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# Equitable Cost Allocation for Rainwater Harvesting System

# - Framework Analysis: Case of Austin, TX

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# - Framework Analysis: Case of Austin, TX

by

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**Professional Report**

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## Dedication

To my family and MJ

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# Abstract

## Equitable Cost Allocation for Rainwater Harvesting System

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Hyun Woo Kim, MSCRP

The University of Texas at Austin, 2011

Supervisor: Kent Butler

The limitation of urban water supplies is becoming worse each year. Several studies estimate that 2 billion of the world's population will suffer from water scarcity by 2050; and urbanization rates is placing an even greater challenge in providing the infrastructure needed to serve growing populations. At this point, rainwater may be considered as the most critical, untapped water resource in a global aspect. Rainwater Harvesting Systems (RWHS) have tremendous potential, not only to provide sufficient water supply, but also to serve as a valuable stormwater management tool. Despite these benefits, RWHS is still not popular among ordinary people in urban situations, due mostly to high installation costs. This study aims to explore the equitable cost reallocation of residential rainwater harvesting systems between the urban utility, land developer and homebuilder, and individual homeowner sectors. It may be possible to re-distribute the cost equitably among the parties based on potential benefits received, thereby making RWHS more affordable and more viable as a new water supply for urban areas.

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# CHAPTER 1: INTRODUCTION

Urban water management systems in growing regions face a constant set of challenges, including providing a sufficient supply of water, minimizing impacts on receiving water quality, and preventing high-risk flooding that results from urbanization and climate change. The issue of limited supplies of water resources in urban areas is becoming more and more critical. Urbanization causes additional environmental impacts such as urban runoff pollution. A solution that could ameliorate these negative impacts is to have in urban areas a decentralized rainwater management system.

Rainwater harvesting has existed as a water supply source technique for at least 4,000 years and very likely much longer (Reid 1982). The most fundamental systems require only a catchment area (rooftop), a conveyance system (gutters, downspouts, and plumbing), and a holding tank (cistern).These systems have been developed, incorporating screening, pumping, treatment, and bypass technologies to serve a range of end uses from irrigation to drinking (Jensen 2010).

Rainwater harvesting systems are, in several states, considered innovative building practices. For example, Texas and Arizona promote rainwater harvesting programs for residential use to lessen the burden on municipal potable water supplies (Texas Water Development Board 2005; Sprouse 2005). In addition, water-starved regions such as southern California are instituting a ban on water usage for irrigation, thus encouraging the use of rainwater to irrigate (Briggs 2010). The cities of Columbia and Queretaro, Mexico have considered rainwater as a primary water source for new urban growth. Bermuda and other Caribbean islands require cisterns to be included with all new construction (The Texas Manual on Rainwater Harvesting 2005). Likewise, Australia and a number of Asian, European, and developing countries have already begun adopting policies and regulations in support of rainwater harvesting systems. These serve not only as an alternative water source but as an integral component of urban water management.

Since rainwater tanks are typically expensive, individuals are reluctant to install them on their own. John Gould reported that some countries subsidize the individual acquiring of rainwater systems (Gloud 1999). Kenya, for example, uses revolving funds; Germany subsidizes installation costs. Many German cities provide grants and subsidies for individuals who construct rainwater tanks and seepage wells. Osnabruck, Germany, offers a grant of $600-$1,200 per household and an additional subsidy of $3 per square meter of roof area draining to any tank linked to a seepage well. A new householder can recover the investment, through savings on water charges and annual rainwater drainage fees waiver, in 12 years. Without the subsidy, the householder recoups the cost in 19 years (Wessels 1994).

Environmental concerns are also pushing these programs. For example, green building programs such as Leadership in Energy and Environmental Design (LEED) and sustainable development programs such as Low Impact Development (LID) aim to protect streams and water bodies from the degradation caused by unmitigated stormwater runoff. As these programs are becoming more important, governmental agencies and advocacy groups increasingly have espoused rainwater harvesting as a key component for new developments (Prince Georges County, Maryland 1999; US Green Building Council 2006; City of Portland 2008; Puget Sound Action Team2008).

Austin, Texas, is a rapidly growing city consuming vast amounts of water. On one list, the city ranked number two among the fastest growing urban areas in the United States. Its population is projected to grow 63% from 2010 to 2040 (Texas Water Development Board 2010). The city, however, already suffers significantly from drainage problems caused by urban runoff. To accommodate the future's rising water demand, a new water treatment plant (WTP4) is currently under construction. However, this kind of supply-side approach may eventually be insufficient to cover the water demand for the next generation. Surface water from the Colorado River and the underground water from Edwards Aquifer will ultimately not be able to keep up with population growth. Thus, instead of short-term water plans to bolster future water supply and structural approaches to mitigate the hazard of flooding, a new paradigm of alternative rainwater harvesting systems which improve the safety, efficiency, and energy consumption of water use are highly recommended (M. Han 2006). A key challenge in considering this approach is finding an equitable and affordable way to pay for the costs of this technology at the household level.

The primary goal of this study is to equitably reallocate the cost for residential rainwater harvesting systems (RWHS) within the city (utility) among the parties that would benefit, namely the city utility, land developers and home builders, and individual homeowners. The initial cost for installing RWHS is too expensive for many if not most single family households to cover. Hence, by finding the potential aggregated benefits for each stakeholder, this investigation will yield a distribution of the cost that equitably allocates costs among the parties based on benefits received and may lead to a faster and more extensive implementation of this technology.

## 1.1 BACKGROUND

### Population

Population is one of the most important factors in making forecasts of future water demand. Thus, population increases, taking into account birth and mortality rates, and mitigating factors should be precisely projected. Austin's population has grown continually since 1900. Its population sharply increased after 1980 and is expected to keep growing steadily through 2040 (Texas Water Development Board 2009).

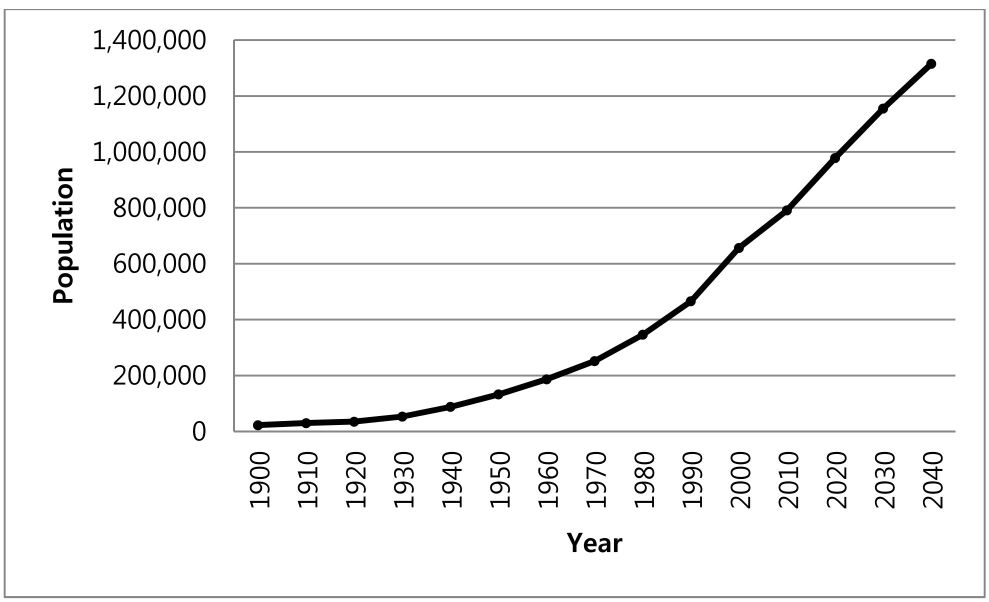


Figure 1: Austin Population Projection, TWDB (2009)

Currently, the city of Austin produces 53 billion gallons of water a year. The first phase of a new water treatment plant (WTP4) is expected to be completed in 2014. In all its planned phases, it would produce approximately 108 billion gallons of water a year accommodating the city's future need (Austin Water Utility) for several decades. However, even considering the population growth trend of Austin, it appears likely that this new water treatment plant will impose a heavy burden not only on residents' water bills but also on the environment.

**Water Demand**

Municipal water is that water supplied by a city for public use, usually including residential and commercial water uses. According to the Texas Water Development Board (TWDB), municipal water usage accounts for 83.6% of total water demand in Travis County. Therefore, as described in the figure below, municipal water should be specifically conserved in Austin to diminish the overall water demand.

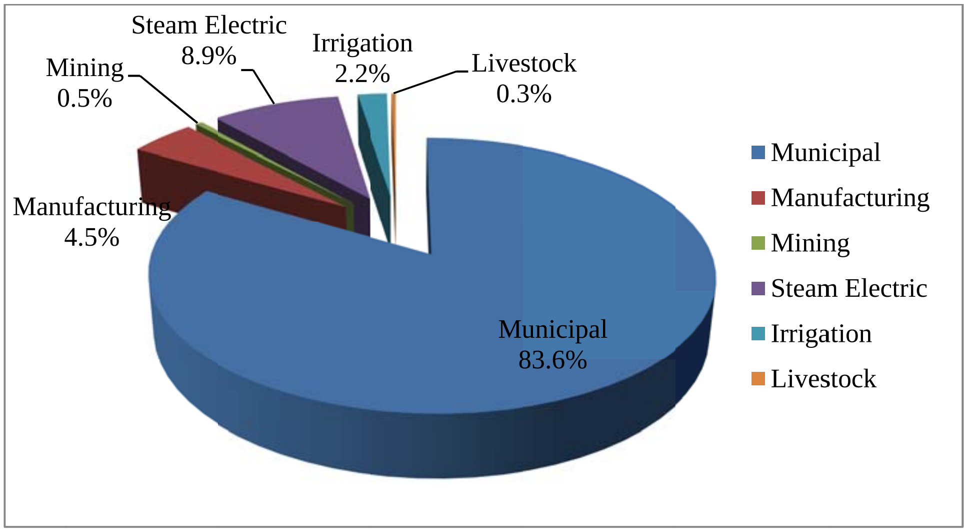


Figure 2:Water Use Survey Estimation in Travis County (2007), TWDB

Recently, the City has adopted a new, revised water conservation plan. The Plan expected an increase in water rates because of the combination of the added cost of WTP and the reduction in per-capita water consumption to 140 gallons per day (AWU 2010). The plan would be implemented through a variety of measures, ultimately leading to a reduction in per capita water demand of 140 gallons per capita-day.

**Rainwater Harvesting Systems**

Every rainwater harvesting system consists of three main components: a catchment surface for collecting rainwater, a storage tank for storing rainwater, and a delivery system for transporting water from the catchment to the storage reservoir (Vivian 2009). Roofs are the most common type of catchment surface for harvesting rainfall. Corrugated steel, wood, and plastic are the common and appropriate roof catchment surfaces (Water 2004).

Three types of rainwater tanks are typical—above ground, underground, and a hybrid of the first two. The above-ground tank, the most common of the roof catchment systems, must have the catchment surface elevated. The underground tank, an effective storage system for the space used, costs twice as much as a surface tank, with no promise on the quality of water. The last type, half aboveground and half underground, combines the first two (Water 2004).

Delivery systems convey rainwater runoff from the catchment surface to the storage tank. Gutters, rain-chains, and downspouts are the common conveyance systems, typically made out of plastic or aluminum (Water 2004; The Texas Manual on Rainwater Harvesting 2005). Further developed components are filtration and treatment mechanisms which improve the water quality, and pumps that increase the water pressure, enabling a wide array of possible uses inside and outside the house.

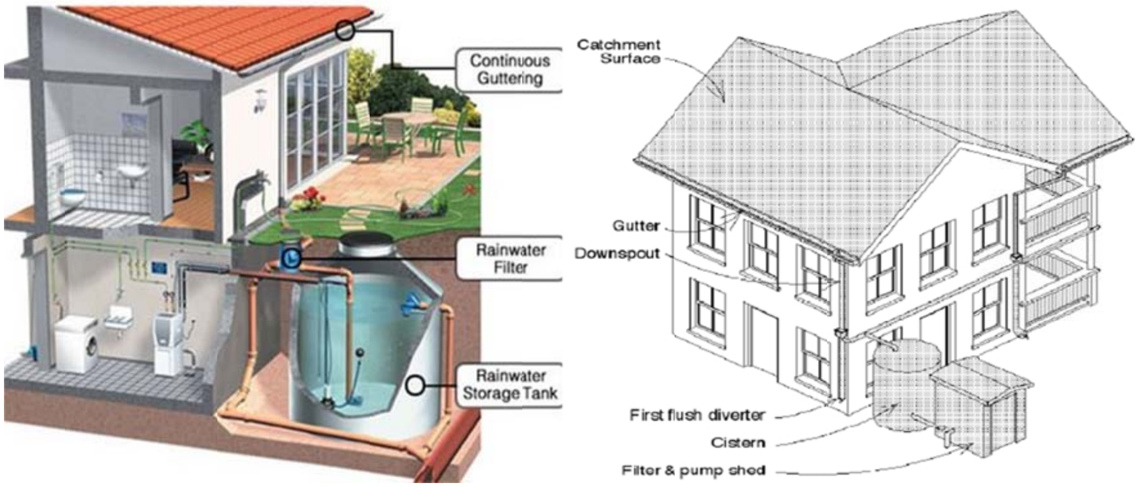


Figure 3: Residential Rainwater Harvesting System, Texas Manual on Rainwater Harvesting, 3rd Edition

**1.2 OBJECTIVES**

This project aims to explore a new concept in making residential rainwater harvesting systems more affordable: a proposed cost reallocation between the city (utility), developer/builder, and individual homeowner sectors. The project has two purposes: (1) to lower individual homeowners’ burden of cost in installing RWHS, and (2) to reduce the municipal water usage and mitigate the problems and risk of urban runoff.

