Augmenting Rainwater Harvesting to Offset Potable Water for Irrigation and Indoor Use within the Tampa Bay Region

A Best Management Practice

Tampa Bay Water

May 23, 2011

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Section 1: Executive Summary

Cost and reliability of supplying water for irrigation purposes from stored rainwater in the Tampa Bay Region for the single family residential sector was examined and analyzed. Research assessed sizing, reliability, cost, payback period and cost effectiveness of offsetting potable water demand from the **water utility** perspective. The utility perspective focused on reliability of approximately 100% potable offset based on whether the system offset the following type of irrigation: automatic, manual, evapotranspiration based, or other technologies. Each irrigation type resulted in varying water storage requirements which drove system storage size and cost.

System size and cost evaluations were based on 500 to 5000 ft² of catchment area at 500 ft² increments of increased storage requirement. Rainfall and reliability calculations were based on 50% average annual rainfall data for west-central Florida that occurs in the spring dry season from March through May (limiting). Water use requirements were based on 500 to 4000 ft² of irrigated turf grass in the spring dry season and were dependent upon the type of irrigation; automatic, manual, or evapotranspiration based. The cost of potable water was set at $6 per thousand gallons and cost effectiveness and paybacks were calculated against that number. To increase the feasibility of using rainwater as a reliable potable offset, air conditioning condensate was added to lessen storage requirements and increase the opportunity for offsetting consistent indoor water uses.

System cost is dependent on system size, which varies based on landscape demand and type of irrigation used (see irrigation assumptions on page 6). An automatic irrigation system irrigating 500 ft² of turf would use about 4700 gallons of water during the spring dry season. During the same period and area, a manual irrigation control system would use about 2800 gallons. While an irrigation control system, based on evapotranspiration rates, would use about 3050 gallons for the same period and square footage. The cost of each of these systems using 2000 ft² of catchment and polypropylene as the storage material would be about $3100 for 4700 gallon system, about $1500 for 2800 gallon system and about $1700 for 3050 gallon system. The simple payback period for each of these systems is 33 years for 4700 gallon system (automatic), 19 years for 2800 gallon system (manual) and 21 years for 3050 gallon system (ET).

Generally, the business sector desires payback periods to be less than 10 years and expectations by many residential water users are similar. When modifications have payback periods longer than 10 years, utilities could create incentives for the installation of these systems to lower the payback period. They could also increase the value of stored water through various techniques (i.e. reduced stormwater runoff and storage of reclaimed water on site).Utilities could also require the system to be sized appropriately for supply reliability purposes if incentives are provided. By providing an incentive, requiring a reliably sized system or increasing the value of the stored water the system cost would decrease and allow the payback periods to end users to become shorter.

Section 2: Introduction

The use of alternative sources of water has the ability to reduce or replace the use of potable water. These alternative water supplies can come from many different sources, including harvested and stored rainwater, augmented with air conditioning (AC) condensate. There are many advantages to using these alternative sources to potable water. Harvesting rainwater has the ability to reduce runoff and potential degradation of receiving water bodies. AC condensate is a free source that generally runs directly into the environment in the residential setting.

Harvesting rainwater is the process of collecting and storing rainwater during periods of precipitation. AC condensate is formed on the coils of air conditioner units as the water vapor from the air cools. Both of these alternative supplies directs and stores the harvested water in cisterns for later use as potable water offset. The water stored from the alternative sources can be used for both irrigation purposes and/or indoor uses.

The amount of rainwater that can be harvested depends on a few variables, such as the area of catchment (i.e. roof), the size of the storage container and the amount of rainfall. The amount of AC condensate that can be collected also depends on a few variables, such as humidity and indoor and outdoor temperatures. When a rainwater harvesting and/or AC condensate system is sized to reliably meet landscape needs, associated with some type of irrigation, or average indoor water use, the potential for up to 100% potable water offset may be achieved in urban areas.

Section 3: Reasoning

This rainwater harvesting and AC condensate Best Management Practice (BMP) includes calculations to determine landscape demand for various sized landscapes and available catchment volumes based on collection area. Calculations are also determined for volume of AC condensate collected for a given size unit. **It assesses the potential these alternative water sources have on reducing potable demand for a water supply utility**. A cost-effectiveness analysis is provided to compare rainwater harvesting and AC condensate system construction, operation and maintenance cost to potable water offset.

Section 4: Audience

Because rainwater harvesting and AC condensate collection is available to many properties in Florida, the potential benefit could be significant. Utilities can use this document as a resource for adding rainwater harvesting as an alternative to potable water use for irrigation purposes, indoor use, or storm water attenuation (although this document does not evaluate storm water impacts). The document can also be used as a guide for property owners to install and determine proper size and potential benefits from a rainwater or AC condensate harvesting system.

Section 5: Rainwater Harvesting Assumptions

To determine if rainwater harvesting systems are a reliable alternative water supply for irrigation, several assumptions were needed and developed, including: types of irrigation control systems, amount and volume of irrigation applications, rainfall data and the area of landscape and catchment to be assessed in calculations.

Rainfall data used in this document is for west-central Florida. Tampa International Airport was used and provides a conservative estimate based on low average annual rainfall compared to more inland sites. Sizing of a rainwater harvesting system for irrigation is dependent upon conditions when need is high and supply is limited. In west-central Florida, this occurs during the spring dry season of March – May. Therefore, historic rainfall during this period is used. To increase supply reliability, 50% of normal monthly rainfall for the spring dry season will be used (this was also assumed in research developed by University of South Florida on rainwater harvesting).

