Rainwater Harvester Feasibility Study: Technical Manual

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INTRODUCTION

Central Texas' water resources are becoming increasingly vulnerable due to the region's population growth as well as the drought prone nature of Texas' climate. Because of this, the Regenerative Rainwater Harvesting Systems Green Fee project was developed to investigate the potential for new rainwater harvesters within The University of Texas at Austin campus. The implementation of additional regenerative rainwater harvesting systems could thus decrease the amount of water piped in from municipal sources by capturing rainwater to use for irrigation.

The following technical manual is a companion piece to the Regenerative Rainwater Harvesting Systems Green Fee report published by the Center of Sustainable Development at The University of Texas at Austin. It seeks to present, in detail, the methodology used to simulate the performance of rainwater harvesters, and how the simulator may be used to assess the feasibility of proposed rainwater harvesting systems. More information about the feasibility study's findings, as well as rainwater harvester precedents, aesthetic considerations, and community outreach can be found in the original full report (Rohrer & Warburton, 2016).

OVERVIEW OF RAINWATER HARVESTERS

While there are several different rainwater harvester configurations used throughout the world, many of them contain the same critical components. This section briefly describes a typical rainwater harvester and its components shown in **Figure 1**. More information on any of these components can be found in the Texas Water Development Board's Manual on Rainwater Harvesting (Texas Water Development Board, 2005).

The most recognizable collection area for a rainwater system is a building's pitched roof. Rainwater coming off buildings is relatively free of debris and is easily concentrated by a conveyance system. This large, mostly impermeable, area allows for considerable amounts of rainwater to be collected and used for irrigation.

After rainwater lands on the collection area, it is collected and transported via the conveyance system. This system, which consists of gutters and downspouts, accumulates the rainwater and carries it toward the cistern. Before reaching the cistern it is advisable to have the water pass through a leaf screen to filter out any large pieces of debris such as leaves and twigs within the water. If debris were to enter the cistern it could obstruct piping or damage the pump, either of which could reduce system efficiency or functionality. This screen must be manually cleaned or replaced on a regular basis in order to prevent the filter from clogging.