A new paradigm of rainwater harvesting management will produce significant benefits not only to society but also to individuals. From reducing the risk of stormwater to stabilizing future water prices, RWHS will generate obvious social benefits. Decentralized residential RWHS will also save on the city’s budget for additional water or wastewater treatment plants. Furthermore, for individuals RWHS will save on their water bills. The pay-back period may be long, but the long-term benefits should be enduring (Han, 2006).

# CHAPTER 2: METHODS

The objectives of equitable allocation of costs can be accomplished through the consideration of three different viewpoints: (1) homeowner, (2) city (utility), and (3) developer (land developer & home builder). Firstly, it will be necessary to show the total original costs and benefits of the RWHS as would affect a homeowner who installs this system. The result will then show the typical pay-back period of constructing the RWHS in a single-family household. Then potential advantages and subsidies that the city and developer sector could provide for the purchase of the RWHS will be converted into current cash value. After finding potential advantages that each sector acquires from the RWHS, the cost for the system will be equitably allocated in order to minimize the single family household's initial cost of RWHS installation. Finally, the pay-back period of the RWHS after the cost reallocation will also be shown.

## Benefits and Costs of the Rainwater Harvesting Systems

The initial cost of installing a RWHS is fairly high, posing a heavy burden on homeowners. This study will first find out the initial costs and benefits of installing RWHS for single family housing and then calculate the length of time before the pay-back period is met. The initial construction costs of the RWHS will be estimated by sizing and analyzing the fundamental components of the system, following the Texas Manual on Rainwater Harvesting, 3rd Edition. Calculation of water-related benefits will then be made, based on the Rainwater Harvesting Calculator provided by the Texas Water Development Board. The volume of rainwater that can be captured by the RWHS will be obtained. Storage volume will then compared with the average single-family water usage in order to find out the specific percentage that the RWHS will harvest, out of the total of all water use. This percentage will be applied to the average water bill and enable the reader to find the actual amount of money that can be saved from the RWHS. After all, the pay-back period will be obtained by a cumulative cost-benefit analysis.

**City (Utility) Share**

The City, mainly Austin Water Utility, could share the initial costs for installing the RWHS in two ways. First, support by the Rainwater Harvesting Rebate Program, and second, delay the construction of phase II Water Treatment Plant 4 (WTP4). By the rebate program, maximum of $5,000 could be rebated. In addition, by delaying the phase II construction for the WTP4, the money for the construction, such as expansion costs, operating costs, and maintenance costs, could be used as another subsidy for installing the RWHS. Knowing that the Rainwater Harvesting Rebate Program has been providing support up to a total of $5,000 to each qualified homeowner, this report seeks to secure and apportion additional subsidies that could be supported by the city. It is possible that, instead of expanding the phase II of WTP4, supporting the same amount of money for the RWHS subsidy would prolong the present demand capacity of Austin (285MGD); thus, delay the construction of the phase II.

**Developer Share**

Developers could reduce the costs of stormwater detention ponds and water quality ponds since the RWHS could capture a certain amount of initial rainfall; thus, reduce the volume of stormwater runoff. The developer, in this study is defined as including both land development and home construction sectors of the industry. Assuming that a residential developer/homebuilder is required to install storm drainage control measures in each subdivision, the RWHS can be considered as an offset to making drainage control investments. The following chapter builds a scenario involving some 300-units in a new subdivision. We will find the detention pond and water quality control pond costs that could be reduced from installing a RWHS on each lot and suggest a share of the RWHS installation cost that developers could justify paying to the homeowners.

# CHAPTER 3: ANALYSIS

## 3.1 BENEFITS AND COSTS OF RAINWATER HARVESTING SYSTEMS

### Rainwater Harvesting System Costs Estimation

Costs for components of rainwater systems for both potable use and for irrigation do vary greatly. Since there are a number of variables that affect the entire cost of a rainwater system, homeowners should precisely calculate the needed and desired storage volume of the rainwater tank before installing the entire systems. Generally, low cost systems are typically installed by the homeowner, while the more expensive ones include professional installation costs. Austin Water Utility has a rebate program that indicates the installation and construction cost per gallon based on the cost of the entire system, but not by specific components. This ranges from $0.50 per gallon to $3.50 per gallon. However, in order to obtain more detail information on cost ranges for standard components of rainwater systems, The Texas Manual on Rainwater Harvesting, 3rd Edition, has been mainly considered in this study.

A number of individual components are available from different manufacturers and installers. However, according to the Texas Manual, the domestic rainwater harvesting system comprises six fundamental components regardless of the complexity; thus, costs for each component were estimated within six categories. In the later part of this report we will make the determination that the storage volume of a typical RWHS will be 7,000 gallons; and the system will be used only for non-potable indoor use and for irrigation. Thus, the costs will be estimated based on these assumptions.

The single largest expense in the RWHS is the storage tank, which varies upon the size and the material. Table 1 shows the different types of storage tanks. Among the eight tank materials shown, the most appropriate tanks that correspond to the average residential use and meet with 7,000 gallons limits are fiberglass and polypropylene. Therefore, the average cost for each of two tanks will be calculated, which is 1.25/gallon (Fiberglass), and 0.675/gallon (Polypropylene). Then, the cost for the fiberglass storage tank will be $8,750 and the polypropylene tank will be $4,725.

| | **Cost** | **Size** | **Comments** |
|---|---|---|---|
| **Fiberglass** | **$0.50-2.00/gallon** | **500-20,000 gallons** | can last for decades without deterioration, easily repaired, can be painted |
| Concrete | $0.30-1.25/gallon | Usually 10,000 gallons or more | risks of cracks and leaks but easily repaired, immobile, smell and taste of water sometimes affected but the tank can be retrofitted with a plastic liner |
| Metal | $0.50-1.50/gallon | 150-2,500 gallons | lightweight and easily transported, rusting and leaching of zinc can pose a problem but can be mitigated with a potable-approved liner |
| **Polypropylene** | **$0.35-1.00/gallon** | **300-10,000 gallons** | durable and light weight, black tanks result in warmer water if tank exposed to sunlight, clear/translucent tanks foster algae growth |
| Wood | $2.00/gallon | 700-50,000 gallons | aesthetically pleasing, sometimes preferable in public areas and residential neighborhoods |
| Polyethylene | $0.74-1.67/gallon | 300-5,000 gallons | |
| Welded Steel | $0.80-4.00/gallon | 30,000-1 million gallons | |
| Rain Barrel | $100 | 55-100 gallons | barrels containing toxic materials to be avoided, add screens for mosquitoes |

Table 1: Costs of Storage Tank, The Texas Manual on Rainwater Harvesting

Gutters and downspouts are important components to collect the water and route it to the tank. Vinyl and plastic are the typical gutters that homeowners can install them by themselves. Thus, the costs for both gutters are approximately same with comparatively low price ($0.30). Aluminum and galvalume gutters, however, are desired to be professionally installed, within costs range from $3.50 to $12 per foot of gutter, including installation and materials (2004 dollars). In this study, however, the cost of gutters is assumed to be borne by the homeowner as a basic home improvement and is not included in the apportionment of costs for the rainwater system. Also, the City of Austin does not allow for rebates for gutters in their rebate program. Nonetheless, conveyance pipes from the roof to the storage tank, overflow pipes, and other segments of the RWHS will require pipes of comparable cost as the more expensive gutter types. In this study we will assume a nominal cost of installed plastic conveyance pipes of $10 per foot and 40 to 41 feet in length, or a total cost of $400 to $410.

The roof washer, which filters small particles for potable systems and avoids clogging drip irrigation emitters, is placed directly above or very close to the storage tank, consisting of a tank with leaf strainers and a filter. Among the three types of roof washers, a box washer, ranges from $400 to $800, is the typical one that uses for the residential. Thus, $600, the average cost of a box washer, is used for the analysis. Below figure shows the components of a box roof washer.

| | Cost | Maintenance | Comments |
|---|---|---|---|
| **Box Washer** | $400-800 | Clean the filter after every substantial rain | neglecting to clean the filter results in restricted or blocked water flow and may become a source of contamination |
| Post Filtering with Sand Filter | $150-500 | Occasionally backwash the filter | susceptible to freezing, a larger filter is best |
| Smart-Valve Rainwater Diverter Kit | $50 for kit | Occasional cleaning | device installed in a diversion pipe to make it self-flushing and prevent debris contamination, resets automatically |

Table 2: Costs of Roof Washers, The Texas Manual on Rainwater Harvesting

The following table shows the cost ranges of pumps and pressure tanks. Separate pressure tanks are not required for Grundfos pumps since this system can supply enough water by instantaneous flow. Since this study is assuming to build a RWHS which has a pressure function, the average costs of a shallow well jet pump and pressure tank are used ($800).

| | Cost | Comments |
|---|---|---|
| Grundfos MQ Water Supply System | $385-600 | requires no separate pressure tank |
| Shallow Well Jet Pump or Multi-Stage Centrifugal Pump | $300-600 | Requires separate pressure tank |
| Pressure Tank | $200-500 | galvanized tanks cheaper than bladder tanks but often become waterlogged, wearing out the pump more rapidly |

Table 3: Costs of Pumps and Pressure Tanks, The Texas Manual on Rainwater Harvesting

Two in-line sediment filters – the 5-micron fiber cartridge filter followed by the 3-micron activated charcoal cartridge filter – followed by ultraviolet light is a popular disinfection array in Texas. Both cartridge filters must be changed regularly and ultraviolet (UV) lights are required to be replaced after a maximum of 10,000 hours of operation (The Texas Manual of Rainwater Harvesting). The 5-micron filter eliminates suspended particles and dust, and the 3-micron filter traps microscopic particles when smaller organic molecules are absorbed by the activated surface (Macomber 2001). Other sizes of filters may be used, depending on the application, but the costs are presumed to be comparable to the ones shown in this study.

This study used two cartridge filters and a UV light disinfection, which are the formal components for the RWHS in Texas. Thus, the total costs for the treatment and disinfection equipment is $755 ($80 + $675), excluding the replacement costs.

| | **Cost** | **Maintenance** | **Effectiveness** | **Comments** |
|---|---|---|---|---|
| **Cartridge Filter** | $20-60 | filter must be changed regularly | removes particles > 3microns | disinfection treatment also recommended |
| Reverse Osmosis Filter | $400-1,500 | filter changed when clogged(depends on the turbidity) | removes particles >0.001microns | disinfection treatment also recommended |
| **UV Light Disinfection** | $350-1,000; $80 to replace UV bulb | UV bulb changed every 10,000hours or 14months,protective cover must be cleaned regularly | disinfects filtered water provided there are < 1,000coliforms per 100 milliliter | water must be filtered prior to exposure for maximum effectiveness |
| Ozone Disinfection | $700-2,600 | effectiveness must be monitored with frequent testing or an in-line monitor ($1,200or more) | less effective in high turbidity, can be improved with pre-filtering | requires a pump to circulate the ozone molecules |
| Chlorine Disinfection | $1/month manual dose or a $600-$3000 automatic self-dosing system | monthly dose applied manually | high turbidity requires a higher concentration or prolonged exposure, can be mitigated with pre-filtering | excessive chlorination maybe linked to negative health impacts. |

Table 4: Costs of Filtering/Disinfection, The Texas Manual on Rainwater Harvesting

The average number of persons in the household is 2.7 in Austin and the collected rainwater will be used for both outdoor irrigation and indoor uses. However, the RWHS in this study will not be used for potable water use.