Two types of irrigation controls were evaluated to determine use: automatic and manual control. Automatic systems, for this document, are operated on a timer and may turn on before the landscape needs additional water. Manually controlled systems, as might be imagined, are turned on and off manually and are considered a more conservative user of water.

Turf grass and shrub landscape water use was evaluated for sizing purposes. Water use assumptions are linked between irrigation control type and landscape type(s). Specific irrigation assumptions used for rainwater harvesting storage sizing include:

- Automatic irrigation systems irrigate turf grass four times a month during March and eight times each month during both April and May. [1]
- Automatic irrigation systems irrigate shrubs four times each month during March, April and May. [1]
- Manually controlled irrigation systems irrigate turf grass and shrubs four times each month during March, April and May. [1]
- All irrigation applications, both automatic and manually controlled, were developed to apply ¾ inch of water to the landscape area per application.
- Landscape irrigated areas (square feet) are developed in 500 sq ft increments starting at 500 sq ft and going to 4000 sq ft (although this could be made larger).
- Catchment area (roof size) is in 500 square foot increments from 500 to 5000 sq ft.
- Assumptions are carried through all calculations.

There is also a need to compare the evapotranspiration (ET) rates of turf grass to the water use calculations. The use of ET rates allows for water use control technology to be incorporated into the calculations and is listed in Appendix A, Table 1 as an annual average. One common technology control device is a soil moisture sensor (SMS), which measures the moisture of the soil to determine if the area needs to be irrigated. The use of technology with automatic controllers is considered a more conservative user of water. The University of Florida evaluated the water use of varying irrigation technology controls and established some calculations similar to those presented in this document. Soil moisture sensors evaluated in the University of Florida document applied, on average, 0.34 inches of water per application. The ET rate calculations presented in this document account for 0.75 inches of water per application. The average water usage for the soil moisture sensor within the UF document is listed in Appendix A, Table 2. Soil

[1] Assumes no technology to control system based on rainfall or antecedent conditions. These assumptions provide a level of certainty for water supply utilities. Where once/week restrictions are enforced, assumptions can change.

Moisture Sensor compared to ET rate use less water per month (see Appendix A, Table 1). When soil moisture sensors are installed on a property, their results should end up being lower than the ET rate calculations, and will be evaluated further.

Section 6: Spring Demand Calculations

A series of calculations were developed to determine rainwater and AC condensate harvesting reliability. Landscape demand for each type of irrigation control and landscape type combination was determined based on assumptions provided. The equation used for landscape demand was;

$$\textbf{Landscape Demand of month X} = \textbf{area (sq ft)} \times \tfrac{3}{4}\ \textbf{in} \times \textbf{applications in month X} \times \textbf{0.623}$$

Landscape demand for turf grass using an automatic irrigation system output can be found in Appendix A, Table 3. Landscape demand of turf grass using manually controlled irrigation and shrub landscape demand using automatic or manually controlled irrigation results are found in Appendix A, Table 4.

To determine landscape demand using evapotranspiration rate this equation was used:

$$\textbf{ET Demand of month X} = (\textbf{area (sq ft)} \times \textbf{ET Rate} \times \textbf{0.623}) - \textbf{rainfall for month X}$$

Landscape demands using evapotranspiration rate are provided in Appendix A, Table 5. Technology controls, such as soil moisture sensors, will lower the landscape demand and are provided in Appendix A, Table 6.

Section 7: Catchment Volumes with Reliability Calculations

The total volume that can be harvested from a catchment area depends on rainfall and catchment area size. To increase supply reliability associated with rainfall variability, 50% average rainfall data for March-May is used for catchment volume calculations. The equation used to determine catchment volume was;

$$\textbf{Catchment Volume (gallons)} = \textbf{area (sq ft)} \times \textbf{50\% monthly rainfall (in)} \times \textbf{0.5}$$

Catchment volume, dependent on catchment area size, and based on 50% rainfall data for west-central Florida in the spring dry season results, are provided in Appendix A, Table 7.

Calculations are designed to create a cistern storage size effectively allowing for 100% offset of potable water supply, except in extreme events or changed operation.

The deficit between demand and catchment amount is calculated to determine which month, March, April or May, was the first to a have catchment size water deficit. The equation used to determine the proper cistern size was;

Cistern size = (catchment volume of month X – landscape demand of month X) + demand of earliest deficit month

Landscape demand and catchment area size determined optimal cistern size provided in Appendix A, Table 8 through 11. Specifically:

- Appendix A, Table 8 identifies cistern size for turf grass landscape using automatic irrigation control.
- Appendix A, Table 9 identifies cistern size for turf grass landscape using manual irrigation control and/or shrub landscape using automatic or manual irrigation control.
- Appendix A, Table 10 identifies cistern size for turf grass landscape based on ET rate.
- Appendix A, Table 11 identifies cistern size for turf grass landscape using SMS data collected from the University of Florida research.

Section 8: Cost of Rainwater Harvesting System

Rainwater harvesting system costs are based on multiple pieces of equipment integrated into an overall cost. The collection, storage, and distribution system consisting of a cistern, treatment materials and a pump are all necessary for a rainwater harvesting system. Many factors must be considered when establishing the potential cost of a system, with the largest being cistern size and material type. (Material type affects cost directly).

Five cistern materials; polypropylene, concrete, metal, polyethylene and fiberglass were used for cost comparisons in this document. Minimum, maximum and average cost of the varying cistern materials are provided in Appendix B, Table 1. Another storage option, a rainwater pillow (a flexible storage unit that can be stored underneath a deck or crawlspace of a property) was evaluated. The cost per gallon of this type of system is included in Appendix B, Table 1.

However, the rainwater pillow is significantly more expensive per gallon than other materials and no further calculations were completed.

