows that the percentage of demand satisfied increases as the tank volume increases, as tank volumes become larger the change is demand satisfied is smaller, and the graph shows there is a point at which increasing tank size makes little difference. For the purpose of demonstrating this clearer, this graph was built using smaller tank sizes, from 0.15 m^3 and larger tanks to 12.5 m^3 to make the behavior more evident. Figure 32 illustrates the percentage of annual water demand that can be satisfied depending on different tank volumes. The graph also shows prices for different volumes of polyethylene tanks. Though costs are analyzed on the next section in more detail, this graph displays how the increase in tank volume may increase the percentage of demand satisfied slightly, while costs increase substantially.

Appendix 2 presents a summary of the results obtained from the precipitation analysis. The table condenses the graphs presented above, the percentage of days each year when all precipitation can be captured, days each year when there would be no supply from rainwater and the percentage of annual demand that can be covered by implementing a rainwater harvesting system at a household level. Different tank volumes were analyzed for different rooftop areas in order to compare best options.

Based on these results, it becomes clear that increasing tank volume will result in more water being captured, more supply and more demand satisfied, but there is a point at which increasing volume, does not reflect in a high increase in water capture or demand satisfied nor in a significant decrease of days when there will be no rainwater supply. This point depends on roof size, but based on the graph it would be safe to assume that after 2 m^3 and 3 m^3 tanks, prices do not vary as significantly for the volume captured.

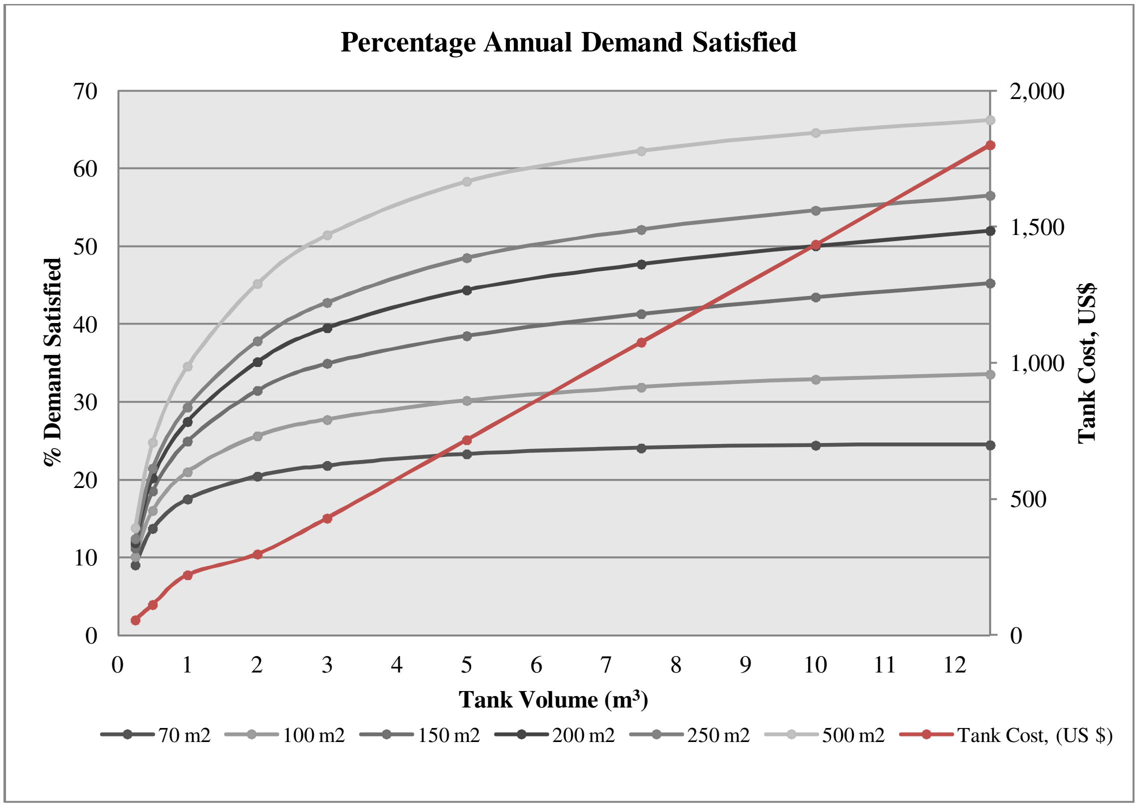


Figure 32: Percentage of Annual Demand Satisfied for each tank volume and cost for each size.

All this information was used to determine what would be the volume beyond which there would be no benefits on the percentage of demand satisfied , number of days with no rainwater supply and the percentage of days each year when all precipitation can be captured but costs increase significantly after that voume (see Table 8).

The roof areas considered were determined by beginning with the basic unit or social housing size and progressively increasing area, considering homes larger than 500 m^2 are not suffering from so severe water scarcity and typically pay less for water. Tank sizes considered were commercial volumes.

Table 9 Tank Volumes based on Precipitation Analysis (Beyond this volume, benefits are very small compared to costs)

Roof Area (m^2)	**Tank Volume (m^3)**
70	3
100	5
150	5
200	7.5
250	7.5
500	10

Costs for these tank sized were estimated with the purpose of determining which one can bring the most benefits for users.

<u>Economic Analysis</u>

Rainwater harvesting systems in Tegucigalpa have a high potential to alleviate water scarcity problems. Implementing such technology requires not only a technical analysis of water quality and precipitation records. An analysis of the costs and benefits of installing a catchment structure is a very important section of this study, as it might be the decisive factor for such a project. Costs for implementing rainwater harvesting include the initial investment, maintenance and operation costs and these will be compared to the benefits that can be obtained from it. These benefits include savings for local buyers and savings for service provider among other added benefits that might not be as quantifiable or immediate. This study focuses on a domestic rainwater system in an urban setting, which is the most appropriate option for the region. The complexity of the system and the materials that can be used will depend on the available funds, available space, water demand and storage needs.

In rural areas, where there is more space, larger underground tanks are more common and typically shared by several homes. However, in urban areas, where there is not as much land, tanks are usually elevated and independent for each household, as managing and maintaining communal structures is more complicated. Tanks can be made from polyethylene, ferro-cement and reinforced concrete. Costs for the three alternatives were considered using the most current information available from Honduras, from the chamber of commerce's price publications, similar projects developed in the area and local suppliers. Some costs taken from previous applications of the technology in Honduras were for 2008 and 2007, and in order to update these prices, inflation rates for the last 5 years were used from the annual publication of the Central Bank of Honduras.

The three alternatives analyzed for this study, as considered the most suitable options based on reviewed literature from previous projects in the region and publications, were:

1) ferro-cement storage tank, rainwater catchment system and elevated polyethylene tank for supply;

2) Polyethylene tank for storage and supply, elevated platform and rainwater catchment system; and,

3) a polyethylene tank for storage, rainwater catchment system, elevated platform and polyethylene supply tank.

Tables 10, 11 and 12 show the alternatives considered. Prices were calculated for all alternatives, considering 2 scenarios: 1) there is no storage tank already working and entire systems need to be installed, and 2) a tank is already installed and only a rainwater collection structure is needed. (Detailed costs are included in Appendix 3)

Analyzing the two different scenarios for each alternative was very important because as water shortages are so severe that people are forced to have water storage tanks, this being the case in most homes in Tegucigalpa.

Honduran currency is the Lempira; the exchange rate used for this study is 19.2746 Lempiras= 1 US dollar, using the Honduran Central Bank rate as of March 28th, 2012.

From the precipitation analysis, the best tank volumes for each roof size were determined from a technical design perspective. However, determining whether these are feasible will depend not only on the technical aspect; costs need to be considered as they would probably be the decisive factor for implementing this type of system.

The purpose of the cost analysis is to determine whether the benefits of implementing this technology outweigh the costs. In order to determine this, the costs of installing the rainwater catchment system were compared with the value of water that can be supplied through its implementation.

Alternative 1 includes a ferro-cement storage tank, a rainwater catchment system and is analyzed for a scenario where a smaller polyethylene tank is installed for supply to the house. Scenario 2 considers that homes have an installed tank already operating for water scarcity issues in the city. This is typical in many homes throughout the city because shortages are so common, that tanks become a need.

Alternative two considers an elevated polyethylene tank for storage and supply, a platform for the tank and the required drains and channels for rainwater collection. Scenario considers tanks are already installed and only the drains for water collection are considered, including accessories and a filter.

The third alternative includes 2 polyethylene tanks, one for storage and an elevated one for supply, platform and a rainwater catchment system, filter and as well as the other alternatives, it was also analyzed considering a tank is already installed. Appendix 3 includes more detailed tables on the costs for each alternative.

All alternatives considered labor costs assuming the Honduras' minimum wage. This is a conservative calculation, considering that ideally these projects are community inclusive and aim for citizen participation. If such a technology were to be implemented, a very strong component that would impact its success would be the level of involvement from the community. Community members would have to actively engage in learning how to install the system, maintain it and operate it as well as implement water treatment procedures to improve water quality.

The price of water was estimated using the market prices established by SANAA and the reported payment to private vendors. Many factors must be considered for the analysis, according to the World Health Organization (WHO), back in 2000, 98% of urban water supply systems worked intermittently on average only 6 hours per day. According to Strand, 1998, households in peri-urban areas, where access to water is remote, users reported 7.2% of their income is used to cover water expenditures, while wealthier areas with better access reported to use 1% of their income in these expenses.

In order to put a price to water, the water demand was estimated. As reported by the National Institute of Statistics, 4.4 people live on an average house in urban areas of the country. This means that during a year, 192.72 m^3 are used, this is what can be considered as the ideal demand as seen in Table 10.

Table 10: Annual Water Demand for an Average Urban House

Daily Water demand in average house	528	liters per day
	0.528	m^3/day
Monthly demand	15.84	m^3/month
Annual demand	1923	m^3/year

This demand was used to determine the annual cost of water by SANAA standards. Water rates vary for different segments in the capital. Monthly rates include maintenance costs, connection costs, minimum costs and a 25% for sewerage system connection and services. Table 11 includes rates for the four different segments in the capital, minimum consumption, fixed costs, maintenance costs and calculation, in Lempiras and Dollars, of the monthly and annual costs for an average household.

Table 11: Monthly and Annual Water Costs for an Average Urban Household (Water Rates SANAA, 2010)

Annual Water Cost	
Segment 1 (Cost paid for water)	
HON Lps.	US $
495.00	25.68
Segment 2 (Cost paid for water)	
HON Lps.	US $
1,302.00	67.53
Segment 3 (Cost paid for water)	
HON Lps.	US $
2,184.00	113.34
Segment 4 (Cost paid for water)	
HON Lps.	US $
3,942.00	204.54

Detailed water pricing is provided in Appendix 3.