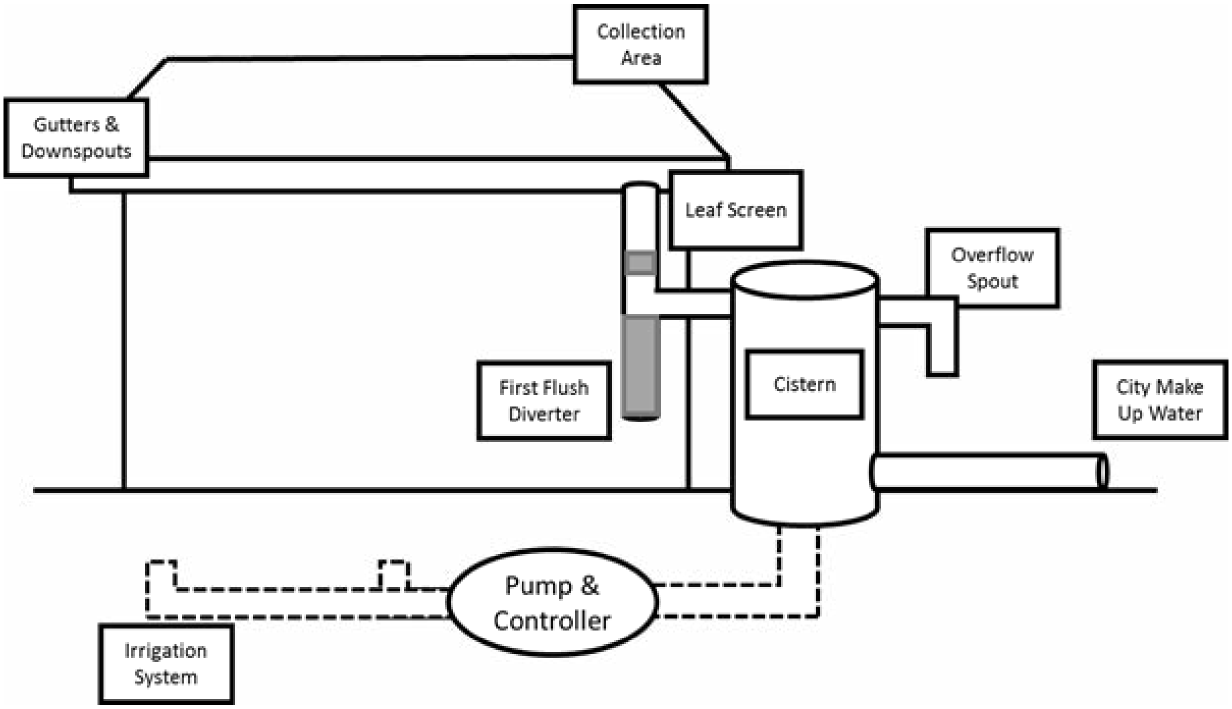

Figure 1: Typical rainwater harvester

Once the rainwater passes through the leaf screen, it enters the first flush diverter, shown in **Figure 2**. When a rain event begins, the initial water entering the downspout contains the majority of the debris that had accumulated on the collection surface. This device uses a stand pipe, with or without a ball valve, to discard the initial contaminated water while allowing all remaining water to pass into the cistern. The contaminated water is then slowly drained via a dripping hose bibb into a nearby bioswale or rain garden. Finally, the cleanout plug is regularly removed and the filter chamber cleaned of any debris buildup in order to maintain the filter's effectiveness.

After filtering, the debris-free water is transferred to the cistern. This storage tank holds the collected rainwater until it is needed for irrigation. The tank is typically opaque in order to reduce algal growth, and utilizes mosquito screens to prevent infestations. Well designed cisterns allow for easy accessibility for any maintenance or cleaning that may need to take place within the system's lifetime.