In conclusion, the total initial estimated costs for the rainwater harvesting system in Texas can be from minimum to $6,905 to maximum to $11,315 depends on the types of storage tank (fiberglass or polypropylene). Table 5 summarizes the cost calculations of each of the components of the rainwater harvesting system in Texas. This study, therefore, analyzed the data based on a range between two costs, the low-end cost and the high-end cost.

| **Type** | | **Cost** | **Size** | **Estimated Cost** |
|---|---|---|---|---|
| **Storage Tank** | fiberglass | 1.25 | 7,000 gallons | $8,750 |
| | polypropylene | 0.675 | 7,000 gallons | $4,725 |
| **Plastic Conveyance** | plastic | 10 | 41 foot | $410 |
| **Roof Washers** | box washer | 600 | 1 | $600 |
| **Pumps & Pressure Tanks** | multi-stage centrifugal pump | 450 | 1 | $450 |
| | pressure tank | 350 | 1 | $350 |
| **Filtering / Disinfection** | cartridge filters (5-micron + 3-micron) | 80 | 1 | $80 |
| | UV light disinfection | 675 | 1 | $675 |
| **Total Costs using Fiberglass Tank** | | **with plastic gutters** | | **$11,315** |
| **Total Costs using Polypropylene Tank** | | **with plastic gutters** | | **$7,290** |

Table 5: Cost Estimation of Typical Rainwater Harvesting System in Texas, The Texas Manual on Rainwater Harvesting

## Rainwater Harvesting System Benefits Estimation

### Rainwater Harvesting Calculator Inputs

Based on the Rainwater Harvesting Calculator, inputs and outputs will be estimated. Inputs to this analysis include parameters for water sources, rainwater tank size, and water demands.

### Water Sources

The water source for the RWHS is typically from the rainfall collected from roof surfaces. Thus, data for average monthly rainfall is needed. Table 6 shows the average monthly precipitation in Austin, Texas from 1971 to 2000. For 30 years, the annual average rainfall in Austin was 34.72 inches and May was the highest month of rainfall, with an average of 5.12 inches (Texas Water Development Board 2009).

| Month | Average Monthly Rainfall (in.) | Average Monthly Rainfall (gal. per sq.ft.) |
|---|---|---|
| **January** | 2.21 | 1.37 |
| **February** | 2.02 | 1.25 |
| **March** | 2.36 | 1.46 |
| **April** | 2.63 | 1.63 |
| **May** | 5.12 | 3.17 |
| **June** | 3.42 | 2.12 |
| **July** | 2.03 | 1.26 |
| **August** | 2.51 | 1.56 |
| **September** | 2.88 | 1.79 |
| **October** | 3.99 | 2.47 |
| **November** | 3.02 | 1.87 |
| **December** | 2.53 | 1.57 |
| **Annual** | **34.72** | |

Table 6: Average Monthly Rainfall in Austin, TX, TWDB

For the catchment area (roof), there are specific runoff coefficients for different kinds of roofs. Seven different substrates are typically used for roofs on U.S. houses and different coefficients are shown in the following table. Water quality from different roof catchments is a function of the type of roof material, climatic conditions, and the surrounding environment (Vasudevan 2002). For this project, 'Asphalt Shingle' which is the most common roof for U.S. single family housings is used. Runoff coefficient for this roof is 0.90; meaning that 90% of the precipitation that is collected upon the area is calculated to enter the cistern.

| No | Substrate | Coeff |
|---|---|---|
| **1** | metal or glass | 0.95 |
| **2** | EPDM rubber membrane | 0.95 |
| **3** | **asphalt shingle** | **0.90** |
| **4** | tar and gravel | 0.80 |
| **5** | cement tile | 0.75 |
| **6** | clay tile | 0.50 |
| **7** | green roof | 0.28 |

Table 7: Roof Coefficients, TWDB

In order to discover the actual catchment area (roof area), average size of single family (SF) homes in the U.S. is required. Typical SF homes' roof area is approximately 90% of the house size (some houses are one-story, some are two-story). According to the 2008 U.S. census, the average size of a single-family home is 2,629sq.ft. By multiplying by 90%, we obtain 2,366sq.ft as the average roof area. However, gutters which are placed on the edges of the roof could also capture an additional amount of rainfall. Thus, this report assumed that the overall catchment area will be 2,400sq.ft.

The equation that estimates the monthly supply to the collection tank is:

*Average monthly rainfall (inch) × 0.62 × Size of roof area (sq.ft.)× 0.9*

Through this equation, the volume of rainwater that can be collected from RWHS will be obtained. As shown in Table 8, 46,497 gallons of rainwater can be generated annually with 2,400sq.ft. roof area. May, which is the month that precipitation is typically highest in a year, will likely capture the largest volume of rainwater, which is 6,857 gallons.

| **Month** | **(A)Average monthly rainfall (in.)** | **(B) = (A)×0.62 Average monthly rainfall (gal. per sq.ft.)** | **(C) = (B) × 2,400 Potential volume of water from collection area (gal.)** | **(D) = (C) × 0.9 Estimated monthly supply to collection tank (gal.)** |
|---|---|---|---|---|
| **January** | 2.21 | 1.37 | 3,288 | 2,960 |
| **February** | 2.02 | 1.25 | 3,006 | 2,705 |
| **March** | 2.36 | 1.46 | 3,512 | 3,161 |
| **April** | 2.63 | 1.63 | 3,913 | 3,522 |
| **May** | 5.12 | 3.17 | 7,619 | 6,857 |
| **June** | 3.42 | 2.12 | 5,089 | 4,580 |
| **July** | 2.03 | 1.26 | 3,021 | 2,719 |
| **August** | 2.51 | 1.56 | 3,735 | 3,361 |
| **September** | 2.88 | 1.79 | 4,285 | 3,857 |
| **October** | 3.99 | 2.47 | 5,937 | 5,343 |
| **November** | 3.02 | 1.87 | 4,494 | 4,044 |
| **December** | 2.53 | 1.57 | 3,765 | 3,388 |
| ***Annual*** | ***34.72*** | | | ***46,497*** |

Table 8: Estimated Monthly Supply to Collection Tank

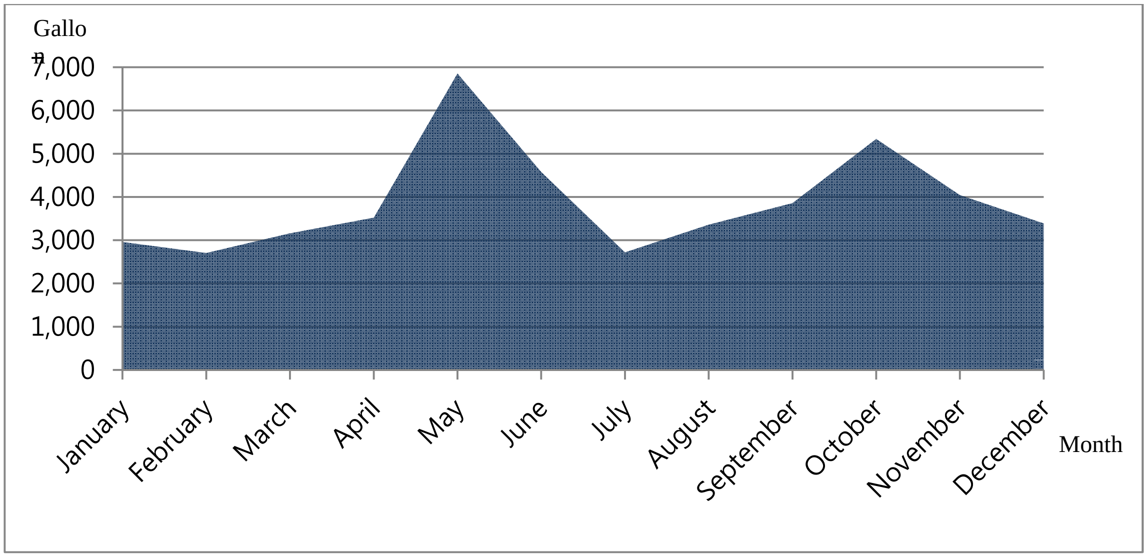


Figure 4: Estimated Monthly Storage of Rainwater

**Rainwater Tank Size**

Based on the Rainwater Harvesting Calculator model, the maximum target volume of rainwater storage is 6,857 gallons in May. This explains that the tank size does not need to exceed 7,000 gallons since it will not overflow over 6,857 gallons. However, it may run over the capacity because of heavy rain or unexpected disaster. Thus, sufficient capacity is recommended in order to prepare these kinds of activities. Additionally, leaving tank spaces will also store more stormwater and eventually prevent runoffs. In this study, however, we used 7,000 gallons for the tank capacity since the collected amount of rainwater is considerably small except in May, June, and October. Larger or smaller houses or lot sizes or family sizes will inevitably justify larger or smaller tank sizes, but 7,000 gallons is presumed to be a reasonable average requirement for large numbers of homes.

| Month | Estimated monthly supply to collection tank (gal.) | 7,000 gal excess capacity |
|---|---|---|
| **January** | 2,960 | 4,040 |
| **February** | 2,705 | 4,295 |
| **March** | 3,161 | 3,839 |
| **April** | 3,522 | 3,478 |
| **May** | **6,857** | **143** |
| **June** | 4,580 | 2,420 |
| **July** | 2,719 | 4,281 |
| **August** | 3,361 | 3,639 |
| **September** | 3,857 | 3,143 |
| **October** | 5,343 | 1,657 |
| **November** | 4,044 | 2,956 |
| **December** | 3,388 | 3,612 |
| **Total Annual Amount** | **46,497** | **-** |
| **Monthly Average Amount** | **-** | **3,125** |

Table 9: Estimated Monthly Storage and 7,000 gallon Excess Capacity

**Water Demands**

Khastagir & Jayasuriya (2007) revealed that rainwater can be used effectively for non potable purposes, such as toilet flushing, garden use, laundry use or a combination of these. Likewise harvested rainwater can be used for various purposes (uses), including but not limited to irrigation, laundry, toilet, kitchen, and car wash. The range of uses for which rainwater systems can be used are nearly 70 to 80 percent of the normal household usage. According to the Austin Water Utility, the average single family home water usage is 8,500 gallons/month in Austin. Since there were no exact data for the percentage of indoor vs. outdoor water usage in Austin, this report used the average percentage of Florida statewide, which is 50:50 (4,250 gallons indoor and outdoor). Florida is one of the states that has similar climatic conditions as Austin and the proportion of household water use for irrigation is approximately the same as Texas.

**Results**

Based on inputs described above, the baseline harvesting system consists of:

1. 2,400sq.ft of catchment area

2. Cistern size of 7,000 gallons

3. Annual storage amount of 46,497 gallons

Since the average water usage for single family homes is 8,500 gallons in Austin, an average of 102,000 gallons of water will be consumed by one household per a year. Thus, harvested rainwater can provide 46% (46,497 gallons / 102,000 gallons × 100) of the entire water usage.

**Water User Charges**

In this chapter, the residential water bill will be projected based on two scenarios: (1) first scenario with service rate increasing by WTP4 construction and (2) second scenario with historical service rate trend line. Average inflation increase rate from 2001 to 2011 will then be divided on each year in order to transfer the present value into future value. From these results, 46% of service rate will be saved by using the RWHS, and we will accumulate the benefits (saved costs) until it exceeds the initial construction cost of

RWHS. The year when benefits exceed the costs will be the pay-back period of this system.

**Scenario 1**

According to City of Austin Financial Forecast (2010), from 2010 to 2015 AWU plans to increase the water rate by 30.13% to pay off WTP4's construction costs and to achieve the 140 gal. per capita-day goal of the Conservation Plan. This indicates that average annual increase rate is 5.42% on a yearly basis. The Table below shows the increase rate for each year including water, wastewater, and combined.

| | **2011** | **2012** | **2013** | **2014** | **2015** |
|---|---|---|---|---|---|
| **Water:** | **6.80%** | **5.50%** | **6.60%** | **5.70%** | **2.50%** |
| **Wastewater:** | 2.00% | 3.50% | 4.30% | 3.10% | 2.50% |
| **Combined:** | 4.50% | 4.50% | 5.50% | 4.50% | 2.50% |

Table 10: Projected Service Rate Increases, Austin Water Utility

When estimating the future water bill, it is required to convert the future value into present value; thus, the historical average inflation rate over 10 years, which is 2.36%, was used.

Table 11: Historical Average Inflation Rate, usinflationcalculator.com

| **Year** | **Average inflation rate** |
|---|---|
| 2001<br>(March – December) | 2.66 |
| 2002 | 1.58 |
| 2003 | 2.28 |
| 2004 | 2.68 |

Table 11 continues

| | |
|---|---|
| 2005 | 3.38 |
| 2006 | 3.23 |
| 2007 | 2.87 |
| 2008 | 3.85 |
| 2009 | -0.35 |
| 2010 | 1.63 |
| 2011 (January – March) | 2.13 |
| **Total Average** | 2.36 |

In sum, based on a 5.42% service rate increase over five years (2011 – 2015) and a 2.36% inflation rate increase (10 years average increase rate from 2001 to 2011), the cumulative benefits from the RWHS can be seen in Table 12. Future water bill was calculated by geometric extrapolation method, a curve with constant growth rate (Zhang 2010). The curve formula is:

$$W_n = W_0(1+r)^n$$

$W_n$ is the water bill after $n$ years; $W_0$ is the initial water bill, which is the 2010 service rate ($27.29); $r$ is the annual growth rate; and $n$ refers to years beyond 2010. The primary assumption for this method is that the water bill will change by the same percentage each year into the future as the average annual percentage change observed over the base period (Zhang 2010).