These calculations can be applied for those homes where there is a connection to the water supply system; however, one of the big issues with water scarcity in Tegucigalpa is that immigration from rural areas of the country has resulted in a disorganized growth of the city. Peri-urban areas, on the city limits, are growing with illegal settlements with no water supply or sewerage connections. These residents are forced to purchase water from private water suppliers who are not regulated by any authority on their quality or prices. Considering the same annual water demand, water costs for these users were calculated and presented in Table 12. SANAA has a very limited number of water supply tankers that provide water to these areas through a project called Aquabloq. Their price as well as private companies were considered as presented by Rodríguez, 2011.

Table 12: Monthly and Annual Water Costs, Private Suppliers and Aquabloq

Monthly demand	15.84	m^3/month
Annual demand	192.72	m^3/year
Aquabloq (SANAA)	78.45	Lps/m^3
	4.05	US \$/m^3
Private companies	88.66	Lps/m^3
	4.60	US \$/m^3
Monthly Cost Aquabloq	1,242.61	Lps/m^3
	64.15	US \$/m^3
Monthly Cost Private Companies	1,404.42	Lps/m^3
	72.86	US \$/m^3
Annual Cost Aquabloq	15,118.43	Lps/m^3
	780.52	US \$/m^3
Annual Cost Private Companies	17,087.16	Lps/m^3
	886.51	US \$/m^3

After calculating the annual cost of water for an average house, considering a daily demand of 120 liters per person per day, and having the tank volumes that work best for the different rooftop sizes being analyzed, the value of the rainwater that can be captured was obtained. Table 13 shows the value of water that can be satisfied annually for the 4 different segments in which Tegucigalpa is divided for rate setting by SANAA.

Table 13: Value of Annual Rainwater Harvested for different segments SANAA rates

Roof Area (m^2)	Tank Volume (m^3)	% Annual Demand Satisfied	Cost Paid Segment 1		Cost Paid Segment 2		Cost Paid Segment 3		Cost Paid Segment 4	
			Lps/m^3	US $/$m^3$	Lps/m^3	US $/$m^3$	Lps/m^3	US $/$m^3$	Lps/m^3	US $/$m^3$
70	3	22	108.01	5.60	284.11	14.74	476.57	24.73	860.18	44.63
100	5	30	149.33	7.75	392.77	20.37	658.84	34.19	1,189.18	61.70
150	5	38	190.56	9.89	501.22	26.00	840.76	43.63	1,517.53	78.74
200	7.5	48	236.09	12.25	621.00	32.21	1,041.68	54.06	1,880.17	97.56
250	7.5	52	258.20	13.40	679.15	35.23	1,139.22	59.12	2,056.24	106.69
500	10	65	319.82	16.59	841.22	43.63	1,411.09	73.23	2,546.93	132.16

Table 14 presents the annual price of rainwater that can be supplied for the different tank volumes when considering private water suppliers.

Table 14: Value of Annual Rainwater Harvested, private suppliers' rates

Roof Area (m^2)	Tank Volume (m^3)	% Annual Demand Satisfied	Aquabloq		Private Companies	
			Lps/m^3	US $/$m^3$	Lps/m^3	US $/$m^3$
70.0	3.0	21.82	3,298.97	170.32	3,728.56	193.44
100.0	5.0	30.17	4,560.76	235.46	5,154.66	267.43
150.0	5.0	38.50	5,820.06	300.47	6,577.96	341.28
200.0	7.5	47.70	7,210.87	372.27	8,149.88	422.83
250.0	7.5	52.16	7,886.12	407.14	8,913.06	462.43
500.0	10.0	64.61	9,768.05	504.29	11,040.05	572.78

Annual costs of installing the project as well as annual cost of water were compared to determine whether the cost-benefit ratio is enough to make it a good investment and the time in which the project would pay for it itself. The annual costs of water for the 4 different SANAA segments, Aquabloq and Private Companies were compared with annuity values of implementing the project. The project's lifetime considered was 20 years at a 5.67% rate. All three alternatives, each with 2 scenarios (including tank and not including elevated tank), were analyzed to determine the Cost-Benefit Ratio and the Payback time for the investment. Graphs illustrating this analysis are presented (Figures 33-44) to explain the financial aspects of the project. Detailed calculations and tables are included in Appendix 4.

All graphs depicting cost-benefit ratios include a reference line, when benefits=costs and the ratio is equal to 1. Typically, projects with a ratio larger than 1 are considered profitable and ratios smaller than 1 are discarded. Graphs for the Payback period also include a reference line, the project's lifetime. Projects that have revenue or benefits that pay off the project before the project's lifespan ends are considered worthwhile.

It is very important to note that while these tools present a clear perspective of a project's financial aspect, they do not account for the project's social and environmental benefits, which sometimes cannot be monetized. In the end, stakeholders will have to decide if the proposed technology is suitable for their needs, in this case having enough water to supply basic needs may outweigh costs. Another important consideration is that all costs include labor costs, and ideally this type of project is based on the premise that community involvement is very important and part of its socialization includes training residents to install and operate the system, however, being conservative with estimates, this expense is accounted for as external.

Alternative 1: Underground ferro-cement tank and elevated polyethylene tank

Alternative 1 included installing an underground ferro-cement tank for storage, drains, filter, a pump and the two scenarios considered were with and without elevated polyethylene tank.

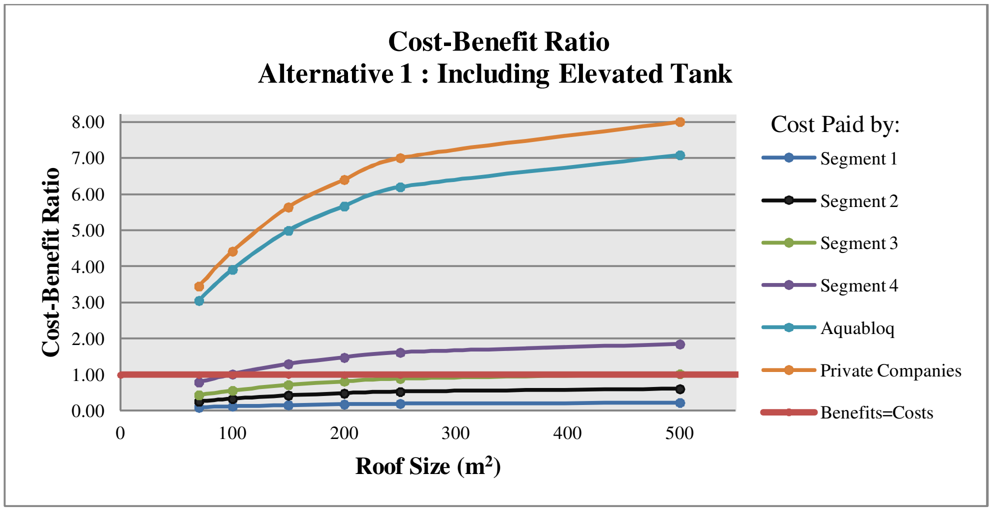


Figure 33; Cost-Benefit Ratio for Alternative 1, including costs for an elevated tank.]

Analyzing the Cost-Benefit Ratio for Alternative 1, scenario 1, which includes the cost of an elevated storage tank, it is evident that as roof size increases the ratio increases. This alternative which includes a ferro-cement storage tank and an elevated polyethylene supply tank renders a positive ratio for most roof sizes in the city's Segment 4, where water rates are higher and when compared to prices from Aquabloq and private suppliers. The highest prices are usually paid by families living in the city's outskirts; they are forced to buy water from private suppliers either because shortages are extremely severe in the poorest areas or because they are not connected to city's public supply system.

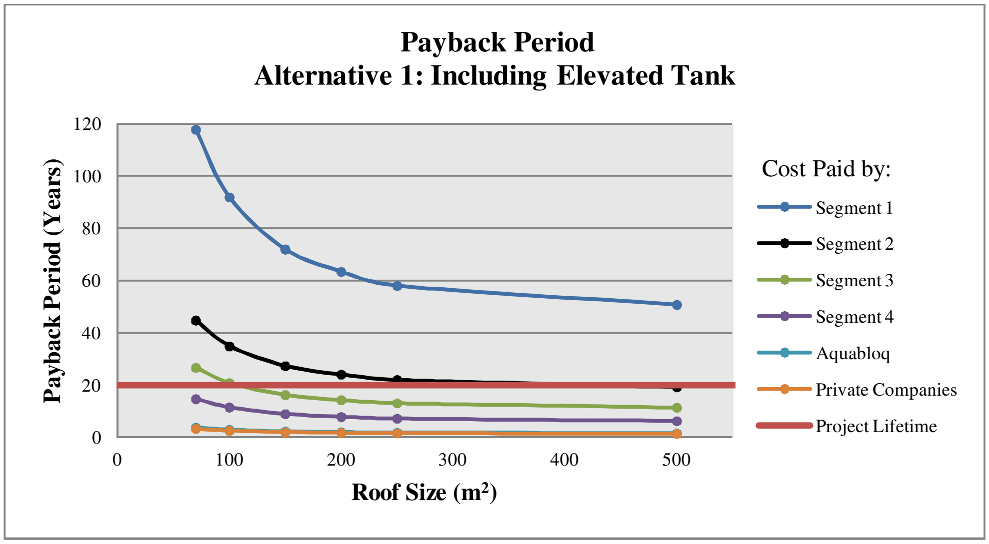


Figure 34: Payback Period for Alternative 1, including costs for an elevated tank.

The number of years needed for the investment to pay for itself through water savings decreases as the roof size increases. In the previous graph most roof sizes from segment 3, segment 4, Aquabloq and private company clients can expect their investment to payoff for itself before the project's lifespan ends.