Based on Table 8, 9, 10 and 11 in Appendix A, required cistern size for 100% offset of potable water ranges between 500 gallons and 40000 gallons. In Appendix B, Table 3, cistern sizes are split into 5000 gallon increments, except for the initial 1000 gallon size. These size increments are applied to illustrate cistern cost for the five material types identified earlier.

Other costs for a rainwater harvesting system include installation of gutters, downspout filters, first-flush diverters or floating filters and pumps (each part adds additional system cost). Major rainwater harvesting components are considered onetime purchases and will need routine maintenance and cleaning. Gutters are an optional cost and the price depends on the roof catchment area. Two different materials for the gutters, vinyl and plastic, are used and have the same cost per foot, as provided in Appendix B, Table 3.

The rainwater harvesting system also requires a pump to pressurize the water supply into an in-ground irrigation system. Two types of pumps are generally used; submersible or centrifugal. A centrifugal pump is best used for cisterns above ground as opposed to below ground due to the water level below or above the pump. The examined pump flow rate is assumed between 20 and 30 gallons per minute and costs are provided in Appendix B, Table 4. The average cost for the pump of $600 is assumed when calculating the total rainwater harvesting system pump cost. Total system cost depending on size and cistern material are provided in Appendix B, Table 5. The total system cost includes cistern, downspout filter, first flush diverter, floating filter and pump.

Electrical costs to run the pumps were considered. This is an indirect system cost that is taken into account. Electricity is billed in kilowatt-hour units. The Tampa Bay area has two main suppliers of electricity, Tampa Electric Company (TECO) and Progress Energy. For this BMP, the billing rates are averaged to account for rainwater harvesting systems in either billing area. The cost to run the pump depends upon the amount of water pumped as well as the wattage used by the water pump. Annual electric costs to run the water pump are considered minimal and are not included in the total system cost.

Section 9: Cost of Potable Water for Irrigation

Costs to irrigate a landscape with potable water are used in comparison with rainwater harvesting system cost. For BMP evaluation, landscape areas and watering frequencies/amounts are constant on an annual basis. The cost of potable water is controlled by the entity supplying water. Volumetric rates for water are generally inverted in the Tampa Bay region and new supplies are more costly than existing supplies. Therefore, the assumption is a rate of $6 per 1000 gallons potable water. The annual use and savings in potable water for turf grass using automatic irrigation control and turf grass using manual irrigation and shrubs using automatic or manual and turf grass using SMS control is provided in Appendix C, Table 1, 2, 3 and 4, respectively. To determine annual savings, some assumptions for number of applications per month over the year were assumed. Assumptions are:

- Automatic irrigation control of turf grass applied 4 times a month from January to March and June to December and 8 times a month during April and May. Annual applications = 56
- Manual irrigation control of turf grass applied 1 time each month in July and August; 2 times a month during January, February, June, September, November and December; and 4 times a month in March, April, May and October. Annual applications = 30
- Manual irrigation control of shrubs applied 0 times during July and August; 1 time each month during January, February, June, September, November, and December; 2 times during October; and 4 times in March, April and May. Annual applications = 20
- Soil Moisture Sensor irrigation control of turf grass applied on average 2.3 applications per month

The Annual Water Use is calculated using;

Annual Use = Landscape Area (sq ft) × 0.75 in × number of applications × 0.623

The Annual Potable Water Savings is calculated using;

Annual Savings = Annual Use × $6/1000 gallons

Section 10: Payback period and Cost Effectiveness of Rainwater Harvesting System

Simple payback is used to determine the number of years it will take for the system to payback from the potable water savings. A payback period of 20 years or less is desired in this evaluation from the utility perspective. The cost effectiveness is calculated to determine what rate (of potable water) is needed to have a 20 year payback period. Landscape type and method of irrigation cause different payback periods and cost effectiveness because of the varying system sizes and costs.

Simple payback is calculated using;

Simple Payback = Cost of System / Annual Savings

Cost effectiveness is calculated using;

Cost Effectiveness = Cost of System / 20 year water use / 1000

Payback period and cost effectiveness for an automatic irrigation system of various sizes of turf grass with a 2000 sq ft catchment area using polypropylene as the cistern material is identified in Appendix D, Table 1. Payback period and cost effectiveness for manual irrigation of turf grass with 2000 sq ft catchment area using polypropylene as cistern material are identified in Appendix D, Table 2 with the following assumptions:

- Automatic irrigation system usage and water savings for payback
- Automatic irrigation system use for cost effectiveness

Payback periods and cost effectiveness for turf grass, with irrigation technology using ET rates, a 2000 sq ft catchment area, using polypropylene as cistern material and making the assumptions above, is identified in Appendix D, Table 3. The same assumptions and sizes were evaluated with the SMS irrigation control and the payback periods and cost effectiveness is identified in Appendix D, Table 4.

Section 11: AC Condensate Collection

Rainwater is not the only alternative water supply source to potable water that can be used for irrigation purposes. AC condensate is formed when water vapor present in the outside air cools and condenses on the coils of an air conditioning unit. The water draining from the unit is typically routed to the wastewater line on a property or dripped into the landscape near the unit and is never collected. If the wastewater line were to be rerouted to a cistern it would serve as another alternative water supply to potable water, in addition to rainwater. The amount of water that can be collected from an AC unit depends on a few variables. San Antonio Water System and Building Green LLC have developed an AC condensate calculator which can be found online (http://www.buildinggreen.com/calc/calc_condensate.cfm). This calculator uses the assumptions below:

- The average indoor air temperature is 72°F
- The average indoor humidity is 40%
- The tonnage of the AC system is calculated at 4 tons and the percentage of outside air is 20%
- The outdoor temperatures were obtained from (www.weather.com) and the outdoor humidity percentages were obtained from the Southeast Regional Climate Center website (http://www.sercc.com/climateinfo/historical/avgrh.html).