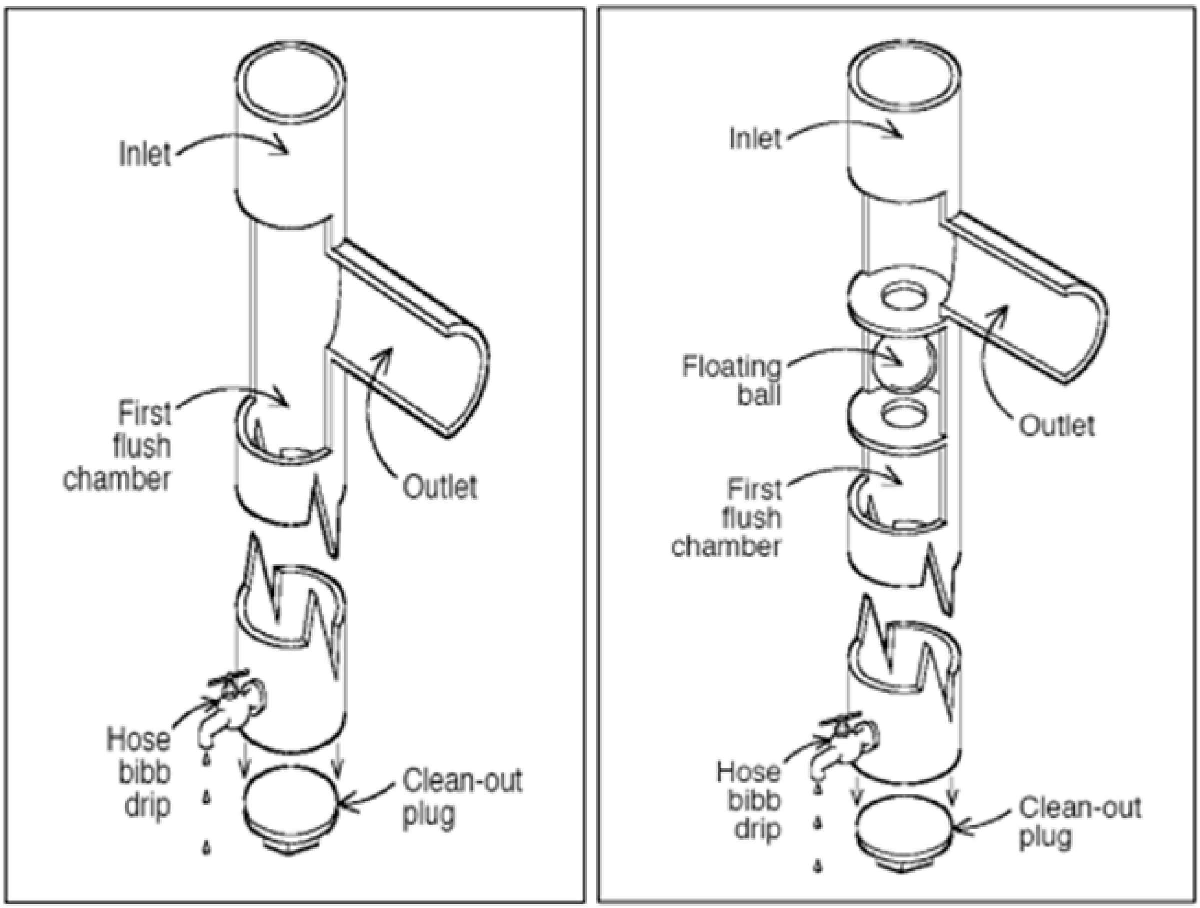

Figure 2: Typical first flush diverters (Texas Water Development Board, 2005).

When designing a rainwater harvester, there are several materials commonly used to fabricate cisterns. Fiberglass, polypropylene, galvanized steel, and even concrete are all viable options and are readily available from several suppliers. Because the cistern is the most expensive component of the system, the water savings potential and return on investment is heavily influenced by the cistern size and therefore must be optimized for each system.

In addition to the rainwater supply inlet, there are additional pipelines connected to the cistern. The tank may be connected to municipal water should the tank run dry and need to be refilled. The cistern must also include an overflow spout that allows excess rainwater to be properly disposed of once the cistern is full. Possible methods of responsible overflow management include bioswales and rain gardens. Finally, the tank is connected to the irrigation system via a pump and controller. The system pumps water on to the landscape reducing dependence on municipal water.

FEASIBILITY STUDY METHODOLOGY

In order to provide an initial site analysis of potential rainwater harvesters, a rudimentary cistern simulator was built using Microsoft Excel. Cell references cited in this manual correspond to the cells located within the Feasibility Simulator Excel document which can be found as an attachment to this report. This program has been vetted by members of the University's Landscape Services department and allows users to easily estimate a potential system's water savings and return on investment by simulating the University's current irrigation practices. The following section explains how the simulator works and how it can be used to determine the feasibility of a specific site. It should also be noted that this is a purely economic analysis and does not take the intrinsic value of resource conservation, SITES accreditation, or flood mitigation into account.

Central Texas Rainfall Distribution

To accurately simulate a rainwater harvester, the distribution of central Texas rainfall must first be defined. This was done by developing a web scraping script that gathered and organized 40 years of daily rainfall data from central Texas (The Weather Channel, 2015). A two term exponential regression was found to be an acceptable fit to describe the probability of a given daily rainfall amount (Hanson, 2008). The results of the analysis, **Figure 3**, show that the regression closely matches the historical rainfall frequency and can be used to accurately simulate central Texas weather. This rainfall data was then used to populate the simulated precipitation used throughout the feasibility simulator.