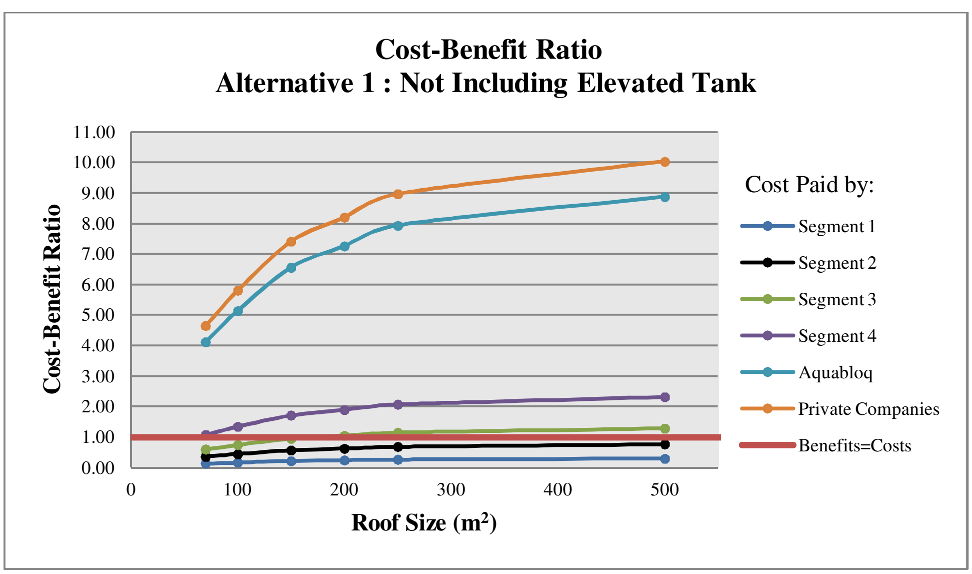


Figure 35: Cost-Benefit Ratio for Alternative 1, not including costs for an elevated tank.

When the costs of an elevated tank are not accounted for the ratio slightly increases because the assumption that users already have an elevated tank decreases costs. Larger roofs from segment 3, segment 4, Aquabloq and private suppliers show a ratio larger than 1.

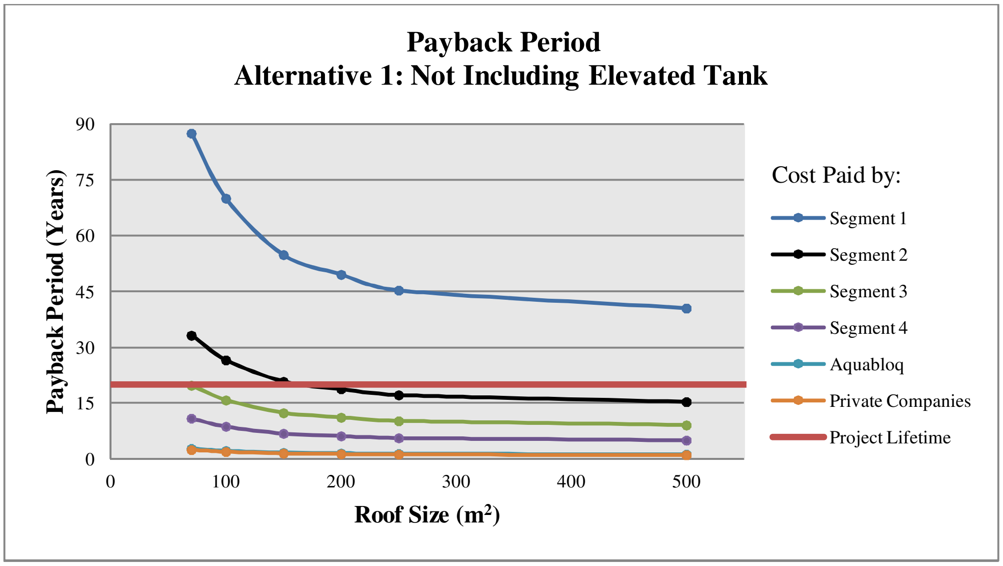


Figure 36: Payback Period for Alternative 1, not including costs for an elevated tank.

Alternative 1 is a good option, especially when an elevated tank is already installed and presents a good investment for users that pay private water suppliers.

Alternative 2: Elevated Polyethylene Tank and Platform

Alternative 2 included an elevated polyethylene tank, a concrete platform for the tank, filter, drains and was analyzed for the two scenarios considered: an elevated tank is already installed or not.

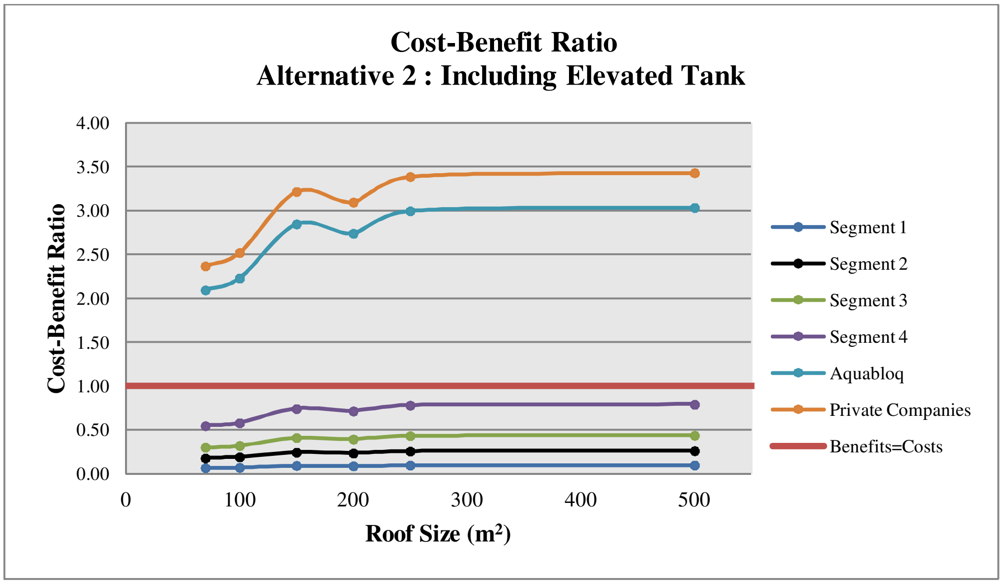


Figure 37: Cost-Benefit Ratio for Alternative 2, including costs for an elevated tank.

Alternative considers using polyethylene tanks instead ferro-cement for water storage. Polyethylene tanks are more expensive and only when considering prices from Aquabloq or private companies, there are ratios larger than 1.

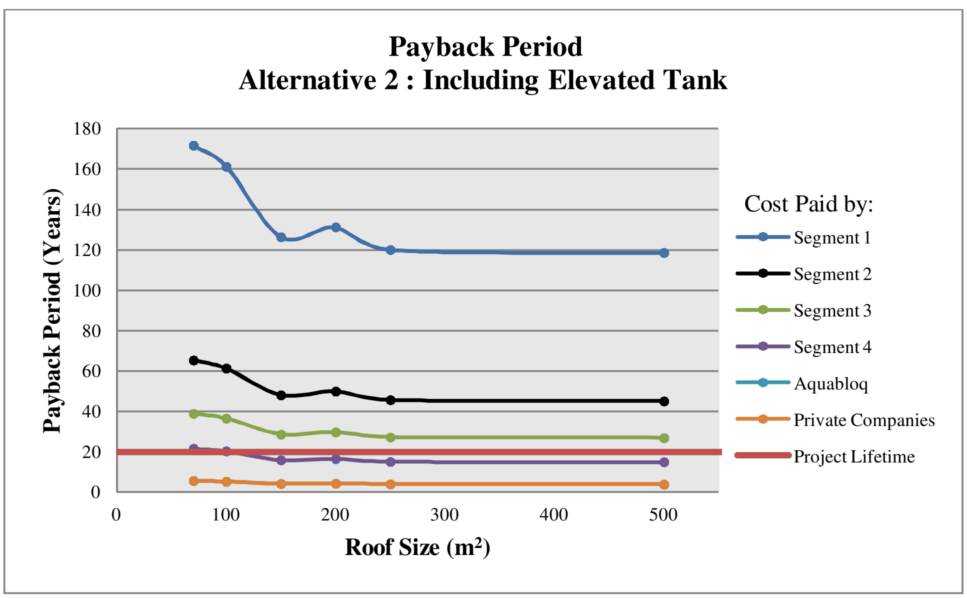


Figure 38: Payback Period for Alternative 2, including costs for an elevated tank.

Payback period for Aquabloq and private companies is very similar, and so the lines are superimposed. Most roof sizes for Segment 4 would also have a payback period shorter than the system's lifetime.

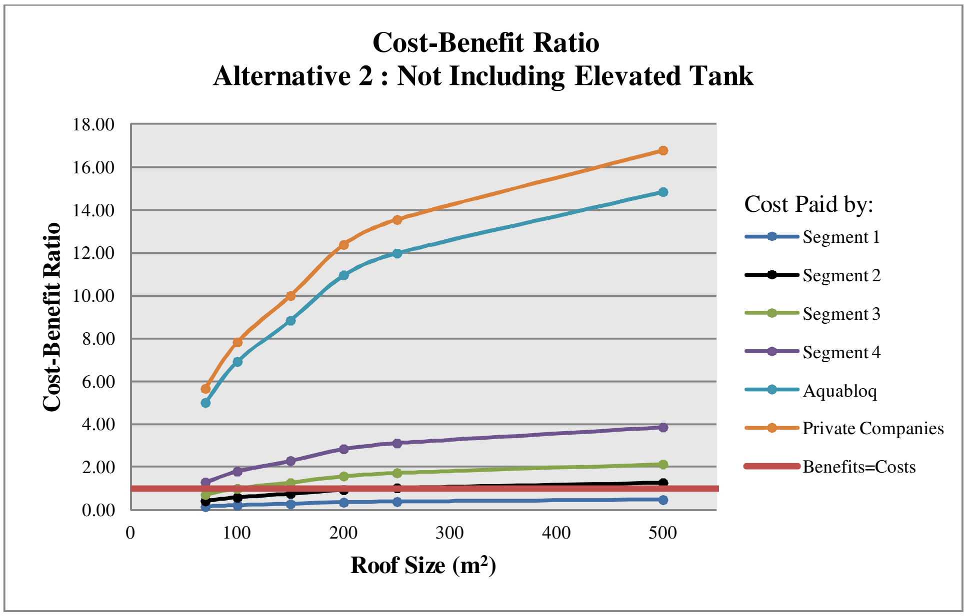


Figure 39: Cost-Benefit Ratio for Alternative 2, not including costs for an elevated tank.

When an elevated tank is assumed to be in place, and the costs are not included, roofs larger than 250 m^2 in segment 3, larger than 100 m^2 in segment 3, all roofs in segment 4 and users purchasing water from Aquabloq or private suppliers would see that the benefits received from implementing this system could outweigh installation costs.