However, since the rainwater that was captured by the RWHS can only be used to meet 46% of the entire residential water usage, the portion of the water bill that a homeowner can save will be limited to 46%. After converting future value into present value, we can estimate the cumulative water bill that can be saved by using the RWHS.

Table 12: Benefits from the RWHS, Scenario 1

| Year | (A) = $W_0(1+0.0542)^n$ Water Bill / Year | (B) = (A) × 0.4559 Saved Bill from RWHS (45.59%) | (C) = (B)/1.0236 Present Value | (D) Cumulative Value |
|---|---|---|---|---|
| **2010** | 327.48 | 149.30 | 149.30 | **149.30** |
| **2011** | 345.23 | 157.39 | 153.76 | **303.06** |
| **2012** | 363.94 | 165.92 | 162.10 | **465.15** |
| **2013** | 383.67 | 174.91 | 170.88 | **636.04** |
| **2014** | 404.46 | 184.39 | 180.14 | **816.18** |
| **2015** | 426.38 | 194.39 | 189.91 | **1,006.08** |
| **2016** | 449.49 | 204.92 | 200.20 | **1,206.28** |
| **2017** | 473.86 | 216.03 | 211.05 | **1,417.33** |
| **2018** | 499.54 | 227.74 | 222.49 | **1,639.82** |
| **2019** | 526.61 | 240.08 | 234.55 | **1,874.37** |
| **2020** | 555.16 | 253.10 | 247.26 | **2,121.63** |
| **2021** | 585.25 | 266.81 | 260.66 | **2,382.29** |
| **2022** | 616.97 | 281.27 | 274.79 | **2,657.08** |
| **2023** | 650.41 | 296.52 | 289.68 | **2,946.76** |
| **2024** | 685.66 | 312.59 | 305.38 | **3,252.15** |
| **2025** | 722.82 | 329.53 | 321.94 | **3,574.08** |
| **2026** | 762.00 | 347.39 | 339.38 | **3,913.47** |
| **2027** | 803.30 | 366.22 | 357.78 | **4,271.25** |
| **2028** | 846.84 | 386.07 | 377.17 | **4,648.42** |
| **2029** | 892.73 | 407.00 | 397.61 | **5,046.03** |
| **2030** | 941.12 | 429.06 | 419.16 | **5,465.20** |
| **2031** | 992.13 | 452.31 | 441.88 | **5,907.08** |
| **2032** | 1045.90 | 476.83 | 465.83 | **6,372.91** |
| **2033** | 1102.59 | 502.67 | 491.08 | **6,863.99** |
| **2034** | 1162.35 | 529.92 | 517.70 | **7,381.69** |
| **2035** | 1225.35 | 558.64 | 545.76 | **7,927.45** |
| **2036** | 1291.76 | 588.92 | 575.34 | **8,502.79** |
| **2037** | 1361.78 | 620.83 | 606.52 | **9,109.31** |
| **2038** | 1435.59 | 654.48 | 639.39 | **9,748.70** |
| **2039** | 1513.39 | 689.96 | 674.05 | **10,422.75** |
| **2040** | 1595.42 | 727.35 | 710.58 | **11,133.33** |

Table 12 continues

| | | | | |
|---|---|---|---|---|
| **2041** | 1681.89 | 766.77 | 749.10 | **11,882.43** |
| **2042** | 1773.05 | 808.33 | 789.70 | **12,672.13** |
| **2043** | 1869.15 | 852.15 | 832.50 | **13,504.62** |
| **2044** | 1970.46 | 898.33 | 877.62 | **14,382.24** |
| **2045** | 2077.26 | 947.02 | 925.19 | **15,307.43** |

As shown in Figure 5, the benefits will exceed the minimum initial costs (construction costs of RWHS, $7,290) between 2033 and 2034, and water bills saved as a result of the RWHS will exceed the maximum initial costs ($11,315) between 2040 and 2041. Therefore, the pay-back period according to the scenario 1 will be 23 years and 30 years without any subsidy.

For the initial tank cost, this study assumed that all the expenditures will be paid in the first year, which is in year 2010, in order to show the simplest aspect of the cost effectiveness analysis. If the cost distributed by home owners through ten or more years as would be the case if it were financed as a part of the home mortgage, then inflation rates, interest rates, and other factors should be also calculated; and thus, a lot more research will be needed. Further study should consider these aspects and analyze with various assumptions.

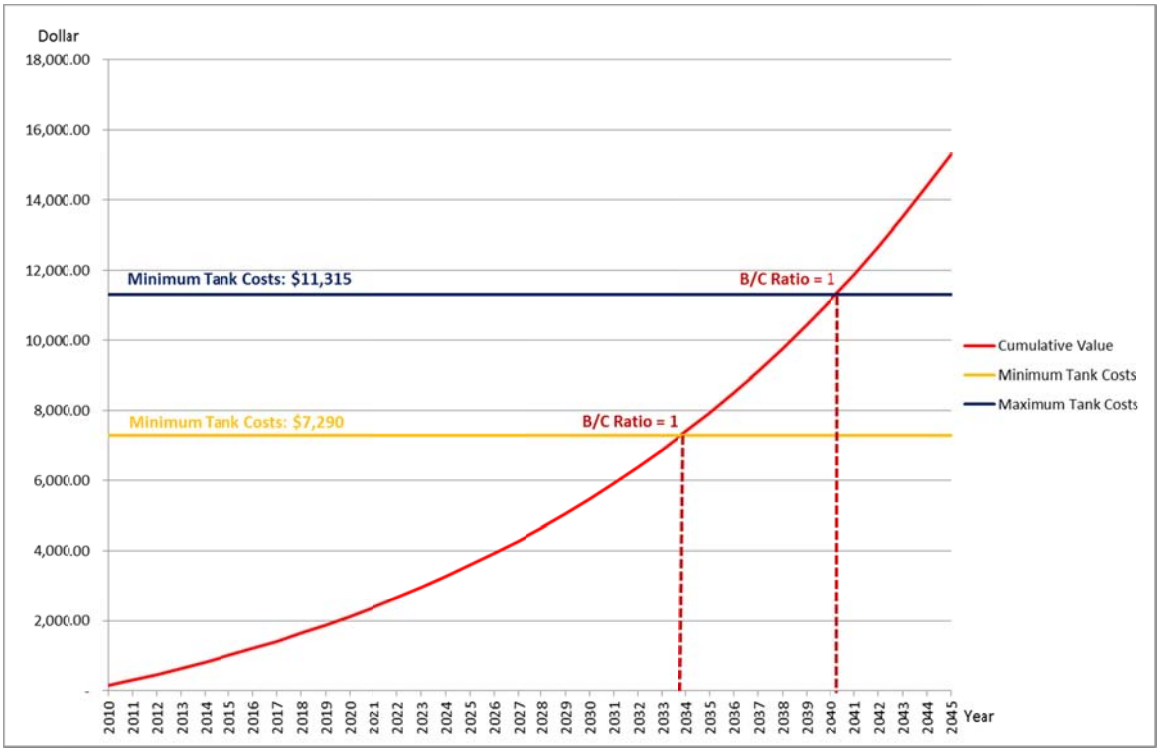


Figure 5: Pay-Back Period of RWHS, Scenario 1

**Scenario 2**

In this scenario, a residential water bill was estimated by a six-year historical average water bill of residential water use (8,500 gallons / month). From 2002 to 2008, the service rate increased 41.49%. On a yearly basis, 5.96% of the water rate has been increased.

| **Year** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** |
|---|---|---|---|---|---|---|---|
| **Water Bill** | $18.85 | $19.84 | $21.66 | $22.01 | $23.14 | $24.32 | $26.67 |

Table 13: Historical Average Residential Water Bill, Austin Water Utility

Using the same method of scenario 1, we can develop a projection of future water billings, as well as the projected value of savings in water bills as a result of RWHS, as displayed in Table 14.

Table 14: Benefits from the RWHS, Scenario 2

| Year | (A) = $W_0(1+0.0542)^n$ Water Bill / Year | (B) = (A) × 0.4559 Saved Bill from RWHS (45.59%) | (C) = (B)/1.0236 Present Value | (D) Cumulative Value |
|---|---|---|---|---|
| **2010** | 327.48 | 149.30 | 149.30 | **149** |
| **2011** | 347.00 | 158.20 | 154.55 | **304** |
| **2012** | 367.68 | 167.62 | 163.76 | **468** |
| **2013** | 389.59 | 177.62 | 173.52 | **641** |
| **2014** | 412.81 | 188.20 | 183.86 | **825** |
| **2015** | 437.42 | 199.42 | 194.82 | **1,020** |
| **2016** | 463.49 | 211.30 | 206.43 | **1,226** |
| **2017** | 491.11 | 223.90 | 218.73 | **1,445** |
| **2018** | 520.38 | 237.24 | 231.77 | **1,677** |
| **2019** | 551.39 | 251.38 | 245.58 | **1,922** |
| **2020** | 584.26 | 266.36 | 260.22 | **2,183** |
| **2021** | 619.08 | 282.24 | 275.73 | **2,458** |
| **2022** | 655.98 | 299.06 | 292.16 | **2,750** |
| **2023** | 695.07 | 316.88 | 309.58 | **3,060** |
| **2024** | 736.50 | 335.77 | 328.03 | **3,388** |
| **2025** | 780.39 | 355.78 | 347.58 | **3,736** |
| **2026** | 826.91 | 376.99 | 368.29 | **4,104** |
| **2027** | 876.19 | 399.45 | 390.24 | **4,494** |
| **2028** | 928.41 | 423.26 | 413.50 | **4,908** |
| **2029** | 983.74 | 448.49 | 438.15 | **5,346** |
| **2030** | 1,042.37 | 475.22 | 464.26 | **5,810** |
| **2031** | 1,104.50 | 503.54 | 491.93 | **6,302** |
| **2032** | 1,170.33 | 533.55 | 521.25 | **6,823** |
| **2033** | 1,240.08 | 565.35 | 552.32 | **7,376** |
| **2034** | 1,313.99 | 599.05 | 585.24 | **7,961** |
| **2035** | 1,392.30 | 634.75 | 620.12 | **8,581** |

Table 14 continues

| | | | | |
|---|---|---|---|---|
| **2036** | 1,475.28 | 672.58 | 657.07 | **9,238** |
| **2037** | 1,563.21 | 712.67 | 696.24 | **9,934** |
| **2038** | 1,656.38 | 755.14 | 737.73 | **10,672** |
| **2039** | 1,755.10 | 800.15 | 781.70 | **11,454** |
| **2040** | 1,859.70 | 847.84 | 828.29 | **12,282** |
| **2041** | 1,970.54 | 898.37 | 877.66 | **13,160** |
| **2042** | 2,087.98 | 951.91 | 929.96 | **14,090** |
| **2043** | 2,212.43 | 1,008.65 | 985.39 | **15,075** |
| **2044** | 2,344.29 | 1,068.76 | 1,044.12 | **16,119** |
| **2045** | 2,484.01 | 1,132.46 | 1,106.35 | **17,225** |

Assuming a 5.96% service rate (on a yearly basis) increase and a 2.36% inflation rate, the benefits will exceed the minimum RWHS costs ($7,290) between 2032 and 2033 and the maximum RWHS costs ($11,315) between 2038 and 2039. Thus, the pay-back periods are 22 and 28 years respectively, meaning that after these years the benefit/cost ratio will exceed 1.0.