The minimum, maximum and average volume of AC condensate able to be collected is displayed in Appendix E, Table 1.

This alternative water source is ideal for water use outdoors, especially irrigation. The condensate can be easily stored in the same tank as the harvested rainwater. The ability to mix the two sources in one tank cuts down on the cost of having to add another storage tank and parts to the property. When this additional water source is added to a property, the size of the cistern decreases when compared to the previous calculations not including the capture of AC condensate (see Appendix E, Table 2, 3, 4 and Appendix A, Table 8, 9, 10). The simple payback and cost effectiveness of a system capturing the AC condensate is also reduced compared to the results for only using rainwater as the alternative supply to potable water (see Appendix F, Table 1, 2, 3).

Section 12: Indoor Use of Harvested Rainwater and AC Condensate

Rainwater and AC condensate that is harvested can be used for more than just irrigation purposes. This stored alternative water supply can be used within homes. For these alternative water supplies to be used indoors, disinfection treatment is required.

There are a few options for treatment of rainwater and AC condensate to meet potable water quality standards. The most common disinfection technology used is an Ultraviolet light (UV) system. These systems use UV to alter the DNA configuration of microorganisms living within the water which disables the organism's ability to reproduce. Because these systems add another component, there is additional costs and maintenance associated with using the collected water as an indoor potable water supply. The UV disinfection system is a onetime purchase of approximately $1800 and the UV lights are recommended to be changed every 12 months but at a considerably lower cost than the UV system, approximately $200 for two replacement bulbs. The UV system and parts costs average about $2000 and are identified in Appendix G, Table 1. This cost is added to the cost of the rainwater harvesting system calculated previously and identified in Appendix G, Table 2.

When water that has been harvested, from rainfall and/or AC condensate, is used indoors, there is a daily, somewhat uniform, demand for the stored water. There is little seasonal change in the demand of indoor use, meaning water usage can be easily predicted by looking at the average gallons of potable water used within a household per day. The consistency of indoor usage causes the size of the storage unit to decrease because of the lack of peak dry season demand which reduces that need for assessing peak potable water system reliability.

The American Water Works Association Research Foundation issued a report of Residential End Uses in 1999. The data presented in the report identified the sources and volume of water used indoors with conservation and is identified in Appendix H, Table 1. The average water use per person per month is identified in Appendix H, Table 2. The required cistern size for indoor use using captured rainwater and AC condensate is determined by the size of the catchment area and is identified in Appendix H, Table 3. A system that is sized for indoor use using the collection of rainwater and AC condensate will range in size from 1500 gallons to 10000 gallons, depending on the catchment area which ranges from 500 sq ft to 5000 sq ft.

The annual savings and usage of indoor potable water is identified in Appendix H, Table 4 using a rate of $6/1000g for potable water offset. The simple payback and cost effectiveness of a rainwater harvesting and AC condensate system with disinfection for indoor water use is identified in Appendix H, Table 5. Compared with the simple payback and cost effectiveness of the systems used for outdoor use only, these indoor use systems are not as cost effective and they have a much longer simple payback period. This is largely due to the cost of the disinfection system that is required to treat collected water for potable indoor uses.

Section 13: Results

There are many factors considered when proposing and constructing a water harvesting system. Rainwater and AC condensate harvesting systems can be evaluated and used as alternative water supply by water supply agencies with the potential for 100% potable water offset under the right sizing conditions. The desired payback period, for this BMP, is 20 years or less. This 20 year payback period or shorter occurs under very few conditions. A property with a manual irrigation system, 500 sq ft of turf grass and a rainwater harvesting system has a payback period of 19 years (see Appendix D, Table 2). A property with SMS irrigation control irrigating 500 sq ft of turf grass with a rainwater harvesting system has a payback period of 14 years (see Appendix D, Table 4). A property with a manual irrigation system of turf grass or an automatic or manual irrigation system of shrubs with rainwater and AC condensate harvesting system has a payback period of 19 and 18 years for 500 sq ft and 1000 sq ft of landscape, respectively (see Appendix F, Table 2).

When a property owner changes from a turf grass landscape using automatic irrigation control to a turf grass landscape with either manual irrigation or a technology control, the correctly sized system proves to be much more cost effective and has a shorter payback period. Comparing automatic control to manual control in Appendix D, Table 1 and 2, the payback period for the automatic irrigation system is 39 years compared to the manual irrigation control whose payback is 19 years. For this reduction in payback periods to occur, landscapes may need to be modified to limit landscape demand or multiple alternative water supply sources can be added. Each change would lower payback period and be a more cost effective conservation tool for utilities to utilize as an alternative supply source. The installation of technology control could also be used to lower payback periods. The University of Florida study on soil moisture sensors resulted in reduced water use compared to the ET rate calculations performed in this document. Thus, installing a soil moisture sensor on a property could cut the payback period to between 7 and 14 years, based on the data provided in the University of Florida research. The addition of a soil moisture sensor to a rainwater harvesting system results in a much more cost effective option to offsetting potable water use.