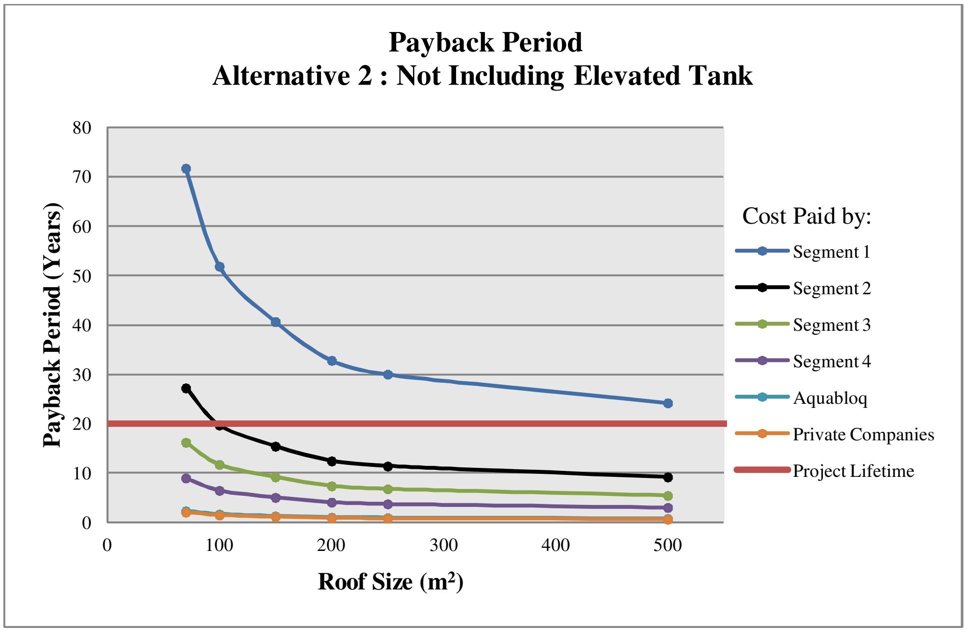


Figure 40: Payback Period for Alternative 2, not including costs for an elevated tank.

Besides houses in segment 1and smaller ones in segment 2, payback periods are smaller than the project's lifetime so it would appear to be a good investment from a financial perspective. Alternative 2 is an option worth considering as it is the simplest system, a basic structure similar to what is used for water storage by users connected to the public supply system. It is also a good option for houses that have limited space as tanks are elevated and require less area than underground or level ground systems.

Aternative 3: Polyethylene Storage and Supply Tanks

Alternative 3 included large polyethylene tank for water storage, and a smaller polyethylene tank for supply. An elevated platform for the tank, PVC drains and accessories as well as filter were included. Two alternatives were analyzed: 1) assuming an elevated tank is needed and 2) an elevated tank is already installed.

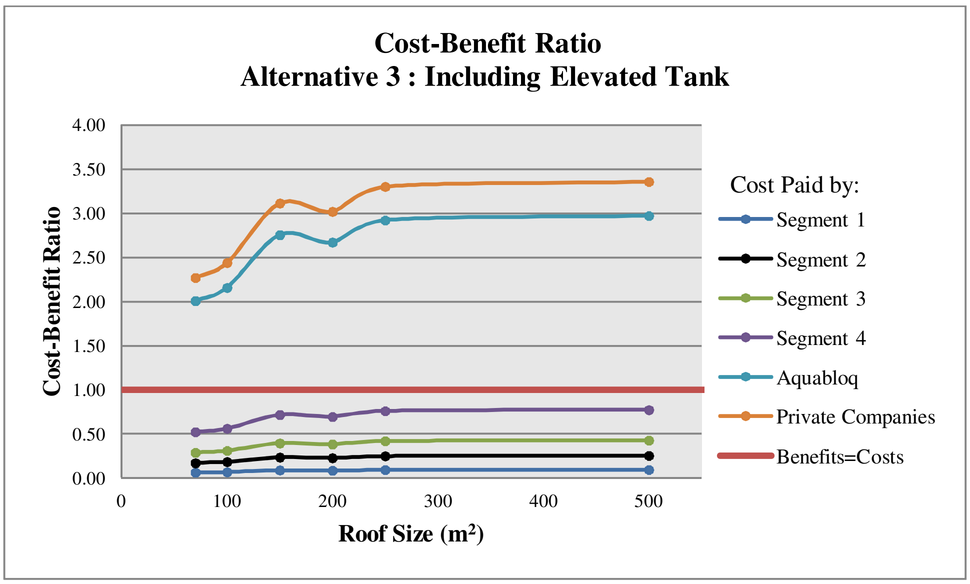


Figure 41: Cost-Benefit Ratio for Alternative 3, including costs for an elevated tank.

For alternative 3, including costs for an elevated tank, only users paying Aquabloq and private companies for water supply would see greater financial benefits than costs.

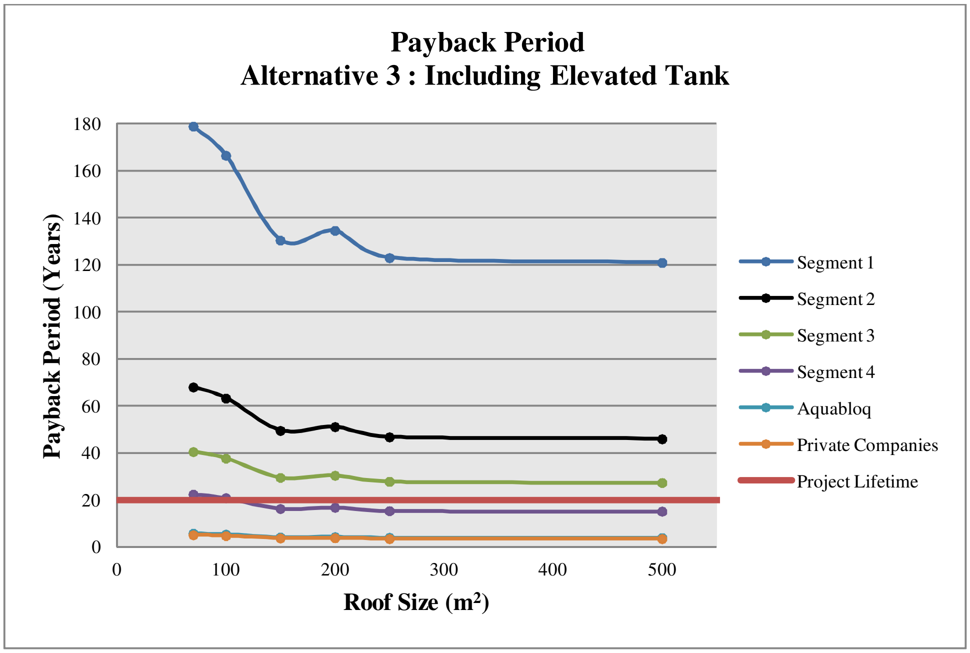


Figure 42: Payback Period for Alternative 3, including costs for an elevated tank.

Larger houses from segment 4, Aquabloq and clients from private suppliers would see the return of their investment in a period of time shorter than what the systems are expected to last.

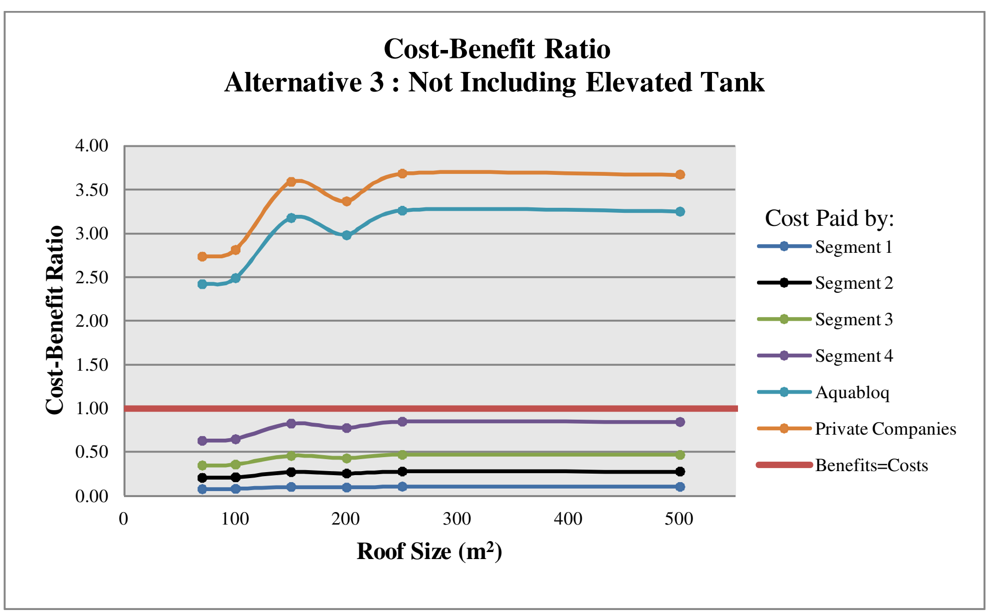


Figure 43: Cost-Benefit Ratio for Alternative 3, not including costs for an elevated tank.

This alternative is the most expensive one, and this can be seen in Figures 44 and 45, for the scenario that does not consider costs of an elevated tank. For this scenario, only users from private suppliers would see a return of their investment and would have the project pay back the original investment.

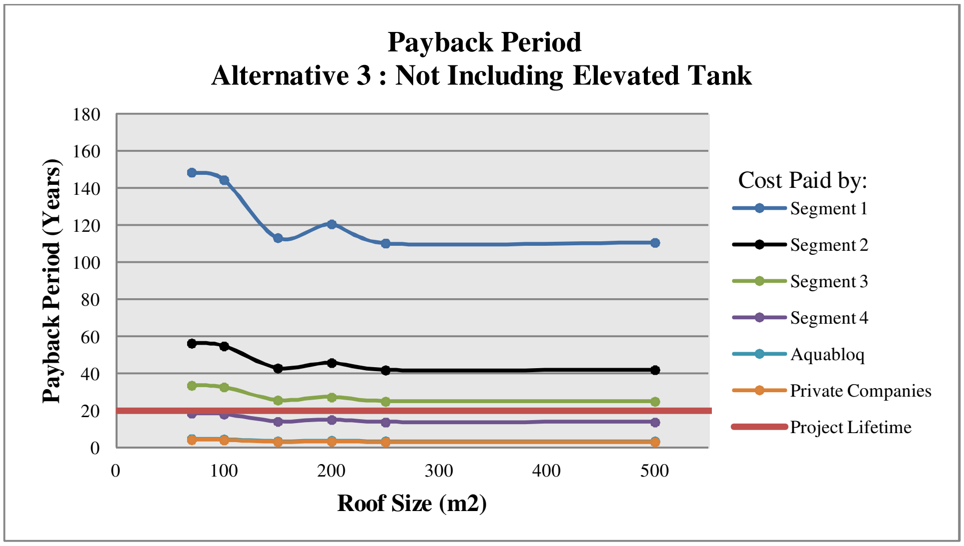


Figure 44: Payback Period for Alternative 3, not including costs for an elevated tank

Payback periods decrease with scenario 2, however, though in less years, the same clients would be able invest in the system and see their investment paid through the annual benefits received in concept of water savings. Overall, alternative 3 is a good investment for users buying water from private suppliers and homeowners that have

enough space for locating a storage tank and a platform for an elevated tank.