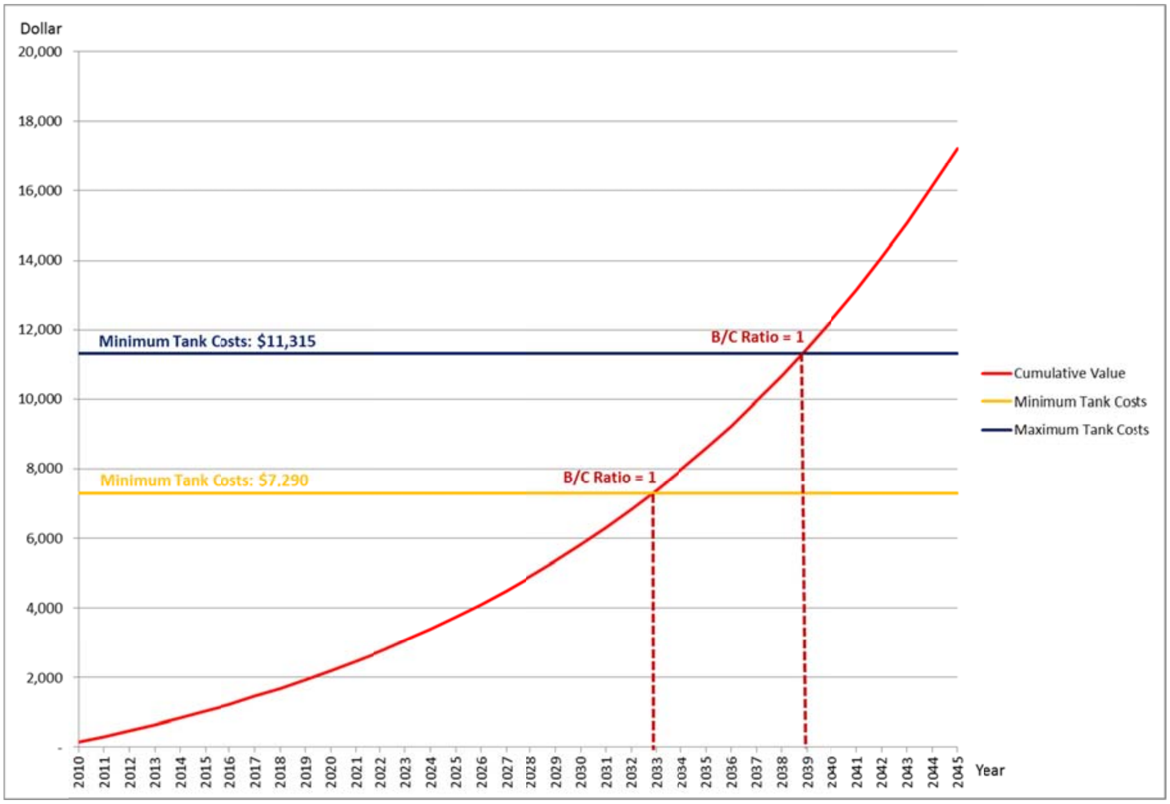


Figure 6: Pay-Back Period of RWHS, Scenario 2

## 3.2 City (Utility) Share

### Rainwater Harvesting Rebate Program Background

The Austin Water Utility is currently operating a Rainwater Harvesting Rebate Program. They are offering a financial incentive to encourage rainwater harvesting for non-potable uses, for systems that have been purchased on or after July 1, 2010. "Rebates of $0.50 per gallon are available for non-pressurized systems (i.e. rainbarrels) and $1.00 per gallon for pressurized systems (i.e. large cisterns with a pump) not to exceed 50% of system cost. Rebates are limited to no more than half the project cost with a lifetime maximum rebate of $5,000 (Webster 2011)." The rainwater tank, pad, screens, filter, first-flush, and selected piping installation will be covered by the rebate program.

However, gutters, irrigation system components, or backflow preventers are excluded in the rebate program.

For the core system requirements, tanks 500 gallons and larger require the installation of a first-flush diversion system and a sturdy, level base constructed of gravel, sand, or concrete. In addition, unlined galvanized collection tanks are not eligible. However, metal tanks with liners may be approved by submitting tank specifications. It is the applicant's responsibility to ensure that the system does not violate City Code requirements (including setbacks, impervious cover, etc.) and homeowners association enforced restrictions. The rebate is not disbursed until the system is constructed.

The assumed City share of rebate in this study, based on a storage capacity of 7,000 gallons and a total construction cost of $7,290 to $11,315 as calculated above, will be in the range of $3,452 to the maximum of $5,000.

**Water Treatment Plant 4 (WTP4) Background**

In the late 1970s and early '80s, Austin proposed WTP4 to address its growing water needs. Since the proposed location was in an environmentally sensitive area, the proposal suffered several setbacks. After a number of discussions and public meetings, the city recently started construction of a new water treatment facility. Located in northwest Austin, the facility will draw water from Lake Travis. Three major factors drove the city to build an additional WTP: 1) population growth, 2) system reliability, and 3) energy savings (AWU 2011).

The City of Austin Planning Department projects population growth of 500,000 people by the year 2040. Along with long-term demand projections, Austin will over time need to continually upgrade WTP 4 to meet projected demand growth. Austin currently has only two water treatment plants –Davis, built in 1954, and Ullrich, built in 1969. Both WTPs can produce 285 MGD and handle Austin's current water demand by drawing water from Lake Austin. However, to ensure reliability for future demand, the city must look to another water supply (Lake Travis; Austin Water Utility 2011).

Lake Travis, at a higher elevation, will enable the utility to distribute the water using not electric pumps but gravity. This factor alone will save 20,000 megawatt hours annually, the electricity needed to power more than 2,000 homes for a year (Austin Water Utility 2011).

AWU projects that over the next 100 years it will need treatment capacity of approximately 600 to 800 MGD. Planning a 150 or 300 MGD facility on Lake Travis and the associated transmission systems provides Austin an expandable facility to meet customer demand for decades into the future. Shown below is a summary of all projected phases of WTP 4 to its maximum 300 MGD capacity:

Phase 1: 50 MGD

Phase 2: 25 MGD

Phase 3: 75 MGD

Phase 4: 150 MGD (this last phase is only potential)

Build-out Total: 300 MGD

Figure 7 displays the milestones of Austin water treatment plants. Since Austin's population is expected to exceed a million people by2018, WTP4 is necessary to accommodate the future demand.

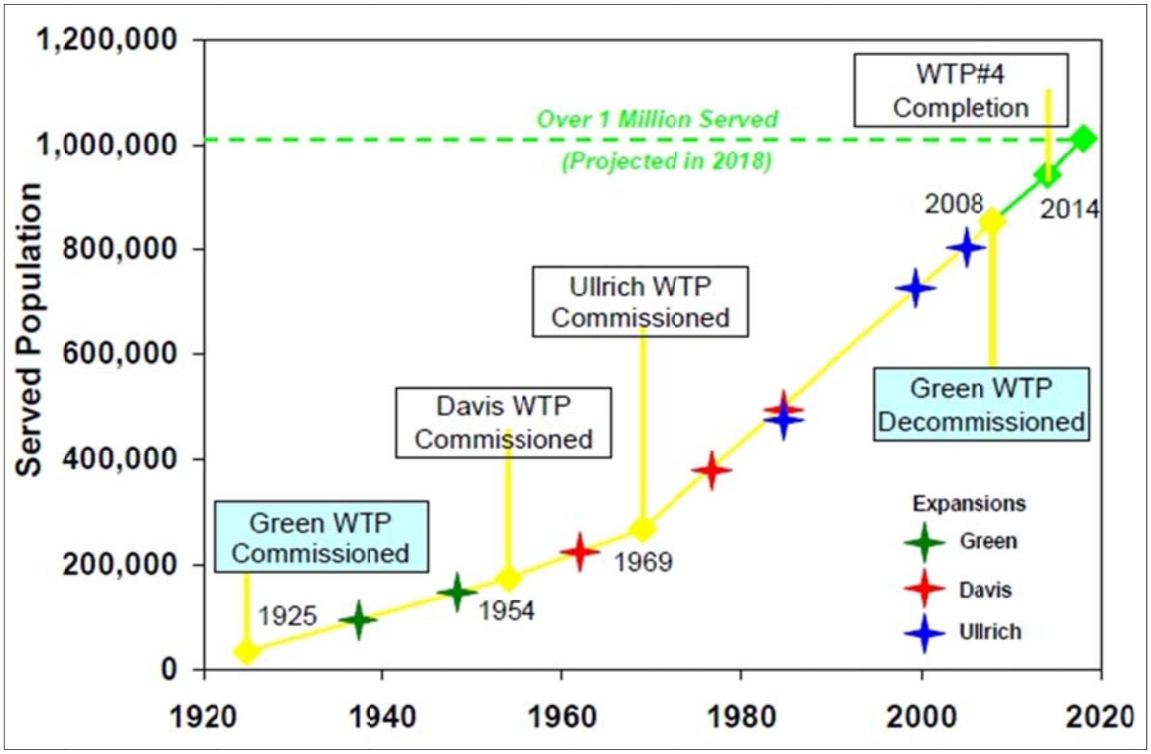


Figure 7: Austin Water Treatment Plant Milestones, Austin Water Utility

When planning for future plant expansions, it is important to recognize that the exponential regression approach results in a long-term peak day demand projection. In any given year, the city must be prepared to accommodate the demands generated by unusually hot and dry conditions, which will require higher demand than usual (Austin Water Utility 2006).

WTP 4 Phase I is currently scheduled to be completed in 2014 or 2015, thus providing an additional 50 MGD will be covered by the city. However, according to the current trend of water demand and population growth of Austin, the city should not need to construct phase II until 2019 or even later, which will expand the capacity by an additional 25 MGD, in order to accommodate future growth in demand. If RWHS can be installed to a number of single-family residential units, however, a significant amount of water demand may be reduced. Therefore, the city could delay the construction of phase II, and provide subsidy for RWHS from the saved costs, such as construction, maintenance, and operation costs.

By projecting future peak-day demand using historical data, the potential year for expanding phase II can be determined. Next, the storage capacity of 7,000 units' RWHS in July, which is a typical month that the peak-day demand had been historically occur most frequently, will be analyzed in order to find out how many years can phase II construction be delayed by installing the RWHS. Then the costs of municipal bonds, operation, and maintenance for the expansion will be estimated based on the Ullrich WTP expansion as an example, which was recently expanded (2006). Finally, we will estimate the savings that could be earned when constructing 7,000 units with rainwater harvesting systems; thus, the subsidy that the city could offer to each home-owner will be estimated. The rationale for the City supporting 7,000 RWHS in lieu of the phase II expansion of WTP 4 will be explained later in this report.

**Projecting Specific Year for Phase II**

For water systems, peak-day criteria consist of the highest single-day demand placed on a water-treatment plant in a calendar year. This demand can be 150 to 200 percent greater than the average-day demand. Therefore, a reduction in the peak day demand can affect the sizing and timing of a water treatment plant expansion. Water treatment plants are mainly constructed based on the peak-day demand of the utility (watercrunch.com 2007).

In the water utility industry, historical data is frequently used to extrapolate future projections. When extrapolating data, the more data available, typically the better the extrapolation. As Austin's water demand characteristics have changed dramatically over time, however, very old data could skew future projections. Furthermore, the City's newly adopted conservation plans are expected to cause an additional trimming of per-capita water demand. To reflect the latest trends in water demand characteristics, Austin Water Utility used the last 20 years of data to develop a relationship between population and demand (AWU 2006). Specifically, 20 years of data from 1990 to 2009 was used in their analysis.

Figure 8 shows the historical peak-day demand from 1984 to 2009. As the water service area and population increased, Austin's peak-day demand grew from 154 MGD (millions of gallons per day) to 244 MGD. In 2004 and 2007, the city imposed a strict conservation program because of serious droughts in those years. Thus, for those years peak-day demand was significantly lower than in other years.

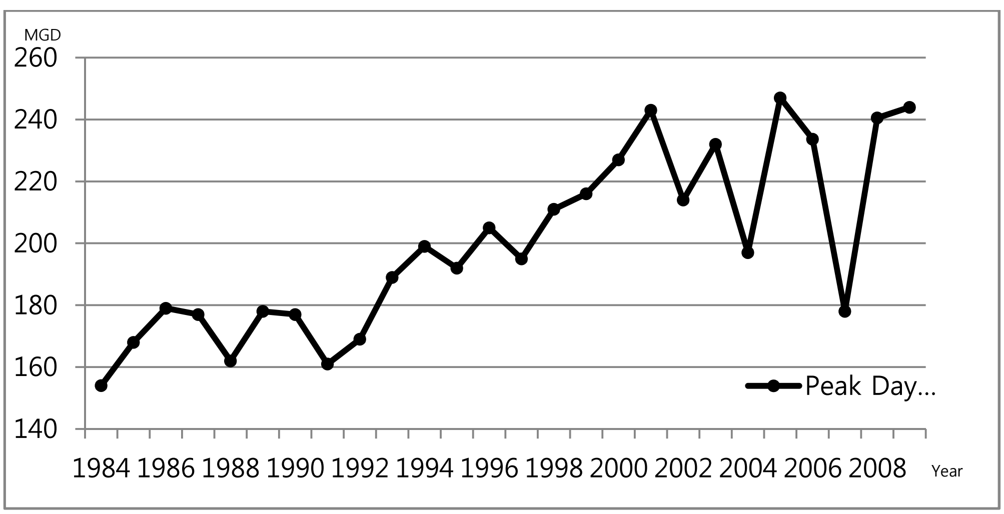


Figure 8: Historical Peak-Day Demand in Austin, Austin Water Utility

A scenario was developed in projecting the future peak-day demand. The peak-day demand for 2004 and 2007 were relatively lower than other years because of the conservation program in those years. For this reason, it may seem that exempting these two years is appropriate to estimate future demand. However, since the restrictions on outdoor water use are now the law in Austin, as well as 140 GPCD Conservation Plan is continuously applying from the Austin Water Utility, this study did not exclude the data for 2004 and 2007. Thus, this scenario assumed that there will be additional conservation policies that would reduce the peak-day demand and it was projected using all the historical data. Exponential regression approach was used in this scenario to estimate the trend line. In order to prepare for unexpected hot or dry weather and to provide stabilized water supply, the capacity of a water treatment plant should not be less than 110 percent of the peak-day demand. Thus, the demand projection with a 10% variation factor is shown in the graph to estimate the needed year for the phase II to be operational.