When alternative water supply sources are added to rainwater harvesting such as AC condensate, cistern size required decreases as illustrated in Appendix A, Table 9 and Appendix E, Table 3. A rainwater harvesting system manually irrigating 1000 ft^2 of turf grass with 2000 ft^2 of catchment is about 3700 gallons, according to Appendix A, Table 9. A rainwater and AC condensate system size, irrigating the same size landscape with same catchment area, is about 2800 gallons, according to Appendix E, Table 3. Additionally, system cost decreases causing payback period to decrease and system cost effectiveness to increase, illustrated in Appendix D, Table 2 showing payback period is 21 years and Appendix F, Table 2 showing payback period is 18 years. However, adding disinfection to water harvesting systems for indoor use, simple payback increases and cost effectiveness decreases due to relatively high cost for disinfection. It appears benefits for disinfected rainwater and AC condensate harvest systems may be greater on the owner side with a well planned system desiring partial potable water offset. A system that is sized for partial potable water offset may have a lower cost and a shorter payback period, although this is not quantified within this document. This will prove to be more beneficial for the owner than the utility because of partial savings for the owner. However, the utility will still have to supply potable water to the user when the system runs dry.

Appendices

Appendix A:

Calculations of Demand, Catchment and Cistern Size

Month	J	F	M	A	M	J	J	A	S	O	N	D
Water Use (inches)	2.0	2.5	3.4	4.2	5.2	4.3	4.8	4.8	3.9	3.4	2.5	1.9

Table 1: Annual ET rate for Turf Grass in west-central Florida

Month	J	F	M	A	M	J	J	A	S	O	N	D
Water Use (inches)	0.35	0.43	0.78	1.26	0.94	0.71	0.47	0.71	0.79	1.26	0.94	0.79

Table 2: Annual water use for Turf Grass using data from Soil Moisture Sensor presented in the University of Florida document.

Turf Grass using Automatic Irrigation Control (gallons)								
Landscape size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
March	934.5	1869	2803.5	3738	4672.5	5607	6541.5	7476
April	1869	3738	5607	7476	9345	11214	13083	14952
May	1869	3738	5607	7476	9345	11214	13083	14952
TOTAL	4672.5	9345	14017.5	18690	23362.5	28035	32707.5	37380

Table 3: Landscape demand for turf grass using automatic irrigation system assumptions

Turf Grass using Manual Irrigation Control AND Shrub using Automatic OR Manual Irrigation Control (gallons)								
Landscape size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
March	934.5	1869	2803.5	3738	4672.5	5607	6541.5	7476
April	934.5	1869	2803.5	3738	4672.5	5607	6541.5	7476
May	934.5	1869	2803.5	3738	4672.5	5607	6541.5	7476
TOTAL	2803.5	5607	8410.5	11214	14017.5	16821	19624.5	22428

Table 4: Landscape demand for turf grass using manual irrigation control assumptions and landscape demand shrubs using automatic or manual irrigation control assumptions

Turf Grass Landscape using ET Rate (gallons)								
Landscape size (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
March	704.1	1408.2	2112.3	2816.4	3520.5	4224.6	4928.7	5632.8
April	1083.3	2166.6	3249.9	4333.2	5416.5	6499.8	7583.1	8666.4
May	1263.6	2527.1	3790.7	5054.2	6317.8	7581.3	8844.9	10108.4
TOTAL	3051	6101.9	9152.9	12203.8	15254.8	18305.7	21356.7	24407.6

Table 5: Landscape demand for turf grass using ET rate assumptions

Turf Grass Landscape using SMS data (gallons)								
Landscape Size (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
March	245.3	490.6	735.8	981.1	1226.3	1471.7	1716.9	1962.2
April	392.4	784.9	1177.3	1569.8	1962.2	2354.7	2747.1	3139.5
May	294.3	588.7	882.9	1177.3	1471.7	1765.9	2060.3	2354.6
TOTAL	932	1864.1	2796.1	3728.2	4660.2	5592.3	6524.3	7456.4

Table 6: Landscape demand for turf grass using SMS data

Catchment Volume based on 50% Average Rainfall Data and Catchment Area (gallons)										
Catchment Area (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**
March	355	710	1065	1420	1775	2130	2485	2840	3195	3550
April	225	450	675	900	1125	1350	1575	1800	2025	2250
May	356	713	1069	1425	1781	2138	2494	2850	3206	3563
TOTAL	936	1873	2809	3745	4681	5618	6554	7490	8426	9363

Table 7: Catchment volume based upon the 50% rainfall data for west central Florida and the catchment area in square feet.

	Turf Grass Landscape using Automatic Irrigation Control							
Landscape Area (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area (sq ft)	**Cistern Size Required (gallons)**							
500	4671	10278	15885	21492	27099	32706	38313	43920
1000	3735	9342	14949	20556	26163	31770	37377	42984
1500	3863	8405	14012	19619	25226	30833	36440	42047
2000	3282	7469	13076	18683	24290	29897	35504	41111
2500	2701	6533	12140	17747	23354	28961	34568	40175
3000	2120	7727	11204	16811	22418	28025	33632	39239
3500	2163	7145	10267	15874	21481	27088	32695	38302
4000	1938	6564	12171	14938	20545	26152	31759	37366
4500	1869	5983	11590	14002	19609	25216	30823	36430
5000	1869	5402	11009	13066	18673	24280	29887	35494

Table 8: Cistern size (gallons) based on the catchment area (square feet) and turf grass landscape demand (square feet) using automatic irrigation control.