Implementation of Rainwater Collection Compared to No Action

An attempt was made to measure the incremental benefits arising from the implementation of rainwater harvesting (Belli, Anderson, Barnum, Dixon & Tan, 1998). In this study, the costs were determined for continuation of business as usual that an average family in Tegucigalpa would have to pay considering their total demand was supplied by SANAA, Aquabloq or private companies. All these scenarios were included in the analysis. Prices for the different segments within SANAA rates were used assuming they could satisfy a demand of 120 liters per person per day, equaling an annual demand of 192.72 m^3/year.

Costs for supplying water demand were compared with the costs that would be paid to suppliers if rainwater harvesting systems were installed. Different roof areas were analyzed and from Figure 45, it is clear that all alternatives present a better scenario when rainwater is harvested to supply for part of the water required for household uses.

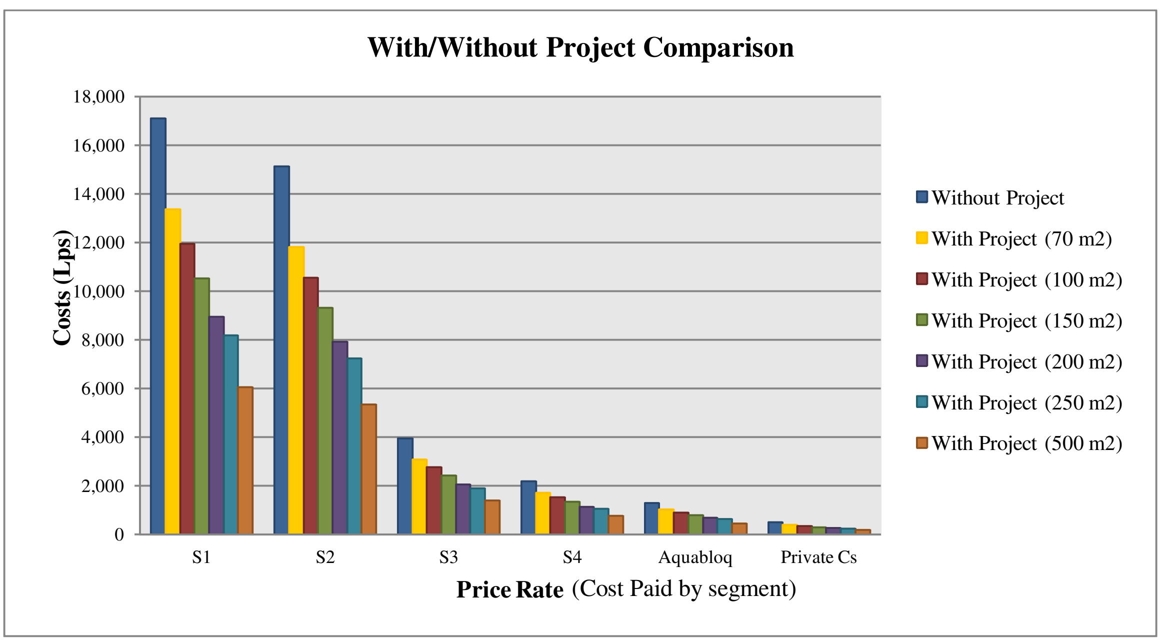


Figure 45: With/Without Project Comparison

It is important to see this difference between implementing and not implementing the project because this type of projects can be funded by public companies such as SANAA or Non-governmental organizations that aim to improve living conditions in developing countries and it being able to see the positive economic impact for the population would be of importance.

According to Rodriguez (2011), last year 145,855 people in Tegucigalpa bought their water from private companies that supply different areas of the capital with tankers. Usually, when people buy their water from tankers, they have storage units to keep the water, so in that case collecting rainwater would be an even better situation as investment costs reduce significantly.

With the purpose of analyzing whether financing such a project, at a larger scale in the city, a basic analysis was performed to calculate the costs for implementing the system for the users who are currently getting their water supply from private companies. Based on the reported population mentioned before, using 4.4 people per average urban home, approximately 33,149 houses are buying water at very high rates. This number, multiplied by the investment cost per house will render the total investment and that can be compared with water costs to determine whether or not it is a good investment for SANAA. As the numbers used are the same as what was used for the cost-benefit Analysis, it is clear that there would be savings for SANAA, as they have to supply water to the city

TRIPLE BOTTOM LINE ANALYSIS APPROACH

The Triple Bottom Line (TBL) is an accounting framework that incorporates three dimensions of performance: social, environmental and financial. This differs from traditional reporting frameworks as it includes ecological (or environmental) and social measures that can be difficult to assign appropriate means of measurement. The TBL dimensions are also commonly called the three Ps: people, planet and profits, referred to as the 3Ps from here on. (Slaper & Hall, 2011)

The triple bottom line framework was introduced in the mid-1990s by John Elkington as the concept of achieving sustainability became a goal for companies, projects, and the public sector. The idea behind the TBL paradigm is that a corporation's ultimate success or health can and should be measured not just by the traditional financial bottom line, but also by its social/ethical and environmental performance. (Norman & MacDonald, 2004)

Implementing rainwater harvesting systems in Tegucigalpa implies not only analyzing whether or not it is financially reasonable to invest, but also requires an integrated evaluation of the social, economic and environmental impacts. A Triple Bottom Line Analysis includes positive and negative impacts on those three areas that sometimes are difficult to measure but can determine if a project is worthwhile implementing.

If such a project were to be implemented a TBL analysis would be very appropriate if it considered costs for all possible impacts. A Triple Bottom Line Analysis includes a scorecard valuing all aspects. This project outlines the considerations for the social, economic and environmental components that would be used in a final analysis. In this study a similar approach was taken, a frame for a Triple Bottom Line Analysis, analyzing each aspect including a basic

SWOT analysis (Strengths, weaknesses, opportunities and threats) trying to cover as much as possible from the possible outcomes and effects from the project as presented in Table 15.

Table 15: Triple Bottom Line Outline with SWOT Analysis

	Economic	Social	Environmental
Strengths	-Low maintenance and operation costs. -Many homes in Tegucigalpa already have a water storage tank, decreasing investment costs. -Tanks can be used for rainwater during the rainy season and for other sources during the dry months.	-Can be used as buffer security in areas where shortages are not that severe. -As the system is to be for individual homes, there should be no conflict between users. -Improved water security. -There are areas where this would be the best alternative as water prices are too high. -Owners can manage their system and supply.	-Relatively good quality water for non-potable uses. -The tropical weather in Tegucigalpa allows for 6 months of water supply. -No electricity or power is required for the system to work. -Water is valued more by users and used more responsibly.
Weaknesses or Limitations	-SANAA rates are very low, this makes the system cost effective for houses with big roof areas or homes with no connection to the supply system. -Roof areas are insufficient. -High initial investment.	-Lack of knowledge on the technology and poor awareness. -Low priority given to RWH by donors and governments. -Insufficient area for tanks and unstable structures to support storage tanks. -Community might not feel engaged into participating (apathy).	-Highly dependable on rainfall. -Not enough to supply all the demand. -Users will have to monitor water and give basic treatment.
Opportunities	-Offers investment potential at household level and institutional level. -SANAA could invest at a larger scale with lower interests. -The system can be installed in homes that already have a storage tank. -The system can be implemented for small rural communities with larger storage tanks. -Tanks can be used for rainwater during the rainy season and for other sources during the dry months.	-Users can manage their own systems. -Independence from greedy private supply companies. -It can decrease severe water deficit. -It can give users a sense of "certainty" that they don't have from other sources. -It can increase awareness on investors or stakeholders. -Can help teach users responsible water use.	-The system can help in flood prevention. -Increasing the residence time of runoff flow in a catchment through rainwater harvesting may have positive environmental as well as hydrological implications/impacts. (Welderufael, Woyessa & Edossa, 2011) -Immediate needs can be prioritized over future consequences.
Threats	-Although it can be a good venture for users, initial investment might be too high to afford. -Users may not be willing to pay. -It is not cost effective for all users, it depends on the roof size and rates paid. -Materials and labor prices can increase, making investment costs higher. -It may be hard for users to get funds for investing (loans). -Applying this technology at a large scale could affect water rates. -Operation and maintenance were not considered because they would be minimal. However if the system fails costs would be high.	-Poor knowledge can lead to poor use. -Poor maintenance and operation can make the system fail by users. -The project may be considered unacceptable for higher social classes. -Lack of community solidarity or participation can be treat to motivate residents to use this system.	-Climate change, drought periods can make the project fail. -Water consumption at upstream level is an issue of concern for downstream water availability. -Expansion of rainwater harvesting practices could have unintended hydrological consequences on river basin water resources and may have negative implications on downstream water availability to sustain hydro-ecological and ecosystem services. (Welderufael, Woyessa & Edossa, 2011) -Water quality may be threatened by animal feces, pollution and other particles and illnesses may spread.

CONCLUSIONS AND RECOMMENDATIONS

- Water scarcity issues are one of the biggest problems in Tegucigalpa, Honduras. Many factors are contributing to aggravate this situation, increasing immigration from rural areas settling on the city's outskirts, growing population, disorganized estate development, insufficient storage infrastructure, poor governance from authorities and lack of initiatives from public and private sectors. There are parts of the city receiving water only once a week or no water at all, users are forced to get their supply from private providers that sell water at excessive prices and offering very poor quality. Rainwater harvesting is a solution worth exploring, though not proposed as a single answer to solve water scarcity, it can be used as complement to alleviate the need in many areas of the city.
- Rainwater harvesting consists of collecting precipitation from rooftops and storing it in tanks. Rooftops can have particles and pathogens that might contaminate water that falls through them. Based on the results from the water quality analysis, though not all parameters complied with Honduran Standards, there are basic treatment methods that users can implement at household levels like Solar Disinfection, boiling water and chlorine disinfection that will be low-cost solutions that users can learn to do.
- If such a solution was to be sponsored or promoted by public or private institutions, periodical water quality monitoring is highly recommended to prevent any health threatening diseases. Water stored from rainwater harvesting practices is not intended for human consumption, but since there would be direct contact with it, quality measurements and treatment are important cautions to take in consideration. It is also

important for users to maintain clean storage tanks, clean filters, gutters, drains and rooftops and it is recommended to let water from the first strong rainfall of the season wash out the roof without collecting it because it will be more contaminated. A first rain diverter may be installed to ensure better quality from the water stored in tanks. From the results of the water quality analysis, samples collected in between rainy days had higher quality than samples taken from a precipitation event after several days of no rain.