As described in Figure 9, phase I of the WTP 4 will be completed in 2014 and an additional 50 MGD will be available as a new supply. However, the future trend line of the scenario shows that growth in the demand will cause 335 MGD to be exceeded between 2018 and 2019. Thus, Phase II, which will provide 25 MGD, may need to be constructed until 2019.

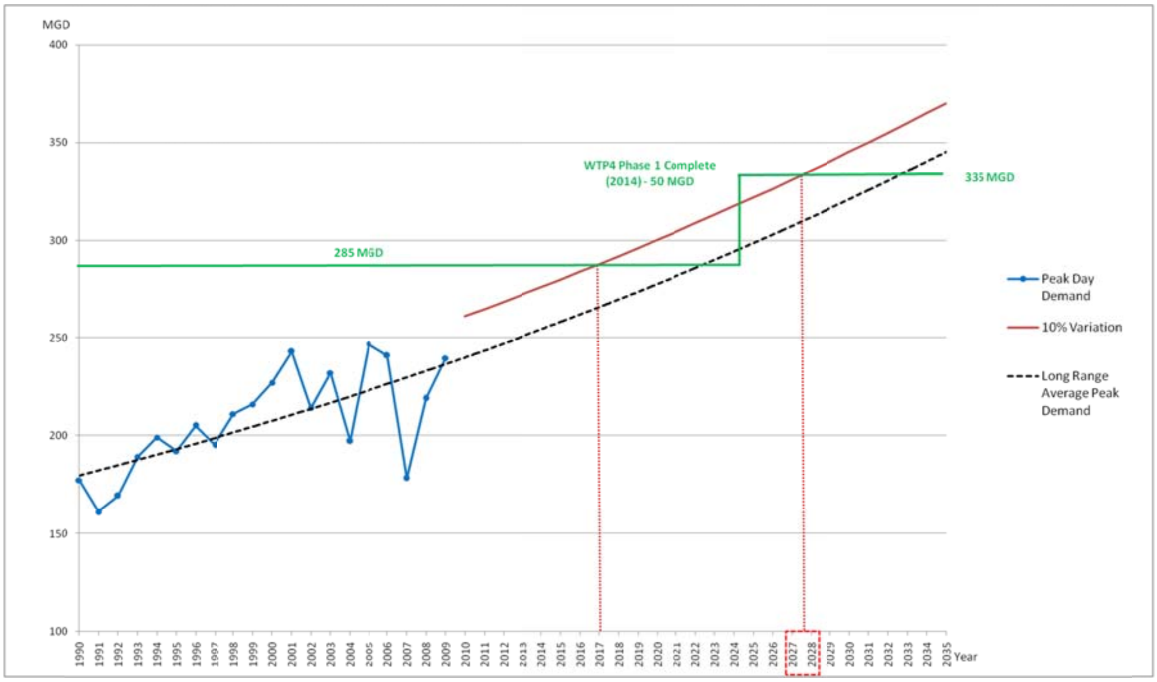


Figure 9: Projection of Future Peak-day Demand

**Storage Capacity of RWHS**

Peak-day demand mostly occurs in the summer, especially in July and August, when water consumption is highest due to the hot weather. Thus, the storage capacity of RWHS in July and August is required in order to find out the percentage of water demand that can be reduced over the entire water demand.

Using the Rainwater Harvesting System Sizing Calculator provided by the Texas Water Development Board, the capacity of monthly storage for a 7,000 gallons tank with a 2,400sq.ft catchment area (roof) can be obtained. A total of 46,497 gallons of rainfall can be captured annually; and 2,719 and 3,361 gallons can be collected in July and August, respectively, or approximately 3,040 per month in this summer period (Table 15).

| Month | Estimated Monthly Supply to Collection Tank (gal.) |
|---|---|
| January | 2,960 |
| February | 2,705 |
| March | 3,161 |
| April | 3,522 |
| May | 6,857 |
| June | 4,580 |
| July | 2,719 |
| August | 3,361 |
| September | 3,857 |
| October | 5,343 |
| November | 4,044 |
| December | 3,388 |
| Total | 46,497 |

Table 15: Estimated Monthly Storage of RWHS

Assuming 7,000 new single-family units in Austin install RWHS, a monthly average of 21,280,000 gallons (3,040 gallons × 7,000 units) of rainwater can be saved in July. Since the peak-day demand in July and August was 239.7 MGD (in July of 2009), 8.88% (21,280,000 gallons / 239,700,000 gallons × 100) of peak-day demand can be reduced by installing these 7,000 RWHS units. Therefore, as displayed in figure 10, when RWHS installed, phase II expansion phase II expansion may be delayed by approximately 7.5 years.

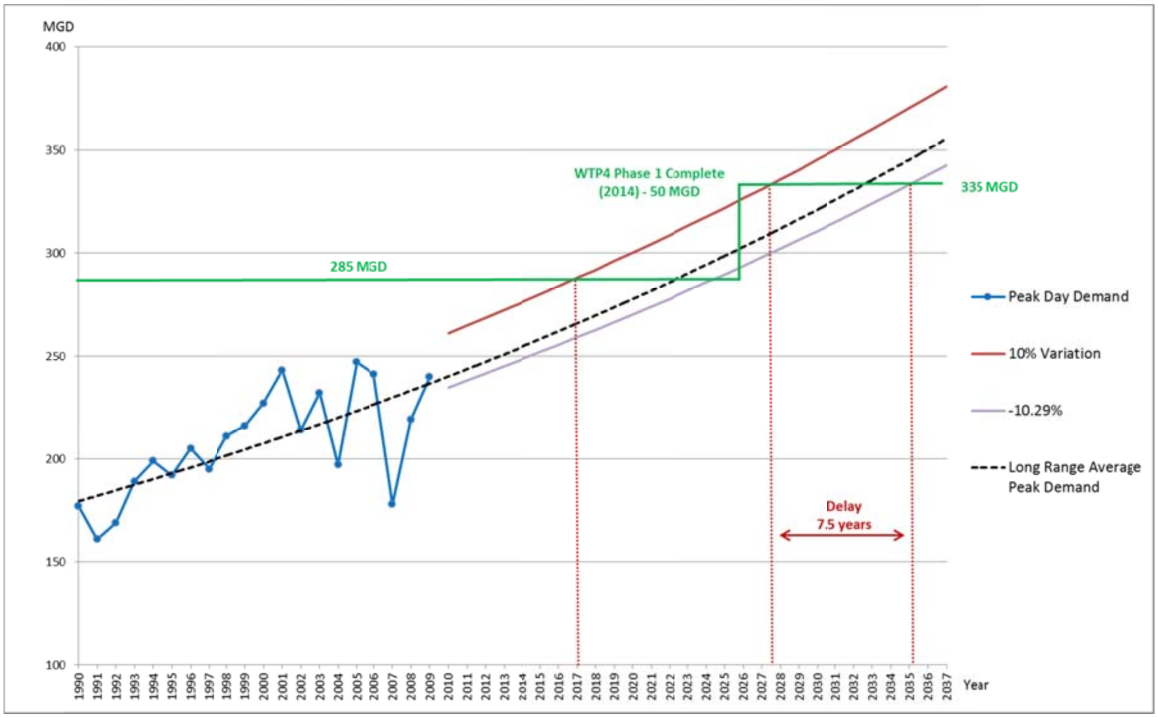


Figure 10: Delayed Periods for Phase II

**Phase II Expansion Cost Estimation**

The City of Austin could save a significant amount of money by delaying the Phase II expansion. The savings would be seen in terms of principal and interest and other charges on municipal bonds, operating costs, and maintenance costs. Phase I WTP4 (50 MGD) and transmission mains have cost the city of Austin $508 million. This includes 80% of bond-funded construction and 20% of cash-funded construction (AWU 2009). Austin Water Utility has not yet estimated Phase II costs – its construction, operating, and maintenance costs. Thus, in order to estimate the expansion costs, the costs for Ullrich water treatment plant, which recently expanded 100 MGD to 160 MGD capacity, are used, as it appears to be representative of the marginal cost of expansion of an existing plant. In addition, the municipal bond, operation and maintenance fee for the construction is projected based on the phase I WTP4 plan.

Taking two years to complete (2004 – 2006), the Ullrich WTP cost $61 million. In increasing its capacity by 60 MGD, the City of Austin included various improvements, including the construction of two new up-flow clarifiers, new roadways, new process piping, new pumping facilities, substantial electrical upgrades, and associated improvements (axiomtexas.com 2004). $61 million was spent for a 60 MGD expansion, which translates into $1.017 million for 1 MGD. Since Phase II WTP4 will expand the capacity by another 25 MGD, the total cost ought to be, in 2004 dollars, around $25.42 million ($1.017 × 25 MGD).

Table 16 displays monthly and annual rates of historical inflation rates from 2001 to 2011. Rates of inflation are calculated using the Current Consumer Price Index published monthly by the Bureau of Labor Statistics (usinflationcalculator.com 2011). From 2004 to 2011, the cumulative inflation rose 18.3%, making $25.42 million in 2004 and $30.07 million in 2011.

Table 16: U.S. Inflation Rate, usinflationcalculator.com

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **January** | | 1.1 | 2.6 | 1.9 | 3 | 4 | 2.1 | 4.3 | 0 | 2.6 | 1.6 |
| **February** | | 1.1 | 3 | 1.7 | 3 | 3.6 | 2.4 | 4 | 0.2 | 2.1 | 2.1 |
| **March** | 2.9 | 1.5 | 3 | 1.7 | 3.1 | 3.4 | 2.8 | 4 | -0.4 | 2.3 | 2.7 |
| **April** | 3.3 | 1.6 | 2.2 | 2.3 | 3.5 | 3.5 | 2.6 | 3.9 | -0.7 | 2.2 | |
| **May** | 3.6 | 1.2 | 2.1 | 3.1 | 2.8 | 4.2 | 2.7 | 4.2 | -1.3 | 2 | |
| **June** | 3.2 | 1.1 | 2.1 | 3.3 | 2.5 | 4.3 | 2.7 | 5 | -1.4 | 1.1 | |
| **July** | 2.7 | 1.5 | 2.1 | 3 | 3.2 | 4.1 | 2.4 | 5.6 | -2.1 | 1.2 | |
| **August** | 2.7 | 1.8 | 2.2 | 2.7 | 3.6 | 3.8 | 2 | 5.4 | -1.5 | 1.1 | |
| **September** | 2.6 | 1.5 | 2.3 | 2.5 | 4.7 | 2.1 | 2.8 | 4.9 | -1.3 | 1.1 | |

Table 16 continues

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **October** | 2.1 | 2 | 2 | 3.2 | 4.3 | 1.3 | 3.5 | 3.7 | -0.2 | 1.2 | |
| **November** | 1.9 | 2.2 | 1.8 | 3.5 | 3.5 | 2 | 4.3 | 1.1 | 1.8 | 1.1 | |
| **December** | 1.6 | 2.4 | 1.9 | 3.3 | 3.4 | 2.5 | 4.1 | 0.1 | 2.7 | 1.5 | |
| **Average** | **2.8** | **1.6** | **2.3** | **2.7** | **3.4** | **3.2** | **2.8** | **3.8** | **-0.4** | **1.6** | **2.1** |

While $30.07 million indicates the total costs for Phase II construction, the city could, by delaying the expansion, save municipal bonds. In Phase I, long term revenue bonds assumed for a 30-year term at a 5.0% interest rate with levelized debt service. Austin Water Utility has historically obtained superior bond ratings (Table 17) and Standard & Poor's recently gave them a AA bond rating (AWU 2010). Thus, we can assume a 5.0% municipal bond rate for the construction, coming to $1,503,582 per year.

| AWU Separate Lien Bond Ratings | Standard & Poor's Rating |
|---|---|
| **Refunding Bonds, Series 2009** | AA |
| **Variable Rate Bonds, Series 2008** | A+ |
| **Refunding Bonds, Series 2007** | A+ |
| **Refunding Bonds, Series 2006A** | A+ |
| **Refunding Bonds, Series 2006** | A |
| **Refunding Bonds, Series 2005A** | A |
| **Refunding Bonds, Series 2005** | A |
| **Refunding Bonds, Series 2004A** | A |
| **Refunding Bonds, Series 2004** | A |

Table 17: History of Bond Ratings, Austin Water Utility

Additional costs, such as electrical and chemical costs forWTP4 are assumed to be $0.245 per 1,000 gallons pumped based on an average of costs associated with Ullrich WTP and Davis WTP (AWU 2010). Since 25 MGD will be provided from phase II, it will save $6,125 ($0.245/1,000 gallons × 25,000,000) per year as a result of delaying the expansion. WTP4 other operations and maintenance costs including staffing, plant building electrical, and other operating costs assumed at $2.5 million per year (AWU 2010). Since the objective of phase II is expanding the MGD after the construction of phase I, there will be a small number of buildings constructed. Thus, this study assumes that the operation and maintenance costs will take only 20 percent of phase I, which will be 500,000.