	Turf Grass Landscape using Manual Irrigation Control AND Shrub Landscape using Automatic OR Manual Irrigation Control							
Landscape Area (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area (sq ft)	**Cistern Size Required (gallons)**							
500	2802	6540	10278	14016	17754	21492	25230	28968
1000	1866	5604	9342	13080	16818	20556	24294	28032
1500	1194	4667	8405	12143	15881	19619	23357	27095
2000	969	3731	7469	11207	14945	18683	22421	26159
2500	935	2795	6533	10271	14009	17747	21485	25223
3000	935	2388	5597	9335	13073	16811	20549	24287
3500	935	2163	4660	8398	12136	15874	19612	23350
4000	935	1938	3807	7462	11200	14938	18676	22414
4500	935	1869	3582	6525	10264	14002	17740	21478
5000	935	1869	3357	5590	9328	13066	16804	20542

Table 9: Cistern size (gallons) based on the catchment area (square feet) and turf grass landscape demand (in square feet) using manual irrigation and shrub landscape demand (square feet) using automatic and manual irrigation control.

	Turf Grass Landscape using ET Rate and 50% Rainfall Data							
Landscape Area (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area (sq ft)	**Cistern Size Required (gallons)**							
500	2819	6574	10329	14084	17839	21594	25349	29104
1000	2268	5638	9393	13148	16903	20658	24413	28168
1500	1686	4701	8456	12211	15967	19722	23477	27232
2000	1267	4535	7520	11275	15030	18785	22540	26295
2500	1264	3954	6584	10339	14094	17849	21604	25359
3000	1264	3373	6803	9403	13158	16913	20668	24423
3500	1264	2792	6222	8466	12222	15977	19732	23487
4000	1264	2533	5640	9071	11285	15040	18795	22550
4500	1264	2308	5059	8489	10349	14104	17859	21614
5000	1264	2527	4478	7908	11338	13168	16923	20678

Table 10: Cistern Size (gallons) based on the catchment area (sq ft) and turf grass landscape demand (sq ft) based on ET rates for turf grass.

	Turf Grass Landscape using SMS Data							
Landscape Area (sq ft)	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area (sq ft)	**Cistern Size Required (gallons)**							
500	559.9	1418.4	2595.7	3773	4950.4	6127.7	7305	8482.3
1000	392.4	1119.8	1659.5	2836.8	4014.1	5191.4	6368.8	7546.1
1500	392.4	894.8	1679.6	2573.1	3077.9	4255.2	5432.5	6609.8
2000	392.4	784.9	1454.6	2239.5	3071.1	3318.9	4496.3	5673.6
2500	392.4	784.9	1229.6	2014.5	2799.4	3584.3	4648.2	4737.3
3000	392.4	784.9	1177.3	1789.5	2574.4	3359.3	4144.2	5146.2
3500	392.4	784.9	1177.3	1569.8	2349.4	3134.3	3919.2	4707.6
4000	392.4	784.9	1177.3	1569.8	2124.4	2909.3	3694.2	4479.1
4500	392.4	784.9	1177.3	1569.8	1962.2	2684.3	3469.2	4254.1
5000	392.4	784.9	1177.3	1569.8	1962.2	2459.3	3244.2	4029.1

Table 11: Cistern Size (gallons) based on the catchment area (sq ft) and turf grass landscape demand (sq ft) based on SMS data from University of Florida research.

<u>Appendix B</u>:

Cost of Rainwater Harvesting Systems

Material	Min and Max Cost/gallon	Average Cost/gallon
Polypropylene	$0.35-1.00	$0.675
Concrete	$0.30-1.25	$0.775
Metal	$0.50-15.0	$1.00
Polyethylene	$0.74-1.67	$1.205
Fiberglass	$0.50-2.00	$1.25
Rainpillow	$1.40-2.50	$1.88

Table 1: Minimum, maximum and average cistern cost per gallon for five different cistern materials. (*Texas Guide to Rainwater Harvesting, Third Edition,* Texas Water Development Board,2005) (http://www.rainwaterpillow.com/product/product-cost.aspx)

Size (gallons)		1000	5000	10000	15000	20000	25000	30000	35000	40000
Material	**$/gal**	**Cistern Cost (dollars)**								
Polypropylene	**0.675**	675	3375	6750	10125	13500	16875	20250	23625	27000
Concrete	**0.775**	775	3875	7750	11625	15500	19375	23250	27125	31000
Metal	**1.00**	1000	5000	10000	15000	20000	25000	30000	35000	40000
Polyethylene	**1.205**	1205	6025	12050	18075	24100	30125	36150	42175	48200
Fiberglass	**1.25**	1250	6250	12500	18750	25000	31250	37500	43750	50000

Table 2: Cistern cost for five material types ranging in size from 1000 gallons to 40000 gallons

Part	Average Cost
Gutter (Vinyl or Plastic)	$0.30/foot
Downspout Filter	$27/unit
First Flush Diverter	$35/unit
Floating Filter	$180/unit

Table 3: Average cost of additional pieces to a rainwater harvesting system (*RainHarvest Systems www.Rainharvest.com)* (*Texas Guide to Rainwater Harvesting, Third Edition*, Texas Water Development Board,2005).

Pump Type	Cost
Submersible	$500-700
Centrifugal	$500

Table 4: Average cost of water pump (*RainHarvest Systems www.Rainharvest.com)*

Cistern Size (gallons)	**1000**	**5000**	**10000**	**15000**	**20000**	**25000**	**30000**	**35000**	**40000**
Material	**Cost of Rainwater Harvesting System (dollars)**								
Polypropylene	1517	4217	7592	10967	14342	17717	21092	24467	27842
Concrete	1617	4717	8592	12467	16342	20217	24092	27967	37842
Metal	1842	5842	10842	15842	20842	25842	30842	35842	40842
Polyethylene	2047	6867	12892	18917	24942	30967	36992	43017	49042
Fiberglass	2092	7092	13342	19592	25842	32092	38342	44592	50842

Table 5: Total system cost for five cistern materials in 5000 gallon increments from 1000 to 40000 gallons.