- Water scarcity in Tegucigalpa is so severe in part because there is not enough infrastructure to store the amount of water needed to supply the on growing population. Many initiatives have been aimed to the construction of dams, reservoirs and improvement of connection systems. However, nothing is being done, users receive water for a few hours only some each week in the best cases and private suppliers are not regulated so they can sell water at any price, take advantage of the desperate need and sell the water they purchased at very low prices for much more.
- Rainwater harvesting is a solution that could give users some independence from high-pricing companies and inefficient utility companies, being a chance for them to use the water they collect for their best interests. However, rainwater-harvesting systems are very dependent on the amount of precipitation falling during the wet season in Tegucigalpa. Droughts, climate change, varying precipitation patterns make this system uncertain and that is why it is recommended as a complement to other solutions.
- From the 3 alternatives analyzed, the scenario where we assume that there is an elevated water tank already installed, gives the best outcome. Polyethylene tanks are recommended over the other alternatives considered, though not the cheapest option, they require less maintenance, can be cleaned easily, have smooth surfaces that prevent algae

growth, they are usually made up from dark material that prevents sun from passing through, thus preventing photosynthesis and can be transported and installed easier and faster.

- Many users, who buy water from different sources or store water on the few days when they receive the service from SANAA, already have storage tanks or deposits to help them get through the days when they do not receive service. This represents a great opportunity and advantage for these users to harvest rainwater at lower costs. For users who cannot afford bigger tanks, there is the option to buy 32-gal containers that are sold for $25, and buy a few as needed.
- The project is cost-effective for users that purchase water from private companies, they would see the return of their investment in a period of time shorter than the project's lifetime and the savings rendered from using rainwater rather than buying their supply from private providers make the cost-benefit ratio very high. This means that though the initial investment may be high, the savings coming from it would be even higher.
- The highest cost-benefit ratios and shorter payback periods come from larger roofs and areas of the city where water costs are higher. This type of project, however, aims to alleviate scarcity conditions for users who cannot afford high prices and typically live in the poorest areas, where homes tend to be smaller. These users, who often are not connected to the public water supply system from SANAA or receive water once a week only for a few hours would see a great improvement in their living conditions by applying rainwater collection.
- When analyzing the implementation of a rainwater catchment system compared to no action, it is clear that for every price scenario evaluated and all roof sizes considered,

taking no action and buying water would be more expensive. It makes sense from an economic perspective and could be an option worth considering by SANAA to implement at a larger scale. Taking no action also means users relying on authorities to take action and depending on poor infrastructure and severe shortages.

- Projects like this cannot be analyzed solely from a financial perspective to determine their feasibility. Social conditions and environmental factors play important roles in the process of analyzing a project's viability. The triple bottom line analysis integrated with the SWOT analysis is a good way to analyze a project from a wider perspective. The framework presented for a TBL analysis shows that sometimes, social benefits or opportunities can outweigh the financial situation of an initiative. The need for water may be so critical, and the benefits for a community so large that they cannot be measured by financial tools. The idea of installing rainwater catchment systems in urban areas of Tegucigalpa is not a permanent answer for water scarcity, however it alleviates an immediate need and improves overall quality of lives in the city, as access to water is an indicator of development.
- This type of solution, analyzed here for a household level, could be implemented at a larger scale for small communities, some of which are managed through water boards or as neighborhood initiatives. SANAA, being responsible for providing water for citizens of Tegucigalpa, could sponsor and promote this technology to ensure better coverage.

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APPENDICES

APPENDIX 1

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
01	16/11/11	5 :18 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	COL. SAN ANGEL

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☒)	0.0 mg/litro	16 de Noviembre 2011	1:46 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	6 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	0 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.3	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	44.8 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de una lamina de asbesto.

DIRECCION GENERAL DE SALUD PUBLICA
Región Metropolitana
Depto. Saneamiento Básico
Control de Calidad Agua
AREA No. 1
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 17 de Noviembre 2011

C/c. Archivo.

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
02	16/11/11	5 :26 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	col. SAN ANGEL

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☒)	0.0 mg/litro	16 de Noviembre 2011	1:50 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA:
Desconocida	José Alonso Miralda

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	5 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	0 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	6	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.03	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	18.88 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de una lamina de zinc , no hay presencia de coliformes fecales.

DIRECCIÓN GENERAL DE SALUD PÚBLICA
Región Metropolitana
Depto. Saneamiento Básico
Control de Calidad Agua
AREA No. 1
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 17 de Noviembre 2011

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 3	16/11/2011	5 :35 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	Col. SAN ANGEL

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☒)	0.0 mg/litro	16 de Noviembre 2011	2:00 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	4 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	0 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.2	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	26.0 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de teja , hay presencia de coliformes totales

DIRECCION GENERAL DE SALUD PUBLICA
Región Metropolitana
Depto. Saneamiento Básico
Control de Calidad Agua
AREA No. 1
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 17 de Noviembre 2011

C/c. Archivo.

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 4	12/12/2011	9 :00 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	VILLA FLOR

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☐)	0.0 mg/litro	12 de Diciembre 2011	1:26 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA:
Desconocida	José Alonso Miralda

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	23 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	15 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.4	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	70.5 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de tejá, hay presencia de coliformes fecales y totales

Dirección General de Salud Pública
Región Metropolitana
Depto. Saneamiento Básico
Control de Calidad Agua
AREA No. 1
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 14 de Diciembre 2011

C/c. Archivo.

Elaborado por: N. Mejía

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 5	12/12/2011	9 :05 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	VILLA FLOR

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☐)	0.0 mg/litro	12 de Diciembre 2011	1:28 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	17 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	12 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.3	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	61.5 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de lamina de asbesto , hay presencia de coliformes fecales y totales

DIRECCION GENERAL DE SALUD PUBLICA Región Metropolitana Dpto. Saneamiento Básico Control de Calidad de Agua Honduras

Firma del Coordinador de Salud

Fecha: 14 de Diciembre 2011

C/c. Archivo.

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 6	12/12/2011	9 :10 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	VILLA FLOR

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☐)	0.0 mg/litro	12 de Diciembre 2011	1:30 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	17 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	10 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.5	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	65.0 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de lamina de zinc , hay presencia de coliformes fecales y totales

Dirección General de Salud Pública
Región Metropolitana
Depto. Saneamiento Básico
Control de Calidad Agua
AREA No. 1
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 14 de Diciembre 2011

C/c. Archivo.

Elaborado por: N. Mejía

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 1	12/12/2011	9 :05 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	VILLA NUEVA

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☐)	0.0 mg/litro	12 de Diciembre 2011	1:20 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	24 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	13 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.2	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	63.6 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de una lamina de zinc , hay presencia de coliformes fecales y totales

DIRECCION GENERAL DE SALUD PUBLICA
Región Metropolitana
Depto.Saneamiento Basico
Control de Calidad Agua
AREA No. 1
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 14 de Diciembre 2011

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SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 2	12/12/2011	9 :15 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	VILLA NUEVA

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☐)	0.0 mg/litro	12 de Diciembre 2011	1:22 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	21 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	16 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.05	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	63.5 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de teja hay presencia de coliformes fecales y totales

Firma del Coordinador de Salud

Fecha: 14 de Diciembre 2011

C/c. Archivo.

SECRETARIA DE SALUD
REGION SANITARIA METROPOLITANA
LABORATORIO DE CONTROL Y CALIDAD DEL AGUA
TEGUCIGALPA, M. D. C.

Secretaría de Salud
Honduras

HOJA DE RESULTADO DE ANÁLISIS DE LABORATORIO

DATOS DE RECOLECCIÓN DE LA MUESTRA

MUESTRA N°	FECHA	HORA	RECOLECTADA POR:
# 3	12/12/2011	9 :20 AM	NEPTALI PEÑA

UNIDAD DE SALUD	DIRECCIÓN:
RSM	VILLA NUEVA

PRUEBA DE CLORO RESIDUAL	RESULTADO mg/l	FECHA DEL ANALISIS	HORA DEL ANALISIS
SI: (☐) NO: (☐)	0.0 mg/litro	12 de Diciembre 2011	1:24 PM

TIPO DE FUENTE	COORDINADOR SA, ANALISTA DE AGUA: José Alonso Miralda
Desconocida	

RESULTADO DEL ANÁLISIS BACTERIOLÓGICO

DETERMINACION O PARÁMETRO ANALIZADO	VALOR DE LA NORMA	RESULTADO DEL ANÁLISIS	TIEMPO DE INCUBACION
RECUENTO DE COLIFORMES TOTALES	0 UFC/100 ml	15 UFC/100 ml	24 horas
RECUENTO DE COLIFORMES FECALES	0 UFC/100 ml	10 UFC/100 ml	24 horas

RESULTADO DEL ANÁLISIS QUÍMICO

DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS	DETERMINACION O PARÁMETRO	VALORES NORMA Mg/Lts	RESULTADOS
TEMPERATURA	18 c° A 30 c°	20.5°	NITRATOS (NO3)	25	
P.H.	6.5 – 8.5	7	NITRITOS (NO2)	0	
CLORO LIBRE	0.5 - 1.0		AMONIO (NH4)	0.05	
TURBIDEZ	1 ntu.	1.02	HIERRO (FE)	0	
CLORUROS	25		FLUORURO	0	
DUREZA	400		CONDUCTIVIDAD	400 us/cm	65.2 us/cm

NOTA: Los valores de la pauta obtenida corresponden a los estipulados en la norma técnica nacional para la calidad del agua potable Decreto N° 084 del 31 de julio de 1995; Método de análisis bacteriológico utilizado: Placas Petrifilm.

Observaciones: Agua no apta para consumo humano, esta muestra proviene de agua lluvia tomada de lamina de asbesto , hay presencia de coliformes fecales y totales

DIRECCIÓN GENERAL DE SALUD PUBLICA
Región Metropolitana
Depto. Saneamiento Básico
Control de Calidad Agua
AREA ...
Tegucigalpa, Honduras

Firma del Coordinador de Salud

Fecha: 14 de Diciembre 2011

C/c. Archivo.