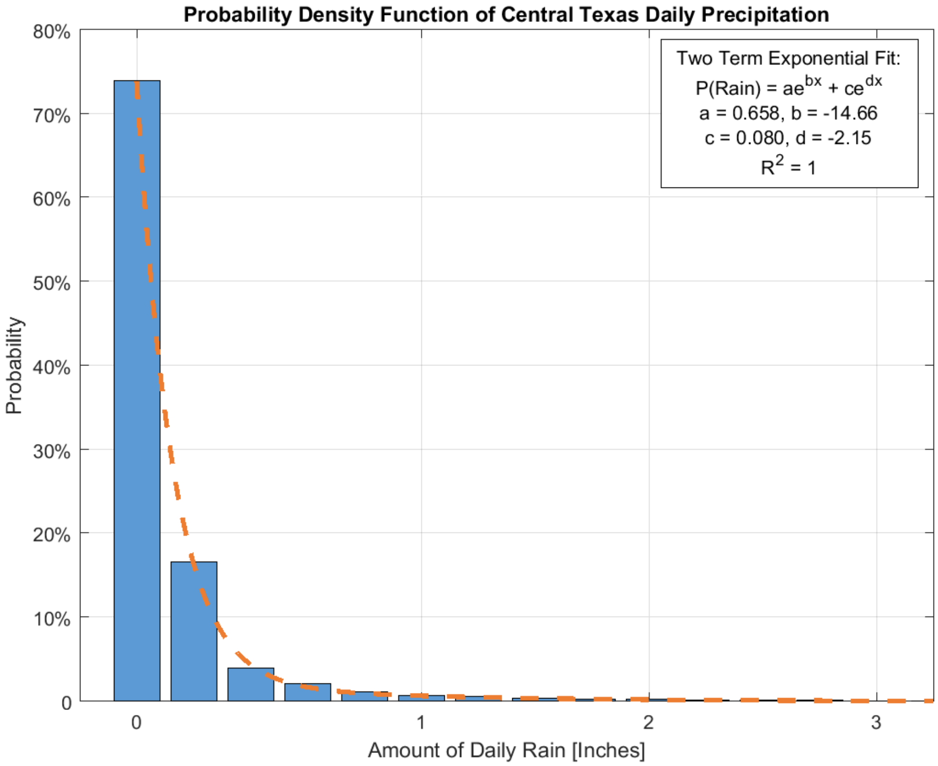

Figure 3: Two term exponential regression of daily central Texas rainfall.

Simulator Example

To demonstrate how the feasibility simulator can be used to check the practicality of a rainwater harvesting system on The University of Texas at Austin main campus, the Living Learning Center (LLC) complex is used as an example. Although the LLC is scheduled to be demolished in the future,it is shown here because it is a straightforward example of a typical feasibility analysis result due to its relatively small footprint, simple rainwater conveyance layout, and lack of a dedicated irrigation water meter (The University of Texas at Austin Campus Master Plan, 2012).

The first parameters that must be determined when planning for new rainwater harvesting system are the proposed collection and irrigation areas. This can be done several ways, one of them being Daft Logic's Area Calculator online tool (Daft Logic, 2016), which can easily evaluate user defined areas from satellite maps. Using this tool, it can be quickly determined that the LLC building has a foot print of approximately 4,400 square feet, as shown in **Figure 4.**

Figure 4: LLC collection area using Daft Logic Area Calculator (Daft Logic, 2016).

The following collection and irrigation areas found for the LLC complex, shown in **Figure 5**, were entered into the simulator worksheet (cells D2 and D5).

Next, the system's collection and irrigation efficiencies must be fixed (cells D3 and D6). The collection efficiency, which is nominally set to 90% for pitched roofed buildings, accounts for losses due to absorption and evaporation of rainwater on the collection surface as well as any water loss while being conveyed to the cistern (Texas Water Development Board, 2005).

Due to water losses from runoff, leaks, and evaporation, not all of the water used to irrigate reaches the turf. These losses are accounted for with an irrigation efficiency term which is a function of the equipment used to irrigate the landscape. The Department of Energy (DOE) estimates that well maintained sprinkler systems achieve an efficiency of 65%, while drip style system can deliver efficiencies up to 85% (US Department of Energy, 2010).

Figure 5: LLC collection and irrigation areas.

DOE estimates are also used to determine the water needs of specific landscapes. Their irrigation tables suggests that warm weather turf grass in central Texas needs approximately 10.82 gallons per square foot per year in addition what is normally provided from the region's rainfall (US Department of Energy, 2010). This value is stored in cell D4.

Once water needs have been determined, water savings can be calculated. **Table 1** describes the possible marginal costs that make up the City of Austin's water rates (Austin Water, 2016). If a particular fee is not applicable for the given landscape, it can be disregarded by setting the corresponding cell in column J to "False".

Off Peak Water Demand Supply (Nov.-Jun.)	$5.82
Peak Demand Water Supply (Jul.-Oct.)	$6.40
Water Disposal	$9.08
Water Stability Fund	$0.19

Table 1: University of Texas Water Rates per 1,000 gallons

Next, the user can select whether the cistern will be installed above or below ground in cell D10. This is used to create an initial estimation of the cost of the cistern and is solely a function of the size. Above ground corrugated steel cisterns are less expensive than underground fiberglass systems, as shown in **Figure 6**, (Rain Harvest Systems, 2016). Also, an additional 40% of the cistern cost is added to the total cost to provide an initial estimation of the cistern installation and other necessary items (Hicks, 2008).