In sum, total savings from delaying phase II expansion will be $2,009,707 per a year. Since this scenario delays 7.5 years, savings will be approximately $15,073,000 ($2,009,707 × 7.5 years).

**Assumed Rebate Support of AWU for New RWHS**

As a demonstration of the ability to invest in RWHS instead of making the phase 2 expansion of WTP4 in the next 10 more years, we made the assumption that 7,000 new housing units would install RWHS using City of Austin rebates. As was discussed earlier, the assumed rebate given by AWU under the scenario is between $3,452 and $5,000 per RWHS, or an average of $4,226 per unit. The construction cost of 7,000 RWHS units, using an average rebate by AWU of $4,226, is $29.58 million, which is slightly less than but comparable.

**Subsidy**

In conclusion, if 7,000 new single-family homes install a RWHS in their backyards in 2011, Austin could, depending on the scenario, gain $15,072,799. According to the scenario, approximately $2,153 ($15,072,799 / 7,000 units) can be provided as a subsidy. Thus, it is feasible and beneficial for the city to provide an additional subsidy to homeowners based on the benefits that the city obtains from installed RWHS.

All in all, the city can feasibly share in the installation cost of $2,153 per RWHS unit, based on the savings achieved by delaying construction of phase II WTP4. However, besides the treatment plant capacity costs, there are also other benefits that the City could obtain from installing RWHS, which could not be quantified, such as reducing overall future water demand.

| | **Scenario** | **Percentage** |
|---|---|---|
| Rainwater Harvesting Rebate Program | $4,226 | 100% |
| Subsidy from Delaying Phase II | $2,153 | 51% |

Table 18: Summary of Total

### 3.3 Developer Share

**Detention Pond**

One development cost that developers can get around is that which goes into constructing detention ponds. Detention ponds are open basins that provide live storage volume to enable the reduction of storm water runoff flow rates and allow a return to pre-developed flow durations discharged from a developed project site. Detention ponds are commonly used for flow control in locations where space is available for above ground facility but where infiltration of runoff is infeasible (Washington State Department of Transportation 2008).

In developing a subdivision in Austin, the developer detention ponds are required to be built to manage post-development stormwater runoff. The typical size of a detention pond for a 300-home subdivision, based on recent data from developers/homebuilders, is 186,000sq.ft. The construction cost of such a basin is approximately $170,000 (without landscaping) in Austin (Steve Plevak KB Homes). Pitt reported that construction costs for an initial wet detention pond are roughly estimated to be about $40,000 per acre of pond surface, excluding land costs, which is very comparable to the numbers used in this study (Pitt 2004).

By installing RWHS in each newly built single-family home in a subdivision, the amount of stormwater generated will be reduced, assuming that the continuous use of the RWHS will result in considerable capacity to receive and hold some, but not all, of the storm runoff. Such reductions in turn reduce the size of a detention pond, and thus the costs of overall construction. These savings can go toward a subsidy for RWHS. Assuming a development for a suburban single-family subdivision, this study will find out how much the installation of a RWHS can reduce stormwater detention and quality costs. Once this reduction is determined, the study will suggest an amount that developers can pass through to homeowners as a result of avoiding these costs.

The study defines a developer as a company, such as KB Homes, that performs both land development and home construction. Since land developers benefit from a reduction of detention ponds and home builders are the professionals who install the RWHS, the developer’s role in this analysis is to make adjustments, both for the size and expense of the detention and water quality ponds and the costs of constructing the RWHS. Implicit in this assumption is the notion that the RWHS will be essentially paid for by the homeowner; and any share of the cost borne by the developer will ultimately be factored in the purchase price of the house.

**Water Quantity (floods)**

Based on Austin zoning districts, the minimum lot size for a single-family residence (SF-3) is 5,750 square feet. We can assume that four (4) units could be built per one acre, measured in terms of gross residential density. One inch of rainfall on one acre will amount to 27,154 gallons (325,851/12). As such, each house should be accountable for approximately 5,431 gallons. Then, we can determine the amount of rain that could be captured by a RWHS on each house that receives 1 inch of rain. The calculation formula for rainwater catchment is:

*Square feet of catchment area × 0.9 ×0.625 = gallons of water captured*

Assuming the roof catchment area is 2,400sq.ft. (the average size of single family homes in Austin), using a roof material loss coefficient of 0.9 and an area catchment coefficient of 0.625 (one inch of rainfall equals 0.625 gal./sq.ft. of roof area), we can determine the amount of rainfall captured by a tank.

In our scenario, we would use 2,400 × 0.9 × 0.625 = 1,350 gallons per inch of rainfall. This results in approximately a 25% reduction in stormwater detention costs.

In addition, the cost of the land must be purchased for the pond. According to the representatives of KB Homes, the typical suburban residential density is four lots per acre, that is, a 75 acre subdivision would yield 300 housing units. Also, KB Homes mentioned that the value of a lot in a suburban area in a well planned subdivision is the range of

$12,000 to $15,000. In this study, the total area committed to water quantity and runoff volume control is assumed as 186,000 sq.ft., which is approximately 4.27 acres. Since 4 units are in one acre, the amount of land reserved for the detention pond is approximately equivalent to 16.8 lots. By multiplying the average lot cost and the total land area, we can determine the land costs for a detention pond, which is $226,800. In sum, the entire cost for a detention pond is assumed to be about $400,000 ($170,000 + $226,800). Developers, therefore, could save $100,000 ($400,000 * 0.25).

**Water Quality**

For water quality, a detention pond must capture and filter the first 1/2 inch of runoff from all impervious surfaces. The typical suburban subdivision has 40% impervious cover, or 17,424 square feet/acre. 1/2 inch of runoff over one acre of land (or17,424sq.ft. impervious cover) is 13,600 gallons. Then, each house should be accountable for 3,400 gallons (13,600 gallons / 4 units per acre) of water quality filtration volume. Since a RWHS on each house in a one inch rainfall event (assuming that this yields 1/2 inch of runoff) could capture 1,350 gallons, yielding approximately a 40% (1,350 gallons / 3,400 gallons) reduction will be estimated from the stormwater quality costs.

The land cost for the water quality pond is assumed to be $54,000 per acre in order to be conservative, for a one-acre pond serving 300 housing units. In addition, the construction cost of a water quality pond will vary from 50,000 to 150,000 (Butler 2011). Assuming $100,000 to be the construction costs, the general costs for the entire water quality pond is estimated to be $150,000. After all, a developer could approximately save 40 percent of the entire cost, which is $60,000.

Overall, developers could, in theory, reduce 25% of stormwater detention and 40% of water quality filtration. Thus, the total savings for the detention and water quality ponds, for 300 housing units, would be approximately $160,000, or $533 per housing unit. Now, the RHWS cistern may already have a lot of stored water when a large storm occurs, and so will not necessarily be completely available for capturing a large storm. We might assume that one-half of the new storm volume can be captured and detained, yielding a benefit to the developer/builder of approximately $267.

Installing the rainwater harvesting systems up front during construction will save a significant amount of money over installing the system later and having to add the necessary infrastructure. Home builders can incorporate these costs into a mortgage where the resident can pay for it over the life of the home rather than in a lump sum, very cost prohibitive decision for homeowners.

# CHAPTER 4: RESULTS

## 4.1 PAY BACK PERIOD

All parties concerned –the city (utility), the land developers, the home builders, and the homeowners can benefit from installing rainwater harvesting systems. The benefits are potentially high and can be explained economically by converting them into current cash value.

If a high enough number of RWHS is installed, the peak demand for water treatment could be reduced so much that the city could justify the delay of Phase II of WTP4.It would reduce not only the overall water demand but also the peak-day demand. According to the analyzed scenario, Phase II can be delayed for 7.5 years and thus, gain $15,072,799 due to saving the municipal bond interest, operation cost, and maintenance cost of Phase II. This scenario assumes that RWHS will be installed on 7,000 units, and therefore a subsidy of $2,153 ($15,072,799 / 7,000 units) could be granted. On top of this, Austin Water Utility started a Rainwater Harvesting Rebate Program in July of 2010. AWU offers a rebate of $4,226. Since there are other benefits that the City could obtain from the RWHS, we assumed that the average rebate fee of $4,226 (average of $3,452 and $5,000) will be contributed by the City.

Since installing the RWHS reduces the size of detention ponds and water quality ponds, developers also benefit. A detention pond, which holds runoff and then releases it, is the most common stormwater management system (Environmental Research Group, University of New Hampshire 2008). RWHS capture a certain amount of rainwater and thereby diminishes the volume of stormwater runoff. This study found that if a developer installs RWHS in a 300-unit subdivision it will reduce stormwater detention by 25 percent of and water quality filtration by 40 percent. The study also found a developer could subsidize one household with $267.

Table 19 delineates the total subsidy that can be supported by the city and developer sector. Based on above calculation, total of $4,226 will be supported from the City and a developer.

| | | |
|---|---|---|
| **City Share** | Rainwater Harvesting Rebate Program | $4,226 |
| **Land Developer & Home Builder Share** | Subsidy from Reducing the Size of Detention Pond | $267 |
| **Total Subsidy** | | **$4,493** |

Table 19: Subsidy from the City and Developer

From the above results, we can now obtain the pay-back period of RWHS for the homeowner, after the reallocation. First, the cost of RWHS will be reduced because of the subsidies from the city and developer sector. Since the minimum cost of RWHS was only $7,290, the pay-back period under this assumed cost will be relatively shorter than the maximum cost ($11,315). From the above scenario, the homeowner share will be $2,797 ($7,290- $4,493).

The maximum cost of RWHS is $11,315. Thus, in this case, when a subsidy from the above scenario subtracted from the initial maximum cost of the RWHS, $6,822 will be the payment that homeowners should ultimately pay for it (homeowner share).

To find the final pay-back period, this study applies the benefits (savings in water bills from installing the RWHS) used in identifying the initial pay-back period. Figure 11 shows the final pay-back period for minimum and maximum scenario. The RWHS will be paid off under the minimum scenario by the time of 2022 and 2023; thus, the pay-back period is approximately 12 years. Under the maximum scenario, the RWHS will be paid off between 2032 and 2033, meaning that the pay-back period is about 22 years.