APPENDIX 2

Roof Area (m^2)	70			100			150		
	% Total Capture	Days 0 Supply	% Annual Demand Satisfied	% Total Capture	Days 0 Supply	% Annual Demand Satisfied	% Total Capture	Days 0 Supply	% Annual Demand Satisfied
Tank Volume (m^3)									
0.25	87	245	9	85	245	10	82	245	11
0.50	92	245	14	90	245	16	87	245	19
1.00	96	237	18	95	232	21	92	227	25
2.00	99	229	20	98	220	26	96	209	31
3.00	100	226	22	99	215	28	98	200	35
5.00	100	223	23	100	209	30	99	192	38
7.50	100	221	24	100	205	32	100	184	41
10.00	100	220	24	100	202	33	100	179	43
12.50	100	220	24	100	201	34	100	173	45
20.00									

Roof Area (m^2)	200			250			500		
	% Total Capture	Days 0 Supply	% Annual Demand Satisfied	% Total Capture	Days 0 Supply	% Annual Demand Satisfied	% Total Capture	Days 0 Supply	% Annual Demand Satisfied
Tank Volume (m^3)									
0.25	80	245	12	79	245	12	75	245	14
0.50	85	245	20	83	245	21	79	245	25
1.00	90	225	27	88	221	29	83	212	35
2.00	95	201	35	93	196	38	88	178	45
3.00	97	190	40	95	182	43	91	160	51
5.00	99	177	44	98	166	49	95	140	58
7.50	99	167	48	99	155	52	97	128	62
10.00	100	161	50	100	149	55	98	120	65
12.50	100	156	52	100	144	57	99	114	66
20.00							100	101	71

APPENDIX 3

Costs for Alternative 1 Including Annuity

Roof Area (m^2)	Tank Volume (m^3)	Alternative 1							
		Including Elevated Tank				Not Including Elevated Tank			
		Cost		Annuity		Cost		Annuity	
		HON Lempiras	US Dollars	HON Lempiras	US Dollars	HON Lempiras	US Dollars	HON Lempiras	US Dollars
70	3	12,731.81	660.55	1,080.47	56.06	9,455.09	490.55	802.39	41.63
100	5	13,736.29	712.66	1,165.71	60.48	10,459.57	542.66	887.64	46.05
150	5	13,736.29	712.66	1,165.71	60.48	10,459.57	542.66	887.64	46.05
200	7.5	14,991.89	777.81	1,272.26	66.01	11,715.17	607.80	994.19	51.58
250	7.5	14,991.89	777.81	1,272.26	66.01	11,715.17	607.80	994.19	51.58
500	10	16,247.49	842.95	1,378.82	71.54	12,970.77	672.95	1,100.74	57.11

Costs for Alternative 2 Including Annuity

Roof Area (m^2)	Tank Volume (m^3)	Alternative 2							
		Including Elevated Tank				Not Including Elevated Tank			
		Cost		Annuity		Cost		Annuity	
		HON Lempiras	US Dollars	HON Lempiras	US Dollars	HON Lempiras	US Dollars	HON Lempiras	US Dollars
70	3	18,551.76	962.50	1,574.37	81.68	7,751.76	402.18	657.84	34.13
100	5	24,085.09	1,249.58	2,043.95	106.04	7,751.76	402.18	657.84	34.13
150	5	24,085.09	1,249.58	2,043.95	106.04	7,751.76	402.18	657.84	34.13
200	7.5	31,001.76	1,608.43	2,630.92	136.50	7,751.76	402.18	657.84	34.13
250	7.5	31,001.76	1,608.43	2,630.92	136.50	7,751.76	402.18	657.84	34.13
500	10	37,918.43	1,967.27	3,217.89	166.95	7,751.76	402.18	657.84	34.13

Costs for Alternative 3 Including Annuity

Roof Area (m^2)	Tank Volume (m^3)	Alternative 3							
		Including Elevated Tank				Not Including Elevated Tank			
		Cost		Annuity		Cost		Annuity	
		HON Lempiras	US Dollars	HON Lempiras	US Dollars	HON Lempiras	US Dollars	HON Lempiras	US Dollars
70	3	19,328.49	1,002.80	1,640.28	85.10	16,051.76	832.79	1,362.21	70.67
100	5	24,861.82	1,289.87	2,109.86	109.46	21,585.09	1,119.87	1,831.79	95.04
150	5	24,861.82	1,289.87	2,109.86	109.46	21,585.09	1,119.87	1,831.79	95.04
200	7.5	31,778.49	1,648.72	2,696.83	139.92	28,501.76	1,478.72	2,418.76	125.49
250	7.5	31,778.49	1,648.72	2,696.83	139.92	28,501.76	1,478.72	2,418.76	125.49
500	10	38,695.16	2,007.57	3,283.81	170.37	35,418.43	1,837.57	3,005.73	155.94

		(0.25 m3)		(0.5 m3)		(1 m3)		(2 m3)		(3 m3)	
Component	Qty.	Cost		Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Ferrocement Cistern (0.25 m3)	1	95.80	4.97	251.12	13.03	502.24	26.06	1004.48	52.11	1506.72	78.17
Honduflexi pump	1	196.60	10.20	196.60	10.20	196.60	10.20	196.60	10.20	196.60	10.20
Elevated Tank	1	3276.72	170.00	3276.72	170.00	3276.72	170.00	3276.72	170.00	3276.72	170.00
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total		11320.89	587.35	11476.21	595.41	11727.33	608.43	12229.57	634.49	12731.81	660.55

		(5 m3)		(7.5 m3)		(10 m3)		(12.5 m3)	
Component	Qty.	Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Ferrocement Cistern (5 m3)	1	2511.20	130.29	3766.80	195.43	5022.40	260.57	6278.00	325.71
Honduflexi pump	1	196.60	10.20	196.60	10.20	196.60	10.20	196.60	10.20
Elevated EMAS Tank (0.095 m3)	1	3276.72	170.00	3276.72	170.00	3276.72	170.00	3276.72	170.00
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total		13736.29	712.66	14991.89	777.81	16247.49	842.95	17503.09	908.09

		(0.25 m3)		(0.5 m3)		(1 m3)		(2 m3)		(3 m3)	
Component	Qty.	Cost		Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Polyethilene Tank (12.5 m3)	1	1087.50	56.42	0.00	0.00	4275.00	221.79	5750.00	298.32	8300.00	430.62
ElevatedTank	1	3276.72	170.00	3276.72	0.00	3276.72	285.35	3276.72	285.35	3276.72	285.35
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total	1	12115.99	628.60	11028.49	402.18	15303.49	909.32	16778.49	985.84	19328.49	1118.14

		(5 m3)		(7.5 m3)		(10 m3)		(12.5 m3)	
Component	Qty.	Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Polyethilene Tank (12.5 m3)	1	13833.33	717.70	20750.00	1076.55	27666.67	1435.40	34708.34	1800.73
Elevated Tank	1	3276.72	285.35	3276.72	285.35	3276.72	285.35	3276.72	1435.40
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total	1	24861.82	1405.2221	31778.49	1764.07	38695.16	2122.92	45736.83	3638.30

		(0.25 m3)		(0.5 m3)		(1 m3)		(2 m3)		(3 m3)	
Component	Qty.	Cost		Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	1730.11	89.76	1730.11	89.76	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	521.65	27.06	521.65	27.06	27.06	521.65	27.06
Polyethilene Tank (12.5 m3)	1	1087.50	56.42	2175.00	4275.00	221.79	5750.00	298.32	52.11	8300.00	430.62
Elevated Platform	1	2500.00	129.70	2500.00	2500.00	285.35	2500.00	285.35	10.20	2500.00	285.35
Labor	1	5500.00	285.35	5500.00	5500.00	285.35	5500.00	285.35	0.00	5500.00	285.35
Total		11339.26	588.30	12426.76	14526.76	909.32	16001.76	985.84	285.35	18551.76	1118.14
		(5 m3)		(7.5 m3)		(10 m3)		(12.5 m3)			
Component	Qty.	Cost		Cost		Cost		Cost			
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars		
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76		
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06		
Polyethilene Tank (12.5 m3)	1	13833.33	717.70	20750.00	1076.55	27666.67	1435.40	34708.34	1800.73		
Elevated Platform	1	2500.00	285.35	2500.00	285.35	2500.00	285.35	2500.00	1435.40		
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35		
Total	1	24085.09	1405.22	31001.76	1764.07	37918.43	2122.92	44960.10	3638.30		

		(0.25 m3)		(0.5 m3)		(1 m3)		(2 m3)		(3 m3)	
Component	Qty.	Cost		Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Polyethilene Tank (12.5 m3)	1	1087.50	56.42	2175.00	112.84	4275.00	221.79	5750.00	298.32	8300.00	430.62
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total	1	8839.26	458.60	9926.76	515.02	12026.76	623.97	13501.76	700.50	16051.76	832.79
		(5 m3)		(7.5 m3)		(10 m3)		(12.5 m3)			
Component	Qty.	Cost		Cost		Cost		Cost			
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars		
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76		
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06		
Polyethilene Tank (12.5 m3)	1	13833.33	717.70	20750.00	1076.55	27666.67	1435.40	34708.34	1800.73		
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35		
Total	1	21585.09	1119.87	28501.76	1478.72	35418.43	1837.57	42460.10	2202.90		

		(0.25 m3)		(0.5 m3)		(1 m3)		(2 m3)		(3 m3)	
Component	Qty.	Cost		Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Ferrocement Cistern (0.25 m3)	1	95.80	4.97	251.12	13.03	502.24	26.06	1004.48	52.11	1506.72	78.17
Honduflexi pump	1	196.60	10.20	196.60	10.20	196.60	10.20	196.60	10.20	196.60	10.20
Elevated Tank	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total		8044.16	417.35	8199.49	425.40	8450.61	438.43	8952.85	464.49	9455.09	490.55

		(5 m3)		(7.5 m3)		(10 m3)		(12.5 m3)	
Component	Qty.	Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Ferrocement Cistern (5 m3)	1	2511.20	130.29	3766.80	195.43	5022.40	260.57	6278.00	325.71
Honduflexi pump	1	196.60	10.20	196.60	10.20	196.60	10.20	196.60	10.20
Elevated EMAS Tank (0.095 m3)	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total		10459.57	542.66	11715.17	607.80	12970.77	672.95	14226.37	738.09

		(0.25 m3)		(0.5 m3)		(1 m3)		(2 m3)		(3 m3)	
Component	Qty.	Cost		Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total		7751.76	402.18	7751.76	402.18	7751.76	402.18	7751.76	402.18	7751.76	402.18

		(5 m3)		(7.5 m3)		(10 m3)		(12.5 m3)	
Component	Qty.	Cost		Cost		Cost		Cost	
		Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars	Lempira	US Dollars
Prefabricated Drain PVC 4" (including accessories)	14 LM	1730.11	89.76	1730.11	89.76	1730.11	89.76	1730.11	89.76
Zinc filter (including accessories)	1	521.65	27.06	521.65	27.06	521.65	27.06	521.65	27.06
Labor	1	5500.00	285.35	5500.00	285.35	5500.00	285.35	5500.00	285.35
Total	1	7751.76	402.18	7751.76	402.18	7751.76	402.18	7751.76	402.18