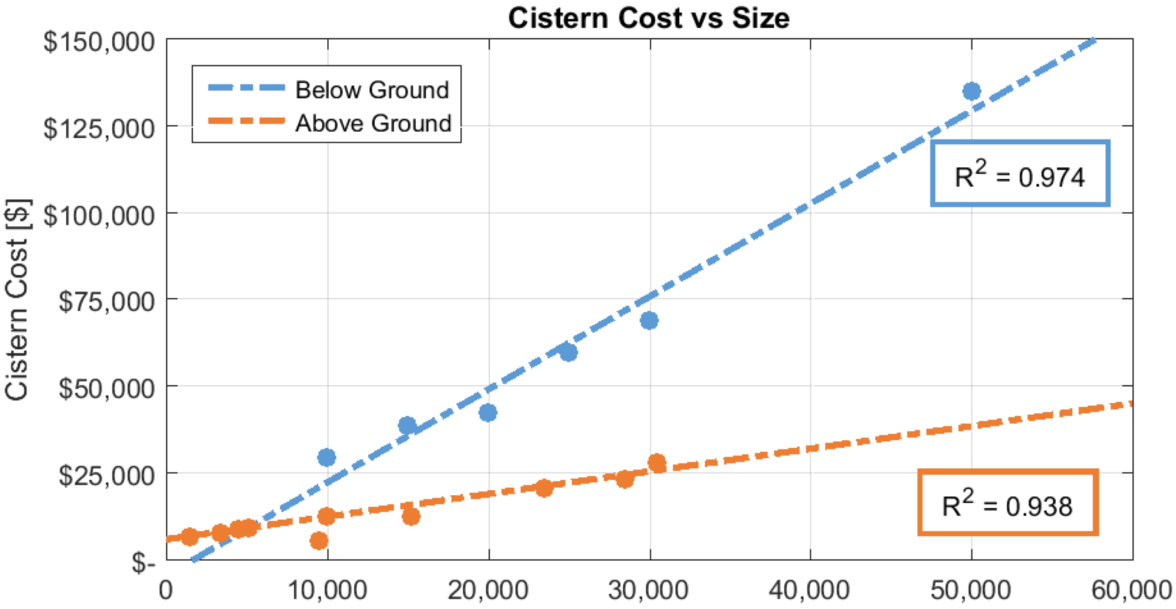

Figure 6: Installation cost for above and below ground cisterns as a function of size.

After the installation cost has been found, the user can input any expected project rebates in cell I13. Currently, the City of Austin offers a $5,000 rebate for large pressurized water harvesting systems (Austin Water, 2016).

Finally, the cistern size can be entered in cell D7. This value has a large impact on the effectiveness of the system. If the cistern size is too small, there will not be enough water savings to justify the cost of the cistern. Furthermore, if the cistern size is too big the installation cost will outweigh any potential water savings that can be achieved within the cistern lifetime. The potential LLC system's ROI is shown as a function of cistern size in **Figure 7**.

In order to assist in the cistern sizing procedure, a simple Virtual Basic for Applications sweep macro is included in the simulator. In this program, the values cells AB21 and AC21 designate the cell to be changed during each iteration of the simulation while cells AB22 and below contain the new value of the changing variable. When the ROI analysis program is executed, the cell designated in AB21 and AC21 is changed to the value in column AB and the system performance is recorded and plotted. This program allows the user to optimize the size of the water cistern and can be easily adjusted to see the effects of other variables.