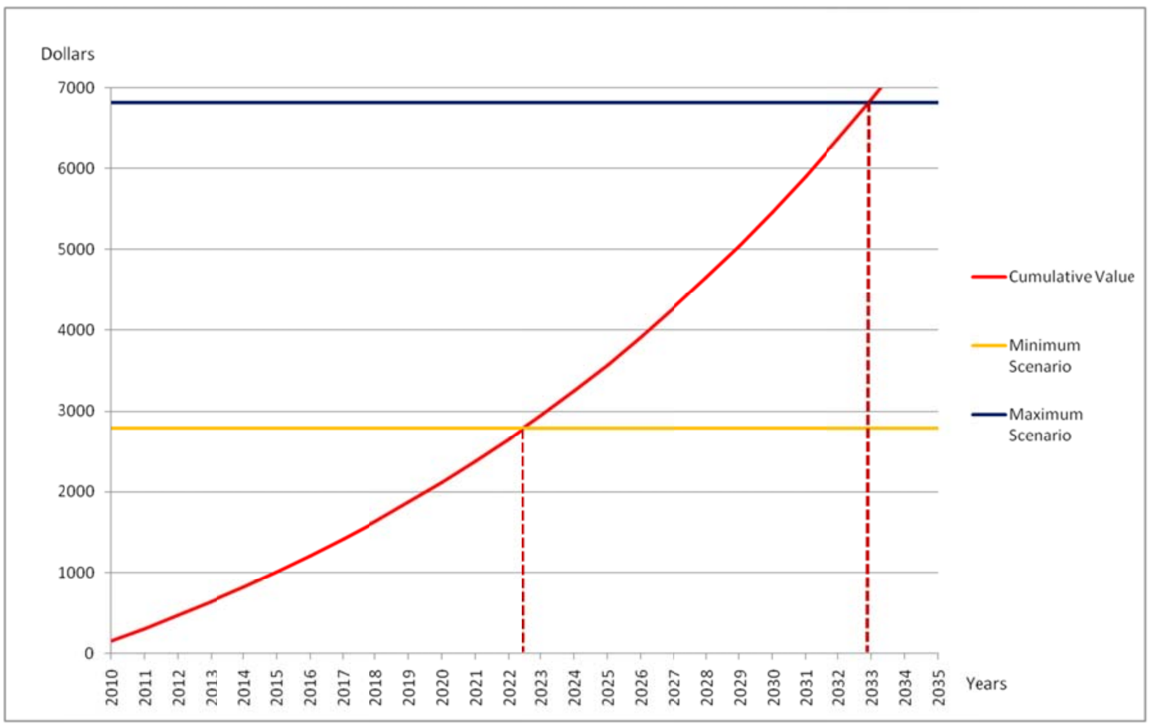


Figure 11: Pay-back Period of the RWHS after Reallocation

Finally, this study shows that the allotment of the City (utility) will be 72.41% in the minimum scenario and 44.19% in the maximum scenario. On the other hand, developer sector will only take 5.46% and 3.33% respectively, which are quite low. In the end, the homeowner will take a minimum of 22.71% to a maximum of 52.8% of the construction cost. This show that the installation of low price RWHS enables rational price for individuals with little or no pressure or financial burden in comparison to the benefits. However, it still will take significant time and expense to install a high cost RWHS.

| | ***Minimum Scenario*** | | ***Maximum Scenario*** | |
|---|---|---|---|---|
| | Share ($) | Share (%) | Share ($) | Share (%) |
| City | 4,226 | 57.97 | 4,226 | 37.35 |
| Developer | 267 | 3.66 | 267 | 2.36 |
| Homeowner | 2,797 | 38.37 | 6,822 | 60.29 |
| Total | 7290 | 100 | 11,315 | 100 |

Table 20: Price Allotment of Each Sector

### 4.2 ANNUAL SAVINGS AND COSTS TREND

The analysis presented above, referring to Pay Back Period and Benefit/Cost breakeven points, assumed that the initial construction cost for the RWHS will be paid in full in the beginning of the first year of operation. However, by using residential mortgage financing, the cost can be distributed, thereby relieving the burden of the high cost in the initial stage. In this way, the RWHS could be more easily installed without any financial burden. This study will show the annual savings and costs by introducing mortgage financing into the RWHS.

In order to find out the annual costs for a homeowner, we should first determine the share of the costs allocated to an individual. The results show that the minimum cost of the RWHS is $6,905 and the maximum cost of the RWHS is $11,315. In the minimum scenario, the City could support $4,226 and a developer could subsidize $267 and thus, a homeowner's share will be $2,797. On the other hand, a homeowner's share of the RHWS will be $6,822 for the maximum scenario.

Assuming the amortization period of the mortgage to be 30 years, the mortgage rate could be determined. Since the mortgage rate declined gradually during 2010 and fairly stabilized after 2010, this study will obtain the average mortgage rate based on the mortgage rate from March, 2010 to March, 2011, which is 4.83%. However, since interest rate is deductible as an expense against income on the federal income tax policy, we subtracted one percent; thus, the actual mortgage rate for this study was assumed to be 3.83%.

| **Month** | **30 years** |
|---|---|
| March, 2010 | 5.09 |
| April, 2010 | 5.12 |
| May, 2010 | 5.12 |
| June, 2010 | 5.00 |
| July, 2010 | 4.84 |
| August, 2010 | 4.70 |
| September, 2010 | 4.58 |
| October, 2010 | 4.46 |
| November, 2010 | 4.38 |
| December, 2010 | 4.61 |
| January, 2011 | 4.85 |
| February, 2011 | 4.97 |
| March, 2011 | 5.06 |
| **Average** | **4.83** |

Table 21: FHFA 30-Years Mortgage Rate (2010-2011), mortgagenewsdaily.com

Annual costs can be then obtained with the use of Microsoft Excel, using mortgage formula, '=pmt (interest rate, n years, present value)'. In the minimum scenario, individual homeowners only need to pay $158.43 in 2010 and require to pay $386.41 for the maximum scenario. In order to project the annual payment for the 30 years mortgage, inflation rate should be divided. Table below shows the cash flow of the 30 years mortgage payment in present value.

Table 22: Present Value of Mortgage Cost

| | **Minimum Scenario** | | **Maximum Scenario** | |
|---|---|---|---|---|
| | Mortgage Cost | Present Value | Mortgage Cost | Present Value |
| **2010** | $158.43 | $158.43 | $386.41 | $386.41 |
| **2011** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2012** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2013** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2014** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2015** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2016** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2017** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2018** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2019** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2020** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2021** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2022** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2023** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2024** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2025** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2026** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2027** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2028** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2029** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2030** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2031** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2032** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2033** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2034** | $158.43 | $154.78 | $386.41 | $377.50 |

Table 22 continues

| | | | | |
|---|---|---|---|---|
| **2035** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2036** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2037** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2038** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2039** | $158.43 | $154.78 | $386.41 | $377.50 |
| **2040** | $158.43 | $154.78 | $386.41 | $377.50 |

Annual Savings in here will use the future annual water bills that are projected in table 12, which are saved residential water bills from installing rainwater harvesting systems (45.59%). As described in the figure below, when a homeowner installs the minimum cost of RWHS ($7,290) using the mortgage instrument, annual benefits will be gained from three year later. However, if maximum cost of RWHS is installed, annual benefits will be occurred after 19 years, which is 2029.

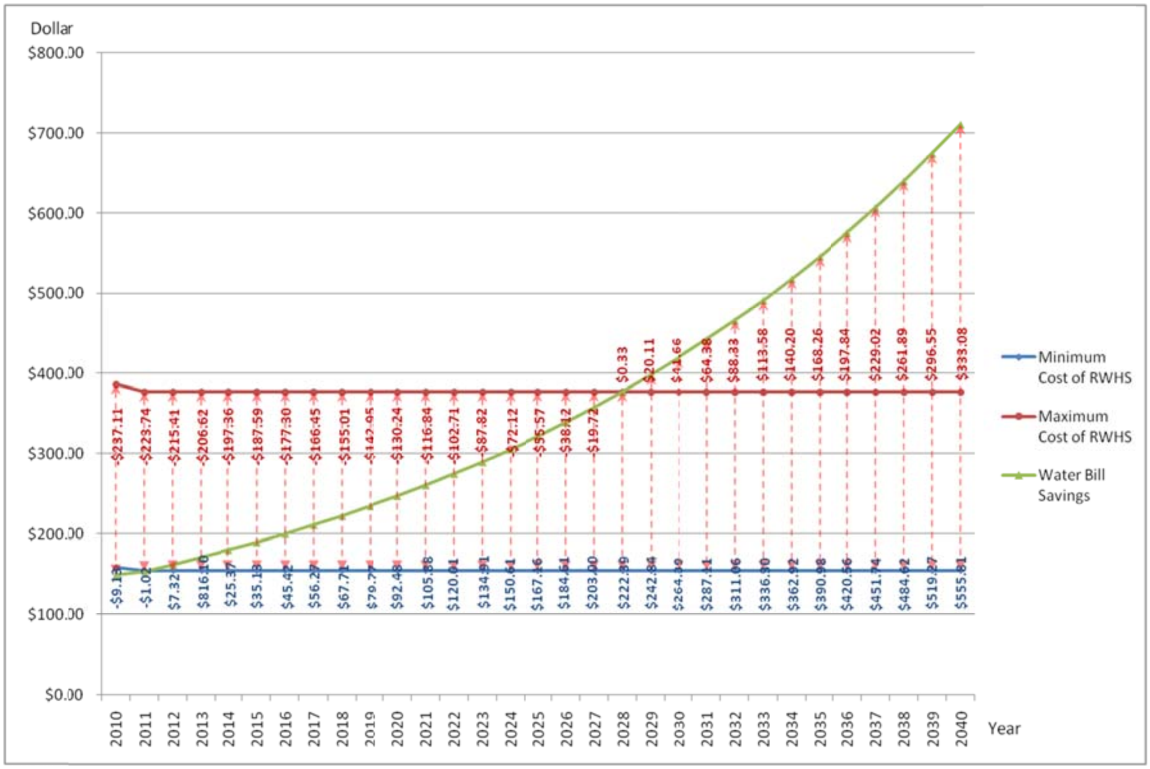


Figure 12: Annual Savings and Costs Trend

# CHAPTER 5: CONCLUSION

Rainwater Harvesting Systems can be used effectively in single-family households as a potential water source. This study used the Rainwater Harvesting Calculator model to calculate the volume of rainwater collected from a rooftop. It found that captured rainwater can cover approximately 46% of the entire average residential water usage.

In two scenarios, however, the pay-back period of the typical RWHS ranged from 22 years up to 30 years. Even though the RWHS is sustainable and profitable, its initial cost is prohibitive for ordinary single-family homeowners. The study equitably allocated the costs and benefits that each sector gains from the RWHS. Results showed that homeowners can lessen the financial burden by sharing it with the city (utility) and developers. With RWHS, the city could delay Phase II expansion of WTP4 as well as curb future water demand. Developers can save significant amounts of expenditures by reducing the size of detention pond. Ultimately, based on the assumptions and scenarios used in this report, homeowners need to spend approximately $2,797 or $6,822 for the RWHS depending on the costs of the RWHS materials. In addition, the pay-back period will be decreased to 12 years or 22 years depending on scenarios.

The results presented above provide insight into the broad applicability of RWHS in all residential areas in Austin, as well as in similarly situated small and medium-sized plants. However, the analysis in this study has a number of assumptions and limitations that need to be further examined and researched.

In deciding the costs of the RWHS, this study focused on six basic components described in the Texas Manual on Rainwater Harvesting. However, a number of components comprise the RWHS. For example, Hicks breaks down the components into seven categories in his report and the costs were twice as high as those cited in this study. Rain Harvesting Inc. in Australia divided the system components into 12 sections. Since this study focused on the Austin area, the analysis used appropriate components and costs. We recommend, however, that other regions or countries adjust for their own regions' conditions, such as land, material, and labor costs.

In calculating the costs and benefits of the RWHS, this report mostly used numbers common to most people, such as roof size, roof coefficient, amount of water consumption, rainfall, and etc. Although this kind of approach enables us to embrace average conditions, a number of exceptions do not correspond with this study. Thus, materials and costs can differ case by case. Furthermore, when calculating the pay-back period of both scenarios, this study assumed that the costs of RWHS would be paid in a lump sum. Therefore, maintenance and operation fees and interest charges for the RWHS are not included in this analysis.

Regarding the developer's share, this study primarily considered how developers could benefit by reducing the detention pond. The cost of a detention pond for a 300-unit subdivision was obtained from KB Homes. However, construction cost for a detention pond can differ according to location. Various factors, such as degree of slope, type of soil, land cover, and so forth enable either a relatively less expensive or a much more expensive construction than the typical development. In addition, the analysis would be more reliable if the cost data for a detention pond came from diverse sources rather than one. Since the exact cost data is not easily available to the public, more data should be gathered through individual interviews with various developers.

We assumed that the developer's benefit would be limited to a reduced cost of the detention pond and water quality pond. Indeed, by capturing significant amount of rainfall into the tank, the RWHS will diminish the flow of stormwater runoff. Further examination of the stormwater runoff record could provide the quantity of runoff per event. This information could help an analyst better judge the reasonableness of the assumption.

More detailed research can be conducted by using stormwater interfaces, such as RWHTools program (Jensen, 2010). RWHTools was coded in Java to calculate daily mass balance using historical precipitation and indoor, outdoor, and total water use data. Using this program, a researcher can analyze the output files, such as catchment runoff volumes, rainwater captured, and indoor, outdoor, and total water use volumes for each year of record. Likewise, the program is able to compute percentage capture of total site runoff and catchment runoff and percentage of indoor, outdoor, and total water supplied by rainwater (Jensen, 2010).Thus, further study could find and apply a more exact volume of stormwater runoff and, based on such data, enable one to more accurately calculate the costs and benefits.

Results of this analysis were calculated based on 7,000 single-family homes to be constructed in 2011. This data was expected from the Growth Watch data created by the Planning and Development Review Department of the City of Austin.

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# Vita

Hyun Woo Kim was born in Seoul, South Korea. After completing his work at Dan-kook High School in Seoul, he entered Yonsei University, South Korea. He received his bachelor's degree in Urban Planning and Engineering in 2009. Shortly thereafter, he worked at the Ministry of Land, Transportation, and Maritime Affairs in South Korea before entering the Graduate School at The University of Texas at Austin in August 2009. During his two years at the Community and Regional Planning Program, he was specifically interested in urban environmental and housing issues. He worked as a GIS intern at the Texas General Land Office for one year and completed internship at the Hanwha Engineering and Construction, Seoul, South Korea.

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