Category	Range m^3/month	Min Consumption	Rate Lps/month	Fixed Cost	Monthly Bill for a Household with a monthly use of 15.84 m^3			Monthly Bill for a Household with a monthly use of 15.84 m^3			Annual Water Cost	
Segment 1	0-20	31.80	1.59 (US$ 0.08)		For a demand of 15.84 m^3			For a demand of 15.84 m^3			Segment 1	
	21-30	US $ 1.65	3.17 (US$ 0.16)		1.59 Lps per m^3	Lps.	31.80	0.08 US$ per m^3	US$	1.65		
	31-40		5.23 (US$ 0.27)	Exempt	Sewerage 25%	Lps.	7.95	Sewerage 25%	US$	0.41		
	41-50		9.10 (US$ 0.47)		Maintenance	Lps.	1.50	Maintenance	US$	0.08		
	51-55		12.92 (US$ 0.67)		Fixed cost/connection	Lps.	0.00	Fixed cost/connection	US$	0.00	HON Lps.	US $
	56-more		16.11 (US$ 0.84)		Total	Lps.	41.25	Total	US$	2.14	495.00	25.68
Segment 2	0-20	65.60	3.28 (US$ 0.17)		For a demand of 15.84 m^3			For a demand of 15.84 m^3			Segment 2	
	21-30	US $ 3.40	4.05 (US$ 0.21)		3.28 Lps per m^3	Lps.	65.60	0.17 US$ per m^3	US$	3.40		
	31-40		6.18 (US$ 0.32)	25.00	Sewerage 25%	Lps.	16.4	Sewerage 25%	US$	0.85		
	41-50		10.54 (US$ 0.55)	US$ 1.30	Maintenance	Lps.	1.50	Maintenance	US$	0.08		
	51-55		13.12 (US$ 0.68)		Fixed cost/connection	Lps.	25.00	Fixed cost/connection	US$	1.30	HON Lps.	US $
	56-more		16.79 (US$ 0.87)		Total	Lps.	108.50	Total	US$	5.63	1,302.00	67.53
Segment 3	0-20	88.40	4.42 (US$ 0.23)		For a demand of 15.84 m^3			For a demand of 15.84 m^3			Segment 3	
	21-30	US $ 4.59	5.23 (US$ 0.27)		4.42 Lps per m^3	Lps.	88.40	0.23 US$ per m^3	US$	4.59		
	31-40		7.37 (US$ 0.38)	70.00	Sewerage 25%	Lps.	22.1	Sewerage 25%	US$	1.15		
	41-50		11.40 (US$ 0.59)	US$ 3.63	Maintenance	Lps.	1.50	Maintenance	US$	0.08		
	51-55		14.42 (US$ 0.75)		Fixed cost/connection	Lps.	70.00	Fixed cost/connection	US$	3.63	HON Lps.	US $
	56-more		18.24 (US$ 0.95)		Total	Lps.	182.00	Total	US$	9.45	2,184.00	113.34
Segment 4	0-20	141.60	7.08 (US$ 0.37)		For a demand of 15.84 m^3			For a demand of 15.84 m^3			Segment 4	
	21-30	US $ 7.35	8.90 (US$ 0.46)		7.08 Lps per m^3	Lps.	141.60	0.37 US$ per m^3	US$	7.35		
	31-40		10.93 (US$ 0.57)	150.00	Sewerage 25%	Lps.	35.4	Sewerage 25%	US$	1.84		
	41-50		13.58 (US$ 0.70)	US$ 7.78	Maintenance	Lps.	1.50	Maintenance	US$	0.08		
	51-55		16.86 (US$ 0.87)		Fixed cost/connection	Lps.	150.00	Fixed cost/connection	US$	7.78	HON Lps.	US $
	56-more		19.42 (US$ 1.01)		Total	Lps.	328.50	Total	US$	17.05	3,942.00	204.54

APPENDIX 4

Roof Area (m2)	Tank Volume (m3)	Alternative 1: Including Elevated Tank							
		Public SANAA Price							
		Segment 1		Segment 2		Segment 3		Segment 4	
		CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years
70	3	0.10	118	0.26	45	0.44	27	0.80	15
100	5	0.13	92	0.34	35	0.57	21	1.02	12
150	5	0.16	72	0.43	27	0.72	16	1.30	9
200	7.5	0.19	63	0.49	24	0.82	14	1.48	8
250	7.5	0.20	58	0.53	22	0.90	13	1.62	7
500	10	0.23	51	0.61	19	1.02	12	1.85	6

Roof Area (m2)	Tank Volume (m3)	Alternative 1: Not Including Elevated Tank							
		Public SANAA Price							
		Segment 1		Segment 2		Segment 3		Segment 4	
		CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years
70	3	0.13	88	0.35	33	0.59	20	1.07	11
100	5	0.17	70	0.44	27	0.74	16	1.34	9
150	5	0.21	55	0.56	21	0.95	12	1.71	7
200	7.5	0.24	50	0.62	19	1.05	11	1.89	6
250	7.5	0.26	45	0.68	17	1.15	10	2.07	6
500	10	0.29	41	0.76	15	1.28	9	2.31	5

Roof Area (m2)	Tank Volume (m3)	Alternative 1: Including Elevated Tank			
		AQUABLOQ		Private Suppliers	
		CBA	Payback Period Years	CBA	Payback Period Years
70	3	3.05	4	3.45	3
100	5	3.91	3	4.42	3
150	5	4.99	2	5.64	2
200	7.5	5.67	2	6.41	2
250	7.5	6.20	2	7.01	2
500	10	7.08	2	8.01	1

Roof Area (m2)	Tank Volume (m3)	Alternative 1: Not Including Elevated Tank			
		AQUABLOQ		Private Suppliers	
		CBA	Payback Period Years	CBA	Payback Period Years
70	3	4.11	3	4.65	3
100	5	5.14	2	5.81	2
150	5	6.56	2	7.41	2
200	7.5	7.25	2	8.20	1
250	7.5	7.93	1	8.97	1
500	10	8.87	1	10.03	1

Roof Area (m2)	Tank Volume (m3)	Alternative 2: Including Elevated Tank							
		Public SANAA Price							
		Segment 1		Segment 2		Segment 3		Segment 4	
		CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years
70	3	0.07	172	0.18	65	0.30	39	0.55	22
100	5	0.07	161	0.19	61	0.32	37	0.58	20
150	5	0.09	126	0.25	48	0.41	29	0.74	16
200	7.5	0.09	131	0.24	50	0.40	30	0.71	16
250	7.5	0.10	120	0.26	46	0.43	27	0.78	15
500	10	0.10	119	0.26	45	0.44	27	0.79	15

Roof Area (m2)	Tank Volume (m3)	Alternative 2: Not Including Elevated Tank							
		Public SANAA Price							
		Segment 1		Segment 2		Segment 3		Segment 4	
		CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years
70	3	0.16	72	0.43	27	0.72	16	1.31	9
100	5	0.23	52	0.60	20	1.00	12	1.81	7
150	5	0.29	41	0.76	15	1.28	9	2.31	5
200	7.5	0.36	33	0.94	12	1.58	7	2.86	4
250	7.5	0.39	30	1.03	11	1.73	7	3.13	4
500	10	0.49	24	1.28	9	2.15	5	3.87	3

Roof Area (m2)	Tank Volume (m3)	Alternative 2: Including Elevated Tank			
		AQUABLOQ		Private Suppliers	
		CBA	Payback Period Years	CBA	Payback Period Years
70	3	2.10	6	2.37	6
100	5	2.23	5	2.52	5
150	5	2.85	4	3.22	4
200	7.5	2.74	4	3.10	4
250	7.5	3.00	4	3.39	4
500	10	3.04	4	3.43	4

Roof Area (m2)	Tank Volume (m3)	Alternative 2: Not Including Elevated Tank			
		AQUABLOQ		Private Suppliers	
		CBA	Payback Period Years	CBA	Payback Period Years
70	3	5.01	2	5.67	2
100	5	6.93	2	7.84	2
150	5	8.85	1	10.00	1
200	7.5	10.96	1	12.39	1
250	7.5	11.99	1	13.55	1
500	10	14.85	1	16.78	1

Roof Area (m2)	Tank Volume (m3)	Alternative 3: Including Elevated Tank							
		Public SANAA Price							
		Segment 1		Segment 2		Segment 3		Segment 4	
		CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years
70	3	0.07	179	0.17	68	0.29	41	0.52	22
100	5	0.07	166	0.19	63	0.31	38	0.56	21
150	5	0.09	130	0.24	50	0.40	30	0.72	16
200	7.5	0.09	135	0.23	51	0.39	31	0.70	17
250	7.5	0.10	123	0.25	47	0.42	28	0.76	15
500	10	0.10	121	0.26	46	0.43	27	0.78	15

Roof Area (m2)	Tank Volume (m3)	Alternative 3: Not Including Elevated Tank							
		Public SANAA Price							
		Segment 1		Segment 2		Segment 3		Segment 4	
		CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years	CBA	Payback Period Years
70	3	0.08	149	0.21	56	0.35	34	0.63	19
100	5	0.08	145	0.21	55	0.36	33	0.65	18
150	5	0.10	113	0.27	43	0.46	26	0.83	14
200	7.5	0.10	121	0.26	46	0.43	27	0.78	15
250	7.5	0.11	110	0.28	42	0.47	25	0.85	14
500	10	0.11	111	0.28	42	0.47	25	0.85	14

Roof Area (m2)	Tank Volume (m3)	Alternative 3: Including Elevated Tank			
		AQUABLOQ		Private Suppliers	
		CBA	Payback Period Years	CBA	Payback Period Years
70	3	2.01	6	2.27	5
100	5	2.16	5	2.44	5
150	5	2.76	4	3.12	4
200	7.5	2.67	4	3.02	4
250	7.5	2.92	4	3.31	4
500	10	2.97	4	3.36	4

Roof Area (m2)	Tank Volume (m3)	Alternative 3: Not Including Elevated Tank			
		AQUABLOQ		Private Suppliers	
		CBA	Payback Period Years	CBA	Payback Period Years
70	3	2.42	5	2.74	4
100	5	2.49	5	2.81	4
150	5	3.18	4	3.59	3
200	7.5	2.98	4	3.37	3
250	7.5	3.26	4	3.68	3
500	10	3.25	4	3.67	3