Appendix C:

Annual Use and Savings of Potable Water for Irrigation

Landscape Size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Annual Use (gallons)	13083	26166	39249	52332	65415	78498	91581	104664
Annual Savings (dollars)	79	157	236	314	392	471	550	628

Table 1: Annual Use and Savings in Potable water use ($6/1000g) for Turf Grass using Automatic Irrigation Control vs. Landscape Size

Landscape Size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Annual Use (gallons)	7008	14017	21026	28035	35043	42052	49061	56070
Annual Savings (dollars)	42	84	126	168	210	252	295	336

Table 2: Annual Use and Savings in Potable Water use ($6/1000g) for Turf Grass using Manual Irrigation Control vs. Landscape Size

Landscape Size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Annual Use (gallons)	4672	9345	14017	18690	23362	28035	32707	37380
Annual Savings (dollars)	28	56	84	112	140	168	196	224

Table 3: Annual Use and Savings in Potable Water use ($6/1000g) for Shrub Landscape using Manual Irrigation Control vs. Landscape Size

Landscape Size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Annual Use (gallons)	2943	5887	8830	11773	14717	17660	20603	23547
Annual Savings (dollars)	18	35	53	71	88	106	124	141

Table 4: Annual Use and Savings in Potable Water use ($6/1000g) for Shrub Landscape using SMS Irrigation Control vs. Landscape Size

<u>Appendix D</u>:

Payback Period and Cost Effectiveness

(Rainwater Harvesting System)

Turf Grass (sq. ft.)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	3282	7469	13076	18683	24290	29897	35504	41111
Cost of System (dollars)	3057	5884	9668	13453	17238	21022	24807	28592
Simple Payback (years)	39	37	41	43	44	45	45	46
Cost Effectiveness ($/1000gallons)	11.68	11.24	12.32	12.85	13.18	13.39	13.54	13.66

Table 1: Payback period and cost effectiveness for Automatic Irrigation of Turf Grass with 2000 sq ft catchment area using Polypropylene as cistern material

Turf Grass (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	969	3731	7469	11207	14945	18683	22421	26159
Cost of System (dollars)	1496	3360	5884	8407	10930	13453	15976	18499
Simple Payback (years)	19	21	25	27	28	29	29	30
Cost Effectiveness ($/1000 gallons)	5.72	6.42	7.50	8.03	8.35	8.57	8.72	8.84

Table 2: Payback period and cost effectiveness for Manual Irrigation of Turf Grass with 2000 sq ft catchment area using Polypropylene as cistern material

Turf Grass (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	1267	4535	7520	11275	15030	18785	22540	26295
Cost of System (dollars)	1697	3903	5918	8453	10987	13522	16057	18591
Simple Payback (years)	21	25	25	27	28	29	29	30
Cost Effectiveness ($/1000 gallons)	6.49	7.46	7.54	8.08	8.40	8.61	8.77	8.88

Table 3: Payback period and cost effectiveness for turf grass based on ET rate with 2000 sq ft catchment area using polypropylene as cistern material.

Turf Grass (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	392	785	1455	2240	3071	3319	4496	5674
Cost of System (dollars)	1107	1372	1824	2354	2915	3082	3878	4672
Simple Payback (years)	14	9	8	8	7	7	7	7
Cost Effectiveness ($/1000 gallons)	4.23	2.62	2.32	2.99	2.23	1.96	2.12	2.23

Table 4: Payback period and cost effectiveness for turf grass based on SMS data with 2000 sq ft catchment area using polypropylene as cistern material.

Appendix E:

AC Condensate Catchment and Cistern Size

Condensate Volume (gallons)				
Month	**Minimum**	**Maximum**	**Average**	**Totals**
January	-1.4	8.74	2.99	92.69
February	-0.85	9.61	3.71	103.88
March	1.01	12.66	6.71	208.01
April	2.51	15.63	8.71	261.3
May	6.68	20.02	13.18	408.58
June	11.74	25.39	18.55	556.5
July	13.2	27.47	20.32	629.92
August	13.86	28.51	21.18	656.58
September	12.7	26.9	19.79	593.7
October	7.35	20.42	13.34	413.54
November	2.78	14.64	8.46	253.8
December	-0.09	10.21	4.75	147.25
Average				4325.75

Table 1: Minimum, Maximum and Average volume of condensate about to be caught per month

	Turf Grass Landscape Demand using Automatic Control							
Landscape Area	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area	**Cistern Size Required (gallons)**							
500	3793	9400	15007	20614	26221	31828	37435	43042
1000	2857	8464	14071	19678	25285	30892	36499	42106
1500	3193	7527	13134	18741	24348	29955	35562	41169
2000	2612	6591	12198	17805	23412	29019	34626	40233
2500	2352	7638	11262	16869	22476	28083	33690	39297
3000	2127	7057	10326	15933	21540	27147	32754	38361
3500	1902	6475	9389	14996	20603	26210	31817	37424
4000	1869	5894	11501	14060	19667	25274	30881	36488
4500	1869	5313	10920	13124	18731	24338	29945	35552
5000	1869	4965	10339	15946	17795	23402	29009	34616

Table 2: Cistern Size Required for Turf Grass using Automatic Irrigation Control.