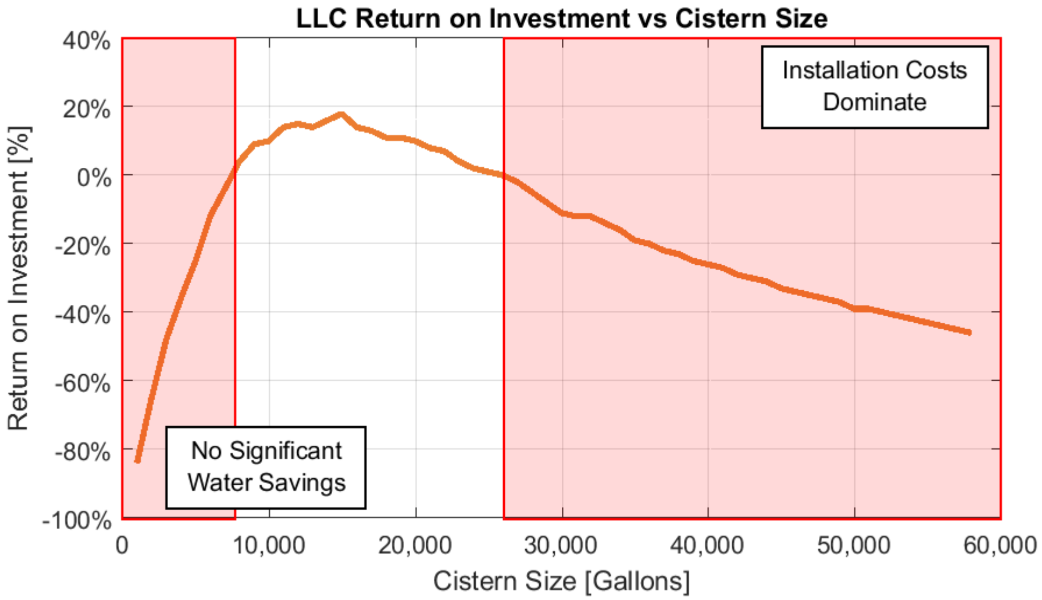

Figure 5: LLC collection and irrigation areas.

The results of the analysis suggest that an underground cistern in the LLC courtyard of 15,000 gallons would yield the maximum return on investment of 18%, and would reduce potable irrigation water by 60% along with over $92,000 in water savings over the estimated 20 year lifetime of the system. This is shown in **Figure 8**.

Finally, once the cistern parameters have been entered and the optimal cistern size has been found, the user can examine the performance of the cistern in detail in cells L2:N17. This table tells the designer important information such as the maximum and average overflow of the cistern, the expected number of refills per year, as well as the economic and water savings potential of the system. The user should ensure that these results are acceptable before moving to a more thorough site and cost analysis.

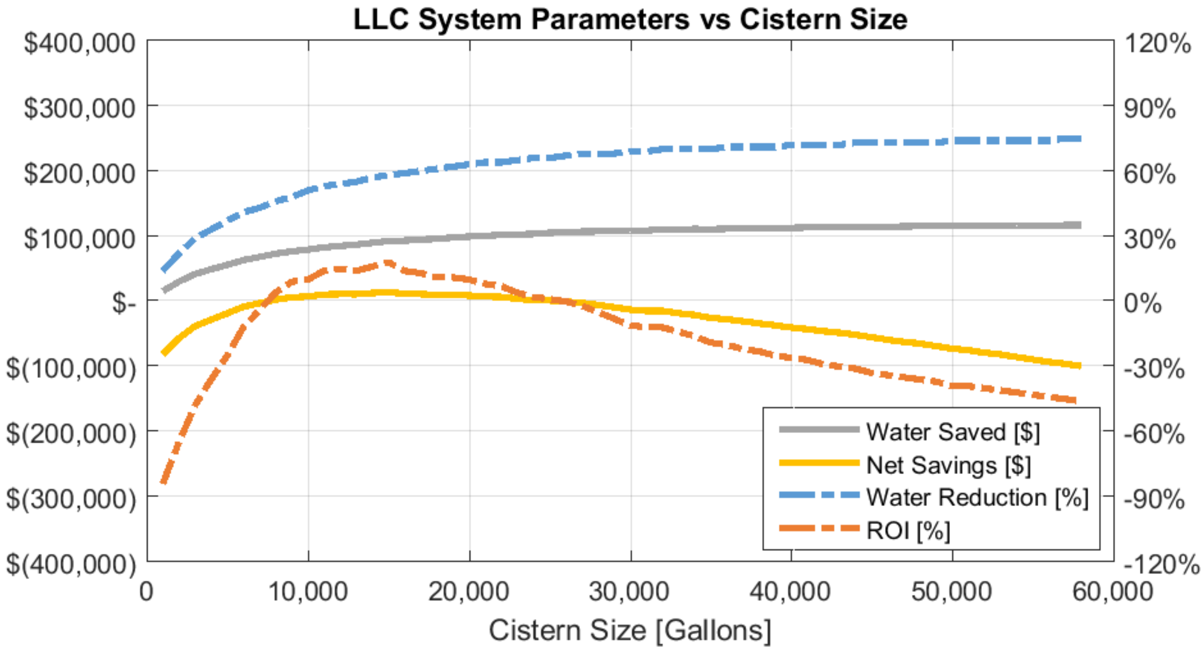

Figure 8: LLC Cistern Size Simulation Results.

SUMMARY

Using the methodology and simulator as described above, the user is able to quickly determine economic feasibility of any particular rainwater harvester system. The simulator is flexible enough to be adapted to model several changing circumstances such as changes in water rates, project rebates, and system efficiencies. It is also designed in an open manner such that it may be easily adjusted by the end user to model a rainwater harvester in any environment.

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