	Turf Grass demand using Manual Irrigation Control AND Shrub demand using Automatic OR Manual Irrigation Control							
Landscape Area	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area	**Cistern Size Required (gallons)**							
500	1924	5662	9400	13138	16876	20614	24352	28090
1000	1174	4726	8464	12202	15940	19678	23416	27154
1500	935	3789	7527	11265	15003	18741	22479	26217
2000	935	2853	6591	10329	14067	17805	21543	25281
2500	935	2352	5655	9393	13131	16869	20607	24345
3000	935	2127	4719	8457	12195	15933	19671	23409
3500	935	1902	3882	7520	11258	14996	18734	22472
4000	935	1869	3546	6854	10322	14060	17798	21536
4500	935	1869	3321	5648	9386	13124	16862	20600
5000	935	1869	3096	4965	8450	12188	15926	19664

Table 3: Cistern Size Required for Turf Grass using Manual Irrigation control AND Shrubs using Automatic or Manual Controls

	Turf Grass Demand using ET rate							
Landscape Area	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
Catchment Area	**Cistern Size Required (gallons)**							
500	1941	5696	9451	13206	16961	20716	24471	28226
1000	1598	4760	8515	12270	16025	19780	23535	27290
1500	1230	3823	7579	11334	15089	18844	22599	26354
2000	1264	3865	6642	10397	14152	17907	21662	25418
2500	1264	3284	5706	9461	13216	16971	20726	24481
3000	1264	2722	6133	8525	12280	16035	19790	23545
3500	1264	2497	5552	8982	11344	15099	18854	22609
4000	1264	2272	4971	8401	10407	14162	17917	21673
4500	1264	2527	4389	7819	9471	13226	16981	20736
5000	1264	2527	3989	7238	10668	12290	16045	19800

Table 4: Cistern Size Required for Turf Grass using ET Rate

<u>Appendix F</u>:

Payback Period and Cost Effectiveness

(Rainwater Harvesting and AC Condensate Collection)

Turf Grass (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	2612	6591	12198	17805	23412	29019	34626	40233
Cost of System (dollars)	2608	5291	9076	12860	16645	20430	24215	27999
Simple Payback (years)	33	34	38	41	42	43	44	45
Cost Effectiveness ($/1000 gallons)	9.97	10.11	11.56	12.29	12.72	13.01	13.22	13.38

Table 1: Simple Payback and Cost Effectiveness of Turf Grass using Automatic Irrigation Control and 2000 sq ft catchment area

Turf Grass (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	935	2853	6591	10329	14067	17805	21543	25281
Cost of System (dollars)	1473	2768	5291	7814	10337	12860	15384	17907
Simple Payback (years)	19	18	22	25	26	27	28	29
Cost Effectiveness ($/1000 gallons)	5.63	5.29	6.74	7.47	7.90	8.19	8.40	8.55

Table 2: Simple Payback and Cost Effectiveness of turf Grass using Manual Control AND Shrub using Automatic or Manual control and 2000 sq ft catchment area

Turf Grass (sq ft)	500	1000	1500	2000	2500	3000	3500	4000
Cistern Size (gallons)	1264	3865	6642	10397	14152	17907	21662	25418
Cost of System (dollars)	1695	3451	5325	7860	10337	12929	15464	17999
Simple Payback (years)	21	22	23	25	26	27	28	29
Cost Effectiveness ($/1000 gallons)	6.47	6.59	6.78	7.51	7.90	8.24	8.44	8.60

Table 3: Simple Payback and Cost Effectiveness of Turf Grass using ET Rate and 2000 sq ft catchment area

<u>Appendix G</u>:

Water Harvesting System cost (UV Treatment)

Cost of Disinfection System	
Part	**Cost (dollars)**
UV System	1785
Replacement Bulbs	220

Table 1: Cost of UV system and replacement bulbs (2) from the Watertiger website (http://www.watertiger.net/UV/upstream.htm#specs)

Cistern Size (gallons)	1000	5000	10000	15000	20000	25000	30000	35000	40000
Part	**Cost of Storage and Disinfection System (dollars)**								
Cistern	675	3375	6750	10125	13500	16875	20250	23625	27000
System Parts	842	842	842	842	842	842	842	842	842
Disinfection	2005	2005	2005	2005	2005	2005	2005	2005	2005
TOTAL	3522	6222	9597	12972	16347	19722	23097	26472	29847

Table 2: Total cost of the Rainwater/ AC condensate storage system, parts and disinfection system and using Polypropylene as cistern material

Appendix H:

Indoor Water Use, Size, Payback and Cost Effectiveness

Source	Demand (gallons per day)
Faucet	10.8
Showers	10.0
Clothes Washers	10.6
Toilets	9.6
Dish Washers	1.0
Baths	1.2
Leaks	5.0
Other	1.5
TOTAL	49.7

Table 1: Average per person indoor water use (American Water Works Association 1999 study)

Month	Water Use (gallons per month)
January	1540.7
February	1391.6
March	1540.7
April	1491.0
May	1540.7
June	1491.0
July	1540.7
August	1540.7
September	1491.0
October	1540.7
November	1491.0
December	1540.7
Annual	18140.5

Table 2: Average monthly water use (American Water Works Association 1999 study)

Catchment Area (sq ft)	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Cistern Size (gallons)	9759	7069	4739	2854	1899	1513	1541	1541	1541	1541

Table 3: Required cistern size depending on the catchment area size

	Indoor Use
Annual Use (gallons)	18141
Annual Savings (dollars)	109

Table 4: Annual use and annual savings potable water ($6/1000g) for indoor use

Catchment Size (sq ft)	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Cistern Size (gallons)	9759	7069	4739	2854	1899	1513	1541	1541	1541	1541
Cost of System (dollars)	9434	7619	6046	4773	4129	3868	3887	3887	3887	3887
Simple Payback (years)	87	70	55	44	38	35	36	36	36	36
Cost Effectiveness ($/1000 gallons)	26.00	21.00	16.66	13.17	11.38	10.66	10.71	10.71	10.71	10.71

Table 5: Simple Payback and Cost Effectiveness for Indoor water use

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